SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

PERMIT PROCESSING HANDBOOK

VOLUME 1

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DISCLAIMER

Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

ABSTRACT

The objective of this handbook is to provide the user with a tool to evaluate permit applications for equipment categories commonly processed by the South Coast Air Quality Management District's (SCAQMD) Engineering Division. This handbook contains the following information for each equipment category:

- equipment description and control technologies;
- permit unit description (as seen on a permit to construct and operate);
- emissions and emission factors;
- equations to quantify emissions and review design parameters;
- listing of applicable rules and regulations;
- listing of enforceable operating conditions;
- permit processing worksheet(s); and
- reference information.

This handbook evaluates common equipment requiring a permit to construct and operate within the South Coast Air Basin. The user should be aware that the handbook is designed to determine the compliance status of equipment based on the Rules and Regulations of the SCAQMD. Therefore, the user must realize the limitations and applicability of the text information and permit processing worksheets for each equipment category.

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INTRODUCTION

The SCAQMD Engineering Division processes approximately 10,000 permit applications each year. These applications are included in the 200+ categories of equipment or industrial processes operating in the South Coast Air Basin. The engineers responsible for evaluating permit applications are divided into eleven permit processing groups according to the type of industries they are handling such as chemical, petroleum, combustion, coating, landfill, etc.. Each group is assigned applications related to the industries they are handling. However, there are several categories of equipment that are used by multiple industries. For example, a boiler may be used by either the petroleum, chemical, landfill, or refuse-to-energy industries.

To meet the challenge for cleaner air, new rules are adopted and existing rules are amended. These changes require additional knowledge to accurately evaluate equipment or a process for permit. New engineers are hired or current staff are reassigned to other permit processing groups outside of there field of expertise depending on the needs of the Division. A Permit Processing Handbook is needed to train and cross-train staff to ensure each equipment category is evaluated accurately and uniformly.

This handbook will help the user perform four functions: (1) ensure uniform processing of identical and similar equipment throughout the Division, (2) apply uniform and enforceable operating conditions, (3) train new staff and cross-train existing staff, and (4) reduce the time required to process simpler applications.

Handbook Updates

This handbook is intended to be a "living" reference document. Therefore, all users should be aware that the handbook will be updated periodically to keep current with advances in process and control technologies. Each section number, revision number, and date of revision is given in the upper right-hand corner of each page.

Written comments regarding the material contained in the Permit Processing Handbook are welcome and should be addressed to:

South Coast
Air Quality Management District
9150 Flair Drive
El Monte, CA 91731

Attn: Director of Engineering

If you would like to be included on the mailing list for notification of future Permit Processing Handbook updates write to:

South Coast
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SECTION 1

Diesel-fired Stationary Internal Combustion Engines Used In Standby Non-Utility Electrical Generation

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Section 1

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SECTION 1: DIESEL-FIRED STATIONARY INTERNAL COMBUSTION ENGINES USED IN STANDBY NON-UTILITY ELECTRICAL GENERATION

1.1 General Description

Stationary reciprocating internal combustion (IC) engines are being used in a multitude of applications due to their short construction time, ease of installation, and remote operation capability. These applications include, but are not limited to, oil and gas piping and production, construction, electrical power generation, and industrial applications which require mechanical work in the form of shaft power. IC engines can operate on a variety of fuels over a large range of speeds and loads. Some typical types of fuel are gasoline, diesel fuel, natural gas, sewage gas, landfill gas, and certain mixtures of these fuels.

Currently, many diesel-fired IC engines are used to generate non-utility electrical power in case of utility power failure. The engines are paired with electrical generators. These emergency standby engine/generator sets are being installed at hospitals, insurance companies, banks, and other facilities where maintaining electrical power is critical. Typically, medium-powered, high-speed (100 HP/cylinder and greater than 1,000 RPM) engines are used.[2] Many engines are turbocharged and aftercooled.

IC engines are classified by the methods of igniting the fuel and air mixture. These methods are spark ignition (Otto Cycle) and compression ignition (Diesel Cycle).

All gasoline or gas engines (Otto Cycle) are spark ignition (SI) engines, in which a spark plug is used to ignite a premixed air-fuel mixture. The fuel is usually mixed with air in a carburetor (for gasoline) or at the intake valve (for gaseous fuels), then ignited in the cylinder by the spark of an electrical discharge.

All diesel-fueled engines (Diesel Cycle) are compression ignition (CI) engines. Air is introduced into the cylinders. High-pressure compression raises the air temperature to the ignition temperature of the diesel fuel. The diesel fuel is then injected into the hot air resulting in spontaneous combustion of the fuel.

Figure 1-1 illustrates the operation of the diesel engine if the spark plug is replaced by a fuel injection valve. The diesel cycle involves the following cycle of events:[1]

1. An intake stroke to induct air alone into the cylinder, Fig 1-1a (intake valve open).

2. A compression stroke to raise the air temperature to a temperature higher than the ignition point of the fuel - compression ratios of 15-18 used, Fig 1-1b (both valves closed).

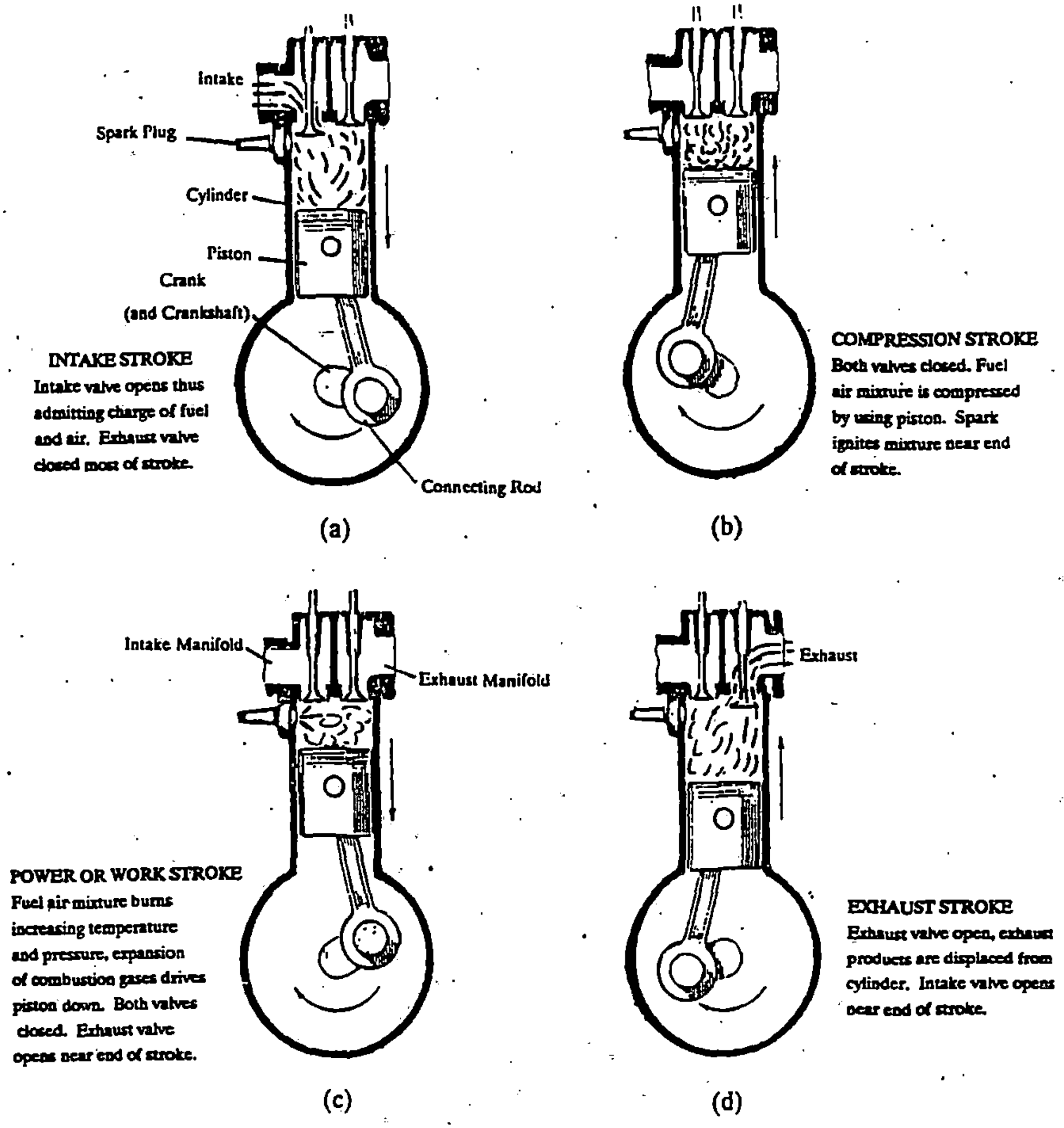
3. Ignition of the fuel during the first part of the expansion stroke at a rate such that combustion maintains the pressure constant, followed by expansion to the initial volume of the cylinder, Fig 1-1c (both valves closed).

4. An exhaust stroke to purge the burned gases from the cylinder, Fig 1-1d (exhaust valve open).

This description applies to a naturally aspirated engine which uses the vacuum created behind the moving piston to suck in the fresh air charge.

One method to increase the power output and efficiency of a diesel-fired IC engine is by turbocharging or supercharging. Both use a blower or compressor to increase the supply of air or combustible mixture to the cylinders beyond the amount normally pumped or sucked in by the pistons at the prevailing atmospheric pressure. The main difference between turbocharging and supercharging is that turbocharger uses the energy in the relatively hot exhaust gases to drive the turbine which is mechanically coupled to a compressor and the supercharger is driven by the engine's crankshaft.[2] Turbocharging is the most common method of air pressurization for diesel-fired IC engines in the SCAQMD.

Air pressurization (compressing the air) increases the amount of air that can be introduced into the fixed volume of the cylinders. Since the air-to-fuel ratio at maximum power is fixed by combustion requirements, more fuel can be introduced with high pressure air than with atmospheric pressure air. Increasing the amount of



INTAKE STROKE
Intake valve opens thus admitting charge of fuel and air. Exhaust valve closed most of stroke.

(a)

COMPRESSION STROKE
Both valves closed. Fuel air mixture is compressed by using piston. Spark ignites mixture near end of stroke.

(b)

POWER OR WORK STROKE
Fuel air mixture burns increasing temperature and pressure, expansion of combustion gases drives piston down. Both valves closed. Exhaust valve opens near end of stroke.

(c)

EXHAUST STROKE
Exhaust valve open, exhaust products are displaced from cylinder. Intake valve opens near end of stroke.

(d)

FIGURE 1-1 THE FOUR-STROKE SPARK-IGNITION (SI) CYCLE. FOUR STROKES OF 180 DEGREES OF CRANKSHAFT ROTATION EACH, OR 720 DEGREES OF CRANKSHAFT ROTATION PER CYCLE.

the combustible mixture increases the amount of power obtained from a given cylinder configuration. Turbochargers are normally deigned to increase an engines output to approximately 1.5 times its original power.[2] However, if the engine's structure is constructed to withstand the higher internal pressures, turbocharging can be used to raise the engine's capacity to 2 to 3 times its naturally aspirated value.[2]

Larger turbocharged IC engines normally use an intercooler or aftercooler (heat exchanger) to lower the temperature of the intake air after it has been heated up by turbocharging. This heat exchanger is located between the turbocharger and the intake manifold. Decreasing the temperature increases the density (and decreases the volume of that air), thereby allowing more air to enter the cylinder. Increasing the mass of air permits higher fuel flow rates. Burning the additional fuel results in higher power output. Also, decreasing the inlet air temperature has a secondary effect of reducing the peak combustion temperature, hence, the formation of (thermal) oxides of nitrogen (NO_X) emissions.[2]

There are approximately 400 permitted diesel-fired emergency standby engines in the South Coast Air Basin. Most of these engines are four cycle, turbocharged, and aftercooled. A four cycle engine completes its power cycle in two revolutions of the crank shaft as compared to one revolution for the two cycle. Two cycle engines have the advantage of higher horsepower to engine weight ratio compared to four cycle engines when operating at the same speed. This is due to the fact that the two cycle design has twice as many power strokes per unit time as the four cycle. However, combustion can be better controlled in a four cycle engine and they do not require excess air to purge the cylinders, as is the case with two cycle engines.[3] Therefore, two cycle engines tend to be slightly less efficient, and uncontrolled models tend to emit slightly more pollutants (primarily unburned hydrocarbons) than their four cycle counterparts.[3]

1.2 Equipment Description

Generally, an internal combustion engine is described in the permit as follows:

INTERNAL COMBUSTION ENGINE, MANUFACTURER'S NAME, DIESEL-FUELED, EMERGENCY ELECTRICAL GENERATION, MODEL NO., SERIAL NO., TURBOCHARGED, AFTERCOOLED, NO. OF CYLINDERS, TWO/FOUR CYCLE, ENGINE BRAKE HORSEPOWER.

1.3 Emissions

Sources of emissions from IC engines are crankcase blowby, the fuel tank, and the exhaust. Crankcase blowby are the gases vented from the oil pan after they have escaped from the cylinders past the piston rings. Emissions from the crankcase blowby is minor because the fuel (hydrocarbons) is not present during the compression of the charge. Emissions from the fuel tank are insignificant due to the low volatility of the diesel fuel. The majority of the emissions from diesel engines are from the exhaust.[3]

The primary air contaminants from IC engine exhaust are oxides of nitrogen (NO_x), reactive organic gases (ROG), carbon monoxide (CO), oxides of sulfur (SO_x), and particulate matter (PM). NO_x formation is a function of temperature and pressure during the combustion process and the nitrogen content of the fuel. Sulfur compounds, essentially SO_2, are a function of the sulfur content of the fuel. The other contaminants, ROG, CO, and PM are primarily the result of incomplete combustion.[2]

1.3.1 Emission Factors

Occasionally, engine manufacturers include emission data with their specifications sheet, or at least fuel consumption data. If emission data is not provided, the emission factors for diesel no. 2 listed in Table 1-3 should be used to quantify emissions.

Table 1-3: Emission Factors For Diesel Internal Combustion Engines [a]

Air Contaminant	Emission Factor (lb/gal)
Reactive Organic Gas (ROG)	0.0445
Oxides of Nitrogen (NOx)	0.4690
Oxides of Sulfur (SOx)	0.0071
Carbon Monoxide (CO)	0.1020
Particulate Matter (PM)	0.0335

[a] Reference 4; SO_x emissions corrected to 0.05% sulfur.

1.4 Calculations

1.4.1 Operational Data

Emission calculations must be performed to determine the compliance status of the IC engine. In order to determine compliance, the applicant must provide the following information :

- Operating Schedule

Maximum:	hr/day, day/week
For Maintenance Purposes:	hr/day, day/week
Engine Brake Horsepower:	
Fuel Type:	
Fuel Consumption Rate:	gal/hr

Exhaust Volume:	dry standard cubic feet per minute (DSCFM), or actual cubic feet per minute (ACFM)

1.4.2 Emissions Calculations

Emissions must be calculated for both the actual (average) and maximum operating conditions. Actual emissions are used in emission inventory. Maximum emissions are used to determine compliance with the SCAQMD's Rules and Regulations.

Actual and maximum hourly (lb/hr) emission rates must be converted into daily (lb/day) emission rates by multiplying the hourly rates by the appropriate equipment daily operational time factor (T, hr/day). In addition, the maximum daily emissions are multiplied by the Regulation XIII On-Site Offset Factor (1.1). These daily emissions increase are accumulated for each facility in the SCAQMD's New Source Review (NSR) Record.

1.4.2.1 Uncontrolled Emissions (R_1) Calculations

Uncontrolled emissions from the internal combustion engine may be calculated using the following equation:

$$R_1 = EF \times FCR \qquad \textbf{(Equation 1.1)}$$

where:

R_1 = Uncontrolled emissions, lb/hr
EF = Emission factor, lb/gal fuel
FCR = Fuel consumption rate, gal/hr

This procedure is repeated for each air contaminant.

By incorporating emission factors shown in Tables 1-1, Equation 1.1 can be simplified as follows:

$$\begin{aligned} R_{1,ROG} &= 0.0445(D) \\ R_{1,NOX} &= 0.4690(D) \\ R_{1,SOX} &= 0.0071(D) \\ R_{1,CO} &= 0.1020(D) \\ R_{1,PM} &= 0.0335(D) \end{aligned} \qquad \textbf{(Equation 1.2)}$$

where:

R_1 = uncontrolled emissions, lb/hr
D = diesel fuel consumption rate, gal/hr

1.4.3 Total Particulate Matter Emissions - Concentration

The particulate matter mass emission rate (lb/hr) must be converted into total particulate matter concentration (grains/dscf). If the exhaust gas flow rate is given in terms of "actual" exhaust conditions, the flow rate must be converted into dry "standard" conditions by using the following equation:

$$F_1 = F_2 \times \frac{T_1 \times P_2}{T_2 \times P_1} \times \left(1 - \frac{M}{100}\right) \qquad \textbf{(Equation 1.3)}$$

where:

F_1 = dry standard cubic feet per minute, dscfm
F_2 = actual cubic feet per minute, acfm
T_1 = standard temperature, degrees Rankine ($60^{o}F + 460$)
T_2 = exhaust temperature, degrees Rankine ($t_2{}^{o}F + 460$)
P_1 = standard pressure,in Hg (29.92 in Hg)
P_2 = actual (or rated) exhaust pressure, in Hg (typically 29.92 in Hg)
M = percent moisture in exhaust gas (typically 10%)

Total particulate matter concentration is then determined using Equation 1.4.

$$C = \frac{(R_1)(7{,}000 \text{ grains/lb})}{(F_1)(60 \text{ min/hr})} \qquad \textbf{(Equation 1.4)}$$

where:

C = particulate concentration, grains/dscf

R_1 = particulate mass emission rate, lb/hr

F_1 = dry standard cubic feet per minute, dscfm

1.5 Rules Evaluation

Rule 401 - Visible Emissions

During start-up, the visible emissions may exceed 20% opacity. However, these emissions are not expected to last greater than three minutes. Under normal operation, the visible emissions from this engine should not exceed 20% opacity (or Ringlemann No. 1).

Rule 402 - Nuisance

Odor in the exhaust and noise can be a problem with diesel-fired engines. However, when the engine is operating on an emergency standby basis, no nuisance complaints are expected.

Rule 404 - Particulate Matter - Concentration

A person shall not discharge into the atmosphere from any source, particulate matter in excess of the concentration at standard conditions, as shown in TABLE 404(a) of the South Coast Air Quality Management District's Rules and Regulations.

If the engine is vented by multiple stacks, the total exhaust flow rate must be determined. The total exhaust volume is determined by summing the volume from all the stacks. The allowable concentration from the Table 404(a) is based on the total volume. Compare the actual concentration in each stack to that allowed concentration. Concentration from any stack in excess of that allowed concentration based on the total volume is a violation of Rule 404.

When evaluating an application to alter or modify existing equipment by combining emissions from two or more stacks into a single stack (or into fewer stacks than originally existed), you must ensure that the alteration/modification does not deliberately dilute the exhaust stream to circumvent the Rule. It is not considered circumvention when:

- Dilution air serves a useful purpose such as cooling the exhaust stream(s); or

- The use of a common exhaust stack minimizes cost.

Rule 431.2 - Sulfur Content of Liquid Fuels
When operating a diesel-fired IC engine, a person shall not use diesel fuel with sulfur content greater than 0.05 percent by weight.

Rule 1110.1 - Emissions From Stationary Internal Combustion Engines
An emergency standby IC engine is exempt from this rule if it operates less than 200 hours in any one calendar year.

If the emergency standby IC engine has a rating of 50 break horsepower (BHP) or more and operates in excess of 200 hours in any one calender year, the applicant (owner/operator) must submit a Control Plan. The Control Plan must include the following information for each stationary source:

- A list of all engines with the type of engine ,service and permit or identification number.

- Engine manufacturer, model number, rated break horsepower, type of fuel and type of ignition .

- List of all engines to be controlled and type of emission controls to be applied to such engines, including construction schedule.

If the BHP rating of the IC engine is greater than the value specified in Rule 219 and is 50 BHP or more, the applicant must submit an application for permit to construct and operate for that engine. The requirements for the Control Plan will be considered during the evaluation for permit to construct and operate.

Regulation XIII - New Source Review
Emergency standby equipment used exclusively for non-utility electrical power generation must be equipped with Best Available Control Technology (BACT). If the maximum daily emissions of any air contaminant for the emergency standby diesel IC engine, when added to the facilities NSR accumulated emissions, result that facility exceeding the threshold limits specified in 1303(a)(2), the applicant must substantiate with modeling or any other approved analysis that the increase in emissions for <u>any</u> air contaminant will not cause a violation, or make measurably worse an existing violation, of any ambient air quality standard.

Rule 1304(b)(1), however, <u>exempts</u> the emergency standby engine from the following requirements:

- Offsetting the accumulated emission increases of air contaminants that exceed the threshold limits; and
- Written certification that all stationary sources emitting 25 tons per year or more, of any air contaminant, which is owned or operated by the applicant in the State of California are in compliance with federal and state standards.

Best Available Control Technology (BACT)
Best Available Control Technology (BACT) for diesel-fired internal combustion engines used in emergency standby non-utility electrical generation is as follows:

ROG:	none
NO_x:	ignition timing retarded at least 4^0 relative to the standard timing and intercooling for turbocharged engines

SO_2: fuel containing 0.05% sulfur by weight or less
CO: none
PART: none

The BACT requirements are less stringent for diesel-fired internal combustion engines used in emergency standby non-utility electrical generation than for diesel-fired engines used for other purposes. However, if the emergency engine operates in excess of 200 hours in any one year, a cost effectiveness analysis may be required to determine if additional control is needed.

The South Coast Air Quality Management District's BACT Guideline should be consulted to ensure that the current BACT requirements are applied to this equipment.

1.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, the following conditions must be required:

- THIS ENGINE MUST NOT BE OPERATED MORE THAN 200 HOURS IN ANY ONE YEAR.
- AN ELAPSED TIME METER MUST BE (INSTALLED) (MAINTAINED), SO AS TO INDICATE IN CUMULATIVE HOURS, THE AMOUNT OF TIME THE ENGINE HAS OPERATED.
- THE FUEL OIL SUPPLIED TO THIS ENGINE MUST NOT EXCEED (NUMBER OF) GALLONS IN ANY ONE DAY.
- A FLOW METER MUST BE (INSTALLED) (MAINTAINED) IN THE FUEL SUPPLY LINE, SO AS TO INDICATE IN GALLONS, THE AMOUNT OF FUEL OIL SUPPLIED TO THE ENGINE.

- THE FUEL INJECTION TIMING OF THIS ENGINE MUST BE RETARDED AT LEAST FOUR (4) DEGREES RELATIVE TO STANDARD TIMING.

- THE IGNITION TIMING OF THIS ENGINE MUST BE INSPECTED, ADJUSTED, AND CERTIFIED, AT A MINIMUM, ONCE EVERY THREE YEARS OF OPERATION. INSPECTIONS, ADJUSTMENTS, AND CERTIFICATIONS MUST BE PERFORMED BY A QUALIFIED MECHANIC AND ACCORDING TO THE ENGINE MANUFACTURER'S PROCEDURES.

- AN OPERATING RECORD OF THIS EQUIPMENT MUST BE MAINTAINED IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT, KEPT FOR A MINIMUM OF TWO YEARS, AND MADE AVAILABLE UPON REQUEST OF DISTRICT PERSONNEL. THE RECORD MUST INCLUDE, AT A MINIMUM, THE DAYS AND HOURS OF OPERATION, THE AMOUNT OF FUEL OIL SUPPLIED TO THIS ENGINE, AND THE DATE(S) OF INSPECTION(S), ADJUSTMENT(S), AND CERTIFICATION(S) OF THE IGNITION TIMING OF THIS ENGINE.

REFERENCES

(1) Obert, E. F., "Internal Combustion Engines and Air Pollution Control," Intext Educational Publishers, New York, 1973.

(2) "Stationary Internal Combustion Engines," EPA-450/2-78-125a, July 1979.

(3) Patterson, D. T. and N. A. Henein, "Emissions From Internal Combustion Engines And Their Control," Ann Arbor Service, 1972, pp. 44-45, 117, 128-129.

(4) Compilation of Air Pollution Emission Factors, AP-42, Fourth Edition, September 1985, Table 3.3-1.

APPENDIX 1A

WORKSHEET FOR EMERGENCY DIESEL IC ENGINES

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 4	PAGE 1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

Applicability: This processing form can only be used for emergency diesel-fueled internal internal combustion (IC) engines/generator sets used to generate non-utility electrical power.

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ____________

INTERNAL COMBUSTION ENGINE, , DIESEL-FUELED, EMERGENCY ELECTRICAL GENERATION, MODEL NO. , SERIAL NO. , TURBOCHARGED, AFTERCOOLED, CYLINDERS, TWO/FOUR CYCLE, BHP, WITH EXHAUST(S).

HISTORY:

PROCESS DESCRIPTION:

The engine/generator set will generate _____ kilowatts of emergency electrical power. The engine will be exercised _____ hour(s) per day, _____ day(s) per week, _____ weeks per year. During an extended power failure, the engines may be operated 24 hours per day, 7 days per week. Each engine will consume _____ gallons per hour of No. 2 diesel fuel at the rated full load capacity.

DATA:

	Source
Operating Schedule	
Actual (T_a) : ___ hr/day, ___ day/wk, ___ wk/yr	Applicant
Maximum (T_m) : ___ hr/day, ___ day/wk, ___ wk/yr	Applicant
Engine Brake Horsepower : _____ BHP	"
Exhaust Volume : _____ ACFM (DSCFM)	"
Fuel Consumption Rate (FCR), Diesel (D) : _____ gal/hr	"
NO. 2 Diesel Fuel	"
Sulfur Content : 0.05%	
Density : 7.076 lb/gal	

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES	PAGE
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APPL. NO.	DATE
PROCESSED BY	CHECKED BY

Source
AP-42, Table 3.3-1

Diesel Fuel Emission Factors
* Reactive Organic Gases (ROG) : 0.0445 lb/gal
Oxides of Nitrogen (NO_x) : 0.4690 "
Oxides of Sulfur (SO_x) : 0.0071 "
Carbon Monoxide (CO) : 0.1020 "
Particulate Matter (PM) : 0.0335 "

CALCULATIONS:

1. Emissions

Uncontrolled (R_1) emissions must be multiplied by appropriate operating time (T) factor to determine actual and maximum hourly and daily emissions. (NSR Emissions = Maximum Daily x 1.1)

$$R_1 = EF \times FCR \ (\times T)\ (\times 1.1)$$

Uncontrolled Emissions (R_1)	Actual lb/hr	Max lb/hr	Max lb/day	NSR lb/day
R_1 ROG = 0.3750(D) = lb/hr	____	____	____	____
R_1 NOX = 0.4690(D) = lb/hr	____	____	____	____
R_1 SOX = 0.0071(D) = lb/hr	____	____	____	____
R_1 CO = 0.1020(D) = lb/hr	____	____	____	____
R_1 PM = 0.0335(D) = lb/hr	____	____	____	____

2. Exhaust Gas Flow Rate (DSCFM)

$$F_1 = F_2 \times \frac{T_1 \times P_2}{T_2 \times P_1} \times \left(1 - \frac{M}{100}\right)$$

$$F_1 = \underline{\quad}\ \text{ft}^3/\text{min} \times \frac{{}^\circ R \times \text{in Hg}}{{}^\circ R \times \text{in Hg}} \times \left(1 - \frac{\underline{\quad}}{100}\right)$$

$$= \underline{\quad}\ \text{DSCFM}$$

3. Exhaust Gas Total Particulate Concentration (PC)

$$PC = \frac{\text{lb PM/hr (Max)} \times 7{,}000 \text{ grains/lb}}{\text{ft}^3/\text{min} \times 60 \text{ min/hr}}$$

$$= \underline{\quad\quad}\ \text{grains/dscf}$$

EVALUATION:

RULE 401 : Based on experience with similar equipment, this engine is (is not) expected to comply with the visible emission limits.

RULE 402 : Operating on a standby basis, nuisance complaints are (are not) expected.

RULE 404 : For an exhaust volume of ______ DSCFM, the rule allows a maximum total particulate concentration of ______ grains/DSCF. Calculations indicate a particulate concentration of _____ grains/DSCF. Compliance of Rule 404 is/is not expected.

RULE 431.2 : The Rules and Regulations of the South Coast Air Quality Management District require that the diesel fuel supplied to this equipment must contain less than 0.05 percent sulfur by weight. Compliance of Rule 431.2 is (is not) demonstrated.

RULE 1110.1 : Emergency standby engines operating less than 200 hours in any one calendar year are exempt from this rule. If the emergency standby engine operates in excess of 200 in any one calendar year, a Control Plan is required. The requirements of 1110.1 (have)(have not) been satisfied.

REG XIII : Emergency standby equipment used exclusively for non-utility electrical power generation located at a minor stationary source is exempt from the provisions of Rule 1304(b)(2)(A) & (C) by Rule 1304(c)(1).

BACT : NO_x:ignition timing retarded at least 4° and intercooling for turbocharged engines; and

SO_x : fuel oil containing 0.05% sulfur by weight or less.

BACT (is)(is not) satisfied.

MODELING : Maximum daily emissions of NO_x from this stationary source (will) (will not) exceed Regulation XIII's threshold limit (100 lb/day), therefore, modeling is (is not) required. Modeling results indicate that an increase in emissions from this equipment (will) (will not) cause a violation, or make measurably worse an existing violation of any ambient air quality standards.

CONCLUSIONS/RECOMMENDATIONS:

This engine is expected to (will not) comply with all applicable District Rule and Regulations. The following is recommended:

( ) Issue a Permit to Construct/Operate subject to the following conditions:

CONDITIONS:

1. THIS ENGINE MUST NOT BE OPERATED MORE THAN   HOUR(S) IN ANY ONE DAY AND MORE THAN 200 HOURS IN ANY ONE YEAR.
2. AN ELAPSED TIME METER MUST BE (INSTALLED) (MAINTAINED), SO AS TO INDICATE IN CUMULATIVE HOURS, THE AMOUNT OF TIME THE ENGINE HAS OPERATED.

3. THE FUEL OIL SUPPLIED TO THIS ENGINE MUST NOT EXCEED GALLONS IN ANY ONE DAY.

4. A FLOW METER MUST BE (INSTALLED) (MAINTAINED) IN THE FUEL SUPPLY LINE, SO AS TO INDICATE IN GALLONS, THE AMOUNT OF FUEL OIL SUPPLIED TO THE ENGINE.

5. THE FUEL INJECTION TIMING OF THIS ENGINE MUST BE RETARDED AT LEAST FOUR (4) DEGREES RELATIVE TO STANDARD TIMING.

6. THE IGNITION TIMING OF THIS ENGINE MUST BE INSPECTED, ADJUSTED, AND CERTIFIED, AT A MINIMUM, ONCE EVERY THREE YEARS OF OPERATION. INSPECTIONS, ADJUSTMENTS, AND CERTIFICATIONS MUST BE PERFORMED BY A QUALIFIED MECHANIC AND ACCORDING TO THE ENGINE MANUFACTURER'S PROCEDURES.

7. AN OPERATING RECORD OF THIS EQUIPMENT MUST BE MAINTAINED IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT, KEPT FOR A MINIMUM OF TWO YEARS, AND MADE AVAILABLE UPON REQUEST OF DISTRICT PERSONNEL. THE RECORD MUST INCLUDE, AT A MINIMUM, THE DAYS AND HOURS OF OPERATION, THE AMOUNT OF FUEL OIL SUPPLIED TO THIS ENGINE, AND THE DATE(S) OF INSPECTION(S), ADJUSTMENT(S), AND CERTIFICATION(S) OF THE IGNITION TIMING OF THIS ENGINE.

<u>OR</u>

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) __________ of the Rules and Regulations of the South Coast Air Quality Management District.

SECTION 2

Unconfined Abrasive Blasting

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Section 2

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

Author

Minh H. Pham

Reviewer

Joseph Tramma

Contributor

Joseph Tramma

SECTION 2: UNCONFINED ABRASIVE BLASTING

2.1 General Description

Abrasive blasting is the cleaning or preparing of a surface by forcibly propelling a stream of material against the surface. Some applications of abrasive blasting are:

- Removing rust, scale, or paint;
- Roughening surfaces in preparation for bonding, painting or coating;
- Removing burrs;
- Developing a matte surface finish; and
- Removing flash from molding operations.

In the District, abrasive blasting operations are classified into two general categories: confined and unconfined.

Confined abrasive blasting operations are defined by the California Air Resources Board under Title 17, Subchapter 6 of the California Administrative Code, Section 92000 as follows:

> Confined blasting is any abrasive blasting conducted in an enclosure which significantly restricts air contaminants from being emitted to the atmosphere, including but not limited to shrouding, tanks, drydocks, buildings and structures.

Unconfined blasting operations are conducted outside of an enclosure.

State legislation gives the California Air Resources Board (ARB) authority over abrasive blasting operations. The ARB has set the visible emission and performance standards for unconfined abrasive blasting operations. No district may impose limitations stricter or less strict than those promulgated by the ARB for unconfined abrasive blasting operations. Each individual district remains free to impose limitations on confined abrasive blasting operations. For example, if a storage tank's structure is being abrasive blasted in an open area, the blasting operation is considered unconfined and is subject only to the ARB's limitations adopted by and included in the District's Rules and Regulations. However, if the same tank was used as an enclosure in which abrasive blasting operations were conducted, these abrasive blasting operations would be subject to all applicable District Rules and Regulations.

Since the permit processing standards for confined and unconfined abrasive blasting systems differ significantly, each category will be discussed in separate sections of the Permit Processing Handbook. Section 3 discusses confined abrasive blasting systems. This section will discuss unconfined abrasive blasting systems.

2.1.1 Abrasive Materials

Abrasive materials are generally classified as (i) sand, (ii) metallic shot or grit, and (iii) other. Cost and the properties of the abrasive material dictate their application.

Sand is the least expensive abrasive material. It is commonly used where reclaiming the abrasive is not feasible such as in unconfined abrasive blasting operations. It has a rather high breakdown rate which can result in a dusting problem. The dusting problem limits the sand's use in abrasive blasting cabinets and rooms due to reduced visibility in these enclosures. Synthetic abrasives, such as silicon carbide and aluminum oxide, are becoming popular substitutes for sand. The cost of synthetic abrasives are three to four times that of silica sand. However, they are more durable and lower dusting than sand. They are predominantly used in blasting enclosures and some unconfined blasting operations where abrasive reclaiming is employed.

Metallic abrasives are made from cast iron and steel. Cast iron shot is made by spraying molten cast iron into a water bath. The shot is hard and brittle. Cast iron grit is made by crushing the oversize and irregular particles formed during the manufacture of cast iron shot. Steel shot is produced by blowing molten steel. Steel shot is not as hard as cast iron shot, but is much tougher. Due to the higher costs associated with metallic abrasives, they are predominantly used in abrasive blasting enclosures with abrasive reclaiming equipment.

Glass beads, crushed glass, cut plastics and nutshells are included in the "other" category, and as with synthetic and metallic abrasive materials, they are used in operations where the abrasive material are reclaimed.

The type of abrasive is usually specific to the blasting method. Dry abrasive blasting is usually done with sand, aluminum oxide, silica carbide, metallic grit or shot. Wet blasting is usually done with sand, glass beads, or any materials that will remain suspended in water. Table 2-1 lists several abrasive materials and their applications.

2.1.2 Abrasive Blasting Methods

Typically, all abrasive blasting systems include three basic components: an abrasive blasting pot, a propelling device, and abrasive blasting nozzle(s).

There are three basic types of propelling methods: centrifugal wheels, air pressure, or water pressure. The centrifugal wheels use centrifugal and inertial forces to propel the abrasive media, whereas the air blast uses compressed air. The water blast method uses either compressed air or high pressure water as the propelling force. The most popular methods of propelling the abrasive are air pressure and water pressure. Therefore, this section will only describe these methods.

The compressed air suction, the compressed air pressure, and the wet abrasive blasting systems utilize the air blast method. The hydraulic blasting system utilizes the water blast method.

The compressed air suction system has two rubber hoses connected to a blasting gun. One of the hoses is connected to the compressed-air supply; the other is connected to the bottom of the abrasive supply tank or pot. The gun, as shown in Figure 2-1, consists of an air nozzle that discharges into a larger nozzle. The high velocity air jet (expanding into the larger nozzle) creates a partial vacuum in the chamber. This vacuum draws the abrasive in, then expels it through the discharge nozzle. Figure 2-2 shows a typical suction type blasting machine.

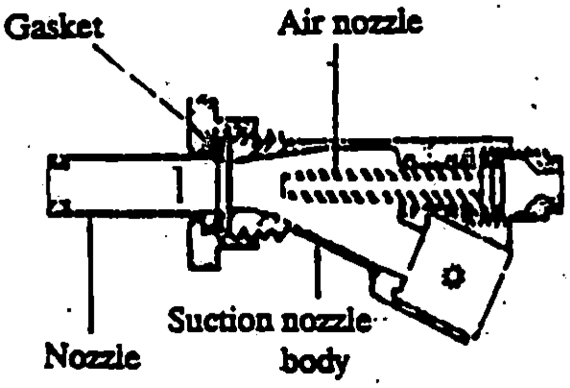

FIGURE 2-1: SUCTION BLAST NOZZLE ASSEMBLY

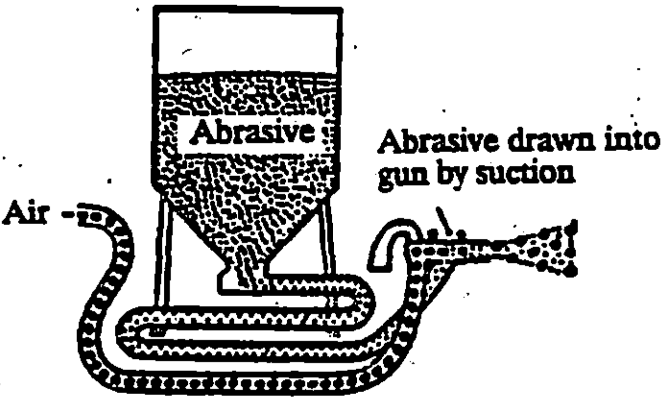

FIGURE 2-2: SUCTION-TYPE BLASTING MACHINE

The compressed air pressure system consists of a pressure tank (pot) in which the abrasive is contained. The use of a pressure tank forces abrasive through the blast hose rather than siphoning it. The compressed air line is connected to both the top and bottom of the pressure tank. This allows the abrasive to flow by gravity into the discharge hose without loss of pressure (see Figure 2-3).

The wet abrasive blasting system (see Figure 2-4) uses a specially designed pressure tank. The mixture of abrasive and water is propelled by compressed air. An alternate method uses a pressure tank and a modified abrasive blasting nozzle. This modified abrasive blasting nozzle is shown in Figure 2-5.

Hydraulic blasting uses high pressure water instead of compressed air as the propelling force.

Pressure blast systems generally give a faster, more uniform finish than suction blast system. They produce high abrasive velocities with less air consumption as compared to suction blast systems. They can operate as low as 1 psig to blast delicate parts and up to pressures of 125 psig to handle the most demanding cleaning and finishing operations.[2]

Suction blast systems are generally selected for light-to-medium production requirements, limited space and moderate budgets. However, suction blast systems can blast continuously, as opposed to pressure blast systems, without stopping for abrasive changes and refills.[2]

2.2 Permit Unit Description

The majority of the unconfined abrasive blasting systems operated in the South Coast Air Basin use compressed air to propel the abrasive. Compressed air for abrasive blasting operations is typically generated by a compressor in close proximity to the blasting equipment. One method to generate compressed air is by an electrically driven air compressor. A second common method of generating compressed air is with a compressor driven by an internal combustion (IC) engine. If a piston type IC engine with a brake horsepower (BHP) rating less than or equal

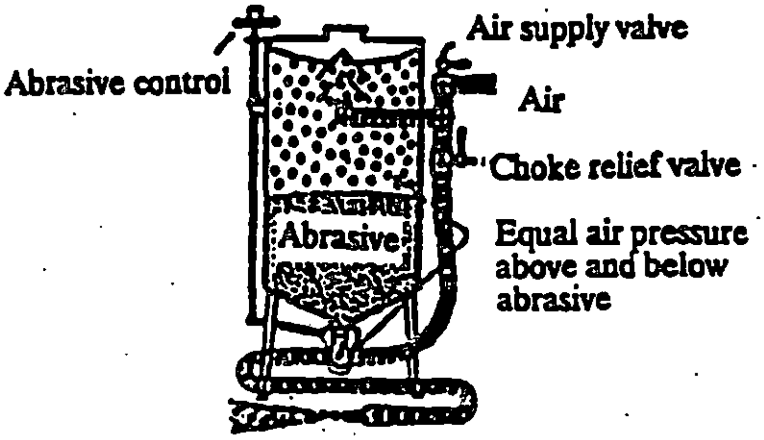

FIGURE 2-3: PRESSURE-TYPE BLASTING MACHINE

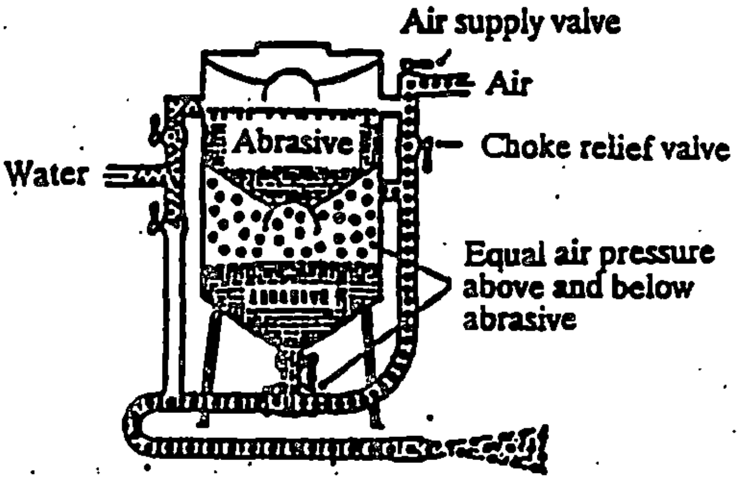

FIGURE 2-4: WET BLASTING MACHINE

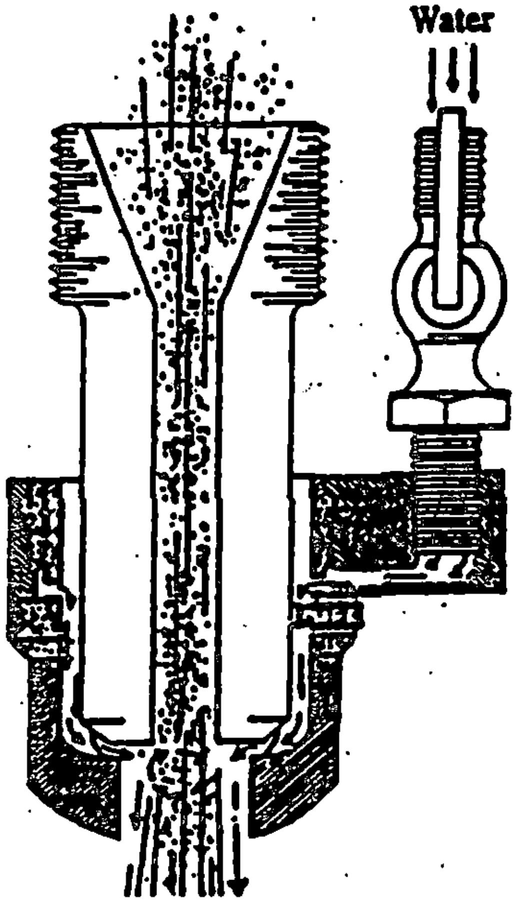

FIGURE 2-5: ADAPTER NOZZLE CONVERTING A DRY BLASTING UNIT TO A WET BLASTING UNIT

Table 2-1: Media Commonly Used In Blasting[a]

Type of medium	Sizes normally available	Applications
Glass beads	8 to 10 sizes from 30- to 440- mesh; also many special gradations	Decorative blending; light deburring; peening general cleaning; texturing; non-contaminating
Aluminum oxide	10 to 12 sizes from 24- to 325-mesh	Fast cutting; matte finishes; descaling and cleaning of coarse and sharp textures
Garnet	6 to 8 sizes (wide-band screening) from 16- to 325-mesh	Noncritical cleaning and cutting; texturing, noncontaminating for brazing steel and stainless steel
Crushed glass	5 sizes (wide-band screening) from 30- to 400-mesh	Fast cutting; low cost; short life; abrasive; noncontaminating
Steel shot	12 or more sizes (close gradation) from 8- to 200-mesh	General-purpose rough cleaning (foundry operation, etc.); peening
Steel grit	12 or more sizes (close gradation) from 10- to 325-mesh	Rough cleaning; coarse textures; foundry welding applications; some texturing
Cut plastic	3 sizes (fine, medium, coarse); definite-size particles	Deflashing of thermoset plastics; cleaning; light deburring
Crushed nutshells	6 sizes (wide-band screening)	Deflashing of plastics; cleaning; very light deburring; fragile parts

a. Reference 1

to the value specified in District Rule 219, "Equipment Not Requiring A Written Permit Pursuant To Regulation II", is used, that engine is included in the permit description of the abrasive blasting system. If the BHP rating is greater than the value specified in Rule 219, the IC engine is evaluated as a separate permit unit.

2.2.1 Unconfined Abrasive Blasting Systems

The permit description wording for an unconfined abrasive blasting system is as follows:

UNCONFINED ABRASIVE BLASTING SYSTEM CONSISTING OF:

1. ABRASIVE BLASTING POT, MANUFACTURER, MODEL NUMBER, POUNDS CAPACITY.

2. ____ABRASIVE BLASTING NOZZLE(S) WITH A MAXIMUM INTERNAL DIAMETER OF ____ IN.

3. INTERNAL COMBUSTION ENGINE, MANUFACTURER'S NAME, DIESEL-FUELED (GASOLINE-FUELED), MODEL NO., SERIAL NO., NO. OF CYLINDERS, TWO/FOUR CYCLE, ENGINE BRAKE HORSEPOWER, DRIVING A COMPRESSOR WITH A MAXIMUM DELIVERY RATE OF ____ CFM AT ____ PSIG.

<u>OR</u>

3. PLANT AIR WITH A MAXIMUM DELIVERY RATE OF ____ CFM AT ____ PSIG.

<u>OR</u>

3. COMPRESSOR, MANUFACTURER'S NAME, MODEL NUMBER, ____ HORSEPOWER RATING, WITH A MAXIMUM DELIVERY RATE OF ____ CFM AT ____ PSIG.

2.3 Emissions

Sources of emission from an unconfined abrasive blasting system are the point of impact of the abrasive media on the surface being blasted, and when used, the exhaust from the internal combustion (IC) engine driving an air compressor. The primary air contaminant resulting directly from the abrasive blasting action is particulate matter (PM). Abrasive blasting systems using an internal combustion (IC) engine must include the products of combustion emissions in the evaluation. The primary air contaminants from the compressor driven by an IC engine are reactive organic gas (ROG), oxides of nitrogen (NOx), oxides of sulfur (SOx), carbon monoxide (CO), and particulate matter (PM). If the IC engine is part of the abrasive blasting system permit unit (see Section 2.4 - Permit Unit Description), both "blasting" and "engine" emissions are summed to determine total emissions. If the IC engine and the abrasive blasting system are separate permit units, the "blasting" and "engine" emissions are attributed to their respective permit unit.

2.3.1 Emission Factors

(A) Blasting Machine:
Table 2-2 lists the emission factors for typical abrasives.

(B) Compressor:
Table 2-3 lists the emission factors for gasoline and diesel fueled internal combustion engines used to drive an the air compressor.

2.4 Calculations

2.4.1 Operational Data

Emission calculations must be performed to determine the compliance status of abrasive blasting system. To determine compliance, the applicant must provide the following information:

Table 2-2: Emission Factors For Abrasives [a]

Abrasive	Emission Factor (lb PM/lb Abrasive)
Sand	0.041
Grit	0.010
Shot	0.004
Other	0.010

[a] Reference 3

Table 2-3: Emission Factors For Gasoline And Diesel Internal Combustion Engines [a]

Air Contaminant	Emission Factor in (lb/gal)	
	Gasoline	Diesel
Reactive Organic Gas (ROG)	0.1320[b]	0.0375
Oxides of Nitrogen (NOx)	0.1020	0.4690
Carbon Monoxide (CO)	3.9400	0.1020
Oxides of Sulfur (SOx)	0.0053	0.0071
Particulate Matter (PM)	0.0065	0.0335

[a] Reference 4 (SO_x emissions for diesel corrected to 0.05% sulfur)

[b] The emission rate of Reactive Organic Gases due to crankcase blowby and evaporation loss of gasoline is 0.221 lbs/hr. Diesel has negligible crankcase blowby and evaporation loss.

Abrasive Used:	Material	(Sand, Grit, Shot, or Other)
	Density	(lb/ft^3)
	Flow Rate	(lb/hr)
Blasting Method:	Dry or Wet	(% of time blasting)
Nozzles:	Number	
	Maximum Internal Diameter	(in)
Blasted Item:	Name	
	Dimensions	(ft)
Compressor:	Maximum Capacity	(cfm at psig)
	Gasoline Consumption Rate	(gal/hr)
	Diesel Consumption Rate	(gal/hr)
Operating Schedule:	Maximum	(hr/day, day/wk, wk/yr)
	Actual	(hr/day, day/wk, wk/yr)

2.4.2 Emission Calculations

Emissions must be calculated for both the actual (average) and maximum operating conditions. Actual emissions are used for emission inventory purposes. Maximum emissions are used to determine compliance with the District's Rules and Regulations.

Actual and maximum hourly (lb/hr) emission rates can be converted to daily (lb/day) emission rates by multiplying the hourly rates by the appropriate equipment daily operational time factor (T, hr/day). In addition, the maximum daily emissions are multiplied by the Regulation XIII On-Site Offset Factor (1.1). These daily emissions increase are accumulated for each facility in the District's New Source Review Record.

2.4.2.1 Process Weight Calculation

To calculate the particulate matter emissions from the blasting, the abrasive flow rate through the nozzle must be known. The flow rate of abrasive through the abrasive blasting nozzle approximates the process weight. If the flow rate is not provided by the applicant, it can be estimated by using the data in Table 2-4 and Equation 2.1.

Table 2-4 lists the flow rate (lb/hr) of sand versus inner diameter (in) of the nozzle at various nozzle pressure (psig). Equation 2.1 adjusts flow rates listed in Table 2-4 for different abrasives and different nozzle diameter.

$$FR = FR_1 \times \frac{(ID)^2}{(ID_1)^2} \times \frac{\rho}{\rho_1} \qquad \textbf{(Equation 2.1)}$$

where:

FR = abrasive flow rate (lb/hr) with nozzle internal diameter ID
FR_1 = sand flow rate (lb/hr) with nozzle diameter ID_1
ρ = density of abrasive (lb/ft^3)
ρ_1 = density of sand (lb/ft^3)
ID = actual nozzle internal diameter (in)
ID_1 = nozzle inner diameter (in) from Table 2-4

2.4.2.2 Uncontrolled Emissions (R_1) Calculations

Uncontrolled PM emission from the nozzle ($R'_{1,PM}$) is determined by:

$$R'_{1,PM} = EF' \times FR \times (1 - w/200) \qquad \textbf{(Equation 2.2)}$$

Uncontrolled emissions (R''_1) of PM, ROG, NOx, SOx and CO from the gasoline or diesel-driven compressor are determined by Equation 2.3:

$$R''_1 = EF'' \times FCR \qquad \textbf{(Equation 2.3)}$$

Table 2-4: **Flow Rate Of Sand Through A Blasting Nozzle As A Function Of Nozzle Pressure And Internal Diameter** [a]

Nozzle Internal Diameter (inches)	Sand Flow Rate Through Nozzle (lb/hr)							
	Nozzle Pressure (psig)							
	30	40	50	60	70	80	90	100
1/8	28	35	42	49	55	63	70	77
3/16	65	80	94	107	122	135	149	165
1/4	109	138	168	195	221	255	280	309
5/16	205	247	292	354	377	420	462	507
3/8	285	355	417	477	540	600	657	720
7/16	385	472	560	645	755	820	905	940
1/2	503	615	725	835	945	1050	1160	1265
5/8	820	990	1170	1336	1510	1680	1850	2030
3/4	1140	1420	1670	1915	2160	2400	2630	2880
1	2030	2460	2900	3340	3780	4200	4640	5060

[a] Reference 5

Table 2-5: **Density Of Abrasive** [a]

Abrasive	Density (lbs/ft^3)
Aluminum Oxides	160
Sand	99
Steel	487

[a] Reference 6

where:

R''_1 = Uncontrolled emissions (lb/hr)
EF'' = Emission Factor (lb/gal) from Table 2-3
FCR = Fuel consumption rate (gasoline or diesel, gal/hr)

The total uncontrolled (R_1) particulate matter (PM) emissions are determined by summing emissions from the nozzle and the compressor driven by an IC engine:

$$R_{1,\,PM} = R'_{1,\,PM} + R''_1(PM) \qquad \textbf{(Equation 2.4)}$$

By incorporating emission factors shown in Tables 2-2 and 2-3, Equation 2.4 can be simplified as follows: (Note that Equation 2.1 can be used to calculate the abrasive flow rate represented by the following variables: s, g, sh, and o.)

$$\begin{aligned}
R_{1,ROG} &= 0.1320(G) + 0.2210 \quad \underline{\text{or}} \\
&= 0.0375(D) \\
R_{1,NOX} &= 0.1020(G) \text{ or } 0.4690(D) \\
R_{1,SOX} &= 0.0053(G) \text{ or } 0.0071(D) \qquad \textbf{(Equation 2.5)} \\
R_{1,CO} &= 3.9400(G) \text{ or } 0.1020(D) \\
R_{1,PM} &= 0.0065(G) \text{ or } 0.0335(D) \\
&\quad + [0.0410(s) + 0.01(g) + 0.004(sh) \\
&\quad + 0.01(o)]\,(1 - w/200)
\end{aligned}$$

where:

R_1 = uncontrolled emissions, lb/hr
G = gal/hr of gasoline
D = gal/hr of diesel
s = lb/hr of sand
g = lb/hr of grit
sh = lb/hr of shot
o = lb/hr of other abrasive material (plastic, glass, etc.)
w = percent of time that wet blasting is performed

2.5 Rules Evaluation

The State of California has set the standards for abrasive blasting operations in Health and Safety Code Sections 41900, 41902, 41904 and 41905. The Health and Safety Code Section 41904 states that the abrasive blasting standards shall be statewide, and no rule and regulation of any district shall be stricter or less strict than the standards adopted by the state board. The Health and Safety Code also authorizes the Air Resources Board to adopt air pollution standards for abrasive blasting operations. The standards adopted by the Air Resources Board are listed under Title 17, Subchapter 6 of the California Administrative Code, Section 92000, 92100, 92200, 92210, 92400, 92500, 92510, 92520, 92530, and 92540. The South Coast Air Quality Management District has adopted abrasive blasting standards based on the California Administrative Code. The standards for the District are listed under Rule 402 and Rule 1140. If the abrasive blasting system includes an internal combustion engine with a rating of 50 brake horsepower (BHP) or more, the applicant (owner/operator) must meet the requirements of Rule 1110.1.

Rule 402 - Nuisance

Abrasive blasting is not expected to cause a public nuisance.

Rule 1110.1 - Emissions From Stationary Internal Combustion Engines

If the abrasive blasting system includes an internal combustion engines with a rating of 50 brake horsepower (BHP) or more and is operated at a specific stationary source for more than one year, the applicant (owner/operator) must submit a Control Plan. The Control Plan must include the following information for each stationary source:

- A list of all engines with the type of engine service and permit or identification number.

- Engine manufacturer, model number, rated brake horsepower, type of fuel and type of ignition.

- List of all engines to be controlled and type of emission controls to be applied to such engines, including construction schedule.

If the BHP rating of the IC engine is greater than the value specified in Rule 219 and is 50 BHP or more, the applicant must submit an application for permit to construct and operate for that engine. The requirements for the Control Plan will be considered during the evaluation for permit to construct and operate.

Rule 1140

1. Unconfined abrasive blasting operation is only allowed when:
   - (A) Steel or iron shot/grit is used;
   - (B) California Air Resource Board (ARB) certified abrasives are used to conduct *dry* unconfined abrasive blasting. Appendix 2B contains the list of ARB certified abrasives; or
   - (C) Wet abrasive blasting is used; and
   - (D) Blasted item exceeds 8 ft in height, 8 ft in width or 10 ft in length; or
   - (E) The structure or surface is blasted at its permanent or ordinary location.

3. Abrasive blasting of stucco and concrete must be performed by wet abrasive blasting, hydroblasting, or vacuum blasting except for special cases listed under 1140(b)(7)

4. Abrasive blasting for pavement marking removal or for surface preparation for raised traffic delineating markers must comply with Rule 1140(b)(5).

5. Visible emissions of 40% opacity (Ringlemann 2) aggregating less than 3 minutes in any one hour period are allowed if the abrasive blasting operation complies with one of the following performance standards:
   - (A) Confined blasting shall be used;
   - (B) Wet abrasive blasting shall be used;
   - (C) Hydroblasting shall be used;

(D) Dry unconfined blasting using ARB certified abrasives; or

(E) Steel shot/grit.

If the abrasive blasting operation does not comply with any of the performance standards listed above, only visible emissions of 20% opacity (Ringlemann 1) aggregating less than three (3) minutes in any one (1) hour period are allowed.

Regulation XIII

Portable abrasive blasting equipment complying with all State laws are exempt from the requirements of Regulation XIII, as per California Health and Safety Code Section 41904.

2.6 Permit (Operating) Conditions

A Permit to Construct/Operate is issued subject to the following conditions:

CONDITIONS

THE DIRECTOR OF ENFORCEMENT MUST BE NOTIFIED OF THE FOLLOWING AT LEAST 48 HOURS PRIOR TO PLACING THE EQUIPMENT IN OPERATION IN THE DISTRICT:

(A) THE LOCATION WHERE THE EQUIPMENT WILL BE OPERATED.

(B) THE ESTIMATED CALENDAR TIME THE EQUIPMENT WILL BE OPERATED AT THE NEW LOCATION.

REFERENCES

(1) Metals Handbook, American Society for Metals, 1985.

(2) "Empire Pro-Finish Systems," Empire Abrasive Equipment Corporation, 1983

(3) Memorandum from J. Tramma to Metallurgical Engineers, Subject: Abrasive Blasting Emission Factors, August 13, 1980.

(4) Compilation of Air Pollution Emission Factors, AP-42, Fourth Edition, September 1985.

(5) Memorandum from J. Nenzell to Metallurgical Processing Engineers, Subject: Abrasive Blasting, March 13,1975.

(6) ASM Metals Reference Book, American Society For Metals, 1981.

APPENDIX 2A

WORKSHEET FOR UNCONFINED ABRASIVE BLASTING

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES	PAGE
3	1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

> Applicability: This processing form can only be used for unconfined blasting system using an air or water blast propelling devices.

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. __________

UNCONFINED ABRASIVE BLASTING SYSTEM CONSISTING OF:

1. ABRASIVE BLASTING POT, POUNDS CAPACITY.

2. ABRASIVE BLASTING NOZZLE(S), WITH A MAXIMUM INTERNAL DIAMETER OF IN.

3. PLANT AIR AT WITH A MAXIMUM DELIVERY RATE OF CFM AT PSIG.

<u>or</u>

3. INTERNAL COMBUSTION ENGINE, DIESEL-(GASOLINE-) FUELED, MODEL NO. , SERIAL NO. , CYLINDERS, TWO (FOUR) CYCLE, BHP, DRIVING A COMPRESSOR WITH A MAXIMUM DELIVERY RATE OF CFM AT PSIG.

<u>or</u>

3. COMPRESSOR, , , HP, WITH A MAXIMUM DELIVERY RATE OF CFM.

HISTORY:

PROCESS DESCRIPTION:

The applicant uses this abrasive blasting system to blast __________. An operator will direct a high velocity stream of __________ at the parts, which will remove rust, paint, and other surface contaminants from the objects. Abrasive cleaning will be conducted ____ hours per day, but due to the nature of the operation, actual abrasive will be flowing through the nozzle ____ hours during that time period. Compressed air is generated by an electrically driven compressor.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES	PAGE
3	2
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

DATA:

	Source
Nozzle Max Internal Dia (ID_2) : ____ in	Applicant
Number, Total : ____	"
Air Pressure, Maximum : ____ PSIG	"
Abrasive Material(s) : ________	"
Sand Flow Rate (FR_1) : ____ lb/hr ____ PSIG	Table 3-4,Eq 3.1
Abrasive Density (ρ) : ____ lb/ft^3	
Sand Density (ρ_1) : 99 lb/ft^3	Table 3-5
Operating Schedule(T) : ____ hr/day, ____ day/wk, ____ wk/yr	Applicant
Equipment Operating Factor : _____ %	"
Type of Blasting (% of time) : Dry (d) ____ Wet (w) ____	"
Max Compressor Operating Capacity : ______ CFM @ ______ PSIG	"
Fuel Consumption Rate (FCR), Gas/Diesel (G/D) : _____ gal/hr	"
Dimensions of Blasted Item : ______ W x ______ L x ______ H	"

CALCULATIONS:

1. Abrasive Flow Rate (FR): $FR = FR_1 \times (ID^2/ID_1^2) \times \rho / \rho_1$

$FR = \_\_\_\_ \text{ lb/hr} \times (\_\_\_\_^2 \text{ in}^2/\_\_\_\_^2 \text{ in}^2) \times (\_\_\_\_ \text{ lb/ft}^3/\_\_\_\_ \text{ lb/ft}^3)$

$= \_\_\_\_ \text{ lb/hr}$

2. Emissions

The uncontrolled (R_1) emissions must be multiplied by appropriate operating time (T) factor to determine actual and maximum hourly and daily emissions. (NSR Emissions = Maximum Daily x 1.1)

Uncontrolled Emissions (R_1)	Actual lb/hr	Max lb/hr	Max lb/day	NSR lb/day
$R_{1\,ROG} = 0.3120(G) + 0.2210$ or $0.375(D)$	____	____	____	____
$R_{1\,NOX} = 0.1020(G)$ or $0.4690(D)$	____	____	____	____
$R_{1\,SOX} = 0.0053(G)$ or $0.0071(D)$	____	____	____	____
$R_{1,CO} = 3.9400(G)$ or $0.1020(D)$	____	____	____	____
$R_{1\,PM}'$ (nozzle) $= [0.041(s) + 0.01(g) + 0.004(sh) + 0.01(o)](1 - W/200)$	____	____	____	____
$R_{1\,PM}''$ (engine) $= 0.0065(G)$ or $0.0335(D)$	____	____	____	____
$R_{1\,PM,Total} = R_{1\,PM}' + R_{1\,PM}''$	____	____	____	____

Revision: 0 Date: 8/18/89

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PROCESSED BY	CHECKED BY

RULES EVALUATION:

RULE 402 : The operation of this equipment (is not) (is) expected to cause public nuisance.

RULE 1140 : 1. Visible emissions (are not) (are) expected to exceed 40% opacity for more than 3 minutes in any 1 hour period.

2. This blasting operation complies with one of the following:
   ☐ Wet abrasive blasting is used.
   ☐ Dry, unconfined blasting is used and one of the following is met:
      ☐ Steel,Iron shot/grit or an ARB certified abrasive is used.
      ☐ Blasted item exceeds one of the following: 8' H. or 8' W. or 10' L.
      ☐ Structure/surface blasted at its permanent/ordinary location.

3. Blasting of stucco and concrete complies with one of the following:
   ☐ Wet blasting, hydroblasting, or vacuum blasting is used;
   ☐ Dry blasting is used on the structures listed under 1140(b)(7).

4. Surface preparation for raised traffic delineating markers and pavement marking removal using abrasive blasting complies with one of the following:
   ☐ Wet blasting, hydroblasting, or vacuum blasting is used.
   ☐ Dry unconfined blasting is used only under the conditions listed under 1140(b)(5)(B).

CONCLUSIONS/RECOMMENDATIONS:

This equipment (is) (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

☐ Issue a Permit to Construct/Operate subject to the following conditions:

CONDITIONS

THE DIRECTOR OF ENFORCEMENT MUST BE NOTIFIED OF THE FOLLOWING AT LEAST 48 HOURS PRIOR TO PLACING THE EQUIPMENT TO OPERATION IN THE DISTRICT:

(A) THE LOCATION WHERE THE EQUIPMENT WILL BE OPERATED.

(B) THE ESTIMATED CALENDAR TIME THE EQUIPMENT WILL BE OPERATED AT THE NEW LOCATION.

OR

☐ Deny the Permit to Construct/Operate. It is my opinion that the operation of this equipment will cause a violation of Rule (402)(1140) of the Rules and Regulations of the South Coast AQMD.

APPENDIX 2B

CALIFORNIA AIR RESOURCES BOARD CERTIFIED ABRASIVES

California Air Resources Board Certified Abrasives

Pursuant to California Administrative Code, Subchapter 6, Section 92520(b), the Air Resources Board is required to certify the abrasives used for dry, unconfined blasting comply with specific performance standards as set forth in the code.

Executive Order G-390 of Air Resources Board lists the abrasive materials that are certified for until May 20, 1988. The Executive Order is updated every year. Questions regarding the test method evaluation, the certification process, and the updated Executive Order in the future can be directed to Gary Zimmerman, Manager of the Source Testing Section, Air Resources Board at (916)322-2886.

The following list of certified abrasives is taken from the Executive Order G-390.

1.	Blackhawk Slag Products	Blackwawk Utility Blackwawk Medium Blackwawk Fine
2.	California Silica Products Company	#16 #20 #30
3.	Corona Industrial Sand Company	Cisco #12 #16 #20 #30
4.	Earthguard Pollution Control Company	Earthguard Premium Abrasives EPA-A EPA-D EPA-B EPA-A-E EPA-C
5.	E.I. du Pont de Nemours & Company, Inc.	Coarse Staurolite
6.	P.W. Gillibrand	Gillibrand #16 Silver #20 Silver #30 Silver

7.	Gordon Sand Company	Golden Flint G-16 G-20 G-30 Lapis Luster G-12
8.	Grangrit, Inc. - Stan-Blast	Gangrit Medium
9.	Halliburton Industrial Sevices	Halco Blast - Coarse Halco Blast - Medium
10.	Harsco Corporation	Green Diamond 1040 Green Diamond 1636 Green Diamond 1650 Green Diamond 2050 Black Beauty 1240 Black Beauty 2040
11.	Hedrick-Apache, Inc.	Apache-Blast 12-50
12.	Leisure Investment Company	Kleen Blast 16 - 30 Kleen Blast 35 Kleen Blast 16 Kleen Blast 8 - 12 Kleen Blast 30 - 60
13.	Lone Star Industries, Inc.	Lapis Lustre and Clementina No. 3 No. 2/16, No. 1/20, No. 0/30, No. 1C, No. 2/12
14.	Minerals Research and Recovery Of Arizona, Inc.	F-80 M-60 U-40
15.	Monterey Sand Company	Crystal Amber #3 Crystal Amber #2/Monterey #16 Crystal Amber #2/Monterey #20 Crystal Amber #1C Crystal Amber #1 Crystal Amber #0/Monterey#30
16.	Myers Metals & Minerals, Inc.	Grade #25
17.	Paull & Griffin Company	U.S. Technology
18.	Rocky Mountain Energy Company	Copper Blast Coarse Copper Blast Medium Copper Blast MSR (fine)
19.	Stan-Blast Abrasive Company, Inc.	Stan Blast - Heavy Stan Blast - Medium

20.	Unimin Corporation	Granusil #16 Granusil #20 Uni-Blast #3
21.	U.S. Silica Company Of California	No. 12 No. 16 No. 20 No. 30
22.	Virginia Materials Corporation	VMC Black Blast VMC #2
23.	RDM Multi-Enterprises, Incorporated	Ferro-Blast

SECTION 3

Confined Abrasive Blasting Cabinets/Rooms

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Section 3

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

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SECTION 3: CONFINED ABRASIVE BLASTING CABINETS/ROOMS

3.1 General Description

Abrasive blasting is the cleaning or preparing of a surface by forcibly propelling a stream of material against the surface. Some applications of abrasive blasting are:

- Removing rust, scale, or paint
- Roughening surfaces in preparation for bonding, painting or coating
- Removing burrs
- Developing a matte surface finish
- Removing flash from molding operations.

In the District, abrasive blasting operations are classified into two general categories: confined and unconfined.

Confined abrasive blasting operations are defined by the California Air Resources Board under Title 17, Subchapter 6 of the California Administrative Code, Section 92000 as follows:

> Confined blasting is any abrasive blasting conducted in an enclosure which significantly restricts air contaminants from being emitted to the atmosphere, including but not limited to shrouding, tanks, drydocks, buildings and structures.

Unconfined blasting operations are conducted outside of an enclosure.

State legislation gives the California Air Resources Board (ARB) authority over abrasive blasting operations. The ARB has set the visible emission and performance standards for unconfined abrasive blasting operations. No district may impose limitations stricter or less strict than those promulgated by the ARB for unconfined abrasive blasting operations. Each individual district remains free to impose limitations on confined abrasive blasting operations. For example, if a storage tank's structure is being abrasive blasted in an open area, the blasting operation is considered unconfined and is not subject to the District's Rules and Regulations. However, if the same tank was used as an enclosure in which abrasive blasting operations were conducted, these abrasive blasting operations would be subject to all applicable District Rules and Regulations.

Since the permit processing standards for confined and unconfined abrasive blasting systems differ significantly, each category will be discussed in separate sections of the Permit Processing Handbook. Section 2 discusses unconfined abrasive blasting systems. This section will discuss two confined abrasive blasting operations that are vented to an air pollution control system: abrasive blasting cabinets and abrasive blasting rooms.

3.1.1 Abrasive Materials

Abrasive materials are generally classified as (i) sand, (ii) metallic shot or grit, and (iii) other. Cost and the properties of the abrasive material dictate their application.

Sand is the least expensive abrasive material. It is commonly used where reclaiming the abrasive is not feasible such as in unconfined abrasive blasting operations. It has a rather high breakdown rate which can result in a dusting problem. The dusting problem limits the sand's use in abrasive blasting cabinets and rooms due to reduced visibility in these enclosures. Synthetic abrasives, such as silicon carbide and aluminum oxide, are becoming popular substitutes for sand. The cost of synthetic abrasives are three to four times that of silica sand. However, they are more durable and lower dusting than sand. They are predominantly used in blasting enclosures and some unconfined blasting operations where abrasive reclaiming is employed.

Metallic abrasives are made from cast iron and steel. Cast iron shot is made by spraying molten cast iron into a water bath. The shot is hard and brittle. Cast iron grit is made by crushing the oversize and irregular particles formed during the manufacture of cast iron shot. Steel shot is produced by blowing molten steel. Steel shot is not as hard as cast iron shot, but is much tougher. Due to the higher costs associated with metallic abrasives, they are predominantly used in abrasive blasting enclosures with abrasive reclaiming equipment.

Glass beads, crushed glass, cut plastics and nutshells are included in the "other" category, and as with synthetic and metallic abrasive materials, they are used in operations where the abrasive material are reclaimed.

The type of abrasive is usually specific to the blasting method. Dry abrasive blasting is usually done with sand, aluminum oxide, silica carbide, metallic grit or shot. Wet blasting is usually done with sand, glass beads, or any materials that will remain suspended in water. Table 3-1 lists several abrasive materials and their applications.

3.1.2 Abrasive Blasting Methods

Typically, all abrasive blasting systems include three basic components: an abrasive blasting pot, a propelling device, and abrasive blasting nozzle(s). A permanent enclosure, in which abrasive blasting operations are conducted, abrasive reclaiming devices, conveyors, elevators, and air pollution control devices, ect. can also be part of the abrasive blasting system.

There are three basic types of propelling methods: centrifugal wheels, air pressure or water pressure. The centrifugal wheels use centrifugal and inertial forces to propel the abrasive media, whereas the air blast uses compressed air. The water blast method uses either compressed air or high pressure water as the propelling force. The most popular methods of propelling the abrasive are air pressure and water pressure.

The compressed air suction, the compressed air pressure, and the wet abrasive blasting systems utilize the air blast method. The hydraulic blasting system utilizes the water blast method.

The compressed air suction system has two rubber hoses connected to a blasting gun. One of the hoses is connected to the compressed-air supply; the other is connected to the bottom of the abrasive supply tank or pot. The gun, as shown in

Table 3-1: Media Commonly Used In Blasting [a]

Type of medium	Sizes normally available	Applications
Glass beads	8 to 10 sizes from 30- to 440- mesh; also many special gradations	Decorative blending; light deburring; peening general cleaning; texturing; non-contaminating
Aluminum oxide	10 to 12 sizes from 24- to 325-mesh	Fast cutting; matte finishes; descaling and cleaning of coarse and sharp textures
Garnet	6 to 8 sizes (wide-band screening) from 16- to 325-mesh	Noncritical cleaning and cutting; texturing, noncontaminating for brazing steel and stainless steel
Crushed glass	5 sizes (wide-band screening) from 30- to 400-mesh	Fast cutting; low cost; short life; abrasive; noncontaminating
Steel shot	12 or more sizes (close gradation) from 8- to 200-mesh	General-purpose rough cleaning (foundry operation, etc.); peening
Steel grit	12 or more sizes (close gradation) from 10- to 325-mesh	Rough cleaning; coarse textures; foundry welding applications; some texturing
Cut plastic	3 sizes (fine, medium, coarse); definite-size particles	Deflashing of thermoset plastics; cleaning; light deburring
Crushed nutshells	6 sizes (wide-band screening)	Deflashing of plastics; cleaning; very light deburring; fragile parts

[a] Reference 1

Figure 3-1, consists of an air nozzle that discharges into a larger nozzle. The high velocity air jet (expanding into the larger nozzle) creates a partial vacuum in the chamber. This vacuum draws the abrasive in, then expels it through the discharge nozzle. Figure 3-2 shows a typical suction type blasting machine.

The compressed air pressure system uses a pressure tank (pot) in which the abrasive is contained . The use of a pressure tank forces abrasive through the blast hose rather than siphoning it. The compressed air line is connected to both the top and bottom of the pressure tank. This allows the abrasive to flow by gravity into the discharge hose without loss of pressure (see Figure 3-3).

The wet abrasive blasting system, as shown in Figure 3-4, uses a specially designed pressure tank. The abrasive supply tank (pot) is flooded with water. The mixture of abrasive and water is propelled by compressed air. An alternate method uses a pressure tank and a modified abrasive blasting nozzle. This modified abrasive blasting nozzle is shown in Figure 3-5.

Hydraulic blasting uses high pressure water instead of compressed air as the propelling force.

Pressure blast systems generally give a faster, more uniform finish than suction blast system. They produce high abrasive velocities with less air consumption as compared to suction blast systems. They can operate as low as 1 psig to blast delicate parts and up to pressures of 125 psig to handle the most demanding cleaning and finishing operations. [2]

Suction blast systems are generally selected for light-to-medium production requirements, limited space and moderate budgets. However, suction blast systems can blast continuously, as opposed to pressure blast systems, without stopping for abrasive changes and refills. [2]

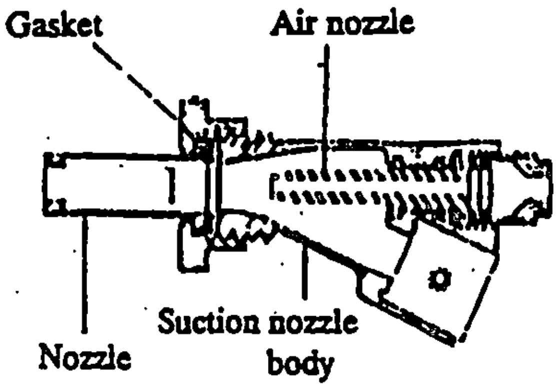

FIGURE 3-1: SUCTION BLAST NOZZLE ASSEMBLY

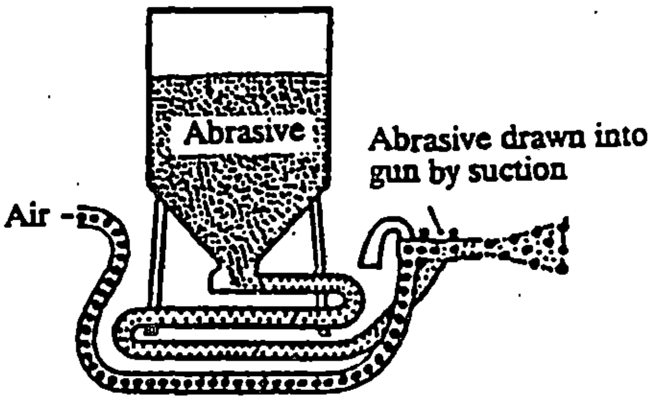

FIGURE 3-2: SUCTION-TYPE BLASTING MACHINE

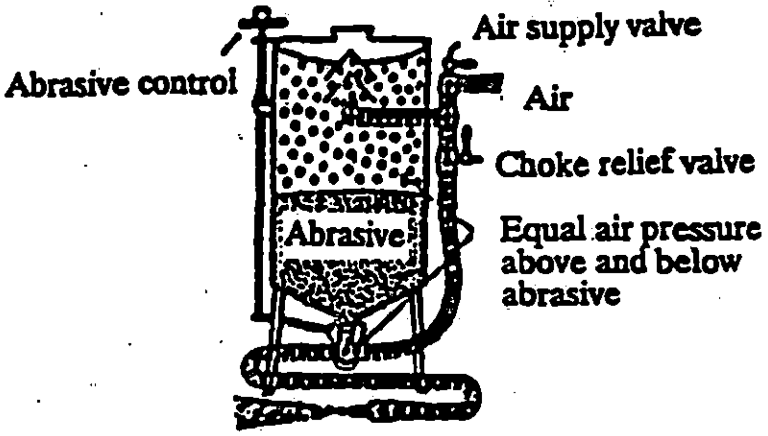

FIGURE 3-3: PRESSURE-TYPE BLASTING MACHINE

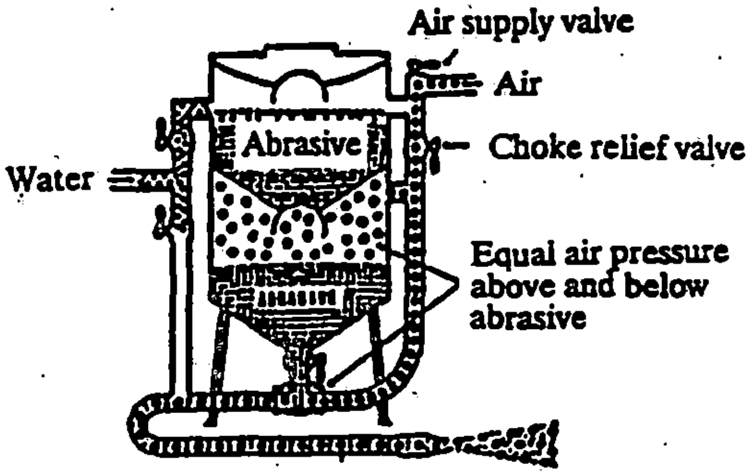

FIGURE 3-4: WET BLASTING MACHINE

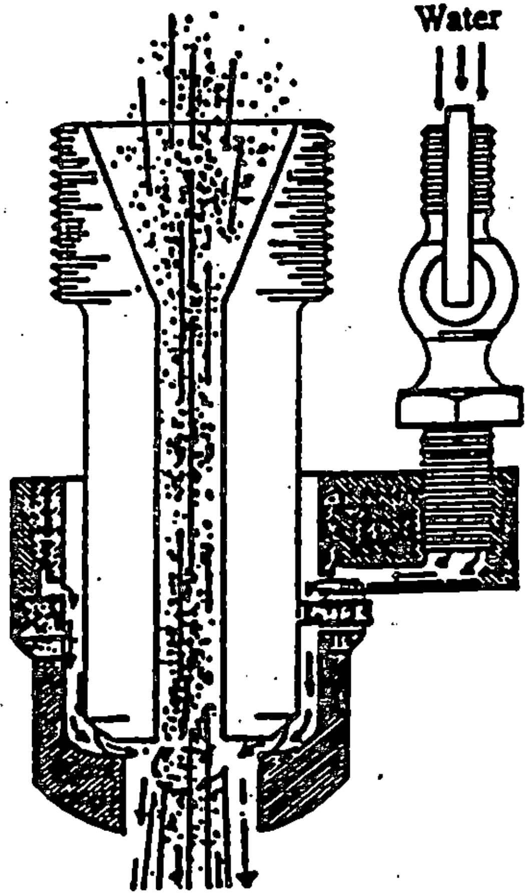

FIGURE 3-5: ADAPTER NOZZLE CONVERTING A DRY BLASTING UNIT TO A WET BLASTING UNIT

3.1.3 Abrasive Blasting Enclosures

The two most commonly used enclosures in confined abrasive blasting are abrasive blasting cabinets and abrasive blasting rooms.

3.1.3.1 Abrasive Blasting Cabinets

The blasting cabinet is a relatively small enclosure frequently used to clean or prepare small parts. The internal working volume typically ranges from one cubic foot upwards to seventy-two cubic feet. The operator works outside the cabinet. He passes his hands and arms, protected by heavy rubber gloves, through sealed openings in the cabinet front. The operator manipulates the blasting gun (nozzle) and positions the objects to be abrasive blasted with his hands and varies the abrasive flow rate and action by a treadle type control valve. Stepping on the foot treadle starts the blast; releasing it stops the blast instantly. Figure 3-6 and Figure 3-7 show a typical abrasive blasting glove and gun and abrasive blasting cabinet, respectively.

The cabinets are equipped with either a front or side loading door and a large dust tight view window. The cabinet is illuminated for maximum vision by a lamp located on the ceiling of the cabinet. The lamp is protected from dust and abrasives by a fine mesh screen.

As the operator directs the high velocity stream of abrasive material at the object(s) being blasted, the heavier materials generated by the cleaning action fall through the floor grate above the cabinet hopper. The lighter entrained particulate matter is directed to an air pollution control (APC) device by an exhaust blower. The APC system can be included (integral, manufactured as a common unit) with the cabinet or it can be a separate, distinct external system. The most commonly used APC devices for dry abrasive blasting operations are tube- or cartridge-type baghouses (or dust collectors). As a matter of convention, the District defines cloth filter devices with a minimum of 400 square feet of actual filter cloth area as a baghouse, while those with less than 400 cubic feet are dust collectors.

FIGURE 3-6: ABRASIVE BLASTING GLOVE AND GUN

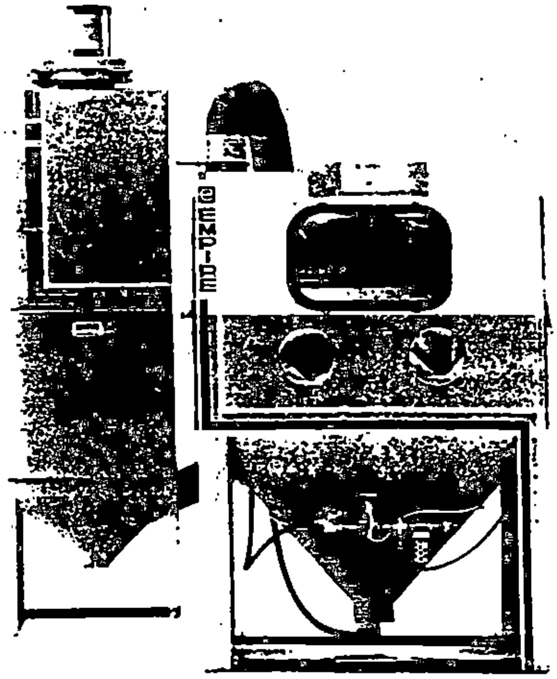

FIGURE 3-7: ABRASIVE BLASTING CABINET AND BAGHOUSE

To replace the air which is removed from the cabinet by the exhaust system, a baffled air intake is located in the front roof section of the cabinet. As the particulate entrained air is drawn towards the back bottom portion of the blasting cabinet, an equal volume of fresh air is drawn into the cabinet through the air intake port. The movement or velocity of air from the front top section towards the back bottom section results in a sweeping action inside the cabinet that enhances the operator's view of the operation.

3.1.3.2 Abrasive Blasting Rooms

The oldest and most widely used device to confine and control abrasive blasting operations is a blasting room. (3) The blasting room is similar to an abrasive blasting cabinet, except that the operator is located inside the room. The rooms typically include an automatic abrasive recovery system.

Blasting rooms vary widely in construction. The contemporary design is a prefabricated reinforced steel room with floor grating and a completely automatic abrasive recovery system. The rooms have either single or double main doors, and a smaller size man-door. Typically, one or both side walls or the front wall can be completely opened for easier access to the room. The rooms are equipped with monorail conveyors, rail cars or rotating tables to assist the operator in handling the large and heavy objects. Older designs include rooms of wooden, concrete or brick construction and usually do not include recovery systems or equipment to assist the operator.

As the operator directs the high velocity stream of abrasive material at the object(s) being blasted, the heavier materials generated by the cleaning action fall through the perforated floor plate of the room. Floor conveyors, elevators, and blowers transport the spent abrasive and abraded materials to screens and cyclones to separate the components. The abrasive is returned to the abrasive hopper while the undesirable material is collected for disposal. The floor conveyors, elevators, and other similar conveying and reclaiming equipment are collectively referred to as the abrasive reclaim system.

The lighter entrained particulate matter is directed to an air pollution control (APC) device by an exhaust blower. The most commonly used APC devices are tube-type baghouses or cartridge dust collectors.

To replace the air which is removed from the room by the exhaust system, air intakes are added. The air intakes are located in the front or top sections of the room opposite the exhaust air intakes. They include rain deflecting louvers and baffles. Air intake ports located in the front section of the blasting room result in a movement (velocity) of air called a crossdraft. Air intake ports located in the roof section of the blasting room create a downdraft. Minimum crossdraft and downdraft velocities, in addition to other structural guidelines, are listed in Appendix 3B, "Guidelines For Basic Design of Abrasive Blasting Enclosures and Their Associated Air Pollution Control Equipment." A typical abrasive blasting room is shown in Figure 3-8.

3.2 Permit Unit Description

The majority of the abrasive blasting cabinets and rooms operated in the South Coast Air Basin use compressed air to propel the abrasive. Compressed air for abrasive blasting operations is typically generated by an electrically driven air compressor in close proximity to the blasting equipment.

If the abrasive blasting cabinet or room is vented to an external air pollution control (APC) system, that APC system must be evaluated as a separate permit unit. Those abrasive blasting systems with an integral APC system (baghouse) must include the APC in the abrasive blasting system permit description.

3.2.1 Abrasive Blasting Cabinet

The permit description wording for an abrasive blasting cabinet is as follows:

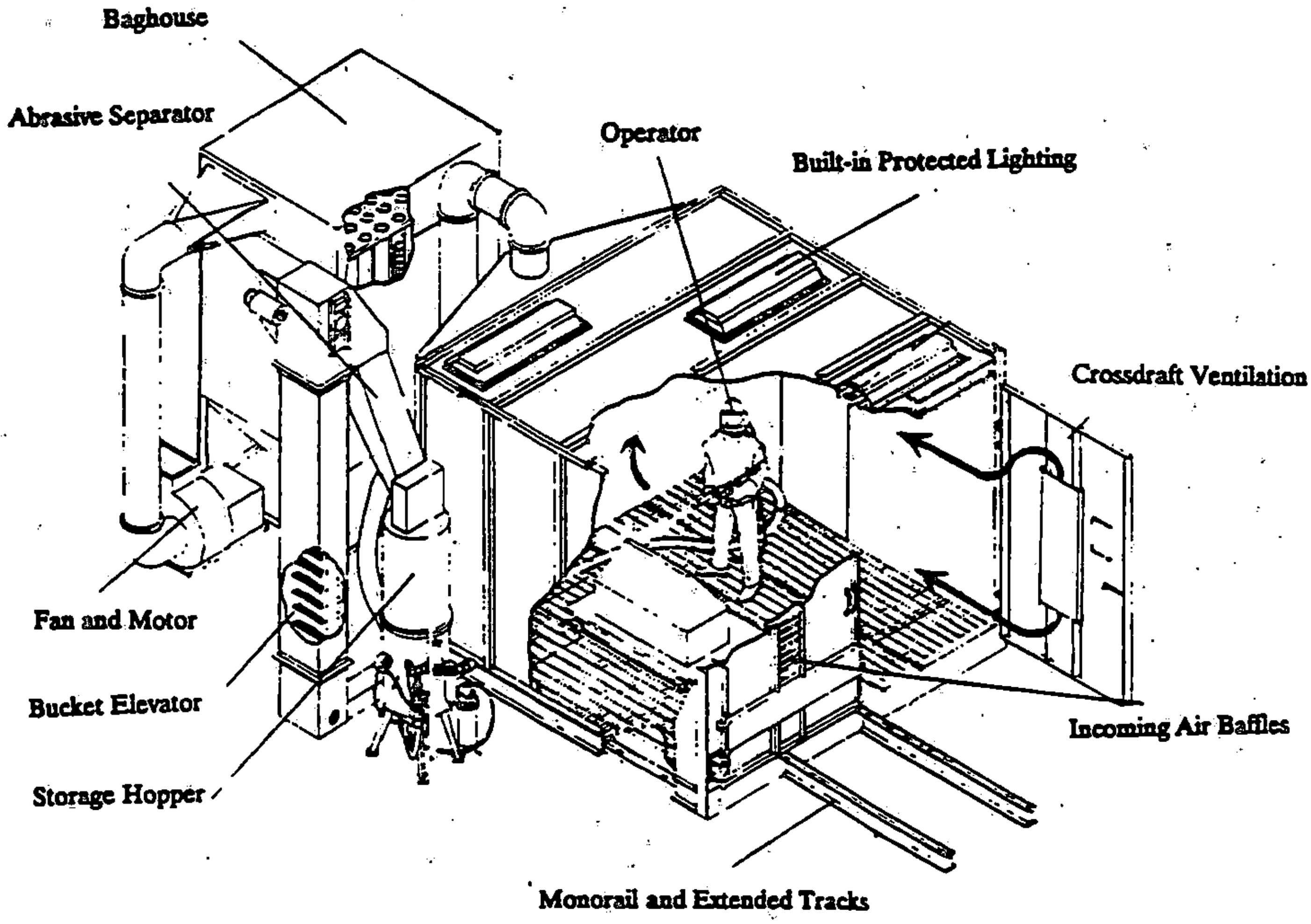

FIGURE 3-8: ABRASIVE BLASTING ROOM AND BAGHOUSE

ABRASIVE BLASTING SYSTEM CONSISTING OF:

1. CABINET, MANUFACTURER,MODEL NUMBER, (INTERNAL DIMENSIONS) WIDTH x LENGTH x HEIGHT.
2. PRESSURE POT, MANUFACTURER, MODEL NUMBER, POUNDS CAPACITY.
3. ____ NOZZLE(S) WITH A MAXIMUM INTERNAL DIAMETER OF ____ IN.
4. PLANT AIR WITH A MAXIMUM DELIVERY RATE OF ____ CFM AT ____ PSIG.

Additional equipment associated with the abrasive blasting cabinet such as an abrasive reclaimer must be included in the permit wording description and must conform with the District's permit wording description standards.

3.2.2 Abrasive Blasting Cabinet With Integral Control

The permit description wording for an abrasive blasting cabinet with integral is as follows:

ABRASIVE BLASTING SYSTEM WITH INTEGRAL CONTROL CONSISTING OF:

1. CABINET, MANUFACTURER,MODEL NUMBER, (INTERNAL DIMENSIONS) WIDTH x LENGTH x HEIGHT.
2. PRESSURE POT, MANUFACTURER, MODEL NUMBER, POUNDS CAPACITY.

3. ___ NOZZLE(S) WITH A MAXIMUM INTERNAL DIAMETER OF ___ IN.

4. PLANT AIR WITH A MAXIMUM DELIVERY RATE OF ___ CFM AT ___ PSIG.

5. INTEGRAL (BAGHOUSE) (DUST COLLECTOR) WITH ___ (FILTER BAGS) (CARTRIDGES), (____ SQ. FT. ACTUAL FILTER AREA), (DIAMETER x LENGTH), AND A ___ HP BLOWER

Additional equipment associated with the abrasive blasting cabinet such as an abrasive reclaimer must be included in the permit wording description and must conform with the District's permit wording description standards.

3.3.3 Abrasive Blasting Room

The permit description wording for an abrasive blasting room is as follows:

ABRASIVE BLASTING SYSTEM CONSISTING OF:

1. ROOM, MANUFACTURER,MODEL NUMBER, (DIMENSIONS) WIDTH x LENGTH x HEIGHT.

2. PRESSURE POT, MANUFACTURER, MODEL NUMBER, POUNDS CAPACITY.

3. ___ NOZZLE(S) WITH A MAXIMUM INTERNAL DIAMETER OF ___ IN.
4. PLANT AIR WITH A MAXIMUM DELIVERY RATE OF ___ CFM AT ___ PSIG.

Additional equipment associated with the abrasive blasting room (abrasive reclaimers, conveyors, elevators) must be included in the permit wording description and must conform with the District's permit wording description standards.

3.3 Emissions

Emission from a confined abrasive blasting system result from the discharged abrasive material impacting a surface. The primary air contaminant resulting directly from the abrasive blasting action is particulate matter (PM). Most abrasive blasting cabinets or rooms use plant (facility) compressed air which is derived from an electrically-driven compressor.

3.3.1 Emission Factors

Table 3-2 lists the emission factors for typical abrasives:

Table 3-2: Emission Factors For Abrasives [a]

Abrasive	Emission Factor (lb PM/lb Abrasive)
Sand	0.041
Grit	0.010
Shot	0.004
Other	0.010

[a] Reference 4

3.4 Calculations

3.4.1 Operational Data

Emission calculations must be performed to determine the compliance status of abrasive blasting system. To determine compliance, the applicant must provide the following information:

Abrasive used:	Material	(Sand, Grit, Shot, or Other)
	Density	(lb/ft^3)
pry		
	Flow Rate	(lb/hr)
Blasting Type:	Dry or Wet	(% of time blasting)
Nozzles:	Number of Nozzles	
	Maximum Inner Diameter	(in)
Blasted Item:	Name	
	Dimensions	(ft)
Compressor:	Maximum Capacity	(cfm at psig)
Operating Schedule:	Maximum	(hr/day, day/wk, wk/yr)
	Actual	(hr/day, day/wk, wk/yr)

3.4.2 Emission Calculations

Emissions must be calculated for both the actual (average) and maximum operating conditions. Actual emissions are used in emission inventory. Maximum emissions are used to determine compliance with the District's Rules and Regulations.

Actual and maximum hourly (lb/hr) emission rates must be converted to daily (lb/day) emission rates by multiplying the hourly rates by the appropriate equipment daily operational time factor (T, hr/day). In addition, the maximum daily emissions are multiplied by the Regulation XIII On-Site Offset Factor (1.1). These daily emissions increase are accumulated for each facility in the District's New Source Review Record.

3.4.2.1 Process Weight Calculation

To calculate the particulate matter emissions from the abrasive blasting operation, the abrasive flow rate through the nozzle must be known. The flow rate of abrasive through the abrasive blasting nozzle approximates the process weight. If the flow rate is not provided by the applicant, it can be estimated by using the data in Table 3-4 and Equation 3.1. Table 3-4 lists the flow rate (lb/hr) of sand versus internal diameter (in) of the nozzle at various nozzle pressures (psig). Equation 3.1 adjusts flow rates listed in Table 3-4 for different abrasives and different nozzle diameter.

$$FR = FR_1 \times \frac{(ID)^2}{(ID_1)^2} \times \frac{\rho}{\rho_1} \qquad \textbf{(Equation 3.1)}$$

where:
FR = abrasive flow rate (lb/hr) with nozzle internal diameter ID
FR_1 = <u>sand</u> flow rate (lb/hr) with nozzle diameter ID_1
ρ = density of abrasive (lb/ft^3)
ρ_1 = density of sand (lb/ft^3)
ID = actual nozzle internal diameter (in)
ID_1 = nozzle internal diameter (in) from Table 3-4

3.4.2.2 Uncontrolled Emissions (R_1) Calculations

Uncontrolled PM emission from the nozzle (R_1') is determined by:

$$R_1 = EF \times FR \times (1 - w/200) \qquad \textbf{(Equation 3.2)}$$

where:
R_1 = uncontrolled PM emission from the nozzle (lb/hr)
EF = emission factor (lb PM/lb abrasive) from Table 3-1
FR = flow rate of abrasive through the nozzle (lb/hr), Eqn. 3.1

w = percent of time wet blasting. The expression (1 - w/200) denotes that wet blasting emissions are estimated to be 50% less than dry blasting emissions)

Table 3-4: Flow Rate Of Sand Through A Blasting Nozzle As A Function Of Nozzle Pressure And Inner Diameter [a]

Nozzle Diameter (inches)	Sand Flow Rate Through Nozzle (lb/hr) Nozzle Pressure (psig) 30	40	50	60	70	80	90	100
1/8	28	35	42	49	55	63	70	77
3/16	65	80	94	107	122	135	149	165
1/4	109	138	168	195	221	255	280	309
5/16	205	247	292	354	377	420	462	507
3/8	285	355	417	477	540	600	657	720
7/16	385	472	560	645	755	820	905	940
1/2	503	615	725	835	945	1050	1160	1265
5/8	820	990	1170	1336	1510	1680	1850	2030
3/4	1140	1420	1670	1915	2160	2400	2630	2880
1	2030	2460	2900	3340	3780	4200	4640	5060

[a] Reference 6

The density of several popular abrasives are listed in Table 3-5.

Table 3-5: Density Of Abrasive [a]

Abrasive	Density (lbs/ft^3)
Aluminum Oxides	160
Sand	99
Steel	487

[a] Reference 7

3.4.2.3 Controlled Emissions (R_2) Calculations

Particulate matter evolved by the abrasive blasting are reduced prior to discharge into the atmosphere by an air pollution control (APC) system. The most common (APC) system for an abrasive blasting cabinet or room is a baghouse and its' exhaust blower (fan). The reduction in particulate matter is calculated by Equation 3.6 as shown below:

$$R_2 = R_1 \times (1 - \eta) \qquad \text{(Equation 3.6)}$$

where:

R_2 = Controlled particulate matter emission rate (lb/hr)

R_1 = Uncontrolled particulate matter emission rate (lb/hr) from blasting

η = Efficiency of baghouse (as a decimal)

3.4.3 Total Particulate Matter Emission - Concentration

The total particulate matter mass emission rate (lb/hr) must be converted into total particulate matter concentration (grains/dscf). The particulate matter concentration is calculated by:

$$C = \frac{R_2 \times 7000 \text{ (grains/lb)}}{F \times 60 \text{ (min/hr)}} \qquad \textbf{(Equation 3.8)}$$

where:

C = Particulate matter concentration (grains/dscf)
R_2 = Total particulate matter emission rate (lb/hr)
F = Exhaust air flow rate in dry standard cubic feet per minute (dscfm)

3.4.4 Abrasive Blasting Enclosure Design Calculations

3.4.3.1 Abrasive Blasting Cabinet Design Calculation

The design ventilation rate for abrasive blasting cabinets is the number of air changes that occur per minute. The design ventilation rate is calculated using Equation 3.9.

$$DVR = \frac{VFR}{CAB_{vol}} \qquad \textbf{(Equation 3.9)}$$

where:

DVR = Design ventilation rate (air changes per minute)
VFR = Air volumetric flow rate, exhaust blower (ft^3/min)
CAB_{vol} = Internal volume of cabinet

3.4.3.2 Abrasive Blasting Room Design Calculations

As air in the blasting room is drawn out by the exhaust blower of the air pollution control system, it must be replaced with an equal volume of air. Minimum air velocities through the room and through the air inlet ports must be achieved to ensure proper collection of the particulate entrained air.

3.4.3.2.1 Crossdraft Velocity Calculation

Air inlet port(s) located on the wall opposite the exhaust section of the blasting room result a movement (velocity) of air known as the crossdraft. Crossdraft is calculated as follows:

$$V_c = \frac{VFR}{A_f} \qquad \text{(Equation 3.10)}$$

where:

V_c = Crossdraft velocity (ft/min)

VFR = Air volumetric flow rate, exhaust blower (ft^3/min)

A_f = Cross-sectional area of the front wall (ft^2)

3.4.3.2.2 Downdraft Velocity Calculation

Air inlet port(s) located in the ceiling of the blasting room result in a movement (velocity) of air known as the downdraft. Downdraft is calculated as follows:

$$V_d = \frac{VFR}{A_c} \qquad \text{(Equation 3.11)}$$

where:

V_d = Downdraft velocity (ft/min)

VFR = Air volumetric flow rate, exhaust blower (ft^3/min)

A_c = Cross-sectional area of the ceiling (ft^2)

3.4.3.2.3 Air Inlet Port Velocity Calculation

The velocity of air through the air inlet port(s) can be calculated by Equation 3.12.

$$V_i = \frac{VFR}{A_p} \qquad \text{(Equation 3.12)}$$

where:

V_i = Velocity of air through air inlet port(s) (ft/min)

VFR = Air volumetric flow rate, exhaust blower (ft^3/min)

A_p = Cross-sectional area of the air inlet ports (ft^2)

3.4.5 Baghouse (Filter Bags/Cartridges) Design Calculation

The air-to-cloth (A/C) ratio can be calculated using Equation 3.13.

$$A/C = \frac{VFR}{A_b} \quad \text{(Equation 3.13)}$$

where:

A/C = Air-to-Cloth ratio (ft/min)

VFR = Air volumetric flow rate, exhaust blower (ft^3/min)

A_b = Actual filter cloth area of bags or cartridges (ft^2)

3.5 Rules Evaluation

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing the permit.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 404 - Particulate Matter - Concentration
Limits for particulate matter concentrations in an effluent gas stream at standard conditions are listed in Table 404(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 405 - Particulate Matter - Weight

Limits for particulate matter emission rates from any source are listed in Table 405(a) of the South Coast Air Quality Management District's Rules and Regulations.

The total flow rate through the abrasive blasting nozzle is considered as the process weight. Where the process weight per hour is between figures listed in Table 405(a), the exact weight of permitted discharge shall be determined by linear interpolation. The emission rate for particulate matter must be less than or equal to the exact weight of allowed discharge.

Rule 1140

The visible emission shall not exceed 20 % opacity (Ringlemann 1) for more than 3 minutes in any one hour period.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT for particulate matter emissions from an abrasive blasting cabinent or room is a baghouse or equivalent control device.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

3.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, Permit (Operating) Conditions must be required. Permit (Operating) Conditions for the abrasive blasting cabinet or room and their associated air pollution control equipment (baghouse) are listed on the following page:

Abrasive Blasting Cabinet or Room

1. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT

WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO CONSTRUCT BY THE EXECUTIVE OFFICER.

2. SILICA TYPE ABRASIVES MUST NOT BE USED IN THIS EQUIPMENT. (If crossdraft or downdraft is less than 80 ft/min).

Baghouse

1. A MECHANICAL GAUGE MUST BE INSTALLED SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE (BAGS) (CARTRIDGES).

2. DUSTS COLLECTED IN THE (BAGHOUSE) (DUST COLLECTOR) MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS

REFERENCES

(1) Metals Handbook, American Society for Metals, 1985.

(2) "Empire Pro-Finish Systems," Empire Abrasive Equipment Corporation, 1983

(3) "Abrasive Blast Cleaning," Air Pollution Engineering Manual (AP-40), Second Edition, 1973.

(4) Memorandum from J. Tramma to Metallurgical Engineers, Subject: Abrasive Blasting Emission Factors, August 13, 1980.

(5) Compilation of Air Pollution Emission Factors, AP-42, Fourth Edition, September 1985.

(6) Memorandum from J. Nenzell to Metallurgical Processing Engineers, Subject: Abrasive Blasting, March 13,1975.

(7) ASM Metals Reference Book, American Society For Metals, 1981.

APPENDIX 3A

WORKSHEET FOR ABRASIVE BLASTING CABINETS/ROOMS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PERMIT TO CONSTRUCT/OPERATE

Applicability: This processing form can only be used for abrasive blasting cabinets/rooms with an air or water blast propelling device and a baghouse as the control device.

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. __________ (Basic)

ABRASIVE BLASTING SYSTEM CONSISTING OF:

1. ABRASIVE BLASTING CABINET (ROOM), , MODEL NO. , '- " W. X '- " L. X '- " H.
2. PRESSURE POT, LBS. CAPACITY.
3. ABRASIVE BLASTING NOZZLE(S), WITH A MAXIMUM INTERNAL DIAMETER OF IN.
4. PLANT AIR AT WITH A MAXIMUM DELIVERY RATE OF CFM AT PSIG.

If Integral Control Unit

5. (BAGHOUSE) (DUST COLLECTOR), , MODEL NO. , (FILTER BAGS) (CARTRIDGES), '- " DIA. X '- "L., SQ. FT. ACTUAL FILTER AREA, AND A -HP BLOWER.

APPLICATION NO. __________ (Control)

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. (BAGHOUSE) (DUST COLLECTOR), , MODEL NO , (FILTER BAGS) (CARTRIDGES), SQ. FT. ACTUAL FILTER AREA, WITH (MECHANICAL) (REVERSE PULSE JET) CLEANING.
2. EXHAUST SYSTEM WITH A -H.P. BLOWER VENTING AN ABRASIVE BLASTING SYSTEM APPLICATION (PERMIT) NO.

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ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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HISTORY:

PROCESS DESCRIPTION:

The applicant uses this abrasive blasting system to blast ________________. The items to be processed will be placed in the blasting enclosure. An operator will direct a high velocity stream of abrasive material at the parts, which will remove rust, paint, and other surface contaminants from the objects. The heavier materials generated by the cleaning action will fall to the enclosure's floor, while the lighter component will be entrained in the air flow through the enclosure caused by a exhaust blower. The material on the floor will be collected, then transferred manually (automatically) the abrasive pressure pot. The exhaust and air from the enclosure (and reclaiming system) is directed to a baghouse. Baghouse filter bags (cartridges) will separate the particulate matter from the air stream discharging clean air to the atmosphere. Abrasive cleaning will be conducted _____ hours per day, but due to the nature of the operation, actual abrasive will be flowing through the nozzle _____ hours during that time period. Compressed air is generated by an electrically driven compressor.

DATA:

		Source
Nozzle Max Internal Dia (ID_2) :	____ in	Applicant
Number, Total :	____	"
Air Pressure, Maximum :	____ PSIG	"
Abrasive Material(s) :	____________________	"
Cabinet/Room Dimensions :	____ W x ____ L x ____ H	"
Indraft Port Dimensions :	____ W x ____ L	"
Number of Indraft Ports :	____	"
Sand Flow Rate (FR_1) :	____ lb/hr @ ____ PSIG	Table 3-4, Eq 3.1
Abrasive Density ( ) :	____ lb/ft^3	"
Sand Density ( ) :	99 lb/ft^3	Table 3-5
Baghouse Efficiency :	____ %	Applicant
Baghouse Filter Area (A_b) :	____ ft^2	"
Exhaust Blower Flow Rate (VFR) :	____ CFM	"
Operating Schedule (T) :	____ hr/day, ____ day/wk, ____ wk/yr	"
Equipment Operating Factor (F) :	____ %	"
Type of Blasting (% of time) :	Dry (d) ____ Wet (w)	"
Max Compressor Operating Capacity	____ CFM @ ____ PSIG	"
Fuel Consumption Rate (FCR), Gas/Diesel (G/D) :	____ gal/hr	"

CALCULATIONS:

1. Abrasive Flow Rate (FR): $FR = FR_1 \times (ID^2/ID_1^2) \times \; /_1$

$FR = \_\_\_\_ \text{ lb/hr} \times (\quad \text{in}^2/ \quad {}_1\text{in}^2) \times (\quad \text{lb/ft}^3/ \quad \text{lb/ft}^3)$

$= \_\_\_\_ \text{ lb/hr}$

2. Emissions

Both uncontrolled (R_1) and controlled (R_2) emissions must be multiplied by appropriate operating time (T) factor to determine actual and maximum hourly and daily emissions. (NSR Emissions = Maximum Daily x 1.1)

$R_{1,PM} = EF \times PW \times (1 - w/200) \times F = \text{lb/hr} \;(\times T) = \text{lb/day}$

Uncontrolled PM Emissions (R_1)	Actual lb/hr	Max lb/hr	Max lb/day	NSR lb/day
	____	____	____	____

$R_{2PM} = R_{1,PM} \times (1 - \;)$

Controlled PM Emissions (R_2)	Actual lb/hr	Max lb/hr	Max lb/day	NSR lb/day
	____	____	____	____

3. Exhaust Gas Total Particulate Concentration (PC)

$$PC = \frac{\text{lb PM/hr (Max)} \times 7{,}000 \text{ grains/lb}}{\_\_\_\_ \text{ ft}^3\text{/min} \times 60 \text{ min/hr}} = \_\_\_\_ \text{ grains/dscf}$$

4. Baghouse Air-to-Cloth Ratio (A/C)

$A/C = VFR/A_b = \_\_\_\_ \text{ CFM}/ \_\_\_\_ \text{ ft}^2 = \_\_\_\_$

5. Room Crossdraft Velocity (V_c)

$V_c = VFR/W \times H = \_\_\_\_ \text{ CFM}/\_\_\_\_ \text{ ft} \times \_\_\_\_ \text{ ft} = \_\_\_\_ \text{ FPM}$

6. Air Inlet Port Velocity (V_i)

$V_i = VFR/W \times H = \_\_\_\_ \text{ CFM}/ \_\_\_\_ \text{ ft}^2 = \_\_\_\_ \text{ FPM}$

7. Cabinet Air Changes Per Minute (CAC)

$CAC = VFR/W \times L \times H = \_\_\_\_ \text{ CFM}/ \_\_\_\_ \text{ ft}^3 = \_\_\_\_ \text{ /min}$

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Abrasive Blasting Cabinet Guidelines Review

	Item	Required	Actual	Compliance	
a.	Air Changes Per Minute	10 - 20	______	yes	no
b.	Baffled Air Inlet Ports	yes	______	yes	no

Abrasive Blasting Room Guidelines Review

	Item	Required	Actual	Compliance	
a.	Crossdraft/Downdraft Velocity (FPM)				
	Silica type abrasive	80	______	yes	no
	Non-silica type abrasive	50	______	yes	no
b.	Air Ports Opposite Exhaust Duct	yes	______	yes	no
c.	Indraft Velocity (FPM)	500	______	yes	no
d.	Room Structural Requirements	Enclosed	______	yes	no
e.	Man-Door Installation				
	Main door > 40 sq. ft.	yes	______	yes	no
	Main door < 40 sq. ft.	no	______	yes	no

Abrasive Blasting Baghouse Guidelines Review

	Item	Required	Actual	Compliance	
a.	Air-to-Cloth Ratio				
	Shaker type cleaning	3.0:1 Min.	______	yes	no
		3.5:1 Max.	______	yes	no
	Reverse pulse jet cleaning	8.0:1 Max.	______	yes	no
b.	Baghouse Shakers				
	Cloth area > 400 sq. ft.	powered	______	yes	no
	Cloth area < 400 sq. ft.	manual	______	yes	no
c.	Baghouse Access Door, Tubular-Type Bags				
	Cloth area > 200 sq. ft.	yes	______	yes	no
	Cloth area < 200 sq. ft.	no	______	yes	no
d.	Baghouse Access Door, Screen-Type Bags				
	Cloth area > 400 sq. ft.	yes	______	yes	no
e.	Enclosed Dust Container	yes	______	yes	no
f.	Baghouse Differential Pressure Gauge				
	Cloth area > 400 sq.ft.	yes	______	yes	no

RULES EVALUATION:

RULE 401 : Not applicable due to Rule 401(d).

RULE 402 : The location of the equipment will be in an industrial/commercial area. Calculations show (low) (excessive) particulate emissions to the atmosphere. Compliance of 402 (is) (is not) expected.

RULE 404 : For an exhaust flow rate of _____ DSCFM, the rule allows for a maximum particulate matter concentration of _______ grains/DSCF. Calculations indicate a particulate matter concentration of ___ grains/DSCFM. Compliance of Rule 404 (is) (is not) expected.

RULE 405 : For a process weight of _____ lb/hr, the rule allows for a maximum solid particulate matter emission rate of ______ lb/hr. Calculations indicate a maximum emission rate of _____ lb/hr. Compliance of Rule 405 (is) (is not) expected.

RULE 1140 : The abrasive blasting (cabinet) (room) (is) (is not) totally enclosed and (is) (is not) vented to an air pollution control equipment. This arrangement (does) (does not) provide(s) adequate control to minimize visible emissions. Compliance of Rule 1140 (is) (is not) expected.

REG XIII : As shown by the Emission Threshold/New Source Sheet Table below, this facility (will) (will not) operate in compliance of Regulation XIII:

	NSR Emissions in Pounds Per Day				
	ROG	NO_X	SO_2	CO	PM
Facility Emissions Since 10-8-76	____	____	____	____	____
A/N ________	____	____	____	____	____
A/N ________	____	____	____	____	____
Net Emission Increase	____	____	____	____	____

BACT Best Available Control Technology (BACT) for abrasive an blasting cabinet/room is a baghouse or a equivalent control system. The applicant (will) (will not) provide a _______________. BACT (is) (is not) satisfied.

CONCLUSION

Evaluation of the abrasive blasting and air pollution control systems indicate that this equipment (should) (will not) operate in compliance of all the applicable Rules and Regulations of the South Coast Air Quality Management District. Therefore, the following is recommended:

( ) Issue a permit to construct/operate subject to the following conditions:

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ENGINEERING DIVISION

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APPLICATION NO. _____ (Basic)

CONDITIONS

1. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO CONSTRUCT BY THE EXECUTIVE OFFICER.
2. SILICA TYPE ABRASIVES MUST NOT BE USED IN THIS EQUIPMENT.

APPLICATION NO. _____ (Control)

CONDITIONS

1. A MECHANICAL GAUGE MUST BE (INSTALLED) (MAINTAINED) SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE (BAGS) (CARTRIDGES).
2. DUSTS COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS.

If the baghouse is an integral part of the abrasive blasting (basic) permit unit, the appropriate control permit conditions must be included as part of the basic permit unit.

OR

( ) Deny the Permit to Construct/Operate. It is my opinion that the operation of this equipment will be in violation of Rule(s) _______ of the Rules and Regulations of the South Coast AQMD.

APPENDIX 3B

GUIDELINES FOR BASIC DESIGN OF ABRASIVE BLASTING ENCLOSURES AND THEIR AIR POLLUTION CONTROL EQUIPMENT

Abrasive Blasting Cabinets

1. The design ventilation rate for abrasive blasting cabinets shall be 20 air changes per minute, with a minimum of 10 air changes per minute.

2. Baffled air inlet ports must be provided.

Abrasive Blasting Rooms

1. For rooms where the primary movement of air is parallel to the floor, the minimum crossdraft shall be 50 ft/min. When silica type abrasives are used, the minimum crossdraft shall be be 80 ft/min.

2. For rooms where the movement of air is downward and is removed at the lower section of the side walls, the minimum velocity of air shall be 50 ft/min. When silica type abrasives are used, the minimum crossdraft shall be be 80 ft/min.

3. For rooms where the primary movement of air is perpendicular to the floor and the air is removed uniformly over the entire area of the floor, the minimum downdraft velocity of air shall be 50 ft/min. When silica type abrasives are used, the minimum crossdraft shall be be 80 ft/min.

4. The air inlet port(s) must be on the opposite side of the enclosure from the exhaust duct.
5. The minimum indraft velocity through the air ports must be 500 ft/min and the air ports must be adequately baffled to keep all dust abrasive within the room.

6. All abrasive blasting rooms must be enclosed with structural material on all four sides and roof.

7. Where the main door is larger than 40 square feet, an additional man door is necessary.

Tube- (Or Cartridge-) Type Baghouses

1. The air-to-cloth filter ratio for non-reverse air cleaning baghouses shall be 3.0:1, with a maximum of 3.5:1. The filter ratio for reverse-air, pulse cleaning type baghouses shall be a minimum of 8.0:1.

2. On baghouses where the total filter are is greater than 400 square feet, a power shaker must be provided for shaking the the bags. On baghouses with less than 400 square feet of total cloth filter area, either power shaker or hand shaker shall be provided.

3. On baghouses with tubular-type bags where the filter cloth area is greater than 200 square feet, an access door must be provided which is large enough to allow for changing the bags and maintenance of the interior.
4. On baghouses with screen-type bags where the filter cloth area is greater than 400 square feet, an access door shall be provided

5. Adequate space for the removal of captured dust must be provided under the baghouse. An enclosed dust container must be provided for each hopper of a baghouse.

6. On baghouses where the total filter cloth area is greater than 400 square feet, a mechanical gauge indicating static pressure differential across the bags must be installed and maintained

SECTION 4

Storage Tanks

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Section 4

ACKNOWLEDGEMENTS

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SECTION 4: STORAGE TANKS

4.1 General Description

A storage tank is any container used to store liquids or gases such as crude oil, gasoline, liquefied petroleum gases, liquefied natural gases, or asphalt. These storage facilities can be classified as above ground or underground storage tanks. They can also be classified as closed or open storage tanks. Fixed roof tanks, pressure tanks, floating roof tanks, and conservation tanks are examples of the above ground, closed storage tanks. Reservoirs, pits, and ponds are examples of the underground, open storage tanks. Pipe line and caverns are examples of underground, closed storage tanks.

Tanks are generally selected based on the following considerations:

- chemical characteristic of the product to be stored such as volatility, explosivity, solubility, reactivity, and corrosivity;
- cost of the tank; and
- cost of emission control devices required by environmental regulations.

This section discusses three common types of storage vessels: the fixed roof tank, the external floating roof tank, and the internal floating roof tank.

4.1.1 Fixed Roof Tank

In general, the fixed roof tank is the least expensive to construct and is considered as the minimum acceptable equipment for the storage of volatile organic liquids. A fixed roof tank is an active system that is continuously breathing out vapor during the day and drawing in fresh air at night. A typical fixed roof storage tank is equipped with a pressure-vacuum relief vent not to exceed the maximum or minimum operating pressure of the tank. When the pressure setting of the relief vent is exceeded, the vapor is forced out of the tank. When the tank pressure drops due to liquid withdrawal or atmosphere cooling, outside air is drawn in. Several variations of the fixed roof are listed below:

- *Supported Cone Roof*: a roof formed to approximately the surface of the right cone, with its principal provided by either rafters on girders and columns or rafters on trusses with or without columns;
- *Self-Supporting Cone Roof*: a roof supported only at its periphery;
- *Self-Supporting Dome Roof*: a roof formed to approximately a spherical shape, supported only at its periphery; and
- *Self-Supporting Umbrella Roof*: a modified dome roof consisting of regular polygon roof plates, supported only at its periphery.

The operating pressure of the fixed roof tank is limited by the thickness and structure of the roof. A 1/16" roof can sustain an operating pressure of 0.3 ounces/in^2 whereas a 1/4" roof can sustain up to 1.3 ounces/in^2.[1] A cone roof can sustain up to 4 ounces/in^2 by structural reinforcement of the roof.[1] Use of unsupported dome shaped roofs is another method of increasing the allowable operating pressure of a fixed roof tank. Figure 4-1 shows a typical fixed roof tank.

4.1.2 External Floating Roof Tank

In general, the floating roof tank has many advantages over the fixed roof tank. Some of them are:

- low evaporation loss;
- negligible filling loss;
- the elimination of moisture in the vapor space reduces the corrosion problem; and
- the elimination of the vapor space above the liquid surface results in a low fire risk.

An external floating roof tank is a cylindrical steel shell equipped with a roof which floats on the surface of the stored liquid. The roof rises and falls with the liquid level. The liquid surface is completely covered by the floating roof, except at the small annular space between the roof and the tank wall. A seal attached to the roof

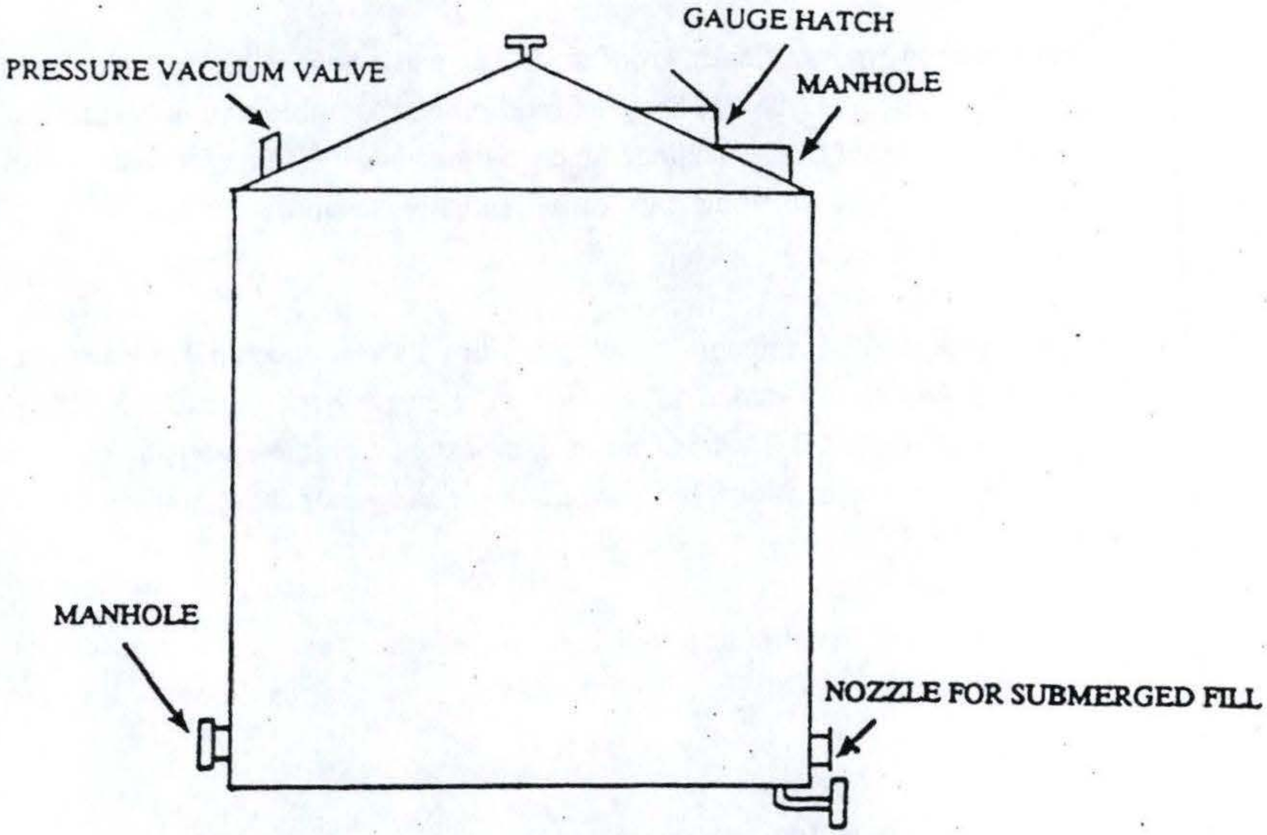
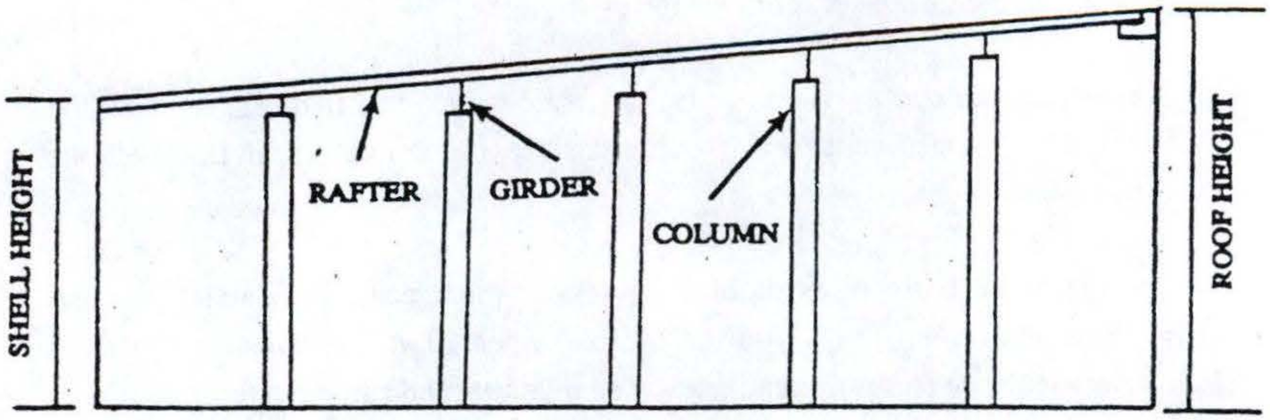


FIGURE 4-1 TYPICAL CONE ROOF WELDED STORAGE TANK [2]



contacts the tank wall and covers the annular space. The seal slides against the tank wall as the roof is raised or lowered.

Three common types of floating roof tanks are: pan, pontoon, and double deck (see Figure 4-2). The pan type floating roof requires considerable support to prevent the flat metal plate roof from buckling. Since the metal roof is in direct contact with the liquid surface, solar heating can cause excessive evaporation loss around the periphery of the roof.

To overcome the disadvantage of roof instability, a series of compartmented annular rings of pontoons are added to the top of a single deck. Included with some pontoon roof designs is a vapor trap or dam installed on the underside of the roof. This trap helps retain vapor and converts the dead vapor space into an insulation layer.

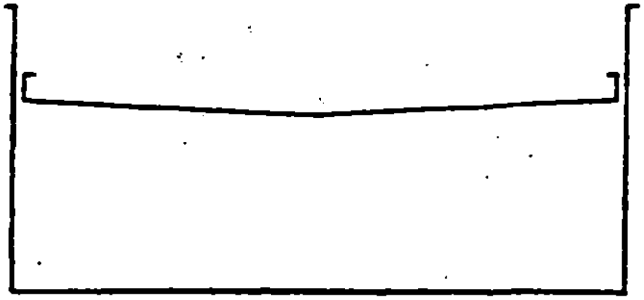
The double deck type floating roof has two separate decks with an insulating air space between them. This style is most efficient in preventing the vapor losses.

4.1.2.1 Floating Roof Seal System

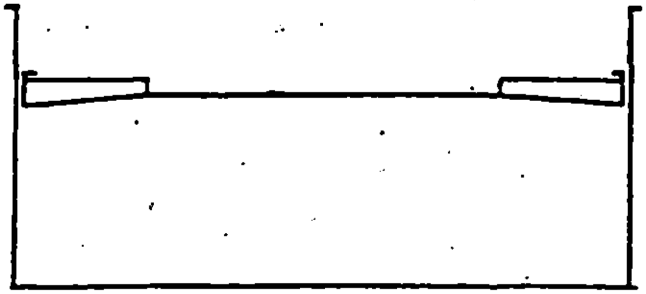
The floating roof tank has an annular rim space between the tank shell and the outer periphery of the floating roof. The annular rim space must have an effective seal system to control the evaporative losses.

A seal system can consist of one or two separate seals. The first seal is called the primary seal. The second seal mounted above the primary seal is called the secondary seal.

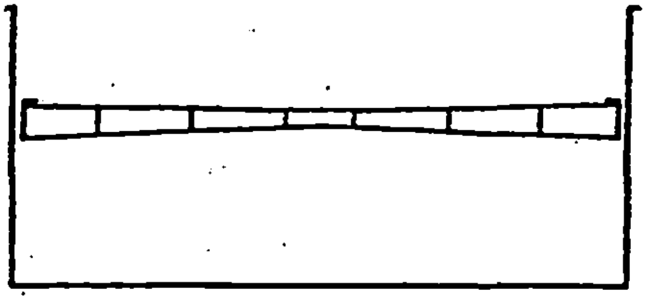
There are three basic types of primary seals: the mechanical (metallic) shoe, resilient (nonmetallic) filled, and the flexible wiper. Two basic configurations of secondary seals are currently available: shoe mounted and rim mounted.



PAN FLOATING ROOF



PONTOON FLOATING ROOF



DOUBLE-DECK FLOATING ROOF

FIGURE 4-2 GENERAL TYPES OF FLOATING ROOF TANKS [3]

4.1.2.1.1 Primary Seals

(a) Mechanical (Metallic) Shoe Primary Seals

The primary seal uses a metallic band, which is called a *shoe*, as the sliding contact with the tank shell. The shoe is supported and held against the tank shell by a mechanical device. The shoes are joined together to form a ring. The shoes are normally 3 to 5 ft long and extend below the liquid surface to confine the vapor space between the shoe and the floating roof rim.

The rim space bounded by the shoe, the floating roof, and the liquid surface is sealed from the atmosphere by a coated fabric. This is called the primary seal fabric. The primary seal fabric is bolted or clamped from the shoes to the roof by two different methods. In the most commonly used method, the fabric is attached to the top of the shoe and the rim plate of the floating roof. In the reduced vapor space method, the fabric is attached to the shoe and the roof near the surface of the liquid stored. The two positions of the primary seal fabric are shown in Figure 4-3.

(b) Resilient (Nonmetallic) Filled Primary Seals

The primary seal uses an elastomeric coated fabric envelope as the sliding contact with the tank shell, as shown in Figure 4-4.

The envelope can be filled with liquid, resilient foam, or gas to expand the envelope, thus providing contact with the tank shell. The seal can be mounted on the floating roof such that it either touches the liquid surface (liquid-mounted) or allows for a vapor space between the liquid and the seal (vapor-mounted).

The main advantage of the resilient filled seal over the mechanical shoe seal is its flexibility which allows better contact with the tank shell. However, the resilient filled seal requires higher maintenance costs than the mechanical shoe seal. The vapor-mounted seals have an associated rim vapor space. This vapor space tends to contribute to evaporative loss. On the other hand, the vapor-mounted seal is not subject to fast deterioration from contact with hydrocarbon products.

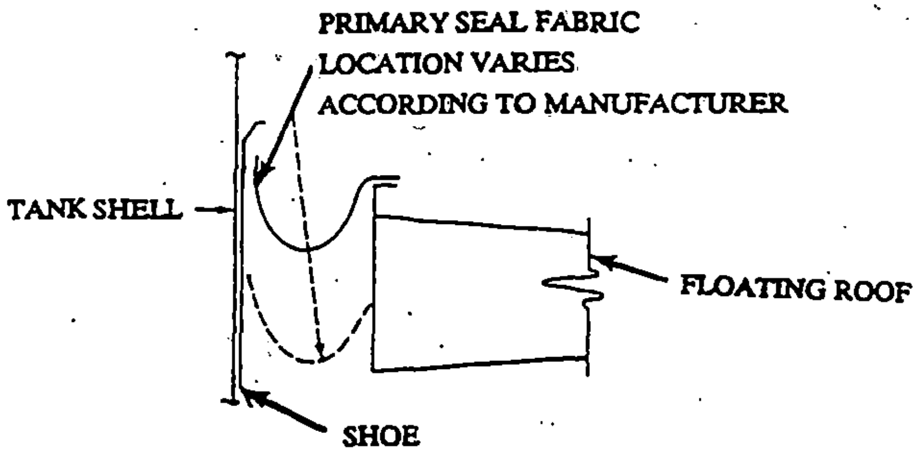


FIGURE 4-3 MECHANICAL SHOE PRIMARY SEAL [4]

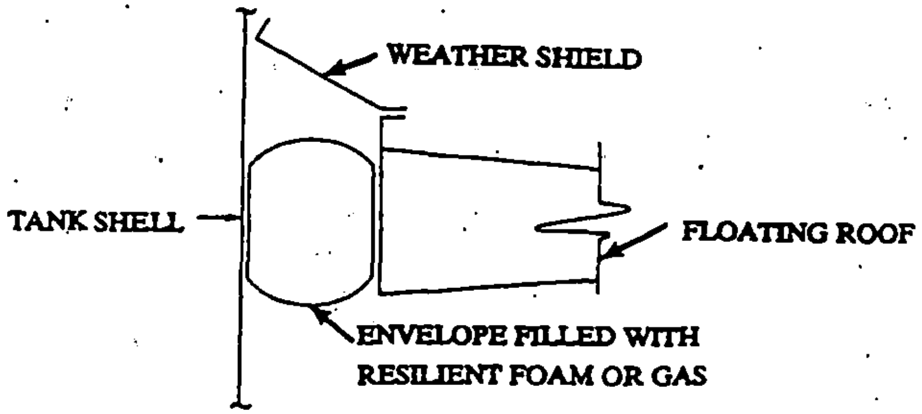


FIGURE 4-4 RESILIENT FILLED PRIMARY SEAL [4]

(c) Flexible Wiper Primary Seals

The primary seal uses an elastomeric blade as the sliding contact with the tank shell, as shown in Figure 4-5. The flexible wiper seal bridges the annulus between the floating roof and the tank shell and uses its own stiffness or mechanical means to push the seal against the tank shell. The wiper seal is usually mounted above the liquid to avoid fast deterioration resulting from liquid contact.

4.1.2.1.2 Secondary Seals

Shoe-mounted secondary seals (see Figure 4-6) are effective at reducing losses from gaps between the shoe and the tank shell but do not control losses from primary seal fabric defects or connections. The rim-mounted secondary seals (see Figure 4-7), the most common type encouraged in the industry, are more effective in reducing losses because they cover the entire rim space.

4.1.2.1.3 Weather Shields

When not equipped with secondary seals, most tanks having resilient filled seals are furnished with weather shields, as shown in Figure 4-4. Weather shields may be of metallic, elastomeric, or composite construction. Weather shields increase primary seal life by protecting the fabric from weather and debris.

4.1.3 Internal Floating Roof Tanks

An internal floating roof tank consists of floating roof in a fixed roof tank. The internal floating roof, usually called the *deck*, reduces evaporation and filling losses. The floating deck design is similar to the external floating roof design. There are two basic types of floating decks: contact. and non-contact. A contact deck floats on

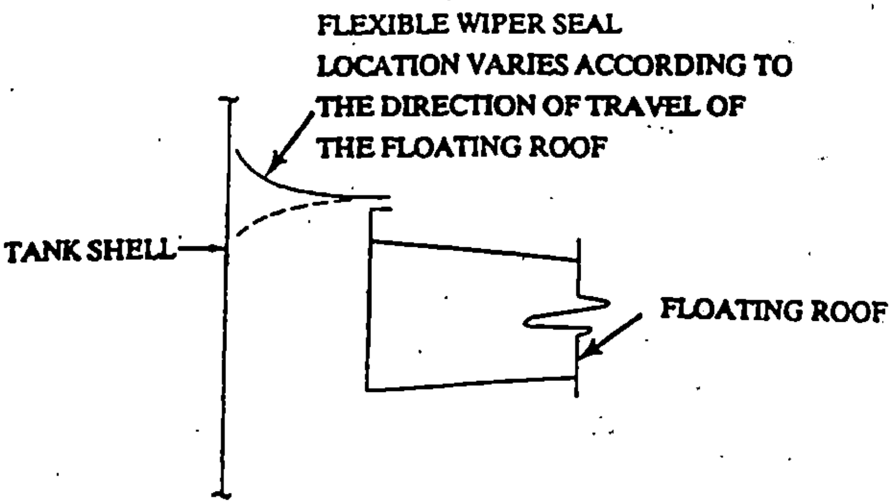


FIGURE 4-5 FLEXIBLE WIPER PRIMARY SEAL [4]

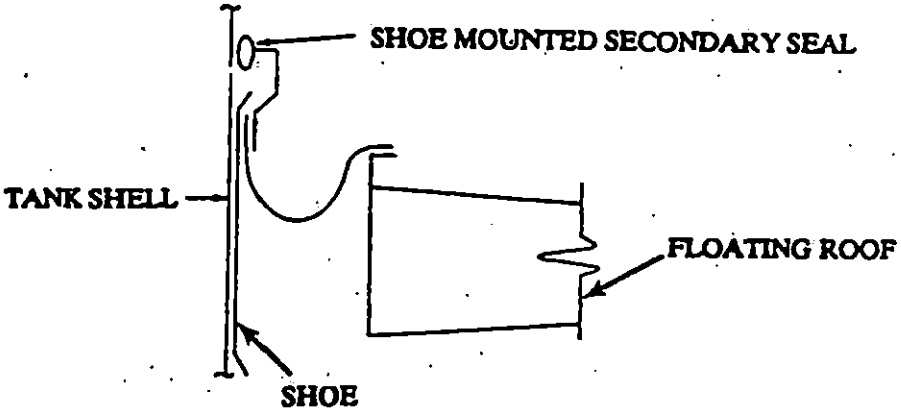


FIGURE 4-6 MECHANICAL SHOE PRIMARY SEAL WITH A SHOE MOUNTED SECONDARY SEAL [4]

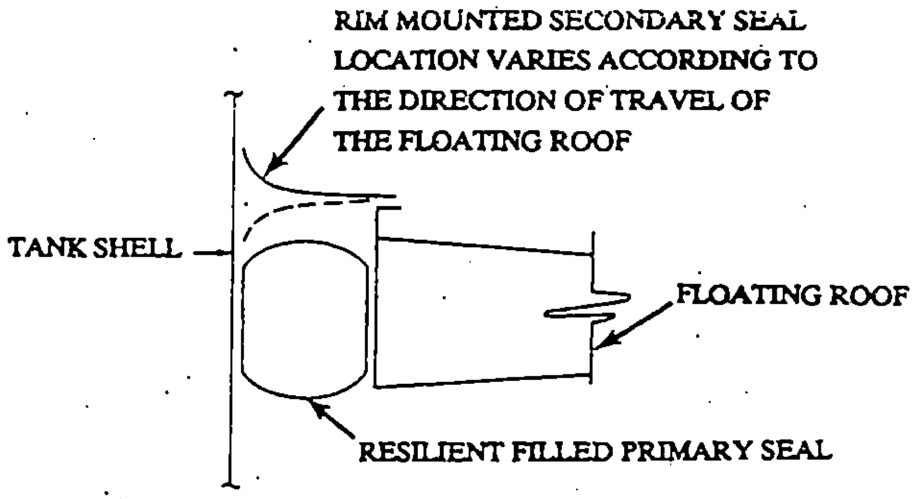


FIGURE 4-7 RESILIENT FILLED PRIMARY SEAL WITH A RIM MOUNTED SECONDARY SEAL [4]

the liquid surface with or without pontoons, and a non-contact deck is supported above the liquid surface by pontoons or other buoyant structures. Both types of deck incorporate rim seals. Figure 4-8 shows typical internal floating decks and rim seal systems.

4.1.4 Air Pollution Control Devices For Storage Tanks

Emissions of organic gases from fixed-roof tanks and underground tanks are normally controlled by air pollution devices such as: carbon adsorber, refrigerated condenser, incinerator, vapor recovery system, etc. No external control devices are used with floating roof tanks because of low working losses.

4.2 Permit Unit Description

4.2.1 Fixed Roof Petroleum Storage Tanks

STORAGE TANK NUMBER, DIMENSIONS (DIAMETER, LENGTH), CAPACITY, VENTED TO AN AIR POLLUTION CONTROL DEVICE.

4.2.2 Fixed Roof Chemical Storage Tanks

STORAGE TANK NUMBER, DIMENSIONS (DIAMETER, LENGTH), CAPACITY, VENTED TO AN AIR POLLUTION CONTROL DEVICE.

4.2.3 External Floating Roof Storage Tanks

STORAGE TANK NUMBER, DIMENSIONS (DIAMETER, LENGTH), CAPACITY, TYPE OF SEAL (DOUBLE OR SINGLE).

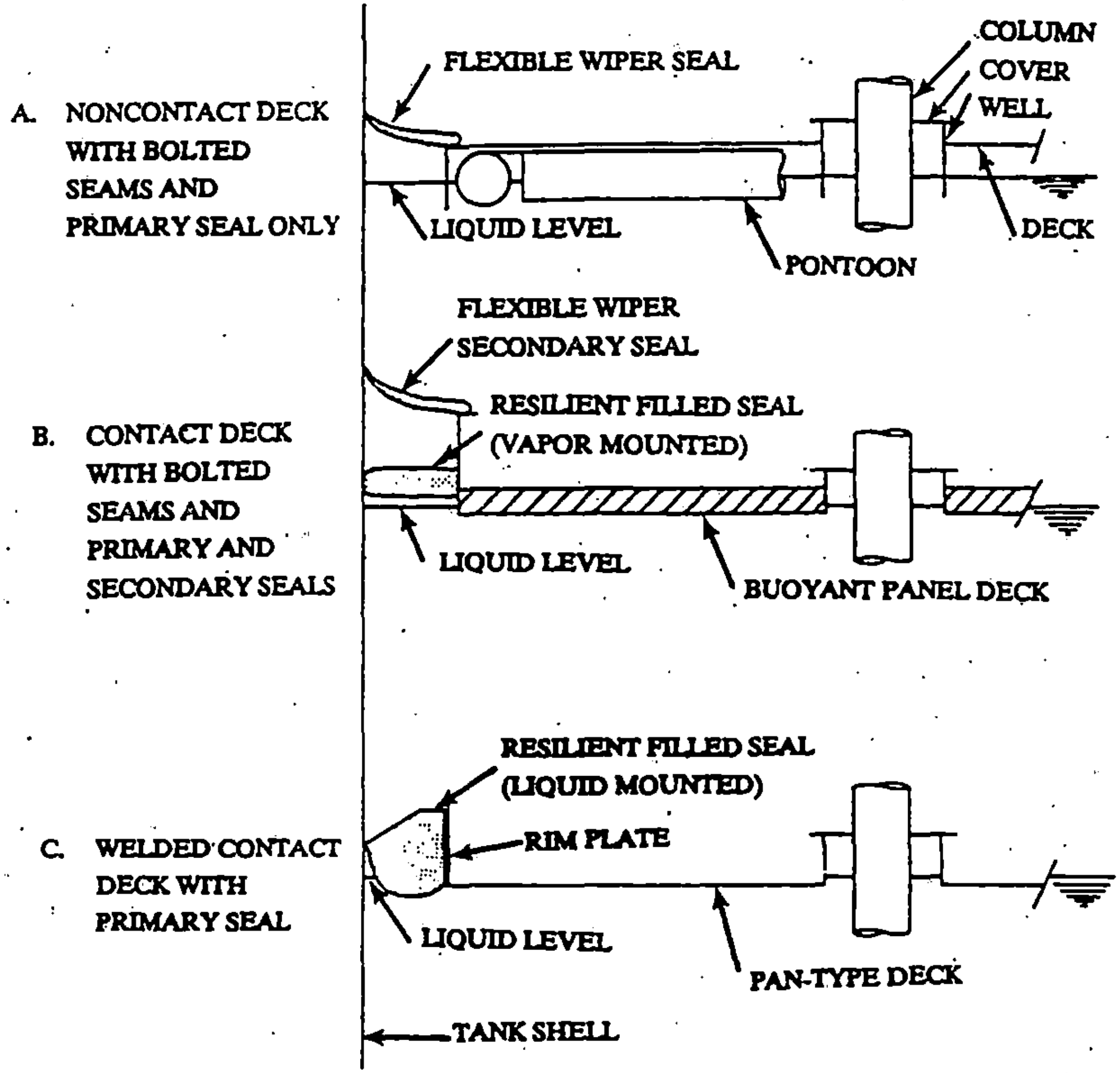


FIGURE 4-8 TYPICAL INTERNAL FLOATING DECKS AND TYPICAL RIM SEAL SYSTEMS [5]

4.2.4 Internal Floating Roof Storage Tanks

STORAGE TANK NUMBER, DIMENSIONS (DIAMETER, LENGTH), CAPACITY, TYPE OF SEAL (DOUBLE OR SINGLE).

4.3 Emissions

Emissions of organic gases from storage tanks depend upon the tank type. Two significant losses of emissions from fixed roof tanks are breathing loss and working loss. Two significant losses of emissions from floating roof tanks are standing storage loss and withdrawal loss.

Breathing loss is the expulsion of vapor from a tank through vapor expansion and contraction due to changes in temperature and barometric pressure. This loss occurs without any liquid level change in the tank and is negligible in most cases compared to the working loss.

Working loss is a combination loss from filling and emptying the tank. Filling results in expulsion of part or all of the vapors from the tank. Emptying draws in fresh air which subsequently becomes saturated with organic vapor and expands. Vapor loss from this expansion is negligible compared to the filling loss.

The standing storage loss is caused by the capillary flow of the liquid between the outer side of the sealing ring and the inner side of the tank wall. As the liquid is drawn from the tank, the floating roof moves downward, the film of liquid on the tank's innerwall evaporates as it is exposed to the atmosphere. This evaporation loss is called the withdrawal loss.

Section 4.4.2 is used to calculate the emissions of non-toxic organic gases. The emissions of toxic organic gases are calculated based on the method described in Appendix B.

4.4 Calculations

4.4.1 Operational Data

Total Throughput Per Year ______ gal/yr, OR
Number of Fill Per Day ______ fill/day
Filling Rate ______ gal/min
Duration Of Fill ______ hour/fill

4.4.2 Emission Calculations

Emissions must be calculated for both the actual and maximum operating conditions. Actual emissions are used in emission inventory. Maximum emissions are used to determine compliance with the District's Rules and Regulations.

In addition, the maximum daily emissions are multiplied by the Regulation XIII [12] Onsite Offset Factor (i.e. 1.1). These daily emissions increases are accumulated for each facility in the District's New Source Review Record.

In the sections below, emissions will be calculated at atmospheric pressure. If the equipment is located at higher elevations, pressure adjustment may be required.

4.4.2.1 Fixed Roof Petroleum Storage Tank

Breathing losses from a vertical storage tank can be estimated from: [6, 7]

$$L_B = 2.26 \times 10^{-2} M_V \left(\frac{P}{14.7 - P} \right)^{0.68} D^{1.73} H^{0.51} T^{0.5} F_P C K_{cb} \qquad \textbf{(Equation 4.1)}$$

Working losses can be estimated from: [6, 7]

$$L_W = 2.40 \times 10^{-5} M_V P V N K_N K_{cw} \qquad \textbf{(Equation 4.2)}$$

where:

L_B = Fixed roof breathing loss (lb/yr)

L_W = Fixed roof working loss (lb/yr)

M_V = Molecular weight of vapor in storage tank (lb/lb mole)

The molecular weight of vapor can be determined by Table 4-1 for selected petroleum liquids and volatile organic liquids. Where mixtures of organic liquids are stored in a tank, M_V can be estimated from the liquid composition. Consider a liquid mixture of component A and B with mole fraction in the liquid X_a and X_b, vapor pressure P_a and P_b, and the molecular weights of the pure components M_a and M_b, respectively M_V is calculated by:

$$M_V = \left(\frac{M_a P_a X_a}{P_t}\right) + \left(\frac{M_b P_b X_b}{P_t}\right) \qquad \textbf{(Equation 4.3)}$$

where P_t, by Raoult's law is

$$P_t = P_a X_a + P_b X_b \qquad \textbf{(Equation 4.4)}$$

P = True vapor pressure at bulk liquid conditions (psia)

P is equal to P_t for a liquid mixture. True vapor pressure of petroleum products can be determined from Figure 4-9, or Figure 4-10, or Table 4-1 given their Reid vapor pressure. In order to use these figures, the stored liquid temperature, T_S, must be determined in degrees Fahrenheit. T_S is determined from Table 4-2.

D = Tank diameter (ft)

H = Average vapor space height (ft). Assume H equals one half tank height

T = Average daily temperature change, if not known use 20 ^{o}F

F_P = Paint Factor (dimensionless), see Table 4-3

C = Adjustment Factor for small tanks (dimensionless), see Figure 4-11

K_{cb} = Crude oil factor (dimensionless)

For crude oil K_{cb} = 0.65, for other organic liquid K_{cb} = 1.0

V = Tank capacity (gal)

N = Number of turnover per year (dimensionless) = (Total throughput per year (gal) / Tank capacity V (gal))

K_N = Turnover factor (dimensionless), see Figure 4-12

K_{cw} = Crude oil factor (dimensionless), For crude oil K_{cw} = 0.84, for other organic liquids, K_{cw} = 1.00

Equations 4-1 and 4-2 give the working losses per year (L_W). The average working losses per day are then equal to $L_W/365$.

4.4.2.2 Fixed Roof Chemical Storage Tank

The SCAQMD uses Equation 4.5 to calculate the breathing loss from vertical and horizontal fixed roof chemical storage tanks:

$$L_B = V_o \left(\frac{\Delta T}{T_{AV}}\right)\left(\frac{1}{v}\right)\left(\frac{P}{14.7}\right) M_V \qquad \textbf{(Equation 4.5)}$$

where:

L_B = Breathing loss from fixed roof tank (lb/day)

V_o = Volume of vapor above the liquid surface (ft^3)

ΔT = Average daily temperature change (^oR or ^oF)

T_{AV} = Average daily temperature (^oR)

$\left(\frac{V_o \Delta T}{T_{AV}}\right)$ = Volume of vapor expelled from the tank due to average temperature change (ft^3)

P = True vapor pressure (psia)

v = Molar volume (ft^3)/lbmole

$$= 10.73 \left(\frac{\text{ft3 psia}}{\text{lbmole } ^oR}\right) T_{AV} (^oR) \left(\frac{1}{14.7 \text{ psia}}\right) \qquad \textbf{(Equation 4.6)}$$

M_V = Molecular weight of vapor (lb/lbmole)

Since Regulation XIII[12] of the SCAQMD requires <u>maximum</u> emissions per day, the SCAQMD uses Equation 4.7 to calculate maximum working losses per day from fixed roof chemical storage tanks:

$$L_W = F \left(\frac{1\ \text{ft}^3}{7.48\ \text{gal}}\right)\left(\frac{1\ \text{lbmole}}{380\ \text{ft}^3}\right) M_V \left(\frac{P}{14.7\ \text{psia}}\right)$$

$$= 2.4 \times 10^{-5}\ F\ P\ M_V \qquad \textbf{(Equation 4.7)}$$

where:

L_W = Working loss from fixed roof tank (lb/day)
F = Filling rate (gal/day)
P = True vapor pressure (psia)
M_V = Molecular weight of vapor (lb/lbmole)

Appendix 4H lists the molecular weight and the vapor pressure (at 70 ^oF) for several common chemical compounds.

4.4.2.3 External Floating Roof Tank

Standing storage loss can be estimated from:[4, 5, 6]

$$L_S = K_S\ v^n\ P^*\ D\ M_V\ K_c \qquad \textbf{(Equation 4.8)}$$

Withdrawal loss can be estimated from:[4, 5, 6]

$$L_{WD} = 0.943\left(\frac{Q\ C\ W_L}{D}\right)\left(1 + \left(\frac{N_C F_C}{D}\right)\right) \qquad \textbf{(Equation 4.9)}$$

where:

L_S = Standing storage loss (lb/yr)
L_{WD} = Withdrawal loss (lb/yr)
K_S = Seal factor (lbmole/(ft(mi/hr)^n yr)), see Table 4-4
v = Average wind speed at tank site (mi/hr), see Table 4-5
n = Wind speed exponent (dimensionless), see Table 4-4

P^* = Vapor pressure function (dimensionless)

P^* can be calculated by

$$P^* = \left[\frac{(P/14.7)}{(1 + (1 - P/14.7)^{0.5})^2} \right] \qquad \textbf{(Equation 4.10)}$$

or read directly from Figure 4-13

P = Defined in Equation 4.1 and 4.2

D = Tank diameter (ft)

M_V = Vapor molecular weight (lb/lbmole)

K_c = Crude oil factor (dimensionless)

For crude oil $K_c = 0.4$, for other product $K_c = 1.0$

W_L = Liquid density (lb/gal), see Table 4-1

Q = Throughput (bbl/yr)

C = Shell clingage factor (bbl/1,000 ft^2), see Table 4-6

N_C = Number of columns (dimensionless)

For self-supporting fixed roof or an external floating roof tank, $N_C = 0$. For internal floating roof tank with column supported fixed roof, see Table 4-7

F_C = Effective column diameter (ft) = (Column perimeter (ft) / π)

For (9inch x 7 inch) columns $F_C = 1.1$, for 8 inch diameter pipe columns $F_C = 0.7$, and $F_C = 1$ if column construction details are not known

4.4.2.4 Internal Floating Roof Tank

In addition to the standing storage loss and the withdrawal loss, the internal floating roof tank also has the deck fitting loss and deck seam loss. The deck seam loss only applies to the internal floating roof tank with bolted decks.

Deck fitting loss can be estimated from: [5, 6]

$L_F = F_f\, P^*\, M_V\, K_c$ **(Equation 4.11)**

Deck seam loss (only applies for internal floating roof with bolted decks) can be estimated from: [5, 6]

$L_D = K_D\, S_D\, D^2\, P^*\, M_V\, K_c$ **(Equation 4.12)**

where:

L_F = Deck fitting loss (lb/yr)

L_D = Deck seam loss (lb/yr)

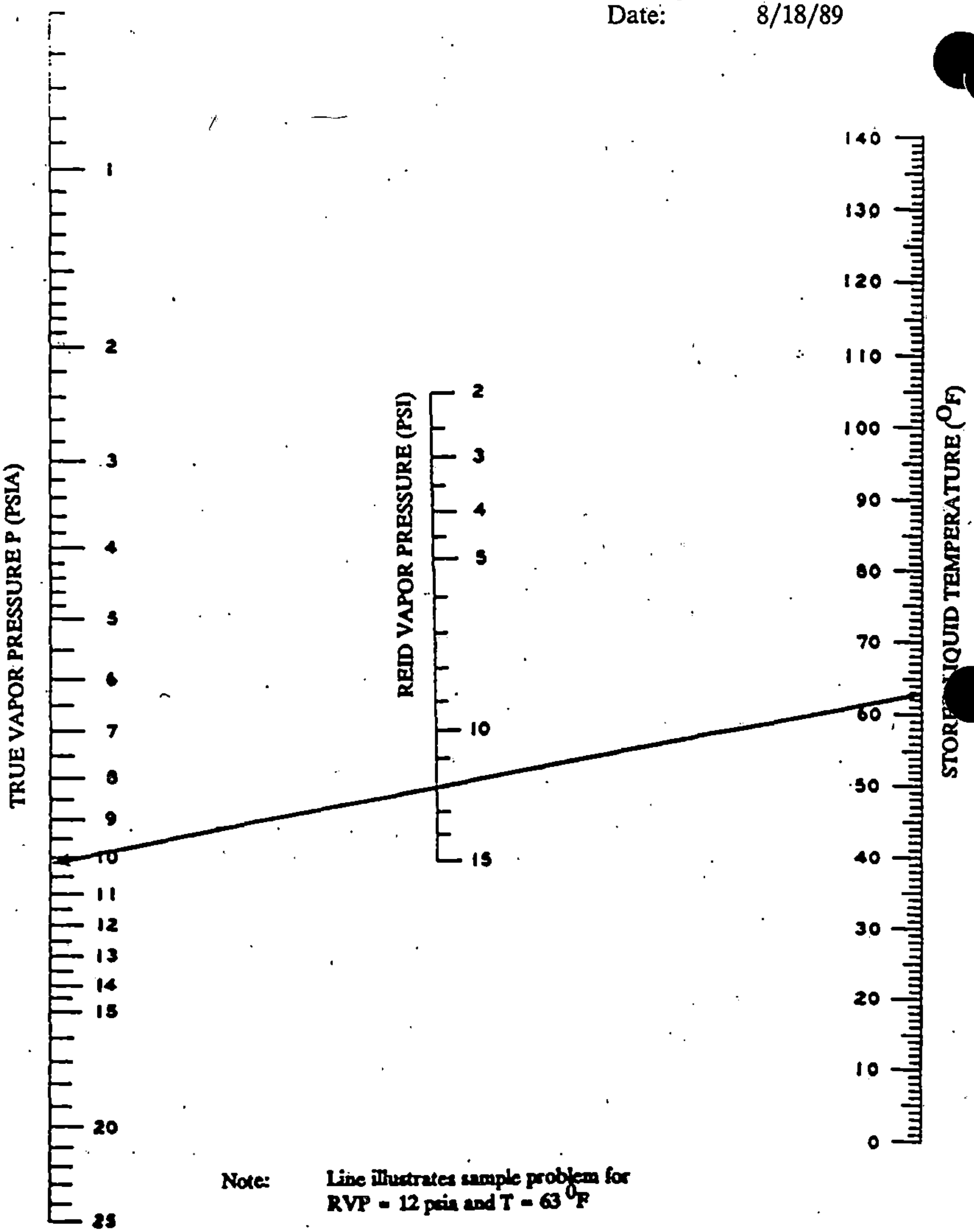
F_f = Deck fitting loss factor (lbmole/yr)
F_f can be found from Figures 4-14, and 4-15

K_D = Deck seam loss per unit seam length factor (lbmole/ft-yr). For bolted deck, $K_D = 0.34$; for welded deck and external floating roof, $K_D = 0.0$

P^*, M_V, K_c, and D are defined in Equation 4.8

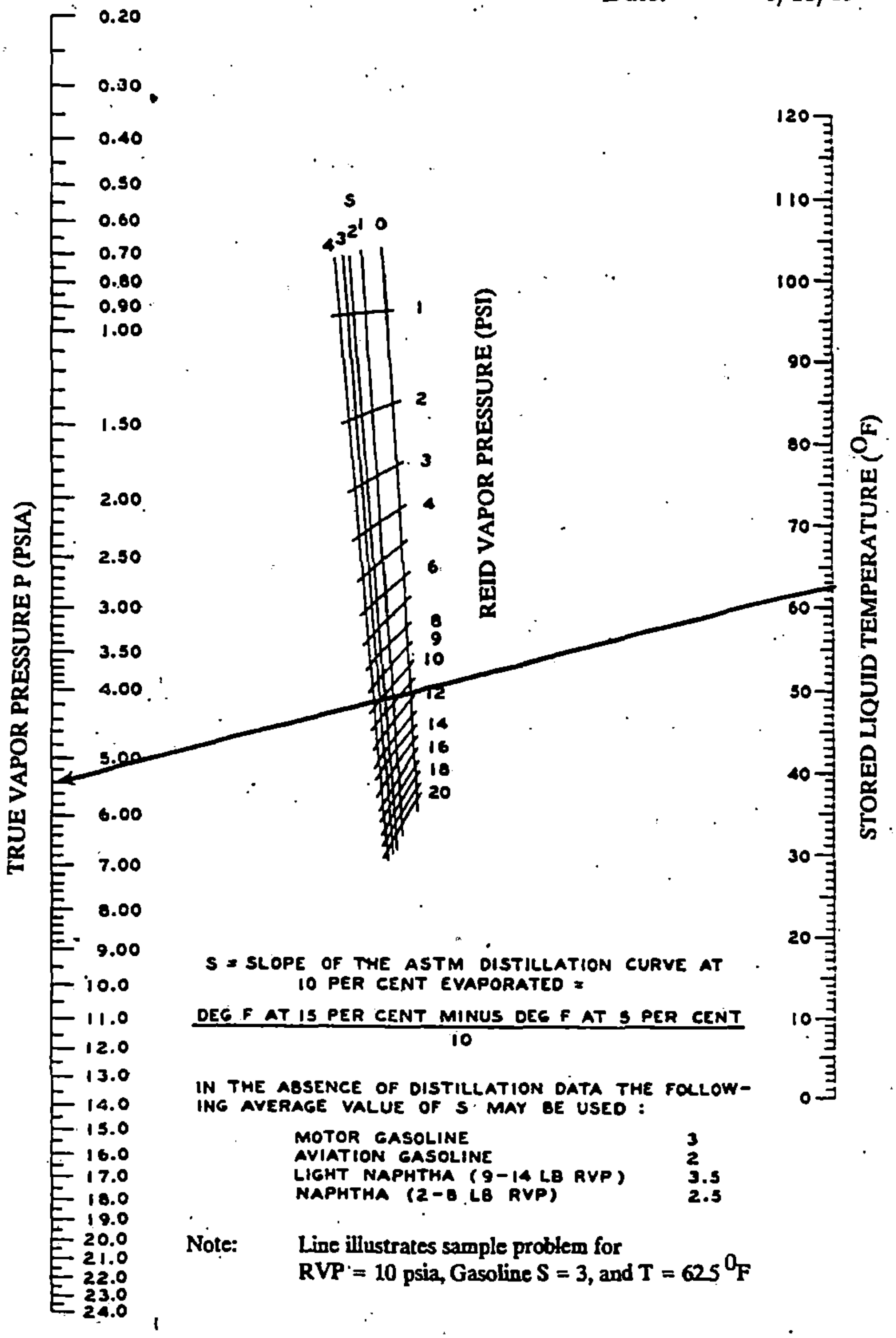
S_D = Deck seam length factor (ft/ft^2) = L_{Seam} / A_{Deck}
where:
L_{Seam} = Total length of deck seam (ft)
A_{Deck} = Total area of deck (ft^2) = $\pi D^2/4$

If the total length of deck seam is not known, Table 4-8 can be used to determine S_D. If the sheet width or size of the deck panel is not known, S_D is assumed to be 0.20 (ft/ft^2).



Note: Line illustrates sample problem for RVP = 12 psia and T = 63 °F

FIGURE 4-9 TRUE VAPOR PRESSURE (P) OF CRUDE OILS (2-15 PSI RVP)[4, 6]



S = SLOPE OF THE ASTM DISTILLATION CURVE AT 10 PER CENT EVAPORATED =

$$\frac{\text{DEG F AT 15 PER CENT MINUS DEG F AT 5 PER CENT}}{10}$$

IN THE ABSENCE OF DISTILLATION DATA THE FOLLOWING AVERAGE VALUE OF S MAY BE USED :

MOTOR GASOLINE	3
AVIATION GASOLINE	2
LIGHT NAPHTHA (9-14 LB RVP)	3.5
NAPHTHA (2-8 LB RVP)	2.5

Note: Line illustrates sample problem for RVP = 10 psia, Gasoline S = 3, and T = 62.5 °F

FIGURE 4-10 TRUE VAPOR PRESSURE (P) OF REFINED PETROLEUM LIQUIDS LIKE GASOLINE AND NAPTHAS (1-20 PSI RVP) [4, 6]

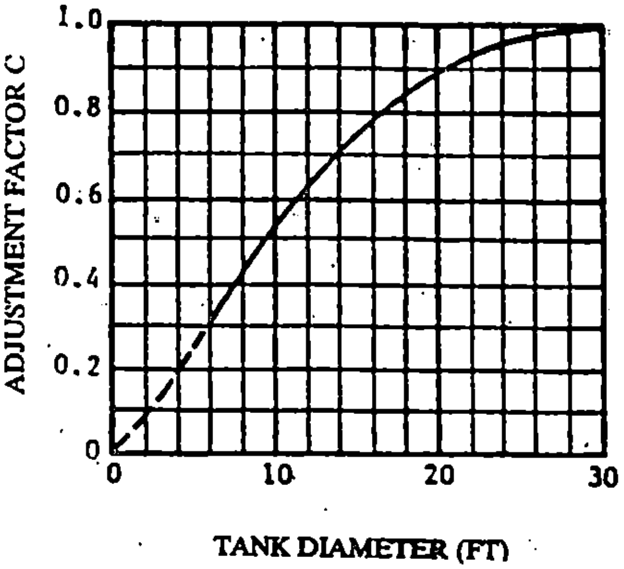
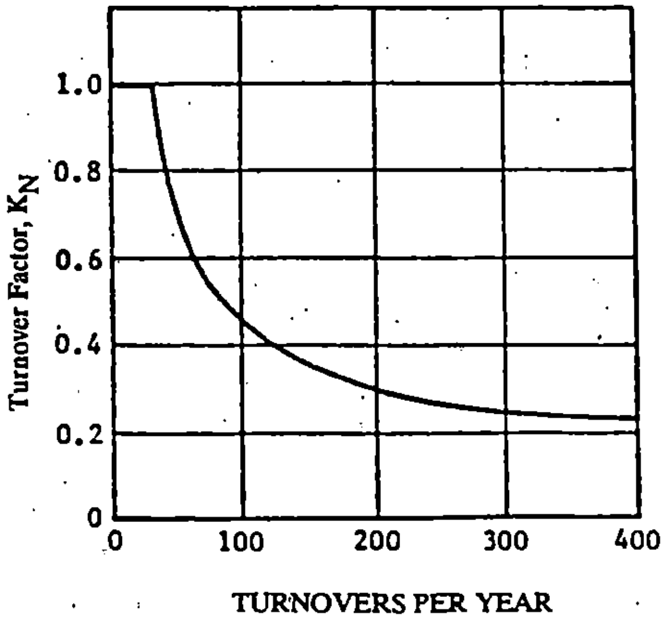


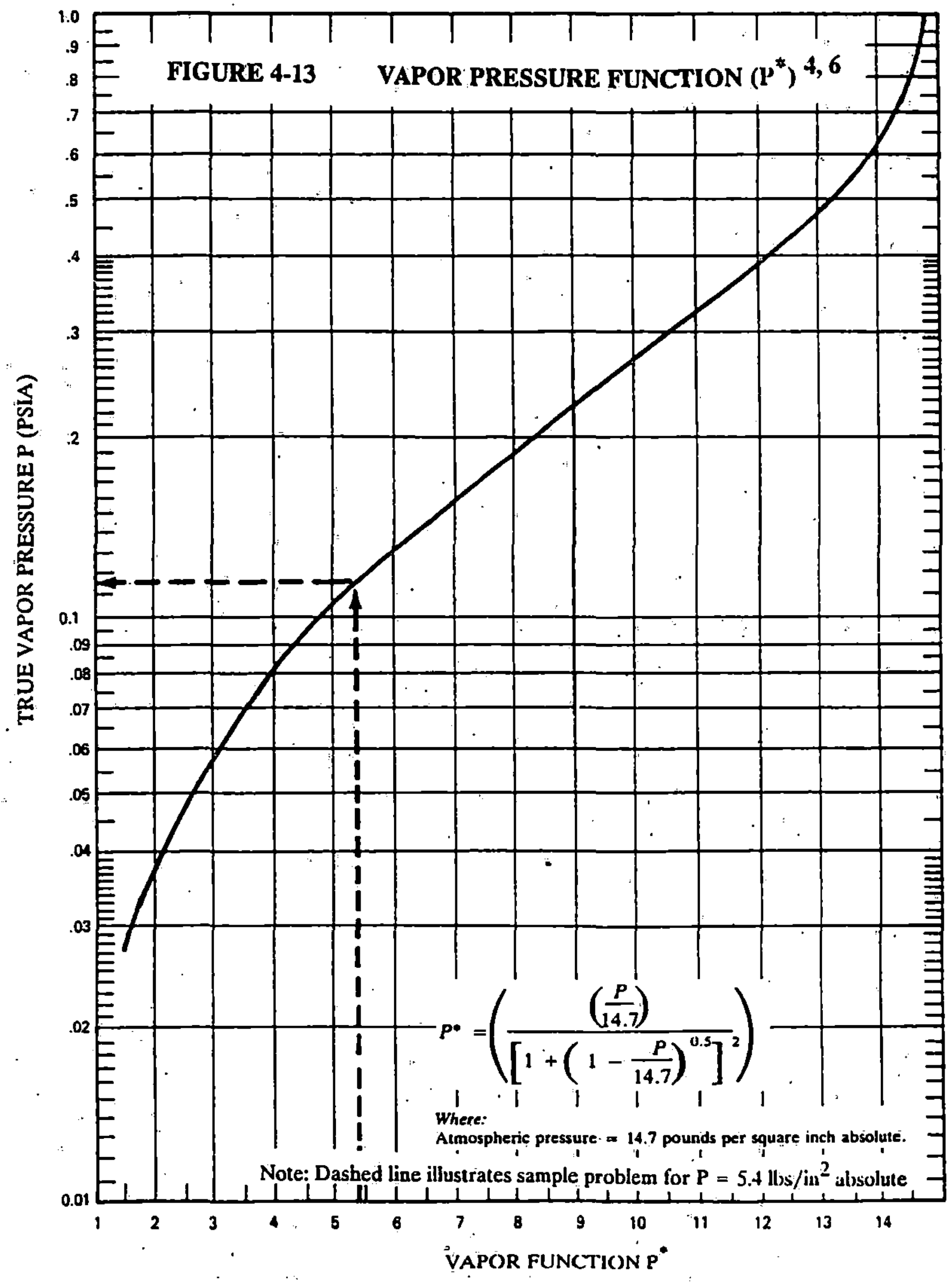
FIGURE 4-11 ADJUSTMENT FACTOR (C) FOR SMALL DIAMETER TANKS 6, 11



NOTE: FOR 36 TURNOVERS PER YEAR OR LESS, $K_N = 1.0$

FIGURE 4-12 TURNOVER FACTOR FOR FIXED ROOF TANKS 6, 11

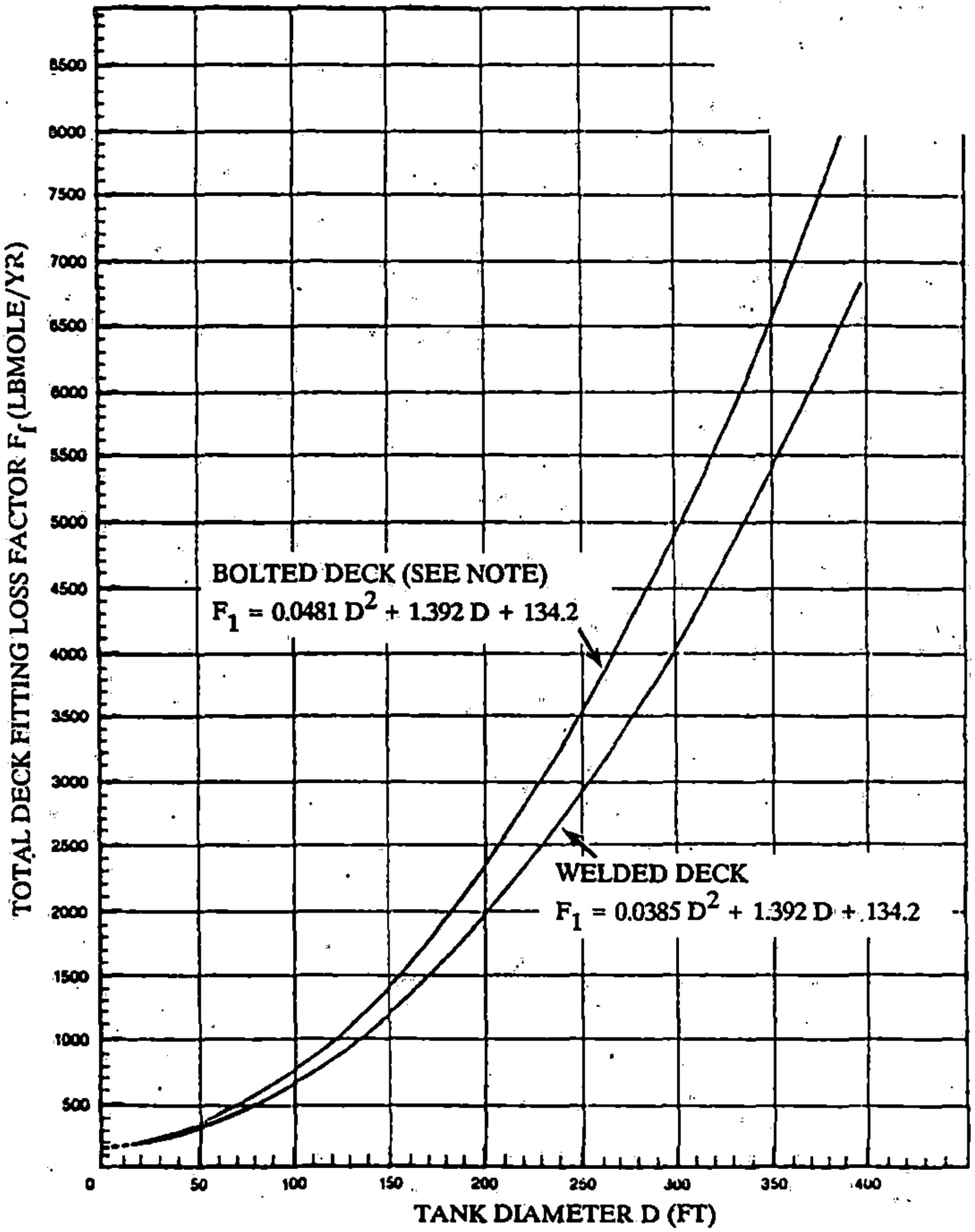
FIGURE 4-13 VAPOR PRESSURE FUNCTION (P^*)[4, 6]



$$P^* = \left(\frac{\left(\frac{P}{14.7}\right)}{\left[1 + \left(1 - \frac{P}{14.7}\right)^{0.5}\right]^2} \right)$$

Where:
Atmospheric pressure = 14.7 pounds per square inch absolute.

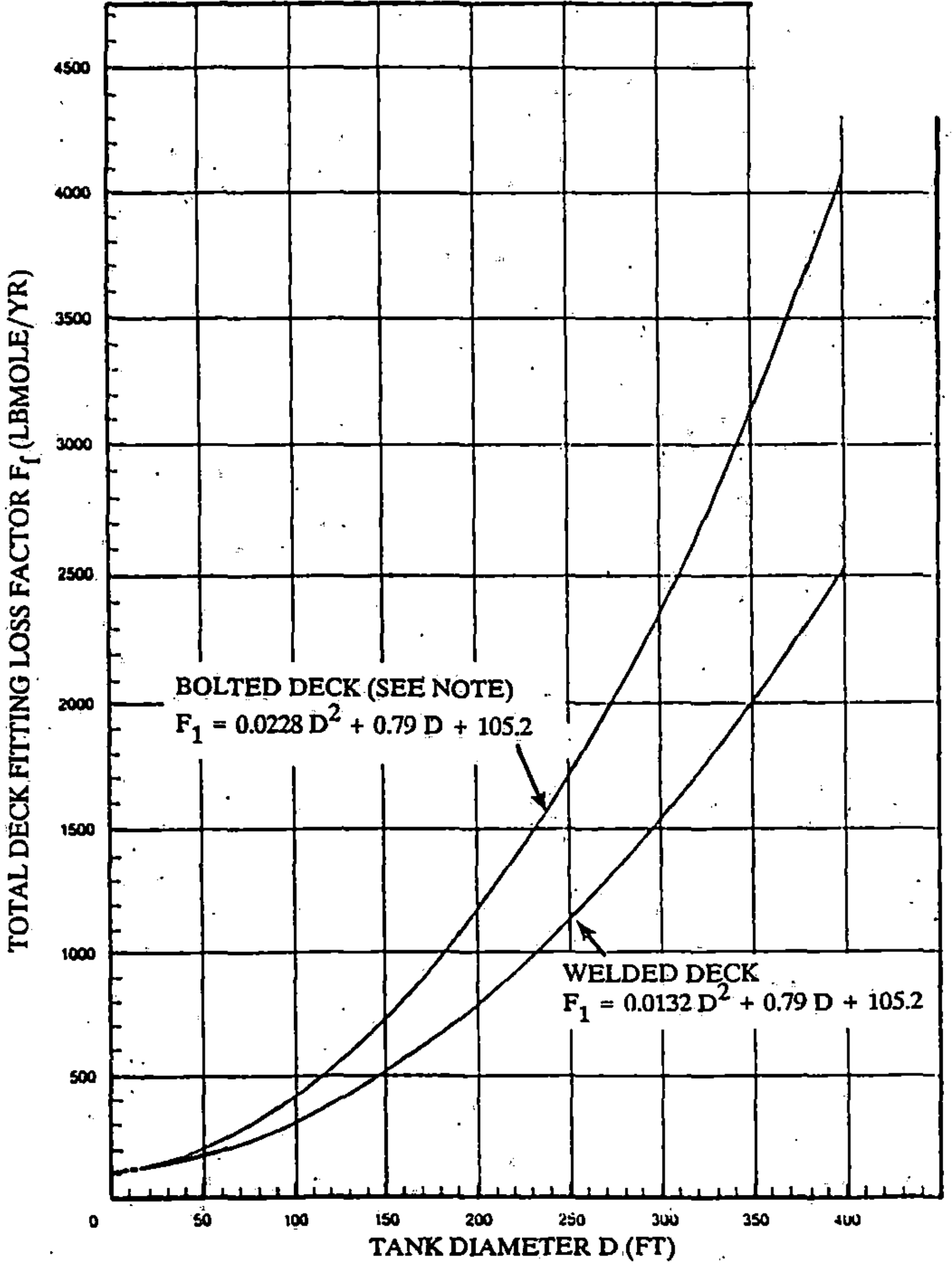
Note: Dashed line illustrates sample problem for P = 5.4 lbs/in^2 absolute



BASIS Fittings include: (1) access hatch, with ungasketed, unbolted cover; (2) built-up column wells, with ungasketed, sliding cover; (3) adjustable deck legs; (4) gauge float well, with ungasketed, unbolted cover; (5) ladder well, with ungasketed sliding cover; (6) sample well, with slit fabric seal (10 percent open area); (7) 1-inch diameter stub drains (only on bolted deck); and (8) vacuum breaker, with gasketed weighted mechanical actuation. This basis was derived from a survey of users and manufacturers. Other fittings may be typically used within particular companies or organizations to reflect standards and/or specifications of that group. This figure should not supersede information based on actual tank data.

NOTE If no specific information is available, assume bolted decks are the most common/typical type currently in use in tanks with column-supported fixed roofs.

FIGURE 4-14 Approximated total deck fitting loss factors (F_f) for typical fittings in tanks with column supported fixed roofs and either a bolted deck or a welded deck.[6] This figure is to be used only when tank specific data on the number and kind of deck fittings are unavailable.



BASIS Fittings include: (1) access hatch, with ungasketed, unbolted cover; (2) adjustable deck legs; (3) gauge float well, with ungasketed, unbolted cover; (4) sample well, with slit fabric seal (10 percent open area); (5) 1-inch diameter stub drains (only on bolted deck); and (6) vacuum breaker, with gasketed weighted mechanical actuation. This basis was derived from a survey of users and manufacturers. Other fittings may be typically used within particular companies or organizations to reflect standards and/or specifications of that group. This figure should not supersede information based on actual tank data.

NOTE If no specific information is available, assume welded decks are the most common/typical type currently in use in tanks with self-supporting fixed roofs.

FIGURE 4-15 Approximated total deck fitting loss factors (F_f) for typical deck fittings in tanks with self-supporting fixed roofs and either a bolted deck or a welded deck.[5] This figure is to be used only with tank specific data on the number and kind of deck fittings are unavailable.

TABLE 4-1 PHYSICAL PROPERTIES OF TYPICAL ORGANIC LIQUIDS [a]

ORGANIC LIQUID [b]	Vapor Molecular Weight at 60°F	Product Density Lb/gal at 60°F	Condensed Vapor Density Lb/gal at 60°F	TRUE VAPOR PRESSURE IN PSIA AT						
				40°F	50°F	60°F	70°F	80°F	90°F	100°F
PETROLEUM LIQUIDS [c]										
Gasoline RVP 13	62	5.6	4.9	4.7	5.7	6.9	8.3	9.9	11.7	13.8
Gasoline RVP 10	66	5.6	5.1	3.4	4.2	5.2	6.2	7.4	8.8	10.5
Gasoline RVP 7	68	5.6	5.2	2.3	2.9	3.5	4.3	5.2	6.2	7.4
Crude oil RVP 5	50	7.1	4.5	1.8	2.3	2.8	3.4	4.0	4.8	5.7
Jet naphtha (JP-4)	80	6.4	5.4	0.8	1.0	1.3	1.6	1.9	2.4	2.7
Jet kerosene	130	7.0	6.1	0.0041	0.0060	0.0085	0.011	0.015	0.021	0.029
Distillate fuel No.2	130	7.1	6.1	0.0031	0.0045	0.0074	0.0090	0.012	0.016	0.022
Residual oil No.6	190	7.9	6.4	0.00002	0.00003	0.00004	0.00006	0.00009	0.00013	0.00019
VOLATILE ORGANIC LIQUIDS										
Acetone	58	6.6	6.6	1.7	2.2	2.9	3.7	4.7	5.9	7.3
Acrylonitrile	53	6.8	6.8	0.8	1.0	1.4	1.8	2.4	3.1	4.0
Benzene	78	7.4	7.4	0.6	0.9	1.2	1.5	2.0	2.6	3.3
Carbon disulfide	76	10.6	10.6	3.0	3.9	4.8	6.0	7.4	9.2	11.2
Carbon tetrachloride	154	13.4	13.4	0.8	1.1	1.4	1.8	2.3	3.0	3.8
Chloroform	119	12.5	12.5	1.5	1.9	2.5	3.2	4.1	5.2	6.3
Cyclohexane	84	6.5	6.5	0.7	0.9	1.2	1.6	2.1	2.6	3.2
1,2-Dichloroethane	99	10.5	10.5	0.6	0.8	1.0	1.4	1.7	2.2	2.8
Ethylacetate	88	7.6	7.6	0.6	0.8	1.1	1.5	1.9	2.5	3.2
Ethyl alcohol	46	6.6	6.6	0.2	0.4	0.6	0.9	1.2	1.7	2.3
Isopropyl alcohol	60	6.6	6.6	0.2	0.3	0.6	0.7	0.9	1.3	1.8
Methyl alcohol	32	6.6	6.6	0.7	1.0	1.4	2.0	2.6	3.5	4.5
Methylene chloride	85	11.1	11.1	3.1	4.3	5.4	6.8	8.7	10.3	13.3
Methylethyl ketone	72	6.7	6.7	0.7	0.9	1.2	1.5	2.1	2.7	3.3
Methylmethacrylate	100	7.9	7.9	0.1	0.2	0.3	0.6	0.8	1.1	1.4
1,1,1-Trichloroethane	133	11.2	11.2	0.9	1.2	1.6	2.0	2.6	3.3	4.2
Trichloroethylene	131	12.3	12.3	0.5	0.7	0.9	1.2	1.5	2.0	2.0
Toluene	92	7.3	7.3	0.2	0.2	0.3	0.4	0.6	0.8	1.0
Vinylacetate	86	7.8	7.8	0.7	1.0	1.3	1.7	2.3	3.1	4.0

---

a. Reference 6, 8, 9

b. For a more comprehensive listing of volatile organic liquids refer to Reference 8

c. RVP = Reid Vapor Pressure

TABLE 4-2 AVERAGE STORAGE TEMPERATURE (T_S) AS A FUNCTION OF TANK PAINT COLOR [a]

TANK COLOR	AVERAGE STORAGE TEMPERATURE T_S (°F)
White	T_a[b] + 0.0
Aluminum	T_a + 2.5
Gray	T_a + 3.5
Black	T_a + 5.0

a. Reference 4, 6, 11
b. T_a is the average annual ambient temperature in degrees Fahrenheit

TABLE 4-3 PAINT FACTORS FOR FIXED ROOF TANKS [a]

(F_p)		PAINT FACTOR	
TANK COLOR		PAINT CONDITION	
ROOF	SHELL	GOOD	POOR
White	White	1.00	1.15
Aluminum (Specular)	White	1.04	1.18
White	Aluminum (Specular)	1.16	1.24
Aluminum (Specular)	Aluminum (Specular)	1.20	1.29
White	Aluminum (Diffuse)	1.30	1.38
Aluminum (Diffuse)	Aluminum (Diffuse)	1.39	1.46
White	Gray	1.30	1.38
Light Gray	Light Gray	1.33	1.44[b]
Medium Gray	Medium Gray	1.40	1.58[b]

a. Reference 6, 7, 11
b. Estimated from the ratios of the seven preceding paint factor

TABLE 4-4 SEAL RELATED FACTORS FOR FLOATING ROOF TANKS [a]

TANK AND SEAL TYPE	WELDED TANK		RIVETED TANK	
	K_S	n	K_S	n
A. EXTERNAL FLOATING ROOF TANKS [b]				
1. Metallic shoe seal				
a. Primary seal only	1.2	1.5	1.3	1.5
b. With shoe mounted secondary seal	0.8	1.2	1.4	1.2
c. With rim mounted secondary seal	0.2	1.0	0.2	1.6
2. Liquid mounted resilient seal				
a. Primary seal only	1.1	1.0	NA [c]	NA
b. With weather seal	0.8	0.9	NA	NA
c. With rim mounted secondary seal	0.7	0.4	NA	NA
3. Vapor mounted resilient seal				
a. Primary seal only	1.2	2.3	NA	NA
b. With weather seal	0.9	2.2	NA	NA
c. With rim mounted secondary seal	0.2	2.6	NA	NA
B. INTERNAL FLOATING ROOF TANKS [d]				
1. Liquid mounted resilient seal				
a. Primary seal only	3.0	0.0	NA	NA
b. With rim mounted secondary seal [e]	1.6	0.0	NA	NA
2. Vapor mounted resilient seal				
a. Primary seal only	6.7	0.0	NA	NA
b. With rim mounted secondary seal [e]	2.5	0.0	NA	NA

---

a. Based on emissions from tank seal systems in reasonably good working condition, no visible holes, tears, or unusually la gaps between the seals and the tank wall. The applicability of K_s decreases in cases where the actual gaps exceed the ga assume during development of the correlation

b. Reference 4, 6

c. NA = Not Applicable

d. Reference 5, 6

e. If tank specific information is not available about the secondary seal on an internal floating roof tank, then assume only primary seal is present

TABLE 4-5 ANNUAL WIND SPEED [a]

COUNTY	MPH
Los Angeles	6.8
Orange	6.3
Riverside	6.2
San Bernadino	7.4

a. Reference 13

TABLE 4-6 AVERAGE CLINGAGE FACTORS (C) (bbl/1,000 ft^2)[a]

	SHELL CONDITION		
LIQUID	LIGHT RUST[b]	DENSE RUST	GUNITE LINED
Gasoline	0.0015	0.0075	0.15
Single components stocks	0.0015	0.0075	0.15
Crude oil	0.0060	0.0300	0.60

a. Reference 4, 6.

b. If no specific information is available, these values can be assumed to represent the most common condition of tanks currently in use.

TABLE 4-7 TYPICAL NUMBER OF COLUMNS AS A FUNCTION OF TANK DIAMETER FOR INTERNAL FLOATING ROOF TANKS WITH COLUMNS SUPPORTED FIXED ROOF [a]

TANK DIAMETER RANGE	TYPICAL NUMBER OF COLUMNS, N_C
$0 < D \leq 85$	1
$85 < D \leq 100$	6
$100 < D \leq 120$	7
$120 < D \leq 135$	8
$135 < D \leq 150$	9
$150 < D \leq 170$	16
$170 < D \leq 190$	19
$190 < D \leq 220$	22
$220 < D \leq 235$	31
$235 < D \leq 270$	37
$270 < D \leq 275$	43
$275 < D \leq 290$	49
$290 < D \leq 330$	61
$330 < D \leq 360$	71
$360 < D \leq 400$	81

a. Reference 6, 10. This table was derived from survey of users and manufacturers. The actual number of columns in a particular tanks may vary greatly with age, fixed roof style, loading specifications, and manufacturing prerogatives. Data in this table should not supersede information on actual tanks.

TABLE 4-8 DECK SEAM LENGTH FACTORS FOR TYPICAL DECK CONSTRUCTION FOR INTERNAL FLOATING ROOF TANKS [a]

DECK CONSTRUCTION	TYPICAL DECK SEAM LENGTH FACTOR S_D (FT/FT^2)
Continuous sheet construction [b]	
5 ft wide	0.20 [c]
6 ft wide	0.17
7 ft wide	0.14
Panel Construction [d]	
5 x 7.5 ft rectangular	0.33
5 x 12 ft rectangular	0.28

a. Reference 5. Deck seam loss applies to bolted decks only.
b. $S_D = 1/W$ where W = Sheet width (ft)
c. If no specific information is available, these factors can be assumed to represent the most common bolted decks currently in use.
d. $S_D = (L + W)/(L \times W)$, where W = panel width (ft) and L = panel length (ft).

4.5 Rules And Regulations

The following District Rules and Regulations are applicable to storage tanks: Rule 212, 401, 402, 463 and Regulation XIII. [12]

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing the permit.

Rule 401 - Visible Emissions
No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 463 - Storage of Organic Liquids
Rule 463 requires storage facilities that meet any one of the following criteria to be equipped with a vapor control devices:

(1) Any stationary tank with capacity greater than or equal to 39,630 gallons holding any organic liquid having a true vapor pressure of 0.5 psia or greater under actual storage conditions.

(2) Any above-ground stationary tank with capacity greater than 19,815 gallons but less than 39,630 gallons holding any organic liquid having a true vapor pressure of 1.5 psia or greater under actual storage conditions.

(3) Any above-ground gasoline stationary tank with capacity less than or equal to 19,815 gallons but greater than 2,000 gallons installed and in service prior to January 9, 1976.

(4) Any above-ground gasoline stationary tank with capacity less than or equal to 19,815 gallons but more than 251 gallons installed on or after January 9, 1976.

The summary of Rule 463 requirements are outlined in Table 4-9 below.

TABLE 4-9 APPLICATION OF RULE 463

Installation Date	Location	Capacity (Gallons)	True Vapor Pressure (psia)	Type Of Roof	Type Of Shell	Type Of Primary Seal	Applicable Sections Of Rule 463
N/A	Above-Ground	V · 39,630 39,630 > V > 19,815	· 0.5 · 1.5	External Floating	Welded	Metallic Shoe	(a)(1)(A) (a)(1)(D) (a)(1)(E) (a)(1)(F) (a)(1)(G) (a)(1)(H) (a)(4) (e) (f) (g)
N/A	Above-Ground	V · 39,630 39,630 > V > 19,815	· 0.5 · 1.5	External Floating	Welded Or Riveted	Resilient Toroid	(a)(1)(B) (a)(1)(D) (a)(1)(E) (a)(1)(F) (a)(1)(G) (a)(1)(H) (a)(4) (e) (f) (g)
N/A	Above-Ground	V · 39,630 39,630 > V > 19,815	· 0.5 · 1.5	External Floating	Riveted	Metallic Shoe	(a)(1)(C) (a)(1)(D) (a)(1)(E) (a)(1)(F) (a)(1)(G) (a)(1)(H) (a)(4) (e) (f) (g)
N/A	Above Ground	V · 39,630 39,630 > V > 19,815	· 0.5 · 1.5	Fixed Roof With Internal Floating Roof			(a)(2) (a)(4) (e) (f) (g)
N/A	Above-Ground	V · 39,630 39,630 > V > 19,815	· 0.5 · 1.5	Fixed Roof			(a)(3) (a)(4) (a)(g)
Prior to 1/9/76 On Or After 1/9/76	Above-Ground	19,815 · V · 2,000 19,815 · V · 251	Gasoline Gasoline	Pressure OR Loss	Vacuum Control	Valve Device	(b) (e) (f) (g)

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility reactive organic gases (ROG) emissions in excess of one pound per day, Best Available Control Technology (BACT) is required.

Reactive organic gases in the SCAQMD is defined as any gaseous chemical compound which contains the element carbon; excluding carbon monoxide, carbon dioxide, carbonic acid, carbonates and metallic carbides; and excluding methane, 1,1,1-trichloethane, methylene chloride, trifluoromethane, trichlorotrifluoromethane, dichlorodifluoromethane, trichlorofluoromethane, chlorodifluoromethane, dichlorotetrafluoroethane, and chloropentafluoroethane.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[14] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

Table 4-10, 4-11, 4-12, 4-13, and Table 4-14 list the current BACT for different categories of storage tanks.

(2) If the accumulated maximum emission of ROG from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), which is 75 lb/day, in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

4.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, Permit (Operating) Conditions must be required. Permit (Operating) Conditions are listed Appendix 4E.

TABLE 4-10 BEST AVAILABLE CONTROL TECHNOLOGY FOR STORAGE TANK [14]

Equipment or Process: Storage Tank - Fixed Roof, Organic Liquids
Equipment Rating: < 19,815 Gallons

Revision: 1
Date: 9/06/89

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]					
BACT Achieved in Practice or Contained in EPA Approved SIP[2]	Vapor Recovery System with an Overall System Efficiency of ≥ 95%: - Vapor Balance System; or - Carbon Adsorber; or - Refrigerated Condenser; or - Incinerator; or - Equivalent				
BACT For Small Business[2]	Vapor Recovery System with an Overall System Efficiency of ≥ 95%: - Vapor Balance System; or - Carbon Adsorber; or - Refrigerated Condenser; or - Incinerator; or - Equivalent				
Alternate Basic Equipment or Process[1]					

1. Requires Economic Analysis.
2. No Economic Analysis.

TABLE 4-11 BEST AVAILABLE CONTROL TECHNOLOGY FOR STORAGE TANK [14]

Equipment or Process: Storage Tank - Fixed Roof, Organic Liquids
Equipment Rating: ≥ 19,815 Gallons

Revision: 1
Date: 9/06/89

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]					
BACT Achieved in Practice or Contained in EPA Approved SIP[2]	Vapor Recovery System with an Overall System Efficiency of ≥ 95%: - Carbon Adsorber; or - Refrigerated Condenser; or - Incinerator; or. - Equivalent				
BACT For Small Business[1]	Vapor Recovery System with an Overall System Efficiency of ≥ 95%: - Carbon Adsorber; or - Refrigerated Condenser; or - Incinerator; or - Equivalent				
Alternate Basic Equipment or Process[1]					

1. Requires Economic Analysis.
2. No Economic Analysis.

TABLE 4-12 BEST AVAILABLE CONTROL TECHNOLOGY FOR STORAGE TANK 14

Equipment or Process: Storage Tank - Internal Floating Roof, Organic Liquids
Equipment Rating: All

Revision: 1
Date: 9/06/89

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]					
BACT Achieved in Practice or Contained in EPA Approved SIP[2]	Multiple Dual Wiper Seals with Drip Curtain and SCAQMD Approved Roof				
BACT For Small Business[1]	Multiple Dual Wiper Seals with Drip Curtain and SCAQMD Approved Roof				
Alternate Basic Equipment or Process[1]					

1. Requires Economic Analysis.
2. No Economic Analysis.

TABLE 4-13 BEST AVAILABLE CONTROL TECHNOLOGY FOR STORAGE TANK [14]

**Equipment or Process: Storage Tank - External Floating Roof,
Organic Liquids**
Equipment Rating: All, VP ≤ 11 psia

Revision: 1
Date: 9/06/89

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]					
BACT Achieved in Practice or Contained in EPA Approved SIP[2]	Multiple Dual Wiper Seals with Drip Curtain and SCAQMD Approved Roof				
BACT For Small Business[1]	Multiple Dual Wiper Seals with Drip Curtain and SCAQMD Approved Roof				
Alternate Basic Equipment or Process[1]					

1. Requires Economic Analysis.
2. No Economic Analysis.

TABLE 4-14 BEST AVAILABLE CONTROL TECHNOLOGY FOR STORAGE TANK [14]

Equipment or Process: Storage Tank - Underground, Organic Liquids
Equipment Rating: > 250 Gallons

Revision:
Date: 10/07/88

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]					
BACT Achieved in Practice or Contained in EPA Approved SIP[2]	≥ 95% Removal Efficiency				
BACT For Small Business[1]	≥ 95% Removal Efficiency				
Alternate Basic Equipment or Process[1]					

1. Requires Economic Analysis
2. No Economic Analysis

REFERENCES

1. Air Pollution Engineering Manual, AP 40, 2nd Edition, 1973.

2. Petroleum Storage Principles, Alex Marks, PennWell Publishing Company, 1983.

3. API Bulletin On Evaporation Loss From Floating Roof Tanks, Bulletin No. 2517, American Petroleum Institute, Washington, D.C., February 1962.

4. Evaporation Loss From External Floating Roof Tanks, 2nd Edition, Bulletin No. 2517, American Petroleum Institute, Washington, D.C., February 1980.

5. Evaporation Loss From Internal Floating Roof Tanks, 3rd Edition, Bulletin No. 2519, American Petroleum Institute, Washington D.C., 1983.

6. Compilation of Air Pollutant Emission Factors, AP 42, 4th Edition, 1985.

7. Background Documentation for Storage of Organic Liquids, EPA Contract no 68-02-3174, TWR Environmental, Inc., Research Triangle Park, NC, May 1981.

8. Petroleum Evaporation Loss From Storage Tanks, Bulletin No. 2525, American Petroleum Institute New York, NY 1969.

9. Properties of Aircraft Fuels, NACA-TN 3276, Henry C. Barnett, et al., Lewis Flight Propulsion Laboratory, Cleveland, OH, August 1956.

10. VOC Emissions Volatile Organic Liquid Storage Tanks - Background Information For Proposed Standards, EPA-450/3-81-003a, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1984.

11. Evaporation Loss From Fixed Roof Tanks, Bulletin No. 2518, American Petroleum Institute, Washington D.C., June 1962.

12. Rules and Regulations, South Coast Air Quality Management District (SCAQMD).
Rule 212, Standard For Approving Permits, Amended March 3rd, 1989.
Rule 219, Equipment Not Requiring A written Permit Pursuant To Regulation II, Amended June 3rd, 1988.
Rule 401, Visible Emissions , Amended April 7, 1989.
Rule 402, Nuisance, Adopted May 7th, 1976.
Rule 463, Storage of Organic Liquids, Amended June 1st, 1984.
Regulation XIII, New Source Review, Amended September 5th, 1986.

13. South Coast Air Quality Management District (SCAQMD) Form B-6.

14. South Coast Air Quality Management District (SCAQMD) Best Available Control Technology (BACT) Guidelines, October 7, 1988.

APPENDIX 4A

WORKSHEET

FIXED ROOF PETROLEUM STORAGE TANKS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 4	PAGE 1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

> Applicability: This permit application form applies only to fixed roof storage tank(s) containing organic liquid which are not exempted under Rule 219(n).

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ______________

STORAGE TANK NO. , ' - " DIA., ' - " L., CAPACITY BBL (OR GALS), VENTED TO A (VAPOR RECOVERY UNIT) (THERMAL OXIDIZER).

HISTORY:

CALCULATION

1. Breathing Loss From Fixed Roof Tank:

$$L_B = 2.26 \times 10^{-2} M_V \left(\frac{P}{14.7 - P}\right)^{.68} D^{1.73} H^{.51} T^{.5} F_P C K_{cb}$$

$$= \_\_\_\_\_ \text{ lb/yr}$$

2. Working Loss From Fixed Roof Tank:

$$L_W = 2.40 \times 10^{-5} M_V P V N K_N C_{cw} = \_\_\_\_\_ \text{ lb/yr}$$

3. Maximum Uncontrolled Emissions From Fixed Roof Tank:

$$L_1 = L_B + L_W = \_\_\_\_\_ \text{ lb/yr} = \_\_\_\_\_ \text{ lb/day} = \_\_\_\_\_ \text{ lb/hr}$$

4. Maximum Controlled Emissions From Fixed Roof Tank:

$$L_2 = L_1 (1 - EFF) = \_\_\_\_\_ \text{ lb/yr} = \_\_\_\_\_ \text{ lb/day} = \_\_\_\_\_ \text{ lb/hr}$$

5. New Source Review Emissions:

$$R_1 = L_1 \text{ (lb/day)} \times 1.1 = \_\_\_\_\_ \text{ lb/day}$$
$$R_2 = L_2 \text{ (lb/day)} \times 1.1 = \_\_\_\_\_ \text{ lb/day}$$

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES	PAGE
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	VARIABLE		NOTE	VALUE	
a.	Tank diameter	(D)	1	____	ft
b.	Tank volume	(V)	1	____	gal
c.	Average outage	(H)	1 or 3	____	ft
d.	Adjustment factor for small tanks	(C)	9	____	
e.	Average daily temperature change	(T)	4	____	°F
f.	Average storage temperature	(T_S)	1 or 5	____	°F
g.	Tank color				
	Roof		1	____	
	Shell		1	____	
	Condition		1	____	
h.	Paint factor	(F_P)	10	____	
i.	Molecular weight	(M_V)	1 or 6	____	lb/lbmol
e					
j.	True vapor pressure	(P)	1 or 7	____	psia
k.	Crude oil factor				
	Breathing	(K_{cb})	2	____	
	Working	(K_{cw})	2	____	
l.	Annual throughput		1	____	gal/yr
m.	Annual turnover	(N)	1	____	
n.	Turnover factor	(K_N)	11	____	
o.	Efficiency of control system	(EFF)	1 or 8	____	

NOTE

1. Data given by the Applicant.
2. Data taken from AP 42.
3. If not given, H is estimated to be half of the tank height.
4. Average daily temperature change is assumed to be 20°F.
5. If not given, T_S is estimated from Table 4-2, Section 4, Permit Processing Handbook assuming ambient temperature = ______ °F.
6. If mixture of organic is stored in the tank, M_V is estimated using Equation 4.3, and Equation 4.4, Section 4, Permit Processing Handbook.
7. If not given,P is estimated from Figure 4-9, Figure 4-10, or Table 4-1, Section 4, Permit Processing Handbook.
8. If not given, efficiency of vapor recovery system is assumed to be 95% and thermal oxidizer is assumed to be 99%.
9. Figure 4-11, Section 4, Permit Processing Handbook.
10. Table 4-3, Section 4, Permit Processing Handbook.
11. Figure 4-12, Section 4, Permit Processing Handbook.

RULES EVALUATION:

RULE 401 - Visible Emission

[] Since the storage tank contains unheated liquid, it is not expected to violate Rule 401.

[] Asphalt or coal tar pitch stored in the tank shall not exceed 350°F or shall be handled in a manner approved by the Executive Office. The opacity in this case will be less than 40%.

RULE 402 - Nuisance

Nuisance complaints are(are not) expected.

REGULATION XIII - New Source Review

Rule 1303 - Applicability and analysis.

[] As shown by the Emission Threshold/New Source Sheet Table below, this new or modified equipment causes an increase in ROG emissions in excess of one pound per day. Therefore, Best Available Control Technology (BACT) is required.

BACT for this equipment is ____________. The applicant will (will not) provide BACT.

[] As shown by the Emission Threhold/New Source Sheet Table below, the net emission increase from the facility exceeds the threshold limit specified in 1303(a)(2). Therefore, the following steps are required in addition to BACT:

- () The company must obtain offsets from other facilities.
- () The company must use a mathematical model approved by the District's Executive Officer to assess the impact of the plant on the area around it.
- () The company must certify in writing that all of its facilities in the state that emits 25 tons per year or more of ROG comply with federal, state, and local air quality laws.

	NSR Emissions in Pounds Per Day				
	ROG	NO_x	SO_2	CO	PM
Facility Emissions Since 10-8-76	____	____	____	____	____
A/N	____	____	____	____	____
A/N	____	____	____	____	____
Net Emission Increase Since 10-8-76	____	____	____	____	____

APPENDIX 4B

WORKSHEET

FIXED ROOF CHEMICAL STORAGE TANKS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT	PAGES 4	PAGE 1
ENGINEERING DIVISION	APPL. NO.	DATE
APPLICATION PROCESSING AND CALCULATIONS	PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

Applicability: This permit application form applies only to fixed roof storage tank(s) containing organic liquid which are not exempted under Rule 219(n).

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ______________

STORAGE TANK NO. , ' - " DIA., ' - " L., CAPACITY BBL (OR GALS), (WITH A VAPOR RETURN SYSTEM) OR (VENTED TO A VAPOR CONTROL SYSTEM) OR (VENTED TO A SPARGER).

HISTORY:

CALCULATION:

1. Breathing Loss From Fixed Roof Tank:
   $L_B = V_o \frac{T}{T_{AV}} \frac{1}{v} \frac{P}{14.7} M_V =$ _____ lb/day

2. Working Loss From Fixed Roof Tank:
   $L_W = F \left(\frac{1\ ft^3}{7.48\ gal}\right)\left(\frac{1\ lbmole}{380\ ft^3}\right) M_V \left(\frac{P}{14.7\ psia}\right)\left(\frac{60\ min}{1\ hr}\right)$
   = _____ lb/hr = _____ lb/day

3. Maximum Uncontrolled Emissions From Fixed Roof Tank:
   $L_1 = L_B + L_W =$ _____ lb/day = _____ lb/hr

4. Maximum Controlled Emissions From Fixed Roof Tank:
   $L_2 = L_1 (1 - EFF) =$ _____ lb/day = _____ lb/hr

5. New Source Review Emissions:
   $R_1 = L_1$ (lb/day) x 1.1 = _____ lb/day
   $R_2 = L_2$ (lb/day) x 1.1 = _____ lb/day

	VARIABLE		NOTE	VALUE	
a.	Volume of vapor above the liquid surface	(V_o)	1	____	ft^3
b.	Average daily temperature change	(T)	1 or 2	____	^oF
c.	Average daily temp.	(T_{AV})	1	____	^oR
d.	Molecular weight	(M_V)	1 or 3	____	lb/lbmole
e.	True vapor pressure	(P)	1 or 4	____	psia
f.	Molecular volume	(v)	5	____	ft^3/lbmole
g.	Efficiency of vapor control system	(EFF)	1 or 6	____	
h.	Filling rate	(F)	1	____	gal/min

NOTE

1. Data given by the Applicant.
2. Average daily temperature change is assumed to be 20^{o}F.
3. If mixture of organic is stored in the tank, M_V is estimated using Equation 4.3, and Equation 4.4, Section 4, Permit Processing Handbook.
4. If not given, P is from Appendix 4H, Section 4, Permit Processing Handbook.
5. $v = 10.73 \left(\frac{ft^3\ psia}{lbmole\ ^oR}\right) T_{AV}(^oR) \left(\frac{1}{14.7\ psia}\right)$
6. If not given, efficiency of vapor control system is assumed to be 95%

RULES EVALUATION:

RULE 401 - Visible Emission

[] Since the storage tank contains unheated liquid, it is not expected to violate Rule 401.

[] Asphalt or coal tar pitch stored in the tank shall not exceed 350^{o}F or shall be handled in a manner approved by the Executive Office. The opacity in this case must be less than 40%.

RULE 402 - Nuisance

Nuisance complaints are(are not) expected.

REGULATION XIII - New Source Review
Rule 1303 - Applicability and analysis.

[] As shown by the Emission Threshold/New Source Sheet Table below, this new or modified equipment causes an increase in ROG emissions in excess of one pound per day. Therefore, Best Available Control Technology (BACT) is required.

BACT for this equipment is ____________. The applicant will (will not) provide BACT.

☐ As shown by the Emission Threhold/New Source Sheet Table below, the net emission increase from the facility exceeds the threshold limit specified in 1303(a)(2). Therefore, the following steps are required in addition to BACT:

() The company must obtain offsets from other facilities.
() The company must use a mathematical model approved by the District's Executive Officer to assess the impact of the plant on the area around it.
() The company must certify in writing that all of its facilities in the state that emits 25 tons per year or more of ROG comply with federal, state, and local air quality laws.

	NSR Emissions in Pounds Per Day				
	ROG	NO_x	SO_2	CO	PM
Facility Emissions Since 10-8-76	____	____	____	____	____
A/N	____	____	____	____	____
A/N	____	____	____	____	____
Net Emission Increase Since 10-8-76	____	____	____	____	____

<u>RULE 463</u> - Storage of Organic Liquid
In order to find what specific section(s) of Rule 463 are applied for this application, use Table 4-9, Section 4, Permit Processing Handbook.

	Requirement	Section	Compliance	
			Yes	No
1.	Vapor control system, efficiency of 95%	(a)(3)	☐	☐
2.	Leak free accessories (piping, valves...)	(a)(3)	☐	☐
3.	Records showing type of liquid stored, true vapor pressure range and throughput data.	(a)(4)	☐	☐
4.	Pressure vacumn valve set at 10% maximum allowable working pressure.	(b)	☐	☐
5.	Exempted from 463(a) because heating for shipment only occurs less than 48 hours and not more than once every 20 hour period.	(g)	☐	☐

The equipment is(is not) in compliance with Rule 463.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

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CONCLUSIONS/RECOMMENDATIONS:

This application is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

( ) Issue a Permit to Construct/Operate subject to the following conditions: (Refer to Appendix 4E for the wording of conditions).

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ____________________ of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 4C

WORKSHEET

EXTERNAL FLOATING ROOF STORAGE TANKS

R SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

Applicability: This permit application form applies only to external floating roof storage tank(s) containing organic liquid which are not exempted under Rule 219(n).

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ________________

STORAGE TANK NO. , ' - " DIA., ' - " L., CAPACITY BBL
(OR GALS), (DOUBLE)(SINGLE) SEAL.

HISTORY:

CALCULATION:

1. Standing Loss From Floating Roof Tank:
   $L_S = K_S v^n P^* D M_V K_c =$ _____ lb/yr
2. Withdrawal Loss From Floating Roof Tank:

   $$L_{WD} = \frac{.943\ Q\ C\ W_L}{D} = \_\_\_\_\_ \text{ lb/yr}$$
3. Total Emissions (Controlled or Uncontrolled) From Floating Roof Tank:
   $L_1 = L_2 = L_{WD} + L_S =$ _____ lb/yr = _____ lb/day = _____ lb/hr
4. New Source Review Emissions From Floating Roof Tank:
   $R_1 = R_2 = L_1$ (lb/day) x 1.1 = _____ lb/day

	VARIABLE		NOTE	VALUE	
a.	Tank diameter	(D)	1	____	ft
b.	Type of shell construction		1	____	
c.	Type of primary seal		1	____	
d.	Type of secondary seal		1	____	
e.	Seal factor	(K_S)	6	____	
f.	Wind speed exponent	(n)	6	____	
g.	Average wind speed	(v)	7	____	mile/hr
h.	Molecular weight	(M_V)	1 or 3	____	lb/lbmole
i.	True vapor pressure	(P)	1 or 4	____	psia
j.	Vapor press function	(P)	5	____	
k.	Crude oil factor	(K_C)	2	____	
l.	Clingage factor	(C)	8	____	
m.	Shell condition		1	____	
n.	Annual throughput	(Q)	1	____	bbl/yr
o.	Density of liquid	(W_L)	1	____	lb/gal

NOTE

1. Data given by the Applicant.
2. Data taken from AP 42.
3. If mixture of organic is stored in the tank, M_V is estimated using Equation 4.3, and Equation 4.4, Section 4, Permit Processing Handbook.
4. If not given, P is estimated from Figure 4-9, Figure 4-10, or Table 4-1, Section 4, Permit Processing Handbook.
5. P is estimated using Equation 4.10, Section 4, Permit Processing Handbook.
6. Table 4-4, Section 4, Permit Processing Handbook.
7. Table 4-5, Section 4, Permit Processing Handbook.
8. Table 4-6, Section 4, Permit Processing Handbook.

RULES EVALUATION:

RULE 401: - Visible Emission

☐ Since the storage tank contains unheated liquid, it is not expected to violate Rule 401.

☐ Asphalt or coal tar pitch stored in the tank shall not exceed 350°F or shall be handled in a manner approved by the Executive Office. The opacity in this case must be less than 40%.

RULE 402: - Nuisance

Nuisance complaints are(are not) expected.

RULE 463: - Storage of Organic Liquid.

In order to find what specific section(s) of Rule 463 are applied for this application, use Table 4-9, Section 4, Permit Processing Handbook.

Gaps between the tank shell and the seal comply with the following:

		Requirements	Section	Compliance	
				Yes	No
1.	a)	No gap shall exceed 1.5".	(a)(1)(A,B,C)	☐	☐
	b)	No continuous gap greater than 1/8" exceeds 10% tank's circumference.		☐	☐
	c)	Accumulative length of gaps that fall between 1.5" and 1/2" must not exceed 10% of the tank's circumference.		☐	☐
	d)	Accumulative length of gaps that falls between 1/2" and 1/8" must not exceed 30% of the tank's circumference.		☐	☐
	e)	Accumulative length of gaps that is smaller than 1/8" must not exceed 60% of the tank's circumference.		☐	☐
2.		If the seal is installed on or after 8/1/77, one end of the shoe should be installed into the stored liquid and the other end extends a minimum vertical distance of 24" above the liquid surface.	(a)(1)(A,C)	☐	☐
3.		The maximum gap between the primary seal and the tank shell for a length of 18" in the vertical plane above the liquid surface shall not exceed 3".	(a)(1)(A,C)	☐	☐
4.		The seal is in perfect condition, no holes and tears or openings which allow the emission of organic vapors.	(a)(1)(A,C)	☐	☐
5.	a)	No gap shall exceed 1/2".	(a)(1)(A,B,C)	☐	☐
	b)	Accumulative length of gaps that fall between 1/2" and 1/8" must not exceed 5% of the tank's circumference.		☐	☐
	c)	Accumulative length of gaps that is smaller than 1/8" must not exceed 95% of the tank's circumference.		☐	☐

	Requirements	Section	Compliance Yes	Compliance No
6.	The secondary seal allows easy insertion of probes up to 1.5" in order to measure gaps in the primary seal.	(a)(1)(A,C)	☐	☐
7.	The secondary seal shall extend from the roof to the tank shell and shall not be attached to the primary seal.	(a)(1)(A,C)	☐	☐
8.	The secondary seal allows easy insertion probes up to 1.5" in order to measure gaps in the primary seal.	(a)(1)(B)	☐	☐
9.	The secondary seal shall extend from the roof to the tank shell and shall not be attached to the primary seal.	(a)(1)(B)	☐	☐
10.	This application is exempted from Rule 463(a)(1)(A), 463(a)(1)(B) or 463(a)(1)(C) since prior to use or installation of a closure device, an actual emission test, or a pressure leak test will be performed. The method of measurement shall be prior approved by the Executive Officer.	(a)(1)(D)	☐	☐
11.	a) Primary seal shall be made available for inspection once every year at locations selected randomly along the circumference and inspected prior to the installation of the secondary seal.	(a)(1)(E)	☐	☐
	b) After the secondary seal is installed, primary seal shall be inspected for its full circumference every five years.		☐	☐
12.	All openings in the roof, except pressure vacuum valves, set to within 10% of the maximum allowable working pressure of the roof, shall provide a projection below the liquid surface, and shall be equipped with a cover, seal or lid.	(a)(1)(F)	☐	☐
13.	Any emergency roof drain shall be provided with a slotted membrane fabric cover, or equivalent, that covers at least nine-tenths of the area of the opening.	(a)(1)(G)	☐	☐

	Requirements	Section	Compliance Yes	Compliance No
14.	This tank must not be used to store organic liquid having a vapor pressure greater or equal to 569 mmHg (11 psia) under actual storage conditions.	(a)(1)(H)	☐	☐
15.	Records containing type of liquid stored, true vapor pressures range and throughput data should be available for inspection by the District.	(a)(4)	☐	☐
16.	Tank is equipped with pressure vacumn valve set at 10% of maximum allowable working pressure of the tank or seals which comply with 463(a) requirements.	(b)	☐	☐
17.	Procedures for emptying, cleaning, or repairing the tank must be approved by the Executive Officer.	(e)	☐	☐
18.	Crude oil contains less than 70ppm of H_2S.	(f)	☐	☐
19.	Exempted from Rule 463(a) because monthly average throughput is less than 30 barrels per day and tank installed prior to 6/1/84.	(g)	☐	☐
20.	Exempted from Rule 463(a) because failure to comply only occurs when heated for shipment. Such period occurs less than 48 hours and not more than once every 20 hour period.	(g)	☐	☐

<u>REGULATION XIII</u> - New Source Review
Rule 1303 - Applicability and analysis.

☐ As shown by the Emission Threshold/New Source Sheet Table below, this new or modified equipment causes an increase in ROG emissions in excess of one pound per day. Therefore, Best Available Control Technology (BACT) is required.

BACT for this equipment is ____________. The applicant will (will not) provide BACT.

[] As shown by the Emission Threhold/New Source Sheet Table below, the net emission increase from the facility exceeds the threshold limit specified in 1303(a)(2). Therefore, the following steps are required in addition to BACT:

- () The company must obtain offsets from other facilities.
- () The company must use a mathematical model approved by the District's Executive Officer to assess the impact of the plant on the area around it.
- () The company must certify in writing that all of its facilities in the state that emits 25 tons per year or more of ROG comply with federal, state, and local air quality laws.

	NSR Emissions in Pounds Per Day				
	ROG	NO_x	SO_2	CO	PM
Facility Emissions Since 10-8-76					
A/N					
A/N					
Net Emission Increase Since 10-8-76					

In addition to all of the above rules, the external floating roof tank has to satisfy additional requirements listed in Appendix 4F. The approved seals and seal systems are listed in Appendix 4G.

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. Therefore, the following disposition is recommended:

( ) Issue a Permit to Construct/Operate subject to the following conditions: (Refer to Appendix 4E for the wording of conditions).

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ______________________ of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 4D

WORKSHEET

INTERNAL FLOATING ROOF STORAGE TANKS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

> Applicability: This permit application form applies only to internal floating roof storage tank(s) containing organic liquid which are not exempted under Rule 219(n).

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ____________

STORAGE TANK NO. , ' - " DIA., ' - " L., CAPACITY BBL (OR GALS), (DOUBLE)(SINGLE) SEAL.

HISTORY:

CALCULATION:

1. Standing Loss From Internal Floating Roof Tank:
$L_S = K_S V^n P^* D M_V K_c =$ _____ lb/yr

2. Withdrawal Loss From Internal Floating Roof Tank:
$L_{WD} = \frac{0.943\ Q\ C\ W_L}{D}(1 + \frac{N_C F_C}{D}) =$ _____ lb/yr

3. Total Emissions (Controlled or Uncontrolled) From Internal Floating Roof Tank:
$L_1 = L_2 = L_{WD} + L_S =$ _____ lb/yr = _____ lb/day = _____ lb/hr

   The internal floating roof tank also has deck fitting loss and deck seam loss. These losses are negligible compared to the standing and withdrawal losses.

4. New Source Review Emissions From Internal Floating Roof Tank:
$R_1 = R_2 = L_1$ (lb/day) x 1.1 = _____ lb/day

	VARIABLE		NOTE	VALUE	
a.	Tank diameter	(D)	1	___	ft
b.	Shell construction type		1	___	
c.	Type of primary seal		1	___	
d.	Type of secondary seal		1	___	
e.	Seal factor	(K_S)	8	___	
f.	Wind speed exponent	(n)	8	___	
g.	Average wind speed	(v)	9	___	mile/hr
h.	Molecular weight	(M_V)	1 or 3	___	lb/lbmole
i.	True vapor pressure	(P)	1 or 4	___	psia
j.	Vapor press function	(P)	5	___	
k.	Crude oil factor	(K_C)	2	___	
l.	Clingage factor	(C)	10	___	
m.	Shell condition		1	___	
n.	Annual throughput	(Q)	1	___	bbl/yr
o.	Density of liquid	(W_L)	1	___	lb/gal
p.	No. of columns	(N_C)	1 or 6	___	
q.	Effective column diameter	(F_C)	7	___	

NOTE

1. Data given by the Applicant.
2. Data taken from AP 42.
3. If mixture of organic is stored in the tank, M_V is estimated using Equation 4.3, and Equation 4.4, Section 4, Permit Processing Handbook.
4. If not given, P is estimated from Figure 4-9, Figure 4-10, or Table 4-1, Section 4, Permit Processing Handbook.
5. P is estimated using Equation 4.7, Section 4, Permit Processing Handbook.
6. $N_C = 0$ for self-supported internal floating roof tank. If not given by the applicant, N_C is estimated from Table 4-7, Section 4, Permit Processing Handbook for column-supported internal floating roof tank.
7. Effective column diameter for an internal floating roof tank: 1.1 for 9" x 7" column, 0.7 for 8" diameter column, and 1 if details not shown (AP 42).
8. Table 4-4, Section 4, Permit Application Handbook.
9. Table 4-5, Section 4, Permit Application Handbook.
10. Table 4-6, section 4, Permit Application Handbook.

RULES EVALUATION:

RULE 401: - Visible Emission

[] Since the storage tank contains unheated liquid, they are not expected to violate Rule 401.

☐ Asphalt or coal tar pitch stored in the tank shall not exceed 350°F or shall be handled in a manner approved by the Executive Office. The opacity in this case must be less than 40%.

RULE 402: - Nuisance
Nuisance complaints are(are not) expected.

RULE 463: - Storage of Organic Liquid.

In order to find what specific section(s) of Rule 463 are applied for this application, use Table 4-9, Section 4, Permit Processing Handbook.

Gaps between the tank shell and the seal comply with the following:

	Requirements	Section	Compliance Yes	No
1.	Tank is equipped with either liquid mounted primary seals only or two seals a primary and a secondary seal which are in compliance with 463(a)(1)(A).	(a)(2)	☐	☐
2.	Gaps between tank's shell and primary seal:			
	a) No gap shall exceed 1.5".	(a)(1)(A)	☐	☐
	b) No continuous gap greater than 1/8" exceeds 10% tank's circumference.		☐	☐
	c) Accumulative length of gaps that fall between 1.5" and 1/2" must not exceed 10% of the tank's circumference.		☐	☐
	d) Accumulative length of gaps that fall between 1/2" and 1/8" must not exceed 30% of the tank's circumference.		☐	☐
	e) Accumulative length of gaps that are smaller than 1/8" must not exceed 60% of the tank's circumference.		☐	☐
3.	If the seal is installed on or after 8/1/77, one end of the shoe should be installed into the stored liquid and the other end extends a minimum vertical distance of 24" above the liquid surface.	(a)(1)(A)	☐	☐

	Requirements	Section	Compliance Yes	Compliance No
4.	The maximum gap between the primary seal and the tank shell for a length of 18" in the vertical plane above the liquid surface shall not exceed 3".	(a)(1)(A)	☐	☐
5.	The seal is in perfect condition, no holes and tears or openings which allow the emission of organic vapors.	(a)(1)(A)	☐	☐
6.	Gaps between tank's shell and secondary seal:			
	a) No gap shall exceed 1/2".	(a)(1)(A)	☐	☐
	b) Accumulative length of gaps that falls between 1/2" and 1/8" must not exceed 5% of the tank's circumference.		☐	☐
	c) Accumulative length of gaps that is smaller than 1/8" must not exceed 95% of the tank's circumference.		☐	☐
7.	The secondary seal allows easy insertion of probes up to 1.5" in order to measure gaps in the primary seal.	(a)(1)(A)	☐	☐
8.	The secondary seal shall extend from the roof to the tank shell and shall not be attached to the primary seal.	(a)(1)(A)	☐	☐
9.	This tank must not be used to store organic liquid having a vapor pressure greater or equal to 569 mmHg (11 psia) under actual storage conditions.	(a)(2)	☐	☐
10.	The hydrocarbon concentration in the vapor space above the internal floating roof must not exceed (50%)(30%) of the lower explosion limit.	(a)(2)	☐	☐
11.	Secondary seals should be inspected semi-annually by the applicant. Records shall be maintained and made available for review by the District.	(a)(2)	☐	☐
12.	The District will be notified to inspect the internal floating roof prior to filling the tank.	(a)(2)	☐	☐

	Requirements	Section	Compliance Yes	Compliance No
13.	Records containing type of liquid stored, true vapor pressures range and throughput data should be available for inspection by the District.	(a)(4)	☐	☐
14.	Tank is equipped with pressure vacuum valve set at 10% of maximum allowable working pressure of the tank or seals which comply with 463(a) requirements.	(b)	☐	☐
15.	Procedures for emptying, cleaning or repairing the tank must be approved by the Executive Officer.	(e)	☐	☐
16.	Crude oil contains less than 70ppm of H_2S.	(f)	☐	☐
17.	Exempted from Rule 463(a) because monthly average throughput is less than 30 barrels per day and tank installed prior to 6/1/84.	(g)	☐	☐
18.	Exempted from Rule 463(a) because failure to comply only occurs when heated for shipment. Such period occurs less than 48 hours and not more than once every 20 hour period.	(g)	☐	☐

<u>REGULATION XIII</u> - New Source Review
Rule 1303 - Applicability and Analysis.

☐ As shown by the Emission Threshold/New Source Sheet Table below, this new or modified equipment causes an increase in ROG emissions in excess of one pound per day. Therefore, Best Available Control Technology (BACT) is required.

BACT for this equipment is ____________. The applicant will (will not) provide BACT.

☐ As shown by the Emission Threhold/New Source Sheet Table below, the net emission increase from the facility exceeds the threshold limit specified in 1303(a)(2). Therefore, the following steps are required in addition to BACT:

() The company must obtain offsets from other facilities.
() The company must use a mathematical model approved by the District's Executive Officer to assess the impact of the plant on the area around it.
() The company must certify in writing that all of its facilities in the state that emits 25 tons per year or more of ROG comply with federal, state, and local air quality laws.

	NSR Emissions in Pounds Per Day				
	ROG	NO_x	SO_2	CO	PM
Facility Emissions Since 10-8-76					
A/N					
A/N					
Net Emission Increase Since 10-8-76					

In addition to all of the above rules, the internal floating roof tank has to satisfy additional requirements listed in Appendix 4F, Section 4, Permit Application Handbook. The approved seals and seal systems are listed in Appendix 4G, Section 4, Permit Application Handbook.

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

( ) Issue a Permit to Construct/Operate subject to the following conditions: (Refer to Appendix 4E for the wording of conditions).

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ______________ of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 4E

STORAGE TANK OPERATING CONDITIONS

I. FIXED ROOF STORAGE TANK OPERATING CONDITIONS

1. THIS TANK (TANK NO. _____) CAN ONLY STORE ____.

2. THIS TANK MUST NOT BE USED FOR STORING ORGANIC LIQUID HAVING A VAPOR PRESSURE OF _____ mm Hg (_____ PSIA) <u>OR</u> GREATER UNDER ACTUAL STORAGE CONDITIONS.

3. THIS TANK MUST NOT BE OPERATED UNLESS VENTED TO A VAPOR CONTROL SYSTEM WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO (OPERATE)(CONSTRUCT) BY THE EXECUTIVE OFFICER.
   <u>OR</u>
   DURING FILLING, THIS EQUIPMENT MUST BE VENTED ONLY TO THE VESSEL FROM WHICH IT IS BEING FILLED.

4. THROUGHPUT TO THIS TANK OF ORGANIC LIQUIDS MUST NOT EXCEED _____ TURNOVERS PER YEAR.
   <u>OR</u>
   THE MAXIMUM QUANTITY OF ____________ FILLED INTO THIS EQUIPMENT MUST NOT EXCEED _____ GALLONS PER DAY.
5. THIS TANK MUST COMPLY WITH ALL REQUIREMENTS OF REGULATION IX.

6. <u>   (COMPANY NAME)   </u> MUST COMPLY WITH RULE 1113 DURING PAINTING OPERATION.

7. THE DIRECTOR OF ENFORCEMENT MUST BE NOTIFIED A MINIMUM OF 24 HOURS PRIOR TO THE COMMENCEMENT OF PAINTING THIS EQUIPMENT.

8. THROUGHPUT RECORDS, THOSE RECORDS REQUIRED BY RULE 463 (a)(4), AND THE PAINTING OPERATION RECORDS. MUST BE MAINTAINED IN A FORMAT APPROVED BY THE DIRECTOR OF ENFORCEMENT, KEPT ON FILE FOR A MINIMUM OF TWO YEARS, AND MADE AVAILABLE UPON REQUEST OF DISTRICT PERSONNEL.

9. ASPHALT STORED IN OR PUMPED INTO THIS TANK SHALL NOT EXCEED 350 °F <u>OR</u> SHALL BE HANDLED IN A MANNER APPROVED BY THE EXECUTIVE OFFICER THAT DOES NOT VIOLATE RULE 401.

10. A TEMPERATURE GAGE MUST BE INSTALLED TO MONITOR THE TEMPERATURE OF MATERIALS STORED IN THIS TANK. THE TEMPERATURE MUST NOT EXCEED _____ °F.

11. THIS TANK MUST NOT BE FILLED UNLESS THE VENT GASES ARE SPARGED AT LEAST _____ INCHES BELOW THE SURFACE OF A TRAP CONTAINING A MINIMUM OF ____ GALLONS OF (ACIDIC SOLUTION)(WATER)(CAUSTIC SOLUTION) MAINTAINED AT pH ______ <u>OR</u> (GREATER)(LOWER).

12. A PRESSURE RELIEF VALVE MUST BE INSTALLED FOR THIS TANK AND SET AT _____ mm Hg (_____ PSIA).

13. THIS TANK CAN ONLY BE USED FOR STORING SOUR WATER IF A ONE FOOT LAYER OF DISTILLATE (DIESEL) OIL IS FLOATED ON THE WATER'S SURFACE AND THE TANK IS VENTED TO A VAPOR RECOVERY SYSTEM APPROVED BY THE EXECUTIVE OFFICER.

II. EXTERNAL FLOATING ROOF STORAGE TANK OPERATING CONDITIONS

1. THROUGHPUT TO THIS TANK (TANK NO _____) OF ORGANIC LIQUIDS SHALL NOT EXCEED _____ TURNOUVERS PER YEAR.

2. THIS TANK MUST NOT BE USED FOR STORING PETROLEUM LIQUID HAVING A VAPOR PRESSURE OF_____ mm Hg (____ PSIA) OR GREATER UNDER ACTUAL STORAGE CONDITIONS.

3. THIS TANK MUST NOT BE USED FOR STORING PURE ORGANIC COMPOUNDS.

4. THIS TANK MUST COMPLY WITH ALL REQUIREMENTS OF REGULATION IX.

5. ____(COMPANY NAME)____ MUST COMPLY WITH RULE 1113 DURING PAINTING OPERATION.

6. THE DIRECTOR OF ENFORCEMENT MUST BE NOTIFIED A MINIMUM OF 24 HOURS PRIOR TO THE COMMENCEMENT OF PAINTING THIS EQUIPMENT.

7. THROUGHPUT RECORDS, THE RECORDS REQUIRED BY RULE 463 (a)(4), AND THE PAINTING OPERATION RECORDS MUST BE MAINTAINED IN A FORMAT APPROVED BY THE DIRECTOR OF ENFORCEMENT, KEPT ON FILE FOR A MINIMUM OF TWO YEARS, AND MADE AVAILABLE UPON REQUEST BY AUTHORIZED DISTRICT PERSONNEL.

8. INSTALLATION OF THE APPROVED SECONDARY SEAL IS NOT TO BEGIN UNTIL THE SHOE/TUBE/WIPER PRIMARY SEAL HAS BEEN INSPECTED AND APPROVED.

9. GAPS BETWEEN THE SECONDARY SEAL AND THE RIVETED SHELL MUST NOT EXCEED 1/2" WIDTH, EXCEPT FOR GAPS CAUSED EXCLUSIVELY BY THE VERTICAL LAP JOINTS/BUTT STRAPS WHICH ARE 1/2" THICK OR GREATER. IN CASES WHERE THE VERTICAL LAP JOINTS/BUTT STRAPS ARE MORE THAN 1/2" THICK , THE ALLOWABLE GAP WIDTH SHALL BE NO GREATER THAN 1/8" MORE THAN THE THICKNESS OF THE BUTT STRAP, AND THE GAP LENGTH (IN EXCESS OF 1/2" WIDE) NO LONGER THEN 1.75 TIMES THE THICKNESS OF THE LAP JOINT/BUTT STRAP.

10. GAPS BETWEEN THE MODIFIED MALONEY SEAL AND THE TANK WALL MUST NOT EXCEED 1/4" IN WIDTH. GAPS THAT FALL BETWEEN 1/8" AND 1/4" WIDE MUST NOT HAVE AN ACCUMULATED LENGTH OF MORE THAN 5% OF THE TANK'S CIRCUMFERENCE.

11. ____(COMPANY NAME)____ SHALL PROVIDE WRITTEN PROCEDURES FOR REMOVAL OF ANY FLOATING ROOF TANK FROM SERVICE THAT HAS STORED OUTER CONTINENTAL SHELF (OCS) CRUDE OIL. SUCH PROCEDURES MUST BE APPROVED BY THE EXECUTIVE OFFICER.

12. AFTER THE PROPOSED ALTERATION/CONSTRUCTION OF THIS TANK HAS BEEN COMPLETED, THE DIRECTOR OF ENFORCEMENT MUST BE NOTIFIED A MINIMUM OF 48 HOURS PRIOR TO FILLING THE TANK TO ALLOW INSPECTION OF THE FLOATING ROOF BY DISTRICT PERSONNEL.

III. INTERNAL FLOATING ROOF STORAGE TANK OPERATING CONDITIONS

1. THROUGHPUT TO THIS TANK (TANK NO. _____) OF ORGANIC LIQUIDS MUST NOT EXCEED _____ TURNOVERS PER YEAR.

2. THIS TANK MUST NOT BE USED FOR STORING PETROLEUM LIQUID HAVING A VAPOR PRESSURE OF_____ mm Hg (____ PSIA) OR GREATER UNDER ACTUAL STORAGE CONDITIONS.

3. THIS TANK MUST NOT BE USED FOR STORING PURE ORGANIC COMPOUNDS.

4. THIS TANK MUST COMPLY WITH ALL REQUIREMENTS OF REGULATION IX.

5. ____ (COMPANY NAME) ____ MUST COMPLY WITH RULE 1113 DURING PAINTING OPERATION.

6. THE DIRECTOR OF ENFORCEMENT MUST BE NOTIFIED A MINIMUM OF 24 HOURS PRIOR TO THE COMMENCEMENT OF PAINTING THIS EQUIPMENT.

7. THROUGHPUT RECORDS, THE RECORDS REQUIRED BY RULE 463 (a)(4), AND THE PAINTING OPERATION RECORDS MUST BE MAINTAINED IN A FORMAT APPROVED BY THE DIRECTOR OF ENFORCEMENT, KEPT ON FILE FOR A MINIMUM OF TWO YEARS, AND MADE AVAILABLE UPON REQUEST OF DISTRICT PERSONNEL.

8. INSTALLATION OF THE APPROVED SECONDARY SEAL IS NOT TO BEGIN UNTIL THE SHOE/TUBE/WIPER PRIMARY SEAL HAS BEEN INSPECTED AND APPROVED BY DISTRICT PERSONNEL.

9. GAPS BETWEEN THE SECONDARY SEAL AND THE RIVETED SHELL MUST NOT EXCEED 1/2" WIDTH, EXCEPT FOR GAPS CAUSED EXCLUSIVELY BY THE VERTICAL LAP JOINTS/BUTT STRAPS WHICH ARE 1/2" THICK OR GREATER. IN CASES WHERE THE VERTICAL LAP JOINTS/BUTT STRAPS ARE MORE THAN 1/2" THICK , THE ALLOWABLE GAP WIDTH SHALL BE NO GREATER THAN 1/8" MORE THAN THE THICKNESS OF THE BUTT STRAP, AND THE GAP LENGTH (IN EXCESS OF 1/2" WIDE) NO LONGER THEN 1.75 TIMES THE THICKNESS OF THE LAP JOINT/BUTT STRAP.

10. GAPS BETWEEN THE MODIFIED MALONEY SEAL AND THE TANK WALL MUST NOT EXCEED 1/4" IN WIDTH. GAPS THAT FALL BETWEEN 1/8" AND 1/4" WIDE MUST NOT HAVE AN ACCUMULATED LENGTH OF MORE THAN 5% OF THE TANK'S CIRCUMFERENCE.

11. _____(COMPANY NAME)_____ SHALL PROVIDE WRITTEN PROCEDURES FOR REMOVAL OF ANY FLOATING ROOF TANK FROM SERVICE THAT HAS STORED OUTER CONTINENTAL SHELF (OCS) CRUDE OIL. SUCH PROCEDURES MUST BE APPROVED BY THE EXECUTIVE OFFICER.

12. AFTER THE PROPOSED ALTERATION/CONSTRUCTION OF THIS TANK HAS BEEN COMPLETED, THE DIRECTOR OF ENFORCEMENT MUST BE NOTIFIED A MINIMUM OF 48 HOURS PRIOR TO FILLING THE TANK TO ALLOW INSPECTION OF THE FLOATING ROOF BY THE DISTRICT PERSONNEL.

13. THE HYDROCARBON CONCENTRATION IN THE VAPOR SPACE ABOVE THE INTERNAL FLOATING ROOF MUST NOT EXCEED_____% OF THE LOWER EXPLOSIVE LIMIT.

APPENDIX 4F

REQUIREMENTS FOR FLOATING ROOF STORAGE TANKS

(AS OF JUNE 24, 1985)

I. REQUIREMENTS FOR EXTERNAL FLOATING ROOF STORAGE TANKS

1. All vapor-mounted primary seals (excluding tube/log and shoe type) must have four (4) 90° radial vapor barriers (impeders) extending 2" or more into the stored liquid surface.
2. For wiper type primary and secondary seals, multiple (2 or more) wiper layer seals must be provided for riveted shell tanks (double layer wipers - primary or secondary are adequate for welded shell tanks).
3. The tube/log type primary seal must be at stored liquid level.
4. The secondary seal in all cases must be removable, without affecting the primary seal or its fabric.
5. An anti-rotational device is required for each seal/roof system to maintain roof integrity per API standards.

Other requirements for external floating roof tank are listed in Rule 463(a)(1)(A-H).

II. REQUIREMENTS FOR INTERNAL FLOATING ROOF STORAGE TANKS

A. ALL DECKS

1. For any deck of bolted construction, the distance between any two consecutive bolts must not exceed 12".
2. The overlapping deck sheet in any bolted construction deck at any joint must employ butt straps/spacers with teeth <u>or</u> gasket material in between.
3. The tube/log type primary seal must be at the stored liquid level.
4. An anti-rotational device is required for each seal/roof system to maintain roof integrity.
5. Wiper type primary and secondary seals may both be single-layer wipers for welded tank service and must be multiple-layer wipers (2 <u>or</u> more) for riveted tank service.

B. NON CONTACT DECKS

1. Vapor height = r+2" where r= Radius of pontoon (Pontoon Decks) and 2" is for the spacer member riding on the pontoon.
2. Vertical skirts for all appurtenances/wells must penetrate stored liquid to depth greater than <u>or</u> equal to the required vapor height (including the roof rimplate).
3. Diaphragms/seals in all appurtenances/wells must isolate any vapor below <u>or</u> at the deck level.
4. Spacer channels must be provided between primary and secondary wiper seals.
5. Four 90° radial vapor barriers (impeders) must be provided on vapor-mounted primary seals and penetrate product liquid 2" <u>or</u> more to deem equivalency with a liquid mounted seal.

C. CONTACT DECKS

1. Vertical skirts and rimplate for all appurtenances/wells must penetrate liquid to a 2" depth <u>or</u> more.

2. Diaphragms/seals in all appurtenances/wells must isolate and vapor below <u>or</u> at deck level.

3. Spacer channels must be provided between primary and secondary wiper seals.

4. Four 90° radial vapor barriers (impeders) must be provided on vapor-mounted primary seals penetrating product liquid 2" <u>or</u> more to deem equivalency with a liquid-mounted seal.

5 Full service steel pan contact decks are limited to diameters less than <u>or</u> equal to 110 feet. No limit on buoyant panel type full surface contact decks.

Other requirements for internal floating roof tank are listed in Rule 463(a)(2)(A-F).

APPENDIX 4G

APPROVED SEALS AND SEAL SYSTEMS

(AS OF MARCH 11, 1988)

I. APPROVED SHOE-TYPE PRIMARY SEALS FOR WELDED AND RIVETED TANKS

1. AMERICAN BRIDGE, DIV. OF USS CORP. - Shoe Seals AB-1 and AB-1S as shown in Drawing MS-1.
2. ATLAS TANK INC. - Shoe seal as shown in Drawing No. C-101.
3. B.E. BISSETT CO., INC. - Shoe seal as shown on Figure 1 in package of data submitted to SCAQMD.
4. CHICAGO BRIDGE & IRON CO. - Shoe Seal SR-1 as shown in Sketch A.
5. GATX TANK ERECTION CORP. - Shoe seal as shown in Drawing 14A-129.
6. GRAVER SOUTHWEST - Shoe seal as shown in Sketch No. 2.
7. HMT, INC. - Shoe seal as shown in Drawings LA-STD-1030, LA-STD-1030B, LA-STD-1031 and LA-STD-1032.
8. LACY TANK & STEEL CORP (FORMERLY PACIFIC ERECTORS CORP.) - Shoe seal as shown in Drawings C-101, C-102, C-103, and C-104 for welded tanks only.
9. PITTSBURGE-DES MOINES STEEL CO. - Shoe seal as shown in Drawings 4DK-1 and 4DK-2. Metallic shoe -type (Pantagraph) primary seal as shown on PDM DWG NO 4 DM-1, and spring support type as shown in DWG NO.4DR-1, 4DR-2.
10. REPUBLIC FABRICATORS, INC. - "Volume Maximizing Seal System", primary and secondary seals.
11. TANK SERVICES, INC. - Shoe seal as shown in Drawings S.R. CA. STD., Sheets 1 through 4, and DWG A-0695.
12. TARSCO - Metallic shoe type (Spring/Pantagraph combination) as shown on DWG NOS STD-5 through 7.
13. TRICO SUPERIOR, INC. - Shoe seal as shown in Drawing D-70-100-13834.
14. WEBCO TANK, INC. - Shoe seal as shown in Drawings M-890-D (shoe seal version), M-891-B and M-892-B
15. WESTERN PETRO-CHEM SERVICES, INC., - Drawing 8001.
16. W.G. SEALS, INC.- Shoe type as shown in DWG NO. FORM PS for welded tanks.

II. APPROVED RESILIENT-TOROID TYPE PRIMARY SEALS FOR WELDED TANKS

(IF TOROID SEAL VAPOR MOUNTED, VAPOR BARRIERS MUST BE INSTALLED EVERY 90° EXTENDING FROM THE BOTTOM OF THE SEAL TO AT LEAST TWO INCHES BENEATH THE LIQUID SURFACE)

1. ATLAS TANK, INC. - Primary seal as shown in Drawing STD-2.
2. CHICAGO BRIDGE & IRON CO. - Revised Primary Seal SR-9 as shown in revised Sketch B of October 31, 1977, or as shown in Sketch E.
3. CHICAGO BRIDGE & IRON CO. - Primary Seal SR-7A as shown in Sketch D of April 23, 1982.
4. PETREX INC. - Primary seal P-1.
5. PITTSBURGH-DES MOINES STEEL CO. - TUBESEAL, primary seal as shown in Drawing ES-438-5-DF, DELTASEAL, primary seal as shown in Drawing ES-438-4-DM.
6. REPUBLIC FABRICATORS, INC. - Primary seal as shown in Drawing RFI #1008 REV. 0.
7. SAN LUIS TANK & PIPING - Primary seal as shown in Drawings 1, 2, 3, 4, and 5.
8. TARSCO - Primary seal as shown in DWG RTS-2.
9. TEXACO, INC. - Primary seal as shown in Tank Services Drawing CA-STD-001 REV. 2.
10. WEBCO TANK, INC. - Primary seal as shown in Drawing M-890-D (tube seal version).

III. APPROVED WIPER-TYPE PRIMARY SEALS FOR WELDED TANKS AND RIVETED TANKS

A. FOR WELDED TANKS

HMT. INC. - Primary seal as shown in DWG LA-STD-1006 to 1009.

B. FOR RIVETED TANKS

1. HMT. INC. - Primary seal as shown in DWG LA-STD-1010-1013.
2. TANK SEAL TECHNOLOGY, INC. - Type "X" as shown in DWG NO. TST-REVT-PRI-0111.
3. W.G. SEALS, INC. - Wiper type primary seal for riveted tanks as shown in DWG. NO. FORM RP-W.G.

IV. APPROVED SECONDARY SEALS FOR WELDED AND RIVETED TANKS

A. FOR WELDED TANKS

1. ALTECH INDUSTRIES, INC. - Double-wiper type spring seal described by the letter of November 11, 1977, to the SCAQMD: single-wiper type seal as shown in Drawing SK-0017.

2. ASSOCIATED ENVIRONMENTAL SYSTEMS CO., INC. - Secondary seal as shown in Drawings A-79008, B-79001 and B-79002.

3. ATLAS TANK, INC. - Modified Maloney secondary seal as shown on Drawing STD-4.

4. B.E. BISSETT CO., INC. - Wiper-type secondary seal as shown on Drawing 77135 (Figures 1 and 2) and Drawing 3-14-78LM.

5. CHICAGO BRIDGE & IRON CO. - Secondary seal BWB-CBI-1000 as shown in Sketches A and B.

6. GATX TANK ERECTION CORP. - Secondary seal as shown on Drawing 14B-316, 14B-372 and 14B-373.

7. HMT, INC. - Secondary seal as shown on Drawing LA-STD-1000 through LA-STD-1002.

8. GRAVER SOUTHWEST - Secondary seals as shown in Sketches Nos. 1 and 4.

9. INTER-PACIFIC TANK & PIPELINE - Secondary seal as shown in DWG No. IT & P-1.

10. MESA RUBBER COMPANY - Secondary seal as shown in DWG NOS SI-1028 & SI-1073.

11. MOBIL OIL CORP. - 18" Wiper-type secondary seal as shown in DWG STD-AD-311, Sheets 1,2,and 3, submitted with letter dated 12/15/77.

12. PETREX INC. - Secondary seal S-1.

13. PITTSBURGH-DES MOINES STEEL CO. - Secondary seal as shown in Drawings SS-1 or ES438-5 DPI.

14. PLANT & FIELD SERVICE CORP. - Secondary seal Design Nos. P.F.-101 & P.F.-101A.

15. REPUBLIC FABRICATORS, INC. - Secondary seal as shown in Figures 1,2, and 3 of "Weather-Guard Seal" brochure.

16. SEAL EQUIPMENT COMPANY - Secondary seal as shown in DWG AOK.

17. STOP-LOS CO. - Secondary "magnetic seal" as shown in Figures 1 and 2 of Stop-Los Co. sales brochure.

18. TANK SERVICES, INC. - "Mini-Pac" secondary seal as shown on Drawings CA-STD-003, CA-STD-015, CA-STD-016; Maloney seal attachment secondary seal as shown on Drawing CA-STD-005.

19. TEXACO, INC. - Secondary seal as shown in Drawing B-3607.

20. TRELLEBORG RUBBER CO., INC. - Secondary seal as shown in Drawings C-12452 and C-12453.

21. TRICO SUPERIOR, INC. - Secondary seal as shown in Drawing D-70-100-13675.

22. UNION OIL COMPANY OF CALIFORNIA - Secondary seal as shown in sheet 1.

23. UNITED TANK TECHNOLOGY, INC. - UTT wiper seal as shown on Drawing No. 1543.

24. WEBCO TANK, INC. - "WEB-1980" secondary seal.

25. W-G SEALS, INC. - Secondary seals as shown in DWG NOS FORMS WS, & DS, and double wiper seals as shown in DWG NO. FORM VM.

B. FOR RIVETED TANKS

1. H.M.T., INC. - serrated finger seal as on Drawing LA-STD-001. Wiper-type as shown in DWG NOS. LA-STD-1003 through LA-STD-1005.

2. MOBIL OIL CORP. - serrated finger seal as on Drawing STD-AD-312-S/1. Submitted with letter dated 6/21/78.

3. REPUBLLIC FABRICATORS, INC. - Mufti-wiper seal as shown on Drawing RFI-1005.

4. SEAL METHODS, INC. - serrated finger seal as on Drawing SMI-4179.

5. TANK SERVICE, INC. - Double foam log seal as shown on Drawing CA-STD-014.

6. UNDERWOOD TANK SERVICE - "Mini-Pac" type as shown in DWG NO UTS-1.

7. W.G. SEALS INC. - Secondary seals as shown in DWG NO. FORM RS.

C. FOR RIVETED TANKS (WITH LIMITED APPROVAL)

1. ALTECH INDUSTRIES, INC. -Double foam wiper seal as shown on Drawings SR-78010 and SR-78023.

2. ASSOCIATED ENVIRONMENTAL SYSTEMS CO., INC. - Aesco Mark III secondary seal as on Drawings A-79009 and D-79002.

3. ATLANTIC RICHFIELD CO. - Arco mufti-seal (rim-mounted secondary, shoe-mounted tertiary).

4. B.E. BISSETT CO., INC. - serrated double loop secondary seal.

5. LOUIS LIEDELMEYER CO. - Double foam wiper spring seal as shown on Drawing No. 1; Triple wiper seal as shown on Drawing No. 2.

6. MESA RUBBER CO. - Triple wiper seal as on Drawing SI-1085.

7. UNITED TANK TECHNOLOGY, INC. - UTT wiper seal as on Drawing No. 1543.

V. APPROVED INTERNAL FLOATING ROOFS AND SEALS

A. FOR WELDED TANKS

1. ATLAS TANK, INC., Resilient-Toroid type seals as shown in DWG NOS. 301-2 (STANDARD #2A), and 301-3 (STANDARD #2B)
2. BMT (GATX) SLIM LINE EVERSEAL - Internal Floating Roof Seal as shown on Drawings 14AB-120A, 14AB-119A.
3. CHICAGO BRIDGE & IRON CO. - Internal cover fitted with SR-8 or SR-9 as primary seals with secondary seal as shown in DWG NO. BWB-CBI-1000.
4. CONSOLIDATED ALUMINUM CORPORATION - Vaconodeck II tubular internal floating cover with their single-wiper seal as shown in Drawing No. TF-1.
5. M-T VAPOR FLOAT CO. - Roof and seal as shown on Drawing S-1.
6. MAYFLOWER VAPOR SEAL CORPORATION - Wiper type internal cover and wiper type foam filled seal as described in Design Bulletin MVS-01-1276, DWG NO. 5942.
7. PITTSBURGH-DES MOINES STEEL CO. - Conservatek internal cover with their continuous wiper seal or with the foam-filled DELTASEAL.
8. PETREX INC. - Primary & secondary wiper type as shown in DWG. NOS. H (REV 1) AND H-1 (REV 0). PETREX liquid mounted tube seal as shown in DWG NOS. STD-2005 (REV-1), STD-4203-S, STD-4304-S, STD-5313-S, STD-5420-S, STD-5512-S.
9. PITTSBURGH-DES MOINES STEEL CO. - Internal floating roof and toroid-type seal as shown in Drawing ES-419-5 CN.
10. REPUBLIC FABRICATORS, INC. - Aluminum pontoon internal floating cover and seal.
11. SAN LUIS TANK & PIPING - Internal floating and toroid-type seal as shown in Drawing Nos. 6 & 7.
12. TARSCO - Resilient toroid type as shown in DWG NO. RST-1.
13. ULTRAFLOTE CORP. - Ultraflote internal cover and Ultraseal wiper-type seal, Double ULTRASEAL 1 DWG NO. 20242 C.
14. UNITED TANK TECHNOLOGY, INC. - Internal floating roof and seal.

15. W-G SEALS, INC. - As shown in DWG NOS. FORM WPS AND FORM DPS.

B. FOR RIVETED TANKS

1. CONSOLIDATED ALUMINUM CORP., Vaconodeck II tubular internal floating cover with multiple wiper seal as shown in Drawing SK-926.
2. ULTRA FLOTE INTERNAL COVER - FOUR LAYER ULTRA SEAL II C DWG NO. 20267.
3. W-G SEALS, INC.- As shown in DWG NO. FORM RP.

C. FOR WELDED OR RIVETED TANKS

1. ALTECH DIVISION OF JUSTISS OIL COMPANY, INC.,- Double waffle seal, and. liquid mounted primary tube/log seal as shown in DWG NOS. PRO 20, PRO 21, PRO 4, PRO 14, AND PRO 16-A TO PRO 19-A.
2. HMT TANK SERVICE INC., - Liquid mounted Foam Log primary seal as shown in DWG NOs. LA 1051, primary and secondary wiper seals as shown in DWG NOS. LA-STD-5001 and LA-STD-5002.

VI. <u>MISCELLANEOUS APPROVED SYSTEMS EQUIVALENT TO A SHOE AND A SECONDARY SEAL SYSTEM FOR WELDED TANKS</u>

REPUBLIC FABRICATORS, INC. - "Volume Maximizing Seal System", primary and secondary seals.

APPENDIX 4H

MOLECULAR WEIGHT AND VAPOR PRESSURE AT 70 °F FOR SELECTED PETROCHEMICAL COMPOUNDS

MOLECULAR WEIGHT AND VAPOR PRESSURE AT 70 ^{o}F FOR COMMON PETROCHEMICAL COMPOUNDS

COMPOUND NAME	MOLECULAR WEIGHT (M_V, lb/lbmole)	VAPOR PRESSURE (P, psia)
Acetic Acid	60.05	0.3
Acetone	58.08	3.60
Acetonitile	41.05	1.4
Allyl Alcohol	58.08	0.4
Butyl Formate	102.13	0.4
Butyl Acrylate	142.19	0.1
Isobutyl Acetate	116.16	0.31
Isobutyl Alcohol	74.12	0.17
Isobutyl Isobutyrate	144.21	0.07
n-Butyl Acetate	116.16	0.19
n-Butyl Alcohol	74.12	0.11
sec-Butyl Alcohol	74.12	0.23
tert-Butyl Alcohol	74.12	0.6
n-Butyl Chloride	92.57	1.7
Carbon Disulfide	76.14	6.0
Cumene (Isopropyl Benzene)	120.19	0.1
Cresylic Acid (Cresol)	108.13	0.3
Cyclohexane	84.16	1.6
Cyclopentane	70.13	5.2
Diethyl Ether	74.12	8.7
Diethylamine	73.14	3.9
Diisopropyl Ether	102.17	2.7
1,4 Dioxane	88.10	0.6
Dipropyl Ether	102.17	1.1
Ethyl Acetate	88.10	1.5
Ethyl Acrylate	100.11	0.6
Ethyl Alcohol	46.07	0.85
Ethylene Glycol Monoethyl Ether	90.12	0.09
Ethylene Glycol Monomethyl (Methyl Cellosolve)	76.09	0.12
Trichlorofluoromethane (Freon 11)	137.38	13.4
n-Heptane	100.20	0.7
n-Hexane	86.17	2.5
Hydrogen Cyanide	27.03	11.9

COMPOUND NAME	MOLECULAR WEIGHT (M_V, lb/lbmole)	VAPOR PRESSURE (P, psia)
Iso-octane	114.22	0.8
Isopentane	72.15	12.5
Isoprene	68.11	9.7
Isopropyl alcohol	60.09	0.61
Isopropyl Ether	102.17	2.69
Mesityl Oxide (Isopropyllideneacetone)	98.14	0.15
Methanol (Methyl Alcohol)	32.04	1.86
Methyl Acetate	144.10	2.46
Methyl Acrylate	102.18	1.4
Methylamyl Acetate	144.10	0.07
Methylamyl Alcohol (Methylisobutyl Carbinol)	102.18	0.04
Methyl Butyl Ketone	100.16	0.1
Methacrylonitrile	67.09	1.2
Methylcyclohexane	98.18	0.7
Methylcyclopentane	84.00	2.2
Methyl Ethyl Ketone	72.10	1.38
Methylisobutyl Acetate (Isopropyl Acetate)	102.13	0.93
Methylisobutyl Ketone	100.16	0.29
Methyl Methacrylate	100.12	0.5
Methyl Propyl Ether	74.12	7.1
Neosol A	116.16	0.9
Nitromethane	61.04	0.54
n-Pentane	72.15	0.34
Perchloroethylene (Tetrachloroethylene)	165.8	0.29
n-Propyl Acetate	102.03	0.54
n-Propylamine	59.11	5.3
Styrene (Phenyl Ethylene)	104.14	0.1
Toluene	92.13	0.43
Trichloroethane	133.42	2.0
Vinyl Acetate	86.09	1.7
Xylene	106.16	0.10

SECTION 5

Dry Cleaning Operations Petroleum and Synthetic Solvents

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Section 5

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SECTION 5 : DRY CLEANING INDUSTRY : PETROLEUM AND SYNTHETIC SOLVENTS

5.1 General Description

Dry cleaning is a fabric washing process which uses a non-aqueous organic solvent. The solvent is either a petroleum-type solvent or a synthetic- (halogenated hydrocarbon) type solvent, to which small amounts of dry cleaning detergents and other soil removing compounds are added. Like aqueous laundering, the dry cleaning cycle consists of three steps: washing, extracting (spinning), and drying. Washing agitates the dirty articles in the solvent; extracting separates the soil-laden solvent from the fabric by centrifuging; and drying vaporizes the remaining solvent by tumbling the articles in a stream of hot air. These processes are performed in either of two basic operations: transfer or dry-to-dry.

Transfer operations require transferring the articles from the washer/extractor to the tumbler/dryer. The washing and extracting processes are performed in one unit, and the drying process in another. The transfer operation is a semi-batch process. All petroleum solvent facilities at present, are transfer type operations.

Dry-to-dry operations use one machine to perform all three processes. The washing, extracting, and drying take place in one unit. The clothes are placed in the unit dry and are removed from the same unit dry. This is a batch process. The advantages of this type of operation are: reduced solvent loss by eliminating exposure of solvent-laden articles to the atmosphere, and simpler operation. The disadvantage is that one machine is occupied for the entire cycle, processing approximately one-half as many loads as a transfer-type operation. Most synthetic solvent facilities use the dry-to-dry method because of reduced solvent loss and savings earned in lower emission penalties.

Non-aqueous organic solvents have a strong affinity with most "soils" and dissolve them into a concentrated form. Aqueous solvents emulsify or suspend the "soil" and require large amounts of water. Dry cleaning solvents have fiber-preserving and shape-retaining properties, whereas water tends to swell, deform and weaken the fiber. Detergents are added to dry cleaning solvents to help remove water soluble "soils", but are strictly controlled to minimize water retention in the solution.

5.1.1 Solvents

Dry cleaning facilities use petroleum and synthetic-type solvents.

Petroleum solvents are inexpensive (see Table 5-1 for solvent cost comparison), combustible hydrocarbon mixtures (C_8's to C_{12}'s) similar to kerosene.

TABLE 5-1 1988 COST FOR DRY CLEANING SOLVENTS

SOLVENT	COST/GALLON [1]
Petroleum	\$ 2.00
Perc	\$ 5.75
Valclene^R	\$ 17.00

R - Registered Trademark of DuPont

Table 5-2 lists the chemical properties of several petroleum solvents.

Petroleum dry cleaning solvents with aromatic compounds of eight carbons or more and exceeding eight percent by volume composition are considered photochemically reactive by the SCAQMD under Rule 102. Those solvents which are four percent by volume or greater in photochemically reactive compounds may not be used unless their emission to the atmosphere is reduced ninety (90) percent by weight (see section 5.5, Rule 442). The low flash point temperatures of petroleum solvents indicate their relative volatility. To reduce the potential for ignition, petroleum solvent vapors must be diluted with air and vented rather than condensed.

Synthetic solvents are more expensive halogenated hydrocarbons. The two most common synthetic dry cleaning solvents are perchloroethylene (1,1,2,2 tetrachloroethylene), and trichlorotrifluoroethane (trade name- valclene^R or refrigerant 113). Both are considered non photochemically reactive (see section 5.3 Emissions).

TABLE 5-2 PROPERTIES OF PETROLEUM DRY CLEANING SOLVENTS[2]

Trade Name	Boiling Point °F	Flash Point °F	Vapor Pressure mm Hg at 20 °F	Avg. Mol. Wt.	Lbs./Gal at 60 °F	Composition, Vol. %				
						Paraffins	Naphthenes	Aromatics		Olefins
								C_8 +	Total	
Skellysolve S-66	305	104	3.2	142	6.48	43.4	49.4	6.8	6.8	0.4
Varsol 3	310	105	10.0		6.46			19.0	19.0	
325	320	105	5.0	138	6.57	35.4	62.2			
AMSCO Napthol MS	313	106	3.0	138	6.32	64	35		1	
Varsol 1	313	106	10.0		6.56			18	18	
Skellysolve "S-2"	314	102	3.1		6.47	39.5	48.2	11.7	11.7	0.6
Kwik-Dri	315	105	<10	128	6.46	57	41	2	2	0.3
Mineral Spirits	315	105	<10	145	6.55	54	36	9.5	9.5	0.3
Mineral Spirits 66/3	315	105	<10	145	6.55	57	41	2	2	0.2
Varsol 18	315	110	10		6.42			7.6	7.8	
AMSCO Mineral Spirits 66/3	315	104	1.1		6.55	61	37	2.0	2.0	
Sol 340	316	104	2.8		6.37	47.2	50.2	2.6	2.6	
Mineral Spirits 145EC	317	112	2.7		6.49	47.5	45.1	7.4	7.4	
AMSCO Odorless MS	354	128	<1.0		6.33	86	14			
Odorless MS	355	128	<10		6.33	87	13			
140 Solvent	362	140	<10		6.54	60	37	3.0	3.0	0.3
Skellysolve "I"	363	143	0.7		6.57	35.3	54.5	9.3	9.3	0.9
AMSCO 140 Solvent 66/3	368	146	<1.0		6.51	55	44	1.0	1.0	
Sol 140	371	143	<1.0		6.56	54.9	39.2	5.9	5.9	

Perchloroethylene (perc), is the most widely used solvent in the dry cleaning industry. Of 1,876 dry cleaning facilities reportedly operating in the South Coast Air Basin in 1987, 1,808 used perc.[3] Since perc decomposes when exposed to sunlight or heat ($>150\ ^{o}C$), special handling is required. Stabilizers are added to most commercial brands of perchloroethylene. See Table 5-3 for properties of perc.

Valclene^R and other chlorofluorocarbons are less toxic than perchloroethylene. They are stable, non-combustible, and decompose only at temperatures over $200^{o}C$ (see Table 5-3 Synthetic Dry Cleaning Solvents - Properties).

5.1.2 Detergents and Moisture

Detergents are usually added to the solvent to increase the solubility of most water soluble soils and stains. Solvents to which detergents have been added are known as charged solvents. Most charged solvents contain between one and four percent detergent by volume. The side effect of adding detergents is that it increases the solubility of water in the solvent. In general, the greater the concentration of detergent, the greater the amount of water that can be held in solution. Moisture content must be limited and carefully controlled to maximize its cleaning effects and minimize its damaging effects (shrinking and wrinkling of the articles).

The water that is retained in the solvent must also be removed to permit reuse of the solvent. Water separating devices, which are commonly found on reclaiming dryers, stills, muck cookers, and vapor reclaimers, remove or separate water that has become mixed with the solvent.

5.1.3 Equipment Description

The dry cleaning process is characterized by the type of solvent and operation employed. Dry cleaning equipment can be classified as equipment which utilizes synthetic solvents or as equipment which utilizes petroleum solvents. Equipment using synthetic solvents are designed to reduce solvent losses to a greater degree than equipment using petroleum solvent. This is because of the significantly higher

TABLE 5-3 SYNTHETIC DRY CLEANING SOLVENTS - PROPERTIES[4]

	Chlorinated hydrocarbons	**Fluorocarbons**	
	Perchloroethylene	**R 11**	**R 113 (Valclene^{R})**
Chemical formula	C_2Cl_4	CCl_3F	$C_2Cl_3F_3$
Boiling point (°C)	+121.1	+ 23.7	+ 47.6
Specific weight of fluid (20°C)	1.62	1.49	1.58
Heat of vaporization at boiling point (kcal/kg)	50.1	43.5	34.6
Solubility of water (% by weight)	0.01	0.14	0.017
Azeotropic mixtures			
Solvent proportion %	84.1	99.6	99.0
Water proportion %	15.9	0.4	1.0
Boiling point of mixture (°C)	+87.1	+23.2	+44.5
Maximum workroom concentration (ppm)	25	1000	1000

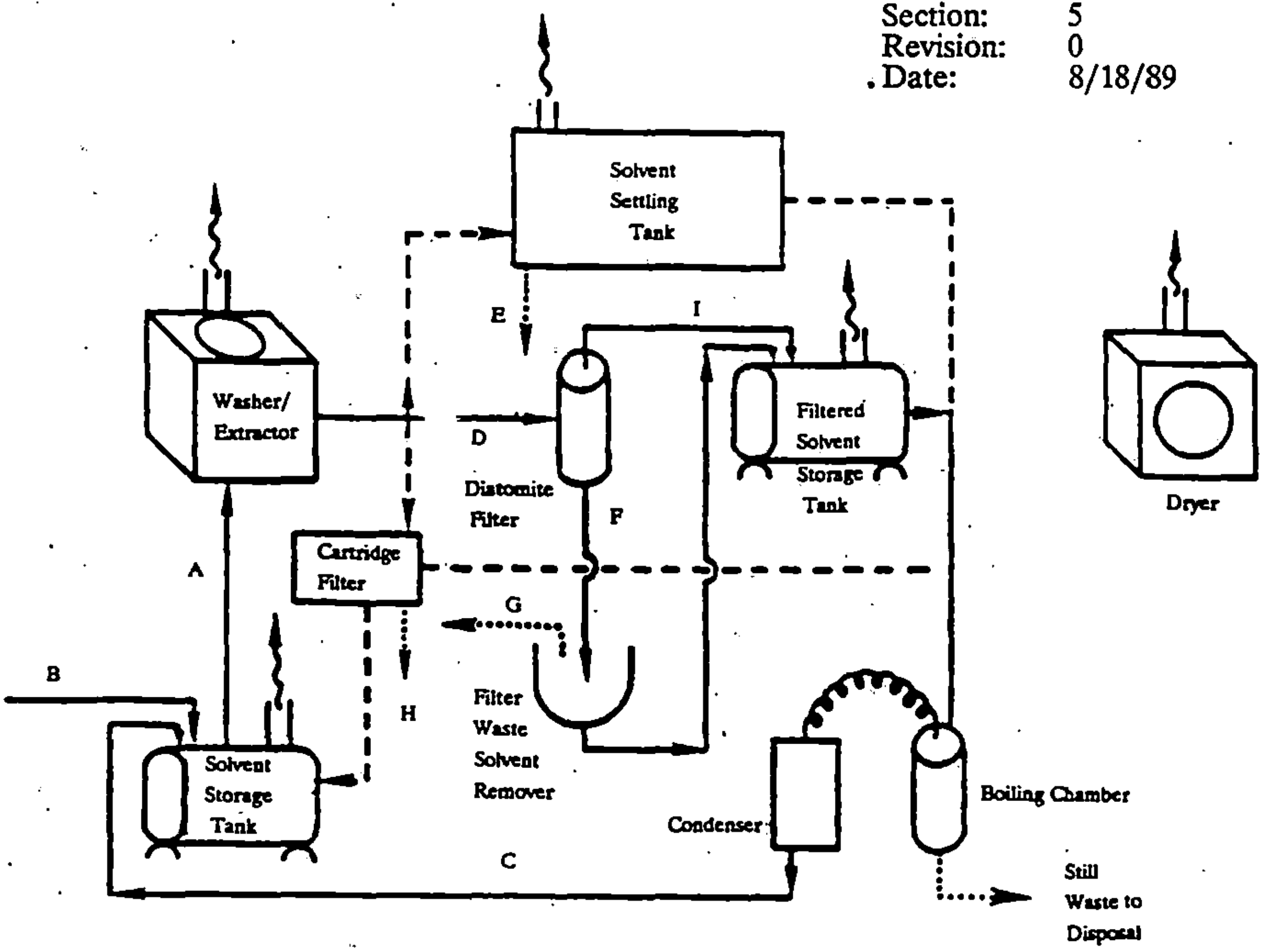
cost of synthetic solvents and the problems associated with recovering petroleum solvents by conventional methods (see section 5.1.4.2).

Although there are design differences in the equipment used for each solvent, the cleaning process is the same. The "clothes" are immersed and agitated in solution, spun rapidly to remove most of the liquid solvent, then tumbled in warm air to remove residual solvent. This cleaning process can be accomplished in one or two separate pieces of equipment. Other equipment recondition the spent solvent for reuse.

The equipment used in a dry cleaning facility is divided into basic equipment and solvent regeneration equipment. Basic equipment covered in this section includes the washer/extractor and dryer or tumbler. Solvent regeneration equipment, covered in section 5.1.4, includes both liquid and vapor phase solvent recovery methods. Spent solvent in the liquid state is reconditioned by filters, stills, muck cookers, and solvent/water separators (see Figures 5-1 - Petroleum Dry Cleaning, and 5-2 - Perc Dry Cleaning). Solvent vapors vented from the washer/extractor and dryer in Figure 5-1 are partially controlled and recovered in a vapor recovery system (condenser), (see also section 5.1.5 - Emission Controls).

5.1.3.1 Washing/Extracting Unit

The washing unit is essentially a perforated cage in which the articles to be cleaned are agitated in the solvent. Its shape, size and rotating speed as well as the number, size and shape of the impeller, and the type, dimension, number and arrangement of the perforations are factors influencing the cleaning results.[4] One important component of the cleaning system is the filter. The soil removal rate depends on the filter surface area and the cross-sectional area of the piping. These criteria also influence the cleaning time. The extractor is essentially a centrifuge which rotates the cage and its load (the articles) at high speed, mechanically separating the solvent from the fabric (see Figure 5-3).



LEGEND

Vapor Emission

Solvent Flow

Solid Waste Emission

Alternate Solvent Flow

A - Solvent Out
B - New Solvent In
C - Distilled Solvent
D - Spent Solvent
E - Settling Tank Sludge
F - Filter Waste
G - Filter Waste to Disposal
H - Spent Cartridges
I - Filtered Solvent

FIGURE 5-1 PETROLEUM DRY CLEANING PLANT

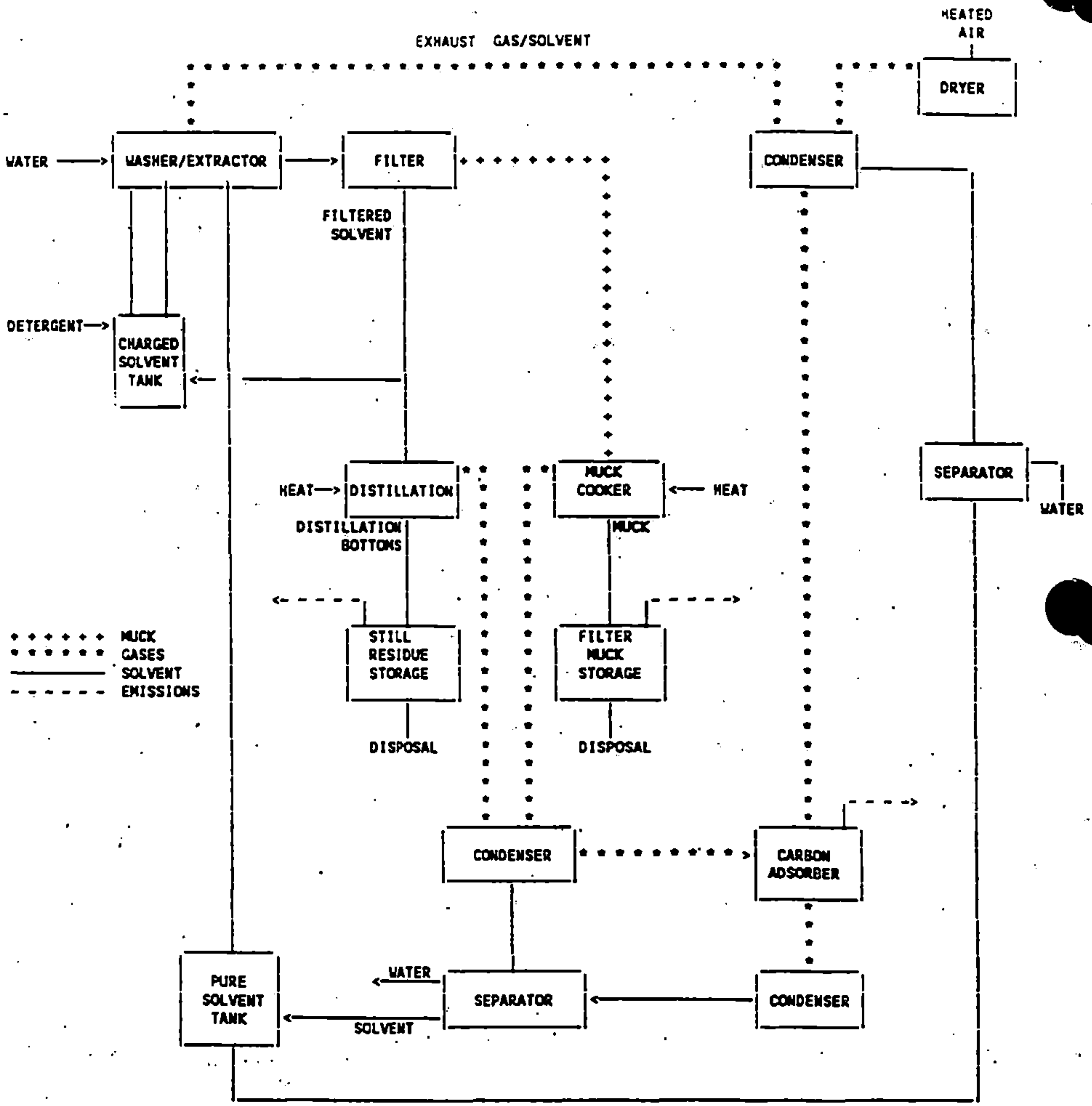


FIGURE 5-2 PERCHLOROETHYLENE DRY CLEANING PLANT

5.1.3.2 Dryer

The extraction process precedes the drying process and is strictly a mechanical operation. In contrast, the drying process uses heat to vaporize the remaining solvent from the garments. The drying can be performed in a separate unit as in a transfer operation or in the combined washer-extractor-dryer unit in a dry-to-dry operation. In both cases, the dryer tumbles the articles in a circulating current of hot air. The solvent-laden air is vented to a vapor recovery system (condenser) or to the atmosphere depending upon the type of solvent used and the permissible emission limits (see Figure 5-4). In a reclaim tumbler, the air is constantly recirculated in a closed loop process, condensing the solvent from the air stream via a condenser. The air stream leaving the condenser is reheated in a heater and returned to the tumbler to collect more solvent vapor (see section 5.1.4.2.3 - Reclaim Tumbling with Water Condensation). Although reclaim tumbling is used in a transfer type operation, the method of closed-loop recovery, as described above, is common practice in modern dry-to-dry units.

5.1.4 Solvent Regeneration

Regeneration is the method by which the spent solvent is processed for reuse. Solvent regeneration occurs in both the liquid phase and the vapor phase. Liquid phase recovery methods use filters, muck cookers and stills while vapor phase recovery methods use condensation, and adsorption to capture vaporized solvent.

5.1.4.1 Liquid Solvent Regeneration

Liquid solvent regeneration refers to the recovery and processing of the liquid solvent for reuse. The method employed is based on the mode of operation of the plant. Small to moderate operations use filtration to remove insoluble contaminants (dirt and lint) as well as certain water-soluble contaminants (perspiration, dyes, and food stains) from the dry cleaning solvent. Large industrial facilities with heavy throughputs typically omit filtration. These facilities rely primarily on settling tanks to partially remove solids and non-solvent soluble contaminants. The solvent reclaimed by filtration or settling is sent on to the still to

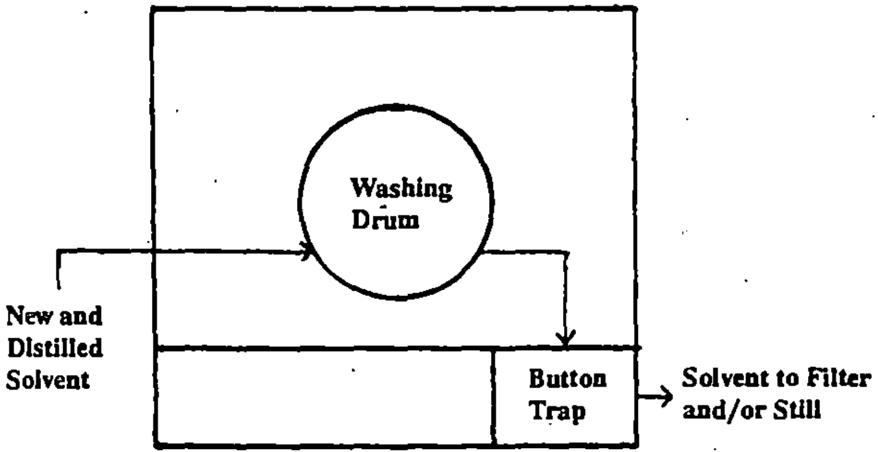


FIGURE 5-3 WASHER/EXTRACTOR

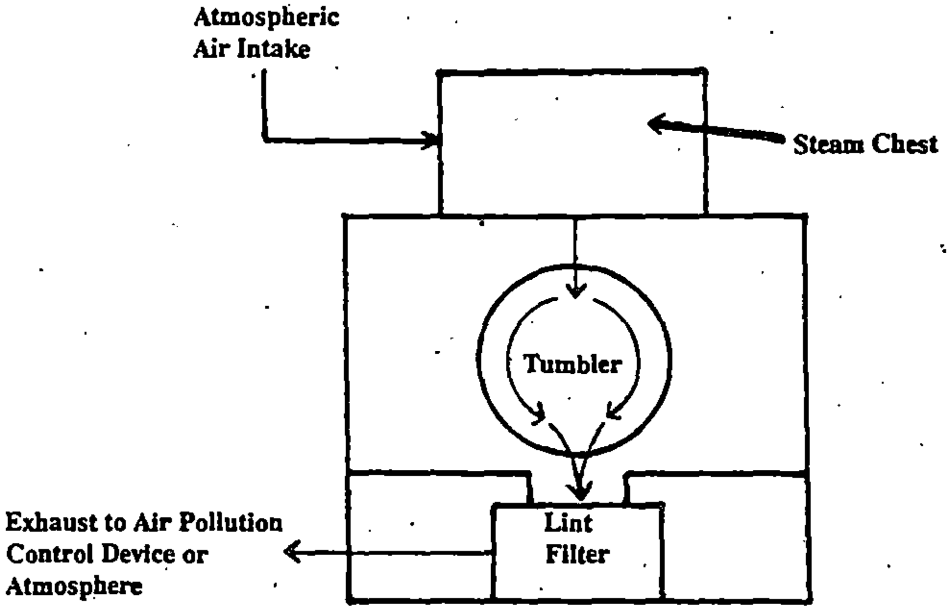


FIGURE 5-4 STANDARD DRYER

remove oils, fats, greases, and other soluble impurities. The solvent saturated solids are periodically collected and sent to a "muck cooker" to boil off the solvent.

5.1.4.1.1 Filtration

The two types of filtration systems used in the dry cleaning industry are precoat filters and cartridge filters.

5.1.4.1.2 Precoat Filters

Precoat filters or diatomaceous earth filters are classified by their structure and working method into:

- single-charge;
- single/multi-charge; or
- multi-charge types.

Rarely seen in modern dry cleaning machines, single-charge filters have elements which are precoated with only the quantity of filter powder needed for one cleaning cycle. At the end of the cleaning process, the used filter powder is sent to the still. In multi-charge filters, the elements are precoated with a quantity of filter powder sufficient for ten or more cleaning cycles. The same applies to single/multi-charge filters with the difference that the powder is shaken off the elements between cleaning cycles. The single/multi-charge filters are then precoated for reuse. The filter contents are not dumped to the still until the powder is exhausted (as indicated by a pressure rise across the filter) (see Figures 5-5 , 5-6).

5.1.4.1.3 Cartridge Filters

Cartridge filters, originally fitted to coin-operated units, but now extended to professional dry cleaning machines, do not use filter elements requiring precoating with powder. The filter surface itself is a filter element. Cartridge filtration vessels contain either finely pored paper, plastic, or textile fabric filters, a carbon-core filter surrounded with fabric filters, or an all-carbon filter (see Figures 5-7 , 5-8). Cartridge filters are multi-charge filters. Usually one hundred (100) loads or more can be cleaned with one set of cartridges prior to replacement. A rise in filter

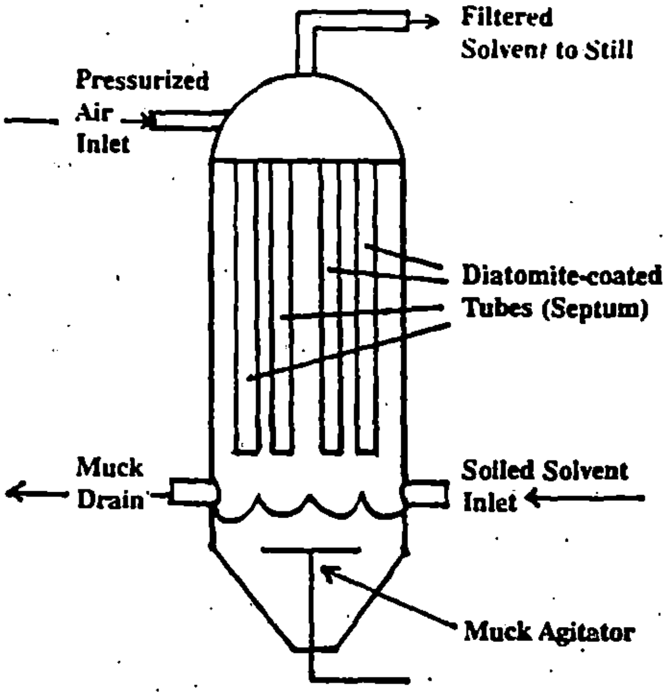


FIGURE 5-5 DIATOMITE FILTER

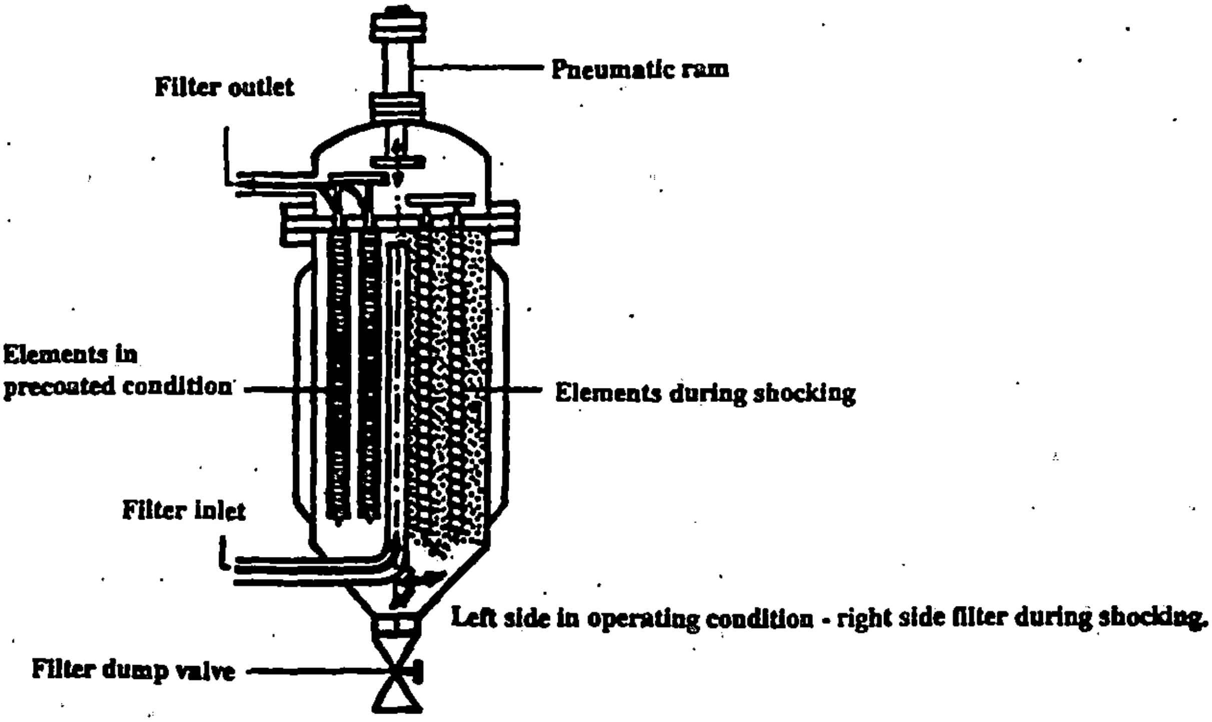


FIGURE 5-6 BOWE EXPANDER FILTER

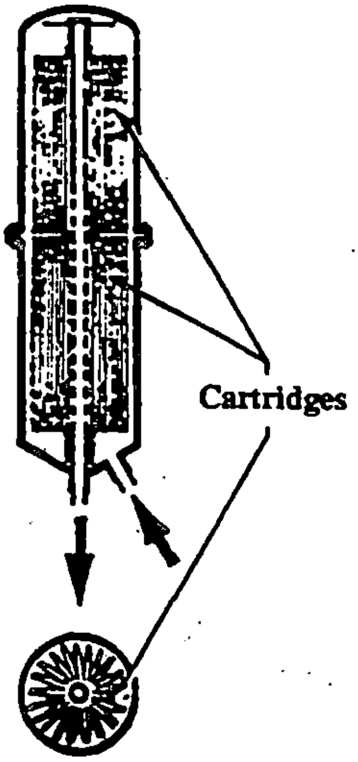


FIGURE 5-7. DOUBLE CARTRIDGE FILTER

Cartridge filters differ from precoat filters. Cartridge filters do not use a filter element requiring a powder precoating. The filter "body" of the cartridge filter is itself the filter, and is made of finely pored paper, plastic or textile fabric.

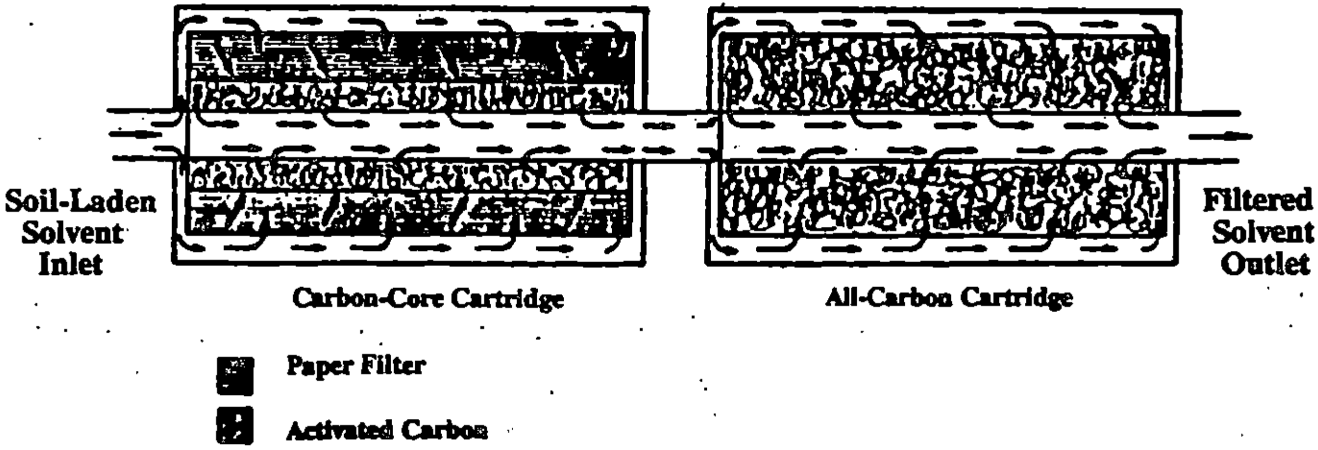


FIGURE 5-8 CARTRIDGE FILTRATION SYSTEM SCHEMATIC

pressure indicates the filter is exhausted. Regeneration of exhausted fabric-type filters is not possible. Once saturated, the solvent is reclaimed and the filter disposed of as hazardous waste.

Cartridge filtration, as used in the dry cleaning industry, is a two-stage process. In the first stage, the soil-laden solvent is forced under pressure through a carbon-core cartridge surrounded with fabric filters to remove entrained solids of lint and dirt. The activated carbon removes the soluble impurities. Next, the solvent is diverted to one or more filter cartridges containing only activated carbon to remove any remaining soluble impurities. The filtered solvent is transferred to storage for distillation and subsequent reuse.

Cartridge filtration is considered very effective and is often used in place of diatomite (precoat) filtration. Cartridge filtration can reduce the frequency of solvent distillation and the solvent content of disposed wastes by 80 - 90%. Therefore, cartridge filtration releases less solvent into the atmosphere compared to diatomite filtration.

The operating costs of cartridge filters are higher than those of precoat filters. However, cartridge filters are virtually maintenance-free and simplify the distillation process since there is no exhausted filter powder dumped to the still which would require purification.

Filter cake (the layers of fine filtered material) and collected solids (muck) are periodically removed from the filter elements. If deemed economically feasible, the muck is sent to a muck cooker to boil off the solvent. The solvent vapors are condensed and separated from the aqueous layer, then sent to the pure solvent tank for reuse.

5.1.4.1.4 Distillation

Distillation (a "still") is frequently used in petroleum solvent installations and is usually included with synthetic solvent installations to separate the liquid solvent from the solvent soluble impurities. The solution is brought to a boil to produce a water-solvent vapor. The resulting vapor is condensed into a solvent-moisture mixture and the water removed in a gravity water separator. The separated solvent is pumped back to the solvent storage tank for reuse. Petroleum solvent stills are continuous vacuum-type stills because of their higher boiling temperature range. Synthetic solvent stills are atmospheric batch-type stills.

5.1.4.2 Vapor Solvent Recovery

Vapor solvent recovery techniques are widely used to recover synthetic solvents such as perchloroethylene and valclene^R. Their physical properties and higher costs make recovery attractive. Petroleum solvents, on the other hand, are cheaper, and hence, provide little economic incentive for recovering the solvent vapor. Secondly, they are physically incompatible with conventional methods of vapor recovery. For example, petroleum vapor solvent regeneration via carbon adsorption yields an inseparable water-oil emulsion when regenerating the carbon bed with steam. Also, the petroleum solvent's low flash point temperatures present the danger of igniting if brought into contact with the compressor of a refrigerant condenser (see section 5.1).

Vapor recovery techniques for synthetic solvents include: carbon adsorption, refrigerant condensation, water condensation, reclaim tumbling with water condensation, and solvation.

5.1.4.2.1 Carbon Adsorption

Adsorption is the phenomenon that defines how the surface tension (or energy per unit area) of a solid attracts molecules of a fluid or gas to its surface via van der Waal's forces. Consequently, the greater the surface area, the greater accumulation of molecules. In this respect, carbon adsorption uses porous activated carbon, a "nonpolar" adsorbent, to collect organic "nonpolar" molecules. With millions of interconnecting pores and a large internal pore structure, one pound of carbon may contain as much as six million square feet of active surface. The molecules make their way through the pores to a vacant site on the carbon surface. Pore diameters can be tailored for selective adsorption.[5] Hydrocarbon vapors from the washer vent, the tumbler vent, and miscellaneous vapor hoods are conveyed by air to the carbon adsorber (see Figure 5-9). The hydrocarbon molecules are adsorbed on to the

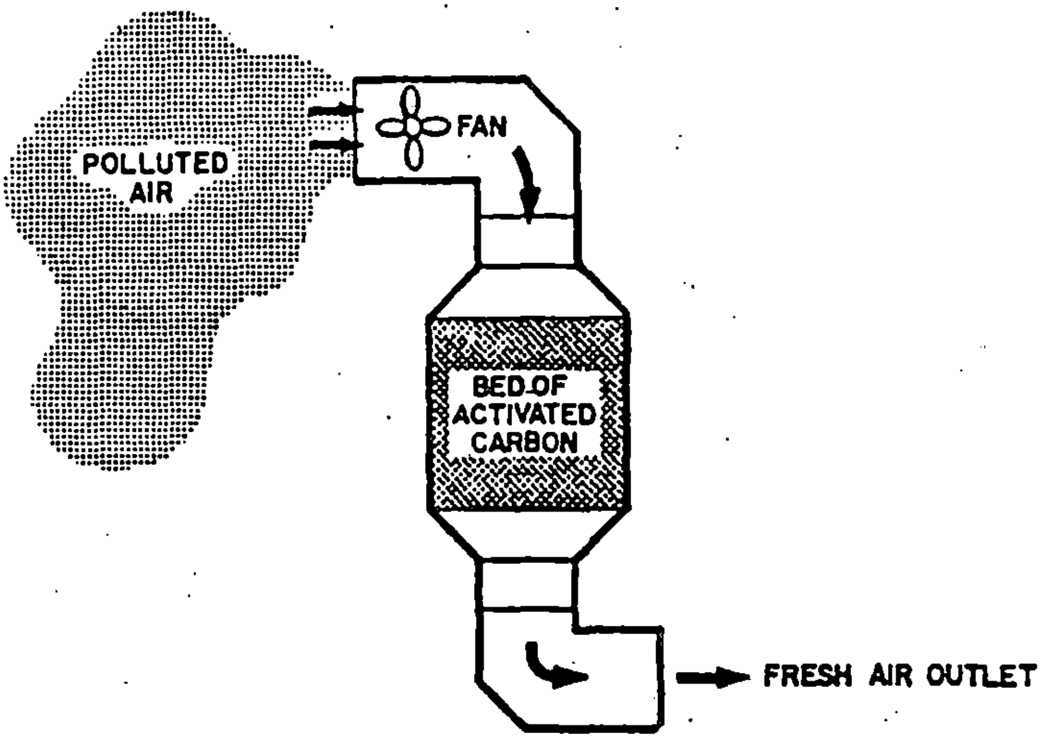


FIGURE 5-9 CARBON ADSORBER - ADSORPTION CYCLE

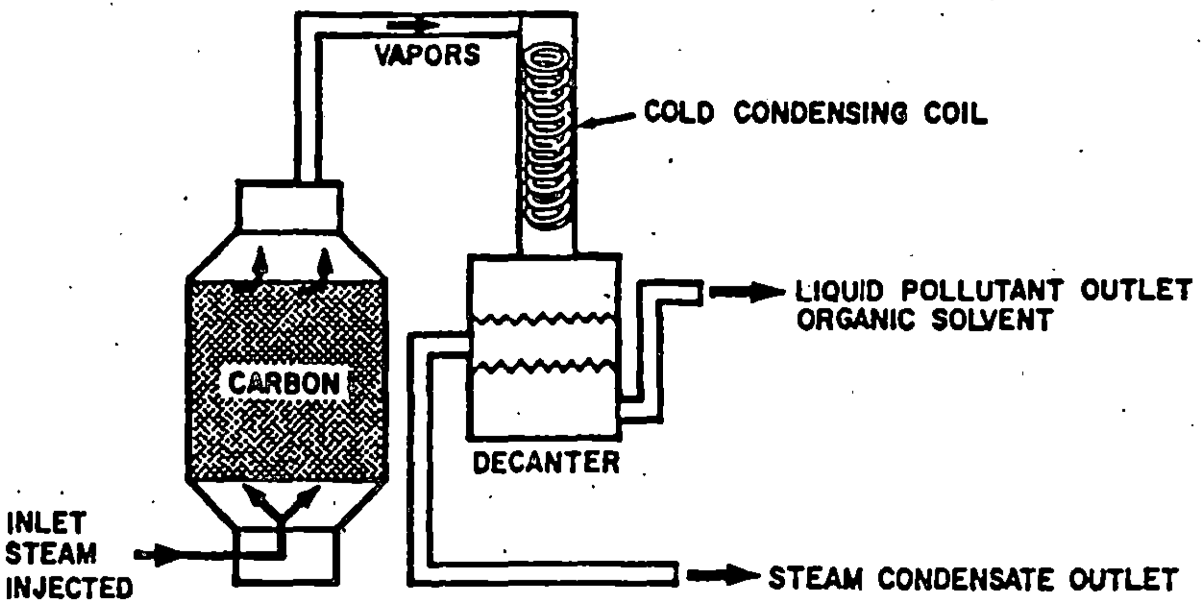


FIGURE 5-10 CARBON ADSORBER - DESORPTION CYCLE

carbon surface and the "cleaned" air is exhausted to the atmosphere. Carbon adsorption has demonstrated a 98% removal efficiency for dry cleaning solvent vapors. Its efficiency diminishes geometrically as the available surface sites decrease, requiring a desorption process to reactivate the carbon bed.

Desorption of the carbon via steam injection reactivates the carbon surface for more adsorption. The high temperature water molecules displace the halogens in the carbon bed. The resultant is a water laden bed which must be dried thoroughly before reuse. A bed which is not dry will retain little or no perc and is essentially non-effective. The use of steam also helps to displace the air from the carbon adsorber. A cool water condensing coil condenses both the steam and the solvent, the air being no longer present in the process (see Figures 5-10, 5-11). A water/solvent decanter gravimetrically separates the solvent from the waste water (steam condensate), (see Figure 5-12). The solvent is then returned to the solvent storage tank for reuse.

To maintain the optimal efficiency of a carbon adsorber, adsorption and desorption must be continuous or simultaneous. Since this is not possible using a single carbon bed, most vapor adsorbers consist of at least two carbon beds - alternating between adsorption and desorption. The frequency of reactivation is based on a percent by weight adsorption bed capacity, which is the weight of solvent per weight of carbon. APPENDIX C - Carbon Adsorber Regeneration Calculations contains equations to determine the frequency of regeneration for the "spent" carbon. The carbon beds will eventually become contaminated over time and will need new activated carbon. The contaminated carbon is sent to a hazardous waste site for proper disposal.

5.1.4.2.2 Condensation

Condensation is the most common method of recovering solvent vapor and involves less maintainence relative to carbon adsorption. The vapor is condensed into a liquid by transferring the heat in the vapor to a colder medium (e.g. for perc: either cold water or a refrigerant (freon), and for valclene^R: a refrigerant). This exchange of heat lowers the vapor temperature to permit condensation to the liquid state. The lower boiling point and higher vapor pressure of valclene^R, relative to perc, requires the use of an unvented refrigerant condenser to recover the solvent vapor

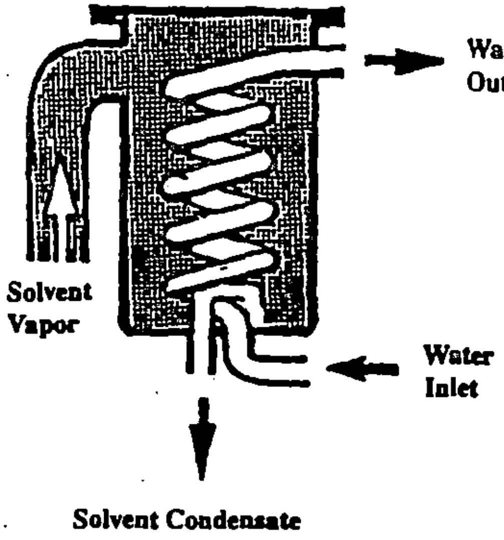


FIGURE 5-11 CONDENSER

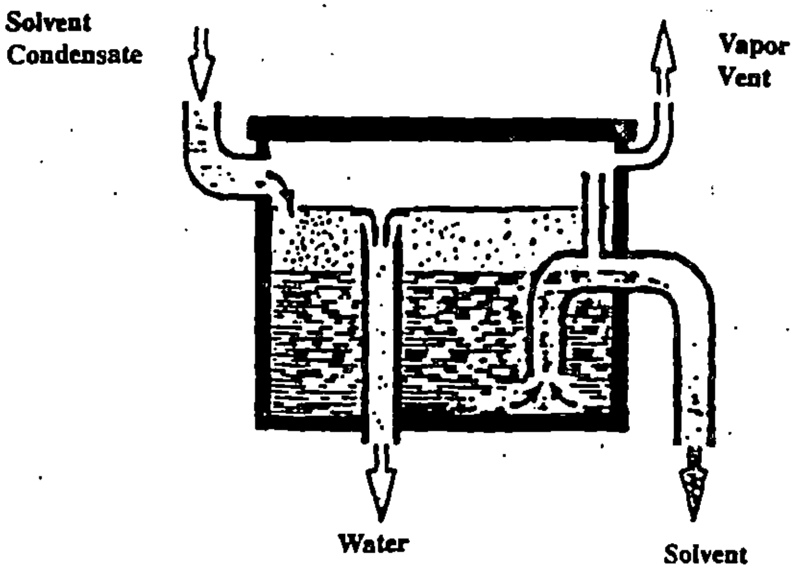


FIGURE 5-12 WATER SEPARATOR

The purification of the condensate takes place in the water separator. Here the water and solvent are completely separated. The functional principle of a water separator is very simple: the heavier solvent separates from the water by virtue of its specific gravity.

Requirements for separation:

1. Low condensate temperature
2. Low flow rate within the vessel
3. Sufficient time
4. Absence of emulsifying substances such as cleaning and

(see Figure 5-13). The refrigerant in the cooling coils has a lower temperature compared to the condensing solvent vapor, and hence, extracts heat from the solvent vapor. The solvent vapors contact the coils, transfer their heat, and condense to a liquid. The refrigerant, in turn, boils and vaporizes and must be returned to a liquid state before reusing. This is done by compressing, condensing and expanding the refrigerant. A compressor increases the pressure (and temperature) of the refrigerant. The condenser lowers the temperature of the refrigerant while keeping the pressure constant, thus, allowing condensation to the liquid state. Finally, the liquid is expanded through an expansion valve to lower the pressure and temperature for reuse in the solvent condenser. Provided there are no leaks in this system a single charge of condenser refrigerant can be used indefinitely.

The liquid which condenses from the drying process is a mixture of solvent and water. Water is naturally retained in the fabrics and is vaporized and condensed along with the solvent. Separation of solvent from water is done by gravity in a water separator with the heavier (bottom) solvent layer returned to the pure solvent tank for reuse.

A water condenser, applicable for use on perc units only, operates on the same thermodynamic principles as the refrigerant condenser. However, in the case of a water condenser the coolant (water) does not undergo a change of state and does not require the use of a compressor, a condenser and expansion valve (see Figure 5-11). A water condenser passes water through a coil on which the warm vapor cools and condenses into a liquid condensate. Here too, solvent and water condensates are separated in a water separator. Because of the saturation limits of the air for vaporized perc solvent, very low temperatures are needed to condense all the perc from the air stream. Using a refrigerant condenser, then, is more effective at condensing perc than is a cold water condenser and is the method most commonly employed in modern perc dry-to-dry units. Further extraction of uncondensed perc is done by passing the airstream through a carbon adsorber.

5.1.4.2.3 Reclaim Tumbling with Water Condensation

In transfer-type cleaning systems, a reclaim (solvent recovery) tumbler is commonly used in the drying operation to recover the solvent vapor. The water condenser of

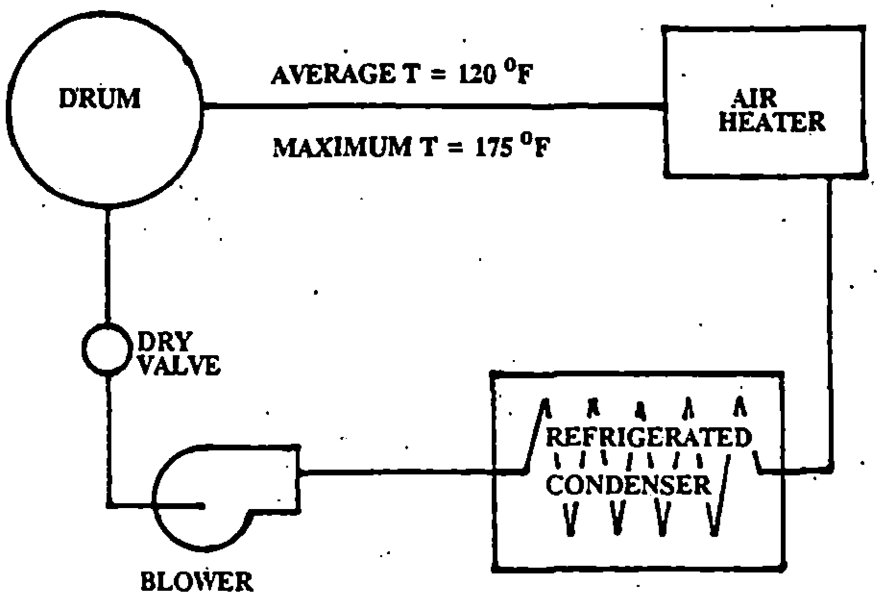


FIGURE 5-13 A TYPICAL FLUOROCARBON DRYING CIRCUIT

the reclaim tumbler is the primary recovery unit with a carbon adsorber (or refrigerated condenser or solvation unit) to collect the blow-off during the aeration cycle. The reclaim process is basically a loop of heating, vaporizing, and condensing stages. A steam-heated air stream is directed around and through a tumbling load of drying articles by a blower. The blower forces the solvent-laden air stream through a lint filter and then to a condenser. The air stream is ducted from the condenser to a steam chest where it is reheated, then vented to the tumbler where the cycle of solvent evaporation repeats. Uncondensed vapors from this cycle are vented with the air to a carbon adsorber (or refrigerated condenser or solvation unit), (see Figure 5-14).

The most important component of this solvent recovery system is the water cooled condenser. The condenser gradually reduces the concentration of both solvent and water vapors in the air stream during each evaporation-condensation cycle. This is accomplished by steadily reducing the vapor temperature (under the existing conditions of vapor flow and pressure).

5.1.4.2.4 Solvation

An alternate method in recovering perc is solvation. The solvation process as outlined in Figure 5-15 is a closed-loop process. Solvent "rich" vapors from the tumbler are condensed over the cooling coil yielding a solvent "poor" vapor stream. This vapor stream is then ducted to the solvation (sparging) tank and bubbled through cold (approx. 75°F) water to remove more solvent and humidify the air stream. The water-saturated air stream is passed through and heated in the hot tumbler to about 100°F. In the tumbler the air stream collects more perc vapor and once again becomes solvent "rich". The cycle is then repeated as many times as needed to remove all the perc from the fabrics.[6] One theory on how the solvation process works is that water, which has a greater affinity for the fabric than perc, displaces the perc from the fabric, allowing the perc to be carried off and condensed. This displacing process is similar to the regeneration of a carbon bed by means of steam. Solvent is collected in the solvation tank, but its liquid level remains almost constant, since water is lost to the garments in the tumbler. Theoretically, all of the solvent can be removed from the garments if sufficient time

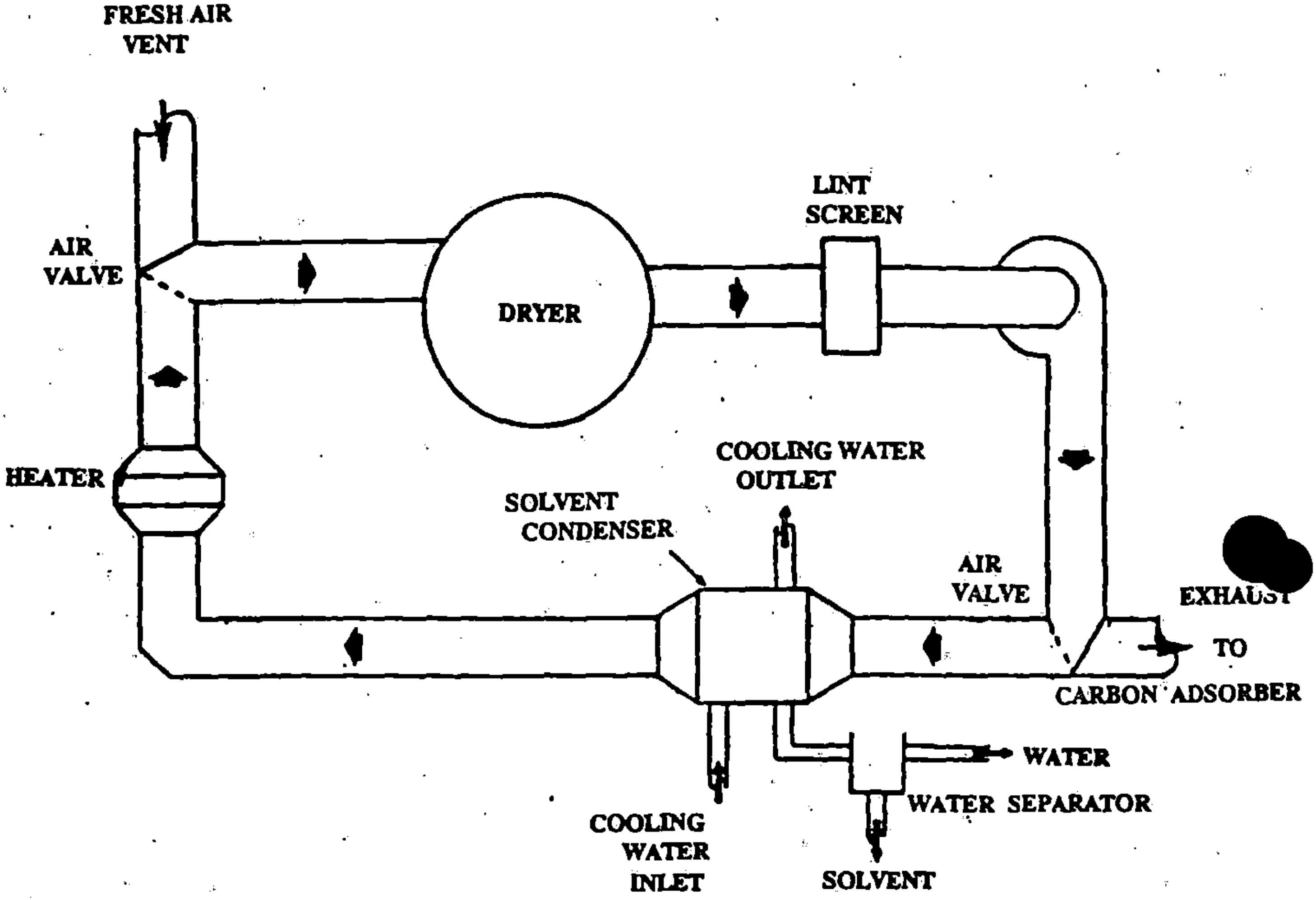


FIGURE 5-14 A TYPICAL RECLAIMING DRYER

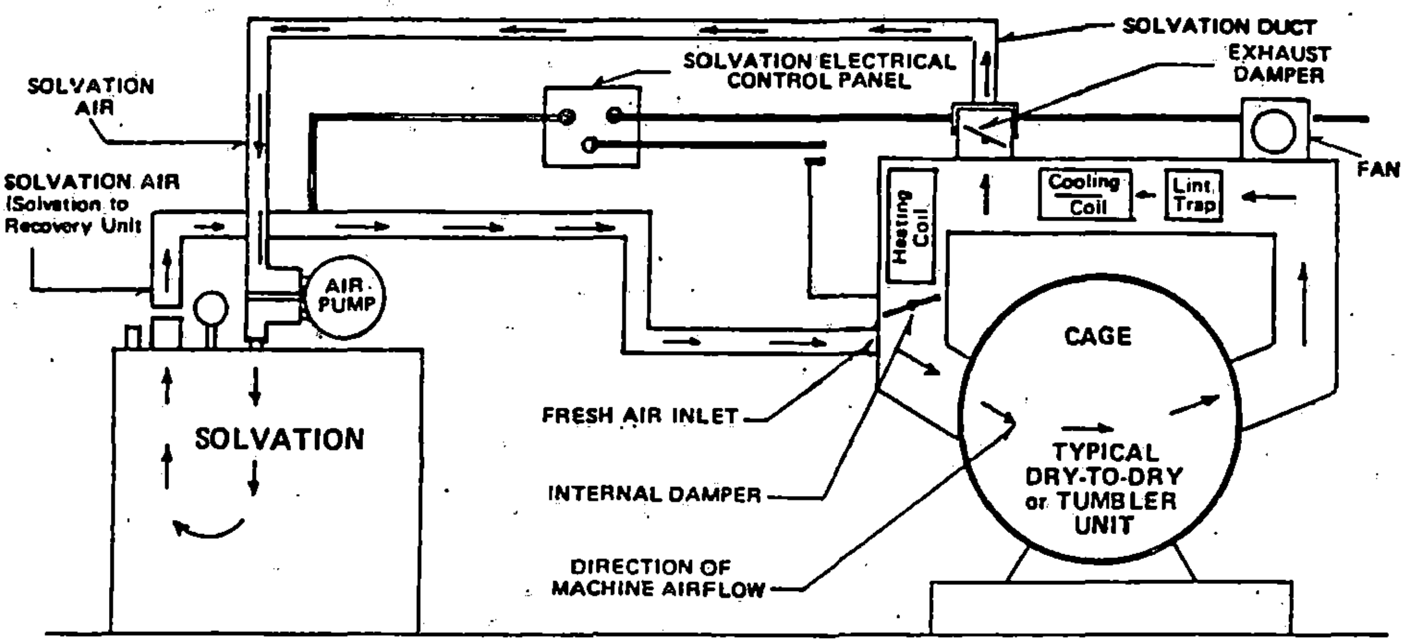


FIGURE 5-15 SOLVATION RECOVERY of PERC

is given to purge the tumbler with the humidified air. In practice, however, only a few minutes is allowed for the "solvation" to take place; hence, complete perc removal is not achieved, leaving the garments with a distinct perc odor when removed from the tumbler.

5.1.5 Emission Control

Emissions from a dry cleaning operation are the dry cleaning solvent vapors. Dry cleaning solvents are volatile and their vapors emanate from the various steps in the process and from solvent exposure to the atmosphere. Synthetic solvent facilities, with their high solvent costs, recover a significant portion of the vaporized solvent and recycle it for reuse. Petroleum solvent facilities with their lower solvent costs, are less concerned with recovering the solvent, and hence, rely on operating techniques and control devices to limit their emissions. Depending on the permitted emission limit and the degree of recovery, a vapor recovery system in a synthetic solvent dry cleaning facility may eliminate the need for an emission control system.

Emission levels which exceed regulated limits are controlled by various means. For perchloroethylene facilities, the Best Available Control Technology (BACT) in the SCAQMD is either a refrigerant condenser , a carbon adsorber, or a scrubber in conjunction with a carbon adsorber. For valclene^R, a freon based solvent, BACT is a refrigerant condenser. For petroleum solvents, the BACT listed is a water condenser. A refrigerant condenser is technologically feasible for petroleum solvent vapor control; however, the potential explosive hazard associated with petroleum solvent vapors and the heat generated by the refrigerant compressor (see section 5.1.4.2.2 Condensation) make it presently unsafe and unacceptable. Alternative control devices for petroleum solvents (not listed as BACT) are an afterburner (incinerator) or a carbon adsorber (see Section 5.4, Rule 1102). Strict, organized operating practices which reduce solvent exposure to the atmosphere are also very effective in reducing solvent losses and emissions, e.g. operators of transfer-type processes should properly schedule transfer operations so that "wet" solvent-laden clothes entering a dryer are exposed to the atmosphere for a minimum amount of time; also, enough drying time should be given to allow complete removal of solvent from the fabric.

5.2 Permit Unit Description

The permit wording description for dry cleaning facilities is divided into the following groups:

5.2.1 Facilities Without Air Pollution Control Equipment

1) Constructed before January 1, 1983, and
2) Solvent usage is less than 320 gallons per year for perchloroethylene.

Permit Wording:
SYNTHETIC SOLVENT DRY CLEANING FACILITY CONSISTING OF:
1. DRY CLEANING UNIT, MAKE, MODEL, SERIAL NO.
2. RECLAIM TUMBLER, MAKE, MODEL, SERIAL NO.
3. FILTER, MAKE, MODEL, SERIAL NO.
4. STILL, MAKE, MODEL, SERIAL NO.
5. MUCK COOKER, MAKE, MODEL, SERIAL NO.

5.2.2 Facilities With Air Pollution Control Equipment

5.2.2.1 Control Units Exterior to Dry Cleaning Units

Permit Wording:
SYNTHETIC SOLVENT DRY CLEANING FACILITY CONSISTING OF:
A. DRY CLEANING SYSTEM
1. DRY CLEANING UNIT, MAKE, MODEL, SERIAL NO.
2. RECLAIM TUMBLER, MAKE, MODEL, SERIAL NO.
3. FILTER, MAKE, MODEL, SERIAL NO.
4. STILL, MAKE, MODEL, SERIAL NO.
5. MUCK COOKER, MAKE, MODEL, SERIAL NO.

B. AIR POLLUTION CONTROL SYSTEM
  1. REFRIGERATED VAPOR CONDENSER, MAKE, MODEL, SERIAL NO. <u>OR</u>
     CARBON ADSORBER, MAKE, MODEL, SERIAL NO.
  2. EXHAUST SYSTEM VENTING A MAXIMUM OF (NUMBER) DRY CLEANING EQUIPMENT SOURCES.

5.2.2.2 Control Units Integral to Dry Cleaning Units

Permit Wording:
SYNTHETIC SOLVENT DRY CLEANING UNIT, MAKE, MODEL,SERIAL NO., WITH A BUILT-IN CARBON ADSORBER (OR REFRIGERATED VAPOR CONDENSER).

5.2.3 Fluorocarbon Solvent Dry Cleaning Facilities

Permit Wording:
FLUOROCARBON SOLVENT DRY CLEANING UNIT, MAKE, MODEL, SERIAL NO.

5.2.4 Petroleum Solvent Dry Cleaning Facilities

Permit Wording:
PETROLEUM SOLVENT DRY CLEANING FACILITY CONSISTING OF:

1. WASHER, MAKE, MODEL, SERIAL NO.
2. EXTRACTOR, MAKE, MODEL, SERIAL NO.
3. TUMBLER, MAKE, MODEL, SERIAL NO.
4. FILTER, MAKE, MODEL, SERIAL NO.
5. STILL, MAKE, MODEL, SERIAL NO.
6. SOLVENT TANK, MAKE, MODEL, SERIAL NO.

5.3 Emissions

The primary emission concern from a dry cleaning facility is the vaporized solvent.

Petroleum based solvents contain photochemically reactive compounds, namely aromatics with eight carbon atoms or more per molecule and olefins. The aggregate of these compounds may not exceed four percent by volume unless their atmospheric emission is reduced ninety (90) percent by weight.

Perchloroethylene is classified as a non-reactive organic compound, but its vapor has a Threshold Limit Value - Time Weighted Average (8-hour workday, 40-hour workweek) exposure limit of 100 ppm as specified by the National Institute for Occupational Safety and Health (NIOSH) 1985.

Chlorofluorocarbon solvents are also classified as non-reactive organic compounds. However, recent evidence has linked chlorofluorocarbons (CFC's) to stratospheric ozone depletion and the greenhouse effect. In support of this evidence, thirty-one nations signed the Montreal Protocol on Substances that Deplete the Ozone Layer in September of 1987. This agreement will freeze CFC and halon production at 1986 levels and then reduce production to fifty percent by 1999. Trichlorotrifluoroethane or Refrigerant 113 (Valclene^{R}) is one of these CFC's. [7] The Threshold Limit Value for this solvent is 1,000 ppm by weight.

The amount of solvent vapor emitted from a dry cleaning facility is directly related to the type of equipment used, its maintenance and operation. (see section 5.1.5 Emission Controls).

5.3.1 Emission Factors

Emissions are determined by actual solvent consumption or by a statistical relation between the amount of clothes cleaned (pounds) and the type of solvent and system used. The SCAQMD uses actual solvent consumption to determine dry cleaning solvent emissions and is presently correlating information from local facilities to develop an emission factor based on pounds of clothes cleaned.

Table 5-4 lists emission factors from the Compilation of Air Pollution Emission Factors, 4th Edition (AP-42) for petroleum, perchloroethylene, and trichlorotrifluoroethane dry cleaning operations.

5.4 Calculations

5.4.1 Operational Data

In order to determine the compliance status of the dry cleaning operation, the applicant will need to supply the following information :

Max. Days of Operation/Week (O_w) : ---------------------------------- (days/week)
Max. Hours of Operation/Day (O_d) : ---------------------------------- (hours/day)
Amount of Clothes Cleaned/Day (W) : ---------------------------------- (lb/day)
Start Time : End Time :
Type of Solvent Used :
Solvent Usage (V_s) : ---------------------------------- (gal/month)
Solvent Density (D_s) : ---------------------------------- (lb/gal)
Supplier's Name :

5.4.2 Emission Calculations

Emissions from the dry cleaning process may be calculated using the following equation:

$$R_2 = \frac{(V_s \times D_s)}{(O_w \times O_d \times G)} \qquad \text{(Equation 5-1)}$$

where:

R_2 = Rate of solvent consumption (actual) (lb/hour)
V_s = Solvent consumed per month (gal/month)
D_s = Density of the solvent at room temp. (lb/ gal.)

O_w = Operating schedule (hours/week)
O_d = Operating schedule (hours/day)
G = Average number of weeks per month
G = (52 weeks/year) / (12 months/year) = 4.33 weeks/month

$$R_1 = \frac{R_2}{(1 - F_R)} \quad \text{(Equation 5-2)}$$

where:

R_1 = Rate of solvent emission without control (lb/hour)

F_R = Fraction recovered. This is the assumed fraction of emissions that are recovered through control measures, based on solvent loss emission factors (statistics) for dry cleaning operations.
e.g. · for perc solvent and transfer operations, $F_R = 0.5$;
for perc solvent and dry-to-dry operation, $F_R = 0.35$ [1]

Emissions must be calculated for both the actual and maximum operating conditions. Actual emissions are used in emission inventory. Maximum emissions are used to determine compliance with the District's Rules and Regulations.

Actual and maximum hourly (lb/hr) emission rates must be converted to daily (lb/day) emission rates by multiplying the hourly rates by the appropriate equipment daily operational time factor (T, hr/day).

In addition, the maximum daily emissions are multiplied by the Regulation XIII On-Site Offset Factor (1.1). These daily emissions increase are accumulated for each facility in the District's New Source Review Record.

5.4.3 Fugitive Emissions

Fugitive emissions are usually minor emissions which emanate from a number of sources in a facility. These emissions are estimated through emission factors and

TABLE 5-4 SOLVENT LOSS EMISSION FACTORS FOR DRY CLEANING OPERATIONS[a]
EMISSION FACTOR RATING: B[b]

Solvent Type (Process used)	Source	Emission Rate[c] Typical System kg/100 kg (lb/100 lb)	Well controlled System kg/100 kg (lb/100 lb)
Petroleum (transfer process)	washer/dryer[d]	18	2[e]
	filter disposal		
	uncooked (drained)		8
	centrifuged		0.5 - 1
	still residue disposal	1	0.5 - 1
	miscellaneous[f]	1	1
Perchloroethylene (transfer process)	washer/dryer/ still/muck cooker	8[g]	0.3[e]
	filter disposal		
	uncooked muck	14	
	cooked muck	1.3	0.5 - 1.3
	cartridge filter	1.1	0.5 - 1.1
	still residue disposal	1.6	0.5 - 1.6
	miscellaneous[f]	1.5	1
Trichlorotrifluoroethane (dry-to-dry process)	washer/dryer/still[h]	0	0
	cartridge filter disposal	1	1
	still residue disposal	0.5	0.5
	miscellaneous[e]	1 - 3	1 - 3

[a] Reference 8

[b] Emission ratings (A - E), with A being the most reliable and accurate rating. See Reference 6.

[c] References 9 - 11. Units are in terms of weight solvent per weight of clothes cleaned (capacity x loads). Emissions also may be estimated by determining the amount of solvent consumed. Assuming that all solvent input is eventually evaporated to the atmosphere, an emission factor of 2000 lb/ton (1000 kg/Mg) of solvent consumed can be applied.

[d] Different material in wash retains a different amount of solvent (synthetics, 10 kg/100 kg; cotton, 20 kg/100kg; leather, 40 kg/100kg).

[e] Emissions from washer, dryer, still, muck cooker are passed collectively through a carbon adsorber.

[f] Miscellaneous sources include fugitives from flanges, pumps, pipes and storage tanks, and fixed losses such as opening and closing dryers, etc.

[g] Uncontrolled emissions from washer, dryer, still and muck cooker average about 8 kg/100 kg (8 lb/100 lb).

[h] About 15% of solvent emitted is from washer, 75% dryer, 5% each from still and muck cooker. Based on the typical refrigeration system installed in fluorocarbon plants.

are included in the total solvent consumption estimates. In the dry cleaning industry, fugitive emissions include emissions from the extraction cycle of a washer, during the transfer of solvent-laden articles from washers or dryers, liquid and vapor leaks in tanks and piping, and the evaporation of solvent from open solvent containers. Additional fugitive emissions are from the filter muck and still residue storage tanks.

5.4 Rules Evaluation

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing a permit.

Rule 401 - Visible Emissions
No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 442 - Solvent Usage
This rule does not apply to synthetic solvents.
Under subparagraph (d), only petroleum solvents with less than 4% by volume photochemically reactive solvent content can be used, unless the emission of organic materials into the atmosphere has been reduced at least 90% by weight.

Rule 1102 - Petroleum Solvent Dry Cleaners
No liquid leaks permitted. Solvent exposure to the atmosphere must be kept to an absolute minimum. Still residue must be stored in sealed containers. Use and proper disposal of an effective filter is required. Hydrocarbon vapors to the atmosphere must be reduced by at least 90% by weight.

Rule 1102.1 - Perchloroethylene Dry Cleaning Systems

No liquid or visible mist leaks are permitted.

Solvent exposure to the atmosphere kept to an absolute minimum. Filter residue must be less than 60% by weight for non-diatomaceous earth types and less than 25% by weight for diatomaceous earth types.

Perchloroethylene concentration cannot exceed 100 ppm from a carbon adsorber control device as measured over a period of one (1) minute prior to dilution.

The air temperature at the outlet of a refrigerated condenser must reach 45° F or less during cool-down period.

A temperature gauge with a minimum range of 0 - 150° F must be installed on the condenser outlet.

The demonstrated control efficiency of any other air pollution control (APC) device must be at least 90% by weight based on the inlet to the APC device.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT for dry cleaning operations are as follows:

ROG : Carbon Adsorber in Conjunction with a Reclaim Dryer --------- Perchloroethylene
: Carbon Adsorber --------------- Perchloroethylene and Petroleum
: Refrigerant Condenser ------- Perchloroethylene and Fluorocarbons
: Water Condenser -------------- Perchloroethylene and Petroleum
: Afterburner --------------------- Petroleum

NOx : None
SO2 : None
CO : None
PART : None

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[15] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

5.5 Permit (Operating) Conditions

In order to ensure compliance with the Rules and Regulations of the SCAQMD, permit conditions are imposed on dry cleaning equipment as follows:

I. DRY-TO-DRY UNITS WITH REFRIGERATION CONDENSERS

1. NO MORE THAN _______ LOADS MAY BE PROCESSED IN THIS EQUIPMENT IN ANY ONE DAY BASED ON THE MAXIMUM LOAD CAPACITY OF THE UNIT.

2. A TEMPERATURE GAUGE WITH A MINIMUM RANGE FROM 0°F TO 150°F MUST BE INSTALLED IN THE OUTLET DUCT OF THE CONDENSER.

3. THE REFRIGERATION CONDENSER ON THE DRY-TO-DRY UNIT MUST BE OPERATED DURING THE CLOSED LOOP COOL-DOWN PERIOD UNTIL THE AIR TEMPERATURE FROM THE CONDENSER OUTLET IS 45°F OR LOWER.

4. COMPLETE RECORDS OF PERCHLOROETHYLENE USAGE AND THE NUMBER OF LOADS PROCESSED PER DAY MUST BE LOGGED AND RETAINED FOR NOT LESS THAN TWO YEARS AND MUST BE MADE AVAILABLE TO THE DISTRICT UPON REQUEST. THE RECORDS MUST BE IN A FORM ACCEPTABLE TO THE EXECUTIVE OFFICER.

II. TRANSFER UNITS WITH REFRIGERATION CONDENSERS

1. NO MORE THAN __________ LOADS MAY BE PROCESSED IN THIS EQUIPMENT IN ANY ONE DAY.

2. A TEMPERATURE GAUGE WITH A MINIMUM RANGE FROM 0°F TO 150°F MUST BE INSTALLED IN THE OUTLET DUCT OF THE CONDENSER.

3. THE REFRIGERATION CONDENSER ON THE RECLAIM TUMBLER MUST BE OPERATED DURING THE CLOSED LOOP COOL-DOWN PERIOD UNTIL THE AIR TEMPERATURE FROM THE CONDENSER OUTLET IS 45°F OR LOWER.

4. DURING THE TRANSFER FROM THE WASHER-EXTRACTOR TO THE RECLAIM TUMBLER, WET CLOTHES MUST NOT BE OUTSIDE THE MACHINES FOR MORE THAN ONE MINUTE. THE CHARGE DOORS ON BOTH UNITS MUST BE KEPT CLOSED EXCEPT DURING LOADING, UNLOADING, OR TRANSFER.

5. THE REFRIGERATION CONDENSER ON THE WASHER-EXTRACTOR MUST COOL THE EXHAUST AIR PASSING THROUGH THE CONDENSER TO 45°F OR LOWER.

6. COMPLETE RECORDS OF PERCHLOROETHYLENE USAGE AND THE NUMBER OF LOADS PROCESSED PER DAY MUST BE LOGGED AND RETAINED FOR NOT LESS THAN TWO YEARS AND MUST BE MADE AVAILABLE TO THE DISTRICT UPON REQUEST. THE RECORDS MUST BE IN A FORM ACCEPTABLE TO THE EXECUTIVE OFFICER.

III. <u>OLD EQUIPMENT USING LESS THAN 320 GPY PERC, NO CONTROL</u>

1. NO MORE THAN ________ LOADS MAY BE PROCESSED IN THIS EQUIPMENT IN ANY ONE DAY.

2. COMPLETE RECORDS OF PERCHLOROETHYLENE USAGE AND THE NUMBER OF LOADS PROCESSED PER DAY MUST BE LOGGED AND RETAINED FOR NOT LESS THAN TWO YEARS AND

MUST BE MADE AVAILABLE TO THE DISTRICT UPON REQUEST. THE RECORDS MUST BE IN A FORM ACCEPTABLE TO THE EXECUTIVE OFFICER.

3. PERCHLOROETHYLENE CONSUMPTION IN ALL THE EQUIPMENT AT THIS LOCATION MUST NOT EXCEED (150) (320) GALLONS IN ANY ONE YEAR.

IV. CARBON ADSORBER CONTROL

1. NO MORE THAN ____________ LOADS MAY BE PROCESSED IN THIS EQUIPMENT IN ANY ONE DAY.

2. THE CARBON ADSORBER MUST BE REGENERATED IN PLACE WITH STEAM AFTER NOT MORE THAN __________ NUMBER OF LOADS OF DRY CLEANING OPERATION. DURING REGENERATION, ALL GASES FROM THE CARBON ADSORBER MUST BE DIRECTED THROUGH THE CONDENSER AS RECOMMENDED BY THE MANUFACTURER.

3. COMPLETE RECORDS OF PERCHLOROETHYLENE USAGE, NUMBER OF LOADS PROCESSED PER DAY, CARBON ADSORBER REGENERATION, CARBON ADSORBER TESTING, CARBON REPLACEMENT MUST BE LOGGED AND RETAINED FOR NOT LESS THAN TWO YEARS AND MUST BE MADE AVAILABLE TO THE DISTRICT UPON REQUEST. THE RECORDS MUST BE IN A FORM ACCEPTABLE TO THE EXECUTIVE OFFICER.

4. A TEST PORT OF AT LEAST 3/8-INCH DIAMETER MUST BE INSTALLED IN THE OUTLET DUCT OF THE CARBON ADSORBER(S) BEFORE DILUTION.

V. SOLVATION

1. NO MORE THAN __________ LOADS MAY BE PROCESSED IN THIS EQUIPMENT IN ANY ONE DAY.

2. THE CARBON ADSORBER MUST BE REGENERATED IN PLACE WITH STEAM AFTER NOT MORE THAN TEN (10) COMPLETED CYCLES OF DRY CLEANING OPERATION.

3. DURING REGENERATION, ALL GASES FROM THE CARBON ADSORBER MUST BE DIRECTED THROUGH THE CONDENSER AS RECOMMENDED BY THE MANUFACTURER.

4. DURING THE AERATION CYCLE, THE (RECLAIM TUMBLER) (DRY-TO-DRY UNIT) MUST VENT ONLY TO THE CONDENSER AND THE SOLVATION UNIT. THE TEMPERATURE OF THE INLET WATER TO THE CONDENSER MUST NOT EXCEED 75°F; AND THE TEMPERATURE OF PERCHLOROETHYLENE VAPORS LEAVING THE SOLVATION UNIT MUST NOT EXCEED 90°F AS INDICATED ON A PERMANENTLY FIXED AND CALIBRATED TEMPERATURE GAUGE.

5. THE (WASHER-EXTRACTOR AND RECLAIM TUMBLER) (DRY-TO-DRY UNIT) MUST VENT TO THE CARBON ADSORBER, ONLY WHEN THE ACCESS DOORS ARE OPEN FOR LOADING OR UNLOADING OF CLOTHES.

6. A TEST PORT OF AT LEAST 3/8-INCH DIAMETER MUST BE INSTALLED IN THE OUTLET DUCT OF THE CARBON ADSORBER(S) BEFORE DILUTION.

7. COMPLETE RECORDS OF PERCHLOROETHYLENE USAGE, THE NUMBER OF LOADS PROCESSED PER DAY, REGENERATION, CARBON ADSORBER TESTING, AND CARBON REPLACEMENT MUST BE LOGGED AND RETAINED FOR NOT LESS THAN TWO

YEARS AND MUST BE MADE AVAILABLE TO THE DISTRICT UPON REQUEST. THE RECORDS MUST BE IN A FORM ACCEPTABLE TO THE EXECUTIVE OFFICER.

REFERENCES

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2. Control of Volatile Organic Compound Emissions from Large Petroleum Dry Cleaners, TRW Environmental Engineering Division, EPA - 450/3-82-009, Sept. 1982.
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6. Diversitron Corporation, Fresh Meadows, New York.
7. "Chlorofluorocarbons: A Valuable Chemical Threatens The Atmosphere", Health and Environmental Digest, Volume 2, No. 4, May 1988.
8. Compilation of Air Pollutant Emission Factors - AP 42, 4th Edition, Sept. 1985.
9. Air Pollution Engineering Manual - AP 40, 2nd Edition, May 1973.
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13. Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems, EPA - 450/2-78-050, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1978.
14. Control of Volatile Organic Emissions from Petroleum Dry Cleaners (Draft), Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 1981.
15. South Coast Air Quality Management District, Best Available Control Technology Guidelines, October 7, 1988.

APPENDIX 5A

PERMIT PROCESSING WORKSHEET FOR A DRY CLEANING FACILITY

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. __________________

SYNTHETIC (PERC/VALCLENE)/PETROLEUM (TYPE) SOLVENT DRY CLEANING FACILITY CONSISTING OF:

(A) DRY CLEANING SYSTEM

1. DRY CLEANING UNIT, , MODEL NO. , SERIAL NO. .
2. EXTRACTOR, , MODEL NO. , SERIAL NO. .
3. TUMBLER / RECLAIM TUMBLER, , MODEL NO. , SERIAL NO. .
4. FILTER, , MODEL NO. , SERIAL NO. .
5. STILL, , MODEL NO. , SERIAL NO. .
6. MUCK COOKER, , MODEL NO. , SERIAL NO. .
7. SOLVENT TANK, , MODEL NO. , SERIAL NO. .

(B) AIR POLLUTION CONTROL SYSTEM: INTEGRAL/EXTERIOR

1. A. CARBON ADSORBER, , MODEL NO. , SERIAL NO. .
   B. REFRIGERATED VAPOR CONDENSER, , MODEL NO. , SERIAL NO. .
   C. SOLVENT RECOVERY UNIT (SOLVATION), , MODEL NO. , SERIAL NO. .

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2. EXHAUST SYSTEM VENTING A MAXIMUM OF DRY CLEANING EQUIPMENT SOURCES.

HISTORY:

PROCESS DESCRIPTION:

The __________ solvent dry cleaning facility will clean ________ pounds of articles per day and operate ________ days per week. The hours of operation will be from ________ am/pm, to am/pm, (M Tu W Th F S Su) and from ________ am/pm to ________ am/pm, (M Tu W Th F S Su). The equipment will be operated ________ hours/week, ________ weeks/year and use a maximum of ________ gallons of solvent/month.

DATA:

Type of Solvent: ______________

Solvent Density, (D_S):________ (lb/gal)

Solvent Densities -

Petroleum	:	6.3 - 6.6	lb/gal	@ 60° F
Perc	:	13.5	lb/gal	@ 60° F
Refrigerant 11	:	12.4	lb/gal	@ 60° F
Refrigerant 113 (Valclene)	:	13.2	lb/gal	@ 60° F

Operating Schedule (Average and Maximum)
Source : Applicant

Average	Maximum
(O_w) ______ days/week	______ days/week
(O_d) ______ hours/day	______ hours/day
(W) ______ lb clothes/day	______ lb clothes/day
(V_S) ______ gal solvent/month	______ gal solvent/month

Assumptions:

Table 5-4 of the Permit Processing Handbook lists emission factors published in the "Compilation of Air Pollution Factors" (AP-42). Table 5-4 should be consulted to verify the applicant's solvent consumption data.

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APPLICATION PROCESSING AND CALCULATIONS

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CALCULATIONS:

1. Controlled Emissions (R_2)

$$R_2 = \frac{(V_s \times D_s)}{(O_w \times O_d \times G)}$$

or

$$R_2 = \frac{(W)}{O_d} \times F$$

where: R_2 = Actual rate of solvent consumption (lb/hour).
V_s = Solvent consumed per month (gal/month).
D_s = Density of solvent at room temp. (lb/gal).
O_w = Operating schedule (days/week).
O_d = Operating schedule (hours/day).
W = Wash load (lb clothes/day).
G = Average number of weeks/month = 4.33 weeks/month.
EF = Emission factor (lb / 100 lb clothes) - Table 5-4.

$$NSR = R_2\text{max} \times 1.1$$

where: NSR = New Source Review. NSR emissions are maximum controlled emissions (R_2 max) multiplied by the Reg XIII On-Site Offset Factor of 1.1.

Controlled Emissions (R_2)	Actual lb/hr	Maximum lb/hr	Maximum lb/day	NSR lb/day
ROG				
NO_x				
SO_x				
CO				
PM				

2. Uncontrolled Emissions (R_1).

$$R_1 = \frac{R_2}{(1 - F_R)}$$

where: R_1 = Rate of solvent emission without controls (lbs./hour)

F_R = Fraction recovered. This statistical value represents the percent increase in solvent vapor recovery for a controlled system using a particular solvent and operation.

For perc solvent - transfer operations, $F_R = 0.5$
For perc solvent - dry-to-dry operations, $F_R = 0.35$
For systems not using solvent vapor recovery methods, $F_R = 0$

Uncontrolled Emissions (R_1)	Actual lb/hr	Maximum lb/hr	Maximum lb/day	NSR lb/day
ROG				
NO_x				
SO_x				
CO				
PM				

RULES EVALUATION:

RULE 212 : Public notice is (is not) required.

RULE 401 : Based on experience with similar equipment, this facility is (is not) expected to comply with the visible emission limits.

RULE 402 : Based on experience with similar equipment, nuisance complaints are (are not) expected.

RULE 442 : Petroleum solvent with less than 4% by volume of photochemically reactive compounds is used; or atmospheric emission of solvent containing more than 4% by volume of photochemically reactive compounds is reduced at least 90% by weight.

RULE 1102 : PETROLEUM SOLVENT DRY CLEANERS - The facility is(is not) expected to comply with the regulations concerning unnecessary solvent exposure to the atmosphere. Hydrocarbon emissions are (are not) reduced at least 90% by weight.

RULE 1102.1 : PERCHLOROETHYLENE SOLVENT DRY CLEANERS - The facility is (is not) expected to comply with the regulations concerning unnecessary solvent exposure to the atmosphere.

REG XIII : The net increase in emissions resulting from the operation of this equipment does (does not) exceed the limitations specified in Regulation XIII as shown by the Emission Threshold/New Source Sheet table as follows:

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	NSR Emissions in Pounds Per Day ROG	NO_X	SO_2	CO	PM
Facility Emissions Since 10-8-76	____	____	____	____	____
A/N	____	____	____	____	____
A/N	____	____	____	____	____
Net Emission Increase Since 10-8-76	____	____	____	____	____

BACT : The Best Available Control Technology (BACT) for a ____________ solvent dry cleaning operation is a ____________. The applicant will (will not) provide a ____________ as BACT. The South Coast Air Quality Management District's BACT Guideline should be consulted to ensure that the current BACT requirements are applied to this equipment.

CONCLUSIONS/RECOMMENDATIONS:

This dry cleaning facility is (is not) expected to comply with all applicable Rules and Regulations of the South Coast Air Quality Management District. Therefore, the following disposition is recommended:

( ) Issue a Permit to Construct/Operate subject to the following conditions:

APPLICATION NO. ____________

CONDITIONS:

Use appropriate conditions listed in Appendix 5-B of the Permit Processing Handbook).

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ____________ of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 5B

CARBON ADSORBER REGENERATION CALCULATIONS

The following equations are used to determine the frequency of regeneration of carbon in a carbon adsorber for the dry cleaning process.

$$L_r = \frac{A_c \times X_c}{S_l}$$

$$S_l = \frac{S_t}{(L_h \times O_h)} \quad \text{or} \quad S_l = \frac{V_s \times D_s}{L_t}$$

$$S_t = \frac{V_s \times D_s}{O_d} \qquad L_t = L_h \times O_d \times O_h$$

where:

L_r = Maximum number of loads before regeneration.
S_l = Fabric solvent consumption ----------------------------(lb/load)
S_t = Rate of solvent consumption---------------------------(lb/day)
L_t = Loading schedule ---------------------------------------(loads/month)
L_h = Loading schedule ---------------------------------------(loads/hour)
V_s = Volumetric rate of solvent consumption---------------(gal/month)
D_s = Density of solvent at room temperature ---------------(lb/gal)
O_d = Operation schedule--------------------------------------(days/month)
O_h = Operation schedule--------------------------------------(hours/day)
A_c = Percent by weight adsorption capacity ----------------(fractional)
(For PERC $A_c = 20\%$ or 0.20)
X_c = Amount of available carbon in bed -------------------(lb)

SECTION 6

Plastic Extrusion

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Section 6

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

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SECTION 6: PLASTIC EXTRUSION

6.1 General Description

In typical plastics extrusion processing, polymer and resin raw materials in the form of powders, pellets, and emulsion, are fed from a hopper into the extruder. The extruder, usually a horizontally mounted cylindrical barrel incorporating a rotating screw-type conveyor or a ram-type piston, forces molten plastic through a shaping die to yield the desired product. The raw materials entering the extruder are melted by externally applied heat and internally derived shear heat (induced by the motion of the screw or ram piston), to form a uniform, viscous, and workable mixture. See Figure 6-1 for a block diagram and Figure 6-2 for a schematic of plastic extrusion processing.

Plastic extrusion is responsible for more than 40% of the plastic products produced in the United States.[1] The products and their respective process are:

pellets for further processing (see Figure 6-3);
pipe, tubing, and other profile shapes (see Figure 6-4);
plastic feed for blow molding;
monofilaments;
film (see Figure 6-5);
sheet (see Figure 6-6);
wire and cable coating (insulation) (see Figure 6-7); and
coextruded (multi-layer) products (see Figure 6-8).

Plastic processing facilities in the United States tend to be located near sales centers (to minimize transportation costs). Many are located in Connecticut, Massachusetts, New York, New Jersey, Pennsylvania, Ohio, Michigan, Illinois, and California. As of February 1988, 264 permitted extrusion units were operated in the South Coast Air Basin. These included 143 plastics and resin extrusion operations, 34 polystyrene extrusion operations, and 87 PVC extrusion operations.

Plastic extruders use a variety of mechanical principles to convey or process the plastic and force it through a die orifice. The two most common designs are ram-

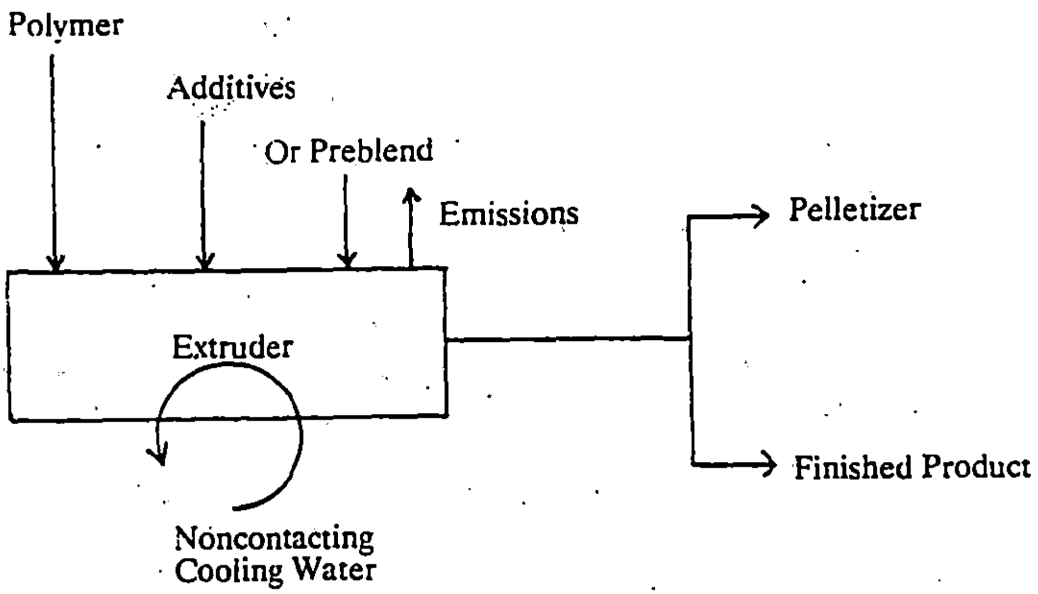


FIGURE 6-1 EXTRUSION - BLOCK DIAGRAM

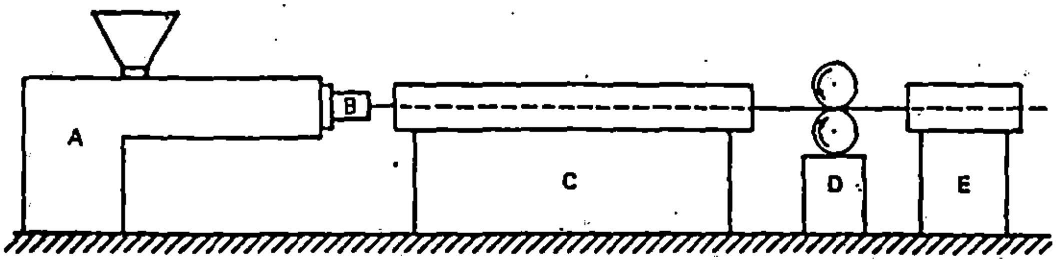


FIGURE 6-2 EXTRUSION - SCHEMATIC DIAGRAM

(A) EXTRUDER
(B) DIE
(C) SIZER COOLER (WATER TROUGH)
(D) PULL ROLLS
(E) CUTTER (COILER)

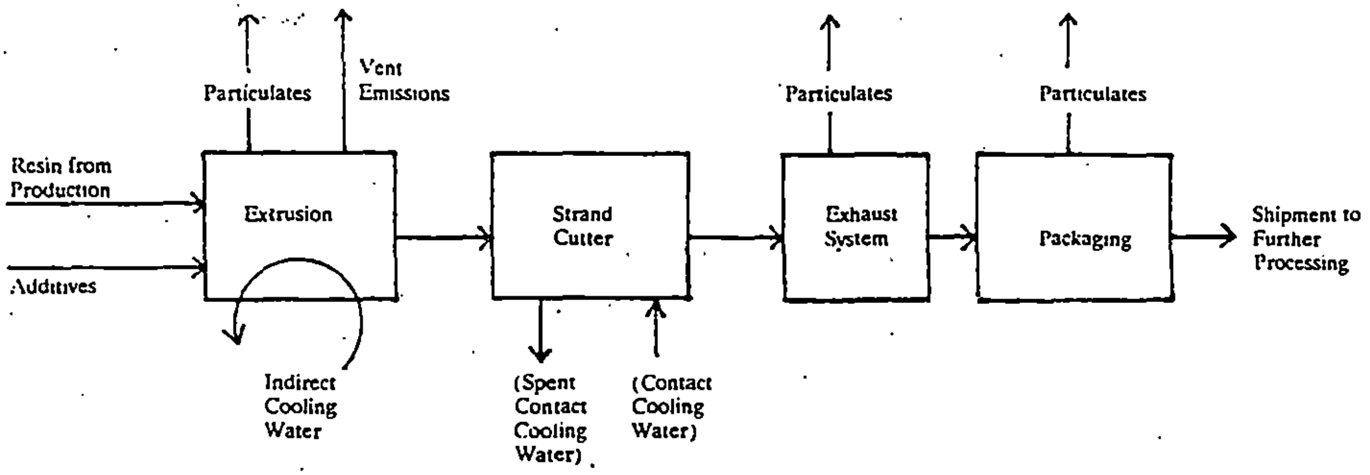


FIGURE 6-3 PELLETIZING OPERATION

Parenthesis indicate that the stream is not present in all pelletizing operations.

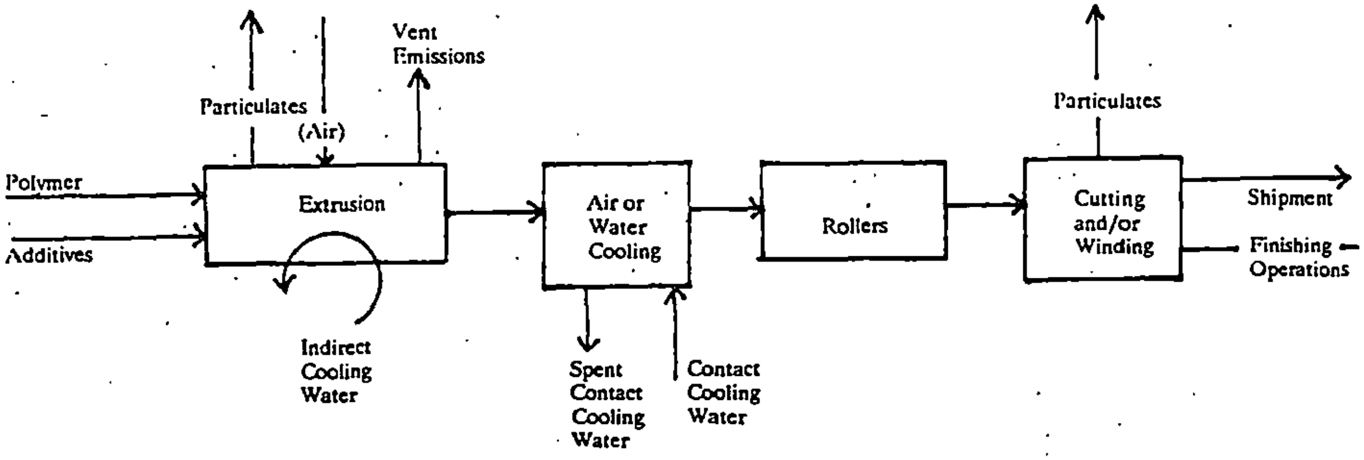


FIGURE 6-4 PROFILE, PIPE and TUBE OPERATION

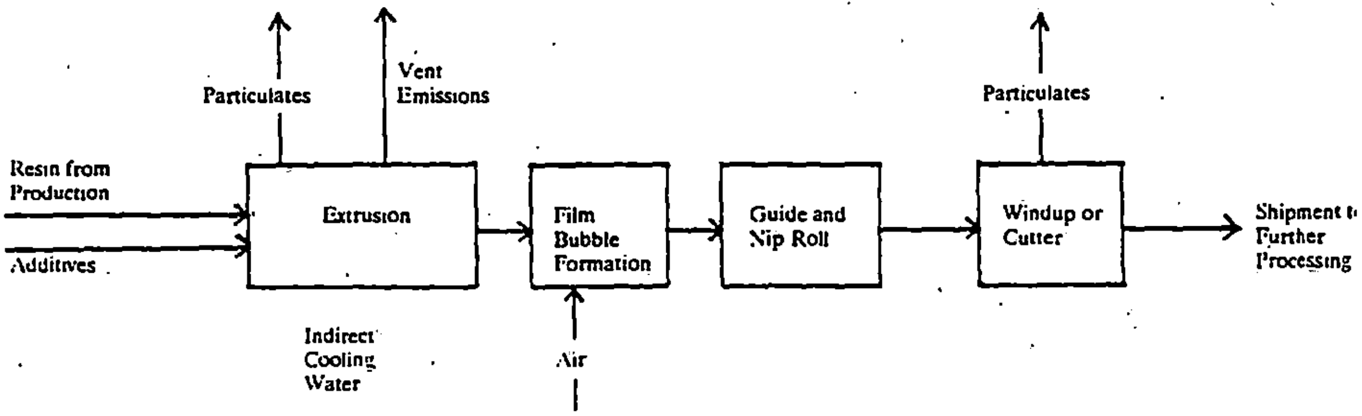


FIGURE 6-5 BLOWN FILM OPERATION

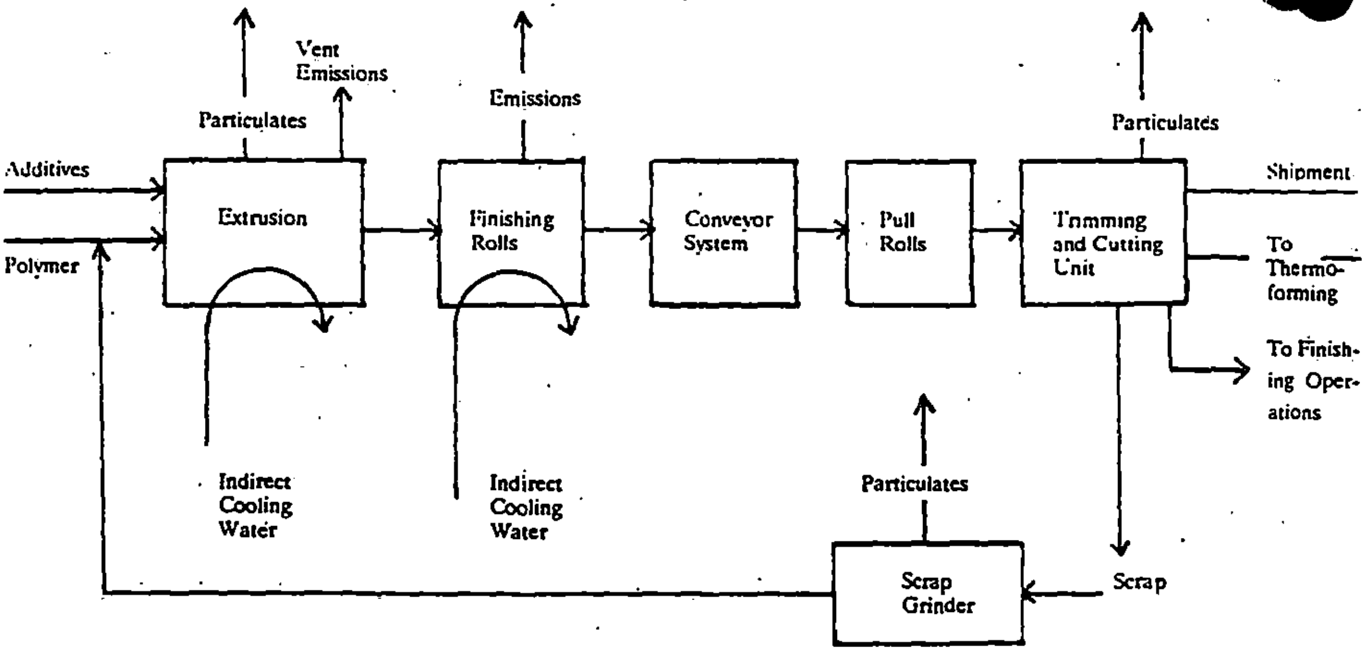


FIGURE 6-6 PLASTIC SHEET OPERATION

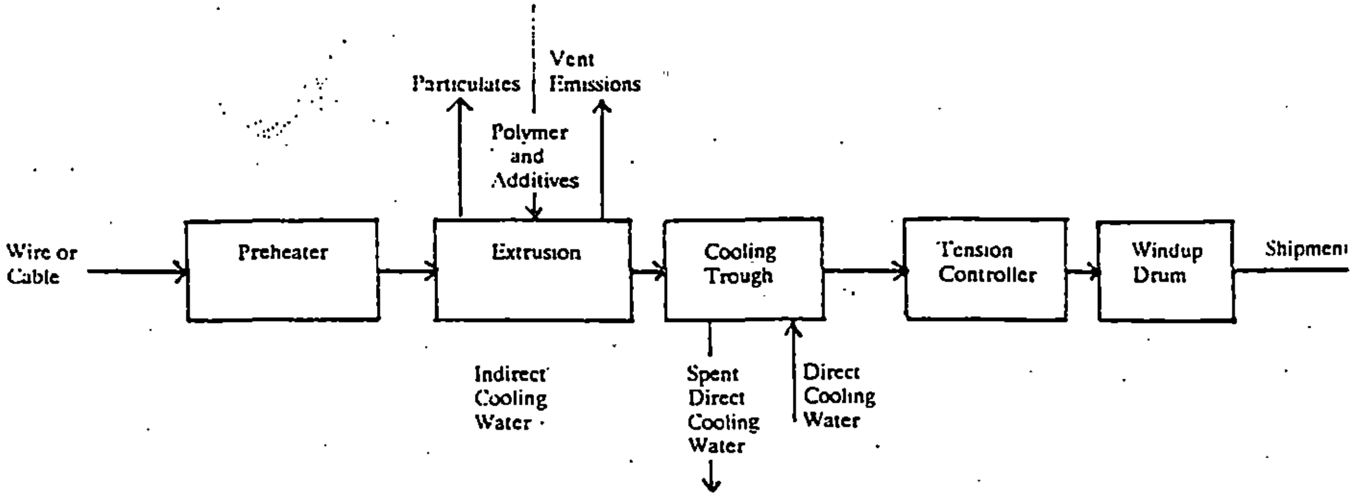


FIGURE 6-7 WIRE and CABLE COATING OPERATION

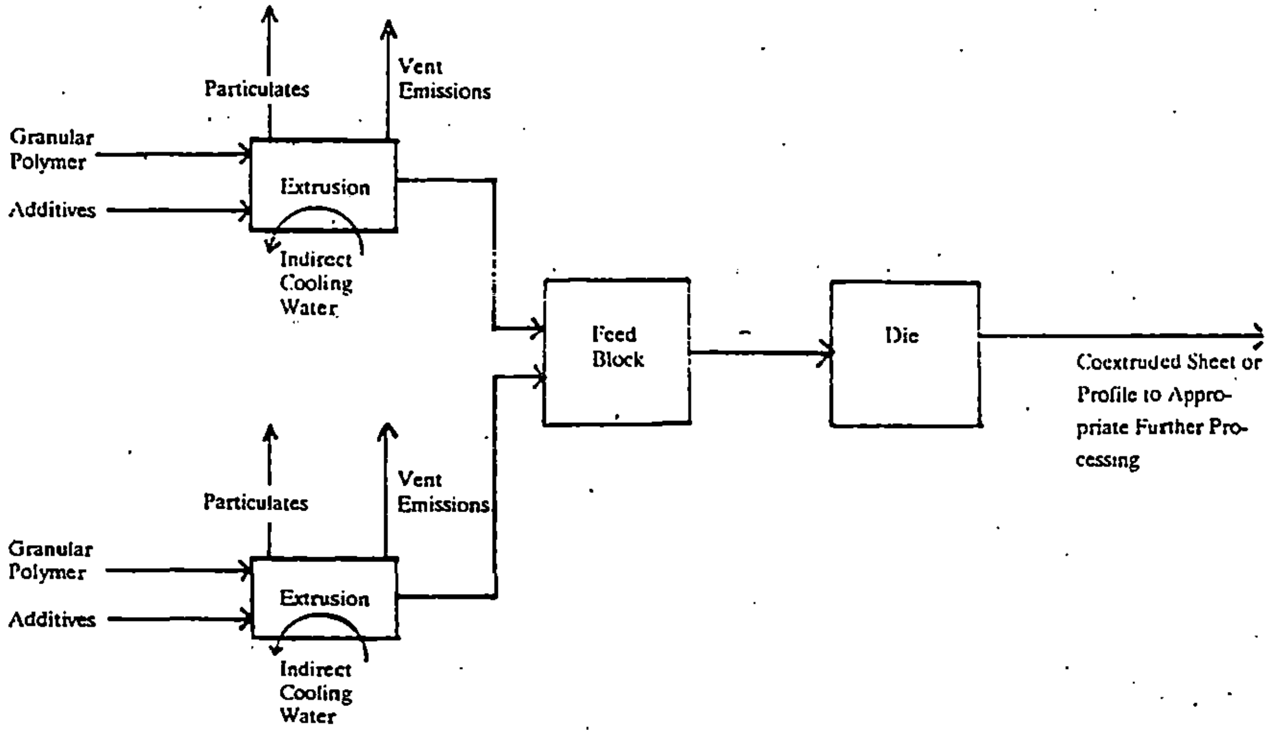


FIGURE 6-8 COEXTRUDED (MULTI-LAYER PRODUCTS)

type and screw-type extruders as shown in Figures 6-9 and 6-10. Screw-type extruders are divided into single-screw and twin-screw extruders (see Figures 6-11 and 6-12). Other designs include the spiral disc extruder, the elastic melt extruder, and the smooth disc (Weissenberg) or gear pump extruder. The ram-type and screw-type extruders are discussed further.

6.1.1 Ram Extruders

Ram extrusion, one of the oldest methods for extruding plastics, is a simple operation employing a piston sliding in a cylinder, pushing or "ramming" the polymer through the die opening. The ram extruder is a direct, or positive-displacement pump. The polymer feed is delivered in set quantities to the front of the piston through a hopper. The feed is compressed, heated to a working state, and extruded through the die. This is a batch-type operation. Ram extruders are designed to withstand high pressures (up to 50,000 psi) which make them well suited to PTFE (polytetrafluoroethylene or Teflon^R - registered trademark of DuPont) extrusion and injection molding.[2] Since little flow occurs in the cylinder, frictional (shear) heating effects are insignificant. Primary heating of the material is performed by external electric heaters which conduct heat through the wall of the cylinder. The mixing and shear are limited to the flow and entry effects into the die orifice. Ram-type extruders make up a very small percentage of the plastic extrusion industry due to their lack of versatility and product quality and uniformity. The most commonly used type of plastic extruder is the continuous screw-type extruder.

6.1.2 Screw Extruders

Screw extruders, classified as either a single screw or a twin screw extruder, offer a broad range of application. Screw-type extrusion is a continuous process and fulfills many functions not available to ram-type extrusion. Screw extruders perform three actions in processing plastics:

- It melts or plasticizes the material;

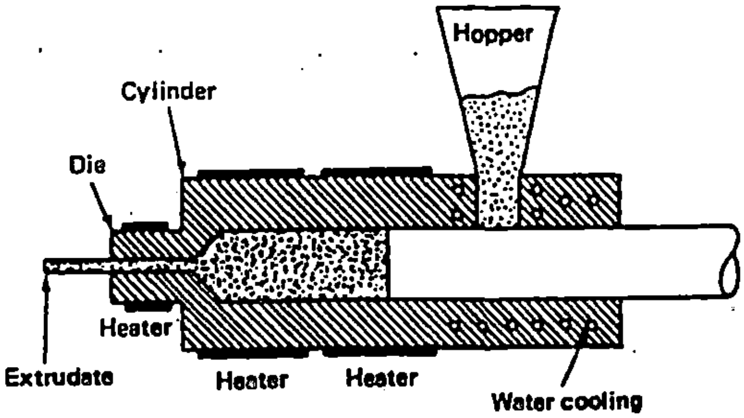


FIGURE 6-9 SCHEMATIC OF A SIMPLE RAM EXTRUDER

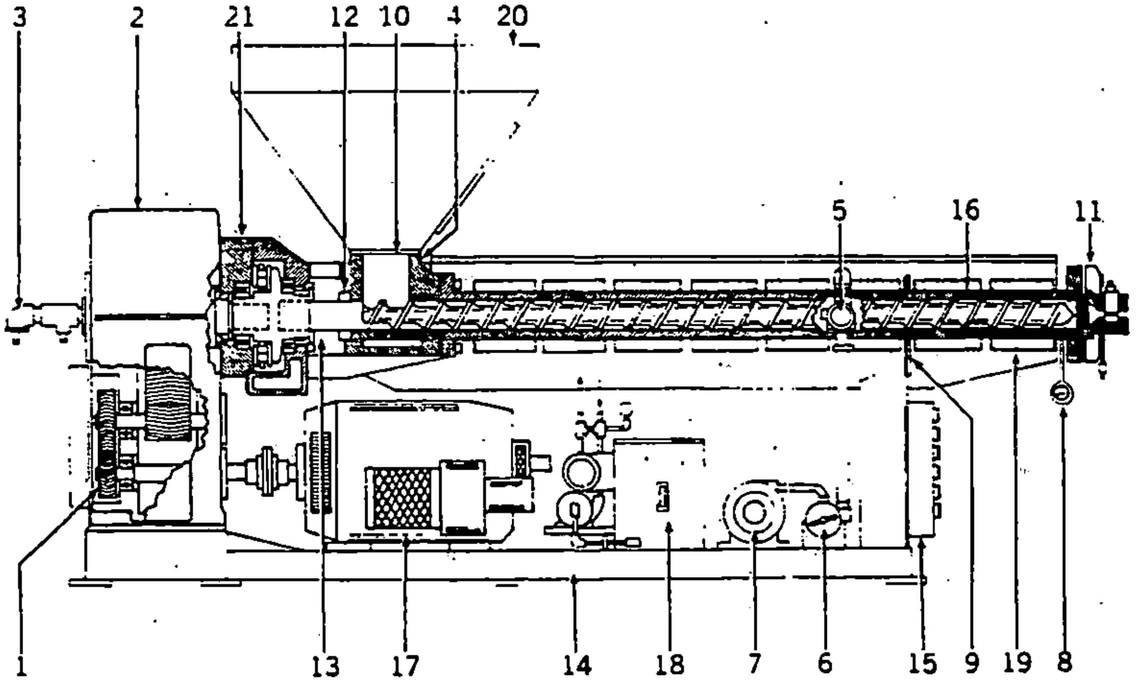


FIGURE 6-10 SCHEMATIC OF A SIMPLE SCREW EXTRUDER (Vented and Water-Cooled) Courtesy of HPM Corporation

1. Change gears; 2. Gear reducer; 3. Rotary union; 4. Feed throat; 5. Side vent; 6. Trap; 7. Vacuum pump; 8. Pressure measurement; 9. Front barrel support; 10. Large rectangular feed opening; 11. Hinged swing gate; 12. Rear seal; 13. Large air spacer; 14. Extruder base; 15. Electrical box; 16. Heavy wall cylinder; 17. Motor; 18. Barrel water cooler; 19. Barrel heating and cooling; 20. Hopper; 21. Thrust bearing assembly.

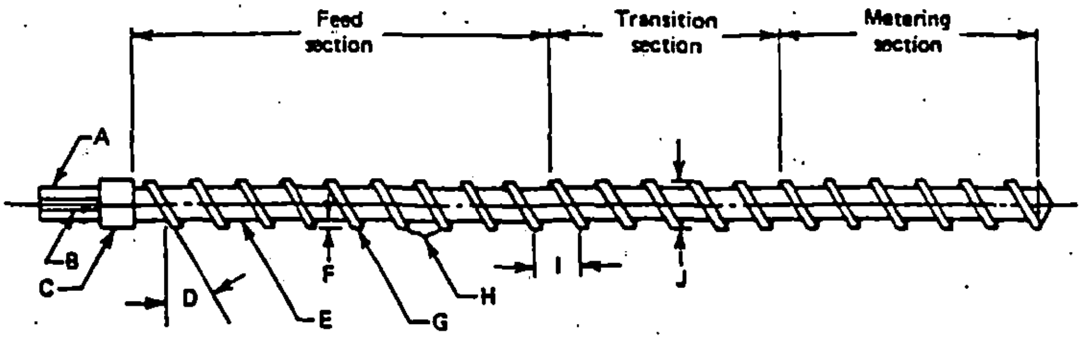


FIGURE 6-11 SINGLE SCREW

(A) SHANK
(B) KEY
(C) HUB
(D) HELIX ANGLE
(E) ROOT
(F) CHANNEL DEPTH
(G) FLIGHT
(H) CHANNEL
(I) PITCH
(J) DIAMETER

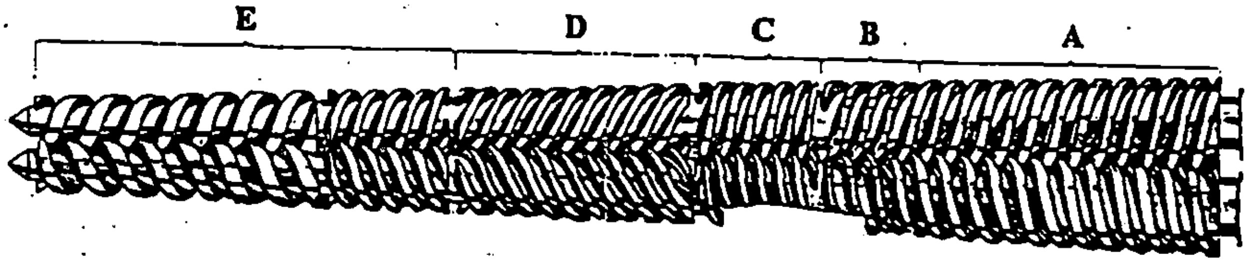


FIGURE 6-12 TWIN SCREW

(A) METERING ZONE
(B) VENTING ZONE
(C) COMPRESSION ZONE
(D) MIXING ZONE
(E) FEEDING ZONE

- It generates pressure on the material to force it through the die orifice;
- It shears and mixes the material.

Each screw design performs these steps differently, thereby, imparting different characteristics to the melt. Screw extruders rotate a screw within a heated barrel. Granules of polymer (pellets, regrinds, etc.) are fed from a hopper into the barrel. The feed is conveyed forward by the screw at a controlled rate, pressure, and temperature so that a uniform material is forced through the die to produce the desired product. Barrel length divided by barrel diameter (L/D ratio) is typically used to describe the extruder. The barrel is made from high strength steel and designed to withstand pressures of 7,500 to 10,000 psi. Electric, steam, or fluid heating can be used to externally heat the cylinder wall and either water or air is generally used to cool it.[1] The barrel is usually equipped with a vent to remove air which gets entrained in the molten polymer. This vent is plugged when not required. This venting process takes place in the low pressure zone after melting is complete (see Section 6.1.6 Venting or Vacuum Extraction in Screw Extruders).

The screw is the heart of the extrusion process. It utilizes a helical thread or threads and a varying channel depth to accomplish multiple functions of conveying, compacting, melting, mixing, and pumping. The screw is typically divided into four sections (see Figure 6-13).

1. The feed section where the channel depth is relatively deep;
2. A transition or compression (melting) section where the channel depth is decreasing;
3. A metering or a pumping section where the channel depth is relatively shallow; and
4. The die section where the plastic is forced out through the die opening and formed into the shape desired.

6.1.2.1 Single Screw Extruders

Single screw extrusion basically involves rotating a helical screw in a close-fitting cylindrical barrel. The screw is divided into four sections as mentioned previously.

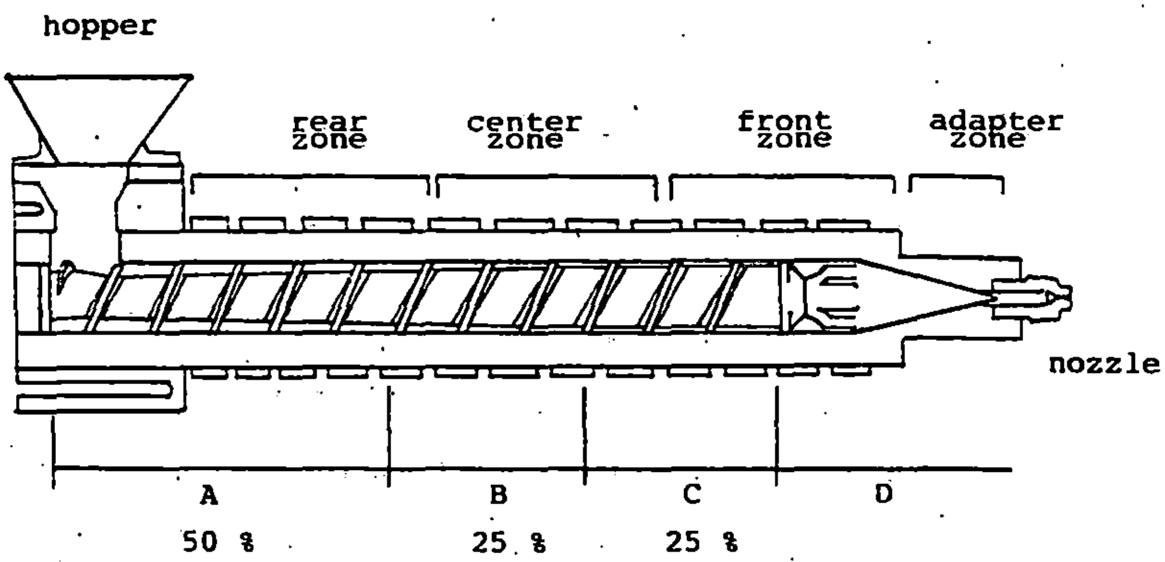


FIGURE 6-13 SCREW EXTRUDER SHOWING BARREL ZONES and DIE ZONES

(A) FEED ZONE
(B) COMPRESSION ZONE
(C) METERING ZONE
(D) DIE ZONE

The length and depth of these sections greatly affect extruder performance which in turn depends upon frictional and melting characteristics of the polymer and the rheology of the polymer melt.[3] Single screw extruders operate by viscous-drag flow, hence, the viscosity of the polymer is the governing material property (see Section 6.1.3.1 Melting-Rate Properties). Single screw extruders are suitable for working with highly viscous fluids, and are capable of operating at high pressures and temperatures.

Melting of the polymer is primarily done through shear heating and to a lesser extent by external heating.[3] In many instances melting starts in the constant-depth feed section and continues into the shallower constant-depth metering section. Figures 6-14 and 6-15 show idealized cross sectional depictions of the melting mechanism in the screw channel in the melting zone. The solid particles are subjected to shearing action between the base of the screw and the thin film of polymer melt along the barrel surface. They are then smeared around the barrel in a direction normal to the screw axis until they meet the leading edge of the advancing thread. Here they are mixed with previously molten material, forced downward into the channel initiating a helical circulating path. This circulation is confined to the rear portion of the channel in each turn, the forward portion being filled largely with unfluxed material. This mechanism produces complete fluxing and a homogeneous product before discharge through the die.[3]

In single screw extrusion shear rate, material temperature, and mixing are highly interdependent and cannot be controlled separately. For elevated throughput rates stable operation is often difficult to achieve.

Single screw extruder length/diameter (L/D) ratios are typically 20/1, 24/1, or 30/1. Table 6-1 lists typical extruder sizes, outputs, and drive power.

6.1.2.2 Twin-Screw Extruders

Twin- or other multiple-screw extruders use intermeshing corotating or counterrotating screws to build up pressure on the polymer melt. The unit is a

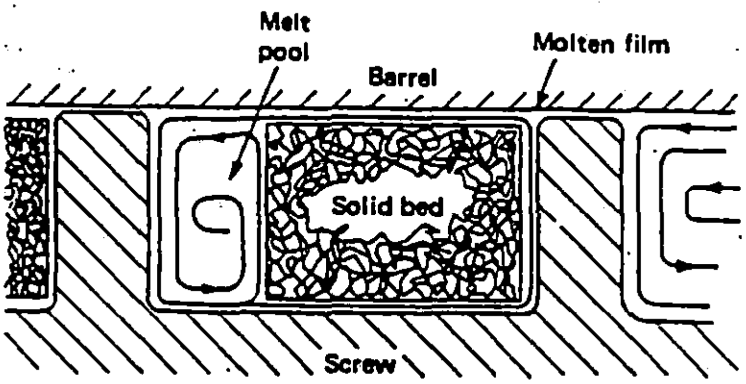


FIGURE 6-14 SCHEMATIC OF MELTING MECHANISM IN A SINGLE - SCREW EXTRUDER

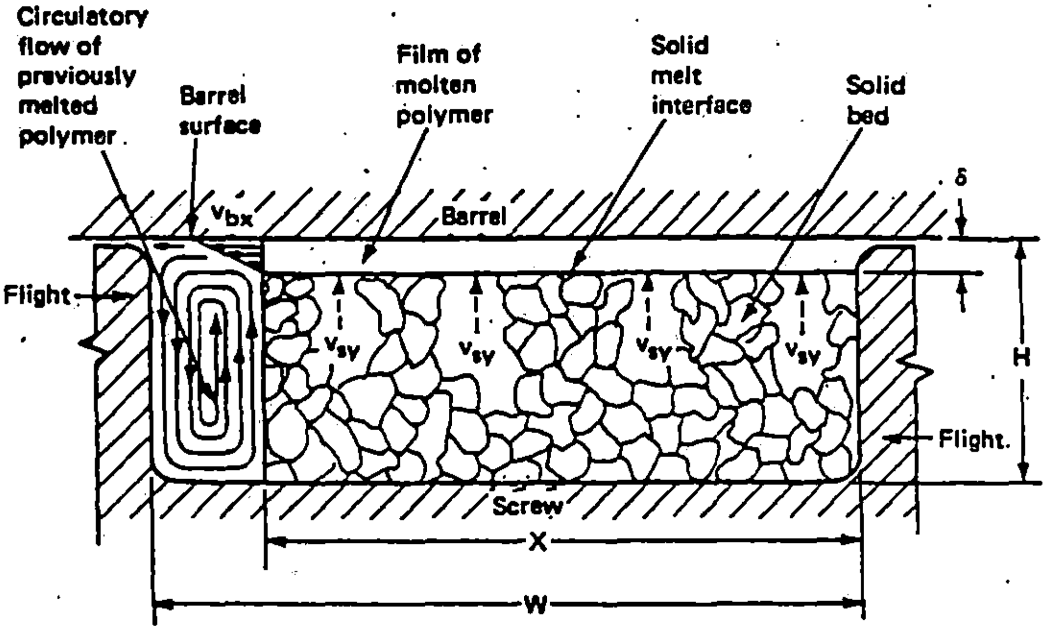


FIGURE 6-15 IDEALIZED CHANNEL CROSS SECTION SHOWING MELTING MECHANISM

V_{bx} = Velocity of barrel relative to screw flight.
V_{sy} = Velocity of solid polymer towards the barrel wall
H = Depth of screw flight
X = Length of unmelted polymer
W = Length of screw flight

TABLE 6-1 TYPICAL EXTRUDER SIZES, OUTPUTS, AND DRIVE POWERS [a]

Extruder Size			Output Capacity	Drive Power
(in.)	(mm)	L/D	kg/hr	H.P.
1.5	38.1	24:1	110 - 132	10 - 15
2	50.8	24:1	198 - 264	20 - 30
2.5	63.5	24:1	330 - 550	35 - 60
3.5	88.9	24:1	660 - 880	40 - 75
3.5	88.9	30:1	770 - 990	55 - 80
4.5	11.43	24:1	1,540 - 2,200	80 - 125
6	15.24	24:1	2,640 - 3,520	150 - 300
8	20.32	24:1	4,400 - 7,700	300 - 600

a. Reference 1.

positive displacement pumping device that does not depend on material characteristics for the delivery rate. Twin screws are independent of shearing effects. Since the functions of pressure buildup and shear mixing are essentially independent, it is possible to independently vary each by appropriate screw design and machine control. The heat needed to melt the material is provided by an external source with a relatively small amount generated by shear heating. Twin-screw extruders find extensive use in mixing, compounding and formulating operations, color blending, and for extruding difficult materials such as PVC powder blends for pipes, siding, and other PVC products. Many twin-screw machines are also equipped with injection ports along the barrel to introduce additional materials such as colorants, plasticizers, and fillers downstream from the main feed. The output of a twin-screw extruder is about three times that of a single-screw extruder of the same screw diameter and speed; however, in normal operation, twin-screw speeds are less than those of a single-screw machine. Twin-screw extruders are more costly compared to single-screw extruders for the same output, but their design inherently offers tighter controls on process conditions, such as larger heating (or cooling) surface per unit length and relatively less mechanical energy dissipated as heat. The benefits of the twin-screw design are realized when the degradation temperature of a polymer is slightly above its melting temperature (as in PVC processing).

6.1.3 Materials

6.1.3.1 Melting-Rate Properties

The melting-rate of a polymer is highly dependent upon its physical and rheological properties. The melting-rate rises with increasing values of melt density, thermal conductivity, and melt viscosity, but decreases with increasing specific heat or heat of fusion.[3] Rheology describes the manner in which the material deforms in response to an applied stress. In the case of plastics in the melt condition, the stress applied is pressure (the ratio of shear force to shear area), and the response is continuous deformation and flow. The flow is dependent on the shear characteristics of the material, and the response can be of several types. Figure 6-16 shows typical forms of viscous flow.

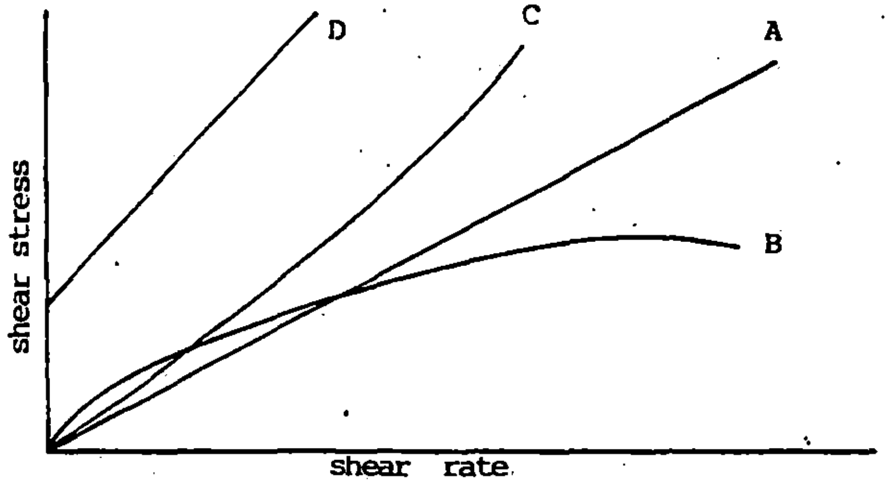


FIGURE 6-16 FORMS OF VISCOUS FLOW
A = Newtonian; B = Shear thinning (or pseudoplastic);
C = Shear thickening; D = Bingham (or Plastic)

Viscosity is the ratio between shear stress and shear rate (see Figure 6-16).

$$\text{Viscosity} = \frac{\text{shear stress}}{\text{shear rate}}$$

A material with a constant viscosity, at constant temperature and pressure (a constant ratio), is called a Newtonian fluid. Most polymer melts behave as

Newtonian or shear-thinning (pseudoplastics) fluids.[4] The more viscous and amorphous a material is the faster it melts.

6.1.3.2 Thermosetting Plastics and Thermoplastics

Two types of plastics are used in extrusion operations, thermosetting plastics and thermoplastics. Thermosetting plastics are obtained from fusible ingredients that undergo condensation and polymerization reactions under the influence of heat, pressure and a catalyst, and form rigid shapes that resist the actions of heat and solvents.[5] Thermoplastics, however, after being formed into rigid shapes, are able to be reheated, reworked, and reshaped without losing their physical properties. Ram-type extrusion is used to process thermoset plastics, including silicones, phenolics, melamines, epoxies, and alkyds, and some high melt viscosity thermoplastics such as polytetrafluoroethylene (PTFE). Screw-type extrusion is used to process most thermoplastics polymers as listed in Table 6-2. Screw-type extrusion also allows for formulation or compounding operations, in which additives such as speciality chemicals, plasticizers, UV stabilizers, and colorants can be blended with the polymer in the screw extruder cylinder.

6.1.4 Compounding

Polymer compounding refers to the mixing of additives and speciality chemicals with a raw polymer before, during, or after polymer production and prior to or during processing to make plastic applicable to its intended use. The type of chemicals and additives blended with the polymer include plasticizers, stabilizers, antioxidants, ultraviolet absorbers, organic peroxides, colorants, and flame retardants.

Compounding imparts physical and chemical properties which the polymer does not exhibit alone, reduces the cost of finished products, and increases the ease of production and processing. Since different raw polymers have widely different characteristics, formulations are tailor-made to meet the needs of the particular polymer and its application. Virtually all polymers require some formulation prior

TABLE 6-2 POLYMER FEED MATERIAL [a]

- Acrylic Resins
- Acrylonitrile-Butadiene-Styrene (ABS)
- Ethylene-Vinyl-Acetate (EVA)
- Nylon
- Phenylene Oxide
- Polyacetal
- Polybutylene
- Polycarbonate
- Polyester Fluoroplastics
- Polyethylene
  - High Density (HDPE)
  - Linear Low Density(LLDPE)
  - Low Density (LDPE)
  - High Molecular Weight (HMWPE)
- Polypropylene
- Polystyrene
- Polyurethane
- Polyvinyl Chloride (PVC)
- Styrene-Acrylonitrile (SAN)
- Sulfone Polymers
- Thermoplastic Polyesters (PBT & PET)

- Vinylidene Chloride

[a] Reference 1.

---

to processing.[6] The mixing and blending operations of extrusion are considered compounding techniques. Polymer pellets and additives are mixed in a hopper or preblended in a mixer. The mixing action of the screw together with the heat supplied and the heat generated, mixes and melts the resin and additives into a uniform compound. Both single and twin screw extruders are used in compounding because of their inherent blending characteristics.

Some typical temperatures for extruder blending operations are listed in Table 6-3. The wide range of temperatures illustrates the variability of blending processes. Pressure ranges typical of extruder blending operations are 100 - 600 psi. See APPENDIX 6B for a list of Compounding Agents.

6.1.4.1 Plasticizers

Plasticizers, usually high-boiling, low-volatility esters, are added to thermoplastics to improve processing characteristics or physical and mechanical properties of the products. Addition of a plasticizer increases flexibility and lowers the polymer melt

TABLE 6-3 PROCESS TEMPERATURES FOR POLYMERS [a]

Polymer	Typical Temperature (^{o}C)
ABS	150-250
ABS/PVC Alloys	191-210
Acrylic Resins	230
Fluoroplastics	260-330
High Density Polyethylene (HDPE)	260
Low Density PE	250-260
Linear Low Density PE	250-260
Nylon	260-310
Phenolics	280-340
Polyacetal	188-205
Polyamides	205-415
Polybutylene	130-190
Polycarbonates	220-350
Polyester	
Thermoplastic	270-300
Aromatic	232-260
Polyphenylene Sulfide	302-357
Polypropylene	200-280
Polystyrene	125-230
Polyurethane	150-200
PVC	190-210
Polyvinylidene Chloride	198-210
SAN	175-230

a. Reference 1

viscosity, producing an effect similar to increasing the temperature of the unplasticized polymer. Some polymers must be plasticized to enable processing below the decomposition temperature. Another class of plasticizer, either a complete polyester made from glycol, or an epoxy compound, is known as a "permanent" plasticizer because of its nonvolatility. The epoxy types are used with other plasticizers in vinyl compounds and also function as stabilizers.

In general, the hardness, elastic modulus, and tensile strength of the plastic is decreased by the addition of a plasticizer. The selection of a plasticizer for a plastics compound is based on compatibility, efficiency, processibility, permanence, and of course, cost. See APPENDIX 6C.

6.1.4.2 Stabilizers and Antioxidants

Polymers are subject, in varying degrees, to degradation by heat, light, and oxidation. Polyvinyl chloride (PVC) in particular requires stabilization because the process temperatures required for the development of rigid products are high enough to initiate decomposition. In PVC production, the main emission concern is hydrochloric acid. Table 6-4 lists the highest processing temperature, the decomposition temperature, and the decomposition products of various polymers. Antioxidants are divided into five classes: phenol derivatives, amines, esters, organic phosphites, and miscellaneous. Low density polyethylene and polypropylene use phenols alone or in conjunction with sulfur-containing esters or phosphites. Polystyrene is relatively stable to oxidation but sensitive to light degradation.

6.1.4.3 Organic Peroxides and Colorants

Organic peroxides and hydroperoxides are derivatives of hydrogen peroxide and are used in addition polymerization.

Colorants are inorganic or mineral pigments, organic pigments, or lakes (coloring compounds), deposited on alumina. Dyes must be used for transparent plastics to avoid visible particles in the finished product.

TABLE 6-4 DECOMPOSITION PRODUCTS[a]

Polymer	Highest Processing Temperature (°C)[b]	Decomposition Temperature (°C)[c]	Decomposition Products
ABS	230	300	*
Acrylic Resins	230	320	*
Fluoroplastics	330	300	HF
Nylons	310	300	CO, CO_2
Modified Phenylene Oxide	#	#	*
Polyacetal	205	250	*
Polybutylene	190	300	*
Polycarbonate	300	330	*
Polyester			
(Thermoplastic)	300	300	acetaldehyde
(Aromatic)	260	275	*
Polyethylene	230	100	Ketone carbonyl groups form due to oxidation
Polypropylene	230	300	*
Polystyrene	230	300	*
Polyurethane	200	300	*, ##
PVC	210	100	HCl
Styrene Acrylonitrile	230	300	*

[a] Reference 1.

* Decomposition products are not formed at or near extrusion processing temperatures.

[b] This is the highest possible temperature reached by the normal extrusion of all formulations of the polymer listed.

[c] This is the lowest temperature at which decomposition products begin to form.

Temperatures not found in the reference literature.

The presence of humidity at processing temperatures may cause hydrolysis of the urethane functional groups.

6.1.4.4 Flame Retardants

To meet nonflammability criteria, all polymers (except PVC and fluorocarbons) require the addition of flame retardants. The flame retardants most commonly used are compounds of bromine, chlorine, antimony, and phosphorous.

6.1.4.5 Fillers and Reinforcements

These fall into five categories: mineral and synthetic inorganic powders, carbon blacks, cellulosics, metal powders, and microspheres. Reinforcements include cotton and asbestos flocks, glass fibers, carbon fibers, and mineral whiskers. Fillers include wood flour; asbestos flock, which greatly increases impact strength; and aluminum, magnesium, and titanium oxides, which give added stiffness to composites.

6.1.5 Extruded Thermoplastic Foams

Extrusion operations are also used to process thermoplastic foams by incorporating a gas-forming expanding agent (blowing agent) into the thermoplastic. Thermoplastic foams are low to medium density materials with desirable mechanical and insulating properties. Their major application is in packaging and building products. A large volume application is foam polystyrene sheet used for meat and produce trays, egg cartons, and snack food service. Cups, containers, and glass bottle shields also account for a substantial volume. The largest volume of extruded foam products are stock products which require further fabricating to become final products. These fabrication operations include cutting, shaping, cementing, and thermoforming. See Figures 6-17, 6-18 for block diagrams of foam extrusion processes.

Each polymer must be formulated in order to provide the properties necessary in the final product. Such formulations are similar to those used for solid polymer extrusion, and like solid extrusion, are dependent upon the processing conditions and end use requirements of the specific polymer.[1]

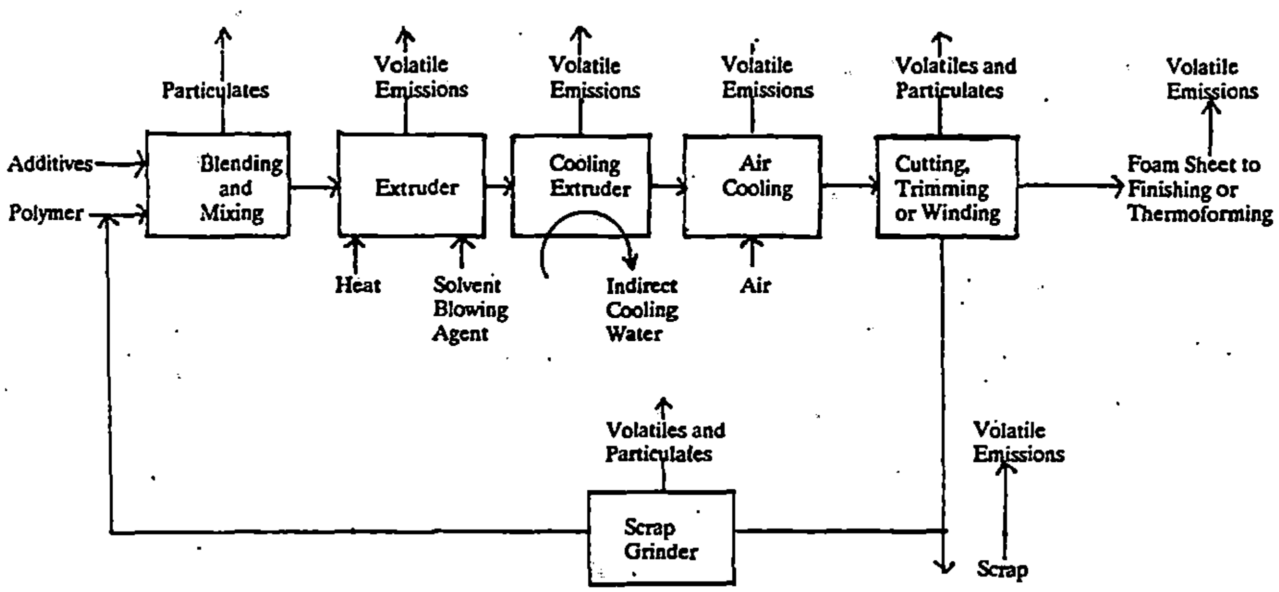


FIGURE 6-17 FOAM EXTRUSION BLOCK DIAGRAM - CHEMICAL BLOWN

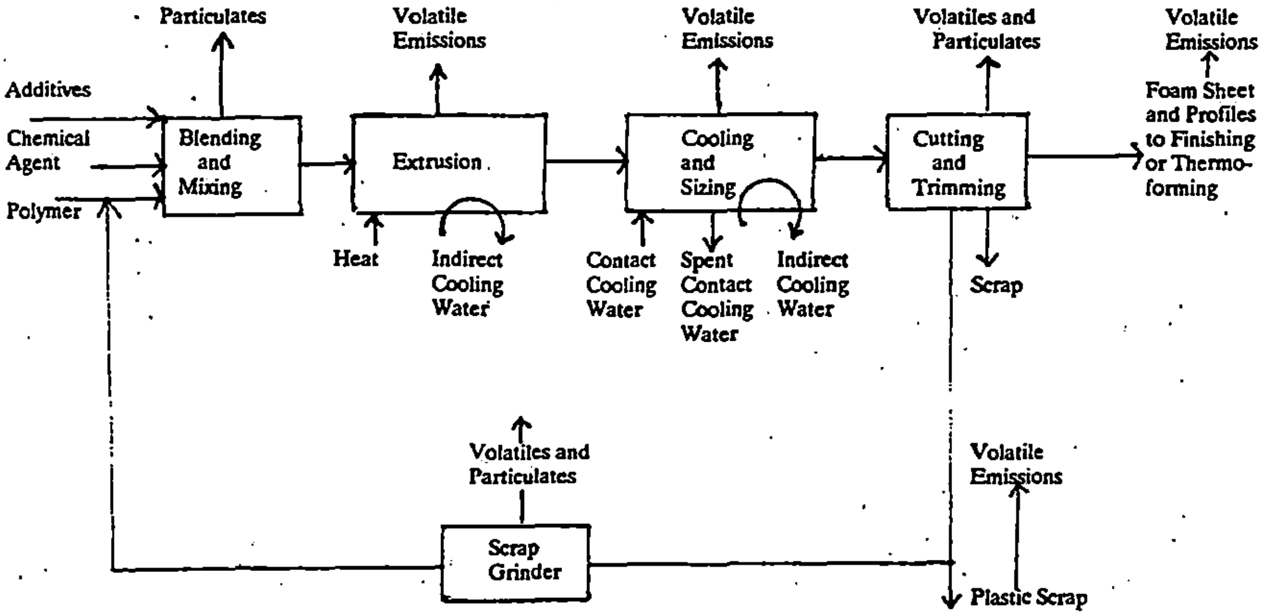


FIGURE 6-18 FOAM EXTRUSION BLOCK DIAGRAM - SOLVENT BLOWN

Blowing agents are unique to foam processing, and can be either chemical (dry) blowing agents which decompose upon heating to form gaseous materials or physical (solvent) blowing agents, such as low boiling hydrocarbons and halogenated hydrocarbons. Tables 6-5A and 6-5B list some typical blowing agents.

6.1.5.1 Chemical Blowing Agents

In applications using chemical blowing agents, the agents are dry blended with the polymer in the feed hopper prior to extrusion. A chemical blowing agent may comprise 0.5 to 3 percent of the blend. The blend is processed in a screw extruder under carefully controlled pressure and temperature conditions. Proper polymer melt viscosity is necessary to produce uniform cells. If the melt viscosity is too low, the foam cells will rupture as the blowing agent expands. As the melt reaches the extrusion temperature, the chemical agent decomposes into large volumes of gas. Typical foam extrusion temperatures for commonly extruded polymers are listed in Table 6-6. Polymers which commercially utilize chemical blowing agents include polyvinyl chloride (PVC), polystyrene, acrylonitrile-butadiene-styrene (ABS), and polypropylene.[1]

A typical formulation for rigid PVC foam, using a chemical blowing agent, is shown in Table 6-7.

6.1.5.2 Physical Blowing Agents

Extrusion operations employing solvent blowing agents use a liquid which will boil to produce a gas at the extrusion temperature. Liquid solvent blown foam extrusion is the most common and economical method of producing low density extruded thermoplastic foams. Commercially produced polyethylene and polystyrene foams use solvent blowing agents.

The solvent foam extrusion process requires softening the formulated polymer in the extruder barrel and injecting the blowing agent into the melt under high pressure to prevent the liquid from boiling. This is carried out in a single or twin-

TABLE 6-5A CHEMICAL - FOAM EXTRUSION BLOWING AGENTS [a]

Chemical Blowing Agents	Decomposition Temperature, °C	Gases Released
Azodicarbonamide	220	N_2, CO_2, CO, NH_3
4,4' - Oxybis (benzene-sulfonylhydrazide)	150 - 190	N_2
p-Toluene sulfonyl semicarbazide	193	N_2, CO_2, CO, NH_3
5-Phenyl tetrazine	230	N_2
N-dinitrosopenta-methylenetetramine	190 - 200	
3,3'- Sulfonbis (benzene-sulfonyl hydrazide)	148	
Azobisisobutyronitrile	105	N_2

a. Reference 1.

TABLE 6-5B PHYSICAL - FOAM EXTRUSION BLOWING AGENTS [a]

Physical Blowing Agents	Boiling Point, °C
Isopentane	27.9
Carbon Dioxide	-78.5
Nitrogen	-195.8
Ammonia	-33.4
Fluorocarbon-11 (monofluorotrichloromethane)	23.6
Fluorocarbon-12 (dichlorodifluoromethane)	-29.8
Methylene Chloride	40
Pentane	36.1

a. Reference 1.

TABLE 6-6 TYPICAL FOAM EXTRUSION MELT TEMPERATURE [a]

Polymer	Melt Temperature °C
Acrylonitrile-Butadiene-Styrene (ABS)	175 - 230
High Density Polyethylene (HDPE)	200 - 230
Polypropylene	200 - 230
Polystyrene	190 - 230
Polyvinyl Chloride (PVC)	190 - 210

---

a. Reference 1.

TABLE 6-7 TYPICAL PVC FORMULA [a]

Material	Parts by Weight
PVC Dispersion Grade Resin	100
Acetone (increases blowing agent efficiency)	70
Dibasic Lead Phosphite (stabilizer)	10
N,N '-Dimethyl-N,N '-Dinitrosoterephthalamide (blowing agent component)	17.5
White Mineral Oil (blowing agent component)	7.5

---

a. Reference 1.

screw extruder designed specifically for plasticizing and mixing. The blowing agent is injected into one or more orifices in the extruder cylinder by a piston or diaphram pump. The polymer/blowing agent mixture is then passed through a second extruder to lower its temperature and increase its viscosity. This extruder is larger, and is designed to maximize cooling and conveying rates while minimizing shear energy and screw speed. It is equipped with cooling jackets and cooling water circulation systems. With the desired temperature established, the uniformly cooled melt is forced through the die. The blowing agent boils just after emergence from the die due to the release and reduction in pressure.

NOTE: Fluorocarbons used as blowing agents in the polymer industry have recently been linked to the depletion of stratospheric ozone (the ozone layer). As a result of these findings, a multi-national agreement to control the use and production of these compounds is in effect. Table 6-8 lists the eight halocarbons controlled under the Montreal Protocol on Substances that Deplete the Ozone Layer, signed in September 1987.

6.1.6 Venting or Vacuum Extraction in Screw Extruders

The purposes of venting are:

- to remove air trapped in the feed section;
- to remove water vapor on or in solid feed material;
- to remove residual volatiles, e.g. monomer, diluent; and
- to remove degradation products produced during heating in the screw.

The most common method of venting uses an opening on the top of the barrel located above the decompression section of the screw (see Figure 6-19). In singlescrew extruders venting is done at the end of the first section (the feed and compression sections) where vapor pressure is developed from heating and melting the polymer. The resulting increase in pressure is reduced to zero at the vent. The second section (the metering and die sections), which is shallower, is used to raise the pressure and force the polymer through the die (see Figure 6-20). Effective removal of volatiles depends upon the nature of the volatiles and polymer melt, the surface area exposed, the melt temperature and the residence time. In general, very high volatiles content is handled better with twin screws.[3] Also, venting in twin-

TABLE 6-8 HALOCARBONS CONTROLLED UNDER THE MONTREAL PROTOCOL

Substance	Ozone-depleting potential [a]	Atmospheric lifetime years	Major Uses
Group 1 - Production Cuts Mandated			
$CFCl_3$ (CFC-11)	1.0	75	Flexible foam, rigid polyurethane foam, refrigeration, air-conditioning
CF_2Cl_2 (CFC-12)	1.0	111	Rigid polyurethane and nonpolyurethane foam, refrigeration, air-conditioning, aerosols, sterilization, food freezing.
$C_2F_3Cl_3$ (CFC-113)	0.8	90	Solvent
$C_2F_4Cl_2$ (CFC-114)	1.0	185	Rigid nonurethane foam, refrigeration, air-conditio[illegible]
C_2F_5Cl (CFC-115)	0.6	380	Refrigeration, air-conditioning
Group 2 - Production Freeze Mandated			
CF_2BrCl (Halon-1211)	3.0	25	Portable fire extinguishers
CF_3Br (Halon-1301)	10.0	110	Total flooding fire-extinguishing systems
$C_2F_4Br_2$	b	na	Fire extinguishers

a. Estimates depending on chlorine and bromine content and atmospheric lifetime. Potentials are set relative to CFC-11, which is assigned a value of 1.0.

b. To be determined

na. not available

Source: Environmental Protection Agency

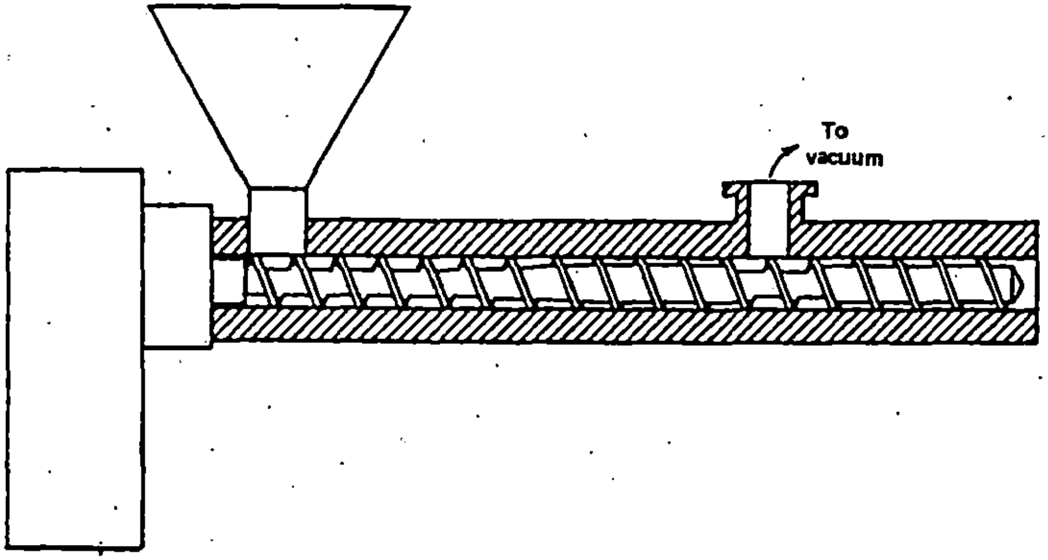
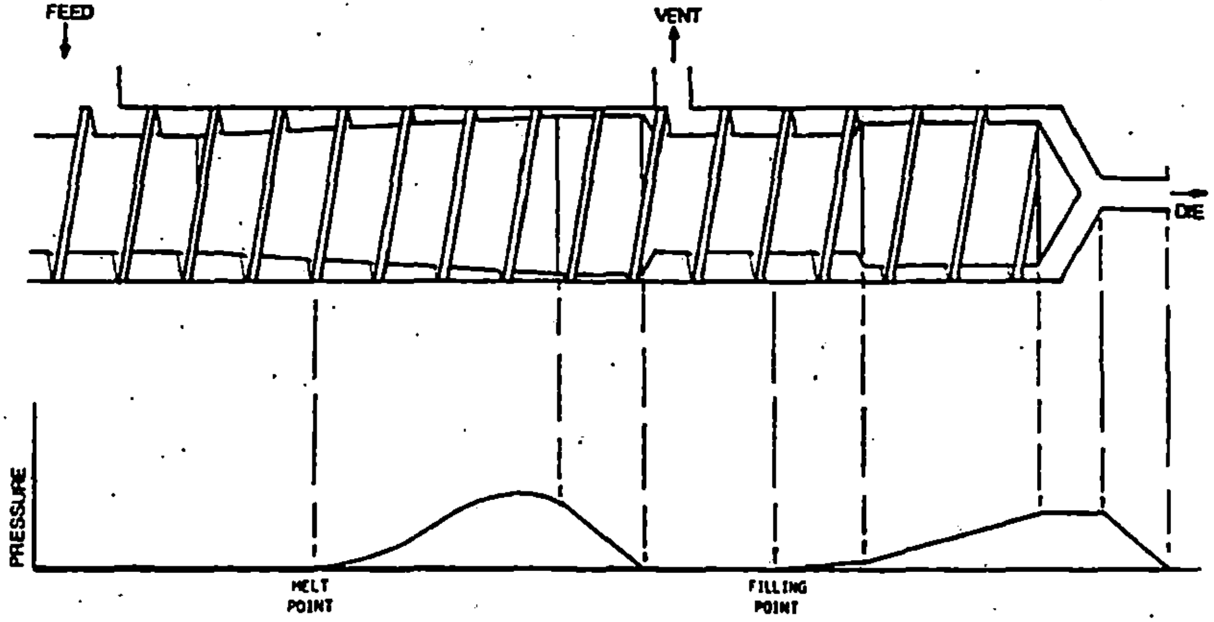


FIGURE 6-19 VENTED EXTRUDER



Two-stage vented screw—pressure profile.

FIGURE 6-20 VENTING - PRESSURE PROFILE

screw extruders is far more important than in single screw extruders because the positive pumping action of twin screws can lead to undesirable air entrapment and porous extrudates.

6.1.7 Emission Control

Emission controls on plastic extruders focus primarily on volatile emissions. Solid particulates generated in mixing and grinding operations are collected by fabric filters. Volatile emissions which are heavy enough to condense under atmospheric conditions are controlled by an electrostatic precipitator (ESP) or a fiber mist filter. Other volatiles can be controlled through the use of a small afterburner.

6.2 Permit Unit Description

The permit wording description for plastic extrusion operations is:

(PROCESSED MATERIAL) EXTRUSION SYSTEM CONSISTING OF:

1. EXTRUDER, MANUFACTURER, MODEL, SERIAL NUMBER, H.P. RATING, LENGTH, DIAMETER, WITH A (WEIGHT AND VOLUME) CAPACITY HOPPER, USING (NUMBER) HEATER(S) WITH A (KW) RATING (EACH), AND (MODE) COOLING.
2. NUMBER, TYPE OF SHAPING AND SIZING SYSTEM(S), MANUFACTURER, MODEL, SERIAL NUMBER, H.P. RATING, DIMENSIONS.
3. BLENDING SYSTEM, MANUFACTURER, MODEL, SERIAL NUMBER
4. FEED CONVEYANCE SYSTEM, TYPE, NUMBER, H.P. RATING.

The permit unit boundary for an extrusion system is defined as:

All extrusion lines fed or charged from the same source permit; or

The extrusion lines discharge to common storage or packaging equipment via common conveying equipment.

Each Air Pollution Control device venting such equipment shall be considered a separate permit unit.

6.3 Emissions

6.3.1 Discussion

The air emissions from plastics processing operations consist of both particulate and volatile emissions. All of the processing operations have the potential to produce particulate emissions during the feeding, loading, and blending of dry polymers and additives, the trimming of parts, and the grinding of thermoplastic scrap for recycle. Point source emissions from the extruder include particulate emissions from the hopper, cutter, shaker, screen, and drier. Additional particulates are produced during pelletizing operations. Pellettizing and finishing operations generally produce particulates which contain the compounded additives. Properly designed and operated mixing and grinding equipment should keep particulate emissions to a minimum. Generally particulate control techniques make use of fabric filters.

All processing operations have the potential to release volatile emissions. Emissions are also released when large surface areas of hot polymer are exposed to air. Most emissions will contain volatilized monomer, plasticizer, other additives, and decomposition products which generally condense at room temperature.

Fluoroplastics, polyesters, polyethylenes, and polyvinyl chloride are the polymers which are most susceptible to decomposition at typical processing temperatures. Decomposition products result when existing operating conditions (usually temperature) cause the polymer to decompose. Decomposition can be limited by formulating the polymer with heat stabilizer additives.[5] Volatile emissions including residual monomer, low boiling additives, and polymer degradation products could be expected from the die and the drier.

6.3.2 Emission Factors

Emission factors for the wide variety of materials and operating conditions in the plastic extrusion process are not readily available, hence, emission evaluations are generally based on factual assumptions. See Section 6.4 Calculations.

6.4 Calculations

Volatile emissions and particulate emissions are calculated from tabulated data and information obtained from the applicant and the manufacturer of the plastic raw materials used.

6.4.1 Operational Data

In order to determine the compliance status of the plastic extruder, the applicant is required to provide the following information:

Max. Days of Operation/Week:____________________(days/week)
Max. Hours of Operation/Day:____________________(hr/day)
Start time:__________ End time:__________
Type of Material Processed:____________________
Manufacturer:____________________
Trade Name:__________ Code No.:__________
Amount of Material Used:____________________(lb/hr)
Content of Free Monomer:____________________(%)
Particle Size:_____(gr) Shape:_____ Density:__________(lb/ft^3)

Type of Additive(s) Used, e.g. Plasticizer, Blowing Agent:
Manufacturer:____________________
Trade Name:__________ Code No.:__________
Amount of Additive Used:_______________(phr)[a]__________%
Particle Size:_____(gr) Shape:_____ Density:__________(lb/ft^3)
Percent in Feed:__________ Percent in Product:__________

Max. Rated Capacity of Extruder:____________________(lb/hr)
Manufacturer of Extruder:____________________
Barrel Diameter of Extruder:____________________(in)
Length of Heated Portion of Extruder:____________________(ft)
Number of Heat Zones:__________ Rating:____________________(kW)
Mode of Quenching: Water / Air / None / Other:____________________
Mode of Venting: Atmosphere / Vacuum - ____________________ (in H_2O)
Method of Feed Conveyance:____________________
Type of Product Manufactured:____________________
Particle Size:__________(gr) Shape:__________ Density:____________________(lb/ft^3)

a. phr = parts per hundred resin.

6.4.2 Plasticizer Emission Calculations

The estimation of volatile emissions of a plasticizer in plastic extrusion is based on the assumption that the plasticizer loss is proportional to:

- Surface area of hot plastic between the die face and the cooling tank;
- Volatility of the plasticizer; and
- Concentration of the plasticizer in the resin (in weight percent).

The plasticizer emission from an extruder using a plasticizer resin is determined as follows:

Obtain the total area of the hot plastic between the die and the cooling trough;

Obtain the type of plasticizer in the resin used for extrusion and ascertain its volatility (mg/sq. cm./hr.); and

Multiply the surface area of the hot plastic by the volatility factor and the plasticizer concentration (weight fractions).

$H_e = S_a \times V_f \times W$ **(Equation 6.1)**

$R_1 = H_e \times 0.0000022$ lb/mg **(Equation 6.2)**

where:

R_1 = Uncontrolled emission rate ----------------------------(lb/hr)
H_e = Uncontrolled hydrocarbon emission -------------------(mg/hr)
S_a = Surface area --(sq.cm.)
V_f = Volatility factor---(mg/sq.cm./hr)
W = Weight fraction--(fraction)

The volatility factors for some plasticizers are listed in Appendix 6C - Properties of Plasticizers.

6.4.3 Blowing Agents Emission Calculations

The evaluation of volatile emissions from plastic extrusion operation using a blowing agent is based on the following information obtained from the applicant:

BA_{in} = Percent blowing agent in the feed,
BA_{out} = Percent blowing agent in the product,
P_{max} = Maximum daily production, in pounds/day

Composition of the blowing agent (from manufacturer) including:
percent ROG -- %ROG and
percent non-ROG -- % non-ROG

Therefore, the rate of uncontrolled ROG emission (lb/day) is:

$R_1 = P_{max} \times (BA_{in} - BA_{out}) \times (\%ROG)$; **(Equation 6.4)**

and the rate of uncontrolled non-ROG produced is:

$R_{1,NR} = P_{max} \times (BA_{in} - BA_{out}) \times (\%non\text{-}ROG)$ **(Equation 6.5)**

6.4.4 Particulates Emission Calculations

Particulate emissions from a plastic extrusion operation can be estimated using an emission factor or the following information:

$$R_{1,PM} = P_w \times M_f \times A_f \qquad \text{(Equation 6.6)}$$

where:

$R_{1,PM}$ = Uncontrolled particulate matter emission rate, (lb/hr)
P_w = The process weight of the material (lb/hr)
M_f = The percent of the material subject to emission (fraction)
A_f = The percent of material airborn (fraction)

Particulate matter evolved by the extrusion process are reduced prior to discharge into the atmosphere by an air pollution control (APC) system. The most common (APC) system for a plastic extruder is an electrostatic precipitator or fiber mist filter. Current BACT guidelines should be consulted to obtain the most recent control methods for this equipment.

The reduction in particulate matter is calculated by Equation 6.7:

$$R_{2,PM} = R_{1,PM} \times (1 - ECF) \qquad \text{(Equation 6.7)}$$
$$NSR = R_2max \times 1.1 \qquad \text{(Equation 6.8)}$$

where:

$R_{2,PM}$ = Controlled particulate matter emission rate, (lb/hr).
ECF = Control efficiency of the air pollution control system, (fraction).
NSR = New Source Review. The threshold limit is evaluated by multiplying R_2max by the Regulation XIII on-site offset factor of 1.1.
R_2max = The maximum rating for controlled emissions (at maximum equipment rating and maximum operating schedule).

Emissions must be calculated for both the actual and maximum operating conditions. Actual emissions are used in emission inventory. Maximum emissions are used to determine compliance with the District's Rules and Regulations.

Actual and maximum hourly (lb/hr) emission rates must be converted to daily (lb/day) emission rates by multiplying the hourly rates by the appropriate equipment daily operational time factor (T, hr/day).

In addition, the maximum daily emissions are multiplied by the regulation XIII On-Site Offset Factor (1.1). These daily emissions increase are accumulated for each facility in the District's New Source Review Record.

6.4.5 Total Particulate Matter Emission - Concentration

The total particulate matter mass emission rate (lb/hr) must be converted into total particulate matter concentration (grains/dscf). The particulate matter concentration is calculated by:

$$C = \frac{R_2 \times 7000\ (\text{grains/lb})}{F \times 60\ (\text{min/hr})} \qquad \textbf{(Equation 6.9)}$$

where:

C = Particulate matter concentration, (grains/dscf)
R_2 = Total (controlled) particulate matter emission rate, (lb/hr)
F = Exhaust air flow rate in dry standard cubic feet per minute, (dscfm)

6.5 Rules Evaluation

Rule 212 - Standards For Approving Permits

Section (e) of this Rule requires public notification of certain cases be made prior to issuing a permit.

Rule 401 - Visible Emissions

No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 404 - Particulate Matter - Concentration
Limits for particulate matter concentrations in an effluent gas stream at standard conditions are listed in Table 404(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 405 - Particulate Matter - Weight
Limits for particulate matter emission rates from any source are listed in Table 405(a) of the South Coast Air Quality Management District's Rules and Regulations.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT for particulate matter emissions from plastic extruding operations is a an electric precipitator or fiber mist filter

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[20] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

6.6 Permit (Operating) Conditions

In order to ensure compliance with the Rules and Regulations of the South Coast Air Quality Management District, any or all of the following permit conditions may be imposed on the equipment.

1. PLASTICIZERS MUST NOT BE USED IN THIS EQUIPMENT.

2. EMISSIONS VENTED FROM THE BARREL OF THE EQUIPMENT MUST BE PASSED THROUGH A WATER SPARGING UNIT.

3. THE WEIGHT OF THE PLASTICS PROCESSED IN THIS EQUIPMENT MUST NOT EXCEED (NUMBER OF) POUNDS IN ANY ONE DAY.

4. THE WEIGHT OF THE PLASTICIZER PROCESSED IN THIS EQUIPMENT MUST NOT EXCEED (NUMBER OF) POUNDS IN ANY ONE DAY.

5. THE MAXIMUM TEMPERATURE THAT THIS EQUIPMENT MAY OPERATE AT IS ____ °F.

6. A CALIBRATED, FULL-RANGE TEMPERATURE GAUGE MUST BE INSTALLED.

7. RECORDS INCLUDING THE AMOUNT OF ALL MATERIAL(S) PROCESSED BY THIS EQUIPMENT, IN POUNDS PER DAY, MUST BE MAINTAINED TO PROVE COMPLIANCE WITH CONDITIONS TWO (2), THREE (3), FOUR (4), AND FIVE (5). THE RECORDS MUST BE KEPT IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT OF THE DISTRICT. THE RECORDS MUST BE MAINTAINED FOR AT LEAST TWO YEARS, AND MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

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APPENDIX 6A

PERMIT PROCESSING WORKSHEET FOR PLASTIC EXTRUSION

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES	PAGE
6	1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME :

MAILING ADDRESS :

EQUIPMENT LOCATION :

EQUIPMENT DESCRIPTION

APPLICATION NO. :

PLASTIC SHEET EXTRUSION SYSTEM CONSISTING OF:

1. EXTRUDER, TYPE, MANUFACTURER - ,
   SERIAL NO. , H.P., INCH BARREL DIAMETER,
   INCH BARREL LENGTH, WITH A HOPPER OF LB CAPACITY, USING
   ELECTRIC/STEAM HEATERS OF KW/BTU/HR RATING EACH, AND
   WATER/AIR COOLING.

2. FINISHING ROLLERS, MANUFACTURER - ,
   SERIAL NO. , H.P., WATER/AIR COOLED.

3. CONVEYOR SYSTEM, TYPE, MANUFACTURER - ,
   SERIAL NO. , H.P.

4. PULL ROLLS, H.P.

5. TRIMMING AND CUTTING UNIT, TYPE, H.P.

6. SCRAP GRINDER, MANUFACTURER ,
   SERIAL NO. , H.P.

7. BLENDER, TYPE, MANUFACTURER - ,
   SERIAL NO. , H.P.

8. FEED CONVEYOR, TYPE, H.P.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 6	PAGE 2
APPL. NO.	DATE
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HISTORY

PROCESS DESCRIPTION

Pellets, regrinds, and/or scraps of ____________ polymer are vacuum/(other) loaded to a hopper. In addition plasticizers / blowing agents / stabilizers / antioxidants / ultraviolet absorbers / organic peroxides / colorants / flame retardants / fillers are added. The polymer is heated to _____ °F/°C in the extruder via electric / steam heaters and extruded to water-cooled rollers. The polymer is drawn over a conveyor by pull rolls to the trimming and cutting unit, then sent to the shipment / thermoformer / finishing operation. The scrap is passed through a scrap grinder and returned to the extruder for reprocessing. The shape/form of the final product is a(n) ___________ The extrusion system will operate ___ hours/day, ____ days per week, ____ weeks/year.

CALCULATIONS

Polymer used: ______________________________

Operating Schedule (Average and Maximum)
Source : Applicant

Average		Maximum	
(O_w) ______________	days/week	______________	days/week
(O_d) ______________	hours/day	______________	hours/day

Assumptions:

Emissions from plasticizers are determined using volatility factors obtained from the plasticizer manufacturer and values in APPENDIX 6B. Particulate emissions are determined from emission factors or from airborn fraction values of the process material.

Plasticizer Emissions

Plasticizer type:__________________________________ Amount: phr

phr = parts per hundred resin.

$$R_1 = H_e \times 0.0000022 \text{ lb/mg} \quad (\times\ O_d \text{ and } O_w)$$

$$He = S_a \times V_f \times W$$

$$R_2 = R_1 \times (1 - ECF)$$

$$NSR = R_2\text{max} \times 1.1$$

where:

R_1 = Uncontrolled emission rate (avg., max.) (lb/hr)
H_e = Uncontrolled hydrocarbon emission rate (avg.,max.) (mg/hr)
R_2 = Controlled emission rate (avg., max.) (lb/hr)
S_a = Surface area of the extruded plastic between extruder die and cooling tank (sq.cm.)
V_f = Volatility factor (mg/sq.cm./hr)
W = Weight fraction (concentration) of plasticizer (%)
ECF = Emission control factor, (percent removal efficiency) (%)
NSR = New Source Review. NSR emissions are maximum controlled emissions (R_2 max) multiplied by the Reg XIII On-Site Offset Factor of 1.1.

Particulate Matter (Polymer)

R_1 = $P_w \times M_f \times A_f$ ($\times O_d$ and O_w)

R_2 = $R_1 \times (1 - ECF)$

NSR = $R_2max \times 1.1$

where:

R_1	=	Uncontrolled emission rate, (avg., max.)	(lb/hr)
R_2	=	Controlled emission rate, (avg., max.)	(lb/hr)
P_w	=	Process weight per hour, (avg., max.)	(lb/hr)
M_f	=	Material subject to emission	(%)
A_f	=	Airborn fraction of M_f	(%)
NSR	=	New Source Review. NSR emissions are maximum controlled emissions (R_2 max) multiplied by the Reg XIII On-Site Offset Factor of 1.1.	

EMISSIONS:

	Uncontrolled, R_1			Controlled, R_2			
	Actual lb/hr	Maximum lb/hr	Maximum lb/day	Actual lb/hr	Maximum lb/hr	Maximum lb/day	NSR lb/day
ROG							
NO_x							
SO_x							
CO							
PM							

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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APPL. NO.	DATE
PROCESSED BY	CHECKED BY

EVALUATION

RULE 401 : Based on experience with similar equipment, this facility is (is not) expected to comply with the visible emission limits.

RULE 402 : Based on experience with similar equipment, nuisance complaints are (are not) expected.

RULE 404 : Solid particulate matter concentration emission is (is not) expected to comply with the amount permitted in Table 404(a) for the stated process weight per hour.

RULE 405 : Solid particulate matter weight emission is (is not) expected to comply with the amount permitted in Table 405(a) for the stated process weight per hour.

REG XIII : The net increase in emissions resulting from the operation of this equipment does (does not) exceed the limitations specified in Regulation XIII as shown by the Emission Threshold/New Source Sheet table below:

	NSR Emissions in Pounds per Day					
	RHC	NO_x	SO_2	CO	PM	UnRHC
Cumulative Facility Emissions Since 10/08/76						
A/N__________						
A/N__________						
Facility Net Emission Increase Since 10/08/76						

Facility Net Emission (does not) exceed(s) threshold, applicant (does not) provide(s) offsets.

BACT *: The Best Available Control Technology (BACT) for a plastic extrusion operation is ________________________.

The applicant will (will not) provide a ______________________ as BACT.

* The South Coast Air Quality Management District's BACT Guideline should be consulted to ensure that the current BACT requirements are applied to this equipment.

CONCLUSIONS/RECOMMENDATIONS

This plastic extruding facility is (is not) expected to comply with all applicable Rules and Regulations of the South Coast Air Quality Management District. Therefore, the following disposition is recommended:

( ) Issue a Permit to Construct/Operate subject to the following conditions:

CONDITIONS

1. PLASTICIZERS MUST NOT BE USED IN THIS EQUIPMENT.
2. EMISSIONS VENTED FROM THE BARREL OF THE EQUIPMENT MUST BE PASSED THROUGH A WATER SPARGING UNIT
3. THE WEIGHT OF THE PLASTICS PROCESSED IN THIS EQUIPMENT MUST NOT EXCEED ____ POUNDS IN ANY ONE DAY.
4. THE WEIGHT OF THE PLASTICIZER PROCESSED IN THIS EQUIPMENT MUST NOT EXCEED ___ POUNDS IN ANY ONE DAY.
5. THE MAXIMUM TEMPERATURE THAT THIS EQUIPMENT MAY OPERATE AT IS ____ °F.
6. A CALIBRATED, FULL-RANGE TEMPERATURE GAUGE MUST BE INSTALLED.
7. RECORDS INCLUDING THE AMOUNT OF ALL MATERIAL(S) PROCESSED BY THIS EQUIPMENT, IN POUNDS PER DAY, MUST BE MAINTAINED TO PROVE COMPLIANCE WITH CONDITIONS TWO (2), THREE (3), FOUR (4) AND FIVE (5). THE RECORDS MUST BE KEPT IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT OF THE DISTRICT. THE RECORDS MUST BE MAINTAINED FOR AT LEAST TWO (2) YEARS, AND MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

<u>OR</u>

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 6B

COMPOUNDING AGENTS

COMPOUNDING OPERATIONS AND AGENTS

Compounding Operation	Compounding Agent
Anti blocking agents (for polyvinyl chloride)	- silicates - waxes
Antioxidants (for polyolefins, polystyrene, ABS)	- amines - alkylated phenols - phosphates - thio compounds
Blowing agents	- azodicarbonamide - azobisisobutyronitrile - methylene chloride
Blow agent by-products	- N_2 - CO - CO_2 - tetramethylsuccicononitrile
Colorants	- carbon black - titanium dioxide - Cd sulfoselenide - phtalocyanines - anthroquinone red - monoazo yellow
Crosslinking agents (for polystyrene)	- divinyl benzene
(for polyethylene)	- organic peroxides
Curing agents (for polyesters, amino resins, phenolics)	- azo compounds - peroxides - amines
(for polyurethanes)	- organo tin compounds - amines

COMPOUNDING OPERATIONS AND AGENTS

Compounding Operation	Compounding Agent
Fillers	- calcium carbonate
	- kaolin
	- diatomaceous earth
	- marble dust
	- iron fillings
	- plaster
	- vermiculite
	- wood dust
	- talc (no asbestos)
Flame retardants	- antimony oxide
	- alumina trihydrate
	- trixylenyl phosphate
	- decabroodiphenyl oxide
	- chlorinated paraffin wax
Heat stabilizers (for polyvinyl chloride and polvinylidene chloride)	- tribasic lead sulfate
	- barium/cadimium stearate
	- calcium/zinc stearate
Lubricants	- hydrocarbon oils
	- paraffin waxes
	- mica
	- talc
Plasticizers	- di-n-octyl phthalate
	- diisoctyl phtalate
	- diisodecyl phtalate
	- tricresyl phosphate
	- di-(2-ethylhexyl) phthalate
Reinforcing agents	- asbestos
	- silica
	- glass fibers
Slip promoters (for polvinyl chloride)	- silicates
	- waxes
UV stabilizers	- benzotriazides
	- benzophenones

APPENDIX 6C

PROPERTIES OF PLASTICIZERS

Properties of Commercially Available Plasticizers Arranged in Order of Ascending Number of Carbon Atoms.

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
Acetin	$C_5H_{10}O_4$	134	1.190 (at 25°C)		
o-and p-Toluene-sulfonamides(mixture)	$C_7H_9O_2NS$	171	1.353		
Diacetin	$C_7H_{12}O_5$	176	1.178		
N-Ethyl-p-toluene-sulfonamide	$C_9H_{13}O_2NS$	199	1.171 (at 65°C)		
N-Ethyl-o- and p-toluene-sulfonamides (mixture)	$C_9H_{13}O_2NS$	199	1.190 (at 25°C)	0.55	101
Triacetin	$C_9H_{14}O_6$	218	1.157 (avg.)		
Dimethyl phtalate	$C_{10}H_{10}O_4$	194	1.191	>4.0	>1000
0-Nitrobiphenyl	$C_{12}H_9O_2N$	199	1.203 (at 25°C)		
Diethyl phtalate	$C_{12}H_{14}O_4$	222	1.118	3.40	>500
Triethyl citrate	$C_{12}H_{20}O_7$	276	1.136 (at 25°C)		
Dimethyl sebacate	$C_{12}H_{22}O_4$	230	0.986 (at 30°C)		
Di-n-butyl tartrate	$C_{12}H_{22}O_6$	262	1.094	1.50	143
Tri-n-butyl phosphate	$C_{12}H_{27}O_4P$	266	0.978	>4	502

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
Monomethyl phtalate ethyl glycoate ester	$C_{13}H_{14}O_6$	266	1.227	0.65	61
N-Cyclohexyl-p-toluenesulfonamide	$C_{13}H_{19}O_2NS$	253	1.125	0.05	26
Monoethyl phtalate ethyl glycolate ester	$C_{14}H_{16}O_6$	280	1.186	0.50	93
Di(methyl)phtalate	$C_{14}H_{18}O_6$	282	1.169	0.16	61
Triethyl acetylcitrate	$C_{14}H_{22}O_8$	318	1.13		>525
Diisobutyl adipate	$C_{14}H_{26}O_4$	258	0.957		
Tributyrin	$C_{15}H_{26}O_6$	302	1.036		
Methyl laurate	$C_{15}H_{30}O_3$	258	0.894 (at 25°C)		
Di-n-butyl phtalate	$C_{16}H_{22}O_4$	278	1.048	0.98	148
Di phthalate	$C_{16}H_{22}O_6$	310	1.120	0.15	30
n-Butyl laurate	$C_{16}H_{32}O_2$	256	0.857 (at 25°C)		
Methyl myristate	$C_{17}H_{34}O_3$	286	0.895 (at 25°C)		
Di(butyl Carbitol)formal	$C_{17}H_{36}O_6$	336	0.97		
Triphenyl phosphate	$C_{18}H_{15}O_4P$	326	1.268 (at 60°C)	0.02	22
Bis(dimethylbenzyl)ether	$C_{18}H_{22}O$	286	1.008		
n-Butyl cyclohexyl phthalate	$C_{18}H_{24}O_4$	304	1.078		75

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
Mono-n-butyl phthlate n-butyl glycoate ester	$C_{18}H_{24}O_6$	336	1.103	0.08	31
Tri-n-butyl citrate	$C_{18}H_{34}O_7$	360	1.045	0.16	44
Triethylene glycol di(2-ethylbutyrate)	$C_{18}H_{34}O_6$	346	0.995	0.86	
Butyl laurate	$C_{18}H_{36}O_3$	300	0.882 (at 25°C)		
Di-n-hexyl adipate	$C_{18}H_{34}O_4$	314	0.933 (at 25°C)		
Di(1,3-dimethylbutyl) adipate	$C_{18}H_{34}O_4$	314	0.926		
Di-n-butyl sebacate	$C_{18}H_{34}O_4$	314	0.926		
Di(butyl)adipate	$C_{18}H_{34}O_6$	346	0.997		58
n-Butyl myristate	$C_{18}H_{36}O_2$	284	0.861 (at 25°C)		
Triphosphate	$C_{18}H_{39}O_7P$	398	1.022		
Cresyl diphenyl phosphate	$C_{19}H_{17}O_4P$	340	1.208 (at 25°C)		
n-Butyl benzyl phthalate	$C_{19}H_{20}O_4$	312	1.116 (at 25°C)		29
Bis(dimethylbenzyl) carbonate	$C_{19}H_{22}O_3$	298	1.083		32
Methyl penta-chlorostearate	$C_{19}H_{33}O_2Cl_5$	471	1.204		7
Methyl ricinoleate	$C_{19}H_{36}O_3$	312	0.925 (at 25°C)		

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
Methyl palmitate	$C_{19}H_{36}O_3$	314	0.891 (at 25°C)		
Methyl hydroxystearate	$C_{19}H_{38}O_3$	314			
Diphenyl phthalate	$C_{20}H_{14}O_4$	318	1.28	0.006	10
Dicyclohexyl phthalate	$C_{20}H_{26}O_4$	330	1.23		
2-Ethylhexyl diphenyl phosphate	$C_{20}H_{27}O_4P$	362	1.092		44
Di-n-hexylphthalate	$C_{20}H_{30}O_4$	334	1.007		43
Di(2-ethylbutyl) phthalate	$C_{20}H_{30}O_4$	334	1.016	0.20	65
Di(1,3-dimethylbutyl) phthalate	$C_{20}H_{30}O_4$	334	0.995		>150
Di(butyl)phthalate	$C_{20}H_{30}O_6$	366	1.063	0.06	24
Diphthalate	$C_{20}H_{30}O_8$	398	1.150	0.08	18
Tri-n-butyl acetylcitrate	$C_{20}H_{34}O_8$	402	1.046 (at 25°C)		61
n-Butyl palmitate	$C_{20}H_{40}O_2$	313	0.865 (at 25°C)		
Tricresyl phosphate	$C_{21}H_{21}O_4P$	368	1.165	0.01	7
n-Butyl benzyl sebacate	$C_{21}H_{32}O_4$	348	1.004		
Methyl acetylricinoleate	$C_{21}H_{38}O_4$	355	0.936		
Methyl oleate	$C_{21}H_{40}O_3$	341	0.902	0.12	29
Di(2-ethylbutyl)azelate	$C_{21}H_{40}O_4$	357	0.930		43

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
Propylene glycol monoricinoleate	$C_{21}H_{40}O_4$	357	0.950 (at 25°C)		
Methyl stearate	$C_{21}H_{42}O_3$	343	0.877 (at 25°C)		30
n-Butyl ricinoleate	$C_{22}H_{42}O_3$	355			
Di(1,3-dimethylbutyl) sebacate	$C_{22}H_{42}O_4$	371	0.911		
Di(2-ethylhexyl) adipate	$C_{22}H_{42}O_4$	0.927		41	
Diisooctyl adipate	$C_{22}H_{42}O_4$	371	0.928		38
Dicapryl adipate	$C_{22}H_{42}O_4$	371	0.915		
Diethylene glycol dipelargonate	$C_{22}H_{42}O_5$	387	0.963		
Di(butyl)sebacate	$C_{22}H_{42}O_6$	403	0.970	0.04	
Triethylene glycol di(2-ethyl hexanoate)	$C_{22}H_{42}O_6$	403	0.968	0.18	50
Triethylene glycol dicaprylate	$C_{22}H_{42}O_6$	406 (avg)	0.973		
Dibutyl adipate	$C_{22}H_{42}O_8$	435	1.02 (at 16°C)		
n-Butyl stearate	$C_{22}H_{44}O_2$	341	0.858		59
n-Butyl oleate	$C_{22}H_{42}O_2$	339	0.864 (at 25°C)		
Tetrahydrofufuryl oleate	$C_{23}H_{42}O_3$	366	0.925		

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
Methyl acetylricinoleate	$C_{23}H_{42}O_5$	399	0.955		12
o-Xenyl diphenyl phosphate	$C_{24}H_{19}O_4P$	402	1.233	0.005	20
Dibenzyl sebacate	$C_{24}H_{30}O_4$	382	1.055 (at 30°C)		
Di(2-ethylhexyl)phthalate	$C_{24}H_{38}O_4$	390	0.986	0.02	24
Diisooctyl phthalate	$C_{24}H_{38}O_4$	390	0.987		19
Dicapryl phthalate	$C_{24}H_{38}O_4$	390	0.966		22
Di(2-ethylhexyl)tetrahydro phthalate	$C_{24}H_{42}O_4$	395	0.969 (at 20°C)	1.466	30
Tetra-n-butyl thiodisuccinate	$C_{24}H_{42}O_8S$	491	1.054		6
Di(2-ethylhexyl) hexahydrophthalate	$C_{24}H_{44}O_4$	397	0.956		37
n-Butyl acetylricinoleate	$C_{24}H_{44}O_4$	397	0.929		30
Butyl oleate	$C_{24}H_{46}O_3$	383	0.885 (at 25°C)		
Dinonyl adipate	$C_{24}H_{46}O_4$	398	0.914 (at 25°C)		
n-Octyl n-decyl adipate (mixture)	$C_{24}H_{46}O_4$	398	0.920		
Polyethylene glycol di(2-ethylhexanoate)	$C_{24}H_{46}O_7$	447	0.989		44
Butyl stearate	$C_{24}H_{48}O_3$	385	0.882		26

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
Tri(2-ethylhexyl) phosphate	$C_{24}H_{51}O_4P$	435	0.926		39
Di(2-ethylhexyl) azelate	$C_{25}H_{48}O_4$	413	0.918		20
n-Octyl n-decyl phthalate (mixture)	$C_{26}H_{42}O_4$	418	0.975		8
Isooctyl n-octyl n-decyl phthalate (mixture)	$C_{26}H_{42}O_4$	418	0.978		
Di(2-ethylhexyl) sebacate	$C_{26}H_{50}O_4$	427	0.912		12
Diisooctyl sebacate	$C_{26}H_{50}O_4$	427	0.917		
Dicapryl sebacate	$C_{26}H_{50}O_4$	427	0.907		
2-Ethylhexanoic acid diester of N,N-bis (2-hydroxyethyl)-2-ethylhexanamide	$C_{28}H_{53}O_5N$	484	0.956		12
Tri(p-tert-butylphenyl) phosphate	$C_{30}H_{39}O_4P$	495			0.9
Glyceryl triricinoleate	$C_{57}H_{104}O_9$	933	0.959 (at 25°C)		
Glyceryl tri(acetyl-ricinoleate)	$C_{63}H_{110}O_{12}$	1060	0.964		0.7
Aroclor 1242, chlorinated biphenyl			1.378-1.388 (at 25°C)	2.50	146
Flexol plasticizer R-2H, polyester			1.055		0.5
G.E. 2557, polyester			1.028		3

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
G.E. 2559, polyester			1.060		1
Paracril C, nitrile rubber		0.984		0.2	
Paraplex G-25, polyester		ca 8000	1.06		
Paraplex G-40, polyester		ca 6000	1.15		0.6
Paraplex G-50, polyester		ca 2200	1.084		1
Plastolein 9720, polyester		ca 850	1.043		2
Dow 276-V2, polymolecular product derived from alpha-methylstyrene			1.021		
HB 40, partially hydrogenated mixture of isomeric terphenyls		1.007		115	
Kenflex L, hydrocarbon resin made by reaction of formaldehyde + dimethylnaphthalenes			1.01 (at 15.6°C)		
Nevillac 10° (PHO), a hydrindyl phenol derivative		240	1.075-1.10 (at 15.6°C)		
Nevinol			1.03-1.08 (at 15.6°C)		
Panaflex BN-1, alkynated aromatic hydrocarbon mixture			0.955		
Sovaloid C, alkylated aromatic hydrocarbon mixture			1.038		
Arneel TOD, mixture of oleic, linoleic, and cyclic nitriles		ca 278	0.910		

Name	Formula	Mol. Wt.	Specific Gravity at 20 °C	Volatility of Free Plasticizer in Air (mg./sq.cm./hr.)	
				212 °F (100 °C)	375 °F (191 °C)
n-Butyl acetyl polyricinoleate, PG16		362	0.913 (at 25°C)		
Chlorinated paraffin 40			1.164		
Flexol plasticizer B-400, polpropylene glycol mono-n-butyl ether			0.995		ca.60
Glyceryl polyricinoleate No. 15 oil			1.031 (at 25°C)		
Mineral Oil (Flashpoint 463°F)				0.03	5 25 (at 425°F)

SECTION 7

Storage Silos - Receiving and Storage Systems

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Appendix 7A Worksheet For Receiving and Storage Systems Using Pneumatic Conveying 7A-1

Appendix 7B Worksheet For Receiving and Storage Systems Using Mechanical Conveying 7B-1

Section 7

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SECTION 7: STORAGE SILOS - RECEIVING AND STORAGE SYSTEMS

7.1 General Description

Storage vessels are used by many industries to receive and store ingredients and the final product for future use. The materials stored can be gases, liquids, or bulk solids. A bulk solid is defined as solid material which may be processed in a form varying from fine powder to large chunks in which individual pieces are not individually positioned for processing. Storage vessels designed to store gases and liquids are called storage tanks. Storage vessels designed to store bulk solid material are called storage silos and surge bins. A storage silo or bin is defined as any receptacle or container which serves to receive and accumulate bulk solid material. Examples of solid material stored in silos and surge bins include grain, corn, gypsum, soap (flakes), fertilizer, cement, flyash, and sand.

If the capacity of the bulk solid material storage vessel is such that it can hold more than one days use (requirement) or production, the vessel is called a storage silo. If the bulk solid material storage vessel can hold less than one days use or production, the vessel is called a surge bin. A storage silo can be its own permit unit or it can be part of a Receiving and Storage System permit unit. Surge bins are included as part of the basic equipment permit unit which they are associated with.

Typically, storage silos are constructed of steel, cylindrical in shape with a conical bottom section and are 8-10 feet in diameter and 40-50 feet in height. However, larger concrete silos have been used to store flour, grains, and cement.

A pneumatic bulk material Receiving and Storage System is shown in Figure 7-1. Figure 7-2 shows a cement Receiving and Storage System using a screw conveyor and a bucket elevator to transfer the cement from the truck to the storage silo.

Storage silos storing the same or similar materials at a facility are generally grouped together with a conveying mechanism known collectively as a "Receiving and Storage System." Typically, the conveying mechanism is a pneumatic-type system consisting of a blower or compressor and a filling tube.

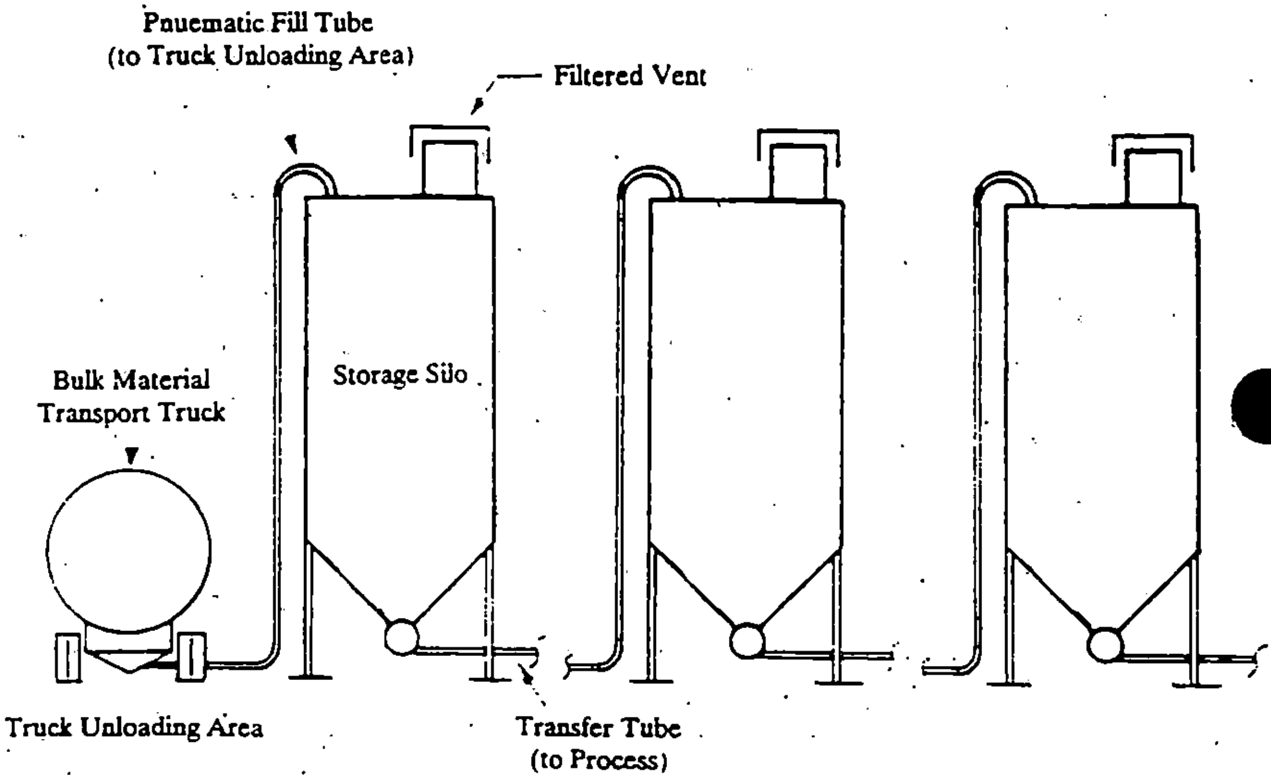

FIGURE 7-1 RECEIVING AND STORAGE SYSTEM

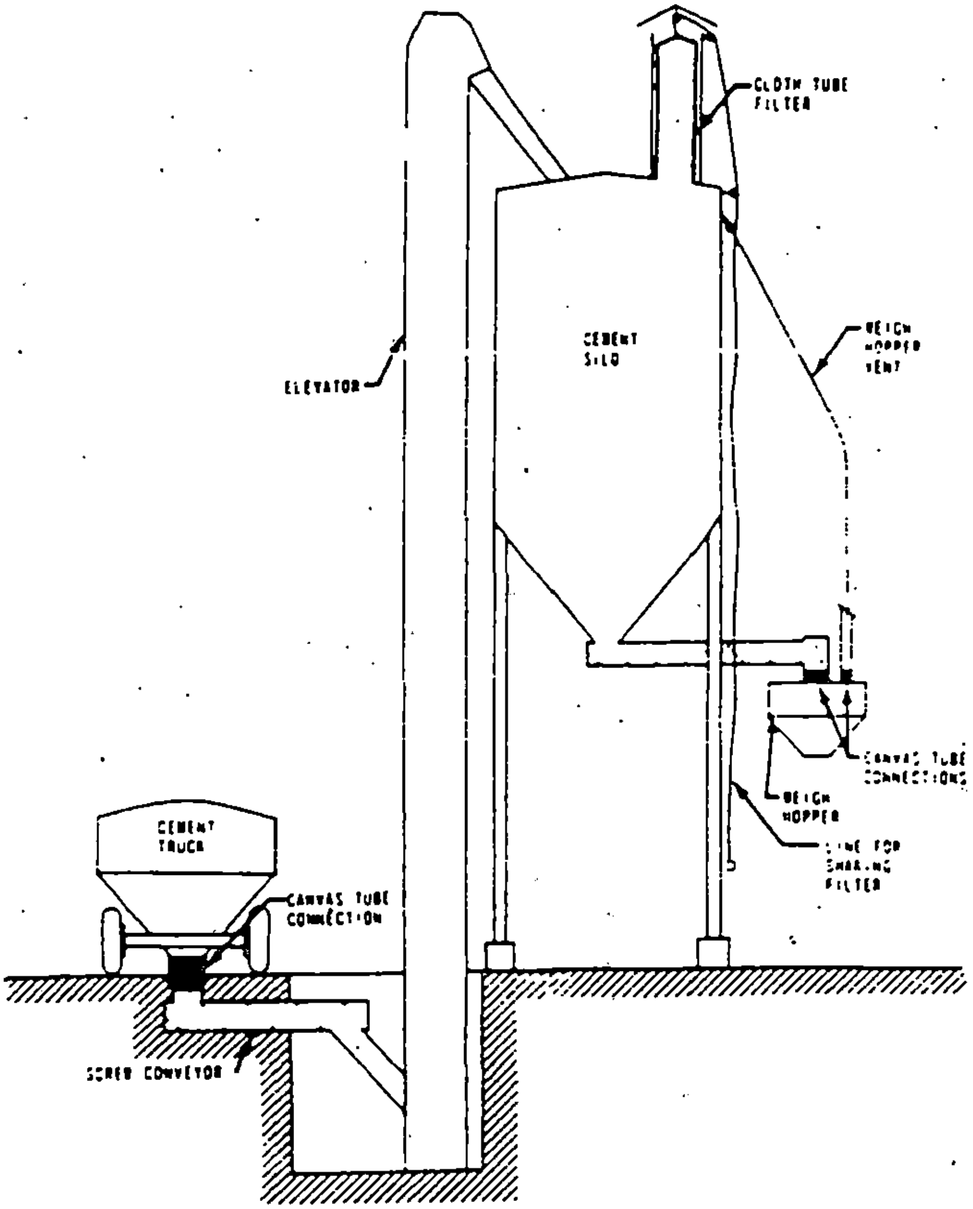

FIGURE 7-2 CEMENT RECEIVING AND STORAGE SYSTEM

A storage silo can be vented to a baghouse or to a filtered vent attached to the silo. Both baghouses and filtered vents are equivalent and effective methods to remove particulate matter from a Receiving and Storage System's exhaust air stream. A baghouse usually controls several or all of the silosincluded in the receiving and storage system. A clear distinction between a baghouse and a filtered vent is the driving force conveying the particulate matter entrained air from the silo to the control device. The baghouse requires an exhaust blower (or fan). The filtered vent uses the air flow created by the blower or compressor from the bulk transport truck or the unloading station.

Since the majority of silo applications for permit to construct and operate received are part of a receiving and storage system, this section of the Handbook will address the Receiving and Storage System.

7.2 Permit Unit Description

The majority of the Receiving and Storage Systems operated in the South Coast Air Basin use a blower fan or compressor to pneumatically convey the bulk solid material. The blower or compressor is typically located in close proximity to the Receiving and Storage System. This blower or compressor can be powered by an electric motor or internal combustion (IC) engine permanently located at the site, powered by an electric motor or IC engine on the trailer of the bulk transport truck, or powered by the IC engine of the bulk transport truck delivering material to the site. Most Receiving and Storage Systems use a compressor that is mounted on the truck to convey the bulk solid material. Typically, blowers are permanently located at the receiving area.

The power generated by the truck's engine directed to the compressor is accomplished by a system known as "power take off" or PTO. When the PTO is engaged, a percentage of the mechanical energy generated by the truck's engine is directed to the compressor. The amount of power directed from the engine to the compressor varies with the size of the engine and the size of the compressor. Although some of the truck's engine horsepower is used as a primary mover of the bulk solid material from the truck to the storage silos, the District currently considers the truck's engine as a mobile source and not subject to permit evaluation requirements. Similarly, a separate IC engine situated on the truck for the purpose of loading and unloading material is currently considered as part of that mobile source.

Occasionally, an IC engine is used at a remote receiving and storage site to power the blower. If a piston type IC engine with a break horsepower (BHP) rating less than or equal to the value specified in District Rule 219, "Equipment Not Requiring A Written Permit Pursuant To Regulation II", is used, that engine must be included in the permit description of the receiving and storage system. If the BHP rating is greater than the value specified in Rule 219, the IC engine must be evaluated as a separate permit unit.

If the Receiving and Storage System is vented to an external air pollution control (APC) system, that APC system must be evaluated as a separate permit unit. Those silos of the Receiving and Storage systems with an integral APC system (filtered vent) shall include the APC device as a part of the permit unit _if_ all of the collected material is directly returned to the storage vessel being vented.

A storage vessel can be included with the permit unit from which it receives material if the following conditions are satisfied [1]:

- the material is bulk solid; and
- the material is received from only one source permit unit; and
- the storage vessel is physically united to the source permit unit by conveyor, chute, pipe or hose.

The storage vessel will be considered a separate permit unit if any one of the following conditions is true [1]:

- the material being stored is a liquid or gas; or
- the material is received from more than one source permit unit; or

- the storage vessel is not united physically to the source permit unit.

In processing bulk solid materials, the permit unit includes all equipment in the process line, beginning at the discharge from raw material storage and ending at the product storage or the start of another process. All processing lines of equipment for bulk solid material physically united for flow through one or more pieces of common equipment are considered as a single permit unit. Also, if the permit unit is to include more than one silo, all silos should have the same dimensions and capacity.

7.2.1 Pneumatic Receiving And Storage System Venting to External Control

A Receiving And Storage System using pneumatic conveying is described in the permit as follows:

(MATERIAL) RECEIVING AND STORAGE SYSTEM CONSISTING OF:

1. (NUMBER OF) STORAGE SILO(S), (BULK SOLID MATERIAL), EACH (INTERNAL DIMENSIONS) DIAMETER X HEIGHT, (VOLUMETRIC CAPACITY) CUBIC FEET.

2. TRUCK UNLOADING STATION WITH (NUMBER OF) PNEUMATIC FILL TUBE.

<u>If Applicable</u>

3. INTERNAL COMBUSTION ENGINE, MANUFACTURER'S NAME, DIESEL-FUELED (GASOLINE-FUELED), MODEL NO., SERIAL NO., NO. OF CYLINDERS, TWO/FOUR CYCLE, ENGINE BRAKE HORSEPOWER, DRIVING A BLOWER.

7.2.2 Mechanical Receiving And Storage System Venting to External Control

A Receiving And Storage System using mechanical conveying is described in the permit as follows:

(MATERIAL) RECEIVING AND STORAGE SYSTEM CONSISTING OF:

1. (NUMBER OF) STORAGE SILO(S), (BULK SOLID MATERIAL), EACH (INTERNAL DIMENSIONS) DIAMETER X HEIGHT, (VOLUMETRIC CAPACITY) CUBIC FEET.
2. RECEIVING HOPPER, (INTERNAL DIMENSIONS) WIDTH X LENGTH X HEIGHT.
3. SCREW CONVEYOR, HORSEPOWER RATING.
4. BELT CONVEYOR, HORSEPOWER RATING.
5. BUCKET ELEVATOR, HORSEPOWER RATING.

<u>If Applicable</u>

6. INTERNAL COMBUSTION ENGINE, MANUFACTURER'S NAME, DIESEL-FUELED (GASOLINE-FUELED), MODEL NO., SERIAL NO., NO. OF CYLINDERS, TWO/FOUR CYCLE, ENGINE BRAKE HORSEPOWER, DRIVING A BLOWER.

7.2.3 Pneumatic Receiving And Storage System With Integral Control

A Receiving and Storage System using pneumatic conveying with a filtered vent (integral control device) is described in the permit as follows:

(MATERIAL) RECEIVING AND STORAGE SYSTEM CONSISTING OF:

1. (NUMBER OF) STORAGE SILO(S), (BULK SOLID MATERIAL), EACH (INTERNAL DIMENSIONS) DIAMETER X HEIGHT, (VOLUMETRIC CAPACITY) CUBIC FEET, WITH A FILTERED VENT, MANUFACTURER, MODEL NUMBER, (NUMBER OF) BAGS, EACH (INTERNAL DIMENSIONS) DIAMETER X HEIGHT, AND (NUMBER OF) SQUARE FEET ACTUAL FILTER AREA.

2. TRUCK UNLOADING STATION WITH (NUMBER OF) PNEUMATIC FILL TUBE.

If Applicable

3. INTERNAL COMBUSTION ENGINE, MANUFACTURER'S NAME, DIESEL-FUELED (GASOLINE-FUELED), MODEL NO., SERIAL NO., NO. OF CYLINDERS, TWO/FOUR CYCLE, ENGINE BRAKE HORSEPOWER, DRIVING A BLOWER.

7.2.4 Mechanical Receiving And Storage System Venting to External Control

A Receiving And Storage System using mechanical conveying is described in the permit as follows:

(MATERIAL) RECEIVING AND STORAGE SYSTEM CONSISTING OF:

1. (NUMBER OF) STORAGE SILO(S), (BULK SOLID MATERIAL), EACH (INTERNAL DIMENSIONS) DIAMETER X HEIGHT, (VOLUMETRIC CAPACITY) CUBIC FEET.

2. RECEIVING HOPPER, (INTERNAL DIMENSIONS) WIDTH X LENGTH X HEIGHT.

3. SCREW CONVEYOR, HORSEPOWER RATING.

4. BELT CONVEYOR, HORSEPOWER RATING.

5. BUCKET ELEVATOR, HORSEPOWER RATING.

If Applicable

6. INTERNAL COMBUSTION ENGINE, MANUFACTURER'S NAME, DIESEL-FUELED (GASOLINE-FUELED), MODEL NO., SERIAL NO., NO. OF CYLINDERS, TWO/FOUR CYCLE, ENGINE BRAKE HORSEPOWER, DRIVING A BLOWER.

7.3 Emissions

7.3.1 Description

Source(s) of emission from a Receiving and Storage System, if properly vented and controlled, is primarily from the baghouse or the filtered vent(s). The primary air contaminant resulting directly from the transfer of bulk solid material is particulate matter (PM). Most Receiving and Storage Systems use air to convey the bulk solid material. This conveying air is usually derived from an electric motor or an IC engine at the site or on the bulk transport truck. Receiving and Storage Systems using an internal combustion (IC) engine located permanently at the site must include the products of combustion emissions in the evaluation for permit to construct and operate. The primary air contaminants from the IC engine driving the blower or compressor are reactive organic gas (ROG), oxides of nitrogen (NOx), oxides of sulfur (SOx), carbon monoxide (CO), and particulate matter (PM). If the IC engine is part of the receiving and storage system permit unit (see Section - Permit Unit Description), both "unloading" and "engine" emissions are summed to determine total emissions. If the IC engine and the receiving and storage system are separate permit units, the "unloading" emissions are the total emissions for the receiving and storage system permit unit. The mechanical conveying equipment (screw and belt conveyors and bucket elevators) are usually enclosed resulting in negligible particulate emissions. Any emission from this transfer equipment is typically directed to the control device for the silo. However, these fugitive emissions can be vented to other control equipment not venting the silo.

7.3.2 Emission Factors

Particulate matter emissions from Receiving and Storage Systems are generated by conveying the bulk solid material from the truck to the storage silo(s). These emissions are the small fraction of bulk solid material which remains entrained in the moving air stream. This air stream is eventually exhausted to the atmosphere. Also, as bulk solid material fills the silo, the air in the silo is displaced. Bulk solid material or particulate matter entrained in this displaced air is also exhausted to the atmosphere. Particulate matter is removed from the total air stream by a air pollution control device or system, then vented or exhausted to the atmosphere. In those systems where a Rule 219 permit exempt IC engine is used, the products of combustion emissions must be added to the conveying and displaced air emissions to determine the total emissions.

(A) Receiving and Storage:
There is a variety of bulk solid materials that can be received and stored. Emission factors for some common bulk solids are listed in Table 7-1.

(B) Internal Combustion Engines:
Table 7-2 lists emission factors for internal combustion engines driving the blower or compressor.

7.4 Calculations

7.4.1 Operational Data

Emission calculations must be performed to determine the compliance status of the Receiving and Storage System. To determine compliance, the applicant must provide the following information:

Bulk solid Material:	
Process Information:	lb/load, hr/load, load/hr
Operating Schedule	

Maximum:	hr/day, day/week
Average:	hr/day, day/week
Filtered Vent/Baghouse Filter Area	ft^2
Baghouse Blower Horsepower	H.P.
Blower Capacity:	ACFM
Engine Brake Horsepower:	BHP
Fuel Type:	
Fuel Consumption Rate:	gal/hr or scf/hr
Exhaust Volume:	DSCFM or ACFM
Receiving Hopper Dimensions	feet and inches
Screw Conveyor Horsepower Rating	H.P.
Belt Conveyor Horsepower Rating	H.P.
Bucket Elevator Horsepower Rating	H.P.

7.4.2 Process Weight Calculations

The process weight (PW) is defined as the total weight of all materials introduced into any specific process which may discharge contaminants into the atmosphere. Material which is recycled is considered in calculating process weight each time it is recycled. Therefore, material collected by the filtered vent or APC system from the receiving and storage system (or silo) is part of the process weight.

The process weight per hour, or process weight rate (PWR), is the total process weight divided by the number of hours in one complete operation from the beginning of any given process to the completion thereof, excluding any time during which the equipment is idle. Therefore, if the complete process operation or cycle is less than one hour, the process weight rate would be the total (prorated) amount of materials that would have been introduced to the process if the operation required one full hour to complete.

The PWR for a receiving and storage system is calculated in the following manner:

Table 7-1 **Uncontrolled Emission Factors for Commonly Stored Bulk solids** [a]

Bulk solid Material	Emission Factor (lb PM/ton PW)[b]	Reference	
Feed and Grain	0.6-1.0	AP-42,	Table 6.4-2
Ammonium Nitrate	< 0.02	AP-42,	Table 6.8-1
Normal Superphosphate	0.56[c]	AP-42,	Table 6.10.1-1
Triple Superphosphate	14-18[c]	AP-42,	Table 6.10.2-4
Ammonium Phosphate	6[c]	AP-42,	Table 6.10.3-4
Glass Fiber Mfg	3	AP-42,	Table 8.11-8
Sand/Gravel	0.024-0.056	AP-42,	Table 8.19.1-1
Bauxite/Alumina	1.1	AP-42,	Table 8.23-4
All Metallic Minerals but Bauxite	0.12	AP-42,	Table 8.23-4
Cement	2	SCAQMD Memo [d]	

[a] Reference 2

[b] PM = Particulate Matter
PW = Process Weight : Weight of Material Received and Stored

[c] Values From Reference Converted to Uncontrolled Emission Factors

[d] Reference 3

Table 7-2: **Emission Factors For Internal Combustion Engines**

Air Contaminant	Emission Factor			
	Gasoline[a] (lb/gal)	Diesel[a] (lb/gal)	Natural[b] Gas (lb/scf)	LPG[b] (lb/gal)
Reactive Organic Gas (ROG)	0.1320[c]	0.0375	0.0069	0.0830
Oxides of Nitrogen (NOx)	0.1020	0.4690	3.4000	0.1390
Carbon Monoxide (CO)	3.9400	0.1020	0.4300	0.1290
Oxides of Sulfur (SOx)	0.0053	0.0071	0.0001	0.0004
Particulate Matter (PM)	0.0065	0.0335	0.0014	0.0050

a Reference 2 (SO_x emissions for diesel corrected to 0.05% sulfur)

b Reference 4

c. The emission rate of Reactive Organic Gases due to crankcase blowby and evaporation loss of gasoline is 0.221 lbs/hr.

Diesel has negligible crankcase blowby and evaporation loss.

$$PWR = \frac{\text{pounds of material per load}}{\text{hours to unload the material}} \qquad \text{(Equation 7.1)}$$

where:

PWR = Process weight rate (flow rate of bulk solid material, lb/hr)

7.4.3 Emission Calculations

Emissions must be calculated for both the actual and maximum operating conditions. Actual emissions are used in emission inventory. Maximum emissions are used to determine compliance with the District's Rules and Regulations.

Actual and maximum hourly (lb/hr) emission rates must be converted to daily (lb/day) emission rates by multiplying the hourly rates by the appropriate equipment daily operational time factor (T, hr/day). In addition, the maximum daily emissions are multiplied by the Regulation XIII On-Site Offset Factor (1.1). These daily emissions increases are accumulated for each facility in the District's New Source Review Record.

7.4.3.1 Uncontrolled Emissions (R_1) Calculations

Uncontrolled particulate matter (PM) emission from conveying bulk solid material from the truck to the storage silos is determined by Equation 7.2.

$$R'_{1,PM} = \frac{EF' \times PWR}{2,000} \qquad \text{(Equation 7.2)}$$

where:

$R'_{1,PM}$ = Uncontrolled PM emission from material transfer (lb/hr)

EF' = Emission factor (lb PM/ton PWR) from Table 7-1
PWR = Process weight rate (flow rate of bulk solid material, lb/hr)
2,000 = conversion factor - pounds per ton (lb/ton)

For those Receiving and Storage Systems including a Rule 219 permit exempt IC engine, uncontrolled products of combustion emissions (PM, ROG, NO_x, SO_x, and CO) for the IC engine are determined by using Equation 7.3.

$$R''_1 = EF'' \times FCR \qquad \textbf{(Equation 7.3)}$$

where:

R''_1 = Uncontrolled emissions (lb/hr)
EF'' = Emission Factor (lb/gal or lb/scf) from Table 7-2
FCR = Fuel consumption rate (gal/hr or scf/hr)

The total uncontrolled (R_1) particulate matter (PM) emissions are determined by summing emissions resulting from conveying the bulk solid material to the silo(s) and from the IC engine driving the blower or compressor, as shown in Equation 7.4:

$$R_{1,PM} = R'_{1,PM} + R''_{1,PM} \qquad \textbf{(Equation 7.4)}$$

7.4.3.2 Controlled Emissions (R_2) Calculations

Particulate matter evolved by the conveying of bulk solid material to the storage silos is reduced prior to discharge into the atmosphere by an air pollution control (APC) *device* or *system*. The most common APC *device* for a Receiving and Storage System is a filtered vent. The most common APC *system* for a Receiving and Storage System is a baghouse and it's exhaust blower (fan). The particulate emission from the control device or system is calculated using Equation 7.5.

$$R_{2,PM} = R'_{1,PM} \times (1 - EFF) \qquad \textbf{(Equation 7.5)}$$

where:

$R_{2,PM}$ = Controlled particulate matter emission rate (lb/hr)
$R'_{1,PM}$ = Uncontrolled particulate matter emission rate (lb/hr) from bulk solid material transfer
EFF = Efficiency of filtered vent or baghouse (as a decimal)

If the emissions from the IC engine are vented to an APC device or system (catalyst), emissions reductions could be calculated by inputting the appropriate values in Equation 7.5.

7.4.3.3 Total Particulate Matter Emissions Vented to the Atmosphere

If the Receiving and Storage System does not include a permit exempt IC engine, the total PM mass emission rate to the atmosphere is the value determine by Equation 7.5.

If an IC engine exempt from permit requirements (as per Rule 219) is part of the Receiving and Storage System, the total amount of particulate matter released into the atmosphere after the APC device or system is calculated using Equation 7.6.

$$R'_{2,PM} = R_{2,PM} + R''_{1,PM} \qquad \textbf{(Equation 7.6)}$$

where:

$R'_{2,PM}$ = Total (controlled and uncontrolled) particulate matter emission rate (lb/hr)
$R_{2,PM}$ = Controlled particulate matter emission rate from bulk solid material transfer (lb/hr)
$R''_{1,PM}$ = Uncontrolled IC engine emissions (lb/hr)

The values of particulate matter emission rate (lb PM/hr) calculated using Equation 7.5 (or Equation 7.6) is used to determine compliance with Rule 405. If the complete process operation or cycle is less than one hour, the allowable emission rate would be prorated (based on the fraction of the time the process operated during that one hour period).

7.4.4 Total Particulate Matter Emission - Concentration

The controlled particulate matter mass emission rate (lb PM/hr) calculated by using Equation 7.5 must be converted into total particulate matter concentration (grains/dscf) to determine compliance with Rule 404. The particulate matter concentration is calculated by:

$$C = \frac{R_{2,PM} \times 7000\ (\text{grains/lb})}{VFR \times 60\ (\text{min/hr})} \qquad \textbf{(Equation 7.7)}$$

where:

C = Particulate matter concentration (grains/dscf)
$R_{2,PM}$ = Total particulate matter emission rate (lb/hr)
VFR = Exhaust air flow rate in dry standard cubic feet per minute (dscfm)

For pneumatic conveying Receiving and Storage Systems, the air volumetric flow rate through the baghouse or filtered vent is the summation of conveying air created by the compressor or blower and the displaced air created by the filling of the silo. For all practical purposes, the displaced air flow rate is negligible compared to the conveying air flow rate due to the amount of time required to unload a bulk solid material transport truck.

For mechanical conveying Receiving and Storage Systems, the displaced air is the only source of air volumetric flow rate.

7.4.5 Baghouse/Filtered Vent Design Calculation

The air-to-cloth (A/C) ratio can be calculated using Equation 7.8.

$$A/C = \frac{VFR}{A_b} \qquad \textbf{(Equation 7.8)}$$

where:

A/C = Air-to-Cloth ratio (ft/min)

VFR = Air volumetric flow rate through baghouse or filtered vent, (ft^3/min)

A_b = Actual filter cloth area of bags or cartridges (ft^2).

7.4.6 Duct Velocity Calculation

The velocity of air entrained with entrained particulate matter in the conveying line(s) can be calculated using Equation 7.9. and Equation 7.10.

$$A_d = 0.00545 \times D^2 \qquad \textbf{(Equation 7.9)}$$

$$V_d = \frac{VFR}{A_d} \qquad \textbf{(Equation 7.10)}$$

where:

A_d = Cross-sectional area of the conveying line or duct, (ft^2).

D = diameter of duct, (in inches)

V_d = velocity in duct

VFR = Air volumetric flow rate through baghouse or filtered vent, (ft^3/min)

note: 0.00545 is a conversion factor converting the diameter, (in inches) to cross sectional area (in square feet)

7.5 Rules Evaluation

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing the permit.

Rule 401 - Visible Emissions
No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 403 - Fugitive Dust
Visible fugitive dust is prohibited beyond the boundary of the facility (exemptions apply). In addition, particulate concentration in the downwind sample(s) may not exceed that in the upwind sample(s) by more than 100 micrograms per cubic meter.

Rule 404 - Particulate Matter - Concentration
Limits for particulate matter concentrations in an effluent gas stream at standard conditions are listed in Table 404(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 405 - Particulate Matter - Weight
Limits for particulate matter emission rates from any source are listed in Table 405(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 1110.1 - Emissions From Stationary Internal Combustion Engines
If the receiving and storage system includes an internal combustion engines with a rating of 50 break horsepower (BHP) or more, the applicant (owner/operator) must submit a Control Plan. The Control Plan must include the following information for each stationary source:

- A list of all engines with the type of engine service and permit or identification number.

- Engine manufacturer, model number, rated break horsepower, type of fuel and type of ignition .

- List of all engines to be controlled and type of emission controls to be applied to such engines, including construction schedule.

If the BHP rating of the IC engine is greater than the value specified in Rule 219 and is 50 BHP or more, the applicant must submit an application for permit to construct and operate for that engine. The requirements for the Control Plan will be considered during the evaluation for permit to construct and operate.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT for particulate matter emissions from a receiving and storage system is a baghouse, a filtered vent, or equivalent.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

7.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, Permit (Operating) Conditions must be required: Permit (Operating) Conditions for the receiving and storage system and their associated air pollution control equipment (baghouse) are listed below:

Receiving and Storage System

1. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

<u>or</u>

THE CLOTH BAG(S) IN THE SILO(S) FILTERED VENT(S) MUST BE THOROUGHLY CLEANED IMMEDIATELY AFTER EACH LOAD OF MATERIAL IS RECEIVED.

2. THE TOTAL WEIGHT OF MATERIAL RECEIVED AND STORED BY THIS EQUIPMENT MUST NOT EXCEED (NUMBER OF) POUNDS IN ANY ONE DAY.

3. A DAILY LOG OF MATERIAL RECEIVED AND STORED BY THIS EQUIPMENT, THE AMOUNT IN POUNDS PER DAY, MUST BE MAINTAINED IN A FORMAT APPROVED BY THE DIRECTOR OF ENFORCEMENT, KEPT ON FILE FOR A MINIMUM OF TWO YEARS, AND MADE AVAILABLE UPON REQUEST OF DISTRICT PERSONNEL.

Baghouse (If Applicable)

1. A MECHANICAL GAUGE MUST BE INSTALLED SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS (CARTRIDGES).

2. DUSTS COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS

REFERENCES

(1) Administration of the Permit System, A Manual of the Engineering Division, Fourth Edition, p. 12, January 1968

(2) Compilation of Air Pollution Emission Factors, AP-42, Fourth Edition, September 1985.

(3) Memorandum from W. Hammond to Engineering Division, Subject: Emission Factors for Concrete Batch Plants, March 2,1978.

(4) Instruction for the Emission Data System Review and Update Report, Appendix III, Air Resources Board, February 1986.

APPENDIX 7A

WORKSHEET FOR RECEIVING AND STORAGE SYSTEMS USING PNEUMATIC CONVEYING

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ________________

RECEIVING AND STORAGE SYSTEM CONSISTING OF:

1. STORAGE SILOS, STORAGE, EACH '- " DIA. X '- " H., CU. FT. CAPACITY, WITH A FILTERED VENT, MODEL NO. , BAGS, EACH '- " DIA. X '- "H., AND SQ. FT. ACTUAL FILTER AREA.
2. TRUCK UNLOADING STATION WITH PNEUMATIC FILL TUBE(S).
3. RAILCAR UNLOADING STATION WITH PNEUMATIC FILL TUBE(S).

APPLICATION NO. ________________

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. BAGHOUSE (DUST COLLECTOR), , MODEL NO. , WITH FILTER BAGS (CARTRIDGES), EACH '- " DIA. X '-" H., SQ. FT. ACTUAL FILTER AREA.
2. EXHAUST SYSTEM WITH A - H.P. BLOWER VENTING A RECEIVING AND STORAGE SYSTEM.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PROCESSED BY	CHECKED BY

HISTORY:

PROCESS DESCRIPTION:

The applicant uses this receiving and storage system to unload and store ____________. The solid material is pneumatically (mechanically) conveyed from the bulk transport truck to the storage silo(s) with the use of air blower powered by the internal combustion engine (electric motor) located on the truck (at the receiving station). Particulate matter is removed from the air conveying the solid material from the truck to the storage silo with a filtered vent (baghouse).

DATA:

	Source
Operating Schedule: (T_a): ____ hr/day, ____ day/wk, ____ wk/yr	Applicant
Operating Schedule: (T_m): ____ hr/day, ____ day/wk, ____ wk/yr	"
Process Information: ____ lb/load, ____ hr/load, ____ load/day	"
Filtered Vent/Baghouse Efficiency (EFF): ____ %	"
Filtered Vent/Baghouse Filter Area (A_b): ____ ft^2	"
Exhaust Blower Flow Rate (VFR): ____ CFM	"
Particulate Emission Factor, (EF): ____ lb/ton	AP-42, p.____

Reg XIII On-Site Offset Factor For Maximum Daily Emissions: 1.1

CALCULATIONS:

1. Process Weight Rate (PWR) = (____ lb/load)(____ hr/load)

   = ____ lb/hr (____ ton/hr)

2. Uncontrolled Particulate Matter Emissions (R_1)

   Uncontrolled emissions must be multiplied by appropriate operating time factor (T_a or T_m) to determine actual and maximum hourly and daily emissions.

   $R_{1,PM}$ = EF x PWR = lb/hr (x T_a or T_m) = lb/day

   where:

   $R_{1,PM}$ = Uncontrolled emissions, lb/hr
   EF = Emission factor, lb PM/ton PW
   PWR = Process weight rate, ton/hr
   T_a or T_m = Time of operation, hr/day (avg and max)

Uncontrolled PM Emissions (R_1)	Actual lb/hr	Maximum lb/hr	Maximum lb/day

3. Controlled Particulate Matter Emissions (R_2)

$R_{2,PM} = R_{1,PM} \times (1 - EFF)$ (x 1.1 for NSR lb/day)

Controlled PM Emissions (R_2)	Actual lb/hr	Maximum lb/hr	Maximum lb/day	NSR lb/day

4. Exhaust Gas Total Particulate Concentration (PC)

$$PC = \frac{(R_2) \text{ lb PM/hr} \times 7{,}000 \text{ grains/lb}}{\text{ft}^3\text{/min} \times 60 \text{ min/hr}} = \_\_\_\_ \text{ grains/dscf}$$

5. Baghouse (Filter Vent) Air-to-Cloth Ratio (A/C)

$A/C = VFR/A_b = \_\_\_\_ \text{ CFM} / \_\_\_\_ \text{ ft}^2 = \_\_\_\_ \text{ ft/min}$

where: VFR = air volumetric flow rate thru baghouse (filter vent)
A_b = actual area of bag filters (cartridges)

6. Duct Velocity (V_d)

$A_d = 0.00545 \times d = 0.00545 \times \_ = \_\_\_ \text{ ft}^2$
$V_d = VFR/A_d = \_\_\_ \text{ CFM}/\_\_\_ \text{ ft}^2 = \_\_\_ \text{ ft/min}$

where: A_d = area of duct
d = diameter of duct (in inches)
VF = air volumetric flow rate thru baghouse (filter vent)

RULES EVALUATION

RULE 401: This equipment is (is not) vented to a baghouse (filtered vent). Compliance with Rule 401 is (is not) expected.

RULE 402: The location of the equipment will be in an industrial/commercial area. Calculations show low (excessive) particulate emissions to the atmosphere. Compliance with Rule 402 is (is not) expected.

RULE 430: Fugitive emissions are (are not) expected from the operation of this Compliance with Rule 403 is (is not) expected.

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ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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RULE 404: For an exhaust flow rate of ______ DSCFM, the rule allows a maximum particulate matter concentration of _____ grains/DSCF. Calculations indicate a particulate matter concentration of _____ grains/SCFM. Compliance with Rule 404 is (is not) expected.

RULE 405: For a process weight of ______ lb/hr, the rule allows a maximum solid particulate matter emission rate of ______ lb/hr. Calculations indicate a maximum emission rate of _____ lb/hr. Compliance with Rule 405 is (is not) expected.

REG XIII: As shown by the Emission Threshold/New Source Sheet Table below, this facility will (will not) operate in compliance with Regulation XIII:

	Emissions in Pounds Per Day				
	ROG	NO_X	SO_2	CO	PM
Facility Emissions	___	___	___	___	___
Since 10-8-76 A/N	___	___	___	___	___
A/N	___	___	___	___	___
Net Emission Increase Since 10-8-76	___	___	___	___	___

BACT: Best Available Control Technology (BACT) for receiving and storage system is a baghouse or filter vent. The applicant will (will not) provide BACT.

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

[] Issue a Permit to Construct/Operate with the following conditions:

APPLICATION NO. _____ (Basic)

CONDITIONS

1. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

or

THE CLOTH BAGS IN THE SILO(S) FILTERED VENTS(S) MUST BE THOROUGHLY CLEANED IMMEDIATELY AFTER EACH LOAD OF MATERIAL IS RECEIVED.

2. THE TOTAL WEIGHT OF MATERIAL RECEIVED AND STORED BY THIS EQUIPMENT MUST NOT EXCEED POUNDS IN ANY ONE DAY.

3. A DAILY LOG OF MATERIAL RECEIVED AND STORED BY THIS EQUIPMENT, THE AMOUNT IN POUNDS PER DAY, MUST BE MAINTAINED ON FILE FOR A MINIMUM OF TWO YEARS AND MADE AVAILABLE UPON REQUEST OF DISTRICT PERSONNEL.

APPLICATION NO. ______ (Control)

CONDITIONS

1. A MECHANICAL GAUGE MUST BE INSTALLED SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS (CARTRIDGES).

2. DUSTS COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS.

OR

[] Deny the Permit to Construct/Operate. It is my opinion that the operation of this equipment will cause a violation of Rule(s) ________________ of the Rules and Regulations of the South Coast AQMD.

APPENDIX 7B

WORKSHEET

RECEIVING AND STORAGE SYSTEMS USING MECHANICAL CONVEYING

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PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO.

RECEIVING AND STORAGE SYSTEM CONSISTING OF:

1. ( ) STORAGE SILOS, EACH '- " DIA. x '- " H., CU. FT. CAPACITY, WITH A FILTER VENT, , MODEL NO. , BAGS, EACH '- " DIA. x '- "H., SQ. FT. ACTUAL FILTER AREA.
2. RECEIVING HOPPER, '- " W. x '- " L. x '- " H.
3. SCREW CONVEYOR, H.P.
4. BELT CONVEYOR, H.P.
5. BUCKET ELEVATOR, H.P.

APPLICATION NO.

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. BAGHOUSE (DUST COLLECTOR), , MODEL NO. , WITH FILTER BAGS (CARTRIDGES), EACH '- " DIA. x '- " H., SQ. FT. ACTUAL FILTER AREA.
2. EXHAUST SYSTEM WITH A -H.P. BLOWER VENTING A RECEIVING AND STORAGE SYSTEM.

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HISTORY:

PROCESS DESCRIPTION:

The applicant uses this receiving and storage system to unload and store _______. The solid material is pneumatically (mechanically) conveyed from the bulk transport truck to the storage silo(s) with the use of air blower powered by the internal combustion engine (electric motor) located on the truck (at the receiving station). Particulate matter is removed from the air conveying the solid material from the truck to the storage silo with a filter vent (baghouse).

DATA:

	Source
Operating Schedule (T_a): ______ hr/day, _________ day/wk, _________ wk/yr	Applicant
Operating Schedule (T_m): ______ hr/day, _________ day/wk, _________ wk/yr	"
Process Information : _________ lb/load, _________ hr/load, _________ load/day	"
Filter Vent/Baghouse Efficiency (EFF): __________ %	"
Filter Vent/Baghouse Filter Area (A_b): __________ ft^2	"
Exhaust Blower Flow Rate (VFR): _____________ CFM	"
Particulate Emission Factor, (EF): _____________ lb/ton	AP-42, p.___

Reg XIII On-Site Offset Factor For Maximum Daily Emissions: 1.1

CALCULATIONS:

1. Process Weight Rate (PWR) = (lb/load)(hr/load)

   = lb/hr (ton/hr)

2. Uncontrolled Particulate Matter Emissions (R_1)

   Uncontrolled emissions must be multiplied by appropriate operating time factor (T_a or T_m) to determine actual and maximum hourly and daily emissions.

$R_{1,PM}$ = EF x PWR = ________ lb/hr (x T_a or T_m) = _____________ lb/day

where,

$R_{1,PM}$ = Uncontrolled emissions, lb/hr
EF = Emission factor, lb PM/ton PW
PWR = Process weight rate, ton/hr
T_a or T_m = Time of operation, hr/day (avg and max)

Uncontrolled PM Emissions (R_1)	Actual lb/hr	Maximum lb/hr	Maximum lb/day
	______	______	______

3. Controlled Particulate Matter Emissions (R_2)

$R_{2,PM} = R_{1,PM} \times (1 - EFF)$ (x 1.1 for NSR lb/day)

Controlled PM Emissions (R_2)	Actual lb/hr	Maximum lb/hr	Maximum NSR lb/day
	______	______	______

4. Exhaust Gas Total Particulate Concentration (PC)

$$PC = \frac{(R_2) \text{ lb PM/hr} \times 7{,}000 \text{ grains/lb}}{\text{ft}^3\text{/min} \times 60 \text{ min/hr}} = \_\_\_\_\_\_\_\_\_\_\_\_ \text{grains/dscf}$$

5. Baghouse (Filter Vent) Air-to-Cloth Ratio (A/C)

$A/C = VFR/A_b = \_\_\_\_$ CFM/$\_\_\_\_$ ft^2 = $\_\_\_\_\_\_\_\_$ ft/min

where,

VFR = air volumetric flow rate thru baghouse (filter vent)
A_b = actual area of bag filters (cartridges)

6. Duct Velocity (V_d)

$A_d = 0.00545 \times d = 0.00545 \times \_\_\_\_ = \_\_\_\_ ft^2$

$V_d = VFR/A_d = \_\_\_\_$ CFM/$\_\_\_\_$ ft^2 = $\_\_\_\_$ ft/min

where,

A_d = area of duct
d = diameter of duct (in inches)
VFR = air volumetric flow rate thru baghouse (filter vent)

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RULES EVALUATION

RULE 401 : This equipment is (is not) vented to a baghouse (filter vent). Compliance with Rule 401 is (is not) expected.

RULE 402 : The location of the equipment will be in an industrial/commercial area. Calculations show low (excessive) particulate emissions to the atmosphere. Compliance with Rule 402 is (is not) expected.

RULE 430 : Fugitive emissions are (are not) expected from the operation of this Compliance with Rule 403 is (is not) expected.

RULE 404 : For an exhaust flow rate of___ DSCFM, the rule allows a maximum particulate matter concentration of ______ grains/DSCF. Calculations indicate a particulate matter concentration of___ grains/SCFM. Compliance with Rule 404 is (is not) expected.

RULE 405 : For a process weight of___ lb/hr, the rule allows a maximum solid particulate matter emission rate of _____ lb/hr. Calculations indicate a maximum emission rate of _____ lb/hr. Compliance with Rule 405 is (is not) expected.

REG XIII : As shown by the Emission Threshold/New Source Sheet Table below, this facility will (will not) operate in compliance with Regulation XIII:

	NSR Emissions in Pounds per Day					
	RHC	NO_x	SO_2	CO	PM	UnRHC
Cumulative Facility Emissions Since 10/08/76	____	____	____	____	____	____
A/N__________	____	____	____	____	____	____
A/N__________	____	____	____	____	____	____
Facility Net Emission Increase Since 10/08/76	____	____	____	____	____	____

BACT : Best Available Control Technology (BACT) for receiving and storage system is a baghouse or filter vent. The applicant will (will not) provide BACT.

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

[] Issue a Permit to Construct/Operate with the following conditions:

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ENGINEERING DIVISION

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APPLICATION NO. ________ (Basic)

CONDITIONS

1. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

   or

   THE CLOTH BAGS IN THE SILO(S) FILTERED VENTS(S) MUST BE THOROUGHLY CLEANED IMMEDIATELY AFTER EACH LOAD OF MATERIAL IS RECEIVED.

2. THE TOTAL WEIGHT OF MATERIAL RECEIVED AND STORED BY THIS EQUIPMENT MUST NOT EXCEED POUNDS IN ANY ONE DAY.

3. A DAILY LOG OF MATERIAL RECEIVED AND STORED BY THIS EQUIPMENT, THE AMOUNT IN POUNDS PER DAY, MUST BE MAINTAINED ON FILE FOR A MINIMUM OF TWO YEARS AND MADE AVAILABLE UPON REQUEST OF DISTRICT PERSONNEL.

APPLICATION NO. ________ (Control)

CONDITIONS

1. A MECHANICAL GAUGE MUST BE INSTALLED SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS (CARTRIDGES).

2. DUSTS COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS.

OR

☐ Deny the Permit to Construct/Operate. It is my opinion that the operation of this equipment will cause a violation of Rule(s) ________________ of the Rules and Regulations of the South Coast AQMD.

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Lithographic Printing Presses

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Section 8

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

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SECTION 8: LITHOGRAPHIC PRINTING PRESSES

8.1 General Description

There are four main printing processes: *relief*, *planographic*, *intaglio*, and *stencil*. In the *relief printing process*, as shown in Figure 8.1, the image or printing surface is raised above the non-image or non-printing surface. This raised surface is inked by rollers and then pressed against the paper to make the impression. The image carrier or plate can be made of metal, plastic, or rubber. *Letterpress* and *flexographic printing* are examples of relief printing. Letterpress printing presses use metal or plastic image carrier, whereas flexographic printing presses use rubber plates.

In the *planographic printing process*, as shown in Figure 8-2, the image and non-image areas are on the same plane. The image area is chemically treated so that it accepts ink and rejects water, while the non-image area is treated to accept water and reject ink. *Lithographic printing* is an example of the planographic printing process.

In the *intaglio process*, as shown in Figure 8-3, the printing image is recessed or etched into the plate at different depths and filled with liquid ink, the non-image area is wiped free of ink. *Gravure printing* is an example of the intaglio printing process.

In the *stencil printing process*, as shown in Figure 8-4, the printing ink passes through a web or a fabric to which a refined form of stencil has been applied. The stencil openings determine the forms and dimensions of the imprint. *Silk or screen printing* are examples of the stencil printing process. Table 8-1 lists the advantages and disadvantages of each process.

Any one of the four printing processes described above can be printed directly or indirectly to the paper. In *direct printing*, the image is transcribed directly from the image carrier or plate to the paper. Most letterpress and gravure and all screen printing is direct printing. In *indirect printing*, as shown in Figure 8-5, the image is

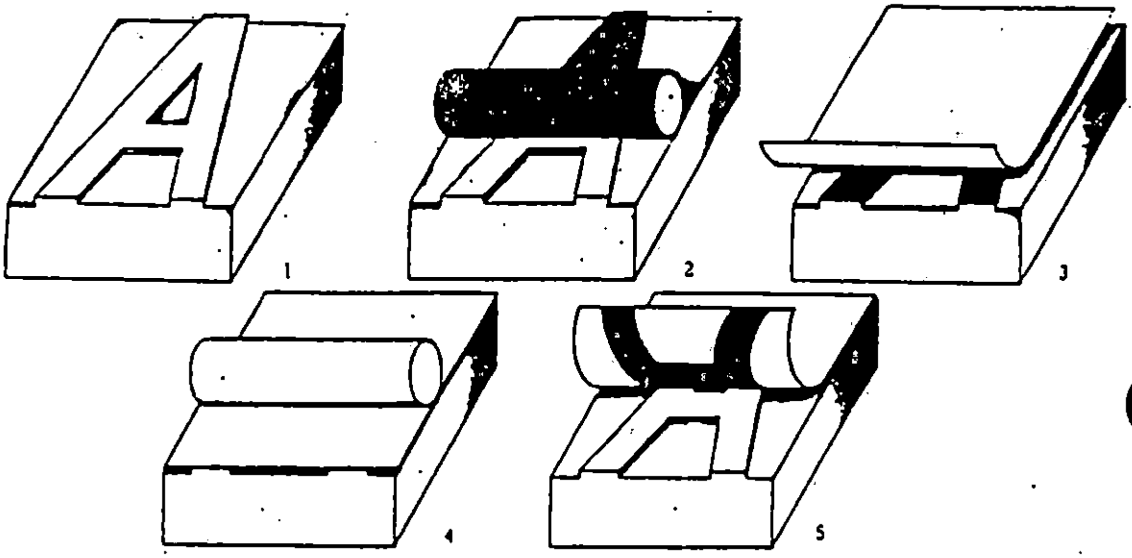


FIGURE 8-1 LETTERPRESS [1]

The image areas of the letterpress engraving are raised while non-image areas are recessed so that they do not pick up ink. The press (1) is inked by roller (2). Paper is placed over the inked image (3) and pressed on to the image (4) in the press by an impression cylinder, resulting in the image being printed on the paper (5).

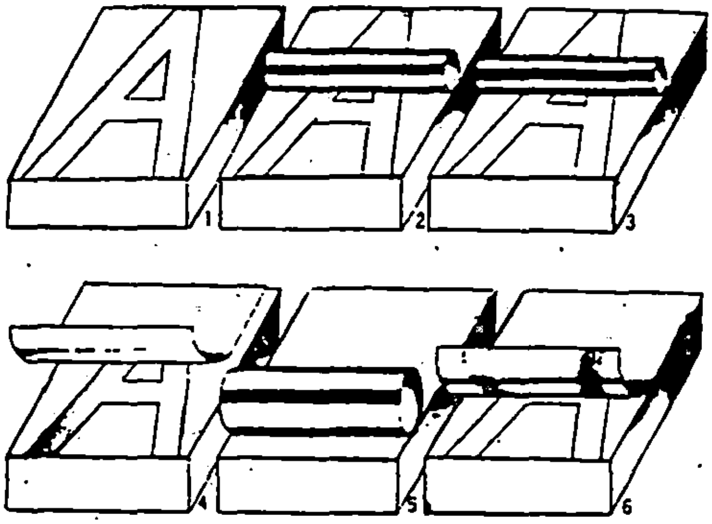


FIGURE 8-2 LITHOGRAPHY [1]

A planographic printing process utilizes the principle that grease and water do not mix. The image area of the plate is treated with greasy medium (1) and then dampened by rollers (2). The plate is inked (3), the ink adhering to the greasy image but not to the dampened areas. The paper is moved into position over the plate (4) and then plate and paper are run through the press (5), producing the printed page (6).

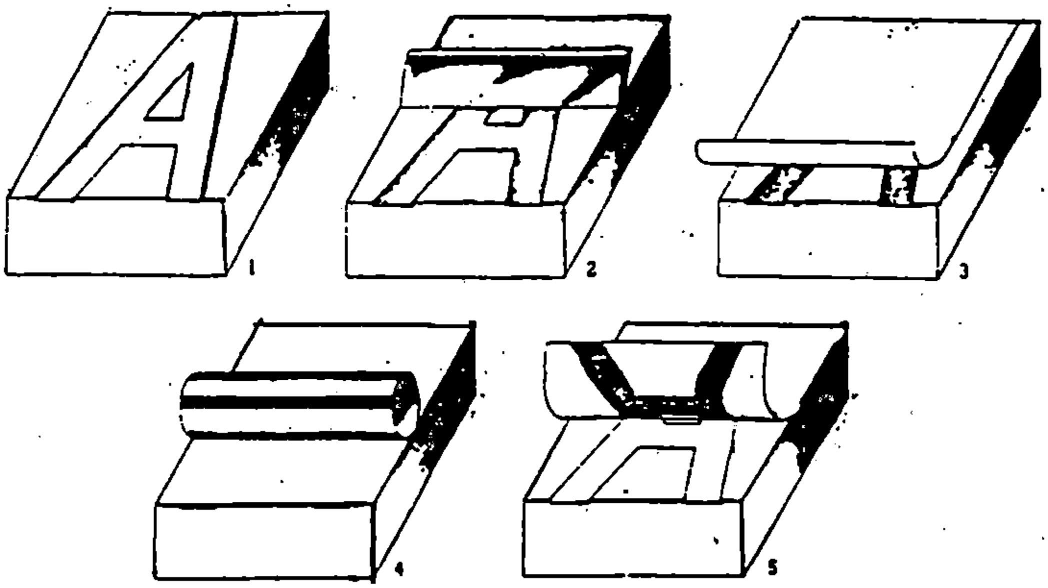
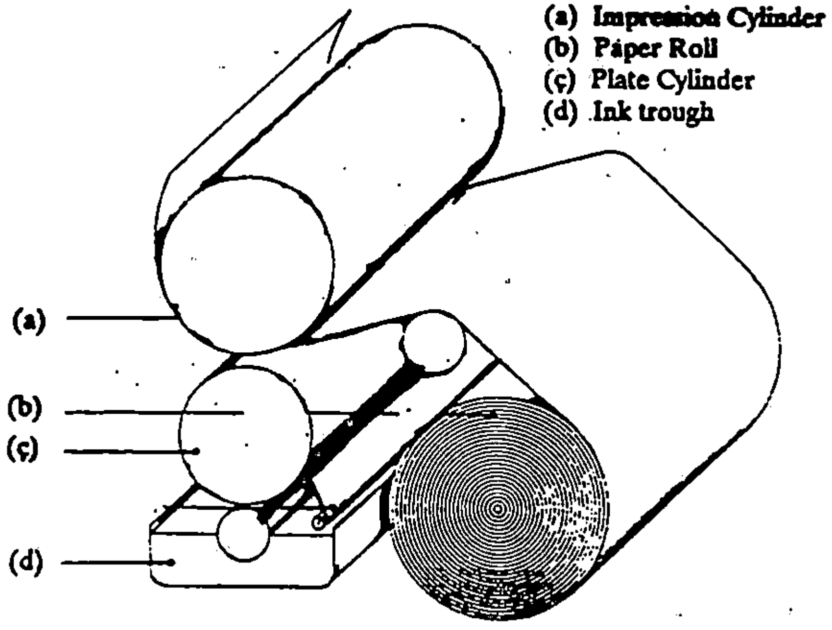


FIGURE 8-3 **GRAVURE** 1

The image to be printed has to be etched into the printing plate (1). Ink is applied by a roller and a thin, flexible steel blade (a doctor blade) is drawn across the plate, removing excess ink from the non-printing areas (2). The paper is then positioned over the plate (3) and pressed against it by a rubber-coated roller (4). The pressure forces the paper into the recesses of the plate so that it picks up ink, thus forming the image. The finished print is then removed (5).



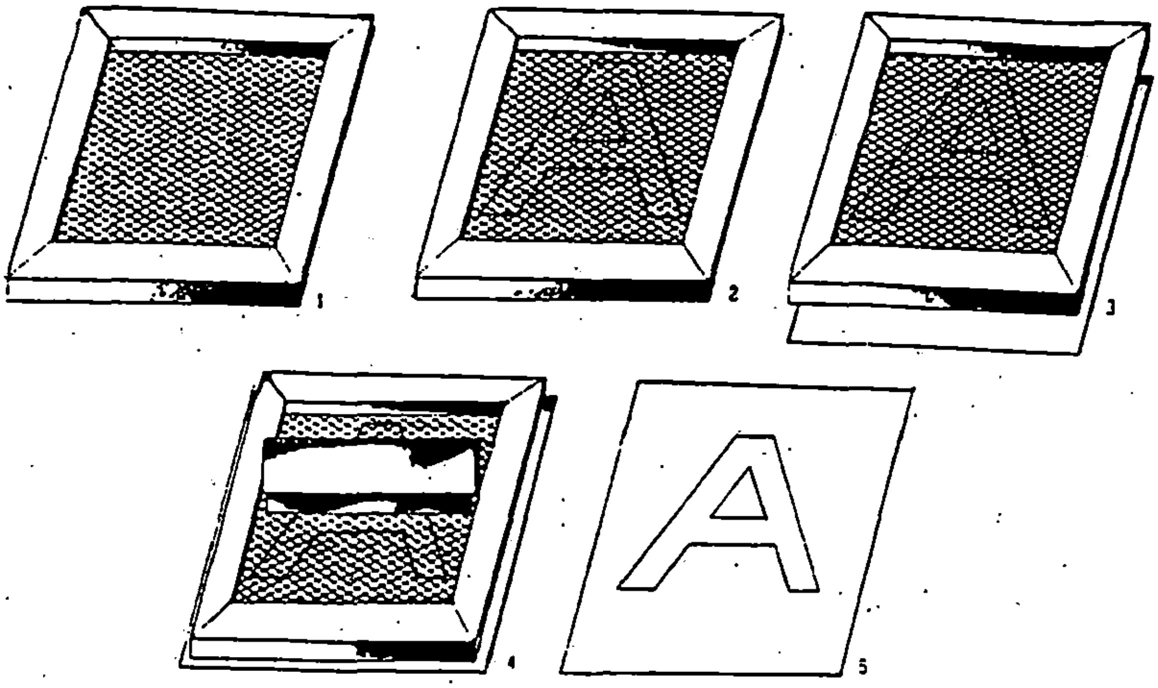


FIGURE 8-4 SILKSCREEN PRINTING [1]

A fine gauze, stretched over a wooden frame, forms the frame (1). The stencil is then transferred to the underside of the frame by heat and the stencil's protective backing is peeled away, masking off the non-image areas so they do not print (2). The paper is placed beneath the screen (3) and ink is applied to the top of it and spread by a squeegee (4). The ink passes through the screen in the areas where the stencil is cut away to produce the image (5). In commercial silk screen printing, photostencil are used.

TABLE 8-1 ADVANTAGES AND DISADVANTAGES OF PRINTING PRESSES[1]

TYPE	ADVANTAGES	DISADVANTAGES
LETTERPRESS	1. Dense ink 2. Good printing of type for high-quality book 3. No problems with ink and water balance 4. Less paper wastage than other processes	1. High cost of printing surface 2. Costlier paper needed to get same results as other processes 3. Sheet-fed machines run slowly 4. Modern preparation methods suit other processes better
OFFSET LITHOGRAPHY	1. Good reproduction of detail and photographs 2. Cheap printing surface 3. Fast make-ready 4. Rubber blanket enables the use of a wide range of papers 5. Lends itself to photographic preparation methods 6. Rotary principle means higher printing speeds	1. Color variation due to problems with ink/water balance 2. Dampening can cause paper-stretch 3. Dense ink films difficult to achieve
GRAVURE	1. Simple printing method and press mechanism 2. Can maintain consistent color 3. High speed 4. Straighforward drying by evaporation 5. Good results obtainable on cheaper paper.	1. High costs of plates or cylinders 2. Web-fed gravure viable only for long runs (300,000 +) 3. Color correction and last minute corrections difficult and expensive 4. Proofing expensive
SCREEN PRINTING	1. Can print a heavy film of ink 2. Economical for short runs (even below 100 copies) 3. Can print virtually on any material.	1. Difficult to achieve fine detail 2. Low output 3. Drying requirements

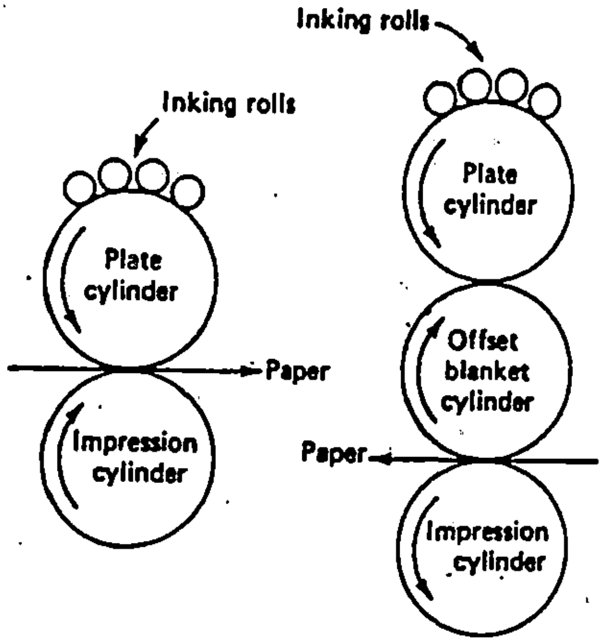


FIGURE 8-5 DIRECT AND INDIRECT (OFFSET) PRINTING[2]

transferred from the image carrier to an intermediate rubber covered blanket cylinder, from which it is transferred to the paper. The image is offset from the image carrier to the blanket, then offset from the blanket to the paper. Most lithography is printed indirectly and therefore lithography is usually referred to as *offset printing.*

Some advantages of offset printing over direct printing from plate to paper are:

- Offset printing uses an intermediate rubber covered blanket cylinder. The rubber blanket conforms better to the surface variations of the paper than a metal plate. Therefore, offset printing produces a sharper image than direct printing.
- If the images go directly from plate-to-paper, they would have to be backwards on the plate. In offset printing, the images go from plate-to-blanket, then blanket-to-paper. The images on the plate are right reading, they can be read directly, for offset printing. Right reading plates are easy to proof read.
- The delicate lithoplate comes in contact with the rubber blanket instead of the paper surface thereby increasing the useful life of the plate.
- Less water comes in contact with paper which results in less smudging.

All printing processes require the paper to be either *sheet-fed* or *web-fed.* In the sheet-fed process, the paper is cut into sheets of the right size before being printed. In the web-fed process, the paper is supplied to the machine in the form of rolls. At the end of the printing process, the rolls are folded and/or cut into sheets.Figure 8-6 illustrates the web-fed and sheet-fed processes.

The advantages of web-fed printing over sheet-fed printing are speed and cost. Folding can be done at the same time as printing and paper on rolls is cheaper than paper in sheets. On the other hand, web-fed printing requires more make-ready time, including time to set up the press to accept the size and thickness of the rolls and to adjust the color.

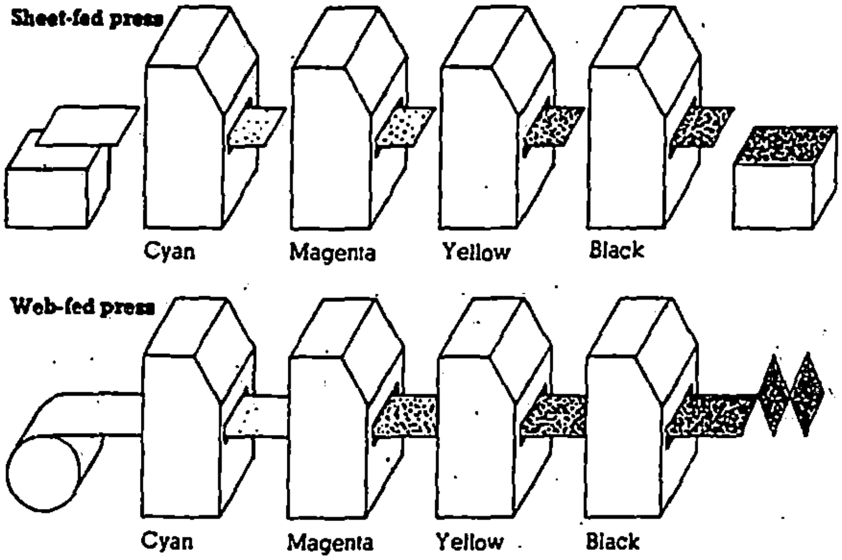


FIGURE 8-6 WEB-FED AND SHEET-FED PRESS [1]

This section of the Permit Processing Handbook will give a general description of the *offset lithographic sheet-fed* and *web-fed* printing processes and address the District Rules and Regulations related to these processes.

Lithographic sheet-fed presses are categorized by size. Small sheet-fed presses are machines used by instant printers and small local printers. The machines print sheets up to 14 x 17 inches in size. Some of the manufacturers of small sheet-fed presses are A.B. Dick, Chief, Davidson, and Multilith.

Medium sheet-fed presses are machines that print on paper up to 25 x 38 inches in size. Most print two or more colors. They are used by medium or large commercial printers for publicity brochures. Some of the manufacturers of medium sheet-fed presses are Harris, Heidelberg, Miller, Solna, Maruka, Komori, and Royal Zenith.

Large sheet-fed presses can run stock anywhere from 12 x 18 to 55 x 78 inches in size. Large sheet-fed presses are very efficient and are used for large jobs. Eight copies of a flier can fit on one plate of a large press. Therefore, a press with a speed of 8000 sheets per hour can print 64,000 fliers in 60 minutes.

Lithographic web-fed presses are categorized not only by size but also by their ability to dry ink. *Non-heatset* or *coldset* presses allow the ink to dry on its own. *Heatset* presses pass the printed paper through dryers before cutting it into sheets. Methods of drying include hot air, gas-flame, ultraviolet and infra-red radiation. Coldset presses can only print on uncoated stock. Heatset presses, on the other hand, can print on coated stock. To achieve high ink gloss on coated stock, heat-set webs require chill rollers that harden the ink.

An offset lithographic press has four basic components: *the feeding and register unit*, *the ink and water unit*, *the printing unit*, and *the delivery unit*. The feeding and register unit delivers paper into the machine and assures that paper is placed under the printing unit at the right position. The ink and water unit conveys liquid to plates. The printing unit transfers the images to the paper. The delivery unit removes and stacks the printed paper. The delivery unit normally includes a system for spraying a fine powder over the paper to inhibit the transferring of wet ink from the front of one sheet to the back of another. Figure 8-7 shows an offset lithographic press.

Since the ink, water and printing unit are important to the printing process, they are described in more details.

8.1.1 Ink Units

Lithographic ink is usually called *paste ink*. Lithographic ink is made of *pigments*, *binders*, *solvents* and various *additives*. *Pigments* are finely solid organic or inorganic compounds which produce colors. *Binders* are organic resins, oils or polymers which lock the pigments to the paper. *Solvents* are organic compounds that dissolve and disperse the pigments and binders. The combination of binders and solvents is called the *vehicle*. To impart special characteristics to inks, *additives* such as driers, waxes, lubricants, or reducing oils are used. Driers act as catalysts which accelerate the hardening of the vehicle after printing. Waxes are used to prevent setoff and sheet sticking. Lubricants help the ink to distribute and transfer properly. Reducing oils aid penetration and rapid setting.

The compositions of lithographic inks vary, but most inks contains special oils which are characterized by high viscosities, low vapor pressures and high boiling points. Typical lithographic oils include linseed oil, rosin oil, petroleum oils, and high boiling point petroleum solvents. These oils are treated to develop the special properties required for lithographic inks. Magie oil is a well known name of the lithographic oils produced by one oil manufacturer. For more information regarding lithographic inks, refer to Reference 4 and Reference 11.

The *ink unit* contains mainly the ink fountain and the ink rollers. The number of fountains and rollers varies with the press size. A small press has only one ink fountain, while a large press may have up to eight ink fountains. The ink fountain serves as a reservoir of ink. The ink rollers serve as the ink distribution system. The system must perform the following functions: (1) "work" the ink from the gel-like consistency to a semi-liquid state; (2) distribute an even thin film of ink around all

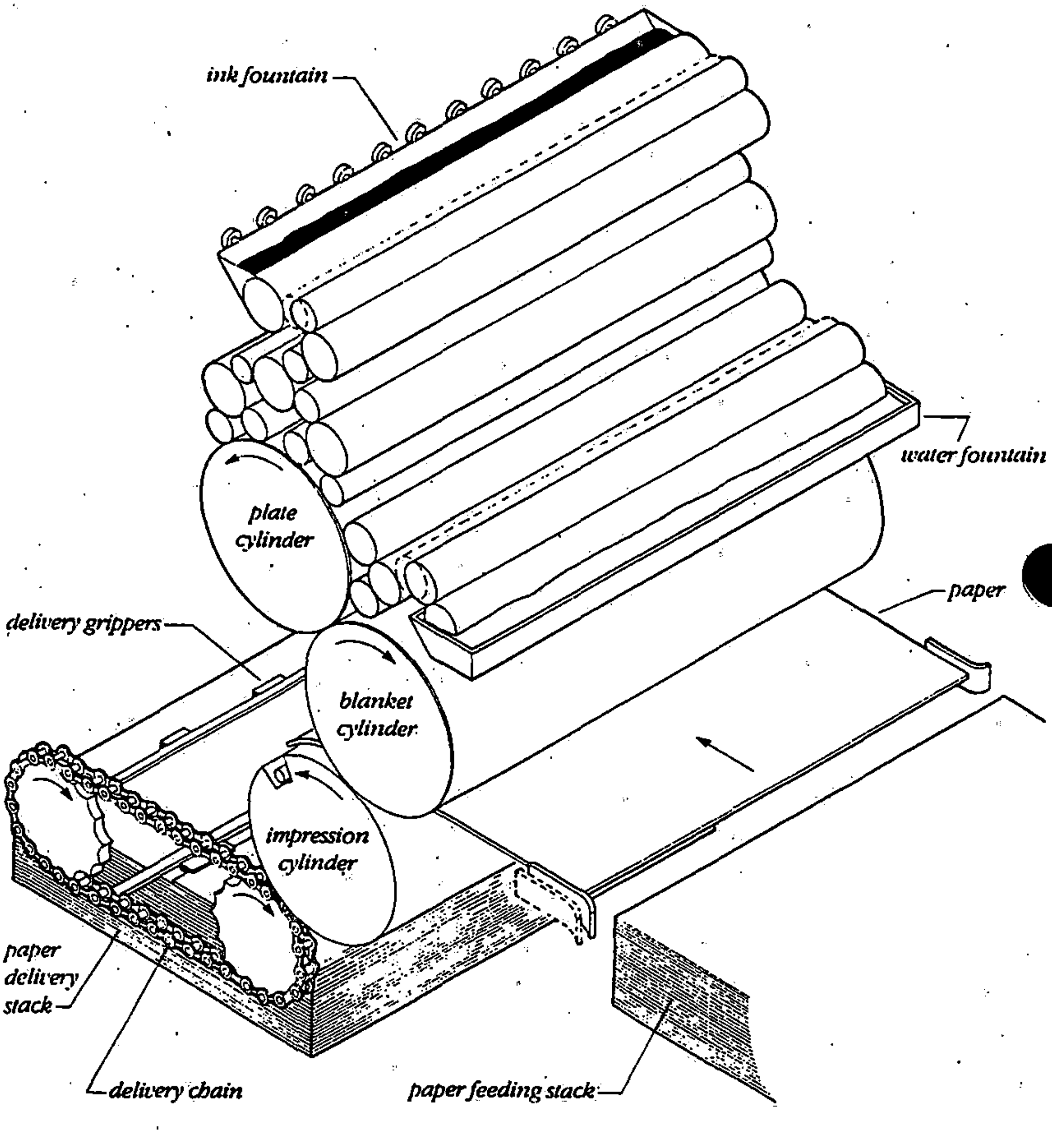


FIGURE 8-7 OFFSET PRINTING PRESS [3]

of the rollers; (3) deposit an uniformly thin film of ink on the image areas of the plate; (4) pick up fountain solution from the image plate and emulsify some of it into the ink; and (5) pick up loose particles of foreign matter from the image plate, and hold them in suspension until the entire system is cleaned.

8.1.2 Water Units

In the lithographic printing process, as mentioned earlier, the image areas of the plate are hydrophobic (not receptive to water) and the non-image areas are hydrophilic (receptive to water). To maintain these properties, the image areas must be wetted with ink and the non-image areas must be wetted with water simultaneously during the process. The application of water, however, leads to the formation of a water-in-ink emulsion on the image areas. If too much water is applied to the plate, watermarks occur and the print becomes washed out in appearance. The craft of offset printing depends heavily on maintaining proper balance between ink and water.

The water used usually contains additional ingredients such as an etchant (usually phosphoric acid) to maintain acidity, gum arabic, and a dampening aid (such as isopropyl alcohol). Press operators refer to this mixture as the *dampening solution.* The SCAQMD refers to it as the *fountain solution.* Isopropyl alcohol as a dampening aid provides excellent characteristics to the fountain solution, but it has a normal boiling point of 180 ^{O}F and readily evaporates in the pressroom. Low volatility organic compounds with normal boiling point above 300 ^{O}F can also be used in place of isopropyl alcohol. In this case, insignificant amounts of these compounds will evaporate in the pressroom at the pressroom conditions.

The *water unit* basically contains rollers to deliver water to the image plate in a similar way that ink is delivered to the plate. The rollers used in the water unit are sometimes referred to as the fountain rollers to distinguish them from the ink rollers. Occasionally, the water unit and the ink unit share the same rollers.

8.1.3 Printing Units

Lithographic presses are generally rotary presses. Basically, a rotary press consists of a *plate cylinder*, an *offset blanket cylinder*, and an *impression cylinder*.

The plate cylinder, which has a curved, flexible metal or plastic plate around it, first revolves against fountain rollers to wet the non-image areas; then revolve against ink rollers allowing the ink to adhere to the image areas; and finally makes an impression on the blanket cylinder. The standard blanket cylinder has a three-ply fabric base. On the surface of the blanket is a rubber coat held under a certain tension. The blanket cylinder receives ink from the image areas of the plate cylinder, and transfers ink to the paper which is pressed against it by the impression cylinder.

Presses may have one or more printing units depending on the number of colors they will print. A press with four printing units is referred to as a four-color press. Some presses print both sides of the paper simultaneously as the paper travels between the two blanket cylinders, others automatically turn the paper over to print on the other side. A press that can print both sides of the paper simultaneously is called *blanket-to-blanket* press. The blanket-to-blanket press, as shown in Figure 8-8, may not have an impression cylinder. Each blanket cylinder acts as an impression cylinder for the other. Figure 8-9 is a schematic of the entire lithographic printing process.

After printing, the rollers and the blanket are washed with the cleanup solution. The blanket is cleaned by hand-wiping with rags which have been wetted with the blanket wash. The soft rubber blanket has a tendency to absorb a portion of the solvent when it is cleaned. This residual solvent on the blanket is then absorbed by the paper which is then subsequently vaporized. The remaining of solvent is retained in the cleaning rags. The rags are placed in sealed drums and sent out for solvent reclamation after usage. There are also solvents which are used primarily as an agent to promote rapid drying and restoration of the wet blanket. These solvents usually have low boiling points and therefore readily evaporate at ambient temperature.

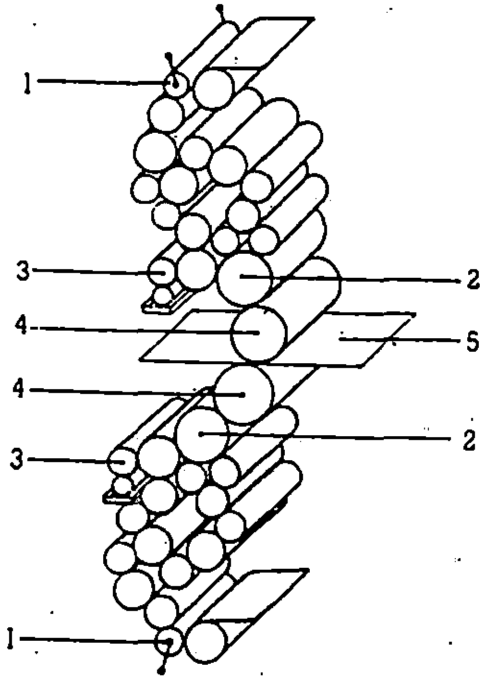


FIGURE 8-8 BLANKET-TO-BLANKET PRINTING [1]

(1) Inking rollers, (2) Plate cylinder,
(3) Dampening rollers, (4) Blanket cylinder, (5) Paper.

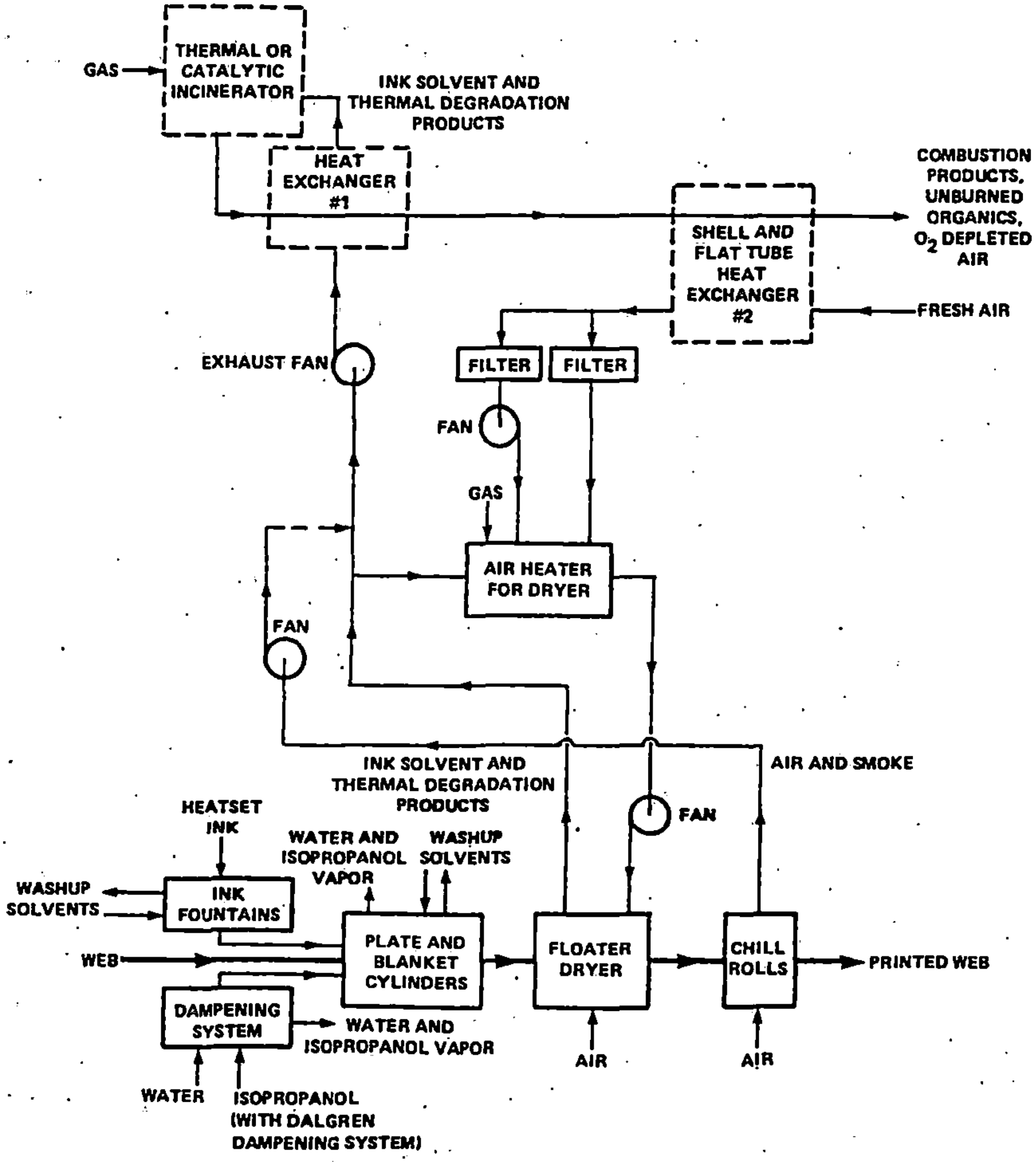


FIGURE 8-9 WEB-OFFSET LITHOGRAPHY PUBLICATION PRINTING LINE [5]

To clean the ink rollers, solvent is squirted from a plastic bottle onto the smooth steel surfaces of the rollers. The solvent softens and dissolves the ink. The ink and solvent mixture is then scraped off the rollers with a wide blade and collected in the wash up tray below. The waste material in the tray is put into the steel drums and handled as a liquid waste. This cleaning process takes only five to ten minutes. Since the steel ink rollers are non-absorptive, only a negligible amount of solvent reaches the dryer.

A company may use various types of cleanup solvents. R.R. Donneley & Sons Company, for example, has used three kinds of cleanup solvents: Chevron 325 Solvent (Stoddard Solvent) is used to clean the ink rollers. Graphic Chemical GC-12 is used to clean the blankets, and Chevron Thinner 225 (Lacquer Diluent) is used to dry the blanket after cleaning. [13]

Table 8-2 summarizes properties of lithographic ink for eleven use classifications.

8.2 Permit Unit Description

LITHOGRAPHIC PRINTING PRESS SYSTEM CONSISTING OF:

1. LITHOGRAPHIC PRINTING PRESS, MANUFACTURER'S NAME, (WEB-FED)(SHEET-FED)(BLANKET-TO-BLANKET)(OFFSET), MODEL NO, (WEB)(SHEET) WIDTH, SERIAL NO, TOTAL HORSE POWER.

2. OVEN, MANUFACTURER'S NAME, MODEL NO, SERIAL NO. DIMENSIONS (WIDTH, LENGTH, HEIGHT), RATING IN BTU PER HOUR, (GAS FIRED)(OIL FIRED)(ELECTRICALLY HEATED), WITH AIR BLOWER(S), HORSE POWER EACH, AND/OR SUPPLY FAN(S), HORSE POWER EACH.

TABLE 8-2 COMMON PROPERTIES OF LITHOGRAPHIC INKS [4]

USE CLASSIFICATIONS	DRYING MANNER	STOCK FEED	INK CONSISTENCY	APPROXIMATE PRINTING SPEED	TYPICAL VEHICLE COMPOSITIC
News (papers & comics)	HS	Web-fed	Liquid-medium	300-450 m/min	Min oil, res-S-O
Publications (magazines, periodicals)	HS,QS,uv	Web-fed	Soft-medium	300-370 m/min	res-S-O, acr
		Sheet-fed		3500-7500 sph	
Commercial (display, document pamphlet; label)	QS,Ox,ir,uv	Sheet-fed	Medium	3500-7500 sph	res-O-S, acr
Business documents and forms	QS, HS, ir	Sheet-fed	Medium	2000-4000 sph	res-S-O
	Web-fed			10-180m/min	res-O-S-min. oil
Folding cartoons (food, soap drug, detergents)	QS, Ox, uv	Sheet-fed	Medium-heavy	3500-8000 sph	res-O-S, acr
Containers and boxes	Ox, MS, pen, FW	Sheet-fed	Medium-heavy	2500-5000 sph	res-O, res-G
Books	Ox, pen	Sheet-fed	Soft-medium	2000-7000 sph	res-O-S
		Web-fed		120-240 m/min	res-min.oil-S
Bags (paper, cloth, plastic)	HS, Ox, MS	Web-fed	Medium	80-180 m/min	res-S-O, res-O, res-
Wrappers	MS, HS	Web-fed	Medium	120-240 m/min	res-G, res-S
Metal containers	HC, uv	Sheet-fed	Medium-heavy	2000-5000 sph	alkyd-S, res-O-S,
		pr. can		100-500 cpm	alkyd-amines-S, acr
Plastic (cups, book covers)	HS, Ox, uv	pr. can	Medium-heavy	100-200 cpm	res-S, res-O-S, acr
		sheet-fed		2000-4000 sph	

ABBREVIATIONS: pen = penetration, HS = heat-set, ir = infrared, Ox = oxidation, QS = quick-set, FW = fiber wetting, MS = moisture set, uv = ultraviolet, HC = heat cure, pre.can = preformed can, sph = sheets per hour, cpm = container per minute, min.oil = mineral oil, res = resin, S = solvent, O = oil, G = glycol

8.3 Emissions

Emissions from printing operations consist primarily of reactive organic gases (ROG). The emissions vary with the printing process, ink formulation, coverage, press size and speed, and the operating time. The type of paper (coated or non-coated) has little effect on the quantity of emissions.

Emission points from the web-offset lithographic printing presses include the ink and water unit, the printing unit, the drying oven (if used), the chill rolls (if used), and the products themselves.

8.4 Calculations

8.4.1 Operational Data

In order to determine the compliance status of the lithographic printing press, the applicant is required to provide the following information:

8.4.1.1 Ink

For each type of ink used, the following information is required:

Daily consumption	gal/day
Type of solvent used	________
Solvent content	lb/gal less water and/or exempt solvent; OR lb/gal including water and/or exempt solvent; OR % by volume (or weight) including water and/or exempt solvent
Ink and Solvent density	lb/gal

8.4.1.2 Fountain Solution

For each type of fountain solution, the following information is required:

Daily consumption	gal/day
Type of solvent used	______
Solvent content	% by volume including water and/or exempt solvent
Solvent density	lb/gal

8.4.1.3 Wash Solution

For each type of wash solution used, the following information is required:

Daily consumption	gal/day
Type of solvent used	______
Solvent content	% by volume including water and/or exempt solvent
Solvent density	lb/gal

8.4.2 Emission Calculations

The total ROG emission is calculated based on Equation 8.1:

$$R_{Total} = R_{ink} + R_{ws} + R_{fs} \qquad \textbf{(Equation 8.1)}$$

where

R_{Total} = Total solvent emission, lb/day

R_{ink} = Total solvent emission from ink, lb/day

R_{ws} = Total solvent emission from wash solution, lb/day

R_{fs} = Total solvent emission from fountain solution, lb/day

$$R_{ink} = \sum_{i} C_i G_i D_i (F_{p,i} + F_{d,i}(1 - EFF)) \qquad \textbf{(Equation 8.2)}$$

where

i = Type of ink

C_i = Solvent content, fraction by weight

G_i = Ink consumption, gal/day
D_i = Ink density, lb/gal
$F_{p,i}$ = Fraction by weight of solvent evaporated in the pressroom
$F_{d,i}$ = Fraction by weight of solvent evaporated in the dryer
EFF = Efficiency of the control device, fraction

Little quantitative information is available for the percentage of ink solvent retained on the web, the percentage of ink solvent evaporated in the pressroom, and the percentage of ink solvent evaporated in the dryer (if used). For a heatset web offset lithographic printing operation, the EPA recommends the following distribution factors:[8]

20	%	retained on the web
80	%	evaporated in the drying oven
0	%	evaporated in the pressroom

The distribution factors recommended by the EPA, however, are still in the review stage. Extensive source testing using various types of ink solvents on a variety of substrates needs to be conducted to determine the accuracy of these values. Until such data are available, the SCAQMD will use the values listed in Table 8-3 to estimate the emissions in the pressroom associated with the lithographic oils in the lithographic ink unless more specific information is available on the case by case basis.

TABLE 8-3 EMISSION FACTORS FOR LITHOGRAPHIC OILS CONTAINED IN LITHOGRAPHIC PRINTING INKS[12]

EMISSION FACTOR
(Percent of Lithographic Oil by Weight)

PRINTING OPERATION	COLD SET	HEAT SET UV/IR	HEAT SET GAS/ELECTRIC
Sheet Fed	10	50	80
Web Fed	10	50	80

If the lithographic ink contains "free" solvents as well as the lithographic oils, usually all of the "free" solvents will be evaporated in the pressroom. The lithographic oils evaporated in a heatset operation may be controlled by an afterburner. In this case the efficiency of the afterburner will be used to reduce these uncontrolled emissions.[12]

$$R_{fs} = \sum_{j} C_j G_j D_j (F_{d,j}(1 - EFF) + F_{p,j}) \qquad \textbf{(Equation 8.3)}$$

where

j = Type of fountain solution
C_j = Solvent content, fraction by volume
G_j = Fountain solution consumption, gal/day
D_j = Solvent density, lb/gal
$F_{d,j}$ = Fraction by weight of solvent evaporated in the dryer
$F_{p,j}$ = Fraction by weight of solvent evaporated in the pressroom
EFF = Efficiency of the control device, fraction

Little information is available on the distribution of fountain solution. The SCAQMD assumes the following distribution:

0	%	retained on the web
100	%	evaporated in the pressroom

For a heatset web offset lithographic printing operation, the EPA recommends the following distribution:[8]

50	%	evaporated in the drying oven
50	%	evaporated in the pressroom

The 50% of the solvent evaporated in the dryer can be controlled by an afterburner.

$$R_{ws} = \sum_{b,r} C_b G_b D_b F_{p,b} + C_r G_r D_r F_{p,r} \qquad \textbf{(Equation 8.4)}$$

where

b = Type of blanket wash solution

r = Type of rollers/trays wash solution

C_b, C_r = Solvent content, fraction by volume

G_b, G_r = Wash solution consumption, gal/day

D_b, D_r = Solvent density, lb/gal

$F_{p,b}, F_{p,r}$ = Fraction of the wash solvent evaporated in the pressroom

Unless specific information is available on a case by case basis, the SCAQMD will assume that all of the wash solvents will evaporate in the pressroom. The amount of blanket wash solvents retained on the cleaning rags for reclamation will be considered if there are extensive supporting records.

8.4.3 Equivalency Calculations

Equivalency or *averaging* allows a facility to average the emissions from the graphic arts materials they are using that fall well below the limit of the rule with the graphic arts materials that have ROG content above the limit. [7] The *daily weighted average* for all of these graphic arts materials should exactly meet or better the limit of the rule. [7] The solvent content limit for graphic arts materials, 2.5 lb/gal excluding water and exempt solvents or 25% by volume, is specified in SCAQMD Rule 1130.

Reference 6 and 7 discuss the procedures to calculate equivalency based on the Control Technique Guidelines (CTGs) recommendations for General Surface Coating. This procedure is now used in this section to calculate the average solvent content, in pounds per gallon excluding water and exempt solvents, for the offset printing presses. The term *coating* used in Reference 6 and 7 is understood as *graphic arts materials* for this section.

References 6 and 7 state that there is a misconception in an equivalency calculation to simply average the reactive organic gases of the graphic arts materials used assuming that an equal volume of graphic arts materials will be required to cover a given area regardless of the amount of solids in the graphic arts materials.

An example is taken from Reference 7 to illustrate this point. Two types of graphic arts materials are used, the non-compliant type A and the compliant type B. The type A usage is 2 gal/day with ROG content of 4.5 lb/gal less water. The type B usage is 5 gal/day with ROG content of 1.5 lb/gal less water. Assuming that an equal volume will be required to cover a same given area, the average ROG content is calculated as follows:

(2 gal)(4.5 lb/gal) = 9.0 lb/gal
(5 gal)(1.5 lb/gal) = 7.5 lb/gal

Therefore, the average ROG content is (16.5/7) = 2.36 lb/gal. One might then compare 2.36 lb/gal with the ROG content limit to determine compliance. This method, however, is not acceptable. The proper procedures for calculating equivalency must take solids content of both type A and B into consideration. An example is taken from Reference 6 to illustrate this point.

Current graphic arts materials

Given:

1.	Solvent content:	5.90 lb/gal less water
2.	Solvent density:	7.36 lb/gal
3.	Daily usage:	300 gals

Calculate:

4. Volume percent solvent:
   ((5.9 lb/gal)/(7.36 lb/gal))100 = 80%
5. Volume percent solids:
   (100 - 80) = 20%
6. Volume of solids applied daily:
   (300 gal/day)(20%) = 60 gal/day
   The key item is that 60 gallons of solids are applied daily. This is assumed to remain constant.
7. Volume of solvent used daily:
   (300 gal/day)(80%) = 240 gal/day
8. Mass of solvent used daily:
   (240 gal/day)(7.36 lb/gal) = 1766 lb/day

Compliant graphic arts materials

Given:

9. Solvent content: 3.00 lb/gal less water
10. Solvent density: 7.36 lb/gal
11. Required daily solids usage (as determined in Item 6): 60 gals

Calculate:

12. Volume percent solvent:
    ((3 lb/gal)/(7.36 lb/gal))100 = 40%
13. Volume percent solids:
    (100 - 40) = 60%
14. Volume of compliant graphic arts materials to meet daily solids requirement:
    (60 gal/day solids)/(60%) = 100 gal/day
15. Volume of solvent in daily required gallons of compliant graphic arts materials:
    (100 gal/day solids)(40%) = 40 gal/day
16. Mass of solvent in daily required gallons of graphic arts materials:
    (40 gal/day)(7.36 lb/gal) = 294 lb/day
17. Required percent reduction from add-on control:
    ((1766 - 294)/1766)(100) = 83%

8.5 Rules Evaluation

The District Rules and Regulations applicable for offset lithographic press are: Rule 212, 401, 402, 442, 1130, and Regulation XIII. ^{9}

Rule 212 - Standards For Approving Permits

Section (e) of this Rule requires public notification of certain cases be made prior to issuing the permit.

Rule 401 - Visible Emissions

No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance

Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 442 - Solvent Usage

The use of cleanup solvents is controlled by either Rule 442(f) or by Rule 1130. If the printing press is subject to Rule 1130, the requirements of Rule 1130 will preempt the requirements of Rule 442(f).

Rule 442(f) requires the press operator to use the non-photochemically reactive cleanup solvents or to reduce the emissions from any photochemically reactive solvents by at least 85% by weight. A photochemically reactive solvent is defined in Rule 102.

Rule 1130 - Graphic Arts

A person shall not operate any graphic arts process on porous substrate, excluding detergent packages, or on non-porous substrate, including detergent packages, unless one of the following conditions is satisfied at all times:

(a) Use only low-solvent graphic arts materials. Low solvent graphic arts material contains less than 2.5 lb/gal of ROG excluding water and/or exempt solvents, or contains no more than 25 % ROG on a volume basis determined by the procedure outlined in Rule 107; <u>OR</u>

(b) Install and operate on the line an approved emission control system capable of reducing ROG emissions by at least 90 percent on a mass basis; <u>OR</u>

(c) Show compliance by equivalency by reducing emissions from the graphic arts lines of the whole facility such that the total emissions using high- and low-solvent graphic arts materials when combined are equivalent to the emissions that would result when low-solvent graphic arts materials are used.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[10] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case. Table 8-4 and 8-5 list the current BACT for lithographic printing presses.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

TABLE 8-4 BEST AVAILABLE CONTROL TECHNOLOGY (BACT) FOR LITHOGRAPHIC OR OFFSET PRINTING - HEATSET PROCESS [10]

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]	No VOC Fountain Solution, Low VOC (< 3% by Vol. VOC as determined by Rule 107) Blanket Wash, Low VOC (< 3% by Vol. as determined by Rule 107) Roller, Tray and Miscellaneous Equipment Wash, and Kerosene-like Oil Based Inks				Oven Venting to an Afterburner (≥ 0.3 Sec. Retention Time at ≥ 1400 °F; 90% Overall Efficiency) with Ink Usage at ≤ 95 lbs/day
BACT Achieved in Practice or Contained in EPA Approved SIP[2]	Low VOC Fountain Solution (<12% by Vol. VOC as Determined by Rule 107), Minimum Possible VOC Blanket Wash and Roller and Tray Washes, and Kerosene-like Oil Based Inks				Oven Venting to an Afterburner (≥ 0.3 Sec. Retention Time at ≥ 1400 °F; 90% Overall Efficiency) with Ink Usage at > 95 lbs/day

1. Requires Economic Analysis
2. No Economic Analysis

TABLE 8-4 BEST AVAILABLE CONTROL TECHNOLOGY (BACT) FOR LITHOGRAPHIC OR OFFSET PRINTING - HEATSET PROCESS[10]

	ROG	NOx	SOx	CO	PART.
BACT For Small Business[1,3]	1. No VOC Fountain Solution, Low VOC (< 3% Vol. VOC as Determined by Rule 107) Blanket Wash, Low VOC (< 3% by Vol. as Determined by Rule 107) Roller, Tray and Miscellaneous Equipment Wash, and Kerosene-like Oil based by Vol. VOC), Minimum Possible VOC Blanket Wash, Roller and Tray Washes, and Kerosene-like Oil Based Inks. 2. Low VOC Fountain Solution (< 12% by Vol. VOC as Determined by Rule 107), Minimum Possible VOC Blanket Wash, Roller and Tray Washes, and Kerosene-like Oil Based Inks				Oven Venting to an Afterburner (≥ 0.3 Sec. Retention Time at ≥ 1400 °F; 90% Overall Efficiency) with Ink Usage at > 95 lbs/day
Alternate Basic Equipment or Process[1]					

1. Requires Economic Analysis
2. No Economic Analysis
3. Control technologies are in descending order of efficiency. The most efficient control technology must be considered first when conducting an economic analysis.

TABLE 8-5 BEST AVAILABLE CONTROL TECHNOLOGY (BACT) FOR LITHOGRAPHIC OR OFFSET PRINTING - NON-HEATSET PROCESS [10]

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]	No VOC Fountain Solution, Low VOC (< 3% by Vol. VOC as determined by Rule 107) Blanket Wash, Low VOC (< 3% by Vol. as determined by Rule 107) Roller, Tray and Miscellaneous Equipment Wash, and Kerosene-like Oil Based Inks				
BACT Achieved in Practice or Contained in EPA Approved SIP[2]	Low VOC Fountain Solution (<12% by Vol. VOC as Determined by Rule 107), Minimum Possible VOC Blanket Wash and Roller and Tray Washes, and Kerosene-like Oil Based Inks				

1. Requires Economic Analysis
2. No Economic Analysis

TABLE 8-5 BEST AVAILABLE CONTROL TECHNOLOGY (BACT) FOR LITHOGRAPHIC OR OFFSET PRINTING - NON-HEATSET PROCESS[10]

	ROG	NOx	SOx	CO	PART.
BACT For Small Business[1,3]	1. No VOC Fountain Solution, Low VOC (< 3% Vol. VOC as Determined by Rule 107) Blanket Wash, Low VOC (< 3% by Vol. as Determined by Rule 107) Roller, Tray and Miscellaneous Equipment Wash, and Kerosene-like Oil based by Vol. VOC), Minimum Possible VOC Blanket Wash, Roller and Tray Washes, and Kerosene-like Oil Based Inks. 2. Low VOC Fountain Solution (< 12% by Vol. VOC as Determined by Rule 107), Minimum Possible VOC Blanket Wash, Roller and Tray Washes, and Kerosene-like Oil Based Inks				
Alternate Basic Equipment or Process[1]					

---

1. Requires Economic Analysis
2. No Economic Analysis
3. Control technologies are in descending order of efficiency. The most efficient control technology must be considered first when conducting an economic analysis.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

8.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, Permit (Operating) Conditions must be required. Permit (Operating) Conditions are listed in Appendix 8B.

REFERENCES

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3. M. Beach, S.Shepro, K. Russon, Getting It Printed, Coast to Coast Books, 1986.

4. Encyclopedia Of Chemical Technology, Volume 13, Third Edition, 1982, John Wiley & Sons, Inks, pp 374 - 398.

5. Compilation of Air Pollutant Emission Factors, AP 42, Section 4.9, Graphic Arts, 4th Edition, 1985.

6. Procedure To Calculate Equivalency With The CTG Recommendations For Surface Coating, Transmittal Notice 82-80-TD, Dated 23/5/80, from Chief, Air Planning Branch, Air & Hazardous Materials Division, to State Air pollution Agencies and Air Pollution Control Districts.

7. Getting Into Compliance With California's Air Pollution Laws For Industrial Coatings. A Manual of Laws, Coating Technologies And Available Coatings, Ron Joseph & Associates, Inc., Coating Consultants.

8. Control Of Volatile Organic Compound Emissions From Full-Web Process-Color Heatset Web Offset Lithographic Printing - Draft - EPA Guideline Series - August 1981.

9. Rules and Regulations, South Coast Air Quality Management District (SCAQMD).
   Rule 212, Standard for Approving Permit, Amended March 3, 1989.
   Rule 219, Equipment Not Requiring A Written Permit Pursuant to Regulation II, Amended June 3, 1988.
   Rule 401, Visible Emissions, Amended April 7, 1989.
   Rule 402, Nuisance, Adopted May 7, 1976.
   Rule 442, Solvent Usage, Amended March 5, 1982.
   Rule 1130, Graphic Arts, Amended May 5, 1989.
   Regulation XIII, New Source Review, Amended September 5, 1986.

10. South Coast Air Quality Management District (SCAQMD) Best Available Control Technology (BACT) Guideline, October 7, 1988.

11. Printing Ink Handbook, National Association of Printing Ink Manufacturers, Inc., 4th Edition, 1980.

12. Memorandum from Fred E. Lettice, Supervisor Air Quality Engineer, to the General Coatings Unit, South Coast Air Quality Management District, Engineering Division, Subject "Emission Factors for Lithographic Printing Inks", October 27th, 1988.

13. R. R. Donneley & Sons Company, Permit to Operate Number M36593, Application Number 110762, Company Identification Number 003585.

APPENDIX 8A

WORKSHEET

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 4	PAGE 1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

Applicability: This permit application form applies only to offset lithographic printing presses

APPLICANT'S NAME

MAILING ADDRESS

EQUIPMENT ADDRESS

EQUIPMENT DESCRIPTION

APPLICATION NO.

LITHOGRAPHIC PRINTING PRESS SYSTEM CONSISTING OF:

1. LITHOGRAPHIC PRINTING PRESS, , (WEB-FED)(SHEET-FED)(BLANKET-TO-BLANKET)(OFFSET), MODEL NO. , (WEB)(SHEET) WIDTH ", SERIAL NO. , H.P.
2. OVEN, , MODEL NO. , SERIAL NO. , '- " W., '- " L., '- " H., BTU/HR, (GAS FIRED)(OIL FIRED)(ELECTRICALLY HEATED) WITH AIR BLOWER(S), H.P. EACH, AND SUPPLY FAN(S), H.P. EACH.

HISTORY

CALCULATION

Data given by the applicant:

(1) Ink Type		____	____	____	____
Solvent content (lb/gal w/o water&exempt solvents) (% by vol)		____	____	____	____
Solvent density	(lb/gal)	____	____	____	____
Ink density	(lb/gal)	____	____	____	____
Daily consumption	(gal/day)	____	____	____	____

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 4	PAGE 2
APPL NO.	DATE
PROCESSED BY	CHECKED BY

(2) Fountain Solution Name ____ ____ ____ ____
Solvent content (% by vol) ____ ____ ____ ____
Solvent density (lb/gal) ____ ____ ____ ____
Daily consumption (gal/day) ____ ____ ____ ____

(3) Wash Solution Name ____ ____ ____ ____
Solvent content (% by vol) ____ ____ ____ ____
Solvent density (lb/gal) ____ ____ ____ ____
Daily consumption (gal/day) ____ ____ ____ ____

(4) Operation Schedule: ____ hr/day, ____ day/wk, ____ wk/yr

(5) Fraction Distribution:

Type	Ink	Rollers Or Trays Wash	Blanket Wash	Fountain Solution
Retained on the web	____	____	____	____
Evaporated in the dryer	____	____	____	____
Evaporated in the pressroom	____	____	____	____

(6). Afterburner Efficiency ____ %

The total emission is calculated based on Equation 8.1, 8.2, 8.3, and 8.4 using the basic program "Emission" in Appendix 8D. The input and output are attached below. The equivalency calculation is performed using the basic program "Litho" in Appendix 8C. The input and output are attached below.

RULES EVALUATION

RULE 401 With proper maintenance and operation, this equipment (is not)(is) expected to violate Rule 401.

RULE 402 Nuisance complaints (are not)(are) expected.

RULE 442

☐ Since this equipment is not exempt from Rule 1130, the cleanup solvent(s) used by this equipment are not subject to Rule 442.

☐ Since this equipment is exempt from Rule 1130, the cleanup solvent(s) used by this equipment are subject to Rule 442. To comply with Rule 442, the cleanup solvent(s) must be non-photochemically reactive OR the emission of ROG must be reduced by at least 85% by weight.

RULE 1130

☐ The total ROG emissions from this equipment is less than 20 lb/day. Therefore, this equipment is exempt from Rule 1130 per Section 1130(g)(2).

☐ The solvent content of ink, fountain solution and cleaning solution are either less than 2.5 lb/gal less water or no more than 25% by volume. Therefore, this equipment meets the requirement of Rule 1130 per Section 1130(b).

☐ The average solvent content of ink, fountain solution, and cleaning solution when combined is less than 25% by volume. Therefore, this equipment meets the requirement of Rule 1130 per Section 1130(c)(1).

REGULATION XIII

[] The new or modified equipment has an increase in ROG emission more than 1 lb/day, therefore BACT is required.

[] Since the net emission increase from the facility exceeds the threshold limit specified in 1303(a)(2), the following steps are required in addition to BACT:

- () The company must obtain offsets from other facilities.
- () The company must certify in writing that all of its facilities in the state that emit 25 tons per year or more of ROG comply with federal, state, and local air quality laws.

CONCLUSIONS/RECOMMENDATIONS

This equipment (is)(is not) expected to comply with all applicable District Rules and Regulations. Therefore, the following disposition is recommended:

( ) Issue a Permit to Construct/Operate subject to the following conditions: (Refer to Appendix 8B for the wording of conditions).

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ____________________ of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 8B

OPERATING CONDITIONS

1. ORGANIC SOLVENTS USED BY THIS EQUIPMENT MUST BE CLEARLY LABELED AS NON-PHOTOCHEMICALLY REACTIVE BY THE SUPPLIER OR, FOR BULK SHIPMENTS, SHOWN TO BE NON-PHOTOCHEMICALLY REACTIVE ON BILLS OF LADING OR INVOICES.

2. THIS EQUIPMENT COMPLIES WITH RULE 1130 BY EQUIVALENCY.

3. THE TOTAL QUANTITY OF SOLVENTS AND INKS USED IN THIS EQUIPMENT MUST NOT EXCEED _____ GALLONS IN ANY ONE DAY OR _____ GALLONS IN ANY ONE HOUR.

4. THE TOTAL QUANTITY OF CLEAN-UP SOLVENTS USED IN THIS EQUIPMENT MUST NOT EXCEED _____ GALLONS IN ANY ONE DAY OR _____ GALLONS IN ANY ONE HOUR, AND MUST BE NON-PHOTOCHEMICALLY REACTIVE.

5. THE TOTAL QUANTITY OF SOLVENTS AND INKS USED AT THIS PLANT MUST NOT EXCEED _____ GALLONS IN ANY ONE DAY OR _____ GALLONS IN ANY ONE HOUR.

6. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS (IT)(THE) _________________ (IS)(ARE) VENTED ONLY TO AN AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO (CONSTRUCT)(OPERATE) BY THE EXECUTIVE OFFICER

7. ADEQUATE RECORDS MUST BE MAINTAINED TO VERIFY DAILY USAGE IN A FORMAT APPROVED BY THE DIRECTOR OF ENFORCEMENT, KEPT ON FILE FOR THE MINIMUM OF TWO YEARS, AND MADE AVAILABLE UPON REQUEST BY AUTHORIZED DISTRICT PERSONNEL.

APPENDIX 8C

COMPUTER PROGRAM TO DETERMINE OF COMPLIANCE BASED ON EQUIVALENCY METHOD

Litho program is coded in Fortran with the following variables:

C1(I)	=	Solvent content	lb/gal less water and/or exempt solvents, or % by vol
C2(I)	=	Solids content	% by vol
CM	=	Compliant solvent content	2.5 lb/gal less water and/or exempt solvents,or 25% by vol
CM1(I)	=	Compliant solvent content	% by vol
CM2(I)	=	Compliant solids content	% by vol
D(I)	=	Solvent density	lb/gal
G(I)	=	Daily consumption of graphic arts materials	gal/day
G1(I)	=	Daily consumption of solvent	gal/day
G2(I)	=	Daily consumption of solids	gal/day
GM	=	Daily consumption of graphic arts materials	% by vol
G1M	=	Daily consumption of compliant solvent	% by vol
L1(I)	=	Daily consumption of solvent	lb/day
L2(I)	=	Daily consumption of solids	lb/day
LM(I)	=	Daily consumption of compliant solvent	lb/day
LT	=	Total consumption of current solvents	lb/day
LTM	=	Total consumption of compliant solvents	lb/day
N	=	Choice of unit for current solvent content N = 1 for unit in lb/gal N = 2 for unit in % by vol	
M	=	Choice of unit for compliant solvent content M = 1 for unit in lb/gal M = 2 for unit in % by vol	
R	=	Additional percent reduction	%
T	=	Total number of solvent used	

To verify *Litho* program, a test run is performed with the following input:

T = 2
D(1) = 7.36 lb/gal D(2) = 7.36 lb/gal
CM1(1) = 2.80 lb/gal CM1(2) = 2.80 lb/gal
C1(1) = 4.50 lb/gal C1(2) = 1.50 lb/gal
G1(1) = 5.00 gal/day G1(2) = 7.00 gal/day

Step-by-step hand-calculations are used to check against the computer output:

C1(1) = (4.50 lb/gal/(7.36 lb/gal))100 = 61.14 % by vol
C1(2) = ((1.50 lb/gal/(7.36 lb/gal))100 = 20.38 % by vol
C2(1) = (100 - 61.1413) = 38.86 %
C2(2) = (100 - 20.3804) = 79.62 %
G1(1) = (5 gal/day)(61.1413 %) = 3.06 gal/day
G1(2) = (7 gal/day)(20.3804 %) = 1.43 gal/day
G2(1) = (5 gal/day)(38.8587 %) = 1.94 gal/day
G2(2) = (7 gal/day)(79.6196 %) = 5.57 gal/day
L1(1) = (3.0571 gal/day)(7.36 lb/gal) = 22.50 lb/day
L1(2) = (1.4266 gal/day)(7.36 lb/gal) = 10.50 lb/day
LT = (0 + 22.5003 + 10.4998) = 33.00 lb/day
CM1(1) = ((2.8 lb/gal)/(7.36 lb/gal)100 = 38.04 % by vol
CM1(2) = ((2.3 lb/gal)/(7.36 lb/gal))100 = 31.25 % by vol
CM2(1) = 100 % - 38.0435 % = 61.96 %
CM2(2) = 100 % - 31.2500 % = 68.75 %
GM(1) = (1.9429 gal/day / 61.9565 %) = 3.14 gal/day
GM(2) = (5.5732 gal/day / 68.7500 %) = 8.11 gal/day
G1M(1) = (3.1360 gal/day)(38.0435 %) = 1.19 gal/day
G1M(2) = (8.1065 gal/day)(31.2500 %) = 2.53 gal/day
LM(1) = (1.1930 gal/day)(7.36 lb/gal) = 8.78 lb/day
LM(2) = (2.5333 gal/day)(7.36 lb/gal) = 18.65 lb/day
LTM = 0 + 8.7805 + 18.6450 = 27.43 lb/day
R = ((33.000 - 27.426)/33.0001) 100 = 16.89%

The computer input and output for this example are attached on page 8C-5 to 8C-8.

```
10 '                 ************************************
20 '                 *          LITHO PROGRAM           *
30 '                 ************************************
40 ' ******************************************************************
50 ' * THIS PROGRAM IS USED TO CALCULATE THE TOTAL ROG EMISSION FROM  *
60 ' * GRAPHIC ARTS MATERIALS HAVING DIFFERENT SOLVENT CONTENTS AND   *
70 ' * TO COMPARE THIS TOTAL EMISSION WITH THE TOTAL ROG EMISSION     *
80 ' * FROM THE COMPLIANT GRAPHIC ARTS MATERIALS.                     *
90 ' *                                                                *
100 '* THIS PROGRAM CAN BE USED TO DETERMINE COMPLIANCE WITH RULE 1130*
110 '* FOR LITHOGRAPHIC PRINTING PRESSES USING EQUIVALENCY METHOD.    *
120 '*****************************************************************
130 '
140 DIM G(10), D(10), C1(10), C2(10), G1(10), LM(10)
150 DIM G2(10), L1(10), CM1(10), CM(10), CM2(10), GM(10), G1M(10)
160 '
170 INPUT "INPUT NUMBER OF GRAPHIC ARTS MATERIALS USED, T = "; T
180 PRINT "INPUT CHOICE OF UNIT FOR CURRENT SOLVENT CONTENTS"
190          PRINT "     N = 1 IF USE LB/GAL LESS WATER"
200          PRINT "     N = 2 IF USE % BY VOLUME"
210          INPUT "     N = "; N
220 PRINT "INPUT CHOICE OF UNIT FOR COMPLIANT SOLVENT CONTENTS"
230          PRINT "     M = 1 IF USE LB/GAL LESS WATER"
240          PRINT "     M = 2 IF USE % BY VOLUME"
250          INPUT "     M = "; M
260 PRINT "INPUT COMPLIANT SOLVENT CONTENTS"
270          FOR I = 1 TO T
280                   INPUT "           CM = "; CM(I)
290          NEXT
300 PRINT "INPUT AMOUNT OF CURRENT GRAPHIC ARTS MATERIALS USED"
310          FOR I = 1 TO T
320                   INPUT "            G = "; G(I)
330          NEXT
340 PRINT "INPUT SOLVENT CONTENTS OF CURRENT GRAPHIC ARTS MATERIALS "
350          FOR I = 1 TO T
360                   INPUT "           C1 = "; C1(I)
370          NEXT
380 PRINT "INPUT DENSITIES OF CURRENT GRAPHIC ARTS MATERIALS"
390          FOR I = 1 TO T
400                   INPUT "            D = "; D(I)
410          NEXT
420 GOTO 910
430 '*******************************************************************
440 '*CONVERT SOLVENT CONTENTS FROM LB/GAL LESS WATER TO PERCENT BY VOLUME *
450 '*******************************************************************
460 IF N =2 GOTO 540
470 FOR I = 1 TO T
480        C1(I) =(C1(I)/D(I))*100
490 NEXT
500 '***************************************************************
510 '*CALCULATE AMOUNT OF ROG IN LB/DAY RELEASED USING CURRENT GRAPHIC*
520 '*ARTS MATERIALS                                                 *
530 '***************************************************************
540 LT = 0
550 FOR I = 1 TO T
560        C2(I) = 100-C1(I)
570        G1(I) = G(I)*C1(I)/100
580        G2(I) = G(I)*C2(I)/100
590        L1(I) = G1(I)*D(I)
600        LT = LT + L1(I)
610 NEXT
```

```
620 '*****************************************************************
630 '*CONVERT COMPLIANT SOLVENT CONTENTS FROM LB/GAL LESS WATER TO    *
640 '*PERCENT BY VOLUME                                               *
650 '*****************************************************************
660 IF M =2 GOTO 710
670 FOR I =1 TO T
680         CM1(I) = (CM(I)/D(I))*100
690 NEXT
700 GOTO 780
710 FOR I =1 TO T
720         CM1(I) = CM(I)
730 NEXT
740 '*********************************************************************
750 '*CALCULATE AMOUNT OF ROG IN LB/DAY RELEASED IF USING COMPLIANT GRAPHIC*
760 '*ARTS MATERIALS                                                      *
770 '*********************************************************************
780 LTM = 0
790 FOR I =1 TO T
800         CM2(I) = 100 - CM1(I)
810         GM(I) = G2(I)/(CM2(I)/100)
820         G1M(I) = GM(I)*CM1(I)/100
830         LM(I) = G1M(I) *D(I)
840         LTM = LTM + LM(I)
850 NEXT
860 '******************************************************************
870 '* CALCULATE ADDITIONAL PERCENT REDUCTION REQUIRED                *
880 '******************************************************************
890 R = ((LT -LTM)/LT)*100
900 GOTO 1220
910 LPRINT
920 LPRINT
930 LPRINT "                    **************"
940 LPRINT "                    *   INPUT:   *"
950 LPRINT "                    **************"
960 LPRINT "NUMBER OF GRAPHIC ARTS MATERIALS USED = "; T
970          IF N = 1 GOTO 1000
980          NPRINT$ = "PERCENT BY VOLUME"
990          GOTO 1010
1000         NPRINT$ = "LB/GAL LESS WATER"
1010         IF M = 1 GOTO 1040
1020         MPRINT$ = "PERCENT BY VOLUME"
1030         GOTO 1050
1040         MPRINT$ = "LB/GAL LESS WATER"
1050 LPRINT "COMPLIANT SOLVENT CONTENTS"
1060         FOR I = 1 TO T
1070                 LPRINT "           CM = "; CM(I), MPRINT$
1080         NEXT
1090 LPRINT "CURRENT SOLVENT CONTENTS"
1100         FOR I = 1 TO T
1110                 LPRINT "           C1 = "; C1(I), NPRINT$
1120         NEXT
1130 LPRINT "AMOUNT OF CURRENT GRAPHIC ARTS MATERIALS USED"
1140         FOR I = 1 TO T
1150                 LPRINT "           G = "; G(I), "GAL/DAY"
1160         NEXT
1170 LPRINT "DENSITIES OF CURRENT GRAPHIC ARTS MATERIALS "
1180         FOR I = 1 TO T
1190                 LPRINT "           D = "; D(I),  "LB/GAL"
1200         NEXT
```

```
1210 GOTO 430
1220 LPRINT
1230 LPRINT
1240 LPRINT "                    ****************"
1250 LPRINT "                    *   RESULTS:   *"
1260 LPRINT "                    ****************"
1270 LPRINT "SOLVENT CONTENTS OF CURRENT GRAPHIC ARTS MATERIALS "
1280          FOR I = 1 TO T
1290                   LPRINT "          C1 = "; C1(I), "% BY VOLUME"
1300          NEXT
1310 LPRINT "SOLID CONTENTS OF CURRENT GRAPHIC ARTS MATERIALS "
1320          FOR I = 1 TO T
1330                   LPRINT "          C2 = "; C2(I), "% BY VOLUME"
1340          NEXT
1350 LPRINT
1360 LPRINT
1370 LPRINT "AMOUNT OF SOLVENTS RELEASED USING CURRENT GRAPHIC ARTS MATERIALS
1380          FOR I = 1 TO T
1390                   LPRINT "          G1 ="; G1(I), "GAL/DAY"
1400          NEXT
1410 LPRINT "AMOUNT OF SOLIDS RELEASED USING CURRENT GRAPHIC ARTS MATERIALS"
1420          FOR I = 1 TO T
1430                   LPRINT"         G2 = "; G2(I), "GAL/DAY"
1440          NEXT
1450 LPRINT
1460 LPRINT
1470 LPRINT "AMOUNT OF SOLVENTS RELEASED USING CURRENT GRAPHIC ARTS MATERIALS
1480          FOR I = 1 TO T
1490                   LPRINT "          L1 = "; L1(I), "LB/DAY"
1500          NEXT
1510 LPRINT
1520 LPRINT
1530 LPRINT "AMOUNT OF SOLIDS RELEASED USING COMPLIANT GRAPHIC ARTS MATERIALS
1540          FOR I = 1 TO T
1550                   LPRINT "          GM = "; GM(I), "GAL/DAY"
1560          NEXT
1570 LPRINT "AMOUNT OF SOLVENTS RELEASED USING COMPLIANT GRAPHICS ARTS MATERIA
"

1580          FOR I = 1 TO T
1590                   LPRINT "          G1M = "; G1M(I), "GAL/DAY"
1600          NEXT
1610 LPRINT
1620 LPRINT
1630 LPRINT "AMOUNT OF SOLVENTS RELEASED USING COMPLIANT GRAPHICS ARTS MATERIA
"

1640          FOR I = 1 TO T
1650                   LPRINT "          LM = "; LM(I), "LB/DAY"
1660          NEXT
1670 LPRINT
1680 LPRINT
1690 LPRINT "TOTAL AMOUNT OF SOLVENTS RELEASED USING COMPLIANT GRAPHIC ARTS MA
RIALS"
1700          LPRINT "          LTM = "; LTM, "LB/DAY"
1710 LPRINT "TOTAL AMOUNT OF SOLVENTS RELEASED USING CURRENT GRAPHIC ARTS MATEI
ALS"
1720          LPRINT "          LT = "; LT, "LB/DAY"
1730 LPRINT
1740 LPRINT
1750 LPRINT "ADDITIONAL PERCENT REDUCTION REQUIRED = "; R
```

```
                    ***************
                    *   INPUT:    *
                    ***************
  NUMBER OF GRAPHIC ARTS MATERIALS USED =  2
  COMPLIANT SOLVENT CONTENTS
            CM =  2.8          LB/GAL LESS WATER
            CM =  2.3          LB/GAL LESS WATER
  CURRENT SOLVENT CONTENTS
            C1 =  4.5          LB/GAL LESS WATER
            C1 =  1.5          LB/GAL LESS WATER
  AMOUNT OF CURRENT GRAPHIC ARTS MATERIALS USED
            G =  5             GAL/DAY
            G =  7             GAL/DAY
  DENSITIES OF CURRENT GRAPHIC ARTS MATERIALS
            D =  7.36          LB/GAL
            D =  7.36          LB/GAL
                  ****************
                  *   RESULTS:   *
                  ****************
 SOLVENT CONTENTS OF CURRENT GRAPHIC ARTS MATERIALS
          C1 =  61.14131     % BY VOLUME
          C1 =  20.38043     % BY VOLUME
 SOLID CONTENTS OF CURRENT GRAPHIC ARTS MATERIALS
          C2 =  38.8587      % BY VOLUME
          C2 =  79.61957     % BY VOLUME


 AMOUNT OF SOLVENTS RELEASED USING CURRENT GRAPHIC ARTS MATERIALS
          G1 = 3.057065      GAL/DAY
          G1 = 1.42663       GAL/DAY
 AMOUNT OF SOLIDS RELEASED USING CURRENT GRAPHIC ARTS MATERIALS
          G2 =  1.942935     GAL/DAY
          G2 =  5.57337      GAL/DAY


 AMOUNT OF SOLVENTS RELEASED USING CURRENT GRAPHIC ARTS MATERIALS
          L1 =  22.5         LB/DAY
          L1 =  10.5         LB/DAY


 AMOUNT OF SOLIDS RELEASED USING COMPLIANT GRAPHIC ARTS MATERIALS
          GM =  3.135965     GAL/DAY
          GM =  8.10672      GAL/DAY
 AMOUNT OF SOLVENTS RELEASED USING COMPLIANT GRAPHICS ARTS MATERIALS
          G1M =  1.19303     GAL/DAY
          G1M =  2.53335     GAL/DAY


 AMOUNT OF SOLVENTS RELEASED USING COMPLIANT GRAPHICS ARTS MATERIALS
          LM =  8.780702     LB/DAY
          LM =  18.64546     LB/DAY


 TOTAL AMOUNT OF SOLVENTS RELEASED USING COMPLIANT GRAPHIC ARTS MATERIALS
          LTM =  27.42616    LB/DAY
 TOTAL AMOUNT OF SOLVENTS RELEASED USING CURRENT GRAPHIC ARTS MATERIALS
          LT =  33           LB/DAY

 ADDITIONAL PERCENT REDUCTION REQUIRED =  16.89043
```

APPENDIX 8D

COMPUTER PROGRAM TO CALCULATE EMISSIONS FROM LITHOGRAPHIC PRINTING PRESSES

Equation 8.1, 8.2, 8.3, and 8.4 are coded in this basic program called *Emission*. The program is listed below:

```
10 '*********************- *******************************************
20 '*                          EMISSION PROGRAM                        *
30 '*********************************~*************************
40 DIM C(5,4,10), D(5,4,10), G(5,4,10), R   5,4,10), R2D(5,  10),
R1P(5,4,10)
50 DIM FP(5,4),FD(5,4), R1(5,4,10), R2(5,4,10), VOC(5), V(5),
CV(5,4,10)
60 DIM R1TL 5), R2TD(5), R1TH(5), R2TH(5), HR(5), R1NSR(5), R2NSR(5)
70 DIM LIMIT(5), EFF(5), APPLN(5), DS(5,1,10), R1T(5,4), R2T(5,4), N(5)
80 DIM M(5), P(5), Q(5)
90 '
100 '*****************************************************************
110 '*                     ZERO OUT THE INPUT MATRIX                  *
120 '*****************************************************************
130 FOR L =1 TO 5 : FOR I = 1 TO 4:FOR J = 1 TO 10:C(L,I,J) =
0:G(L,I,J) = 0
140 D(L,I,J) = 0 : DS(L,1,J) = 0 : FP(L,I) = 0 : FD(L,I) = 0 : NEXT :
NEXT : NEXT
150 '
160 '*****************************************************************
170 '*                    FORMAT OUTPUT STATEMENTS                   *
180 '*****************************************************************
190 L1$ = STRING$(70, 42)
200 L2$ = "*" + SPACE$(27) + "INPUT VARIABLES" + SPACE$(26) + "*"
210 L3$ = "*" + SPACE$(24) + "EMISSION CALCULATION" + SPACE$(24) + "*"
220 L4$ = "INK" : L5$ = "FOUNTAIN SOLUTION" : L6$ = "BLANKET WASH
SOLUTION"
230 L7$ = "ROLLERS-TRAYS WASH SOLUTION" : L8$ = "NUMBER OF TYPES USED =
"
240 L9$ = SPACE$(9) + "SOLVENT" + SPACE$(8) + "DAILY"
250 L10$ = SPACE$(14) +"SOLVENT"+ SPACE$(3) + "EVAPORATED IN"
260 L11$ = SPACE$(9) + "CONTENT" + SPACE$(8) + "USAGE"
270 L12$ = SPACE$(4) + "DENSITY"+ SPACE$(3) + "DENSITY" + SPACE$(3)
280 L12$ = L12$ + "PRESSROOM" + SPACE$(3) + "DRYER"
290 L13$ = SPACE$(14) + "DENSITY" + SPACE$(3)
300 L13$ = L13$ + "PRESSROOM" + SPACE$(3) + "DRYER"
310 L14$ = " TYPE" + SPACE$(2) + "(% BY WEIGHT)"
320 L15$ = " TYPE" + SPACE$(2) + "(% BY VOLUME)"
330 L16$ = SPACE$(2) + "(GAL/DAY)" + SPACE$(2) + "(LB/GAL)" + SPACE$(2)
340 L16$ = L16$ + "(LB/GAL)" + SPACE$(4) + "(% BY WEIGHT)"
350 L17$ = SPACE$(2) + "(GAL/DAY)" + SPACE$(12) + "(LB/GAL)"
360 L17$ = L17$ + SPACE$(4) + "(% BY WEIGHT)"
370 L18$ = SPACE$(1) + "##" + SPACE$(6) + "###.##" + SPACE$(7) +
"###.##"
380 L18$ = L18$ + SPACE$(16) + "###.##" + SPACE$(5) + "###.##" +
SPACE$(3)
390 L18$ = L18$ + "###.##"
```

```
400 L19$ = SPACE$(6) +"INK" + "     SOLVENT" + SPACE$(3) + "EVAPORATED
IN"
410 L21$ = SPACE$(37) + "##" + SPACE$(11) + "#####.##" + SPACE$(3) +
"#####.##"
420 L22$ = "              TOTAL DAILY UNCONTROLLED EMISSIONS  = " +
"#####  LB/DAY"
430 L23$ = "              TOTAL DAILY CONTROLLED EMISSIONS    = " +
"#####  LB/DAY"
440 L24$ = "              TOTAL HOURLY UNCONTROLLED EMISSIONS = " +
"####.## LB/HR"
450 L25$ = "              TOTAL HOURLY CONTROLLED EMISSIONS   = " +
"####.## LB/HR"
460 L28$ = "*" + SPACE$(22) + "EQUIVALENCY CALCULATION" + SPACE$(23) +
"*"
470 L29$ = "EQUIVALENCY CALCULATION IS NOT REQUIRED BECAUSE THE AMOUNT
OF VOC"
480 L29$ = L29$ + " EMITTED IS LESS THAN 20 LBS PER DAY (RULE
1130(g)(2))"
490 L32$ = "AVERAGE SOLVENT CONTENT          = ###.## % BY VOLUME"
500 L33$ = SPACE$(1) + "##" + SPACE$(6) + "###.##" + SPACE$(7) +
"###.##"
510 L33$ = L33$ + SPACE$(6) + "##.##" + SPACE$(5) + "##.##" + SPACE$(4)
+ "###.##"
520 L33$ = L33$ + SPACE$(4) + "###.##"
530 L34$ = "EQUIVALENCY CALCULATION IS NOT REQUIRED BECAUSE VOC CONTENT
OF ALL"
540 L34$ = L34$ + " THE GRAPHIC ART MATERIALS ARE NO MORE THAN 25% BY
VOLUME"
550 L34$ = L34$ + " (RULE 1130(b))"
560 '
570 '******************************************************************
580 '*        OPEN THE DATA FILE AND READ THE INPUT VARIABLES         *
590 '******************************************************************
600 CLS: INPUT "WANT TO INPUT WITH PROMPT (ENTER Y OR N, DEFAULT = Y)";
A1$
610 PRINT : IF A1$ = "N" GOTO 810
620 INPUT "NUMBER OF COMPUTER RUN YOU WANT TO MAKE"; R : PRINT
630 FOR L = 1 TO R
640 INPUT "APPLICATION NUMBER"; APPLN(L) : PRINT
650 GOSUB 2110 : GOSUB 2120 : GOSUB 2140 : GOSUB 2270 : GOSUB 2390
660 GOSUB 2510 : GOTO 700
670 IF A3 = 1 THEN GOSUB 2110 ELSE : IF A3 = 2 THEN GOSUB 2120 ELSE
680 IF A3 = 3 THEN GOSUB 2140 ELSE : IF A3 = 4 THEN GOSUB 2270 ELSE
690 IF A3 = 5 THEN GOSUB 2390 ELSE : IF A3 = 6 THEN GOSUB 2510
700 INPUT "WANT TO CORRECT ANY INPUT (ENTER Y OR N, DEFAULT = Y)"; A2$
: PRINT
710 IF A2$ = "N" GOTO 800
720 PRINT "ENTER CHOICE OF INPUT YOU WANT TO CORRECT"
730 PRINT "    1 FOR OPERATING HOURS"
740 PRINT "    2 FOR AFTERBURNER EFFICIENCY"
750 PRINT "    3 FOR INK INFORMATION"
760 PRINT "    4 FOR FOUNTAIN SOLUTION INFORMATION"
```

```
770 PRINT "    5 FOR BLANKET WASH INFORMATION"
780 PRINT "    6 FOR ROLLERS/TRAYS WASH INFORMATION"
790 INPUT A3 : PRINT : GOTO 670
800 NEXT : GOTO 1020
810 INPUT "DATA FILE NAME"; FILE1$
820 FILE1$ = "A:" + FILE1$ + ".DOC"
830 OPEN "I",#1,FILE1$
840 INPUT#1, R
850 FOR L = 1 TO R
860 INPUT#1, APPLN(L), HR(L), EFF(L)
870 INPUT#1, N(L) : IF N(L) = 0 THEN GOTO 890
880 FOR J = 1 TO N(L) : INPUT #1, C(L,1,J), G(L,1,J), D(L,1,J),
DS(L,1,J): NEXT
890 INPUT#1, M(L) : IF M(L) = 0 THEN GOTO 910
900 FOR J = 1 TO M(L) : INPUT #1, C(L,2,J), G(L,2,J), D(L,2,J) : NEXT
910 INPUT#1, P(L) : IF P(L) = 0 THEN GOTO 930
920 FOR J = 1 TO P(L) : INPUT #1, C(L,3,J), G(L,3,J), D(L,3,J) : NEXT
930 INPUT#1, Q(L) : IF Q(L) = 0 THEN GOTO 950
940 FOR J = 1 TO Q(L) : INPUT #1, C(L,4,J), G(L,4,J), D(L,4,J) : NEXT
950 FOR I = 1 TO 4 : INPUT#1, FP(L,I) : NEXT
960 FOR I = 1 TO 4 : INPUT#1, FD(L,I) : NEXT
970 NEXT : CLOSE#1
980 '
990 '*****************************************************************
1000 '*      OPEN THE OUTPUT FILE AND WRITE THE INPUT VARIABLES        *
1010 '*****************************************************************
1020 INPUT "OUTPUT FILE NAME"; FILE2$ : PRINT
1030 FILE2$ = "A:" + FILE2$ + ".DOC"
1040 OPEN "O",#2,FILE2$
1050 FOR L = 1 TO R
1060  PRINT#2, "APPLICATION NUMBER  "; APPLN(L) :
PRINT#2,:PRINT#2,:PRINT#2,
1070  PRINT#2, L1$ : PRINT#2, L2$ : PRINT#2, L1$
1080  PRINT#2, "OPERATING HOURS PER DAY    = "; HR(L)
1090  PRINT#2, "AFTERBURNER EFFICIENCY EFF = "; EFF(L)
1100  FOR  I = 1 TO 4 : PRINT#2,
1110  IF I = 1 THEN GOSUB 1940 : GOTO 1150
1120  IF I = 2 THEN GOSUB 1980 : GOTO 1150
1130  IF I = 3 THEN GOSUB 2020 : GOTO 1150
1140 IF I = 4 THEN GOSUB 2060
1150 PRINT#2,USING L26$; K : IF K = 0 THEN GOTO 1200
1160  PRINT#2, L31$ : PRINT#2, L20$ : PRINT#2, L27$
1170    FOR J = 1 TO K
1180    IF I = 1 THEN PRINT#2, USING L33$;
J,C(L,1,J),G(L,1,J),D(L,1,J),DS(L,1,J),FP(L,1),FD(L,1)
1190    IF I > 1 THEN PRINT#2,USING L18$;
J,C(L,I,J),G(L,I,J),D(L,I,J),FP(L,I),FD(L,I) : NEXT J
1200  NEXT I : PRINT#2, CHR$(12)
1210 '
```

```
1220 '***********************************************************   ***
1230 '*CALCULATE THE AMOUNT OF SOLVENT EVAPORATED FROM ALL THE GRAPHIC*
1240 '*ARTS MATERIALS USED AND WRITE THE RESULTS IN THE OUTPUT FILE   *
1250 '*****************************************************************
1260 PRINT#2, "APPLICATION NUMBER  "; APPLN(L)
:PRINT#2,:PRINT#2,:PRINT#2,
1270 PRINT#2,L1$ : PRINT#2,L3$ : PRINT#2,L1$
1280 PRINT#2,TAB(56) "R1" TAB(66) "R2"
1290 PRINT#2,TAB(53) "(LB/DAY)" TAB(63) "(LB/DAY)"
1300 '
1310 '*****************************************************************
1320 '*                      EMISSION CALCULATION                     *
1330 '*****************************************************************
1340 R1TD(L) = 0 : R2TD(L) = 0
1350 FOR I = 1 TO 4
1360 IF I = 1 THEN GOSUB 1940 : GOTO 1400
1370 IF I = 2 THEN GOSUB 1980 : GOTO 1400
1380 IF I = 3 THEN GOSUB 2020 : GOTO 1400
1390 IF I = 4 THEN GOSUB 2060
1400 IF K = 0 THEN GOTO 1550
1410 PRINT#2,MATERIAL$
1420 R1T(L,I) = 0 : R2T(L,I) = 0
1430    FOR J = 1 TO K
1440    R1D(L,I,J) = (C(L,I,J)/100)*G(L,I,J)*D(L,I,J)*(FD(L,I)/100)
1450    R2D(L,I,J) = R1D(L,I,J)*(1-EFF(L)/100)
1460    R1P(L,I,J) = (C(L,I,J)/100)*G(L,I,J)*D(L,I,J)*(FP(L,I)/100)
1470    R1(L,I,J) = R1D(L,I,J) + R1P(L,I,J)
1480    R2(L,I,J) = R2D(L,I,J) + R1P(L,I,J)
1490    R1T(L,I) = R1T(L,I) + R1(L,I,J)
1500    R2T(L,I) = R2T(L,I) + R2(L,I,J)
1510    PRINT#2,USING L21$; J, R1(L,I,J), R2(L,I,J)
1520    NEXT J
1530 R1TD(L) = R1TD(L) + R1T(L,I)
1540 R2TD(L) = R2TD(L) + R2T(L,I)
1550 NEXT I
1560 R1TH(L) = R1TD(L)/HR(L)
1570 R2TH(L) = R2TD(L)/HR(L)
1580 R1NSR(L) = 1.1*R1TD(L) : R2NSR(L) = 1.1*R2TD(L)
1590 PRINT#2,"NSR EMISSIONS" : PRINT#2,USING L22$; R1NSR(L)
1600 PRINT#2,USING L23$; R2NSR(L) : PRINT#2,"AEIS EMISSIONS"
1610 PRINT#2,USING L24$; R1TH(L) : PRINT#2,USING L25$; R2TH(L)
1620 '
1630 '*****************************************************************
1640 '*                       EQUIVALENCY CALCULATION                 *
1650 '*****************************************************************
1660 PRINT#2,: PRINT#2,:PRINT#2,:PRINT#2,L1$ : PRINT#2,L28$ : PRINT
#2,L1$
1670 IF R2TD(L) < 20 THEN GOTO 1880
1680 FOR J = 1 TO M(L)
1690 CV(L,1,J) = C(L,1,J) * D(L,1,J) / DS(L,1,J)
1700 IF CV(L,1,J) > 25 THEN GOTO 1770
1710 NEXT
```

```
1720 FOR I = 2 TO 4
1730   FOR J = 1 TO 10
1740   IF C(L,I,J) > 25 THEN GOTO 1770
1750   NEXT : NEXT
1760 PRINT#2, L34$ : GOTO 1890
1770 V(L) = 0 : VOC(L) = 0
1780 FOR I = 1 TO 4 : FOR J = 1 TO 10 : V(L) = V(L) + G(L,I,J) :
NEXT:NEXT
1790 FOR J = 1 TO M(L)
1800 VOC(L) = VOC(L) + (FP(L,1)/100)*C(L,1,J) * D(L,1,J)*G(L,1,J)/(100
* DS(L,1,J))
1805 NEXT
1810 FOR I = 2 TO 4 : FOR J = 1 TO 10
1820 VOC(L) = VOC(L) + (C(L,I,J)/100)*G(L,I,J)
1830 NEXT : NEXT
1840 LIMIT(L) = (VOC(L)/V(L)) * 100
1850 PRINT#2,USING "TOTAL ORGANIC COMPOUNDS USED     = ###.## GAL/DAY";
VOC(L)
1860 PRINT#2,USING "TOTAL GRAPHIC ART MATERIALS USED = ###.## GAL/DAY";
V(L)
1870 PRINT#2,USING L32$; LIMIT(L) : GOTO 1890
1880 PRINT#2, L29$
1890 PRINT#2, CHR$(12) : NEXT L : CLOSE #2 : END
1900 '
1910 '******************************************************************
1920 '*                           SUBROUTINE                           *
1930 '******************************************************************
1940 K = N(L) : L20$ = L11$ + L12$ : L26$ = L4$ + SPACE$(42) + L8$ +
"##"
1950 L27$ = L14$ + L16$: L31$ = L9$ + L19$
1960 MATERIAL$ = "INK" + SPACE$(33) + "TYPE"
1970 RETURN
1980 K = M(L) : L20$ = L11$ + L13$ : L26$ = L5$ + SPACE$(28) + L8$ +
"##"
1990 L27$ = L15$ + L17$ : L31$ = L9$ + L10$
2000 MATERIAL$ = "FOUNTAIN SOLUTION" + SPACE$(19) + "TYPE"
2010 RETURN
2020 K = P(L) : L20$ = L11$ + L13$ : L26$ = L6$ + SPACE$(24) + L8$ +
"##"
2030 L27$ = L15$ + L17$ : L31$ = L9$ + L10$
2040 MATERIAL$ = "BLANKET WASH SOLUTION"+ SPACE$(15) +"TYPE"
2050 RETURN
2060 K = Q(L) : L20$ = L11$ + L13$ : L26$ = L7$ + SPACE$(18) + L8$ +
"##"
2070 L27$ = L15$ + L17$ : L31$ = L9$ + L10$
2080 MATERIAL$ = "ROLLERS/TRAYS WASH SOLUTION" + SPACE$(9) + "TYPE"
2090 RETURN
2100 '
2110 INPUT "OPERATING HOURS PER DAY"; HR(L) : RETURN
2120 INPUT "AFTERBURNER EFFICIENCY (%)"; EFF(L) : PRINT : RETURN
2130 '
2140 INPUT "NUMBER OF INK USED"; N(L)
```

```
2150 IF N(L) = 0 THEN GOTO 2250
2160 PRINT L9$;L19$, L11$;L12$; L14$;L16$
2170 FOR J = 1 TO N(L)
2180 PRINT J;: INPUT;"              ",C(L,1,J) : PRINT TAB(26)
2190 INPUT;"",G(L,1,J) : PRINT TAB(36)
2200 INPUT;"",D(L,1,J) : PRINT TAB(46)
2210 INPUT;"",DS(L,1,J) : PRINT TAB(56)
2220 INPUT;"",FP(L,1) : PRINT TAB(66)
2230 INPUT;"",FD(L,1)
2240 PRINT : NEXT
2250 PRINT :RETURN
2260 '
2270 INPUT "NUMBER OF FOUNTAIN SOLUTION USED"; M(L)
2280 IF M(L) = 0 THEN GOTO 2370
2290 PRINT L9$;L10$, L11$;L13$; L14$;L17$
2300 FOR J = 1 TO M(L)
2310 PRINT J;: INPUT;"              ",C(L,2,J) :   INT TAB(26)
2320 INPUT;"",G(L,2,J) : PRINT TAB(36)
2330 INPUT;"",D(L,2,J) : PRINT TAB(56)
2340 INPUT;"",FP(L,2) : PRINT TAB(66)
2350 INPUT;"",FD(L,2)
2360 PRINT : NEXT
2370 PRINT : RETURN
2380 '
2390 INPUT "NUMBER OF BLANKET WASH SOLUTION USED"; P(L)
2400 IF P(L) = 0 THEN GOTO 2490
2410 PRINT L9$;L10$, L11$;L13$; L14$;L17$
2420 FOR J = 1 TO P(L)
2430 PRINT J;: INPUT;"              ",C(L,3,J) : PRINT TAB(26)
2440 INPUT;"",G(L,3,J) : PRINT TAB(46)
2450 INPUT;"",D(L,3,J) : PRINT TAB(56)
2460 INPUT;"",FP(L,3) : PRINT TAB(66)
2470 INPUT;"",FD(L,3)
2480 PRINT : NEXT
2490 PRINT : RETURN
2500 '
2510 INPUT "NUMBER OF ROLLERS/TRAYS WASH SOLUTION USED" ; Q(L)
2520 IF Q(L) = 0 THEN GOTO 2610
2530 PRINT L9$;L10$, L11$;L13$; L14$;L17$
2540 FOR J = 1 TO Q(L)
2550 PRINT J;: INPUT;"              ",C(L,4,J) : PRINT TAB(26)
2560 INPUT;"",G(L,4,J) : PRINT TAB(46)
2570 INPUT;"",D(L,4,J) : PRINT TAB(56)
2580 INPUT;"",FP(L,4) : PRINT TAB(66)
2590 INPUT;"",FD(L,4)
2600 PRINT : NEXT
2610 PRINT : RETURN
```

To verify the *Emission* program, a test run is performed. The computer output for this example are attached below:

```
APPLICATION NUMBER   183160


**********************************************************************
*                           INPUT VARIABLES                          *
**********************************************************************
OPERATING HOURS PER DAY    =  24
AFTERBURNER EFFICIENCY EFF =  0

INK                                          NUMBER OF TYPES USED =  1
         SOLVENT        DAILY      INK     SOLVENT   EVAPORATED IN
         CONTENT        USAGE    DENSITY     PRESSROOM    DRYER
 TYPE  (% BY WEIGHT)  (GAL/DAY)  (LB/GAL)  (LB/GAL)    (% BY WEIGHT)
  1       22.19        23.87       8.38      6.78     10.00      0.00

FOUNTAIN SOLUTION                            NUMBER OF TYPES USED =  1
         SOLVENT        DAILY              SOLVENT   EVAPORATED IN
         CONTENT        USAGE              DENSITY   PRESSROOM   DRYER
 TYPE  (% BY VOLUME)  (GAL/DAY)            (LB/GAL)    (% BY WEIGHT)
  1       12.00        83.33                  6.60     100.00     0.00

BLANKET WASH SOLUTION                        NUMBER OF TYPES USED =  1
         SOLVENT        DAILY              SOLVENT   EVAPORATED IN
         CONTENT        USAGE              DENSITY   PRESSROOM   DRYER
 TYPE  (% BY VOLUME)  (GAL/DAY)            (LB/GAL)    (% BY WEIGHT)
  1      100.00         5.00                  6.25     100.00     0.00

ROLLERS-TRAYS WASH SOLUTION                  NUMBER OF TYPES USED =  0
```

```
APPLICATION NUMBER   183160


**********************************************************************
*                       EMISSION CALCULATION                         *
**********************************************************************
                                                     R1          R2
                                                 (LB/DAY)    (LB/DAY)
INK                                  TYPE
                                      1            4.44         4.44
FOUNTAIN SOLUTION                    TYPE
                                      1           66.00        66.00
BLANKET WASH SOLUTION                TYPE
                                      1           31.25        31.25
NSR EMISSIONS
              TOTAL DAILY UNCONTROLLED EMISSIONS  =   112  LB/DAY
              TOTAL DAILY CONTROLLED EMISSIONS    =   112  LB/DAY
AEIS EMISSIONS
              TOTAL HOURLY UNCONTROLLED EMISSIONS =    4.24 LB/HR
              TOTAL HOURLY CONTROLLED EMISSIONS   =    4.24 LB/HR


**********************************************************************
*                     EQUIVALENCY CALCULATION                        *
**********************************************************************
TOTAL ORGANIC COMPOUNDS USED      =  15.65 GAL/DAY
TOTAL GRAPHIC ART MATERIALS USED = 112.20 GAL/DAY
AVERAGE SOLVENT CONTENT           =  13.95 % BY VOLUME
```

SECTION 9

Landfill Gas Control Systems : Gas Collection, Flare And Condensate Handling/Treatment Systems

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Appendix 9B Worksheet For Landfill Gas Collection System 9B-1

Appendix 9C Worksheet For Landfill Gas Condensate Leachate Handling System 9C-1

Appendix 9D Worksheet For Landfill Gas Condensate Leachate Treatment System 9D-1

Section 9

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SECTION 9: LANDFILL GAS CONTROL SYSTEMS: GAS COLLECTION, FLARE, AND CONDENSATE HANDLING/TREATMENT SYSTEMS

9.1 General Description

An effective landfill gas (LFG) migration control system consists of:

- *collection system;*
- *flare station; and*
- *condensate handling/treatment system.*

Collection systems have been designed depending on the purpose of collection, either migration control and/or energy recovery. The collection systems are designed to avoid problems associated with condensate accumulation and are constructed with materials resistant to the corrosive elements of the raw gas. Meanwhile, ground LFG flares incinerate the gas extracted by the collection system to control the gaseous combustible emissions and resultant odors. Flaring reduces the toxicity, mobility, and volume of LFG. In addition to flaring, methane gas from LFG may also be extracted and recovered from a sanitary landfill for use as an energy resource; such as employing internal combustion engines or gas turbines to generate electricity or upgrading raw LFG to produce synthetic natural gas. As LFG is recovered from the collection wells, reduction in temperature of the LFG (from 110-150 ^{o}F to 60-80 ^{o}F) results in potentially large amounts of condensate liquids. These liquids may accumulate in the collection and recovery system so the processing equipment loses its efficiency. Thus, this problem is remedied by installing recovery system pipe so that the condensate drains away from the processing equipment. The condensate is then pumped off and treated by various methods.

Emission of LFG from the landfill site causes air contamination with potential public health impacts because of the hazardous constituents present in the LFG. Table 9.1 is a list of the typical composition and characteristics of LFG. LFG is generally composed of 50% methane and 50% carbon dioxide produced by the decompositions of refuse within the landfill. LFG produced from the decomposition of refuse tends to migrate both vertically and horizontally within the

Table 9.1 **Typical Landfill Gas Composition and Characteristics**[16]

Component	**Component Percent (dry volume basis)**
Methane	47.5
Carbon dioxide	47.0
Nitrogen	3.7
Oxygen	0.8
Paraffin hydrocarbons	0.1
Aromatic and cyclic hydrocarbons	0.2
Hydrogen	0.1
Hydrogen sulfide	0.01
Carbon monoxide	0.1
Trace compounds*	0.5

Characteristic	**Value**
Temperature	106 °F
High heating value	476 BTU/scf
Specific gravity	1.04
Moisture content	Saturated

---

* Trace compounds include sulfur dioxide, benzene, toluene, methylene chloride, perchlorethylene, and carbonyl sulfide in concentrations up to 50 ppm. Table 9.2 is a list of compounds identified in Class II landfills.

landfill. The migration of LFG poses potential for fire and explosion if methane gas collects in concentrations above the lower explosive limit.

The Environmental Protection Agency (EPA) has established LFG controls based on regulatory requirements and potential health risks posed by the current gas problems. Flare emissions can contain particulates, as well as sulfur dioxide, nitrogen oxide, and carbon monoxide, which are all regulated pollutants. Criteria established by the EPA under the authority of the Resource Conservation and Resource Art (RCRA) act as both incentive and constraint to LFG recovery projects. A criterion established for LFG requires a lower explosive limit (LEL) of 10 percent (5 percent methane) at the landfill boundary which makes a migration control system mandatory at many landfills. This requirement may act as an incentive for LFG recovery since the requirement for a control system could make recovery more likely. Two other regulations of importance for controlling LFG are listed below:

- California Waste Management Board (CWMB) requires that subsurface methane concentrations be controlled to less than 5 percent methane (the explosive limit) at the site boundary; and

- The South Coast Air Quality Management District (SCAQMD) requires that surface emissions be controlled to concentrations of less than 50 parts per million (ppm) total organic compounds over the surface of the landfill over an integrated basis, and less than 500 ppm at any single instantaneous point on the landfill surface.[1]

In addition, two developments have contributed to the interest in LFG gathering. First, due to the scarcity of energy sources and the rising prices of natural gas and fossil fuels, the generation of LFG is essential. The second is the emergence of regulatory standards to control the hazard posed by migrating methane gas. In concentrations between 5 to 15 percent by volume in air, methane is flammable at atmospheric pressure and normal temperatures. The hazard potential is increased by the ease with which methane can migrate subterraneously. Public safety may be endangered if methane accumulates in a poorly ventilated area and subsequently achieves combustible concentrations.

9.1.1 Sanitary Landfilling

Sanitary landfilling is a method of disposing of solid wastes on land by spreading the wastes in layers, compacting it, and covering it at the end of the day. A landfill is made up of cells and lifts, as shown in Figures 9-1 and 9-2. A cell is a unit of compacted solid wastes that is enclosed by natural soil or cover material. The cell height generally varies from 8 to 30 feet and the density of the compacted solid wastes in a cell is typically 800 to 1000 lb/ft^3 depending on the waste type and operating method.[2]

A lift is a compacted layer of solid wastes and cover material. It is generally composed of several cells. The daily cover material, usually soil, clay, or wood chips, is normally 6 to 12 inches deep. When completed, a final cover of 2 to 4 feet is placed in the landfill. The landfill consists of many lifts. Some landfills are greater than 100 feet deep. Grading is desired to prevent ponding of rainwater and eventual infiltration into the landfill due to the hydraulic head created.[2]

There are various methods used for disposing of solid wastes by landfilling depending on the terrain and the hydrogeologic nature of the area. The trench and area method, as shown in Figures 9-3 and 9-4, are two basic methods. In the trench method, a trench is excavated and the soil is later used for cover material. Wastes can then be spread and compacted in the trenches. In the area fill method, wastes are unloaded and spread in long narrow strips in the surface of the land in a series of layers, which are compacted as the filling progresses. Cover material is usually hauled to these landfill sites.[2]

Cover material serves many purposes. It helps in the control of disease-spreading vectors (rodents, birds, insects, small animals); helps control odor, litter, erosion, and air emissions; enhances aesthetics, lessens the chance and spread of fires; reduces infiltration of rainwater and thus decreases leachant generation potential and contamination of surface and groundwater; and enhances the site utilization after the landfill is full. Generally, a cover of at least 6 inches of thick compacted soil will control odor, litter, fire, disease transmittance, and moisture content if applied at the end of each operating day. Note that using more than 6 inches would

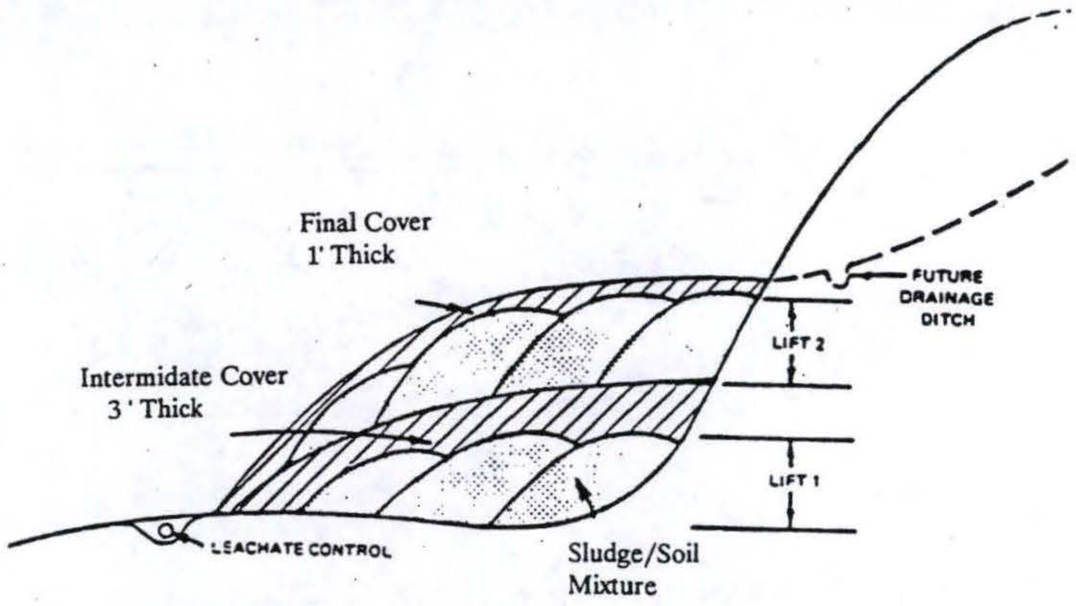


FIGURE 9-1 CROSS SECTION OF TYPICAL AREA FILL OPERATION[13]

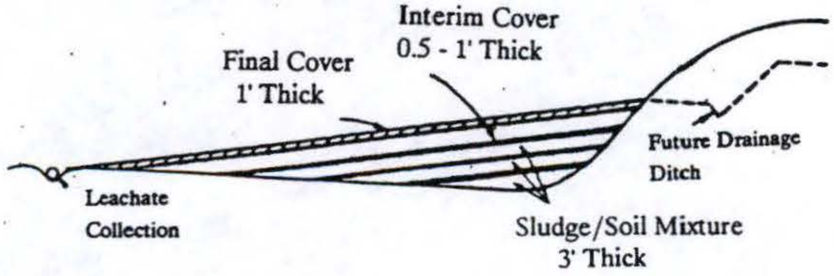


FIGURE 9-2 CROSS SECTION OF TYPICAL AREA FILL LAYER OPERATION[13]

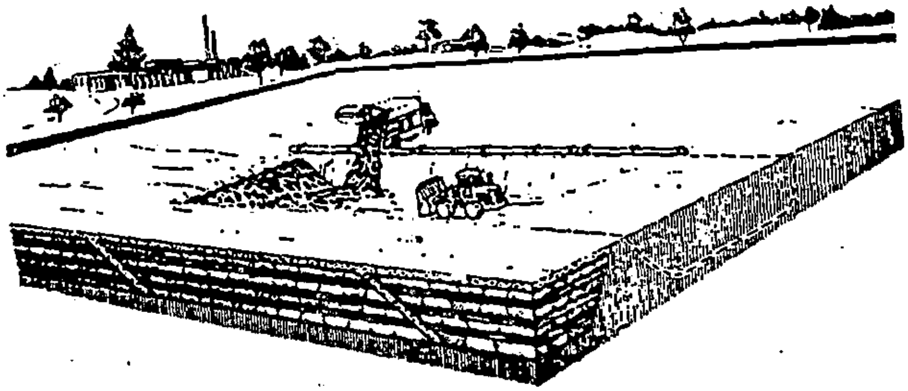


FIGURE 9-3 TRENCH METHOD OF SANITARY LANDFILLING[2]

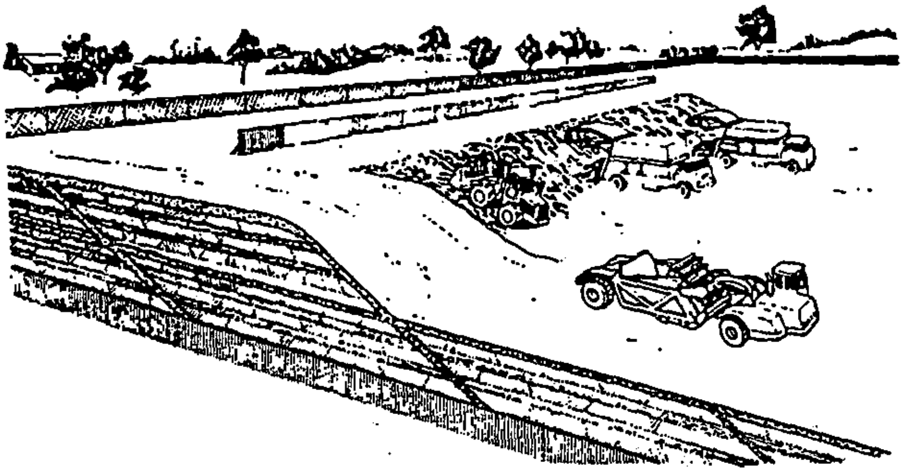


FIGURE 9-4 AREA FILL METHOD OF SANITARY LANDFILLING[2]

waste soil cover and cause the landfill to be filled up more quickly thus decreasing its usable life.[13]

Six inches of cover material may not be required at all landfills. The EPA has stated that "if owners/operators of hazardous waste landfills can demonstrate successfully that the possibility of fire or explosion, harboring, feeding and breeding of land-burrowing animals and disease vectors; or that the human health and environment are controlled and protected to an equivalent degree, then covers of different thickness and/or frequencies may be employed."[13]

9.1.2 Reactions Within the Landfill

An effective landfill gas gathering system must collect and control gaseous combustible emissions and maximize gas recovery without disturbing anaerobic conditions within the landfill through air intrusion. Refuse is deposited, spread into thin layers, compacted, and covered with soil in the sanitary landfill. The wastes then begin a process of physical, chemical, and biological decomposition to produce solid, liquid, and gaseous products. LFG production is a natural process that occurs through bacterial decomposition of organic matter in a landfill. Refuse is placed daily in individual "cells" that are then covered with soil. The gas generated from the entire landfill reflects a summation of the decomposition occurring in the individual cells. Within an individual cell, an aerobic reaction occurs initially. Once the chemically available oxygen in the refuse is consumed, the anaerobic digestion of the organic material in the landfill will produce methane gas.[2]

Biological activity within the complex organic wastes follows a specific pattern, as shown in Figure 9-5. Initially, aerobic decomposition occurs within the wastes resulting in the production of organic acids, carbon dioxide, water, and nitrates. Once the oxygen supply is depleted, anaerobic and facultative microorganisms predominate. Temperature within the landfill rise because of microbial activity. During this second stage, the organic acids are consumed by "methanogenic" bacteria and converted to methane and carbon dioxide. Methanogenic bacteria are anaerobic microorganisms. Small amounts of oxygen are toxic to them. Anaerobic products of decomposition include methane, carbon dioxide, water, organic acids, nitrogen, ammonia, hydrogen sulfide, and sulfides of iron and manganese.[6]

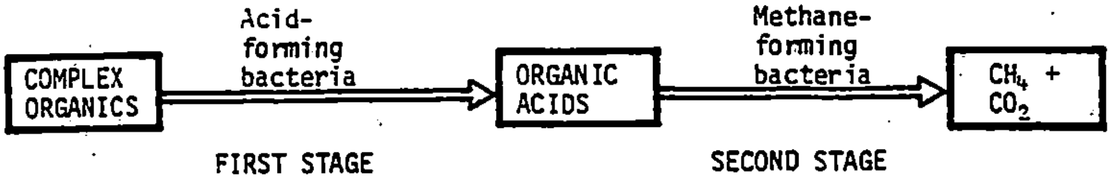


FIGURE 9-5 TWO STAGE DECOMPOSITION OF COMPLEX ORGANIC WASTES[14]

TABLE 9-2 FAVORABLE ENVIRONMENTAL CONDITIONS FOR METHANE PRODUCTION

- Moisture	
- Sufficient Nutrients: organic matter, nitrogen, phosphorus, and other nutrients	
- Absence of oxygen and other toxic materials	
- pH	6.7 - 7.2
- Alkalinity	> 2000 mg/l as $CaCO_3$
- Organic acids	< 3000 mg/l as CH_3COOH
- Temperature	
mesophyllic	30 - 40 ^{o}F
thermophilic	50 - 55 ^{o}F

The rate of organic degradation and landfill gas generation are dependent on the physical, chemical, and biological composition of the refuse, temperature, environmental pH, availability of O_2, moisture content, microbial population available, and the type of synthesis occurring.[9] Methane production is enhanced by relatively high moisture, neutral pH, and an abundance of biodegradable waste products, as noted in Table 9-2. Methane formation begins only after all O_2 has been depleted. As stated earlier, the presence of O_2 is toxic to the methane-forming bacteria. Also, production is stimulated by a high percentage of biodegradable materials such as food and garden wastes, paper, textiles, and wood.[14]

Moisture content is probably the most important variable in landfill gas generation. Moisture permits bacterial growth and maintenance and acts as the transfer medium for micronutrients and the intermediate products at the various stages of decomposition. The product gas compositions average 50 to 60% volume methane and 40 to 50% carbon dioxide plus trace gases for typical solid household, commercial, and light industrial refuse.[10]

Landfills within the District are either categorized as either Class I or Class II. Class I sites are landfills licensed to receive industrial wastes, while Class II sites receive ordinary trash. A District study in December, 1986, has shown that a large number of toxic compounds are found in landfills that receive ordinary household trash (Class II landfills). These compounds are only supposed to be permitted in landfills licensed to receive industrial wastes (Class I landfills). The laboratory had found a wide variety of volatile organic compounds (VOCs) in gas samples from Class II landfills. The VOCs include vinyl chloride, chlorinated solvents, benzene, toluene, other aromatics, saturated hydrocarbons, plus some oxygenated solvents, methyl ethyl ketone, and methyl isobutyl ketone. Either vinyl chloride or benzene was found in 85 percent of the Class II landfills studied. In more than 50 percent of these Class II landfills, the concentration of vinyl chloride or benzene was 1 ppm or higher.[18] Table 9-3 is a list of compounds identified by gas chromatograph or mass spectroscopy (GC/MS) in Class II landfills. In California, Class II landfills are not allowed to accept, in any quantity, any of the compounds mentioned above. These compounds entered the landfills illegally, accidentally, or were produced in the landfill.

TABLE 9-4 COMPOUNDS IDENTIFIED BY GAS CHROMATOGRAPH/MASS SPECTROSCOPY IN CLASS II LANDFILLS[18]

1. ISOBUTANE
2. VINYL CHLORIDE
3. BUTENE
4. N-BUTANE
5. METHYL MERCAPTAN
6. FLURODICHLOROMETHANE
7. ISOPENTANE
8. ETHANOL
9. ACETONE
10. N-PENTANE
11. DIMETHYL SULFIDE
12. CARBON DISULFIDE
13. ISOPROPANOL
14. DICHLOROMETHANE
15. METHYL ACETATE
16. t-1,2,-DICHLOROETHENE
17. 2,3,-DIMETHYLBUTANE
18. 1,1-DICHLOROETHANE
19. 2-METHYLPENTANE
20. N-PROPANOL
21. 3-METHYLPENTANE
22. METHYLETHYL KETONE
23. C-1,2-DICHLOROETHENE
24. 2-METHYLFURAN
25. N-HEXENE
26. 2-BUTANOL
27. ETHYL ACETATE
28. METHYL CYCLOPENTANE
29. 1,1,1-TRICHLOROETHANE
30. ISOBUTANOL
31. BENZENE
32. CYCLOHEXANE
33. 1,1,-DIMETHYL CYCLOPENTANE
34. 2-METHYLHEXANE
35. N-BUTANOL
36. 3-METHYLHEXANE
37. METHYLISOBUTANOATE
38. TRICHLOROETHENE
39. DIMETHYLCYCLOPENTANE
40. ISOOCTANE
41. N-HEPTANE
42. METHYLCYCLOHEXANE
43. METHYL BUTANOATE
44. 1,1,3-TRIMETHYLCLOPENTANE
45. PROPYLACETATE
46. ETHYL CLYCLOPENTANE
47. METHYLISOBUTYL KETONE
48. 1,2,4-TRIMETHYLCYCLOPENTANE
49. 1,2,3-TRIMETHYLCYCLOPENTANE
50. TOLUENE
51. 2,3,4-TRIMETHYLPENTANE
52. 2,3,3-TRIMETHYLPENTANE
53. ETHYLISOBUTANOATE
54. 3-ETHYL-2-METHYLPENTANE
55. 2-HEXANOL
56. 1,4, DIMETHYLCYCLOHEXANE
57. ETHYLMETHYLCYCLOPENTANE
58. 1,2, DIMETHYLCYCLOHEXANE
59. PERCHLOROETHYLENE
60. ETHYLBUTANOATE
61. N-OCTANE
62. CHLOROBENZENE
63. 1,1,3-TRIMETHYLCYLCOHEXANE
64. ETHYLBENZENE
65. 1,2,4-TRIMETHYLCYLCOHEXANE
66. M+P-XYLENE
67. 1,3,5,7-CYCLOOCTATETRAENE
68. O-XYLENE
69. PROPYLBUTANOATE
70. N-NONANE
71. ETHYLTOLUENE
72. -PINENE
73. TRIMETHYLBENZENE
74. DICHLOROBENZENE
75. 3-CARENE
76. N-DECANE
77. LIMONENE

LFG can impact the surrounding area by two modes of transport: airborne transport and gas migration. Airborne transport occurs when LFG escapes through the surface of the landfill and into the air. The compounds in the gas are then carried off the landfill and diluted by the wind. Gas migration involves the subsurface escape of gas from the landfill. It may be through cracks in the ground or through porous soil layers.[18] Gas migration is discussed further in Section 9.1.3.

9.1.3 Gas Migration

Methane is a potential hazard in landfills due to it high combustibility. The gas is explosive in air for concentrations between 5 to 15 percent by volume. Landfill methane migration and accumulation in enclosed spaces can result in a fire or explosion.

This potential hazard is heightened by the ease with which methane may migrate through the soil. The components of LFG are separated when LFG diffuses through sandstone or other porous layers. Compounds with low boiling points, such as vinyl chloride, arrive in homes at higher relative concentrations than do compounds with higher boiling points, such as perchloroethylene. Methane, which is light and very mobile, thus precedes heavier components. Therefore, subsurface migration can produce explosive levels of methane in confined spaces without the presence of odors.[18] Movement of the gas will occur in sand, silt or clay soil as long as there are permeable. Movement will be greatest through continuous highly porous sand or gravel and least in dense clay soils.[7]

Gas movement into areas surrounding a landfill occurs by two basic processes. According to Pacey, these two are *convection*, where movement is due to the presence of a pressure gradient, and *diffusion*, where movement is from a high gas concentration area to that of a lower concentration.[15] Because methane is lighter than air, it tends to move vertically and enter the atmosphere (see Figure 9-6). If upward movement is restricted, landfill methane will migrate laterally, as shown in Figure 9-7. Depending on the cover material, 80 to 90 percent of the gas produced by a landfill will exit through the cover soil due to the relatively small size of methane molecules.[7] The lateral extent and rate of methane movement varies with

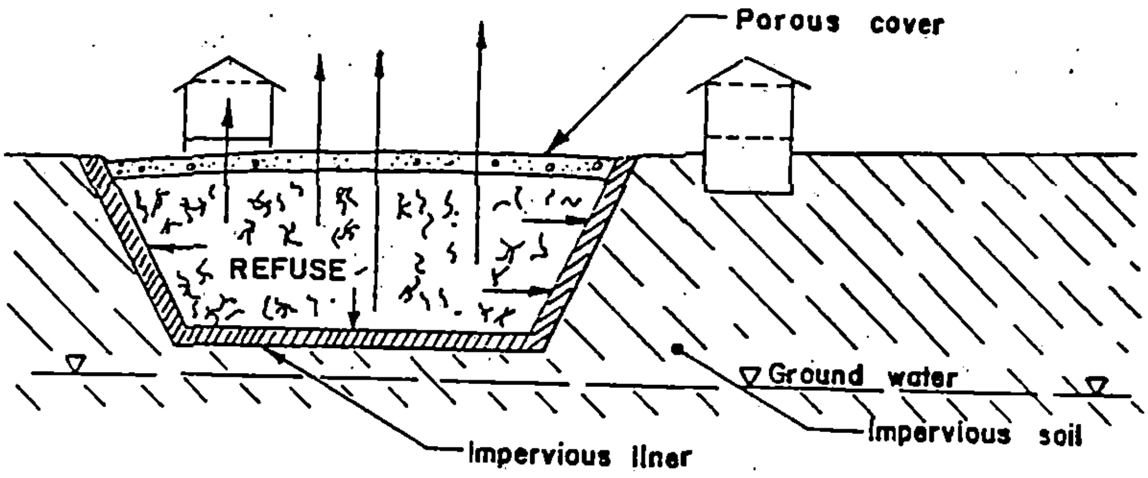


FIGURE 9-6 EXTENSIVE VERTICAL MIGRATION IN A LANDFILL[7]

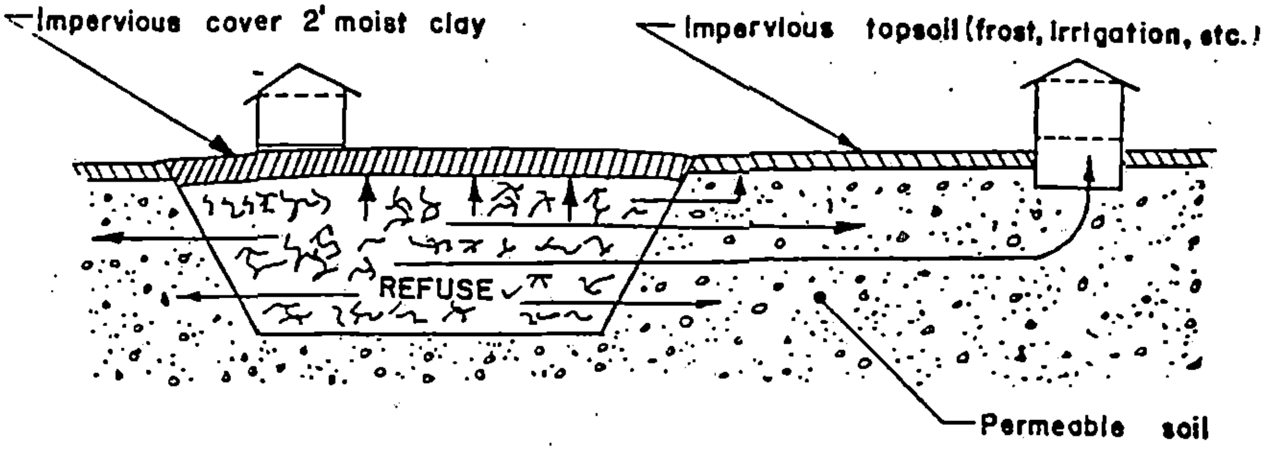


FIGURE 9-7 EXTENSIVE LATERAL MIGRATION IN A LANDFILL[7]

the characteristics of the cover material and the surrounding soil. The cover material on a landfill can cause enough resistance to encourage lateral movement of the gas. This is achieved by sealing the vertical path with rain-saturated cover soil, pavement, or "capping" with impermeable clay, synthetic membrane liners or asphalt. Natural soil barriers such as clay may serve as highly efficient barriers to gas migration, provided the soil is kept nearly saturated. Dry soils (even clays) are ineffective barriers, since they provide a continuous void system through which gas may migrate. (See Table 9-4 and Figure 9-8)[2,7]

Perimeter and interior vent systems include gravel trenches, rubble vent stacks, gravel-filled vent walls, and any combination thereof. Venting may be accomplished through either passive or induced exhaust system, with selection depending on site conditions:[7]

- Passive systems rely on high permeable material, such as gravel, placed in the flow of the gas path. Since the permeable material offers a path more conductive to convective gas flow than the surrounding soil, some gas is diverted to a point of controlled release.

- Induced exhaust flow systems are effective in migration control. These systems usually employ suitable designed vertical wells or trenches which are connected to a vacuum exhaust system. (See Figure 9-9)

9.1.4 Landfill Gas Collection Systems

Landfill gas control systems are designed to address various problems that arise from the generation of landfill gases. Containment of migrating gas around the landfill may be accomplished by the installation of impervious liner materials, such as synthetic membranes, clay, or asphalt. These types of systems do not extract and dispose of the gases, but rather rechannel them to other points of eventual emission. Landfill gas extraction systems, however, collect the gases and route them to flares for thermal destruction or to energy recovery facilities. Figure 9-10 is a diagram of a perimeter gas control system.

Sealant		Remarks
Classification	Representative types	
Compacted soil		Should contain some clay or fine silt
Compacted clay	Bentonites, illites, kaolinites	Most commonly used sealant for landfills; layer thickness varies from six to 48 inches; layer must be continuous and not allowed to dry out and crack
Inorganic chemicals	Sodium carbonate, silicate, or pyrophosphate	Use depends on local soil characteristics
Synthetic chemicals	Polymers, rubber latex	Experimental, use not well established
Synthetic membrane liners	Polyvinyl chloride, butyl rubber, hypalon, polyethylene, nylon-reinforced liners	Expensive, may be justified where gas is to be recovered
Asphalt	Modified asphalt, rubber-impregnated asphalt, asphalt-covered polypropylene fabric, asphalt concrete	Layer must be thick enough to maintain continuity under differential settling conditions
Others	Gunite concrete, soil cement, plastic soil cement.	

TABLE 9-4 LANDFILL SEALANTS FOR CONTROLLING GAS AND LEACHATE MOVEMENT[7]

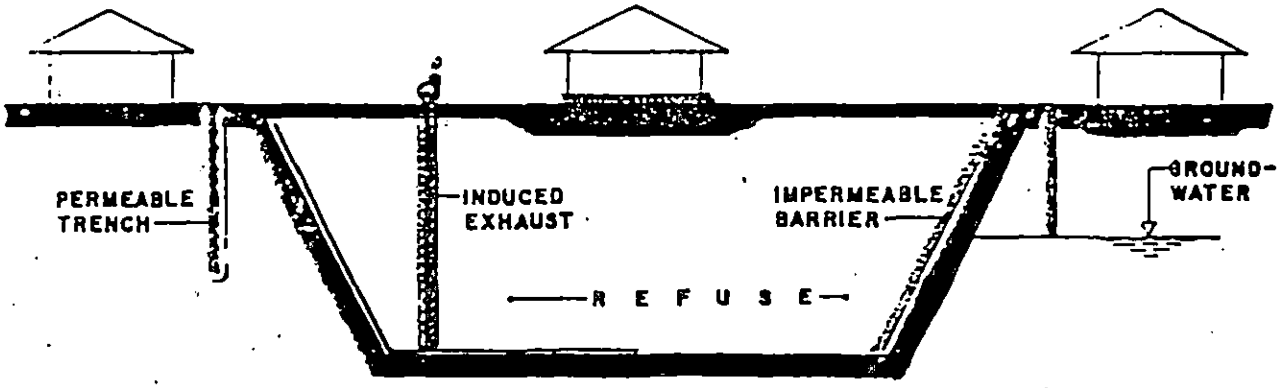


FIGURE 9-8 COMMON LOCATIONS FOR GAS CONTROL SYSTEMS[7]

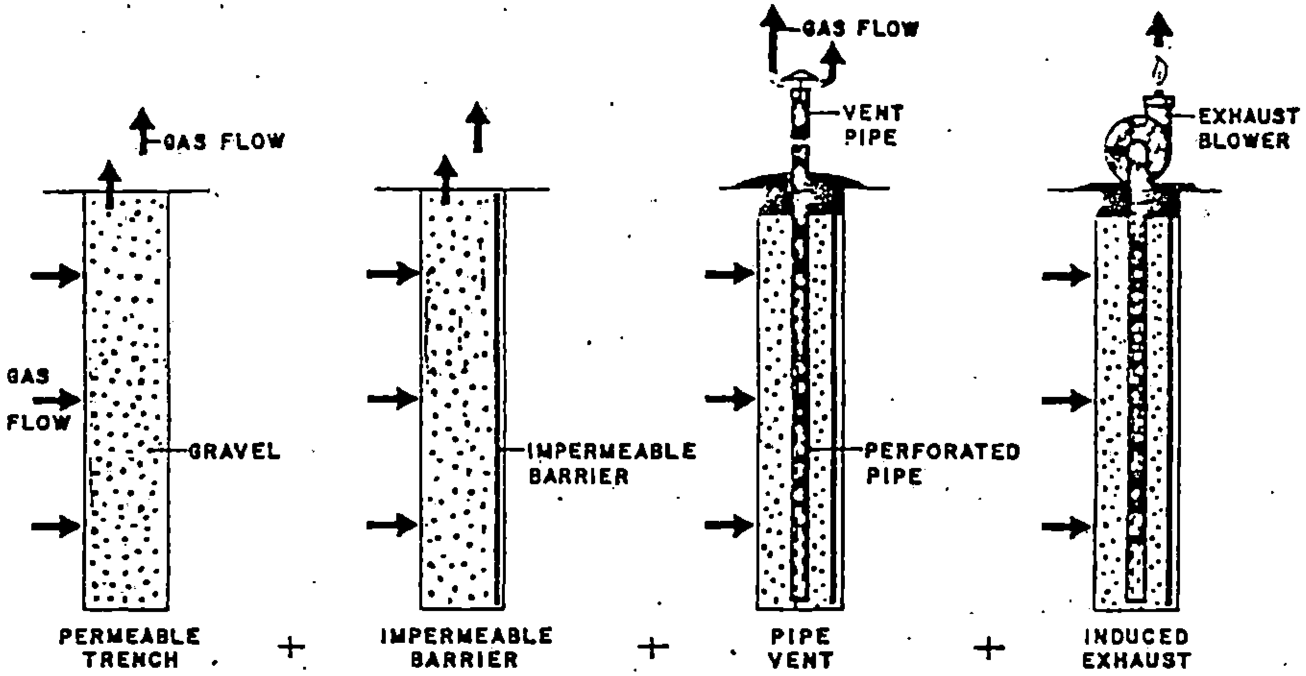


FIGURE 9-9 SCHEMATIC OF GAS CONTROL SYSTEMS[7]

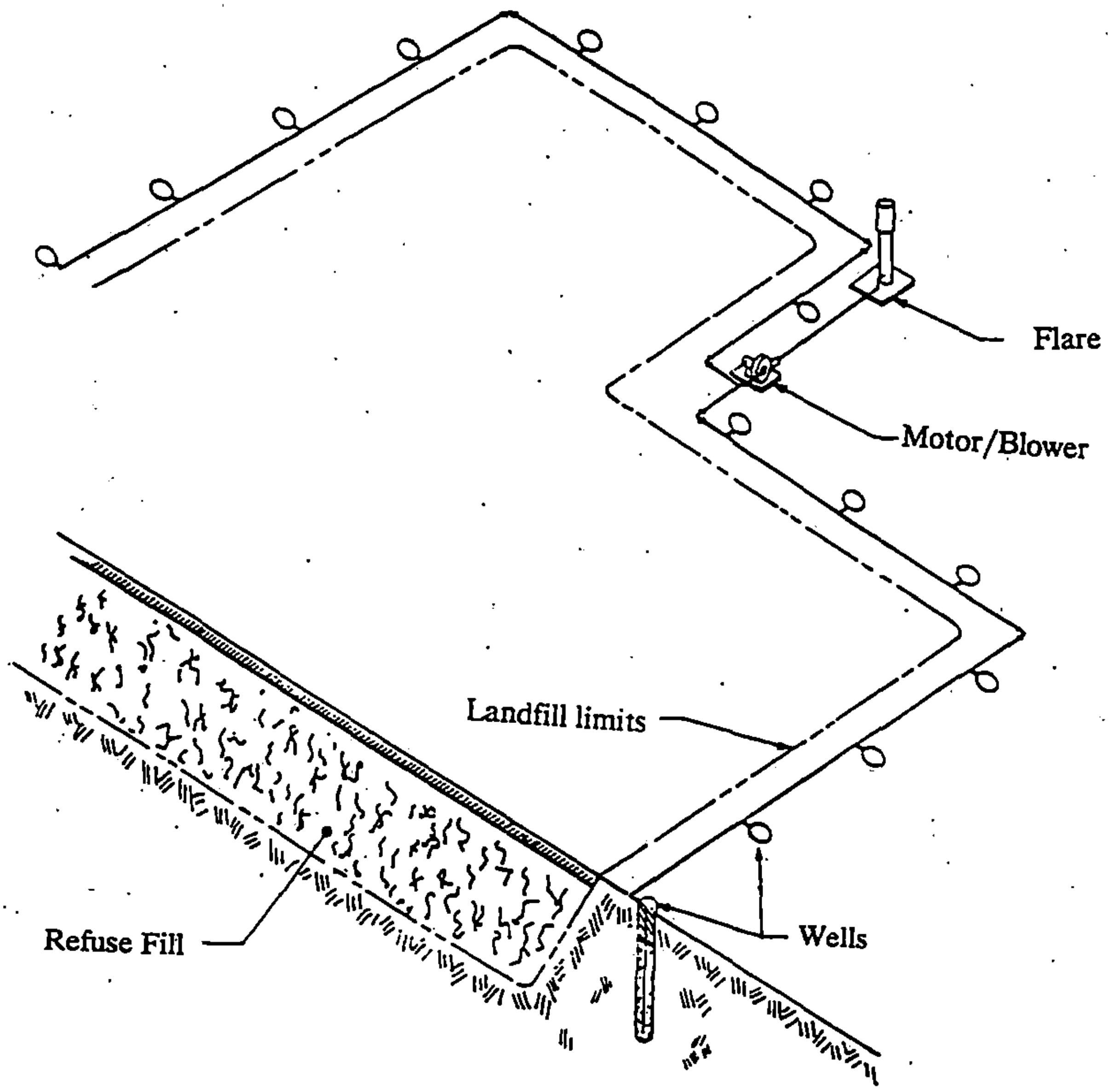


FIGURE 9-10 PERIMETER GAS CONTROL SYSTEM[7]

The layout of the wells and the gas gathering system depends on a number of factors including results of field testing and the purpose of the collection system. Testing at a landfill will indicate which areas of the landfill might provide the most gas of high quality (heating value > 460 BTU/scf) for a gas recovery system. For instance, at the Palos Verdes landfill located in Rolling Hills, Calif, the gas removed from the perimeter and interior of the landfill was found to contain the following:[2]

	Perimeter Gas	Interior Gas
Methane	17.5%	53.6%
Carbon Dioxide	23.4%	45.4%
Oxygen	10.6%	0.25%
Nitrogen	48.5%	0.75%

Figure 9-11 is an illustration of gas recovery system with interior and perimeter gas controls.

9.1.4.1 Recovery Wells

One of the first steps in constructing a LFG recovery system is the drilling and installation of extraction wells. The gathering or collection of LFG follows the assumption that gas tends to move toward an area of least resistance. Permeable passages are utilized to proved paths of least resistance. Gas recovery systems have utilized both vertical and horizontal wells drilled or placed into the landfill to create vertical or horizontal permeable passages. In the case of lateral gas migration, vertical static vent wells have proven effective. Vertical gas migration has been controlled using a horizontal well system.[2]

Vertical LFG recovery wells typically consist of a perforated pipe placed in a vertical hole drilled into the refuse and backfilled with gravel around the pipe itself. LFG recovery wells then employ an induced exhaust well system. Most of the available gas produced can be collected with a vacuum through the pipe system. With the LFG recovery well placed into the refuse and backfilled with gravel around the perforations, the well is sealed off against the inflow of atmospheric air and is connected to a control point by means of a gas collection header pipe

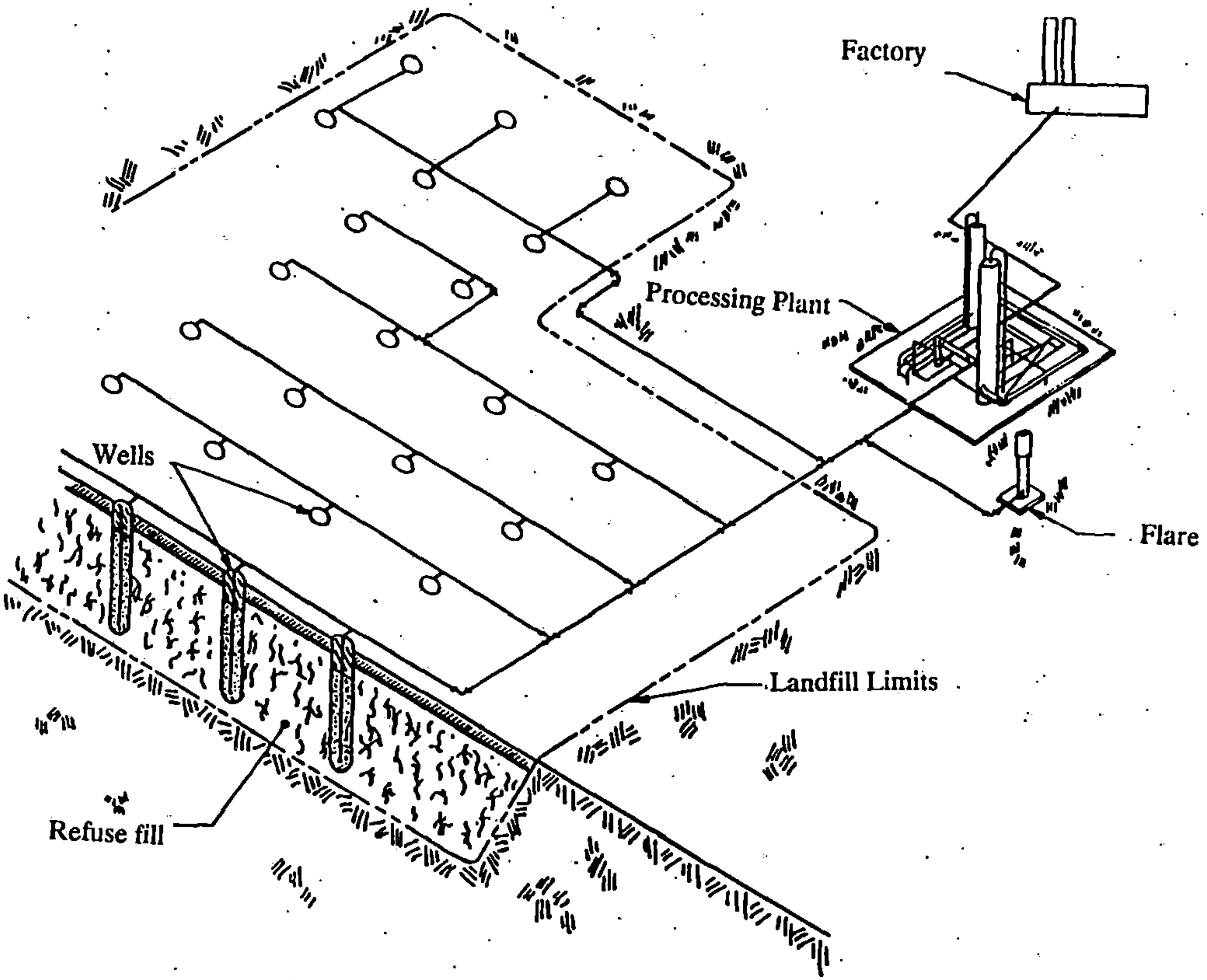


FIGURE 9-11 RECOVERY SYSTEM WITH INTERIOR AND PERIMETER GAS CONTROL

network. Other backfill materials may include concrete, refuse, and ground soil materials.

Horizontal wells installed along the bottom and excavated side interface can also be utilized to control lateral and vertical gas movement. The LFG is collected by a series of horizontal gas collection lines at various elevations within the landfill with the collected gas burned in the flare. This type of well configuration allows immediate gas removal as the refuse begins to decompose. Another advantage is that the horizontal wells can be constructed without drilling into the refuse. [17]

Extraction wells can be designed to permit gas recovery at selected depth intervals. One design concept consists of a small well inside a larger well with special details to allow extraction at different depths. Some LFG recovery wells are equipped with slip joints or are telescoped since the surface of a landfill can be expected to settle 5 to 20 percent. The depth of the extraction well is 50 to 100 percent of the thickness.[2] Greater depth wells are utilized at the more shallow landfills (i.e. Mountain View Landfill in Northern California has an average landfill depth of 40 feet) and the lesser depth wells used for the deeper landfills. This is done due the fact that most of the gas will leave deep well-contained landfills by upward flow. Thus, even relatively shallow wells will capture most of the gas produced in the lower levels. As a result, the lower 15 to 80 percent of the recovery well pipe is usually perforated. Many well perforation patterns and methods have been put to use. The main requirement of the perforations are that they remain open, do not require excessive pressure losses to draw the gas through them, and do not weaken the pipe.

Figure 9-12 shows the typical recovery well used at most recovery sites. The well must be monitored for air intrusion, which is indicated by a reduction of methane content and by an increase in the nitrogen content of the collected gas. The diameter of extraction wells have ranged from 4 inches to 36 inches, with the most frequent size being 24 inches. Variations in well design include installation of perforated pipe and placement of perforated pipe in slightly undersized drilled holes. Polyvinyl chloride (PVC) is the most common material used because of its relatively low cost and its general satisfactory performance for well casing. Other types of material include fiberglass, high density polyethylene, and steel.

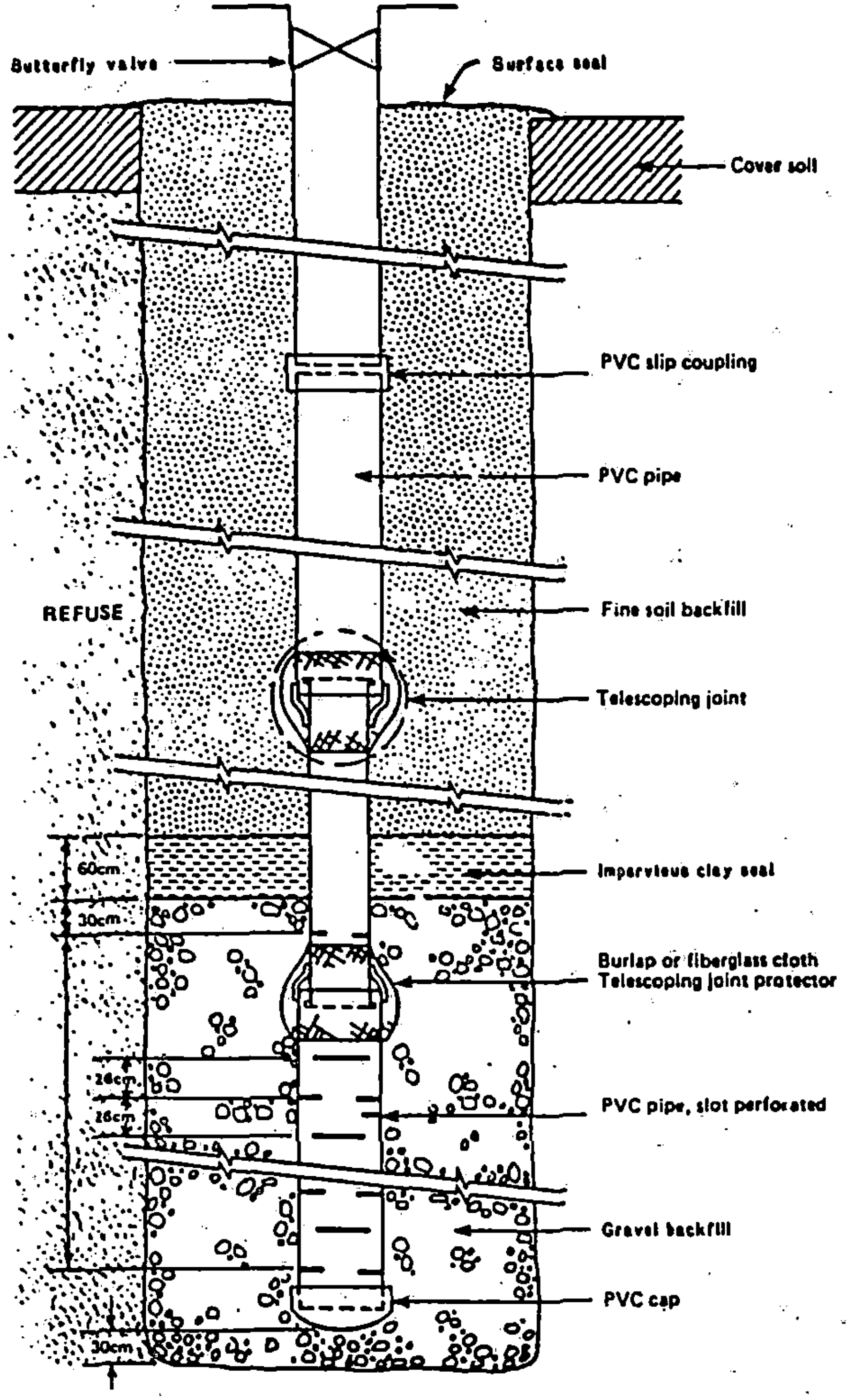


FIGURE 9-12 TYPICAL DESIGN OF GAS RECOVERY WELL

If migration control of the landfill gases is the only consideration, then collection wells would be located around the boundary of the landfill. In most cases, the low-BTU LFG would be routed to one or more locations to be vented or flared. Generally, an internal well and piping system would be used to recover the gases for use in an energy application. It may be necessary to have two separate collection systems; one for migration control and another for gas recovery and utilization.

One of the main concerns with a recovery well is the entry of oxygen into the system. Oxygen will kill or inhibit the anaerobic bacteria in the landfill. "Overstressing" a landfill by extracting gas at too great a rate will cause substantial air intrusion, thus causing aerobic regions within the landfill and a reduction of the gas recovery rate and for the total gas volume to be captured. High vacuum stresses should be induced near the refuse cover soil. For this reason, most extraction wells extract gas at a considerable depth below the landfill surface. Generally, the deeper the extraction interval, the higher the applied vacuum can be and/or the greater the well spacing can be.[2]

9.1.4.2 Headers

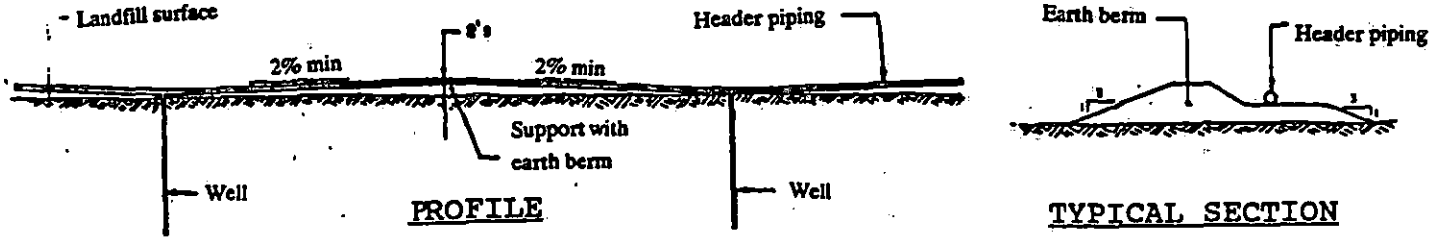
Lateral header pipes connect the individual wells to a vacuum source such as a pump or blower. Headers have been made from a variety of materials. Common materials include polyvinyl chloride (PVC), high density polyethylene, or fiberglass-reinforced polyester. Sizing of header systems is based on evaluation of the head loss of gas flowing in the system. Most header pipes are 4 to 12 inches (10 to 30 cm) in diameter. The collection system must be provided with condensate traps that allow liquids collected in the pipe to be sent to a storage tank or an underground sump. Suction is applied to each well casing, thus creating a pressure gradient. The gas is gathered to the well by the predominantly convective flow and is then removed at the well head. Each well head is normally equipped with a butterfly valve for flow rate control permitting flexibility in system operation. With this decreased pressure near the well, gas is collected into the well, removed at the well header, and then routed to the disposal point or recovery point.[10]

Due to the mild weather conditions in the landfill areas within the District's jurisdiction, most headers are located above ground. Soil cover can usually provide the best practical means of pipe protection if the pipes are buried. The choice is whether to lay the pipe on the surface and mound soil over it or to lay the pipe in a trench and backfill with soil. Trenching is used if a flat surface or if the landfill is located in a climate where the header pipe must be protected from freezing or forming condensate during winter months. A detail of exposed and buried header configurations are shown in Figure 9-13.[2]

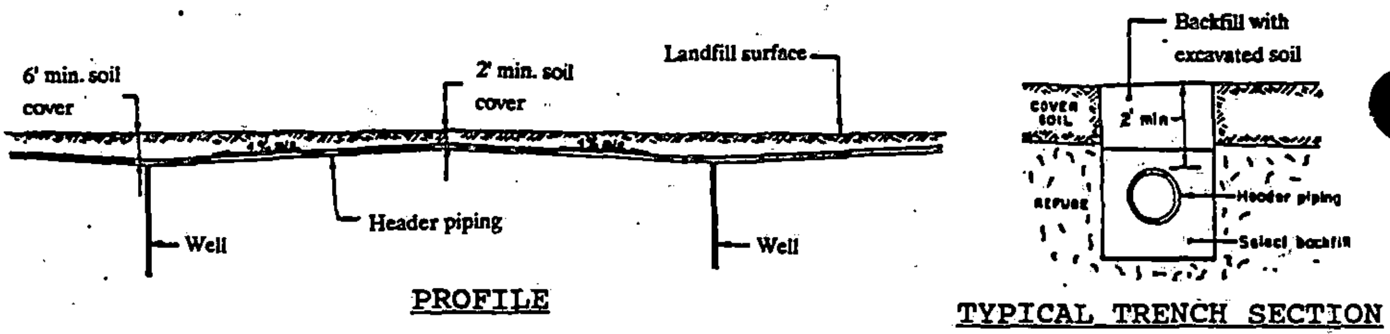
9.1.5 Resource Recovery System

The preferred control method for excess gases and vapors is to recover them in a resource recovery system such as a LFG-fired boiler to produce steam or electricity. When the heating value of large continuous LFG flows is high, vapor recovery or the use of the vapor as fuel is preferred over flaring since the high heat waste stream is too valuable to waste in a flare. For small continuous flow of gases, flares are sometimes used even though fuel or heat is either lost or wasted. In these cases, a flare is more economical to use. Low-BTU landfill methane gas may not be economically feasible to recover due to the cost of having to upgrade the gas. Widespread venting of waste gases into the atmosphere causes safety and environmental problems. Therefore, it is now required to collect gases from the recovery wells and burn them in a ground flare.

Fuel gas can be made from raw LFG by dehydration. After passing through a separator to remove condensate and heavy hydrocarbons, the LFG is compressed and cooled by refrigeration or absorbed in glycol solution. After absorbing the water, the rich glycol solution is circulated to a stripper where the water is vaporized and the lean glycol solution is recycled to the absorption tower. Vapors containing odorous heavy hydrocarbons from the stripper are condensed and delivered to a landfill injection well and non-condensibles are incinerated. Dehydrated LFG has a heat content of approximately 450 to 500 BTU/scf. It is compressed and used on site to power equipment or may be piped off site to a power plant or industrial users.[8]



HEADER PIPING EXPOSED



HEADER PIPING BURIED

Not to scale

FIGURE 9-13 HEADER INSTALLATIONS

Raw LFG may even be upgraded to 975 BTU/scf to produce synthetic natural gas by removing water and carbon dioxide. Commercial processes for removing carbon dioxide include adsorption and absorption. Raw LFG will pass through a separator to remove condensation and heavy hydrocarbons. Figure 9-14 illustrates a typical process using dehydration by glycol absorption followed by carbon dioxide removal by either molecular sieve adsorption or absorption using methyl ethanol amine (MEA). Some of the product gas is used to power internal combustion (IC) engine-driven compressors. The synthetic natural gas is injected into the natural gas utility pipeline and blended to meet standard specifications.[8]

Both IC gas engines and gas turbines have powered electrical generators by burning dehydrated LFG. Gas turbines are more economical to operate in conjunction with larger size electric generators than IC combustion engines. Heavy duty low speed IC engines are of two types: rich-burn, spark-injection and lean-burn non-sparking type. A catalytic converter has been achieved in practice to reduce reactive organic gases (ROG), carbon monoxide (CO), and oxides of nitrogen (NOx) for rich-burn engines while operating on LFG. Figure 9-15 is a flow diagram of an IC engine or gas turbine generating electricity.[8]

9.1.6 Condensate or Leachate Control and Treatment

LFG recovered generally has been found to be saturated with moisture. During collection in the header system, the gas undergoes an expansion and temperature decline (from 110-150 ^{o}F to 60-80 ^{o}F), and some water condenses, accumulating in the bottom of the header lines. If this condensate is allowed to accumulated in low spots of the line, the header pipe may become partially or completely blocked. To avoid the line blockage problem, condensate drains should be constructed along the header line, and the line should be always sloped toward a condensate drain into a sump.[1]

Leachate can be generated simply from the excess moisture in the materials received at the landfill. Leachate is also produced when groundwater or infiltrating surface water, such as rainfall, moves through the solid waste. This leachate generated from the solid waste is a mixture of dissolved and finely suspended solid matter and microbial waste products. Leachate may leave the landfill at the ground

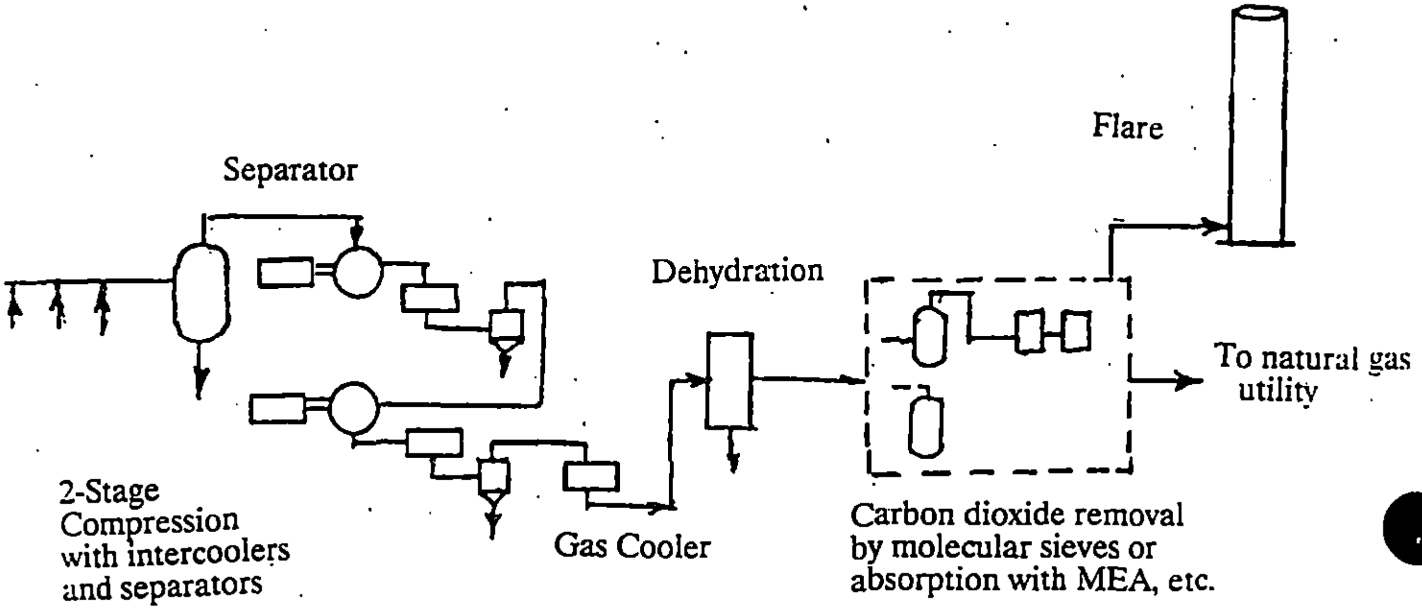


FIGURE 9-14 SYNTHETIC NATURAL GAS MANUFACTURE[8]

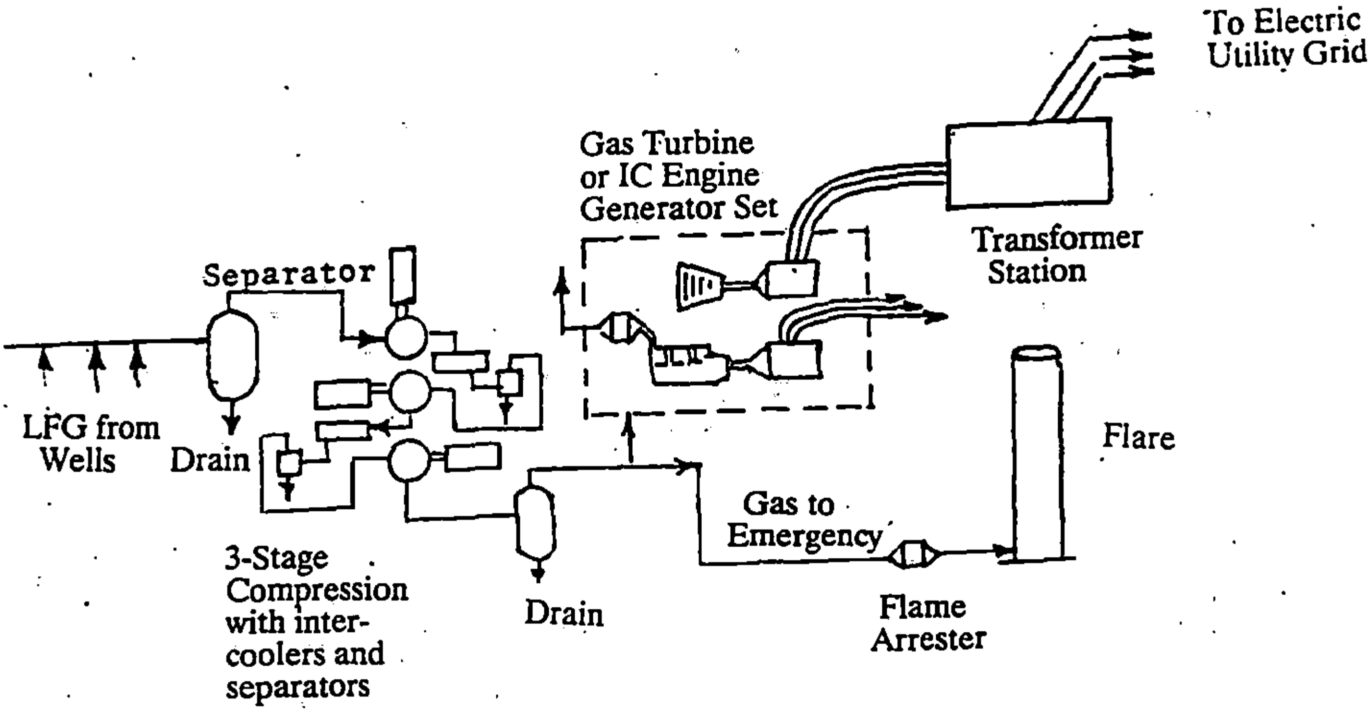


FIGURE 9-15 ELECTRICITY GENERATION USING IC ENGINE OR GAS TURBINE DRIVE[8]

surface as a spring or percolate through the soil and rock that lie below and surround the waste. Thus, it contains products of decomposition of organic materials and soluble ions.[20] As a result, leachate can cause serious pollution of groundwater and surface water if not properly controlled.

Leachate generation rates are dependent on the amount of liquid the waste originally contained and the quantity of precipitation that enters the landfill through the cover or falls directly on the waste. Chemical characteristics will be affected by the biological decomposition of biodegradable organic materials, chemical oxidation processes, and dissolving of organic and inorganic materials in the waste.[20]

This leachate, condensate, and other heavy odorous liquid hydrocarbons separated from raw LFG can no longer be injected back into the well as deemed by new requirements of the Water Quality Control Board and other agencies. Many landfills within the District have installed LFG condensate and/or leachate handling and treatment system to properly dispose of the liquid. A *separate* permit must be issued for these types of LFG condensate handling/treatment systems. Because of the specificity of a condensate treatment system within a landfill, a brief description of LFG condensate handling/treatment systems will be discussed here. Treatment of LFG condensate and leachate has been handled in the District by one or more of the following methods:

- condensate air stripping;
- chemical treatment; and/or
- biological aeration.

For the air stripping system, condensate is pumped through a pressurized oil/water separator and subsequently through the air stripping tower. The treated condensate will then be pumped directly to the sewer. Exhaust air from the stripping tower will be discharged into a vent pipe and then into a LFG collection header. Generally, ambient air is withdrawn through the air stripper by way of vacuum from a LFG blower in the flare station.

In a chemical treatment process, LFG condensate or leachate collected by a flare station trap will discharge to a condensate sump. Once the liquid level in the sump reaches a specified high level, a sump pump will pump the liquid to a condensate chemical treatment tank. In this treatment tank, the liquids will flow through a hydrocarbon skimmer compartment, pH neutralization using caustic soda and clarification compartments, and then a final mixing compartment for final pH adjustment before being sent through a carbon canister and then released into the atmosphere. The recovered hydrocarbons will then be discharged periodically.

Biological aeration involves adding nutrients containing nitrogen and phosphorous and oxygen to the condensate in an aeration tank. Bacteria will then grow and eventually form a sludge. This activated sludge heavily saturated with hydrocarbons is then sent through carbon where the hydrocarbons are adsorbed onto the packed carbon beds.

9.1.7 Landfill Flare Systems

Landfill flares are used for the control of gaseous combustible emissions of methane and reactive organic gases. Flare systems were developed to incinerate the gas extracted to prevent migration and resultant odors. Flaring safely disposes large amounts of waste gas at a relatively inexpensive cost.

There are two main considerations in deciding whether to flare a waste gas. These are the expected maximum volume of the stream to be flared and the heat content of the LFG. LFG volumes as great as 3000 scfm have been incinerated by a single flare. In addition, some waste gases cannot support their own combustion. Generally, a waste gas with a heating value greater than 200 BTU/ft^3 can be flared successfully. The heating values of perimeter gas may range from 150-300 BTU/ft^3 and that for the interior gas may be 350-550 BTU/ft^3.

9.1.7.1 Design Criteria

A ground flare consists of a burner and auxiliaries, such as a flame arrester, pilot burner, and ignitor, as shown in Figure 9-16. Ground flares may consist of multiple burners enclosed within a refractory shell. The flare flame of these flares is concealed and smokeless burning usually occurs at a low noise level. The gases to be flared are connected by a manifold to a series of burner heads which discharge

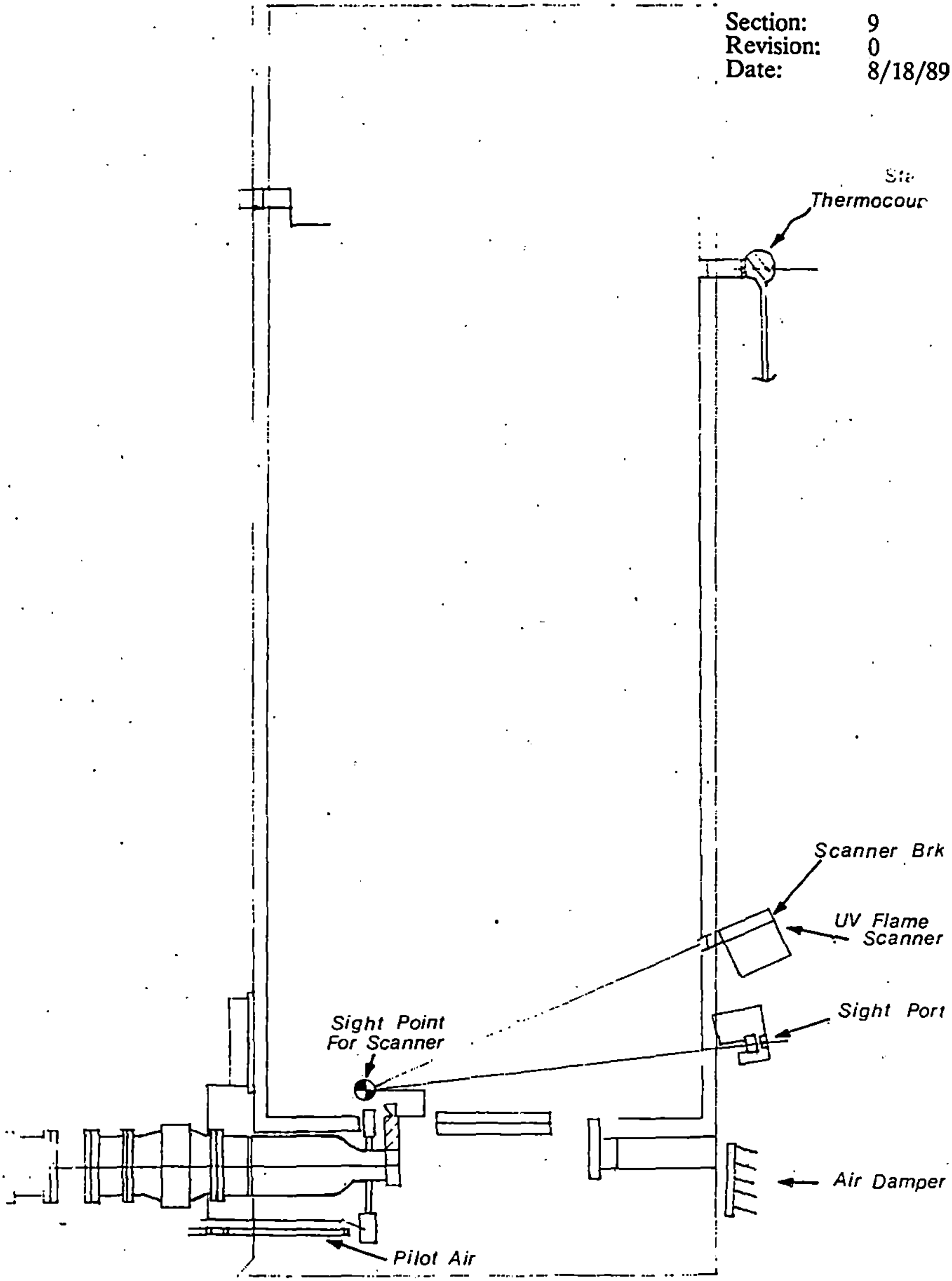


FIGURE 9-16 TYPICAL LANDFILL GAS FLARE

the gas into a refractory enclosure. Mixing of the gas and air is accomplished by a series of burners. Combustion air is provided by the natural draft of the enclosure. Due to the natural draft and the enclosure, smokeless burning is obtained with little or no steam because of the turbulence and temperature of the burning zone. The size of the enclosure will depend upon the capacity of the flare.

Typical landfill flare diameters vary from 4 to 12 feet. The height may range from 18 to 50 feet. Sizing is based on the minimum combustion temperature and the residence time required; for instance, a longer residence time requires a taller flare stack. A landfill gas flare may have the gas flow rate between 200 scfm for a minimum size flare to 5000 scfm for a maximum size flare.

The gas temperature entering the flare may range between 60 to 120 ^{O}F. The flare must meet stringent state and federal requirements of 1400 ^{O}F and higher incineration temperatures at residence times of at least 0.6 second which insure almost total destruction of the combustibles present. The District expects that flares have the capability to attain at least a 99% destruction efficiency for total non-methane hydrocarbons.

The shell of the flare is generally made of carbon steel plate of low or intermediate tensile strength.[4] The shell is insulated internally to protect the shell from overheating and to contain the heat within the flare. The burner assembly must generate minimum incineration temperatures to ensure at least a 99% destruction of combustibles. Important burner features to consider include low CO and NOx emission levels, a flame stabilizer to produce a short, intensive combustion zone and prevent the flame from being extinguished, high-alloy stainless steel materials for durability and resistance to high temperatures, and a very high surface area to volume ratio to insure optimum heat transfer. Equally important is to have very high length to diameter (L/D) ratio on burner ports to prevent backflash into the gas supply line.

Flame arresters inhibit flame propagation. A flame arrester used in the gas lines prevents the passage of flames without obstructing the flow of gas. The methane gas going into the flare must contain sufficient air or oxygen to maintain its own combustion. Thus, a flame arrester must be installed to prevent flashback.

Depending on the flow rate of the LFG into the flare and the size of the flare itself, flame arresters range from 2 to 30 inches. They are constructed of aluminum, carbon steel, stainless steel, and other corrosion resistant materials. (See Figure 9-17)

A flow meter and recorder should be installed between the blower outlet and the flare to continuously measure the amount of gas being collected and flared. The exhaust gas temperature will also be measured by some type of thermocouple on the flare. A flare safety system is needed to prevent unburned gas from being released into the atmosphere. In the event of a flame-out of the flare, the safety system will automatically trigger the control valve to close the inlet of the flare and an alarm will be activated. To facilitate the performance of source testing, an approved heat shield or sufficient insulation in the shroud around the test ports must be placed on the flare where samples are taken. All new flares are required to have an outside skin temperature of less than 250 ^{0}F to avoid heat stress to source testing personnel. To be issued a permit to construct and operate, the District requires that LFG flares be equipped with the following or comparable equipment:

- an UV flame scanner to ensure the flame is operating;
- a continuous exhaust gas temperature probe or thermocouple;
- a temperature controller to automatically adjust the air louvers for combustion air regulation;
- flame arrester;
- sight ports;
- sampling ports;
- safety system to shut off burner (flame failure alarm, gas shut-off valve;
- exhaust temperature and inlet flow recorders;
- recording devices synchronized with respect to time of day;
- burner assembly; and
- gas pilot or electronic ignitor.

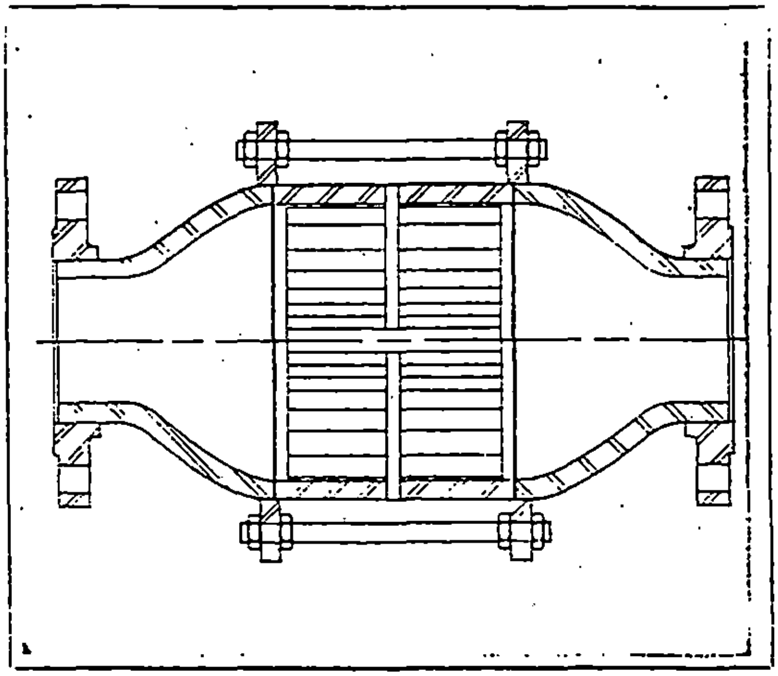


Figure 9-17 Flame Arrester used in Ground Flares

9.2 Permit Unit Description

The Waste and Energy Management Unit's current practice is to separate a landfill gas control system into three permit units:

- *Landfill Gas Collection System*, which includes all wells and gas collection piping, as well as booster blowers and condensate traps or tanks if each is 250 gallons or less in capacity; and
- *Landfill Gas Flare System*, which includes all equipment at the flare station;
- *Landfill Gas Condensate or Leachate Handling/Treatment System*.

9.2.1 Landfill Gas Collection System Permit Unit Description

The permit unit description for landfill gas collecting or gathering system should be the following:

LANDFILL GAS COLLECTION (OR GATHERING) SYSTEM CONSISTING OF:

1. LANDFILL GAS BLOWER, (MANUFACTURER), MODEL # H.P. ________.
2. AUTOMATIC BLOWER DISCHARGE SHUT-OFF VALVE, ____________ TYPE.
3. ________ (__) LANDFILL GAS COLLECTION WELLS, EACH APPROXIMATELY ______ FEET DEEP, WITH _____ INCH DIAMETER, ___________ (TYPE OF MATERIAL) CASING.

9.2.2 Landfill Gas Flare System Permit Unit Description

The permit unit description for *landfill gas flare system* should be the following:

LANDFILL GAS TREATING AND FLARING SYSTEM CONSISTING OF:

1. FLARE NO. ______, VENTING (INTERIOR OR PERIMETER) LANDFILL GAS, (MANUFACTURER), MODEL ______, ______" ODIA X ______" H., __________ BURNER, (GAS, ELECTRIC, ETC) IGNITOR, UV FLAME SCANNER, THERMOCOUPLE WITH TEMPERATURE INDICATOR AND RECORDER, AND AN AUTOMATIC COMBUSTION AIR REGULATING SYSTEM (AIR DAMPERS).
2. (_) FLAME ARRESTER(S), ______ TYPE, MODEL #______, (DIMENSIONS), (MANUFACTURER).
3. LANDFILL GAS FLOW ELEMENTS WITH RECORDERS.
4. AUTOMATIC LANDFILL GAS SHUT-OFF VALVE, ______ TYPE.
5. AUTOMATIC LANDFILL GAS PRESSURE CONTROL VALVE, _____ TYPE, WITH PRESSURE INDICATING CONTROLLER.
6. INTERIOR LANDFILL GAS SEPARATOR, ____________.
7. PERIMETER LANDFILL GAS SEPARATOR, ____________.
8. GAS TURBINE SUPPLY GAS SEPARATOR, ____________.
9. KNOCKOUT VESSEL FOR PARTICULATE CONTROL, ______" DIA. X _______" L, MODEL ________, SERIAL NO. ________.

9.2.3 Landfill Gas Condensate or Leachate Handling Permit Unit Description

The permit unit description for *landfill gas condensate or leachate air stripping (handling) system* should be the following:

LANDFILL GAS CONDENSATE (LEACHATE) AIR STRIPPING SYSTEM CONSISTING OF:

1. CONDENSATE SUMP, ___'- ______" DIA. x ___ ' - _____" DEEP.
2. CONDENSATE TANK, ____________ (TYPE OF MATERIAL) TANK, __________ GALLONS CAPACITY, WITH (PRESSURE AND LEVEL) CONTROLS.
3. INFLUENT (CONDENSATE) (VACUUM) PUMP, ______________ (MANUFACTURER), MODEL _______________, _______GPM AT _______ FEET HEAD, WITH A _____________ H.P. MOTOR.
4. OIL/WATER SEPARATOR, __________ (MANUFACTURER), PRESSURIZED TANK, WITH AUTOMATIC OIL DISCHARGE VALVE.
5. AIR STRIPPING TOWER, ____________ (MANUFACTURER), _____'-___" DIA. x _____'- _______" H., WITH __________ FEET PACKING, (DEMISTER, AND A BLOWER, ___________ (MANUFACTURER), MODEL _______________, _______ CFM AT _____" W.C., WITH A _________ H.P. MOTOR,) VENTED TO THE LANDFILL GAS COLLECTION AND FLARING SYSTEM.
6. EFFLUENT (VACUUM) PUMP, _____________ (MANUFACTURER), MODEL # ___________, _______ GPM AT ______ FEET, WITH A __________ H.P. MOTOR.

9.2.4 Landfill Gas Condensate or Leachate Treatment Permit Unit Description

The permit unit description for *landfill gas condensate or leachate treatment system* should be the following:

LANDFILL GAS CONDENSATE (LEACHATE) TREATMENT SYSTEM CONSISTING OF:

1. CONDENSATE SUMP, (UNDERGROUND), _____'- _____" DIA. x ____'- _____" DEEP, WITH _______ H.P. SUMP PUMP.
2. CONDENSATE TREATMENT TANK, ____________ (TYPE OF MATERIAL) TANK, _____'- ______" DIA. x ___' - _____" DEEP __________ GALLONS CAPACITY, WITH _______ H.P. MIXER, AND EFFLUENT PH CONTROL SYSTEM.
3. CARBON CANISTER, VENTING TREATMENT TANK, (TYPE), WITH _____________ SEAL.

9.3 Emissions

Depending on the chemical constituents in the landfill, the air contaminants resulting directly from the flaring of landfill gases are reactive organic gases (ROG), particulate matter (PART), nitrogen oxides (NOx), sulfur oxides (SOx), and carbon monoxide (CO). Landfills may consist of carcinogenic or non-carcinogenic toxic hydrocarbons. Carcinogenic compounds such as vinyl chlorides and methylene chloride have been found in both non-hazardous and hazardous waste landfills. Toluene and xylenes have also been found at various landfills in the District. As a result of the presence of these compounds in both Class I and II landfills, a health risk assessment must be performed. The Division is currently following the Risk Assessment Policy outlined in Mr. William J. Dennison's memorandum, dated November 4, 1987. This risk assessment must be done for all toxic compounds from the flaring station and the condensate handling facility such as an air stripper.

Carcinogenic or non-carcinogenic toxic hydrocarbon emissions are controlled by operating the flare at several hundred degrees (^{o}F) above the volatile organic compound autoignition temperature.[3] The autoignition temperature is the temperature at which combustible mixtures of the VOC in air will ignite without an external source such as a spark. Table 9-5 presents some autoignition temperatures for various organics in the air. Thus, destruction of these organics will be achieved by operating the flare at either 1400^{o}F or 1500^{o}F.

TABLE 9-5 AUTOIGNITION TEMPERATURES OF SELECTED ORGANICS IN AIR[3]

Substance	Autoignition Temperature, °F	Substance	Autoignition Temperature, °F
Acetone	1000	Ethylene Dichloride	775
Acrolein	453	Hydrogen	1076
Acrylonitrile	898	Hydrogen Cyanide	1000
Ammonia	1200	Hydrogen Sulfide	500
Benzene	1075	Isobutane	950
m-Butane	896	Methane	999
1-Butene	783	Methanol	878
m-Butyl Alcohol	693	Methyl Chloride	1170
Carbon Monoxide	1205	Methyl Ethyl Ketone	960
Chlorobenzene	1245	Phenol	1319
Cyclohexane	514	Propane	871
Ethane	986	Propylene	851
Ethanol	799	Styrene	915
Ethyl Acetate	907	Toluene	1026
Ethylbenzene	870	Vinyl Chloride	882
Ethyl Chloride	965	Xylene	924
Ethylene	842		

9.3.1 Emission Factors

Emission factors for various pollutants vary among landfills. These factors depend on the type of landfill (hazardous or non-hazardous) and what has been deposited (toxics, food wastes, etc.) in the landfill. Flare emissions may be based on emission factors given by manufacturers specifications or they may be calculated from source test data. Hydrocarbon emission factors are represented by a destruction efficiency (DRE). Both NOx and CO emission factors are given by pounds of contaminant per MMBTU. Table 9-6 lists the emission factors from a typical landfill gas flare.

9.4 Calculations

9.4.1 Operational Data

Emission calculations are performed to determine compliance with District Rules and Regulations. A health risk assessment should also be done following the guidelines set forth in current District policy. To determine compliance, the applicant must provide the following LFG composition and flare specifications:

Landfill Gas Composition and Flare and Condensate Treatment Specifications

(1) Landfill Gas Composition
- *(a)* CH_4 ____________________%
- *(b)* CO_2 ____________________%
- *(c)* H_2O ____________________%
- *(d)* N_2 and inerts ____________________%
- *(e)* O_2 ____________________%
- *(f)* H_2S ____________________ppm
- *(g)* Other sulfur compounds ____________________ppm
- *(h)* Other hydrocarbons
  - ____________________ ____________________ppm
  - ____________________ ____________________ppm
  - ____________________ ____________________ppm
  - ____________________ ____________________ppm
  - ____________________ ____________________ppm

TABLE 9-6: TYPICAL EMISSION FACTORS FOR LANDFILL GAS FLARE[21]

Air Contaminant	Emission Factor
Reactive Hydrocarbons, RHC	95% - 99% DRE*
Unreactive Hydrocarbons, methane	99% - 99.9% DRE*
NOx	0.06 lb/MM BTU input
CO	0.05 - 0.20 lb/MM BTU input
SOx	100% conversion of H_2S and other sulfur compounds
Particulates	60 - 80 lb/MMcf 10 - 20 lb/MMcf with knockout vessel and/or other particulate removal device

* Destruction Efficiency

(i) Particulates ______________ gr/dscf

(2) Heat Loss Percentage (Approximate) ______________ %

(3) Proposed Total LFG Inlet Flow Rate

(a) Perimeter = ______________ scfm

(b) External = ______________ scfm

(c) Air Stripper = ______________ scfm

(c) MAXLFG = *(a)* + *(b)* + *(c)* ______________ scfm

(4) Proposed Total Gas Outlet (Exhaust) Flow Rate ______________ scfm

(5) LFG Dry Inlet Flow Rate*, INDRY = ______________ scfm

(6) Flare Dry Exhaust Flow Rate*, EXDRY = ______________ dscfm

(7) Maximum Gas Back Pressure** ______________ in. W.C.

(8) Maximum ambient air temperature ______________ °F

(9) Minimum combustion temperature at thermocouple elevation, TEMPT = ______________ °F

(10) Maximum outside skin temperature on flare ______________ °F

(11) Diameter of Flare, D ______________ feet

(12) Height of Flare ______________ feet

(13) Maximum condensate traps capacity ______________ gal/day

(14) Condensate volume delivered to treatment system ______________ gal/day

* From source tests.

** Back pressure includes the pressure drop through the automatic valve, flame arrester, and burner.

9.4.2 LFG Molecular Weight Calculation

The average molecular weight (MW) of the LFG gas must be calculated to determine the mean LFG heat capacity. Given the LFG concentrations of the major components, the average molecular weight is calculated using the following equation:

$$MWLFG = \sum (x_i)(MW_i) \qquad \textbf{(Equation 9.1)}$$

where,

MWLFG = Molecular Weight of LFG (lb/lb-mole)
x_i = Volume percent of gas constituent (%)
MW_i = Molecular Weight of gas constituent (lb/lb-mole)
i = Gas constituent: CH_4, CO_2, O_2, H_2O, N_2 and inerts

9.4.3 Mean Heat Capacity Calculation

Depending on the minimum combustion temperature of the flare, use the following heat capacity, C_p, data and equations to calculate the mean heat capacity of the flue gas, $C_{p,mean}$.

		C_p, BTU/lb-mol °F[19]	
		1400 °F	1500 °F
$C_{p,CO2}$	=	11.43	11.55
$C_{p,H2O}$	=	8.909	8.983
$C_{p,O2}$	=	7.778	7.830
$C_{p,N2}$	=	7.331	7.368

$$C_{p,\text{mole mean}} = \sum (x_i)(C_{p,i}) \qquad \textbf{(Equation 9.2)}$$

$$C_{p,\text{mean}} = \frac{C_{p,\text{mole mean}}}{MWLFG} \qquad \textbf{(Equation 9.3)}$$

where,

y_i = lb-mol percentage of gas constituent
$C_{p,\text{mole mean}}$ = mean molecular heat capacity, BTU/lb-mol °F
$C_{p,\text{mean}}$ = mean heat capacity of flare flue gas, BTU/lb °F

9.4.4 LFG Heating Value Calculation

The LFG BTU content must be known to calculate pollutant emissions. This heating value may either be calculated or found by total combustion analysis (TCA) of carbonaceous materials. The latter method of finding the heating value is preferred and is obtained from source testing. If no heating value is available through source test, the LFG BTU content may be estimated using Equation 9.4 with the following information:

1. If the concentration of the non-methane hydrocarbons (NMHC) is less than 1%, assume these combustibles are negligible. Obtain the BTU content of the NMHC in the LFG from source tests if the NMHC concentration exceeds 1% (10,000 ppm).

2. Obtain the heating value of CH_4 in the LFG from source tests. If this BTU content is not available, 1000 BTU/scf may be assumed for the heating value of CH_4. The higher heating value of combustion of methane is 1013 BTU/scf and the lower heating value is 913.1 BTU/scf.[11]

3. 1 lb-mole LFG occupies 379 scf at standard temperature (60 °F) and pressure (1 atm).

$$BTU_{LFG} = (BTU_{CH4})(x_{CH4}) + (BTU_{NMHC})(x_{NMHC})$$

(Equation 9.4)

where,

BTU_{LFG} = LFG BTU content, BTU/scf
BTU_{CH4} = CH_4 BTU content, BTU/scf
BTU_{NMHC} = NMHC BTU content, BTU/scf
x_{CH4} = Concentration CH_4, %
x_{NMHC} = Concentration NMHC, %

9.4.5 Theoretical Air Requirements

Because the flaring of LFG is a combustion process, the theoretical air requirement (TAR) and air flow rate must be considered. The balanced equation of the combustion process is given by

$$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O$$

Air contains approximately 21% O_2 and 79% N_2, thus for 1 lb-mole O_2 there are 3.76 lb-moles N_2 involved. The complete combustion equation may be represented by

$$\begin{aligned}
&[\,\%CH_4\ CH_4 + \%CO_2\ CO_2 + \%H_2O\ H_2O + \%N_2\ N_2 + \%O_2\ O_2\,] + \\
&\quad [\,(2 \times \%CH_4 - \%O_2)\ O_2 + 3.76 \times (2 \times \%CH_4 - \%O_2)\ N_2\,] \longrightarrow \\
&\ [\,(\%CH_4 + \%CO_2)\ CO_2 + (2 \times \%CH_4 + \%H_2O)\ H_2O\,] + \\
&\qquad [\,3.76\,(2 \times \%CH_4 - \%O_2) + \%N_2\,]\ N_2
\end{aligned}$$

9.4.6 Excess Air Calculation

The amount of excess air the flares will operate at must be known in calculating the retention time of the flares. The excess air percentage may be calculated when the flue gas CO is known through source test. Generally, this is not known when performing preliminary calculations. The excess air amount may be anywhere between 50% to 200%. Thus, assume the excess air to be approximately between 100% to 200%.

Should the concentration of CO be known from source test. The following equations may be used to calculate the excess air percentage.

$$XAIR = \frac{(x_{O2}) - (0.5)(x_{CO})}{(21\%/79\%)(x_{N2}) - x_{CO} - (0.5)(x_{CO})} \times (100\%)$$

(Equation 9.5)

where,

XAIR = Excess air in flare, %

9.4.7 Retention Time Calculation and Operating Temperature

The Best Available Control Technology (BACT) for controlling reactive organic gases in a ground level shrouded LFG flare is to operate at 1400°F (non-hazardous waste landfill) or 1500°F (hazardous waste landfill) at a retention time of at least 0.6 seconds. To calculate the retention time of the flare:

1. Obtain the LFG inlet flow rate (perimeter, interior, or MAXLFG, scfm) and the minimum combustion temperature of the flare, TEMPT(°F).
2. Calculate the molecular flow rate of the LFG by dividing the LFG flow rate by 379 scf/lb-mol LFG, MOLES, (Equation 9.6).
3. From LFG analysis, calculate the theoretical air required, TAIR, for combustion (lb-moles) (Equation 9.7).
4. Approximate the amount of excess air in the flare, XAIR (lb-moles) (Section 9.4.6 or Equation 9.5).
5. Calculate the total air in the flare, AIR (lb-moles) (Equation 9.8) by multiplying the amount of theoretical air required, TAIR (lb-moles)(Equation 9.7) and the excess air percentage, XAIR (lb-moles).
6. Calculate the products of combustion, PC_i (lbs or lb-mols) of the major gas constituents by using Equations 9.9 to 9.12.

7. Sum the products of combustion (PC) of the major gas constituents to obtain the total weight of the products of combustion, P_{TOT} (lbs) (Equation 9.13).

8. With the LFG molecular flow rate, RATE, calculated in Equation 9.6, obtain the products of combustion mass flow rate, $FLOW_{PC}$ (lbs/min), using Equation 9.14.

9. In order to calculate the net flue gas enthalpy, the following must be considered:
   a. Calculate the heat of combustion, HEAT (BTU/min) with Equation 9.15;
   b. The heat loss due to evaporation, EVAP (BTU/min) is calculated using Equation 9.16;
   c. Using AIR, $C_{p,mean}$, and RATE, the sensible heat loss, SENSE (BTU/min), is found with Equation 9.17;
   d. The radiation heat loss, RADIA (BTU/min) (Equation 9.18), is obtained by multiplying the assumed heat loss percentage by the heat of combustion, HEAT (BTU/min) (Equation 9.15); and
   e. With HEAT, EVAP, SENSE, RADIA, and $FLOW_{PC}$, the flue gas enthalpy, H (BTU/lb) is calculated with Equation 9.19.

10. Calculate the moisture in the flue gas, MOIST (%), using Equation 9.20.

11. Calculate the total combustion flow rate, COMB (scfm) (Equation 9.21) by summing the combustion air flow, AIR (Equation 9.8) and the LFG inlet flow rate.

12. Using the total combustion flow rate, COMB (scfm) (Equation 9.21) and OPTEMPT, ^{o}F, calculate the volumetric or exhaust flow rate, acfm (Equation 9.22).

13. Calculate the combustion volume, VOLUME (cf or acf)(Equation 9.23).

14. Obtain the diameter of the flare, D (ft), and the height from the flare top of the flare burner to the thermocouple, h (ft).

15. The retention time, TIME (sec) (Equation 9.24), is calculated by dividing the combustion volume, VOLUME (cf or acf) (Equation 9.23), by the exhaust flow rate, EXHAUST (acfm) (Equation 9.22).

Minimum Required Flame Temperature, TEMPT = ________________ °F

LFG Composition, based on *100 lb-moles LFG*:

CH_4	*(1a)*________________	lb-moles
CO_2	*(1b)*________________	lb-moles
H_2O	*(1c)*________________	lb-moles
N_2 and inerts	*(1d)*________________	lb-moles
O_2	*(1e)*________________	lb-moles

LFG Molecular Flow Rate, RATE

RATE = *(3)*______________/MOLES = ________________ $\frac{\text{lb-mol}}{\text{min}}$

(Equation 9.6)

Excess Air in Flare, XAIR *(Section 9.4.6 or Equation 9.5)*

=________________%

Theoretical Air Required for Combustion, TAIR

$$\text{TAIR} = (1a)\underline{\hspace{3cm}}\ (2 + 3.76 \times 2)\ \frac{\text{lb-mol air}}{\text{lb-mol } CH_4} - (1e)\underline{\hspace{3cm}}\ (1 + 3.76)\ \frac{\text{lb-mol air}}{\text{lb-mol } O_2}$$

= ______________ lb-moles air

(Equation 9.7)

Total Air in Flare, AIR

AIR = (TAIR) (XAIR) = ________________ lb-moles

(Equation 9.8)

Products of Combustion, PC

PC_{CO2} = *(1a)* __________ x 1 + *(1b)* __________ = *(18)* ______ lb-moles

= *(18)* __________ (MW_{CO2}) = *(19)* ________________ lbs

(Equation 9.9)

PC_{H2O} = *(1a)* __________ x 2 + *(1c)* ________________ +

$$\frac{(AIR + 100)\,(MW_{AIR})\,(0.013)}{(MW_{H2O})}$$

= *(20)* ________________ lb-moles

= *(20)* ________________ (MW_{H2O}) = *(21)* ____________ lbs

(Equation 9.10)

PC_{N2} = (AIR) (0.79) + *(1d)* ________________ = *(22)* ______ lb-moles

(22) ____________ (MW_{N2}) = *(23)* ____________________ lbs

(Equation 9.11)

PC_{O2} = (AIR – TAIR) (0.21) = *(24)* ____________________ lb-moles

(24) ____________ (MW_{O2}) = *(25)* ________________ lbs

(Equation 9.12)

Total Products of Combustion, PC_{TOT}

$PC_{TOT} = PC_{CO2} + PC_{H2O} + PC_{N2} + PC_{O2}$

= ____________________ lbs

(Equation 9.13)

Products of Combustion Mass Flow Rate at LFG Flow Rate, $FLOW_{PC}$

$$FLOW_{PC} = \frac{(PC_{TOT})\,(RATE)}{100 \text{ lb-mol LFG}}$$

= ______________ lbs/min **(Equation 9.14)**

Heat of Combustion, HEAT

HEAT = *(3)*____________ (BTU$_{LFG}$)*(1a)*______________ /100 lb-mol LFG

= ______________ BTU/min **(Equation 9.15)**

Evaporation Loss, EVAP

EVAP = *(20)*____________ $\dfrac{(18.919)\ (\text{RATE})}{100 \text{ lb-mol LFG}}$

= __________ BTU/min **(Equation 9.16)**

Sensible Heat Loss, SENSE

SENSE = $\dfrac{(\text{AIR})(\text{MW}_{\text{AIR}})(C_{p,\text{mean}})(\text{TEMPT} - 60\ ^{\circ}\text{F})\ (\text{RATE})}{100 \text{ lb-mol LFG}}$

= __________ BTU/min **(Equation 9.17)**

Radiation Loss, RADIA

RADIA = *(2)*______________ % (HEAT) = _____ BTU/min **(Equation 9.18)**

Flue Gas Enthalpy, H

H = $\dfrac{\text{HEAT - EVAP - SENSE - RADIA}}{\text{FLOW}_{\text{PC}}}$ = ______________ BTU/lb **(Equation 9.19)**

Moisture in Flue Gas, MOIST

MOIST = (100%) *(21)*__________________ /PC$_{TOT}$ = ______________ % **(Equation 9.20)**

Figure 9-18 shows correlations between the enthalpy of flue gas above 80 $^{\circ}$F and moisture in the gas. Based on the net flue gas enthalpy, H, and the moisture in the flue gas, MOIST, the flue gas temperature is________________ $^{\circ}$F, OPTEMPT.

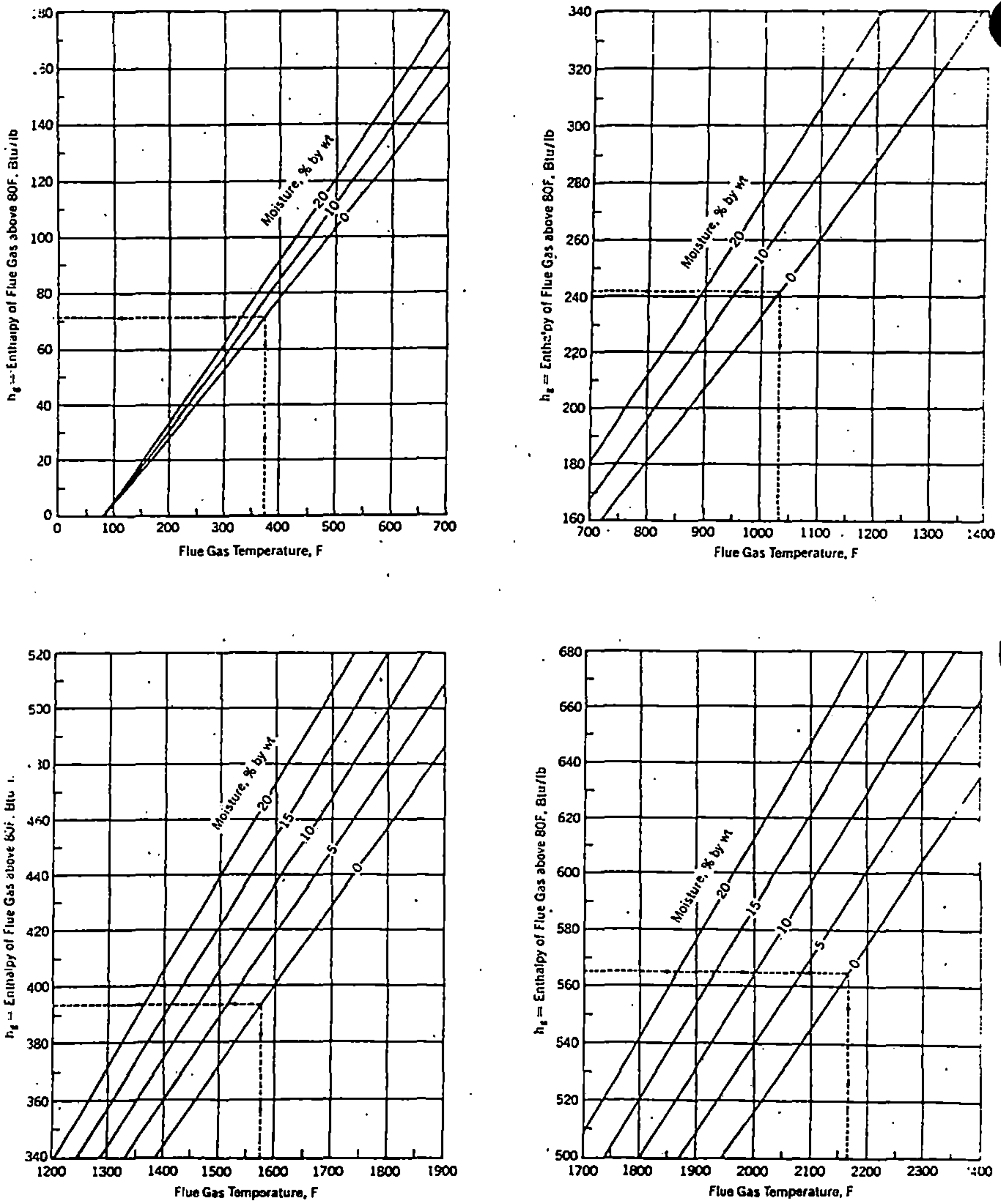


FIGURE 9-18 ENTHALPY OF FLUE GAS ABOVE 80 ^{O}F AT 30 in. HG, BTU/LB[18]

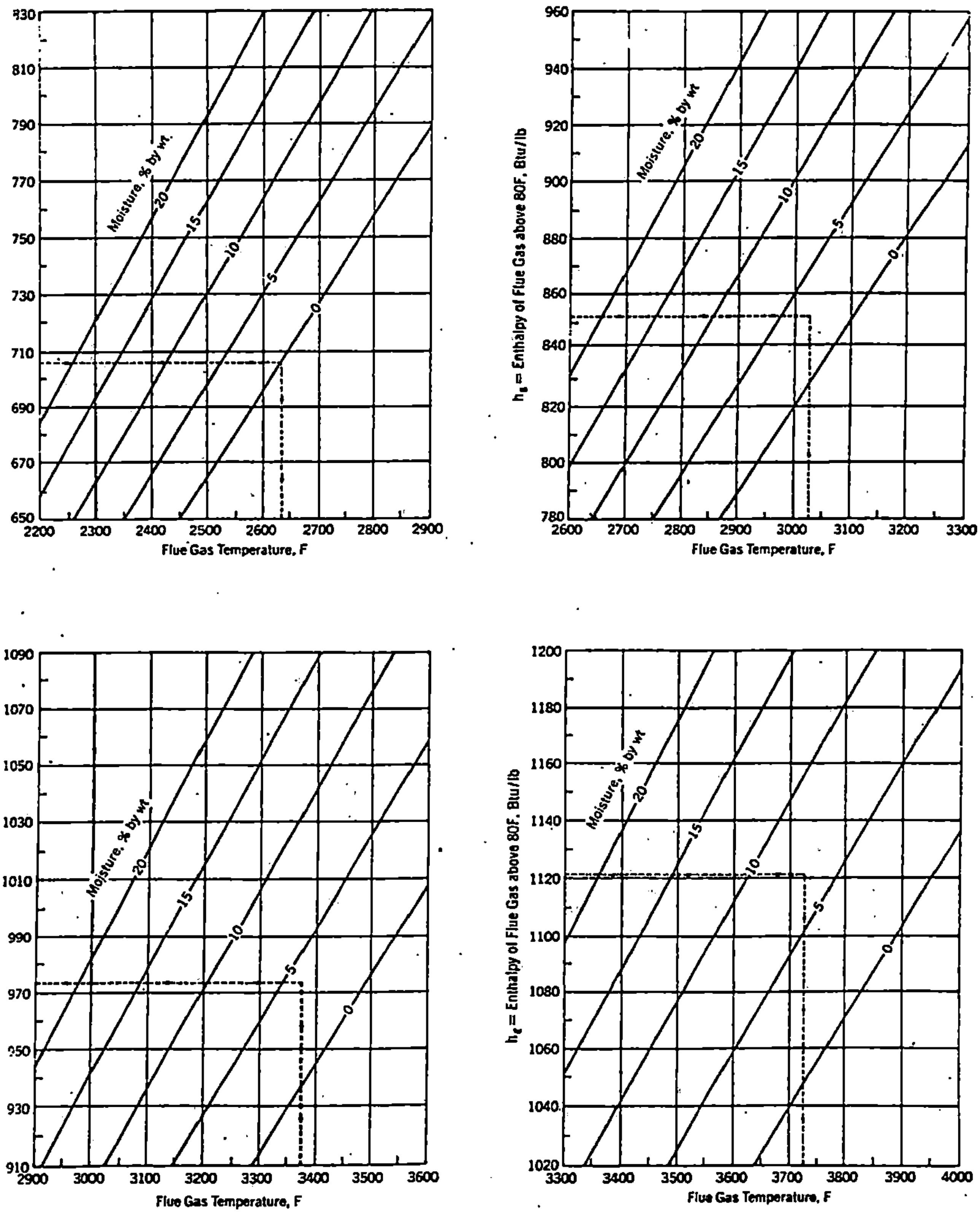


FIGURE 9-18 (CONT'D) ENTHALPY OF FLUE GAS ABOVE 80 °F AT 30 in. HG, BTU/LB[18]

Total Combustion Flow Rate, COMB

COMB = (AIR)*(3)*__________/100 lb-mol LFG + *(3)*__________________

= __________________scfm

(Equation 9.21)

Volumetric or Exhaust Flow Rate, EXHAUST

$$\text{EXHAUST} = \frac{(\text{COMB})(460\,^{\circ}\text{F} + \text{OPTEMPT})}{(460\,^{\circ}\text{F} + 60\,^{\circ}\text{F})} = \_\_\_\_\_\_\_\_\_\_ \text{acfm}$$

(Equation 9.22)

Combustion Volume, VOLUME

$$\text{VOLUME} = \frac{\pi (D^2)(h)}{4} = \_\_\_\_\_\_\_\_\_\_ \text{cf or acf}$$

(Equation 9.23)

Retention Time, TIME

$$\text{TIME} = \frac{\text{VOLUME}}{\text{EXHAUST}} \left(\frac{1 \text{ min}}{60 \text{ sec}}\right) = \_\_\_\_\_\_\_\_\_\_ \text{sec}$$

(Equation 9.24)

where,

AIR = Total air required for combustion, lb-moles (Equation 9.8)

BTU_{LFG} = LFG heating value or BTU content, BTU/scf (Equation 9.4)

BTU_{CH4} = CH_4 BTU content, BTU/scf

BTU_{NMHC} = NMHC BTU content, BTU/scf

COMB = Total combustion flow rate, scfm (Equation 9.21)

$C_{p,\text{mean}}$ = mean heat capacity of flare flue gas, BTU/lb °F (Equation 9.3)

$C_{p,\text{mole mean}}$ = mean molecular heat capacity of flare flue gas, BTU/lb-mol °F (Equation 9.2)

D = Diameter of flare, ft

EVAP = Heat loss due to evaporation, BTU/min (Equation 9.16)
EXHAUST = Volumetric or exhaust flow rate, acfm (Equation 9.22)
$FLOW_{PC}$ = Products of combustion mass flow rate at LFG flow rate, lbs/min (Equation 9.14)
h = Height from flare base to thermocouple, ft
H = Flue gas enthalpy, BTU/lb (Equation 9.19)
HEAT = Heat of combustion, BTU/min (Equation 9.15)
i = Gas constituent: CH_4, CO_2, O_2, H_2O, N_2 and inerts
MOIST = Amount of moisture in flue gas, % (Equation 9.20)
MOLES = LFG molecular volume = 379 scf/lb-mol
MW_{AIR} = Molecular weight of air, 29 lbs/lb-moles
MWLFG = Molecular weight of LFG, lb/lb-mole (Equation 9.1)
MW_i = Molecular weight of gas constituent (lb/lb-mole)
OPTEMPT = Flare operating temperature, °F
PC_i = Products of combustion, lb or lb-mol (Equations 9.9 - 9.12)
PC_{TOT} = Total weight of products of combustion, lbs (Equation 9.13)
RADIA = Radiation heat loss, BTU/min (Equation 9.18)
RATE = LFG molecular flow rate, lb-mol/min (Equation 9.6)
SENSE = Sensible heat loss, BTU/min (Equation 9.17)
TAIR = Amount of theoretical air in flare, lb-moles (Equation 9.7)
TEMPT = Minimum combustion temperature, °F
TIME = Retention time, sec (Equation 9.24)
VOLUME = Combustion volume, cf or acf (Equation 9.23)
XAIR = Excess air in flare, %
x_i = Volume percent of gas constituent (%)

% Excess Air ________________%
RATE ________________lb-moles/min
COMB ________________scfm
Retention Time ________________sec
Operating Temperature ________________°F

The minimum operating temperature and residence time is achieved by adjusting the combustion air damper to a position equivalent to the excess air percentage. Should the residence time and operating temperature not reach the minimum operating temperature (1400 ^{O}F or 1500 ^{O}F) and residence time, the percentage of excess air must either be increased or decreased.

9.4.8 Principal Pollutant Emission Calculation

To calculate the principal pollutant emissions, the emission factors for the pollutant must be known. They may either be given by the flare manufacturer, source tests, or calculated using the following equations.

9.4.8.1 NMHC Emission Factor, EF_{NMHC}

From total combustion analysis (TCA) given by source tests, the inlet and outlet concentration of the NMHC as CH_4 (if EPA Method 25 is used, the concentration would be as C_1) must be known. Using this information, the destruction efficiency may be calculated using Equation 9.25

Inlet Concentration NMHC =______________ppm as C_1
Outlet Concentration NMHC =______________ppm as C_1

$$NMHC_{in} = \frac{(INDRY)(x_{NMHC})(MW_{CARBON})(60\ min/hr)}{(MOLES)}$$

(Equation 9.25)

$$NMHC_{out} = \frac{(EXDRY)(OUT_{NMHC})(MW_{CARBON})(60\ min/hr)}{(MOLES)}$$

(Equation 9.26)

$$EF_{NMHC} = \frac{(NMHC_{in} - NMHC_{out})\ (100\%)}{NMHC_{in}}$$

(Equation 9.27)

where,

EF_{NMHC} = Emission factor of NMHC
EXDRY = Flare dry exhaust flow, dscfm
INDRY = LFG dry inlet flow, scfm
MOLES = LFG molecular volume = 379 scf/lb-mol
MW_{CARBON} = Molecular weight of methane, 16 lb/lb-mol
$NMHC_{in}$ = NMHC inlet concentration, lb/hr
$NMHC_{out}$ = NMHC outlet concentration, lb/hr

9.4.8.2 NOx Emission Factor, EF_{NOx}

To calculate the emission factor for NOx, first obtain the average concentration of NOx as NO_2 from source tests. Then use the following equations:

NOx Concentration as NO_2 =____________________ppm

$$NO_{2,out} = \frac{(x_{NOx})(EXDRY)(MW_{NO2})}{(MOLES)}$$

(Equation 9.28)

$$EF_{NOx} = \frac{(NO_{2,out})}{(INDRY)(BTU_{LFG})}$$

(Equation 9.29)

where,

EF_{NOx} = NOx emission factor, lb/MMBTU
MW_{NO2} = NO_2 molecular weight, 46 lb-mol/mol
$NO_{2,out}$ = NO_2 flow rate, lb/min

9.4.8.3 CO Emission Factor, EF_{CO}

From the average concentration of CO, use the following equations to calculate the emission factor of CO:

$$CO_{in} = \frac{(x_{NOx})(EXDRY)(MW_{CO})}{(MOLES)}$$

(Equation 9.30)

$$EF_{CO} = \frac{(CO_{in})}{(INDRY)(BTU_{LFG})}$$

(Equation 9.31)

where,

CO_{in} = CO inlet flow rate, lb/min
EF_{CO} = CO emission factor, lb/MMBTU
MW_{CO} = CO molecular weight, 28 lb-mol/mol

9.4.8.4 SOx Emission Factor, EF_{SOX}

Obtain the maximum concentration of total sulfur compounds as H_2S from source test data. This maximum value is used as the emission factor for SOx.

EF_{SOx} = Maximum H_2S conc. = ____________ppm

9.4.8.5 Particulate Emission Factor, EF_{PART}

Obtain the concentration of particulates from source test data and use the following equations to calculate the emission factor for particulates.

$$EF_{PART} = \frac{(x_{PART})(1\ lb/7000\ gr)(EXDRY)(100 - MOIST)}{(100)(MAX_{LFG})}$$

(Equation 9.24)

where,

EF_{PART} = Particulate emission factor, lb/scf
MOIST = Moisture content
x_{PART} = Particulate concentration, gr/dscf

9.4.8.6 CH_4 Emission Factor, EF_{CH4}

The inlet and outlet concentration of CH_4 from source tests must be known to calculate the DRE of methane.

Inlet Concentration CH_4 = $x_{CH4,in}$ =____________________ppm
Outlet Concentration CH_4 = $x_{CH4,out}$ =____________________ppm

$$CH_{4,in} = \frac{(INDRY)(x_{CH4,in})(MW_{CH4})}{(MOLES)}$$

(Equation 9.33)

$$CH_{4,out} = \frac{(EXDRY)(x_{CH4,out})(MW_{CH4})}{(MOLES)}$$

(Equation 9.34)

$$EF_{CH4} = \frac{100\%\ (CH_{4,in} - CH_{4,out})}{CH_{4,in}}$$

(Equation 9.35)

where,

$CH_{4,in}$ = CH_4 inlet flow rate, lb/min
$CH_{4,out}$ = CH_4 outlet flow rate, lb/min

EF_{CH4} = CH_4 emission factor, DRE
MW_{CH4} = CH_4 molecular weight, 16 lb/lb-mol

Emission Factors

EF_{CH4} = ______________________DRE
EF_{NMHC} = ______________________DRE
EF_{NOx} = ______________________lbs/MMBTU
EF_{CO} = ______________________lbs/MMBTU
EF_{SOx} = ______________________lb/MMBTU
EF_{PART} = ______________________lb/MMscf

9.4.9 Pollutant Emission Calculations

Using the emission factors calculated in Section 9.4.8 (or those given by the flare manufacturer or source tests) and the known pollutant concentrations, the pollutant emission calculations may be obtained in the following manner:

$$CH_4 = \frac{(MAX_{LFG})(x_{CH4})(MW_{CH4})(1\text{-}EF_{CH4})(1440\ \text{min/day})}{\text{MOLES}}$$

(Equation 9.36)

$$NMHC = \frac{(MAX_{LFG})(x_{NMHC})(MW_{CH4})(1\text{-}EF_{NMHC})(1440\ \text{min/day})}{\text{MOLES}}$$

(Equation 9.37)

$$NOx = (MAX_{LFG})(BTU_{LFG})(EF_{NOX})(1440\ \text{min/day})$$

(Equation 9.38)

$$CO = (MAX_{LFG})(BTU_{LFG})(EF_{CO})(1440 \text{ min/day})$$

(Equation 9.39)

$$SO_X = \frac{(MAX_{LFG})(EF_{SOx})(MW_{SO2})(1 \text{ scf } So_2/1 \text{ scf } H_2S)(1440 \text{ min/day})}{\text{MOLES}}$$

(Equation 9.40)

	Emissions, lb/day	
Pollutant	Actual	Maximum*
CH_4		
NMHC		
CO		
NOx		
SOx		
PART		

* Maximum Emissions, lb/day = (Actual Emissions, lb/day) (1.1)

9.4.10 Health Risk Assessment

As a result of the presence of both non-carcinogenic and carcinogenic compounds in both Class I and II landfills, a health risk assessment must be performed. Currently, the Division is following the Risk Assessment Policy outlined in Mr. William J. Dennison's memorandum, dated November 4, 1987. This risk assessment must be done for all toxic compounds from the flaring station and the condensate or leacheate handling facility. For sources with a carcinogenic source strength (CSS) or risk greater than one-in-one million (1×10^{-6}), a California Environmental Quality Act (CEQA) document will be required. If approved mitigation measures are employed, a source is allowed a risk of ten-in-one-million (10×10^{-6}) probability of contracting cancer.

9.5 Rules Evaluation

Rule 53 - Sulfur Compounds - Concentration

Sulfur dioxide, SO_2, released into the atmosphere may not exceed a specific concentration by volume at the point of discharge depending on which county the flare system is located:

County	SO_2 Emission Limit
Los Angeles	0.2 percent
Orange	500 ppm
Riverside	
- west-central area	0.05 percent
- remaining portion	0.15 percent

Rule 53A - San Bernardino County - Specific Contaminants

The limit on specific contaminants existing as liquid or gas at standard conditions emitted in the San Bernardino County must not exceed the following concentrations:

Pollutant	Limitations (by volume)
Sulfur Dioxide, SO_2	
before January 1, 1975	0.1 percent
after January 1, 1975	500 ppm
Combustion Contaminants	
before January 1, 1975	0.1 grain/ft^3
after January 1, 1975	0.3 grain/ft^3
Hydrogen Fluoride, HF	400 ppm
Hydrogen Chloride, HCl	800 ppm
Hydrogen Bromide, HBr	50 ppm
Bromine, Br_2	50 ppm
Chlorine, Cl_2	450 ppm
Fluorine, Fl_2	50 ppm

Rule 212 - Standards For Approving Permits

Section (e) of this Rule requires public notification of certain cases be made prior to issuing permit.

Rule 401 - Visible Emissions

No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance

Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent uasage, odorous materials, and prior complaints.

Rule 403 - Fugitive Dust

Visible fugitive dust is prohibited beyond the boundary of the facility (exemptions apply). In addition, particulate concentration in downwind sample may not exceed that in upwind sample by more than 100 micrograms per cubic meter.

Rule 404 - Particulate Matter - Concentration

Limits for particulate matter concentrations in an effluent gas stream at standard conditions are listed in Table 404(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 405 - Particulate Matter - Weight

Limits for particulate matter emission rates from any source are listed in Table 405(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 407 - Liquid and Gaseous Air Contaminants

Carbon monoxide should not exceed 2000 ppm by volume, measured on a dry basis, averaged over 15 consecutive minutes. SOx emission should be below 500 ppm by volume averaged over 15 consecutive minutes.

Rule 466.1 - Valves and Flanges

All valves and flanges handling the recovered hydrocarbons are subject to liquid leak control requirements. A permit condition will be included to assure compliance.

Rule 1150.1 - Control of Gaseous Emissions from Active Landfills

Gaseous emissions from active landfills must be reduced to prevent public nuisance and possible detriment to public health due to exposure to such emissions. Controls must be installed to reduce emissions of odors, ROGs, and hazardous air contaminants. Air intrusion into the landfill must be limited to prevent generation of explosive gas mixtures or fire hazards. The system must properly dispose of gas collected. Also, sampling probes are required to be installed at the perimeter of the landfill to determine whether migration exists.

A maximum of 500 ppm limit for total organic compounds (methane) at any point on the surface of the landfill to prevent an odor nuisance caused by a "hot spot" emission point. Analysis of the integrated air samples collected on the surface of the landfill must be reported and the control system must prevent the total organic compound from exceeding 50 ppm.

Periodic analysis and reporting of three additional samples pursuant to the requirements of California Assembly Bill 3525. The samples required are:

1. LFG collected by gas control system.
2. LFG from the perimeter sampling probes.
3. Ambient air at the perimeter of the landfill.

Ultimate disposal of collected landfill gas demonstrating maximum achievable ROG or toxics reduction efficiency must occur. Efficiency of the collected gas disposal system must be measured once the control system begins operation and annually thereafter. Approved mitigation measures must be taken during installation of the LFG control system to prevent public nuisance.

Rule 1150.2 - Control of Gaseous Emissions From Inactive Landfills

A reduction in gaseous emissions from inactive landfills must be achieved to hinder public exposure to such emissions, which may cause public nuisance and possible detriment to health. An active landfill is a "site where refuse had been disposed of on or before January 1, 1982, and no more later refuse disposal activity has been conducted with the site."

A landfill gas control system must be installed and maintained to lessen emissions of odors, ROGs, and dangerous air contaminants. Proper disposal of collected gases is required. This gas collection device must not overdraw the gases to causes excessive aerobic decomposition, fires, or damaging effects on the gas disposal system.

Offsite migration is monitored by installing sample probes at the perimeter of the landfill. A maximum limit of 500 ppm organic compounds as methane, measured at any point on the surface of the landfill is allowed. The average concentration of total organic compounds over a certain area on the surface of the landfill must not exceed 50 ppm. Analysis of gaseous samples will be collected and reported. The sampling must consist of the following:

1. LFG collected by gas control system.
2. LFG from the perimeter sampling probes.
3. Ambient air at the perimeter of the landfill.

The efficiency of the combustion process will be evaluated and must demonstrate satisfaction in disposing of ROG and toxic compounds when the system begins operation and every year subsequently.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day, Best Available Control Technology (BACT) is required.

Best Available Control Technology (BACT) which has been achieved in practice for either a hazardous or non-hazardous waste landfill gas flare is given by the following:

ROG: (non-hazardous waste) - a shrouded ground level flare with a minimum retention time at least 0.6 seconds at 1400 °F with auto combustion air control, automatic shutoff gas valve, and automatic re-start system.
(hazardous waste) - a shrouded ground level flare with a minimum retention time at least 0.6 seconds at 1500 °F with auto combustion air control, automatic shutoff gas valve, and automatic re-start system.
NOx: 0.06 lbs/MM BTU
SOx: none
CO: (non-hazardous waste) - a shrouded ground level flare with a retention time at least 0.6 seconds at 1400°F with auto combustion air control.
(hazardous waste) - a shrouded ground level flare with a retention time at least 0.6 seconds at 1500°F with auto combustion air control.
PART: Knockout vessel

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[22] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceed the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State

Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated under the New Source Review Database. These emissions are included in determining compliance with the threshold limits.

9.6 Permit (Operating) Conditions

9.6.1 Landfill Gas Flares Permit Conditions

Permit (operating) conditions are required to meet compliance with pertinent SCAQMD Rules and Regulation. These permit conditions for both *hazardous and non-hazardous waste landfill gas flares* are as follows:

1. Construction and operation of the flare system shall be conducted in conformance with all data and specifications submitted with the application under which the permit to construct is issued unless otherwise noted below.
2. This equipment shall be operated and maintained by personnel properly trained in its operation.

3. This equipment shall be properly maintained and kept in good operating condition at all times.
4 Prior to operation, four (4) sampling ports (or two (2) sampling ports if the shroud diameter is less than 7 feet) shall be installed in each flare stack and located at least two (2) feet above the flame zone and at least three (3) feet below the top of the flare shroud or half the diameter of the flare, whichever is greater. Each sampling port must be a minimum of four (4) inches in diameter. Each port shall be installed at 90 degrees apart and shall consist of four (4) inch couplings with plugs. Adequate and safe access to all source test ports shall be provided by the applicant within twenty-four (24) hours upon a request by the District to conduct a test.
5. A sampling port, or other method approved by the Executive Officer, shall be installed at the inlet gas line to each flare.
6. The flare shall be equipped with a temperature indicator and recorder which measures and records the gas temperature in the flare stack. This temperature indicator and recorder must operate continuously.
7. The thermocouple used to measure the flare temperature shall be above the flame zone and at least 3 feet below the top of the flare shroud and at least 0.6 seconds downstream of the burner.
8. Whenever the flare is in operation, a temperature of at least __________ ^{o}F (1400 ^{o}F, non-hazardous waste or 1500 ^{o}F, hazardous waste) measured by the temperature indicator must be maintained in the flare stack.
9. The flare shall be equipped with a failure alarm with automatic blower and landfill gas supply valve shut-off system, which has been approved by the Executive Officer, in order to isolate the flare from the landfill gas supply line, to shut off the blower, and to notify a responsible party of the shutdown.
10. The safety system specified in Condition No. 9 shall be tested monthly for proper operation and the results recorded.
11. The landfill gas flow rate to each flare shall be monitored by flow indicators and recorders, which will operate continuously.

12. Daily readings of BTU content of the gas at the inlet to the flare shall be taken using an approved GC/MS method.
13. All recording devices shall be synchronized with respect to the time of day.
14. A pressure differential indicator must be maintained across each flame arrester.
15. The total volume of landfill gas burned in each flare shall not exceed ____________ cubic feet per day.
16. The total volume of landfill gas burned in the flare station shall not exceed ____________ cubic feet per day.
17. The skin temperature of the flare shroud within four feet of all the source test ports shall not exceed 250 ^{O}F. If a heat shield is required to meet this requirement, its design shall be approved by the Executive Officer prior to construction. The heat shield, if required to meet the temperature requirement, shall be in place whenever a source test is conducted by the District.
18. Emissions resulting from the flare station shall not exceed the following:

Contaminant	lbs/day
NO_x, as NO_2	____________
SO_x, as SO_2	____________
CO	____________
PART	____________
ROG	____________

19. Emissions of NO_x from each flare shall not exceed 0.06 lbs per million BTU of heat input.
20. Any breakdown or malfunction of the landfill gas flare resulting in the emission of raw landfill gas shall be reported to the SCAQMD Director of Enforcement within one hour after occurrence, and immediate remedial measure shall be undertaken to correct the problem and prevent further emissions into the atmosphere.
21. The owner or operator of the equipment must conduct _____ source test(s) under the following conditions:

A. The test(s) must be conducted and a written report submitted to the Director of Engineering within 60 days after achieving maximum production rate at which the equipment will be operated, but not later than 180 days after initial startup.

B. The performance tests shall be conducted at the inlet landfill gas flare and the flare exhaust and shall include, but may not limited to, a test for:

a. Methane
b. Total non-methane organics
c. Oxides of nitrogen (flare exhaust only)
d. Carbon monoxide (flare exhaust only)
e. Total particulates (flare exhaust only)
f. Hydrogen sulfide (flare inlet only)
g. C_1 through C_3 sulfur compounds (speciated, inlet flare only)
h. Carbon dioxide
i. Qualitative and quantitative identification of non-methane hydrocarbons using a gas chromatograph/mass spectrometry method (GC/MS) for speciation.
j. Oxygen
k. Nitrogen
l. Moisture content
m. Temperature
n. Gas flow rates
o. BTU content (inlet only)

C. A source test plan must be submitted to the Director of Engineering not later than 60 days before the proposed test date and must be approved by the Director before the test commences. The plan must include the proposed operating conditions of the equipment during the test, the identity of the testing laboratory, a statement from the testing laboratory certifying it meets the criteria in District Rule 304 (1), and a description of all sampling and analytical procedures to be used.

D. The District engineer identified on the permit to construct must be notified of the date and time of the test at least 10 days prior to the test, or within the time period agreed upon by the District engineer.

22. All records shall be kept for a period of at least two (2) years in a form approved by the Director of Enforcement and shall be made available to the Executive Officer upon request.

9.6.2 Landfill Gas Collection System Permit Conditions

The permit conditions for both hazardous and non-hazardous waste *landfill gas collection systems* are as follows:

1. Operation of this equipment must be conducted in compliance with all data and specifications submitted with the application under which this permit is issued unless otherwise noted below.
2. This equipment must be properly maintained and kept in good operating condition at all times.
3. Construction spoils are landfill trash, material that is mixed with landfill trash, material that has been in contact with landfill trash, or odorous material that is excavated during construction of the landfill gas collection system and/or flare station. During construction, all working areas, construction spoils and unpaved roadways shall be watered down until the surface is moist and then maintained in a moist condition to minimize dust.
4. Construction spoils must be covered within one hour of removal or as deemed necessary by the District.
5. During construction, if a considerable number of complaints are received, all work shall cease and approved mitigation measure implemented immediately.

6. Excavated refuse shall be placed along the trench edge or directly into the vehicle which will haul it. All excavated refuse shall be transferred to the working face within one hour of removal from the trench unless otherwise noted below.
7. If a District odor level (level III or greater) resulting from the trenching is detected at the property line, the following mitigation measures shall be implemented until determined acceptable to return to previous procedures:

   a. No more than 50 linear feet of trench which exposes landfill material to the atmosphere shall be open at any time prior to backfilling.
   b. Excavated refuse shall not be stockpiled on-site. All excavated refuse shall be deposited directly into the vehicle which will haul it to the working face.

   Odor levels shall be determined by SCAQMD personnel or an onsite safety coordinator in the absence of SCAQMD personnel. Only SCAQMD personnel shall have the authority to determine that is acceptable to return to previous operating procedures.

8. The exterior of vehicles hauling excavated material shall be cleaned off prior to leaving the trench site for the working face.
9. All excavated refuse shall be transported to the appropriate disposal site by the end of the day.
10. Mitigation measure, other than those indicated in these conditions, which are deemed appropriated by SCAQMD personnel as necessary to protect the comfort, repose, health or safety of the public, shall be implemented upon request.
11. All landfill gas collected shall be directed to a treatment or combustion facility which can adequately process the volume of gas collected and has been issued a valid permit to construct or operate.
12. Horizontal gas collection line trenches which expose landfill material to the atmosphere shall be covered at all times except when work is actually in progress.

13. Construction of the condensate traps and collection of the condensate from the condensate traps shall be performed in conformance with data and specifications submitted with the application.
14. Condensate traps shall remain covered at all times unless treatment of the condensate is taking place.
15. As-built drawings of this collection system shall be submitted to the District within thirty (30) days after construction is completed. These drawings shall include locations of the wells, trenches, well depths, pipe lengths, diameters, condensate traps, and layout of the system.

9.6.3 Landfill Gas Condensate or Leachate Handling System Permit Conditions

The permit conditions for the *landfill gas condensate or leachate handling system* are as follows:

1. Operation of this equipment must be conducted in compliance with all data and specifications submitted with the application under which this permit is issued unless otherwise noted below.
2. This equipment must be properly maintained and kept in good operating condition at all times.
3. This equipment shall be operated by personnel properly trained in its operation.
4. This equipment shall not be operated unless the vacuum pump exhaust is vented to the landfill gas collection system which is in full operation and is issued a valid permit from the District.
5. This equipment shall be equipped with solid covers with all openings sealed to prevent vapors from releasing into the atmosphere. Any gauging, sampling, and leak detection device shall be covered and sealed at all times except when the device is in actual use.

9.6.4 Landfill Gas Condensate or Leachate Treatment System Permit Conditions

The permit conditions for the *landfill gas condensate or leachate treatment system* are as follows:

1. Operation of this equipment must be conducted in compliance with all data and specifications submitted with the application under which this permit is issued unless otherwise noted below.
2. This equipment must be properly maintained and kept in good operating condition at all times.
3. This equipment shall be operated by personnel properly trained in its operation.
4. This equipment shall not be operated unless the __________ seal (and carbon canister) is (are) properly connected to the vent of the treatment tank.
5. The carbon canister shall be checked at least once a month with a OVA or other approved means to determine if the adsorption capacity has been exhausted. An exhausted carbon canister shall be replaced within one hour after it is detected. The results of each testing and each replacement shall be recorded in a log book and made available to the District upon request.
6. This equipment shall be equipped with solid covers with all openings sealed to prevent vapors from releasing into the atmosphere. Any gauging, sampling, and leak detection device shall be covered and sealed at all times except when the device is in actual use.
7. All valves and flanges in contact with the recovered hydrocarbons shall comply with the provisions of Rule 466.1 with respect to liquid leaks.
8. The containers holding the recovered hydrocarbons shall be covered and sealed. The handling of these hydrocarbons shall be subject to the applicable requirements of federal, state, and local agencies for hazardous wastes.

9. This equipment shall not be operated unless the vacuum pump exhaust is vented to the landfill gas collection system which is in full operation and is issued a valid permit from the District.

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APPENDIX 9A

WORKSHEET

LANDFILL GAS FLARE SYSTEM

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES	PAGE
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APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

COMPANY ID:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

LANDFILL GAS COLLECTION (OR GAS TREATING) AND FLARING SYSTEM CONSISTING OF:

1. FLARE NO. , VENTING (INTERIOR OR PERIMETER) LANDFILL GAS, , MODEL NO. , '- " DIA. X '- " H., BURNER, (GAS, ELECTRIC, ETC) IGNITOR, UV FLAME SCANNER, THERMOCOUPLE WITH TEMPERATURE INDICATOR AND RECORDER, AND AN AUTOMATIC COMBUSTION AIR REGULATING SYSTEM (AIR DAMPERS).
2. ( ) FLAME ARRESTER(S), TYPE, MODEL NO. ,
3. LANDFILL GAS FLOW ELEMENTS WITH RECORDERS.
4. AUTOMATIC LANDFILL GAS SHUT-OFF VALVE , TYPE.
5. AUTOMATIC LANDFILL GAS PRESSURE CONTROL VALVE, TYPE, WITH PRESSURE INDICATING CONTROLLER.
6. INTERIOR LANDFILL GAS SEPARATOR, .
7. PERIMETER LANDFILL GAS SEPARATOR, .
8. GAS TURBINE SUPPLY GAS SEPARATOR, .
9. KNOCKOUT VESSEL FOR PARTICULATE CONTROL, " DIA. X " L, MODEL NO. ,SERIAL NO. .

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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HISTORY:

PROCESS DESCRIPTION:

The applicant uses this landfill ground flare system to remove and control excess methane gas generated in the landfill. The gas extraction system will collect gas from wells placed in the refuse. The collected gas will be transported via pipes to the flaring station that will be located on the (east, west, south, or north) end of the landfill site. The landfill gas is delivered by scfm gas blower(s) to the flare for incineration. The flare is designed to incinerate up to scfm of % CH4 LFG, or MMBTU/hr. The flare will operate at a minimum temperature of ^{o}F.

DATA:

Given (applicant's data):

(1) Landfill Gas Composition — Based on 100 lb-mol

(a)	CH_4	______% or	______lb-mol
(b)	CO_2	______% or	______lb-mol
(c)	H_2O	______% or	______lb-mol
(d)	N_2 and inerts	______% or	______lb-mol
(e)	O_2	______% or	______lb-mol
(f)	H_2S	______ppm	
(g)	Other sulfur compounds	______ppm	
(h)	Other hydrocarbons		
	______	______ppm	
	______	______ppm	
	______	______ppm	
	______	______ppm	
	______	______ppm	
(i)	Particulates	______gr/dscf	

(2) Heat Loss Percentage (Approximate) ______%

(3) Proposed Total LFG Inlet Flow Rate
(a) Perimeter= ____________________ scfm
(b) External= ____________________ scfm
(c) Air Stripper= ____________________ scfm
(d) MAXLFG= *(a)* + *(b)* + *(c)* ____________________ scfm

(4) Proposed Total Gas Outlet
(Exhaust) Flow Rate ____________________ scfm

(5) LFG Dry Inlet Flow Rate*, INDRY= ____________________ scfm
(6) Flare Dry Exhaust Flow Rate*, EXDRY = ____________________ dscfm

(7) Maximum Gas Back Pressure** ____________________ in. W.C.
(8) Maximum ambient air temperature ____________________ ^{o}F
(9) Minimum combustion temperature at
thermocouple elevation, TEMPT= ____________________ ^{o}F
(10) Maximum outside skin temperature on flare ____________________ ^{o}F
(11) Diameter of Flare, D ____________________ feet
(12) Height of Flare ____________________ feet

* From source tests.
** Back pressure includes the pressure drop through the automatic valve, flame arrester, and burner.

CALCULATIONS:

1. LFG Molecular Weight

$$\text{MWLFG} = \sum (x_i)(MW_i)$$

2. Mean Heat Capacity of Flue Gas

	C_p, BTU/lb-mol ^{o}F*	
	1400 ^{o}F	1500 ^{o}F
$C_{p,CO2}$ =	11.43	11.55
$C_{p,H2O}$ =	8.909	8.983
$C_{p,O2}$ =	7.788	7.830
$C_{p,N2}$ =	7.331	7.368

* From Felder and Rousseau, Elementary Principles of Chemical Processes, 1978.

$$C_{p,\text{mole mean}} = \sum (x_i)(C_{p,i})$$

$$C_{p,\text{mean}} = \frac{C_{p,\text{mole mean}}}{MWLFG}$$

3. LFG Heating Value, BTU_{LFG}

1. The LFG BTU content, BTU_{LFG}, is generally obtained by total combustion analysis (TCA) from source testing. If a TCA is not available, the equation below may be used to calculate BTU_{LFG} with the following assumptions:

   a. If the concentration of the non-methane hydrocarbons (NMHC) is less than 1%, assume these combustibles are negligible. Obtain the BTU content of the NMHC in the LFG from source tests if the NMHC concentration exceeds 1% (10,000 ppm).

   b. Obtain the heating value of CH_4 in the LFG from source tests. If this BTU content is not available, 1000 BTU/scf may be assumed for the heating value of CH_4. The higher heating value of combustion of methane is 1013 BTU/scf and the lower heating value is 913.1 BTU/scf.[11]

   c. 1 lb-mole LFG occupies 379 scf at standard temperature (60 °F) and pressure (1 atm).

$$BTU_{LFG} = (BTU_{CH4})(x_{CH4}) + (BTU_{NMHC})(x_{NMHC})$$

4. Flare Excess Air

The excess air in the flare is estimated to be anywhere between <u>100%</u> to <u>200%</u>. If the concentration of carbon monoxide (CO) is known, the equation below may be used to calculate the excess air in the flare.

Excess Air in Flare, XAIR = *(See Section 9.4.6 or Equation Below)*

= ____________________ %

$$XAIR = \frac{(x_{O2}) - (0.5)(x_{CO})}{(21\%/79\%)(x_{N2}) - x_{CO} - (0.5)(x_{CO})} \times (100\%)$$

5. LFG Molecular Flow Rate, RATE
RATE = *(3)*________ /MOLES = ________ $\frac{\text{lb-mol}}{\text{min}}$

6. Theoretical Air Required for Combustion, TAIR
TAIR = *(1a)*________ $(2 + 3.76 \times 2)\ \frac{\text{lb-mol air}}{\text{lb-mol } CH_4}$
- *(1e)*________ $(1 + 3.76)\ \frac{\text{lb-mol air}}{\text{lb-mol } O_2}$
= ________ lb-moles air

7. Total Air in Flare, AIR
AIR = *(TAIR)* (XAIR) = ________ lb-moles

8. Products of Combustion, PC

PC_{CO2} = *(1a)*________ x 1 + *(1b)*________ = *(18)*________ lb-moles
= *(18)*________ (MW_{CO2}) = *(19)*________ lbs

PC_{H2O} = *(1a)*________ x 2 + *(1c)*________ +

$$\frac{(AIR + 100)\ (MW_{AIR})\ (0.013)}{(MW_{H2O})}$$

= *(20)*________ lb-moles
= *(20)*________ lb-mol (MW_{H2O}) = *(21)*________ lbs

PC_{N2} = *(AIR)* (0.79) + *(1d)*________ = *(22)*________ lb-moles
*(22)*________ (MW_{N2}) = *(23)*________ lbs

PC_{O2} = *(AIR - TAIR)* (0.21) = *(24)*________ lb-moles
*(24)*________ (MW_{O2}) = *(25)*________ lbs

9. Total Products of Combustion, PC_{TOT}

$$PC_{TOT} = PC_{CO2} + PC_{H2O} + PC_{N2} + PC_{O2}$$

= ________ lbs

10. PC Mass Flow Rate at LFG Flow Rate, $FLOW_{PC}$

$$FLOW_{PC} = \frac{(PC_{TOT})\,(RATE)}{100\ \text{lb-mol LFG}}$$

= ________________ lbs/min

11. Heat of Combustion, HEAT

HEAT = *(3)*________________ (BTU_{LFG})*(1a)*________________/100 lb-mol LFG

= ________________ BTU/min

12. Evaporation Loss, EVAP

EVAP = *(20)*____________ $\frac{(18.919)\,(RATE)}{100\ \text{lb-mol LFG}}$

= _______________ BTU/min

13. Sensible Heat Loss, SENSE

$$SENSE = \frac{(AIR)(MW_{AIR})(C_{p,mean})(TEMPT - 60^{o}F)\,(RATE)}{100\ \text{lb-mol LFG}}$$

= _________ BTU/min

14. Radiation Loss, RADIA

RADIA = *(2)*_______________% (HEAT) = ___________ BTU/min

15. Flue Gas Enthalpy, H

$H = \frac{HEAT - EVAP - SENSE - RADIA}{FLOW_{PC}}$ = ______________BTU/lb

16. Moisture in Flue Gas, MOIST

MOIST = (100%) *(21)*____________________$/PC_{TOT}$ = ____________ %

Figure 9-18 shows correlations between the enthalpy of flue gas above 80 °F and moisture in the gas. Based on the net flue gas enthalpy, H, and the moisture in the flue gas, MOIST, the flue gas temperature is ______ °F, OPTEMPT.

17. Total Combustion Flow Rate, COMB
COMB = (AIR)*(3)*____________/100 lb-mol LFG + *(3)*____________

= ____________ scfm

18. Volumetric or Exhaust Flow Rate, EXHAUST

$$\text{EXHAUST} = \frac{(\text{COMB})\,(460\,^{o}\text{F} + \text{OPTEMPT})}{(460\,^{o}\text{F} + 60\,^{o}\text{F})} = \underline{\hspace{3cm}}\ \text{acfm}$$

19. Combustion Volume, VOLUME

$$\text{VOLUME} = \frac{\pi(D^2)(h)}{4} = \underline{\hspace{3cm}}\ \text{cf or acf}$$

17. Retention Time, TIME

$$\text{TIME} = \frac{\text{VOLUME}}{\text{EXHAUST}}\ \frac{(1\ \text{min})}{60\ \text{sec}} = \underline{\hspace{3cm}}\ \text{sec}$$

% Excess Air ____________ %
RATE ____________ lb-moles/min
COMB ____________ scfm
Retention Time ____________ sec
Operating Temperature ____________ °F

The minimum operating temperature and residence time is achieved by adjusting the combustion air damper to a position equivalent to the excess air percentage. Should the residence time and operating temperature not reach the minimum operating temperature (1400 °F or 1500 °F) and residence time, the percentage of excess air must either be increased or decreased.

where,

AIR = Total air required for combustion, lb-moles
BTU_{LFG} = LFG heating value or BTU content, BTU/scf
BTU_{CH4} = CH_4 BTU content, BTU/scf
BTU_{NMHC} = NMHC BTU content, BTU/scf
COMB = Total combustion flow rate, scfm
$C_{p,mean}$ = mean heat capacity of flare flue gas, BTU/lb °F
$C_{p,mean\ mole}$ = mean molecular heat capacity, BTU/lb-mol °F
D = Diameter of flare, ft
EVAP = Heat loss due to evaporation, BTU/min
EXHAUST = Volumetric or exhaust flow rate, acfm
$FLOW_{PC}$ = Products of combustion mass flow rate at LFG flow rate, lbs/min
h = Height from flare base to thermocouple, ft
H = Flue gas enthalpy, BTU/lb
HEAT = Heat of combustion, BTU/min
i = Gas constituent: CH_4, CO_2, O_2, H_2O, N_2 and inerts
MOIST = Amount of moisture in flue gas, %
MOLES = LFG molecular volume = 379 scf/lb-mol
MW_{air} = Molecular weight of air, 29 lb/lb-mole
MWLFG = Molecular weight of LFG (lb/lb-mole)
MW_i = Molecular weight of gas constituent (lb/lb-mole)
OPTEMPT = Flare operating temperature, °F
PC_i = Products of combustion, lb or lb-mol
PC_{TOT} = Total weight of products of combustion, lb
RADIA = Radiation heat loss, BTU/min
RATE = LFG molecular flow rate, lb-mol/min
SENSE = Sensible heat loss, BTU/min
TAIR = Amount of theoretical air in flare, lb-moles
TEMPT = Minimum combustion temperature, °F
TIME = Retention time, sec
VOLUME = Combustion volume, cf or acf
XAIR = Excess air in flare, %
x_i = Volume percent of gas constituent (%)

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Emission Factors:

1. NMHC Emission Factor, EF_{NMHC}

Inlet Concentration NMHC, $x_{NMHC,in}$ = ______________ ppm as C_1
Outlet Concentration NMHC, $x_{NMHC,out}$ = ______________ ppm as C_1

$$NMHC_{in} = \frac{(INDRY)(x_{NMHC,in})(MW_{CARBON})(60\ min/hr)}{(MOLES)}$$

$$NMHC_{out} = \frac{(EXDRY)(x_{NMHC,out})(MW_{CARBON})(60\ min/hr)}{(MOLES)}$$

$$EF_{NMHC} = \frac{(NMHC_{in} - NMHC_{out})\,(100\%)}{NMHC_{in}}$$

where,

EF_{NMHC} = Emission factor of NMHC
EXDRY = Flare dry exhaust flow, dscfm
INDRY = LFG dry inlet flow, scfm
MOLES = LFG molecular volume = 379 scf/lb-mol
MW_{CARBON} = Molecular weight of methane, 16 lb/lb-mol
$NMHC_{in}$ = NMHC inlet concentration, lb/hr
$NMHC_{out}$ = NMHC outlet concentration, lb/hr

2. NOx Emission Factor, EF_{NOX}

NOx Concentration as NO_2, x_{NOx} = ______________ ppm

$$NO_{2,out} = \frac{(x_{NOx})(EXDRY)(MW_{NO2})}{(MOLES)}$$

$$EF_{NOx} = \frac{(NO_{2,out})}{(INDRY)(BTU_{LFG})}$$

where,

EF_{NOx} = NOx emission factor, lb/MMBTU
MW_{NO2} = NO_2 molecular weight, 46 lb-mol/mol
$NO_{2,out}$ = NO_2 flow rate, lb/min

3. CO Emission Factor, EF_{CO}

CO concentration, x_{CO} = ________________ppm

$$CO_{in} = \frac{(x_{CO})(EXDRY)(MW_{CO})}{(MOLES)}$$

$$EF_{CO} = \frac{(CO_{in})}{(INDRY)(BTU_{LFG})}$$

where,

CO_{in} = CO inlet flow rate, lb/min
EF_{CO} = CO emission factor, lb/MMBTU
MW_{CO} = CO molecular weight, 28 lb-mol/mol

4. SOx Emission Factor, EF_{SOX}

EF_{SOx} = Maximum H_2S conc. = ______________ppm

5. Particulate Emission Factor, EF_{PART}

$$EF_{PART} = \frac{(x_{PART})(1\ lb/7000\ gr)(EXDRY)(100\text{-}MOIST)}{(100)(MAX_{LFG})}$$

where,

EF_{PART} = Particulate emission factor, lb/scf
MOIST = Moisture content
MAX_{LFG} = Proposed total LFG inlet flow rate, scfm
x_{PART} = Particulate concentration, gr/dscf

6. Methane Emission Factor, EF_{CH4}

Inlet Concentration CH_4, $x_{CH4,in}$ = ________________ ppm
Outlet Concentration CH_4, $x_{CH4,out}$ = ________________ ppm

$$CH_{4,in} = \frac{(INDRY)(x_{CH4,in})(MW_{CH4})}{(MOLES)}$$

$$CH_{4,out} = \frac{(EXDRY)(x_{CH4,out})(MW_{CH4})}{(MOLES)}$$

$$EF_{CH4} = \frac{100\% \ (CH_{4,in} - CH_{4,out})}{CH_{4,in}}$$

where,

$CH_{4,in}$ = CH_4 inlet flow rate, lb/min
$CH_{4,out}$ = CH_4 outlet flow rate, lb/min
EF_{CH4} = CH_4 emission factor, DRE
MW_{CH4} = CH_4 molecular weight, 16 lb/lb-mol

Emission Factors

EF_{CH4} = ________________ DRE
EF_{NMHC} = ________________ DRE
EF_{NOx} = ________________ lbs/MMBTU
EF_{CO} = ________________ lbs/MMBTU
EF_{SOx} = ________________ lb/MMBTU
EF_{PART} = ________________ lb/MMscf

Principal Pollutant Emissions:

$$R_{1,CH4} = \frac{(MAX_{LFG})(x_{CH4})(MW_{CH4})(1-EF_{CH4})(1440 \text{ min/day})}{MOLES}$$

$$R_{1,NMHC} = \frac{(MAX_{LFG})(x_{NMHC})(MW_{CH4})(1-EF_{NMHC})(1440 \text{ min/day})}{MOLES}$$

$$R_{1,NOx} = (MAX_{LFG})(BTU_{LFG})(EF_{NOX})(1440\ \text{min/day})$$

$$R_{1,CO} = (MAX_{LFG})(BTU_{LFG})(EF_{CO})(1440\ \text{min/day})$$

$$R_{1,SOX} = \frac{(MAX_{LFG})(EF_{SOx})(MW_{SO2})(1\ \text{scf}\ SO_2/1\ \text{scf}\ H_2S)(1440\ \text{min/day})}{\text{MOLES}}$$

	Emissions, lb/day	
Pollutant	Actual	Maximum*
CH_4		
NMHC		
CO		
NOx		
SOx		
PART		

* Maximum Emissions, lb/day = (Actual Emissions, lb/day) (1.1)

RULES EVALUATION:

RULE 53 : From emission calculations of SOx, this facility is (is not) expected to comply with emission limitations.

RULE 53A : If this facility is located in the San Bernardino County, this flaring system is (is not) expected to comply with emission limitations on specific contaminants given by source tests.

RULE 212 : The equipment is (is not) designed, controlled, or equipped with air pollution equipment so that it may (may not) be expected to operate without emitting air contaminants. Public notice will (will not) be distributed to addresses within a 1/4 mile radius of the project.

RULE 401 : Visible emissions are (are not) expected from the flare due to the nature of the equipment and the type of operation.

RULE 402 : The operation of the flares is expected to control odors from the landfill and prevent raw landfill gas emissions into the atmosphere. With the type of operation considered, nuisance complaints are (are not) expected.

RULE 403 : Fugitive dust is (is not) expected from the flaring system itself.

RULE 404 : Solid particulate matter concentration emission is (is not) expected to exceed the values shown in Table 404(a) in the District Rules and Regulation Book.

RULE 405 : Solid particulate matter weight emission is (is not) expected to exceed the values shown in Table 405(a) in the District Rules and Regulation Book.

RULE 407 : CO and SO_2 emission concentrations are (are not) below the limits of this rule.

RULE 1150.1: An emission control system for this active landfill site will (will not) be installed according to a design and in a manner approved by the Executive Officer. Approved mitigation measures will (will not) be taken during installation of the LFG control system to prevent public nuisance.

OR

RULE 1150.2: Contaminants from this inactive landfill site have (have not) been characterized and controlled. An emission control system for this inactive landfill site will(will not) be installed according to a design and in a manner approved by the Executive Officer. Approved mitigation measures will (will not) be taken during installation of the LFG control system to prevent public nuisance.

REG XIII : The net increase in emissions resulting the operation of this equipment does (does not) exceed the limitations specified in Regulation XIII as shown by the Emission Threshold/New Source Review table shown:

		Net Emissions (lbs/day)			
	ROG	NO_x	SO_2	CO	PART
Facility Emissions Since 10/8/76	______	______	______	______	______
A/N ____________	______	______	______	______	______
A/N ____________	______	______	______	______	______
Net Emission Increase Since 10/8/76	______	______	______	______	______

This facility will (will not) operate with compliance of Regulation XIII.

BACT: Best Available Control Technology (BACT) for hazardous or non-hazardous landfill flare is a shrouded ground flare with a retention time at least 0.6 seconds at 1400 ^{O}F or 1500 ^{O}F with automatic shutoff gas valve, and automatic restart system for ROG and CO control. A knockout vessel will be employed for control of PART emissions. BACT is (is not) satisfied.

CONCLUSION AND RECOMMENDATION:

Based on the information submitted by the applicant and the analysis above, the proposed construction/operation of the flares at the proposed maximum flow rates are expected to comply with all the applicable rules and regulations, issuance (or denial) of a conditional permit to construct (or operate) is recommended.

APPENDIX 9B

WORKSHEET

LANDFILL GAS COLLECTION SYSTEM

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
ENGINEERING DIVISION
APPLICATION PROCESSING AND CALCULATIONS

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PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

COMPANY ID:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

LANDFILL GAS COLLECTING (OR GATHERING) SYSTEM CONSISTING OF:

1. LANDFILL GAS BLOWER, , MODEL NO. , H.P.
2. AUTOMATIC BLOWER DISCHARGE SHUT-OFF VALVE, TYPE.
3. ( ) LANDFILL GAS COLLECTION WELLS, EACH APPROXIMATELY '- " DEEP, WITH " DIA., CASING.

HISTORY:

PROCESS DESCRIPTION:

The applicant uses this landfill gas collection system to remove and control excess methane gas generated in the landfill. The gas collection sytem will collect gas from about wells to be placed in the refuse. The collected gas wil be transported via (underground or above ground) pipes to the flaring station. The gas collection wells will provide approximately scfm of landfill gas to the flare for incineration (and/or boiler). The blower(s) is rated at scfm. inch perorated pipe will collect the gas. Each will have a (throttling valve and pressure tap or sampling port). The well will be backfilled with (gravel, sand, etc.) and sealed with (e.g. concrete).

DATA:

Maximum condensate traps condensate ____________ gal/day

Condensate volume delivered to treatment system ____________ gal/day

RULES EVALUATION:

RULE 401 : Visible emissions are (are not) expected from the landfill gas collection system due to the nature of the equipment and the type of operation.

RULE 402 : The operation of the collection system is expected to control odors from the landfill and prevent raw landfill gas emissions into the atmosphere. With the type of operation considered, nuisance complaints are (are not) expected.

RULE 403 : Fugitive dust is (is not) expected from the collection system itself.

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REG XIII : The net increase in emissions resulting the operation of this equipment does (does not) exceed the limitations specified in Regulation XIII as shown by the Emission Threshold/New Source Review table shown:

	ROG	Net Emissions (lbs/day) NO_x	SO_2	CO	PART
Facility Emissions Since 10/8/76	______	______	______	______	______
A/N ____________	______	______	______	______	______
A/N ____________	______	______	______	______	______
Net Emission Increase Since 10/8/76	______	______	______	______	______

This facility will (will not) operate with compliance of Regulation XIII.

CONCLUSION AND RECOMMENDATION:

Based on the information submitted by the applicant and the analysis above, the proposed 9onstruction/operation of the landfill gas collection system at the proposed maximum flow rates is expected to comply with all the applicable rules and regulations, issuance (or denial) of a conditional permit to construct (or operate) is recommended.

APPENDIX 9C

WORKSHEET

LANDFILL GAS CONDENSATE (LEACHATE) HANDLING SYSTEM

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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APPLICANT'S NAME:

COMPANY ID:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

LANDFILL GAS CONDENSATE AIR STRIPPING SYSTEM CONSISTING OF:

1. CONDENSATE SUMP, '- " DIA. x '- " H.
2. CONDENSATE TANK, TANK, GALLONS CAPACITY, WITH (PRESSURE AND LEVEL) CONTROLS.
3. INFLUENT (CONDENSATE) (VACUUM) PUMP, , MODEL NO. , GPM AT ' HEAD, WITH A H.P. MOTOR.
4. OIL/WATER SEPARATOR, , PRESSURIZED TANK, WITH AUTOMATIC OIL DISCHARGE VALVE.
5. AIR STRIPPING TOWER, , '- " DIA. x '- " H., WITH ' PACKING, (DEMISTER, AND A BLOWER, , MODEL NO. , CFM AT " W.C., WITH A H.P. MOTOR,) VENTED TO THE LANDFILL GAS COLLECTION AND FLARING SYSTEM.
6. EFFLUENT (VACUUM) PUMP, , MODEL NO. , GPM AT ', WITH A H.P. MOTOR.

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HISTORY:

PROCESS DESCRIPTION:

The proposed air stripping system will be used for the treatment of landfill gas condensate (and leachate). Condensate will be collected throughout the gas collection system and flow to the influent storage tank. Once the condensate level in the tank reaches a specified high level, the influent pump will be activated. The condensate will be pumped though the pressurized oil/water separator and then through the air stripping tower. The treated condensate will then be pumped directly to the on-site sewer. Exhaust air from the stripping tower will (will not) be discharged into the landfill gas collecion header. The system is designed to withdraw ambient air through the air stripper by way of vacuum from the landfill gas blower at the flare station. A standby air blower will (will not) be used if the vacuum from the landfill gas header is insufficient. An automatic valve in the exhaust line wil remain closed when the air stripper is not in operation.

This system is designed to treat gpm of condensate at cfm of air flow rate. The system may (may not) be operated continuously. The average operating hours is hours per day.

DATA:

EVALUATION:

The addition of cfm of exhaust air from the proposed air stripper to the flares will not (will) significantly reduce the landfillgas collection capacity. The gas collection system will not (will) need to be modified due to the additional exhaust air from the air stripper. Exhaust air will be combined with the existing vent pipe of the air stripper before it is ventted to the landfill gas collection system.

From a health risk assessment performed as outlined in the Risk Assessment Policy in Mr. William J. Dennison's memorandum (dated November 4, 1987), the toxic compounds to be added to the flare station and emitted from it are (are not) expected to be minimal. The carcinogenic source strength (CSS) calculations show that the total CSS increase is , which is less than (greater than) the allowable , Type , Area . Further risk analysis is thus not required (required).

RULES EVALUATION:

RULE 401 : Visible emissions are (are not) expected from the condensate handling system due to the nature of the equipment and the type of operation.

RULE 402 : The operation of the air stripper is expected to control odors from the landfill and prevent raw landfill gas emissions into the atmosphere. With the type of operation considered, nuisance complaints are (are not) expected.

RULE 403 : Fugitive dust is (is not) expected from the condensate handling system itself.

REG XIII : The addition of exhaust air will not (will) affect the compliance status of the flare station. The net increase in emissions resulting the operation of this equipment does (does not) exceed the limitations specified in Regulation XIII as shown by the Emission Threshold/New Source Review table shown:

		Net Emissions (lbs/day)			
	ROG	NO_x	SO_2	CO	PART
Facility Emissions Since 10/8/76					
A/N					
A/N					
Net Emission Increase Since 10/8/76					

This facility will (will not) operate with compliance of Regulation XIII.

CONCLUSION AND RECOMMENDATION:

Based on the information submitted by the applicant and the analysis above, the proposed construction/operation of the landfill gas condensate handling (air stripper) system at the proposed maximum flow rates are expected to comply with all the applicable rules and regulations, issuance (or denial) of a conditional permit to construct (or operate) is recommended.

APPENDIX 9D

WORKSHEET

LANDFILL GAS CONDENSATE (LEACHATE) TREATMENT SYSTEM

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

COMPANY ID:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

LANDFILL GAS CONDENSATE TREATMENT SYSTEM CONSISTING OF:

1. CONDENSATE SUMP, (UNDERGROUND), '- " DIA. x '- " H., WITH H.P. SUMP PUMP.
2. CONDENSATE TREATMENT TANK, TANK, '- " DIA. x '- " H., GALLONS CAPACITY, WITH H.P. MIXER, AND EFFLUENT PH CONTROL SYSTEM.
3. CARBON CANISTER, VENTING TREATMENT TANK, , WITH SEAL.

HISTORY:

PROCESS DESCRIPTION:

DATA:

EVALUATION:

The system is (is not) an enclosed design which should (can not) effectively reduce objectable odor. The seal to be installed at the vent for the treatment tank should (can not) reduce hydrocarbon loss. Thus, the ROG emissions from this system are (are not) negligible during normal operation.

RULES EVALUATION:

RULE 401 : Visible emissions are (are not) expected from the flare due to the nature of the equipment and the type of operation.

RULE 402 : Nuisance is (is not) expected if the equipment is properly maintained; all openings are (are not) properly sealed and the recovered hydrocarbons are (are not) properly stored in sealed containers.

RULE 403 : Fugitive dust is (is not) expected from the condensate treatment system itself.

RULE 466.1 : All valves and flanges handling the recovered hydrocarbons are subject to liquid leak control requirements. A permit condition will be included to assure compliance.

REG XIII : The net increase in emissions resulting the operation of this equipment does (does not) exceed the limitations specified in Regulation XIII as shown by the Emission Threshold/New Source Review table shown:

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		Net Emissions (lbs/day)			
	ROG	NO_x	SO_2	CO	PART
Facility Emissions Since 10/8/76					
A/N ______					
A/N ______					
Net Emission Increase Since 10/8/76					

This facility will (will not) operate with compliance of Regulation XIII.

CONCLUSION AND RECOMMENDATION:

Based on the information submitted by the applicant and the analysis above, the proposed construction/operation of the landfill gas condensate treatment system at the proposed air flow rate(s) is (is not) expected to comply with all the applicable rules and regulations, issuance (or denial) of a conditional permit to construct (or operate) is recommended.

SECTION 10

Concrete Batch Plants

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Section 10

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SECTION 10: CONCRETE BATCH PLANTS

10.1 General Description

In general, a concrete batch plant stores, conveys, measures, and then discharges the ingredients for making concrete to mixing, packaging or transportation equipment. The primary ingredients used in the manufacture of concrete include sand, aggregate, cement, fly ash, and water. The raw materials are delivered to a plant by rail, truck, or barge. The ingredients are stored separately such that specific amounts can later be dispensed. Depending on the type of operation employed, the ingredients are blended either in a mixer at the plant, in a mixer on a truck en route to the job site, or at the job site. The basic equipment in a concrete batch plant include hoppers, conveyors (belt, screw, and pneumatic), elevators, storage silos, mixers, and packaging and transportation equipment (trucks). Figure 10-1 shows a typical concrete batching process.

The primary air pollution concern from a concrete batch plant is particulate matter or dust generated from the dry materials during transportation, conveyance, mixing, and charging and discharging of silos, trucks, and hoppers. Typical control methods include water sprays, enclosures, hoods, shrouds, movable and telescoping chutes, and venting to a baghouse or fabric filter.

10.1.1 Types of Concrete Batch Plants

Concrete batch plants are facilities that prepare and distribute made-to-order batches of concrete in bulk or packaged form. Concrete is typically prepared by one of the following methods depending on where the order is to be delivered, when it will be used, how much is needed, and what form it is in.

- wet batch (transit-mixed);
- dry batch (dry mixed and packaged); and
- central plant batch (or ready-mixed concrete).

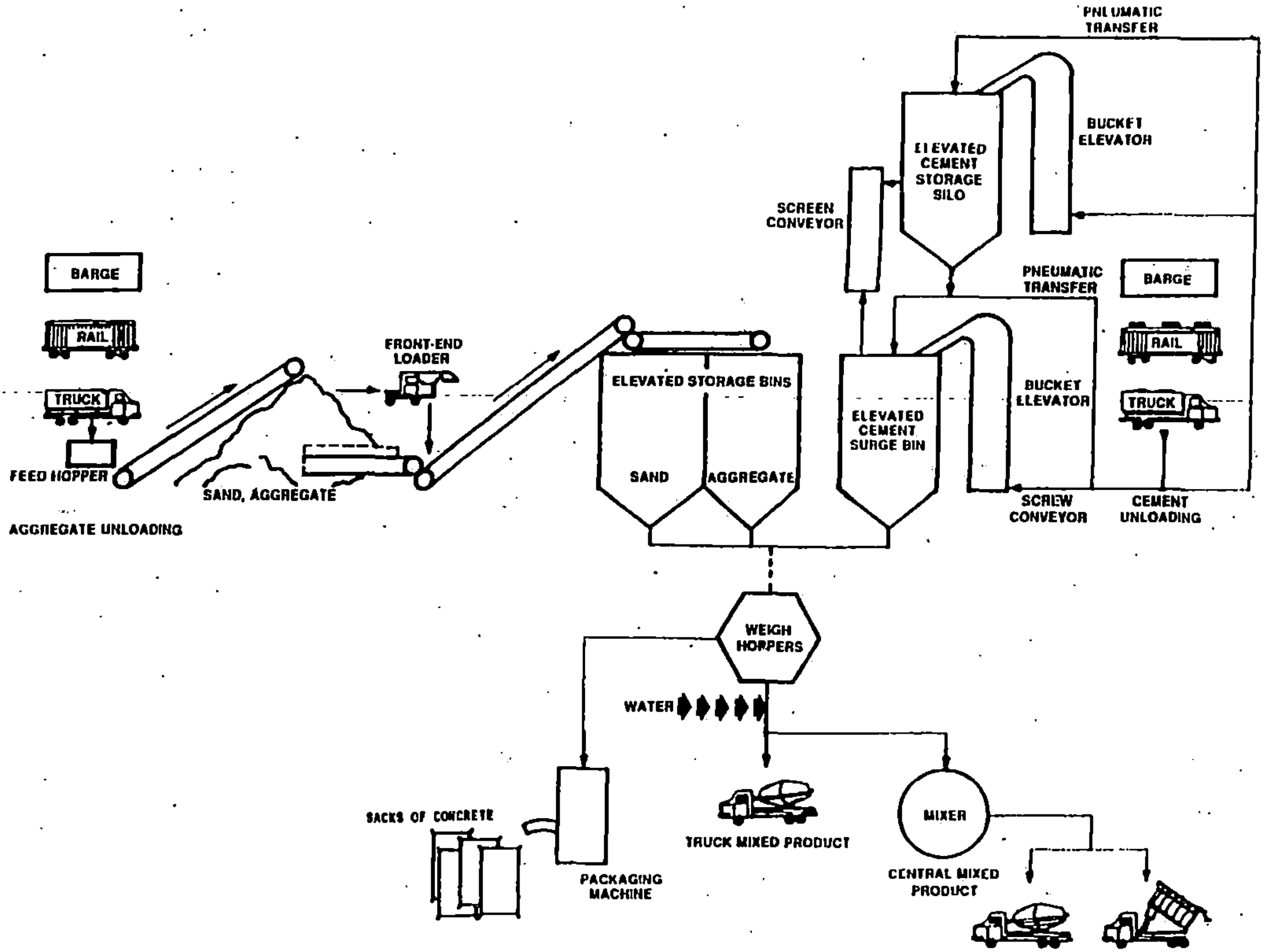


FIGURE 10-1 TYPICAL CONCRETE BATCHING PROCESS

Approximately seventy-five percent (75%) of the concrete batching plants in the United States use wet batch or transit-mixed methods. [1] In the wet batch process, weighed amounts of sand, aggregate, fly ash, and cement are charged to a gathering hopper. The hopper dumps the dry ingredients into a transit-mix truck. Water is added to the dry ingredients and the mixing is performed en route to the job site. Wet batch plants can be portable.

A dry batch operation is normally employed to produce sacks of dry concrete mix. The process differs from that of the wet batch plant in that a dryer is employed to dry aggregate before it reaches the aggregate surge bin. Appropriate amounts of cement and aggregate are weighed and discharged into an automatic packaging machine. Sacks are manually positioned under the feed nozzle of the packaging machine, filled and sealed. On rare occasions, dry concrete mix is discharged onto an open bed truck. The truck bed may be outfitted with partitions to separate the cement from the aggregate. If the bed is not partitioned, the cement is folded into the batch by simultaneously dumping cement and aggregate. Because no water is used in the dry mix process, it has a greater potential to generate dust. In addition, the dryer produces combustion air contaminants. Of the three methods, dry batch operations constitute the smallest percentage of the concrete batching industry.

A central plant operation performs all the necessary mixing and blending at the plant. Ready-to-use concrete is discharged from a batch mixer into a dump truck or transit-mix truck for transportation to the job site. The ready-mixed concrete is in a slurry form when dumped from the mixer into the truck. Central mix facilities makeup approximately 25 percent of the concrete batching industry. [1]

Concrete batch plants store each material separately from one another. Aggregate is usually placed in a stockpile while cement is either pneumatically or mechanically elevated from bottom discharge hopper trucks to a storage silo (see Figure 10-2). Aggregate stockpiles and storage silos are considered separate permit units from the concrete batch plant. These silos are used to store cement in case truck delivery is not immediately available. Cement is usually discharged directly from trucks into a smaller surge bin for normal operation. If the material held in a silo is less than the amount processed in one day, the silo is considered a surge bin. Otherwise, it is a storage silo and is considered a separate permit unit.

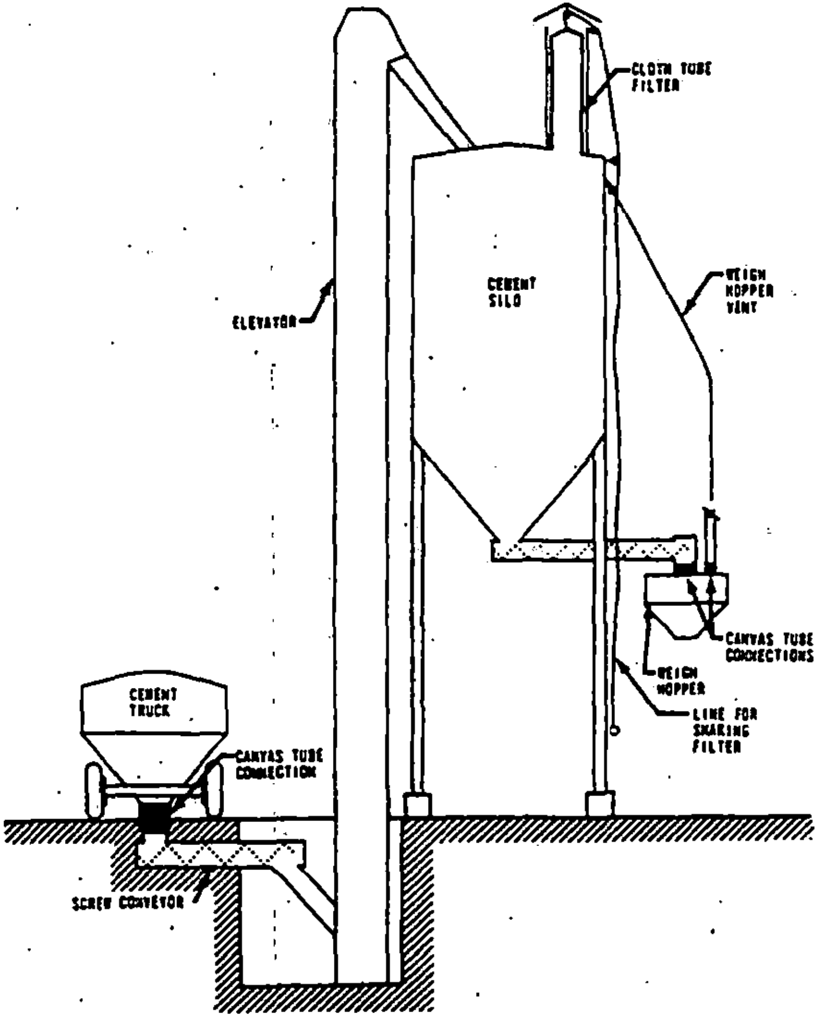


FIGURE 10-2 CEMENT RECEIVING and STORAGE SYSTEM

Before batching all of the dry ingredients, cement, sand and aggregate are elevated into overhead bins for dispensing to individual weigh hoppers. Aggregate is weighed by individual component, then collected together in the gathering hopper. The cement is usually weighed in its own weigh hopper and kept separate from the aggregate (see Figures 10-3 and 10-4). Customer specifications and standards govern the amount of each component in the batch and the type of processing best suited to their project. Hence, the composition of the concrete, the time at which water is added, and the mixing process can vary from order to order.

A typical material charging sequence for concrete batch plants is shown in Figure 10-5. Water leads and follows all solid materials, with coarse aggregate leading and following the cement. Admixtures should always enter the mixer at the same point in the sequence (see Figure 10-6).

10.1.2 Materials

The materials used in manufacturing concrete include aggregate, cement, water, fly ash, admixtures, air entraining agents and pozzolans.

Aggregate or filler material occupy between sixty and eighty percent (60-80%) of the volume of typical concrete (see Figure 10-5). Aggregate should have uniform moisture content and grading, be free of contaminating materials, and must meet specific requirements. Coarse aggregate is considered crushed stone, gravel, air-cooled blast furnace slag, or a combination of these materials. Fine aggregate is natural sand, manufactured sand, or a combination of the two.

Aggregate is graded by sieve analysis and based on the percent of particles falling within a range of sieve sizes (see Table 10-1). Sand consists of fine particles passing a No. 4 screen.

Cement, although made of common earth materials, is a very complex compound. The raw materials used to manufacture cement are common rocks, sand, silt and clay. They are carefully analyzed to give the proper mixture of basic chemicals from which the cement is made. The number of raw materials required at any one plant

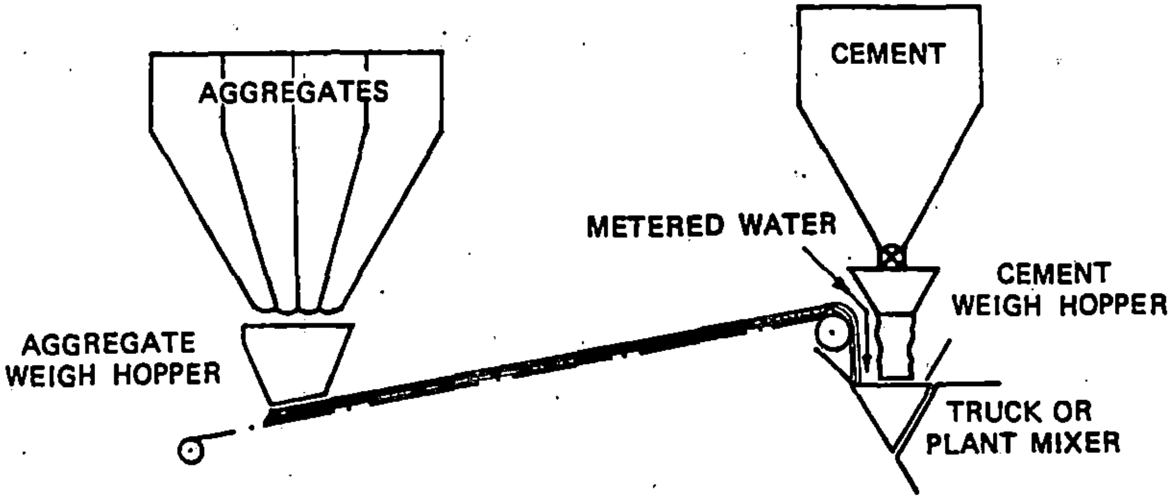


FIGURE 10-3 WEIGH HOPPER SYSTEM

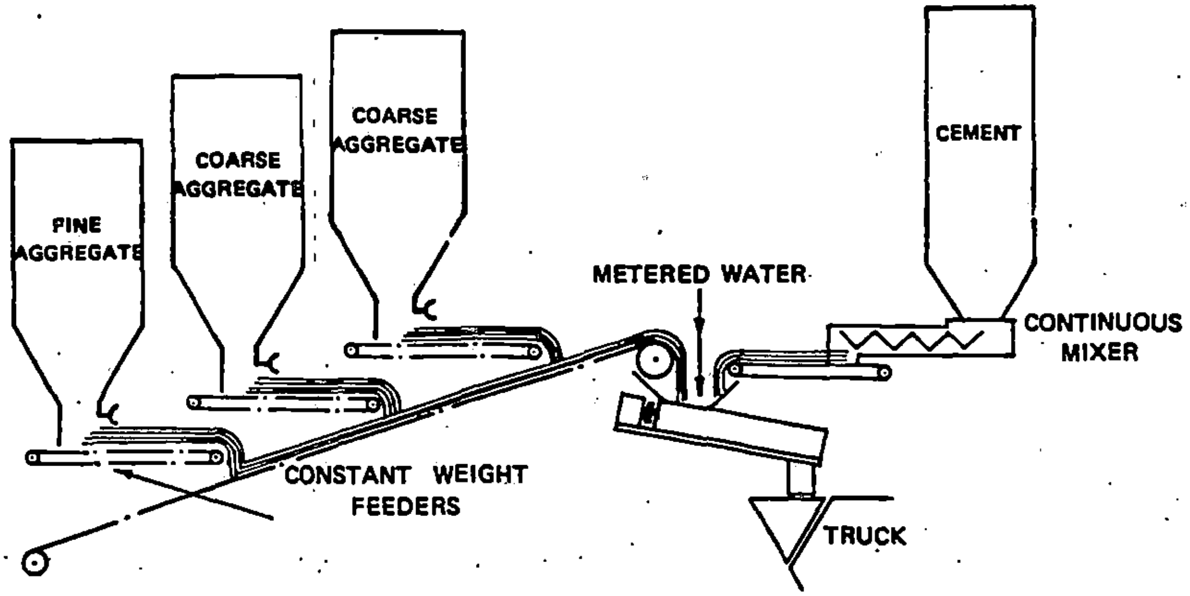


FIGURE 10-4 CONSTANT WEGHT FEEDER SYSTEM

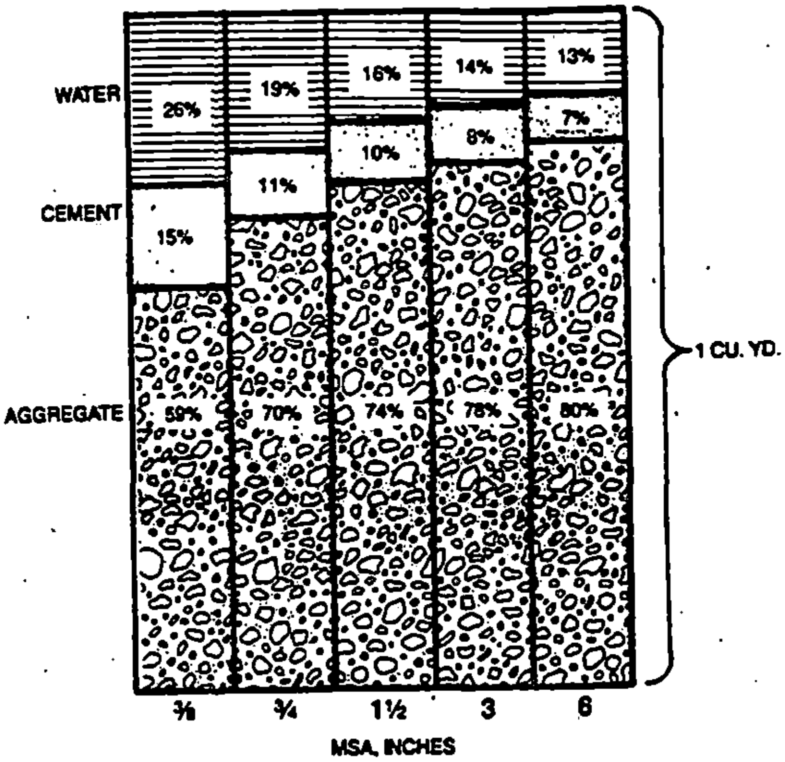


FIGURE 10-5

TYPICAL CONCRETE COMPOSITIONS

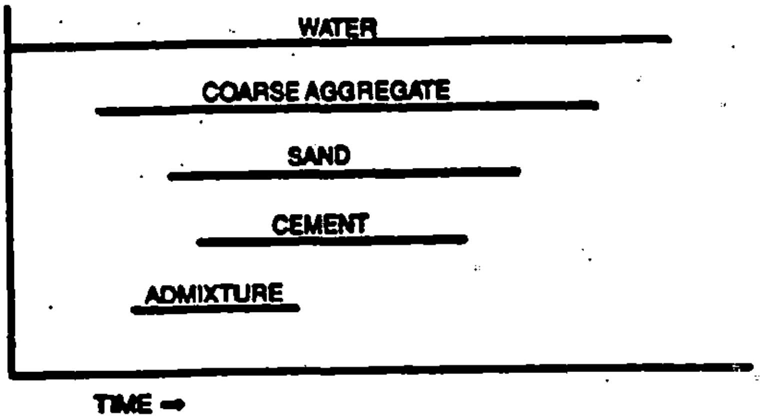


FIGURE 10-6 TYPICAL CHARGING SEQUENCE

The best charging sequence is one in which the water leads and follows all solid materials, with the coarse aggregate leading and following the cement. Admixtures should always enter the mixer at the same point in the sequence.

TABLE 10-1 GRADING REQUIREMENTS FOR REGULAR AGGREGATES USED IN STRUCTURAL CONCRETE

COARSE Grade Aggregate

	Percentage (by weight) Passing Sieve Having Square Openings												
Aggregate Size (inches)	100 mm (4in)	90mm (3.5in)	75mm (3in)	63mm (2.5in)	50mm (2in)	37.5mm (1.5in)	25mm (1in)	19mm (3/4in)	12.5mm (1/2in)	9.5mm (3/8in)	4.75mm (No.4)	2.36mm (No.8)	1.18mm (No.16)
3.5 - 1.5	100	90-100	—	25-60	—	0-15	—	0-5	—	—	—	—	—
2.5 - 1.5	—	—	100	90-100	35-70	0-15	—	0-5	—	—	—	—	—
2 - 1	—	—	—	100	90-100	35-70	0-15	—	0-5	—	—	—	—
2 - No.4	—	—	—	100	95-100	—	35-70	—	10-30	—	0-5	—	—
1.5 - 0.75	—	—	—	—	100	90-100	20-55	0-15	—	0-5	—	—	—
1.5 - No.4	—	—	—	—	100	95-100	—	35-70	—	10-30	0-5	—	—
1 - 0.5	—	—	—	—	—	100	90-100	20-55	0-10	0-5	—	—	—
1 - 3/8	—	—	—	—	—	100	90-100	40-85	10-40	0-15	0-5	—	—
1 - No.4	—	—	—	—	—	100	95-100	—	25-60	—	0-10	0-5	—
3/4 - 3/8	—	—	—	—	—	—	100	90-100	20-55	0-15	0-5	—	—
3/4 - No.4	—	—	—	—	—	—	100	90-100	—	20-55	0-10	0-5	—
1/2 - No.4	—	—	—	—	—	—	—	100	90-100	40-70	0-15	0-5	—
3/8 - No.8	—	—	—	—	—	—	—	—	100	90-100	40-70	0-15	0-5

FINE Grade Aggregate

	Percentage (by weight) Passing Sieve Having Square Openings								
Aggregate Size	19.0mm (3/4in)	12.5mm (1/2in)	9.5mm (3/8in)	4.75mm (No.4)	2.36mm (No.8)	1.18mm (No.16)	600um (No.30)	300um (No.50)	150um (No.100)
Fine	—	—	100	95-100	50-85	25-60	10-30	0-10	0-5

depends on the composition of these materials and the kind of cement being manufactured. Limestone, principally calcium carbonate, constitutes the largest portion of the raw material. Cement is ground so fine that a pound of it contains about 150 billion particles. Approximately ninety-five percent (95%) of these particles will pass through a sieve with 100,000 openings per square inch. [2]

Water used in concrete batch plants is usually obtained from municipal water supplies.

Use of fly ash in concrete manufacturing has greatly expanded over the years. There are two basic classes of fly ash. Class F is normally produced from burning anthracite or bituminous coal. Class C is normally produced from burning lignite or subbituminous coal. Fly ash is beneficial in high strength as well as moderate strength concrete.

An admixture can be defined as any substance, other than cement, aggregate or water, that is added to a batch of fresh concrete for the purpose of altering any of the properties of the concrete, either in the fresh or hardened condition, to make it more suitable for a specific application. [2] The admixture is put into solution, then added to the batch. This will assure complete distribution of the admixture throughout the batch.

The three general classes of admixtures are chemical admixtures, air entraining agents, and pozzolans.

Chemical admixtures include water reducing admixtures; retarding admixtures; accelerating admixtures; water reducing and retarding admixtures; water reducing and accelerating admixtures; water reducing and high range admixtures; water reducing high range, and retarding admixtures.

Water reducers are used to lower the mixing water requirements while providing equal or superior workability. Chemicals commonly used for this purpose are the lignosulfonates (calcium, sodium or ammonium) and salts of hydroxy-carboxylic acids.

Retarders slow the chemical process of hydration so that the concrete remains plastic and workable for a longer time than concrete without the retarder. Chemicals commonly used for this purpose are metallic salts of lignosulfonic acid, such as calcium lignosulfonate, or salts of organic hydroxy-carboxylic acid.

Accelerators speed up the setting time or increase the rate of early strength development, or both. Calcium chloride is the common material available for this purpose.

Air entraining agents, such as organic salts of sulfonated hydrocarbons and salts of sulfonated lignin, are recommended for use in exposed concrete applications. Synthetic detergents, petroleum acid salts, fatty and resinous acids and salts of wood resins can also be used as air entraining agents.

Pozzolans are: "siliceous or siliceous and aluminous material, which in itself posses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cement like properties." [2]

10.1.3 Emission Controls

The type of equipment used to control emissions from a concrete batch plant are discussed for each type of operation used.

10.1.3.1 Wet Concrete Batching Plants

Cement Receiving and Storage System - Figure 10-2 depicts one type of cement receiving and storage system. The receiving hopper is at or below ground level. The discharge tube of the hopper truck is positioned over the receiving hopper. If the discharge tube and receiving hopper fit closely, little or no dust is emitted at this point. The receiving hopper feeds a conveyor which in turn feeds an elevator. Cement elevators are either the vertical screw type or the enclosed bucket type. The elevator unloads the cement to the cement silo. Dust emissions at the various material transfer points are prevented by the use of rubber seals which are difficult to maintain. This makes elevators undesirable for cement conveying. Air displaced by the incoming cement must be vented through a fabric filter device to capture entrained cement dust.

Pneumatic conveyance is the more widely accepted method for conveying the cement from truck to silo. An air stream from a blower is used to fluidize and convey the cement to the silo. The filtering of cement dust from the conveying air is needed before releasing it to the atmosphere. This filtering process normally requires a baghouse. A self-cleaning (shaking, reverse air, etc.) mechanism is also needed to prevent blinding of the baghouse filters. Either of the two methods described above can also be used to load the cement surge bin which is the main source of cement.

Cement weigh hopper - The cement weigh hopper may be a separate unit or a compartment in the aggregate weigh hopper. Cement is usually delivered from the surge bin to the weigh hopper by an enclosed screw conveyor or by gravity. To permit accurate weighing and prevent material loss during transfer, a flexible and non-permeable tubing is used to connect the screw conveyor to the weigh hopper. The weigh hopper is filled at a fairly rapid rate producing a significant amount of cement dust. This dust can be controlled by venting the air back to the cement silo, by installing a filtered vent on the weigh hopper, or by venting the system to a baghouse.[3] Proper air-to-cloth (A/C) ratios should be used to effectively remove entrained particulate matter. This ratio is determined by the actual air flow rate, the characteristics of the particles, the type of filter material used, and the method used to clean the filter media.

Aggregate Conveying Equipment - Dust emissions occur at material transfer points such as between belt conveyors. Wet suppression is mainly used to control dust emissions from transferring of aggregate. Aggregate is usually received wet and does not require additional watering unless it is left standing for a long period of time. Additional watering can be achieved by spraying the aggregate piles with water from water trucks or from water nozzles located at the surge hopper or at the end of belt conveyors.

16.	**Mixer**
17.	**Depending spout**
20.	**Dust collecting shroud**
21.	**Dust conduit**
25.	**Filtering unit**
26.	**Flexible tubular sleeve**
28.	**Horizontal support plate**
31.	**Pair of cables**
41.	**Lower funnel-like inlet section**
42.	**Butterfly-type valve**
43.	**Upper main housing**
48.	**Exhaust fan**
49.	**Exhaust fan**
56.	**Bottom outlet**

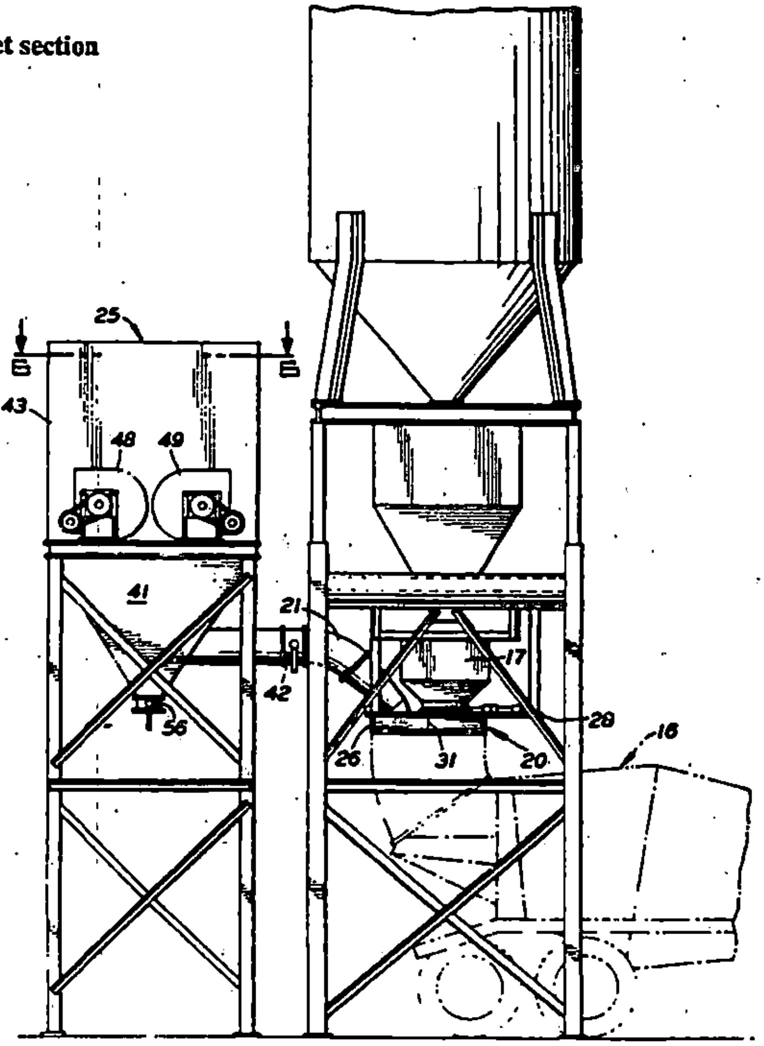
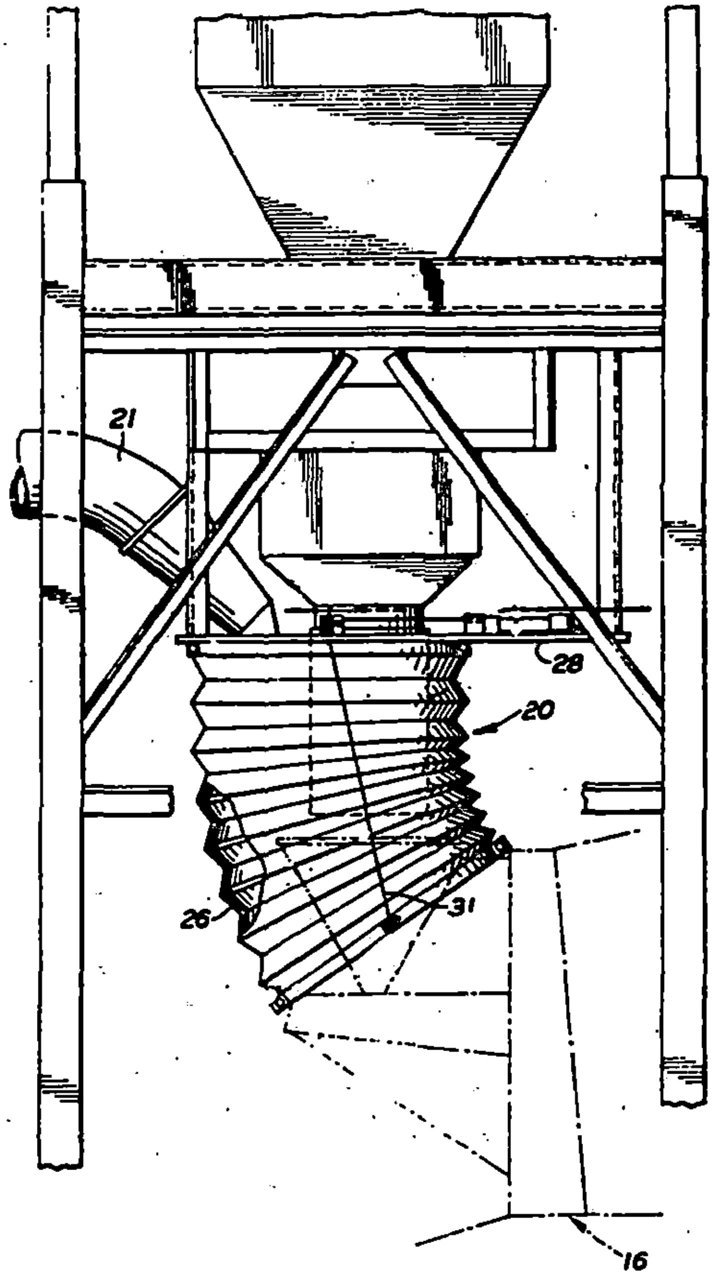


FIGURE 10-7 DUST CONTROL SYSTEM FOR BATCH PLANT CHARGING OF TRANSIT MIXERS (courtesy of the U.S. Patent Office)



20. Dust collecting shroud
21. Dust conduit
26. Flexible tubular sleeve
28. Horizontal support plate
31. Pair of cables

FIGURE 10-8 RETRACTABLE SHROUD FOR TRANSIT MIX TRUCK LOADING (courtesy of the U.S. Patent Office)

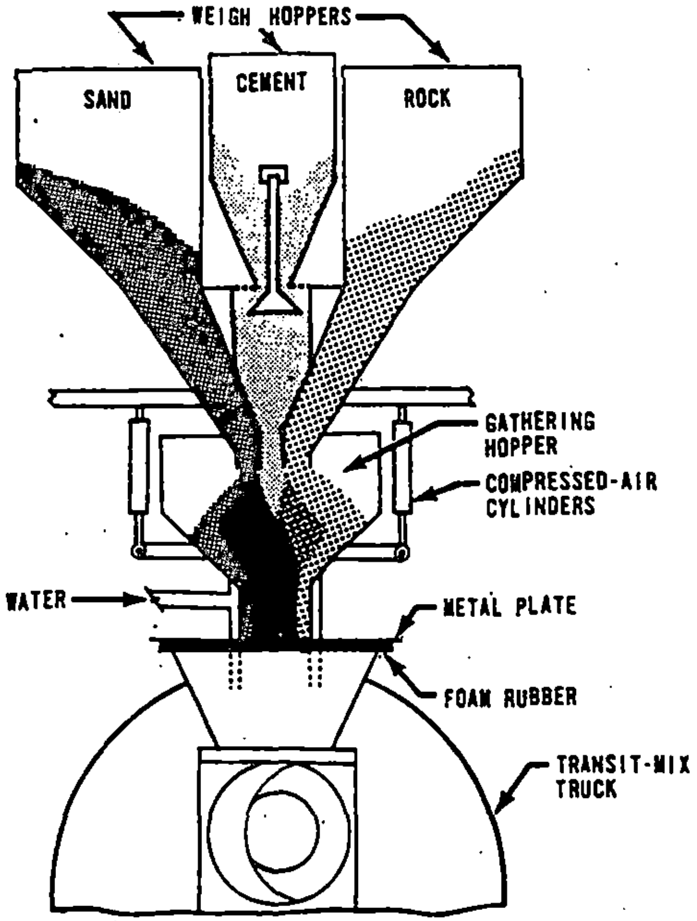


FIGURE 10-9 ADJUSTABLE GATHERING HOPPER

Gathering hopper - Cement and aggregate from the weigh hoppers are directed to a gathering hopper which acts as a funnel for discharging into transit-mix trucks. Dust emissions occur at the various material transfer points and must be controlled with a fabric filtering device. The design and location of the gathering hopper are critical in minimizing dust emissions and in efficient capturing of the dust emissions. The gathering hopper should properly contact the truck's receiving hopper; its vertical position should be adjustable. Typically, a retractable shroud is used to cover the spout and receiving hopper (see Figures 10-7 and 10-8). Figure 10-9 illustrates a design that has been successful in minimizing dust emissions. Compressed air cylinders raise and lower the gathering hopper to accommodate trucks of various heights. A steel plate with a foam rubber backing is attached to the bottom of the gathering hopper and is lowered until it rests on top of the truck's receiving hopper. Water for the mix is introduced through a jacket around the discharge spout of the gathering hopper and forms a water curtain around the added solid materials. Cement is discharged into the center of the aggregate stream through the restricted opening between the weigh hopper and gathering hopper. This configuration suppresses dust emissions from the top of the gathering hopper.[3]

10.1.3.2 Dry Concrete Batching Plants

Dry batching operations pose a much more difficult dust control problem than wet batching operations because material is handled dry. In addition, the dryer presents an extra source of combustion air contaminants. Each material transfer point has to be vented to air pollution control device which usually is a baghouse. The exhaust from the dryer also has to be vented to a baghouse. In this instance, the baghouse has to be insulated to prevent condensation due to cooling of the flue gas stream. During packaging operations, the packer hopper and packer spouts are vented to a baghouse. In some cases, the entire packaging station is vented via a canopy hood to a baghouse.

10.1.3.3 Central-Mixed Plants

Central-mixed plant differs from wet concrete batch plant only in that a mixer is used to produce ready mixed concrete. The concrete is discharged into dump trucks in a slurry form, and transported to the pouring site. The mixer is an additional source of dust emission. However, it is easily controlled through hooding and ventilation to a baghouse. Dust generation during discharge to the open dump-truck is insignificant as the concrete is in slurry form.

10.2 Permit Unit Description

The permit wording description for concrete batch plants is specific for each type of operation:

Transit-Mixed Concrete Batch Plant;
Dry Mix Concrete Batch Plant; and
Central-Mixed Concrete Batch Plant.

A permit unit boundary is defined by where a storage operation begins or ends. The permit unit can be a continuous line of equipment which processes the feed to the final product or to a facility defined as storage. Typically, a concrete batch plant has more than one permit unit. Usually the cement unloading station, which unloads to the storage silo, and together with the storage silo are grouped in a single permit unit. The aggregate receiving and stacking equipment is grouped into a permit unit if a storage pile is formed prior to charging the aggregate to the surge hoppers. The actual batch processing of raw materials through the final discharge operation (transit-mix truck, dump truck, or packaging) is another permit unit. Also, the air pollution control device (typically a baghouse) and the exhaust system (including the blower) are grouped in a separate permit unit.

Figure 10-10 shows a block flow diagram of a typical concrete batch plant. Such diagram is very helpful in showing the arrangement of the equipment, following the flow of material, determining permit unit boundaries, and estimating emissions at

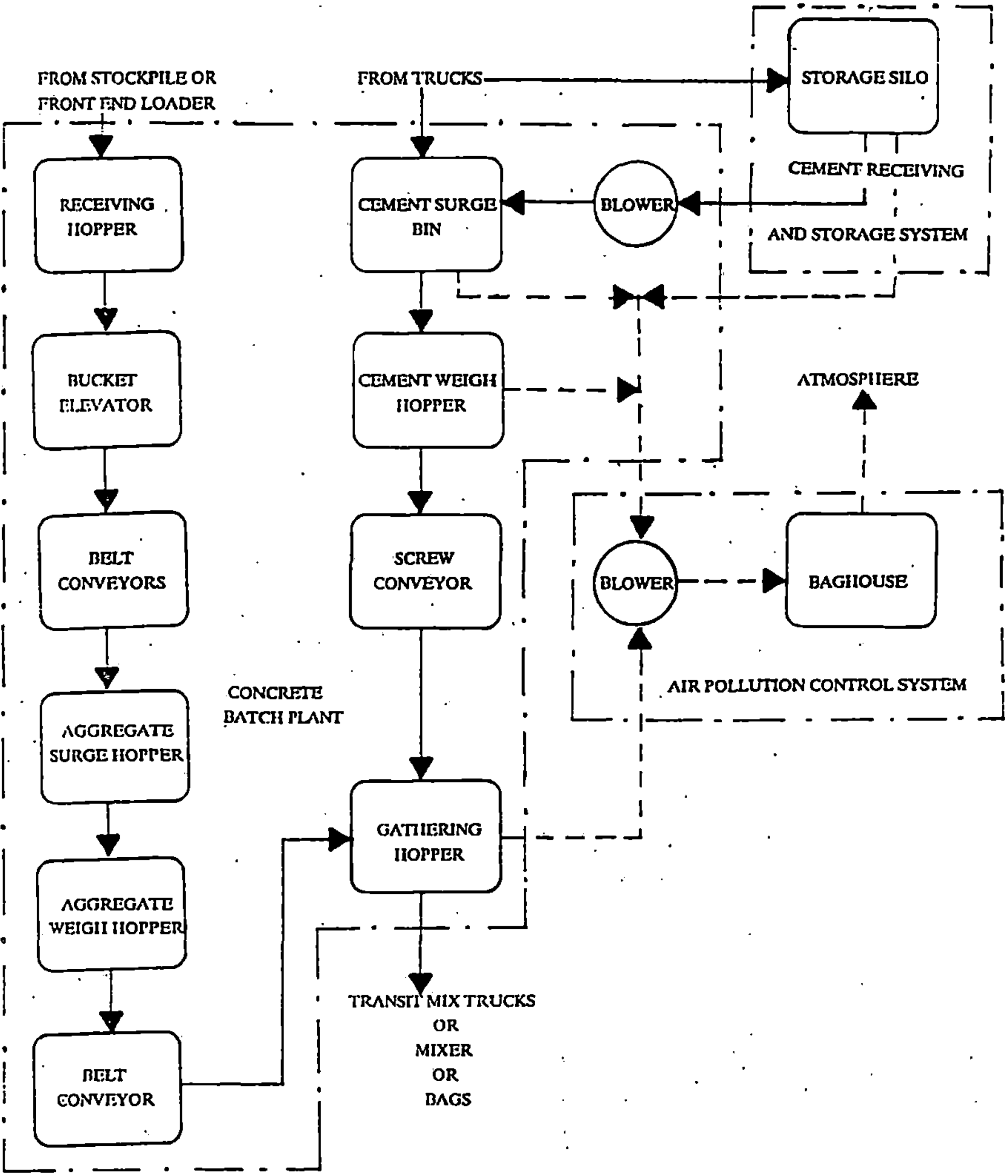


FIGURE 10-10 BLOCK FLOW DIAGRAM OF A TYPICAL CONCRETE BATCH PLANT

each material transfer points. This kind of block flow diagram is highly recommended for evaluating complex material flow.

10.2.1 Transit-Mixed Concrete Batch Plant

The correct permit wording for a Transit-Mixed Concrete Batch Plant is:

TRANSIT-MIXED CONCRETE BATCH PLANT CONSISTING OF:

1. AGGREGATE RECEIVING HOPPER, (DIMENSIONS, CAPACITY).
2. BUCKET ELEVATOR, H.P.
3. BELT CONVEYOR, H.P.
4. AGGREGATE SURGE HOPPER, (NO. OF) COMPARTMENTS, ' "W. x ' "L. x ' "H., TONS CAPACITY.
5. AGGREGATE WEIGH HOPPER, (VOLUME) CU. YDS. CAPACITY.
6. CEMENT SURGE HOPPER, ' "DIA. x ' "H., (WEIGHT OR VOLUME CAPACITY).
7. CEMENT WEIGH HOPPER, LBS. CAPACITY.
8. CEMENT SCREW CONVEYOR, H.P.
9. GATHERING HOPPER, ' "W. x ' "L. x ' "H.
10. TRUCK LOADING STATION, WITH A RETRACTABLE CARRIAGE SHROUD, (PNEUMATIC OR MOTOR) DRIVEN, (H.P.).
11. AIR COMPRESSOR, H.P.

10.2.2 Dry Mixed Concrete Batch Plant

The correct permit wording for a Dry Mixed Concrete Batch Plant is:

DRY MIXED CONCRETE BATCH PLANT CONSISTING OF:

1. AGGREGATE RECEIVING HOPPER, (DIMENSIONS, CAPACITY).
2. BELT CONVEYOR, H.P.
3. DRYER, BTU PER HOUR, (NATURAL GAS) FIRED, WITH A H.P. COMBUSTION AIR BLOWER.

4. BUCKET ELEVATOR, H.P.
5. BELT CONVEYOR, H.P.
6. (TYPE) SCREEN, ' "W. x ' "L., SHAKEN BY A H.P. MOTOR.
7. AGGREGATE SURGE HOPPER, (NO. OF) COMPARTMENTS, ' "W. x ' "L x ' "H., TONS CAPACITY.
8. AGGREGATE WEIGH HOPPER, (VOLUME) CU. YDS. CAPACITY.
9. CEMENT SCREW CONVEYOR, H.P.
10. CEMENT WEIGH HOPPER, LBS. CAPACITY.
11. CEMENT SCREW CONVEYOR, H.P.
12. GATHERING HOPPER.
13. CONCRETE MIX BAG PACKER, MAKE, MODEL, TYPE, (H.P.).

10.2.3 Central-Mixed Concrete Batch Plant

The correct permit wording for a Central-Mixed Concrete Plants is:

CENTRAL-MIXED CONCRETE BATCH PLANT CONSISTING OF:

1. AGGREGATE RECEIVING HOPPER, (DIMENSIONS, CAPACITY).
2. BUCKET ELEVATOR, H.P.
3. BELT CONVEYOR, H.P.
4. AGGREGATE SURGE HOPPER, NO. OF COMPARTMENTS, CU. YDS. CAPACITY.
5. AGGREGATE WEIGH HOPPER, CU. YDS. CAPACITY.
6. (NO.) AGGREGATE BELT CONVEYOR(S), H.P.
7. CEMENT WEIGH HOPPER, TONS CAPACITY.
8. CEMENT SCREW CONVEYOR, H.P.
9. MIXER, CU. YD. CAPACITY, H.P., (WITH A -H.P. TIPPING MOTOR).
10. TRUCK LOADING STATION.
11. AIR COMPRESSOR, H.P.

10.2.4 Air Pollution Control System

The correct permit wording for an Air Pollution Control System is:

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. BAGHOUSE, MAKE, TYPE, MODEL, SERIAL NO., WITH (QUANTITY) (TYPE) FILTER BAGS, EACH ' "DIA. x ' "L., AND TOTAL FILTER AREA OF SQ. FT.

2. EXHAUST SYSTEM WITH A -H.P. BLOWER VENTING (A CEMENT SURGE BIN, CEMENT WEIGH HOPPER, GATHERING HOPPER, ETC.).

10.3 Emissions

The primary emission concern from a concrete batch plant is particulates or dust. The type and amount of dust depend on the type of operation used. Cement dust is the most common source of dust in the concrete batch plant. Particle size distribution and other characteristics of cement dust vary according to the grade of cement. A range of 10% to 20% by weight of particles of 5 micron size or less is typical for the various grades used.

The locations of dust emission in a concrete batch plant include :

Aggregate transfer points - hopper charging and between conveyors;
Cement transfer points - silos and hopper charging and between conveyors;
Mixer loading;
Batch discharge to trucks and packers; and
Open aggregate stockpiles.

Most of the emission points listed above, except those involving aggregate only, requires air pollution control equipment in order to operate in compliance with District's Rules. Baghouse or fabric filter is the most commonly accepted air pollution control equipment for controlling dry particulates emission in concrete batch plants. Particulate emissions from aggregate handling are usually controlled by maintaining high moisture content in the aggregate. This could be achieved by receiving wet aggregate, spraying water by tank trucks onto the open stockpiles, and operating water sprays at end of aggregate belt conveyors. Fugitive dust emissions caused by traffic (truck and front endloaders) within the facility is also a major concern. These emissions can cause a public nuisance if they are allowed to escape to the neighboring area. They can be minimized by watering and keeping the roadways wet.

10.3.1 Emission Factors

Emission factors applicable to a concrete batch plant are presented in Appendix B. These factors are average numbers for the process listed in the references and may not be applicable to a specific case. Data from source testings of actual or similar plant operation should be used whenever available. The following factors were extracted from the list of factors and can be used in the absent of more accurate data:

Cement Handling:	
Pneumatic Conveying:	0.27 lb/ton/transfer point
Mechanical Conveying: (including bin or hopper charging)	0.02 lb/ton/transfer point
Aggregate Handling:	
Mechanical Conveying: (including bin or hopper charging)	0.001 lb/ton/transfer point

10.3.2 Operational Information

The following information should be obtained from the applicant in order to evaluate the process for a permit: (both the maximum and average rates should be included)

Material Flow Diagram (Preferably in the form of a block flow diagram)
Hours of Operation Per Day ———————— (hours/day)
Type of Batch Operation ———————— (wet, dry, central)
Throughput Per Day of Concrete ———————— (tons/day)
Volume of Concrete Produced Per Day ———————— (cu.yd./day)
Composition of a Cubic Yard of
Concrete Produced ———————— (% cement, sand, aggregate, admixture, water, fly ash)

Type and Amount of Aggregate
Delivered Per Day ———————— (grade)
———————— (tons/day),

Amount of Cement Delivered Per Day ———————— (tons/day)
Amount of Flyash Delivered Per Day ———————— (tons/day)

Baghouse Specifications:
    Filter Cloth Area ———————— (sq.ft.)
    Air Flow ———————— (cu.ft./min.)
    Blower Rating ———————— (h.p.)
    Filter Cleaning System Employed
    Vented Transfer Points Identified
    Static Pressure Gauge - Manometer

For Dry Mix Facilities in particular:

Number of Bags of Dry Mix produced Per Day ———————— (#/day)
Size of Bags of Dry Mix Produced ———————— (lb)
Kind and Amount of Fuel Consumed in Dryer ———————— (cu.ft./day or gals/day)
Kind (if any) of Back-up Fuel————————

10.4 Calculations

10.4.1 Emission Calculations

Emission calculations must be performed to determine the compliance status of the concrete batch plant. The calculation of emissions involves the uncontrolled emission (R_{11} and R_{12}) and the controlled emission (R_2). These are based on the throughput rate of individual material and the emission factor at each transfer point in the process. Total particulate matters emitted to the atmosphere is the summation of particulate matters from controlled and uncontrolled sources (aggregate transfer points are usually uncontrolled), as shown in Equation 10.4. For purpose of determining compliance with New Source Review Rules (Regulation XIII), daily emission rate can be calculated as shown in Equation 10.5.

$$R_{11} = A \times AT \times 0.001 \text{ lb/ton/transfer point} \qquad \textbf{(Equation 10.1)}$$

$$R_{12} = C \times (CPT \times 0.27 \text{ lb/ton/transfer point} + CMT \times 0.02 \text{ lb/ton/transfer point}) \qquad \textbf{(Equation 10.2)}$$

$$R_2 = R_{12} \times \text{(assumed efficiency of the control device serving the emission points of } R_{12}\text{)}. \qquad \textbf{(Equation 10.3)}$$

$$R_T = R_{11} + R_2 \quad \text{(lb/hr)} \qquad \textbf{(Equation 10.4)}$$

$$R_T = (R_{11} + R_2) \times O \quad \text{(lb/day)} \qquad \textbf{(Equation 10.5)}$$

where:

A = throughput rate of aggregate, (tons/hr).
AT = number of aggregate transfer points, (transfer points).
C = throughput rate of cement, (tons/hr).
CPT = number of cement pneumatic transfer points, (transfer points).
CMT = number of cement mechanical transfer points, (transfer points).
R_{11} = uncontrolled emission rate due to aggregate handling, (lbs/hr).
R_{12} = uncontrolled emission rate due to cement handling, (lbs/hr).
R_2 = controlled emission rate, (lbs/hr).
R_T = Total emission rate, (lbs/hr).
O = operating hours per day, (hrs/day).

(See Section 10.3.1 Emission Factors and Appendix 10B).

In order to determine compliance with South Coast Air Quality Management District (SCAQMD) Rule 404, particulate concentration (grains/dscf) in an exhaust gas stream to the atmosphere must be calculated. The controlled particulate matter mass emission rate (R_2; lb/hr) must be converted into particulate matter concentration using the air flow rate (dscfm) in the exhaust stack. The particulate matter concentration is calculated in Equation 10.6. This equation assumes emissions occur in an hourly basis. If emissions occur during discrete periods of time, emission rate should be expressed in lb/batch and time per batch (min/batch) should be used instead of 60 min/hr in Equation 10.6.

$$C = \frac{R_2(\text{lb/hr}) \times 7{,}000\ (\text{grains/lb})}{F \times 60\ (\text{min/hr})} \qquad \textbf{(Equation 10.6)}$$

where:

C = Particulate matter concentration (grains/dscf)
F = Exhaust air flow rate in dry standard cubic feet per minute (dscfm)

10.4.2 Baghouse Design Calculation

The air-to-cloth (A/C) ratio can be calculated using Equation 10.7.

$$A/C = \frac{VFR}{A_b} \qquad \textbf{(Equation 10.7)}$$

where:
A/C = Air-to-Cloth ratio (ft/min)
VFR = Air volumetric flow rate, exhaust blower (ft^3/min)
A_b = Actual filter cloth area of bags or cartridges (ft^2)

10.5 Rules Evaluation

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing a permit.

Rule 401 - Visible Emissions
No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 403 - Fugitive Dust
Visible fugitive dust is prohibited beyond the boundary of the facility (exemptions apply). In addition, particulate concentration in the downwind sample(s) may not exceed that in the upwind sample(s) by more than 100 micrograms per cubic meter.

Rule 404 - Particulate Matter - Concentration
Limits for particulate matter concentrations in an effluent gas stream at standard conditions are listed in Table 404(a) of the SCAQMD's Rules and Regulations.

Rule 405 - Particulate Matter - Weight
Limits for particulate matter emission rates from any source are listed in Table 405(a) of the SCAQMD's Rules and Regulations.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT for particulate matter emissions from concrete batch plant is a baghouse for cement handling and adequate moisture in aggregate.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[6] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

10.6 Permit (Operating) Conditions

Conditions that are most commonly imposed are listed below. Additional conditions may be necessary for special cases.

CONCRETE BATCH PLANT
APPLICATION NO.:

1. NOT MORE THAN CUBIC YARDS OF CONCRETE SHALL BE PRODUCED BY THIS EQUIPMENT IN ANY ONE DAY.
2. AGGREGATE CHARGED AND AGGREGATE PROCESSED SHALL BE KEPT SUFFICIENTLY MOIST TO PREVENT VISIBLE DUST EMISSIONS.
3. THIS EQUIPMENT SHALL NOT BE OPERATED UNLESS THE (CEMENT SURGE BIN, CEMENT WEIGH HOPPER, GATHERING HOPPER, ETC.) ARE VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED (AN OPERATING PERMIT OR A PERMIT TO CONSTRUCT) BY THE EXECUTIVE OFFICER.

AIR POLLUTION CONTROL EQUIPMENT
APPLICATION NO.:

1. A MECHANICAL GAUGE SHALL BE INSTALLED SO AS TO INDICATE, IN INCHES OF WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS.
2. DUST COLLECTED BY THE BAGHOUSE FILTER SHALL BE DISCHARGED INTO CLOSED CONTAINERS ONLY.
3. THE CLOTH BAGS IN THE BAGHOUSE MUST BE THOROUGHLY CLEANED IMMEDIATELY AFTER EACH DAY OF OPERATION.

REFERENCES

1. Compilation of Air Pollution Emission Factors, AP-42, Fourth Edition, September 1985.
2. Waddel, Joseph J., CONCRETE MANUAL, International Conference of Building Officials, 1984.
3. Air Pollution Engineering Manual, AP 40, 2nd Edition, Air Pollution Control District, Los Angeles County, 1973.
4. Murdock, L.J. and Brook, K.M., CONCRETE MATERIALS and PRACTICE, 5th edition, John Wiley & Sons, N.Y., 1979.
5. Active Permits in the South Coast Air Quality Management District.
6. South Coast Air Quality Management District (SCAQMD) Best Available Control Technology (BACT) Guidelines, October 7, 1988.

APPENDIX 10A

WORKSHEET FOR CONCRETE BATCH PLANT

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 6	PAGE 1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME :

MAILING ADDRESS :

EQUIPMENT LOCATION :

EQUIPMENT DESCRIPTION

APPLICATION NO. ________________

TRANSIT-MIXED CONCRETE BATCH PLANT CONSISTING OF:

1. AGGREGATE RECEIVING HOPPER, -CU. YDS. CAPACITY.
2. BUCKET ELEVATOR, H.P..
3. BELT CONVEYOR, '- "W. x '- "L., H.P.
4. AGGREGATE SURGE HOPPER, COMPARTMENTS, WITH DIMENSIONS OF '- "W. x '- "L. x '- "H., -TON CAPACITY.
5. AGGREGATE WEIGH HOPPER, -TON CAPACITY.
6. BELT CONVEYOR, '- "W. x '- "L., H.P.
7. PNEUMATIC CONVEYOR, CEMENT, WITH A -H.P. BLOWER.
8. CEMENT SURGE BIN, '- "DIA. x '- "H., -TON CAPACITY.
9. CEMENT WEIGH HOPPER, -TON CAPACITY.
10. SCREW CONVEYOR, H.P.
11. GATHERING HOPPER, '- "W. x '- "L. x '- "H.
12. TRUCK LOADING HOPPER, WITH A RETRACTABLE CARRIAGE SHROUD, DRIVEN, H.P.
13. AIR COMPRESSOR, H.P.

APPLICATION NO. ________________

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. BAGHOUSE, , MODEL , SERIAL NO. , WITH FILTERS BAGS, EACH '- " DIA. x '- " L., AND A TOTAL FILTER AREA OF SQ. FT,.

2. EXHAUST SYSTEM WITH A -H.P. BLOWER, VENTING

HISTORY

This equipment was (will be) installed at the above equipment address on (in) . The batching process produces tons/day of wet batch (dry batch/packaged) (ready-mixed) concrete and will continue (increase) (decrease) at (from) this level (to tons/day output).

PROCESS DESCRIPTION

The transit-mixed concrete batch plant produces tons of concrete per day maximum and an average of tons of concrete per day. The facility operates from am/pm to am/pm, days/week.

The attached block flow diagram depicts the material flow within the system. The aggregate is dumped into a receiving hopper from an endloader. It is elevated by a bucket elevator to a belt conveyor which drops the aggregate according to its grade into different compartments of the aggregate surge hopper. Underneath the aggregate surge hopper is the aggregate weigh hopper which discharges the weighed amounts of respective aggregate to the gathering hopper via a belt conveyor.

Cement can be (pneumatically) charged into the surge bin either from trucks or from a storage silo which is not included in this evaluation. Cement is gravity fed into the weight hopper and then discharged into the gathering hopper. The (cement storage silo, cement surge bin, cement weigh hopper, and the gathering hopper) are vented to (the air pollution control system).

The gathering hopper discharges the dry components to the transit-mix truck receiving hopper which is covered with a . Water is added to the mixer prior, during and after adding the dry components to prevent dust generation.

CALCULATIONS:

The emissions are calculated based on the following information which is given:

The throughput rate of aggregate	(A - tons/hr)
The throughput rate of cement	(C - tons/hr)
The number of hours of operation per day	(O - hrs/day)
The number of aggregate transfer points	(AT)
The number of cement transfer points(pneumatic)	(CPT)
The number of cement transfer points(mechanical)	(CMT)

Particulate Emission Factors:

Cement Handling:

Pneumatic Conveying:	0.27 lb/ton/transfer point
Mechanical Conveying: (including bin or hopper charging)	0.02 lb/ton/transfer point

Aggregate Handling:

Mechanical Conveying: (including bin or hopper charging)	0.001 lb/ton/transfer point

Capture efficiency of baghouse is assumed to be 99%

1. Emission estimates:

R_{11} = A (tons/hr) x AT transfer point x 0.001 lb/ton/transfer point

R_{11} = _____ lb/hr

R_{12} = C (tons/hr) x (CPT transfer points x 0.27 lb/ton/transfer point + CMT transfer points x 0.02 lb/ton/transfer point)

R_{12} = _____ lb/hr

$R2 = R_{12} \times (1 - 0.99)$

$R_T = R_2 + R_{11}$

$$C = \frac{R_2(PM) \times 7{,}000 \text{ (grains/lb)}}{F \times 60 \text{ (min/hr)}}$$

where:

R_{11}, R_{12} = uncontrolled emission rate, (lb/hr).
R_2 = controlled emission rate, (lb/hr).
R_T = Total particulate matter emitted to atmosphere, (lb/hr).
C = Particulate matter concentration, (grains/dscf).
F = Exhaust air flow rate in dry standard cubic feet per minute, (dscfm).

2. Air-to-Cloth Ratio:

The air-to-cloth (A/C) ratio can be calculated using the equation below:

$$A/C = \frac{F}{A_b}$$

where:
A/C = Air-to-Cloth ratio, (ft/min)
A_b = Actual filter cloth area of bags or cartridges, (ft^2)

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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RULE EVALUATION

RULE 212 : Public notice is (is not) required.

RULE 401 : No visible emissions is expected if the aggregate is kept sufficiently moist and the baghouse is employed for control of cement dust. Equipment is (is not) expected to operate in compliance.

RULE 402 : No nuisance complaints are on file against this applicant, and none is anticipated provided that operations are conducted according to submitted procedures.

RULE 403 : Fugitive dust emissions are minimal due to the venting of the process equipment to the baghouse and if aggregate is kept sufficiently moist.

RULE 404 : Allowed concentration is grains/dscf. The equipment is (is not) operating in compliance with this rule per calculations.

RULE 405 : Allowed emission rate is lbs/hr. The equipment is (is not) operating in compliance with this rule per calculations.

REG XIII : The net increase in emissions resulting from the operation of this equipment does not (does) exceed the limitations specified in Regulation XIII as shown by the Emission Threshold/New Source Sheet table below:

(Emissions in Pounds per Day)

	RHC	NO_X	SO_2	CO	PM	URHC
Cumulative Facility Emissions Since 10-8-76						
A/N (basic)						
A/N (control)						
Facility Net Emission Increase Since 10-8-76						

Facility Net Emission increase (does not) exceed(s) threshold limit. (Applicant has/has not provided offsets.)

BACT: The Best Available Control Technology (BACT) for a transit-mixed concrete-batch plant is . The applicant will (will not) provide a as BACT. Air to cloth ratio of baghouse is (is not) within acceptable range.

CONCLUSIONS / RECOMMENDATIONS

This concrete-batch plant is (is not) expected to comply with all applicable Rules and Regulations of the South Coast Air Quality Management District. Therefore, the following action is recommended:

( ) Issue Permit(s) to Construct/Operate subject to the following conditions:

CONDITIONS

APPLICATION NO. ____________________ (BASIC EQUIPMENT)

1. THE THROUGHPUT RATE OF CONCRETE MUST NOT EXCEED CUBIC YARDS (TONS) IN ANY ONE DAY.
2. AGGREGATE CHARGED AND AGGREGATE PROCESSED MUST BE KEPT SUFFICIENTLY MOIST TO PREVENT DUST EMISSIONS.
3. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS THE (CEMENT SUURGE BIN, CEMENT WEIGH HOPPER, GATERING HOPPER, AND TRUCK LOADING STATION) ARE VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMEN WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED (AN OPERATIN PERMIT) (A PERMIT TO CONSTRUCT) BY THE EXECUTIVE OFFICER.

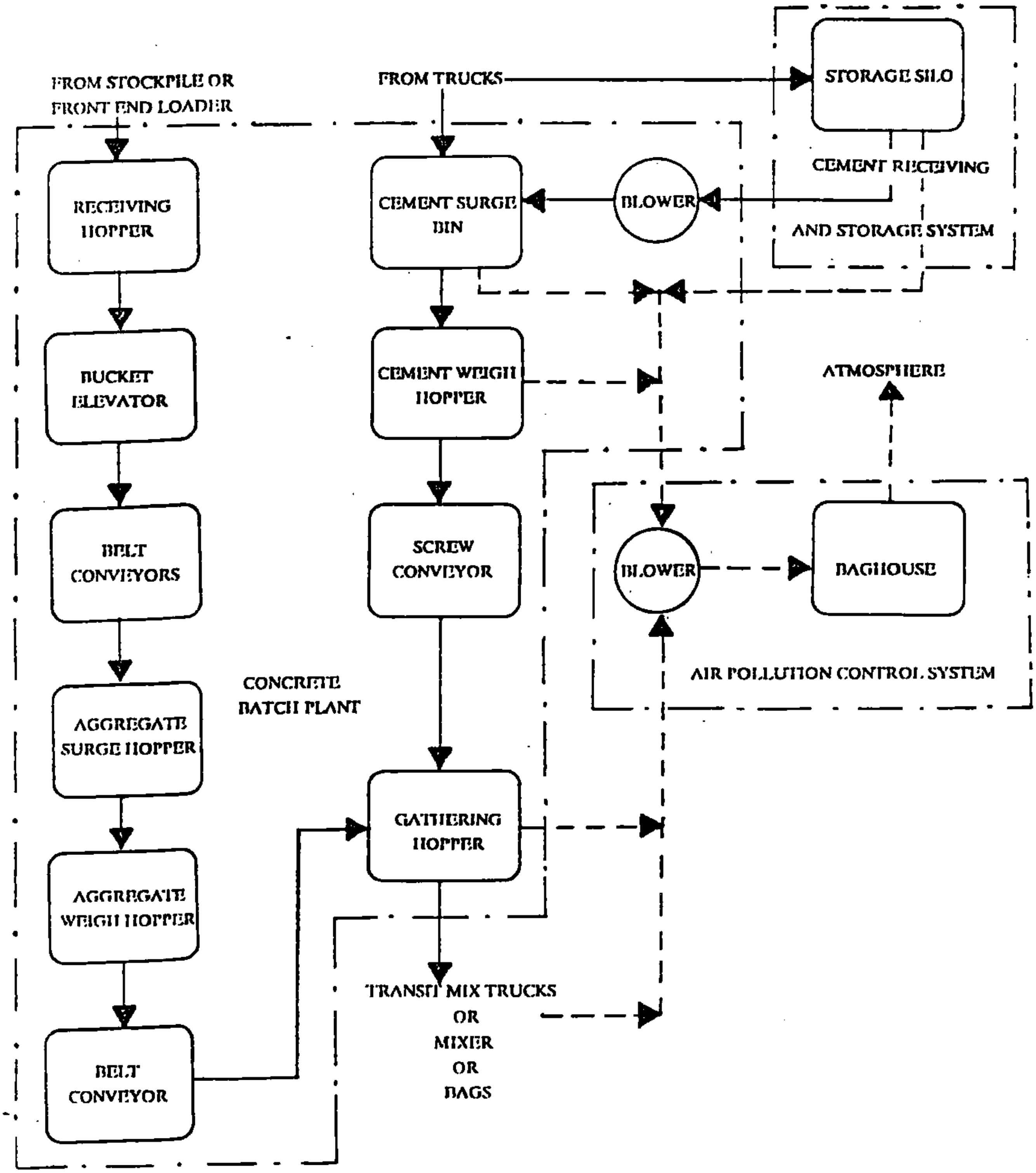
APPLICATION NO. ____________________ (CONTROL EQUIPMENT)

1. THE BAGHOUSE IS TO BE EQUIPPED WITH A MECHANICAL GAUGE WHICH MEASURES STATIC PRESSURE DROP ACROSS THE FILTER IN INCHES OF WATER.
2. DUSTS COLLECTED BY THE BAGHOUSE FILTER MUST BE DISCHARGED INTO CLOSED CONTAINERS ONLY.

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s):__________ of the Rules and Regulations of the South Coast Air Quality Management District.



BLOCK FLOW DIAGRAM

APPENDIX 10B

EMISSION FACTORS FOR CONCRETE-BATCH PLANTS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

MEMORANDUM

DATE: November 21, 1978

TO: All Engineers

FROM: William F. Hammond, Chief Engineer I

SUBJECT: Emission Factors For Aggregate Plants

The following emission factors can be utilized when estimating particulate emissions from a concrete batch plant.

Uncontrolled Particulate Emission Factors

1. Cement Silo 0.001 pounds per pound of cement.
2. Cement Conveying 0.05 pounds per cubic yard of concrete.
3. Aggregate Conveying 0.005 pounds per cubic yard of concrete.

Controlled Particulate Emission Factors

1. Cement Silo 0.00001 pounds per pound of cement.
2. Cement Conveying 0.005 pounds per cubic yard of concrete.
3. Aggregate Conveying 0.005 pounds per cubic yard of concrete

The cement silo emissions are the particulate emissions that occur du to the loading of the cement silo. The controlled emission factor is based on a well designed baghouse or filter vent servicing the cement silo.

The cement conveying emissions are the particulate emissions that occur due to the cement handling processes after the cement leaves it storage silo. The controlled emission factor is based on a well designed baghouse system venting the batching operation.

The aggregate conveying emissions are the particulate emissions that occur due to handling of the aggregate throughout the plant. Both th uncontrolled and controlled emission factors are based on the aggregate being moist enough to prevent excessive visible emissions. The controlled emission factor is the same as the uncontrolled emission factor since the aggregate conveying and handling systems ar usually not vented to control equipment in a concrete batch plant.

FEL:vm

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

MEMORANDUM

DATE: November 21, 1978

TO: All Engineers

FROM: William F. Hammond, Chief Engineer I

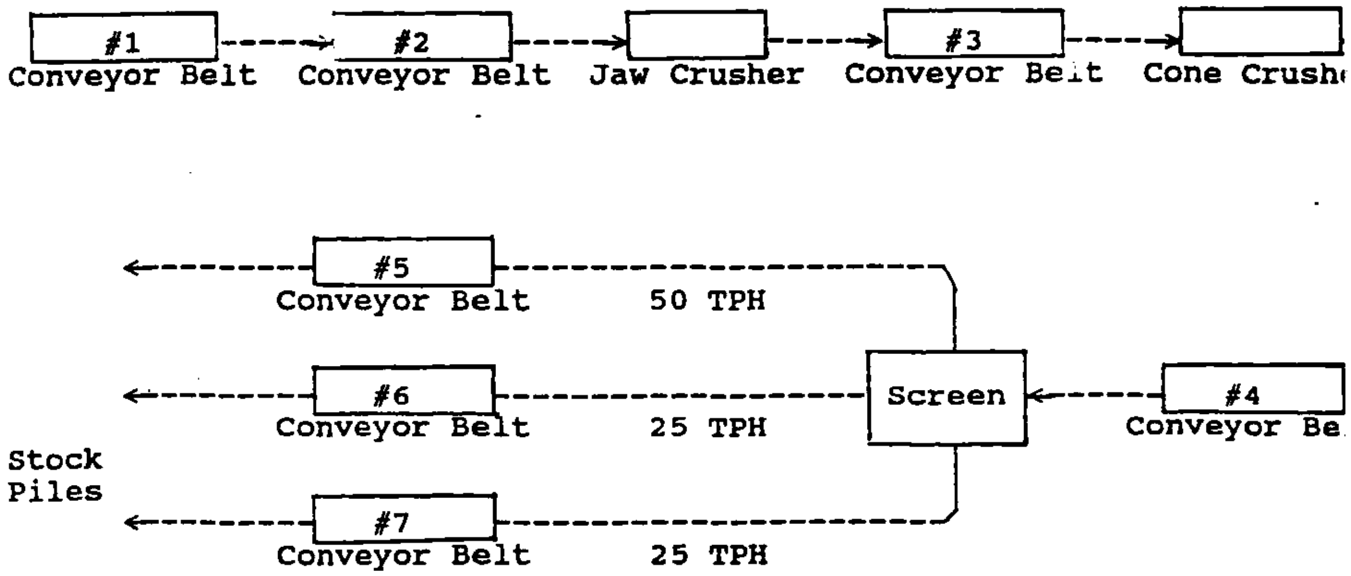
SUBJECT: Emission Factors For Aggregate Plants

The following emission factors can be used as a guideline when estimating particulate emissions from aggregate processing and handling plants. The factors are based on the aggregate's surface being saturated with moisture in order to prevent excessive visible emissions.

Each material transfer point:	0.001 lbs/ton of throughput
Each cone crusher:	0.01 lbs/ton of throughput
Each jaw crusher:	0.005 lbs/ton of throughput

No factors are used for screens, washers, etc., and the loading of th first conveyor belt and the discharge from the last conveyor belt to storage are not considered material transfer points.

For example, assume a plant processes 100 tons/hour and has the following block flow diagram.



The estimated emissions would be:

Equipment or Transfer Point	Emission Factor (Lbs/Ton of Throughput)	Throughput (Tons/Hour)	Estimated Emissio (Lbs/Hour)
Belt #1 to Belt #2	0.001	100	0.1
Belt #2 to Crusher	0.001	100	0.1
Jaw Crusher	0.005	100	0.5
Crusher to Belt #3	0.001	100	0.1
Belt #3 to Crusher	0.001	100	0.1
Cone Crusher	0.01	100	1.0
Crusher to Belt #4	0.001	100	0.1
Belt #4 to Screen	0.001	100	0.1
Screen to Belt #5	0.001	50	0.05
Screen to Belt #6	0.001	25	0.025
Screen to Belt #7	0.001	25	0.025
TOTAL			2.2

Please be reminded that these emission factors are for an averag plant processing relatively moist material and may requir modification based on actual plant observations.

FEL/fb

TABLE 10-2 UNCONTROLLED PARTICULATE EMISSION FACTORS FOR CONCRETE BATCHING [a]

Source	kg/Mg of material	lb/ton of material	lb/yd^3 of concrete [b]	Emission Factor Rating
Sand and aggregate transfer to elevated bin [c]	0.014	0.029	0.05	E
Cement unloading to elevated storage silo via:				
Pneumatic [d]	0.013	0.27	0.07	D
Bucket elevator	0.012	0.24	0.06	E
Weigh hopper loading [e]	0.01	0.02	0.04	E
Truck loading (transit-mix) [f]	0.01	0.02	0.04	E
Mixer loading (central mix) [f]	0.02	0.04	0.07	E
Vehicle traffic (unpaved road) [g]	4.5 kg/VKT	16 lb/VMT	0.2 [h]	C
Wind erosion from sand and aggregate storage piles [i]	3.9 kg/ hectacre day	3.5 lb/ acre day	0.1 [j]	D
Total process emissions (truck mix) [k]	0.05	0.10	0.20	E

a Compilation of Air Pollution Emission Factors, AP-42, Fourth Edition, September 1985.

b Based on a typical cubic yard weighing 1.818 kg (4,000 lb) and containing 227 kg (500 lb) cement, 564 kg (1,240 lb) sand, 864 kg (1,900 lb) coars aggregate and 164 kg (360 lb) water.

c Obtained from Fugitive Dust Assessment at Rock and Sand Facilities in the South Coast Air Basin, Southern California Rock Products Association an Southern California Ready Mix Concrete Association, Santa Monica, CA, November 1979.

d For uncontrolled emissions measured before filter. Based on two tests on pneumatic conveying controlled by a fabric filter.

e From test of mechanical unloading to hopper and subsequent transport of cement by enclosed bucket elevator to elevated bins with fabric socks over b vent.

f Obtained from Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions, EPA-450/3-77-010. U.S. Environmental Protectic Agency, Research Triangle Park, NC, March 1977.

g From Section 11.2.1, "Unpaved Roads", AP 42, 4th Edition, with k = 0.8, s = 12, S = 20, w = 14, and p = 100, VKT = Vehicle Kilometers Travelle VMT = Vehicle Miles Travelled.

h Based on facility producing 23,100 m^3/yr (30,000 yd^3/yr), with average truck load of 6.2 m^3 (8 yd^3) and plant road length of 161 meters (1/10 mile).

i From Section 8.19.1, "Sand and Gravel Processing", AP 42, 4th Edition, for emissions < 30um for inactive storage piles.

j Assumes 1,011 m^2 (1/4 acre) of sand and aggregate storage at plant with production of 23,100 m^3/yr (30,000 yd^3/yr).

k Based on pneumatic conveying of cement at a truck mix facility. Does not include vehicle traffic or wind erosion from storage piles.

SECTION 11

Aluminum Melting Reverberatory Furnaces

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Appendix 11A Worksheet For Non-Sweating Aluminum Melting Reverberatory Furnace Without Fluxing or Alloying 11A-1

Appendix 11B Worksheet For Non-Sweating Aluminum Melting Reverberatory Furnace With Fluxing And/Or Alloying 11B-1

Appendix 11C Worksheet For Sweating Aluminum Melting Reverberatory Furnace 11C-1

Section 11

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

Author

Mark A. Henninger

Reviewers

Alex L. Bailey
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Joseph Tramma

SECTION 11: ALUMINUM MELTING REVERBERATORY FURNACES

11.1 General Description

Reverberatory furnaces are commonly used to melt solid metal and to hold liquid metal for later use. A typical reverberatory furnace consists of a burner, rectangular refractory lined hearth, roof and walls. The metal to be melted is placed in the hearth and melted by the radiant heat from the burner flame and surrounding refractory on the walls and roof. Reverberatory furnaces are both natural gas and oil fired. The burner flame and combustion products come in direct contact with the metal.

Reverberatory furnaces are built in a variety of shapes and sizes depending on the users needs. One of the largest types of reverberatory furnaces is the open hearth furnace shown in Figure 11-1. This furnace is widely used in the steel industry. Aluminum melting reverberatory furnaces are typically rectangular or cylindrical, and vary greatly in size, holding capacity and input. A typical rectangular reverberatory furnace is shown in Figure 11-2. A typical cylindrical tilting reverberatory furnace is shown in Figure 11-3.

Aluminum melting reverberatory furnaces are used for two different processes, sweating and non-sweating. Sweating processes involve the separation of aluminum from scrap metal. The type of reverberatory furnace used for sweating is the dry hearth furnace. In a dry hearth furnace the charge of metal or scrap is placed on a sloping hearth above the level of the molten bath. The floor of the furnace is sloped downward at the rear, so that as the scrap is heated, the aluminum melts and flows to the rear of the furnace. The metals with higher melting temperatures and the dross (metal oxides and contaminants) are left on the hearth and are periodically removed. A typical dry hearth furnace is shown in Figure 11-4.

Non-Sweating processes involve the melting of aluminum in the form of clean or contaminated scrap. Clean metals include ingots, pigs, sows, and uncontaminated scrap. Ingots, pigs and sows are progressively larger sizes of rough cast aluminum bars and blocks. Contaminated scrap is commonly turnings, borings, or other scrap

Figure 11-1, Open Hearth Furnace

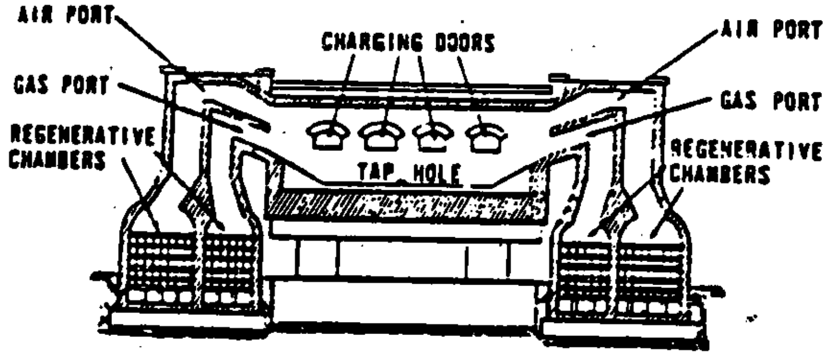


Figure 11-2, Typical Rectangular Reverberatory Furnace

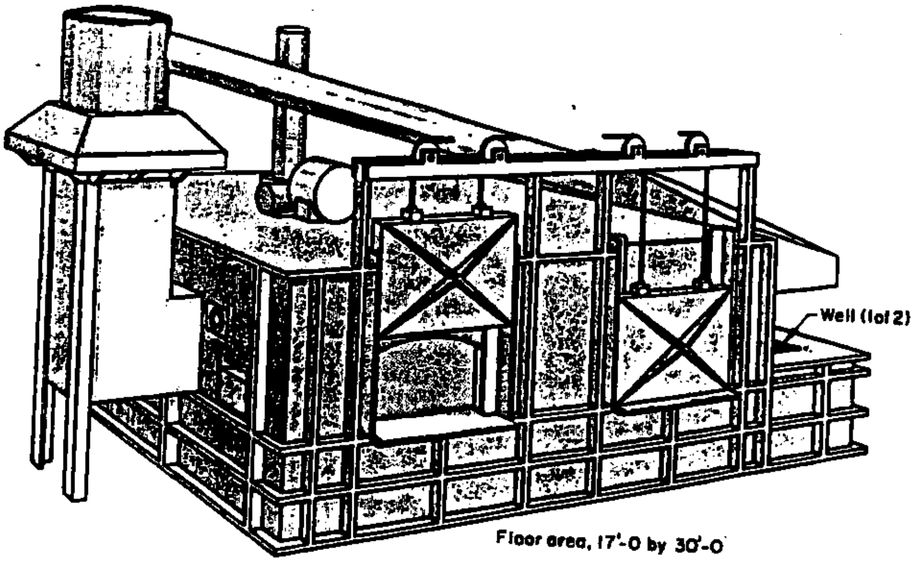


Figure 11-3, Cylindrical Tilting Reverberatory Furnace

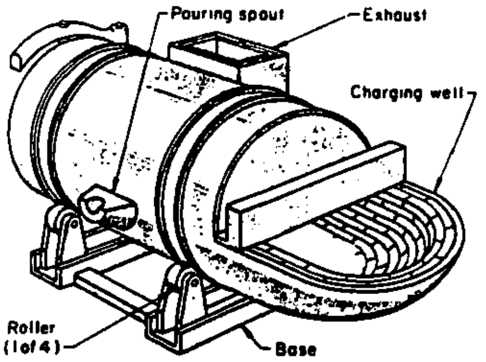
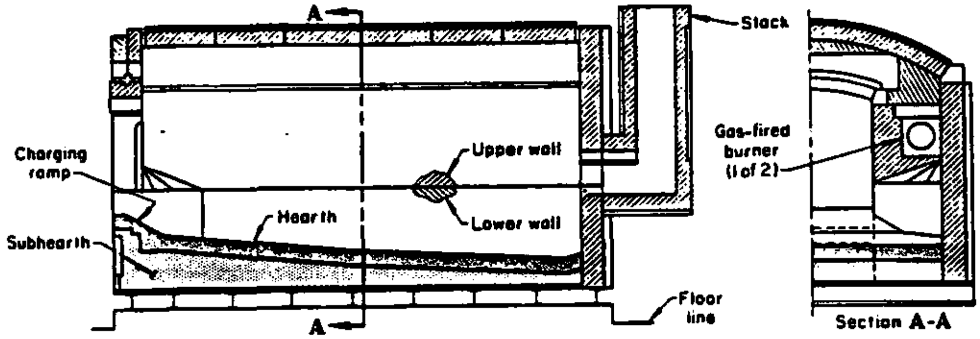


Figure 11-4, Dry Hearth Reverberatory Furnace



that is coated with oil, grease, paint, or paper. Wet hearth furnaces are commonly used for non-sweating processes. In a wet hearth furnace the charge of metal is either placed directly into the chamber, or into a charging well.

Once the metal has been melted in either type of furnace, alloying agents and/or fluxes are added. Alloying agents are materials that are added to the melt in order to change the physical properties of the melt. Fluxes are used to clean the melt.

11.1.1 Fluxing

Fluxes are used to prevent oxides from forming in the melt, and to remove impurities from the melt. There are basically four types of fluxes: cover fluxes, solvent fluxes, degassing fluxes, and magnesium reducing fluxes. Cover fluxes are used to reduce oxidation on the surface of the melt and can also be effective in preventing the absorption of gas into the melt. Cover fluxes, usually in powder form, are spread over the top of the molten metal. Cover fluxes react chemically with oxides on the surface of the melt. The oxides are separated and form a dross on the surface which can be easily skimmed off. Most cover fluxes contain sodium chloride in various proportions with either calcium chloride, calcium fluoride, or borax. Other cover fluxes contain borax, aluminum fluoride, cryolite, or aluminum fluoride with cryolite.

Solvent fluxes are used to remove impurities and oxides by causing them to float to the top of the melt, where the resulting dross can be easily skimmed off. Solvent fluxes usually form a vapor or gas at the temperature of the melt. Solvent fluxes in the form of pellets or pills are most commonly packaged in aluminum foil and plunged to the bottom of the melt. The resulting agitation causes impurities and oxides to rise to the top of the melt, and also aids in removing some of the dissolved gasses in the melt.

Degassing fluxes are used to remove dissolved hydrogen gas from the molten metal. Usually either chlorine, nitrogen, helium, or argon gas is used as the flux. Mixtures of various proportions of chlorine and nitrogen gasses are also used. The degassing flux is introduced near the bottom of the melt through a lance. The flux then bubbles through the molten metal causing an agitation which liberates the dissolved hydrogen gas.

Magnesium reducing fluxes such as chlorine and aluminum fluoride remove magnesium from the melt. Magnesium reducing fluxes are mainly used when scrap aluminum is being processed because scrap aluminum often contains a large amount of magnesium. Typically chlorine gas is bubbled through the melt where it reacts with the magnesium to form magnesium chloride. The magnesium chloride, along with other impurities, floats to the top of the melt where it can be easily skimmed off. The chlorine gas can be injected with a simple lance or by using a spinning nozzle in a launder outside of the furnace. Typically the melt is pumped through the launder while the chlorine is injected through the spinning nozzle. This approach can reduce excess chlorine emissions since atomization and mixing of the chlorine are much better.

11.1.2 Air Pollution Control Techniques

Air contaminants from aluminum melting reverberatory furnaces are created by the combustion of the fuel, the melting process (including charging and tapping), alloying, and fluxing. The combustion of the fuel creates the following air contaminants: reactive organic gas (ROG), oxides of nitrogen (NOx), oxides of sulfur (SOx), carbon monoxide (CO), and particulate matter (PM). The melting process, alloying, and fluxing create PM emissions. The melting of contaminated scrap also creates ROG emissions. Selecting a relatively clean fuel such as natural gas will control the combustion emissions. Oxides of nitrogen emissions are further controlled by the use of low NO_x burners and/or recuperators (heat exchangers). The melting, alloying, and fluxing emissions are controlled by charging the furnace with clean metal and/or by venting the furnace to an external air pollution control device. Air pollution control devices such as baghouses, afterburners, scrubbers, and secondary combustion chambers are used to control emissions created by melting, alloying, and fluxing operations.

11.1.2.1 Baghouses

A baghouse is an air pollution control device used to control particulate matter emissions. The baghouse is a rectangular box with a series of cloth bags or cartridges manifolded together. A hood is placed over the furnace to capture the combustion, melting and fluxing emissions. The emissions are then ducted to the baghouse. The particulate matter is captured by the bags or cartridges, resulting in cleaner air being discharged to the atmosphere. A blower located on either the inlet or outlet air side of the baghouse is used to move the exhaust stream through the baghouse. If the blower is located on the outlet (clean) air side of the baghouse it is called a pull-through baghouse. This configuration is desirable because the blower is protected from the particulates in the exhaust stream. If the blower is located on the inlet (dirty) air side of the baghouse it is called a push-through baghouse. In a push-through baghouse the blower is subjected to the particulate matter and vapors in the exhaust stream which may cause substantial wear on the blower. The filter bags are periodically shaken to remove the particulate matter that builds up. The bags can be shaken manually or automatically with a mechanical shaker, or with a pulse of air. The pulse of air is applied through nozzles in the baghouse.

When a baghouse is installed on a reverberatory furnace special precautions must be taken to protect the filter bags. To prevent the filter bags from burning, spark arrestors are installed in the ducting before the baghouse. Often, baghouses are used on sweating furnaces that are using chlorine gas as a flux.. The chlorine gas fluxing creates emissions of chlorine gas, aluminum chloride, and hydrogen chloride. These emissions are toxic and very corrosive. If these emissions were to reach the baghouse untreated they would destroy the bags and the metal baghouse structure in a very short time. To prevent deterioration of the baghouse the emission are neutralized prior to reaching the baghouse. A neutralizing agent such as limestone flour is either injected into the air stream before the baghouse, or the bags are precoated with the limestone flour (baghouse dopping). A scrubber can also be used to remove corrosive gas from the emission stream.

11.1.2.2 Afterburners

Afterburners are air pollution control devices used to control organic particulate matter, gasses, and vapors. Afterburners convert particulate matter, gasses, and vapors into carbon dioxide (CO_2) and water by combustion. There are two types of afterburners: direct flame and catalytic. Direct flame afterburners use direct flame contact with the air contaminants. Catalytic afterburners preheat the air contaminants and then place them in contact with a catalyst to complete combustion. Direct flame type afterburners operate at higher temperatures than do catalytic afterburners. The majority of afterburners used in the South Coast Air Basin are the direct flame type. The design of the direct flame type afterburner must provide for adequate mixing of the contaminants with the flame, high flame temperature, and sufficient retention time, in order to ensure maximum control efficiency.

Afterburners are used on aluminum melting reverberatory furnaces in conjunction with baghouses. This combination of control devices is used when a furnace is melting scrap that is contaminated with oil, grease, plastic or rags. The contaminated scrap creates particulate matter and aerosol reactive organic gas emissions. If the furnace was vented directly to a baghouse the filter bags would be coated and plugged (blinded) by the aerosol reactive organic matter. The afterburner is used to control these air contaminants before they reach the baghouse. When an afterburner is used in conjunction with a baghouse the exhaust gasses must be cooled before they reach the baghouse. Baghouse dopping as discussed in section 11.1.2.1 is also used to control aerosol reactive organic matter emissions.

11.1.2.3 Scrubbers

Scrubbers are air pollution control devices used control particulates and aerosols. Scrubbers remove particulates and aerosols form exhaust streams by wetting the particles with droplets of liquid, and by impingement of particles on collection surfaces to be flushed with water. There are several methods for wetting the particles including impingement by spray droplets, diffusion, and condensation.

There are several different types of scrubbers each using different methods of wetting and/or impingement to collect the particles. The collection efficiency of scrubbers varies greatly with different designs and exhaust stream characteristics. One of the advantages of scrubbers is that acid gasses and aerosols can be removed by using a caustic solution as the scrubbing liquid.

11.2 Permit Unit Description

Aluminum melting reverberatory furnaces can be fitted with several different types and combinations of air pollution control devices. The air pollution control devices are categorized as external or integral. Both sweating and non-sweating aluminum melting reverberatory furnaces may use external and/or integral air pollution devices. External air pollution control devices are separate pieces of equipment that are attached to the reverberatory furnace. Examples of external air pollution control equipment are baghouse, afterburners, and scrubbers. Integral air pollution control devices are design features that are built into the furnace. Examples of integral control devices are low NO_x burners, recuperators, and secondary combustion chambers.

Sweating type furnaces generally require more control devices than non-sweating furnaces. Sweating furnaces are typically vented to an afterburner and then a baghouse. In some cases the furnace incorporates a secondary combustion chamber which replaces the afterburner. These control devices are used to control particulate matter and reactive organic gas emissions. Sweating furnaces emit relatively large quantities of particulate matter because they are charged with large amounts of flux to clean the contaminated scrap.

Non-sweating furnaces generally require fewer external air pollution controls because they emit less particulate matter. A non-sweating furnace does not require an external air pollution control device if only clean metal is charged into the furnace, alloying agents are not added, and fluxes are not used. If alloying or fluxing is conducted in a non sweating furnace the furnace must be vented to an external air pollution control device.

If the sweating or non-sweating aluminum melting reverberatory furnace is vented to an external control system, the control is considered as a separate permit unit. If a sweating or non-sweating aluminum melting reverberatory furnace is equipped with an integral control device, that control device is included in the permit description for that furnace. A single aluminum melting reverberatory furnace could be equipped with any number of external and integral air pollution control devices.

11.2.1 Aluminum Melting Reverberatory Furnace Without Integral Air Pollution Control Device(s)

An aluminum melting reverberatory furnace is described in the permit as follows:

FURNACE NO., ALUMINUM MELTING (SWEATING), REVERBERATORY TYPE, MANUFACTURER, MODEL NO., SERIAL NO., (EXTERNAL DIMENSIONS) WIDTH X LENGTH X HEIGHT, (HOLDING CAPACITY) POUND CAPACITY, (NUMBER OF BURNERS) MANUFACTURER, MODEL NO., (INPUT) BTU PER HOUR TOTAL, (MAIN FUEL) OR (BACKUP FUEL) FIRED, WITH A (BLOWER SIZE) HP COMBUSTION AIR BLOWER.

11.2.2 Aluminum Melting Reverberatory Furnace With Integral Air Pollution Control Device(s).

An aluminum melting reverberatory furnace with integral air pollution control device(s) is described in the permit as follows:

FURNACE NO., ALUMINUM MELTING (SWEATING), REVERBERATORY TYPE, MANUFACTURER, MODEL NO., SERIAL NO., (EXTERNAL DIMENSIONS) WIDTH X LENGTH X HEIGHT, (HOLDING CAPACITY) POUND CAPACITY, (NUMBER OF BURNERS) MANUFACTURER, MODEL NO., TYPE, (INPUT) BTU PER HOUR TOTAL, (MAIN FUEL) OR (BACKUP FUEL) FIRED, (BLOWER SIZE) HP COMBUSTION AIR BLOWER, WITH A RECUPERATOR (SECONDARY COMBUSTION CHAMBER, ETC.).

11.3 Emissions

11.3.1 Description

Air contaminants from aluminum melting reverberatory furnaces come from the furnace (and afterburner) combustion, the melting process, alloying, and fluxing. The combustion process produces the primary air contaminants reactive organic gas (ROG), oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and particulate matter (PM). Particulate matter is also created by the melting, alloying, and fluxing of the aluminum. Reactive organic gas is also created in the melting process if contaminated scrap is melted. The total uncontrolled PM emissions from an aluminum melting reverberatory furnace are the summation of the combustion, melting, fluxing, and alloying emissions.

11.3.2 Emission Factors

Emission factors are used to determine the quantity of air contaminants produced by a certain process. The amount of air contaminants produced by an aluminum melting reverberatory furnace depends on the fuel used, the type of burner, the metal melted, the use of alloys, the use of fluxes, and the furnace size. Table 11-1 lists emissions factors for the primary air contaminants produced by the combustion of different fuels. Table 11-2 lists the emissions factor for particulate matter (PM) emitted as a result of the melting process. Emission factors for particulate matter evolved as a result of fluxing are listed in Table 11-3.

11.4 Calculations

11.4.1 Operational Data

In order to calculate the emissions from an aluminum melting reverberatory furnace the following operational data must be supplied by the applicant.

Table 11-1: Emission Factors For Aluminum Melting Reverberatory Furnace Combustion Products

Air Contaminant	Emission Factor Propane[a] (lb/10^6 Btu)	 Gas[b] (lb/10^6 Btu)	 Oil[cd] (lb/10^6 Btu)
Reactive organic gas (ROG)	0.003	0.007	0.020
Oxides of Nitrogen (NO_x)	0.128	0.150[e]	0.533
Oxides of Sulfur (SO_x)	0.050	0.001	0.556
Carbon Monoxide (CO)	0.017	0.004	0.004
Particulate Matter (PM)	0.019	0.017	0.048

[a] Reference 5

[b] Reference 4

[c] Reference 4

[d] Note: emission factors for 0.5% sulfur fuel oil

[e] Reference 3

Table 11-2: Emission Factors For Particulate Matter Due To Melting

Air Contaminant	Emission Factor (lb/ton)[a]
Particulate Matter (PM)	1.1[b]
Particulate Matter (PM)	4.3[c]

[a] Note: The units of this factor are in pounds of particulate matter per ton of material processed

[b] Reference 1, Emission factor for melting clean metal

[c] Reference 2, Emission factor for melting contaminated metal

Table 11-3: Emission Factors For Particulate Matter Due to Chlorine Fluxing

Type of Operation	Air Contaminant	Emission Factor (lb/ton)[a]
Chlorination	Particulate Matter	1000[b]

[a] Note: The units of these emission factors are pounds of particulate matter per ton of chlorine charged.

[b] Reference 1

Main fuel:	
Backup fuel:	
Operating schedule	
Maximum:	hr/day, day/week, week/year
Actual:	hr/day, day/week, week/year
Process weight:	lb/load, hr/load, load/hr
Burner Input:	Btu/hr
Combustion air blower capacity:	cfm
Flux description:	(powder, gas, etc.)
Flux flow rate:	lb/load,cfm/load
Alloying material description:	
Alloy process weight:	lb/load
If applicable	
Baghouse	
Filter area:	ft^2
Duct diameter:	inches
Exhaust Blower capacity:	cfm
Afterburner	
Type of Fuel:	(natural gas, propane, etc.)
Input:	Btu/hr
Combustion chamber volume:	ft^3

11.4.2 Process Weight Calculations

The weight of material processed per hour is called the process weight. The process weight is determined by using Equation 11.1 and includes the weight of all material charged into the furnace per load.

$$PW = \frac{W^m + W^a + W^f}{\text{time to melt one load in hours}} \qquad \textbf{(Equation 11.1)}$$

where:

PW = Process weight (ton/hr).
W^m = Weight of aluminum melted per load (ton/load).
W^a = Weight of alloying material added per load (ton/load).
W^f = Weight of flux added per load (ton/load).

11.4.3 Emissions Calculations

11.4.3.1 Uncontrolled Emissions Calculations (R_1)

The uncontrolled emissions (R_1) from furnace combustion, afterburner combustion, melting, alloying, and fluxing are determined as follows.

11.4.3.1.1 Uncontrolled Furnace Combustion Emission Calculations (R'_1)

The uncontrolled combustion emissions of reactive organic gas (ROG), oxides of nitrogen (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), and particulate matter (PM) are determined for each air contaminant by using Equation 11.2.

$$R'_1 = EF' \times Q^f \qquad \textbf{(Equation 11.2)}$$

where:

R'_1 = The particular uncontrolled combustion emission (lb/hr).
EF' = The corresponding combustion emission factor (lb/10^6 Btu) from Table 11-1.
Q^f = The heat input rate of the furnace (10^6 Btu/hr).

11.4.3.1.2 Uncontrolled Afterburner Combustion Emission Calculations (R''_1)

If an aluminum melting reverberatory furnace is vented to an afterburner, then the emissions created by the afterburner must be determined. The combustion emissions (ROG,NO_x, SO_x, CO, and PM) created by an afterburner are calculated by using Equation 11.3.

$$R''_1 = EF'' \times Q^a \qquad \textbf{(Equation 11.3)}$$

where:

R''_1 = The particular uncontrolled afterburner combustion emission (lb/hr).
EF'' = The corresponding combustion emission factor (lb/10^6 Btu).
Q^a = The heat input rate of the afterburner (10^6 Btu/hr).

11.4.3.1.3 Uncontrolled Melting, Alloying, and Fluxing Emissions Calculations (R'''_1)

The uncontrolled particulate matter emissions from melting, alloying, and fluxing are determined by using Equations 11.4, 11.5, and 11.6 respectively.

$$R^M{}_{1,PM} = EF^M \times PW \qquad \textbf{(Equation 11.4)}$$

$$R^A{}_{1,PM} = EF^A \times PW \qquad \textbf{(Equation 11.5)}$$

$$R^F{}_{1,PM} = EF^F \times PW \qquad \textbf{(Equation 11.6)}$$

where:

$R^M{}_{1,PM}$ = Uncontrolled particulate matter emissions from melting (lb/hr).
$R^A{}_{1,PM}$ = Uncontrolled particulate matter emissions from alloying (lb/hr).
$R^F{}_{1,PM}$ = Uncontrolled particulate matter emissions from fluxing (lb/hr).
EF^M = Melting emission factor (lb/ton) from Table 11-2.
EF^A = Alloying emission factor (lb/ton).
EF^F = Fluxing emission factor (lb/ton) from Table 11-3.
PW = Process weight (ton/hr).

The total particulate matter emissions from melting, alloying, and fluxing are determined by summing each of the emissions as shown in Equation 11.7.

$$R'''_{1,PM} = R^{M}_{1,PM} + R^{A}_{1,PM} + R^{F}_{1,PM} \qquad \textbf{(Equation 11.7)}$$

where:

$R'''_{1,PM}$ = The uncontrolled particulate matter emissions from melting, alloying, and fluxing (lb/hr).

The particulate matter emissions from alloying and fluxing may be zero if alloying and fluxing operations are not conducted in the furnace. However, there will always be particulate matter emissions from melting.

11.4.3.1.4 Total Uncontrolled Particulate Matter Emissions ($R_{1,PM}$)

The total uncontrolled particulate matter emissions are determined by summing the emissions created by furnace combustion, afterburner combustion, melting, alloying, and fluxing as shown in Equation 11.8.

$$R_{1,PM} = R'_{1,PM} + R''_{1,PM} + R'''_{1,PM} \qquad \textbf{(Equation 11.8)}$$

where:

$R_{1,PM}$ = The total uncontrolled particulate matter emissions from the aluminum melting reverberatory furnace (lb/hr).

11.4.4 Controlled Emissions Calculations (R_2)

An aluminum melting reverberatory furnace can be vented in several different ways. The furnace can be vented directly to the atmosphere or to an air pollution control system. If the furnace is vented directly to the atmosphere the controlled emissions are equal to the uncontrolled emissions.

The following equations are used to determine the controlled emissions from aluminum melting reverberatory furnaces which are vented to external air pollution control devices. Particulate matter and reactive organic gas emissions from aluminum melting reverberatory furnaces are controlled by the use of baghouses and afterburners respectively. When an afterburner is used to control reactive organic gas emissions, the exhaust must then be vented to a baghouse. If the furnace is vented to an external air pollution control system there are four venting configurations to consider: (1) The furnace combustion, melting fluxing, and alloying emissions are all vented to a baghouse. (2) The furnace combustion, melting, fluxing,and alloying emissions are all vented to an afterburner and then a baghouse. (3) The furnace combustion and melting emissions are vented to the atmosphere, and the fluxing and alloying emissions are vented to a baghouse. (4) The furnace combustion and melting emissions are vented to the atmosphere, and the fluxing and alloying emissions are vented to an afterburner and then a baghouse. Since typically all emissions would be vented to the control device(s), the controlled emissions are determined only for cases 1 and 2.

The emissions from an aluminum melting reverberatory furnace must be calculated for the actual and maximum conditions. Actual emissions are used in emissions inventory. Maximum emissions are used to determine compliance with District Rules and Regulations.The actual and maximum hourly emission rates must be converted to daily (lb/day)emission rates by multiplying the hourly emission rate by the appropriate actual or maximum daily time factor (T_a, T_m, hr/day). In addition the maximum emissions are multiplied by the Regulation XIII On-Site Offset Factor (1.1). These daily emissions increases are accumulated for each facility in the District's New Source Review Record and are used to determine compliance with Regulation XIII.

11.4.4.1 Controlled Particulate Matter Emission Calculations ($R_{2,PM}$)

In order to determine rule compliance the total controlled particulate matter emissions, as well as the controlled particulate matter emissions due to combustion, must be determined. The controlled total and combustion particulate matter emission rates are determined for the two venting cases by using Equations 11.9 - 11.12.

case (1): Emissions controlled by a baghouse only.

$$R_{2,PM} = R_{1,PM} \times (1-EFF_B) \quad \textbf{(Equation 11.9)}$$

$$R'_{2,PM} = R'_{1,PM} \times (1-EFF_B) \quad \textbf{(Equation 11.10)}$$

case (2): Emissions controlled by an afterburner and a baghouse.

$$R_{2,PM} = (((R'_{1,PM} + R'''_{1,PM}) \times (1-EFF_A)) + R''_{1,PM}) \times (1-EFF_B) \quad \textbf{(Equation 11.11)}$$

$$R'_{2,PM} = (R'_{1,PM} \times (1-EFF_A)) + R''_{1,PM}) \times (1-EFF_B) \quad \textbf{(Equation 11.12)}$$

where:

$R_{2,PM}$ = Controlled total particulate matter emission rate (lb/hr).
$R'_{2,PM}$ = The controlled combustion particulate matter emission rate (lb/hr).
EFF_A = The efficiency of the afterburner (expressed as a decimal).
EFF_B = The efficiency of the baghouse (expressed as a decimal).

Note that the afterburner efficiency should reflect the fact that the afterburner will only control the organic portion of the particulate matter.

11.4.4.2 Controlled ROG, NO_x, SO_x, and CO Emission Calculations

The controlled ROG, NO_x, SO_x, and CO emissions must be determined for the two venting cases. For case 1 the controlled ROG, NO_x, SO_x, and CO emissions are equal to the uncontrolled furnace combustion emissions. For case 2 the controlled ROG, NO_x, SO_x, and CO emissions are determined by using Equations 11.13, 11.14, 11.15, and 11.16 respectively. As shown in the calculations the controlled NOx, SOx, and CO emissions are equal to the sum of the respective emissions from the furnace and afterburner combustion. It should be noted, however, that the total controlled

CO emissions may be reduced an afterburner. The afterburner may reduce the uncontrolled CO emission component of the total CO emissions.

$$R_{2,ROG} = R'_{1,ROG} \times (1\text{-}EFF_A) + R''_{1,ROG} \qquad \textbf{(Equation 11.13)}$$

$$R_{2,NOx} = R'_{1,NOx} + R''_{1,NOx} \qquad \textbf{(Equation 11.14)}$$

$$R_{2,SOx} = R'_{1,SOx} + R''_{1,SOx} \qquad \textbf{(Equation 11.15)}$$

$$R_{2,CO} = R'_{1,CO} + R''_{1,CO} \qquad \textbf{(Equation 11.16)}$$

where:

$R_{2,ROG}$ = The total controlled ROG emission rate (lb/hr).
$R_{2,NOx}$ = The total controlled NO_x emission rate (lb/hr).
$R_{2,SOx}$ = The total controlled SO_x emission rate (lb/hr).
$R_{2,CO}$ = The total controlled CO emission rate (lb/hr).

11.4.5 Particulate Matter Emissions - Concentration (C_{PM})

The concentration of the controlled particulate matter emissions vented to the atmosphere must be calculated to determined compliance with Rule 404. The particulate matter concentration is determined by converting the controlled total particulate matter emission rate (lb/hr) into a concentration (grains /dscf) by using Equation 11.17.

$$C_{PM} = \frac{R_{2,PM} \times 7000 \text{ (grains/lb)}}{VFR \times 60 \text{ (min/hr)}} \qquad \textbf{(Equation 11.17)}$$

where:

C_{PM} = The particulate matter concentration at one vent (grains/dscf).
$R_{2,PM}$ = Controlled total particulate matter emission rate (lb/hr).
VFR = Exhaust flow rate of the system in dry standard cubic feet per minute (dscfm).

11.4.6 Carbon Monoxide Concentration Calculation (C_{CO})

The carbon monoxide (CO) concentration in the exhaust vented to the atmosphere must be calculated to determine compliance with Rule 407. The CO concentration is determined by converting the controlled CO emission rate (lb/hr) into a concentration (ppm) using Equation 11.18.

$$C_{CO} = \frac{R_{2,CO}}{VFR \times (4.43 \times 10^{-6})} \qquad \textbf{(Equation 11.18)}$$

where:

C_{CO} = Concentration of carbon monoxide in the exhaust vented to the atmosphere(ppm).

$R_{2,CO}$ = Controlled carbon monoxide emission rate (lb/hr).

VFR = Volumetric flow rate of the exhaust vented to the atmosphere (dscfm).

4.43×10^{-6} = Conversion factor for CO at 60 ^{o}F and 1 atm. (ppm ft^3 hr/lb min).

11.4.7 Sulfur Oxide Concentration Calculation (C_{SOx})

The concentration of sulfur oxides, expressed as SO_2, in the exhaust vented to the atmosphere must be calculated to determined compliance with Rule 407. The sulfur oxide concentration is determined by converting the controlled sulfur oxide emission rate into a concentration using Equation 11.19.

$$C_{SOx} = \frac{R_{2,SOx}}{VFR \times (10.1 \times 10^{-6})} \qquad \textbf{(Equation 11.19)}$$

where:

C_{SOx} = Concentration of sulfur oxides in the exhaust vented to the atmosphere (ppm).

$R_{2,SOx}$ = Controlled sulfur oxide emission rate (lb/hr).

VFR = Volumetric flow rate of the exhaust vented to the atmosphere (dscfm).

10.1×10^{-6} = Conversion factor for SO_x at 60 °F and 1 atm. (ppm ft^3 hr/lb min).

11.4.8 Combustion Particulate Matter Concentration Calculations ($C_{C,PM}$)

The concentration of the combustion particulate matter emissions vented to the atmosphere must be calculated to determined compliance with Rule 409. The concentration of combustion particulate matter is determined by using Equation 11.20.

$$C_{C,PM} = \frac{R'_{2,PM} \times 7000\ (\text{grains/lb})}{\text{VFR} \times 60\ (\text{min/hr})} \qquad \textbf{(Equation 11.20)}$$

where:

$C_{C,PM}$ = Concentration of combustion particulate matter vented to the atmosphere (grains/dscf).

$R'_{2,PM}$ = Controlled combustion particulate matter emission rate (lb/hr).

VFR = The volumetric flow rate of the exhaust vented to the atmosphere (dscfm).

11.4.9 Baghouse Design Calculations

When a baghouse is used as an air pollution control device, two design parameters must be calculated to ensure that the baghouse will operate effectively. The design parameters are air-to-cloth ratio and duct velocity. The air-to-cloth ratio is determined by using Equation 11.21, and should be in the range of 1.0 to 4.0 ft/min for metallurgical fumes, depending on the cleaning mechanism used, filter bag material and particulate concentration.[7] Generally high air to cloth ratios can be used when low concentrations of particulate matter are being filtered and the bags are cleaned frequently. Conversely, lower air to cloth ratios should be used when high concentrations of particulate matter are being filtered and bag cleaning is less frequent.

$$A/C = \frac{VFR}{A_b}$$ **(Equation 11.21)**

where:

A/C = The air to cloth ratio of the baghouse (ft/min).
VFR = The volumetric flow rate of the baghouse exhaust blower (cfm).
A_b = The total cloth area of the bags (ft^2).

The velocity of the air entrained with contaminants traveling in a duct from the furnace to the baghouse is determined by using Equations 11.22, and 11.23. The duct velocity should be in the range of 2000 to 5000 ft/min to ensure that particulate matter does not settle out in the duct work.[8]

$$A_d = \frac{D^2}{183}$$ **(Equation 11.22)**

$$V_d = \frac{VFR}{A_d}$$ **(Equation 11.23)**

where:

A_d = Cross sectional area of the duct (ft^2).
D = Duct diameter (inches).
V_d = Duct velocity (ft/min).
VFR = Volumetric flow rate of air through the duct in actual feet per minute (acfm).

11.4.10 Afterburner Design Calculations

The use of an afterburner as an air pollution control device requires the calculation of the design parameters combustion chamber temperature and retention time to ensure optimal control efficiency. The following equations can be used to determine these design parameters for natural gas fired afterburners. The afterburner retention time, calculated by using Equations 11.24 and 11.25, must be greater than or equal to 0.3 seconds.

$$T_r = \frac{V_c \times 60\ (\text{sec/min})}{VFR^f + VFR^a} \qquad \textbf{(Equation 11.24)}$$

$$VFR^a = \frac{Q^a\ (\text{Btu/hr}) \times 13.53 \times 1860\ ^{o}\text{R}}{60\ (\text{min/hr}) \times 1{,}100\ (\text{Btu/ft}^3) \times 520\ ^{o}\text{R}}$$

(Equation 11.25)

where:

T_r = The retention time of the afterburner (seconds).
V_c = Volume of the afterburner combustion chamber (ft^3).
VFR^f = Volumetric flow rate from the furnace (acfm).
VFR^a = Volumetric flow rate due to the afterburner combustion (acfm).
Q^a = The afterburner input (Btu/hr).
1,100 = The gross heating value for natural gas at standard conditions (Btu/ft^3).
13.53 = The products of combustion from natural gas with20% excess air (ft^3/ft^3 gas).
1860 = The afterburner combustion temperature (^{o}R).
520 = Standard temperature (^{o}R).

Note that the volumetric flow rate through the furnace does not account for air leakage into the furnace. Source tests have shown that this leakage can amount to as much as 300% excess air as opposed to 20%. Therefore, more precise calculations must be made if the retention time and heat required of the afterburner are not approximately twice the values required.

The heat required of the afterburner, and the heat available from the afterburner must be calculated and compared in order to determine if the afterburner can maintain the required combustion chamber temperature of 1400 ^{o}F. The heat required of the afterburner to maintain a combustion chamber temperature of 1400 ^{o}F is determined by using Equation 11.27.

$$Q' = (h_2 - h_1) \times VFR^f \times 60\ (\text{min/hr}) \qquad \textbf{(Equation 11.27)}$$

where:

Q' = The heat required of the afterburner to raise the temperature of the furnace gasses to 1400 ^{o}F (Btu/hr).

h_1 = The enthalpy of the air as it enters the afterburner (Btu/ft^3).

h_2 = The enthalpy of the air at 1400 ^{o}F (Btu/ft^3).

The heat available from the afterburner is determined by Equation 11.28.

$$Q_{available} = \frac{Q^a\ (\text{Btu/hr}) \times 615.4\ (\text{Btu/ft}^3)}{1{,}100\ (\text{Btu/ft}^3)} \qquad \textbf{(Equation 11.28)}$$

where:

$Q_{available}$ = The heat available from the afterburner combustion (Btu/hr).

Q^a = The afterburner input (Btu/hr).

615.4 = The heat available from the combustion of natural gas at 1400 ^{o}F, with 20% excess air (Btu/ft^3).

The heat available from the afterburner (Qavailble) must be greater than the heat required (Q') for the afterburner to maintain a combustion chamber temperature of 1400 ^{o}F.

11.5 Rules Evaluation

Rule 212 - Standards For Approving Permits

Section (e) of this Rule requires public notification of certain cases be made prior to issuing a permit.

Rule 401 - Visible Emissions

No visible emission of 20% opacity or Ringlemann No. 1 or more aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance

Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), odorous materials, and prior complaints.

Rule 404 - Particulate Matter - Concentration

Limits for particulate matter concentrations in an effluent gas stream at standard conditions are listed in Table 404(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 405 - Particulate Matter - Weight

Limits for solid particulate matter emission rates from any source are listed in Table 405(a) of the South Coast Air Quality Management District's Rules and Regulations.

Rule 407 - Liquid and Gaseous Air Contaminants

A person shall not discharge into the atmosphere from any equipment: (1) Carbon monoxide (CO) in excess of 2,000 ppm by volume on a dry basis. (2) Sulfur compounds which would exist as a liquid or gas at standard conditions, calculated as sulfur dioxide (SO_2), in excess of 500 ppm.

Rule 409 - Combustion Contaminant Concentration

A person shall not discharge into the atmosphere from the burning of fuel , combustion particulate matter emissions in excess of 0.1 grains per cubic foot of gas calculated to 12 percent carbon dioxide (CO_2) at standard conditions.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT for non-sweating aluminum melting reverberatory furnaces with inputs less than 5 MM Btu/hr is natural gas for NO_x and SO_x, and natural gas with ingots or non-contaminated scrap charge for PM.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[9] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

11.6 Permit (Operating) Conditions

In order to ensure compliance with applicable Rules and Regulations of the SCAQMD, Permit (Operating) Conditions are required. Permit (Operating) Conditions for an aluminum melting reverberatory furnace and associated air pollution control equipment are listed below. However, not all of the conditions listed are applicable for every furnace.

Aluminum Melting Reverberatory Furnace

1. THIS FURNACE MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

2. METAL CONTAMINATED WITH RUBBER, PLASTIC, PAPER, RAGS, OIL, GREASE, OR SIMILAR SMOKE PRODUCING MATERIAL MUST NOT BE CHARGED TO THIS FURNACE.

3. THE AMOUNT OF ALUMINUM PROCESSED BY THIS EQUIPMENT MUST NOT EXCEED (NUMBER OF) POUNDS PER DAY.

4. A DAILY LOG GIVING THE TOTAL AMOUNT OF ALUMINUM PROCESSED BY THIS EQUIPMENT IN POUNDS, THE AMOUNT OF FUEL CONSUMED IN STANDARD CUBIC FEET (GALLONS), THE AMOUNT OF CHLORINE GAS USED IN CUBIC FEET, AND THE

AMOUNT OF FLUX USED IN POUNDS, MUST BE MAINTAINED AND MADE AVAILABLE UPON THE REQUEST OF DISTRICT PERSONNEL.

5. THE AMOUNT OF FUEL CONSUMED BY THIS FURNACE MUST NOT EXCEED (NUMBER OF) STANDARD CUBIC FEET (GALLONS) PER DAY.

6. FLUORIDES, CHLORINE, OR ALUMINUM CHLORIDE MUST NOT BE USED IN THIS FURNACE.

7. FLUXING OR REFINING MUST NOT BE CONDUCTED IN THIS FURNACE UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

8. THE RATE OF CHLORINE (GAS) USE MUST NOT EXCEED (NUMBER OF) POUNDS (CUBIC FEET) PER MINUTE.

9. NOT MORE THAN (NUMBER OF) POUNDS PER HOUR OF FLUX MAY BE USED IN THIS FURNACE.

Baghouse (If Applicable)

1. A MECHANICAL GAUGE MUST BE INSTALLED (MAINTAINED) SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS.

2. DUST COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS.

Afterburner (If Applicable)

1. A TEMPERATURE OF NOT LESS THAN 1400 °F MUST BE MAINTAINED IN THE AFTERBURNER WHEN THE EQUIPMENT IT SERVES IS IN OPERATION.

REFERENCES

(1) Air contaminant Emission Factors From Metallurgical Operations in Los Angeles County, L.A. County APCD, July 1964

(2) Compilation of Air Pollution Emission Factors, AP - 42, Fourth Edition, September 1985, Table 7.8 - 1, page 7.8 - 6.

(3) Emissions of Oxides of Nitrogen From Stationary Sources in Los Angeles County. Report No. 4, Table II, page 19.

(4) Memorandum from Wayne Zwaicher to Engineering Division, Subject: Metallurgical Emission Factors, January 1975.

(5) South Coast Air Quality Management District Form B - 1, October 1982

(6) Metals Handbook, Volume 5, Forging and Casting; A.S.M. Handbook Committee, Lyman, t.,et. al.,1970

(7) Air Pollution Engineering Handbook, AP-40, Second Edition, May 1973

(8) Industrial Ventilation, 19th Edition, 1986, page 4-7

(9) Best Available Control Technology Guideline, South Coast Air Quality Management District, October 7, 1988.

APPENDIX 11A

WORKSHEET FOR

NON - SWEATING

ALUMINUM MELTING REVERBERATORY FURNACE

WITHOUT FLUXING OR ALLOYING

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PERMIT TO CONSTRUCT/OPERATE

Applicability: This processing form can only be used for non-sweating aluminum melting reverberatory furnaces which do not use flux or alloying, and melt only clean metal.

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ____________________

FURNACE NO. , ALUMINUM MELTING, REVERBERATORY TYPE,
(MANUFACTURER) ,
MODEL NO. , SERIAL NO. ,
' " W. X ' " L. X ' " H.,
POUND HOLDING CAPACITY, BURNER(S),
BTU PER HOUR TOTAL, OR FIRED,
WITH A HP COMBUSTION AIR BLOWER.

APPLICATION NO. ____________________

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. BAGHOUSE , MODEL NO. ,
   WITH FILTER BAGS, EACH '- " DIA. X '- "
   HIGH, SQ. FT. ACTUAL FILTER AREA.
2. EXHAUST SYSTEM WITH A H.P. BLOWER VENTING AN ALUMINUM MELTING REVERBERATORY FURNACE.

HISTORY:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

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PROCESS DESCRIPTION:

The applicant uses this uses this reverberatory furnace to melt clean aluminum . The aluminum melted in this furnace is used to produce ____________. Fluxing and refining are not conducted in this furnace. Alloying agents are not added to the aluminum in this furnace. This furnace is vented directly to the atmosphere (to a baghouse).

DATA:

	Source
Operating Schedule (T_a): ____ hr/day, ____ day/wk, ____ wk/yr	Applicant
Operating Schedule (T_m): ____ hr/day, ____ day/wk, ____ wk/yr	"
Process Information : _____ lb/load, ___ hr/load, ___ load/day	"
Main Fuel: ________	"
Backup Fuel: ________	"
Furnace Heat Input Rate (Q^f): ____________________ Btu/hr	"
Combustion Air Blower Capacity (VFR^f): _______________ cfm	"
Baghouse Efficiency (EFF_B): ________ %	"
Baghouse Filter Area (A_b): ________ ft^2	"
Baghouse Supply Duct Dia.: ________ in.	"
Exhaust Blower Flow Rate (VFR^e): ________ cfm	"
Combustion Emission Factors for the Furnace:	
Reactive Organic Gas (EF'_{ROG}): ________ lb/10^6 Btu	____
Oxides of Nitrogen (EF'_{NOx}): ________ lb/10^6 Btu	____
Oxides of Sulfur (EF'_{SOx}): ________ lb/10^6 Btu	____
Carbon Monoxide (EF'_{CO}) : ________ lb/10^6 Btu	____
Particulate Matter (EF'_{PM}) : ________ lb/10^6 Btu	____
Melting Particulate Matter Emission Factor(EF^M): ________ lb/ton	____
Reg XIII On-Site Offset Factor For Maximum Daily Emissions:	1.1

CALCULATIONS:

1. Process Weight (PW) = (_____ lb/load)/(___ hr/load)(2000 lb/ton) = ____ ton/hr

2. Uncontrolled Combustion Emissions (R'_1).
Uncontrolled combustion emissions of ROG, NO_x, SO_x, CO and PM must be multiplied by the appropriate operating time factor (T_a or T_m) to determine actual and maximum, hourly and daily emissions.

$$R'_1 = EF' \times Q^f = \text{lb/hr} (\times T_a \text{ or } T_m) = \text{lb/day}$$

where: R'_1 = The particular uncontrolled combustion emissions, lb/hr.
EF' = The corresponding combustion emission factor, lb PM/10^6 Btu.
Q^f = Furnace heat input rate, Btu/hr.
T_a or T_m = Time of operation, hr/day (actual and max).

3. Uncontrolled Melting Particulate Matter Emissions ($R^M_{1,PM}$).

$$R^{M}_{1,PM} = EF^{M} \times PW = \text{lb/hr} \ (\times T_a \text{ or } T_m) = \text{lb/day}$$

where: $R^M_{1,PM}$ = Uncontrolled melting particulate matter emissions.
EF^M = Melting emission factor, lb/ton.
PW = Process weight, ton/hr.
T_a or T_m = Time of operation, hr/day (actual and max).

4. Total Uncontrolled Particulate Matter Emissions ($R_{1,PM}$).

$$R_{1,PM} = R'_{1,PM} + R^{M}_{1,PM} = \text{lb/hr} \ (\times T_a \text{ or } T_m) = \text{lb/day}$$

5. Controlled Emissions (R_2).
The controlled emissions of ROG, NOx, SOx, and CO are equal to the uncontrolled emissions. The controlled particulate matter emissions from combustion and total must be calculated.

$$R_{2,PM} = R_{1,PM} \times (1 - EFF_B) \ (\times 1.1 \text{ for NSR lb/day}) = \text{lb/hr}$$

$$R'_{2,PM} = R'_{1,PM} \times (1 - EFF_B) = \text{lb/hr}$$

where: $R_{2,PM}$ = Controlled total particulate matter emissions, lb/hr.
$R'_{2,PM}$ = Controlled combustion particulate matter, lb/hr.
EFF_B = The efficiency of the baghouse(expressed as a decimal).

Controlled Emissions (R_2)	Actual lb/hr	Maximum lb/hr	Maximum lb/day	NSR lb/day
ROG				
NO_x				
SO_x				
CO				
PM				

6. Exhaust Gas Total Particulate Matter Concentration (C_{PM}).

$$C_{PM} = \frac{R_{2,PM}\ (\text{lb/hr}) \times 7{,}000\ (\text{grains/lb})}{VFR\ (\text{ft}^3/\text{min}) \times 60\ (\text{min/hr})} = \underline{\qquad}\ \text{grains/dscf}$$

7. Carbon Monoxide Concentration (C_{CO}).

$$C_{CO} = \frac{R_{2,CO}\ (\text{lb/hr})}{VFR\ (\text{ft}^3/\text{min}) \times (4.43 \times 10^{-6})} = \underline{\qquad}\ \text{ppm}$$

8. Sulfur Oxide Concentration (C_{SOx}).

$$C_{SOx} = \frac{R_{2,SOx}\ (\text{lb/hr})}{VFR\ (\text{ft}^3/\text{min}) \times (10.1 \times 10^{-6})} = \underline{\qquad}\ \text{ppm}$$

9. Combustion Particulate Matter Concentration ($C_{C,PM}$).

$$C_{C,PM} = \frac{R'_{2,PM}\ (\text{lb/hr}) \times 7000\ (\text{grains/dscf})}{VFR\ (\text{ft}^3/\text{min}) \times 60\ (\text{min/hr})} = \underline{\qquad}\ \text{grains/dscf}$$

10. Baghouse Air-to-Cloth Ratio (A/C).

$$A/C = VFR^e/A_b = \underline{\qquad}\ \text{CFM}/\ \underline{\qquad}\ \text{ft}^2 = \underline{\qquad}\ \text{ft/min}$$

where: VFR^e = Volumetric flow rate through the baghouse.
A_b = Actual area of the filter bags.

11. Duct Velocity (V_d).

$$A_d = D^2/183 = \underline{\qquad}\ \text{in}^2/183 = \underline{\qquad}\ \text{ft}^2$$
$$V_d = VFR/A_d = \underline{\qquad}\ \text{CFM}/\ \underline{\qquad}\ \text{ft}^2 = \underline{\qquad}\ \text{ft/min}$$

where: A_d = Area of the duct.
D = Diameter of the duct (in inches).
VFR = Volumetric flow rate through the baghouse.

RULES EVALUATION:

RULE 212 : Public notice is (is not) required.

RULE 401 : This equipment is (is not) vented to a baghouse. Compliance with Rule 401 is (is not) expected.

RULE 402 : The location of the equipment will be in an industrial/commercial area. Calculations show low (excessive) particulate emissions to the atmosphere. Compliance with Rule 402 is (is not) expected.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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RULE 404 : For an exhaust flow rate of ________ dscfm, the rule allows a maximum particulate matter concentration of _____ grains/dscf. Calculations indicate a particulate matter concentration of _____ grains/dscf. Compliance with Rule 404 is (is not) expected.

RULE 405 : For a process weight of ___________ lb/hr, the rule allows a maximum solid particulate matter emission rate of _____ lb/hr. Calculations indicate a maximum emission rate of _____ lb/hr. Compliance with Rule 405 is (is not) expected.

RULE 407 : The rule allows a CO concentration of 2,000 ppm and a SO_x concentration of 500 ppm in the air vented to the atmosphere. Calculations show a CO concentration of _____ ppm, and an SO_x concentration of _____ ppm. Compliance with this rule 407 is (is not) expected.

RULE 409 : The rule allows a combustion particulate matter emission concentration of 0.1 grains/dscf. Calculations show a concentration of _____ grains/dscf. Compliance with Rule 409 is (is not) expected.

REG XIII : As shown by the Emission Threshold/New Source Sheet Table below, this facility will (will not) operate in compliance with Regulation XIII:

	NSR Emissions in Pounds Per Day				
	ROG	NO_X	SO_2	CO	PM
Facility Emissions Since 10-8-76	___	___	___	___	___
A/N	___	___	___	___	___
A/N	___	___	___	___	___
Net Emission Increase Since 10-8-76	___	___	___	___	___

BACT : Best Available Control Technology (BACT) for this type of aluminum melting reverberatory furnace is as follows: (This information is listed in the South Coast Air Quality Management District's BACT Guideline, some determinations of BACT will require cost effectiveness analysis as described in the guideline).

ROG :
NO_x :
SO_x :
CO :
PM :

EQUIPMENT DESIGN COMPLIANCE:

AIR/CLOTH RATIO : Actual air to cloth ratio (A/C) = _________ ft/min. Allowed air to cloth ratio = 0.5 - 9.0 ft/min. Compliance is (is not) expected.

DUCT VELOCITY : Actual duct velocity (Vd) = __________ ft/min. Allowed duct velocity = 2000 - 5000 ft/min. Compliance is (is not) expected.

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

( ) Issue a Permit to Construct/Operate with the following conditions:

APPLICATION NO. ____________________

CONDITIONS:

1. METAL CONTAMINATED WITH RUBBER, PLASTIC, PAPER, RAGS, OIL, GREASE, OR SIMILAR SMOKE PRODUCING MATERIALS MUST NOT BE CHARGED INTO THIS FURNACE.

2. THIS FURNACE MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

3. THE AMOUNT OF ALUMINUM PROCESSED IN THIS FURNACE MUST NOT EXCEED ___________ POUNDS PER DAY.

4. THE OPERATOR SHALL KEEP ADEQUATE DAILY RECORDS TO VERIFY THE TOTAL AMOUNT OF ALUMINUM PROCESSED BY THIS EQUIPMENT IN POUNDS AND THE AMOUNT OF FUEL CONSUMED IN STANDARD CUBIC FEET (GALLONS). SUCH RECORDS SHALL BE RETAINED FOR A PERIOD OF AT LEAST TWO YEARS AND BE MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

5. THE AMOUNT OF FUEL CONSUMED BY THIS FURNACE MUST NOT EXCEED _________ STANDARD CUBIC FEET (GALLONS) PER DAY.

6. FLUORIDES, CHLORINE OR ALUMINUM CHLORIDE MUST NOT BE USED IN THIS FURNACE.

7. FLUXING OR REFINING MUST NOT BE CONDUCTED IN THIS FURNACE.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

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APPLICATION PROCESSING AND CALCULATIONS

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APPLICATION NO. ____________________

CONDITIONS:

1. A MECHANICAL GAUGE MUST BE INSTALLED MAINTAINED SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS.

2. DUSTS COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS.

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ______ of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 11B

WORKSHEET FOR

NON - SWEATING

ALUMINUM MELTING REVERBERATORY FURNACE

WITH FLUXING AND/OR ALLOYING

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 7	PAGE 1
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PERMIT TO CONSTRUCT/OPERATE

Applicability: This processing form can only be used for non-sweating aluminum melting reverberatory furnaces.

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ______________________

FURNACE NO. , ALUMINUM MELTING, REVERBERATORY TYPE,
(MANUFACTURER) ,
MODEL NO. , SERIAL NO. ,
' " W. X ' " L. X ' " H.,
POUND HOLDING CAPACITY, BURNER(S),
BTU PER HOUR TOTAL, OR FIRED,
WITH A HP COMBUSTION AIR BLOWER.

APPLICATION NO. ______________________

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. BAGHOUSE , MODEL NO. , WITH FILTER BAGS, EACH '- " DIA. X '- " HIGH, SQ. FT. ACTUAL FILTER AREA.
2. EXHAUST SYSTEM WITH A H.P. BLOWER VENTING AN ALUMINUM MELTING REVERBERATORY FURNACE.

HISTORY:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PROCESS DESCRIPTION:

The applicant uses this uses this reverberatory furnace to melt clean (contaminated) aluminum in the form of ______. Fluxing with powder flux (and/or chlorine gas) is conducted in this furnace. Alloying agents are (are not) added to the metal in this furnace. The aluminum melted in this furnace is used to produce ____________. This furnace is vented directly to the atmosphere (to a baghouse).

DATA:

	Source
Operating Schedule (T_a): ____ hr/day, ____ day/wk, ____ wk/yr	Applicant
Operating Schedule (T_m): ____ hr/day, ____ day/wk, ____ wk/yr	"
Process Information : ______ lb/load, ___ hr/load, ___ load/day	"
Main Fuel: _________	"
Backup Fuel: _________	"
Furnace Heat Input Rate (Q^f): ________________ Btu/hr	"
Combustion Air Blower Capacity (VFR^f): ______________ cfm	"
Flux Description: ______________	"
Flux Process Information: (W^f): _______ lb/load, _______ cfm	"
Alloy Description: ______________	"
Alloy Process Information (W^a): _______ lb/load	"
Baghouse Efficiency (EFF_B): _________ %	"
Baghouse Filter Area (A_b): _________ ft^2	"
Baghouse Supply Duct Dia.: _________ in.	"
Exhaust Blower Flow Rate (VFR^e): ________ cfm	"
Combustion Emission Factors for the Furnace:	
Reactive Organic Gas (EF'_{ROG}): _________ lb/10^6 Btu	_____
Oxides of Nitrogen (EF'_{NO_x}): _________ lb/10^6 Btu	_____
Oxides of Sulfur (EF'_{SO_x}): _________ lb/10^6 Btu	_____
Carbon Monoxide (EF'_{CO}) : _________ lb/10^6 Btu	_____
Particulate Matter (EF'_{PM}) : _________ lb/10^6 Btu	_____
Melting Particulate Matter Emission Factor(EF^M): ________ lb/ton	_____
Alloying Particulate Matter Emission Factor(EF^A): ________ lb/ton	_____
Fluxing Particulate Matter Emission Factor(EF^F): ________ lb/ton	_____
Reg XIII On-Site Offset Factor For Maximum Daily Emissions:	1.1

CALCULATIONS:

1. Process Weight (PW) $= W^a + W^f + W^m =$ _____ lb/load

(_____ lb/load)/(2000 ton/lb)(_____ hr/load) = _____ ton/hr

2. Uncontrolled Combustion Emissions (R'_1).
Uncontrolled combustion emissions of ROG, NO_x, SO_x, CO and PM must be multiplied by the appropriate operating time factor (T_a or T_m) to determine actual and maximum, hourly and daily emissions.

$$R'_1 = EF' \times Q^f = \text{lb/hr} \ (\times\ T_a \text{ or } T_m) = \text{lb/day}$$

where: R'_1 = The particular uncontrolled combustion emissions, lb/hr.
EF' = The corresponding combustion emission factor, lb PM/10^6 Btu.
Q^f = Furnace heat input rate, Btu/hr.
T_a or T_m = Time of operation, hr/day (actual and max).

3. Uncontrolled Melting, Alloying and Fluxing Particulate Matter Emissions ($R^{M,A,F}{}_{1,PM}$).

$$R^M{}_{1,PM} = EF^M \times PW = \text{lb/hr} \ (\times\ T_a \text{ or } T_m) = \text{lb/day}$$

$$R^A{}_{1,PM} = EF^A \times PW = \text{lb/hr} \ (\times\ T_a \text{ or } T_m) = \text{lb/day}$$

$$R^F{}_{1,PM} = EF^F \times PW = \text{lb/hr} \ (\times\ T_a \text{ or } T_m) = \text{lb/day}$$

where: $R^M{}_{1,PM}$ = Uncontrolled melting particulate matter emissions.
$R^A{}_{1,PM}$ = Uncontrolled alloying particulate matter emissions.
$R^F{}_{1,PM}$ = Uncontrolled fluxing particulate matter emissions.
EF^M = Melting emission factor, lb/ton.
EF^A = Alloying emission factor, lb/ton.
EF^F = Fluxing emission factor, lb/ton.
PW = Process weight, ton/hr.
T_a or T_m = Time of operation, hr/day (actual and max).

4. Total Uncontrolled Particulate Matter Emissions ($R_{1,PM}$).

$$R_{1,PM} = R'_{1,PM} + R^M{}_{1,PM} + R^A{}_{1,PM} + R^F{}_{1,PM} = \text{lb/hr} \ (\times\ T_a \text{ or } T_m) = \text{lb/day}$$

5. Controlled Emissions (R_2).
The controlled emissions of ROG, NOx, SOx, and CO are equal to the uncontrolled emissions. The total controlled particulate matter emissions must be calculated, as well as the controlled particulate matter emissions due only to combustion.

$$R_{2,PM} = R_{1,PM} \times (1 - EFF_B) \text{ (x 1.1 for NSR lb/day)} = \text{lb/hr}$$

$$R'_{2,PM} = R'_{1,PM} \times (1 - EFF_B) = \text{lb/hr}$$

where: $R_{2,PM}$ = Controlled total particulate matter emissions, lb/hr.
$R'_{2,PM}$ = Controlled combustion particulate matter, lb/hr.
EFF_B = The efficiency of the baghouse(expressed as a decimal).

Controlled Emissions (R_2)	Actual lb/hr	Maximum lb/hr	Maximum lb/day	NSR lb/day
ROG				
NO_x				
SO_x				
CO				
PM				

6. Exhaust Gas Total Particulate Matter Concentration (C_{PM}).

$$C_{PM} = \frac{R_{2,PM} \text{ (lb/hr)} \times 7{,}000 \text{ (grains/lb)}}{\text{VFR (ft}^3\text{/min)} \times 60 \text{ (min/hr)}} = \underline{\qquad} \text{ grains/dscf}$$

7. Carbon Monoxide Concentration (C_{CO}).

$$C_{CO} = \frac{R_{2,CO} \text{ (lb/hr)}}{\text{VFR (ft}^3\text{/min)} \times (4.43 \times 10^{-6})} = \underline{\qquad} \text{ ppm}$$

8. Sulfur Oxide Concentration (C_{SOx}).

$$C_{SOx} = \frac{R_{2,SOx} \text{ (lb/hr)}}{\text{VFR (ft}^3\text{/min)} \times (10.1 \times 10^{-6})} = \underline{\qquad} \text{ ppm}$$

9. Combustion Particulate Matter Concentration ($C_{C,PM}$).

$$C_{C,PM} = \frac{R'_{2,PM} \text{ (lb/hr)} \times 7000 \text{ (grains/dscf)}}{\text{VFR (ft}^3\text{/min)} \times 60 \text{ (min/hr)}} = \underline{\qquad} \text{ grains/dscf}$$

10. Baghouse Air-to-Cloth Ratio (A/C).

$$A/C = VFR^e/A_b = \underline{\qquad} \text{ CFM/ } \underline{\qquad} \text{ ft}^2 = \underline{\qquad} \text{ ft/min}$$

where: VFR^e = Volumetric flow rate through the baghouse.
A_b = Actual area of the filter bags.

11. Duct Velocity (V_d).

A_d = $D^2/183$ = _______ $\text{in}^2/183$ = _______ ft^2
V_d = VFR/A_d = _______ CFM/ _______ ft^2 = _______ ft/min

where: A_d = Area of the duct.
D = Diameter of the duct (in inches).
VFR = Volumetric flow rate through the baghouse.

RULES EVALUATION:

RULE 212 : Public notice is (is not) required.

RULE 401 : This equipment is (is not) vented to a baghouse. Compliance with Rule 401 is (is not) expected.

RULE 402 : The location of the equipment will be in an industrial/commercial area. Calculations show low (excessive) particulate emissions to the atmosphere. Compliance with Rule 402 is (is not) expected.

RULE 404 : For an exhaust flow rate of _______ dscfm, the rule allows a maximum particulate matter concentration of _____ grains/dscf. Calculations indicate a particulate matter concentration of _____ grains/dscf. Compliance with Rule 404 is (is not) expected.

RULE 405 : For a process weight of ___________ lb/hr, the rule allows a maximum solid particulate matter emission rate of _____ lb/hr. Calculations indicate a maximum emission rate of _____ lb/hr. Compliance with Rule 405 is (is not) expected.

RULE 407 : The rule allows a CO concentration of 2,000 ppm and a SO_x concentration of 500 ppm in the air vented to the atmosphere. Calculations show a CO concentration of _____ ppm, and an SO_x concentration of _____ ppm. Compliance with this rule 407 is (is not) expected.

RULE 409 : The rule allows a combustion particulate matter emission concentration of 0.1 grains/dscf. Calculations show a concentration of _____ grains/dscf. Compliance with Rule 409 is (is not) expected.

REG XIII : As shown by the following Emission Threshold/New Source Sheet Table, this facility will (will not) operate in compliance with Regulation XIII:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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	NSR Emissions in Pounds Per Day ROG	NO_X	SO_2	CO	PM
Facility Emissions Since 10-8-76					
A/N					
A/N					
Net Emission Increase Since 10-8-76					

BACT : Best Available Control Technology (BACT) for this type of aluminum melting reverberatory furnace is as follows: (This information is listed in the South Coast Air Quality Management District's BACT Guideline, some determinations of BACT will require cost effectiveness analysis as described in the guideline).

ROG :
NO_x :
SO_x :
CO :
PM :

EQUIPMENT DESIGN COMPLIANCE:

AIR/CLOTH RATIO : Actual air to cloth ratio (A/C) = __________ ft/min. Allowed air to cloth ratio = 0.5 - 9.0 ft/min. Compliance is (is not) expected.

DUCT VELOCITY : Actual duct velocity (Vd) = __________ ft/min. Allowed duct velocity = 2000 - 5000 ft/min. Compliance is (is not) expected.

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

( ) Issue a Permit to Construct/Operate with the following conditions:

APPLICATION NO. ______________________

CONDITIONS:

1. METAL CONTAMINATED WITH RUBBER, PLASTIC, PAPER, RAGS, OIL, GREASE, OR SIMILAR SMOKE PRODUCING MATERIALS MUST NOT BE CHARGED INTO THIS FURNACE.

2. THIS FURNACE MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

3. THE AMOUNT OF ALUMINUM PROCESSED IN THIS FURNACE MUST NOT EXCEED ____________ POUNDS PER DAY.

4. THE OPERATOR SHALL KEEP ADEQUATE DAILY RECORDS TO VERIFY THE TOTAL AMOUNT OF ALUMINUM PROCESSED BY THIS EQUIPMENT IN POUNDS AND THE AMOUNT OF FUEL CONSUMED IN STANDARD CUBIC FEET (GALLONS). SUCH RECORDS SHALL BE RETAINED FOR A PERIOD OF AT LEAST TWO YEARS AND BE MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

5. THE AMOUNT OF FUEL CONSUMED BY THIS FURNACE MUST NOT EXCEED _________ STANDARD CUBIC FEET (GALLONS) PER DAY.

6. FLUORIDES, CHLORINE OR ALUMINUM CHLORIDE MUST NOT BE USED IN THIS FURNACE.

7. FLUXING OR REFINING MUST NOT BE CONDUCTED IN THIS FURNACE UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

8. THE RATE OF CHLORINE (GAS) USE MUST NOT EXCEED _________ POUNDS (CUBIC FEET) PER MINUTE.

9. NOT MORE THAN _________ POUNDS OF FLUX PER HOUR MAY BE USED IN THIS FURNACE.

APPLICATION NO. ________________________

CONDITIONS:

1. A MECHANICAL GAUGE MUST BE INSTALLED MAINTAINED SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS.

2. DUSTS COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS.

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ______ of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 11C

WORKSHEET FOR

SWEATING

ALUMINUM MELTING REVERBERATORY FURNACE

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES	PAGE
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PERMIT TO CONSTRUCT/OPERATE

Applicability: This processing form can only be used for sweating type aluminum melting reverberatory furnaces vented to an afterburner and a baghouse.

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ________________

FURNACE NO. , ALUMINUM MELTING, REVERBERATORY TYPE,
(MANUFACTURER) ,
MODEL NO. , SERIAL NO. ,
' " W. X ' " L. X ' " H.,
POUND HOLDING CAPACITY, BURNER(S),
BTU PER HOUR TOTAL, OR FIRED,
WITH A HP COMBUSTION AIR BLOWER.

APPLICATION NO. ________________

AIR POLLUTION CONTROL SYSTEM CONSISTING OF:

1. AFTERBURNER , MODEL NO. ,
   ' " DIA. X ' " L., BTU PER HOUR,
   DIRECT (INDIRECT) FIRED.
2. BAGHOUSE , MODEL NO. ,
   WITH FILTER BAGS, EACH '- " DIA. X '- "
   HIGH, SQ. FT. ACTUAL FILTER AREA.
3. EXHAUST SYSTEM WITH A H.P. BLOWER VENTING AN ALUMINUM
   MELTING REVERBERATORY FURNACE.

HISTORY:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 10	PAGE 2
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PROCESS DESCRIPTION:

The applicant uses this uses this sweating type reverberatory furnace to reclaim aluminum from scrap. Fluxing with powder flux (and/or chlorine gas) is conducted in this furnace. Alloying agents are (are not) added to the metal in this furnace. The aluminum melted in this furnace is used to produce__________. This furnace is vented to an afterburner and a baghouse).

DATA:

	Source
Operating Schedule (T_a): ____ hr/day, ____ day/wk, ____ wk/yr	Applicant
Operating Schedule (T_m): ____ hr/day, ____ day/wk, ____ wk/yr	"
Process Information : _____ lb/load, ___ hr/load, ___ load/day	"
Main Fuel: ________	"
Backup Fuel: ________	"
Furnace Heat Input Rate (Q^f): ________________ Btu/hr	"
Combustion Air Blower Capacity (VFR^f): ____________ cfm	"
Flux Description: ____________	"
Flux Process Information: (W^f): ______ lb/load, ______ cfm	"
Alloy Description: ____________	"
Alloy Process Information (W^a): ______ lb/load	"
Baghouse Efficiency (EFF_B): ________ %	"
Baghouse Filter Area (A_b): ________ ft^2	"
Baghouse Supply Duct Dia.: ________ in.	"
Exhaust Blower Flow Rate (VFR^e): ________ cfm	"
Afterburner Fuel: __________	"
Afterburner Heat Input Rate (Q^a): __________ Btu/hr	"
Afterburner Combustion Chamber Volume : __________ ft^3	"
Combustion Emission Factors for the Furnace:	
Reactive Organic Gas (EF'_{ROG}): ________ $lb/10^6$ Btu	____
Oxides of Nitrogen (EF'_{NOx}): ________ $lb/10^6$ Btu	____
Oxides of Sulfur (EF'_{SOx}): ________ $lb/10^6$ Btu	____
Carbon Monoxide (EF'_{CO}) : ________ $lb/10^6$ Btu	____
Particulate Matter (EF'_{PM}) : ________ $lb/10^6$ Btu	____
Combustion Emission Factors for the Afterburner:	
Reactive Organic Gas (EF''_{ROG}): ________ $lb/10^6$ Btu	____
Oxides of Nitrogen (EF''_{NOx}): ________ $lb/10^6$ Btu	____

Oxides of Sulfur (EF''_{SOx}): ________ $lb/10^6$ Btu ____
Carbon Monoxide (EF''_{CO}) : ________ $lb/10^6$ Btu ____
Particulate Matter (EF''_{PM}) : ________ $lb/10^6$ Btu ____
Melting Particulate Matter Emission Factor(EF^M): ________ lb/ton ____
Alloying Particulate Matter Emission Factor(EF^A): ________ lb/ton ____
Fluxing Particulate Matter Emission Factor(EF^F): ________ lb/ton ____
Reg XIII On-Site Offset Factor For Maximum Daily Emissions: 1.1

CALCULATIONS:

1. Process Weight (PW) $= W^a + W^f + W^m =$ _____ lb/load

   (_____ lb/load)/(2000 ton/lb)(_____ hr/load) = _____ ton/hr

2. Uncontrolled Furnace Combustion Emissions (R'_1).
   Uncontrolled combustion emissions of ROG, NO_x, SO_x, CO and PM must be multiplied by the appropriate operating time factor (T_a or T_m) to determine actual and maximum, hourly and daily emissions.

   $R'_1 = EF' \times Q^f =$ lb/hr (x T_a or T_m) = lb/day

   where: R'_1 = The particular uncontrolled furnace combustion emissions, lb/hr.
   EF' = The corresponding furnace combustion emission factor, lb $PM/10^6$ Btu.
   Q^f = Furnace heat input rate, Btu/hr.
   T_a or T_m = Time of operation, hr/day (actual and max).

3. Uncontrolled Afterburner Combustion Emissions (R''_1).
   Uncontrolled combustion emissions of ROG, NO_x, SO_x, CO and PM must be multiplied by the appropriate operating time factor (T_a or T_m) to determine actual and maximum, hourly and daily emissions.

   $R''_1 = EF'' \times Q^a =$ lb/hr (x T_a or T_m) = lb/day

   where: R''_1 = The particular uncontrolled afterburner combustion emissions, lb/hr.
   EF'' = The corresponding afterburner combustion emission factor, lb $PM/10^6$ Btu.
   Q^a = Afterburner heat input rate, Btu/hr.
   T_a or T_m = Time of operation, hr/day (actual and max).

4. Uncontrolled Melting, Alloying and Fluxing Particulate Matter Emissions ($R^{M,A,F}_{1,PM}$).

$$R^{M}_{1,PM} = EF^{M} \times PW = lb/hr \ (\times T_a \text{ or } T_m) = lb/day$$

$$R^{A}_{1,PM} = EF^{A} \times PW = lb/hr \ (\times T_a \text{ or } T_m) = lb/day$$

$$R^{F}_{1,PM} = EF^{F} \times PW = lb/hr \ (\times T_a \text{ or } T_m) = lb/day$$

where: $R^{M}_{1,PM}$ = Uncontrolled melting particulate matter emissions.
$R^{A}_{1,PM}$ = Uncontrolled alloying particulate matter emissions.
$R^{F}_{1,PM}$ = Uncontrolled fluxing particulate matter emissions.
EF^{M} = Melting emission factor, lb/ton.
EF^{A} = Alloying emission factor, lb/ton.
EF^{F} = Fluxing emission factor, lb/ton.
PW = Process weight, ton/hr.
T_a or T_m = Time of operation, hr/day (actual and max).

5. Controlled Emissions (R_2).
The emissions from a sweating type aluminum melting reverberatory furnace must be vented in such a manner that melting, alloying, and fluxing emissions are vented to an afterburner and a baghouse. Therefore the controlled emissions must be calculated after the exhaust stream passes through the afterburner and baghouse.

6. Controlled Particulate Matter Emissions ($R_{2,PM}$).
The total controlled particulate matter emissions ($R_{2,PM}$), and the controlled particulate matter emissions due to combustion only ($R'_{2,PM}$) must be calculated.

$$R_{2,PM} = (((R'_{1,PM} + R^{M}_{1,PM} + R^{A}_{1,PM} + R^{F}_{1,PM}) \times (1 - EFF_A)) + R''_{1,PM} \times (1 - EFF_B) \quad (\times 1.1 \text{ for NSR lb/day})$$

$$R'_{2,PM} = ((R'_{1,PM} \times (1 - EFF_A)) + R''_{1,PM}) \times (1 - EFF_B) = lb/hr$$

where: $R_{2,PM}$ = Controlled total particulate matter emissions, lb/hr.
$R'_{2,PM}$ = Controlled combustion particulate matter emissions, lb/hr.
EFF_B = Baghouse collection efficiency (expressed as a decimal).
EFF_A = Afterburner destruction efficiency (expressed as a decimal).

7. Controlled Reactive Organic Gas Emissions ($R_{2,ROG}$)

$$R_{2,ROG} = (R'_{1,ROG} \times (1 - EFF_A)) + R''_{1,ROG} = lb/hr$$

8. Controlled NO_x, SO_x, and CO Emissions ($R_{2,NOx,SOx,CO}$).

$$R_{2,NOx} = R'_{1,NOx} + R''_{1,NOx} = \text{lb/hr}$$

$$R_{2,SOx} = R'_{1,SOx} + R''_{1,SOx} = \text{lb/hr}$$

$$R_{2,CO} = R'_{1,CO} + R''_{1,CO} = \text{lb/hr}$$

Controlled Emissions (R_2)	Actual lb/hr	Maximum lb/hr	Maximum lb/day	NSR lb/day
ROG				
NO_x				
SO_x				
CO				
PM				

9. Exhaust Gas Total Particulate Matter Concentration (C_{PM}).

$$C_{PM} = \frac{R_{2,PM}\ (\text{lb/hr}) \times 7{,}000\ (\text{grains/lb})}{\text{VFR}\ (\text{ft}^3/\text{min}) \times 60\ (\text{min/hr})} = \underline{\qquad}\ \text{grains/dscf}$$

10. Carbon Monoxide Concentration (C_{CO}).

$$C_{CO} = \frac{R_{2,CO}\ (\text{lb/hr})}{\text{VFR}\ (\text{ft}^3/\text{min}) \times (4.43 \times 10^{-6})} = \underline{\qquad}\ \text{ppm}$$

11. Sulfur Oxide Concentration (C_{SOx}).

$$C_{SOx} = \frac{R_{2,SOx}\ (\text{lb/hr})}{\text{VFR}\ (\text{ft}^3/\text{min}) \times (10.1 \times 10^{-6})} = \underline{\qquad}\ \text{ppm}$$

12. Combustion Particulate Matter Concentration ($C_{C,PM}$).

$$C_{C,PM} = \frac{R'_{2,PM}\ (\text{lb/hr}) \times 7000\ (\text{grains/dscf})}{\text{VFR}\ (\text{ft}^3/\text{min}) \times 60\ (\text{min/hr})} = \underline{\qquad}\ \text{grains/dscf}$$

13. Baghouse Air-to-Cloth Ratio (A/C).

$$A/C = \text{VFR}^e/A_b = \underline{\qquad}\ \text{CFM}/\ \underline{\qquad}\ \text{ft}^2 = \underline{\qquad}\ \text{ft/min}$$

where: VFR^e = Volumetric flow rate through the baghouse.
A_b = Actual area of the filter bags.

14. Duct Velocity (V_d).

A_d = $D^2/183$ = ______ $in^2/183$ = ______ ft^2
V_d = VFR/A_d = ______ CFM/ ______ ft^2 = ______ ft/min

where: A_d = Area of the duct.
D = Diameter of the duct (in inches).
VFR = Volumetric flow rate through the baghouse.

15. Afterburner Retention Time (T_r).

$$T_r = \frac{V_c\,(ft^3) \times 60\,(sec/min)}{VFR^f\,(scfm) + VFR^a\,(scfm)} = \underline{\qquad\quad} \text{ seconds}$$

$$VFR^a = \frac{Q^a\,(Btu/hr) \times 13.53 \times 1860\,^oR}{60\,(min/hr) \times 1{,}100\,(Btu/ft^3) \times 520\,^oR} = \underline{\qquad\quad} \text{ scfm}$$

where: T_r = The retention time of the afterburner, seconds.
V_c = Volume of the afterburner combustion chamber, ft^3.
VFR^f = Volumetric flow rate from the furnace, scfm.
VFR^a = Volumetric flow rate due to the afterburner combustion, scfm.
1,100 = Gross heating value for natural gas at standard conditions, Btu/ft^3.
13.53 = The products of combustion for natural gas with 20% excess air, ft^3/ft^3 natural gas.
1860 = The afterburner combustion temperature, ^oR
520 = Standard temperature, ^oR

16. Afterburner Heat Required (Q').

$Q' = (h_2 - h_1) \times VFR^f \times 60$ min/hr = ______ Btu/hr where: Q' = The heact required of the afterburner to raise the temperature of the gasses to 1400 ^{o}F, Btu/hr.

h_2 = The enthalpy of the air as it enters the afterburner, Btu/ft^3.

h_1 = The enthalpy of air at 1400 ^{o}F, Btu/ft^3.

17. Afterburner Heat Available ($Q_{available}$).

$$Q_{avaiable} = \frac{Q^{a}\ (Btu/hr)\ \times\ 615.4\ (Btu/ft^3)}{1{,}100\ (Btu/ft^3)} = \underline{\qquad\qquad}\ Btu/hr$$

where: $Q_{available}$ = The heat available from the afterburner combustion, Btu/hr.

615.4 = The heat available from the combustion of natural gas at 1400 ^{o}F with 20% excess air.

RULES EVALUATION:

RULE 212 : Public notice is (is not) required.

RULE 401 : This equipment is (is not) vented to a baghouse. Compliance with Rule 401 is (is not) expected.

RULE 402 : The location of the equipment will be in an industrial/commercial area. Calculations show low (excessive) particulate emissions to the atmosphere. Compliance with Rule 402 is (is not) expected.

RULE 404 : For an exhaust flow rate of _______ dscfm, the rule allows a maximum particulate matter concentration of _____ grains/dscf. Calculations indicate a particulate matter concentration of _____ grains/dscf. Compliance with Rule 404 is (is not) expected.

RULE 405 : For a process weight of ___________ lb/hr, the rule allows a maximum solid particulate matter emission rate of _____ lb/hr. Calculations indicate a maximum emission rate of _____ lb/hr. Compliance with Rule 405 is (is not) expected.

RULE 407 : The rule allows a CO concentration of 2,000 ppm and a SO_x concentration of 500 ppm in the air vented to the atmosphere. Calculations show a CO concentration of _____ ppm, and an SO_x concentration of _____ ppm. Compliance with this rule 407 is (is not) expected.

RULE 409 : The rule allows a combustion particulate matter emission concentration of 0.1 grains/dscf. Calculations show a concentration of _____ grains/dscf. Compliance with Rule 409 is (is not) expected.

REG XIII : As shown by the following Emission Threshold/New Source Sheet Table, this facility will (will not) operate in compliance with Regulation XIII:

	NSR Emissions in Pounds Per Day				
	ROG	NO_X	SO_2	CO	PM
Facility Emissions Since 10-8-76	___	___	___	___	___
A/N	___	___	___	___	___
A/N	___	___	___	___	___
Net Emission Increase Since 10-8-76	___	___	___	___	___

BACT : Best Available Control Technology (BACT) for this type of aluminum melting reverberatory furnace is as follows: (This information is listed in the South Coast Air Quality Management District's BACT Guideline, some determinations of BACT will require cost effectiveness analysis as described in the guideline).

ROG :
NO_x :
SO_x :
CO :
PM :

EQUIPMENT DESIGN COMPLIANCE:

AIR/CLOTH RATIO : Actual air to cloth ratio (A/C) = __________ ft/min. Allowed air to cloth ratio = 0.5 - 9.0 ft/min. Compliance is (is not) expected.

DUCT VELOCITY : Actual duct velocity (Vd) = __________ ft/min. Allowed duct velocity = 2000 - 5000 ft/min. Compliance is (is not) expected.

AFTERBURNER RETENTION TIME : Calculated retention time (T_r) = ________ sec. Allowed retention time is $\geq$ 0.3 seconds. Compliance is (is not) expected.

AFTERBURNER COMB. CHAMB. TEMP. : Heat available ($Q_{available}$) = ________ Btu/hr. Heat required (Q') = ________ Btu/hr. Allowed is $Q_{available} > Q'$. Compliance is (is not) expected.

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

( ) Issue a Permit to Construct/Operate with the following conditions:

APPLICATION NO. ______________________ (basic)

CONDITIONS:

1. METAL CONTAMINATED WITH RUBBER, PLASTIC, PAPER, RAGS, OIL, GREASE, OR SIMILAR SMOKE PRODUCING MATERIALS MUST NOT BE CHARGED INTO THIS FURNACE.

2. THIS FURNACE MUST NOT BE OPERATED UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

3. THE AMOUNT OF ALUMINUM PROCESSED IN THIS FURNACE MUST NOT EXCEED ___________ POUNDS PER DAY.

4. THE OPERATOR SHALL KEEP ADEQUATE DAILY RECORDS TO VERIFY THE TOTAL AMOUNT OF ALUMINUM PROCESSED BY THIS EQUIPMENT IN POUNDS AND THE AMOUNT OF FUEL CONSUMED IN STANDARD CUBIC FEET (GALLONS). SUCH RECORDS SHALL BE RETAINED FOR A PERIOD OF AT LEAST TWO YEARS AND BE MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

5. THE AMOUNT OF FUEL CONSUMED BY THIS FURNACE MUST NOT EXCEED _________ STANDARD CUBIC FEET (GALLONS) PER DAY.

6. FLUORIDES, CHLORINE OR ALUMINUM CHLORIDE MUST NOT BE USED IN THIS FURNACE.

7. FLUXING OR REFINING MUST NOT BE CONDUCTED IN THIS FURNACE UNLESS IT IS VENTED ONLY TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

8. THE RATE OF CHLORINE (GAS) USE MUST NOT EXCEED _________ POUNDS (CUBIC FEET) PER MINUTE.

9. NOT MORE THAN _________ POUNDS OF FLUX PER HOUR MAY BE USED IN THIS FURNACE.

APPLICATION NO. ______________________ (control)

CONDITIONS:

1. A TEMPERATURE OF NOT LESS THAN 1400 ^{o}F MUST BE MAINTAINED IN THE AFTERBURNER WHEN THE EQUIPMENT IT SERVES IS IN OPERATION.

2. THIS EQUIPMENT MUST NOT BE OPERATED UNLESS IT IS VENTED TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND HAS BEEN ISSUED A PERMIT TO CONSTRUCT (OPERATE) BY THE EXECUTIVE OFFICER.

3. A MECHANICAL GAUGE MUST BE INSTALLED MAINTAINED SO AS TO INDICATE, IN INCHES WATER COLUMN, THE STATIC PRESSURE DIFFERENTIAL ACROSS THE BAGS.

4. DUSTS COLLECTED IN THE BAGHOUSE MUST BE DISCHARGED ONLY INTO CLOSED CONTAINERS.

<u>OR</u>

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ______ of the Rules and Regulations of the South Coast Air Quality Management District.

SECTION 12

Boilers

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Section 12

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

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SECTION 12: BOILERS

12.1 General Description

A boiler is basically a steel or cast-iron pressure vessel designed to transfer heat from the combustion of fuel to water contained within the boiler to produce hot water, or steam. The principal components of a boiler are a burner, a firebox, a heat exchanger, and a means of creating and directing gas flow through the unit.

Boilers are classified according to the operating pressure, fuel burned, heat transfer media (tube contents), and energy output. These classifications are listed below: [1]

- *low pressure*	steam boilers for operating pressure $\leq$ 15 psi, and hot water boilers for operating pressure $\leq$ 160 psi and operating temperature $\leq 250\ ^{o}$F;
- *power*	boilers with operating conditions exceeding those specified for the low pressure boilers;
- *watertube*	tubes contain water or steam - hot products of combustion pass outside of the tubes;
- *firetube*	hot products of combustion pass through tubes surrounded by water.

The Environmental Protection Agency (EPA) classifies boilers as follows: [2]

- *commercial*	gross heat output of 0.5 - 10 MMBTU/hr;
- *industrial*	gross heat output of 10 - 100 MMBTU/hr;
- *utility*	gross heat output > 100 MMBTU/hr.

It is common for boilers and burners to be manufactured by different companies. A boiler completely assembled with fuel-burning equipment, mechanical-draft equipment, automactic controls and accessories is called *a packaged boiler*. Figure 12-1 is an illustration of a packaged firetube boiler. The field-erected boiler is larger than packaged boiler and is erected from the ground up at their point of use.

This section of the handbook will give a general discussion only about industrial boilers which include natural gas and liquid fuel fired packaged boilers, the gas and oil fuel burner, and some of the most common NO_x reduction technique for commercial/industrial/institutional boilers.

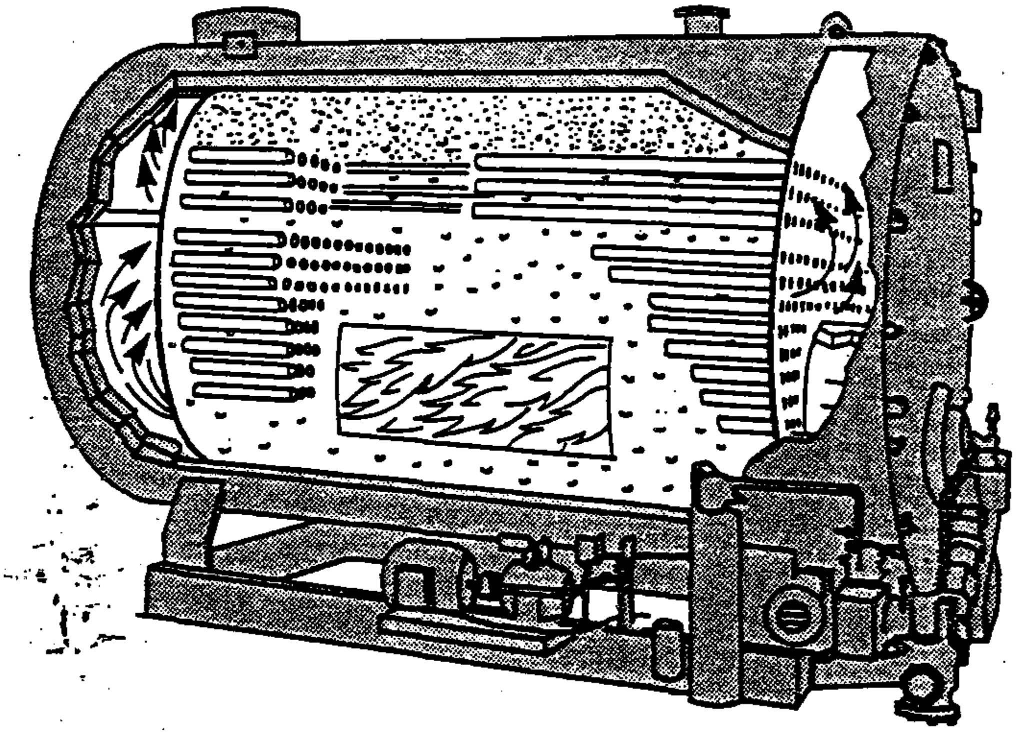


FIGURE 12-1[11] **PACKAGED BOILER**

12.1.1 Firetube Boilers

Firetube boilers, also called portable boilers, are used for producing industrial process steam. Firetube boilers are primarily used where steam demands are relatively small and operating pressures are relatively low. Firetube boilers are produced in sizes up to 15,000 lb steam per hour (nominal 100 percent rating). Low pressure firetube boilers are restricted to 15 psi steam pressure or 160 psi hot water pressure, and the power boiler to about 250 psi steam pressure. [1]

The advantages of firetube boilers compared to watertube boilers are: [1, 3]

- low capital and maintenance cost;
- high efficiencies (80% or higher);
- ability to dampen wide and sudden load fluctuations with only slight pressure change because of the large volume of water stored in the shell; and
- simple installation.

The disadvantages of firetube boilers compared to watertube boilers are: [1, 3]

- more time is required to arrive at operating pressure from a cold start because of the large volume of water stored in the shell; and
- limited ability to handle overfiring.

There are many different types of firetube boilers. Firetube boilers can have a firebox that is water jacketed (e.g. Scotch, locomotive, short firebox, compact, and vertical tubular), or a firebox that is brick-set or steel jacketed (e.g. horizontal return tubular).

The *Scotch boiler*, the most common type, is designed primarily for marine service as a power boiler. If the rear combustion chamber is refractory lined, the boiler is said to be a *dry-back*. A water-jacketed combustion chamber is referred to as a *wet-back*. If the back is refractory lined but the top is water-jacketed, it is a *wet-top*. Figure 12-2 shows the gas and water circulation in the Scotch boiler. [1]

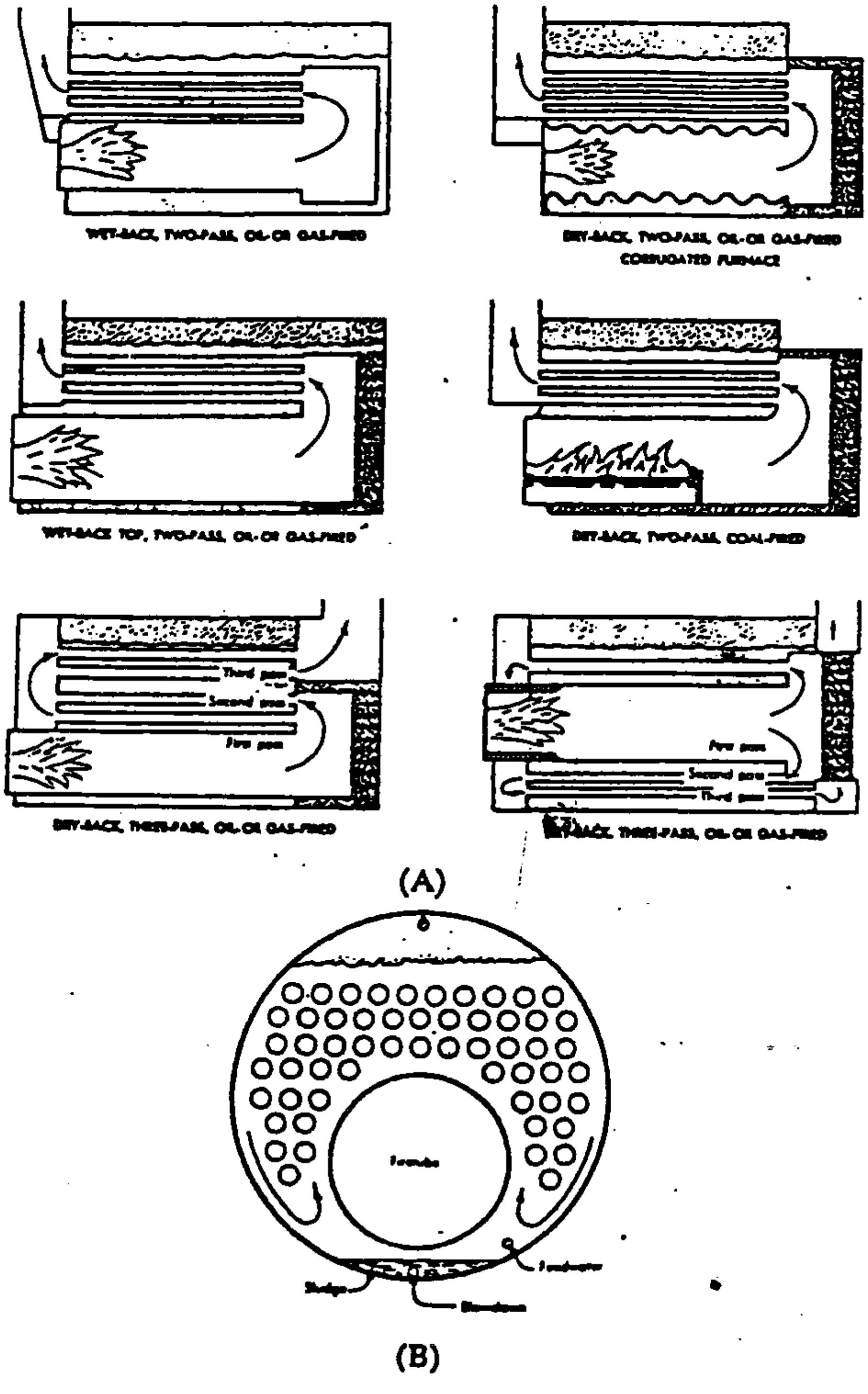


FIGURE 12-2 1
(A) GAS FLOW IN SCOTCH BOILER TYPES
(B) WATER CIRCULATION IN SCOTCH BOILER

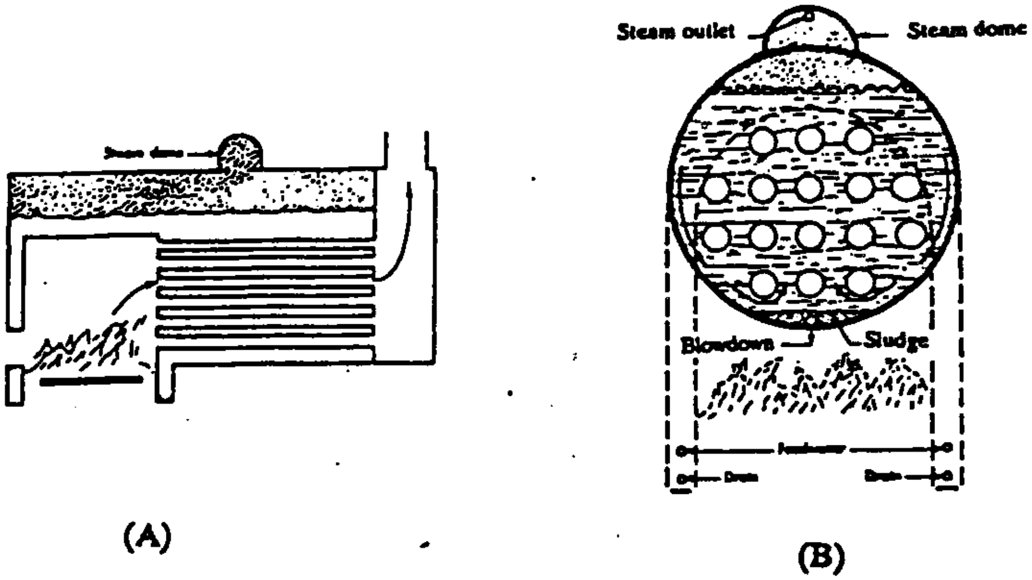
The *locomotive boiler* is an adaptation and modification of the boiler used in the railroad locomotives. This boiler is a portable firebox type and rarely used for heating purposes. It consists of a water-jacketed firebox and a tube shell where the flame and hot gases are emerged before being released to the atmosphere. Figure 12-3 shows the gas and water circulation in the locomotive boiler. [1]

The *short firebox boiler* is commonly used for heating purpose. It is a horizontal, two-pass firetube boiler. The first pass is shorter than the second pass and is located on the side of the firebox to form the rear for the boiler. The extended portion of the second pass sits on top of the firebox. As the fuel is burned in the front portion, products of combustion immediately enter at the front of the first pass, travel to the end, reverse direction, and travel to the second pass before discharging to the atmosphere. Figure 12-4 shows the gas and water circulation in the short firebox boiler. [1]

The *compact boiler* is the most popular boiler for larger residences and commercial or institutional installations. It is a three-pass boiler. Figure 12-5 shows the gas and water circulation in this boiler. [1]

The *vertical boiler* is referred as a power boiler or a residential hot water boiler which is widely used as a mobile steam power source. The boiler consists of a vertical cylindrical shell having basically three designs: the straight type, the tapered course type, and the Manning type, as shown in Figure 12-6. [1]

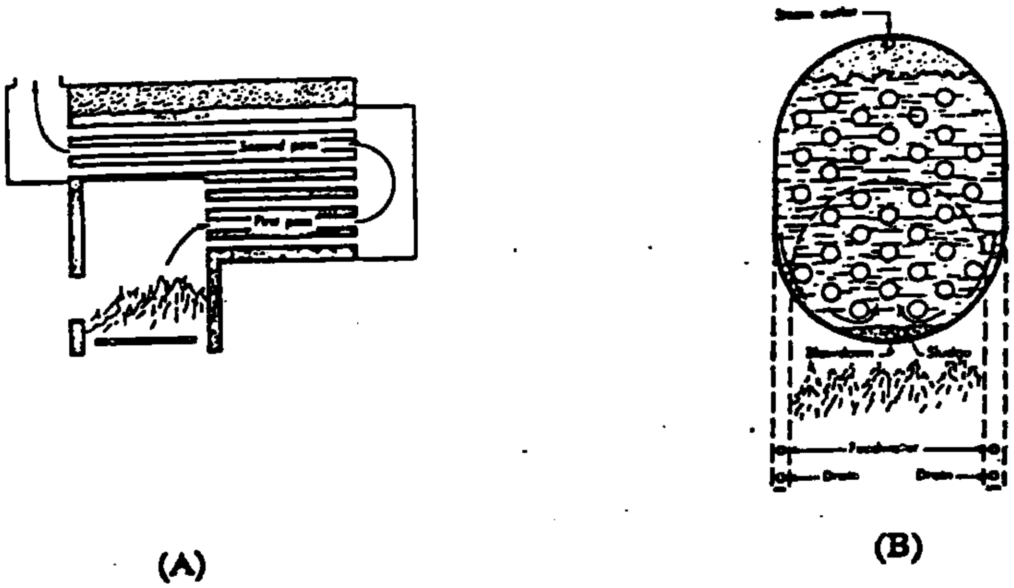
The *horizontal return tubular boiler* (HRT) has been popular for industrial process steam applications in small industrial plants. Many HRT boilers are still used for heating large buildings and factory process steam production; however, they are being replaced by other types requiring less installation cost. The HRT boiler consists of a cylindrical shell with flat end closures, in which a large number of 3-4 inch firetubes are supported. The firebox is located directly below the front end of the shell. The boiler is suspended above an external brickset furnace, hung from suspension rods or bracketed by furnace sidewalls. Occasionally, the furnace is steel encased. Figure 12-7 shows the gas and water recirculation in the HRT boiler. [1]



(A)

(B)

FIGURE 12-3 [1]
(A) GAS FLOW IN LOCOMOTIVE TYPE BOILER
(B) WATER CIRCULATION IN LOCOMOTIVE TYPE BOILER



(A)

(B)

FIGURE 12-4 [1]
(A) GAS FLOW IN SHORT FIREBOX BOILER
(B) WATER CIRCULATION IN SHORT FIREBOX BOILER

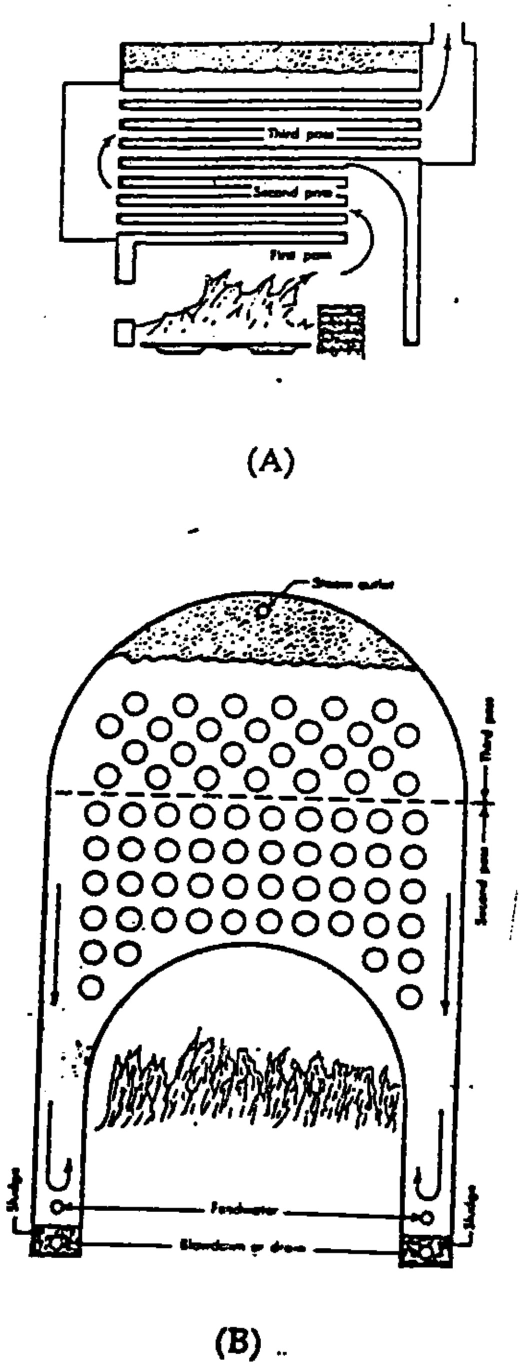
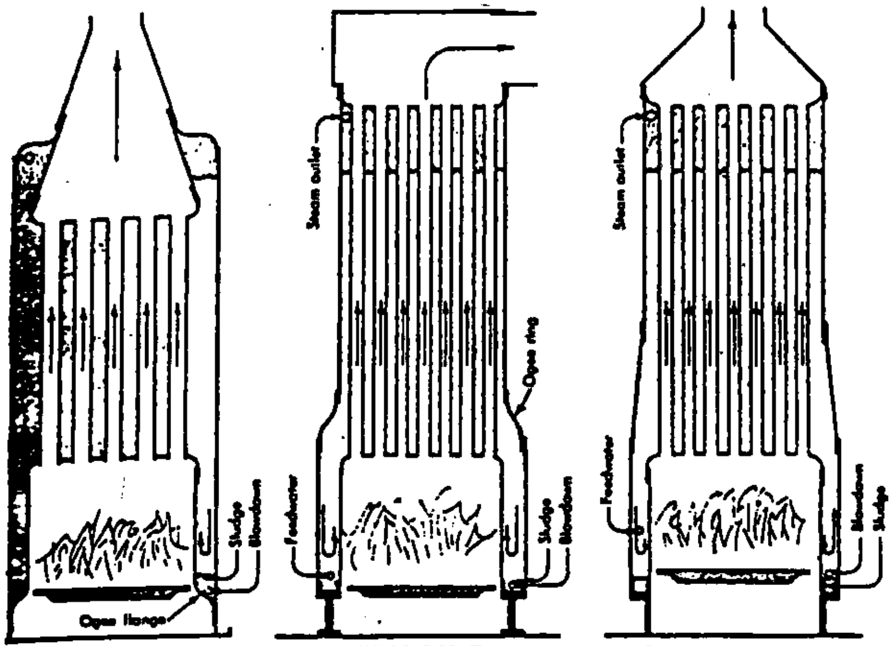


FIGURE 12-5 [1]
(A) GAS FLOW IN COMPACT BOILER
(B) WATER CIRCULATION IN COMPACT BOILER

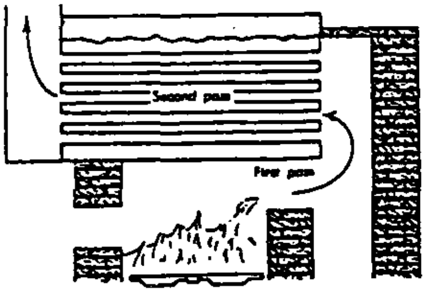


STRAIGHT SHELL BOILER WITH SUBMERGED HEAD

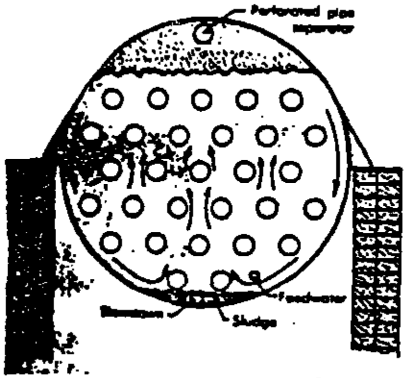
MANNING BOILER WITH ENLARGED FIREBOX

TAPERED-COURSE BOILER WITH ENLARGED FIREBOX

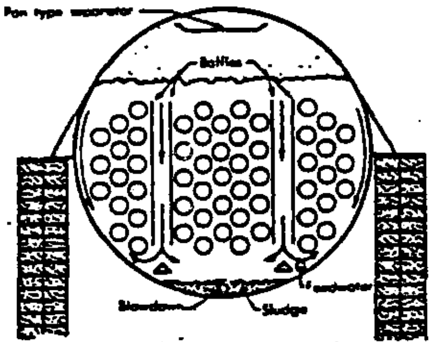
FIGURE 12-6 VERTICAL BOILER TYPES [1]



(A)



STAGGERED TUBE ARRANGEMENT



BAFFLED PARALLEL TUBE ARRANGEMENT

(B)

FIGURE 12-7 HORIZONTAL RETURN TUBULAR BOILER [1]
(A) GAS FLOW
(B) WATER CIRCULATION FLOW

12.1.2 Watertube Boilers

Watertube boilers are primarily used where steam demands and operating pressures are relatively high. Watertube boilers are almost exclusively used for pressures above 150 psi and capacities over 15,000 lb steam per hour. However, some watertube boilers can be operated at a pressure as low as 15 psi. [1]

The watertube boiler is composed mainly of drums and tubes. The tubes are always external to the drums and serve to interconnect them. The surface area of the tubes serves as the heating surface. The drums are used to store water and steam. Since the drums are not used as a heating surface, their diameter can be much smaller than the tubes diameter. However, the drums are thicker to resist higher pressures. Depending on the arrangement of the tubes and drums, watertube boilers are classified as A, D, or O type, as shown in Figure 12-8. [1,4] Other boiler configurations include bent-tube, inclined-tube (Ajax) boilers and vertical, coiled-tube (Clayton) boilers.

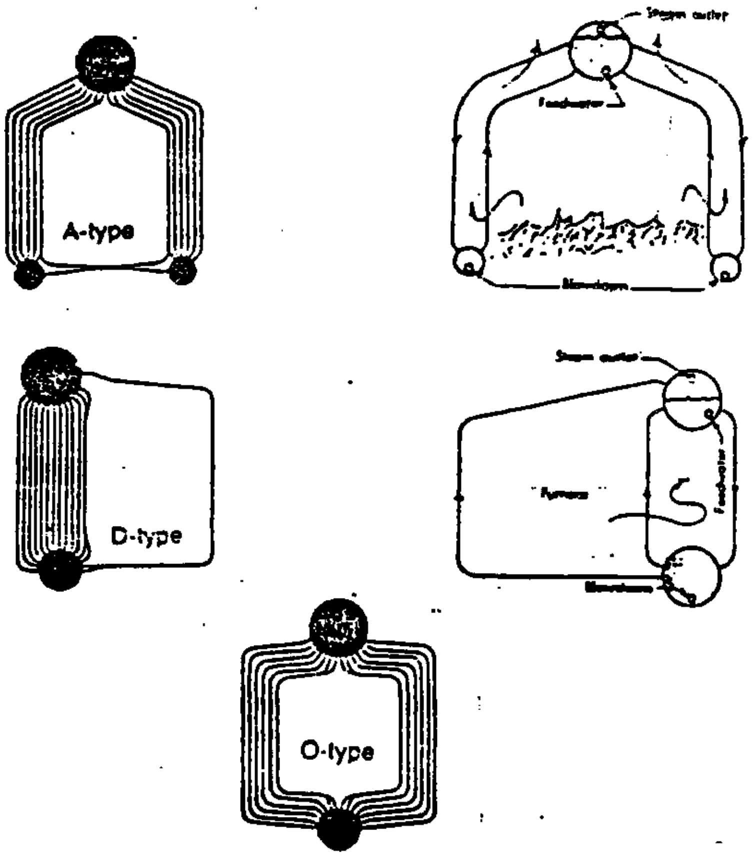


FIGURE 12-8 CIRCULATION IN WATER TUBE BOILER [1]

12.1.3 Gas And Oil Burners

The burner is where the fuel and the combustion air are introduced, mixed, and then combusted. Good burners often meet the following standards:[3]

- Appropriate fuel and air feeding rates, to meet the demand on the boiler;
- A high combustion efficiency, to minimize the unburned products and excess air in the exhaust;
- A large operating range (or load range). (The boiler load range is the ratio of full load to minimum load at which the burner is capable of reliable operation. For example, for a boiler of 100,000 lb/hr steam output capacity, a load range of 4 to 1 means that the unit can be operated from 100,000 lb/hr down to 25,000 lb/hr without changing the number of burners in operation); and
- A low installation cost, to meet all safety standards under all types of operating conditions including starting, stopping, load change, and variation in the fuel.

There are three major different types of gas burners: *premix*, *partial premix*, and *postmix burners*.

Premix burner (Figure 12-9) blends combustion air and fuel before delivery to the burner head. No additional air is required later on for proper combustion.

Partial premix burner (Figure 12-10) blends a portion of primary combustion air and fuel before ignition. Combustion is completed at the burner tip as additional air, secondary combustion air, reacts with the burning mixture.

Postmix burner does not blend combustion air with fuel before ignition. The fuel is introduced in a pattern to provide adequate mixing with oxygen. The most frequently used postmix burners are the circular type burners. Circular type burners introduce fuel to the center of the burner and air tangentially to the fuel stream from the air register. The direction and velocity of the air stream provide the turbulence necessary to completely mix the combustion air and fuel to produce short, compact flames.

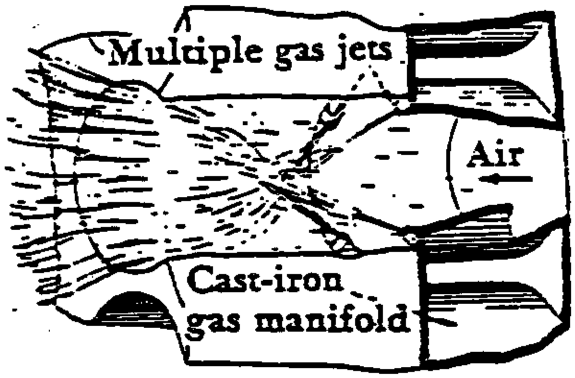


FIGURE 12-9 PREMIX-TYPE GAS BURNER [11]

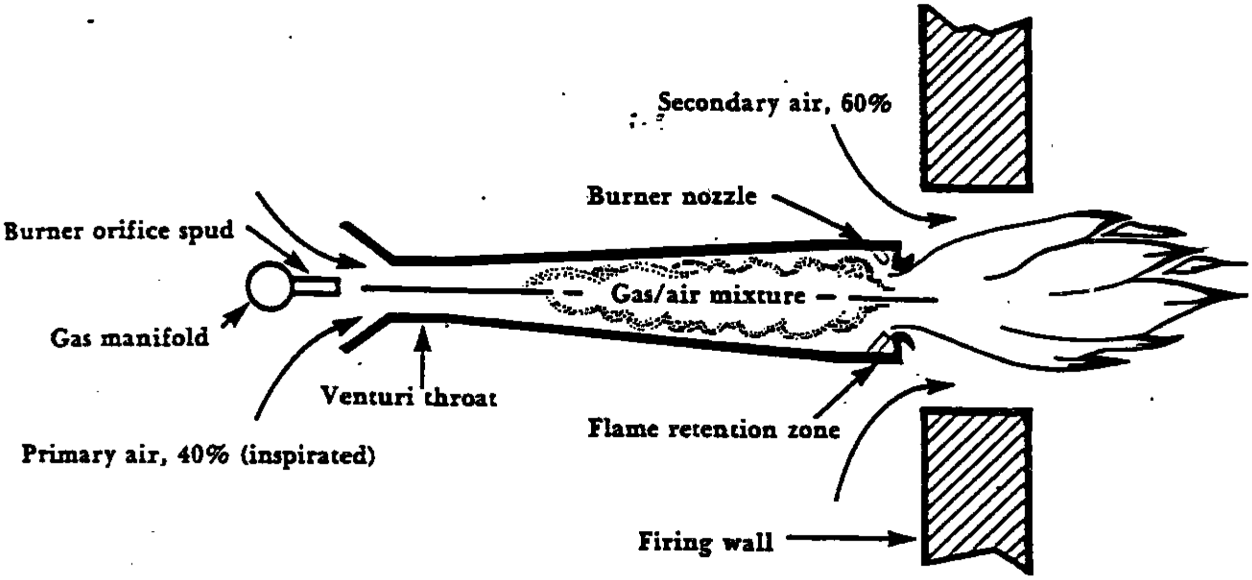


FIGURE 12-10 PARTIAL PREMIX-TYPE GAS BURNER [11]

Figure 12-11 shows a dual air register burner for firing oil or pulverized coal. The circular type dual register burner was developed to reduce thermal NO_x emissions based on the concept of staged combustion. A multifuel fired burner with variable-mix multispud gas elements is capable of changing from one fuel to another without a drop in load or boiler pressure. Simultaneous firing of natural gas and oil in the same burner is acceptable with variable mix multispud type gas elements.[3]

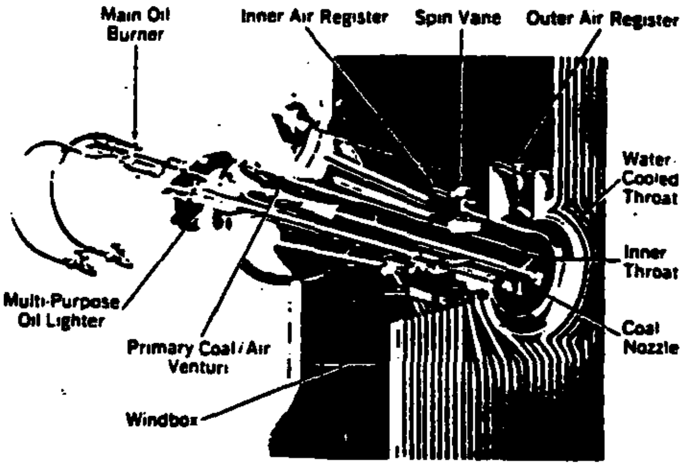


FIGURE 12-11 CIRCULAR TYPE DUAL REGISTER BURNER SHOWING LOCATION OR BURNER COMPONENTS[3]

Unlike gas, oil has to be *atomized*. There are many ways of atomizing fuel oil, but the two most common methods are steam or compressed air atomizers and mechanical atomizers.

Steam or compressed air atomizers, shown in Figure 12-12, are the most widely used. In general, they operate on the principle of producing a steam-fuel (or air-fuel) emulsion which, when released into the combustion chamber, atomizes the oil through the rapid expansion of the steam or compressed air.

Mechanical atomizers utilize the pressure of the fuel itself as the means for atomization. The fuel oil is given a strong whirling action before it is released through the orifice. Figure 12-13 shows a mechanical return-flow oil atomizer in which some of the whirling oil flows through the orifice while excess oil is drawn off through the central oil return line. Refer to Reference 1 and 3 for more details.

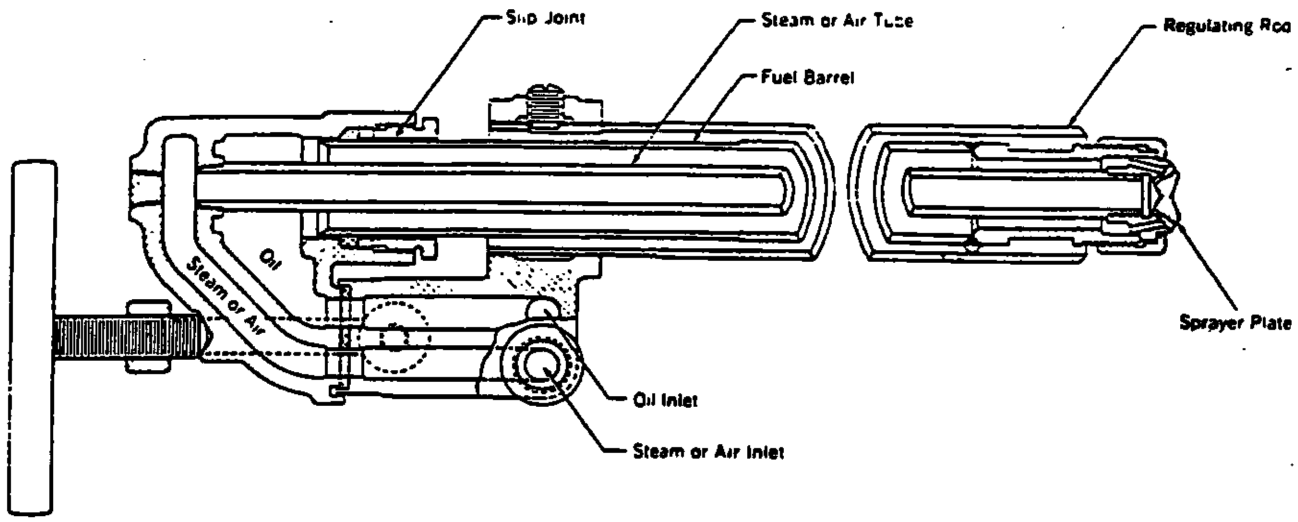


FIGURE 12-12 STEAM OR AIR OIL ATOMIZER ASSEMBLY [3]

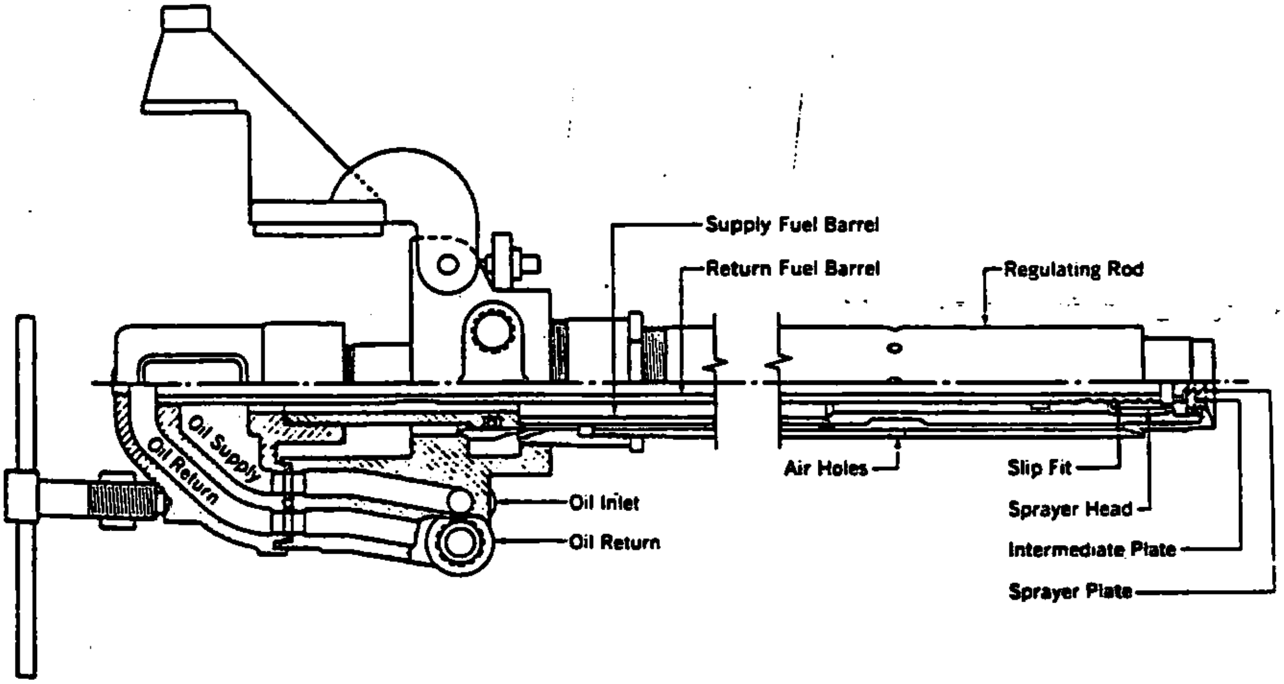


FIGURE 12-13 MECHANICAL RETURN-FLOW OIL ATOMIZER ASSEMBLY [3]

Combustion air is generally delivered to the burners by fans. When a fan is used, the boiler is called a *forced draft* boiler, otherwise, it is called an *atmospheric* boiler. It is necessary to supply more than the theoretical air quantity, usually 5 - 20% by weight, to assure complete combustion of the fuel. A fan offers a way to control this amount of excess air, therefore a forced draft boiler provides greater flexibility and often better combustion than an atmospheric boiler.[3]

12.1.4 Nitrogen Oxides Reduction Techniques

12.1.4.1 Fundamentals Of Combustion In Boilers and Mechanism of NO_X Formation

A boiler requires a source of heat at a sufficient temperature to produce steam. Combustion in the boiler is a rapid chemical combination of oxygen with the combustible elements of a fuel to ideally form carbon dioxide and water. These combustion reactions are exothermic and the heat released is used to heat the feed water to form steam. Combustion air is the usual source of oxygen for a boiler. The typical heat of combustion for natural gas, and fuel oils are listed in Table 12-1. The heat content of fuel oil can also be estimated from Figure 12-14.

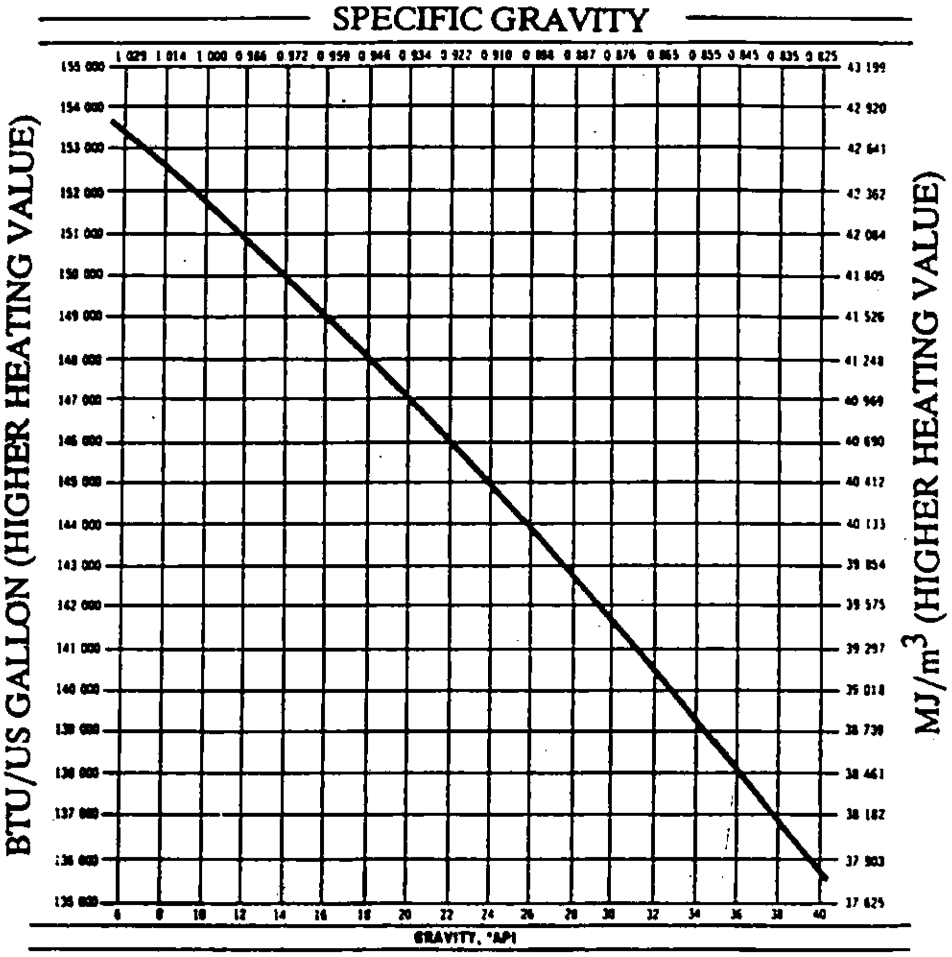
Not all of the energy in the fuel is converted to heat because of incomplete combustion products such as unburned carbon and carbon monoxide. It is practical to use more than the theoretical air requirements to assure sufficient oxygen for complete combustion. However, the excess air not used in the combustion of the fuel leaves the boiler at the stack exhaust temperature. The additional heat required to heat excess air from room temperature to stack temperature serves no purpose and is called stack loss. Therefore, it is necessary to keep the excess air at a minimum in order to reduce stack loss. Stack loss is sometimes reduced in large boilers by using an air preheater to transfer heat from the flue gas to the combustion air.

TABLE 12-1 TYPICAL HEATING VALUE OF VARIOUS FUELS [a]

Fuel Type	Analysis, % by weight				Heating Value		
	C	H	S	Ash	Btu/lb	Btu/gal	Btu/ft^3
Natural gas	75	25					950-1,15
Propane	82	18			19,854		
Butane	83	17			19,620		
Naphtha	85	15	0.03		19,152		
Kerosene	86	13.7	0.07		18,558		
Heating oil	86	13.2	0.3		18,378		
No. 1 fuel oil						137,400	
No. 2 fuel oil						139,600	
No. 4 fuel oil	87	12.5	0.7	0.02		145,100	
No. 5 fuel oil						148,800	
No. 6 fuel oil	87	12	1.0	0.03		152,400	
Bituminous coal					11,500-14,000		
Sub-bituminous coal					9,500-11,500		
Lignite, brown coal					6,300-8,300		
Coke							

a. Reference 4

Note: Natural gas, propane and butane have higher hydrogen contents per unit of weight than liquid or solid fuels, which results in higher heating values. But when equal volumes of gas and oil are burned, the fuel oil gives up more heat because fuel oil contains more hydrocarbons per unit volume (higher specific gravity) than the gas. Also, notice that the heating value of petroleum products is about 19,000/lb.



API Gravity Range of Fuel Oils

Type	API Gravity Range
#2	29° to 39°
#4	24° to 28°
#5	16° to 22°
#6	6° to 15°

Note: API gravity $= \dfrac{141.5}{\text{specific gravity @ 16°C}} - 131.5$

FIGURE 12-14 SPECIFIC GRAVITY OF FUEL OIL VERSUS. HEAT CONTENT [4]

Nitrogen oxides are generated in the combustion processes by two routes:

- thermal NO_x is formed by the reaction of nitrogen and oxygen in the combustion air at elevated temperature; and
- fuel NO_x is formed by the reaction of chemically bound nitrogen in the fuel and the oxygen in the combustion air. Fuel bound nitrogen is mostly found in oil and coal. In natural gas, fuel NO_x is considered negligible.

Nitric oxide (NO) and nitrogen dioxide (NO_2) are the two forms of nitrogen oxides generated by the combustion process in the boiler. Nitric oxide and nitrogen dioxide are formed by two overall reactions:

$$N_2 + O_2 = 2\,NO \qquad \textbf{(Equation 12-1)}$$
$$NO + 1/2\,O_2 = NO_2 \qquad \textbf{(Equation 12-2)}$$

The equilibrium constant of reaction shown in Equation 12-1 increases with increasing temperature, and the equilibrium constant of reaction in Equation 12-2 decreases with increasing temperature. Therefore, thermodynamically, NO formation is favored at conventional combustion temperatures ($> 1500\ ^oK$ or 2250 ^oF).

In addition to temperature dependence, NO formation depends on time and the amount of available excess air. Although the stoichiometric air-fuel ratio essentially leads to the maximum possible combustion temperature, Figure 12-15 shows that the maximum equilibrium NO concentration occurs at the percentage of stoichiometric air somewhat higher than 100 percent.[5, 6] Figure 12-16 shows the importance of residence time in the combustion zone. A fraction of a second in residence time can increase NO_x concentration.[6]

NO in the flue gas is thermodynamically unstable as it enters the environment and its temperature drops. NO is slowly decomposed into N_2 and O_2, or oxidized to NO_2. The decomposition of NO into N_2 and O_2 is limited by the high activation energy of the reaction. Thus, NO formed at high temperatures preferentially forms NO_2 at lower temperatures, rather than decomposing into N_2 or O_2.

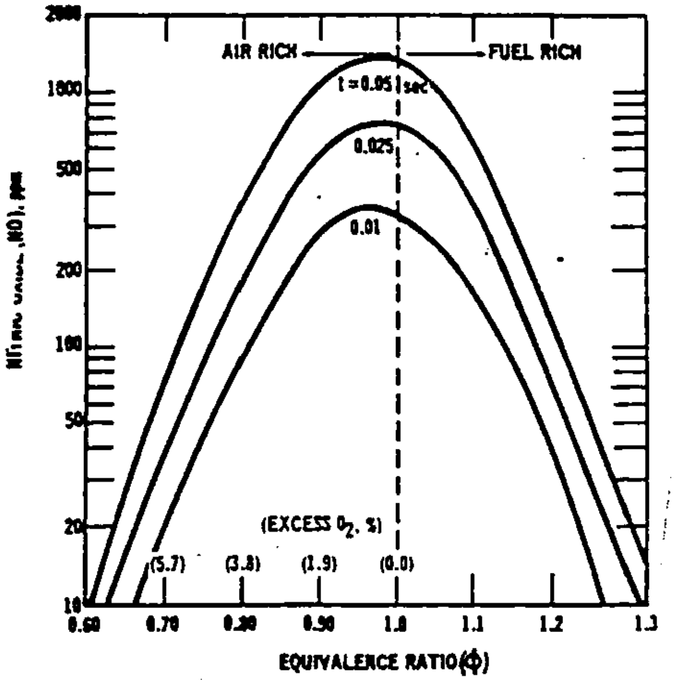


FIGURE 12-15 EFFECT OF EQUIVALENCE RATIO ON KINETIC NITRIC OXIDE (NO) CONCENTRATION FOR VARIOUS CHARACTERISTIC RESIDENCE TIMES (A/F STOICHIOMETRIC = 16.3 AIR PREHEAT = 650°F) [6]

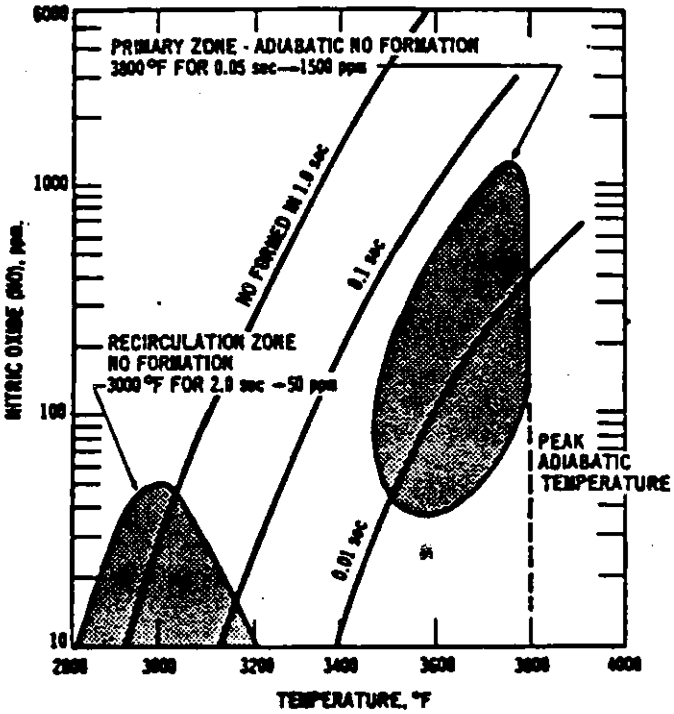


FIGURE 12-16 KINETIC NITRIC OXIDE (NO) FORMATION FOR COMBUSTION OF NATURAL GAS AT STOICHIOMETRIC MIXTURE RATIO, ATMOSPHERIC PRESSURE [6]

The reactions involved in the formation of NO_x from fuel nitrogen are not clearly known. However, variables such as time, oxygen concentration in the exhaust gas stream, and nitrogen content of the fuel are still the major factors which control the fuel NO_x formation.

The art of NO_x control can be classified into two major categories:

- physical modification of the boiler to control the peak combustion temperature or to control the amount of excess air, e.g. flue gas recirculation, and staged combustion; and

- chemical treatment of the flue gas, or the fuel used, e.g. selective catalytic reduction, selective non catalytic reduction, non selective catalytic reduction, and chemical/water injection.

12.1.4.2 Flue Gas Recirculation

Flue gas recirculation, a NO_x reduction method for a forced draft boiler, involves recycling a portion of the low oxygen combustion products from the stack to the windbox. The recirculated gases act as a thermal sink to reduce the overall combustion temperature. Other effects on NO_x may result from increased flame turbulence due to higher mass flow through the burner, lowered oxygen concentration in the incoming air, and alteration of the flame shape and the heat release characteristics. Flue gas recirculation can reduce thermal NO_x emissions by as much as 70% depending on the method of introduction of the recirculated flue gases and the amount of flue gas recirculation. Flue gas recirculation has a little if any affect on the formation of fuel NO_x.[9] Figure 12-17 shows how thermal NOx emission reductions vary with the amount of flue gas recirculation.[11]

There are many ways of introducing the recirculated flue gases; however, care must be taken to avoid operational limitations and problems. If the flue gases are brought into the suction side of the existing forced draft fan, the amount of recirculated flue gases will be limited by the fan capacity. Also, other problems, such as condensation, corrosion and a highly variable supply of the combustion air

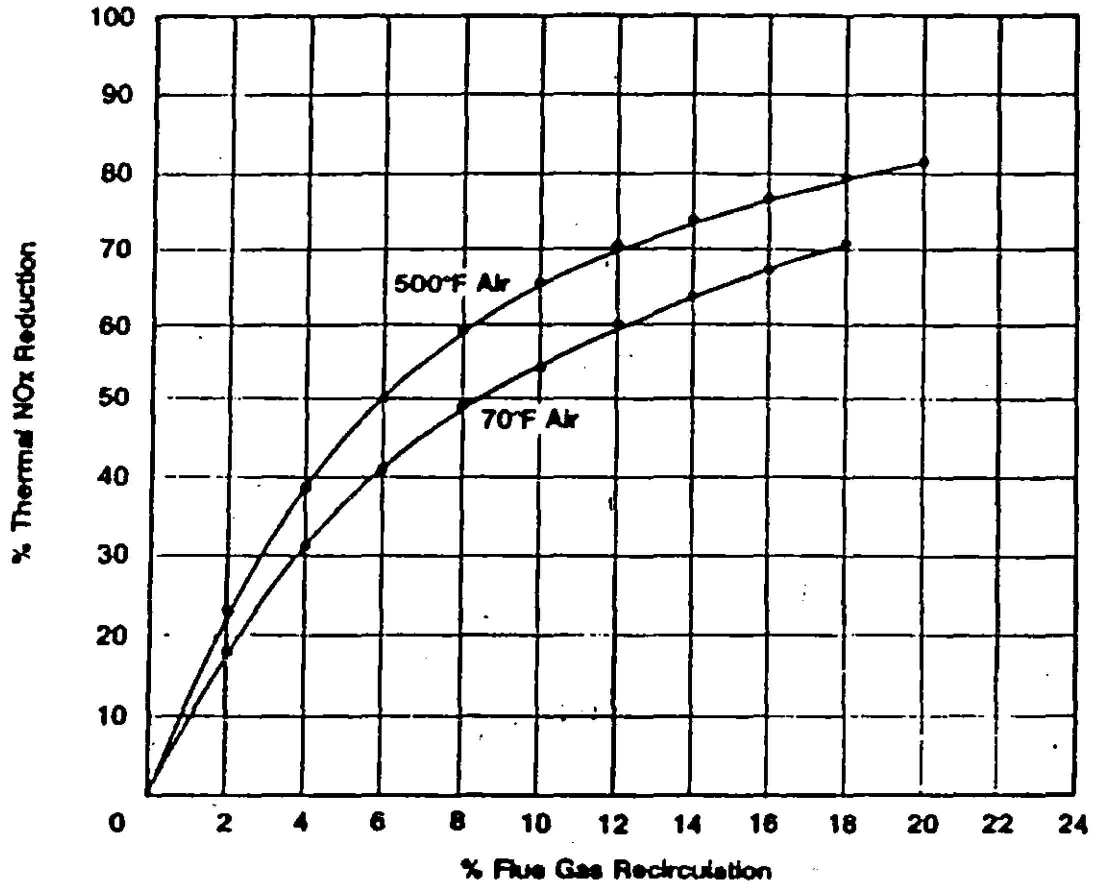


FIGURE 12-17 PERCENT THERMAL NOx REDUCTION VS. PERCENT FLUE GAS RECIRCULATION

can occur and reduce the capacity of the unit. To reduce these problems, Cleaver Brooks, a packaged boiler distributor, uses a separate blower to introduce the recirculated flue gases downstream of the burner and in a symmetrical arrangement wrapping around the flame. [9]

The amount of flue gas recirculation is also important since unstable combustion can occur at too high or too low recirculation rates. Cleaver Brooks recommends limiting natural gas combustion recirculation rate to 20% and fuel oil combustion recirculation rate to 10-12% at high fire. [9]

12.1.4.3 Staged Combustion

Staged combustion can achieve lower NO_x emissions by dividing the combustion process into a number of stages in which the air/fuel ratio is varied to create conditions to reduce NOx formation. There are two types of staged combustion: staged air combustion and staged fuel combustion. [9]

Staged air combustion seeks to control the formation of NO_x by staging the total amount of air required for combustion. A portion of the air is used to form a fuel-rich primary combustion zone in which all of the fuel is partially burned. Some heat from this incomplete combustion is transferred to the boiler tubes prior to the completion of combustion. Combustion is completed with the injection of the remainder of the combustion air in a secondary burnout zone downstream of the fuel-rich primary zone. Because some heat is transferred prior to the completion of combustion, peak combustion temperatures are lower with staged air combustion than with conventional combustion. Lower peak temperature reduces thermal NO_x formation. [11] Staged air combustion can be achieved by low-NOx burners, over-fire air ports, staged air lances, and for multiple burners, burners out of service or off-stoichiometric combustion.

Staged fuel combustion seeks to control the formation of NO_x by staging the amount of fuel required for combustion. In the primary combustion zone, the burners are operated with only a portion of the fuel; however, all of the "required" combustion air is added at this time. Since there is a high level of excess air, the peak combustion temperature is lowered and the NO_x formation is reduced. In the secondary combustion zone, the additional fuel is injected at high pressure and velocity to the combustion products from the primary zone. The entrained combustion products stimulate flue gas recirculation, further reduce the combustion temperature and reduce the partial pressure of oxygen in the secondary combustion zone to a level lower than would normally be encountered. This situation retards the formation of NO_x because of the decreased availability of oxygen.[9]

Staged fuel burners generally result in higher NO_x reductions than staged air burners. The majority of staged fuel burners are designed for firing with gas only; however, John Zink has designed an oil firing burner that utilizes both the staged air and staged fuel principles.[9]

12.1.4.4 Low Excess Air (LEA) Firing

The amount of NOx formation is effected by the amount of excess air in the combustion zone. Therefore, reducing the amount of excess air during combustion reduces NO_x formation. The amount of NOx reduction using LEA firing only is very modest.

Reducing excess oxygen in the flue gas by decreasing the air flow to the burner can lead to a rapid increase in CO, hydrocarbon, and smoke emissions. However, test data have shown that for both gas-fired and oil-fired boilers, as long as the excess air is maintained above 3%, these emissions are not increased.[7] In addition to reducing NO_x emissions, LEA is cost effective because it increases boiler efficiency by reducing the amount of energy needed to heat the excess air to the combustion temperature.

12.1.4.5 Reduced Air Preheat

Many industrial boilers are operated with preheated combustion air to increase the boiler efficiency. Unfortunately, preheated combustion air results in a higher flame temperature which can increase thermal NO_x emissions by 100 to 200 percent. Reducing or even eliminating the amount of preheated combustion air will lower the flame temperature and therefore lower the thermal NO_x formed.

12.1.4.6 Selective Non-Catalytic Reduction

When ammonia is injected in the absence of the catalyst, to reduce nitrogen oxide, the process is called selective non-catalytic reduction (SNCR). The technology involves the injection of ammonia into the hot flue gas within the prescribed temperature range (1800-2000 ^{O}F).

When ammonia is mixed with the flue gas at temperatures in the range of 1800 ^{O}F to 2000 ^{O}F, it reacts with NO_x to form nitrogen and steam based on the following reactions:

$$6\,NO + 4\,NH_3 = 5\,N_2 + 6\,H_2O \qquad \textbf{(Equation 12.3)}$$

$$6\,NO_2 + 8\,NH_3 = 7\,N_2 + 12\,H_2O \qquad \textbf{(Equation 12.4)}$$

12.1.4.7 Selective Catalytic Reduction

The reaction temperature described above can be significantly reduced by the use of a catalyst. This is the basis of the selective catalytic reduction (SCR) process. Ammonia, taken from the storage tank, is vaporized and, after being diluted with air or steam, is injected and mixed with the flue gas. The flue gas containing ammonia enters the reactor where it is distributed through the catalyst bed. The conventional SCR process is designed to treat the flue gas in the range of 600 ^{O}F - 800 ^{O}F. Within this temperature range, the catalyst has the optimum combination of activity and selectivity. An approximate equimolar ratio of ammonia to NO_x is required to achieve 90% NO_x emission reduction.[8] To recover the heat loss in the flue gas, an air preheater or economizer can be used.

12.1.4.8 Non-Selective Catalytic Reduction

When natural gas or other hydrocarbon is injected in the presence of a noble-metal catalyst to reduce nitrogen, carbon monoxide, and unburned hydrocarbon at the same time, the process is called non-selective catalytic reduction (NSCR).

12.1.4.9 Low NO_X Burners

Low NO_X burners may implement one or more of the following concepts: staged air combustion; staged fuel combustion; internal flue gas recirculation; external flue gas recirculation; and ceramic radiant combustion. Figure 12-18 shows a John Zink low NO_X burner which is a concept of staged air combustion: the primery stage is fuel-rich, air is added in the secondary stage to complete the combustion process at the lower temperature zone. The Coen low NO_X burner is also an example of the fuel rich burner. Coen low NO_X burners implement the concept of flue gas recirculation. The burner tip in the Coen low No_X burner is designed to inject fuel at an angle which results in self-recirculation of the combustion gas.[9] Hague Transjet manufactures a low-NOx burners using an internal FGR principle.

One disadvantage of staged-air low NO_X burners is that they tend to have a larger and longer flame compared to the conventional burner. This may result in flame impingement. Also, since some low NO_X burners are larger in size than conventional burners, there may be problems in retrofitting with low NO_X burners.[9]

12.1.4.10 Clean Fuels

Clean fuels such as natural gas and methanol contribute to the reduction of NO_X formation because 1) they are free from fuel bound nitrogen, also sulfur and ash, and 2) they have a lower flame temperature, hence, a lower potential for producing thermal NO_X. These clean fuels are also used in conjunction with water or steam injection and have been shown to reduce NO_X emission levels significantly relative to units firing fuel oil with water or steam injection.

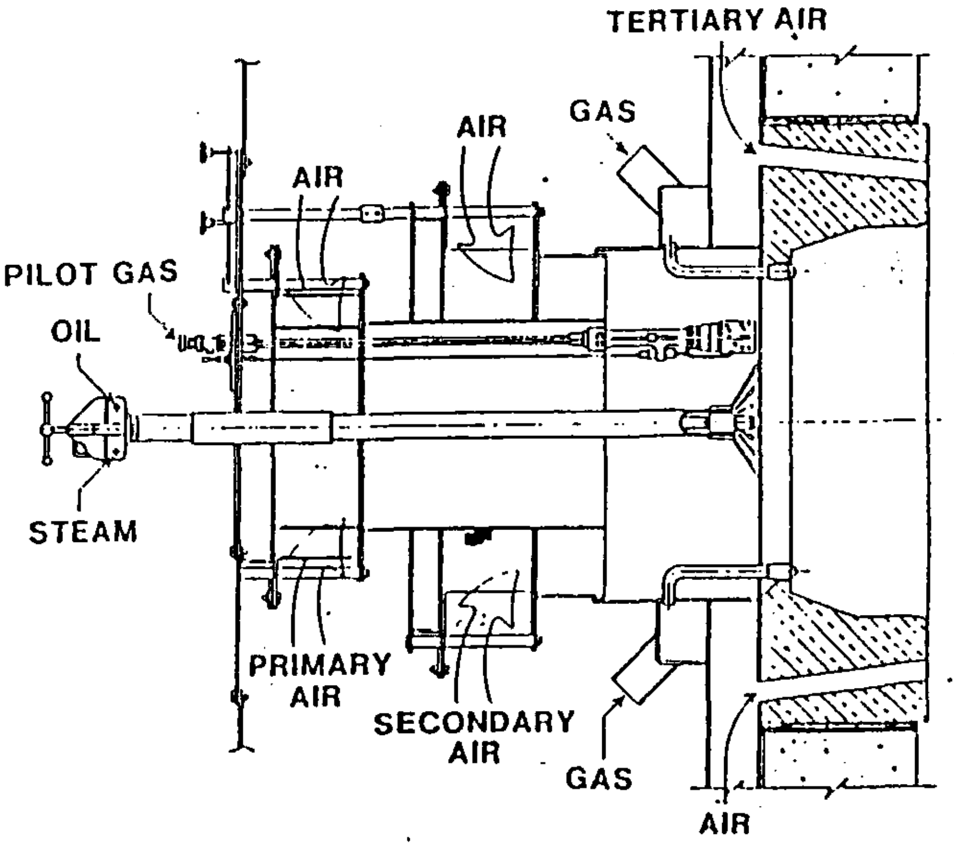


FIGURE 12-18 [12] STAGED AIR LOW-NOX BURNER

12.2 Permit Unit Description

Generally, the permit wording for a boiler is as follows:

BOILER, MANUFACTURER'S NAME, TYPE, MODEL NUMBER, SERIAL NUMBER, RATING IN BTU PER HOUR, TYPE OF BURNER, MANUFACTURER'S NAME, MODEL NUMBER, TYPE OF LOW-NOX BURNER, RATING IN HP OF FLUE GAS RECIRCULATION BLOWER, AND A MODULATED CONTROL VALVE OR RATING IN HP OF COMBUSTION AIR/FLUE GAS RECIRCULATION BLOWER.

12.3 Emissions

Air contaminants from boilers come from the combustion of fuels. These include oxides of nitrogen (NO_X), reactive organic gases (ROG), carbon monoxide (CO), oxides of sulfur (SO_X), and particulate matter (PM). NO_X formation is a function of temperature and pressure during the combustion process and the nitrogen content of the fuel. Sulfur compounds, essentially SO_2, are a function of the sulfur content of the fuel. The other contaminants, ROG, CO, and PM are primarily the result of incomplete combustion.

12.3.1 Emission Factors

12.3.1.1 Fuel Oils

Fuel oils are broadly classified into two major types: distillate and residual. Distillate oils (grade Nos. 1 and 2) are lighter (> 30 degrees API), more volatile, less viscous, have negligible ash and nitrogen contents, and usually contain less than 0.3 weight percent sulfur as compared to residual oil (grade Nos. 4, 5, and 6). No. 4 (Light) oil is similar to No. 1 and No. 2 oils in terms of viscosity and sulfur content but is heavier (< 30 degrees API) and has higher nitrogen content. Table 12-2 lists the emission factors for industrial and commercial boilers divided into distillate and residual oil categories.

Particulate emissions are dependent on the grade of the fuel fired. Combustion of lighter distillate oils result in significantly lower particulate emissions compared to heavier residual oils. As shown in Table 12-2, particulate emissions from boilers firing No. 6 oil can be described as a function of the sulfur content of the oil. Particulate emissions from boilers firing No. 6 oil can be reduced by reducing boiler load. Varying the boiler load has shown no significant particulate emission reductions for boilers firing any of the lighter grade oils.

Sulfur oxides emissions are dependent on the sulfur content of oil, and are not effected by boiler size, burner design, or grade of fuel being fired.

TABLE 12-2 UNCONTROLLED EMISSION FACTORS FOR FUEL OIL COMBUSTION EMISSION FACTOR RATING: A [a]

Boiler Type [b]	Particulate Matter[c] (PM) lb/10^3gal	Sulfur Oxides[d] (SO_x) lb/10^3gal	Carbon Monoxide[e] (CO) lb/10^3gal	Nitrogen Oxides[f] (NO_x) lb/10^3gal	Reactive Organic Gas[g] (ROG) lb/10^3gal	Non-reactive Organic Gas[g] (ROG) lb/10^3gal
Industrial Boilers						
Residual Oil	h	159S	5	55 [i]	1	0.28
Distillate Oil	2	144S	5	20	0.0052	0.2
Commercial Boilers						
Residual Oil	h	159S	5	55	0.475	1.13
Distillate Oil	2	144S	5	20	0.216	0.34

a. Reference 2

b. Boilers can be approximately classified according to their gross (higher) heat rate as shown below:
Industrial boilers: 10×10^6 to 100×10^6 Btu/hr
Commercial boilers: 0.5×10^6 to 10×10^6 Btu/hr

c. Particulate is defined in this section as that material collected by EPA Method 5 (front half catch)

d. S indicated that the weight percent of sulfur in the oil should be multiply by the value given

e. Carbon monoxide emissions can increase by factors of 10 to 100 if the unit is improperly operated or not well maintained

f. Test results indicate that at least 95% by weight of NO_x is NO for all boiler types except residential furnaces, where about 75% is NO

g. Reactive organic compound emissions are generally negligible unless boiler is improperly operated or not well maintained, in which case emissions may increase by several orders of magnitude

h. Particulate emission factors for residual oil combustion are, on the average, a function of fuel oil grade and sulfur content:
Grade 6 oil: 10(S) + 3 lb/10^3 gal, where S is the weight percent of sulfur in the oil. This relationship is based on 81 individual tests and has a correlation coefficient of 0.65
Grade 5 oil: 10 lb/10^3 gal
Grade 4 oil: 7 lb/10^3 gal

i. Nitrogen oxides emissions from residual oil combustion in industrial and commercial boilers are strongly related to fuel nitrogen content, estimated more accurately by the empirical relationship:
lb $NO_2/10^3$ gal = $22 + 400(N)^2$, where N is the weight percent of nitrogen in the oil. For residual oils having high (>0.5 weight %) nitrogen content, use 120 lb $NO_2/10^3$ gal as an emission factor

Nitrogen oxides are formed by two mechanisms: oxidation of fuel bound nitrogen and thermal fixation of the nitrogen from combustion air. Residual oils have more fuel bound nitrogen than distillate oil; therefore fuel bound nitrogen conversion is the important NO_x forming mechanism in residual oil boilers. Thermal fixation is the dominant NO_x forming mechanism in distillate oil boilers.

Reactive organic gases and carbon monoxide emissions are generally negligible unless the boiler is improperly poorly maintained.

12.3.1.2 Natural Gas

The primary component of natural gas is methane. Table 12-3 lists the uncontrolled emission factors for natural gas combustion. A negligible amount of carbon monoxide, hydrocarbon, and sulfur oxides are emitted from the combustion of natural gas. The air contaminants of concern are nitrogen oxides. Thermal fixation of the nitrogen in the combustion air is the major mechanism of formation of NO_x when burning natural gas.

12.3.1.3 Liquified Petroleum Gas

Liquified petroleum gas (LPG) consists of butane, propane, or the mixture of the two, and trace amounts of propylene and butylene. Table 12-4 lists the uncontrolled emission factors for LPG combustion.

As with natural gas, NO_x is the air contaminant of concern. Sulfur dioxide emissions are directly proportional to the amount of sulfur in the fuel. Particulate matter, sulfur oxides, and carbon monoxide emissions are small. Thermal NO_x is the major NO_x formation mechanism.

TABLE 12-3 UNCONTROLLED EMISSION FACTORS FOR NATURAL GAS COMBUSTION [a]

Boiler Type [b]	Particulate Matter (PM)	Sulfur Oxides[c] (SO_x)	Carbon Monoxide[d] (CO)	Nitrogen Oxides[e] (NO_x)	Reactive Organic Gas (ROG)	Non-reactive Organic Gas (nROG)
	$lb/10^6ft^3$	$lb/10^6ft^3$	$lb/10^6ft^3$	$lb/10^6ft^3$	$lb/10^6ft^3$	$lb/10^6ft^3$
Industrial Boilers	1-5	0.6	35	140	2.8	3.0
Domestic and Commercial Boilers	1-5	0.6	20	100	5.3	2.7

a. Reference 2

b. Boilers can be approximately classified according to their gross (higher) heat rate as shown below:
Industrial boilers: 10×10^6 to 100×10^6 Btu/hr
Domestic and Commercial boilers: $< 10 \times 10^6$ Btu/hr

c. Based on an average sulfur content of natural gas of 2000 $gr/10^6$ scf

d. May increase 10 to 100 times with improper operation or maintenance

e. Test results indicate that about 95 weight % of NO_x is NO

TABLE 12-4 UNCONTROLLED EMISSION FACTORS FOR LPG COMBUSTION [a, b]
EMISSION RATING: C

Boiler Type [c]	Particulate Matter (PM)	Sulfur Oxides[d] (SO_x)	Carbon Monoxide (CO)	Nitrogen Oxides[e] (NO_x)	Reactive Organic Gas (ROG)	Non-reactive Organic Gas[g] (ROG)
	$lb/10^3gal$	$lb/10^3gal$	$lb/10^3gal$	$lb/10^3gal$	$lb/10^3gal$	$lb/10^3gal$
Industrial Boilers						
Butane	0.10-0.47	0.09S	3.3	13.2	0.26	0.28
Propane	0.09-0.44	0.09S	3.1	12.4	0.25	0.27
Domestic and Commercial Boilers						
Butane	0.10-0.47	0.09S	1.9	9.4	0.5	0.25
Propane	0.09-0.44	0.09S	1.8	8.8	0.47	0.24

a. Reference 3

b. Assumes emissions (except sulfur oxides) are the same, on a heat input basis, as for nastural gas combustion

c. Boilers can be approximately classified according to their gross (higher) heat rate as shown below:
Industrial boilers: 10×10^6 to 100×10^6 Btu/hr
Domestic and Commercial boilers: $< 10 \times 10^6$ Btu/hr

d. Expressed as SO_2. S equals the sulfur content expressed in $gr/100ft^3$. For example, if sulfur content is 0.16 $gr/100ft^3$ vapor, the SO_2 emission factor would be 0.09 x 0.16 or 0.014 lb of SO_2/1000 gal) butasne burned

e. Expressed as NO_2

12.4 Calculations

12.4.1 Operational Data

In order to determine the compliance status of the boiler, the applicant will need to supply the following information:

Main Fuel:	
Backup Fuel:	
Operating Schedule:	
Maximum:	hr/day, day/week, week/year
Average:	hr/day, day/week, week/year
Burner Input:	BTU/hr
Combustion air blower capacity:	CFM
Average Load:	fraction

12.4.2 Emission Calculation

Emission of each air contaminant must be calculated for both the actual and maximum operating conditions. Actual emissions, based on the actual operating conditions, will be used in emission inventory. Maximum emissions, based on the equipment maximum design capacity and the type of fuel used (natural gas or backup fuel oil), will be used to determine compliance with the District's Rules and Regulations.

Actual and maximum hourly (lb/hr) emission rates must be converted into daily (lb/day) emission rates by multiplying the hourly rates by the equipment daily operational time factor (T, hr/day). In addition, the maximum daily emissions are multiplied by the Regulation XIII On-Site Offset Factor (i.e. 1.1). These daily emissions increase are accumulated for each facility in the SCAQMD's New Source Review (NSR) Record.

The emission of each air contaminant is calculated using emission factors listed in Table 12-2, Table 12-3, and Table 12-4. However, NOx emissions can be calculated more accurately by using exhaust concentration (ppm) which is either provided by the manufacturer or is available from source test data. Table 12-5 lists conversion factors for the most commonly used emission units [13].

Equations 12.6 and 12.7 are used to calculate the maximum emissions and actual emissions, respectively, by using the emissions factors.

$$R_{max} = (Q/H)(EF)(T_{max})(1.1) \qquad \textbf{(Equation 12.6)}$$

$$R_{act} = (Q/H)(L)(EF)(T_{act}) \qquad \textbf{(Equation 12.7)}$$

where:

R_{max} = Maximum Emissions, lb/day
R_{act} = Actual Emissions, lb/day
Q = Maximum Rated Input, BTU/hr or Gal/hr
H = Heating Value of Fuel, BTU/ft^3
EF = Emission Factor, lb/10^6 ft^3 or lb/10^3 gal
T_{max} = Maximum Operating Time, hr/day
T_{act} = Actual Operating Time, hr/day
L = Load Factor

12.5 Rules Evaluation

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing the permit.

Rule 401 - Visible Emissions
No visible emission of 20% opacity or Ringlemann No. 1 or more aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), odorous materials, and prior complaints.

TABLE 12-5 EMISSIONS UNITS CONVERSION FACTORS[13]

Multiply By / To Obtain	% Weight In Fuel	$\frac{\text{lbs}}{10^6 \text{ Btu}}$	$\frac{\text{grams}}{10^6 \text{ Cal}}$	(ppm) Vol. Dry Basis	$\frac{\text{grains}}{\text{SCF of Flue Gas}}$
% Weight In Fuel	1	$\frac{(A)(HV)}{10,000(M)}$	$\frac{(A)(HV)}{18,000(M)}$	$\frac{(A)(N)}{10,000}$	$\frac{(A)(N)(T_R)}{95.9(M)}$
$\frac{\text{lbs}}{10^6 \text{ Btu}}$	$\frac{10,000(M)}{(A)(HV)}$	1	$\frac{1}{1.8}$	$\frac{(M)(N)}{HV}$	$\frac{(N)(T_R)}{.00959(HV)}$
$\frac{\text{grams}}{10^6 \text{ Cal}}$	$\frac{18,000(M)}{(A)(HV)}$	1.8	1	$\frac{1.8(M)(N)}{HV}$	$\frac{(N)(T_R)}{.00533(HV)}$
(ppm) Vol. Dry Basis	$\frac{10,000}{(A)(N)}$	$\frac{HV}{(M)(N)}$	$\frac{HV}{1.8(M)(N)}$	1	$\frac{(T_R)}{.00959(M)}$
$\frac{\text{grains}}{\text{SCF of flue gas}}$	$\frac{95.9(M)}{(A)(N)(T_R)}$	$\frac{.00959(HV)}{(N)(T_R)}$	$\frac{.00533(HV)}{(N)(T_R)}$	$\frac{.00959(M)}{(T_R)}$	1

A = Atomic Weight of basic element considered: A = 14(Nitrogen), A = 32(Sulfur)

HV = Fuel higher heating value: Btu/lb of fuel

M = Molecular weight of oxide emitted from stack: M = 64(SO_2), M = 80(SO_3), M = 30(NO), M = 46(NO_2)

N = Moles of dry flue gas per pound of fuel. Typical values are:

Fuel	N 3% O_2	N 0% O_2	N 15% O_2	N 12% CO_2	HV (btu/lb)
Natural Gas	0.618	0.530	1.85	0.539	23,440
Fuel Oil	0.554	0.474	1.66	0.626	19,100
Coal	0.369	0.316	1.11	0.481	12,280

T_R = Standard Temperature in degrees Rankine used for defining SCF of flue gas: EPA T_R = 530°R, County APCD's T_R = 520°R.

Rule 404 - Particulate Matter - Concentration

Limits for particulate matter concentrations in an effluent gas stream at standard conditions are listed in Table 404(a) of the South Coast Air Quality Management District's Rules and Regulations. However, boilers are exempt from this per Section 404(c).

Rule 407 - Liquid and Gaseous Air Contaminants

A person shall not discharge into the atmosphere from any equipment: (1) Carbon monoxide (CO) in excess of 2,000 ppm by volume on a dry basis. (2) Sulfur compounds which would exist as a liquid or gas at standard conditions, calculated as sulfur dioxide (SO_2), in excess of 500 ppm.

Rule 409 - Combustion Contaminants

A person shall not discharge into the atmosphere from the burning of fuel, combustion particulate matter emissions in excess of 0.1 grain per cubic foot of gas calculated to 12 percent carbon dioxide (CO_2) at standard conditions.

Rule 431.1 - Sulfur Content Of Gaseous Fuels

Gaseous fuels containing more than 80 ppm of Hydrogen Sulfide are not allowed to be used in this equipment.

Rule 431.2 - Sulfur Content Of Liquid Fuels

The sulfur content of an diesel fuel burned must not exceed 0.05% by weight. Other liquid fuels are limited to 0.5% by weight.

Rule 1146 - Emissions Of Oxides Of Nitrogen From Industrial, Institutional, And Commercial Boilers, Steam Generators, And Process Heaters

According to Rule 1146(c)(1), the NO_x emission limit for boilers with a rated heat input capacity equal to or greater than 5 MMBTU/hr, and an annual heat input greater than 9×10^9 BTU/yr is 40 ppm dry, corrected to 3% O_2 and averaged over a 15 minute period.

Boilers that have an annual heat input less than or equal to 9×10^9 BTU/yr do not have to meet the NO_x limit provided one of the following criteria, as listed under Rule 1146(c)(2), is satisfied:

A) The boilers are operated with an exhaust oxygen concentration of less than or equal to 3 percent on a dry basis averaged over any 15-consecutive minute period; or

B) The boilers are tuned once during the second quarter and the fourth quarter each year according to prescribed procedures; or

C) The boilers emit less than or equal to 40 ppm NOx and 400 ppm CO.

Regulation XIII - New Source Review

(1) If the new causes an increase in emissions in excess of one pound per day for any non attainment air contaminant, or if modified equipment causes a greater than one pound per day increase, Best Available Control Technology (BACT) is required.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[10] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should be consulted to properly determine both applicability and BACT which may be different from case to case.

Table 12-6, 12-7, and 12-8 list the most current BACT for different categories of boilers.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant must certify in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

TABLE 12-6 BEST AVAILABLE CONTROL TECHNOLOGY FOR BOILERS[10]

Equipment or Process: Boiler – Forced Draft
Equipment Rating: ≤ 4 MM BTU/Hr

Revision: 1
Date: 9/06/89

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1,3]		1. 30 ppm, Dry, Corrected to 3% O_2 2. 40 ppm, Dry, Corrected to 3% O_2			
BACT Achieved in Practice or Contained in EPA Approved SIP[2]		100 ppm, Dry, Corrected to 3% O_2	Natural Gas or Treated Refinery Gas with < 100 ppm Sulfur Bearing Compounds as Hydrogen Sulfide		Natural Gas or Treated Refinery Gas
BACT For Small Business[1,3]		1. 30 ppm, Dry, Corrected to 3% O_2 2. 40 ppm, Dry, Corrected to 3% O_2 3. 100 ppm, Dry, Corrected to 3% O_2	Natural Gas or Treated Refinery Gas with < 100 ppm Sulfur Bearing Compounds as Hydrogen		Natural Gas or Treated Refinery Gas
Alternate Basic Equipment or Process[1]					
BACT - SCAQMD Board's Clean Fuel Policy[2]		Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology	Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology		Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology

1. Requires Economic Analysis
2. No Economic Analysis
3. Control technologies are in descending order of efficiency. The most efficient control technology must be considered first when conducting an economic analysis.

TABLE 12-7 BEST AVAILABLE CONTROL TECHNOLOGY FOR BOILERS [10]

Equipment or Process: Boiler - Natural Draft
Equipment Rating: ≤ 4 MM BTU/Hr

Revision: 1
Date: 9/06/89

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1]					
BACT Achieved in Practice or Contained in EPA Approved SIP[2]		100 ppm, Dry, Corrected to 3% O_2	Natural Gas or Treated Refinery Gas with < 100 ppm Sulfur Bearing Compounds as Hydrogen Sulfide		Natural Gas or Treated Refinery Gas
BACT For Small Business[1]		100 ppm, Dry, Corrected to 3% O_2	Natural Gas or Treated Refinery Gas with < 100 ppm Sulfur Bearing Compounds as Hydrogen		Natural Gas or Treated Refinery Gas
Alternate Basic Equipment or Process[1]		Forced Draft Boiler			
BACT - SCAQMD Board's Clean Fuel Policy[2]		Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology	Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology		Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology

1. Requires Economic Analysis
2. No Economic Analysis

TABLE 12-8 BEST AVAILABLE CONTROL TECHNOLOGY FOR BOILERS[10]

Equipment or Process: Boiler
Equipment Rating: > 4 MM BTU/Hr Thru < 33.5 MM BTU/Hr

Revision:
Date: 10/07/88

	ROG	NOx	SOx	CO	PART.
BACT Technologically Feasible[1,3]		1. 9 ppm, Dry, Corrected to 3% O_2 2. > 9 ppm but < 30 ppm, Dry, Corrected to 3% O_2 3. 30 ppm, Dry, Corrected to 3% O_2			
BACT Achieved in Practice or Contained in EPA Approved SIP[2]		40 ppm, Dry, Corrected to 3% O_2	Natural Gas or Treated Refinery Gas with < 100 ppm Sulfur Bearing Compounds as Hydrogen Sulfide		Natural Gas or Treated Refinery Gas
BACT For Small Business[1,3]		1. 9 ppm, Dry, Corrected to 3% O_2 2. > 9 ppm but < 30 ppm, Dry, Corrected to 3% O_2 3. 30 ppm, Dry, Corrected to 3% O_2 4. 40 ppm, Dry, Corrected to 3% O_2	Natural Gas or Treated Refinery Gas with < 100 ppm Sulfur Bearing Compounds as Hydrogen Sulfide		Natural Gas or Treated Refinery Gas
Alternate Basic Equipment or Process[1]					
BACT - SCAQMD Board's Clean Fuel Policy[2]		Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology	Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology		Methanol or Other Equivalent Clean Fuels as Standby Fuel or Equivalent Control Technology

1. Requires Economic Analysis
2. No Economic Analysis
3. Control technologies are in descending order of efficiency. The most efficient control technology must be considered first when conducting an economic analysis.

12.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, the following conditions must be required:

1. THIS BOILER MUST BE FIRED ON NATURAL GAS ONLY, EXCEPT DURING PERIODS OF NATURAL GAS CURTAILMENT AND DURING TESTING WITH THE STAND-BY FUEL NOT TO EXCEED 1/2 HOUR PER MONTH.

2. FUEL OIL SUPPLIED AT THE BURNER MUST BE NO. 2 OR LIGHTER GRADE AS DESCRIBED BY THE LATEST ASTM SPECIFICATIONS AND MUST HAVE A SULFUR CONTENT OF NOT MORE THAN 0.05 PERCENT BY WEIGHT.

3. A NON-RESETABLE, TOTALIZING METER MUST BE INSTALLED IN EACH FUEL SUPPLY LINE.

4. THIS BOILER MUST NOT HAVE A HEAT INPUT OF MORE THAN ______ BTUS IN ANY ONE DAY.

5. THE BOILER MUST NOT BURN MORE THAN __________ CUBIC FEET OF NARURAL GAS IN ANY ONE DAY.

6. THE (FLUE GAS RECIRCULATION SYSTEM)(AND THE OXYGEN TRIM SYSTEM) MUST BE IN FULL OPERATION WHENEVER THIS BOILER IS IN OPERATION.

7. WHENEVER THE BOILER STACK TEMPERATURE EXCEEDS _____ DEGREES FAHRENHEIT, THE FLUE GAS RECIRCULATION SYSTEM MUST BE IN FULL USE AND THE OXIDES OF NITROGEN EMISSIONS FROM THE BOILER MUST NOT EXCEED ______ PPM, ON A DRY BASIS CORRECTED TO 3 PERCENT OXYGEN AND AVERAGED OVER 15 CONSECUTIVE MINUTES.

8. CARBON MONOXIDE EMISSSIONS FROM THIS BOILER MUST NOT EXCEED _______ PPM, ON A DRY BASIS CORRECTED TO 3 PERCENT OXYGEN AND AVERAGED OVER 15 CONSECUTIVE MINUTES.

9. RECORDS MUST BE MAINTAINED TO PROVE COMPLIANCE WITH CONDITIONS 1, 2, 4, 5, AND 6 IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT OF THE DISTRICT. THE RECORDS MUST BE KEPT ON FILE FOR AT LEAST TWO YEARS AND MADE AVAILABLE TO THE DISTRICT PERSONNEL UPON REQUEST.

REFERENCES

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2. Compilation of Air Pollutant Emission Factors, AP 42, Section 1.3, 1.4, and 1.5, 4th Edition, Sept. 1985.

3. Steam, Its Generation and Use, Babcock & Wilcox, 2nd Edition, 1978.

4. Manual For Improving Boiler and Furnace Performance, T. Garcia-Borras, Gulf Publishing Company, 1983.

5. Air Pollution, Its Origin and Control, K. Wark, and C. F. Warner, Harper & Row, Publishers, New York, 1981.

6. Air Pollution Engineering Manual, AP 40, 2nd Edition, May 1973.

7. Energy Saving By Increasing Boiler Efficiency, L. H. Yaverbaum, Noyes Data Corporation, 1979.

8. Technology Assessment Report for Industrial Boiler Applications: NO_x Combustion Modification, K. J. Jim et. al, Report No. EPA-600/7-79-178f.

9. Rule 1146 Implementation Workshop, March 23, 1989.

10. South Coast Air Quality Management District (SCAQMD) Best Available Control Technology (BACT) Guidelines, October 7, 1988.

11. A Suggested Control Measure for The Control of Emissions of Oxides of Nitrogen from Industrial, Institutional, and Commercial Boilers, Steam Generators and Process Heaters, Air Resource Board and South Coast Air Quality Management District, April 19, 1987.

12. Combustion Evaluation, APTI Course 427, EPA 450/2-80-063, February 1980.

13. Application of Combustion Modifications to Control Pollutant Emissions from Industrial Boilers - Phase I, Report No. EPA-650/2-74-086a.

APPENDIX 12A

WORKSHEET FOR BOILERS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 5	PAGE 1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

Applicability: This processing form can only be used for industrial and commercial boilers with steam output less than 30 x 10^6 Btu/hr.

APPLICANT'S NAME :

MAILING ADDRESS :

EQUIPMENT LOCATION :

EQUIPMENT DESCRIPTION

APPLICATION NO. ____________

BOILER, , (WATERTUBE) (FIRETUBE) (SECTIONAL) TYPE, MODEL NO , SERIAL NO , BTU/HR, WITH , MODEL NO , (GAS)(OIL)(PROPANE)(BUTANE)(METHANOL) BURNER, (STAGED-AIR)(STAGED-FUEL)(INTERNAL FLUE GAS RECIRCULATION) (CERAMIC) LOW-NOX BURNER, WITH A HP FLUE GAS RECIRCULATION BLOWER AND MODULATED CONTROL VALVE (OR WITH A HP COMBUSTION AIR/FLUE GAS RECIRCULATION BLOWER).

HISTORY

The boiler will be installed in .

PROCESS DESCRIPTION

is an company. The boiler is used to provide (steam)(hot water) for . The boiler is operated on (natural gas)(oil) (propane)(butane) only. The maximum rating capacity is BTU/hr. The maximum operating schedule is hours/day, days/week, weeks/year.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT	PAGES 5	PAGE 2
ENGINEERING DIVISION	APPL. NO.	DATE
APPLICATION PROCESSING AND CALCULATIONS	PROCESSED BY	CHECKED BY

EMISSION CALCULATION

DATA		VALUE	NOTE
Fuel used : Natural Gas/Fuel oil			
Heating Value of Fuel (BTU/ft^3)	H1	______	1
(in BTU/lb)	H2	______	3
Sulfur Content Of Fuel (grain/ft^3)	S	______	4
Emission Factor (lb/10^6ft^3 or lb/10^3gal)	EF		
ROG		______	2
NO_x		______	2
SO_x		______	2
CO		______	2
PM		______	2
UNROG		______	2
Maximum Concentration (ppm)	C	______	4
Maximum Rated Input (MMBTU/hr)	Q	______	4
Average Load Factor	L	______	4 or 5
Operating Schedule			
Maximum (hr/dy, dy/wk, wk/yr)	T_m	______	4 or 5
Actual (hr/dy, dy/wk, wk/yr)	T_a	______	4 or 5

NOTE:
1. AP 42, 4th Edition, App. A
2. AP 42, 4th Edition, Table 1.4-1
3. Reference 11
4. Given by Applicant
5. Assumption.

CALCULATIONS

1. Emissions

Uncontrolled (R_1) emissions must be multiplied by a load factor (L) and/or an appropriate operating time factor (T) to determine actual and maximum hourly or daily emissions. (New Source Review (NSR) Emissions = Maximum daily x 1.1)

$$R_1 = Q/H1\ (x\ L)\ x\ EF\ (x\ T_a \text{ or } T_m)$$

For NOx:

$$R_{2,NOX} = C\ x\ Q/H2\ (x\ L)\ x\ MW\ x\ N_{(@3\%\ Excess\ O2)}\ (x\ T_a \text{ or } T_m)$$

$$R_{1,NOx} = \frac{R_{2,NOx}}{(1 - EFF)}$$

2. Rule 407 Calculation:
Converting R_1 of CO/SO_2 from (lb/hr) to (ppm)

$$CO/SO_2\ (ppm) = \frac{R_1}{Q/H2 \times MW \times N_{@3\%\ Excess\ O2}}$$

3. Rule 409 Calculation:
Converting R_1 of PM from (lb/hr) to (grain/ft^3)

$$PM\ (grain/ft^3) = \frac{R_1 \times 0.00959}{Q/H2 \times T \times N_{@12\%\ CO2})}$$

where:
R_1 = Uncontrolled Emission Rate, (lb/hr).
R_2 = Controlled Emission Rate, (lb/hr).
EF = Emission Factor, (lb/10^6ft^3 or lb/10^3gal).
EFF = Efficiency of Equipment.
H1 = Heating Value of Fuel, (BTU/ft^3).
H2 = Heating Value of Fuel, (BTU/lb).
T_a = Maximum Operating Time, (hr/dy).
T_m = Actual Operating Time, (hr/dy).
L = Load Factor, (fraction).
Q = Maximum Rated Input, (MMBTU/hr).
MW = Molecular Weight of Air Contaminant
N = Moles of Dry Flue Gas per Pound of Fuel (Table 12-5, p.34)
T = Standard Operating Temperature, 530°R

RESULTS

Uncontrolled Emissions

	Actual (lb/hr)	Maximum (lb/hr)	Maximum (lb/day)	NSR (lb/day)
$R_{1,ROG}$				
$R_{1,NOx}$				
$R_{1,SOx}$				
$R_{1,CO}$				
$R_{1,PM}$				

Controlled Emissions

$R_{2,NOx}$				

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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RULES EVALUATION

RULE 212 Public notice is (is not) required.

RULE 401 With proper operation and maintenance,the boiler is (is not) expected to comply with Rule 401.

RULE 402 No nuisance complaints are on file against this applicant, and none is expected provided that the operation is conducted according to submitted procedures. Compliance with Rule 402 is (is not) expected.

RULE 404 This boiler is exempt from Rule 404 per Section 404(c).

RULE 407 The rule allows a CO concentration of 2,000 ppm and a SO_x concentration of 500 ppm in the gas discharged to the atmosphere. Calculations show a CO concentration of ______ ppm, and a SO_x concentration of ______ ppm. Compliance with this rule 407 is (is not) expected.

RULE 409 The rule allowes a combustion particulate matter emission concentration of 0.1 grain/dscf. Calculations show a concentration of ______ grains/dscf. Compliance with Rule 409 is (is not) expected.

RULE 431.2 Compliance is met by the use of less than 0.5% by wt. sulfur fuel oil.

RULE 1146 The rule allows a NOx concentration of 40 ppm and a CO concentration of 400 ppm in the gas discharged to the atmosphere. Calculations show a NO_x concentration of ______ ppm, and a CO concentration of ______ ppm. Compliance with this Rule 1146 is (is not) expected.

REGULATION XIII

Rule 1303 - Applicability and Analysis.

[] As shown by the Emission Threshold/New Source Sheet Table below, this equipment emits more than 1 lb/day increase of NOx and CO, it is subject to BACT.

[] As shown by the Emission Threshold/New Source Sheet Table below, the net emission increase from the facility exceeds the threshold limit specified in 1303(a)(2). Therefore, the following steps are required in addition to BACT:
    () The company must obtain offsets from other facilities.
    () The company must use a mathematical model approved by the District's Executive Officer to assess the impact of the plant on the area around it.
    () The company must certify in writing that all of its facilities in the state that emits 25 tons per year or more of NOx and CO comply with federal, state, and local air quality laws.

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	NSR Emissions in Pounds per Day				
	RHC	NOx	SO_2	CO	PM
Facility Emissions since 10-8-76	----	----	----	----	----
A/N	----	----	----	----	----
Net Emission increase since 10-8-76	----	----	----	----	----

BACT Technologically Feasible for NO_x (BACT Guideline, Date 10/07/88) are as follows:

Boiler size	BACT
≤ 4 MM BTU/HR	1. 30 ppm, dry, corrected to 3% O_2 2. 40 ppm, dry, corrected to 3% O_2
> 4 MM BTU/HR < 33.5 MM BTU/HR	1. 9 ppm, dry, corrected to 3% O_2 2. > 9 ppm but < 30 ppm, dry, corrected to 3% O_2 3. 30 ppm, dry, corrected to 3% O_2

- NO_x emission at 9 ppm or larger than 9 ppm but less than 30 ppm could be achieved by using Selective Catalytic Reduction (SCR) or Selective Non-Catalytic Reduction (SNCR).

  In SNCR, the ammonia is injected into the flue gas at the temperature between 1,600-2,200 °F to form N_2 and H_2O. This reaction depends strongly on temperature. Above 2,200 °F, NH_3 will react with O_2 to form NO_x. Below 1,600 °F, the rate of reaction is very slow. Therefore, the location of NH_3 injection becomes crucial. For large utility boiler, various injection points along the boiler furnace are required to accommodate for different boiler load. This is NOT FEASIBLE for small boiler.

  The economic analysis described in "Evaluation of Control Technologies for Hazardous Air Pollutant", EPA-600/7-86-009a, Feb. 1986, is used to determine the annualized cost of SCR. Attachment A shows a detailed cost analysis for this boiler.

- NO_x emission equal to 30 ppm could be achieved by operating the boiler at high FGR rates. Since the boiler is equipped with a flue gas recirculation system and an oxygen trim system, there is no need for an economic analysis.

BACT Achieved in Practice for SO_x, CO, and PM (from BACT Guideline, Dated 10/07/88) are as follows:

ROG	None
SO_x	Natural Gas
CO	None
PM	Natural Gas

Since natural gas is used as a main fuel, this boiler has BACT Achieved in Practice for SO_x & PM.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

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APPLICATION PROCESSING AND CALCULATIONS

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CONCLUSIONS/RECOMMENDATIONS

This boiler is expected to comply with all applicable District Rules and Regulations. A Permit to Operate is recommended subject to the following condition(s):

1. THIS BOILER MUST BE FIRED ON NATURAL GAS ONLY, EXCEPT DURING PERIODS OF NATURAL GAS CURTAILMENT AND DURING TESTING WITH THE STAND-BY FUEL NOT TO EXCEED 1/2 HOUR PER MONTH.

2. FUEL OIL SUPPLIED AT THE BURNER MUST BE NO. 2 OR LIGHTER GRADE AS DESCRIBED BY THE LATEST ASTM SPECIFICATIONS AND MUST HAVE A SULFUR CONTENT OF NOT MORE THAN 0.05 PERCENT BY WEIGHT.

3. A NON-RESETABLE, TOTALIZING METER MUST BE INSTALLED IN EACH FUEL SUPPLY LINE.

4. THIS BOILER MUST NOT HAVE A HEAT INPUT OF MORE THAN ______ BTUS IN ANY ONE DAY.

5. THE BOILER MUST NOT BURN MORE THAN __________ CUBIC FEET OF NATURAL GAS IN ANY ONE DAY.

6. THE (FLUE GAS RECIRCULATION SYSTEM)(AND THE OXYGEN TRIM SYSTEM) MUST BE IN FULL OPERATION WHENEVER THIS BOILER IS IN OPERATION.

7. WHENEVER THE BOILER STACK TEMPERATURE EXCEEDS _____ DEGREES FAHRENHEIT, THE FLUE GAS RECIRCULATION SYSTEM MUST BE IN FULL USE AND THE OXIDES OF NITROGEN EMISSIONS FROM THE BOILER MUST NOT EXCEED _____ PPM, ON A DRY BASIS CORRECTED TO 3 PERCENT OXYGEN AND AVERAGED OVER 15 CONSECUTIVE MINUTES.

8. CARBON MONOXIDE EMISSIONS FROM THIS BOILER MUST NOT EXCEED PPM, ON A DRY BASIS CORRECTED TO 3 PERCENT OXYGEN AND AVERAGED OVER 15 CONSECUTIVE MINUTES.

9. RECORDS MUST BE MAINTAINED TO PROVE COMPLIANCE WITH CONDITIONS 1, 2, 4, 5, AND 6 IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT OF THE DISTRICT. THE RECORDS MUST BE KEPT ON FILE FOR AT LEAST TWO YEARS AND MADE AVAILABLE TO THE DISTRICT PERSONNEL UPON REQUEST.

ATTACHMENT A

ECONOMIC ANALYSIS

ATTACHMENT A

ECONOMIC ANALYSIS

I. CAPITAL COST

				(Ref.)
SCR		=	-------	(1)
Heat Exchanger		=	-------	(1)
TOTAL_1		=	-------	
Sale tax	(6.5% x TOTAL_1)	=	-------	
Contingency	(3% x TOTAL_1)	=	-------	
Freight cost	(3% x TOTAL_1)	=	-------	
TOTAL_2		=	-------	
Capital Recovery Factor		=	0.163	
Annualized Cost		=	(0.163) (TOTAL_2)	
		=	X_1	

II. DIRECT OPERATING COST

Maintenance cost	=	-------	(1)
Ammonia cost	=	-------	(1)
Utility cost for fan	=	-------	(1)
Utility cost for heater	=	-------	(1)
Catalyst replacement cost	=	-------	(below)
TOTAL	=	X_2	

(Catalyst replacement cost:
The replacement cost for catalyst and the catalyst life (#yr) are provided by applicant. Assuming the life of the plant is 10 years, interest rate is 10%, the annualized replacement cost of catalyst is:

$$(\$\ \text{Cat.})\ [(P/F)^{\#yr} + (P/F)^{\#yr+2} + (P/F)^{\#yr+4} + (P/F)^{\#yr+6}])\ (A/P)^{10} =$$

$$(\$\ \text{Cat.})\ [0.8264 + 0.6830 + 0.5645 + 0.4665])\ (0.1627) = \$\ \text{----})$$

III. INDIRECT OPERATING COST

Overhead	(80% x (Maint.+Repl.))	=	-------	(2, p.5-46)
Property tax	(1% x TOTAL_2)	=	-------	(2, p.5-46)
Insurance	(1% x TOTAL_2)	=	-------	(2, p.5-46)
Administration	(2% x TOTAL_2)	=	-------	(2, p.5-46)
TOTAL		=	X_3	

IV. COST EFFECTIVENESS CALCULATION

Total annualized cost: $(X_1 + X_2 + X_3) = Y$

NOx reduction:
(85-9 ppm)(0.00121 lb/MMBTU-ppm)(Q MMBTU/hr)(8736 hr/yr)
(1 ton/2000lb) = Z ton/year

Cost effectiveness factor: $\frac{Y}{Z} =$ \$ ---- /ton NOx reduced

SCR therefore is (is not) COST EFFECTIVE.

REFERENCES

(1) Applicant Statement.

(2) Evaluation of Control Technologies for Hazardous Air Pollutant, EPA-600/7-86-009a, February 1986

APPENDIX 12B

ECONOMIC ANALYSIS

ECONOMIC ANALYSIS

I. CAPITAL COST

				NOTE
SCR		=	______	(1)
Heat Exchanger		=	______	(1)
TOTAL$_1$00		=	______	
Sale tax	(6.5% x TOTAL$_1$)	=	______	
Contingency	(3% x TOTAL$_1$)	=	______	
Freight cost	(3% x TOTAL$_1$)	=	______	
TOTAL$_2$		=	______	
Capital Recovery Factor		=	0.163	
Annualized Cost		=	(0.163)(TOTAL$_2$)	
		=	X_1	

II. DIRECT OPERATING COST

Maintenance cost	=	______	(1)
Ammonia cost	=	______	(1)
Utility cost for fan	=	______	(1)
Utility cost for heater	=	______	(1)
Catalyst replacement cost	=	______	(below)
TOTAL	=	X_2	

(Catalyst replacement cost:
The replacement cost for catalyst is (Ref. (1)) and the catalyst life is 2 years (p.C-3). Assuming the life of the plant is 10 years, interest rate is 10%, the annualized replacement cost of catalyst is:

(Ref.(1) $[(P/F)^2 + (P/F)^4 + (P/F)^6 + (P/F)^8]) (A/P)^{10}$ =
(Ref.(1) $[0.8264 + 0.6830 + 0.5645 + 0.4665]) (0.1627)$ = $______)

III. INDIRECT OPERATING COST

			NOTE
Overhead (80% x (Maint.+Rep.l))	=	______	(2, p.5-46)
Property tax (1% x TOTAL$_2$)	=	______	(2, p.5-46)
Insurance (1% x TOTAL$_2$)	=	______	(2, p.5-46)
Administration (2% x TOTAL$_2$)	=	______	(2, p.5-46)
TOTAL	=	X_3	

IV. COST EFFECTIVENESS CALCULATION

Total annualized cost: $(X_1 + X_2 + X_3) = Y$

NOx reduction:
(85-9 ppm)(0.00121 lb/MMBTU-ppm)(Q MMBTU/hr)(8736 hr/yr)
(1 ton/2000lb) = Z ton/year

Cost effectiveness factor: $\frac{Y}{Z}$ = $______/ton NOx reduced

SCR therefore is (is not) COST EFFECTIVE.

REFERENCES

1. Applicant Statement.

2. Evaluation of Control Technologies for Hazardous Air Pollutant, EPA-600/7-86-009a, February 1986

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Section 13

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

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SECTION 13: DEGREASERS

13.1 General Description

Degreasers remove grease, fats, oils, water, reflow solder, waxes, tar and like materials from all type of metals and other nonporous surfaces by means of an organic solvent and mechanical action. They are typically used where a subsequent process requires a metal surface to be cleaned and free of foreign substance such as prior to painting, plating, welding, glueing, etc. A degreasing process is usually chosen when satisfactory cleaning of metals or other nonporous surfaces can not be obtained using water or detergent solutions. Degreasing can be used in any stage of metal fabricating where the metal surface needs to be left clean and dry. Degreasing simplifies cleaning operations because it cleans by solvent and mechanical action instead of chemical action. Thus, there is little danger of physical damage from any chemical or corrosive reaction between the solvent and the metals present.

Degreasing operating conditions vary with the application and depend on the item being cleaned. Degreasing is usually performed at atmospheric pressure using solvent at temperatures ranging from 50 ^{o}F to 248 ^{o}F (10 ^{o}C to 120 ^{o}C); the boiling point of the solvent determines this operating temperature. There are five degreasing solvents commonly used within the South Coast air basin: perchloroethylene (PERC), trichlorotrifluoroethane, methylene chloride, trichloroethylene (TCE), and 1,1,1-trichloroethane. Degreasers may be used to clean non-metals, plastics, glass, and all of the common industrial metals, including malleable, ductile, and gray cast iron; carbon and alloy steel; stainless steel; copper; brass; bronze; zinc; aluminum; magnesium; tin; lead; nickel; and titanium.[1] The degreasing process is adaptable to items of a wide range of sizes and shapes, ranging from electronic components to aircraft sections.

The types of common degreasing equipment used in the District are cold cleaners, open top vapor degreasers, and conveyorized vapor degreasers. Cold cleaning operations involve using organic solvents at room temperature. The cold cleaner, shown in Figure 13-1, is usually the simplest and least expensive, consisting of a tank of solvent that may include a cover for nonuse periods and a work surface or basket

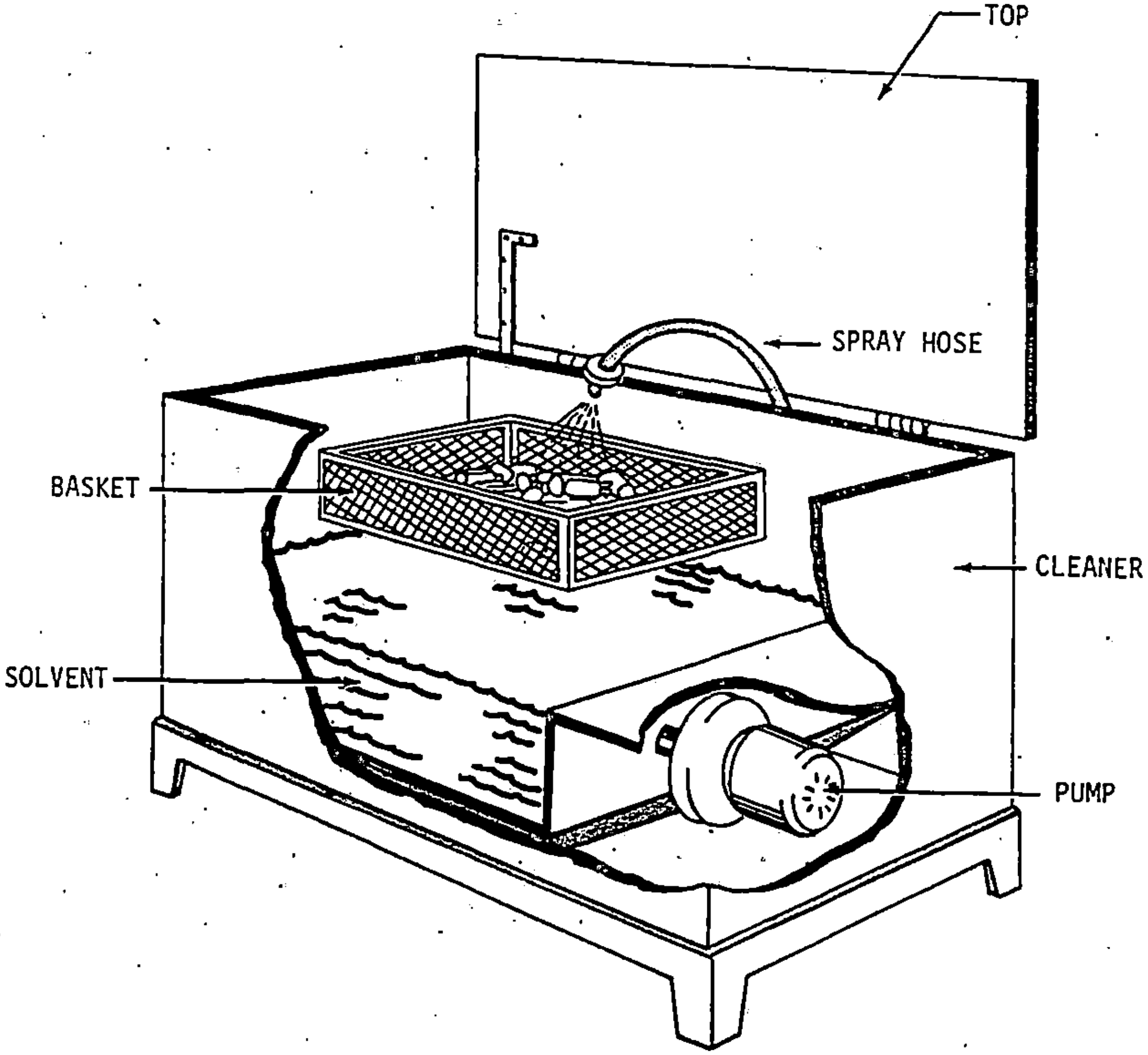


FIGURE 13-1 COLD CLEANER[3]

suspended over the solvent. Cold cleaning methods include wiping, spraying, or dipping of parts in a solvent. In open top vapor degreasing, a part is exposed with solvent in the vapor phase. An open top vapor degreaser, shown in Figure 13-2, resembles a large cold cleaner, but the solvent is heated to its boiling point. This heating creates a vapor zone of solvent confined by a set of cooling coils. Both the cold cleaner and the open top vapor degreaser clean individual batches of parts; thus, they are called "batch loaded." Conveyorized vapor degreasing incorporates the same activity as open top vapor degreasing and cold cleaning, except the parts to be cleaned, continuously move in and out of the degreaser.[3] This type of degreaser is primarily used in a high production environment.

When assessing emissions from degreasing and their environmental effects, the type of degreasing operation and the solvent used in the process determines the amount of emissions and their environmental impact. The type of plant in which the degreasing operation is performed has no effect. Therefore, emissions from degreasing have been assessed on the basis of the type of degreasing performed and the type of solvent used, not on the location and nature of the plant.

The sources of reactive hydrocarbon (RHC) or reactive organic gas (ROG) emissions into the atmosphere from each type of degreasing are: (1) cold cleaning (Figure 13-3) - bath evaporation, solvent carryout, agitation, spray evaporation, and waste solvent evaporation; (2) open top vapor degreasing (Figure 13-4) - diffusion, solvent carryout, turbulence, and waste solvent evaporation; and (3) conveyorized cold or vapor degreasing (Figure 13-5) - diffusion, solvent carryout, exhaust, and waste solvent evaporation.

13.1.1 Process Description

A general flow diagram for degreasers, regardless of type, is shown in Figure 13-6. The item to be cleaned is conveyed either manually or automatically (stream 1) into the degreaser. After degreasing is completed, the item is manually withdrawn or automatically conveyed to the next step in the manufacturing process (stream 2). Solvent may be heated in the degreaser by either steam, gas, or electricity (stream 3). Solvent leaves the degreaser either by diffusion into the atmosphere (stream 4) or by entrainment or "dragout" with the item (stream 5). Other major solvent losses

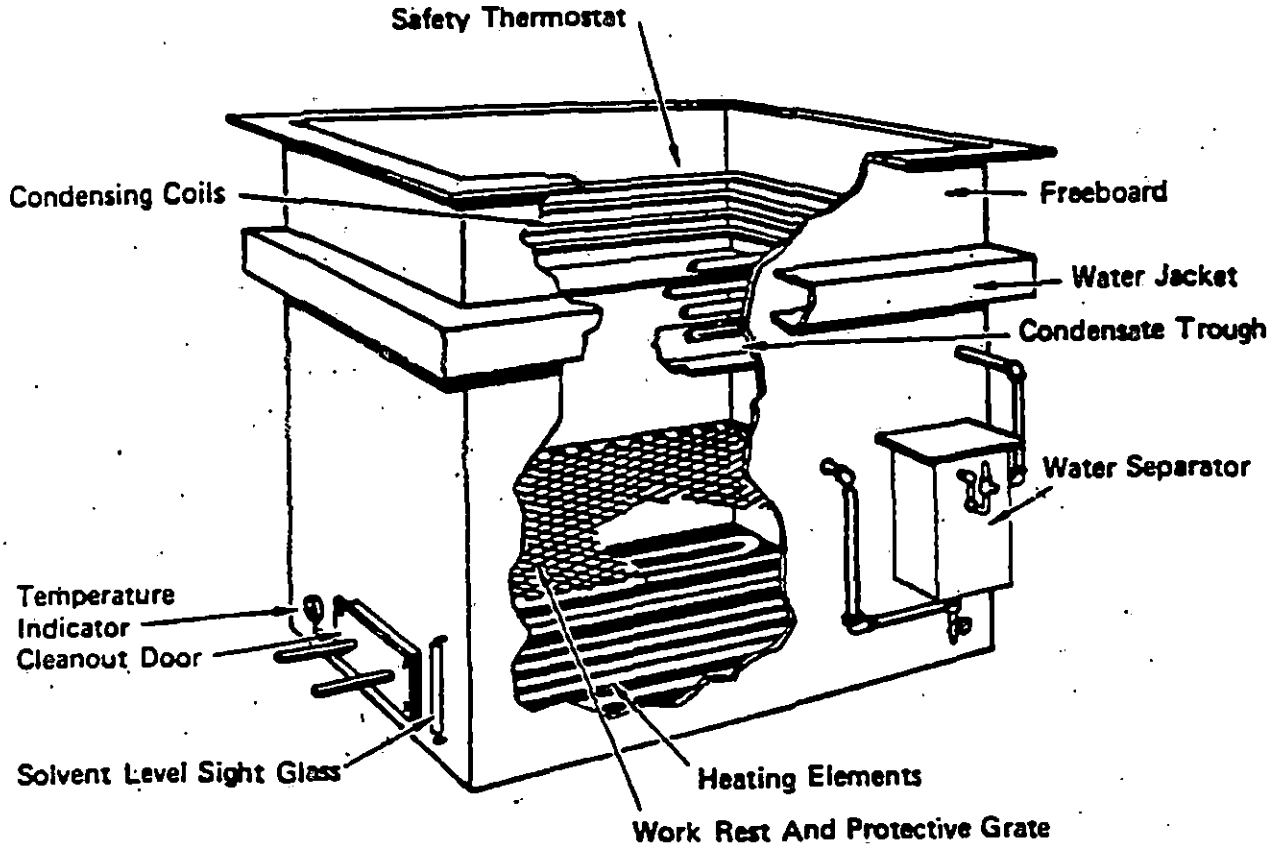


FIGURE 13-2 OPEN TOP DEGREASER[3]

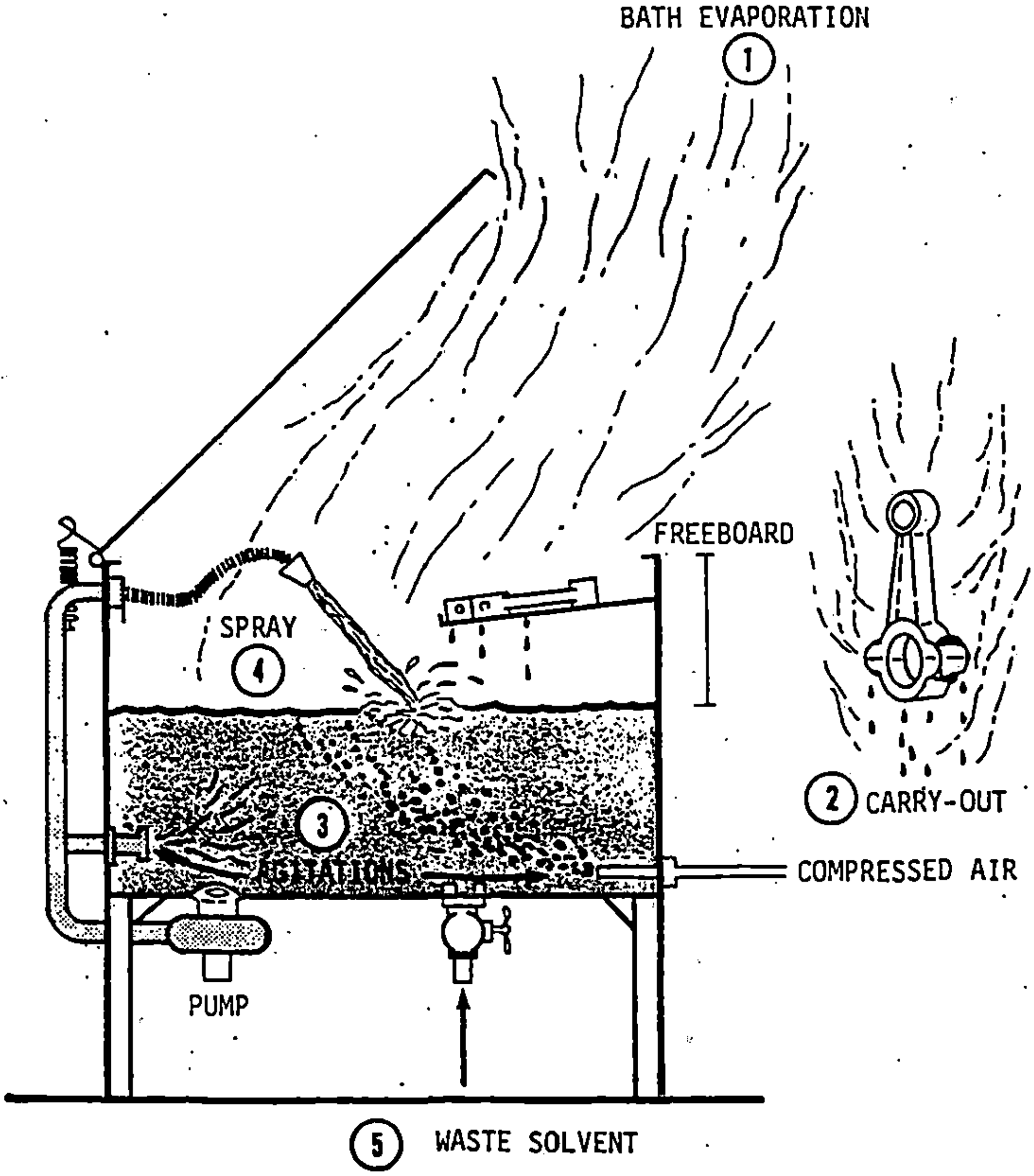


FIGURE 13-3 COLD CLEANER EMISSION POINTS[4]

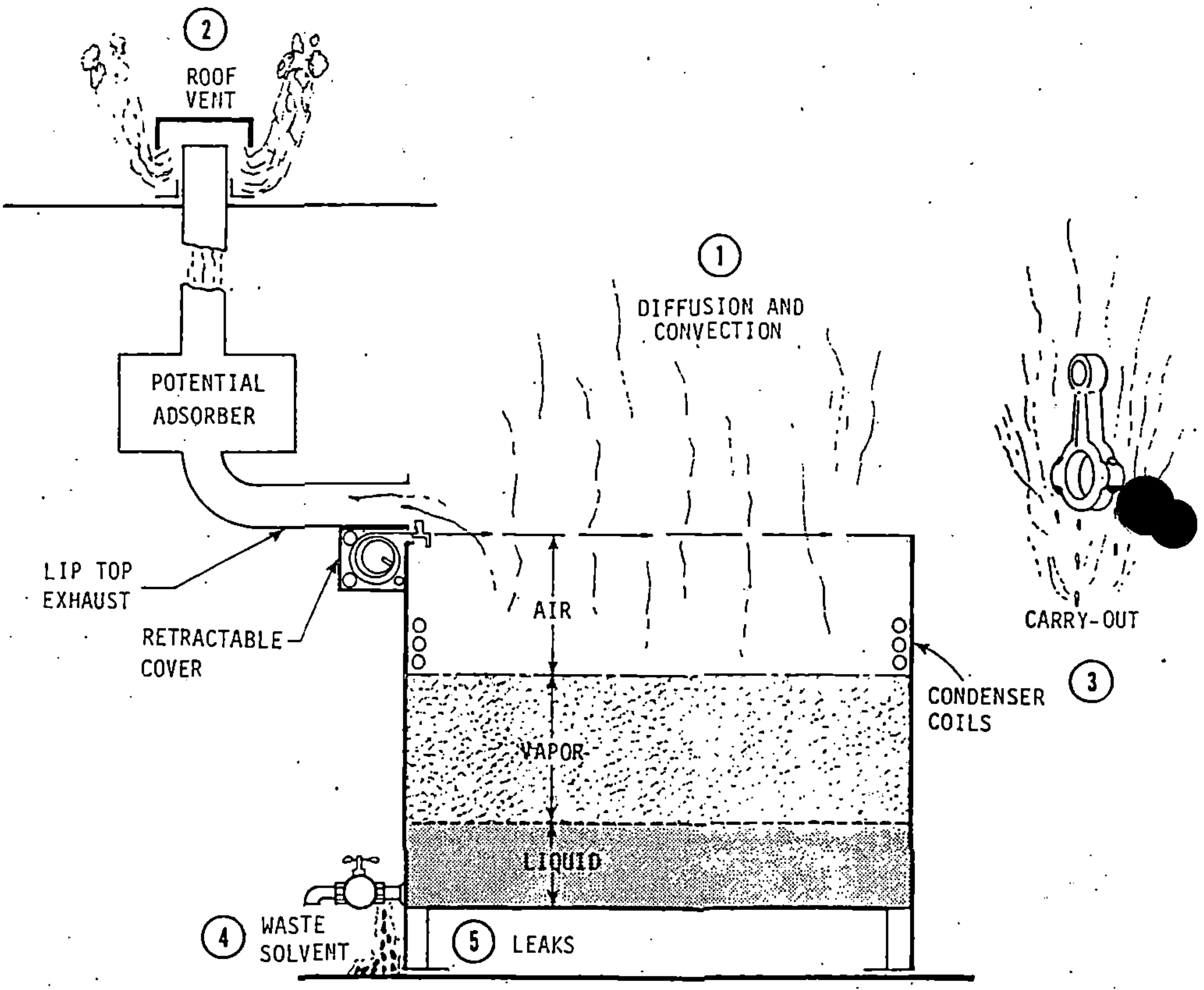


FIGURE 13-4 OPEN TOP DEGREASER EMISSION POINTS[3]

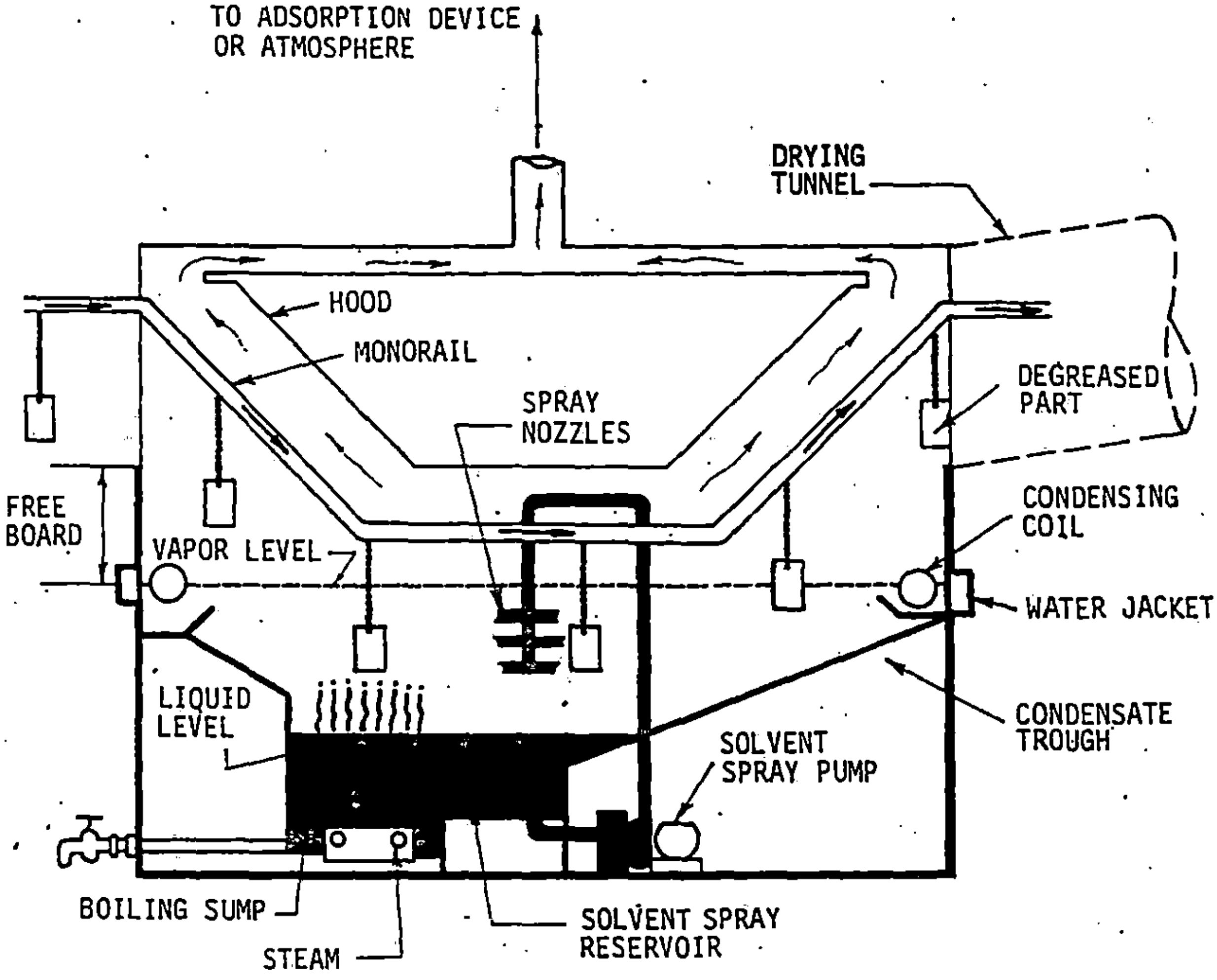
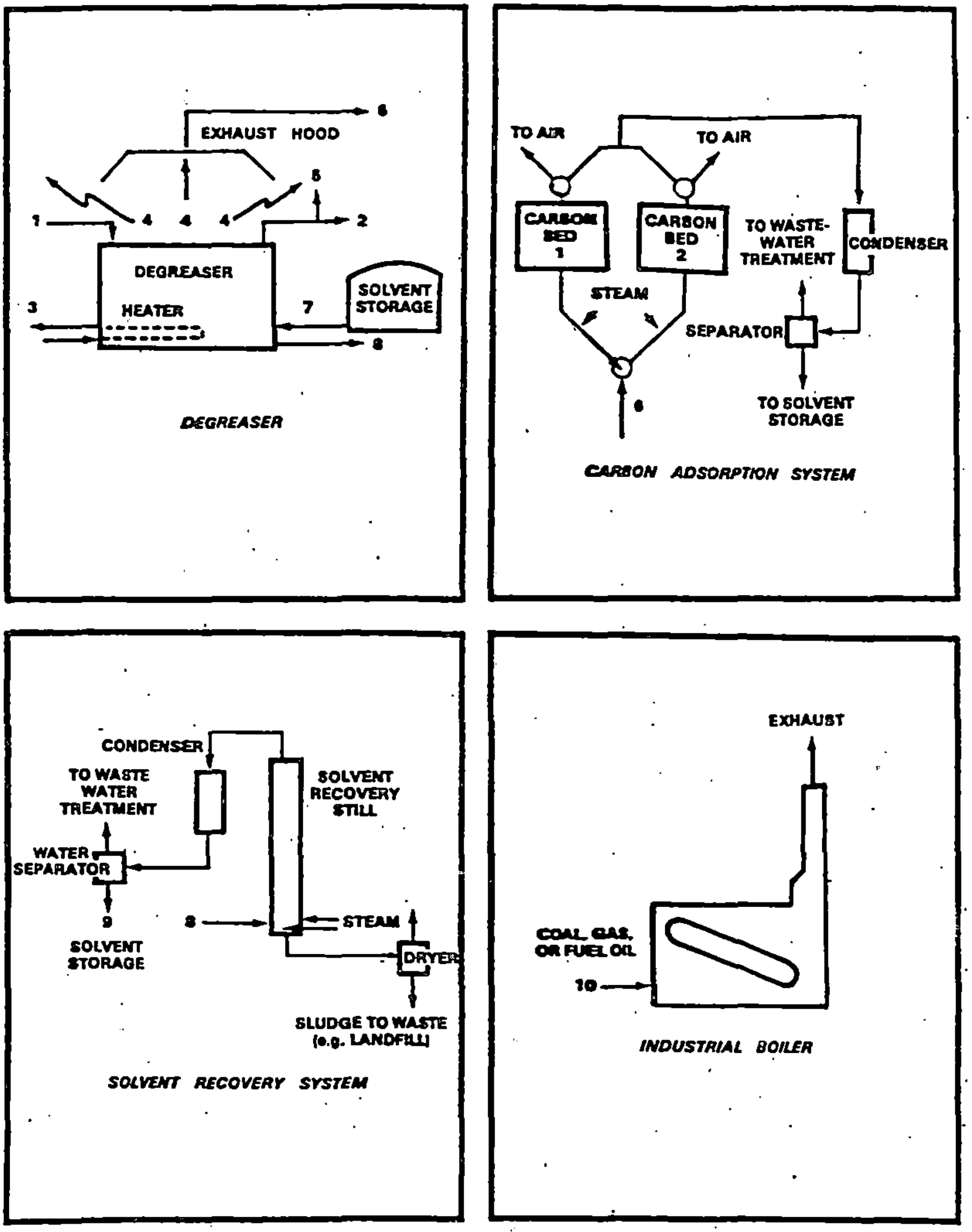


FIGURE 13-5 TYPICAL CONVEYORIZED DEGREASER EMISSION POINTS[3]



DEGREASER

CARBON ADSORPTION SYSTEM

SOLVENT RECOVERY SYSTEM

INDUSTRIAL BOILER

FIGURE 13-6 GENERAL FLOW DIAGRAM FOR DEGREASERS[2] occur during water separation, solvent contamination, sump or still bottom solvent removal, and solvent transfer. Diffused solvent (stream 4) may be collected by an exhaust hood and vented to either the atmosphere or a carbon adsorption system (stream 6). Solvent loss is balanced by the periodic addition of solvent (stream 7) from storage tanks or drums. Finally, "dirty" solvent, which is solvent contaminated with grease or oil, is removed from the system as necessary and sent to the solvent recovery system such as a distillation column (stream 8). The distillate is condensed, sent through a water separator, and finally placed in solvent storage (stream 9). Heating may be provided by a boiler (stream 10) or other source such as electricity or direct gas firing.[2]

13.1.2 Cold Cleaners

Cold cleaning operations include spraying, flushing, and immersion. Occasionally, the solvent is heated in cold cleaners, but its temperature always remains well below its boiling point. The type of cold cleaner and solvent to be used in a given application depends on a number of factors, including the number, size, and shape of the items to be cleaned, the type of soil to be removed, and the degree of cleanliness desired. The most important cold cleaner design factors are tank design, agitation technique, and method of parts handling. These factors and their application in common cold cleaner designs are described below.

There are two basic cold cleaner designs: the conventional cold cleaner, which is basically a dip tank, and the remote reservoir cold cleaner. A typical cold cleaner is shown in Figure 13-1. Remote reservoir units are typically smaller and less expensive than conventional cold cleaners. They are suited for easily-removed soils and applications which require a relatively low degree of cleanliness. Solvent is kept in an enclosed reservoir to avoid evaporation loss when not in use. Parts are cleaned by hand with solvent pumped from the reservoir through a spray nozzle in a sink-like work area which drains directly back into the reservoir.[5]

Agitation can greatly increase the cleaning efficiency of dip tanks. It can be accomplished by several means, including pumping, compressed air, vertical agitation, or ultrasonic agitation. In the pump agitated cold cleaner, the solvent is rapidly circulated in the soaking tank. Air agitation entails dispersing compressed air from the bottom of the soaking tank so that the air bubbles provide a scrubbing action. In the vertically-agitated cold cleaner, dirty parts are placed on a grating which moves up and down while submerged in solvent. In the ultrasonically-agitated tank, the solvent is vibrated by high frequency sound waves. Ultrasonically-agitated liquids often need to be heated to specific temperatures to achieve optimum cavitation. Cavitation is the creation and subsequent "implosion of microscopic vapor pockets within the liquid solvent." Caused by pressure differentials of sound waves in the solvent, these implosions are very active on the surface of the parts thereby greatly increasing the solvent action to break down the soil film on the parts.[5]

13.1.3 Open Top Vapor Degreasers

A vapor degreaser is basically a tank designed to produce and contain solvent vapor. A typical vapor degreaser is shown in Figure 13-2. Depending on the type of operation, vapor degreasing tanks may contain one or more compartments to provide clean solvent for spraying and or immersing.[12] At least one section of the tank is equipped with a heating system that uses steam, electricity, or gas heat to boil the solvent. As the solvent boils, the creation of dense solvent vapor begins to displace the air in the tank above the solvent. Eventually the vapors rise and fill the portion of the tank below the wafer-cooled condenser. These solvent vapors condense on the parts to be cleaned until the temperature of the parts approaches the boiling point of the solvent. The dissolving and flushing action of the condensate removes the soil by both dissolving the oils and providing a washing action to clean the parts. Thus, cleaning of the items results from the solvent vapors condensing on the cool surface of the article. When the article reaches the temperature of the solvent vapor, no more condensation or cleansing occurs and the work is slowly removed from the degreaser's vapor zone. When desired, dirty items can be sprayed with hot solvent by use of a flexible hose and spray pump or immersed in liquid solvent to aid in cleaning.[5]

The upper level of the clean vapors is maintained by condenser coils on the sidewalls of the tank. At the condenser level, a definite interface between the vapor and air can be observed from the top of the tank. This is called the air/vapor interface. This is where solvent condenses and runs into the collection trough. This solvent then flows by gravity through a water separator (to remove entrained moisture) and then into a clean solvent sump. This sump is used as a source of clean distilled solvent for spraying or direct immersion. As pure solvent is distilled off, the contaminated solvent remains in the soil concentrated vapor-generating sump.

The vapor degreasing can essentially be divided into four common processing sequences:

1. Vapor Cycle (Figure 13-7): Used in removal of light solvent soluble soils. The item is suspended in the solvent vapor zone and is dried and cleaned by the condensing solvent. Note, the vapor zone is the volume of vapors above the boiling liquid solvent up to the vapor/ambient air interface that occurs at the cooling coils. This area in the degreaser is pure solvent vapor; the solvent vapors are about 4-1/2 times as heavy as ambient air so they are contained quite efficiently within the degreaser to form a vapor zone in which the vapor degreasing actually occurs.[4]

2. Vapor - Spray - Vapor Cycle (Figure 13-8): Used on both solvent soluble and insoluble oils. Just like the first cycle part, the item is first suspended in the vapor zone. In addition, warm solvent liquid is sprayed afterwards and parts are again vapor cleaned.

3. Warm Liquid - Vapor Cycle (Figure 13-9): Used for removing soils from fine metal surfaces that can not be sprayed. The items are first suspended in vapor and then immersed in liquid solvent and continued by getting cleaned through the vapor zone again.

4. Boiling Liquid - Warm Liquid - Vapor Cycle (Figure 13-10): Used on parts contaminated with stubborn soil where vigorous mechanical action of boiling is required. The item is usually passed through the vapor zone, then followed by immersion in boiling solvent. It is then

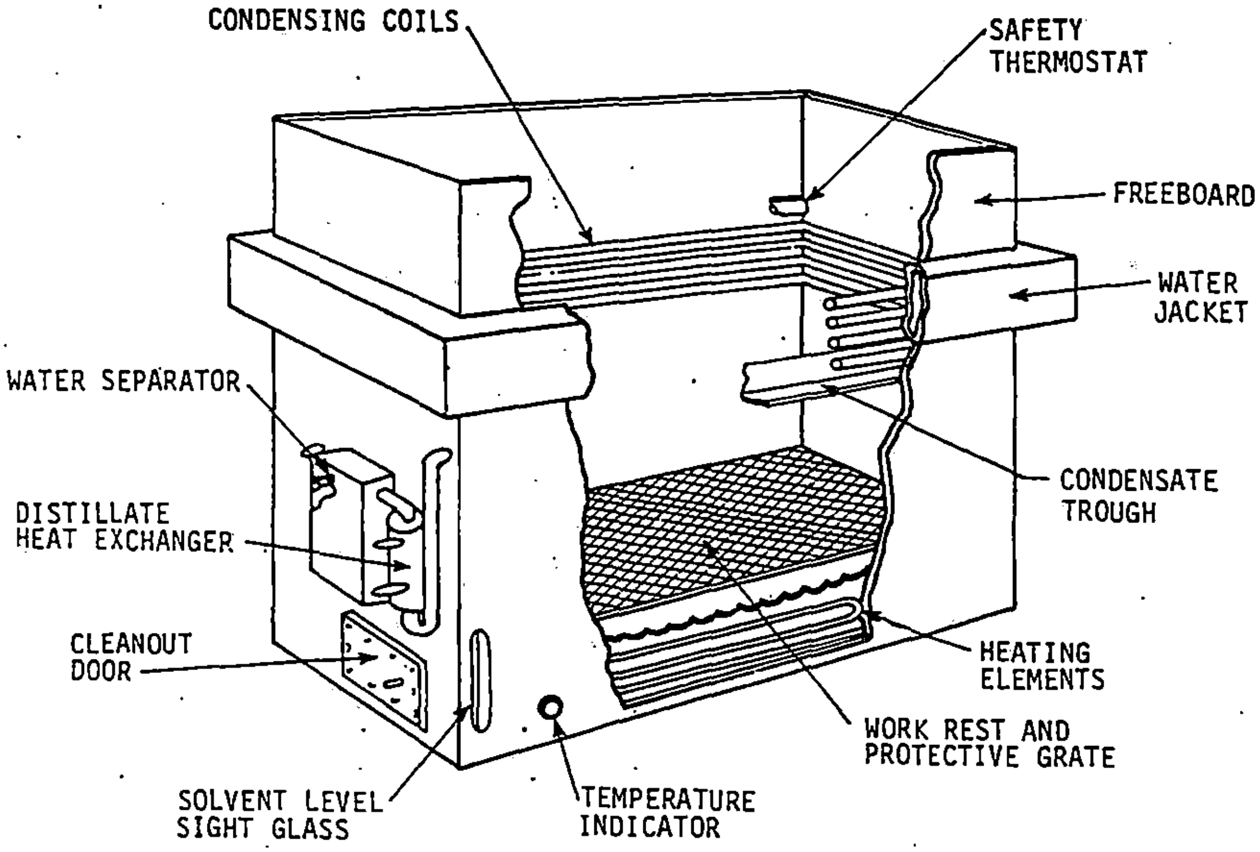


FIGURE 13-7 SINGLE COMPARTMENT VAPOR DEGREASER[4]

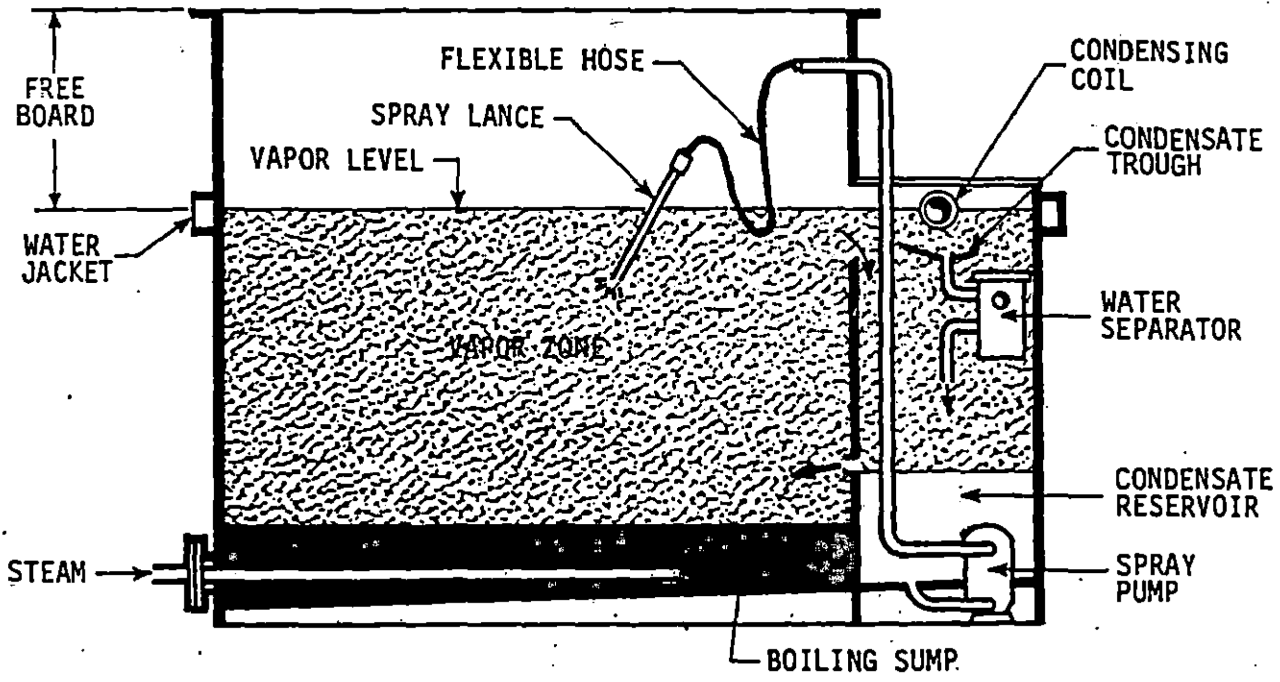


FIGURE 13-8 VAPOR-SPRAY-VAPOR CYCLE DEGREASER[4]

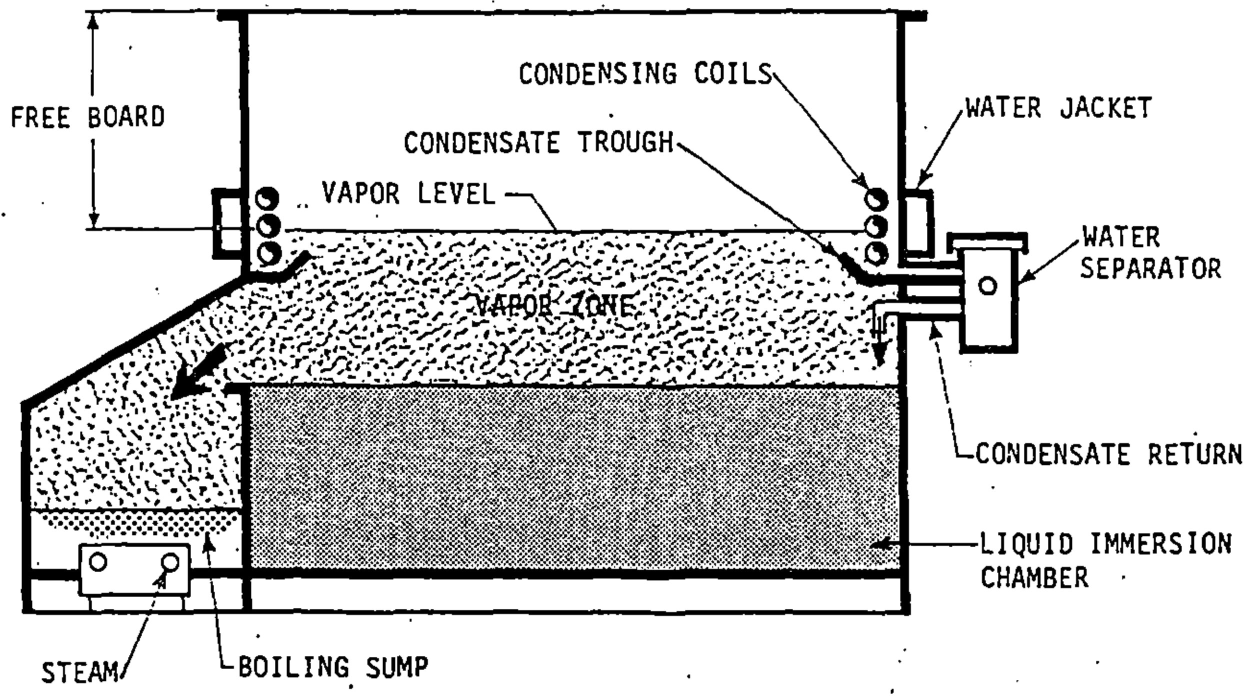


FIGURE 13-9 WARM LIQUID-VAPOR DEGREASER[4]

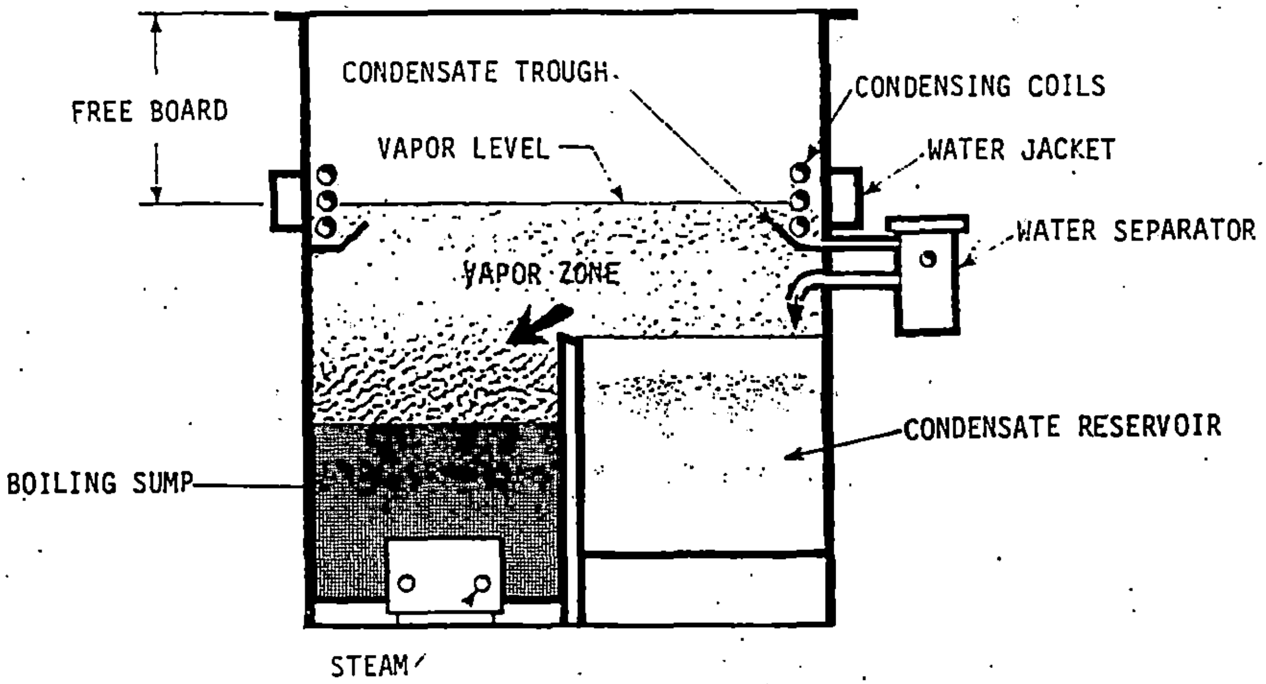


FIGURE 13-10 BOILING LIQUID - WARM LIQUID - VAPOR DEGREASER[4]

cooled and rinsed in warm liquid solvent and finally cleaned in the condensing vapors.

The condensing vapors act as a scrubbing agent and clean the items more thoroughly than a cold cleaner. Because the selected solvents boil at much lower temperatures than do the contaminants, the solvent/soil mixture in the degreaser boils to produce an essentially pure solvent vapor.[3] As a result, the solvent can be used for longer periods with vapor degreasing than cold cleaning; the vapor consists of clean solvent only, whereas the solvent in cold cleaners quickly becomes contaminated with dissolved and suspended soils.

To prevent the vapors from escaping from the tank, cooling coils are installed on the side walls below the top edge of the degreaser tank. The coils consist of four or more pipe coils stacked one above the other and located directly above a vapor condensate trough. The cooling medium is normally tap or process water.[4] Care must be taken in placing the cooling coils since improper installation of the coils will not protect the solvent vapor zone from the air movement around the degreaser. Figure 13-11 depicts an open top degreaser with offset condenser coils.[5] These coils, which are supplied with a coolant such as water, are generally located around the entire inner surface of the degreaser, although for some smaller equipment they are limited to a spiral coil at one end of the degreaser.

The area above the cooling coils to the top of the tank is called the freeboard. The distance from the top of the vapor zone to the top of the degreaser tank is called the freeboard height. Thus, the location of the cooling coils defines the upper limit of the vapor space and the lower limit of the freeboard. The freeboard reduces disturbances at the vapor/air interface and thus reduces solvent vapor emissions. An acceptable freeboard height is usually determined by the freeboard ratio where freeboard height is divided by the smaller of the width or the length of the degreaser solvent area. High freeboard ratios, such as 100 percent, are recommended to reduce further solvent emissions. Best Available Control Technology (BACT) for an open top vapor degreaser using solvents PERC, trichlorotrifluoroethane, and 1,1,1-trichloroethane typically includes a 100 percent freeboard ratio.

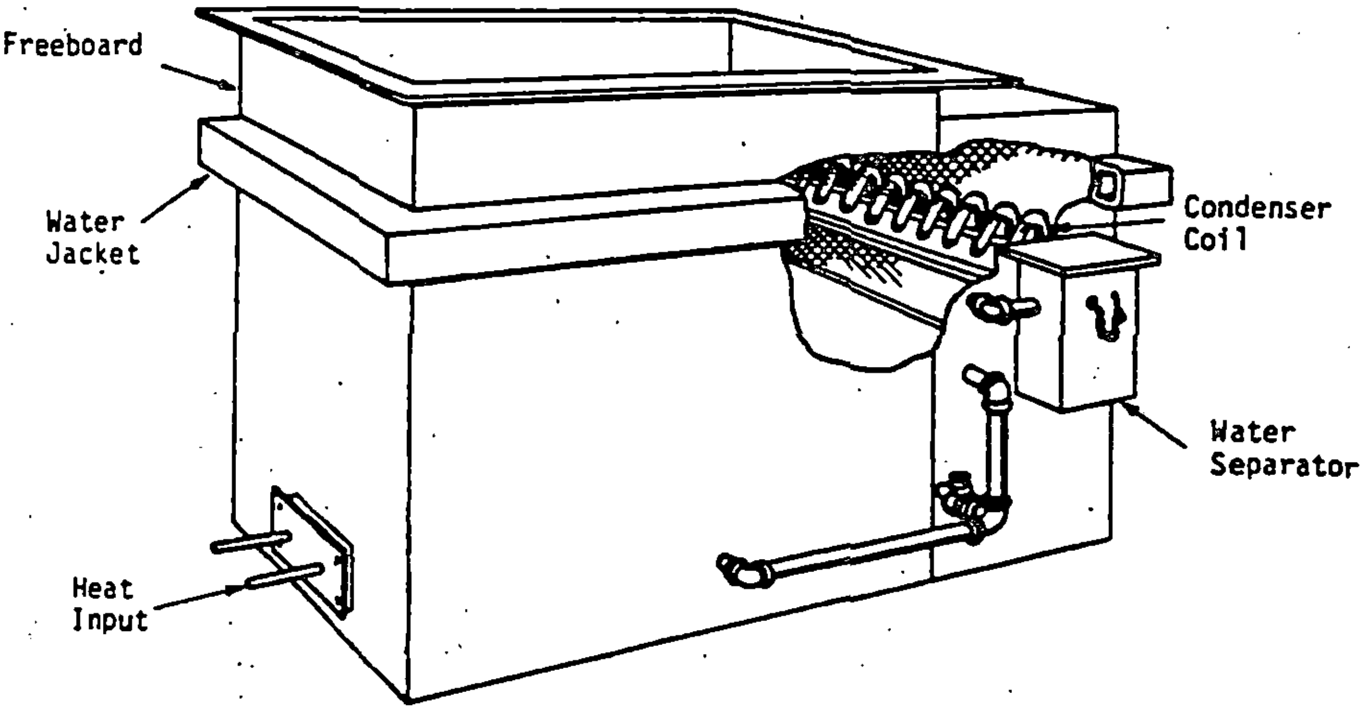


FIGURE 13-11 OPEN TOP DEGREASER WITH OFFSET CONDENSER COILS[3]

Most vapor degreasers are also equipped with a water jacket (Figure 13-2) which provides cooling and prevents the convection of solvent vapors up the degreaser walls. Installed on the outside of the degreaser, a water jacket is a boxed section containing cooling water which circulates around the degreaser in the same approximate area as the cooling coils. The water jacket prevents solvent vapors from convecting up the hot degreaser walls and reduces "sidewall radiation". This heat radiation can increase air turbulence and thus interrupt the cold air blanket in the freeboard area. Water jackets may be used instead of cooling coils in smaller units.[4]

Lip exhausts, such as those shown in Figure 13-12, are used on less than half of the existing open top vapor degreasers. A lip exhaust draws air laterally across the top of the degreaser and vents the air directly to the roof or to a carbon adsorption unit. The primary purpose of a lip exhaust is to limit worker exposure to solvent vapors.[4] These exhaust systems are designed to capture solvent vapors escaping from the degreasers and carry them away from the operating personnel. However, they can disturb the vapor zone and increase solvent losses. In properly designed exhaust systems, the cover closes below the lip exhaust inlet level[3]; and the exhaust flow is kept at a minimum level preventing turbulence and disturbance to the air vapor interface zone.

Most degreasers are equipped with a water separator. The basic principle of a water separator for a vapor degreaser is depicted in Figure 13-13. The water may enter a degreaser through condensation of atmospheric moisture on condenser coils, moisture on work pieces being processed, and/or steam or cooling water leaks. Water forms a low boiling azeotrope with the solvent and is vaporized. Water can cause corrosion, shorten the solvent life, and increase the vaporization rate of solvent. As a result, with a water separator, the condensed solvent-water mixture will fall into the condensate trough below the condenser coils and flow by gravity to the separator.[4]

13.1.4 Conveyorized Degreasers

There are several types of conveyorized degreasers, operating both with cold and vaporized solvents. An average conveyorized degreaser emits about 25 metric tons

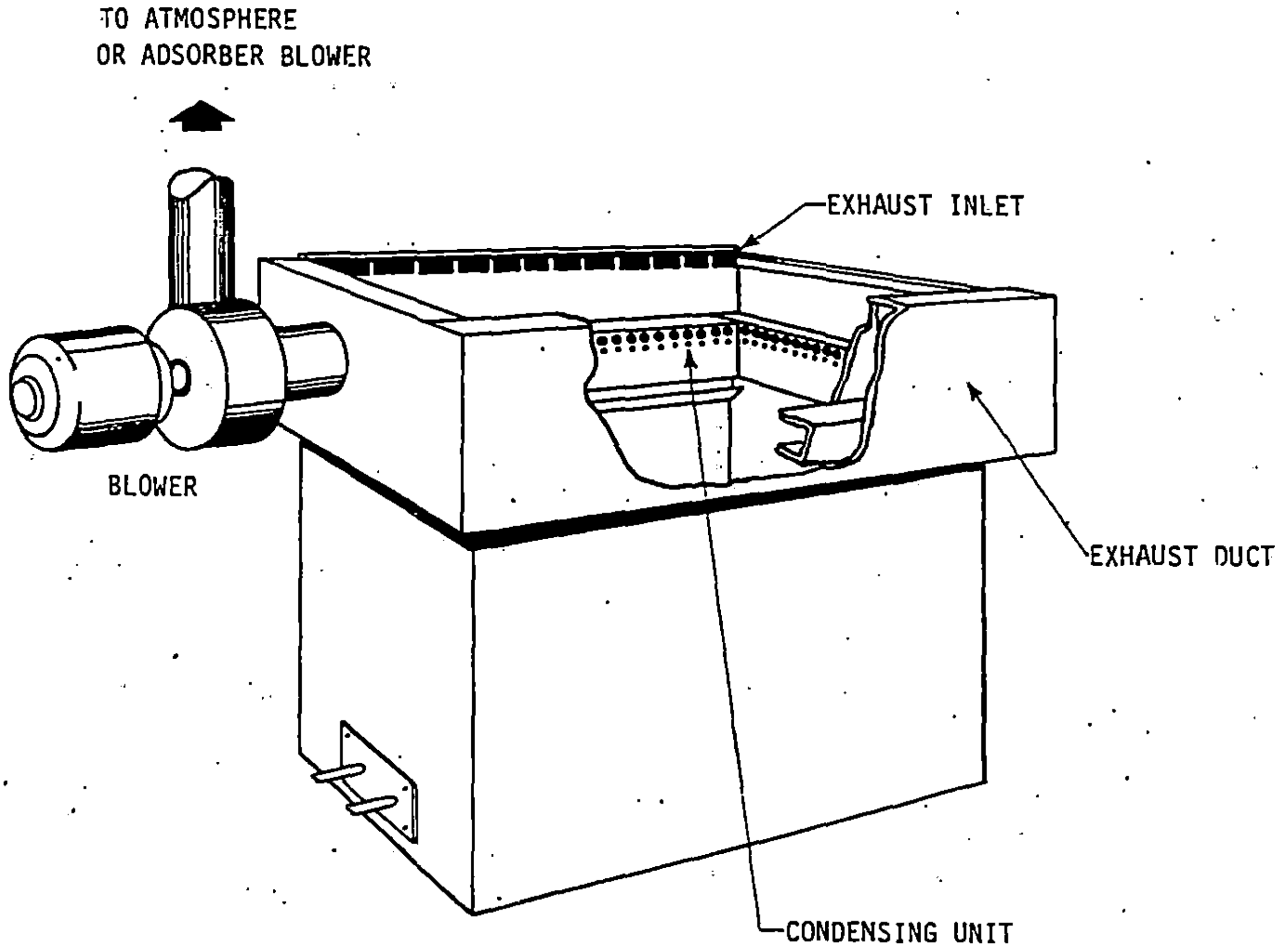


FIGURE 13-12 DEGREASER WITH LIP EXHAUST[3]

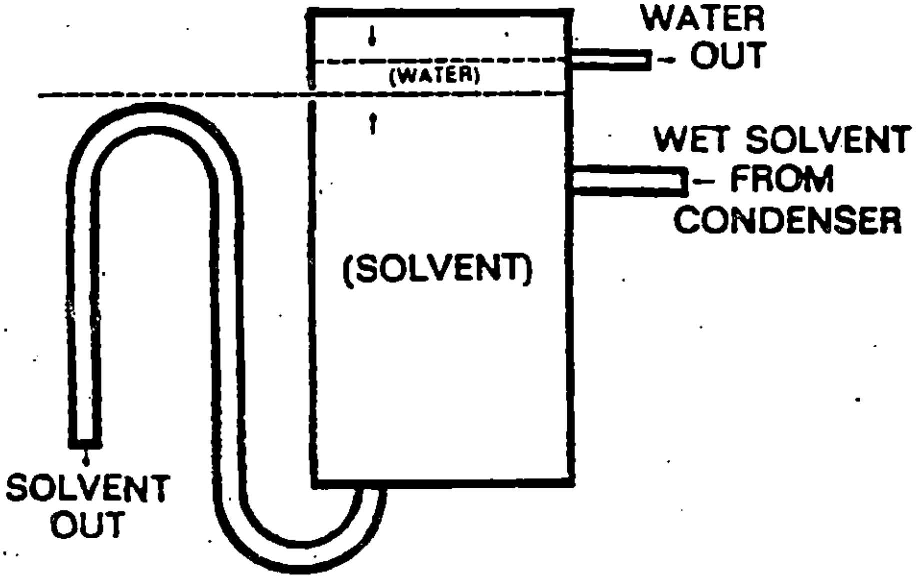


FIGURE 13-13 BASIC PRINCIPLE FOR WATER SEPARATOR FOR VAPOR DEGREASER[3]

per year of solvent; however, because of their limited numbers, they contribute only about 15 percent of the total solvent degreasing emissions.[3]

The basic steps found in the typical conveyorized vapor degreaser include a vapor rinse upon entry to the degreaser vapor space section, liquid immersion, liquid spray, vapor rinse, and finally, a slow withdrawal through a cold air space drying area.[4]

As with the open top vapor degreaser, the nonflammable solvent contained in the lower area of the degreaser, referred to as the boiling sump, is boiled to produce a vapor zone, the height of which is controlled by cooling coils installed above the vapor zone. The freeboard area above the primary condensing coil is designed to be of sufficient height to retard convection losses to the atmosphere.[4] Solvent vapors condense on the work surfaces in the vapor zone and flush the oil and other foreign matter off with the liquid condensate. The removed material accumulates in the boiling sump and only the pure vapor comes in contact with the work load. Vapor flushing may be followed by pure solvent spray and/or liquid immersion. The cool, pure solvent reduces the temperature of the work surface below the vapor temperature, producing a second vapor condensation flushing action on the work surfaces. At the time the work pieces are removed from the vapor zone, they should be clean, dry, and ready for further processing.[4]

In conveyorized equipment, most, and sometimes all, of the manual parts handling associated with open top vapor degreasing has been eliminated. Conveyorized degreasers are typically enclosed so that only the entrance and exit are exposed to the atmosphere.[3] This helps to control solvent losses from the system due to air movement within the plant. Conveyorized degreasers are used by a broad spectrum of metalworking industries, but are most often found in plants where there is a constant stream of parts to be degreased. A continuous or multiple-batch loading system eliminates the manual parts handling associated with open top vapor degreasing or cold cleaning.[3]

There are seven main types of conveyorized degreasers: monorail, cross-rod, vibra, ferris wheel, belt, strip, and circuit board cleaners. While most of the seven types of conveyorized degreasers may be used with cold or vaporized solvent, the first four are almost always vapor degreasers.

The cross-rod degreaser obtains its name from the rods from which parts are suspended as they are conveyed through the equipment by a pair of power-driven chains. Figure 13-14 is a diagram of a cross-rod degreaser. The parts are placed in pendent baskets or, where tumbling of the parts is desired, perforated cylinders. These cylinders are rotated by a rack and pinion design within the solvent and/or the vapor zone to provide the tumbling action required to clean and drain the crevices in the work pieces. Pendent baskets, however, do not rotate and are used to carry small parts that do not require tumbling for cleaning and draining.[3] Cross-rod conveyorized units are generally used for processing small or irregular parts which need to be immersed in solvent for satisfactory cleaning or which require tumbling for solvent drainage from cavities in the parts.[4]

A monorail vapor degreaser is usually chosen when the parts to be cleaned are being transported between manufacturing operations using a monorail conveyor, as shown in Figure 13-15. This design lends itself to automatic cleaning with solvent spray and vapor. The parts can be moved in one side and out the other, as illustrated, or they can turn 180 degrees while in the vapor or spray portions of the equipment and exit the equipment through a tunnel parallel to the entrance.[3] Monorail conveyor system are used for high production of standardized work pieces and are generally found in facilities that use monorail systems to transport materials within the plant.[4]

In a vibra degreaser, dirty parts are fed through a chute which directs them into a pan flooded with solvent, as noted by Figure 13-16. This pan is connected to a rotating spiral elevator. The pan and spiral elevator are vibrated. The parts move from the pan up the spiral to the exit chute. The cooler parts condense solvent vapor as they are vibrated up the spiral and dry as soon as they leave the vapor zone. These degreasers are capable of processing large quantities of small parts.[3] The small work pieces are dipped into solvent, raised on a spiral vibrating elevator , and then counter-flow rinsed with clean solvent vapor. Cleaning action is then effected by the combination of vibration, solvent dip, and solvent vapor condensation.[4] Since

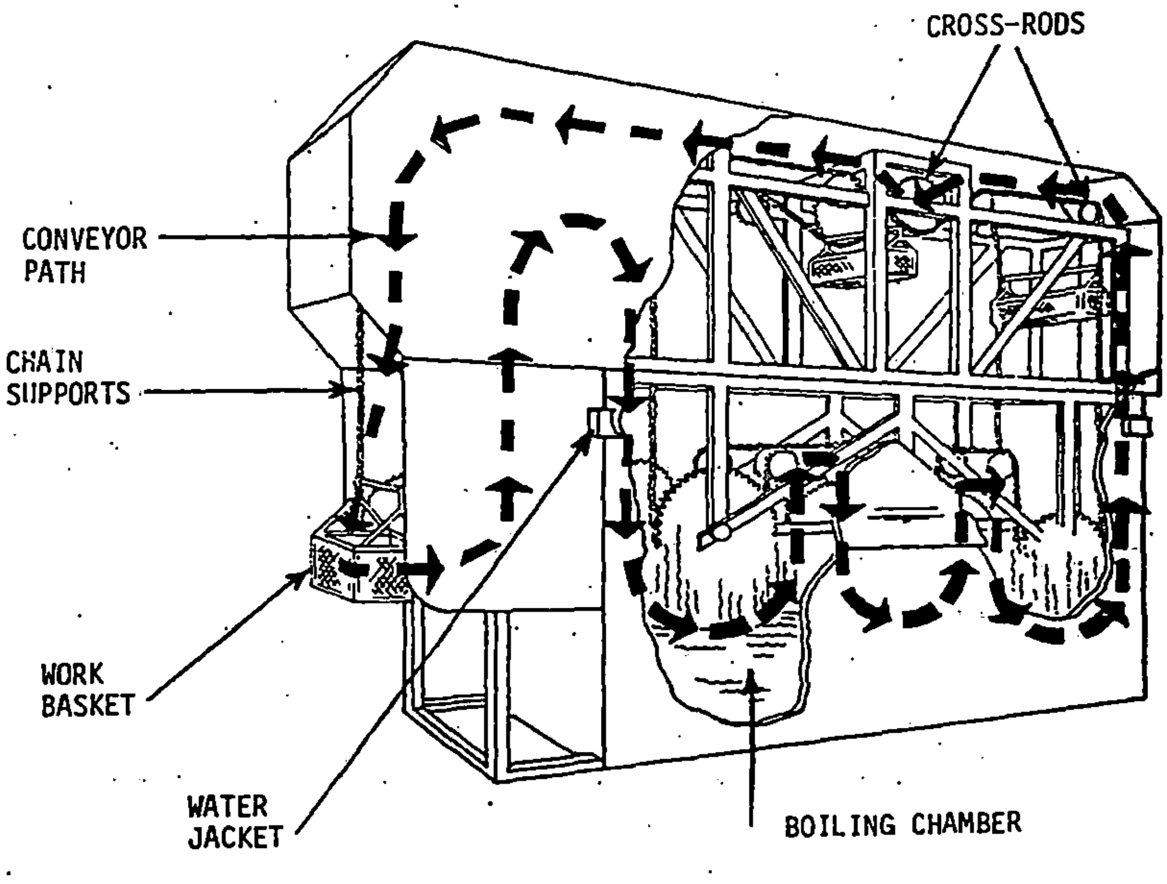


FIGURE 13-14 CROSS-ROD DEGREASER[3]

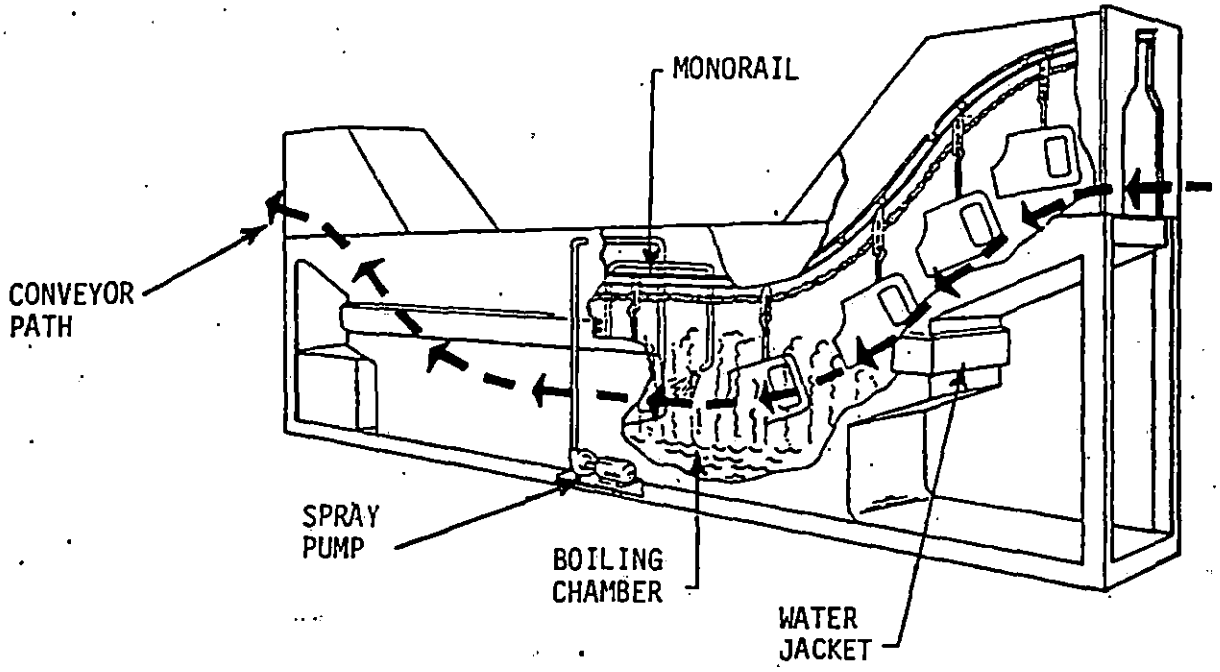


FIGURE 13-15 MONORAIL VAPOR DEGREASER[3]

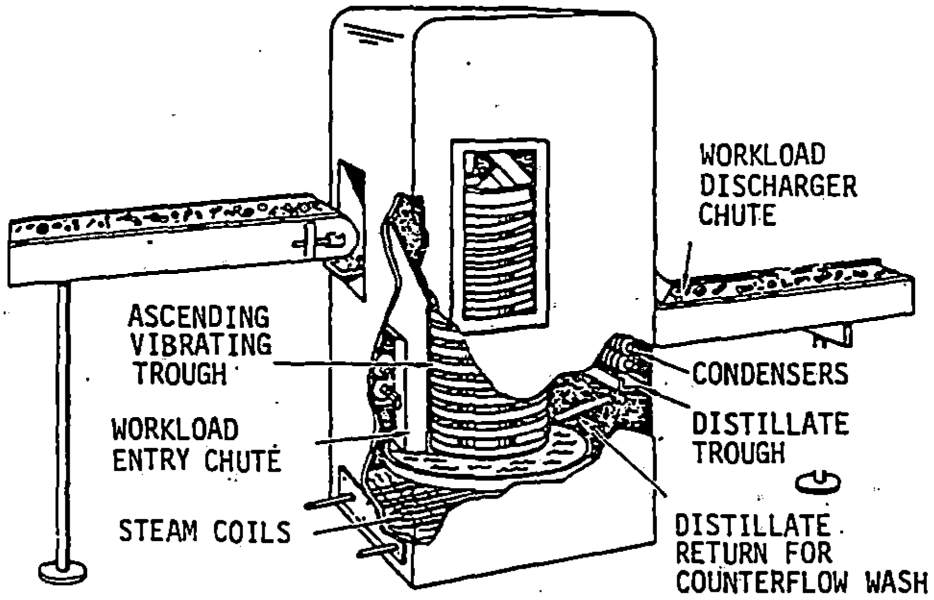


FIGURE 13-16 **VIBRA DEGREASER**[3]

the vibratory action creates considerable noise, acoustical insulation of the equipment is needed or the system must be enclosed in a noise-control booth.[3]

The ferris wheel or gyro degreaser is one of the least expensive and smallest conveyorized degreasers. Figure 13-17 illustrates a gyro degreaser. It generally uses perforated baskets. As a large gear wheel rotates, it tumbles the perforated baskets attached to it via smaller gears. The parts tumble in the baskets, allowing more complete contact of the parts with the solvent.[3] Ferris wheel-type degreasers allow the operator to load and unload the baskets from one work station.[4]

Both the belt degreaser and the strip degreaser are designed to allow simple and rapid loading and unloading of parts. A belt degreaser, shown in Figure 13-18, conveys parts on the belt through a long and narrow boiling chamber in which the parts are cleaned either by the condensing vapor or by immersion in the solvent sump. The strip degreaser is similar to the belt degreaser except that the strip itself is being cleaned. The strip degreaser is designed to clean parts which are long and thin.

The circuit board cleaner is similar to design to the belt degreaser. There are three types of circuit board cleaners: developers, strippers, and defluxers. In the production of circuit boards, ultraviolet rays are projected through a film of an electrical circuit pattern to create an image on a copper sheet covered with resist. The developer degreaser dissolves off the unexposed resist. This copper covered board is then dipped in an acid bath to etch away the copper that is not covered by the hard, developed resist. Next, the stripper degreaser dissolves off the developed resist. Then, a wave of solder passes over the bare copper circuit and bonds to it. Lastly, the defluxer degreaser dissolves off the flux left after the solder hardens. Because of the nature of the material being cleaned, circuit board cleaners can use cold (room temperature) solvents as well as vapor degreasing processes.

13.1.5 Solvents

A degreaser should be designed specifically for the solvent to be employed and should not be used with any other. The ten desirable characteristics in a vapor degreasing solvent are:[14]

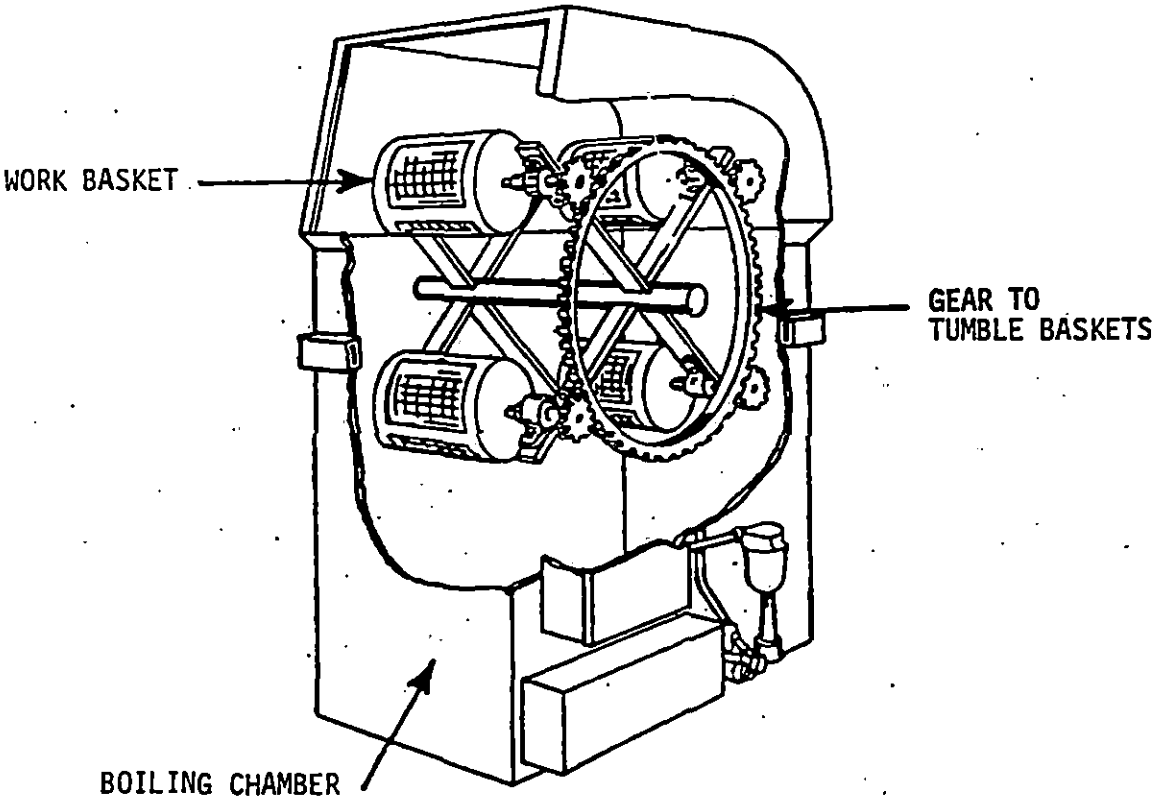


FIGURE 13-17 GYRO OR FERRIS DEGREASER[3]

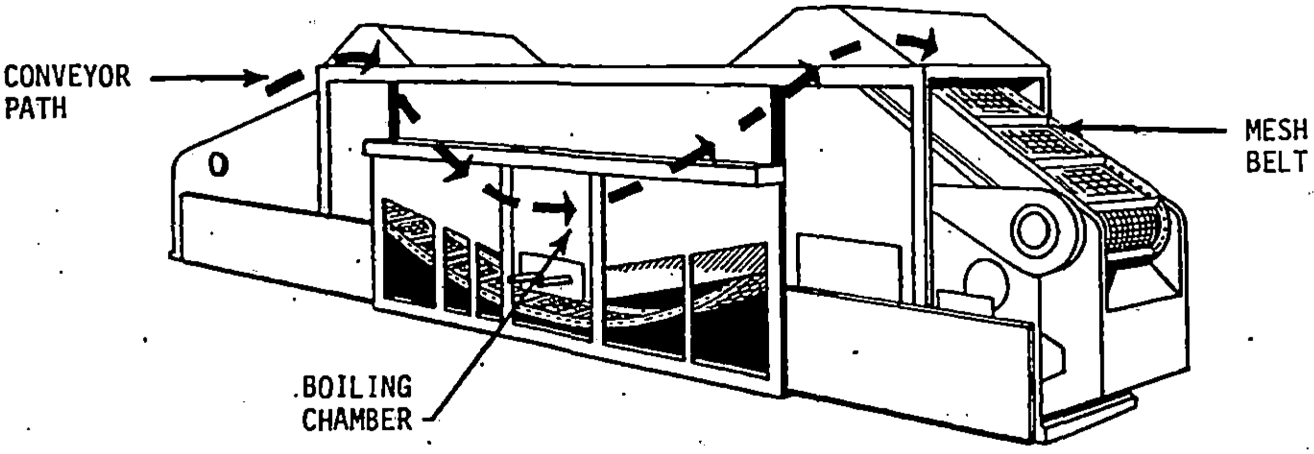


FIGURE 13-18 MESH BELT CONVEYORIZED DEGREASER[3]

1. Good solvency for the soils (oils, greases, and other contaminants) to be removed.

2. Nonflammability and freedom from explosive hazard under the operating conditions of the vapor-degreasing process.

3. A low latent heat of vaporization and a low specific heat to give the greatest amount of condensation on a specific quantity of work to achieve the minimum heat requirements of the degreaser.

4. A low rate of diffusion into the air under normal operating conditions and a high vapor density relative to air so that solvent losses to the atmosphere are minimal.

5. Chemical stability under the conditions of use. The solvent should be able to tolerate all the circumstances confronted during vapor degreasing. These conditions include "exposure to heat, air, active metal chips and fines, acidic metal working lubricants and moisture which may be brought in with the work or from atmospheric condensation." Any pure solvent not meeting these requirements should not be used unless it can be made to do so by adding appropriate stabilizers.

6. Noncorrosiveness to common metals of construction. The solvent must maintain this property after continuous use and redistillation.

7. Low solubility in water and no tendency to hydrolyze under the process conditions. An azeotrope with liquid contaminants or with other solvents must not be formed.

8. Low enough boiling point to allow the solvent to be easily separated from oil, grease, or other contaminants by simple distillation. A low boiling point also serves to retain the temperature of the degreased work at a suitable level for subsequent handling. However, the

boiling point should be high enough so that sufficient solvent vapors will condense on the workload to provide a satisfactory final rinse in the clean vapor. In addition, the solvent should boil at a high enough temperature so that the vapors will readily be condensed by the cooling coils.

9. Obtainable at a reasonable cost. Note this factor should take into consideration not only the cost per gallon but also how much solvent is required to clean the work.

10. Relative safety to personnel who may breathe the fugitive vapors. Vapor concentrations in the workplace should be maintained at a level below the permissible exposure limits for the solvent. Also, the solvent should retain its original composition during use and should not decompose to give toxic by-products under the conditions of the process.

A degreasing solvent may be accompanied by or is a combination of co-solvents or additives which play an important role in the emissions from the equipment. These additives, stabilizers, or inhibitors are added to prolong the degreasing ability of the solvent and to prevent decomposition.

The commercially available solvents which have been used in the vapor degreasing process and which meet some if not all of the above requirements are discussed below. Table 13-1 is a table of common metal cleaning solvents and Table 13-2 is a listing of halogenated solvents used for metal cleaning and its properties.

13.1.5.1 Trichloroethylene (TCE)

Boiling at 188 ^{O}F, trichloroethylene (TCE) has been found adaptable to the majority of vapor-degreasing applications. The trichloroethylene degreaser can be heated with low-pressure steam (5 to 15 psig) and is easily separated from contaminants by simple distillation. Trichloroethylene has a very high solvency for most of the contaminants found in the metal fabrication industry. It does not attack nor etch delicate metal parts. The average vapor concentrations in the working

TABLE 13-1. COMMON METAL CLEANING SOLVENTS[4]

Type of Solvent	Solvent	Solvency for Metal Working Soils	TLV (ppm)	Flash Point	Evaporation Rate[a]	Water Solubility (% wt.)	Boiling Point (Range)	Pounds Per Gal.
Alcohols								
	Ethanol (95%)	poor	1000	60°F	24.7	oo	165-176°F	6.76
	Isopropanol	poor	400	55°F	19	oo	179-181°F	6.55
	Methanol	poor	200	58°F	45	oo	147-149°F	6.60
Aliphatic Hydrocarbons								
	Heptane	good	500	<20°F	26	<0.1	201-207°F	5.79
	Kerosene	good	500	149°F	0.63	<0.1	354-525°F	6.74
	Stoddard	good	200	105°F	2.2	<0.1	313-380°F	6.38
	Mineral Spirits 66	good	200	107°F	1.5	<0.1	318-382°F	6.40
Aromatic Hydrocarbons								
	SC 150	good	200	151°F	0.48	<0.1	370-410°F	7.42
	Toluene	good	200	45°F	17	<0.1	230-232°F	7.26
	Turpentine	good	100	91°F	2.9	<0.1	314-327°F	7.17
	Xylene	good	100	81°F	4.7	<0.1	281-284°F	7.23
Chlorinated Solvents								
	Methylene Chloride	excellent	500	none	363	0.2[b]	104-105°F	10.98
	Perchloroethane	excellent	100	none	16	<0.1[b]	250-254°F	13.47
	1,1,1-Trichloroethane	excellent	350	none	103	<0.1[b]	165-194°F	10.97
	Trichloroethylene	excellent	100	none	62.4	<0.1[b]	188-190°F	12.14
Fluorinated Solvents								
	Trichlorotrifluoroethane (FC-113)	good	1000	none	439	<0.1b	117°F	13.16
Ketones								
	Acetone	good	1000	<0°F	122	oo	132-134°F	6.59
	Methyl ethyl ketone	good	200	28°F	45	27	174-176°F	6.71

a. Evaporation rate determined by weight loss of 50 mls in 125 ml beaker on an analytical balance (ml.dm^2/min)
b. See Table 13-2.

TABLE 13-2. HALOGENATED SOLVENTS USED FOR METAL CLEANING[5]

Solvent	Molecular Weight	Vapor Density (Air=1.0)	Water Solubility (g/100g)	Latent Heat (kJ/kg)	Price ($/kg)
Trichloroethylene	131.40	4.5	0.02 (20°C)	237	0.58
Perchoroethylene	165.85	5.7	0.01 (20°C)	209	0.49
1,1,1-Trichoroethane	133.42	4.6	0.05 (25°C)	237	0.66
Methylene Chloride	84.94	2.9	0.15 (20°C)	330	0.63
Trichlorotrifluoroethane	187.0	6.5	0.01 (24°C)	147	1.70-3.75

areas of the trichloroethylene degreaser can be maintained well below the threshold limit value (TLV) of 100 ppm.[1]

13.1.5.2 Perchloroethylene (PERC)

The colorless, chloroform-smelling perchloroethylene (PERC) boils at 250 $^{\circ}$F and is selected for application where its high boiling point is advantageous. Its high boiling point is beneficial for two reasons: (1) it helps in the removal of high melting waxes and greases and (2) it allows the solvent to condense on the work for a longer period of time, hence giving a longer cleaning cycle. PERC degreasers may be heated by using gas, steam, or electricity.[2] PERC is employed to remove high-melting tars and waxes preceding ultraviolet light inspections, to remove large quantities of water in solvent drying operating, and to clean spot welded seams or fine orifices. High-pressure (50 to 60 psig) is employed in the PERC degreaser. The cleaned parts are very hot for subsequent handling, and workroom temperatures are higher than with TCE degreasing.[1] Because of its high heat requirements, PERC degreasing costs are usually slightly higher than for TCE.

PERC can be stabilized to withstand vapor degreasing conditions encountered and show little tendency to hydrolyze. PERC can be recovered by simple distillation and has good solvency for the majority of the contaminants. Like TCE, no danger of attack or etching of delicate metal parts may be encountered when properly maintained. Average solvent concentrations around the vapor degreaser can be maintained well below the TLV of 100 ppm for PERC.[12]

13.1.5.3 Methylene Chloride

Colorless, toxic methylene chloride boils at 104 $^{\circ}$F and is used for special applications where its low boiling point or high solvent action is desirable. One of its uses is cleaning magnesium casting after being impregnated with sealing compounds. This volatile solvent is very effective in removing the excess compound from the surface of the casting without removing the sealing compound from the casing pores. In contrast, higher-boiling solvent would open the pores and leach out and dissolve the compound. Being a very active solvent, methylene chloride is considered for removal of some paints and resins which are not sufficiently loosened by TCE or PERC.[12]

Losses from solvent diffusion can be minimized because of the solvent's low boiling point and low vapor density. Methylene chloride is used in degreasers with a high freeboard and a source of cooling water. The upper section of the degreaser should be kept cold so that the vapors will not by-pass the condensing coil and heat up the degreaser walls.[12]

Methylene chloride is the most active of the degreasing solvents.[6] It has the lowest boiling point and the highest latent heat of vaporization (330.2 Joules/gram) of the solvents used in vapor degreasers. The solvent attacks some plastics and elastomers and thus cannot be used as a degreasing solvent for these materials. The low boiling point requires refrigerated water (54.9 °F to 60 °F) on the degreaser condensing coil; while the high latent heat of vaporization requires removal of more heat than other solvents.[6,7]

Methylene chloride can withstand the conditions of most vapor-degreasing processes. However, care should be taken when degreasing aluminum or magnesium to avoid accumulation of metal chips or fines. In properly designed equipment, average concentrations in the working zone can be maintained well below the 500 ppm TLV. [12]

13.1.5.4 Trichlorotrifluoroethane

This solvent boils at 118 °F and is used for applications requiring its low vapor temperature and/or its particular solvent action. Because of its low solvency, trichlorotrifluoroethane has been employed for cleaning hermitically sealed motors which employ insulation varnishes which may be affected by other vapor-degreasing solvents. Trichlorotrifluroethane is sometimes formulated with cosolvents to improve solvency for particular jobs. As with methylene chloride, precautions must be taken in degreaser design to minimize solvent losses. The solvent is extremely stable and in properly designed machines, workroom concentrations can be maintained well below its TLV of 1,000 ppm.[12]

13.1.5.5 1,1,1-trichloroethane (Methyl Chloroform)

This colorless solvent boils at 165 ^{O}F and is chosen for applications where its particular solvent action is required and where total freedom from moisture must be maintained in the degreasing operation. An example of its use is in the cleaning of electric motors employing insulation varnishes which might be affected by other solvents.

1,1,1-trichloroethane must be stabilized for degreasing applications because it decomposes in the presence of water to form hydrochloric acid and acetic acid.[6,7] Because of this tendency to hydrolyze under operating conditions where moisture is present, motors are dried in an oven before degreasing to remove any moisture present.[12] This solvent can also decompose in the presence of aluminum or magnesium when not properly stabilized. Thus, when the solvent is recovered by distillation, care must be taken to replenish depleted stabilizers. Vapor concentrations in the work zone atmosphere can be kept well below the TLV of 350 ppm with proper operation of suitably designed equipment.[12]

13.1.6 Control Techniques

Degreaser emissions are mainly due to *solvent bath emissions, waste solvent disposal evaporation*, and *carryout*; *leakage and spillage* are also obvious sources of solvent loss. Emission control devices are applicable to degreaser systems on a case by case basis due to the diversity of the system. Small degreasers using room temperature solvent may either require only a cover, whereas a large degreaser using boiling solvent may require a refrigerated freeboard chiller or a carbon adsorption system. Thus, either a single control device or a combination of devices may be used to form a complete control system. Because degreaser designs and applications vary, an individual evaluation of the process must be performed to determine the optimum control system. Solvent emission control must be considered not only as an obvious means to reduce ROG emission but also as a means to reduce vapor degreasing operating costs. In fact, the largest single item of cost in the vapor-degreasing process is frequently the solvent "used-up" or lost in the process.[12]

13.1.6.1 Solvent Bath Emission Control

Five typical devices employed to reduce emissions from the solvent bath are:

1. Improved cover;
2. High freeboard;
3. Refrigerated freeboard chillers;
4. Carbon adsorption; and
5. Safety switches.

13.1.6.1.1 Improved Covers

The cover is the single most important control device for open top vapor degreasers. Covers are normally provided on open top degreasers as standard equipment. The cover may be simplified so that it will be more frequently used if it is either mechanically assisted, powered, or automated.[2]

For vapor degreasers, covers should open and close in horizontal motion, so that air/vapor interface is not disturbed. Covers of this type include roll-type plastic covers, canvas curtains, or guillotine covers. Automated covers may be powered pneumatically or electrically and are usually manually controlled with an automatic cutoff. The most advanced covering system are automated in coordination with the hoist or conveyor. Covers can be designed so they close while parts are cleaning and drying. Thus the covers would be opened for only a short time while the parts are actually entering or exiting the degreaser. A cover on an open top degreaser has been shown to reduce total emissions by 20% to 40%; effectiveness varies depending upon the frequency of cover use.[3]

Conveyorized degreasers already include covers in their design but additional cover-related controls can be used. These include minimizing openings and covering openings during shutdown hours. The average distance between the side at the opening and the part being cleaned is defined as the "average silhouette clearance". Rule 1122 requires a conveyorized degreaser to have at least an average silhouette clearance of 4 inches (100 mm) or 10% of the opening width.

Covers can be made for the entrance and exit of the conveyorized degreaser so that they can be used after degreaser shutdown. The cover (or downtime cover) can be any material that retards drafts into the degreaser and should cover 80% to 90% of the opening. The use of the cover immediately following shutdown (referred to as the shutdown cover) is most crucial because the hot solvent is cooling by evaporation. Also, the downtime cover will be effective for the more volatile vapor degreasing solvents even after the solvent sump has cooled.[3] For conveyorized degreasers, an estimated 18% of total emissions are due to evaporation during downtime.[3] Most of this loss can be eliminated by downtime cover.

On cold cleaners, covers are generally assisted by means of spring loading or counterweighting. A foot-operating pedal or powered system can facilitate this cover device. Two additional types of covers may be used: the submerged cover and water cover. The submerged cover (or commercially called the turbulence baffle) is a horizontal sheet of material submerged about 2 inches (50 mm) below the entire surface of the liquid in a cold cleaner where the solvent is vigorously pump agitated. The water cover is simply a layer of water about 2 to 4 inches (50 mm to 100 mm) thick over a heavy, non-water solvent.[3] Test data submitted by Dow Chemical Company demonstrated a 90 percent control efficiency for a 2.5 centimeter thick layer of water floating on PERC, compared to solvent exposed directly to air, in an idling mode.[5] Because a water cover will evaporate over time, it is important that additional water be added periodically to replenish losses, thus helping to maintain maximum control efficiency.[5] The water cover cannot be used in applications where water would corrode the metal surface or cause chemical degradation of the halogenated solvent.[3] Some solvents are miscible in, or lighter than water; water covers are ineffective in these cases.[5]

Establishing a single control efficiency for a cold cleaning cover is not possible because emission reduction varies too greatly with respect to solvent volatility, draft velocity, freeboard ratio, operating temperature, and agitation. However, bath evaporation rate does vary directly with solvent volatility at normal operating temperature. Although a closed cover can eliminate bath evaporation, the cover can do nothing to reduce carryout or waste solvent emissions. As a result, a normally closed cover becomes an effective control device only when bath evaporation is the major portion of total emissions. When solvent volatility is moderate to high 0.3 psi at 100 ^{o}F (approximately 2.1 kPa at 38 ^{o}C), closing the cover at all times is an effective control technique when parts are not being cleaned manually in the cold cleaner. The cover should always be closed when the bath is agitated or heated. If none of these conditions apply, the cover should at least be closed during long periods of nonuse, such as shutdown hours and idle periods greater than half an hour.[3]

13.1.6.1.2 High Freeboard

The freeboard serves primarily to reduce drafts near the air/solvent interface. An acceptable freeboard height is determined by its freeboard ratio. The District defines the freeboard ratio in Rule 1122 as the freeboard height divided by the smaller of the length or width of the degreaser.

$$\text{Rule 1122 Freeboard Ratio} = F/D \qquad \textbf{(Equation 13-1)}$$

where,

F = Freeboard height,
Cold solvent cleaning tanks: measured from solvent to opening of tank
Vapor degreasing tanks: measured from vapor to opening of tank
D = Smaller of the degreaser's length or width

The ASTM (ASTM D-26) recommends that open top degreasers using any type of solvent to have a minimum freeboard ratio of 0.75.[5] As deemed by Rule 1122, the freeboard ratio must be greater than or equal to 0.75 for cold solvent cleaners, open-top vapor degreaser, or conveyorized vapor degreaser. An increase in the ratio from 0.5 to 1.09 may yield a 50% reduction in emissions.[3]

Freeboard height has little effect on cold cleaning solvents with low volatilities, such as mineral spirits. An increase of freeboard ratio above typical values yields a benefit only for cold cleaners with high volatility solvents, such as halogenated ones. Nevertheless, the Occupational Safety and Health Administration (OSHA) requires at least a 6 inches (150 mm) freeboard.[3] Equipping the cold cleaner with a visible internal fill line will assist the operator in maintaining the desired freeboard ratio by being able to directly observe if the solvent level is above the proper operating level.[5]

13.1.6.1.3 Refrigerated Freeboard Chillers

Refrigerated freeboard chillers are emission control devices used on vapor degreasers. The primary condensing coils or water jacket will prevent the vapor created within a vapor degreaser from overflowing out of the equipment; they should not be confused with refrigerated freeboard chillers. As noted in Figure 13-19, refrigerated freeboard chillers are located above the primary condenser coils and are used in order to increase the vapor control efficiency. Primary condenser coils control the upper limit of the vapor zone, while refrigerated freeboard chilling coils hinder the diffusion of solvent vapors from the vapor zone into the work atmosphere. This occurs when the air is chilled immediately above the vapor zone and a cold air blanket is created. As a result of this sharper temperature gradient, this blanket also reduces mixing of air and solvent vapors by narrowing the air/vapor mixing zone. Also, chilling decreases the upward convection of warm, solvent-laden air by producing a stable inversion layer.[3]

Freeboard chillers should be designed to achieve less than or equal to 30% of the solvent's boiling point. As a rule of thumb, refrigerated freeboard chillers are generally sized by specifying cooling capacity per length of perimeter. The above-freezing refrigerated freeboard chiller is frequently designed to have a minimum of 500 Btu/hr-ft (865 W/m-°K) cooling capacity per foot (305 mm) of air/vapor interface perimeter. The below-freezing refrigerated freeboard chiller is reported to be normally designed along the following specifications[3]:

Degreaser Width, ft (m)	Minimum Cooling Capacity, Btu/hr-ft (W/m-°K)
< 3.5 (1.1)	200 (346)
> 3.5 (1.1)	300 (519)
> 6 (1.8)	400 (692)
> 8 (2.4)	500 (865)
> 10 (3.0)	600 (1,038)

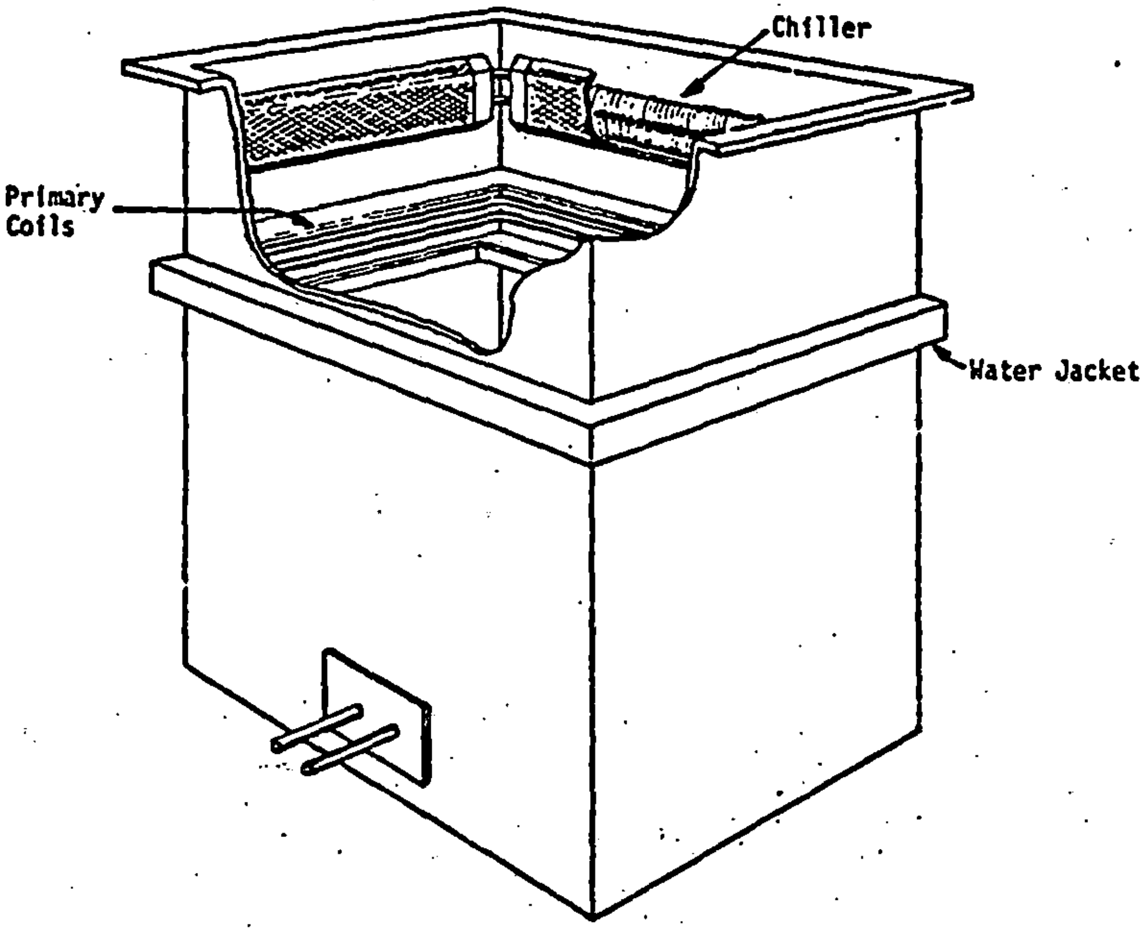


FIGURE 13-19 DEGREASER WITH REFRIGERATED CHILLERS[3]

Normally, each pass of finned cooling coil is expected to remove 100 Btu/hr-ft (173 W/m-°K).[3]

Another type of refrigerated chiller is the refrigerated condenser coil. Refrigerated condenser coils replace primary condenser coils rather than provide an extra set of chilling coils as the freeboard chillers do. If the coolant in the condenser coils is sufficiently refrigerated, this will create a layer of cold air above the air/vapor interface.[2] Du Pont and Rucker Ultrasonics have recommended that the cooling rate of refrigerated condenser coils be equal to 100 % to 120% of the heat input in the boiling sump in order to give optimum emission control.[3] However, the energy consumed in maintaining the optimum cooling rate in large open top vapor degreasers may be too great and costly. As a result, refrigerated condenser coils are normally used on small open top vapor degreasers.[2]

13.1.6.1.4 Carbon Adsorption

Carbon adsorption is used frequently to trap solvent emissions from metal cleaning operations. Figures 13-20, 13-21, and 13-22 depict the carbon adsorber, adsorption cycle, and desorption cycle, respectively. Adsorption is the process of removing liquids molecules from a stream using a solid adsorbent. Adsorbents are materials which selectively remove gases or liquids from air streams. The material which adheres to the adsorbent is called the adsorbate. Adsorption occurs at all solid interfaces but is minimal unless the adsorbent has a large surface area, is porous, and possesses capillaries. The important characteristics of solid adsorbents are their large surface-to-volume ratios and preferential affinity for individual components.

The carbon adsorption process includes three steps. The adsorbent is first contacted with fluid, and a separation by adsorption results. The gas molecules adhere to the surface of the solid adsorbent as a result of intermolecular attractive forces (van der Waals forces) between them.[11] Second, the unadsorbed portion of fluid is separated from the adsorbent. For gases, this operation is completed when gases leave the adsorbent bed. Third, the adsorbent is regenerated by removing adsorbate from the adsorbent. For solvent recovery, typically low pressure steam is used to regenerate

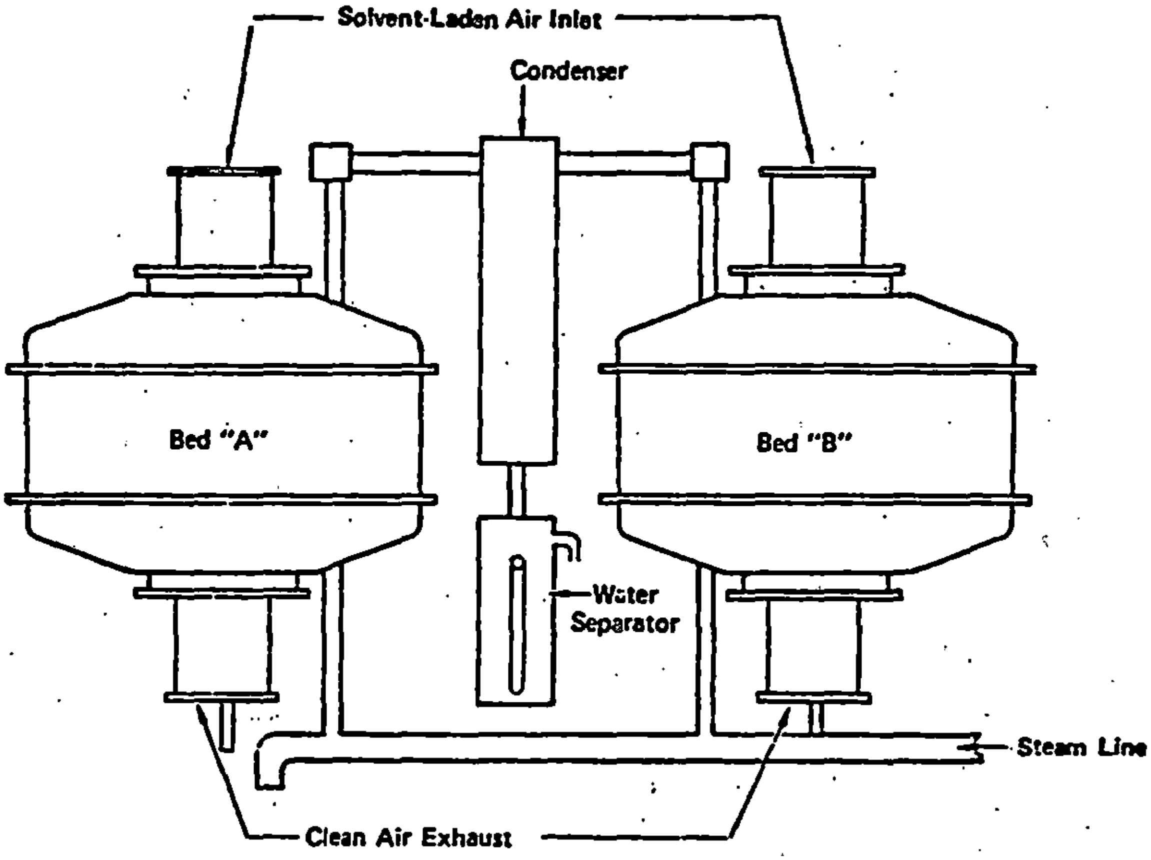


FIGURE 13-20 CARBON ADSORBER[3]

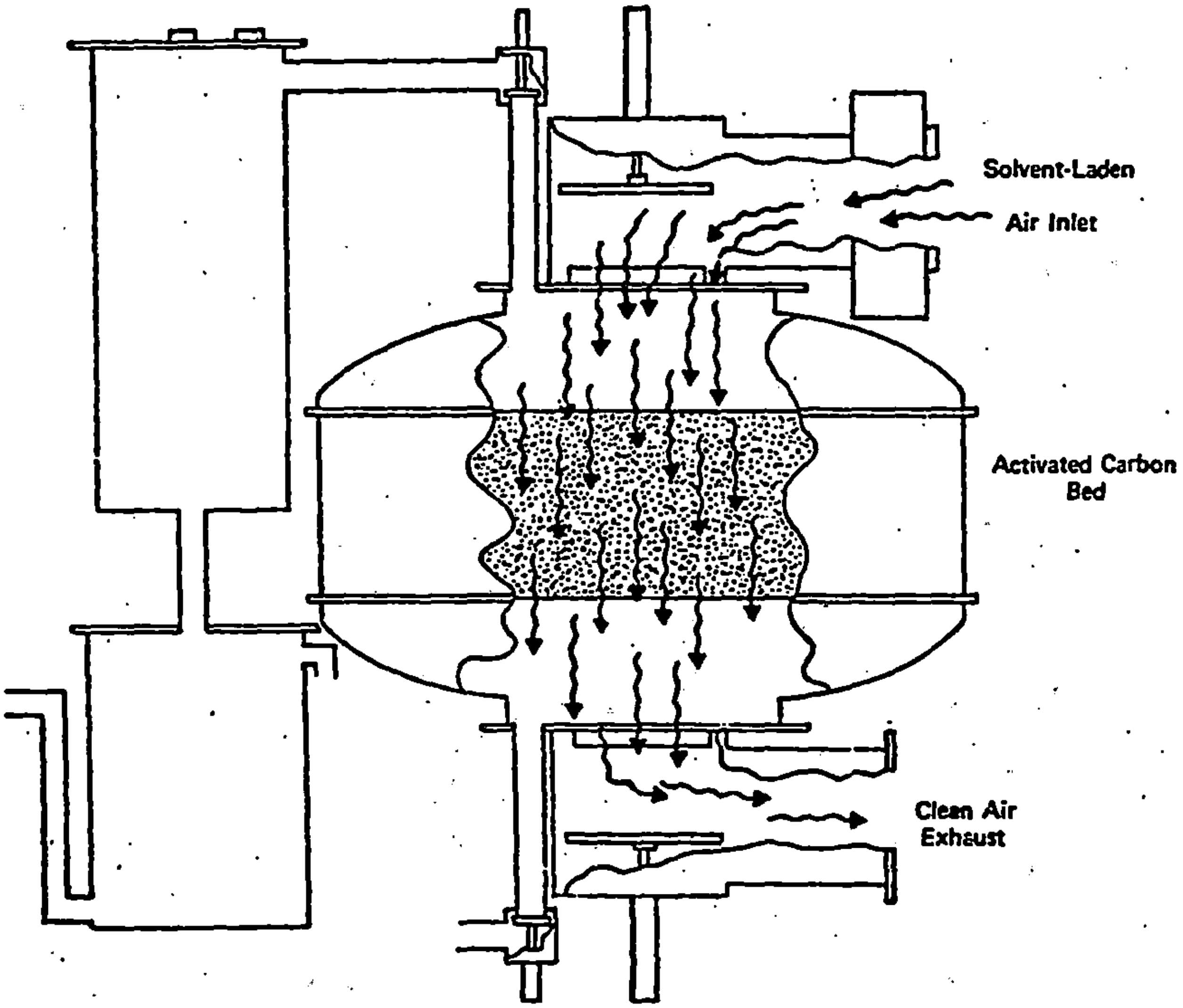


FIGURE 13-21 ADSORPTION CYCLE[3]

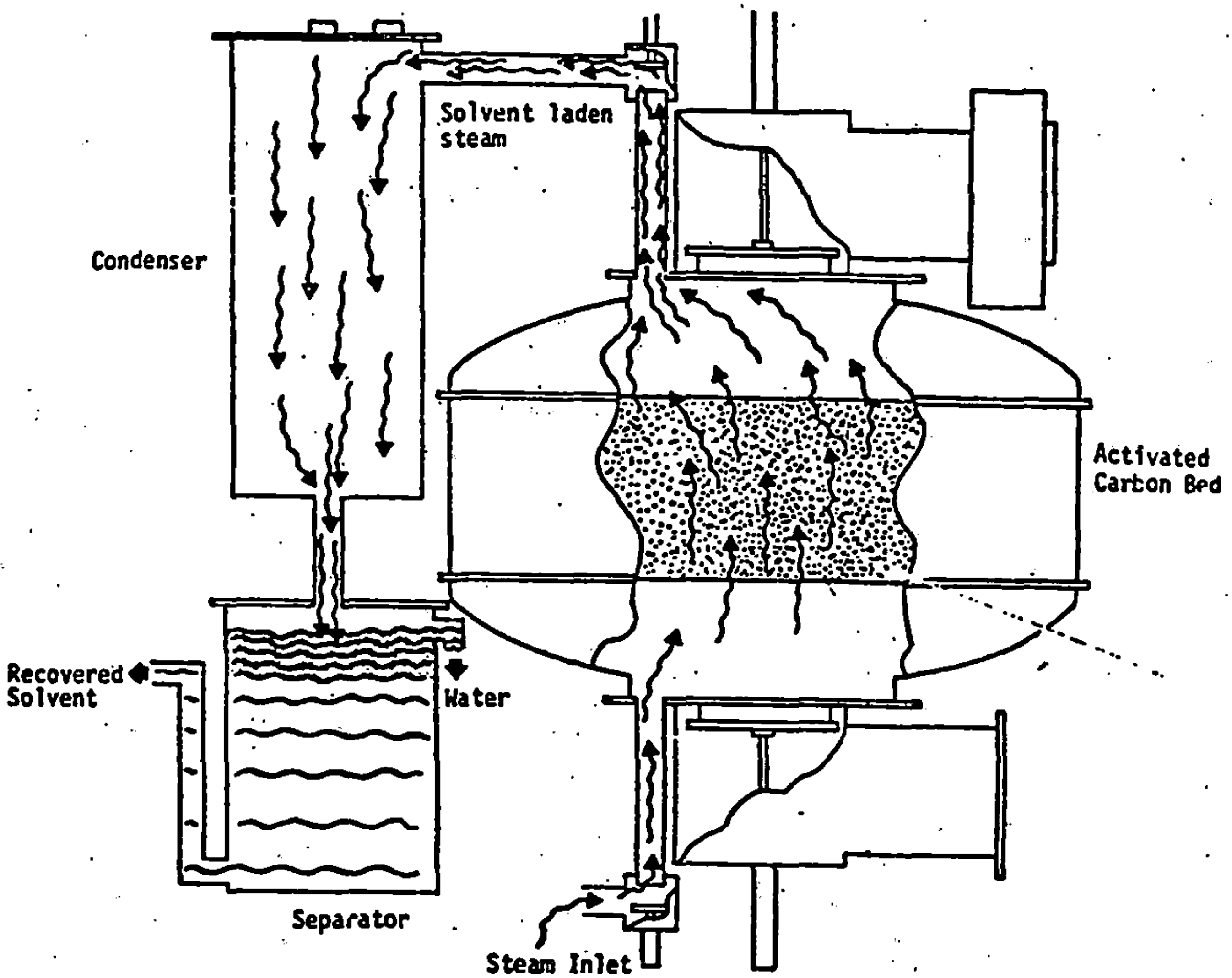


FIGURE 13-22 DESORPTION CYCLE[3]

the adsorbent. The vapors are condensed and separated from the water by decantation, distillation, or both.

Activated carbon is capable of adsorbing 95% to 98% of many organic vapors from air at ambient temperature and even in the presence of water in the gas stream.[9] However, at ambient temperatures, recovery of solvents present in air in small concentrations is low.

When a mixture of solvent vapor in air is passed over activated carbon, removal of solvent vapor is complete at the beginning, but as the activated carbon approaches its adsorptive limit traces of vapor will appear in the exit air. This situation is called breakthrough. As the air flow is continued, the concentration of solvent vapor in the exit air increases until it equals that in the inlet air.[2] No further adsorption can occur at this point and the carbon must be regenerated.

The adsorption rate of a mixture of organic vapors in air is not uniform; the organic constituents in the air with the higher boiling points are considered *less* volatile and thus are more easily adsorbed. As air containing a mixture of organic vapors is passed over activated carbon, vapors are all adsorbed at the start. Thus, as the amount of the higher boiling constituent in the adsorbent increases, the more volatile constituent revaporizes. Thus, the exit vapor consists primarily of the more volatile constituent after breakthrough has been reached. This process continues for each organic constituent until the highest boiling constituent is present in the exit gas. Therefore, to ensure maximum control of organic vapor mixtures, the adsorption cycle should be stopped when the first breakthrough occurs as determined by detection of vapors in the exit gas.[2]

The quantity of organic vapors adsorbed by activated carbon is a function of the particular vapor in question, the adsorbent, the adsorbent temperature, and the vapor concentration. Removal of gaseous vapors by physical adsorption is practical for gases with a molecular weight over 45.[13] Each type of activated carbon has its own adsorbent properties for a given vapor, and the quantity of vapor adsorbed for a particular temperature is best determined experimentally. The quantity of vapor adsorbed increases when vapor concentration increases and adsorbent temperature decreases.[2]

Control of solvent vapor emissions by adsorption on activated carbon is applied when adsorbate recovery is economically desirable. Several aspects of using carbon adsorption with degreasers are distinctive. For example, solvent mixtures are sometimes used. Although combinations will be adsorbed, collected solvent vapors will be rich in the less volatile components so that recovered solvent is rarely identical in concentration to that used in the cleaning system. In addition, there are effluent components that are water soluble, such as acetone or butanol used as cosolvents with fluorocarbons and various stabilizers that are added to most solvents to inhibit decomposition. These water soluble components will be selectively extracted by the steam during the desorption process. In such cases, if the recovered solvent has not decomposed, it can be reused; however, fresh solvent, stabilizers, and/or cosolvents must be added or the water soluble compounds recovered by distillation or some other means.[2]

Carbon adsorption systems for solvent metal cleaning can be expected to achieve only 40% to 65% net reduction of the total solvent emission. This is because the ventilation apparatus of the control system cannot capture all solvent vapors and deliver them to the adsorption bed. Improved ventilation design can increase an adsorber's overall emission control efficiency. Higher ventilation rate alone, however, will not necessarily be advantageous; it will require large, expensive adsorbers and may disrupt the air/vapor interface and thereby increase losses.[2]

13.1.6.1.5 Safety Switches

Safety switches are preventive devices used only for vapor degreasers. They reduce emissions only during malfunctions and abnormal operation. The five main types of safety switches are (1) safety vapor level control thermostat , (2) condenser water flow switch and thermostat, (3) solvent sump thermostat, (4) solvent level control, and (5) spray safety switch. Switches one through four turn off the sump heat, and switch five turns off the spray.

The safety vapor thermostat is the most important switch since it detects the solvent vapor zone once it rises above the condenser coils. Heat is turned off when hot vapors are sensed. The safety thermostats should be the manual reset type and should be checked frequently for operation. As a result, the safety vapor thermostat reduces emissions and protects the operator's health by preventing the vapor level from rising above the condenser coils and causing emissions. OSHA already requires that open top degreasers have a safety vapor thermostat.[2] For conveyorized degreasers, the vapor level control thermostat should activate an alarm system.[3]

The condenser water flow switch and thermostat turn off the sump heat when the condenser water stops circulating or becomes warmer than specified. With the condenser water flow switch and thermostat properly adjusted, this will serve as a backup for the safety vapor thermostat and also ensure the condenser coils are operating efficiently.[2]

Both the third and fourth type of safety switch prevent the sump from overheating and causing solvent decomposition. The boiling sump thermostat cuts off the sump heat when the sump temperature rises above the solvent's boiling point. This is caused by excessive oil concentration in the sump. The solvent level control turns off the heat when the level of the boiling sump drops down to the height of the sump heater coils.[3] Without this control, the heat can decompose the solvent or an exothermic reaction may occur to emit noxious fumes, such as hydrochloric acid, which is very corrosive.[2]

13.1.6.1.6 Incineration

Incineration conceptionally could be used to control emissions from degreasing. It could be applied to systems using petroleum hydrocarbons and oxygenated solvents which readily combust to carbon dioxide and water. Although chlorinated hydrocarbons are nonflammable under normal conditions, they can be pyrolyzed at temperatures in the incineration range. This pyrolytic decomposition will unfortunately release chlorine, hydrochloric acid, and phosgene, depending on decomposition conditions. These products would have to be removed from the off-gas stream of the incinerator before exhausting to the atmosphere requiring sophisticated gas cleaning equipment.[2] Presently, no incinerators are used in the District to control solvent emissions presently.

13.1.6.2 Waste Solvent Disposal Evaporation Control

Evaporation emissions due to waste solvent disposal occurs within all three degreaser types. This type of emission is greatest in cold cleaners, while smallest in conveyorized degreasers.

Waste solvent evaporation depends not only upon the amount but also upon the method of disposal. Acceptable methods of handling waste solvent include proper incineration, distillation, and chemical landfilling, where the waste solvent is buried in enclosed containers and encapsulated by impermeable soil. Disposal routes that result in total emission to the environment include flushing into sewers, spreading waste solvent for dust control, such as on dirt roads, and landfilling where the solvent can evaporate or leach into the soil.[3]

There are four practices that can reduce and nearly eliminate the atmospheric evaporation from waste solvent disposal: boil-down; use of in-house distillation, use of contact reclamation services; and transfer to acceptable disposal facilities.[2]

Boil-down is a technique of distilling pure solvent from the contaminated mixture in the degreaser. As the contaminated solvent is boiled in the sump, pure solvent vaporizes and condenses on the cooling coils where it is routed to and stored in a hold tank. Boil-down can usually reduce the solvent content in the contaminated material to less than 40 to 45 percent by volume.[2]

13.1.6.3 Carryout Emission Control

Carryout or dragout emissions are the solvent emissions resulting when clean parts still contain liquids during extraction from the vapor degreasers. The solvent extracted may exist as a liquid coating the part or a liquid entrapped in irregular surfaces and cavities within or on the part. Proper operating procedures are the best method for reducing carryout emission. There are devices to assist in lessening the carryout from cold cleaners and conveyorized degreasers, but not generally from open top vapor degreasers.

The principle control device for carryout emissions from cold cleaners is a simple drainage facility. Two types of drainage facilities are the external and internal racks or shelves. The external drainage rack is attached to the top side of the cold cleaner. The liquid solvent on the cleaned parts drains onto the drainage shelf and flows back into the cold cleaning bath. An internal drainage facility is located beneath the cover. It may be a basket holding parts that is suspended over the solvent bath or a shelf from which the solvent drains. The carryout emissions may be substantially reduced by allowing longer drainage time. According to ASTM-26, cleaned parts should be drained at least 15 seconds.

For conveyorized degreasers, the main control devices for carryout emissions are a drying tunnel and rotating baskets. A conveyor itself may contribute to carryout emission. Some designs cause less emissions than others. In most cases, these emissions are directly proportional to the surface area entering and leaving the cleaning zone. A drying tunnel is an extension of sheet metal from the exit of the conveyorized degreaser. This tunnel extension provides cleaned parts more time to completely dry. The drying tunnel will work well in combination with carbon adsorption. Rotating baskets may be used on cross-rod degreasers and ferris wheel degreasers. The rotating basket is a perforated cylinder consisting of parts to be cleaned that is slowly rotated through the cleaning system so that the parts cannot trap liquid solvent.[2]

13.2 Permit Unit Description

Generally, degreaser is described in the permit as follows:

DEGREASING SYSTEM CONSISTING OF:

1. DEGREASER, ________________________ (MANUFACTURER'S NAME), ______________________ (VAPOR-SPRAY, WATER-SPRAY, CONVEYORIZED, COLD SOLVENT, ETC.) TYPE, MODEL NO.__________________, _____'-_____" W. x _____'-____" L. x _____'-_____" H. INSIDE, SERIAL NO.__________, ________(RATING:

BTU/HR, H.P., KW) ______________(ENERGY INPUT AND HEATING METHOD), WITH (_________ H.P. SPRAY PUMP, WATER-COOLED CONDENSER COILS AND WATER JACKET, _________ H.P. REFRIGERATED PRIMARY CONDENSER, _________ H.P. REFRIGERATED FREEBOARD CHILLER, _________ H.P. TRANSFER PUMP, A LIP EXHAUST, AND ______'-_________" H. FREEBOARD).

2. SOLVENT STILL, _________________________ (MANUFACTURER'S NAME), MODEL NO.________________________, ____'-____" W. x ____'-_____" L. x ____'-____" H., SERIAL NO.___________, ________ (RATING: BTU/HR, H.P., KW) ______________(ENERGY INPUT AND HEATING METHOD).

13.3 Emissions

The major causes of ROG emissions include leaks, loss of solvent vapor from the tank due to diffusion, convection, and movement of surrounding air, carryout of solvent on the cleaned parts, and evaporation from disposal of waste solvent. The quantity of emissions varies on such factors as the type and size of equipment, hours of operation and operating techniques, and the type of material being cleaned.

13.3.1 Cold Cleaner Emissions

Emissions from cold cleaners are the lowest emission rates per unit among the three basic degreaser types; however, total cold cleaner emissions for all solvents are greater than those for either vapor degreasers or conveyorized units, due to the large number of cold cleaners in operation.

There are various means by which organic solvent vapors can be emitted to the atmosphere from a cold cleaner. These can be noted in Figure 13-3. An obvious emission point is the direct evaporation of solvent from the tank to the atmosphere (location 1). Carryout emissions (location 2) result from liquid solvent that is physically carried out of the degreaser on the cleaned parts and subsequently evaporates. Mechanical agitation of the solvent bath (location 3) increases evaporative losses. Turbulence from spraying (location 4) increases emissions as does overspraying (spraying outside the tank), and excessive spray velocity. Lastly, the emissions from the disposal of waste solvent (location 5) can vary significantly, depending on the techniques used.[4]

Bath evaporation occurs from the solvent surface and from exposed set surfaces inside the cleaning tank. The area of the solvent-air interface within the cold cleaner greatly influences emissions. Evaporation is increased by air movement such as drafts or ventilation and is directly related to the evaporation rate of the solvent used. Thus, evaporation is greatest when highly volatile solvents are used, when the solvent is heated, and when the cover is open.[3] Bath evaporation can be greatly reduced through use of a cover and an adequate high freeboard height. Generally, the cover should be closed whenever the parts are not being handled in the cold cleaner. Although covers are standard equipment on most cold cleaners, keeping the cover closed requires conscientious effort on the part of the operator and his supervision.[3]

Carryout losses are due to the liquid or vaporous solvent entrained on cleaned parts as they are taken out of the degreaser. The less volatile solvents are most likely to be emitted by means of liquid carryout.[10] The liquid solvent eventually evaporates into the atmosphere except for those drippings which are captured by means of drainage racks or shelves. The drainage facility is standard equipment for some cold cleaners and is easily and inexpensively retrofitted for most other cold cleaners. The carryout emissions may be substantially reduced by allowing longer drainage time. According to ASTM-26, cleaned parts should be drained at least 15 seconds.

Mechanical agitation can significantly increase the evaporation rate from the bath. The rate of emission depends on: (1) use of the cover, (2) agitation system adjustments, and (3) volatility of the solvent. If the cover is kept closed during agitation, then emissions usually are insignificant; agitation emissions can increase dramatically with the cover open. This is especially true with ultrasonic agitation of solvents heated to their optimum cavitation temperature. The bath should never be agitated longer than necessary to complete the cleaning. The air flow into air agitated cleaners generally should be about 0.01 to 0.03 m^3 per minute per square meter of opening.[3]

Waste solvent evaporation is the greatest source of emissions from cold cleaners. The size of the cold cleaners and the frequency of disposal influences the amount of waste solvent disposed. The solvent will be disposed of more often when the cleaning job removes large quantities of oil and other contaminants, or requires a high degree of cleanliness. The frequency of disposal may be reduced if the cold cleaner spray system is equipped with a filter.[3]

In addition, evaporation from solvent spraying will increase with the pressure of the spray (causing turbulence and splashing), the fineness of the spray (since finer spray evaporates more quickly), and the tendency to splash and overspray out of the tank. Evaporation is also greater when the spray is used constantly and when volatile solvents are used. Preferably, the spraying pressure should be less than 10 psig, and the spray should be a solid, fluid stream.[10] As a result, Rule 1122(c)(7) requires that solvent flow cleaning be a liquid stream.

13.3.2 Open Top Vapor Degreaser Emissions

As opposed to cold cleaners, open top vapor degreasers lose a relatively small proportion of their solvent in the waste material and as liquid carryout. Most of the emissions are those vapors that diffuse out of the degreaser. Emissions from the degreaser top include the solvent, solvent stabilizers, and the grease or oil removed from the parts being degreased.[2] The only solvents used on open top vapor degreasers are TCE, PERC, 1,1,1-trichloroethane, methylene chloride, trichlorotrifluoroethane, and trichlorotrifluoroethane blends.[3]

An average open top vapor degreaser emits about 0.5 pounds per hour ft^2 (2.5 kilograms per hour per m^3) of opening. This estimate is derived from national consumption data on vapor degreasing solvents and from EPA emission tests. Assuming an average open top vapor degreaser having an open top area of about 18 ft^2 (1.67 m^2), a typical emission rate would be about 9 pounds per hour or 10 tons per year (4.2 kilograms per hour or 9,500 kilograms per year).[3]

The main open top vapor emission sources are shown in Figure 13-4. These emissions can be attributed to (1) diffusion, (2) carryout, (3) turbulence from lip exhaust, and (4) waste solvent evaporation. Diffusion and convection losses are the larger emissions, then followed by carryout losses. Emissions from waste solvent evaporation contribute to less than 25 percent of the total emissions.

Diffusion is the discharge of solvent vapors from the vapor zone out of the degreaser. Solvent vapors mix with air at the top of the vapor zone. This mixing increases with drafts and with disturbances from cleaned parts being moved into and out of the vapor zone. The solvent vapor thus diffuses into the room air and into the atmosphere. These solvent losses include the convection of warm solvent-laden air upwards out of the degreaser.[3]

According to Bollinger, et. al, diffusion losses from the open top vapor degreaser can be minimized by:

- closing the cover;
- minimizing drafts;
- providing sufficient cooling by the condensing coils;
- spraying only below the vapor level; and
- avoiding excessively massive work loads.

Sufficient cooling by the condensing coils should be achieved by following design specifications for the degreaser. Cooling rate is a function of solvent type, heat input rate, coolant temperature, and coolant flow. The cooling rate should be enough to remove the solvent's latent heat of vaporization and prevent entrainment of vapors. Spray pressure should be the minimum necessary for proper performance.

Poor operation can increase convective losses from the solvent bath. For instance, if work baskets are overloaded, the vapor zone may collapse, increasing air vapor mixing and, thus, emissions. This can be avoided by following the manufacturer's specification for allowable work load in tons per hour, which is determined through an energy balance of the system.[3] Solvent vapors should be generated at the same rate at which they are condensed by work entering the vapor zone. If too little vapor is generated, the vapor level will drop and air will be drawn into the degreaser. If too much vapor is generated, the vapor level will rise above the condensing coils and vapor will escape from the machine.[2] These problems may be resolved with the addition of safety switches such as a vapor level sensing feedback system on the vapor degreaser.

As for carryout emissions, crevices and cupped portions of the cleaned parts may capture liquid and vaporous solvents even after the parts appear to be dried. As a result, solvent vapors are emitted as the cleaned part is drawn out of the vapor zone. The hot, cleaned part heats solvent-laden air at the same time, causing it to convect upwards out of the degreaser.[2]

There are seven factors which directly effect the rate of carryout emissions: porosity or absorbency of work loads; size or work loads in relation to the degreaser's vapor area; racking parts for drainage; hoist or conveyor speed; cleaning time in the vapor zone; solvent trapped in cleaned parts; and drying time.[2]

Porous or absorbent materials such as cloth, leather, wood, or rope will absorb and trap condensed solvent. Thus, these materials should not be in the vapor zone.[2]

The work load preferably should not occupy more than one-half of the degreaser's working area. Otherwise, vapors will be pushed out of the vapor zone by means of a piston effect.[2]

Proper racking of parts is needed to lessen entrainment of solvent. For example, parts should be positioned vertically with cups or crevices facing downward.[2]

Cleaning time is the period the work load remains in the vapor zone. If this is not long enough to allow the work load to reach the temperature of the condensing vapor, the parts will not dry properly when removed from the vapor zone. The work load must remain in the vapor zone long enough so that the vapors will no longer condense on the parts. Generally 30 seconds is sufficient; however, larger work loads may require longer periods.[2] Before the cleaned parts emerge from the vapor zone, they should be tipped and/or rotated to pour out any collected liquid solvent. The work load should be removed from the vapor zone slowly.[2] A maximum hoist speed of 11 feet per minute (3.3 meters per minute) has been generally accepted as reasonable by the degreasing industry. Rushing work loads into and out of the degreaser will force solvent vapors out into the air and leave liquid solvent on the cleaned parts which can subsequently evaporate into the air.[2]

Drying time is critical. It should be long enough to allow the solvent to vaporize from the clean part but not significantly longer. When a hot dried part rests just above the vapor level, it causes solvent-laden air to heat up and rise. Typically a work load can dry in 15 seconds.[2]

Solvent emissions may also result from disposing of waste solvent sludge in ways where the solvent can evaporate into the atmosphere. Although the waste solvent evaporation from vapor degreaser sludge is usually less than the diffusion and carryout losses, it still contributes about 5 to 20 percent of the degreaser's total solvent emissions. The volume of waste solvent in sludge from vapor degreasers is much less than that from cold cleaners for equivalent work loads for two reasons. First, the solvent in the vapor degreaser sump can be allowed to become more contaminated than the solvent used in a cold cleaner because the contaminants, with high boiling points, stay in the sump rather than vaporize into the vapor zone. Second, vapor degreasing solvents are halogenated, as such are generally more expensive; thus, they are more often distilled and recycled than cold cleaning solvents.[2]

In some poorly designed exhaust systems, the ventilation rate can be too high. If the air/vapor interface is disrupted by high ventilation rates, more solvent vapors will mix with air and be carried out by the exhaust system. Generally, manufacturers of degreaser equipment and control systems set the exhaust rate at 50 cubic feet per minute per square foot of degreaser opening (15 cubic meters per minute per square meter).[2]

13.3.3 Conveyorized Degreaser Emissions

As shown in Figure 13-4, conveyorized degreasers have the same basic emissions associated with open top vapor degreasers: diffusion from the solvent bath, carryout, exhaust, and waste solvent evaporation. For a similar work load, solvent emissions are much less for conveyorized degreasers than for the open top vapor degreasers. Convection and diffusion losses are small, because conveyorized degreasers are enclosed except for small entrance and exit ports.

Carryout of vapor and liquid solvent is the major emission source from conveyorized degreasers. Thus, it is difficult to reduce carryout emissions since the amount of work load is inherently large. The two main factors affecting carryout emissions are the drainage of cleaned parts and their drying time. Controlling emissions effectively can be accomplished with adequate allowance for draining and drying within the enclosure and proper equipment design and/or equipment retrofitting such as a drying tunnel or rotating baskets.[5] Parts drainage is improved by proper racking. Racking is especially critical in conveyorized degreasers, because there is little an operator can do to reduce carryout from a poorly designed system. The degreaser design should allow sufficient space and time for the cleaned parts to dry completely. Some designs include a shroud extending from the exit to form a drying tunnel. Again the conveyor speed should not exceed 11 feet per minute (3.3 meters per minute) vertical rise.[10]

Evaporation due to waste solvent disposal is the smallest percentage emission from conveyorized degreasers. Most conveyorized degreasers include an external still attached to the unit so that the solvent can be constantly pumped out, distilled, and returned to the sump. Wastes disposed from conveyorized degreasers usually include the sump and still bottoms only, and amount to less than 20 percent of the total emissions.[3,5]

The main adjustment affecting the bath evaporation rate is the heating and cooling balance. Basically, the cooling supplied by the primary condensing coils should be sufficient to condense all the vaporized solvent. Also, the heating rate needs to be large enough to prevent the vapor level from dropping as cold parts enter the vapor zone.[3]

With regard to equipment design, bath evaporation can be reduced by minimizing the entrance and exit areas and by regulating the spray system.[10] Obviously, the smaller the area of opening, the lower the loss of solvent vapors. Partial covers can be placed over the openings which shadow the parts to be cleaned yet give enough margin for safe passage. Sprays should be designed or adjusted so that they do not cause turbulence at the air/vapor interface. Like open top vapor degreasers, spray pressure should be the minimum necessary for proper performance.[3]

13.3.4 Emission Factors

Rather than using emission factors in calculating emissions, the SCAQMD's current practice is to determine degreaser emissions using a mass balance. Emissions for degreasing operations are calculated by determining the difference between the total amount of solvent supplied to the operation and the amount of solvent removed in the degreaser waste solvent activities. Emission factors would only be used when actual waste solvent data are not available, such as with an area source emission inventory.

13.4 Emission Calculations

In order to process the degreaser application or determine the compliance status of the degreaser, the applicant must provide the following information:

Degreaser Type ______________________
  Dimensions ________'________"W, ________'________"L
  Freeboard Height ________'________"
  Open Surface Area ______________________ft^2
  Type of Vapor Controls ______________________
  Method of Heating
    [ ] Gas ______________________BTU/hr
    [ ] Heat Pump ______________________h.p.
    [ ] Electric ______________________KW
    [ ] Steam
  Method of Cooling
    [ ] Refrigeration ______________________h.p.
    [ ] Chilled water,

inlet water tempt. ____________ °F
outlet water tempt. ____________ °F
[ ] Water,
inlet water tempt. ____________ °F
outlet water tempt. ____________ °F

Secondary Method of Cooling Degreaser (if any):

Refrigerated Freeboard Chiller:
Compressor: ____________ h.p.
[ ] Above Freezing [ ] Below Freezing
Temperature of Refrigerant in Freeboard ____________ °F
Cooling Capacity ____________ BTU/hr

Spray Pump Rating ____________ h.p.
Transfer Pump Rating ____________ h.p.

Solvent Used

Density of the Solvent ____________ lbs/gal
% Reactive (by weight): ____________ %
Quantity of Solvent Loss (Does not include solvent removed for reclamation or disposal):

Average: ____________ gal/day
____________ gal/month
Maximum ____________ gal/day
____________ gal/month

Maximum Operating Schedule ____________ hrs/day
____________ days/week
____________ weeks/yr

Emissions should be calculated for both reactive and unreactive hydrocarbons (RHC and UnRHC). To calculate emissions the following equations may be used:

Average Daily Emissions:

RHCavg = v1 x ρ x %RHC
or = v2 x ____ month/yr x 1yr/____ days x ρ x %RHC
= ____________ lb/day (Equation 13-2)

UnRHCavg = v1 x ρ x (100% - %RHC)
or = v2 x ____ mth/yr x 1yr/___ day x ρ x (100% - %RHC)
= ____________ lb/day

(Equation 13-3)

AEIS Emission Calculation:

R1(RHC) = RHCavg x 1 day/_________ hours = _________ lb/hour
R2(RHC) = R1(RHC)

(Equation 13-4)

R1(UnRHC) = UnRHCavg x 1 day/______ hours = _________ lb/hour
R2(UnRHC) = R1(UnRHC)

(Equation 13-5)

Maximum Daily Emissions:

RHCmax = V1 x ρ x %RHC
or = V2 x ___ mth/yr x 1yr/____ days x ρ x %RHC
= ____________ lb/day

(Equation 13-6)

UnRHCmax = V1 x ρ x (100% - %RHC)
or = V2 x ___ mth/yr x 1yr/___ day x ρ x (100% - %RHC)
= ____________ lb/day

(Equation 13-7)

REGULATION XIII:

RHC = RHCmax x 1.1 = ________________ lb/day

(Equation 13-8)

RHC BACT = RHC x (1 - E2/E1) = ________________ lb/day

(Equation 13-9)

where,

F = Freeboard height
Cold solvent cleaning tanks: measured from solvent to opening of tank; or
Vapor degreasing tanks: measured from vapor to opening of tank
D = Smaller of the degreaser's length or width
E1 = Normalized emission of degreaser (basic equipment), MLK's memo October 24, 1983: Vapor Degreasers, Appendix 13B
E2 = Normalized emission of air pollution control device, MLK's memo October 24, 1983: Vapor Degreasers, Appendix 13B
RHC = Maximum Regulation XIII reactive hydrocarbon emission, lb/day
RHC BACT = Maximum Regulation XIII reactive hydrocarbon emission with BACT, lb/day
RHCavg = Average reactive hydrocarbon emissions, lb/day
RHCmax = Maximum reactive hydrocarbon emissions, lb/day
R1(RHC) = Uncontrolled reactive hydrocarbon emissions, lb/hour
R2(RHC) = Controlled reactive hydrocarbon emissions, lb/hour
R1(UnRHC) = Uncontrolled unreactive hydrocarbon emissions, lb/hour
R2(UnRHC) = Controlled unreactive hydrocarbon emissions, lb/hour
UnRHCavg = Average unreactive hydrocarbon emissions, lb/day
UnRHCmax = Maximum unreactive hydrocarbon emissions, lb/day
v1 = Average solvent consumption per day, gal/day
v2 = Average solvent consumption per month, gal/month
V1 = Maximum solvent consumption per day, gal/day
V2 = Maximum solvent consumption per month, gal/month
ρ = Density of the solvent, lb/gal
%RHC = Percentage of the reactive solvent, %
1.1 = Regulation XIII On-Site offset factor

A health risk assessment must be performed if a toxic or carcinogenic solvent is used in the degreaser. Currently, the Division is following the Risk Assessment Policy Memorandum, dated November 4, 1987. This risk assessment must be done for all toxic compounds used for degreasing. For sources with a carcinogenic source strength (CSS) or risk greater than one-in-one million (1×10^{-6}), a California Environmental Quality Act (CEQA) document will be required. If approved mitigation measures are employed, a source is allowed a risk of ten-in-one-million (10×10^{-6}) probability of contracting cancer.

13.5 Rules Evaluation

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing a permit.

Rule 401 - Visible Emissions
No visible emission of 20% opacity or Ringlemann No. 1 or more aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance
Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 442 - Usage of Solvent
Section (a)(4) of this Rule requires that the organic solvent used in the degreasing operation be non-photochemically reactive and under the 600 lb/day limit per equipment;

The emissions from the photochemically reactive solvent has been reduced by at least 85 percent by weight; or

1,1,1-trichloroethane, methylene chloride, or trichlorotrifluoroethane is used and is exempt from the provisions of this rule.

Rule 443 - Labeling of Solvent
Solvent container will be clearly and properly labeled.

Rule 1122 - Solvent Cleaners (Degreaser)
A person who uses solvent containing VOC (Volatile Organic Compounds) to clean or degrease surfaces shall use a device for such operation which includes all equipment and follows all operation requirements depending on the type of degreaser as stated in 1122(b) and 1122(c) of the South Coast Air Quality Management District's Rules and Regulation.

There are exceptions to the requirements of Rule 1122. The provisions for the rules in 1122(b) and 1122(c) shall not apply to equipment which use only the cleaning materials or methods given in 1122(d).

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day of any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT which has been achieved in practice for reactive organic gas emissions for specific types of degreasers is given by the following:

Cold Degreaser Tank:

ROG:
- Compliance with Rule 1122 for all solvents;
- Water cover and compliance with Rule 1122 for methylene chloride with > 6 lbs/day uncontrolled ROG emissions.

Cold Solvent Cleaning Tank:

ROG:
- Compliance with Rule 1122 for all solvents;

- Water cover and compliance with Rule 1122 for methylene chloride with ≥ 6 lbs/day uncontrolled ROG emissions.

Film Cleaning Machine:

ROG: Carbon adsorber for 1,1,1 trichloroethane with ≥ 2.2 lbs/day uncontrolled ROG emissions.

Solvent Spray Booth, Except 1,1,1 Trichloroethane:

ROG: Compliance with Rule 1122 for all solvents.

Solvent Spray Booth, 1,1,1 Trichloroethane:

ROG: Carbon adsorber.

Vapor, Conveyorized Degreaser:

ROG: Compliance with Rule 1122 for all solvents and:

- Carbon adsorber for perchloroethylene with ≥ 337 lbs/day uncontrolled ROG emissions; or
- Refrigerated freeboard chiller for 1,1,1 trichloroethane with ≥ 9,3 lbs/day uncontrolled ROG emissions.

Vapor, Open Top Degreaser:

ROG: Compliance with Rule 1122 for all solvents and:

- Carbon adsorber, programmable hoist, freeboard ratio = 1, enclosed batch type designed for perchloroethylene with > 40 lbs/day uncontrolled emissions;
- Refrigerated freeboard chiller and freeboard ratio = 1, for 1,1,1 trichloroethane;
- Freeboard ratio = 1 for perchloroethylene with uncontrolled ROG emissions ≥ 13.5 but < 40 lbs/day and trichlorotrifluoroethane;

- Carbon adsorber and compliance with Rule 442(e) trichloroethylene with ≥ 18.2 lbs/day uncontrolled ROG emissions; or
- Compliance with Rule 442(e) for trichloroethylene with ≤ 18.2 lbs/day uncontrolled ROG emissions.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[15] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceed the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which are exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits. Chlorinated or fluorinated hydrocarbons are exempt by definition from requirements of this regulations. However, the maximum emissions from co-solvents and additives must be multiplied by Regulation XIII "on-site factor" (1.1) prior to comparing the emissions with the threshold limits.

13.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, the following conditions must be required:

1. THE TOTAL QUANTITY OF SOLVENT LOSS FROM THIS EQUIPMENT (NOT INCLUDING SALVAGED SOLVENT) MUST NOT EXCEED __________ GALLONS PER DAY.

2. ONLY TRICHLOROTRIFLUOROETHANE MAY BE USED AS THE CLEANING SOLVENT IN THIS EQUIPMENT;
   OR

   THE CLEANING SOLVENT USED IN THIS EQUIPMENT MUST CONTAIN AT LEAST ________________ PERCENT BY WEIGHT OF 1,1,1- TRICHLOROETHANE, TRICHLOROTRIFLUOROETHANE, ____________________ OR A COMBINATION OF THESE SOLVENTS.

3. ORGANIC SOLVENTS USED IN THIS EQUIPMENT MUST BE CLEARLY LABELED AS NON-PHOTOCHEMICALLY REACTIVE BY THE SUPPLIER OR, FOR BULK SHIPMENTS, SHOWN TO BE NON-PHOTOCHEMICALLY REACTIVE ON BILLS OF LADING OR INVOICES.

4. THE OPERATORS MUST MAINTAIN RECORDS TO PROVE COMPLIANCE WITH CONDITIONS 1 AND 2A (OR 2B) IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT. SUCH RECORDS MUST BE RETAINED FOR AT LEAST TWO YEARS AND BE MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

5. BECAUSE OF A BEST AVAILABLE CONTROL TECHNOLOGY REQUIREMENT, THE DEGREASER AND OPERATOR MUST COMPLY WITH THE APPLICABLE EQUIPMENT AND OPERATING REQUIREMENTS OF SECTIONS B AND C OF RULE 1122.

6. (IF APPLICABLE) THIS DEGREASER MAY NOT BE OPERATED UNLESS THE AUTOMATED PULLEY SYSTEM AND THE FOUR-SIDED ENCLOSURE ARE USED.

REFERENCES

1. Handbook of Vapor Degreasing, ASTM Special Technical Publication, No. 310, American Society of Testing and Materials, Philadelphia, 1962.

2. Hoogheem, T.J., et. al., "Source Assessment: Solvent Evaporation - Degreasing Operations," EPA - 600/2-79-019f, August, 1979.

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4. Allen, R.D., et. al., "Inspection Source Test Manual for Solvent Metal Cleaning," EPA - 340/1-79-008, June, 1979.

5. "Organic Solvent Cleaners - Background Information for Proposed Standards", EPA - 450/2-78-045A, October, 1979.

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9. Kirk-Othmer Encyclopedia of Chemical Technology, 2nd Edition, Volume 8, New York, John Wiley & Sons, Inc., 1965, p. 376-377.

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11. Wark, K. and Warner C.F., Air Pollution: Its Origin and Control, 2nd Edition, New York, Harper & Row, 1981.

12. Graham, A. K., Electroplating Engineering Handbook, Van Nostrand Reinhold Company, New York, 1971, pp. 127-150.

13. Perry, J.H., ed.,Chemical Engineers' Handbook, 4th edition, New York, McGraw-Hill, 1963.

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APPENDIX 13A

WORKSHEET FOR DEGREASERS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 9	PAGE 1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

COMPANY ID #:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ____________________

DEGREASING SYSTEM CONSISTING OF:

1. DEGREASER, ______________________________(MANUFACTURER'S NAME),________________ (VAPOR-SPRAY, WATER-SPRAY, OPEN TOP, CONVEYORIZED, COLD SOLVENT, ETC) TYPE, MODEL NO. ______________, ______'-______" W. x _____'-_____"L. x _______'-_______" H., SERIAL NO.______________________, ______________ (RATING: BTU/HR, H.P., KW) ______________ (ENERGY INPUT AND HEATING METHOD), WITH (__________ H.P. SPRAY PUMP, WATER-COOLED ________ H.P.CONDENSER COILS AND WATER JACKET, ________ H.P. REFRIGERATED PRIMARY CONDENSER,________ H.P. REFRIGERATED FREEBOARD CHILLER, ________ H.P. TRANSFER PUMP, A LIP EXHAUST, AND ______'-_________" H. FREEBOARD).

2. SOLVENT STILL, ________________________ (MANUFACTURER'S NAME), MODEL NO. ______________, ______'-______" W. x _____'-_____"L. x _______'-_______" H., SERIAL NO.__________________________, _______________ (RATING: BTU/HR, H.P., KW) ______________ (ENERGY INPUT AND HEATING METHOD).

HISTORY:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 9	PAGE 2
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PROCESS DESCRIPTION:

DATA:

Degreaser Type: ______________________

Dimensions (Inside) ________'________"W, ________'________"L

Freeboard Height ________'________"

Open Surface Area ______________________ft²

Type of Vapor Controls ______________________

Method of Heating

[ ] Gas ______________________BTU/hr

[ ] Heat Pump ______________________h.p.

[ ] Electric ______________________KW

[ ] Steam

Method of Cooling

[ ] Refrigeration ______________________h.p.

[ ] Chilled water,

inlet water tempt. ______________________°F

outlet water tempt. ______________________°F

[ ] Water,

inlet water tempt. ______________________°F

outlet water tempt. ______________________°F

Secondary Method of Cooling Degreaser (if any):

Refrigerated Freeboard Chiller:

Compressor: ______________________h.p.

[ ] Above Freezing [ ] Below Freezing

Temperature of Refrigerant in Freeboard ______________________°F

Cooling Capacity ______________________BTU/hr

Spray Pump Rating ______________________h.p.

Transfer Pump Rating ______________________h.p.

Solvent Used: ____________________

Density of the Solvent ____________________ lbs/gal
% Reactive by weight: ____________________ %

Quantity of Solvent Loss (Does not include solvent removed for reclamation or disposal):

Average: ____________________ gal/day
____________________ gal/month
Maximum ____________________ gal/day
____________________ gal/month

Operating Schedule: ____________________ hours/day
____________________ days/week
____________________ weeks/year

CALCULATIONS:

Freeboard Ratio = F/D = ____________________ **(Equation 13-1)**

Average Daily Emissions:

RHCavg = v1 x ρ x %RHC
or = v2 x ________ month/yr x 1yr/______ days x ρ x %RHC
= ______________ lb/day

(Equation 13-2)

UnRHCavg = v1 x ρ x (100% - %RHC)
or = v2 x ________ mth/yr x 1yr/______ day x ρ x (100% - %RHC)
= ______________ lb/day

(Equation 13-3)

AEIS Emission Calculation:

R1(RHC) = RHCavg x 1 day/__________ hours = ______________ lb/hour
R2(RHC) = R1(RHC)

(Equation 13-4)

R1(UnRHC) = UnRHCavg x 1 day/__________ hours = ______________ lb/hour
R2(UnRHC) = R1(UnRHC)

(Equation 13-5)

Maximum Daily Emissions:

RHCmax = V1 x ρ x %RHC
or = V2 x ______ mth/yr x 1yr/____ days x ρ x %RHC
= ____________ lb/day

(Equation 13-6)

UnRHCmax = V1 x ρ x (100% - %RHC)
or = V2 x ______ mth/yr x 1yr/_____ days x ρ x (100% - %RHC)
= ____________ lb/day

(Equation 13-7)

REGULATION XIII:

RHC = RHCmax x 1.1 = ________________ lb/day

(Equation 13-8)

RHC BACT = RHC x (1 - E2/E1) = ________________ lb/day

(Equation 13-9)

where,

F = Freeboard height
Cold solvent cleaning tanks: measured from solvent to opening of tank; or
Vapor degreasing tanks: measured from vapor to opening of tank
D = Smaller of the degreaser's length or width
E1 = Normalized emission of degreaser (basic equipment), MLK's memo October 24, 1983: Vapor Degreasers
E2 = Normalized emission of air pollution control device, MLK's memo October 24, 1983: Vapor Degreasers
RHC = Maximum Regulation XIII reactive hydrocarbon emission, lb/day
RHC BACT = Maximum Regulation XIII reactive hydrocarbon emission with BACT, lb/day
RHCavg = Average reactive hydrocarbon emissions, lb/day
RHCmax = Maximum reactive hydrocarbon emissions, lb/day
R1(RHC) = Uncontrolled reactive hydrocarbon emissions, lb/hour
R2(RHC) = Controlled reactive hydrocarbon emissions, lb/hour
R1(UnRHC) = Uncontrolled unreactive hydrocarbon emissions, lb/hour
R2(UnRHC) = Controlled unreactive hydrocarbon emissions, lb/hour
UnRHCavg = Average unreactive hydrocarbon emissions, lb/day
UnRHCmax = Maximum unreactive hydrocarbon emissions, lb/day
v1 = Average solvent consumption per day, gal/day
v2 = Average solvent consumption per month, gal/month
V1 = Maximum solvent consumption per day, gal/day
V2 = Maximum solvent consumption per month, gal/month
ρ = Density of the solvent, lb/gal
%RHC = Percentage of the reactive solvent, %
1.1 = Regulation XIII On-Site offset factor

RULES EVALUATION:

RULE 402: Nuisance complaints are (are not) expected.

RULE 442(f): Non-photochemically reactive solvent is (is not) used.

RULE 443: Solvent container is (is not) properly labeled.

RULE 1122:

- ☐ The degreaser is exempt from Rule 1122 because RHC emissions are less than 1 lb/day and %RHC is less than 10% by weight.
- ☐ The degreaser is exempt from Rule 1122 since emulsion cleaner used is 2 percent or less by volume per *(d)(1)*.
- ☐ The degreaser is exempt from Rule 1122 since the equipment is used only for wipe cleaning per *(d)(2)*.
- ☐ The degreaser is exempt from Rule 1122 per *(d)(7)* since only non-metal parts are cleaned by perchloroethylene and BACT does not apply.
- ☐ The degreaser complies (does not comply) with all of the following applicable requirements:

(circle or check compliance status)
All Degreasers:

Yes/No/NA *(b)(1)* Container for solvent is provided.

Yes/No/NA *(b)(2)* Tank covered when not in use.

Yes/No/NA *(b)(3)* Drained or dragged-out solvent is returned to the solvent container.

Yes/No *(c)(1)* No leaks are detected from the degreasing equipment.

Yes/No *(c)(2)* Solvent is stored and disposed of in a manner as to not evaporate into the atmosphere.

Yes/No/NA *(c)(3)* Solvent residue is < 20% VOC after distillation recovery of waste solvent.

Yes/No/NA *(c)(4)* The anti-evaporation cover is not displaced or removed > 5 consecutive minutes.

Yes/No/NA *(c)(6)*
☐ Solvent flow is cleaned by liquid stream only, or
☐ Emissions are reduced by 85% or more before being vented to the atmosphere.

Yes/No/NA *(c)(7)* Solvent agitation is by
[ ] ultrasonics;
[ ] liquid recirculation; or
[ ] air agitation at ≤ 2 psig

Cold Solvent Degreaser Requirements

(b)(4) (one of the following):

Yes/No/NA Exempt per *(d)(3)* because solvent vapor pressure at 38 °F is ________ (≤ 33 mm Hg) and freeboard ratio is ____________ (> 0.5 required).

Yes/No/NA Freeboard Ratio = Freeboard height/Width = ______ (> 0.75 required); or

Yes/No/NA Water Cover; or

Yes/No/NA Other:____________________________________.

(c)(5)

Yes/No/NA Cleaned parts are drained until dripping ceases.

Remote Reservior Cold Cleaners Requirement

(c)(11) (all of the following):

Yes/No/NA Cover for the drainage tank is closed at all times when cleaner is in use.

Yes/No/NA Work area is not exposed to drafts > 131 ft/min.

All Vapor Open Top or Conveyorized Degreaser Requirements

(b)(5) (all of the following):

Yes/No/NA High vapor cutoff thermostat has manual reset, and

Yes/No/NA Freeboard ratio = ________ (> 0.75 required), or

Yes/No/NA Uses perchloroethylene and consists of (water jacket, water condensing coil, or refrigerated freeboard chiller).

(b)(6) (one or a combination of the following):

Yes/No/NA Perchloroethylene is exempt from *(b)(6)* per *(d)(6)*.

Yes/No/NA Refrigerant temperature at the degreaser outlet is ≤ 55 °F; Degreaser is exempt from *(b)(6)* per *(d)(5)*.

Yes/No/NA	Degreaser's open solvent surface area of ________ ft^2 and is $\leq$ 10.8 ft^2. Thus, the equipment is exempt from *(b)(6)*.
Yes/No/NA	Degreaser's open solvent surface area is > 10.8 ft^2 and thus one or combination of the following is required:
Yes/No/NA *(A)*	Refrigerated freeboard chiller temperature at degreaser outlet is ________ ^{o}F (< 40 ^{o}F required).
Yes/No/NA *(B)*	Carbon adsorption system has capture efficiency ________ % (> 90% required).
Yes/No/NA *(C)*	Other operating or control technique with capture efficiency > 90%: ________ with efficiency: ________ %.

(c)(8)

Yes/No/NA	If degreaser is equipped with lip exhaust, the exhaust is turned off when degreaser is covered.

(C)(10)(all of the following)

Yes/No/NA *(A)*	The primary condenser and refrigerated freeboard chiller are turned on simultaneously or before the sump heater during start up. This sump heater is turned off simultanously or before the condenser water and refrigerated freeboard chiller are turned off during shutdown.
Yes/No/NA *(B)*	Solvent flow cleaning is done within the vapor region.
Yes/No/NA *(C)*	The work load is done in the vapor zone until condensation stops.

Conveyorized Degreaser Requirements

(b)(7)(all of the following):

Yes/No/NA	Air/vapor interface area of ________ ft^2 is < 21.6 ft^2 and exempt from *(b)(7)(A)* per *(d)(4)*.
Yes/No/NA *(A)*	Hood or enclosure collects emissions, exhausting to approved carbon adsorber or equivalent control method: ________.
Yes/No/NA *(B)*	Drying tunnel or ________ is employed.
Yes/No/NA *(C)*	Minimum entrance and exit clearance is either ________ cm or ________ percent of opening width (< 10 cm or < 10 percent required).

(c)(9)

Yes/No/NA	The vertical speed of the powered hoist or conveyor is less than 11.2 ft/min when lowering and raising parts.

REGULATION XIII - New Source Review
Rule 1303 - Applicability and analysis.

[ ] ROG emission increase from this permit unit is less than 1 lb/day.

[ ] This new or modified equipment causes an increase in ROG emissions in excess of one pound per day. Therefore, Best Available Control Technology (BACT) is required.

BACT for this equipment is ____________________________________.
The applicant will (will not) provide BACT.

[ ] As shown by the Emission Threshold/New Source Sheet Table below, the net emission increase from the facility exceeds the threshold limit specified in 1303(a)(2). Therefore, the following steps are required in addition to BACT:

( ) The company must obtain offsets from other facilities.
( ) The company must use a mathematical model approved by the District's Executive Officer to assess the impact of the plant on the area around it.
( ) The company must certify in writing that all of its facilities in the state that emits 25 tons per year or more of ROG comply with federal, state, and local air quality laws.

	NSR Emissions in Pounds Per Day				
	ROG	NO_x	SO_2	CO	PM
Facility Emissions Since 10/08/76	___	___	___	___	___
A/N ______________	___	___	___	___	___
A/N ______________	___	___	___	___	___
Net Emission Increase Since 10/08/76	___	___	___	___	___

Toxic Materials:

[ ] The solvent used in this equipment is not on the list of toxic or potentially toxic materials.

[ ] The solvent used in this equipment is on the list of toxic or potentially toxic materials and the maximum individual cancer risk complies (does not comply) with District requirements.

CONCLUSIONS/RECOMMENDATIONS:

Emission calculations and equipment analyses show that this equipment is (is not) in compliance with all the applicable Rules and Regulations of the District.

Recommendations:

[ ] Deny Permit to Construct (Operate) because of observed (expected) violation(s) of Rule(s)________________________________.

[ ] Issue Permit to Construct (Operate) subject to the following condition which have been discussed and agreed to by this applicant:

1. THE TOTAL QUANTITY OF SOLVENT LOSS FROM THIS EQUIPMENT (NOT INCLUDING SALVAGED SOLVENT) MUST NOT EXCEED __________ GALLONS PER DAY.

2. ONLY TRICHLOROTRIFLUOROETHANE MAY BE USED AS THE CLEANING SOLVENT IN THIS EQUIPMENT; OR

   THE CLEANING SOLVENT USED IN THIS EQUIPMENT MUST CONTAIN AT LEAST ________________ PERCENT BY WEIGHT OF 1,1,1-TRICHLOROETHANE, __________ TRICHLOROTRIFLUOROETHANE, ____________________ OR A COMBINATION OF THESE SOLVENTS.

3. ORGANIC SOLVENTS USED IN THIS EQUIPMENT MUST BE CLEARLY LABELED AS NON-PHOTOCHEMICALLY REACTIVE BY THE SUPPLIER OR, FOR BULK SHIPMENTS, SHOWN TO BE NON-PHOTOCHEMICALLY REACTIVE ON BILLS OF LADING OR INVOICES.

4. THE OPERATORS MUST MAINTAIN RECORDS TO PROVE COMPLIANCE WITH CONDITIONS 1 AND 2 IN A FORMAT APPROVED IN WRITING BY THE DIRECTOR OF ENFORCEMENT. SUCH RECORDS MUST BE RETAINED FOR AT LEAST TWO YEARS AND BE MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

5. BECAUSE OF A BEST AVAILABLE CONTROL TECHNOLOGY REQUIREMENT, THE DEGREASER AND OPERATOR MUST COMPLY WITH THE APPLICABLE EQUIPMENT AND OPERATING REQUIREMENTS OF SECTIONS B AND C OF RULE 1122.

6. (IF APPLICABLE) THIS DEGREASER MAY NOT BE OPERATED UNLESS THE AUTOMATED PULLEY SYSTEM AND THE FOUR-SIDED ENCLOSURE ARE USED.

APPENDIX 13B

VAPOR DEGREASER MEMORANDUM

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

MEMORANDUM

DATE: October 24, 1983

TO: Combustion Unit Engineers

FROM: Marty Kay, Senior Engineer MLK

SUBJECT: Vapor Degreasers

Enclosed are some excerpts that you should read from an EPA document about vapor degreasing. The entire document is available to you if you are interested.

On page 3-8 separate criteria for cooling capacity are given for above-freezing freeboard chillers, below-freezing freeboard chillers, and refrigerated primary condensers. Use these criteria in your evaluations of degreasers subject to Regulation XIII.

Above-freezing freeboard chillers and refrigerated primary condensers are rated lower than below-freezing freeboard chillers on the BACT list.

Use the attached chart for comparing emissions of a degreaser with different freeboard ratios, condensers and freeboard chillers.

A carbon adsorber should be assumed to achieve an overall control efficiency of 50%, in addition to other reductions from other measures.

NORMALIZED EMISSIONS OF A DEGREASER WITH VARIOUS FREEBOARD RATIOS AND APC EQUIPMENT

(Using 50% freeboard ratio w/water cooled condenser as baseline)

FREEBOARD RATIO	WATER-COOLED CONDENSER	REFRIGERATED PRIMARY CONDENSER	ABOVE-FREEZING FREEBOARD CHILLER	BELOW-FREEZING FREEBOARD CHILL
50%	1.0	0.95	0.95	0.90
75%	0.80	0.75	0.75	0.55
100%	0.60	0.55	0.55	0.45

Example:

What would be the annual emission reduction achieved by increasing a degreaser's freeboard ratio from 75% to 100% and installing a below-freezing freeboard chiller over the existing water-cooled condenser, if the degreaser currently uses 1 barrel of perc per month?

After modification, the degreaser will use

$$\frac{0.45}{0.8} \times \frac{1\ \text{barrel}}{\text{month}} = 0.56\ \frac{\text{barrel}}{\text{month}}$$

for a savings of 1-0.56 = 0.44 barrels/month

$$\frac{\left(0.44\ \frac{\text{barrel}}{\text{month}}\right)\left(\frac{12\ \text{months}}{\text{yr}}\right)\left(13.5\ \frac{\text{lbs}}{\text{gal}}\right)}{2{,}000\ \frac{\text{lbs}}{\text{ton}}} = 2.0\ \frac{\text{tons}}{\text{year}}$$

MK:rg

SECTION 14

Automotive Spray Booths Non-Assembly Line Operations

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Section 14

ACKNOWLEDGEMENTS

Staff of the Engineering Division who have made significant contributions to this section of the Permit Processing Handbook are as follows:

Authors

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SECTION 14: AUTOMOTIVE SPRAY BOOTHS NON-ASSEMBLY LINE OPERATIONS

14.1 General Description

Surface coatings are applied to a great variety of products to provide corrosion protection and an aesthetically pleasing finish. In order to contain and control emissions resulting from the application of these coatings, a spray booth may be utilized. One of the most common uses for such enclosures is in the repair and refinishing of automobiles.

The average automotive spray booth is a rectangular chamber sized to accept the vehicles to be coated. Inside this chamber, the paint is applied, generally by a single operator equipped with a spray gun. At one end of the booth, air is continuously drawn through a bank of inlet filters, to clean the incoming air. A similar set of exhaust filters is located at the opposite end of the booth. These exhaust filters are designed to capture suspended particulates produced by the painting process. The airflow through the booth is produced by one or more fans, each driven by an electric motor.

From this basic design, several variations are derived. These include solid rear wall and drive through designs, as well as reverse flow (in which air flows toward the entrance) and downdraft designs. In addition, provisions may be made to heat and partially recirculate the air after the coating is applied in order to produce a "curing" effect. Representative designs of automotive refinishing spray booths are shown in Figures 14.1 & 14.2.

14.2 Permit Unit Description

An automotive spray booth is described in the permit as follows:

SPRAY BOOTH, (MANUFACTURER & MODEL NO.), AUTOMOTIVE DRY FILTER TYPE, (WIDTH) X (LENGTH) X (HEIGHT), (NUMBER OF) EXHAUST FAN(S), (FAN HORSEPOWER RATING) H.P. EACH, (NUMBER OF) FILTER ELEMENTS EACH (ELEMENT WIDTH) X (ELEMENT HEIGHT), (BTU/HR OR KW RATING) INPUT (GAS FIRED OR ELECTRIC) HEATER.

14.3 Emissions

14.3.1 Description

Two principal categories of emissions are produced by the painting process. The first consists of particulate matter (PM) originating from the solid portion of the coating which fails to adhere to the target surface (overspray). The second consists of Volatile Organic Compounds (VOC) which may be classified as either photochemically or non-photochemically reactive. VOC's can be found in the coating as supplied and in the organic solvent, diluent, or thinner which is used with the coating.

The quantity of PM resulting from overspray is directly dependent upon the method of application used. The most common method used in auto repair and refinishing is air atomization in which compressed air is used to atomize and carry the coating to the target surface. Another method is the airless method in which the coating itself is placed under pressure and forced through a nozzle. These technologies may be combined to form the air-assisted airless method in which 800-1500 psig fluid pressures are assisted by approximately 10 psig air pressure. Each of these methods may in turn be combined with the electrostatic process in which opposite charges are placed on the paint and the target surface causing them to attract. A recently developed method of application is High Volume Low Pressure (HVLP) spray. In this design, large volumes of low pressure air (0.1-10 psig) are used to atomize and carry the coating to its target surface.

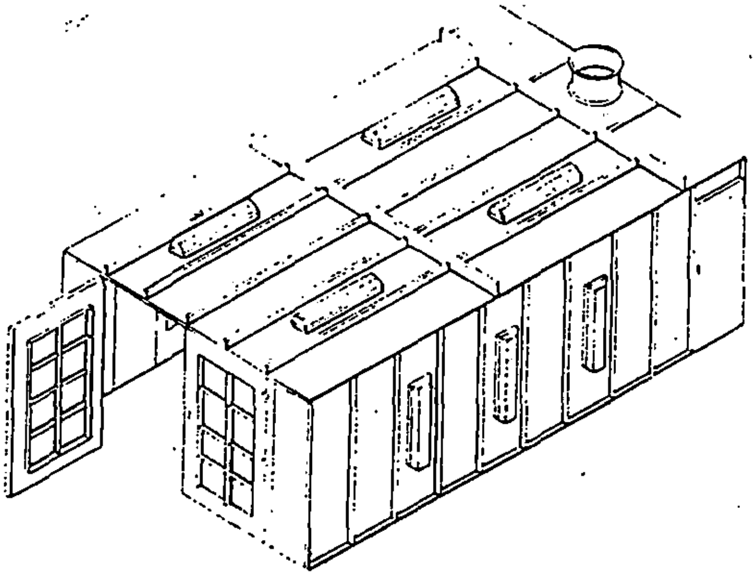

Figure 14.1: Typical Forward Flow Automotive Refinishing Spray Booth

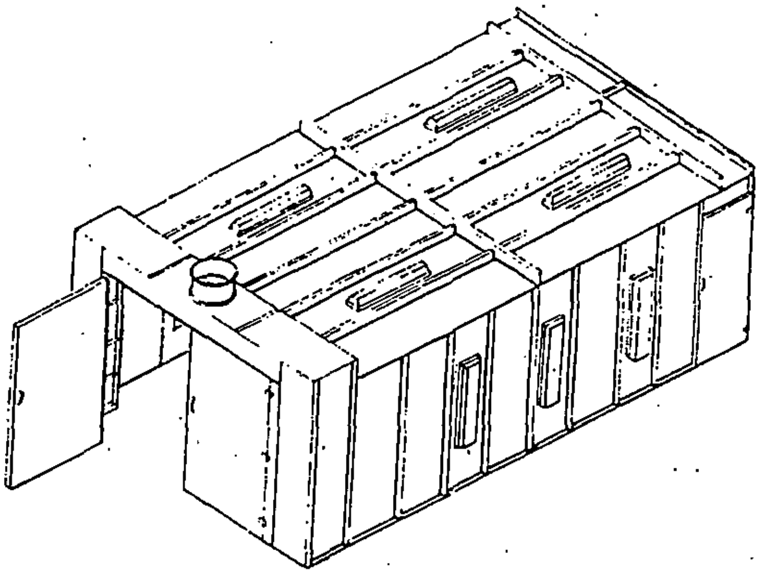

Figure 14.2: Typical Reverse Flow Automotive Refinishing Spray Booth

PM emissions are captured using paint-arrestor filters. Although some spray booths incorporate wet filtration, the most common design for automotive applications utilizes dry filtration. In this design, filter elements constructed of woven fibers or paper are suspended in the air flow by a wire grid (see Figure 14.3). In order to maintain a sufficient air flow rate through the filter the elements must be periodically cleaned or replaced. As a means of monitoring the condition of the filter bank, a differential pressure measuring device (generally a manometer) is used to measure the pressure drop across it. Dirty filters are indicated by high readings (over 0.25 inches of water) while ripped or missing elements are evidenced by low readings (under 0.07 inches of water).

The VOC emissions produced by a spray operation are not removed by dry filtration or water wash. The quantity of VOC's produced is dependent on the amount of VOC in the coating (as applied) and volume of coating sprayed. For this reason, the most effective controls on VOC emissions are to require coatings containing less volatile organic compounds or to limit the quantities of coatings used. Should these solutions prove impractical, either carbon adsorption or incineration (afterburner) may be employed.

14.3.2 Emission Factors

In order to calculate the emissions from a spray booth, emission factors must be used to relate the amount of pollutants produced to the amount of coating used. The most accurate method of obtaining these values is to consult the manufacturer's data (often available on the container label or in published brochures) for each specific coating. In the event that this is not possible, a list of average values are given in Table 14-1. The particulate matter emission factors are simply the percent solids of the coatings.

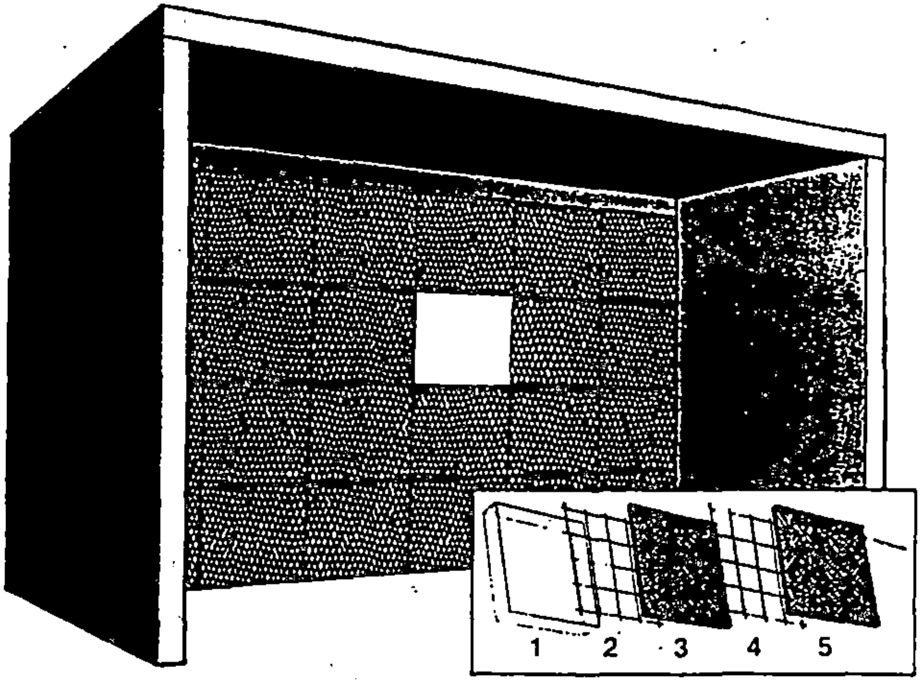

Figure 14.3: Dry filter Detail

Components:

1) Holding Frame
2) Snap-In Grid
3) Secondary Filter Element
4) Snap-In Grid
5) Primary Filter Element

Table 14-1 Average Emission Factors for Some Common Coatings[a]

Coating	VOC Emission Factor (lb/gal)	PM Emission Factor (lb/gal)
Enamel	4.5	5.5
Lacquer	5.5	4.5
Clean-Up Solvent	6.8	0.0
Reducer	7.0	0.0
Primer	5.0	3.0

[a] Reference 1

14.4 Calculations

14.4.1 Operational Data

In order to calculate the emissions from an automotive spray booth the following operational data must be supplied by the owner or operator of the equipment.

Booth Manufacturer:
Model:
Dimensions: ____width
____height
____length

Operating Schedule:	Actual	Maximum
	____hr/day	____hr/day
	____day/wk	____day/wk
	____wk/yr	____wk/yr

Coating Usage	Actual	Maximum
Enamels:		
__________	_____gal/day	_____gal/day
__________	_____gal/day	_____gal/day
Lacquers:		
__________	_____gal/day	_____gal/day
__________	_____gal/day	_____gal/day
Clean-Up Solvent:		
__________	_____gal/day	_____gal/day
Reducers:		
__________	_____gal/day	_____gal/day
__________	_____gal/day	_____gal/day
Primers:		
__________	_____gal/day	_____gal/day
__________	_____gal/day	_____gal/day
Others:		
__________	_____gal/day	_____gal/day
__________	_____gal/day	_____gal/day

Filter Section

Number Of Elements: _____

Element Dimensions: _____width
_____height
_____thickness

No. Of Fans: _____

Fan Horsepower Rating(s) _____hp

Fan Diameter(s): _____in

Application Method:

☐ Air Atomization
☐ Airless
☐ Electrostatic/Air Atomization
☐ Electrostatic/ Airless
☐ HVLP
☐ Air-Assisted Airless
☐ Electrostatic/Air-Assisted Airless

14.4.2 Emission Calculations

Emissions must be calculated for both the actual and maximum operating conditions. Actual emissions are used in emission inventory. Maximum emissions are used to determine compliance with the South Coast Air Quality Management District's Rules and Regulations. In addition, the maximum daily emissions are multiplied by the Regulation XIII On-Site Offset Factor (1.1). These daily emissions increases are accumulated for each facility in the District's New Source Review Record.

14.4.2.1 Uncontrolled Emissions (R_1) Calculations

The total uncontrolled VOC emissions are a summation of the VOC emissions from each individual coating, thinner and clean-up solvent. These individual amounts are determined using the appropriate values in Equation 14.1. The total VOC emissions are the sum of these values, as in Equation 14.2

$$R_{1,VOC,n} = UR_n \times EF_{VOC,n} \qquad \textbf{(Equation 14.1)}$$

$$R_{1,VOC} = \Sigma R_{1,VOC,n} \qquad \textbf{(Equation 14.2)}$$

where:

$R_{1,VOC}$ = Total uncontrolled VOC emissions, (lb/day).
$R_{1,VOC,n}$ = Uncontrolled VOC emissions from material "n", (lb/day).
UR_n = Daily usage rate of material "n", (gal/day).
$EF_{VOC,n}$ = VOC emission factor for material "n", (lb/gal).

The total uncontrolled PM emissions are the summation of the contributions from each individual coating. The PM emissions produced when a coating is applied are determined using Equation 14.3. The total PM emissions are the sum of these values (see Equation 14.4)

$$R_{1,PM,n} = (UR_n \times EF_{PM,n})(1 - TE) \qquad \textbf{(Equation 14.3)}$$

$R_{1,PM} = \Sigma R_{1,PM,n}$ **(Equation 14.4)**

where:

$R_{1,PM}$ = Total uncontrolled PM emissions, (lb/day).
$R_{1,PM,n}$ = Uncontrolled PM emissions from coating "n", (lb/day).
UR_n = Daily usage rate of coating "n", (gal/day).
$EF_{PM,n}$ = PM emission factor for coating "n", (lb/gal).
TE = Transfer efficiency (see Table 14-2), (expressed as a decimal)

Table 14-2 **Transfer Efficiencies for Common Application Methods**[a]

Application Method	Transfer Efficiency (%)
Air Atomization	30
Airless	45
Electrostatic/Air Atomization	70
Electrostatic/Airless	75
HVLP	75[b]

[a] Reference 2 (average)

[b] Reference 3

14.4.2.2 Controlled Emissions (R_2) Calculations

The sole means of control on an (average) automotive spray booth is its dry exhaust filters. These remove from approximately 66% to 90% of PM emissions, but have no effect on VOC emissions. The controlled emissions released to the atmosphere may be calculated by Equations 14.5 and 14.6.

$R_{2,VOC} = R_{1,VOC}$ **(Equation 14.5)**

$$R_{2,PM} = (R_{1,PM}) \times (1 - EFF_f) \qquad \textbf{(Equation 14.6)}$$

where:

$R_{1,VOC}$ = Total uncontrolled VOC emissions, (lb/day).
$R_{2,VOC}$ = Total controlled VOC emissions, (lb/day).
$R_{1,PM}$ = Total uncontrolled PM emissions, (lb/day).
$R_{2,PM}$ = Total controlled PM emissions, (lb/day).
EFF_f = Filter efficiency(expressed as a decimal).

14.4.3 Filter Face Velocity

The minimum and maximum air velocities through the exhaust filter bank must be calculated to verify compliance with SCAQMD Rule 481. The proper filter velocity must be maintained in order to ensure efficient filter operation. This rule applies when greater than 3 gallons per day of coatings are consumed at the booth location.

The first step in calculating filter face velocity is determination of minimum and maximum volumetric flow rates of air through the filters. Fan flow rate can be obtained from manufacturers data or, if that is not available, from Table 14-3. Fan flow rate for each fan, in cubic feet per minute (CFM) is obtained from Table 14-3 by using the fan diameter and horsepower rating. In the case of multiple fans, these are summed to obtain a total flow rate. The face velocity calculation is completed using Equation 14.7.

$$V_{air} = \frac{\text{VFR (CFM)} \times 144\ (\text{in}^2/\text{ft}^2)}{N_{filter} \times A_{filter}\ (\text{in}^2)} \qquad \textbf{(Equation 14.7)}$$

where:

V_{air} = Air velocity, (ft/min).
VFR = Volumetric flow rate (CFM), (from Table 14-3).
144 = Conversion factor, (ft^2 to in^2).
N_{filter} = Total number of filter elements.
A_{filter} = Area of individual filter element, (in^2).

Table 14-3 Spray Booth CFM Values[a]

Fan Diameter (in)	Motor HP	VFR_{max} (CFM)	VFR_{min} (CFM)
24	1	5200	2000
24	1-1/2	6200	4500
24	2	8000	6900
27	1	6600	4400
27	1-1/2	7900	5500
27	2	9000	6400
30	2	8600	6500
30	3	12600	10600
30	5	14500	13300
34	2	10800	7600
34	3	15500	12900
34	5	18200	15300
42	5	22700	20600
42	7-1/2	28100	25500
42	10	31500	28300

[a] Reference 4

14.5 Rules Evaluation

Rule 212 - Standards For Approving Permits

Section (e) of this Rule requires public notification of certain cases be made prior to issuing a permit.

Rule 401 - Visible Emissions

No visible emission greater than 20% opacity or Ringlemann No. 1 aggregating for more than three minutes in any one hour period is allowed.

Rule 402 - Nuisance

Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 442 - Usage of Solvents

(a) A person shall not discharge organic materials into the atmosphere unless such emissions have been reduced by at least 85% or to the following:

   (1) Organic materials that come into contact with or are baked, heat cured or heat polymerized are limited to 3.1 lbs (1.4 kg) per hour, not to exceed 14.3 lbs (6.5 kg) per day.

   (2) Organic materials emitted into the atmosphere from the use of photochemically reactive solvents are limited to 7.9 lbs (3.6 kg) per hour, not to exceed 39.6 lbs (18 kg) per day. All organic materials emitted for a drying period of 12 hours following their application shall be included in this limit.

   (3) On and after December 1, 1980, all organic materials emitted into the atmosphere from the use of non-photochemically reactive solvents are limited to 81 lbs (36.8 kg) per hour, not to exceed 600 lbs (272 kg) per day. All organic materials emitted for a drying period of 12 hours following their application shall be included in this limit.

(c) Emissions of organic materials into the atmosphere required to be controlled by subsection (a) shall be reduced by:

   (1) Incineration, provide that 90% or more of the carbon in the organic material being incinerated is oxidized to non organic materials, or

(2) Incineration, provided that the concentration of organic material following incineration is less than 50ppm, calculated as carbon and with no dilution, or

(3) Adsorption, or

(4) Processing in a manner determined by the Air Pollution Control Officer to be not less effective than (1) or (3) above.

(e) A person shall not use photochemically reactive solvent to thin, reduce or dilute industrial and commercial metal surface coatings unless the emission of organic materials into the atmosphere has been reduced by at least 85% by weight.

(f) A person shall not use photochemically reactive solvent in industrial and commercial surface cleaning or degreasing operations unless the emission of organic materials into the atmosphere has been reduced by at least 85% by weight.

(g) A person shall not during any one day dispose of a total of more than 5 liters (1.3 gallons) of any photochemically reactive solvent, or any material containing more than 5 liters (1.3gallons) of any photochemically reactive solvent by any means which will permit the evaporation of such solvent into the atmosphere.

Rule 443 - Labeling of Solvents

All organic solvents or materials containing organic solvents must be properly labeled.

Rule 481 - Spray Coating Operations

(a) A person shall not use or operate any spray painting or spray coating equipment unless one of the following conditions is met:

(1) The air velocity through the filter shall be between 100 and 300 fpm.

(2) Coatings are applied with electrostatic and or airless spray equipment.

(3) A method of application or control is used which has an effectiveness equal to or greater than the equipment specified in subsection (a)(1) or (a)(2) of this rule.

(b) The provisions of this rule shall not apply to:

(1) Spray coating of three gallons per day or less of coatings at a single location.

(2) Any control enclosure connected to an external air pollution control device with a control efficiency equivalent to the filters specified in subsection (a)(1) of this rule and which has been approved by the Executive Officer.

Rule 1151 - Motor Vehicle and Mobile Equipment Non Assembly Line Coating Operations

(1) A person or facility which refinishes automobiles, or their existing parts (components) or replacement parts (components), shall not apply a coating which has a VOC content in excess of the limits in the following table on and after the dates specified.

(a) Group I Vehicles and Equipment (large size trucks, busses, and mobile equipment).

Limits
Grams of VOC per Liter of Coating
Less Water and Exempt Compounds

Coating	On and after July 1, 1989		On and after January 1, 1990	
	g/L	lb/gal	g/L	lb/gal
Pretreatment	800	6.7	800	6.7
Precoat	---	---	800	6.7
Primer	340	2.8	250	2.1
Topcoats				
General	340	2.8	340	2.8
Extreme Performance	420	3.5	420	3.5

(b) Group II Vehicles (passenger cars, small trucks and vans, medium-sized trucks and vans, and motorcycles).

Limits
Grams of VOC per Liter of Coating
Less Water and Exempt Compounds

Coating	On and after July 1, 1990		On and after January 1, 1992	
	g/L	lb/gal	g/L	lb/gal
Pretreatment	800	6.7	800	6.7
Precoat	800	6.7	800	6.7
Primer	250	2.1	250	2.1
Topcoats	---	---	420	3.5
Acrylic Enamel	624	5.2	---	---
Alkyd Enamel	588	4.9	---	---
Polyurethane Enamel	624	5.2	---	---
Lacquer	744	6.2	---	---

(2) A person or facility shall not apply coatings subject to the provisions of this rule on and after the dates specified below, except by the use of one of the following methods:

(i) Electrostatic application, or

(ii) High Volume Low Pressure spray, or

(iii) Such other coating application methods as are demonstrated to the Executive Officer to be capable of achieving at least 65% transfer efficiency and for which written approval of the Executive Officer has been obtained.

Effective Date	Coatings Applied
On and after January 1, 1990	o All coatings applied on Group I Vehicles and equipment. o Pretreatment, Precoat and Primer applied on Group II vehicles.

On and after July 1, 1990	o All coatings applied on Group I and Group II vehicles and equipment.

(3) (g) Any coating, coating operation, or facility which is subject to this rule shall comply with the provisions of Rule 442 until such time as compliance with the limits specified in this rule are achieved. Any coating, coating operation, or facility which is exempt from all or a portion of the VOC limits of this rule shall comply with the provisions of Rule 442.

Regulation XIII - New Source Review

(1) If the new or modified equipment causes an increase in facility emissions in excess of one pound per day for any non-attainment air contaminant, Best Available Control Technology (BACT) is required. The current BACT for reactive organic gas emissions from automobile refinishing spray booths is $\leq$ 3.5 lbs VOC/gal of coating (as determined by SCAQMD's Rule 107), $\geq$ 65% transfer efficiency, and emissions vented to a carbon adsorber or afterburner achieving $\geq$ 90% overall efficiency.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[5] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which is exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

14.6 Permit (Operating) Conditions

In order to assure compliance with applicable Rules and Regulations of the SCAQMD, Permit (Operating) Conditions must be required. Permit (Operating) Conditions for automotive spray booths are listed below:

1. THIS SPRAY BOOTH MUST NOT BE OPERATED UNLESS ALL EXHAUST AIR PASSES THROUGH FILTER MEDIA AT LEAST 2 INCHES THICK.

2. A GAUGE MUST BE INSTALLED TO INDICATE THE STATIC PRESSURE DIFFERENTIAL ACROSS THE EXHAUST FILTERS. IN OPERATION, THE PRESSURE DIFFERENTIAL MUST NOT EXCEED 0.25 INCHES OF WATER.

3. ORGANIC SOLVENTS USED IN THIS EQUIPMENT MUST BE CLEARLY LABELED AS NON-PHOTOCHEMICALLY REACTIVE BY THE SUPPLIER OR, FOR BULK SHIPMENTS, SHOWN TO BE

NON-PHOTOCHEMICALLY REACTIVE ON BILLS OF LADING OR INVOICES.

4. THE TOTAL QUANTITY OF COATINGS AND SOLVENT USED IN THIS EQUIPMENT MUST NOT EXCEED (NUMBER OF) GALLONS IN ANYONE DAY OR (NUMBER OF) GALLONS IN ANY ONE HOUR.

5. THE TOTAL QUANTITY OF VOLATILE ORGANIC COMPOUND (VOC) EMISSIONS FROM THIS EQUIPMENT MUST NOT EXCEED (NUMBER OF) POUNDS IN ANY ONE DAY.

6. THE OPERATOR SHALL KEEP ADEQUATE RECORDS TO VERIFY DAILY USAGE. SUCH RECORDS SHALL BE RETAINED FOR A PERIOD OF AT LEAST TWO YEARS AND BE MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

REFERENCES

(1) Memorandum to S. M. Weiss from Stanley Caudek, Subject: Standard Factors for Rule 66, June 21, 1968.

(2) Air pollution Engineering Manual, AP-40, Second Edition, May 1973.

(3) Marg, Ken. High-Volume/Low Pressure Paint Spraying. Product Finishing, August 1987, pp 84-87.

(4) Memorandum from Norman Shaffer to Solvent Unit, Subject: Rule 481 - Filter Velocities, December 28, 1977.

(5) Best Available Control Technology Guideline, South Coast Air Quality Management District, October 7, 1988.

APPENDIX 14A

WORKSHEET

AUTOMOTIVE SPRAY BOOTHS

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 5	PAGE 1
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

PERMIT TO CONSTRUCT/OPERATE

Applicability: This processing from can only be used for automotive spray booths used for spray coating automobiles and their parts.

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT ADDRESS:

EQUIPMENT DESCRIPTION:

APPLICATION NO. ____________________

SPRAY BOOTH, MODEL , AUTOMOTIVE DRY FILTER TYPE,
' "W. X ' "L. X ' "H.,
EXHAUST FANS, H.P. EACH,
FILTER ELEMENTS, EACH "W. X "H.

HISTORY:

PROCESS DESCRIPTION:

The applicant uses this spray booth to refinish automobile bodies. The coatings are applied using an ______________ spray process. Particulate matter is removed from exhausted air with a dry filter prior to discharge to the atmosphere.

DATA:

Daily Usage Rate(s):	Actual	Maximum	Source
Enamel (UR_E):	_____gal/day	_____gal/day	Applicant
Lacquer (UR_L):	_____gal/day	_____gal/day	"
Clean-Up Solvent(UR_C):	_____gal/day	_____gal/day	"
Reducer (UR_R):	_____gal/day	_____gal/day	"
Primer (UR_P):	_____gal/day	_____gal/day	"
Other (UR_O) _________:	_____gal/day	_____gal/day	"

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

PAGES 5	PAGE 2
APPL. NO.	DATE
PROCESSED BY	CHECKED BY

Emission Factors:

Coating	VOC Emission Factor $EF_{VOC,n}$ (lb/gal)	PM Emission Factor $EF_{PM,n}$ (lb/gal)	Source
Enamel	____	____	Table 14-1
Lacquer	____	____	"
Clean-Up Solvent	____	____	"
Reducer	____	____	"
Primer	____	____	"
Other	____	____	"

Actual Operating Schedule (T_a): ____hr/day, ____day/wk, ____wk/yr "

Maximum Operating Schedule (T_m): ____hr/day, ____day/wk, ____wk/yr "

Number of Filter Elements (N_{filter}): ____ "

Area of Individual Filter Element (A_{filter}): ________ in^2 "

Number of Exhaust Fans: ____ "

Fan Motor Horsepower Rating: ________ HP "

Fan Diameter: ________ in "

Application Method: ______________ "

Transfer Efficiency (TE): ____ % Table 14-2

Regulation XIII On-Site Offset Factor For NSR Max. Daily Emissions: 1.1

CALCULATIONS:

1. Uncontrolled Volatile Organic Compound Emissions ($R_{1,VOC}$)

Actual lb/day
$R_{1,VOC}$ = $\Sigma(UR_{n,actual}$ (gal/day) x $EF_{n,VOC}$ (lb/gal)) = ____ lb/day

Actual lb/hr
$R_{1,VOC}$ = $R_{1,VOC}$ (actual lb/day) / T_a (hr/day) = ____ lb/hr

Maximum lb/day
$R_{1,VOC}$ = $\Sigma(UR_{n,maximum}$ (gal/day) x $EF_{n,VOC}$ (lb/gal)) = ____ lb/day

	Actual lb/hr	Actual lb/day	Maximum lb/day
Uncontrolled VOC Emissions ($R_{1,VOC}$)	____	____	____

2. Uncontrolled Particulate Matter Emissions ($R_{1,PM}$)

Actual lb/day
$R_{1,PM}$ = $\Sigma(UR_{n,actual}(gal/day) \times EF_{n,PM}(lb/gal) \times (1-TE))$ = ____lb/day

Actual lb/hr
$R_{1,PM}$ = $R_{1,PM}$ (actual lb/day) / T_a (hr/day) = _____ lb/hr

Maximum lb/day
$R_{1,PM}$ = $\Sigma(UR_{n,max.}(gal/day) \times EF_{n,PM}(lb/gal) \times (1-TE))$ = _____lb/day

Uncontrolled PM Emissions ($R_{1,VOC}$)	Actual lb/hr	Actual lb/day	Maximum lb/day
	______	______	______

3. Controlled VOC Emissions ($R_{2,VOC}$)

$R_{2,VOC}$ (actual) = $R_{1,VOC}$ (actual lb/day) = _____ lb/day

$R_{2,VOC}$ (maximum) = $R_{1,VOC}$ (maximum lb/day) = _____ lb/day

$R_{2,VOC}$ (NSR) = $R_{1,VOC}$ (maximum lb/day) x 1.1 = _____ lb/day

Controlled VOC Emissions ($R_{2,VOC}$)	Actual lb/day	Maximum lb/day	NSR lb/day
	______	______	______

4. Controlled PM Emissions ($R_{2,PM}$)

$R_{2,PM}$ (actual) = $R_{1,PM}$ (actual lb/day) X $(1 - EFF_f)$ = _____ lb/day

$R_{2,PM}$ (maximum) = $R_{1,PM}$ (maximum lb/day) X $(1 - EFF_f)$ = _____ lb/day

$R_{2,PM}$ (NSR) = $R_{1,PM}$ (maximum lb/day) X 1.1 = _____ lb/day

Controlled PM Emissions ($R_{2,PM}$)	Actual lb/day	Maximum lb/day	NSR lb/day
	______	______	______

5. Air Velocity

$$V_{air} = \frac{(VFR) \times 144}{\_\_\_\_\_ (N_{filter}) \times \_\_\_\_\_ (A_{filter})} = \_\_\_\_\_\_\_\_\_ \text{ ft/min}$$

where:
V_{air} = Air velocity through the filter, ft/min
VFR = Volumetric flow rate through the filter, CFM
N_{filter} = Number of filter elements
A_{filter} = Area of a single filter element, in^2

RULES EVALUATION:

RULE 212 : Public notice is (is not) required.

RULE 401 : This equipment utilizes a dry filtration system. Compliance with Rule 401 is (is not) expected.

RULE 402 : The location of the equipment will be in an industrial/ commercial area. Solvent usage rates are low (high). Compliance with Rule 402 is (is not) expected.

RULE 442 : Maximum organic emissions are calculated to be ________. Permit conditions to include limits on quantity sprayed and (types of solvent used). Compliance with Rule 442 (a)(2) and (a)(4) is (is not) expected.

RULE 443 : Permit conditions to include proper labeling of solvents. Compliance with Rule 443 is (is not) expected.

RULE 481 : Filter velocity is calculated to be a minimum of _____ ft/min, and a maximum of _____ ft/min. These values are (are not) between the specified values of 100 ft/min minimum and 300 ft/min maximum. Compliance with Rule 481 is (is not) expected.

RULE1151 : The applicant will (will not) be informed of the requirements imposed by Rule 1151 beginning 1/1/90.

REG XIII : As shown by the Emission Threshold/New Source Sheet Table below, this facility will (will not) operate in compliance with Regulation XIII:

	NSR Emissions in Pounds Per Day				
	ROG	NO_X	SO_2	CO	PM
Facility Emissions Since 10-8-76					
A/N					
A/N					
Net Emission Increase Since 10-8-76					

BACT : This equipment causes (does not cause) an increase in VOC or PM emissions. The applicant will (will not) provide BACT as follows: (This information is listed in the SCAQMD's BACT Guideline)

ROG:
NO_x:
SO_x:
CO:
PM :

CONCLUSIONS/RECOMMENDATIONS:

This equipment is (is not) expected to comply with all applicable District Rules and Regulations. The following is recommended:

( ) Issue a Permit to Construct/Operate with the following conditions:

APPLICATION NO. ____________________

CONDITIONS:

1. THIS SPRAY BOOTH MUST NOT BE OPERATED UNLESS ALL EXHAUST AIR PASSES THROUGH FILTER MEDIA AT LEAST 2 INCHES THICK.

2. A GAUGE MUST BE INSTALLED TO INDICATE THE STATIC PRESSURE DIFFERENTIAL ACROSS THE EXHAUST FILTERS. IN OPERATION, THE PRESSURE DIFFERENTIAL MUST NOT EXCEED 0.25 INCHES OF WATER.

3. ORGANIC SOLVENTS USED IN THIS EQUIPMENT MUST BE CLEARLY LABELED AS NON-PHOTOCHEMICALLY REACTIVE BY THE SUPPLIER OR, FOR BULK SHIPMENTS, SHOWN TO BE NON-PHOTOCHEMICALLY REACTIVE ON BILLS OF LADING OR INVOICES.

4. THE TOTAL QUANTITY OF COATINGS AND SOLVENTS USED IN THIS EQUIPMENT MUST NOT EXCEED ____ GALLONS IN ANY ONE DAY AND ____ GALLONS IN ANY ONE HOUR.

5. THE TOTAL QUANTITY OF VOLATILE ORGANIC COMPOUND (VOC) EMISSIONS FROM THIS EQUIPMENT MUST NOT EXCEED ____ POUNDS IN ANY ONE DAY.

6. THE OPERATOR SHALL KEEP ADEQUATE RECORDS TO VERIFY DAILY USAGE. SUCH RECORDS SHALL BE RETAINED FOR A PERIOD OF AT LEAST TWO YEARS AND BE MADE AVAILABLE TO DISTRICT PERSONNEL UPON REQUEST.

OR

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s) ____________ of the Rules and Regulations of the South Coast Air Quality Management District.

SECTION 15

Electric Utility Gas Turbines

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SECTION 15: ELECTRIC UTILITY GAS TURBINES

15.1 General Description

Broadly characterized, turbines are machines that convert energy stored in a fluid into mechanical energy by channeling the fluid through a system of stationary and moving vanes. The moving vanes are attached to a rotor to either turn a shaft, producing work output in the form of torque (rotational mechanical energy), or to generate velocity and pressure energy (thrust) in a jet. Turbines are generally classified according to the type of working fluid used. The most common are water, steam, and gas. Water turbines and steam turbines are generally used to generate electricity. The primary source of electric power generation comes from steam turbines, with single unit outputs ranging into the thousands of megawatts. Steam turbines also perform mechanical work in industrial applications and in propelling oceangoing vessels.

Gas turbines are principally used to propel jet-aircraft. Their stationary uses include electric power generation (usually for peak-load demands), end-of-line voltage booster service for long-distance transmission lines, and for pumping natural gas through long-distance pipelines. Gas turbines are used in combined (cogeneration) and simple-cycle arrangements. This section will consider the simple-cycle electric utility stationary gas turbine.

15.1.1 Operating Characteristics

The working fluid in a gas turbine is usually a combusted air-fuel mixture, typically considered as air for practical purposes (air-to-fuel ratios are very high due to cooling requirements). The basic principles of operation for a gas turbine are the same as any internal combustion engine; air is compressed in the engine and combusted with a fuel to produce a hot expanding exhaust gas which is used to turn a shaft. The difference in operation between a turbine and a conventional piston-type engine is that a turbine operates on a continuous basis, whereas a piston-type IC engine operates on either a two-stroke or four-stroke cycle (see Figure 15-1). A

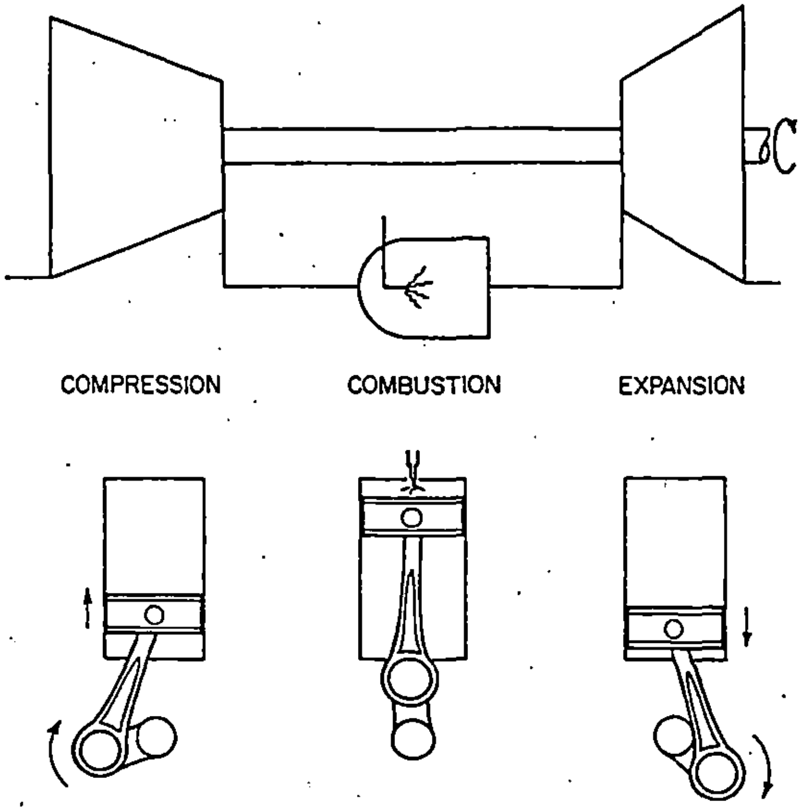


FIGURE 15-1 COMPARISON OF GAS-TURBINE AND PISTON ENGINES

piston-type (or rotary-type) engine must clear the combustion chamber of the exhaust gas between compression and combustion strokes (this applies to both two- and four-stroke cycles), while the gas turbine, with its flow-through design, compresses, combusts, and exhausts the air and fuel continuously. The rotational motion of a gas turbine is less complicated and more efficient than the reciprocating motion of a conventional piston-type engine. In the ideal, simple-cycle (Brayton air cycle), shown in Figures 15-2 and 15-3, air enters the compressor at section 1 at atmospheric pressure and temperature. The air is then compressed at constant entropy (no heat added or subtracted and without friction or other losses) at section 2. The air flows from section 2 into the combustion chamber where fuel is added and burned at constant pressure (raising the temperature to its maximum value for the cycle). The heated gas enters the turbine at section 3, then expands to atmospheric pressure across the turbine blades at section 4 producing shaft work. The amount of work that may be obtained from this process is represented by the enclosed area on both the pressure-volume (P-V) diagram and the temperature-entropy (T-S) diagram in Figure 15-2. In Figure 15-3, the area enclosed by a-1-2-b is the ideal work input to the compressor, while area a-4-3-b is the ideal work output of the turbine, assuming 100% efficiency in both cases. Hence, the net work output is equal to the turbine output less the compressor input, area 1-2-3-4. In the simple ideal cycle, the efficiency depends on the pressure ratio, increasing rapidly at first, and then leveling off slowly. The principle difference between the ideal cycle and the actual cycle is that compression and expansion processes cannot be conducted without friction or other losses as assumed. In actual cycles, approximately 300 percent excess air is used, and about 25% of the available oxygen is consumed. The efficiency of the compressor is about 85 percent, and that of the turbine about 87 percent.[1] Unlike the ideal cycle, actual cycles are evaluated by a temperature ratio. Increasing the maximum temperature of the cycle increases the efficiency of the system. On average, for every 100° F increase in temperature, work output is increased by approximately 10 percent. This results in about a 1.5 percent increase in efficiency.[2]

There are three basic ways to increase the efficiency of the simple-cycle gas turbine : (1) increase the work output of the turbine; (2) decrease work input to the compressor; or (3) decrease the amount of heat added by the fuel.[2]

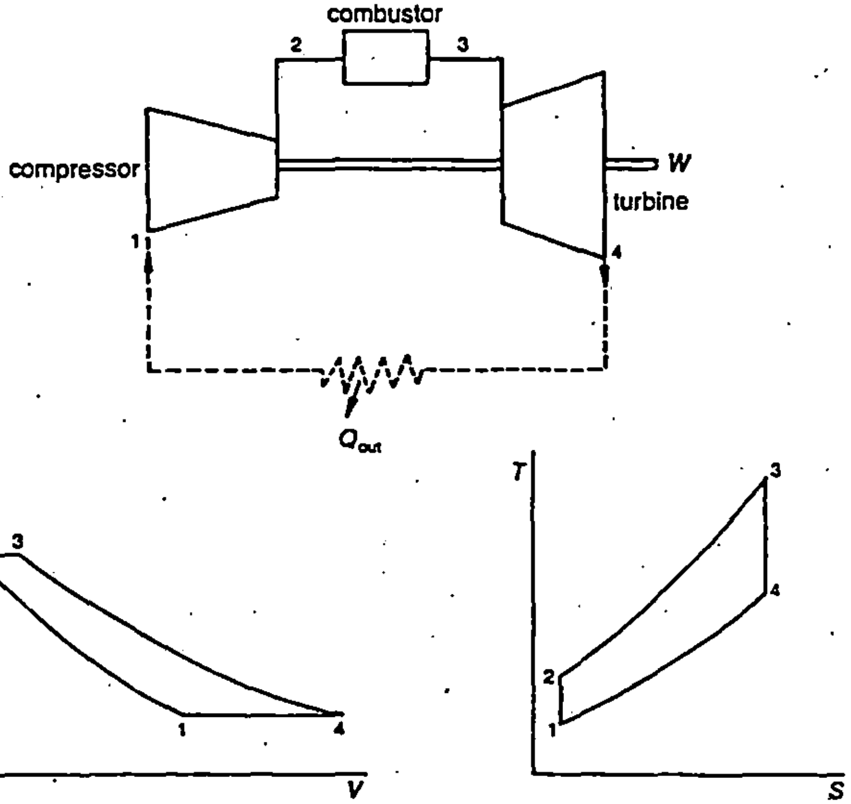


FIGURE 15-2 BRAYTON - CYCLE

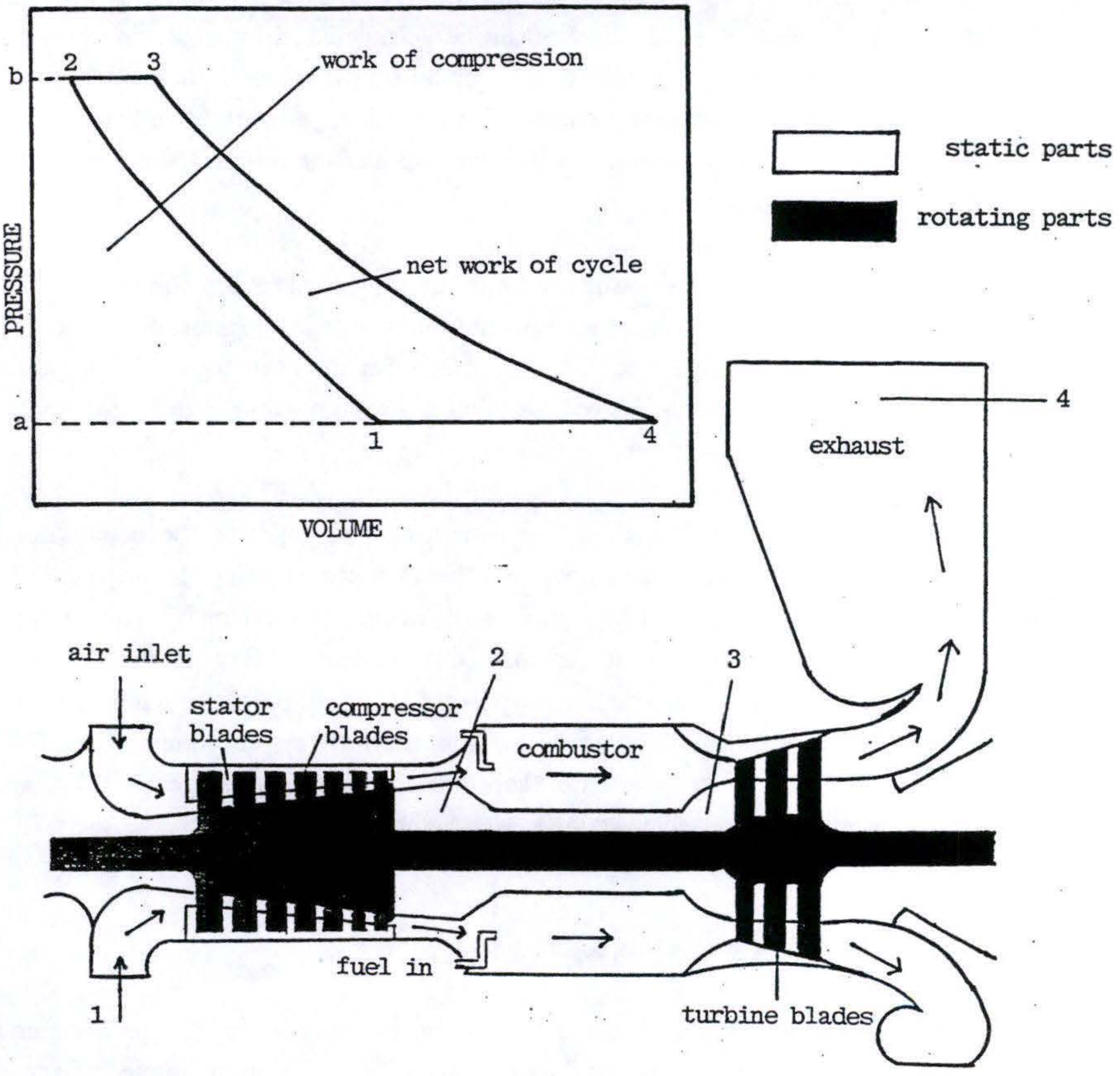


FIGURE 15-3 IDEALIZED GAS-TURBINE CYCLE

The work output of the turbine can be increased by dividing the expansion process into two or more steps. This division can be accomplished by employing a high-pressure and low-pressure turbine with a combustion chamber in between for reheating the air and combustion products. The effect is to increase the volume of the gas undergoing expansion, thus increasing the output of the turbine (see Figure 15-4).[2]

The work input to the compressor can be reduced by compressing the air isothermally. The most practical approach is to use intercooling. In intercooling, the air compressed from one stage is cooled prior to entering the next stage. The purpose of intercooling is to maintain the volume of air as low as possible in order to reduce the power required for compression (see Figure 15-5).[2]

To accomplish the third objective, the compressed air entering the combustion chamber would be warmed by means of a heat exchanger using the hot exhaust gases from the turbine as the heat source. In practice, this warming is accomplished by means of a regenerative heat exchanger or regenerator. Regenerators can increase efficiencies by as much as 15 to 20 percent at current operating temperatures. Optimum pressure ratios are about 7:1 for a regenerative system compared to 18:1 for the simple, non-regenerative cycle. Turbines with regenerators operate at higher inlet temperatures approaching 2000 °F (see Figure 15-6 and 15-7).[1]

15.1.2 Advances in Gas Turbine Technology[3,4]

Advanced gas turbine cycles based on aircraft engines and the use of steam injection are expanding the applications and increasing the efficiencies of the simple-cycle gas turbine. The heavy-duty industrial turbine is the technology of choice for the gas turbine/steam turbine combined cycle system. The aeroderivative turbine and its cycle variations (the steam injected gas turbine, the intercooled steam-injected gas turbine, and the chemically recuperated, steam-injected gas turbine) are new, alternative gas turbine technologies with the potential of increasing electrical efficiencies, lowering power output costs, and reducing combustion emissions from smaller gas turbine systems. The simple cycle gas turbine represents the traditional

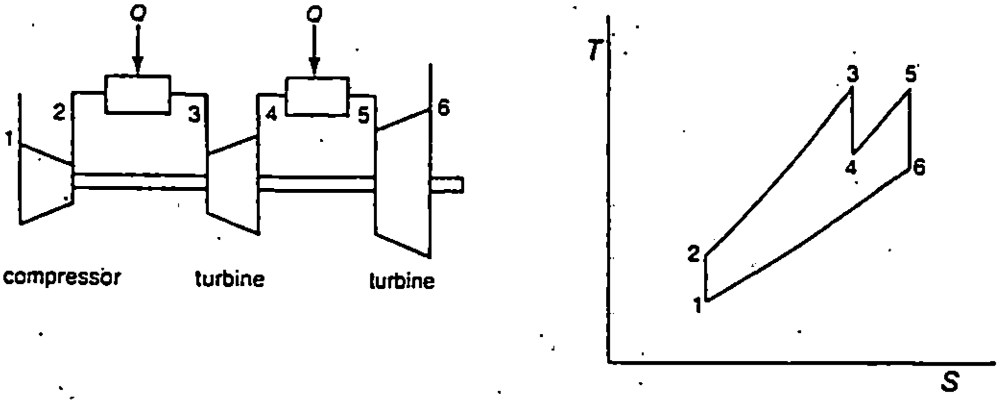


FIGURE 15-4 REHEAT CYCLE AND T-S DIAGRAM

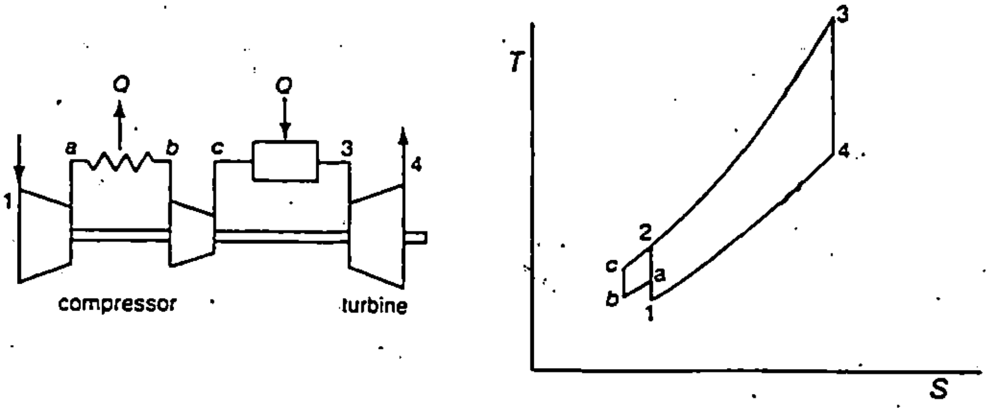


FIGURE 15-5 AIR STANDARD GAS TURBINE CYCLE WITH INTERCOOLING

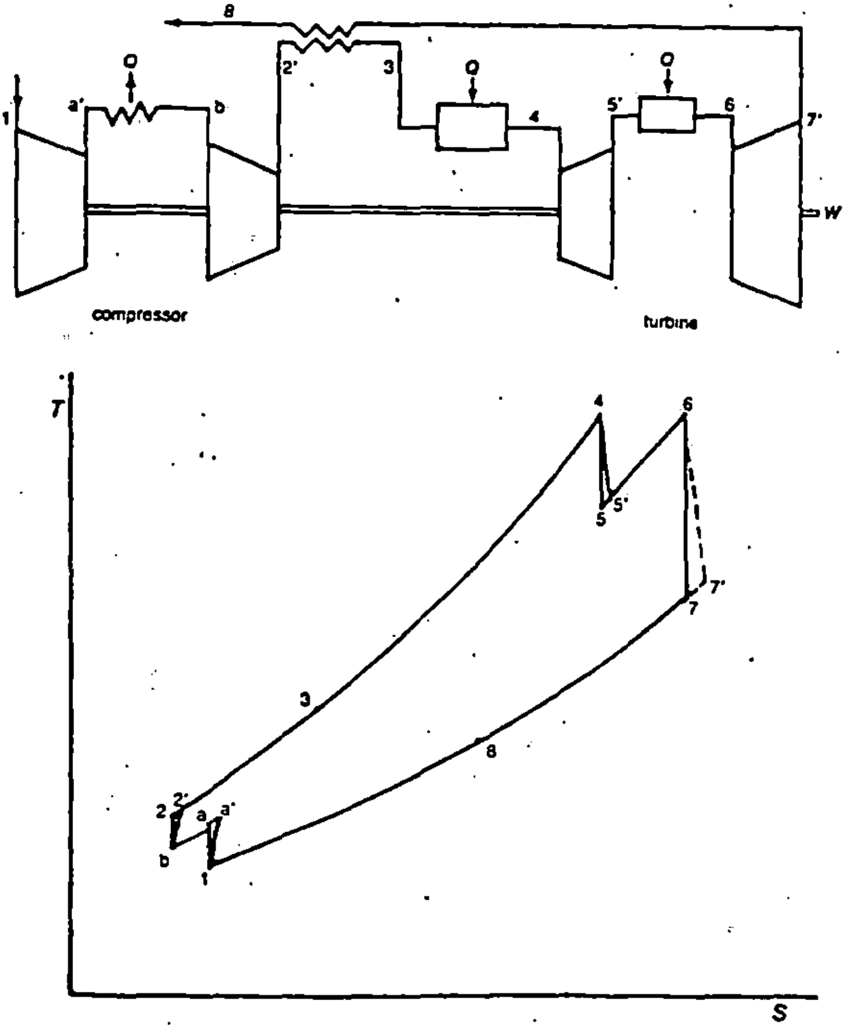


FIGURE 15-6 INTERCOOLED REGENERATIVE SPLIT-SHAFT GAS TURBINE CYCLE

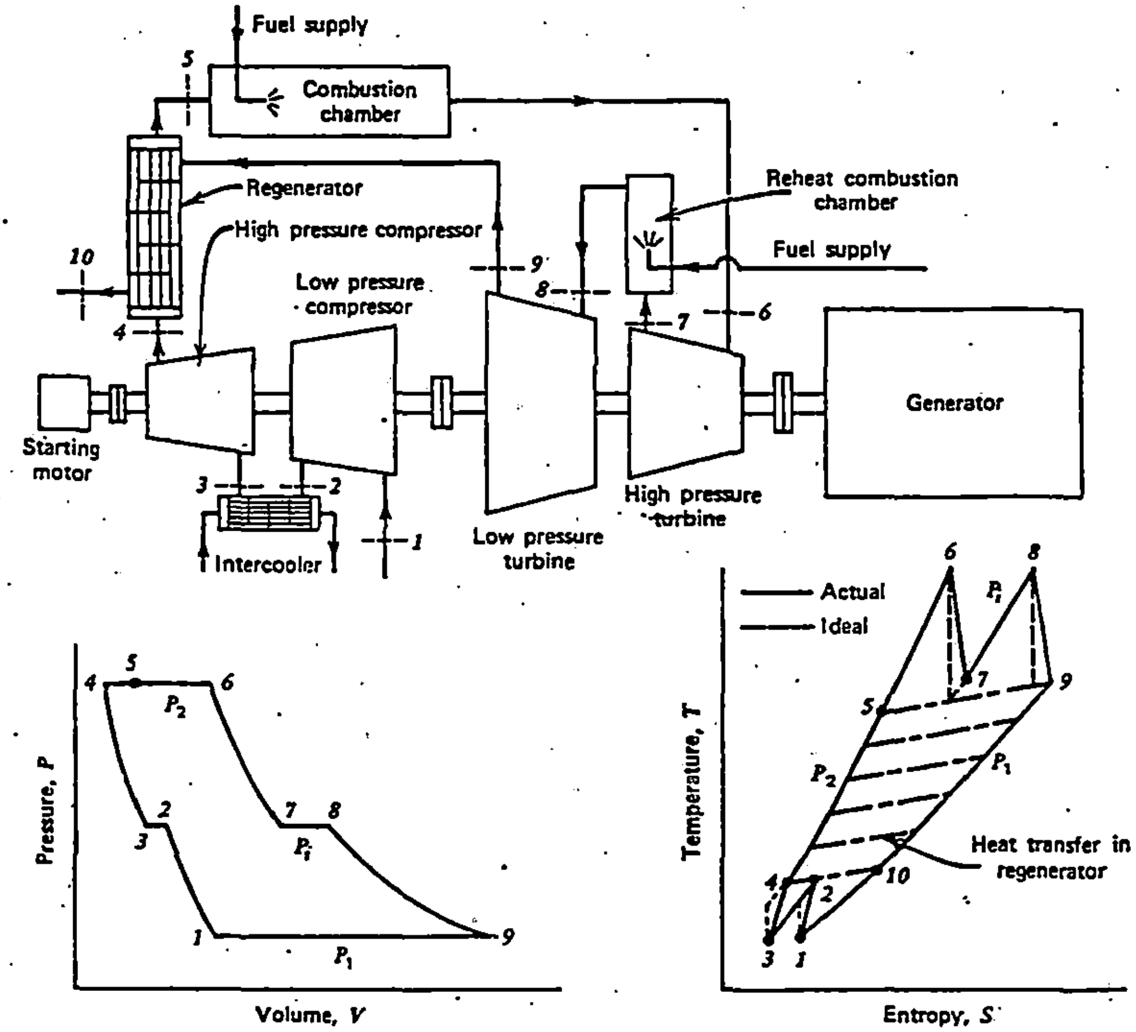


FIGURE 15-7 OPEN CYCLE GAS TURBINE WITH REGENERATION, REHEAT, AND INTERCOOLING

gas turbine system. Figures 15-8 a)-f) illustrate several gas turbine cycles. A major shortcoming of the simple cycle gas turbine in cogeneration is that it is often uneconomical in applications involving highly variable steam loads. (The reason being, a single shaft machine requires constant rotational speed of the compressor to maintain stable operation. Thus, to reduce electrical output, the fuel input is reduced, thereby reducing the inlet temperature and electrical efficiency). Two variations of the simple cycle gas turbine include the Cheng cycle or steam-injected gas turbine (STIG), and the intercooled steam-injected gas turbine (ISTIG). The steam-injected system injects high pressure steam recovered from the heat recovery steam generator (HRSG) into the combustor, where it is heated to the turbine inlet temperature, and then expanded in the turbine. The intercooled version utilizes an intercooler between compressor stages to reduce the compressor output requirements and to provide cooling air to the turbine blades, thereby further increasing the efficiency of the system. Another modification to the simple cycle, the chemically recuperated gas turbine, involves using some of the turbine exhaust heat to reform the fuel with steam in the presence of an appropriate catalyst. For example, methane fuel could be converted into a mixture of hydrogen, carbon monoxide and carbon dioxide by reacting with the steam. Since the steam-reforming reaction is highly endothermic, the chemical energy content of the products is greater than that of the fuel from which it is derived. Thus, steam reforming can convert low-quality heat into high-quality chemical energy.

The most notable atmospheric benefit of these modifications to the simple cycle gas turbine is the reduced emission of NO_X. Increasing the ratio of steam or water to fuel ratio reduces the flame temperature in the primary combustion zone resulting in an exponential decrease in NO_X emissions (see Figure 15-9). Water injection will reduce the flame temperature but adversely affects the efficiency of the system because the energy expended in bringing the water up to the turbine inlet temperature is not offset by the increased mass flow into the turbine. Steam injection however, in the STIG or ISTIG cycles, utilizes high pressure steam which increases efficiency and reduces NO_X. Reducing the flame temperature reduces NO_X, but in turn increases CO. However, at present this is an acceptable tradeoff because the cost of controlling CO emissions (catalytic oxidation) is significantly less than that of controlling NO_X (selective catalytic reduction - SCR).

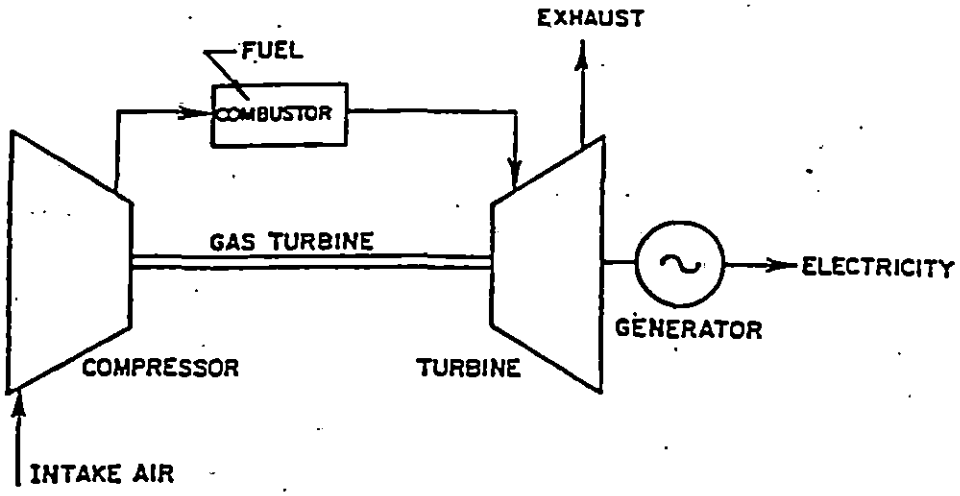


FIGURE 15-8 A) SIMPLE POWER CYCLE - fuel burns in air pressurized by compressor, combustion products drive turbine, and hot turbine exhaust gases are discharged to atmosphere.

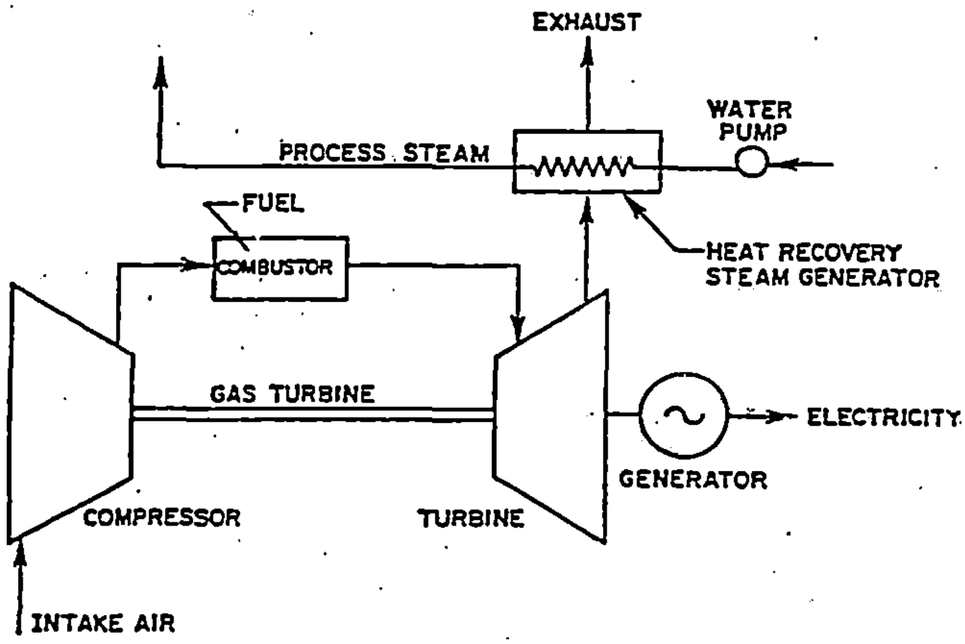


FIGURE 15-8 B) SIMPLE COGENERATION CYCLE - like simple power cycle, except that hot turbine exhaust gases are used to raise steam in HRSG for heating.

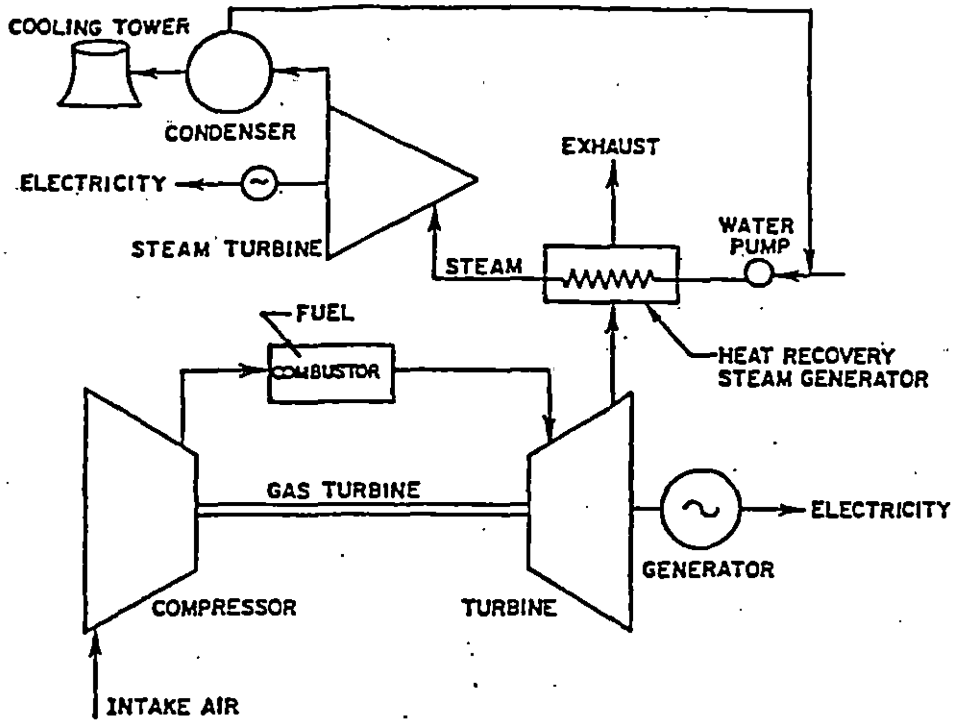


FIGURE 15-8 C) COMBINED CYCLE FOR POWER - like simple cogeneration cycle, except that steam from HRSG is used to produce extra power in condensing steam turbine.

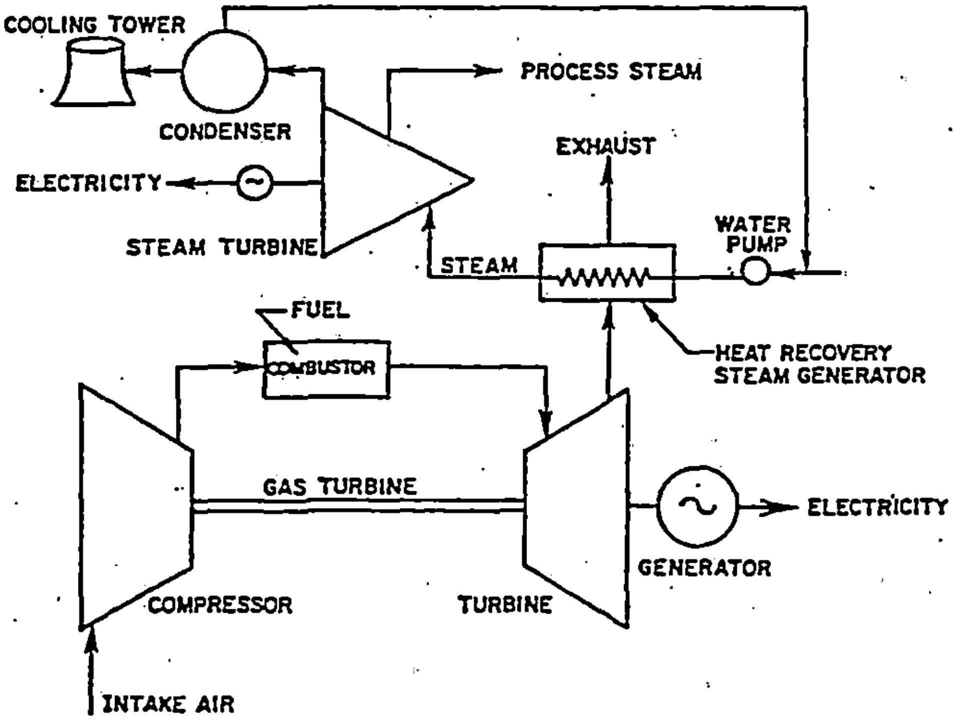


FIGURE 15-8 D) COMBINED CYCLE FOR COGENERATION - like combined cycle for power, except that some steam is bled from steam turbine for heating.

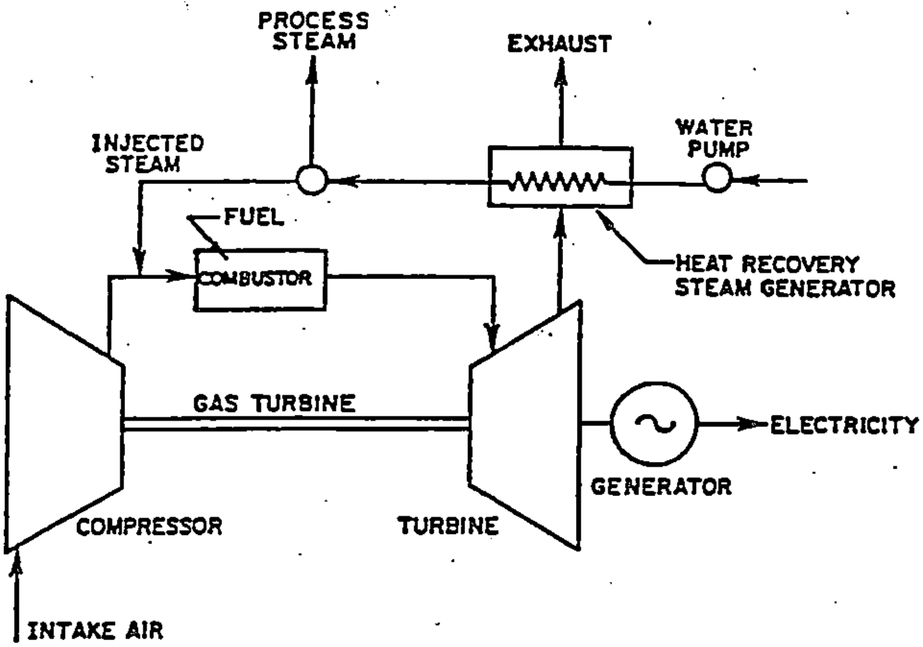


FIGURE 15-8 E) STIG - like simple cogeneration cycle, except that steam not needed for heating is injected into combustor for increased power output and higher electrical efficiency.

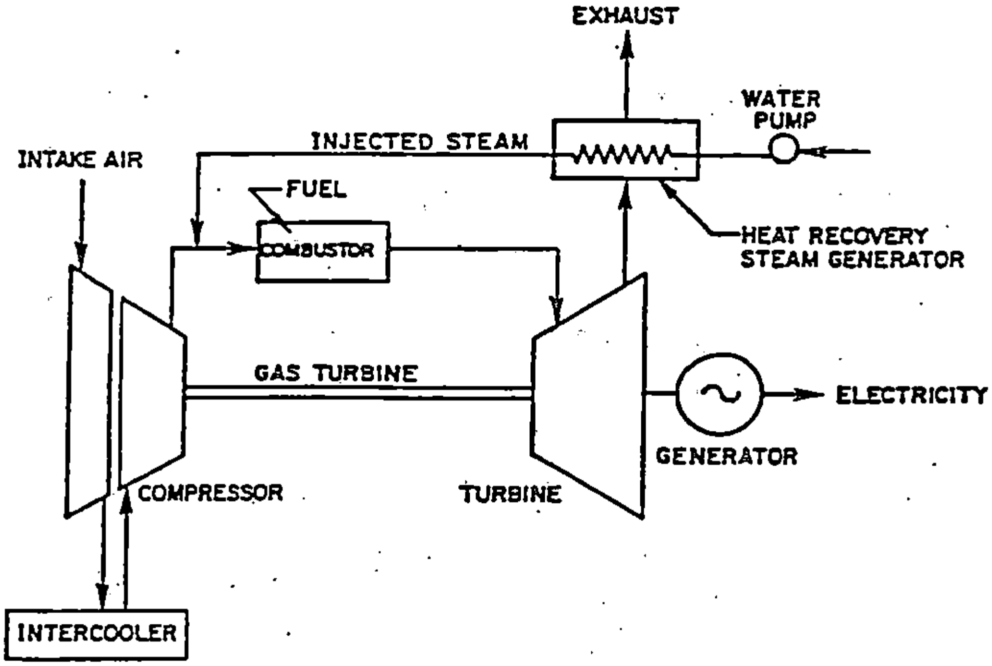


FIGURE 15-8 F) ISTIG - like STIG with full steam injection except that intercooler between compressor stages allows for operation at much higher turbine inlet temperature because of improved air cooling of turbine blades.

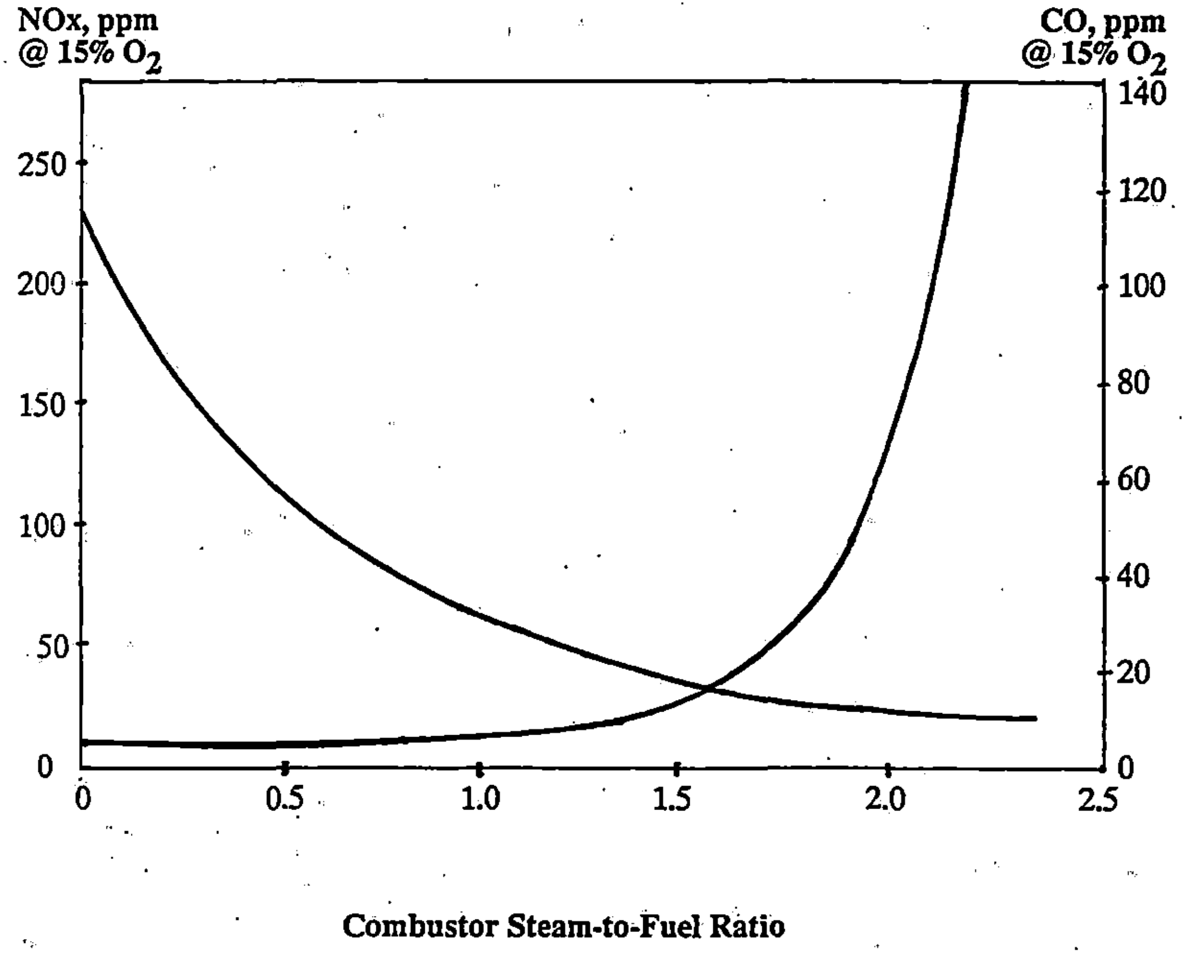


FIGURE 15-9 TYPICAL EFFECTS OF COMBUSTOR STEAM INJECTION ON NOx AND CO EMISSIONS AT FULL LOAD OPERATION.

15.1.3 Applications

The simple-cycle electric utility gas turbine is primarily used as a peaking unit (in an electric power station), an emergency standby engine (powering a generator), or a portable power plant. Peaking units supply above baseline electric power during periods of maximum power usage (typically in summer from 1:00 P.M. to 7:00 P.M., and in winter from 5:00 P.M. to 10:00 P.M.). Short start-up time, simplicity of operation, minimal maintenance and small space requirement make gas turbines an attractive alternative to additional steam turbines in providing peak-load and standby power.

Another similar application of gas turbines is for end-of-line voltage booster service on long-distance transmission lines. A third electrical power application is portable power, where again the size and ease of operation make gas turbines the best choice for mounting on a railroad car or barge.

15.1.4 Classifications

Gas turbines can be classified into four broad groups:

- Industrial, Heavy-Duty Gas Turbines;
- Aircraft-Derivative Gas Turbines;
- Medium-Range Gas Turbines; and
- Small Gas Turbines.

15.1.4.1 Industrial, Heavy-Duty Gas Turbines

Industrial, heavy-duty gas turbines were initially designed after their predecessor, the steam turbine. The overall pressure ratios varied from 5:1 for earlier designs to 15:1 for contemporary designs. Inlet temperatures to the turbine section are usually 1,950 ^{o}F. Projected temperatures of future designs will approach 3,000 ^{o}F with the advent of thermal resistant materials. The most common industrial, heavy-duty gas turbines employ axial flow compressors and turbines. In most U.S. designs, combustors are can-annular type combustors with liners designed to reduce smoke and NO_X emissions. Many units employ dual fuel capability. The advantages of these gas turbines are long life expectancy, high availability and slightly higher overall efficiencies. The largest single users of industrial, heavy-duty gas turbines are electrical utilities for peak-loading services.[1]

15.1.4.2 Aircraft-Derivative Gas Turbines

Aircraft-derivative gas turbines, commonly known as jet gas turbines, consist of two basic components: an aircraft-derivative gas generator and a free-power turbine. The gas generator is the site of fuel combustion. From here the resultant exhaust gases are vented to the turbine at pressures and temperatures approximating 30 psig and 1,100 ^{O}F, respectively. The free-power turbine converts the energy of the gases into mechanical energy. The power turbine permits the combustion gas to expand through one or more turbine stages. Residual gas energy is exhausted into the atmosphere or further utilized as waste heat. The aircraft-type turbine is mostly used by gas transmission companies and on gas reinjection platforms, accounting for 80% of all sales (1982). They are also used as peak-load units in power plants (see Figure 15-10. Note the use of both an axial and centrifugal compressor).[1]

15.1.4.3 Medium-Range Gas Turbines

Medium-range gas turbines are rated from 5,000 to 15,000 H.P. and are similar in design to the large heavy-duty gas turbine. They employ a split-shaft design to increase efficiency in part-load, variable speed operations. The gasifier section operates at maximum efficiency while the power turbine operates over a great range of speeds. The compressor is a 10-16 stage, subsonic, axial-type with a compression ratio of 5:1 to 11:1. Most U.S. designs of the medium-range gas turbine use can-annular (5-10 cans in a circular ring) or annular-type combustors. The gasifier turbine is usually a 2-3 stage axial turbine with an air cooled first stage nozzle and blade. The power turbine can be a single- or two-stage axial flow turbine. Medium- range gas turbines are used on offshore platforms, and petrochemical plants (see Figure 15-11).[1]

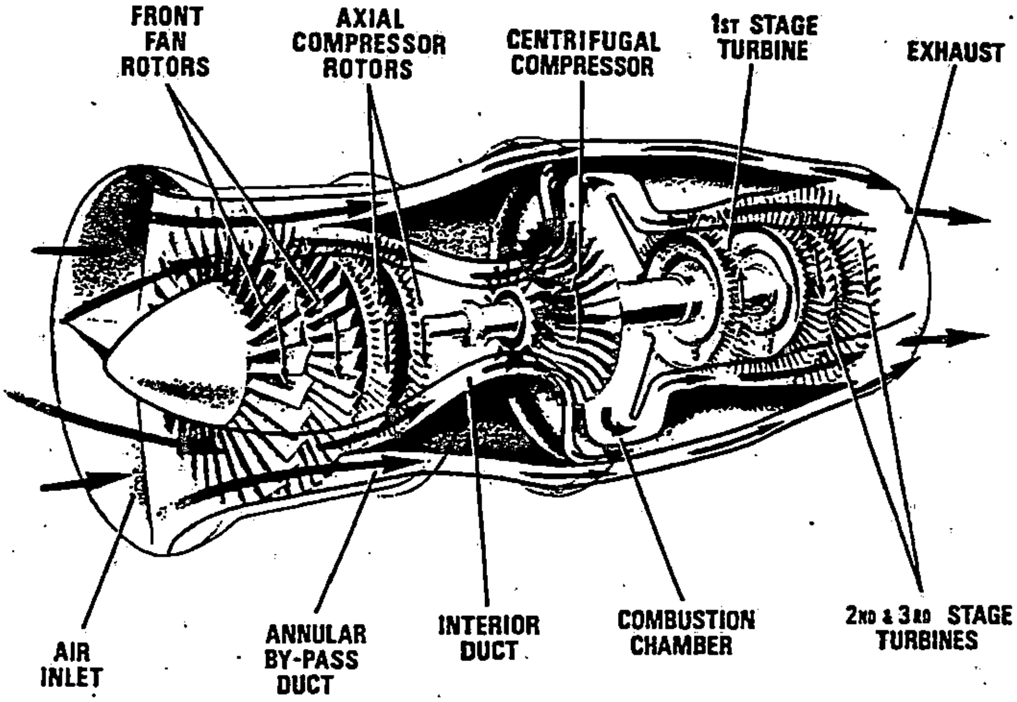


FIGURE 15-10 AIRCRAFT-TYPE GAS TURBINE (Rolls-Royce Limited).

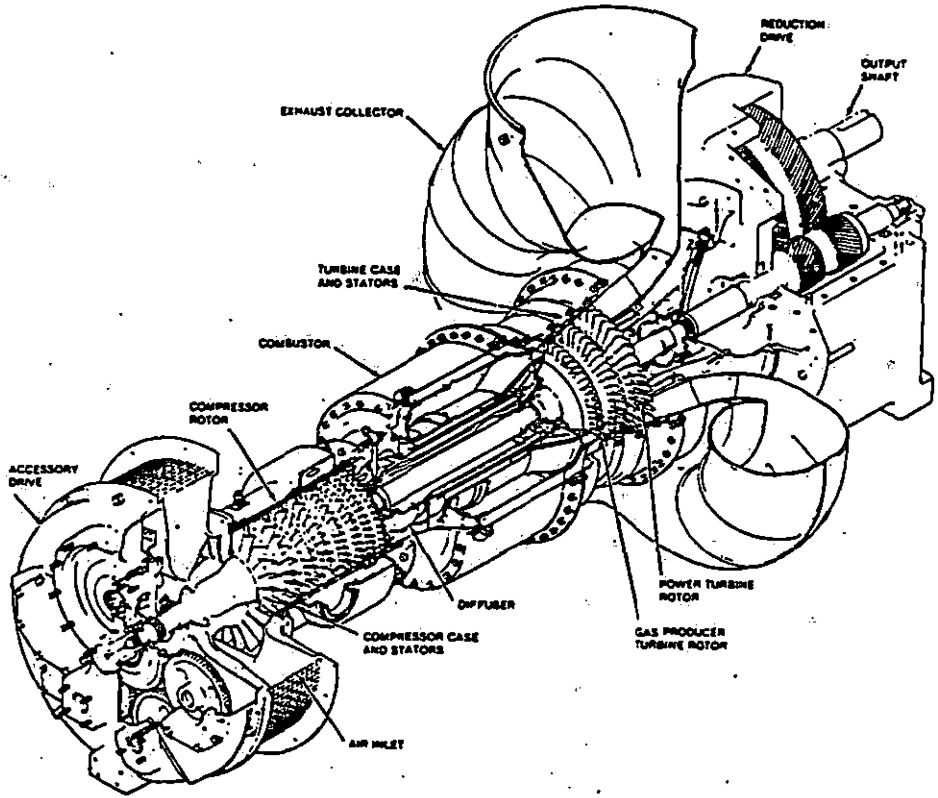


FIGURE 15-11 CUTAWAY VIEW OF A MEDIUM-RANGE GAS TURBINE (Solar Turbines Incorporated).

15.1.4.4 Small Gas Turbines

Small gas turbines are rated at less than 5,000 H.P. Their design is similar to the larger industrial, heavy-duty gas turbine. The small gas turbine, however, incorporates centrifugal compressors or a combination of centrifugal and axial compressors as well as radial in-flow turbines. They most often consist of a single-stage centrifugal compressor producing a compression ratio of approximately 4:1, a single-side combustor where temperatures of approximately 1,600 ^{o}F are reached, and radial in-flow turbines. The efficiencies of a small gas turbine are lower than their larger counterparts due to inlet temperature limitations and lower component efficiencies. Turbine inlet temperature is limited by reduced turbine blade cooling effects. Radial-flow compressors and impellers have inherently lower efficiencies (see Figure 15-12).[1]

15.1.5 Major Gas Turbine Components

The main components of a gas turbine are:

- the compressor;
- the regenerator;
- the combustor; and
- the turbine.

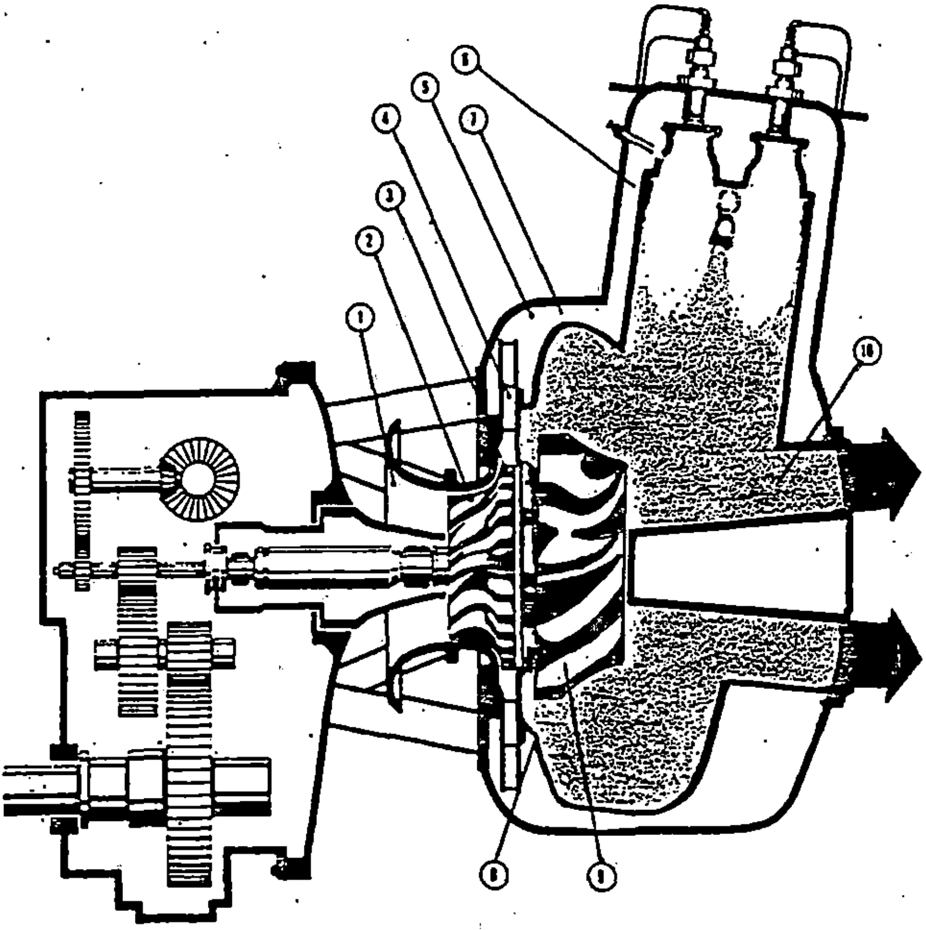
15.1.5.1 Compressor

The compressor in a gas turbine increases the pressure of the incoming air before it is mixed with fuel in the combustion chamber. The two types of compressors used in gas turbines are axial and centrifugal. An axial-flow compressor consists of several stages each of which slightly increase the pressure from the previous stage. These low pressure increases, on the order of 1.1:1 to 1.4:1, result in higher compressor efficiency. The use of multiple stages permits an overall pressure increase of up to 18:1.[1] A stage is comprised of one row of moving blades (the rotor) and one row of stationary blades (the stator). Figure 15-13 shows a schematic of two stages in an axial compressor. The rotor, with its angled blades, accelerates the air toward the stator where the air is diffused. The diffusion process converts the velocity increase gained in the rotor to a static pressure increase. An additional row of fixed blades (inlet guide vanes) is used to direct the entering air to the first-stage rotors at the desired angle. An additional stator at the exit of the compressor section is used to further diffuse the fluid prior to entering the combustion chamber. The airflow path of an axial compressor is helical.

Centrifugal or mixed-flow compressors consist of inlet guide vanes (for high-pressure ratio use only), an inducer, an impeller, a diffuser, and a scroll. In a centrifugal compressor, the air is compressed by centrifugal forces. The inlet air to a centrifugal compressor is directed axially at the inlet and ejected radially at the outlet (see Figure 15-14). Again, the rotor (impeller) and diffuser comprise a single stage. The air enters a centrifugal compressor at the inducer, as shown in Figures 15-15 and 15-16. Here, the angular momentum (the whirl) of the fluid is increased without increasing the radius of rotation. From the inducer, the air is channeled along the impeller from an axial direction to a radial direction (a 90^o turn). As the radius of rotation increases along the impeller, energy is imparted to the fluid by centrifugal force. The air is then discharged into a diffuser where the kinetic energy is converted into static pressure. The flow enters the scroll from which the compressor discharge is taken. The pressure ratio per stage in a centrifugal compressor can vary from about 1.5:1 to 5:1 on production units. Some experimental units have obtained pressure ratios of more than 12:1 for a single stage. The centrifugal compressor is slightly less efficient than the axial-flow compressor, but has a greater operating range.[1]

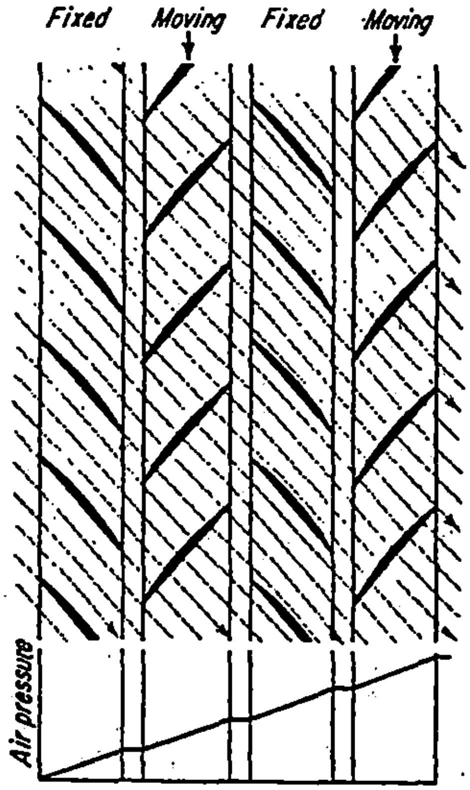
15.1.5.2 Regenerator

Regenerators are heat exchangers which use the exhaust heat from the turbine to preheat the pressurized air entering the combustor region (see Figure 15-7). Preheating the air reduces fuel consumption by reducing the difference between the pressurized air temperature and the combustion temperature. Reducing this temperature difference means that less fuel is needed to heat the air.

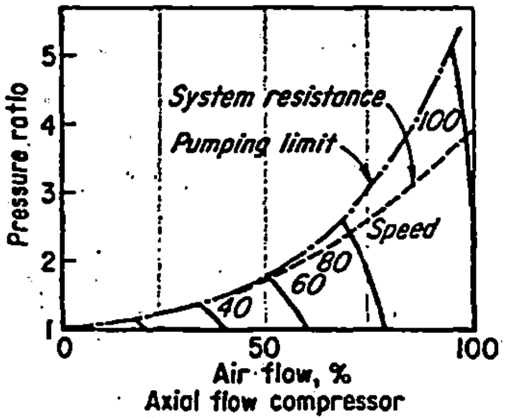


1. Inlet duct to compressor
2. Centrifugal compressor
3. Impellar
4. High-efficiency diffuser
5. Pressure casing
6. Combustion chamber
7. Volute
8. Turbine nozzles
9. Turbine
10. External load

FIGURE 15-12 CROSS SECTION OF A TYPICAL SMALL GAS TURBINE (North American Turbine Corporation).

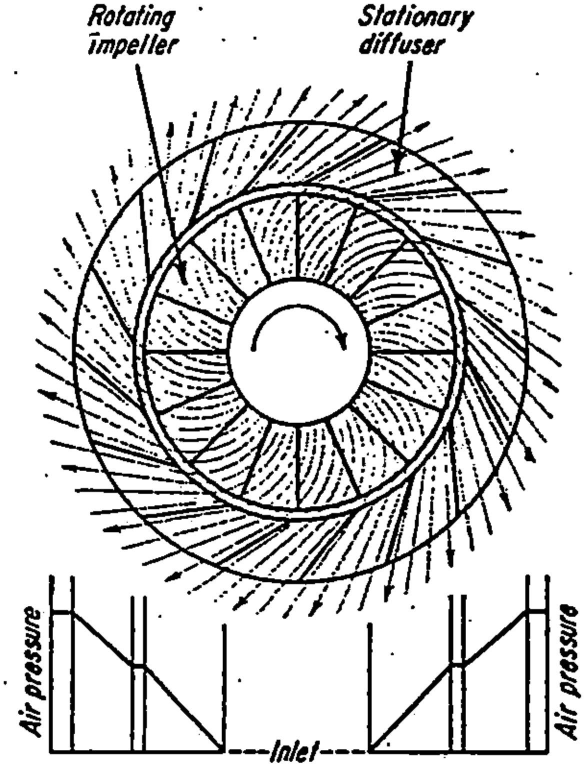


Air speeds up in moving blading and slows in fixed blading by diffusion

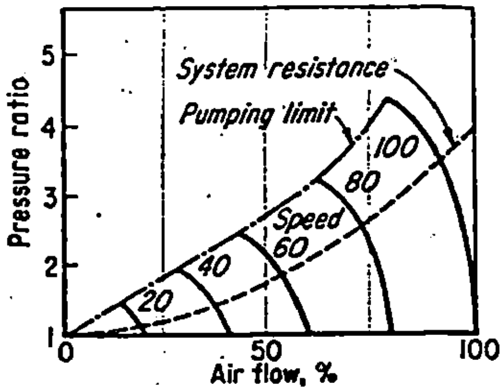


Axial compressors have lower pumping or surge limits than centrifugal units

FIGURE 15-13 SCHEMATIC OF AN AXIAL COMPRESSOR



Centrifugal impeller speeds up the air flow, diffuser pressurizes by slowing it



Centrifugal compressor

FIGURE 15-14 FRONTVIEW SCHEMATIC OF A CENTRIFUGAL COMPRESSOR

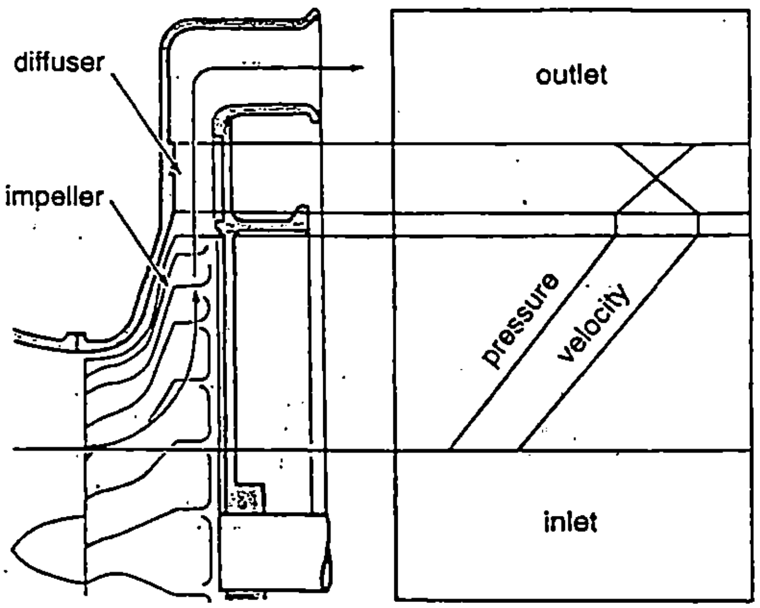


FIGURE 15-15 PRESSURE AND VELOCITY PROFILES THROUGH A CENTRIFUGAL COMPRESSOR

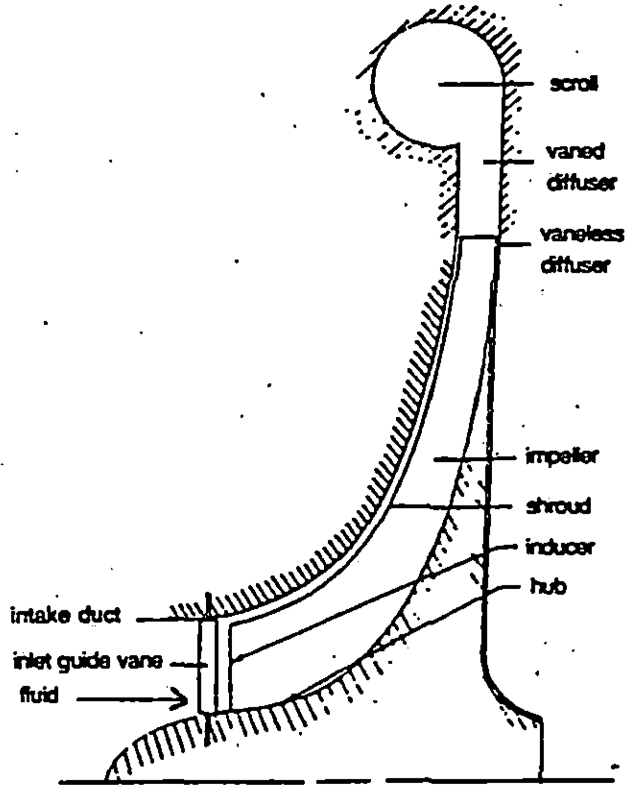


FIGURE 15-16 SIDEVIEW SCHEMATIC OF A CENTRIFUGAL COMPRESSOR

15.1.5.3 Combustor

Combustors serve one purpose - to increase the temperature of the high-pressure gas. Combustor design falls into four categories:

- Tubular (side combustors);
- Can-annular;
- Annular; and
- External (experimental).

Tubular combustors are found on large industrial turbines, especially European designs. They are simple in design, easy to maintain, and last a long time due to low heat release rates. Tubular combustors use a "straight-through" or "reverse-flow" design. The reverse-flow design ducts air through an annulus region bounded by the combustor can and its housing, and have minimal length.

Can-annular and annular combustors are used primarily in aircraft applications. Annular combustors are more popular where higher temperatures or low-Btu gases are involved. The amount of cooling air required when using low-Btu gases is significant because most of the air is used up in the primary zone and little is left for film cooling (see Figure 15-17). Hence, annular combustors have more surface area than can-annular combustors.

External combustors are used on external-combustion gas turbines. They heat the incoming pressurized air in a direct-fired air heater. The primary goal of the air heater is to achieve high temperatures with a minimum pressure decrease.

15.1.5.4 Turbine

The two types of turbines used in gas turbines are the axial-flow type and the radial-inflow type. The axial-flow type is used in more than 80% of all gas turbine applications.

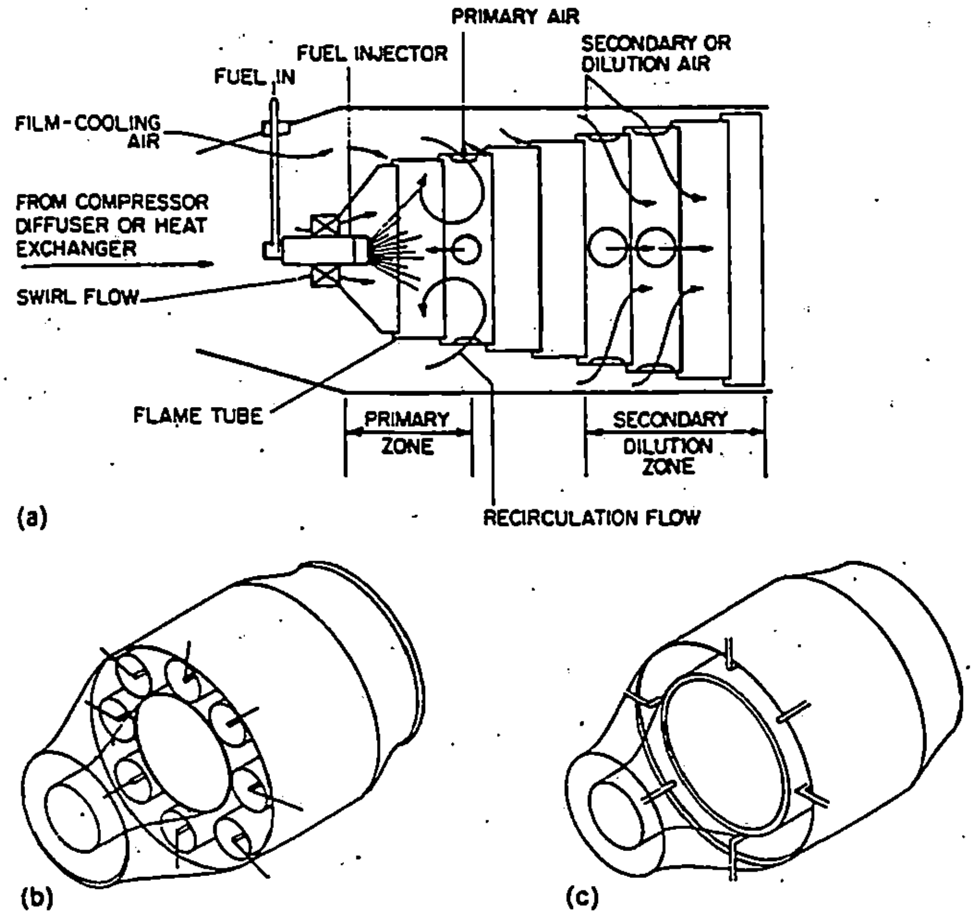


FIGURE 15-17 COMBUSTORS: (a) GENERAL FORM OF A COMBUSTION CHAMBER; (b) CAN-ANNULAR; (c) ANNULAR

Axial-flow turbines direct the flow of the fluid in an axial direction only. The two types of axial turbines used are: the impulse type and the reaction type. The impulse turbine consists of a group of nozzles which discharge the expanding combustion gases to a row of blades (the rotor) which in turn move and rotate the shaft. The gas is expanded in the nozzle, converting the thermal energy into kinetic energy. In the impulse turbine, the entire enthalpy drop occurs in the nozzle. Therefore, the gas has a very high velocity entering the rotor. Different configurations are employed to obtain the most work from the high velocity gases (see Figures 15-18 and 15-19).

The axial-flow reaction turbine is the most widely used turbine. The reaction turbine divides the enthalpy drop in the nozzle and the rotor, therefore, the static pressure decreases in both the fixed and moving blades. The fixed blades act as nozzles and direct the flow to the moving blades at a velocity slightly higher than the moving blade velocity. A common multistage turbine design uses impulse stages in the first few stages to maximize the pressure decrease, followed by 50% reaction turbines. The reaction turbine has a higher efficiency due to blade suction effects.

The radial-inflow turbine is basically a centrifugal compressor with reversed flow and opposite rotation. They are primarily used for smaller loads and over a smaller operational range than the axial turbine. Radial machines are shorter than their axial counterpart making them more suitable for certain applications. There are two types of radial-inflow turbines: the cantilever and the mixed-flow. The cantilever type is similar to an axial-flow turbine, but directs the flow radially inward. The mixed-flow type is almost identical to a centrifugal compressor with the components performing the opposite roles. The flow enters radially and exits axially with little radial velocity.

15.1.6 Start-Up and Shut-Down

Start-up and shut-down of a gas turbine occurs on a scheduled basis as with base-load units shutting down for a scheduled inspection and maintenance or on an

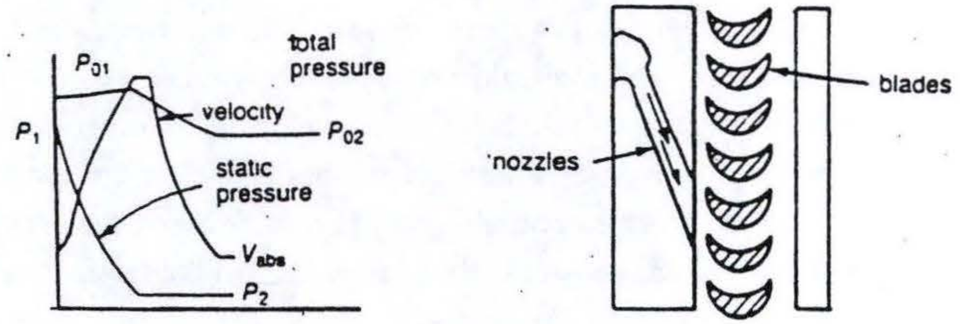


FIGURE 15-18 SINGLE-STAGE IMPULSE TURBINE WITH VELOCITY AND PRESSURE PROFILES

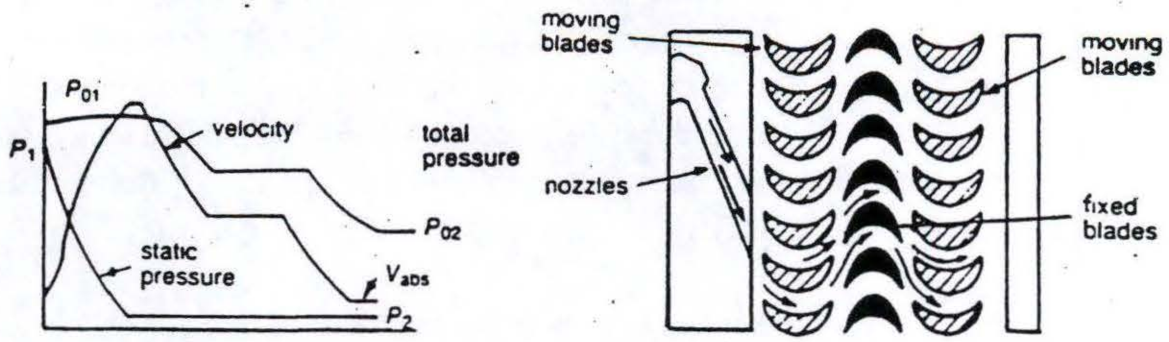


FIGURE 15-19 CURTIS-TYPE IMPULSE TURBINE WITH PRESSURE AND VELOCITY PROFILES

unscheduled basis as with peak-load units which operate with the infrequency of peak-load demands. Start-up operations consist of ramp-loading the unit over a period of time to bring it up to full-load conditions (see Figure 15-20). The time required varies according to the unit and its application. As with the start-up of any process, system variations are encountered until steady-state is reached. In the case of a stationary gas turbine, combustion efficiency (completeness) is reduced the farther the temperature is from the full-load operating temperature. The start-up procedure for a gas turbine requires bringing it up to starting speed (20% - 30% of full-load speed) and maintaining this speed for several minutes in order to purge the casing of residual fuel. This is usually accomplished by using a compressed air, hydraulic, or electric starting motor. Some units require a slow progressive heating of the casing and rotor by burning a nominal amount of fuel in the combustor. The turbine temperature is then increased rapidly to a value above the design temperature, thus producing enough power in the turbine to bring the set up to full speed. [1]

Cold start-up of a gas turbine results in incomplete combustion, producing higher levels of unburned hydrocarbons and carbon monoxide (relative to full load operation). These emissions are counted toward the daily threshold limit, hence, the duration of a start-up operation must be limited by permit conditions. Start-up periods can vary from ten minutes to eight hours. Emission control methods may be required to reduce emission levels of unburned hydrocarbons and carbon monoxide during start-up operations, e.g. an oxidation catalyst. Existing gas turbines (as defined in Rule 1134) are provided an exemption from the oxides of nitrogen limits (Rule 1134) by Rule 429 during start-ups and shut-downs. A variance may be granted to the applicant to bypass an air pollution control (APC) device for the time it takes to bring the turbine up to the operating conditions of the control device (typically for SCR). A variance may be granted by the Hearing Board on a case-by-case basis, but it does not exempt the applicant from employing Best Available Control Technology (BACT).

Shut-down operations are of less concern to the regulatory agency as NO_x emissions decrease at reduced load. Operations at reduced loads are, however, proportionally higher in hydrocarbon and carbon monoxide emissions. Once again, the use of an oxidation catalyst may be required during this type of operation.

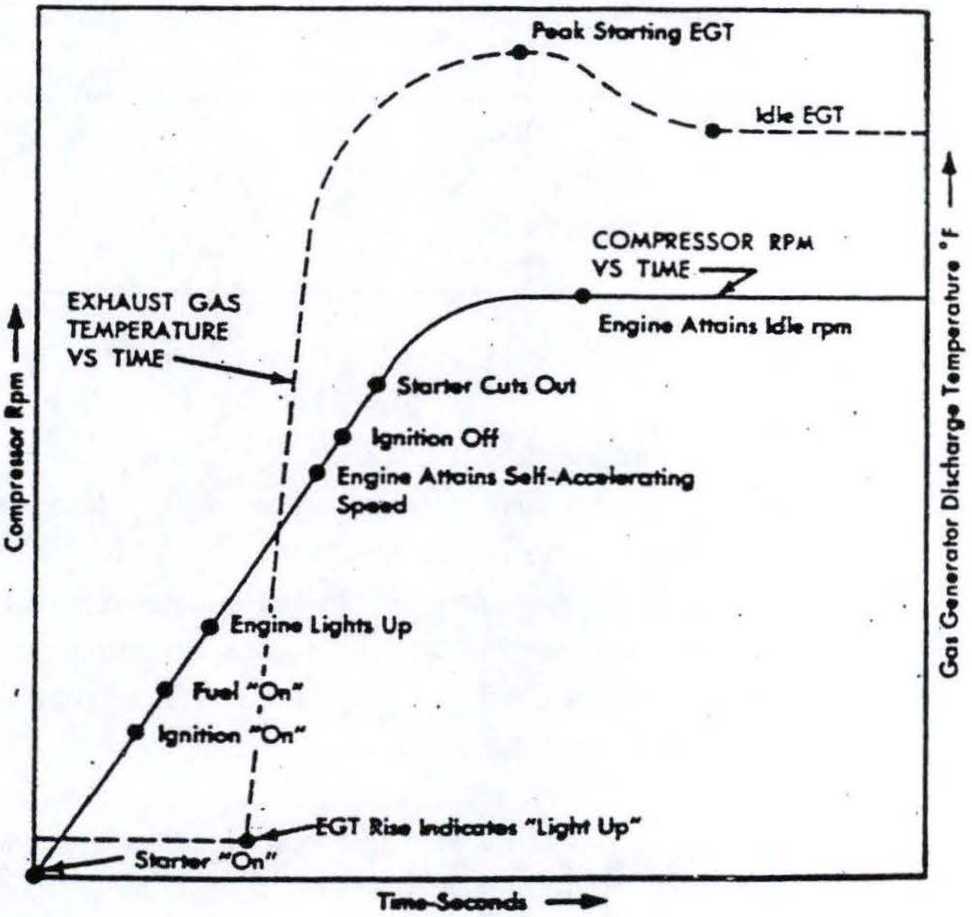


FIGURE 15-20 TYPICAL STARTING SEQUENCE OF A GAS TURBINE

15.1.7 Emission Controls

Unburned hydrocarbon and carbon monoxide emissions are the result of incomplete combustion and are reduced by allowing combustion to go to completion. Exhaust emissions of carbon monoxide, CO, and uncombusted hydrocarbons can be controlled through the use of an oxidizing catalyst.

The primary pollutant from gas turbines is NO_x. Thermal NO_x is produced by the Zeldovich chain reaction:

$$O_2 + M \longleftrightarrow 2O + M \tag{1}$$
$$O + N_2 \longleftrightarrow NO + N \tag{2}$$
$$O_2 + N \longleftrightarrow NO + O \tag{3}$$
$$OH + N \longleftrightarrow NO + OH \tag{4}$$

where M is a third body molecule.[5]

The rate of the forward reaction in formation of NO is highly temperature dependent because of the large activation energy of the equation (2) mechanism. Thermodynamic equilibrium favors NO formation from N_2 oxidation only at high temperatures, although as the gases cool, NO becomes metastable with respect to decomposition into its constituents. Also, as the gases cool within the confines of the equipment, NO is slowly oxidized into NO_2. After emission from the stack, NO is rapidly oxidized to NO_2 under the influence of sunlight.[5]

Since "thermal NO_x" formation is both temperature and oxygen concentration dependent, combustion modification methods based on reducing flame temperature (flue gas recirculation, water injection, steam injection) and oxygen concentration (low excess air, premixed combustion, staged addition of the combustion air) have been found to be quite effective for controlling it.[5] Reducing combustion gas residence time and removing the heat in the combustion region rapidly also reduces NO_x formation.

Methods to control NO_x production in a gas turbine include water injection, steam injection and advanced combustor design. Water injection and steam injection methods serve to cool the peak temperatures in the combustion chamber. The fluid is injected directly into the chamber (see Figures 15-21). When designed properly, the injection of fluid can enhance the performance of the turbine by providing additional mass to the working fluid with a minimal loss in momentum, hence, increasing the force and torque on the turbine (see Figure 15-22). Water injection at rates up to one pound of water per pound of fuel have been shown to substantially reduce NO_x. However, the use of relatively expensive purified water is required to prevent deposit buildup on the turbine blades.[6] Another consideration in the use of water or steam injection is the effect on completeness of combustion. Too much water or steam injection will reduce combustion temperatures, producing higher levels of CO and HC emissions. Partial engine loading accompanied by a reduction in combustion temperature will increase these emissions even further.

Steam injection is also effective for NO_x control and could be readily obtained from the boiler steam circuits. However, this represents a continual loss of high quality boiler makeup water similar to straight water injection.[6]

Considerable research and development has been undertaken to design an advanced low-NO_x burner. Appendix 15B lists 26 candidate design concepts evaluated by an EPA project.[7]

Control of NO_x in the exhaust gas is performed via Selective Catalytic Reduction (SCR). The SCR process converts NO_x into nitrogen and water by the use of ammonia (NH_3) as a reducing agent. SCR is selective in controlling only NO and can be deactivated (poisoned) if the reaction is not complete. The catalyst material used is either a transition metal oxide catalyst such as vanadium oxide or titanium oxide, a base metal oxide catalyst such as cobaltous oxide or chromic oxide, or a
cejp31
ramic (zeolite) catalyst.

The main reaction equation is as shown below:

$$4\,NO + 4\,NH_3 + O_2 \xrightarrow[\text{catalyst}]{} 4\,N_2 + 6\,H_2O$$

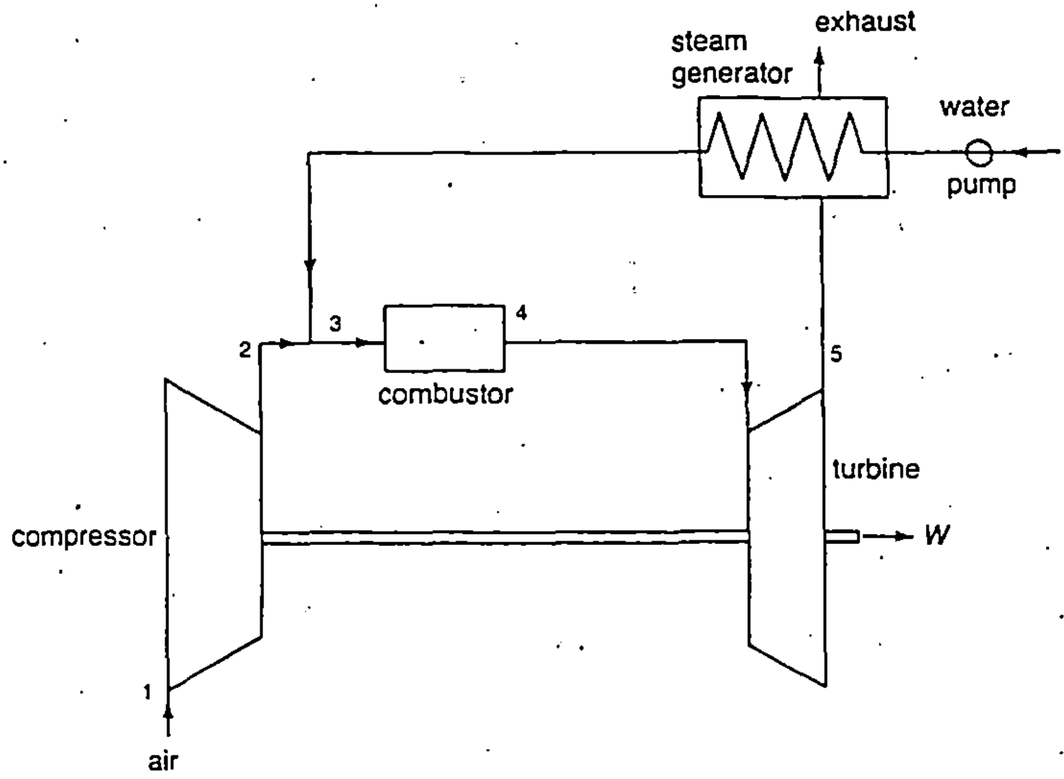
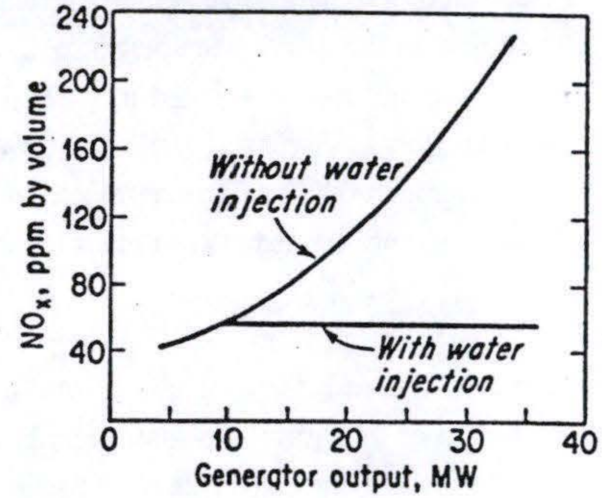
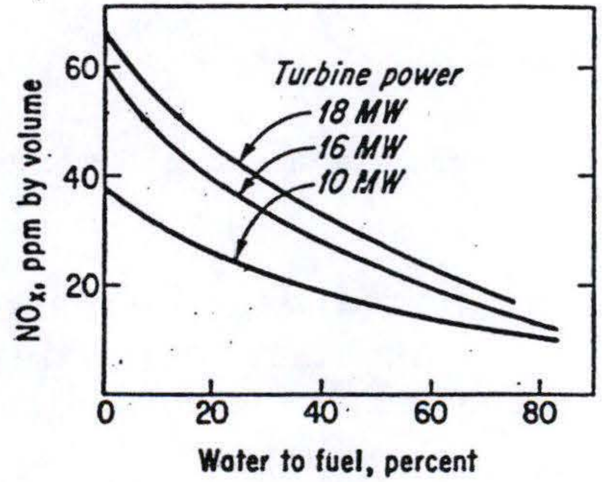


FIGURE 15-21 STEAM INJECTION CYCLE IN A GAS TURBINE



(a) Water injection in peaking turbine burning No. 2 distillate



(b) Turbine using natural gas and water-injection

FIGURE 15-22 WATER INJECTION EFFECTS ON:

(a) Peaking turbine using No. 2 Fuel Oil
(b) Turbine using Natural Gas (water-injection effect decreases as water:fuel ratio approaches 1:1).

The reaction is carried out in a temperature "window" (range) of about 300 - 500 ^{o}C (572 - 930 ^{o}F). Depending on the exhaust temperature, the use of some type of heat exchanger or cooling technique may be needed to meet the operating temperature of the catalyst. A regenerator, as discussed earlier, or a waste heat boiler can serve the purpose of a heat exchanger. Water (demineralized to reduce corrosion effects) or steam can also be used to cool the exhaust to meet the operating condition of the SCR.[5]

A further development in the reduction of NO_X from gas turbines is the use of "clean fuels". Clean fuels such as natural gas and methanol contribute to the reduction of NO_X formation because 1) they are free from fuel bound nitrogen, also sulfur and ash, and 2) they have a lower flame temperature, hence, a lower potential for producing thermal NO_X. These clean fuels are also used in conjunction with water or steam injection and have been shown to reduce NO_X emission levels significantly relative to units firing fuel oil with water or steam injection.

15.2 Permit Unit Description

The proper wording description for an electric utility stationary gas turbine operation is:

> GAS TURBINE, UNIT NO., MANUFACTURER, TYPE, MODEL NO., SERIAL NO., BTU/HR, FUEL(S) TYPE, COMBUSTION MODIFICATION (if any), DRIVING A . KW/MW ELECTRIC GENERATOR.

15.3 Emissions

Emissions from a gas turbine may include hydrocarbons, carbon monoxide, oxides of nitrogen, smoke and particulates, oxides of sulfur, and aldehydes. The emissions from a gas turbine depend on many factors including the type of fuel used, the type of combustion process or the combustion characteristics, and the load. Fuel types vary in the amount of fuel bound nitrogen or sulfur they contain and also in the heating value and peak flame temperature (thermal NO_X is the primary constituent of NO_x formation from a combustion process). The type of combustion process determines the method by which the air-fuel mixture is introduced into the combustion chamber and ignited. In combination with the fuel nozzle, the combustor can design contributes greatly in the control of combustion emissions.

15.3.1 Discussion

Hydrocarbons and carbon monoxide are products of incomplete combustion, typical of lower loads and idle conditions. They are still present during high loads and high combustion temperatures, but to a lesser degree. Idling efficiencies can be improved by designing better atomization systems and providing higher local temperatures.

Oxides of nitrogen (NO_x) are generated in the high temperatures of combustion and are generally reduced by combustion modifications or treating of the exhaust gas.

At low loads NO_x and engine efficiency are lower, and hydrocarbons and carbon monoxide are higher; at high loads, the reverse is true. NO_x and CO emissions vary with ambient temperature. NO_x emissions increase with increasing ambient temperature while CO emissions decrease with increasing ambient temperature. High ambient temperatures tend to reduce peak load and efficiency; vice-versa at low loads. High altitudes and the resulting reduction in air pressure have a similar effect as high ambient temperatures.

Qualitatively, those fuels with a higher flame temperature will generate more NO_x.

15.3.2 Emission Factors

Emission factors are not readily available for gas turbines. Emissions from a gas turbine are based on manufacturers specifications, performance data, and ultimately on a certified source test.

15.4 Calculations

15.4.1 Operational Data

The following operational information must be obtained from the applicant in order to process the permits necessary for construction and operation of an electric utility gas turbine:

- Performance curves at site conditions (altitude, external pressure drops);
- Engineering specifications;
- Emission source test data and test conditions with and without emission control modifications, including start-up, low load, and high load;
- Process description, including maximum input fuel flow rate, exhaust temperature, and injection flow rate of water, steam, or any other fluid which would affect the combustion conditions;
- Piping and Instrumentation (P & I) flow diagram of the system; and
- Equipment drawings.

Please refer to the gas turbine information request sheet and the SCR information request sheet in Appendix 15C.

15.4.2 Emissions Calculations

Since emission factors are not tabulated for gas turbines, emissions must be evaluated from the manufacturer's performance sheets. Manufacturer's performance data on different fuel types should also be requested.

15.5 Rules Evaluation

Rule 212 - Standards For Approving Permits
Section (e) of this Rule requires public notification of certain cases be made prior to issuing a permit.

Rule 401 - Visible Emissions

A visible emission of 20% opacity or greater (or Ringlemann No. 1 or greater) aggregating for more than three minutes in any one hour period is not allowed.

Rule 402 - Nuisance

Emissions which cause or contribute to a nuisance are prohibited. Factors worthy of consideration include location (commercial/residential area), solvent usage, odorous materials, and prior complaints.

Rule 407 - Liquid and Gaseous Air Contaminants

The equipment must comply with:

(a) (1) the carbon monoxide (CO) discharge limit, 2,000 ppmv, measured on a dry basis, averaged over 15 consecutive minutes.

(2) the sulfur compound based discharge limit, 500 ppmv, calculated as sulfur dioxide (SO_2), averaged over 15 consecutive minutes. The equipment may be exempt from this subsection if it is in compliance with Rule 433.1 or is subject to the emission limits and requirements of Regulation XI (Source Specific Rules).

(b) the equipment may be exempt from the provisions of this rule if it is used as the means of propulsion of mobile equipment, or during periods of emergency venting due to equipment failure or process upset.

Rule 429 - Start-Up and Shut-Down Exemption Provisions for Oxides of Nitrogen

This rule shall provide an exemption from the oxides of nitrogen emission limits of Rule 1134 during periods of start-up and shut-down. Start-up or shut-down intervals may not last longer than is necessary to reach stable operating temperatures. In no case may the start-up or shut-down interval last more than fifteen minutes for simple cycle stationary gas turbines and two hours for stationary combined cycle and cogeneration cycle gas turbines per Rule 1134. Prior notification of scheduled start-ups and shut-downs under the requirements of Rule 203 shall be made in a timely manner, and form. The notification shall contain the following information:

(1) Dates and times of the scheduled start-up or shut-down and its duration.

(2) Records shall be maintained and kept on site and made available for two years indicating: the hour-by-hour schedule of firing rates; flue gas tempera-

tures; NO_x emissions; and such process variables such as feed rates, outlet temperatures and heat absorption rates, or any other process variables that are appropriate.

Rule 431.1 - Sulfur Content of Gaseous Fuels

This rule limits the content of sulfur compounds in any gaseous fuel (including any natural, process, synthetic, landfill, sewage digester, or waste gases with a gross heating value of 300 Btu per cubic foot or higher) sold or used in the South Coast Air Basin. The limit for combustion of gaseous fuels is 800 ppm based on a parts per million (ppm) content of sulfur calculated as hydrogen sulfide.

Rule 431.2 - Sulfur Content of Liquid Fuels

This rule limits the content of sulfur compounds in liquid fuels sold or used in the South Coast Air Basin. The limit is 0.05 percent by weight of sulfur in the liquid fuel.

Rule 475 - Electric Power Generating Equipment

This rule limits the discharge of combustion contaminants for electric generating equipment at 11 pounds per hour and 0.01 grains per standard cubic foot calculated at three percent oxygen on a dry basis over fifteen consecutive minutes. The rule applies to new equipment, having a maximum rating of more than 10 net megawatts, and to existing gas turbines (installed and operating after January 1, 1970), having a maximum rating of more than 5.0 net megawatts.

Regulation IX - New Source Performance Standards - Code of Federal Regulations (40 CFR)

Subpart GG: Standards of Performance for Stationary Gas Turbines.

(1) Emission Standard For NO_x (40 CFR 60.332)

Electric utility gas turbines with a heat input at peak load greater than 100 MM Btu/hr based on the lower heating value of the fuel shall comply with the following:

$$\mathrm{STD} = 0.0075 \times \frac{(14.4)}{Y} + F \qquad \textbf{(Equation 15.1)}$$

For stationary gas turbines with a heat input at peak load $\geq$ 10 MM Btu/hr and $\leq$ 100 MM Btu/hr based on the lower heating value of the fuel fired, OR

For stationary gas turbines with a manufacturer's rated base load at ISO conditions (see Definitions) of 30 MW or less, except as provided in any of the above, shall comply with the following:

$$\mathrm{STD} = 0.0150 \times \frac{(14.4)}{Y} + F \qquad \textbf{(Equation 15.2)}$$

where:

STD = allowable NO_x emissions (percent by volume at 15% O_2 and on a dry basis).

Y = Manufacturer's rated heat rate at manufacturer's rated load (Btu/hr) or, actual measured heat rate based on a lower heating value of fuel as measured at actual peak load for the facility. The value of Y shall not exceed 14.4 kJ/ Watt-hr (13.65 Btu/Watt-hr).

F = NO_x emission allowance for fuel-bound nitrogen as defined in Table 15-1.

TABLE 15-1 Fuel Bound Nitrogen Determination

Fuel-bound nitrogen (percent by weight)	F (NO_x percent by volume)
$N \leq 0.015$	0
$0.015 < N \leq 0.1$	0.04 (N)
$0.1 < N \leq 0.25$	0.004 + 0.0067 (N-0.1)
$N > 0.25$	0.005

where:

N = the nitrogen content of the fuel (percent by weight).

See Code of Federal Regulations, Subpart GG, (40 CFR 60.332 - Standard for nitrogen oxides) for exemptions to these conditions, e.g. emergency applications, research and development, construction dates.

(2) Emission Standard For SO_x (40 CFR 60.333)

This rule allows for a maximum of 150 ppmv of SO_2 discharge at 15% oxygen on a dry basis. This rule prohibits the combustion of any fuel which has a sulfur content in excess of 0.8 percent by weight. This rule is less stringent than Rule 431.2 and BACT.

(3) Calculation of Particulate, Sulfur Dioxide, and Nitrogen Oxides Emission Rates by Appendix A, Method 19, Part 5 of the CFR 40.

The tables and equations in this section of the CFR permit the calculation of these emissions. To calculate the pollutant concentration on an oxygen based, dry basis use the equation in part 5.3.1.1 -

$$E = C_d F_d \frac{20.9}{20.9 - \%O_{2d}} \qquad \textbf{(Equation 15.3)}$$

where:

E = Pollutant emission rate (lb/MM Btu)
C_d = Pollutant concentration (lb/scf)
F_d = F factor, dry conditions (dscf/MM Btu)
O_{2d} = Percent oxygen measured on a dry basis

Converting this equation for the concentration term gives -

$$C_d = \frac{F_d}{E} \quad \frac{20.9}{20.9 - \%O_{2d}} \qquad \textbf{(Equation 15.4)}$$

Therefore, C_d can be determined from the F_d factor known from Table 19-1 in the CFR 40, (e.g. for natural, propane, or butane gas, $F_d = 8{,}710$ dscf/MM Btu), the pollution emission rate E, and the measured $\%O_{2d}$. This value for C_d can then be converted using the Concentration Conversion Factors listed below.

CONVERSION FACTORS for CONCENTRATION

From	To	Multiply by -
g/scm	ng/scm	10^9
mg/scm	ng/scm	10^6
lb/scf	ng/scm	1.602×10^{13}
ppm SO_2	ng/scm	2.660×10^6
ppm NO_x	ng/scm	1.912×10^6
ppm SO_2	lb/scf	1.660×10^{-7}
pm NO_x	lb/scf	1.194×10^{-7}

Refer to Appendix A, Method 19, Part 5 for other calculations.

(4) Monitoring of Operations (40 CFR 60.334)

(a) Water injection operations to control NO_x require a continuous monitoring system to record the fuel consumption and the ratio of water to fuel being fired in the turbine. This monitoring system shall be accurate to within ± 5.0 % and approved by the Administrator of the EPA.

(b) Sulfur and nitrogen content of the fuel being fired shall be monitored on a daily basis for fuel stored without intermediate bulk storage or for facilities incorporating bulk storage of fuel on each occasion that fuel is transferred to the storage tank from any other source.

(5) Test Methods and Procedures (40 CFR 60.335)

The standards prescribed shall be ascertained for compliance by using an approved custom method of testing or Reference Method 20 in Appendix A of 40 CFR.

(6) Other Requirements

The applicant will comply with 40 CFR 60, sections 60.4, 60.7, and 60.8 by sending all reports, requests, and other communications to the proper administrators; furnish notification and record keepings, and supply notification of performance tests and methods and test procedures.

Rule 1134 - Emissions of Oxides of Nitrogen from Stationary Gas Turbines
Existing stationary gas turbines 0.3 MW or larger, except existing peaking units used less than 200 hours per calendar year, must comply with the NO_X limits as calculated in 1134(c), and meet the compliance schedule of 1134(d). This rule does not apply to gas turbines used in research and testing, firefighting and/or flood control, chemical processing, or emergency standby operations (used less than 200 hours per calendar year).

Regulation XIII - New Source Review

(1) If the new or modified equipment causes a net emission increase (in excess of one pound per day) of any non-attainment air contaminant, Best Available Control Technology (BACT) is required.

The South Coast Air Quality Management District's Best Available Control Technology Guidelines[11] list BACT for different processes. It is constantly being updated to reflect advances in technology. It should also be consulted to properly determine both applicability and BACT which may be different from case to case.

Table 15-2 and 15-3 list the most current BACT for gas turbines with different heat input rate

(2) If the accumulated maximum emission of any air contaminant from any stationary source exceeds the threshold limits specified in Rule 1303(a)(2), in addition to BACT, the applicant must comply with the following:

(a) The applicant certifies in writing that all of the facilities emitting 25 tons per year or more, which are owned or operated by the applicant, are in compliance with the limitations of the Clean Air Act and the State Implementation Plan or with the limitations of the District, whichever are more stringent.

(b) The applicant must use modeling or other analysis approved by the Executive Officer to demonstrate that the new source or modifications to an existing source will not cause any violation, or make measurably worse an existing violation, of any ambient air quality standard at any receptor location in the District. Modeling shall not be required for any air contaminant if all offset sources which are within the distance of five (5) miles could actually lower the emission of that air contaminant(s) down to the threshold limit.

(c) The applicant must offset the total accumulated increase in emissions from the stationary source.

Note: Under this Regulation, emissions from equipment which are exempt from permit requirement are to be accumulated in the New Source Review Database. These emissions are included to determine compliance with the threshold limits.

15.6 Permit Conditions

1. THIS TURBINE MUST BE FIRED WITH NATURAL GAS OR METHANOL, EXCEPT DURING PERIODS OF NATURAL GAS CURTAILMENT OR FOR TESTING NOT TO EXCEED ONE HALF HOUR PER MONTH.

2. TURBINES USING FUEL OIL MUST USE NO. 2 OR LIGHTER GRADE FUEL OIL AS DESCRIBED BY THE LATEST ASTM SPECIFICATIONS AND MUST HAVE A SULFUR CONTENT OF NO MORE THAN 0.05% BY WEIGHT.

3. THIS TURBINE MAY OPERATE NO MORE THAN __________ HOURS IN ANY ONE DAY.

4. THE EQUIPMENT MUST BE PROPERLY MAINTAINED AND KEPT IN GOOD OPERATING CONDITION AT ALL TIMES.

5. THE WATER (STEAM) INJECTION RATE MUST BE FROM ____ TO POUNDS OF WATER TO POUNDS OF FUEL WHEN OPERATING ON NATURAL GAS AND FROM ___ TO___ POUNDS OF WATER TO POUNDS OF FUEL WHEN OPERATING ON ____________________ .

6. FOR EACH TURBINE, A WRITTEN LOG OF OPERATING TIME (INCLUDING PERIODS OF START-UP AND SHUT-DOWN), TYPE AND QUANTITY OF FUEL USED, WATER- OR STEAM- TO- FUEL RATIOS, AMMONIA USAGE, GAS TURBINE AND STACK OUTLET EMISSIONS (CORRECTED TO 15% O_2, ON A DRY BASIS AND LB/DAY), AND CATALYST EFFICIENCY MUST BE MAINTAINED. RECORDS MUST BE KEPT A MINIMUM OF TWO YEARS AND

MADE AVAILABLE TO THE EXECUTIVE OFFICER UPON REQUEST.

7. THE APPLICANT SHALL BE RESPONSIBLE FOR CONDUCTING, AND WILL CONDUCT, PERFORMANCE TESTS FOR CARBON MONOXIDE, REACTIVE ORGANIC GASES, AND OXIDES OF NITROGEN EMISSIONS AT THE EXHAUST STACK OF THE TURBINE WITH THE USE OF ANY AND ALL FUELS.

8. THIS EQUIPMENT MUST BE OPERATED BY PERSONNEL PROPERLY TRAINED IN ITS OPERATION.

9. THIS EQUIPMENT MUST COMPLY WITH THE CODE OF FEDERAL REGULATIONS, TITLE 40, CHAPTER 1, PART 60, SUBPARTS A AND GG, STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES. IN PARTICULAR, ALL NOTIFICATION RECORD KEEPING, PERFORMANCE TESTING AND MONITORING REQUIREMENTS OF SECTIONS 60.4, 60.7, 60.8, 60.334, AND 60.335 MUST BE MET, UNLESS THEY ARE IN CONFLICT WITH ANOTHER CONDITION ON THIS PERMIT.

10. THE TURBINE MAY ONLY OPERATE AT MAXIMUM CONTINUOUS LOAD, EXCEPT DURING PERIODS OF START-UP AND SHUT-DOWN, OR WHEN PERFORMANCE TESTS ARE BEING CONDUCTED.

11. THIS EQUIPMENT SHALL NOT BE OPERATED UNLESS IT IS VENTED TO AIR POLLUTION CONTROL EQUIPMENT WHICH IS IN FULL USE AND WHICH HAS BEEN ISSUED A PERMIT TO CONSTRUCT BY THE EXECUTIVE OFFICER, EXCEPT DURING START-UPS AND SHUT-DOWNS.

12. EMISSION OF OXIDES OF NITROGEN, MEASURED AS NO_2, SHALL NOT EXCEED ___ PPMV (AS VOLUME PERCENT AT 15% O_2, DRY), EXCEPT DURING START-UPS AND SHUT-DOWNS.

13. EMISSION OF CARBON MONOXIDE SHALL NOT EXCEED ______ PPMV (AS VOLUME PERCENT AT 15% O_2, DRY), EXCEPT DURING START-UPS AND SHUT-DOWNS.

14. EMISSION OF AMMONIA SHALL NOT EXCEED ______ PPMV (AS VOLUME PERCENT AT 15% O_2, DRY).

15. ALL CONCENTRATIONS OF GASEOUS EMISSIONS MUST BE EXPRESSED IN PARTS PER MILLION BY VOLUME CORRECTED TO 15% O_2, ON A DRY BASIS, AND MUST BE MEASURED OVER FIFTEEN MINUTES RUNNING AVERAGE TIME PERIOD.

16. A CONTINUOUS MONITORING SYSTEM MUST BE INSTALLED AND OPERATED TO MONITOR AND RECORD THE FUEL CONSUMPTION AND THE MASS RATIO OF WATER-TO- OR

STEAM-TO- FUEL BEING FIRED IN THE TURBINE. THIS SYSTEM MUST BE ACCURATE TO WITHIN + OR - 5 PERCENT.

17. A CONTINUOUS EMISSION MONITORING SYSTEM MUST BE INSTALLED AND OPERATED TO MEASURE THE GAS TURBINE EXHAUST FOR NO_x, O_2, AND CO CONCENTRATIONS ON A DRY BASIS. IN ADDITION, THE SYSTEM WILL CONVERT THE ACTUAL NO_x AND CO CONCENTRATION TO A CORRECTED CONCENTRATION AT 15% O_2 ON A DRY BASIS AND CONTINUOUSLY RECORD THE GAS TURBINE AND STACK NO_x CONCENTRATION, GAS TURBINE AND STACK O_2 CONCENTRATION, AND CORRECTED GAS TURBINE AND STACK NO_x CONCENTRATION AT 15% O_2. PRIOR TO INSTALLATION THIS MONITORING SYSTEM MUST BE APPROVED BY THE EXECUTIVE OFFICER.

18. WITHIN 60 DAYS AFTER ACHIEVING THE MAXIMUM RATE, BUT NOT LATER THAN 180 DAYS AFTER INITIAL START-UP, THE APPLICANT SHALL CONDUCT PERFORMANCE TESTS IN ACCORDANCE WITH SCAQMD TEST PROCEDURES AND FURNISH THE SCAQMD WITH A WRITTEN RESULT OF SUCH PERFORMANCE TESTS WITHIN 45 DAYS AFTER COMPLETION OF THE TEST. WRITTEN NOTICE OF THE PERFORMANCE TEST SHALL BE PROVIDED TO THE SCAQMD 10 DAYS PRIOR TO THE TESTS SO THAT AN SCAQMD OBSERVER MAY BE PRESENT. THE PERFORMANCE TESTS WILL INCLUDE, BUT NOT BE LIMITED TO, A TEST OF THE EXHAUST STREAM DIRECTLY AFTER THE TURBINE (AND AFTER THE WASTE HEAT BOILER) FOR:

    A. OXIDES OF NITROGEN EMISSIONS (AS VOLUME PERCENT, AT 15% O_2 ON A DRY BASIS).
    B. HYDROCARBONS (METHANE AND NON-METHANE INCLUDING SATURATED AND UNSATURATED).
    C. CARBON MONOXIDE.
    D. PARTICULATES.
    E. FLOW RATE.
    F. NH_3.
    G. ALDEHYDES (SPECIATED FOR FORMALDEHYDES).

19. THE APPLICANT SHALL CONDUCT QUARTERLY TESTS TO DETERMINE STACK OUTLET NH_3 EMISSIONS. TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH SCAQMD TEST PROCEDURES AND THE DISTRICT SHALL BE NOTIFIED IN WRITING SEVEN DAYS PRIOR TO THE TEST SO THAT A SCAQMD OBSERVER MAY BE PRESENT. RESULTS OF SUCH TESTS SHALL BE SUBMITTED TO THE DISTRICT WITHIN THIRTY DAYS AFTER TESTING.

20. THE COLD START-UP PERIOD MUST NOT EXCEED 2 HOURS IN ANY ONE DAY COMMENCING AT MIDNIGHT.

21. THE AMMONIA INJECTION SYSTEM MUST BE UTILIZED WHENEVER THE INLET FLUE GAS TEMPERATURE TO THE SCR CATALYST EXCEEDS ___ DEGREES FAHRENHEIT.

22. ON ANY ONE DAY THAT THERE IS A COLD START-UP, THE GAS TURBINE SHALL NOT OPERATE FOR MORE THAN ____ HOURS, INCLUDING THE START-UP PERIOD, AND THE GAS TURBINE EMISSIONS SHALL NOT EXCEED ___ POUNDS PER DAY OF NO_x (AS NO_2).

23. STEAM INJECTION FOR NO_x CONTROL MUST BE OPERATIONAL AT OR ABOVE ___ MW LOAD.

24. DURING THE COLD START-UP, NO_x EMISSION CONCENTRATION FROM THE STACK MUST NOT EXCEED ____ PPMV, CORRECTED TO 15% O_2, DRY, AVERAGED OVER FIFTEEN MINUTES.

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5. "Combustors: Applications and Design Considerations", W. Bartok, R.K. Lyon, A.D. McIntyre, L.A. Ruth, and R.E. Sommerlad, Chemical Engineering Progress, March 1988, Vol. 84, No.3

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8. Wilson, David Gordon, The Design of High-Efficiency Turbomachinery and Gas Turbines, The Massachusetts Institute of Technology, 1984.

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10. Perry's Chemical Engineering Handbook, 6th edition, pp 24-29 to 24-32, McGraw-Hill, 1984.

11. South Coast Air Quality Management District (SCAQMD) Best Available Control Technology (BACT) Guidelines, October 7, 1988.

APPENDIX 15A

PERMIT PROCESSING WORKSHEET FOR ELECTRIC UTILITY GAS TURBINES

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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PERMIT TO CONSTRUCT/OPERATE

APPLICANT'S NAME:

MAILING ADDRESS:

EQUIPMENT LOCATION:

EQUIPMENT DESCRIPTION

APPLICATION NO. : ____________________

GAS TURBINE, UNIT NO. , (MANUFACTURER), ELECTRIC GENERATING TYPE, MODEL , SERIAL NO. , BTU PER HOUR NATURAL GAS / METHANOL / LIQUIFIED PETROLEUM GAS (LPG) / FUEL OIL / LANDFILL GAS - FIRED, WITH A WATER/STEAM INJECTION SYSTEM, AND DRIVING A KW / MW ELECTRIC GENERATOR.

HISTORY

The application for this equipment was received by the District on ________________________ . The equipment is new / existing and is applying for a permit to construct / operate.

PROCESS DESCRIPTION

Peaking Unit with Water or Steam Injection:

The gas turbine unit is producing approximately ________lb/hr of NO_x operating on __________ gas/fuel. The engine is operated only during peak load periods - in summer from ______ am/pm to ______ am/pm, and in winter from ______ am/pm to ______ am/pm. This unit is (is not) part of a series of peak load gas turbines. In all there are (is) ______ gas turbine(s) used for peak loading service (each) generating approximately ______ kW/MW of electric power. The gas turbine will be (is) install(ed) (with) the Best Available Control Technology (BACT) and will (is) operate (operating) with an exhaust temperature of _____________ °F. NO_x emissions will be controlled through water (steam) injection with a water (steam) / gas (fuel) ratio of ________ lbs. of water (steam) to ________ lbs. of gas (fuel). In the event of primary fuel curtailment the water (steam) / gas (fuel) ratio for the stand-by fuel will be ________ lbs. water (steam) to _________ lbs. gas (fuel). [NO_x emissions will be controlled by use of a Selective Catalytic Reduction system using ammonia injection in the exhaust. The ammonia / gas (fuel) ratio will be ______ lbs. NH_3 to ______lbs. gas (fuel). In the event of primary fuel curtailment the ammonia / gas (fuel) ratio will be ______ lbs. NH_3 to _______ lbs. gas (fuel).]

The gas turbine is a ______________ make, model ______________ gas turbine containing a gas generator, a ______________ type combustor, forward (reverse) drive power turbine. The axial (centrifugal) compressor consists of _______ stages and produces an overall compression ratio of _____: 1 at ISO conditions of standard maximum continuous power. The compressor is coupled to a one / two /_____ stage drive turbine which is air (water) cooled.

The diffuser-combustor is fed by __________ fuel injectors and ignition provided by ___________ igniters. Output power is generated by an axial (radial) type __________-stage power turbine. Rotation is clockwise (counterclockwise) when viewed from the rear or hot end of the engine.

The engine specified is a dual (single) fuel type capable of operating on natural gas / methanol / diesel / LPG / landfill gas fuel(s). The primary fuel is natural gas / methanol / diesel / LPG / landfill gas with natural gas/methanol/diesel/LPG/landfill gas used as a stand-by fuel. The start-up motor is driven by compressed air / electricity / hydraulic power. The power turbine shaft speed is maintained at _________ RPM by a(n) electronic (mechanical), (____________) governor system; the gas generator speed will vary up to ________ RPM depending on the load. Engine exhaust is directed through a silencer and appropriate ducting to an exhaust stack.

At full power the exhaust flow, on average, is _______ lbs./second with a range of _____________ lbs./second to ______ lbs./second. The exhaust temperature at full power is, on average, _________ ^oF with a range of ________ ^oF to ________ ^oF depending on ambient conditions. A humidifier is (will be) installed to maintain the incoming ambient air temperature to ________ ^oF.

DATA

Operating Schedule:				Source
Avg :	_______ hr/day (T_a),	________ day/wk,	________ wk/yr	Applicant
Max :	_______ hr/day (T_m),	________ day/wk,	________ wk/yr	"

Engine Rating:	________________	Btu/hr		Manufacturer
Engine Brake Horsepower:	________________	bhp @ ________	RPM	"
Exhaust Flow Rate:	________________	dscfm/scfm/cfm		"
Exhaust Tempt. :		$^oF/^oC$		"

	Fuel Consumption Rate			Source
Fuel Type	Avg	Max	Units	
A. Natural Gas			1,000 ft^3/hr	
B. Methanol			gal/hr	
C. LPG (Propane)			gal/hr	
D. No. 2 Fuel Oil			gal/hr	
E. Landfill Gas			1,000 ft^3/hr	

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

ENGINEERING DIVISION

APPLICATION PROCESSING AND CALCULATIONS

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CALCULATIONS

1. Emissions

AEIS R1 emissions = ER(avg)
AEIS R2 emissions = ER(avg) x (1 - ECF)
NSR (Actual) emissions = ER(avg) x (1 - ECF) x OH(avg)
NSR (Max) emissions = ER(max) x (1 - ECF) x OH(max) x 1.1

where:

ER	=	Emission rate	(lb/hr)
ECF	=	Emission control factor	(fraction)
OH	=	Daily operating hours	(hr/day)

Fuel Type	AEIS R1 Emission Rate (lb/hr)[1]				
	RHC	NOx	SOx	CO	PM
A					
B					
C					
D					
E					

Fuel Type	AEIS R2 Emission Rate (lb/hr)[1]				
	RHC	NOx	SOx	CO	PM
A					
B					
C					
D					
E					

Fuel Type	NSR (Actual) Emission Rate (lb/day)				
	RHC	NOx	SOx	CO	PM
A					
B					
C					
D					
E					

Fuel Type	NSR (Max.) Emission Rate x 1.1 (lb/day)				
	RHC	NOx	SOx	CO	PM
A					
B					
C					
D					
E					

Ref 1. - Emission rates obtained from turbine manufacturer.

2. Exhaust Gas Total Particulate Concentration (PC) - RULE 404

$$PC = \frac{(R_2)(7{,}000 \text{ grains/lb})}{(F_1)(60 \text{ min/hr})}$$

where:

PC = particulate concentration, grains/dscf.
R_2 = particulate mass emission rate (maximum), lb/hr.
F_1 = dry standard cubic feet per minute, dscfm.

3. Regulation IX : New Source Performance Standards

Subpart GG:

A. Emission Standard for NO_x:

$$STD = C \times \frac{(14.4)}{Y} + F$$

where,

STD = allowable NOx emissions (percent volume @ 15% oxygen and on a dry basis).

C = constant based on the heat input at peak load (based on the lower heating value of the fuel) for the proposed gas turbine.
If the heat input will be > 100 million Btu/hr, C = 0.0075.
If the heat input will be < 100 million Btu/hr and > 10 million Btu/hr, C = 0.015.

Y = heat rate = $\underline{\qquad\qquad} \frac{\text{Btu/hr}}{\text{W}} \times 1.05506 \frac{\text{kJ}}{\text{Btu}} = \underline{\qquad\qquad}$ (kJ/W-hr)

F = NOx emission allowance for fuel-bound nitrogen as defined in paragraph (a)(3) of section 60.332 (40 CFR Ch.I (7-1-87 Edition)).

The exhaust gas must not contain NO_x in excess of:

$$STD = C \times \frac{14.4 \text{ kJ/W-hr}}{Y \text{ (kJ/W-hr)}} = \underline{\qquad\quad} \text{ ppmv @ } 15\% \ O_2 \text{ on a dry basis.}$$

B. Emission Standard for SO_x :

a. SO_x emissions = ___________ lb/hr, from form B-2, for gas turbines (0.6 lb/10^6 ft^3).

Exhaust Flow = ___________ lb/sec.

$$PPMV = \frac{(\qquad lb/hr) \times (\qquad cu.ft./lb)}{(\qquad lb/sec) \times (lb/0.454\ kg) \times (\qquad cu.ft./lb) \times (3600\ sec/hr)}$$

This rule allows 150 ppmv of SO_x emissions @ 15% O_2 on a dry basis.

b. The sulfur content in the fuel is less than the 0.8% by weight allowed by this rule.

RULE EVALUATION

RULE 401 : No visible emission violations are anticipated from this equipment. However, the turbine cannot be evaluated for visible emissions compliance until it is constructed and in full operation.

RULE 402 : No nuisance complaints are on file against this applicant, and none are anticipated due to the isolated location of the facility.

RULE 407 : a) The equipment complies with this rule, not emitting more than ______ ppm of CO emissions. The equipment estimated CO emission is ___ ppmv @___% O2.

: b) The equipment is exempt from this section, since the equipment is in compliance with rule 431.1.

RULE 429 : Start-ups and shut-downs are expected to comply with this rule and be performed in a timely manner (not to exceed fifteen minutes for simple cycle gas turbines; two hours for combined cycle or cogeneration cycle gas turbines) and form.

RULE 431.1 : Sulfur content in any gas phase fuel (natural gas, process gas, landfill, digester, etc.) does not exceed the limits allowed by this rule.

RULE 431.2 : Sulfur content in liquid phase fuel (fuel oil) does not exceed the limits allowed by this rule.

REG. IX : The NO_x emissions from the gas turbine will not exceed_____ ppmv @ 15% O_2.

RULE 1134 : This equipment is not expected to exceed the allowable limit of oxides of nitrogen under load conditions as specified in the Control Plan submitted.

REG. XIII : The turbine and facility do not exceed the emission threshold limits stated in this regulation, and BACT requirements are used where required in accordance with the BACT ANALYSIS in this report and with the latest revision of the BACT Guideline.

RECOMMENDATION

Issue Permit(s) to Construct to this (these) subject to following conditions:

CONDITIONS

1. THIS TURBINE MAY FIRE METHANOL OR ANY OTHER CLEAN FUEL IN THE EVENT THAT NATURAL GAS IS NOT AVAILABLE OR FOR TESTING OF THE TURBINE FOR INSTALLATION.
2. TURBINES USING FUEL OIL MUST USE NO. 2 OR LIGHTER GRADE FUEL OIL AS DESCRIBED BY THE LATEST ASTM SPECIFICATIONS AND MUST HAVE A SULFUR CONTENT OF NO MORE THAN 0.05% BY WEIGHT.
3. THIS TURBINE WHEN OPERATED ON NATURAL GAS, MAY OPERATE NO MORE THAN__ HOURS IN ANY ONE DAY.
4. THE WATER/STEAM INJECTION MUST BE FULLY OPERATIONAL WHENEVER THE TURBINE IS IN OPERATION.
5. THE WATER INJECTION RATE MUST BE A MINIMUM OF 0.8 : 1.0 LBW:LBF WHEN OPERATING ON NATURAL GAS AND 0.9 : 1.0 LBW:LBF WHEN OPERATING ON FUEL OIL NO. 2.
6. ON ANY DAY THAT FUEL OIL IS BURNED, ONLY ONE TURBINE MAY BE USED AT ANY ONE TIME AND THE TOTAL OPERATING HOURS MAY NOT EXCEED __ HOURS.

(continued)

7. FOR EACH TURBINE, A WRITTEN LOG OF OPERATING TIME, AND TYPE AND QUANTITY OF FUEL USED MUST BE MAINTAINED. RECORDS MUST BE KEPT A MINIMUM OF TWO YEARS AND MADE AVAILABLE TO THE EXECUTIVE OFFICER UPON REQUEST.

8. THE APPLICANT OPERATING THE TURBINE SHALL CONDUCT PERFORMANCE TESTS FOR CARBON MONOXIDE, REACTIVE ORGANIC GASES, AND OXIDES OF NITROGEN EMISSIONS AT THE EXHAUST STACK OF THE TURBINE WITH THE USE OF ANY AND ALL FUELS.

9. THIS EQUIPMENT MUST BE OPERATED BY PERSONNEL PROPERLY TRAINED IN ITS OPERATION.

10. THIS EQUIPMENT MUST BE PROPERLY MAINTAINED AND KEPT IN GOOD OPERATING CONDITION AT ALL TIMES.

11. THIS EQUIPMENT MUST COMPLY WITH THE CODE OF FEDERAL REGULATIONS, TITLE 40, CHAPTER 1, PART 60, SUBPARTS A AND GG, STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES. IN PARTICULAR, ALL NOTIFICATION RECORD KEEPING, PERFORMANCE TESTING AND MONITORING REQUIREMENTS OF SECTIONS 60.4, 60.7, 60.8, 60.334, AND 60.335 MUST BE MET, UNLESS THEY ARE IN CONFLICT WITH ANOTHER CONDITION ON THIS PERMIT.

12. THE TURBINES MAY ONLY OPERATE AT MAXIMUM CONTINUOUS LOAD, EXCEPT DURING PERIODS OF START-UP AND SHUT-DOWN, OR WHEN PERFORMANCE TESTS ARE BEING CONDUCTED.

<u>OR</u>

( ) Deny the Permit to Construct/Operate.

It is my opinion that the operation of this equipment will be in violation of Rule(s):

____

____

____

____

____

of the Rules and Regulations of the South Coast Air Quality Management District.

APPENDIX 15B

GAS TURBINE COMBUSTOR CONCEPTS

List and Brief Description of Combustor Concepts[6]

Concept No.	Title and Description
1.	Low-Intensity Flame - Extended length flame jet, fuel rich, mixes slowly with surrounding air. Bound nitrogen NO_x reduced under fuel rich conditions within flame jet
2.	Premixing Catalytic Burner - Catalyst preceded by premixing/preburning module. In low power preburning mode, fuel is partially burned and mixed with air before entering catalyst, thereby ensuring uniform high temperature mixture for efficient operation of catalyst.
3.	Superlean With Heat Recirculation - Premix tube air preheated indirectly in liner convective cooling passages or by other means to improve fuel vaporization and widen flammability limits. Lean burning for low thermal NO_x.
4.	Superlean With Preburner - Premix tube air preheated directly by preburner to improve fuel vaporization and widen flammability limits. Lean burn for low thermal NO_x.
5.	Heat Removal - Coolant tubes inside the combustor reduce temperature of rich burning mixture before excess air is added for CO oxidation and final dilution.
6.	Quench Reheat - Main burning zone is rich, resulting in low flame temperature. This mixture is rapidly quenched to a very lean equivalence ratio, causing excessive formation of CO but very little NO_x. In a reheat zone, effluent from a pilot burner heats the mixture to an intermediate temperature for CO consumption.
7.	Staged Centertube Burner - An axially staged burner configuration with swirl mixing. Concentric centertubes of different lengths determine the axial fuel-air distribution. As an experimental device the configuration allows easy variation of burning and mixing zone lengths. Both rich and lean air schedules were considered.
8.	Exhaust Gas Recirculation - Gas abstracted near the end of the primary zone mixture.
9.	Hydrogen Enrichment - Hydrogen injected along with fuel results in lower lean flammability limit of primary zone.
10.	Surface Combustion - Flame stabilized in contact with surface of porous plate flameholder. Coolant tubes imbedded in plate remove heat from flame.

11. Distributed Flame - Perforated plate flameholder produces many small flames, each stabilized separately, eliminating large scale recirculation and reducing residence times.

12. Ceramic Liner - Wall quenching of flame diminished by the elimination of film cooling and a higher allowable wall temperature.

13. External Combustion - Combustor located outside the gas turbine engine. This concept essentially removes the geometrical and residence time considerations experienced with on-board combustors.

14. Boost-Air Dilution - Dilution air injected at higher pressure than other burner airflow to achieve higher mixing rate reduce lag time in reaching desired equivalence ratios. Compressor or other means of achieving pressure differential required.

15. Artificial Excitation - Vibrational excitation of burning gases in the combustor to increase reaction rates, allowing residence time to be reduced. Method of excitation may be acoustic, electronic, or other means.

16. Extended Injector - Perforated plate flameholder with tubular extension pieces. By varying the number and length of tubes, their routing, and discharge points, mixture and temperature profile can be controlled.

17. Pebble Bed - An external burning concept with a vertical discharge low velocity combustor. Ceramic (or other material) pebbles are fed in near the exit, fall through the flame, and remove heat. They are collected and recycled through a heat exchanger (where pebbles are cooled by inlet air) back into the combustor.

18. Coanda Flame - Flameholder using coanda wall attachment effect. High velocity fuel-air mixture discharges through ring nozzle onto surface of conical nosepiece and entrains flow from surrounding environment. Method of setting up low intensity flame.

19. Electric Assist Nozzles - Atomization of liquid fuel enhanced by an applied electric field, with dispersion of charged droplets which are further guided, vaporized and mixed with air under the influence of electric fields.

20. Virtual Staging - Burning zone expands in volume and elongates as combustor loading increased (from idle to maximum power). Flamefront grows into additional combustion airflow needed at maximum power, thereby providing automatic or virtual staging.

21. Engine Inlet Fuel Injection - Vaporization and premixing of liquid fuel to very lean equivalence ratio for reaction in a catalyst of flameless combustor. Achieved by introducing fuel into engine inlet.

22. Flameless Combustion - Large volume burner operating at very lean equivalence ratios. Consumes fuel by low-temperature long-residence-time flameless reactions.

23. Air Staging - Combustor airflow distribution controlled by variable geometry to maintain desired equivalence ratios in burning zones and elsewhere over the range of engine operating points.

24. Fuel Staging - Multiple fuel injection points provide variable fuel distribution and set up successive zones of desired equivalence ratios.

25. Vorbix - Acronym- Vortex burning and mixing. Swirling air jets cause high rate of mixing in main burning zone. Pilot burner used for rapid vaporization of main fuel and controlled autoignition of resultant mixture. Lean burning for low NO_X.

26. Fuel Air Premixing - Fuel injected into airstream prior to combustion zone to produce a uniform fuel-air mixture and reduce spread in localized equivalence ratios before burning begins.

APPENDIX 15C

GAS TURBINE INFORMATION REQUEST FORM

INFORMATION REQUIRED ON SCR UNITS

1. Catalyst manufacturer.
2. Catalyst and Heat Recovery Steam Generator (HRSG) drawings including catalyst dimensions (if applicable).
3. Ammonia grid details.
4. Ammonia injection rate.
5. Ammonia emission rate.
6. Pressure drop across SCR unit including injection grid.
7. Controls for ammonia injection.
8. TYPE OF CATALYST.
9. CATALYST VOLUME.
10. SPACE VELOCITY (gas flow rate / catalyst volume).
11. Area velocity.
12. Manufacturer's guarantee for efficiency and catalyst life.
13. NO_x concentration in and out of SCR unit.
14. SCR unit total cost.
15. Catalyst replacement cost.
16. Percent decrease in prime mover output.
17. Percent increase in HRSG output (if applicable).
18. SO_2 oxidation rate/SO_3 emissions.
19. Stack temperature after HRSG (if applicable).
20. HRSG and turbine modifications (if applicable).
21. Temperature at which ammonia injection will begin.

APPENDIX 15D

GAS TURBINE INFORMATION

DEFINITION OF TERMS

Definition of Terms

Base Load - the load level at which a gas turbine is normally operated.

Combined Cycle Gas Turbine - any stationary gas turbine which recovers heat from the gas turbine exhaust to heat water or generate steam.

Efficiency - the gas turbine manufacturer's rated heat rate at peak load in terms of heat input per unit of power output based on the lower heating value of the fuel.

Emergency Gas Turbine - any stationary gas turbine which operates as a mechanical or electrical power source only when the primary power source for a facility has been rendered inoperable by an emergency situation.

ISO Standard Day Conditions - The International Organization for Standardization has set conditions at: 288 ^{o}K (58.7 ^{o}F), 60 % relative humidity, and 101.3 kilopascals pressure (14,7 psi).

Peak Load - 100 percent of the manufacturer's design capacity of the gas turbine at ISO standard day conditions

Regenerative Cycle Gas Turbine - any stationary gas turbine which recovers heat from the gas turbine exhaust gases to preheat the inlet combustion air to the gas turbine.

Simple Cycle Gas Turbine - any stationary gas turbine which does not recover heat from the gas turbine exhaust gases to preheat the inlet combustion air to the gas turbine, or which does not recover heat from the gas turbine exhaust gases to heat water or generate heat.

Stationary Gas Turbine - any simple cycle gas turbine, regenerative cycle gas turbine or any gas turbine portion of a combined cycle steam/electric generating system that is not self propelled. It may, however, be mounted on a vehicle for portability.