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 meter squares 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 meter squared 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 following accident scenarios were considered in the analysis of offsite impacts:

- Case 1: Rupture of a existing pipeline (#70) converted from existing service to transport pentane to Marine Terminal 2. The pipeline is assumed to be ruptured due to a digging accident or earthquake. The pipeline releases pentane at the flow rate of the pipe for 10 minutes and forms a pool which spreads out to a one centimeter depth until the pump is shut down. (The maximum flow rate of pipeline #70 is about 1,000 BPH). The released pool is assumed to ignite and burn after 10 minutes of spreading. The incremental risk is estimated by comparing a nonene fire of equivalent size to a pentane fire (nonene is a typical hydrocarbon currently transported in the pipeline).
- Case 2: A catastrophic failure of the new pentane storage tank at Marine Terminal 2 is assumed to release 100,000 BBL of pentane as a vapor cloud which explodes (EPA worst case assumption). The catastrophic failure was assumed to be caused by a major external event like an earthquake. The incremental risk of 100,000 BBL of pentane was compared with 20,000 BBL of nonene (the Pentane replaces the nonene tank).
- Case 3: The contents of the pentane tank (100,000 BBL) are spilled into a dike that is 195 feet high and capable of containing the entire contents of the tank plus ten percent. The liquid in the dike then catches fire. The storage tank failure was assumed to be caused by an external event or degradation of the equipment.
- Case 4: A fire in the vicinity of the pentane tank 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 is compared with a nonene BLEVE.
- Case 5: A 300,000 BBL barge of pentane ignites and burns through a 10,000 square foot opening in the deck. The pentane fire is compared with an MTBE fire to estimate the incremental risk of the conversion project. A barge of ethanol is also compared with MTBE under the same conditions.
- Case 6: The contents of an ethanol tank truck are spilled in a vehicle accident. The entire 8,800 gallons spread in an unconfined manner to a depth of one centimeter and ignites. The impact distance of the fire is calculated.
- Case 7: An ethanol truck is improperly connected/disconnected and releases 200 gallons of ethanol before the emergency shut-off can be activated. The spill spreads in an unconfined manner to a depth of one centimeter and ignites.

- Case 8: The pentane pipeline is ruptured and releases pentane that forms a vapor cloud and explodes after two minutes (1,400 gallons released as vapor). The incremental impact is estimated by comparing it with an equivalent nonene explosion.

The results are summarized in Table C-1.

Table C-1
Distance (meters) to Endpoint from Center to Upset*

Case	Event	Explosion	Pool Fire	BLEVE
1	Rupture Existing Pipeline Pentane	NA	326	NA
1	Rupture Existing Pipeline Nonene	NA	280	NA
2,3,4	Pentane Tank Failure (100,000 BBL)	3,712	344	2,276
2,3,4	Nonene Tank Failure (20,000 BBL)	2,257	132	1,253
5	300K BBL Barge Fire Pentane	NA	193	NA
5	300K BBL Barge Fire MTBE	NA	153	NA
5	300K BBL Barge Fire Ethanol	NA	73	NA
6	Ethanol Truck Fire Unconfined	NA	137	NA
7	Bad Connect/Disconnect	NA	21	NA
8	Rupture Existing Pipeline Pentane (2 Minute Vapor Cloud)	258	NA	NA
8	Rupture Existing Pipeline Nonene (2 Minute Vapor Cloud)	268	NA	NA

* Endpoint – EPA RMP
Explosion endpoint – 1 psi
Fire/BLEVE Endpoint – 5KW/m^2 for 40 seconds or equivalent
NA – Not Applicable