Panel No. 5 Off-Road Control Strategies

Unless otherwise noted, the following recommendations and comments reflect the views of Panel members and other attendees at the 2007 Air Quality Management Plan (AQMP) Summit meeting.

Recommended Control Strategies

General

- Off-road heavy-duty diesel engines last for 30 or more years, and the California Air Resources Board (CARB) is working on developing regulations for these in-use engines.
- Need a more detailed understanding sector by sector to develop regulations.
- CARB has worked on many of the sources: diesel, goods movement, fleet rules, cargo handling equipment, and the forklift Air Toxic Control Measure (ATCM). This will help with AQMP efforts and the emissions inventory.
- Training – must have trained technicians in the field to support the new technology.
- The potential for a huge infrastructure problem has not been addressed.
- Need to work on infrastructure for selective catalytic reduction (SCR).
- Energy efficiency is a critical factor.
- Variety of alternatives – cooperation is key.
- Critically evaluate studies. Need to be honest to gain public trust.

Economic

- Incentive programs would be beneficial for on-road and off-road CARB ATCMs.
- After CARB's ATCMs are passed, less Moyer money can be used because more emission reductions will be categorized as non-surplus. Consider allowing the application of Moyer money to hardship cases.
- Financial assistance for technology development is needed.
- Put more money into demonstration projects.
- Program in place so that it is economically viable to participate in the program.
- Emission / congestion charges via "green box" (rather than black box to signify ecobenefits)
  - Apply to major commercial sources (e.g. heavy-duty trucks, cargo handling, locomotives, commercial boats, lawn/garden maintenance, construction machinery, ships).
  - $/ton of emissions + congestion charges for road vehicles
  - Automatic monitoring/recording:
    With global positioning system + J1939 link + cell modem.
    With backpressure and oxides of nitrogen (NOx) sensors for retrofit controls.
    With "Taximeter" readout on-board.

  - Potential surcharge for critical air days/times.
  - Expand to passenger cars once it is accepted with heavy-duty vehicle use.
- Regulations work better than incentives - don't pay people to pollute less.
- Charge emission fees for portable engines.

Policy

- Use real world data in emissions inventory (e.g. from remote sensing).
- Develop community-based enforcement tools (e.g. remote sensing).
- Currently in-use: Billboards that let people know their vehicle emissions are being tested. People can go to a website specified on the billboard to check their emissions.
- Always measure in-use emissions. Measure everything in ratio to carbon dioxide in order to obtain fuel-based emission results.
- Obtain better in-use test data
  - E55/59 tests (E55 is a gasoline and ethanol blend that contains at least 55% ethanol).
- As more controls are used, will experience an increased ratio of nitrogen dioxide (NO_2) to NOx. This needs to be addressed.
- Reduce hydrocarbons to reduce ozone (e.g. deal with 2-stroke engines, etc.).
- Don't emphasize reducing NOx anymore because it increases ozone. The District's RECLAIM program reduced NOx, but didn't result in ozone reductions.

Controlling Engine Emissions

- Design problems with engines can make retrofits more difficult.
- Only 1% of engines are equipped with after-treatment today.
- Tradeoff in engine design - NOx reduction technologies may result in larger particulate matter (PM) emissions and reduced fuel efficiency.
- Additional NOx reductions can be achieved by modifying engine design (e.g. NOx can be reduced to 11 grams per kilowatt-hour).
- Diesel – cylinder deactivation for catalyst light-off in a cold engine.
- Diesel - homogeneous or stoichiometric charge combustion engines.
- Examine lube oil contributions to PM.
- Caterpillar is working on getting pre-controlled engines to Tier 1 level for retrofit compatibility.
- Technology is available to cleanup diesel exhaust, such as using SCR
  - There are many barriers, but cost is the greatest barrier.
  - More widespread use in Europe (e.g. ferries and locomotives).
- Consider performing repower and after-treatment at same time, because this provides more bang for the buck.
- Can reduce NOx by 98% with SCR on new installations.
- The physical size of SCR is an obstacle to retrofits.
- Study scrubbers for PM reductions.
- Physical size of scrubbers is an obstacle to retrofits.

- Retrofit with compact SCR systems
  - Heavy-duty diesel trucks
  - Locomotives
  - Harbor craft
  - Yard hostlers
  - Container cranes
  - Construction equipment
- AQMD should push to use CARB / Environmental Protection Agency (EPA) reciprocity for verification of control technologies.
- Ultra-clean vehicles for short-range goods movement
  - Natural gas + three-way catalyst
  - E100 spark-ignition + three-way catalyst
  - (Bio)diesel + SCR + diesel particulate filter (DPF) (e.g. 2010 on-road standard)
  - In hybrid yard hostlers, hybrid container shuttle/delivery trucks, shuttle locomotives, and tugboats (shut down main vessel engines and use tugs in the last 20-30 miles).

Ports

- Use cleaner fuels in marine vessels.
- Accelerate cold ironing at the ports.
- Invest effort into the elimination of obstacles that prevent emission reductions at the ports (e.g. promote cooperative efforts among agencies).
- A way to increase cold ironing at the ports and to retire cargo handling equipment early is through lease agreements.
- Goods movement – cleaner ships and fuels, use of shore power. Need rules by air quality agencies.
- Electrification of cranes.

Locomotives

- Locomotives – upgrade switchers in local yards.
  Long term – cleaner locomotives.
- It's important to use regulatory measures to control emissions
  - Maybe locomotive maintenance facilities should be looked at as stationary sources for regulatory purposes.

Aircraft

- Aircraft – Upgraded combustors in 1993 to provide emission reductions.
- Stationary industrial turbines
  - Have achieved significant emission reductions by addressing a combination of fuel, combustion technology, and after-treatment.

  - It is not known how to apply these strategies to aircraft, largely due to the issue of jet fuel and design issues related to a non-stationary source.
- In 2008, new combustion technology will be implemented for aircraft, but no exhaust gas treatment is planned.
- Jet fuel - cannot be altered too much for safety and other reasons.
- Some jet fuel changes are possible, such as altering/reformulating the hydrocarbon content.
- Aircraft combustor technologies - tradeoff between NOx and noise; carbon dioxide and noise.
- Aircraft - in order to obtain near-term, quick reductions, examine operational controls.
- The Department of Defense (DOD) is working on using synthetic fuels in aircraft. The District should work with the DOD on this issue.
- The District should work with the Federal Aviation Administration's environmental center.

Alternative Fuels

- Natural gas
  - Consider on-road engines for off-road applications.
  - On-road natural gas engines can already meet the 2010 standard, certified to 0.2 grams per brake horsepower-hour of NOx.
  - Looking at compressed natural gas (CNG) tests where 0.2 grams per brake horsepower-hour of NOx has already been met.
- Examine liquefied natural gas (LNG) and CNG for reductions in PM and NOx.
- Leaf blowers and lawnmowers – natural gas and liquefied petroleum gas (LPG) are being use in Europe. This technology emits no polycyclic aromatic hydrocarbons (PAHs), and results in no gas can emissions.
- Biodiesel – Every new John Deere engine today leaves the factory with 5% biodiesel. John Deere is presently evaluating 20%.
- Use renewable fuels
  - biodiesel
  - ethanol
- Develop dimethyl ether from coal.

<u>Barriers to the Introduction of Clean Air Technologies</u>

- Cost is the greatest barrier.
- Who will pay for all the improvements?
- There is not a business incentive to invest.
- Hindenburg funding – invest more funding to ensure safety of hydrogen.
- Lack of infrastructure.
- Decreased fuel efficiency.
- Regulatory jurisdictional issues limit adoption of regulations.

- Need more engine design information to make retrofits work.
- CARB requirements for technology verification are expensive and take a lot of time.
- The District should push EPA and CARB into establishing reciprocity in their procedures for verifying diesel emission control strategies.
- Allow on-site CARB verification of new technology.
- Include NOx in CARB's verification protocol.
- No international standard for PM test standards (e.g - dilution method or not?).
- Regulatory/legislative mindset
  - Results in command/control versus overcoming market failures.
  - Subsidies vs. charges for use of public goods.
  - Moyer subsidies limited to capital cost.
- Inadequate real-world emissions data
  - Baseline emission levels for off-road engines.
  - Emission control effectiveness for heavy-duty on-road trucks in question
    - Cycle-beating
    - Realistic driving cycles
    - In-use emissions - selection bias
- Lack of practical, near-term systems combining low greenhouse emissions and low/zero emissions of criteria pollutants.
- Aircraft – Leverage program by working with the Department of Defense on fuel issues.
- Aircraft – safety considerations.

Recommended Research Priorities for the Next 5 to 10 Years

- Need a more detailed understanding sector by sector for rule development.
- On-board, in use emission measurements from heavy-duty mobile & portable emission sources (with and without emission controls)
  - Heavy-duty trucks
  - Locomotives
  - Commercial boats
  - Construction machinery
  - Mobile equipment
- Heavy-duty Miller-cycle E100 engines with three-way catalytic converters
  - Three-way catalyst is ultra-clean, highly reliable
  - Ethanol from cellulose biomass is ~carbon neutral
  - High octane compatible with high-efficiency otto/miller cycle combustion
  - Electro-hydraulic valve actuation minimizes throttling losses, enables Miller cycle
- Fuel emulsification needs to be studied.

Questions and Answer Period:

Q: Is there a possibility that other shipping companies will follow the MAERSK approach?

A: Yes, the Ports of Los Angeles and Long Beach will use leases to obtain agreements for the MAERSK approach. (*Note taker's comment: With the MAERSK approach, vessels use low sulfur diesel fuel within 24 miles off shore*).

Q: Before a lease expires, are there other mechanisms to reduce emissions?
A: Yes, there is the Vehicle Speed Reduction approach (which is voluntary). A Port of Long Beach tariff can be used for compliance with Vehicle Speed Reduction. Also, encourage the use of low sulfur diesel fuel. Negotiate terms with tenants.

Q: With emission reduction technologies such as SCR, are retrofits difficult due to factors such as size? What about new ships?
A: For new ships, it works. For existing ships, it's almost impossible.
- 4-stroke engines have high enough exhaust temperatures to permit SCR installation after the turbocharger.
- 2-stroke engines have lower exhaust temperatures, so SCR needs to be installed before the turbocharger. As a result, SCR installation is even more challenging for 2-stroke engines.
- It's difficult to re-route large pipes.
- SCR is expensive and operating costs are high.
- In Sweden, they provide monetary incentives (e.g. docking fees) for NOx reductions, so SCR is used.

Q: Can ports provide incentives for lower emissions?
A: The Port of Long Beach is looking at alternatives with agencies, such as tariffs, fees.

- In Europe, fuel is expensive, so technology is fuel-cost driven rather than regulatory-driven.
- Note that with an increased use of SCR, there will be an increase in ammonia slip emissions and possibly cyanides. With diesel particulate filters, NO_2 will increase in many cases, causing an increase in ozone.
- Ammonium sulfate and ammonium nitrate are very benign PM components of diesel. Forget about low-sulfur sulfur diesel. Ozone is worse than diesel PM.
- Non-platinum catalyst controls do not increase NO_2.
- The RECLAIM program and the Moyer program have reduced ozone.
- Because NOx in the region is a precursor to both ozone and fine particulate matter, it's essential that NOx emissions be overall controlled in order to achieve the ambient ozone, PM_{10}, and fine particulate ($PM_{2.5}$) standards.
- Colorado places emphasis on regional haze, rather than health.