APPENDIX C

HAZARD IMPACT CALCULATIONS

Consequence modeling was performed for the scenarios identified below. The purpose of the modeling was to estimate the offsite consequences of releases of flammable materials from units that are proposed for installation or modification as the result of the CARB Phase 3 - MTBE Phase Out Project.

The modeling was based on equations from the EPA's RMP Off-Site Consequence Analysis Guidance (May 24, 1996) document for estimating impact distances for explosions, fires, and boiling liquid expanding vapor explosions (BLEVEs). The EPA equations for these events were programmed into an EXCEL™ spreadsheet and used to determine the size of the impact zone. The equations are summarized below.

Vapor Cloud Explosions

For vapor cloud explosion, the total quantity of flammable substance is assumed to form a vapor cloud. The entire cloud is assumed to be within the flammability limits, and the cloud is assumed to explode. Ten percent of the flammable vapor in the cloud is assumed to participate in the explosion. The distance to the one pound per square inch overpressure level is determined using equation C-1.

$$X = 17\left(0.1\ W_f\ \frac{H_{cf}}{H_{CTNT}}\right)^{1/3} \qquad \text{(C-1)}$$

Where:

X = distance to overpressure of 1 psi (meters)

W_f = weight of flammable substance (kg)

H_{Cf} = heat of combustion of flammable substance (joules/kg)

H_{CTNT} = heat of combustion of trinitrotoluene (4.68 E+06 joules/kg)

Pool Fires

The EPA equation is based on factors for estimating the distance to a heat radiation level that could cause second degree burns from a 40-second exposure. This heat radiation level was calculated to be 5,000 watts per square meter. The equation for estimating the distance from pool fires of flammable liquids with boiling points above ambient temperature is:

$$X = H_c \sqrt{\frac{0.0001\ A}{5000\ \Pi\ (H_v + C_p\ (T_B - T_A))}} \qquad \text{(C-2)}$$

Where:

X = distance to the 5 kilowatt per square meter endpoint (m)

H_C = heat of combustion of the flammable liquid (joules/kg)

H_V = heat of vaporization of the flammable liquid (joules/kg)

A = pool area (m^2)

C_P = liquid heat capacity (joules/kg-ºK)

T_B = boiling temperature of the liquid (ºK)

T_A = ambient temperature (ºK)

Boiling Liquid Expanding Vapor Explosion

The equations used by the EPA to estimate impact distances for BLEVEs are summarized below:

$$X = \sqrt{\frac{2.2\ t_a\ R\ H_c\ W_f^{0.67}}{4\ \Pi \left[\frac{3.42\ x\ 10^6}{t}\right]^{0.75}}} \qquad \text{(C-3)}$$

Where:

X = distance to the 5 kilowatts per square meter endpoint (m)

R = radiative fraction of the heat of combustion (assumed to be 0.4)

t_A = atmospheric transmissivity (assumed to be 1)

H_C = heat of combustion of the flammable liquid (joules/kg)

W_f = weight of flammable substance in the fireball (kg)

t = duration of the fireball in seconds (estimated from the following equations)

For W_f < 30,000 kg

$$t = 0.45\ W_f^{1/3} \qquad \text{(C-4)}$$

For $W_f > 30{,}000$ kg

$$t = 2.6\ W_f^{1/6} \qquad \text{(C-5)}$$

The accident scenarios that were considered in the analysis of offsite impacts are given in Table C-1.

Table C-1
Definition of Hazard Scenarios Modeled

Scenario	Hazard	Chemical	Discussion
1	Explosion	Butane	Assumes an explosion in the modified deisobutanizer tower. The impact of modified tower at new capacity (15,700 gallons) is compared with the pre-modified capacity of the tower (14,800 gallons)
2	Explosion	Pentane	A catastrophic failure of the new C4/C5 Splitter at the Refinery due to a major external event, such as an earthquake, is assumed to release 10,900 gallons of pentane as a vapor cloud which explodes. The incremental risk was compared with a zero baseline.
3	Explosion	Pentane and Butane	A catastrophic failure of the converted (to pentane) butane storage tank at the Refinery due to a major external event, such as an earthquake, is assumed to release 10,900 gallons of pentane as a vapor cloud which explodes (US EPA "worst-case" assumption). The incremental risk of 51,000 barrels of pentane was compared with an explosion of 51,000 barrels of butane.
4	Pool Fire	Pentane	The contents of the converted butane tank (51,000 barrels of pentane) are spilled into a containment dike and then catches fire. The storage tank failure was assumed to be caused by an external event or degradation of the equipment. The incremental risk was compared with a zero baseline since butane is not a liquid at ambient temperatures.
5	BLEVE	Pentane and Butane	A fire in the vicinity of a new spheroid pentane tank causes the tank to fail catastrophically, resulting in 10% percent of the contents exploding as a vapor cloud. The incremental risk was compared with a butane BLEVE baseline.
6	Pool Fire	Pentane	A 700-bbl railcar of pentane spills its contents, ignites and burns. The pentane fire is compared with a zero baseline.
7	Explosion	Pentane	A 700-bbl railcar of pentane explodes. The pentane explosion is compared with a zero baseline.
8	Pool Fire	Ethanol	The entire contents of an 8,500-gallon ethanol tank truck at the Refinery are spilled in a vehicle accident. The contents spread in an unconfined manner to a depth of 1-centimeter and then ignites. The fire is compared to a zero baseline.
9	Pool Fire	Ethanol	The entire contents of an 8,500-gallon ethanol tank truck at the Southwestern Terminal are spilled in a vehicle accident. The contents spread in an unconfined manner to a depth of 1-centimeter and then ignites. The fire is compared to a zero baseline.

Table C-1 (Continued)
Definition of Hazard Scenarios Modeled

Scenario	Hazard	Chemical	Discussion
10	Pool Fire	Ethanol	An improperly connected fuel ethanol truck releases 200 gallons of ethanol before the emergency shut-off can be activated. The spill spreads in an unconfined manner to a depth of 1-centimeter and ignites. The fire is compared to a zero baseline.
11	Pool Fire	Ethanol	The contents of the new refinery fuel ethanol tank (40,000 bbl) are spilled into a containment dike and catch fire. The storage tank failure was assumed to be caused by an external event or degradation of the equipment. The incremental risk was compared with a zero baseline.
12	BLEVE	Ethanol	A fire in the vicinity of the new refinery fuel ethanol tank (40,000-bbl) causes the tank to fail catastrophically resulting in a fireball or BLEVE. Ten percent of the contents explode as a vapor cloud. The incremental risk was compared with a zero baseline.
13	Explosion	Pentane	A catastrophic failure of the new FCC Mid-cut Side Stripper Tower releases 1,010 gallons of light ends as a vapor cloud which explodes. The failure was assumed to be caused by a major external event like an earthquake. The incremental risk was compared with a zero baseline.
14	Pool Fire	Ethanol	A 700-bbl railcar of fuel ethanol spills its contents, ignites and burns. The ethanol fire was compared with a zero baseline.
15	Pool Fire	Ethanol and Gasoline	The contents of the converted 60,000-bbl fuel ethanol storage tank at Vernon are spilled into a containment dike (200' x 280' x 6') and catches fire. The storage tank failure was assumed to be caused by an external event or degradation of the equipment. The incremental risk was compared with a 60,000 bbl gasoline baseline.
16	BLEVE	Ethanol and Gasoline	A fire in the vicinity of the converted 60,000-bbl fuel ethanol tank at Vernon causes the tank to fail catastrophically, resulting in a fireball or BLEVE. Ten percent of the contents explode as a vapor cloud. The incremental risk was compared with a 60,000 gasoline baseline.
17	Pool Fire	Ethanol	The contents of the new fuel ethanol tank (15,000-bbl) at Atwood are spilled into a containment dike (130' x 130' x 6') and catches fire. The storage tank failure was assumed to be caused by an external event or degradation of the equipment. The incremental risk was compared with a zero baseline.
18	BLEVE	Ethanol	A fire in the vicinity of the new 15,000-bbl fuel ethanol tank at Atwood causes the tank to fail catastrophically resulting in a fireball or BLEVE. Ten percent of the contents explode as a vapor cloud. The incremental risk was compared with a zero baseline.

Table C-1 (Continued)
Definition of Hazard Scenarios Modeled

Scenario	Hazard	Chemical	Discussion
19	Pool Fire	Ethanol, MTBE, and Gasoline	A 100,000-bbl shipload of fuel ethanol ignites and burns through a 10,000 square foot opening in the deck. The ethanol fire is compared with an MTBE fire of the same size to estimate the incremental risk of the conversion project. A 100,000-bbl gasoline marine tanker fire is compared with a zero baseline to estimate non-CARB gasoline shipments.
20	Pool Fire	Pentane	The pipeline from the refinery C5/LSR storage to the blending area ruptures and the spilled liquid ignites. Flow is assumed to occur for 10 minutes at 1,680 gpm until the flow can be stopped. The impact is compared to a zero baseline.
21	BLEVE	Pentane	The pipeline from the refinery C5/LSR storage to the blending area ruptures and releases a vapor cloud that explodes a fireball or BLEVE. Flow is assumed to occur for 2 minutes at 1,680 gpm and 10% of the released mass is assumed to be consumed in the BLEVE. The impact is compared to a zero baseline.
22	Pool Fire	Pentane	The pipeline from the refinery C5/LSR storage to the blending area ruptures and the spilled liquid ignites. Flow is assumed to occur for 10 minutes at 280 gpm until the flow can be stopped. The impact is compared to a zero baseline.
23	BLEVE	Pentane	The pipeline from the refinery C5/LSR storage to the blending area ruptures and releases a vapor cloud that explodes a fireball or BLEVE. Flow is assumed to occur for 2 minutes at 280 gpm and 10% of the released mass is assumed to be consumed in the BLEVE. The impact is compared to a zero baseline.
24	Pool Fire	Ethanol	Alternative 2A for comparison with project 40,000-bbl ethanol tank pool fire (Scenario 11).
25	BLEVE	Ethanol	Alternative 2A for comparison with project 40,000-bbl ethanol tank BLEVE (Scenario 12).
26	Pool Fire	Ethanol	The fuel ethanol pipeline from the Southwest Terminal to the refinery (Alternative 4) ruptures and the spilled liquid ignites. Flow is assumed to occur for 10 minutes at 2,100 gpm until the flow can be stopped. The impact is compared to a zero baseline.
27	BLEVE	Ethanol	The fuel ethanol pipeline from the Southwest Terminal to the refinery (Alternative 4) ruptures and releases a vapor cloud that explodes a fireball or BLEVE. Flow is assumed to occur for 2 minutes at 2,100 gpm and 10% of the released mass is assumed to be consumed in the BLEVE. The impact is compared to a zero baseline.

The results of the model runs are summarized in Table C-2. It should be noted that the upsets that were modeled are not likely to occur and were very conservatively based on US EPA RMP worst-case and alternate case assumptions.

Table C-2
Distance (meters) to Endpoint from Center to Upset*

Scenario	Event	Explosion	Pool Fire	BLEVE
1a	Deisobutanizer (before)	550	NA	NA
1b	Deisobutanizer (after)	560	NA	NA
2	C4/C5 Splitter Fail (10,900 gal pentane)	510	NA	NA
3a,4,5a	Pentane Spheroid (51K BBL)	2,960	510	1,740
3b,5b	Butane Spheroid (51K BBL)	2,900	NA	1,690
6,7	Pentane RR Tank Car (700 BBL)	710	660	NA
8	Ethanol Tank Truck (8,500 gallons)	NA	130	NA
9	Ethanol Tank Truck (8,500 gallons)	NA	130	NA
10	Bad Connect/Disconnect (200 gallons)	NA	20	NA
11,12	Ethanol Tank Failure (40K BBL)	NA	170	1,350
13	Side Stripper (1,010 gallons pentane)	230	NA	NA
14	Ethanol RR Tank Car (700 BBL)	NA	250	NA
15a,16a	Vernon Ethanol Tank Failure (60K BBL)	NA	170	1,590
15b,16b	Vernon Gasoline Tank Failure (60K BBL)	NA	380	1,930
17,18	Atwood Ethanol Tank Failure (15K BBL)	NA	90	920
19a	100K BBL Ship Fire Gasoline	NA	160	NA
19b	100K BBL Ship Fire MTBE	NA	150	NA
19c	100K BBL Ship Fire Ethanol	NA	70	NA
20,21	C5/LSR 1,680 gpm pipeline rupture	NA	500	110
22,23	C5/LSR 280 gpm pipeline rupture (Alternative 3B)	NA	200	50
24,25	20K BBL ethanol tank failure (Alternative 2A Project Baseline)	NA	140	1,030
26,27	2,100 gpm ethanol pipeline failure (Alternative 4)	NA	210	100

* Endpoint – EPA RMP
Explosion endpoint – 1.0 psi
Fire/BLEVE Endpoint – 5.0 kW/m^2 for 40 seconds or equivalent

NA – Not Applicable

All endpoint distances are rounded to the nearest 10 meters

Chemical Physical Parameters

Input	Chemical	Hc (joules/kg)	Hv (joules/kg)	Cp (joules/kg-K)	Tb (K)	Density (lb/gal)	Reference
1	Diesel	4.81E+07	275218	2183	447.0		1
2	Ethanol	2.97E+07	866265	2407	351.4	6.6	2
3	Gasoline	4.78E+07	300513	2198	398.7	5.89	1
4	Pentane	4.86E+07	356415	2283	309.0	5.26	1
5	MTBE	3.87E+07	320237	2098	327.0	6.18	3
6	n-Nonane	4.77E+07	287192	2190	423.5		1
7	Nonenes	4.71E+07	287285	2124	419.8		4
8	Butane	4.90E+07	384400			4.87	1
9	Hydrogen	1.30E+08	450189				5
10	Propylene	4.88E+07	436497				2

References

1	Petroleum Refining, J. Gary and G Handwerk, Marcel Dekker, Inc, 1975
2	Perry's Chemical Engineering Handbook
3	Conversation with Dennis Feist, Equilon/Shell
4	ARCO Table 1C1.3
5	Standard Handbook for ME, Marks

Scenario Definitions

Scenario	Container	Event Type	Chemical	Barrels	Gallons	Pounds	Kg
1a	Debutanizer (old)	Explosion	Butane	352	14,800	72,076	32,694
1b	Debutanizer (new)	Explosion	Butane	374	15,700	76,459	34,682
2	C4/C5 Splitter	Explosion	Pentane	260	10,900	57,334	26,007
3a	51K BBL Sphere	Explosion	Pentane	51,000	2,142,000	11,266,920	5,110,675
3b	51K BBL Sphere	Explosion	Butane	51,000	2,142,000	10,431,540	4,731,747
4	51K BBL Sphere	Pool fire	Pentane	51,000	2,142,000	11,266,920	5,110,675
5a	51K BBL Sphere	BLEVE	Pentane	51,000	2,142,000	11,266,920	5,110,675
5b	51K BBL Sphere	BLEVE	Butane	51,000	2,142,000	10,431,540	4,731,747
6	700 BBL Railcar	Pool fire	Pentane	700	29,400	154,644	70,147
7	700 BBL Railcar	Explosion	Pentane	700	29,400	154,644	70,147
8	8500 Gal Truck	Pool fire	Ethanol	202	8,500	56,100	25,447
9	8500 Gal Truck	Pool fire	Ethanol	202	8,500	56,100	25,447
10	Bad Connection	Pool fire	Ethanol	5	200	1,320	599
11	40K BBL Tank	Pool fire	Ethanol	40,000	1,680,000	11,088,000	5,029,517
12	40K BBL Tank	BLEVE	Ethanol	40,000	1,680,000	11,088,000	5,029,517
13	Side Stripper	Explosion	Pentane	24	1,010	5,313	2,410
14	700 BBL Railcar	Pool fire	Ethanol	700	29,400	194,040	88,017
15a	Vernon tank	Pool fire	Ethanol	60,000	2,520,000	16,632,000	7,544,275
15b	Vernon tank	Pool fire	Gasoline	60,000	2,520,000	14,842,800	6,732,694
16a	Vernon tank	BLEVE	Ethanol	60,000	2,520,000	16,632,000	7,544,275
16b	Vernon tank	BLEVE	Gasoline	60,000	2,520,000	14,842,800	6,732,694
17	Atwood tank	Pool fire	Ethanol	15,000	630,000	4,158,000	1,886,069
18	Atwood tank	BLEVE	Ethanol	15,000	630,000	4,158,000	1,886,069
19a	Barge fire	Pool fire	Gasoline	100,000	4,200,000	24,738,000	11,221,157
19b	Barge fire	Pool fire	Ethanol	100,000	4,200,000	27,720,000	12,573,792
19c	Barge fire	Pool fire	MTBE	100,000	4,200,000	25,956,000	11,773,642
20	Pipeline 1680 gpm	Pool fire	Pentane	(10-minute flow)	16,800	88,368	40,084
21	Pipeline 1680 gpm	BLEVE	Pentane	(2-minute flow)	3,360	17,674	8,017
22	Pipeline 280 gpm	Pool fire	Pentane	(10-minute flow)	2,800	14,728	6,681
23	Pipeline 280 gpm	BLEVE	Pentane	(2-minute flow)	560	2,946	1,336
24	20K BBL Tank	Pool fire	Ethanol	20,000	840,000	5,544,000	2,514,758
25	20K BBL Tank	BLEVE	Ethanol	20,000	840,000	5,544,000	2,514,758
26	Pipeline 2100 gpm	Pool fire	Ethanol	(10-minute flow)	21,000	138,600	62,869
27	Pipeline 2100 gpm	BLEVE	Ethanol	(2-minute flow)	4,200	27,720	12,574

Confined Spill Surface Area.

Scenario	Description	Tank Vol (BBL)	Tank Vol (Gal)	Volume (cu ft)	Containment Area (sq ft)	Containment Depth (ft)	Area (sq m)
4	51K BBL Sphere	51,000	2,142,000	286,364	71,200	6&4	6,615
11	40K BBL Tank	40,000	1,680,000	224,599	54,400	5	5,054
15a	Vernon tank	60,000	2,520,000	336,898	56,000	6	5,203
15b	Vernon tank	60,000	2,520,000	336,898	56,000	6	5,203
17	Atwood tank	15,000	630,000	84,225	16,900	6	1,570
24	20K BBL Tank	20,000	840,000	112,299	38,000	6	3,530

Unconfined Spill Surface Area. Liquid spreads to a depth of 1 cm depth (0.0328 feet).

Scenario	Description	Tank Vol (BBL)	Tank Vol (Gal)	Volume (cu ft)	Containment Area (sq ft)	Containment Depth (ft)	Area (sq m)
6	700 BBL Railcar	700	29,400	3,930	119,801	0.0328	11,108
8	8500 Gal Truck	202	8,500	1,136	34,636	0.0328	3,212
9	8500 Gal Truck	202	8,500	1,136	34,636	0.0328	3,212
10	Bad Connection	5	200	27	815	0.0328	76
14	700 BBL Railcar	700	29,400	3,930	119,801	0.0328	11,108
19a	Barge fire	100,000	4,200,000	561,497	10,000	-	927
19b	Barge fire	100,000	4,200,000	561,497	10,000	-	927
19c	Barge fire	100,000	4,200,000	561,497	10,000	-	927
20	Pipeline 1680 gpm	(10-min flow)	16,800	2,246	68,458	0.0328	6,347
22	Pipeline 280 gpm	(10-min flow)	2,800	374	11,410	0.0328	1,058
26	Pipeline 2100 gpm	(10-min flow)	21,000	2,807	85,572	0.0328	7,934

Pool Fire. Boiling point above ambient temperature. Distance is to energy flux of 5kW/m^2

Scenario	Description	Size (BBL)	Chemical	Hc (J/kg)	Hv (J/kg)	Cp (j/kgK)	Tb (K)	Ta (K)	A (m**2)	x (m)
4	51K BBL Sphere	51,000	Pentane	4.86E+07	3.56E+05	2.28E+03	3.09E+02	298	6,615	510
6	700 BBL Railcar	700	Pentane	4.86E+07	3.56E+05	2.28E+03	3.09E+02	298	11,108	660
8	8500 Gal Truck	202	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	3,212	130
9	8500 Gal Truck	202	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	3,212	130
10	Bad Connection	5	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	76	20
11	40K BBL Tank	40,000	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	5,054	170
14	700 BBL Railcar	700	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	11,108	250
15a	Vernon tank	60,000	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	5,203	170
15b	Vernon tank	60,000	Gasoline	4.78E+07	3.01E+05	2.20E+03	3.99E+02	298	5,203	380
17	Atwood tank	15,000	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	1,570	90
19a	Barge fire	100,000	Gasoline	4.78E+07	3.01E+05	2.20E+03	3.99E+02	298	927	160
19b	Barge fire	100,000	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	927	70
19c	Barge fire	100,000	MTBE	3.87E+07	3.20E+05	2.10E+03	3.27E+02	298	927	150
20	Pipeline 1680 gpm	(10-minute flow)	Pentane	4.86E+07	3.56E+05	2.28E+03	3.09E+02	298	6,347	500
22	Pipeline 280 gpm	(10-minute flow)	Pentane	4.86E+07	3.56E+05	2.28E+03	3.09E+02	298	1,058	200
24	20K BBL Tank	20,000	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	3,530	140
26	Pipeline 2100 gpm	(10-minute flow)	Ethanol	2.97E+07	8.66E+05	2.41E+03	3.51E+02	298	7,934	210

Based on EPA RMP Off-Site Consequence Analysis Guideline (5/24/96)

Blast. Distance to overpressure of 1 psi.

Scenario	Description	Size (BBL)	Chemical	Wt (kg)	Hc (joules/kg)	x (m)
1a	Debutanizer (old)	352	Butane	3.27E+04	4.90E+07	550
1b	Debutanizer (new)	374	Butane	3.47E+04	4.90E+07	560
2	C4/C5 Splitter	260	Pentane	2.60E+04	4.86E+07	510
3a	51K BBL Sphere	51,000	Pentane	5.11E+06	4.86E+07	2,960
3b	51K BBL Sphere	51,000	Butane	4.73E+06	4.90E+07	2,900
7	700 BBL Railcar	700	Pentane	7.01E+04	4.86E+07	710
8	8500 Gal Truck	202	Ethanol	2.54E+07	2.97E+07	430
13	Side Stripper	24	Pentane	2.41E+03	4.86E+07	230

Based on EPA RMP Off-Site Consequence Analysis Guideline (5/24/96)

Scenario	Description	Size (BBL)	Chemical	Wt (kg)	Hc (joules/kg)	Duration (s) Fire Ball	x (m)
2a	51K BBL Sphere	51,000	Pentane	2.11E+06	4.86E+07	53	1,240
2b	51K BBL Sphere	51,000	Butane	1.93E+06	4.90E+07	53	1,230
15	40K BBL Tank	40,000	Ethanol	5.03E+06	2.97E+07	53	1,320
16a	Vernon tank	60,000	Ethanol	7.54E+06	2.97E+07	52	1,580
16b	Vernon tank	60,000	Gasoline	6.13E+06	4.78E+07	54	1,630
18	Atwood tank	15,000	Ethanol	1.88E+06	2.97E+07	50	650
21	Pipeline 1680 gpm	(5-minute flow)	Pentane	8.02E+03	4.86E+07	4	110
23	Pipeline 280 gpm	(5-minute flow)	Pentane	1.34E+03	4.86E+07	2	50
25	20K BBL Tank	20,000	Ethanol	5.25E+06	2.97E+07	51	1,030
27	Pipeline 2100 gpm	(5-minute flow)	Ethanol	1.30E+04	2.97E+07	2	100

BLEVE. Assumes 10% of total weight is evaporated and explodes. Distance is to energy flux of 5kW/m^2

Analysis of Potential Heat of Combustion for Octyl Nitrate (2-ethylhexyl nitrate) and Comparative Risk with Respect to Ethanol 2/14/2001

Source:
CRC Handbook, 58th Edition, Heats of Combustion for Organic Compounds, pg D274-D279

Compound	Hc (kg/cal)	Compound	Hc (kg/cal)	Difference (%)
ethane	373	Nitroethane (C2H5NO2)	322	-14%
ethane	373	Ethyl Nitrate (C2H5ONO2)	322	-14%
propane	531	Nitropropane (C3H7NO2)	478	-10%
3-ethyl hexane	1302	ethanol	327	-75%
n-hexane	995	ethanol	327	-67%

Estimate Octyl Nitrate Heat of Combustion by ratio based on Ethyl Nitrate and ethane

n-hexane	995	2-ethylhexyl nitrate (C8H17ONO2)	859	-14%
3-ethyl hexane	1302	2-ethylhexyl nitrate (C8H17ONO2)	1124	-14%

Worst-case is the least difference in the heats of combustion

2-ethylhexyl nitrate (C8H17ONO2)	859	ethanol	327	-62%
2-ethylhexyl nitrate (C8H17ONO2)	1124	ethanol	327	-71%

Estimate the ratio of the impacts due to fire and explosion for Alternative 2C vs. Proposed Project
Vapor cloud end point is proportional to mass^0.333 and Hc^0.333
Pool fire end point is proportional to Hc and surface area^0.5
Area and mass are proportional to the volume

	Volume (bbl)	Hc
Alternative 2C (ethanol)	1500	327
Baseline (octyl nitrate)	1500	859

	Pool Fire	Explosion
Ratio of end point distance, Alternative to Baseline	0.38	0.72

Conclusion: Impact of Alternative 2C is less than Proposed Project