8.0 INTRODUCTION

The use of methanol as a fuel for mobile and stationary applications offers significant air quality and energy security benefits. Several demonstrations are being performed throughout the United States to develop and verify methanol fuel use in these applications and to quantify these benefits.[1,2] These demonstrations are all currently using chemical-grade methanol. The Air Products LPMEOH™ process produces a product which without further distillation can be used in these methanol fuel applications. This demonstration will evaluate the emissions and performance characteristics of the fuel methanol produced by the LPMEOH™ process.

8.0.1 Objective

The objective of this project task is to demonstrate the fuel methanol produced by the LPMEOH™ process in both mobile and stationary offsite demonstrations.

8.0.2 Approach

The fuel methanol product will be demonstrated in a variety of projects. The mobile projects involve transit buses and passenger vans. Transit bus demonstrations will occur at the Kanawha Valley Regional Transit Authority (KVRTA) in Charleston, West Virginia, and at the Los Angeles County Metropolitan Transportation Authority (LACMTA) in Los Angeles, California. A vanpool passenger van demonstration will occur at Hughes Aerospace in Los Angeles, California.

Stationary demonstrations include a standby electric power generation engine. This portable engine is operated in Los Angeles County by Valley DDC.

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[1] *Performance and Emissions of Clean Fuels in Transit Buses with Cummins L-10 Engines,* SAE Technical Paper Series 931782, SP-982.

[2] *Chassis Dynamometer Emissions Testing Results for Diesel and Alternative-Fueled Transit Buses,* SAE Technical Paper Series 931783, SP-982.

Another stationary demonstration involves the conversion and operation of a firetube boiler at Hughes Aerospace in Los Angeles, California. In order to demonstrate the concept of coproducing methanol with electricity and burning methanol as load leveling dictates, methanol will also be tested in a utility turbine, assumed to be located in southern California. For these demonstrations, Acurex Environmental will support the vehicle and engine or equipment modifications for methanol fuel, design the appropriate fuel storage facility, install the facilities as appropriate, and arrange for fuel deliveries and/or fuel mixing as needed. In addition, Acurex Environmental will monitor the demonstrations, evaluate the data, and prepare reports. Acurex Environmental will coordinate fuel availability with Air Products.

Table 8-1 shows the location and size of the fueling facilities which will be used for the demonstrations. The quantity of fuel methanol that will be used at each of the demonstration sites is also shown in Table 8-1. Fuel methanol will be delivered in 6,250-gallon ISO containers and 8,500-gallon tank trucks; therefore, if a project requires a total of 60,000 gallons over a period of time, multiple shipments must be made. The total quantity of fuel listed in Table 8-1 indicates the fuel usage over a period of time; thus, storage tanks at each demonstration site may be smaller than the total fuel required, since the tanks may be refilled multiple times.

Fuel methanol will be displacing another fuel in all of the demonstration projects. Therefore, the emission impacts associated with baseline fuels in the existing environments are also presented in the following sections. In some cases, the new fuel methanol may displace either chemical-grade methanol (M100) or a conventional fuel such as natural gas or diesel. In these instances, we have shown the emission factors for both methanol and conventional fuels but based the impact analysis on the most reasonable interpretation of which fuel represents the existing environment. In the case of LACMTA buses, fuel methanol will displace chemical

Table 8-1. Demonstration sites and fueling facilities

Site	Location	Fueling Facility	Gallons
Los Angeles County Metropolitan Transportation Authority (LACMTA)	Los Angeles	Use existing facilities, 20,000-gal underground tank	60,000
Hughes Aerospace Vanpool and Firetube Boiler	Los Angeles	Use existing 20,000-gal underground tank	40,000
Valley DDC Standby Electric Power Generator	Los Angeles	Planned 10,000-gal above-ground tank	20,000
Utility turbine	Los Angeles	Use existing 20,000-gal underground tank	200,000
Kanawha Valley Regional Transit Authority (KVRTA)	West Virginia	Use existing facilities, 20,000 gal underground tank	80,000
Total			400,000

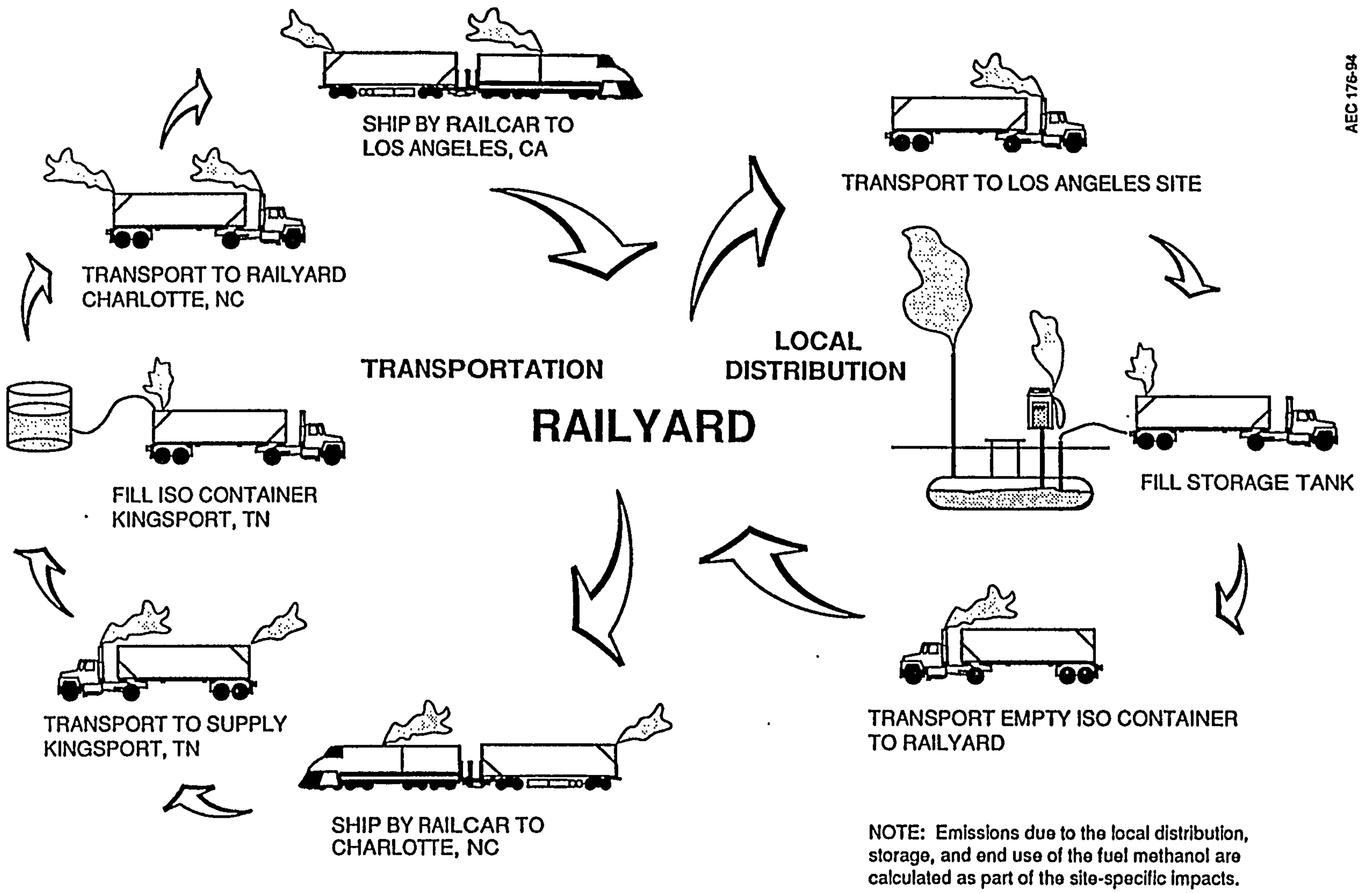
grade methanol, M100. M85 is currently used in the Hughes Aerospace vanpool. For this offsite test facility, fuel methanol will displace the M100 component of M85, but the gasoline component of M85 will still come from the same existing sources. Fuel methanol will displace natural gas in the firetube boiler demonstration. For the Valley DDC generator and KVRTA buses, fuel methanol will again displace M100 in existing applications. Fuel methanol will displace natural gas in the utility turbine.

8.1 ENVIRONMENTAL IMPACT OVERVIEW

This volume is organized into sections describing the impacts associated with methanol use in general, as well as the specific air quality impacts, permit requirements and regulations, and emergency response measures involved in each off-site test facility. The general impacts of methanol use, including methanol spills, flammability, and toxicity, are presented in Section 8.1.

Fuel methanol will be transported from Kingsport, Tennessee, to demonstration sites where it will be stored and used as fuel. Most of the offsite test facilities are in southern California, and these sites share the same fuel transportation pathway to Los Angeles. Figure 8-1 illustrates the general fuel transportation and distribution pathways for the Los Angeles area offsite test facilities. The fuel methanol is first transported from Kingsport to the Los Angeles railyard, and is then distributed locally to the offsite test facilities in the area, where it is stored and used. The empty transport containers are returned to the point of origin.

The West Virginia offsite test facility utilizes a different fuel transportation pathway than that of the Los Angeles sites. Figure 8-2 illustrates the fuel transportation pathway for the West Virginia site. The fuel methanol is trucked from Kingsport to Charleston, where it is stored and used. The empty tank trucks return to the point of origin.



NOTE: Emissions due to the local distribution, storage, and end use of the fuel methanol are calculated as part of the site-specific impacts.

Figure 8-1. Fuel transportation pathway for Los Angeles offsite test facilities

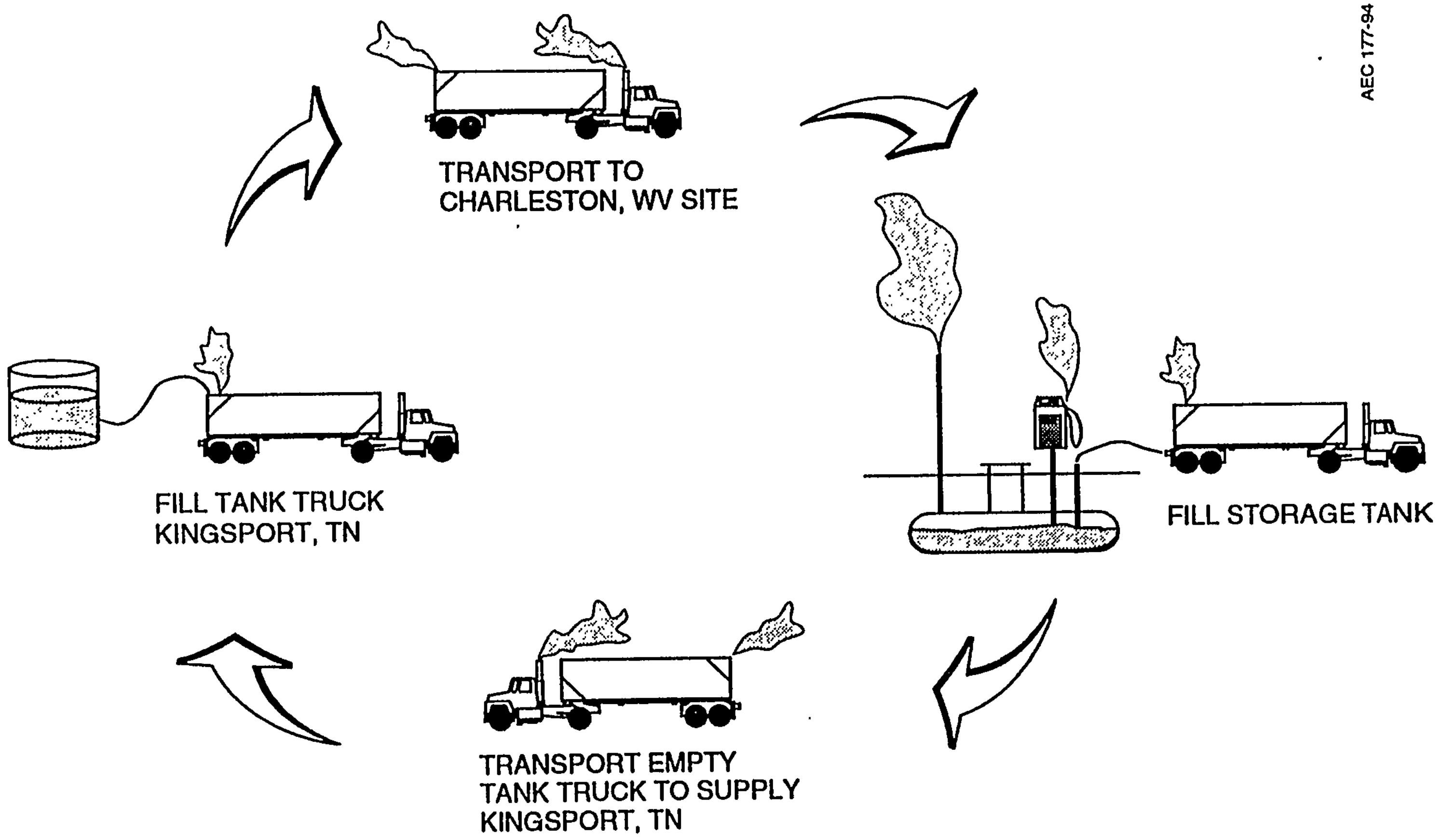


Figure 8-2. Fuel transportation pathway for West Virginia offsite test facility

The fuel transportation is discussed separately from the site-specific impacts of local fuel distribution (applicable to the Los Angeles offsite test facilities), storage, and use, as indicated in Table 8-2. The environmental impacts associated with transporting the fuel methanol to Los Angeles, California, and Charleston, West Virginia, are discussed in Section 8.2. The site-specific environmental impacts for the offsite test facilities are discussed in Sections 8.3 through 8.7. These sections also summarize transportation emissions.

8.1.1 Methanol Spills

Methanol spill hazards have been considered during a public workshop process conducted by California state agencies.[3] During hearings for California's Assembly Bill 234, Dr. Peter D'Eliscu, Professor at West Valley College, discussed methanol spills into bodies of water. He described the impact of methanol on the biota, indicating that some soils contain methanol all of the time. Dr. D'Eliscu believes that the data indicate that species will generally recover from methanol spills. All species eventually recover from methanol spills, although recovery times and severity of impact vary widely. Tolerance depends on the environment and on normal levels of exposure; most areas contain some amount of methanol naturally. In general, methanol spills in surface waters are expected to have less of an impact than petroleum spills and can be treated by increasing ambient oxygen and reseeding.

Actual methanol spills are rare and have not been documented. A typical methanol spill would result in the dispersion of methanol to the soil and surface water. In warm environments, most methanol from a spill would evaporate. Methanol that disperses through the soil would most likely result in some damage to

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[3] *Environmental, Health and Safety Report*, California Advisory Board on Air Quality and Fuels, Volume III, Final Report, 1990.

Table 8-2. Site-specific emissions broken down by transportation and distribution

Site	Fuel Transportation	Fuel Distribution, Storage, and Use
LACMTA	Fill ISO container in Tennessee Truck ISO container to Charlotte, North Carolina Ship ISO container by rail to Los Angeles railyard Return empty ISO container to Tennessee Section 8.2.1	Truck ISO container from railyard to LACMTA Unload fuel Truck ISO container back to railyard Operate buses Section 8.3
Hughes Aerospace		Truck ISO container from railyard to Hughes Aerospace Unload fuel Truck ISO container back to railyard Operate vanpool and firetube boiler Section 8.4
Valley DDC		Truck ISO container from railyard to Valley DDC Unload fuel Truck ISO container back to railyard Operate electric power generator Section 8.5
Utility		Truck ISO container from railyard to utility Unload fuel Truck ISO container back to railyard Operate turbine Section 8.6
KVRTA	Fill tank truck in Kingsport, Tennessee Drive tank truck to Charleston, West Virginia Drive empty truck back to Kingsport, Tennessee Section 8.2.2	Unload fuel Operate buses Section 8.7

the flora and soil organisms which would be similar to a gasoline spill. In the case of a methanol spill, the environment would recover, as methanol rapidly biodegrades.

According to a U.S. Environmental Protection Agency (EPA) study, a methanol spill which reaches the groundwater will disperse rapidly because of its water solubility and rapid aerobic and anaerobic biodegradation.[4] A methanol spill could potentially create a toxic problem if the concentration remains above approximately 1,000 ppm. However, it is believed that any realistic spill scenario would not cause these high concentrations of methanol in the groundwater.

8.1.2 Methanol Flammability

Methanol's physical characteristics and flammability have been compared to other liquid fuels such as diesel, gasoline, and M85.[5] Methanol ignites much less readily in open and restricted spaces than gasoline, and the vapor produced is dispersed more rapidly. Methanol has the highest autoignition temperature of these four fuels and is therefore the least likely to surface ignite. However, based on its fuel properties, methanol is the most likely to ignite in an enclosed space. In order to prevent this occurrence in the fuel tank of a vehicle, a number of preventive measures can be taken to modify the fuel system. One such effective measure is to install a bladder type fuel tank such as used in airplanes and race cars.

In the case of a fire, methanol fires are less severe than gasoline or diesel fires. The low heat release makes the fire less likely to spread and cause personal injury. One key concern with pure methanol is the invisibility of its flame under well-lit conditions, which could lead to situations in which people would be unaware of an existing fire. It has been noted that "the flame is clearly visible at night and in less

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[4] *Flammability and Toxicity Tradeoffs with Methanol Fuels,* SAE Technical Paper Series 872064.

[5] Ibid.

than fully lit conditions."[6] In addition, virtually anytime there is spilled fuel, the spill occurs on a combustible material which burns along with the methanol, providing smoke and a visible flame. The methanol flame can be made luminous throughout the length of the burn by adding aromatic hydrocarbons, as in gasoline; to date, this has only been successful when 15% gasoline has been added, forming M85. Aside from the issue of flame visibility, methanol fires are easier to extinguish than gas or diesel and do not produce the thick heavy black smoke characteristic of those fires, a hazard to firefighters.

8.1.3 Methanol Toxicity

The EPA study[7] also compared the toxic effects of the four fuels through contact mechanisms of inhalation, skin contact, and ingestion. Like gasoline, methanol is very toxic if high concentrations are inhaled. Methanol is also a severe hazard if it is absorbed into the skin in high amounts. Like both gasoline and diesel, methanol is highly toxic if ingested. However, unlike gas or diesel, methanol does occur naturally in the human body and there are antidotes to ingestion. One drawback of methanol is its lack of color, taste, or odor, which would provide a warning. Several different additives have been proposed for this reason, including hydrocarbons (as in M85), mercaptans for odor and a blue-violet dye for color (currently in use in Sweden), as well as bitrex, the most bitter substance known to man, for taste.

8.2 FUEL TRANSPORTATION

The fuel methanol produced in Kingsport, Tennessee, is shipped to the Los Angeles and Charleston offsite test facilities. All of the Los Angeles area offsite test facilities share the same fuel transportation pathway from the point of fuel methanol

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[6] Ibid.

[7] *Flammability and Toxicity Tradeoffs with Methanol Fuels,* SAE Technical Paper Series 872064.

manufacture in Tennessee to delivery in Los Angeles. The impacts of this common fuel transportation pathway are presented in Section 8.2.1. The resulting air quality impacts due to this pathway have been apportioned to the individual offsite test facilities in the Los Angeles area according to the amount of the fuel methanol delivered to each site. Site-specific impacts — arising from local distribution, storage, and use of the fuel methanol — for each of the Los Angeles area offsite test facilities are discussed in Sections 8.3 through 8.6. Similarly, the impacts from the fuel transportation pathway for the Charleston, West Virginia, site are discussed in Section 8.2.2, and the localized site-specific impacts for this offsite test facility are discussed in Section 8.7.

8.2.1 Fuel Transportation to the Los Angeles Area Offsite Test Facilities

All of the Los Angeles area offsite test facilities share the same fuel transportation pathway from the point of fuel methanol manufacture in Tennessee to delivery in Los Angeles. The basic elements of the fuel methanol transportation pathway to Los Angeles are shown in Figure 8-1 and are as follows:

- Loading the fuel methanol into ISO containers at Kingsport, Tennessee
- Trucking the ISO containers to the railyard in Charlotte, North Carolina
- Shipping the ISO containers by rail to Los Angeles, California
- Returning the empty ISO containers by rail and truck to Kingsport, Tennessee

Current transportation plans for the shipment of the fuel methanol by this pathway include a travel distance of 462 miles by truck (231 miles each way from Kingsport, Tennessee, to Charlotte, North Carolina) and 7,248 miles by rail (3,624 miles each way from Charlotte, North Carolina, to Los Angeles, California).

After reaching the railyard in Los Angeles, the ISO containers holding the fuel methanol will be trucked to the individual demonstration sites where the fuel will be unloaded and stored for end use. The impacts associated with the local distribution and use of the fuel methanol at each of the individual demonstration sites, as well as those due to the current use of baseline fuels in the existing environments, are discussed in the sections for each offsite test facility.

Air Quality Impacts

The air quality impacts associated with the transportation of fuel methanol from Kingsport, Tennessee, to Los Angeles, California, arise from the following:

- Evaporative losses from the loading of the ISO containers
- Evaporative losses from the breathing of the ISO containers
- Exhaust emissions from the diesel trucks used to transport the ISO containers to Charlotte, North Carolina
- Exhaust emissions from the locomotives used to haul the ISO containers to Los Angeles

Returning the empty ISO containers to Tennessee has the following air impacts:

- Evaporative losses from the breathing of the ISO containers
- Exhaust emissions from the locomotives used to haul the ISO containers from Los Angeles, California, to Charlotte, North Carolina
- Exhaust emissions from the diesel trucks used to transport the ISO containers from Charlotte, North Carolina, to Kingsport, Tennessee

Baseline fuels are those fuels being displaced by the fuel methanol at the offsite test facilities. Because baseline fuels are already available in the Los Angeles area, the emissions associated with their production and shipment to the Los Angeles area were not included in this analysis. Thus, this analysis provides conservative estimates for the relative impact of the proposed project by maximizing the difference between the existing environment and the proposed scenario using fuel methanol. For purposes of this analysis, transportation of baseline fuels to Los Angeles consists only of loading the fuel into tank trucks for local distribution. The air quality impacts from transporting baseline fuels, therefore, are only those associated with the evaporative losses from the loading of fuel into tank trucks.

Evaporative Emissions

Table 8-3 lists several physical properties of gasoline, reformulated gasoline, methanol (M100), fuel methanol, and diesel No. 2. The gasoline and diesel values are taken from Table 4.3-2 of AP-42. The properties of fuel methanol are assumed to be identical to M100. Evaporative emissions from petroleum fuels are considered to be hydrocarbon emissions, while evaporative emissions from the fuel methanol are considered to be 100% methanol. Emission factors for these evaporative emissions are associated with working losses from the loading the tank trucks or ISO containers and breathing losses from the tank during fuel transportation. Working losses associated with transferring the fuel to the onsite tank for storage are accounted for in the local distribution of each site. In the case of M85, fuel methanol will be shipped to the on-site storage tank and gasoline will be shipped separately. The emissions associated with the fuel methanol shipment to be used for M85 fuel will be the same as those for other fuel methanol shipments. The emission factors for working and transit losses are listed in Table 8-3. Each of these emission factors is discussed below.

Working (Loading) Losses

The emission factors for working losses, associated with filling the ISO container with fuel, are calculated from principles of gas equilibrium using the following equation:

$$L_L = n * f * 1{,}000 \text{ gal}/1{,}000 \text{ gal} * MW * s * TVP / P$$

where:

L_L = Loading losses (lb/1,000 gal)

n = 1 lb-mole/ 379.6 ft^3 , derived from the ideal gas law at 60°F

Table 8-3. Evaporative emissions from fuel transportation

Parameter	Fuel				
	Gasoline	Reformulated Gasoline (RFG)	M100[a]	Fuel Methanol	Diesel No. 2
RVP (psia)	10.0	7.0	4.5	4.5	~0.022
True vapor pressure at 60°F (psia)	5.2	3.5	1.4	1.4	0.0074
Condensed vapor density (w) (lb/gal) at 60°F	5.1	5.2	6.6	6.6	6.1
MW of vapor	66	68	32	32	130
Saturation factors[b]	1.0	1.0	0.5	1.45	0.6
Emission Factors (lb/1,000 gal)					
Pollutant	HC	HC	Methanol	Methanol	HC
Tank truck loading without vapor controls working loss[c]	8.22	5.7	0.54	1.56	0.014
Tank truck loading with vapor controls working loss[c]	0.41	0.285	N.A.[d]	N.A.	N.A.
Tank truck transit breathing loss[e]	0	0	0	0.049	0
Total evaporative emission factors[f]	0.41	0.285	0.54	1.61	0.014

[a] Refers to methanol used as a fuel in the existing environment.

[b] Saturation factors are from Table 4.4-1 of AP-42 and refer to the type of loading. Gasoline and RFG were assumed to be loaded with a vapor balance system; diesel to undergo submerged loading dedicated normal service, and M100 and fuel methanol to use splash loading.

[c] Loading losses are calculated as shown on page 8-15.

[d] N.A. = Not available.

[e] Gasoline transit losses are "extreme" case transit losses from AP-42 Table 4.4-5; other fuel transit losses have been scaled according to their true vapor pressure and their density at 60°F.

[f] For gasoline and RFG, total is sum of loading losses with vapor controls and transit breathing losses.

f = Conversion factor, 1 ft^3/7.4805 gal

1,000 gal/1,000 gal provides a basis of 1,000 gal fuel

MW = Molecular weight, lb/lb-mole

s = Saturation factor (dimensionless), from Table 4.4-1 of AP-42, for calculating petroleum liquid loading losses (see Table 8-4)

TVP = True vapor pressure at 60°F (psia)

P = Atmospheric pressure = 14.7 psia

In using the above equation, several implicit assumptions are made. First, the temperature is assumed to remain constant at 60°F during the loading operation. This temperature is consistent with baseline assumptions in AP-42. Since vapor is transferred from stationary storage tanks with stable fuel temperatures, this temperature appears reasonable. Secondly, the saturation factors, s, are used for all fuels, even methanol, which is not a petroleum liquid. Table 8-4 summarizes the saturation factors that apply to fuels for this project. These saturation factors are EPA-suggested values developed from the principles of equilibrium. There are no values suggested for methanol, but the factors that affect equilibrium should be the same for methanol and gasoline. An s factor associated with any type of fuel loading that uses a vapor balance system is 1.0. A saturation factor for splash loading of a clean cargo tank was assumed for loading methanol into ISO containers. This value is greater than the s for vapor balance fuel transfer, and therefore provides a greater degree of conservatism. Baseline M100 tank trucks are filled in Los Angeles without vapor recovery. In this case, clean truck tanks are bottom filled at the storage terminal, which results in a saturation factor of 0.5. Gasoline trucks are filled using vapor recovery systems.

All loading losses are calculated with vapor controls where appropriate, assuming 95% efficiency of the vapor control. Thus, controlled working loss emission factors are calculated from the following:

Table 8-4. Saturation factors (s) for loading of tank containers

Mode of Operation	Application	Saturation Factor(s)
Submerged loading of a clean tank	Fill M100 tank truck	0.50
Submerged loading: dedicated service	Fill diesel tank truck	0.60
Splash loading: dedicated service	Fill fuel methanol ISO container	1.45
Vapor balance loading	Fill gasoline tank truck	1.0

$$L_L \text{ (control)} = L_L \text{ (uncontrolled)} * (1 - \text{eff}/100)$$

Transit (Breathing) Losses

Evaporative emissions are generated during transit as the fuel resides in tanks. AP-42 contains typical emission values from gasoline truck cargo tanks during transit, compiled from both theoretical and experimental techniques. Evaporative emissions depend upon a number of different parameters that affect the extent of venting from the cargo tank during transit, including the following:

- Vapor tightness of the tank
- Pressure relief valve settings
- Tank pressure at trip start
- Fuel vapor pressure
- Degree of fuel vapor saturation of space in tank

The fuel vapor pressure is the one variable that is known, but it varies with temperature. At this time, it is not possible to determine all the other variables for transportation of fuel methanol in the future. AP-42 lists both "typical" values for transit emissions and "extreme" values that could occur in the unlikely event that all determining factors combined to cause maximum emissions.

AP-42 does not contain transit emission factors for methanol, diesel, or reformulated gasoline. No emission factors for tank transit losses of methanol were found in other sources.

However, if we assume a direct correlation between the true vapor pressure of the fuel at a given temperature and the transit losses, we can estimate the evaporative transit emissions of methanol. A correction must also be made for the molecular weight of methanol. For example:

$$L_B = L_{B\ \text{gasoline}} * (\text{TVP} * \text{MW})_{\text{methanol}} / (\text{TVP} * \text{MW})_{\text{gasoline}}$$

where:

L_B emissions are transit emissions of methanol in lb/1,000 gal

$L_{B\ gasoline}$ = Transit breathing loss for gasoline

MW = Molecular weight (proportional to vapor density for ideal gases)

TVP = True vapor pressure of fuel at 60°F

Gasoline "extreme" transit emission losses for petroleum liquid rail cars and tank trucks are listed in Table 4.4-5 of AP-42. Transit losses occur both when the tank is full of liquid fuel and, on the return, when the tank is full of vapors. For 10 psi RVP gasoline, transit losses are 0.08 and 0.37 lb/1,000 gal for loaded and return with vapor operation, respectively. The TVP of gasoline at 60°F is 5.2 psia.

If all other determining factors are held constant, then the evaporative losses of methanol can be estimated using the appropriate molecular weight and true vapor pressure at 60°F. For example, for fuel methanol (TVP = 1.4 psia at 60°F, MW = 32), transit losses are approximated by the following equation:

Loaded with product: $L_{B\ fuel\ methanol} = 0.08 * (1.4 * 32)/ (5.2 * 66)$

$L_{B\ fuel\ methanol} = 0.01$ lb/1,000 gal (methanol)

Return with vapor: $L_{B\ fuel\ methanol} = 0.37 * (1.4 * 32)/ (5.2 * 66)$

$L_{B\ fuel\ methanol} = 0.048$ lb/1,000 gal (methanol)

Figure 8-3 illustrates the basis of the comparison of the impacts of fuel transport to Los Angeles. As shown in the figure, for the baseline (existing) fuels, only the loading of the fuel into the tank truck for local delivery is included in the analysis. This compares with the numerous emission sources included in the proposed project analysis and shown in Figure 8-1. Breathing or transit losses for all fuels except fuel methanol have been neglected; thus, the values of their breathing loss emissions are listed as zero in Table 8-3.

Figure 8-3. Transportation of baseline fuels to Los Angeles

Loading losses are not associated with transferring the ISO container from truck to train and back to a truck, since the fuel methanol is not transferred; only breathing losses are incurred. Evaporative emissions are also associated with transferring the fuel from the truck tank to the onsite storage tank, but these emissions will be estimated for each specific site in later sections.

Exhaust Emissions from Heavy-Duty Diesel Trucks

The emission factors for heavy-duty diesel trucks are calculated, normalizing the emission factors to a basis of 1,000 gallons of methanol delivered. The following equation is used:

$$A_n = B_n * C * D * E$$

where:

A_n = lb of pollutant n emitted per 1,000 gallons of methanol delivered

B_n = Grams per mile emission factor for pollutant n

C = Number of miles traveled per fuel delivery = 231 * 2 = 462 (distance from Kingsport, Tennessee, to Charlotte, North Carolina, and return to Kingsport with empty ISO container)

D = Number of deliveries made per 1,000 gallons of methanol delivered = 0.16 (assumes one delivery made with each ISO container carrying 6,250 gal of fuel)

E = lb per gram conversion factor = 0.0022

The values for the emission factors B_n and A_n are shown in Table 8-5.

The emission factors for HC, CO, and NO_x in Table 8-5 were derived from AP-42 values from Table 1.7.1, for nontampered exhaust emission rates for low-altitude heavy-duty diesel-powered vehicles. Vehicles of the model years 1991-2000

Table 8-5. Heavy-duty truck emission factors for fuel methanol transport

Emissions Parameter	Fuel	Fuel Economy (mpg)	Criteria Pollutants				
			HC	CO	NO_x	PM	SO_x
Emission factor (g/mi) B_n	No. 2 Diesel	5.3[a]	2.10[b]	9.93[b]	8.01[b]	1.21[c]	0.61[d]
Emission (lb/1,000 gal fuel methanol delivered) A_n	No. 2 Diesel	5.3[a]	0.34	1.61	1.30	0.20	0.10

[a] Based on the 1988 average for heavy-duty combination trucks in the U.S.[8]

[b] Emission factors for model year 1991-2000 heavy-duty diesel trucks with 50,000 miles.[9]

[c] Engineering estimate, based upon typical particulate formation from diesel engines where 0.2 wt % of fuel converts to particulate matter.[10]

[d] Engineering estimate, expressed as SO_2, based upon sulfur content of the fuel at 0.05 wt %.[11]

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[8] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

[9] *Supplement A to Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources,* AP-42, January 1991.

[10] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[11] Ibid.

with 50,000 miles were used as an appropriate basis. The AP-42 emission factors were developed using a basic test procedure that assumes the following:

- Average speed of 20.0 mph, with 36% idle operation
- Average trip length of 6.4 miles
- NO_x emissions uncorrected for humidity

The emissions for each individual pollutant are calculated from the following equation:

$$\text{Emissions of pollutant i} = TF * SCF * BER$$

where:

F = Travel weighting fraction = 1 in this case (individual trucks, not an entire fleet)
SCF = Speed correction factor
BER = Base emission rate, found in Table 1.7.1 of AP-42

The speed correction factor would be calculated from the following equation (Table 1.7.6 of AP-42):

$$SCF (s) = EXP (A + B * s + C * s^{2)}$$

where:

s = Average speed in mph

Table 1.7.6 lists the coefficients A, B, and C for the three pollutants. For example, the most conservative value of SCF would be based on a speed s of 2.5 mph. (This correlation for SCF is only valid in the range of 2.5 to 55 mph). To illustrate the effect of speed on overall emissions, the speed correction factors for HC, CO, and

NO_x, calculated from s = 2.5 mph, are shown in Table 8-6. In our estimations of actual emissions, an SCF of 1.0 was used, because the actual average speed is probably greater than 25 mph. The truck will travel on the freeway, but the actual driving cycle is unknown. In this case, an SCF = 1.0 is conservative because the actual truck speed is greater than 25 mph.

According to EPA, in the AP-42 document[12], heavy-duty diesel-powered vehicles have insignificant crankcase and all other evaporative HC emission components. Furthermore, heavy-duty diesel vehicles are not subject to the type of tampering used to develop emission factors for light-duty vehicles, and no tampering offsets are added to diesel vehicle emission factors. The temperature effect on the emissions from these vehicles is considered relatively insignificant; as there are no quantitative data on these effects, no temperature correction factor is used.

AP-42 contains no emission factors for PM or SO_X. Approximately 0.2 wt % of the diesel fuel burned in the engine forms directly emitted particulate.[13] Thus, the emissions of PM may be estimated from the following equation:

$$\text{PM emissions} = \rho\ /\text{mpg} * 0.002 \text{ lb PM/lb diesel} * 453.6 \text{ g/lb}$$

where:

ρ = Density of diesel No. 2 = 7.1 lb/gal at 60°F

mpg = 5.3 mi/gal[14]

PM emissions = 1.21 g/mi

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[12] *Supplement A to Compilation of Air Pollutant Emission factors, Volume II: Mobile Sources (January 1991), Chapter 7, Heavy-Duty Diesel-Powered Vehicles.*

[13] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[14] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

Table 8-6. Sample speed correction factors for heavy duty diesel trucks (2.5 mph)

Pollutant	Speed(s) (mph)	SCF
HC	2.5	0.789
CO	2.5	3.26
NO_x	2.5	2.2

Similarly, SO_2 emissions are estimated using the sulfur content of the on-road fuel, assumed to be 0.05 wt %.[15] Assuming that all of the sulfur is converted to SO_2, the emissions are calculated from the following equation:

$$SO_2 \text{ emissions} = \rho/\text{mpg} * 0.0005 \text{ lb S/lb diesel} * 453.6 \text{ g/lb} * 2.0 \text{ g } SO_2/\text{g S}$$
$$= 0.61 \text{ g/mi}$$

where:

ρ and mpg are as defined above and 2.0 is the ratio of the molecular weights of SO_2 to S.

Exhaust Emissions from Freight Train Locomotives

The emission factors for freight train locomotives in terms of lb of pollutant emitted per 1,000 gallons of methanol delivered are calculated from the equation:

$$F_n = G_n * H * I * J$$

where:

F_n = lb of pollutant n emitted per 1,000 gallons of methanol delivered

G_n = lb of pollutant n emitted per gallon of diesel fuel consumed by the locomotive

H = Gallons of diesel fuel consumed per revenue ton mile = 0.00282 (based on the 1992 average for US rail freight).[16]

I = Revenue ton miles per ISO container

J = ISO containers used per 1,000 gallons of methanol delivered = 0.16

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[15] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[16] *Railroad Facts, 1993 Edition,* Association of American Railroads.

I, the revenue ton miles per ISO container, is calculated per round trip. The weight of the fuel methanol = 6,250 gal x 6.6 lb/gal/2,000 lb/ton = 20.6 tons. The container weight is 4.4 tons. The total round trip distance traveled is 7,248 miles (based on a distance of 3,624 miles from Charlotte, North Carolina, to Los Angeles, California). The total weight shipped is the weight of the fuel methanol plus twice the ISO container weight (since the empty ISO container is shipped back) = 20.6 + (4.4 x 2) = 29.4 tons. Thus:

$$I = 29.4 \text{ tons} \times 3{,}624 \text{ miles} = 106{,}500 \text{ ton miles/ISO container}$$

The emission factors F_n and G_n are shown in Table 8-7. AP-42 lists the average emission factors G_n as well as emission factors for five specific engine categories. At this time, it cannot be determined which locomotive engine will be used. The individual engine types vary in the severity of their emissions depending upon the pollutant; for example. one engine may produce high levels of CO compared to the other engines, but may produce relatively low emissions of hydrocarbons. Thus, in order to produce realistic yet conservative emissions estimates, the average values are used to ensure that the emission factors will be representative of actual conditions.

Air Quality Impacts Summary for Fuel Transportation

Table 8-8 summarizes the emission factors for the transportation of the fuel methanol to the Los Angeles area. These emission factors are a sum of the evaporative losses, diesel truck exhaust from transport to North Carolina, and locomotive exhaust from shipping to Los Angeles by rail. The emissions from returning the empty ISO container tank are also included. The fuel methanol emission factors are compared with emission factors associated with the existing

Table 8-7. Average locomotive emission factors

Freight Train Locomotive Emissions Parameter	Criteria Pollutant				
	HC	CO	NO_x as NO_2	PM	SO_x as SO_2[a]
Emission factor[17] (lb/gal diesel fuel consumed) G_n[18]	0.094	0.130	0.370	0.025	0.057
Emissions (lb/1,000 gal fuel methanol delivered) F_n	9.04	12.50	35.57	2.40	5.48

[a]Based on a fuel sulfur content of 0.4 percent.

Table 8-8. Summary of emission factors for transport to Los Angeles

Fuel	Emission Factors (lb/1,000 gal of fuel delivered)					
	HC	Methanol	CO	NO_x	PM	SO_x
Fuel Methanol	9.38	1.61	14.11	36.87	2.60	5.58
Gasoline	0.41	0	0	0	0	0
Reformulated gasoline	0.28	0	0	0	0	0
M100[a]	0	0.54	0	0	0	0
Diesel No. 2	0.014	0	0	0	0	0
Natural gas	0	0	0	0	0	0

[a]M100 signifies methanol used as an existing fuel.

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[17] *Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources,* AP-42, Fourth Edition, September 1985.

[18] Ibid, Table II-2.1.

(baseline) fuels. For the purposes of a conservative comparison, the environmental impact of transportation to Los Angeles for all other existing fuels besides fuel methanol are neglected; only evaporative emissions associated from loading the existing baseline fuels into tank trucks in Los Angeles are considered. These evaporative emissions from loading in Los Angeles are calculated as shown previously. Fuel methanol evaporative emissions are pure methanol; evaporative emissions from the other types of existing fuels are hydrocarbon (HC) substances. Since natural gas, the baseline fuel for utility turbines, is transported by pipeline, the emissions associated with its transportation are minimal. Emissions associated with the transportation of natural gas that are consistent with the point of delivery for the other fuels are zero.

This section identifies the emissions associated with transportation of fuel methanol and baseline fuels. The transportation stage results in a full ISO container or tank truck that is ready to deliver fuel to a site. The air quality impacts which are due to the final delivery of the fuels by trucks to the end-use sites will be included in the analysis of the site specific impacts for each of the Los Angeles area demonstration projects.

To calculate the projected air quality impacts due to the transportation of the fuel methanol from Kingsport to the railyard in Los Angeles, the overall transportation emission factors for fuel methanol are multiplied by the proposed quantities of fuel methanol (in thousands of gallons) to be delivered to each of the Los Angeles area offsite test facilities:

$$\text{Emissions (lb)} = \text{Emission factor (lb/1,000 gal)} * \text{Quantity of fuel (1,000 gal)}$$

The total emissions due to transport of fuel methanol to Los Angeles are summarized in Table 8-9. Similarly, to calculate the transportation air quality impacts of the

Table 8-9. Air quality impacts due to fuel methanol transportation to Los Angeles

Site	Demonstration Project	Fuel	Quantity (gal)	Emissions (lb)					
				HC	Methanol	CO	NO_x	PM	SO_x
LACMTA	Transit buses	Fuel methanol	60,000	562.8	96.6	846.6	2,212.2	156	334.8
Hughes Aerospace	Vanpool	Fuel methanol	20,000	187.6	32.2	282.2	737.4	52	111.6
		RFG	3,530[a]	1.0	0	0	0	0	0
	Firetube boiler	Fuel methanol	20,000	187.6	32.2	282.2	737.4	52	111.6
Valley DDC	Standby electric power generator	Fuel methanol	20,000	187.6	32.2	282.2	737.4	52	111.6
Southern California Utility	Utility turbine	Fuel methanol	200,000	1,876	322	2,822	7,374	520	1,116
Totals		Fuel methanol	320,000	3,001.6	515.2	4,515.2	11,798.4	832	1,785.6
		RFG	3,530	1.0	0	0	0	0	0

[a] Quantity of RFG needed to make/blend M85 from 20,000 gallons of methanol.

existing baseline fuels (from tank truck loading only, since transportation to Los Angeles has been neglected for these fuels) the evaporative emission factors for these fuels are multiplied by the quantities of fuel which would be displaced by the proposed project. Table 8-10 summarizes the air quality impacts due to existing fuel transportation to Los Angeles.

8.2.2 Fuel Transport to Charleston, West Virginia, Offsite Test Facility

The basic elements of the fuel methanol transportation pathway to the Charleston, West Virginia, offsite test facility are shown in Figure 8-2 and are as follows:

- Loading the fuel methanol into a tank truck at Kingsport, Tennessee
- Trucking the fuel to the site in Charleston, West Virginia
- Returning the empty tank truck to Kingsport, Tennessee

Current transportation plans for the shipment of the fuel methanol by the pathway include a travel distance of 418 miles by tank truck (209 miles each way from Kingsport, Tennessee, to Charleston, West Virginia).

After reaching the offsite test facility in Charleston, the fuel methanol will be unloaded and stored for end use. The impacts associated with the use of the fuel methanol at the site, as well as those due the current use of baseline fuels in the existing environment, are discussed in Section 8.7 as part of the site-specific impacts for the facility.

Air Quality Impacts

The air quality impacts associated with the transportation of fuel methanol from Kingsport, Tennessee, to Charleston, West Virginia, arise from the following:

- Evaporative losses from the loading of the tank trucks
- Evaporative losses from the breathing of the tank trucks
- Exhaust emissions from the diesel tank trucks used to transport the fuel methanol to Charleston, West Virginia

Table 8-10. Air quality impacts due to baseline fuel transportation

Site	Demonstration Project	Fuel	Quantity (gal)	Emissions (lb)					
				HC	Methanol	CO	NO_x	PM	SO_x
LACMTA	Transit buses	Methanol	60,000	0	32.4	0	0	0	0
Hughes Aerospace	Vanpool	Methanol	20,000	0	10.8	0	0	0	0
		RFG	3,530	1.0	0	0	0	0	0
	Firetube boiler	Natural gas	12,880[b]	0	0	0	0	0	0
Valley DDC	Standby electric power generator	Methanol	20,000	0	10.8	0	0	0	0
Southern California Utility	Utility turbine	Natural gas	128,800[b]	0	0	0	0	0	0
Totals		Methanol	100,000	0	54	0	0	0	0
		RFG	3,530	1.0	0	0	0	0	0
		Natural gas	141,680	0	0	0	0	0	0

[a] Quantity of RFG needed to make/blend M85 from 20,000 gallons of methanol.

[b] The units for natural gas quantities are expressed here in terms of therms, not gallons. The conversion is based on energy equivalency, where methanol has 64,000 Btu/gal (HHV) and there are 100,000 Btu/therm. For example, the utility boiler uses 200,000 gal methanol x 64,400 Btu/gal x therm/100,000 Btu = 128,800 therm.

The return of the empty tank trucks back to Tennessee has the following air quality impacts:

- Evaporative losses from the breathing of the tank trucks
- Exhaust emissions from the diesel tank trucks returning to Kingsport, Tennessee, from Charleston, West Virginia

The baseline fuel, neat methanol (M100), is already available in the Charleston area. For purposes of comparing the two fuels, the emissions associated with M100 production and shipment to the Charleston area were not included in this analysis. Thus, this analysis provides conservative estimates by maximizing the difference between the existing environment and the proposed scenario using fuel methanol. For the purposes of this analysis, the transportation of baseline M100 fuel to the Charleston site consists only of loading the fuel into tank trucks and local distribution. The air quality impacts from transporting baseline fuels, therefore, are only those associated with the evaporative losses from loading of the fuel into tank trucks and the exhaust from the diesel tank trucks which provide final delivery to the site.

Evaporative Emissions

The evaporative emissions from fuel methanol are considered to be 100% methanol. Emission factors for these evaporative emissions are associated with working losses from the loading of the tank trucks and breathing losses from the tanks during transportation. Working losses associated with transferring the fuel to the onsite tank for storage are accounted for in the site specific impacts. The assumptions and calculations used to develop the emission factors for these evaporative losses are the same as those discussed in Section 8.2.1, and the applicable evaporative emission factors for the proposed fuel methanol and the baseline fuel M100 are those presented in Table 8-3.

Exhaust Emissions from Heavy-duty Diesel Trucks

The emission factors for heavy-duty diesel trucks in terms of lb of pollutant emitted per 1,000 gallons of methanol delivered are calculated from the following equation:

$$A_n = B_n * C * D * E$$

where:

A_n= lb pollutant n emitted per 1,000 gallons of methanol delivered

B_n= Grams per mile emission factor for pollutant n

C = Number of miles traveled per fuel delivery

D = Number of deliveries made per 1,000 gallons of fuel methanol delivered

E = lb/gram conversion factor = 0.0022

It is assumed that the fuel methanol delivery system will utilize the existing infrastructure for fuel delivery, i.e., heavy-duty diesel trucks using low-sulfur diesel No. 2 fuel. Therefore, the emission factors, B_n, are the same for both the proposed project and the existing environment. These values are based on the same parameters, assumptions, and corrective factors as discussed previously in Section 8.2.1 for heavy-duty diesel truck exhaust emissions. The emission factors B_n are listed in Table 8-11.

In the case of the proposed project, the value for C is equal to 418 miles (twice the distance from Kingsport, Tennessee, to Charleston, West Virginia), and the value for D is equal to 0.11765 (based on one delivery made with each tank truck carrying 8,500 gallons of methanol). In the case of the existing environment, the value for C is equal to 10 miles (twice the distance from the local methanol fuel terminal to the offsite test facility in Charleston), and the value for D is equal to 0.11765 for the same reason as stated for the proposed project. The corresponding values for A_n based on these two scenarios are shown in Table 8-11.

Table 8-11. Heavy-duty truck emission factors for fuel transport

Emissions Parameter	Fuel	Fuel Economy (mpg)	Criteria Pollutants				
			HC	CO	NO_x	PM	SO_x
Emission factor (g/mi) B_n	No. 2 Diesel	5.3[a]	2.10[b]	9.93[b]	8.01[b]	1.21[c]	0.61[d]
Proposed project emissions (lb/1,000 gal fuel methanol) A_n	No. 2 Diesel	5.3[a]	0.227	1.074	0.867	0.131	0.066
Existing environment emissions (lb/1,000 gal M100) A_n	No. 2 Diesel	5.3[a]	0.005	0.026	0.021	0.003	0.002

[a] Based on the 1988 average for heavy-duty combination trucks in the U.S.[19]
[b] Emission factors for model year 1991-2000 heavy-duty diesel trucks with 50,000 miles.[20]
[c] Engineering estimate, based upon typical particulate formation from diesel engines where 0.2 wt % of fuel converts to particulate matter.[21]
[d] Engineering estimate, expressed as SO_2, based upon sulfur content of the on-road truck fuel at 0.05 wt %.[22]

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[19] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

[20] *Supplement A to Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources,* AP-42, January 1991.

[21] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[22] Ibid.

Air Quality Impacts Summary for Fuel Transportation

Table 8-12 summarizes the emission factors for the transportation of the fuel methanol to the Charleston, West Virginia, offsite test facility. These emissions are the sum of the evaporative losses and diesel truck exhaust emissions. The emissions from returning the empty tank trucks are also included. The fuel methanol emission factors are compared with emission factors associated with the existing M100 fuel. Fuel methanol and M100 evaporative emissions are pure methanol, and are calculated as shown previously.

To calculate the projected air quality impacts due to the transportation of the fuel methanol from Kingsport, Tennessee, to the Charleston, West Virginia, site, the overall transportation emission factors for fuel methanol are multiplied by the proposed quantities of fuel methanol (in thousands of gallons) to be delivered to the offsite test facility:

$$\text{Emissions (lb)} = \text{Emission factor (lb/1,000 gal)} * \text{Quantity of fuel (1,000 gal)}$$

The total emissions due to transport of fuel methanol and the existing M100 are summarized in Table 8-13.

8.2.3 Permits/Regulations for Methanol Transport

Methanol is regulated by U.S. Department of Transportation Hazardous Materials Regulations as a Class 3 hazard FLAMMABLE LIQUID, UN1230, in domestic transportation published under 49 CFR:

- Part 172, (especially 172.101 which lists methanol)
- Part 173 (Shippers Requirements, especially 173.150 and 173.242)
- Part 174 (Railroad Handling, especially 174.63)
- Part 177 (Carriage by Highway)

Table 8-12. Summary of emission factors for fuel transport to Charleston, West Virginia

Fuel	Emissions Source	Emission Factors (lb/1,000 gal of fuel delivered)					
		HC	Methanol	CO	NO_x	PM	SO_x
Fuel methanol	Evaporative losses	0	1.61	0	0	0	0
	Diesel truck exhaust	0.227	0	1.074	0.867	0.131	0.066
	Totals	0.227	1.61	1.074	0.867	0.131	0.066
M100[a]	Evaporative losses	0	0.54	0	0	0	0
	Diesel truck exhaust	0.005	0	0.026	0.021	0.003	0.002
	Totals	0.005	0.54	0.026	0.021	0.003	0.002

[a] M100 signifies methanol used as an existing fuel.

Table 8-13. Air quality impacts due to fuel transportation to Charleston, West Virginia

Scenario	Fuel	Quantity (gal)	Emissions (lb)					
			HC	Methanol	CO	NO_x	PM	SO_x
Proposed project	Fuel methanol	80,000	18.16	128.80	85.92	69.36	10.48	5.28
Existing environment	M100	80,000	0.40	43.20	2.08	1.68	0.24	0.16

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Part 178, (especially Subparts H {Specification for Containers for Motor Vehicle Transportation} and J {Specification for Portable Tanks})

8.2.4 Spill/Emergency Response for Methanol Transport

Chemtrech monitors and responds to emergencies and spills relating to hazardous materials transport. They cover transportation for all carriers. Their emergency response number is (800) 424-9300. The fuel transporter, Union Pacific/Bulktainer, also has an emergency response team which will act in the case of any accident or spill which may occur during transit, covering both trucks and rail. The Union Pacific/Bulktainer emergency response team can be reached 24 hours/day, 7 days/week. Air Products also maintains a group of on-call consultants to advise emergency response teams on the necessary measures to take in the event of an accident for a given fuel/cargo. This service is also operational at all times and can be reached at (800) 523-9374.

8.3 LACMTA TRANSIT BUS DEMONSTRATION

This proposed project involves the operation of two transit buses in the Los Angeles area. The transit buses will be standard 40-ft coaches equipped with Detroit Diesel Corporation 6V-92TA engines, running on neat methanol (M100). The methanol version of this engine was the first of its kind to be certified under the 1991 emissions standards for both California and United States general use, rather than having been granted an exemption. Like the diesel version of the 6V-92TA engine, the methanol engine is a two-stroke, direct-injection design. The methanol version operates with a higher compression ratio, special air system components, and glow plugs, and produces 253 hp at 2,200 rpm. The LACMTA currently operates more than 300 methanol-powered transit buses in the Los Angeles area and is expected to increase its operational fleet over the course of the next year.

No construction or installation of methanol-compatible fueling facilities will be required at the LACMTA facility that will operate the fuel methanol demonstration transit buses because a 20,000-gallon underground methanol fuel tank and fuel dispensing system are already in place. Both the ISO containers used to transport the fuel methanol and the underground fuel storage tank at the LACMTA facility are equipped with Stage 1 vapor recovery systems. Stage 1 vapor recovery returns vapor from the fuel storage tank to the tank truck as the vapor is displaced from the fuel storage tank during filling. The LACMTA methanol fuel dispensing system is also equipped with Stage 2 vapor recovery. Stage 2 vapor recovery returns vapor from the vehicle fuel tank to the fuel storage tank as the vapor is displaced from the vehicle fuel tank during filling.

The existing environment is considered to consist of the following operations:

- Hauling M100 from the San Pedro terminal to the LACMTA facility using heavy-duty diesel tank trucks
- Onsite unloading of fuel into an underground storage tank, tank storage, and fuel dispensing operations
- Returning the tank trucks to the San Pedro terminal
- Operating methanol-powered transit buses

The proposed offsite test facility operations are considered to consist of the following:

- Hauling of the ISO containers from the Los Angeles railyard to the LACMTA facility on heavy-duty diesel trucks
- Onsite unloading of fuel into an underground storage tank, tank storage, and fuel dispensing operations
- Hauling the ISO container from LACMTA back to the Los Angeles railyard
- Operating methanol-powered transit buses

The emissions associated with transporting the fuel to the Los Angeles area — in this case, the rail terminal for fuel methanol and the San Pedro terminal for M100 — are estimated in Section 8.2.

8.3.1 Air Quality Impacts

Fuel methanol will displace methanol (M100), so the air quality impacts of both fuel methanol and M100 are examined. The air quality impacts associated with the use of fuel methanol in this transit bus demonstration project arise from the following:

- Evaporative losses from unloading the methanol from the ISO container into the LACMTA storage tank
- Evaporative losses from dispensing the methanol into LACMTA buses
- Evaporative losses from methanol storage tank breathing
- Exhaust emissions from the diesel trucks (using low-sulfur fuel) during round trip transport of the ISO containers from the railyard to the LACMTA facility
- Exhaust emissions from the regular duty operation of the methanol transit buses

The air quality impacts associated with the use of the baseline fuel (methanol, M100) in the existing environment arise from these same sources, except that the diesel truck exhaust emissions will come from tank trucks instead of trucks hauling ISO containers.

Evaporative Emissions

Site-associated evaporative emissions of both fuel methanol and M100 are due to the following:

- Unloading the fuel from tank trucks or ISO containers into an underground fuel storage tank
- Underground tank breathing

- Vehicle refueling: displacement and spillage

Evaporative losses associated with filling the underground storage tank (loading losses) are calculated in the same manner as presented in Section 8.2. This method is applicable in this case also because it is derived from first principles and does not depend on any tank-specific parameters. Gasoline and methanol unloading systems will consist of a vapor balance system; therefore the appropriate saturation factor, s, for these fuels is 1.0. Diesel loading systems are submerged loading systems (s =0.6). The specific emission factor associated with losses for each type of fuel are listed in Table 8-14.

Vapor emissions also come from underground tank breathing (breathing losses), which are due to fuel evaporation and barometric pressure changes. The frequency of fuel withdrawal affects the quantity of these emissions, because fresh air enhances evaporation. AP-42[23] lists an emission factor for underground tank breathing and emptying for gasoline. The AP-42 values for gasoline were corrected for true vapor pressure at 60°F and the vapor molecular weight (related to the fuel density of an ideal gas) for methanol emissions. 60°F is a reasonable temperature because the underground storage tanks remain at a fairly constant temperature. Breathing losses are calculated according to the following equation:

$$L_{UST} = EF_{gasoline} * MW_{methanol}/MW_{gasoline} * TVP_{methanol}/TVP_{gasoline}$$

where:

L_{UST} = Evaporative losses from the underground storage tank

EF = The breathing loss emission factor for gasoline from AP-42

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[23] *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources,* AP-42, Fourth Edition, Table 4.4-7, September 1985.

Table 8-14. Evaporative emission factors for the LACMTA facility

Parameter	Fuel			
	Gasoline	M100[a]	Fuel methanol	No. 2 Diesel
RVP (psia)	10.0	4.5	4.5	~0.022
True vapor pressure at 60°F (psia)	5.2	1.4	1.4	0.0074
Condensed vapor density (w) (lb/gal) at 60°F	5.1	6.6	6.6	6.1
MW of vapor	66	32	32	130
Saturation factors[b]	1.0	1.0	1.0	0.6
Emission Factors (lb/1,000 gal)				
Pollutant	**HC**	**Methanol**	**Methanol**	**HC**
Tank truck unloading without vapor controls working loss[c]	8.22	1.07	1.07	0.014
Tank truck unloading with vapor controls working loss[c]	0.41	0.054	0.054	N.A.[d]
Underground tank breathing	1.0	0.13	0.13	~ 0
Vehicle fueling working loss	1.1	0.144	0.144	0.002
Vehicle fueling spillage[e]	0.7	0.82	0.82	0.89
Total Evaporative Emission Factors[f]	3.21	1.15	1.15	0.91

[a] Refers to methanol used as a fuel in the existing environment.

[b] Saturation factors are from Table 4.4-1 of AP-42 and refer to the type of loading. Gasoline and methanol are loaded using a vapor balance system; diesel is loaded using a submerged loading system.

[c] Unloading losses are calculated as described in Section 8.2.

[d] N.A. = Not available.

[e] Gasoline spillage losses are from AP-42 Table 4.4-7; methanol and diesel losses have been corrected for density at 60°F (based on values from Table 4.3-2 of AP-42):

0.7 lb/1,000 gal x 6.6 lb/gal / 5.6 lb/gal = 0.82 lb/1,000 gal.

[f] Totals are based on vapor controls.

MW = The vapor molecular weight

TVP = The true vapor pressure in psia at 60°F

For example, an underground storage tank filled with methanol would have the following emission factor for evaporative losses from underground tank breathing:

$$L_{UST} = 1.0 \times 32/66 \times 1.4/5.2 = 0.13 \text{ lb methanol/1,000 gal}$$

Refueling activities also produce evaporative emissions from vapors displaced from the vehicle tank by dispensed fuel. According to AP-42, the quantity of displaced vapors depends on fuel temperature, fuel tank temperature, vapor pressure, and dispensing rate. AP-42 contains an emission factor for gasoline vehicle displacement losses, but does not have any emission factors for methanol displacement. Therefore, the AP-42 value is corrected for vapor pressure and density of methanol (at 60°F):

$$L_{dispensing} = EF_{gasoline} * MW_{methanol}/MW_{gasoline} * TVP_{methanol}/TVP_{gasoline}$$

where:

$L_{dispensing}$ are the dispensing losses and all other terms are defined as above

During fuel dispensing into vehicles, vapor recovery systems will be used to capture vapors with a vapor return hose (Stage 1 vapor recovery). Methanol is dispensed onto vehicles with vapor return lines from the vehicles (Stage 2 vapor recovery).

AP-42 defines spillage loss as "contributions from prefill and postfill nozzle drip and from spit-back and overflow from the vehicle's fuel tank filler pipe during filling." Spillage loss depends upon several factors including service station characteristics, tank configuration, and operator techniques. AP-42 does not list emission factors specifically for spillage of methanol. However, the volume of spillage during vehicle fueling should be independent with respect to fuel type. Thus, by assuming a constant volume spilled per gallon dispensed, the emission factor for spillage is corrected for density to reflect each specific fuel. Since spilled fuel lands on the vehicle or pavement, the spillage is counted as an evaporative emission.

Table 8-14 summarizes the emission factors for tank truck unloading, underground breathing, and fuel dispensing and spillage.

Exhaust Emissions from Heavy-duty Diesel Trucks

The emission factors for heavy-duty diesel trucks in terms of lb of pollutant emitted per 1,000 gallons of methanol delivered are calculated from the equation:

$$A_n = B_n * C * D * E$$

where:

A_n = lb of pollutant n emitted per 1,000 gallons of methanol delivered
B_n = Grams per mile emission factor for pollutant n
C = Number of miles traveled per fuel delivery
D = Number of deliveries made per 1,000 gallons of methanol delivered
E = lb per gram conversion factor = 0.0022

It is assumed that the fuel methanol delivery system will utilize the existing infrastructure for fuel delivery, i.e., heavy-duty diesel trucks using low-sulfur diesel No. 2. Therefore, the emission factors, B_n, are the same for both the proposed project and the existing environment. These values are based on the same parameters, assumptions, and corrective factors discussed in Section 8.2 for heavy-duty diesel truck exhaust emissions. The emission factors B_n are listed in Table 8-15.

In the case of the proposed project, the value for C is equal to 16 miles (twice the distance from the railyard to the LACMTA facility), and the value for D is equal to 0.16 (based on one delivery made for each ISO container carrying 6,250 gallons of fuel methanol). The environmental impact of shipping fuel methanol to LACMTA will be minimal since only 10 total trips will be required. Since LACMTA is in an industrial area, the trucks are not expected to pass through any residential neighborhoods.

In the case of the existing environment, the value for C is equal to 64 miles (twice the distance from the methanol fuel terminal in San Pedro to the LACMTA facility), and the value for D is equal to 0.11765 (based on one delivery made for each tank truck carrying 8,500 gallons of M100). The corresponding values for A_n based on these two scenarios are shown in Table 8-15.

The values of the emission factors in Table 8-15 use a speed correction factor of 1.0, based on a probable average speed of the trucks of 25 mph.

Methanol Transit Bus Emissions

This demonstration project involves the substitution of chemical-grade methanol with fuel methanol. No published data are currently available that describe the differences, if any, between the emissions of vehicles operating on fuel methanol and chemical-grade methanol. However, for the purposes of this analysis, the most probable scenario has been assumed, that there are no significant differences in the emissions of the criteria pollutants (HC, CO, NO_x, and PM) between chemical-grade methanol and fuel methanol over the same vehicle duty cycle. Therefore, no net air quality impact is anticipated due to the exhaust emissions of the transit buses during their operation on fuel methanol.

Table 8-15. Heavy-duty truck emission factors for the Los Angeles area

			Criteria Pollutants				
Emissions Parameter	**Fuel**	**Fuel Economy (mpg)**	**HC**	**CO**	**NO_x**	**PM**	**SO_x**
Emission factor (g/mi) B_n	No. 2 Diesel	5.3[a]	2.10[b]	9.93[b]	8.01[b]	1.21[c]	0.61[d]
Proposed project emissions (lb/1,000 gal fuel methanol) A_n	No. 2 Diesel	5.3[a]	0.012	0.056	0.45	0.006	0.003
Existing environment emissions (lb/1,000 gal M100) A_n	No. 2 Diesel	5.3[a]	0.035	0.164	0.133	0.020	0.010

[a] Based on the 1988 average for heavy-duty combination trucks in the U.S.[24]

[b] Emission factors for model year 1991-2000 heavy-duty diesel trucks with 50,000 miles.[25]

[c] Engineering estimate, based upon typical particulate formation from diesel engines where 0.2 wt % of fuel converts to particulate matter.[26]

[d] Engineering estimate, expressed as SO_2, based upon sulfur content of the on-road truck fuel at 0.05 wt %.[27]

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[24] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

[25] *Supplement A to Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources,* AP-42, January 1991.

[26] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[27] Ibid.

AP-42 does not include emission factor estimates for transit buses powered by methanol fuel. The original diesel transit bus emission factors in AP-42 were based on chassis dynamometer tests performed over the EPA duty cycle. Similar tests have been performed recently at the LACMTA Emission Testing Facility on methanol transit buses over the Central Business District (CBD) duty cycle. Although different than the EPA cycle, the CBD cycle is representative of the downtown Los Angeles routes which the methanol buses will typically drive. The emission results from these tests should therefore yield good estimates of the in-use emissions (air quality impacts) of the fuel methanol transit buses. Table 8-16 lists composite emission factors from chassis dynamometer testing on LACMTA transit buses with 1992 DDC 6V-92TA methanol engines. For comparison, diesel emission factors are also included in the table.

The emission factors for methanol transit buses in terms of lb of pollutant emitted per 1,000 gallons of methanol consumed are calculated from the equation:

$$F_n = G_n * H * I$$

where:

F_n = lb of pollutant n emitted per 1,000 gallons of methanol consumed
G_n = Grams per mile emission factor for pollutant n
H = Fuel economy (mpg) of the methanol buses = 1.21
I = lb per 1,000 gram conversion factor = 2.205

The values for G_n and F_n are shown in Table 8-16.

Air Quality Impacts Summary for the LACMTA Demonstration

The emissions from the various components of the proposed demonstration project and the existing environment are summarized in Table 8-17. These emissions include the following:

Table 8-16. Methanol transit bus emission factors

Exhaust Emissions Parameter	Fuel Economy (mpg)	Pollutants					
		HC	Methanol	CO	NO_X	PM	SO_X
Methanol emission factor (g/mi) G_n[a]	1.21[b]	0	0.72[c]	0.21	9.60	0.25	0
Diesel emission factor (g/mi)[d]	3.0[b]	20	0	7.1	25.4	1.1	0.60[e]
Methanol-fueled transit bus emissions (lb/1,000 gal) F_n		0	1.92	0.56	25.61	0.67	0
Diesel emissions (lb/1,000 gal)		13.2	0	46.9	167.6	7.26	3.96

[a] Values taken from three sets of tests of CBD cycle results for MTA methanol buses 1291 and 1276 with DDC 6V-92TA engines.[28] Emissions data for M100 buses are based on those buses equipped with the correct engine control software and representing a production engine.

[b] Values are for LACMTA M100 and control diesel buses powered by DDC 6V-92TA engines.[29]

[c] In Reference 28, methanol is reported as HC and measured by FID. This exhaust constituent is primarily methanol.

[d] Values taken from tests of CBD cycle results for LACMTA diesel bus 2039 with DDC 6V-92TA engine.[30]

[e] Engineering estimate, expressed as SO_2, based upon sulfur content of the fuel at 0.05 wt %.[31]

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[28] *Chassis Dynamometer Emissions Testing Results for Diesel and Alternative-Fueled Transit Buses,* SAE Technical Paper Series 931783, SP-982.

[29] *Alternate Fuels Section Status Report, July - September 1992,* Southern California Rapid Transit District (now LACMTA).

[30] Ibid.

[31] *Cost-Effectivness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

Table 8-17. Summary of emission factors for the LACMTA test facility

Emissions Source	Emissions (lb/1,000 gal of fuel methanol delivered and used)					
	HC	Methanol	CO	NO_X	PM	SO_X
Fuel Methanol						
Evaporative losses	0	1.15	0	0	0	0
Heavy-duty diesel Trucks	0.012	0	0.056	0.045	0.006	0.003
Methanol transit buses	0	1.92	0.56	25.61	0.67	0
Fuel transport to Los Angeles	9.38	1.61	14.11	36.87	2.60	5.58
Totals	9.39	4.68	14.73	62.53	3.28	5.58
Methanol (M100)						
Evaporative losses	0	1.15	0	0	0	0
Heavy-duty diesel trucks	0.035	0	0.164	0.133	0.02	0.01
Methanol transit buses	0	1.92	0.56	25.61	0.67	0
Fuel transport	0	0.54	0	0	0	0
Total for M100	0.035	3.61	0.724	25.74	0.69	0.0

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The emissions due to transporting the fuel methanol from Kingsport, Tennessee, to Los Angeles, California or loading the M100 into tank trucks at the San Pedro terminal (see Tables 8-8 and 8-10)

- Heavy-duty diesel truck exhaust emissions due to hauling the fuel methanol ISO containers from the railyard to the LACMTA facility or the tank trucks of M100 from the San Pedro terminal (see Table 8-15)
- The evaporative losses for fuel methanol and the baseline chemical-grade methanol due to onsite fuel unloading, tank breathing, and fuel dispensing (see Table 8-14)
- The methanol transit bus exhaust emissions due to regular operation of the buses (see Table 8-16)

The air quality impacts for the proposed test facility and the existing environment are summarized in Table 8-18. These values were calculated by multiplying the total emission factor for each type of methanol (in Table 8-17) by the respective quantities of fuel (in thousands of gallons) to be delivered and used at the site. The differences between emissions associated with the existing environment and emissions associated with the proposed test facility are denoted as "Delta."

8.3.2 Permits/Regulations for LACMTA Test Facility

LACMTA requires no permits to operate its methanol buses. The DDC 6V-92TA methanol engines are certified for operation by the California Air Resources Board (ARB). Because the LACMTA methanol fueling facilities are already in place and operational, all the necessary permits have been acquired:

- A check-off permit from the Los Angeles City Fire Department for successfully meeting the plan check requirements for underground storage tanks

Table 8-18. Air quality impact summary for the LACMTA project

Scenario	Fuel	Quantity (gal)	Emissions (lb)					
			HC	Methanol	CO	NO_X	PM	SO_X
Proposed project	Fuel methanol	60,000	563.5	280.8	883.8	3,751.8	196.8	334.8
Existing environment	Chemical-grade M100	60,000	2.1	216.6	43.4	1,544.6	41.4	0.6
Delta			561.4	64.2	840.4	2,207.2	155.4	334.2

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A series of permits from the California South Coast Air Quality Management District (SCAQMD) allowing the construction of the fuel tanks, the operation of the fuel tanks, and the dispensing of fuel from the tanks

Copies of these permits are on file at the operating divisions of the LACMTA.

8.3.3 Spill/Emergency Response

The LACMTA has an existing emergency spill response plan in place containing procedures for handling vehicle fuel spills. In the event of a spill, whether it occurs at the bus yard or on the streets of Los Angeles, the LACMTA provides a 24 hours/day, 7 days/week emergency hotline. The hotline can be reached at (213) 972-6111 and is staffed by trained personnel able to direct emergency crews. This service works in concert with the Los Angeles Fire Department and copies of the plan are on file at the operating divisions of the LACMTA.

8.4 HUGHES AEROSPACE VANPOOL

This proposed project involves the operation of five vanpool passenger vans in the Los Angeles area. The vans will be medium- or light-duty vehicles equipped with spark-ignited engines in the 100 to 160 hp range, possibly the Ford 4.9L engine. The vans are projected to be 1996 models that meet ARB transitional low-emission vehicle (TLEV) standards. The vans will be operated on a blend of methanol with 15 percent gasoline (M85). In the proposed project, the fuel methanol will replace the M100 component of the M85 fuel. At the time of the demonstration, the gasoline available in the Los Angeles area will be Phase 2 reformulated gasoline (RFG). Therefore, the gasoline component of the fuel will be the same for the baseline M85 as well as for the proposed fuel methanol M85.

The Hughes Aerospace facility has an existing 20,000-gallon underground tank for the storage of methanol. A separate underground storage tank is used to store gasoline. The methanol and gasoline are blended to make M85 immediately before dispensing fuel into the vehicles.

Both the ISO containers used to transport the fuel methanol and the underground fuel storage tank at the Hughes Aerospace facility are equipped with Stage 1 vapor recovery systems, which return vapor from the fuel storage tank to the tank truck as vapor is displaced from the fuel storage tank during filling. The Hughes Aerospace facility is also equipped with a Stage 2 vapor recovery system, which returns vapor from the vehicle fuel tank to the fuel storage tank as the vapor is displaced from the vehicle during filling.

8.4.1 Air Quality Impacts

Fuel methanol will displace the methanol (M100) in the M85 fuel. The gasoline component of the fuel (RFG) is the same for both types of M85. The air quality impacts of M85 using fuel methanol, and M85 using M100, are compared.

The air quality impacts associated with the use of fuel methanol at this offsite test facility arise from the following:

- Evaporative losses from unloading the fuel methanol from the ISO containers and the RFG from the tank trucks into the Hughes Aerospace facility underground storage tanks
- Evaporative losses from dispensing fuel methanol-M85 into the vans (the fuel methanol and RFG are mixed during dispensing)
- Evaporative losses from fuel methanol and RFG storage tank breathing
- Exhaust emissions from the diesel trucks (using low-sulfur fuel) during transport of the ISO containers from the railyard, and tank trucks from the San Pedro terminal, to the Hughes Aerospace facility
- Exhaust emissions from the regular duty operation of the M85 passenger vans

The air quality impacts associated with the use of the baseline fuel, M85, in the existing environment arise from the same sources as those listed above, with one exception. The diesel truck exhaust emissions will come exclusively from tank trucks instead of trucks hauling ISO containers.

Evaporative Emissions

Site-associated evaporative emissions of fuel methanol-M85 and baseline M85 are due to unloading the fuel from tank trucks or ISO containers into an underground fuel storage tank. Hydrocarbon and methanol vapors will be captured with a vapor return hose (Stage 1 recovery), and fuel is dispensed into vehicles with vapor return lines from the vehicles (Stage 2 recovery). The AP-42 emission factors for tank truck unloading and dispensing of fuel methanol, methanol (M100), RFG, and gasoline are shown in Table 8-19. The evaporative emission factors shown in Table 8-19 were developed based upon the same parameters, assumptions, and corrective factors discussed in Section 8.3.1.

Exhaust Emissions

The exhaust emissions associated with the Hughes Aerospace vanpool offsite test facility are due both to the heavy-duty diesel trucks used for transport of M85 fuel stocks to the Hughes Aerospace facility, and to the passenger van emissions. These exhaust emissions are discussed below.

Heavy-duty Diesel Trucks

The emission factors for heavy-duty diesel trucks used to transport methanol and RFG to the Hughes facility in terms of lb of pollutant emitted per 1,000 gallons of methanol or RFG delivered are calculated from the equation:

$$A_n = B_n * C * D * E$$

Table 8-19. Evaporative emission factors for the Hughes vanpool project

	Emissions (lb/1,000 gal)			
Evaporative Emissions Source	**Gasoline**	**Reformulated Gasoline (RFG)**	**M100**	**Fuel Methanol**
Tank truck unloading with vapor controls working loss	0.41	0.285	0.054	0.054
Underground tank breathing	1.0	0.693	0.13	0.13
Vehicle fueling working loss	1.1	1.463	0.144	0.144
Vehicle fueling spillage	0.7	-	0.82	0.82
Total	3.21	2.441	1.15	1.15

where:

A_n = lb of pollutant n emitted per 1,000 gallons of fuel delivered

B_n = Grams per mile emission factor for pollutant n

C = Number of miles traveled per fuel delivery

D = Number of deliveries made per 1,000 gallons of fuel delivered

E = lb per gram conversion factor = 0.0022

It is assumed that the fuel methanol delivery system will utilize the existing infrastructure for fuel delivery, i.e., heavy-duty diesel trucks using low-sulfur diesel fuel No. 2. Therefore, the emission factors, B_n, are the same for both the proposed project and the existing environment. These values are based on the same parameters, assumptions, and corrective factors discussed in Section 8.2 for heavy-duty truck exhaust emissions.

In the case of the proposed project, the value for C is equal to 36 miles (the round trip distance from the railyard to the Hughes Aerospace facility), and the value for D is equal to 0.16 (based on one delivery made with each ISO container carrying 6,250 gallons of fuel methanol). In the case of the existing environment, the value for C is also equal to 36 miles (the round trip distance from the methanol fuel terminal in San Pedro to the Hughes Aerospace facility), and the value for D is equal to 0.11765 (based on one delivery made with each tank truck carrying 8,500 gallons of methanol). The emission factors A_n and B_n are shown in Table 8-20.

The delivery of RFG to the Hughes site by diesel-fueled tank trucks is the same for both the proposed project and the existing environment. The value for C is equal to 36 miles (the round trip distance from the San Pedro fueling terminal to the Hughes facility), and the value for D is equal to 0.11765 (based on one delivery made for each tank truck carrying 8,500 gallons of gasoline).

Table 8-20. Heavy-duty truck exhaust emissions for the Hughes M85 vanpool

			Criteria Pollutants				
Emissions Parameter	Fuel	Fuel Economy (mpg)	HC	CO	NO_x	PM	SO_x
Emission factors (g/mile) B_n	No. 2 diesel	5.3[a]	2.10[b]	9.93[b]	8.01[b]	1.21[c]	0.61[d]
Proposed Project							
Emissions (lb/1,000 gal fuel methanol delivered) A_n	No. 2 diesel	5.3[a]	0.027	0.126	0.102	0.015	0.008
Emissions (lb 1,000 gal RFG delivered) A_n	No. 2 diesel	5.3[a]	0.020	0.093	0.075	0.011	0.006
Existing Environment							
Emissions (lb/1,000 gal M100 delivered) A_n	No. 2 diesel	5.3[a]	0.020	0.093	0.075	0.011	0.006
Emissions (lb/1,000 gal RFG delivered) A_n	No. 2 diesel	5.3[a]	0.020	0.093	0.075	0.011	0.006

[a] Based on the 1988 average for heavy-duty combination trucks in the U.S.[32]

[b] Emission factors for model year 1991-2000 heavy-duty diesel trucks with 50,000 miles.[33]

[c] Engineering estimate, based on typical particulate formation from diesel engines where 0.2 wt % of fuel converts to particulate matter.[34]

[d] Engineering estimate, expressed as SO_2, based upon sulfur content of the onroad truck fuel at 0.05 wt %.[35]

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[32] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

[33] *Supplement A to Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources,* AP-42, January 1991.

[34] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[35] Ibid.

Passenger Van Emissions

This demonstration project involves the substitution of M100 chemical-grade methanol with fuel methanol (fuel-grade methanol) for the methanol component of M85. No published data are currently available that describe the differences, if any, between the emissions of vehicles operating on fuel methanol and M100. For the purposes of this analysis, the most probable assumption has been made, namely that there are no significant differences in the emissions of the criteria pollutants HC, CO, NO_x, and PM between chemical-grade methanol and fuel methanol over the same vehicle duty cycle. Therefore, no net air quality impact is anticipated due to the exhaust emissions of the passenger van during its operation on an M85 blend of fuel methanol and RFG as compared with baseline M85.

The emission factors for M85-fueled passenger vans in terms of lb of pollutant emitted per 1,000 gallons of fuel consumed are calculated from the equation:

$$F_n = G_n * H * I$$

where:

F_n = lb of pollutant n emitted per 1,000 gallons of M85 consumed

G_n = Grams per mile emission factor for pollutant n

H = Fuel economy (mpg) of the M85 passenger vans = 8.0[36]

I = lb per 1,000 gram conversion factor = 2.205

The values for G_n and F_n are shown in Table 8-21.

AP-42 does not include emission factor estimates for passenger vans powered by methanol or M85. Because the van will be a 1996 model, it is assumed

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[36] Personal communication with Hughes motorpool staff.

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Table 8-21. Passenger van exhaust emission factors

Exhaust Emissions Parameter	Fuel Economy (mpg)	Pollutant				
		HC[a]	CO	NO_x	PM	SO_x
TLEV standard[b] (g/mi) G_n	8.0	0.125	3.40	0.40	0	N.A.[c]
Emissions (lb/1,000 gal M85 fuel consumed) F_n		2.2	59.8	7.05	0	0.96[d]

[a] ARB standard is for non-methane organic gas (NMOG).
[b] ARB 1996 standards for TLEVs.
[c] N.A. = Not available.
[d] SO_x emissions based on sulfur content of RFG at 80 ppm by weight maximum, converted to SO_2.[37]

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[37] ARB, *California Phase 2 Reformulated Gasoline Specifications: Proposed Regulations for RFG, Technical Support Doc.,* October 4, 1991.

that, regardless of its fuel composition, it will meet the ARB TLEV emission standards, shown in Table 8-21. Table 8-21 also shows the TLEV standard converted to emissions in lb/1,000 gal, based on a fuel economy of 8.0 mpg for the vehicle.

Air Quality Impacts Summary for the Hughes Aerospace Vanpool Demonstration

The emission factors for the various components of the proposed demonstration project are summarized in Table 8-22. These emissions include the following:

- Emissions associated with transporting the fuel methanol from Kingsport, Tennessee, to Los Angeles, California (see Table 8-8)
- Evaporative emissions associated with the loading of RFG into tank trucks at the San Pedro terminal (see Table 8-8)
- Heavy-duty diesel truck exhaust emissions from local transport of the ISO containers with fuel methanol from the railyard, and tank trucks with RFG from the San Pedro terminal to the Hughes Aerospace facility (see Table 8-20)
- Evaporative losses of fuel methanol and gasoline due to fuel unloading, tank breathing, fuel mixing, and fuel dispensing (see Table 8-19)
- Exhaust emissions from the regular-duty operation of the fuel methanol-M85 passenger van (see Table 8-21)

For comparison, the emission factors associated with the use of baseline M85 in the passenger vans are also summarized in Table 8-22. These baseline emissions include the following:

- Evaporative emissions associated with the loading of methanol (M100) and RFG into tank trucks at the San Pedro terminal (see Table 8-8)

Table 8-22. Summary of emission factors for Hughes vanpool

Scenario	Fuel	Emissions Source	Emissions (lb/1,000 gal of fuel)					
			HC	Methanol	CO	NO_x	PM	SO_x
Proposed project	RFG	Fuel transport Evaporative losses Truck exhaust	2.74	0	0.093	0.075	0.011	0.006
	Fuel methanol	Fuel transport to Los Angeles Evaporative losses Truck exhaust	9.407	2.76	14.236	36.972	2.615	5.588
	M85	Passenger van operation	0	2.2[a]	59.8	7.05	0	0.96[b]
Existing environment	RFG	Fuel transport Evaporative losses Truck exhaust	2.74	0	0.093	0.075	0.011	0.006
	M100	Fuel transport Evaporative losses Truck exhaust	0.020	1.69	0.093	0.075	0.011	0.006
	M85	Passenger van operation	0	2.2[a]	59.8	7.05	0	0.96[b]

[a] The ARB standard is for non-methane organic gases (NMOG). It is reported here as methanol because that is the primary constituent of the exhaust.

[b] SO_x emissions based on sulfur content of RFG at 80 ppm by weight maximum, converted to SO_2.[38]

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[38] ARB, *California Phase 2 Reformulated Gasoline Specifications: Proposed Regulations for RFG, Technical Support Doc.*, October 4, 1991.

Heavy-duty diesel truck exhaust emissions due to transport of the tank trucks carrying the methanol and gasoline to the Hughes facility (Table 8-20)

- Evaporative losses of methanol and gasoline due to fuel unloading, tank breathing, fuel mixing, and fuel dispensing (see Table 8-19)
- Exhaust emissions from the regular duty operation of the baseline M85-fueled passenger van (see Table 8-21)

The total air quality impacts for the proposed project and the existing environment are summarized in Table 8-23. These values were calculated by multiplying the emission totals in Table 8-22 by the respective quantities of fuel (in thousands of gallons) to be delivered and used at the site. The differences between emissions associated with the existing environment and emissions associated with the proposed project are denoted as "Delta."

8.4.2 Hughes Aerospace Firetube Boiler

A firetube boiler at the Hughes Aerospace facility will be converted from natural gas to operate on fuel methanol. There has been very little operating experience with methanol firing in stationary sources, because until recently, the demand for methanol's environmental benefits was not sufficient to justify the increased cost. However, with the fuel oil phaseout in the South Coast Air Basin, methanol is a viable backup fuel for stationary sources. This demonstration of a fuel-methanol-fired firetube boiler will provide valuable technical experience with methanol combustion in stationary sources.

Air Quality Impacts

Fuel methanol will displace natural gas, so the air quality impacts of both fuels are examined. The air quality impacts associated with fuel methanol use at this offsite test facility arise from the following:

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Table 8-23. Air quality impact summary for the Hughes vanpool

Scenario	Fuel	Quantity (gal)	Emissions (lb)					
			HC	Methanol	CO	NO_X	PM	SO_X
Proposed project	RFG	3,530	9.67	0	0.33	0.26	0.04	0.02
	Fuel methanol	20,000	188.14	55.20	284.72	739.44	52.30	111.76
	M85	23,530	0	51.77	1,407.09	165.89	0	22.59
Totals			197.81	106.97	1,692.14	905.59	52.34	134.37
Existing environment	RFG	3,530	9.67	0	0.33	0.26	0.04	0.02
	M100	20,000	0.4	33.80	1.86	1.50	0.22	0.12
	M85	23,350	0	51.77	1,407.09	165.89	0	22.59
Totals			10.07	85.57	1,409.28	167.65	0.26	22.73
Delta			187.74	21.90	282.86	737.94	52.08	111.64

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Exhaust emissions from the diesel trucks handling local delivery of the ISO containers to the Hughes facility

- Evaporative losses from unloading the fuel methanol from the ISO containers into the Hughes storage tank
- Evaporative losses from fuel storage tank breathing and fueling spillage
- Emissions associated with the operation of the firetube boiler

The air quality impacts associated with the use of the baseline fuel, natural gas, in the existing environment are assumed to consist only of emissions associated with the operation of the firetube boiler. Because the natural gas fuel is piped directly to the boiler facility, local transportation and evaporative emissions are considered negligible and are approximated as zero for the purposes of this analysis.

Evaporative Emissions

Site-associated evaporative emissions of fuel methanol are due to the following:

- Unloading of the fuel methanol from ISO containers into the underground fuel storage tank
- Underground tank breathing
- Boiler fueling losses

For the purposes of this analysis, fuel working losses and spillage losses are assumed to be equivalent to emission factors from AP-42 for vehicle fueling. The evaporative emission factors shown in Table 8-24 were developed based upon the same parameters, assumptions, and corrective factors discussed in Section 8.3.1.

Exhaust Emissions

Exhaust emissions associated with the Hughes Aerospace fuel-methanol-fired firetube boiler demonstration project are due to the heavy-duty diesel trucks

Table 8-24. Evaporative emission factors for the Hughes firetube boiler

Emissions Source	Emissions (lb/1,000 gal fuel methanol)
Tank truck unloading with vapor controls working loss	0.054
Underground tank breathing	0.13
Boiler fueling working loss	0.144
Boiler fueling spillage	0.82
Total	1.15

transporting ISO containers of fuel methanol from the railyard to the Hughes Aerospace facility.

The emission factors for heavy-duty diesel trucks in terms of lb of pollutant emitted per 1,000 gallons of fuel methanol delivered are calculated from the following equation:

$$A_n = B_n * C * D * E$$

where:

A_n= lb of pollutant n emitted per 1,000 gallons of fuel methanol delivered
B_n= Grams per mile emission factor for pollutant n
C = Number of miles traveled per fuel delivery
D = Number of deliveries made per 1,000 gallons of fuel methanol delivered
E = lb per gram conversion factor = 0.0022

The emission factors, B_n, are based on the same parameters, assumptions, and corrective factors discussed in Section 8.2 for heavy-duty diesel truck exhaust emissions.

In the case of the proposed project, the value for C is equal to 40 miles (twice the distance from the railyard to the Hughes facility), and the value for D is equal to 0.16 (based on one delivery made for each ISO container carrying 6,250 gallons of fuel methanol).

The emission factors A_n and B_n are shown in Table 8-25. As a conservative estimate, the emissions associated with transportation of the natural gas, the baseline operating scenario, are assumed to be zero.

Boiler Operation Emissions

Emissions estimates for methanol-fired boilers are not available in AP-42.

Table 8-25. Heavy-duty truck emission factor for the Hughes firetube boiler

Emissions Parameter	Fuel	Fuel Economy (mpg)	Pollutants				
			HC	CO	NO_x	PM	SO_x
Emission factor (g/mile) B_n	No. 2 diesel	5.3[a]	2.10[b]	9.93[b]	8.01[b]	1.21[c]	0.61[d]
Proposed project emissions (lb/1,000 gal fuel methanol) A_n	No. 2 diesel	5.3[a]	0.03	0.14	0.11	0.02	0.01

[a] Based on the 1988 average for heavy-duty combination trucks in the U.S.[39]

[b] Emission factors for model year 1991-2000 heavy-duty diesel trucks with 50,000 miles.[40]

[c] Engineering estimate, based upon typical particulate formation from diesel engines where 0.2 wt % of fuel converts to particulate matter.[41]

[d] Engineering estimate, expressed as SO_2, based upon sulfur content of the onroad truck fuel at 0.05 wt %.[42]

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[39] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

[40] *Supplement A to Compilation of Air Pollutant Emission Factors, Volume II: Mobile Source,* AP-42, January 1991.

[41] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control, SAE Technical Paper Series 870556.*

[42] Ibid.

Therefore, AP-42 emission factors for natural gas are used to approximate the criteria pollutant emissions (CO, PM, and SO_x) from the methanol-fired boiler. The NO_x and HC emissions are estimated by multiplying the AP-42 emission factor for NO_x (or HC) by the ratio of the measured NO_x (or HC) emissions from a methanol-fired utility boiler to NO_x (or HC) emissions from a natural-gas-fired utility boiler.[43] Thus, NO_x and HC emissions are estimated through the following equation:

$$\text{Emissions (lb/1,000 gal)} = \text{EF} \times \text{Ratio} \times \text{HHV} \times 1{,}000$$

where:

EF = AP-42 derived emission factor for NO_x or HC from commercial boilers (lb NO_x/MMBtu natural gas) using HHV of natural gas = 103,000 Btu/scf

Ratio = NO_x from methanol-fired utility boiler (lb/MMBtu)/NO_x from diesel-fired boiler (lb/MMBtu)

HHV = Higher heating value of methanol = 64,800 Btu/gal

The emission factors and emissions estimates based on the above equation are shown in Table 8-26.

Air Quality Impacts Summary

The emission factors for the various components of the proposed project are summarized in Table 8-27. These emissions include the following:

- Emissions associated with transporting the fuel methanol from Kingsport, Tennessee, to Los Angeles, California (see Table 8-8)

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[43] Weir, Alexander, et al., *Investigation of Methanol as a Boiler Fuel for Electric Power Generation,* EPRI Project AP 2554, Southern California Edison Company, Rosemead, California, August 1982.

Table 8-26. Emission factors from operation of the Hughes firetube boiler

Emission Factor	Criteria Pollutants				
	HC	CO	NO_x	PM	SO_x
Natural gas (lb/MMBtu)[a]	0.0058	0.021	0.1	0.012	0.0006
Fuel methanol (lb/MMBtu)[b]	0.0018	0.021	0.0216	0.012	0
Natural gas (lb/100 scf)[c]	0.006	0.002	0.01	0.001	0.00006
Fuel methanol (lb/1,000 gal)[d]	0.117	1.36	1.4	0.78	0

[a] From AP-42, July 1993, for a commercial boiler (0.3 to <10 MMBtu/hr).

[b] Assumed to be same as natural gas for CO and PM. $SO_x = 0$. NO_x and HC emission factors are calculated as product of natural gas emission factor and ratio of methanol/natural gas utility boiler emissions from source test data.

[c] Multiply emission factor by HHV of natural gas = 103,000 Btu/100 scf.

[d] Multiply lb/MMBtu by HHV of methanol = 64,800 Btu/lb.

Table 8-27. Summary of emission factors for the Hughes firetube boiler

Emissions Source	Criteria pollutant emissions (lb/1,000 gal)					
	HC	Methanol	CO	NO_x	PM	SO_x
Proposed project - fuel methanol						
Transport to Los Angeles	9.38	1.61	14.11	36.87	2.60	5.58
Evaporative emissions	0	1.15	0	0	0	0
Heavy-duty diesel trucks	0.03	0	0.14	0.11	0.02	0.01
Fuel-methanol-fired boiler	0.12	0	1.36	1.4	0.78	0
Total	9.53	2.76	15.61	38.38	3.40	5.59
Baseline scenario - natural gas (lb/100 scf)						
Transport to Los Angeles	0	0	0	0	0	0
Evaporative emissions	0	0	0	0	0	0
Heavy-duty diesel trucks	0	0	0	0	0	0
Natural-gas-fired boiler	0.006	0	0.002	0.01	0.001	0.00006
Total	0.006	0	0.002	0.01	0.001	0.00006

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Heavy-duty diesel truck exhaust emissions from local transport of the ISO containers from the railyard to the Hughes facility (see Table 8-25)

- Evaporative losses due to fuel unloading, tank breathing, and fuel dispensing (see Table 8-24)
- Exhaust emissions from the regular-duty operation of the fuel-methanol-fired firetube boiler (see Table 8-26)

For comparison, the emission factors associated with the use of baseline natural gas are also summarized in Table 8-27. The baseline emissions include boiler operation emissions only.

The total air quality impacts for the proposed project and the existing environment are summarized in Table 8-28. These values were calculated by multiplying the total emission factors shown in Table 8-27 by the respective quantities of fuel to be used at the site. The differences between the emissions associated with the existing environment and those associated with the proposed test facility are denoted as Delta in Table 8-28. Because the baseline fuel in this case is natural gas, a volume of gas with an energy content equivalent to 20,000 gallons of methanol has been utilized in calculating baseline emissions for the boiler.

8.4.3 Permits/Regulations

Hughes Aerospace requires no permits to operate its M85 passenger vans, the engines of which are ARB-certified for operation. Likewise, Hughes requires no permits to operate its firetube boiler on methanol rather than natural gas. Because the Hughes Aerospace methanol fueling facilities are already in place and operational, all of the necessary permits have been acquired:

- A check-off permit from the Los Angeles City Fire Department for successfully meeting the plan check requirements for underground storage tanks

Table 8-28. Air quality impacts summary for the Hughes firetube boiler

Scenario	Fuel	Quantity	Emissions (lb)					
			HC	Methanol	CO	NO_x	PM	SO_x
Proposed project	Fuel methanol	20,000 gal	190.6	55.2	312.2	767.6	68.0	111.8
Baseline scenario	Natural gas	1.23×10^6 scf[a]	73.8	0	24.6	123	12.3	0.74
Delta			116.8	55.2	287.6	644.6	55.7	111.1

[a] Based on equivalent energy contents. HHV fuel methanol = 64,800 Btu/gal; HHV natural gas = 103,000 Btu/100 scf.

A series of permits from SCAQMD allowing the construction of the fuel tanks, the operation of the fuel tanks, and the dispensing of fuel from the tanks

Copies of these permits are on file at the Hughes Aerospace facility.

8.4.4 Spill/Emergency Response

Hughes Aerospace must prepare an emergency spill response plan containing procedures on handling vehicle fuel spills. Copies of this plan will be made available at the Hughes Aerospace facility.

8.5 VALLEY DDC STANDBY ELECTRIC POWER GENERATOR

A Valley DDC standby electric power generator, currently fueled with M100, will be operated on fuel methanol. This generator is typically used at construction sites in the Los Angeles area to provide accessory power for work crews. For the purposes of this analysis, the generator is assumed to be equivalent to a DDC 6V-92TA methanol engine, the powerplant upon which it is based. Although the Valley DDC facility currently has a 1,000-gallon aboveground tank, equipped with a Stage 1 recovery system, used for methanol (M100) storage, there are plans to install a 10,000-gallon aboveground storage tank with vapor recovery by the time the proposed project begins.

8.5.1 Air Quality Impacts

Fuel methanol will displace methanol (M100), so the air quality impacts of both fuel methanol and M100 are examined. The air quality impacts associated with the use of fuel methanol at this offsite test facility arise from the following:

- Evaporative losses from unloading the fuel methanol from the ISO containers into the Valley DDC storage tank
- Evaporative losses from dispensing the fuel methanol into the generator
- Evaporative losses from storage tank breathing

- Exhaust emissions from heavy-duty diesel trucks during the round-trip transport of the ISO containers from the railyard to the Valley DDC facility
- Exhaust emissions from the regular operation of the generator

The air quality impacts associated with the use of the baseline fuel (methanol, M100) in the existing environment arise from these same sources, except that the diesel truck exhaust emissions will come from tank trucks instead of trucks hauling ISO containers.

Evaporative Emissions

Site-associated evaporative emissions of both fuel methanol and M100 are due to the following:

- Unloading the fuel from ISO containers or tank trucks into the aboveground storage tank
- Storage tank breathing
- Generator (vehicle) refueling, displacement, and spillage

The evaporative emission factors shown in Table 8-29 were developed based upon the same parameters, assumptions, and corrective factors discussed in Section 8.3.1.

Exhaust Emissions

The exhaust emissions associated with the Valley DDC standby generator offsite test facility are due to the heavy-duty diesel trucks used for transporting the fuel methanol from the railyard to the Valley DDC facility. The emission factors for heavy-duty diesel trucks in terms of lb of pollutant emitted per 1,000 gallons of fuel methanol delivered are calculated from the following equation:

$$A_n = B_n * C * D * E$$

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Table 8-29. Evaporative emission factors for the Valley DDC standby generator

Evaporative Emissions Source	Emissions (lb/1,000 gal)	
	M100	Fuel Methanol
Tank truck unloading with vapor controls unloading loss	0.054	0.054
Tank breathing	0.13	0.13
Vehicle fueling working loss	0.144	0.144
Vehicle fueling spillage	0.82	0.82
Total	1.15	1.15

where:

A_n = lb of pollutant n emitted per 1,000 gallons of methanol delivered

B_n = Grams per mile emission factor for pollutant n

C = Number of miles traveled per fuel delivery

D = Number of deliveries made per 1,000 gallons of methanol delivered

E = lb per gram conversion factor = 0.0022

The fuel methanol delivery system will utilize the existing infrastructure for fuel delivery, i.e., heavy-duty diesel trucks using low-sulfur diesel fuel No. 2. Therefore, the emission factors, B_n, are the same for both the proposed project and the existing environment. These values are based on the same parameters, assumptions, and corrective factors discussed in Section 8.2 for heavy-duty truck exhaust emissions.

In the case of the proposed project, the value for C is equal to 38 miles (twice the distance from the railyard to the Valley DDC facility), and the value for D is equal to 0.16 (based on one delivery made with each ISO container carrying 6,250 gallons of fuel methanol).

In the case of the existing environment, the value for C is equal to 48 miles (twice the distance from the San Pedro terminal to the Valley DDC facility), and the value for D is equal to 0.11765 (based on one delivery made with each tank truck carrying 8,500 gallons of M100). The values of the emission factors A_n and B_n are shown in Table 8-30.

Generator Operation Emissions

Emissions from the standby generator are estimated using AP-42 emission factors for the DDC 6V-92TA engine. AP-42 does not have emission factors for this engine fueled on methanol, but it does contain emission factors for this engine with diesel fuel oil No. 2. Previous bus demonstrations using this engine, however, have measured the emissions from this engine fueled on both diesel fuel No. 2 and

Table 8-30. Heavy-duty truck emission factors for the Valley DDC facility

Emission Parameters	Fuel	Fuel Economy (mpg)	Criteria Pollutants				
			HC	CO	NO_x	PM	SO_x
Emission factors (g/mile) B_n	No. 2 diesel	5.3[a]	2.10[b]	9.93[b]	8.01[b]	1.21[c]	0.61[d]
Proposed project emissions (lb/1,000 gal fuel methanol) A_n	No. 2 diesel	5.3[a]	0.028	0.133	0.107	0.016	0.008
Existing environment emissions (lb/1,000 gal M100) A_n	No. 2 diesel	5.3[a]	0.026	0.123	0.100	0.015	0.008

[a] Based on the 1988 average for heavy-duty combination trucks in the U.S.[44]

[b] Emission factors for model year 1991-2000 heavy-duty diesel trucks with 50,000 miles.[45]

[c] Engineering estimate, based upon typical particulate formation from diesel engines where 0.2 wt % of fuel converts to particulate matter.[46]

[d] Engineering estimate, expressed as SO_2, based upon sulfur content of the onroad truck fuel at 0.05 wt %.[47]

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[44] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

[45] *Supplement A to Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources,* AP-42, January 1991.

[46] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[47] Ibid.

methanol.[48] For the purposes of this analysis, emission factors for a methanol-fueled generator are calculated by multiplying the diesel emission factors from AP-42 for this engine by the ratio of methanol to diesel emissions for each of the criteria pollutants from in-use test data. The following equation summarizes this approach:

$$\text{Emissions (lb/1,000 gal)} = \text{EF} \times \text{Ratio}_n \times \text{mpg} \times \text{C} \times 1{,}000$$

where:

EF = AP-42 emission factor for 6V-92TA engine fueled on diesel fuel No. 2, g/mi

Ratio_n = (g/mi methanol-engine emissions)/(g/mi diesel engine emissions) x (mpg methanol/mpg diesel), for pollutant n (refer to Table 8-16)

mpg = mi/gal diesel = 3.0; mi/gal methanol = 1.2

C = lb/g conversion = 0.0022

The emission factors for the methanol-fired generator developed in this manner are shown in Table 8-31. For comparison, the emission factors for diesel fuel No. 2 from AP-42 are also shown.

This proposed project involves the substitution of chemical-grade methanol with fuel methanol. No published data are currently available that describe the differences, if any, between the emissions of vehicles or engines operating on fuel methanol and chemical-grade methanol. However, for the purposes of this analysis, the most probable scenario — that there are no significant differences in the emissions of the criteria pollutants (HC, CO, NO_x, and PM) between chemical-grade methanol and fuel methanol over the same duty cycle — has been assumed.

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[48] Dunlap, L. S., et al., LACMTA, *Chassis Dynamometer Emissions Testing Results for Diesel and Alternative-Fueled Transit Buses,* SAE Technical Paper Series 931783, SP-982.

Table 8-31. Emissions from operation of the Valley DDC standby generator

Fuel	Fuel economy (mpg)	Criteria Pollutants					
		HC	Methanol	CO	NO_x	PM	SO_x
Diesel No. 2 emission factor (g/mi)[a]	3.0[b]	3.1	0	26.2	27.7	4.77	N.A.[c]
Diesel No. 2 emissions (lb/1,000 gal)	3.0[b]	20.5	0	173	183	31.5	7.19[d]
Methanol emissions (lb/1,000 gal)	1.21[b]	0	2.98[e]	2.1	27.8	2.9	0

[a] AP-42.

[b] Fuel economy values for LACMTA M100 and control diesel buses powered by DDC 6V-92TA engines.[49]

[c] N.A. = Not available.

[d] Engineering estimate, based on maximum sulfur content of diesel = 0.05 wt %, converted to SO_2.

[e] Calculated "hydrocarbon" exhaust emissions for methanol-fueled generator are primarily methanol (see Note c of Table 8-16).

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[49] *Alternate Fuels Section Status Report, July-September 1992,* Southern California Rapid Transit District (now LACMTA).

Therefore, no net air quality impact is anticipated due to the exhaust emissions of the electric generator during its operation on fuel methanol.

Air Quality Impacts Summary

The emission factors from the various components of the proposed project and the existing environment are summarized in Table 8-32. These emissions include the following:

- Emissions associated with transporting the fuel methanol from Kingsport, Tennessee, to Los Angeles, California (see Table 8-8)
- Heavy-duty diesel truck exhaust emissions from local transport of the ISO containers from the railyard to the Valley DDC facility (see Table 8-30)
- Evaporative losses due to fuel unloading, tank breathing, and fuel dispensing (see Table 8-29)
- Exhaust emissions from the regular-duty operation of the fuel-methanol-powered standby electric generator (see Table 8-31)

For comparison, the emission factors associated with the use of the baseline fuel M100 are also summarized in Table 8-32. These emissions include the following:

- Emissions associated with loading the M100 into tank trucks at the San Pedro terminal (see Table 8-8)
- Heavy-duty diesel truck exhaust emissions due to transporting the M100 from the San Pedro terminal to the Valley DDC facility (see Table 8-30)
- Evaporative losses due to fuel unloading, tank breathing, and fuel dispensing (see Table 8-29)
- Exhaust emissions from the regular-duty operation of the fuel-methanol-powered standby electric generator (see Table 8-31)

Table 8-32. Summary of emission factors for the Valley DDC standby generator

Emissions Source	Criteria Pollutant emissions (lb/1,000 gal)					
	HC	Methanol	CO	NO_x	PM	SO_x
Proposed Project — Fuel Methanol						
Transport to Los Angeles	9.38	1.61	14.11	36.87	2.60	5.58
Evaporative emissions	0	1.15	0	0	0	0
Heavy-duty diesel trucks	0.028	0	0.133	0.107	0.016	0.008
Fuel-methanol-powered generator	0	2.98	2.1	27.8	2.9	0
Total for projected project	9.41	5.74	16.34	64.78	5.52	5.59
Baseline Scenario — M100						
Evaporative emissions	0	1.69	0	0	0	0
Heavy-duty diesel trucks	0.026	0	0.123	0.100	0.015	0.008
M100-fueled generator	0	2.98	2.1	27.8	2.9	0
Total for baseline scenario	0.026	4.67	2.22	29.90	2.92	0.008

The air quality impacts for the proposed offsite test facility and the existing environment are summarized in Table 8-33. These values were calculated by multiplying the total emission factor for each type of methanol (in Table 8-32) by the respective quantities of fuel to be delivered and used at the site. The differences between emissions associated with the existing environment and emissions associated with the proposed test facility are denoted as Delta.

8.5.2 Permits/Regulations

No permit is required to use fuel methanol rather than M100 in the Valley DDC standby generator. However, Valley DDC will require the following permits in order to install their planned 10,000-gallon aboveground storage tank:

- A check-off permit from the Los Angeles City Fire Department for successfully meeting the plan check requirements for aboveground storage tanks
- A series of permits from SCAQMD allowing the construction of the fuel tank, the operation of the fuel tank, and the dispensing of fuel from the tank

8.5.3 Spill/Emergency Response

Valley DDC must prepare an emergency spill response plan containing procedures on handling vehicle fuel spills. Copies of this plan will be made available at the Valley DDC facility.

8.6 UTILITY TURBINE

A utility turbine will be converted from natural gas to fuel methanol operation. The utility is located in El Segundo, California, a distance of 20 miles from the Los Angeles railyard terminal.

Although the utility does not currently use methanol to fuel its turbine for electricity generation, there is a methanol underground storage tank onsite to provide methanol as a process fuel for other utility operations.

Table 8-33. Air quality impact summary for the Valley DDC standby generator

Scenario	Fuel	Quantity (gal)	Emissions (lb)					
			HC	Methanol	CO	NO_X	PM	SO_X
Proposed project	Fuel methanol	20,000	188.2	114.8	326.8	1,295.6	110.4	111.8
Baseline scenario	M100	20,000	0.52	93.4	44.4	598.0	58.4	0.16
Delta			187.7	21.4	282.4	697.6	52.0	111.6

The ISO containers used to transport the fuel methanol, and the underground fuel storage tank at the utility, are equipped with Stage 1 vapor recovery systems that return vapor from the fuel storage tank to the ISO container (or tank truck) as vapor is displaced from the fuel storage tank during filling.

8.6.1 Air Quality Impacts of the Utility Turbine Project

Air quality impacts of the fuel methanol-fired utility turbine arise from emissions associated with the transport of the fuel methanol from Kingsport, Tennessee, to Los Angeles (discussed in Section 8.2.1), as well as site-specific emissions associated with the use of fuel methanol in the utility turbine. These site-specific impacts arise from the following emission sources:

- Exhaust emissions from heavy-duty diesel trucks during the round-trip transport of the ISO containers from the railyard to the utility in El Segundo
- Evaporative emissions associated with transferring the fuel methanol, storing it in an underground storage tank, and dispensing it to the turbine
- Exhaust emissions from turbine operation

The baseline fuel, natural gas, is transported via pipeline to the utility turbine site. Therefore, as a conservative estimate, emissions associated with transport to Los Angeles, local distribution, and storage of the baseline fuel are assumed to be zero for the purposes of this analysis.

Evaporative Emissions

Site-associated evaporative emissions of fuel methanol are due to unloading the fuel from ISO containers into an underground fuel storage tank. Vapors will be captured with a vapor return hose (Stage 1 vapor recovery). The evaporative emission factors for fuel methanol, shown in Table 8-34, were developed based on the same parameters, assumptions, and corrective factors as discussed previously in

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Table 8-34. Evaporative emission factors for the utility turbine

Evaporative Emissions Source	Emissions	
	Fuel Methanol (lb/1,000 gal)	Natural Gas (lb/100 scf)
Tank truck loading with vapor controls working loss	0.054	0
Underground tank breathing	0.13	0
Dispensing working loss	0.144	0
Dispensing spillage	0.82	0
Total	1.15	0

Section 8.3.1 for the LACMTA offsite test facility. Dispensing fuel working loss refers to the working losses associated with transferring the methanol from the underground storage tank to the turbine. These values are assumed to be equivalent to the vehicle fuel working losses from AP-42. Dispensing fuel spillage emission factors are assumed to be equivalent to emission factors from AP-42 for vehicle fueling. The evaporative emissions from the existing environment, using natural gas, are assumed to be zero.

Exhaust Emissions (Local Distribution)

Exhaust emissions associated with the proposed utility turbine project are due to the heavy-duty diesel trucks used for transport of the fuel methanol from the railyard to the utility in El Segundo.

The emission factors for heavy-duty diesel trucks in terms of lb of pollutant emitted per 1,000 gallons of fuel methanol delivered are calculated from the equation:

$$A_n = B_n * C * D * E$$

where:

A_n = lb pollutant n emitted per 1,000 gallons fuel methanol delivered

B_n = Grams/mile emission factor for pollutant n

C = Number of miles traveled per fuel delivery

D = Number of deliveries made per 1,000 gallons of fuel methanol delivered

E = lb per gram conversion factor = 0.0022

The fuel delivery system will utilize heavy-duty diesel trucks using low-sulfur diesel fuel No. 2. The emission factors, B_n, are based on the same parameters, assumptions, and corrective factors discussed in Section 8.2.1 for heavy-duty diesel truck exhaust emissions. The emission factors, B_n, are listed in Table 8-35.

In the case of the proposed project, the value for C is 40 miles, (twice the distance from the railyard to El Segundo), and the value for D is equal to 0.16 (based on one delivery made with each ISO container carrying 6,250 gallons of fuel methanol). The corresponding values for A_n based on this scenario are also shown in Table 8-35. As indicated earlier, the emissions associated with the transportation of the natural gas, the baseline operating scenario, are assumed to be zero in order to provide a conservative estimate of the impact of the proposed project.

Turbine Operation Emissions

Emissions estimates for methanol-fired utility turbines are not available in AP-42. However, an emissions test of a methanol-fueled gas turbine was conducted by Detroit Diesel Allison on a 501-K turbine.[50] The emissions of NO_x, CO, and HC (as CH_4) from this test were converted into emission factors (units of mass of pollutant emitted per mass of methanol) using test parameters.[51] For the purposes of this analysis, the emissions from a fuel methanol utility turbine are assumed to be identical to those from the methanol turbine in this referenced study. PM and SO_x emissions were not measured in this test and are assumed to be negligible. The derived methanol turbine emission factors are shown in Table 8-36.

The baseline operating scenario is assumed to be a large natural gas turbine with selective catalytic reduction and water injection. The emission factors for the existing environment are taken from AP-42 and are listed in Table 8-36.

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[50] Detroit Diesel Allison, *Methanol Fueled Gas Turbine Emission Test: Final Report.*

[51] Calculations are given in Appendix A.

Table 8-35. Heavy-duty truck emission factors for the utility turbine facility

Emissions Parameter	Fuel	Fuel Economy (mpg)	Criteria Pollutants				
			HC	CO	NO_x	PM	SO_x
Emission factor (g/mi) B_n	No. 2 diesel	5.3[a]	2.10[b]	9.93[b]	8.01[b]	1.21[c]	0.61[d]
Proposed project emissions (lb/1,000 gal methanol) A_n	No. 2 diesel	5.3[a]	0.030	0.14	0.113	0.017	0.0086
Existing environment emissions (lb/100 scf natural gas) A_n	Natural gas	N.A.[e]	0	0	0	0	0

[a] Based on 1988 average for heavy-duty combination trucks in U.S.[52]

[b] Emission factors for model year 1991-2000 heavy-duty diesel trucks with 50,000 miles.[53]

[c] Engineering estimate based upon typical particulate formation from diesel engines where 0.2 wt % of fuel converts to particulate matter.[54]

[d] Engineering estimate, expressed as SO_2, based upon sulfur content of on-road truck fuel at 0.05 wt %.[55]

[e] N.A. = Not available.

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[52] *National Transportation Statistics, 1990 Annual Report,* DOT-TSC-RSPA-90-2.

[53] *Supplement A to Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources,* AP-42, January 1991.

[54] *Cost-Effectiveness of Diesel Fuel Modifications for Particulate Control,* SAE Technical Paper Series 870556.

[55] Ibid.

Table 8-36. Emission factors from operation of the utility turbine

	Criteria Pollutants				
Emission Factor	**HC**	**CO**	**NO_x**	**PM[a]**	**SO_x[a]**
Natural gas[b] (lb/MMBtu)	0.0172	0.0084	0.03	0	0
Fuel methanol[c] (lb/MMBtu)	0.0004[d]	0.0026	0.011	0	0
Natural gas[e] (lb/100 scf)	0.0018	0.00086	0.0031	0	0
Fuel methanol (lb/1000 gal)	0.173[d]	1.13	4.52	0	0

[a] PM and SO_x emissions are assumed to be negligible for both natural gas and methanol-fired turbine.

[b] Emission factors from AP-42, July 1993, for large gas turbines with selective catalytic reduction and water injection.

[c] Converted using HHV of methanol = 64,800 Btu/lb.

[d] As methane.

[e] Converted using HHV of natural gas = 103,000 Btu/lb.

Air Quality Impacts Summary for Utility Turbine

The overall air quality impact of the proposed utility boiler demonstration project using fuel methanol includes the following emission sources:

- The evaporative and exhaust emissions associated with transporting the fuel methanol from Kingsport, Tennessee, to Los Angeles, California (Table 8-8)
- The exhaust emissions from heavy-duty diesel truck transport of the fuel methanol from the Los Angeles railyard to the El Segundo facility (Table 8-35)
- The evaporative losses for fuel methanol due to fuel unloading, tank breathing, and fuel dispensing (Table 8-34)
- The utility turbine emissions during operation with fuel methanol (Table 8-36)

The emissions associated with the existing environment, the utility turbine operating with natural gas, includes only th e emissions associated with operation of the utility turbine itself. Because the natural gas is assumed to be transported via pipeline, there are no associated transport, local distribution, or fuel dispensing losses or emissions.

The emission factors for the proposed demonstration project and the existing environment are summarized in Table 8-37.

The air quality impacts for the proposed offsite test facility and the existing environment are summarized in Table 8-38. These values were calculated by multiplying the total emission factor for each pollutant (in Table 8-37) by the respective quantities of fuel to be delivered and used at the site. The differences between emissions associated with the existing environment and emissions associated with the proposed test facility are denoted as "Delta" in Table 8-38.

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Table 8-37. Summary of emission factors for the utility turbine

Emissions Parameter	Emissions					
	HC	Methanol	CO	NO_X	PM	SO_X
Proposed Project	**(lb/1,000 gal fuel delivered and used)**					
Fuel methanol transport to Los Angeles	9.38	1.61	14.11	36.87	2.60	5.58
Local distribution exhaust emissions	0.03	0	0.14	0.113	0.017	0.0086
Evaporative losses	0	1.15	0	0	0	0
Utility turbine operation	0.173	0[a]	1.13	4.52	0	0
Total for proposed project	9.583	2.76	15.38	41.50	2.62	5.59
Existing Environment	**(lb/100 scf delivered and used)**					
Transport of natural gas to Los Angeles	0	0	0	0	0	0
Local distribution to site	0	0	0	0	0	0
Evaporative losses	0	0	0	0	0	0
Utility turbine operation	0.0018	0	0.00086	0.0031	0	0
Total for existing environment	0.0018	0	0.00086	0.0031	0	0

[a] The amount of methanol in turbine exhaust emissions is not known, but is assumed to be accounted for in the HC emissions.

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Table 8-38. Air quality impact summary for the utility turbine

Scenario	Fuel	Quantity	Emissions (lb)					
			HC	Methanol	CO	NO_X	PM	SO_X
Proposed project	Fuel methanol	200,000 gal	1,917	552	3,076	8,300	524	1,118
Existing environment	Natural gas	8.35×10^7 scf	1,503	0	718	2,588	0	0
Delta			414	552	2,358	5,712	524	1,118

8.6.2 Permits/Regulations

The utility is required to obtain several permits before they may operate the fuel methanol turbine. These required permits include the following:

- Check-off permit from the Los Angeles City Fire Department containing plan check requirements for underground storage tanks
- Series of permits from SCAQMD allowing the construction and operation of fuel tanks
- Permit from SCAQMD allowing the turbine to be operated on methanol

8.6.3 Spill/Emergency Response

The utility is currently developing their emergency response plan. In the event of a spill, the utility immediately notifies the Los Angeles City Fire Department.

8.7 KANAWHA VALLEY REGIONAL TRANSPORTATION AUTHORITY (KVRTA) — WEST VIRGINIA DEMONSTRATION PROJECT

This proposed project involves the operation of three methanol-fueled transit buses in the Charleston, West Virginia, area. The transit buses are standard 35-foot coaches equipped with Detroit Diesel Corporation 6V-92 engines, currently running on neat methanol (M100). The three methanol coaches operate in the downtown Charleston area as well as outside of town.

No construction or installation of methanol-compatible fueling facilities will be required at the KVRTA facility that will operate the fuel methanol demonstration transit buses because a 20,000-gallon underground methanol fuel tank and fuel dispensing system are already in place. Both the tank trucks used to transport the fuel methanol and the underground fuel storage tank at the KVRTA facility are equipped with Stage 1 vapor recovery systems. Stage 1 vapor recovery returns vapor from the fuel storage tank to the tank truck as the vapor is displaced from the fuel storage tank during filling. The KVRTA methanol fuel dispensing system is equipped with Stage 2 vapor recovery. Stage 2 vapor recovery returns vapor from the vehicle fuel tank to the fuel storage tank as the vapor is displaced from the vehicle fuel tank during filling.

8.7.1 Air Quality Impacts

Fuel methanol will displace methanol (M100), so the air quality impacts of both fuel methanol and M100 are examined. The air quality impacts associated with the use of fuel methanol at this offsite test facility arise from the emissions associated with the transport of the fuel methanol to Charleston, West Virginia from Kingsport, Tennessee (which were discussed in Section 8.2.2 and will be summarized here), as well as the site specific emissions associated with use of the fuel methanol in the three transit buses.

The site-specific air quality impacts associated with the use of fuel methanol in this transit bus demonstration project arise from the following emission sources:

- Evaporative losses from unloading the methanol from the tank truck into the KVRTA storage tank
- Evaporative losses from dispensing the methanol into KVRTA buses
- Evaporative losses from methanol storage tank breathing
- Exhaust emissions from the regular duty operation of the methanol transit buses

The air quality impacts associated with the use of the baseline fuel (M100) in the existing environment arise from the same sources as those listed above for the proposed fuel methanol.

Evaporative Emissions

Table 8-39 shows the emission factors from AP-42[56] for tank truck unloading and fuel dispensing for both M100 and fuel methanol, since fuel methanol will be

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[56] *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources,* AP-42, Fourth Edition, September 1985.

Table 8-39. Evaporative emission factors for the KVRTA facility

Evaporative Emissions Source	Emissions (lb/1,000 gal)	
	M100	Fuel Methanol
Tank truck unloading with vapor controls working loss	0.054	0.054
Underground tank breathing	0.13	0.13
Vehicle fueling working loss	0.144	0.144
Vehicle fueling spillage	0.82	0.82
Total	1.15	1.15

displacing M100 currently used at KVRTA. Both fuel methanol and M100 will be unloaded from tank trucks into an underground fuel storage tank. Vapors will be captured with a vapor return hose (Stage 1 vapor recovery). Methanol is dispensed onto vehicles with vapor return lines from the vehicles (Stage 2 vapor recovery). Spillage during vehicle fueling is not predicted to change with fuel type by AP-42, so this value remains the same for both fueling scenarios. The evaporative emission factors shown in Table 8-39 were developed based upon the same parameters, assumptions, and corrective factors as discussed previously in Section 8.3.1 for the LACMTA offsite test facility.

Methanol Transit Bus Emissions

This demonstration project involves the substitution of M100 (chemical-grade methanol) with fuel methanol (fuel-grade methanol). No published data is currently available which describes the differences, if any, between the emissions of vehicles operating on the two fuels. For the purposes of this analysis, the most probable assumption has been made, that there are no significant differences in the emissions of the criteria pollutants (HC, CO, NO_x, and PM) between chemical grade methanol and fuel methanol over the same vehicle duty cycle. Therefore, no net air quality impact is anticipated due to the exhaust emissions of the transit buses during their operation on fuel methanol.

AP-42 does not include emission factor estimates for transit buses powered by methanol fuel. The original diesel transit bus emission factors in AP-42 were based on chassis dynamometer tests performed over the EPA duty cycle. Similar tests have been performed recently at the LACMTA Emission Testing Facility on methanol transit buses over the Central Business District (CBD) duty cycle. Although different than the EPA cycle, the CBD cycle is representative of the downtown Charleston routes which the methanol buses will typically drive. The emission results from these tests should therefore yield good estimates of the in-use emissions (air quality impacts) of the fuel methanol transit buses. Table 8-40 lists composite emission factors from chassis dynamometer testing on MTA transit buses with 1992 DDC 6V-92TA methanol engines.

The emission factors for methanol transit buses in terms of lb of pollutant emitted per 1,000 gallons of methanol consumed are calculated from the equation:

$$F_n = G_n * H * I$$

where:

F_n = lb of pollutant n emitted per 1,000 gallons of methanol consumed
G_n = Grams per mile emission factor for pollutant n
H = Fuel economy (mpg) of the methanol buses = 1.21[57]
I = lb per 1,000 gram conversion factor = 2.205

The emission factors G_n and F_n are presented in Table 8-40.

Air Quality Impacts Summary for the KVRTA Demonstration

The overall air quality impact of the proposed project using fuel methanol includes the following emission sources:

- The evaporative and exhaust emissions associated with transporting the fuel methanol from Kingsport, Tennessee, to Charleston, West Virginia (Table 8-12)
- The evaporative losses for fuel methanol due to fuel unloading, tank breathing, and fuel dispensing (Table 8-39)
- The methanol transit bus exhaust emissions due to regular operation of the buses (Table 8-40)

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[57] *Alternate Fuels Section Status Report, July - September 1992,* Southern California Rapid Transit District (now LACMTA).

Table 8-40. Methanol transit bus emission factors

Exhaust Emissions from M100 and Fuel Methanol Transit Buses	Criteria Pollutants					
	HC	Methanol	CO	NO_x	PM	SO_x
Emission factor[a] (g/mi) G_n	0	0.72[b]	0.21	9.60	0.25	0
Emissions (lb/1,000 gal of methanol consumed) F_n	0	1.92	0.56	25.61	0.67	0

[a] Values taken from three sets of tests of CBD cycle results for LACMTA methanol buses 1291 and 1276 with DDC 6V-92TA engines.[58] Emissions data for M100 buses are based on those buses equipped with the correct engine control software and representing a production engine.

[b] In Reference (58), methanol is reported as HC and measured by FID. This exhaust constituent is primarily methanol.

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[58] *Chassis Dynamometer Emissions Testing Results for Diesel and Alternative-Fueled Transit Buses,* SAE Technical Paper Series 931783, SP-982.

Similarly, the emissions associated with the existing environment, the three M100-fueled buses, include the following sources:

- The evaporative and exhaust emissions associated with local transport of the M100 fuel within the Charleston area (Table 8-12)
- The evaporative losses of M100 due to fuel unloading, tank breathing, and fuel dispensing (Table 8-39)
- The methanol transit bus exhaust emissions due to regular operation of the buses (Table 8-40)

The emissions for the proposed demonstration project and the existing environment are summarized in Table 8-41.

The air quality impacts for the proposed offsite test facility and the existing environment are summarized in Table 8-42. These values were calculated by multiplying the total emission factor for each type of methanol (in Table 8-41) by the respective quantities of fuel (in thousands of gallons) to be delivered and used at the site. The differences between emissions associated with the existing environment and emissions associated with the proposed test facility are denoted as "Delta" in Table 8-42.

8.7.2 Permits/Regulations

KVRTA requires no permits to operate its methanol buses. Neither are any special permits required from local fire departments or the air pollution control district.

8.7.3 Spill/Emergency Response

The KVRTA is currently developing its emergency spill response plan. In the event of a spill, the KVRTA immediately notifies the West Virginia Department of Natural Resources (DNR).

Table 8-41. Summary of emissions factors for the KVRTA facility

Emissions Source	Emissions (lb/1,000 gal of fuel delivered and used)					
	HC	Methanol	CO	NO_x	PM	SO_x
Proposed Project						
Fuel methanol transport to Charleston	0.227	1.61	1.074	0.867	0.131	0.066
Evaporative losses	0	1.15	0	0	0	0
Fuel methanol transit bus operation	0	1.92	0.56	25.61	0.67	0
Totals for the proposed project	0.23	4.68	1.63	26.48	0.80	0.07
Existing Environment						
Local M100 transport within Charleston area	0.005	0.54	0.026	0.021	0.003	0.002
Evaporative losses	0	1.15	0	0	0	0
M100 transit bus operation	0	1.92	0.56	25.61	0.67	0
Totals for the existing environment	0.005	3.61	0.59	25.63	0.67	0.002

Table 8-42. Air quality impact summary for the KVRTA facility

Scenario	Fuel	Quantity (gal)	Emissions (lb)					
			HC	Methanol	CO	NO_x	PM	SO_x
Proposed project	Fuel Methanol	80,000	18.2	374.4	130.7	2,118.2	64.1	5.3
Existing environment	M100	80,000	0.4	288.8	46.9	2,050.5	53.8	0.2
Delta			17.8	85.6	83.8	67.7	10.3	5.1

APPENDIX A

DETERMINATION OF METHANOL-FUELED TURBINE EMISSION FACTORS

A.1 CONVERTING TEST DATA FROM METHANOL TURBINE (DETROIT DIESEL ALLISON) INTO EMISSION FACTORS

At maximum continuous rating (MC), the following parameters apply:

Air flowrate (Wa)	= 2.32 kg/s
Fuel flowrate (Wf)	= 368 kg/hr
NO_x emissions	= 19.17 ppmv
CO emissions	= 7.74 ppmv
HC emissions	= 2.11 ppmv

Emission factors desired units are mass emissions/volume fuel.

Step 1. Convert emissions (ppmv) to emissions ($\mu g/m^3$).

From ideal gas law:

$\mu g/m^3$ air = $ppm_i \times MW_i \times p/RT$

where:

MW_i = Molecular weight of compound i

p = 1,000 mb at STP

R = 0.08314 mb m^3/ K mole

T = 293 K

For example, for NO_x emissions:

$$\mu g/m^3 = 19.17 \text{ ppmv } NO_x \times 46 \ \mu\text{mole/mole} \times 1{,}000/(0.08314*293)$$
$$= 36{,}200 \ \mu g \ NO_x/m^3 \text{ air}$$

Similarly, CO emissions = 8,896 μg CO/m^3 air

and HC emissions = 1,386 μg HC/m^3 air (assuming all HC is molecular weight of methane)

Step 2. Use air and fuel flowrates to convert emissions to a per fuel basis.

Note: at STP (assumed), 1 mole of an ideal gas = 24 L volume

Simply convert units and multiply by the air flowrate/fuel flowrate.

For example, for NO_X emissions:

36,200 µg NO_X/m^3 air x m^3 air/1,000 L x 24 L air/mole air x mole air/29 g air x

1,000 g air/kg air x 2.32 kg air/s x 3,600 s/hr x hr/368 kg methanol x 10^{-6} g/µg

= 0.68 g NO_X/kg methanol

For CO: 0.17 g CO/kg methanol

For HC (as CH_4): 0.026 g HC/kg methanol

Step 3. Convert emission factors from g pollutant/kg methanol to lb pollutant/MMBtu.

Assume that HHV methanol = 64,800 Btu/lb

This conversion involves unit conversions from g and kg to lb.

For example, for NO_X:

0.68 g NO_X/kg methanol x lb NO_X/453.6 g NO_X x kg methanol/2.2 lb methanol

x lb methanol/64,800 Btu x 10^6 Btu/MMBtu

= 0.011 lb NO_X/MMBtu

Similarly, CO emissions = 0.0026 lb CO/MMBtu

and HC (as CH_4) = 0.0004 lb HC/MMBtu

Step 4. Convert emission factors from g pollutant/kg methanol to lb pollutant/1,000 gal methanol.

Assume density of methanol liquid = 0.796 kg/L

For example, for NO_X:

0.68 g NO_X/kg methanol x 0.796 kg methanol/L methanol x 1,000 L/264.17 gal

x lb NO_X/453.6 g x 1,000 gal/1,000 gal

= 4.52 lb NO_X/1,000 gal methanol

Similarly, CO = 1.13 lb CO/1,000 gal methanol and HC = 0.173 lb HC/1,000 gal methanol

A.2 CONVERSION OF NATURAL GAS EMISSION FACTORS FROM AP-42 TO UNITS OF lb/100 scf

Assume HHV of natural gas = 103,000 Btu/100 scf

Total HC = TOC (as methane) plus NMHC = 0.014 + 0.0032 = 0.0172 lb/MMBtu

0.0172 lb/MMBtu x MMBtu/10^6 Btu x 103,000 Btu/100 scf = 0.00177 lb HC/100 scf

Similarly, CO = 0.0084 lb/MMBtu x MMBtu/10^6 Btu x 103,000 Btu/100 scf

= 0.000865 lb CO/100 scf

and NO_x = 0.03 lb/100 scf x MMBtu/10^6 Btu x 103,000 Btu/100 scf = 0.0031 lb/100 scf

A.3 CALCULATION OF AMOUNT OF NATURAL GAS EQUIVALENT TO 200,000 GALLONS OF METHANOL

HHV of natural gas = 103,000 Btu/100 scf

HHV of methanol = 64,800 Btu/lb

Density of methanol = 6.64 lb methanol/gal methanol

200,000 gal methanol x 6.64 lb methanol/gal methanol x 64,800 Btu/lb methanol x 100 scf/103,000 Btu = 8.35 x 10^7 scf natural gas