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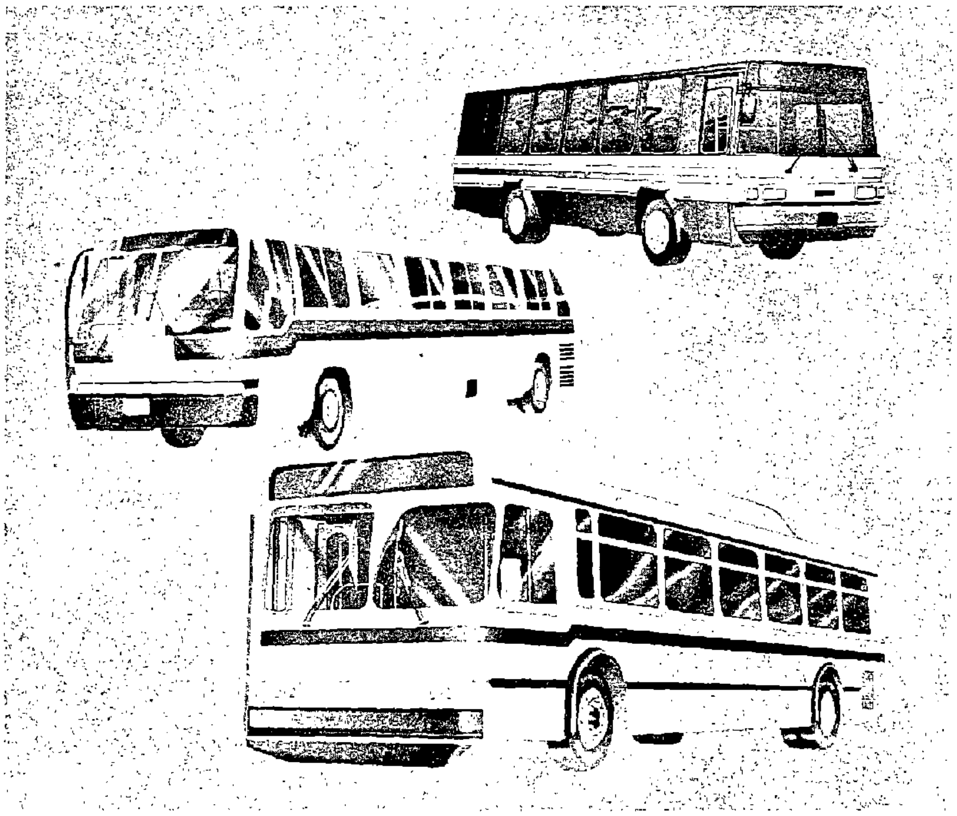
U.S. Department
of Transportation
**Federal Transit
Administration**

Clean Air Program

Design Guidelines for Bus Transit Systems Using Alcohol Fuel (Methanol and Ethanol) as an Alternative Fuel

August 1996
Final Report



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13. ABSTRACT (Maximum 200 words)

The use of alternative fuels to power transit buses is steadily increasing. Several fuels, including Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), and Methanol/Ethanol, are already being used. At present, there are no available comprehensive facilities guidelines to assist transit agencies contemplating converting from diesel to alternate fuels. This document addresses that need.

This guidelines document presents the various facility and, to some extent, bus design issues that need to be considered to ensure safe operations when using alcohol fuels (methanol and ethanol) as the alternative fuel. Fueling facility, garaging facility, and maintenance facility requirements and safety practices are presented. Among the issues discussed are fuel properties, potential hazards, fuel requirements for specified level of service, applicable codes and standards, ventilation, and electrical classification.

A system safety assessment and hazard resolution process is also presented. This approach may be used to select design strategies which are economical, yet ensure a specified level of safety.

This report forms part of a series of monographs being published by the U.S. DOT/FTA on the safe use of alternative fuels. Documents similar in content to this report are being published for CNG, LNG, and LPG.

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Metric/English Conversion Factors

English to Metric

LENGTH (Approximate)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (Approximate)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS-WEIGHT (Approximate)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilograms (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (Approximate)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (Exact)

$[(x - 32)(5/9)]$ °F	=	y °C
$(x + 460)/1.8$	=	y °K

PRESSURE (Exact)

1 psi	=	6.8948 k Pa

ENERGY & ENERGY DENSITY (Exact)

1 Btu	=	1.05506 kJ
1 Btu/lb	=	2.326 kJ/kg

Metric to English

LENGTH (Approximate)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (Approximate)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (he) = 2.5 acres

MASS-WEIGHT(Approximate)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg)	=	1.1 short tons

VOLUME (Approximate)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	13 cubic yards (cu yd, yd^3)

TEMPERATURE (Exact)

$[(9/5)y + 32]$ °C	=	x °F
$(y \times 1.8 - 460)$	=	x °F

PRESSURE (Exact)

1 M Pa	=	145.04 psi

ENERGY & ENERGY DENSITY (Exact)

1 MJ	=	947.81 Btu
1 MJ/kg	=	430 Btu/lb

QUICK INCH-CENTIMETER LENGTH CONVERSION

Inches 0 1 2 3 4 5

Centimeters 0 1 2 3 4 5 6 7 8 9 10 11 12 13

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

Table of Contents

List of Tables

List of Figures

Chapter 1
Introduction

At present over one thousand transit buses in revenue service in the United States use alternative fuels (fuels other than diesel or gasoline); their number continues to increase as additional transit systems begin to use alternative fuel buses. Safety is one of the key issues in the use of alternative fuels both in the operation and servicing of the buses. However, at present, comprehensive guidelines for the safe design and operation of alternative fuel facilities and vehicles do not exist for the transit systems to follow in either retrofit or new facility designs. The Federal Transit Administration (FTA) has therefore initiated the development of "Design Guidelines for Bus Transit Facilities Using Alternative Fuels."

This report provides design guidelines for the safe use of alcohol fuel (Methanol or Ethanol). It is part of a series of individual monographs being published by the FTA providing guidelines for the safe use of Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG) and alcohol fuels (Methanol and Ethanol). Each report in this series describes, for the subject fuel, the important fuel properties, guidelines for the design and operation of bus fueling, storage and maintenance facilities, issues on personnel training and emergency preparedness.

1.1 BACKGROUND

The Clean Air Act Amendments of 1990 mandate the reduction in tailpipe emissions of air pollutants from mobile sources including heavy duty vehicles or engines. In addition, the National Energy Policy Act of 1992 sets a national goal to replace the use of up to 30% of the petroleum fuel with alterative fuels by the year 2010 and mandates the use of alternative fuels in the nation's Federal, State, and fuel provider fleets at a rate not less than the promulgated phase in rate. In addition, several states have promulgated statutes encouraging or requiring the use of alternative fueled vehicles by fleet operators.

The increasing use of alternative fuels in the nation's transit bus fleet is a consequence of the above statutes. The use has also been encouraged by the FTA's Alternative Fuels Initiative (AFI) initiated in 1988 as well as several demonstration programs funded by the FTA. The AFI involved the field testing, demonstration and assistance in revenue service placement of buses powered by CNG, LNG, LPG, alcohol fuels, and hydrogen fuel cells.

Each of these alternative fuels has unique physical and chemical properties which differ from those of traditional diesel fuels in common use in transit bus fleets operating in the U.S. Transit agencies have decades of knowledge and experience on the use, handling and storage of diesel fuels. However, the use of these alternative fuels in buses is relatively new. The unique properties of the fuels affect usage, storage, handling and response to emergencies.

A number of transit agencies are already operating fleets of alternative fueled buses. However, the transition has been made somewhat difficult because of the absence of adequate guidelines to address the issues involved in the design of facilities and vehicles to ensure a safe and smooth transition and operation. The industry as a whole is learning from the experience of some of the pioneers in the transit industry who have successfully converted to operating alternative fuel buses. There is, however, an urgent need to provide guidance to other transit systems that are either contemplating transitions or initiating the process in the near future. This document is intended to provide some guidance to these transit agencies in their efforts to make the transition to alternative fuel safe and efficient.

1.2 PURPOSE AND SCOPE

The purpose of this document is to provide guidance, information on safe industry practices, applicable national codes and standards, and reference data where available which the transit agencies should review when considering modifications to their existing facilities or when planning new bus facilities to safely use an alcohol fuel (Methanol or Ethanol) as an alternate fuel.[1]

The scope of this document is limited, generally, to discussing issues related to bus facilities, e.g., bus fueling, storage and maintenance facilities. The overall safety of an alternative fuel bus facility depends not only on the safety systems designed into the fixed facilities, but also on (safety) systems provided on the buses and on the knowledge and training of the personnel. Therefore, the document also includes design issues related to vehicle safety and personnel training issues.

In Chapter 2, issues and practices related to the use of the specific alternative fuel considered in this document are indicated. The topics covered include:

- Fuel properties relevant to safe operations
- Design issues related to the
  - Fueling facility

[1]A series of documents similar to this in scope and content are to be published by the U.S. DOT/FTA on other alternative fuels, namely, CNG, LNG, LPG.

- Bus storage/parking facility
- Bus repair facility
- Bus fuel system and safety features

◆ Personnel training and operational procedures

◆ Emergency preparedness and other special issues.

Chapter 3 discusses the framework for performing a system safety analysis using the Military (MIL) Standard 882C, "System Safety Program Requirements" as the basis. The system safety process is applicable when guidance on a specific design approach is not available or when a unique design issue warrants the use of detailed hazard analysis. The hazard resolution process requires giving full consideration to all elements of the alternative fuels system, including the vehicle. In addition, this assessment procedure may be beneficial when a transit authority initially begins operation with a small number of alternative fueled vehicles.

For specific guidance, readers are encouraged to use this document and several related publications identified in the Reference Section of this document.

This document is intended to be a reference guideline document on facility design issues and **SHOULD NOT** be considered as a specification manual or a substitute for existing local, state or national codes and regulations. In addition, the reader should consider the following issues when reading this document.

- Every facility that is either being modified or constructed anew should be in compliance with all local, state and national codes and regulations.
- The information provided in this guidebook is by no means exhaustive on the subject of facility design or personnel training or any other associated issues. The transit system should consult with knowledgeable engineers, consultants, fuel supplier, design Architectural & Engineering (A&E) firm(s) and the staff of the local authority having jurisdiction to design the facility consistent with local codes, regulations, and local conditions.
- This document references sections of national codes or regulations. Such references to particular sections of the standards or the regulations are NOT intended to convey the impression that only those sections apply. It is, however, intended to get the reader started or even directed to the appropriate sections in the standards or the codes. It is recommended that the entire provisions of a currently adopted code or standard be reviewed thoroughly.

1.3 EXPLANATORY INFORMATION

Several types of information are presented in special ways, in this document, to make that information "friendlier" to the reader. These methods include several lists at the end of the document. The types of information presented are:

Technical Terms	Terms that have a special meaning relative to the subject matter in this report are ***highlighted (i.e., bolded and italicized)*** where they appear in text. All terms highlighted in text appear in the Glossary, at the end of the report.
Acronyms	When first used in this document, each acronym is expanded with the acronym in parentheses. A list of all acronyms used appears at the end of the document.
Regulations and Standards	Source references to regulations and standards consist of the acronym for the source organization and the section number of the original code or standard (e.g., NFPA 130). All references are to the latest published editions, though they may not be the version adopted by the local or state regulatory authorities. Of course, the requirements in the latest versions take precedence. Transit agencies should identify the version currently used by the communities they serve, compare it with the corresponding passages quoted here, and determine whether they differ sufficiently to warrant obtaining the latest version. Quoted passages from regulations or standards are blocked, italicized, and identified by the logo of the source organization. Quotations are included from two organizations: the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) and the National Fire Protection Association (NFPA). Their logos appear in the list of graphic symbols, at the end of this document, as does the logo for the National Electrical Code, which appears in NFPA 70.
Graphic Symbols	In addition to the organizational logos used to identify quoted codes and standards, a symbol is used to highlight **additional information**. This symbol appears in the list of graphic symbols at the end of this document and is identified by a circled large lowercase ***i***; the information is bolded and enclosed in a box.

Units of Measure — These are expressed in Standard International (SI) units (e.g., meters, kilograms, seconds, and Kelvin). The equivalent in British units, where different from SI, is provided in parentheses. Units of measure appearing in a quotation are reprinted exactly as they appear in the quoted passage.

1.4 LIST OF STATUTES, REGULATIONS AND STANDARDS

Listed below are several statutes, regulations, codes, and standards that are relevant to the use of alternative fuel in buses. Not all of these have been cited or referenced in the text to follow. They are included as sources of additional information.

1.4.1 Statutes

- Clean Air Act Amendments, 1990, Title II, "Provisions Relating to Mobile Sources," Public Law 101-549.

- Energy Policy Act of 1992 (EPACT), Public Law 102-486.

- Alternative Motor Fuels Act of 1988 (AMFA) Public Law 100-494.

1.4.2 Regulations

Copies of the following regulations can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 or by calling (202) 783-3238.

- Code of Federal Regulations (CFR), Title 49, "Transportation." Part 171–Hazardous Materials Regulations. (U.S. DOT)

- Code of Federal Regulations (CFR), Title 40, "Protection of Environment." Part 86 – Control of Air Pollution from New and In-Use Motor Vehicles and New and In-Use Motor Vehicle Engines: Certification and Test Procedure. (U.S. EPA)

- Superfund Amendments and Reauthorization Act (1986), SARA Title III. (U.S. EPA)

- Code of Federal Regulations (CFR), Title 29. Part 1910 – Occupational Safety and Health Standards. (OSHA)

1.4.3 Standards

The following NFPA standards can be obtained from the National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy MA 02269-9101 or by calling (800) 344-3555.

- NFPA 30A — Automotive and Marine Service Station Code. This standard applies to automotive and marine service stations and to service stations located inside buildings.

- NFPA 52 — Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems. This standard applies to the design and installation of CNG engine fuel systems on vehicles of all types including aftermarket and Original Equipment Manufacturers (OEMs) and to their associated fueling (dispensing) systems.

- NFPA 54 — National Fuel Gas Code. This code is a safety code that shall apply to the installation of fuel gas piping systems, fuel gas utilization equipment, and related accessories.

- NFPA 70 — National Electric Code. The purpose of this code is the practical safeguarding of persons and property from the hazards arising from the use of electricity.

- NFPA 88A — Standard for Parking Structures. This standard covers the construction and protection of, as well as the control of hazards in open, enclosed, basement, and underground parking structures. This standard does not apply to one- and two-family dwellings.

- NFPA 88B — Standard for Repair Garages. This standard covers the construction and protection of, as well as the control of hazards in, garages used for major repair and maintenance of motorized vehicles and any sales and servicing facilities associated therewith.

- NFPA 497A — Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas. This recommended practice applies to locations where flammable gases or vapors, flammable liquids or combustible liquids are processed or handled and where their release to the atmosphere may result in their ignition by electrical systems or equipment.

The following standard can be obtained through the American National Standards Institute, Inc. or American Gas Association Laboratories, 8501 East Pleasant Valley Road, Cleveland, Ohio 44131.

- ANSI/AGA NGV2-1992 — Basic requirements for compressed natural gas vehicle (NGV) fuel containers.

Chapter 2
Issues and Practices Related to Alcohol Fuels (Methanol and Ethanol)

2.1 GENERAL PROPERTIES

2.1.1 Physical Properties

Methanol. Methanol (CH_3OH) is a liquid fuel. Methanol is called "M-100" or "***neat***" methanol if it contains few impurities and is not mixed with another fuel. M-100 is the form of methanol fuel used in transit buses, while M-85 (***neat*** methanol mixed with 15% ***gasoline*** by volume) is used most often in automobiles.

Methanol is a colorless liquid made generally from natural gas but can be made from coal or wood products. It has a faint alcohol-like odor that is highly toxic (poisonous). At room temperature, its vapors are slightly heavier than air (1.11 times the density of air) and they tend to settle in low areas (such as maintenance pits) in the absence of a strong air ventilation system. Methanol is more chemically ***reactive*** than ***diesel fuel*** or ***gasoline***. It is more corrosive on some metals such as terneplated (tin and lead plated) fuel tanks, magnesium, copper, lead, zinc, and aluminum parts, and some synthetic gaskets (Methanol Technology and Application in Motor Fuels, 1978).

Ethanol. Ethanol (C_2H_5OH) is a liquid fuel. Ethanol is called "E-100" or "***neat***" ethanol if it contains few impurities and is not mixed with another fuel. Diluted ethanol is the principal constituent of alcoholic beverages. However, when ethanol is used for commercial or industrial purposes it is always ***denatured*** (a small amount of a toxic substance is added) to avoid the federal alcoholic beverage tax. E-95 (***neat*** ethanol mixed with 5% percent ***gasoline***) or E-93 (***neat*** ethanol mixed with 5% methanol and 2% kerosene) are the forms of ethanol fuel used in transit buses, while E-85 (***neat*** ethanol mixed with 15% ***gasoline***) or E-10 (***gasoline*** mixed with 10% ***neat*** ethanol, commonly referred to as gasohol) are used most often in automobiles. None of the ethanol fuel grades are fit for human consumption because of their toxicity and irritability to skin and respiratory systems.

Ethanol is a colorless liquid made generally through the fermentation process from corn, sugar crops, grains, potatoes and other starchy plants. At room temperatures, its vapors are heavier than air

(1.6 times the density of air) and they will settle in low areas. Ethanol is less corrosive than methanol.

General. Unlike diesel or ***gasoline***, methanol and ethanol will readily mix with water in all proportions. Fuel tanks that contain methanol or ethanol will absorb water from the air and the resulting mixture is corrosive to many steel or plated steel fuel tanks and lines. Fuel tanks and their plumbing systems must be compatible with these new fuels.

Both methanol and ethanol alcohol fuels have similar characteristics and will generally be discussed together in the remainder of this chapter. The impacts of these fuels on facility designs are very similar.

2.1.2 Flammability and Associated Hazards

Alcohol fuels are used in the liquid state and can be handled in a manner similar to ***gasoline***. When accidental spillage of the fuel is considered (from a safety perspective), the following issues should be noted. First, the fuel vapors are both toxic and heavier than air. They will migrate into low areas such as service pits and below grade areas within garages. The ventilation necessary to prevent a buildup of fuel vapors is addressed by several NFPA codes currently written for heavier than air fuels such as ***gasoline*** (NFPA 88A, 88B, 30 and 30A).

The important properties of methanol, ethanol, and diesel are indicated in Table 2-1. The ***flash points*** of the alcohol fuels are substantially higher than that of ***gasoline*** but lower than that of ***diesel fuel***. ***Diesel fuel*** has a 348 K (167 °F) ***flash point*** and is considered a Class IIIA ***combustible*** fuel by NFPA. ***Gasoline*** has a ***flash point*** of 230 K (-45 °F) and releases sufficient vapors above this temperature that can mix with air and form an ignitable mixture. (Unless a liquid is heated above its ***flash point***, it will not burn.) Ethanol has a ***flash point*** of 286 K (55 °F) while methanol has a ***flash point*** of 284 K (52 °F). ***Gasoline*** is classified as a Class IA ***flammable*** fluid. Because of their higher boiling points, 337 K (148 °F) for methanol and 351 K (173 °F) for ethanol, the alcohol fuels are classified as Class IB ***flammable liquids***—less hazardous than ***gasoline***. From the perspective of fire safety, a ***flash point*** makes alcohol fuels less hazardous than ***gasoline*** but more hazardous than ***diesel fuel***.

It is worth noting that because of its relative safety, methanol has been used in the Indianapolis 500 auto race cars for the last two decades. In comparison to ***gasoline***, should a fire occur, methanol is less likely to cause injury, death, and property damage because of its low heat of combustion and high ***heat of vaporization***, as well as its low volatility and modest boiling point (Machiele's paper:

"A Health and Safety Assessment of Methanol as an Alternative Fuel," contained in: Methanol as an Alternative Fuel Choice, 1990).

*The following indicates the classification of **flammable/combustible** liquids.*

Flammable Liquids

***Flammable liquids** have **flash points** below 100 °F and **vapor pressures** not exceeding 40 psia at 100 °F.*

***Class I** liquids include those with **flash points** below 100 °F and may be subdivided as follows:*
***Class IA** includes those with **flash points** below 73 °F and with boiling points below 100 °F.*
***Class IB** includes those with **flash points** below 73 °F and with boiling points at or above 100 °F.*
***Class IC** includes those **flash points** at or above 73 °F and below 100 °F.*

***Combustible** Liquids*

*Liquids with **flash points** at or above 100 °F are referred to as **combustible** liquids and may be subdivided as follows:*

***Class II** liquids have **flash points** at or above 100 °F and below 140 °F.*
***Class IIIA** liquids have **flash points** at or above 140 °F and below 200 °F.*
***Class IIIB** liquids have **flash points** at or above 200 °F.*

Source: *Fire Protection Handbook, 15th Edition, (1981), National Fire Protection Association, Quincy, MA.*

Vapors of methanol with a concentration in air higher than the Upper Flammability Limit (UFL) of 13% or lower than the Lower Flammability Limit (LFL) of 6.7% will not ignite. Inside a fuel tank, methanol vapors are potentially explosive because the fuel-air mixture concentration can be within the ignition limits. For this reason, flame arresters are used on methanol tank vents and on the fuel filler neck. In comparison, the vapors inside a fuel tank of ***gasoline*** are too rich to burn and inside a fuel tank of diesel are too lean to burn.

Methanol vapors are ***flammable*** in air. They can be ignited by an open flame, an electrical spark (of energy above the minimum ignition energy), or a very hot surface, if the concentration of methanol vapors in air is between flammability concentrations (see Table 2-1). Even a weak spark due to static electricity discharge from a human body—which may easily produce sparks of 10 mJ of energy— could be sufficient to ignite a ***flammable*** concentration of methanol vapors. However, ignition by a hot surface will require a sufficiently high temperature, greater than 385 °C.

Burning methanol has a nearly invisible flame and is difficult to see when burning by itself in daylight. This means that it may be possible to inadvertently walk into a methanol fire without realizing a fire exists. Heat waves may be the first indication of such a fire. However, when methanol fires consume other surrounding materials, such as tires, plastics, and asphalt, the fire would likely be quite visible, even in daylight. Burning ethanol has a more luminous flame and is therefore more visible.

Among the alternative fuels, methanol vapor is considered the most toxic for inhalation exposure. The measure of fuel toxicity is the Threshold Limit Value (TLV) for vapor exposure and it can be expressed in terms of either a Time-Weighted Average (TWA) for an eight-hour day or a 40-hour week, or as a Short Term Exposure Limit (STEL) expressing the maximum concentration allowable for a 15-minute exposure. For methanol vapor the TLV-TWA value is 200 ppm, while the TLV-STEL value is 250 ppm (Murphy et al. 1995). For ***gasoline*** vapor these values are 300 ppm and 500 ppm, while for ethanol vapor these values are 1,000 ppm and none estimated, respectively. The ability for a person to detect a vapor by smell is its odor threshold value, which is 2,000 ppm for methanol, 10 ppm for ethanol and 0.2 ppm for ***gasoline*** (Properties of Alternative Fuels, Battelle 1994). This means that if you can smell methanol vapors you are probably being exposed to vapors at an unhealthy level, while you will likely smell ***gasoline*** or ethanol vapors before they reach an unhealthy level.

Methanol is highly toxic and small quantities consumed internally can prove fatal. As little as 50 to 100 mL (2 to 4 ounces) usually can cause death; smaller amounts can cause blindness (Methanol Technology & Applications, 1978). Methanol can be absorbed through the skin. As a precautionary measure, methanol fuel spilled on the skin should be immediately washed off with soap and water. If clothes are wet with methanol, they should be changed. Regularly wearing protective gloves and splash goggles whenever refueling or changing fuel filters on methanol buses should be considered.

Glove materials that are acceptable for use with methanol, ethanol, diesel, and ***gasoline*** include: Viton™, nitrile rubber, and Teflon™ (Forsberg and Mansdorf, 1989). Also, an eye wash station should be installed in the methanol service garage and near the fueling island (NIOSH, 1990).

It should be noted that methanol is used routinely as a dry gas additive for automobiles in the winter and as a cleansing agent in the medical/health industry. The safety concern here is about preventing prolonged contact with methanol or exposure to its vapors.

Table 2-1
Important Properties of Alcohol and Diesel Fuels

	Units	#2 Diesel Fuel	M100 Methanol	E100 Ethanol
Energy Content	kJ/l (LHV)	36,386	15,884	21,272
	Btu/gal	91,100	39,770	53,260
Ratio of Volumes for Equal Energy (Theoretical)		1.00	2.29	1.71
Ratio of Volumes for Equal Service (Based on Actual performance)		1.00	2.5-2.8	1.9-2.1
Flash Point	K	331-389	284	286
	°F	136-240	51	55
Autoignition Temperature	K	503	658	638
	°F	445	724	688
Minimum Energy for Ignition in Air	mJ	0.24	0.14	0.2
Relative Vapor Density (air = 1.00)		4-6	1.11	1.6
Upper Flammability Limit (UFL)	Volume %	5.5	13	5.4
Lower Flammability Limit (LFL)	Volume %	0.6	6.7	3.5
Volatility (Reid Vapor Pressure)	k Pa	<5	35	20
Volatility Relative to Diesel	k Pa	1	7	4
Flame Visibility (Relative)		1.0	0.0003	0.03
Vapor Exposure Limit (Time Weighted Average)	ppm	300-500*	200	1,000
Odor Threshold Concentration of Vapor in Air	ppm	0.2*	2,000	10

*Values are for gasoline vapors.

For additional information on Methanol and Ethanol properties, safety precautions, and procedures, the following technical reference(s) should be reviewed/consulted:

"Methanol Use Training Manual." Report No. UMTA-OH-06-0056-90-1, Federal Transit Administration, Washington, D.C., January 1990.

"Industrial Hygiene Survey Reports on Bus Garages in Seattle, New York City and Los Angeles." Report Numbers 163.2 (.01to .03). Published by National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio, 1990.

"Properties of Alternative Fuels," Michael J. Murphy, Battelle, March 1994.

"Summary of the Safety, Health, Environmental and System Risks of Alternative Fuels," DOT-VNTSC-FTA-95-5, August 1995.

"Methanol as an Alternative Fuel Choice: An Assessment," Wilfied L. Kohl, Editor, John Hopkins University, 1990.

"Methanol Technology and Application in Motor Fuels," edited by J.K. Paul, Noyes Data Corp., 1978.

"Methanol Fuel Modification For Highway Use," U.S. Department of Energy, 1978.

"Ethanol Fuels, Reference Guide, a decision-makers guide to ethanol fuels," Solar Energy Research Institute (SERI), October 1982.

"Quick Selection Guide to Chemical Protection Clothing," Forsberg and Mansdorf, 1989.

2.1.3 Fuel Economy and Diesel Equivalence

Alcohol fuels, both methanol and ethanol, have been used in heavy duty diesel cycle engines for both trucking and transit applications. Detroit Diesel, with the support of numerous U.S. transit agencies, has developed its 6V92 engine series to operate monofuel with both of these alcohols. These fuels and engines have been thoroughly field tested during the last ten years and are available for use by transit properties. The alcohol engines operate on the diesel cycle and have high efficiency during light loads and idle conditions. This is important if the alcohol buses are utilized in a central business district route.

The alcohol fuels offer important air quality and energy security benefits that cannot be obtained with typical ***diesel fuel***. Lower particulate matter, carbon monoxide, and carbon dioxide emissions make these fuels more acceptable from a "greenhouse" and global warming perspective. Ethanol fuel is ***listed*** as a renewable energy source as it can be made from a variety of agricultural products such as corn, grains or sugarcane. Methanol is produced primarily from natural gas but other feed stocks such as coal and ***biomass*** are possible.

From the perspective of facilities design, the alcohol fuels are quite similar to ***gasoline***. Regulation and codes that mandate facility features for ***gasoline*** would also be acceptable for alcohol fuels. In California, alcohol fuels are utilized in facilities that have been previously ***approved*** for ***gasoline*** powered vehicles.

Relatively larger amounts of alcohol fuels must be used to obtain equal service (range and load capacity) from the vehicles (when compared to ***diesel fuel***). This characteristic affects both the volume of fuel that must be stored at the transit site for inventory purposes and the number of tanker deliveries needed each week to supply fuel for the bus fleet. To assure similar vehicle range, the total volume (gallons) of fuel the vehicle must carry must also be increased. A typical transit facility that stores 40,000 litres (approximately 10,000 gallons) of diesel would have to store 100,000 litres (approximately 25,000 gallons) of methanol or 76,000 litres (approximately 19,000 gallons) of ethanol, to have the same fleet fuel reserve. These storage requirements may be larger if the transit agency also has "emergency response" responsibilities for the community it serves.

2.1.4 Methanol/Ethanol Supply Quality

Neat methanol and ethanol are normally supplied as a chemical grade liquid. Methanol has been historically produced by the distillation of wood and has therefore been termed "wood alcohol." Methanol can be produced synthetically from natural gas, heavy oil, coal, or wood products. Today most methanol is produced from natural gas. About 96% of the methanol consumed in the U.S. is produced in North America. Consumption of methanol for manufacturing other chemicals (e.g., formaldehyde, methyl tert-butyl ether, and methylene chloride) accounted for about 90% of U.S. methanol production in 1988-89. Methanol itself is widely used: as a solvent (in paints, varnishes, cements, inks, paint strippers, and degreasers); in antifreeze mixtures; as a denaturant for ethanol; and as a fuel for motor vehicles, outdoor stoves, and soldering torches *(NIOSH, 1990)*. At least 92% of the ethanol used in the U.S. is produced domestically. Ethanol is primarily made from the fermentation of corn and is used as a transportation fuel additive (gasohol).

2.2 FUELING FACILITIES

The safety requirements for a methanol and ethanol dispensing facility are the same as those for the dispensing of ***flammable/combustible*** liquids. These requirements are covered in detail in

NFPA 30A "Automobile and Marine Service Station Code." This code covers the requirements for: storage of ***flammable*** and ***combustible*** liquids inside buildings; details of piping, valves, and fittings; fuel dispensing details (including location of dispensing devices and emergency power cut off, dispensing devices, vapor recovery, and processing systems); heating and ventilation requirements; and electrical systems, including classification of various areas. A large part of the material in this section of the guideline document is based on the various requirements in NFPA 30A.

The basic approach in designing a fueling facility is to provide systems that can either eliminate (or at least minimize the quantity of) accidental fuel releases. Also, the design should build in sufficient safeguards to reduce or eliminate the risk of liquid or vapor ignition if a release occurs. These objectives may be achieved by including in the design the use of fuel compatible materials, proper valving and piping, and providing adequate electrical and other sources. In general, the design requirements for a methanol or ethanol dispensing facility will be similar to those for a ***gasoline*** service station because the relative volatility of ***gasoline*** is similar to (but higher than) that of methanol/ethanol (see Table 2-1).

2.2.1 Structural Considerations

A number of agencies that are demonstrating alcohol fuels have changed their facilities to follow design guidelines already in place for ***gasoline*** garages, service facilities and parking structures. Since both fuels (***gasoline*** and alcohols) are considered ***volatile flammable liquids*** and are similar in many other respects, the local regulators and "***authority having jurisdiction***" have had little difficulty in determining facility features that are appropriate. Often they reference design guidance given in the National Electric Code, NFPA 70 (articles 511 and 514), and NFPA 88A and 88B for parking structures and repair garages and 29 CFR OSHA § 1910.106: ***flammable*** and ***combustible*** Liquids.

The structural and building requirements for operating a dispensing facility inside a building are indicated in §6-1, NFPA 30A. Specifically, this code requires that the indoor fueling facility be separated from other portions of the building by a wall, partition, floor, or floor ceiling assemblies having a fire resistance rating of not less than two hours. In addition, the requirements for doors and partition walls are also included.

2.2.2 Dispensing Area: Equipment and Other Requirements

Since the alcohol fuels are considered to present the same hazards as ***gasoline***, outdoor fueling is the normal method. Indoor fueling is possible if changes are made to follow guidelines already in place for indoor ***gasoline*** dispensing systems. These are described in greater detail below. Equipment utilized for ***gasoline*** dispensing systems is familiar to most transit agencies and would be acceptable with minimum modification (only material compatibility issues) for alcohol fuels. However, because it is necessary to dispense a considerably higher (two to three times) volume of alcohol fuel to obtain the same driving range as diesel, it is common practice to use dry break type fueling nozzles at pumping rates up to 160 litres/minute (40 gallons/minute). Such nozzles also reduce, substantially, the spillage during the disconnect process.

Permanent fuel storage systems and dispenser piping must be compatible with the specific alcohol selected. This means that older fuel storage tanks will most likely have to be removed and replaced with new double-wall tankage that is compatible with alcohols. Also, associated plumbing and transfer pumps should be replaced if they are not compatible with alcohol fuels.

The transfer of methanol from the bulk transport tanker truck to fleet storage tank(s) must take into account the fact that any vapor/air mixture that leaks during the transfer operation will create a ***flammable*** volume. In addition, any methanol spill will quickly vaporize and form ***flammable*** vapor/air mixtures. For this reason, it is essential that all hose connectors have mechanical locking features, vapor recovery devices be in place between the tanker truck and the fuel storage tank, and that grounding devices be provided to prevent static electrical discharges from taking place. Also, any vent lines should have spark arresters and the fill line should extend to the bottom of the storage tank. (Murphy et al. 1995).

Water drainage from the fueling areas should continue to be collected and passed through a water/oil separator. This is necessary since other fluids such as engine oil, transmission fluids and coolants may also be dispensed at this service location. If these oils are spilled, they must be separated from any runoff water that drains from the area.

However, since alcohol fuels and coolants will mix in all proportions with water and will not be separable from the water without special distillation equipment, these fluids should be captured and not allowed to enter any sewer or drainage system, and their disposal should follow EPA procedures set forth in 40 CFR EPA, § 260 through 299: Hazardous Waste. The release of ***flammable liquids*** into a sewer system is prohibited by NFPA-30: ***flammable*** and ***combustible*** Liquids Code.

Indoor fuel dispensing should be at street level and less than 15 m (50 feet) from a vehicle exit.

2.2.3 Ventilation

Ventilation requirements for ***flammable*** and ***combustible*** fuels dispensing facilities are indicated in NFPA 30A and should be followed for alcohol fuels. The requirements to prevent a buildup of fuel vapors are contained in NFPA 30, Section 2-5.3: Ventilation, which states:

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> ***2-5.3*** *Storage tank buildings storing Class I liquids or Class II or Class IIIA liquids at temperatures above their* ***flash points*** *shall be ventilated at a rate sufficient to maintain the concentration of vapors within the building at or below 25 percent of the lower* ***flammable*** *limit. Compliance with Sections 2-5.3.2 through 2-5.3.5 shall be deemed as meeting the requirements of 2-5.3.1.*

Note: Methanol and Ethanol are Class **1B** liquids

This code also prohibits the interconnection of the building heating and air conditioning system with the ventilation system for an indoor fueling facility (§6-3.1). Also, the air flow requirements are as follows:

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> ***6-3.3*** *The exhaust system shall be designed to provide air movement across all portions of the dispensing area floor and to prevent the flow of* ***flammable*** *vapors beyond the dispensing area. Exhaust inlet ducts shall not be less than 3 in. (7.6 cm) nor more than 12 in. (0.30 m) above the floor. Exhaust ducts shall not be located in floors, or penetrate the floor of the dispensing area, and shall discharge to a safe location outside the building.*

> ***6-3.4*** *The exhaust systems shall provide ventilation at a rate of not less than 1 cfm per sq ft (0.3 m^3 per min per m^2) of the dispensing area.*

2.2.4 Electrical: Equipment and Other Requirements

The electrical equipment requirements for dispensing units and facilities are presented in Chapter 7, NFPA 30A. In general, the requirements of NFPA 70 "National Electrical Code" for Class I liquids' storage, handling, and dispensing are applicable. NFPA 70 classifies methanol and ethanol as Group D Atmosphere Chemicals. Such a classification requires that within 6 m (20 ft.) of a dispenser Class 1, Division 2 electrical classification be employed. In Table 2-2, the definitions of various electrical classifications are reproduced from NFPA 70. Figure 2-1 shows the classified areas adjacent to dispensers. Table 2-3, taken from NFPA 30A, details the electrical classification required for various equipment and locations in service station areas.

Table 2-2
Definitions of Different Electrical Classifications

*500-4. **Class 1 Locations.*** *Class 1 locations are those in which **flammable** gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. Class 1 locations shall include those specified in (a) and (b) below.*

*(a) **Class 1, Division 1.*** *A Class 1, Division 1 location is a location: (1) in which ignitable concentrations of **flammable** gases or vapors exist under normal operating conditions; or (2) in which ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release ignitable concentrations of **flammable** gases or vapors, and might also cause simultaneous failure of electric equipment.*

> *This classification usually includes: locations where **volatile flammable liquids** or liquefied **flammable** gases are transferred from one **container** to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where **volatile flammable** solvents are used; locations containing open tanks or vats of **volatile flammable liquids**; drying rooms or compartments for the evaporation of **flammable** solvents; locations containing fat and oil extraction equipment using **volatile flammable** solvents; portions of cleaning and dyeing plants where **flammable liquids** are used; gas generator rooms and other portions of gas manufacturing plants where **flammable** gas may escape; inadequately ventilated pump rooms for **flammable** gas or for **volatile flammable liquids**; the interiors of refrigerators and freezers in which **volatile flammable** materials are stored in open, lightly stoppered, or easily ruptured **containers**; and all other locations where ignitable concentrations of **flammable** vapors or gases are likely to occur in the course of normal operations.*

*(b) **Class 1, Division 2.*** *A Class 1, Division 2 location is a location: (1) in which **volatile flammable liquids** or **flammable** gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed **containers** or closed systems from which they can escape only in case of accidental rupture or breakdown of such **containers** or systems, or in case of abnormal operation of equipment; or (2) in which ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class 1, Division 1 location, and to which ignitable concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.*

> *This classification usually includes locations where **volatile flammable liquids** or **flammable** gases or vapors are used, but which, in the judgment of the **authority having jurisdiction**, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of **flammable** material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location.*

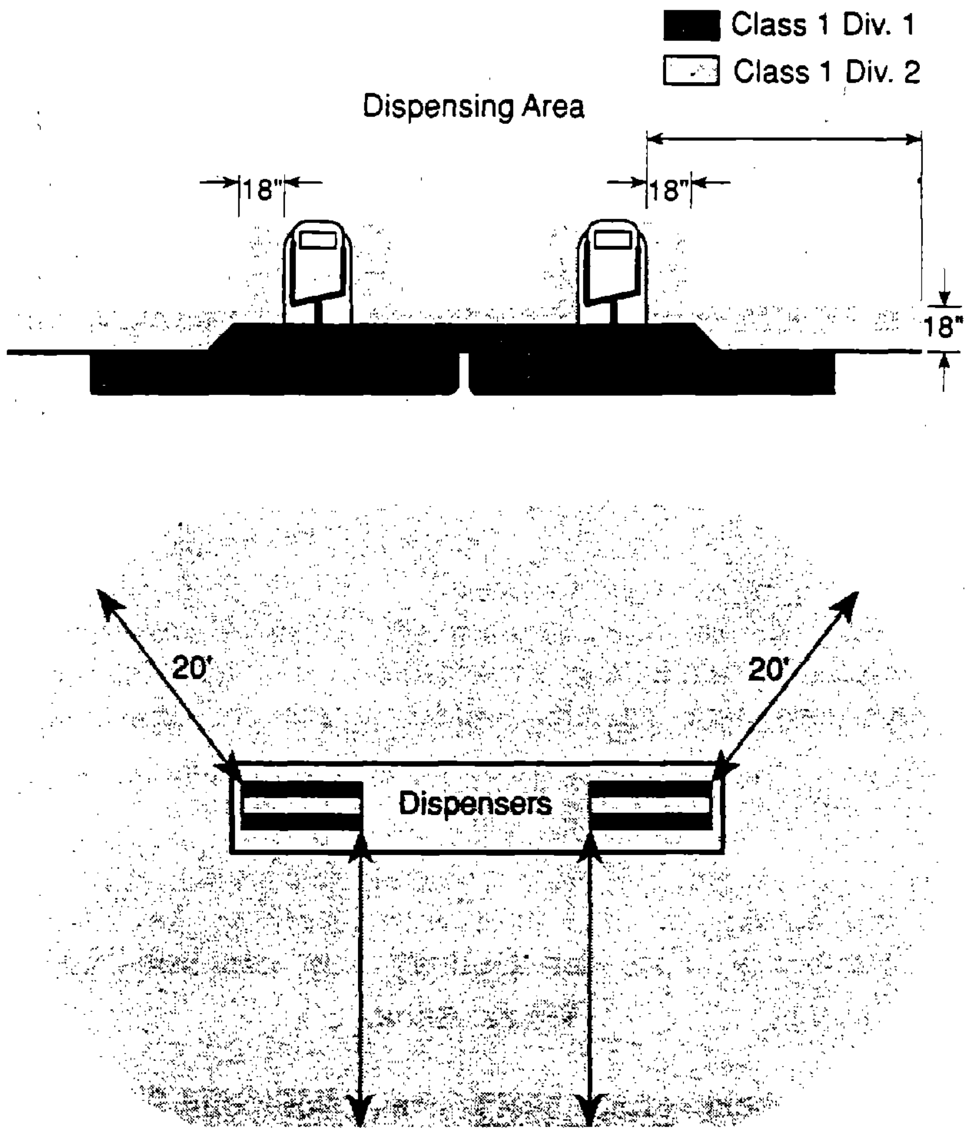

Figure 2-1
Classified Areas Adjacent to Dispensers (Flammable & Combustible Fluids)

Table 2-3
Electrical Equipment Classified Areas-Service Stations

Table 7 Electrical Equipment Classified Areas — Service Stations

Location	NEC Class I, Group D Division	Extent of Classified Area[1]
Underground Tank Fill Opening	1	Any pit, box, or space below grade level, any part of which is within the Division 1 or 2 classified.
	2	Up to 18 in. above grade level within a horizontal radius of 10 ft from a loose fill connection and within a horizontal radius of 5 ft from a tight fill connection.
Vent — Discharging Upward	1	Within 3 ft of open end of vent, extending in all directions.
	2	Area between 3 ft and 5 ft of open end of vent, extending in all directions.
Dispensing Device[2,3] (except overhead type)[4]		
Pits	1	Any pit, box, or space below grade level, any part of which is within the Division 1 or 2 classified area.
Dispenser	2	Within 18 in. horizontally in all directions extending to grade from (1) the dispenser enclosure or (2) that portion of the dispenser enclosure containing liquid handling componants. Area classification inside the dispenser enclosure is covered in ANSI/UL 87, *Power Operated Dispensing Devices for Petroleum Products*.
Outdoor	2	Up to 18 in. above grade level within 20 ft horizontally of any edge of enclosure.
Indoor		
with Mechanical Ventilation	2	Up to 18 in. above grade or floor level within 20 ft horizontally of any edge of enclosure.
with Gravity Ventilation	2	Up to 18 in. above grade or floor level within 25 ft horizontally of any edge of enclosure.
Dispensing Device — Overhead Type[3,4]	1	The area within the dispenser enclosure, and all electrical equipment integral with the dispensing hose or nozzle.
	2	An area extending 18 in. horizontally in all directions beyond the enclosure and extending to grade.
	2	Up to 18 in. above grade level within 20 ft horizontally measured from a point vertically below the edge of any dispenser enclosure.
Remote Pump — Outdoor	1	Any pit, box, or space below grade level if any part is within a horizontal distance of 10 ft from any edge of pump.
	2	Within 3 ft of any edge of pump, extending in all directions. Also up to 18 in. above grade level within 10 ft horizontally from any edge of pump
Remote Pump — Indoor	1	Entire area within any pit.
	2	Within 5 ft of any edge of pump, extending in all directions. Also up to 3 ft above floor or grade level within 25 ft horizontally from any edge of pump.
Lubrication or Service Room — with Dispensing	1	Any pit within any unventilated area.
	2	Any pit with ventilation.
	2	Area up to 18 in. above floor or grade level and 3 ft horizontally from a lubrication pit.
Dispenser for Class I Liquids[3]	2	Within 3 ft of any fill or dispensing point, extending in all directions
Lubrication or Service Room — without Dispensing	2	Entire area within any pit used for lubrication or similar services where class I liquids may be released.
	2	Area up to 18 in. above any such pit and extending a distance of 3 ft horizontally from any edge of the pit.
	2	Entire unventilated area within any pit, belowgrade area, or sub-floor area.
	2	Area up to 18 in. above any such unventilated pit, belowgrade work area, or sub-floor work area and extending a distance of 3 ft horizontally from the edge of any such pit, belowgrade work area, or sub-floor work area.
	Nonclassified	Any pit, belowgrade work area, or sub-floor work area that is ventilated in accordance with 5-1.3.
Special Enclosure Inside Building Per 2-2	1	Entire enclosure.
Sales, Storage, and Rest Rooms	Nonclassified	If there is any opening to these rooms within the extent of a Division 1 area, the entire room shall be classified as Division 1.
Vapor Processing Systems Pits	1	Any pit, box, or space below grade level, any part of which is within Division 1 or 2 classified area or that houses any equipment used to transport or process vapors.
Vapor Processing Equipment Located within Protective Enclosures (see 4-5.7)	2	Within any protective enclosure housing vapor processing equipment.
Vapor Processing Equipment Not within Protective Enclosures (excluding piping and combustion devices)	2	The space within 18 in. in all directions of equipment containing flammable vapors or liquid extending to grade level. Up to 18 in. above grade level within 10 ft horizontally of the vapor processing equipment.
Equipment Enclosures	1	Any area within the enclosure where vapor or liquid is present under normal operating conditions
	2	The entire area within the enclosure other than Division 1.
Vacuum-Assist Blowers	2	The space within 18 in. in all directions extending to grade level. Up to 18 in above grade level within 10 ft horizontally

For SI Units: 1 in. = 2.5 cm; 1 ft = 0.30 m.

[1]For marine application the term "grade level" shall mean the surface of a pier, extending down to water level.

[2]Refer to Figure 7-1 for an illustration of classified areas around dispensing devices.

[3]Area classification inside the dispenser enclosure is covered in ANSI/UL 87, *Power Operated Dispensing Devices for Petroleum Products*

[4]Ceiling mounted hose reel

2.2.5 Dispensing Area Operations and Procedures

Personnel protection and work practices by fuelers need to be modified from normal ***diesel fueling*** practices to minimize potential inhalation and dermal exposures. These include use of safety goggles and impermeable (e.g., nitrile) elbow-length gloves whenever fueling the bus.

2.2.6 Maintenance of Safety Equipment

Regular maintenance of instruments and equipment should be performed. As a minimum, testing and calibration of combustible gas detection and fire systems must be undertaken at manufacturer specified intervals.

Facilities should also undergo a fire prevention inspection. This fire prevention inspection should include all devices which are commonly inspected in transit garages, such as:

- All sprinkler valve assemblies (monthly inspection).
- Yard hydrants and hoses, inside hoses and portable fire extinguishers (monthly inspection). Electrical equipment and storage of flammable liquids should be checked monthly.
- Housekeeping, as well as cutting and welding, smoking regulations, sprinkler alarms and doors at cutoff walls (monthly inspection).
- Operational capability and readiness of systems to verify triggering, interlocks, and automatic controls (threshold should be checked with a simulated gas release event).

Weekly inspections should include:

- General condition of automatic sprinkler heads.
- Dry pipe valves.
- Water supplies.

- Locked valve shutoffs.

In addition to the above, energy systems for ventilation and electrical should be checked monthly. As a final check, it is recommended that whenever any person works on classified electrical enclosures or devices, a trained supervisor verifies the integrity of the device after the maintenance is complete.

2.3 BUS STORAGE FACILITY

The bus storage (also called dead vehicle storage) facility is a building where buses are parked for long periods of time, i.e., 12 or more hours. Issues relating to the design of such buildings for the storage of alcohol fuel buses are discussed in this section.

2.3.1 Design Overview

Standards for storage facility design for transit vehicles that use ***flammable*** and ***combustible*** fuels are provided in NFPA 88A, which focuses on parking structures. There are no specific requirements for vehicle storage facilities in NFPA 30A. The design requirements for facilities storing ***gasoline*** powered vehicles should be considered applicable to methanol/ethanol vehicles as well. These design considerations should include the electrical equipment and their electrical classifications, ventilation and heating, materials of construction, fire protection systems, emergency systems, safety interlocks, and bus movement/operations in the storage facility.

Alcohols must be handled and used with the same respect as other ***volatile, flammable*** and toxic liquid fuels such as ***gasoline***. These Class 1 ***flammable liquids*** (which include ***gasoline*** and alcohols) present a significant increase in fire risk and toxic exposure of workers when compared to ***diesel fuel***. Transit workers that are familiar with procedures for diesel must have additional training to be made aware of potential risks that alcohol fuels could bring to the job.

2.4 BUS MAINTENANCE FACILITY

A bus maintenance facility is generally a partial or fully enclosed building within which repairs and routine servicing of buses are performed. In many transit systems, this facility consists of one or more bays consisting of either a lift or a pit over which the bus to be serviced is parked. Also, a majority of transit systems use the same maintenance facility for servicing buses using diesel and alternative fuels. In large facilities it is common to see several buses being serviced at the same time. Discussed below are special issues of design and operational practices of a bus maintenance facility which will improve safety where alcohol fuel buses are serviced.

The definition of a repair facility can be found in NFPA 88B. Only buildings meeting those definitions (or use) are discussed within this section. Garages without physical barriers between parking (not for vehicle dead storage) and maintenance of vehicles are also within the purview of this section.

In general, requirements for safety in a bus storage area should be assumed to be applicable to a bus maintenance facility also. However, there are exceptions and somewhat more restrictive requirements in a maintenance facility because of the nature of work being performed in this facility and the (increased) potential for fuel release incidents to occur compared to that in a storage facility. Only additional requirements for a maintenance facility are indicated in the sections below.

2.4.1 Electrical Equipment

In a maintenance facility there are both fixed and movable electrical machinery that may or may not be classified. This equipment includes fans, power tools, lights, radios, and heaters. A transit system should assess the potential for ignition from all electrical equipment used (or proposed to be used) in a maintenance facility and initiate appropriate design or use modifications to reduce or eliminate the ignition potential. The design changes may include:

- Electrically classifying the equipment according to the requirements of NFPA 70.
- Replacing electrical spark producing equipment and tools with air operated machinery.
- Avoiding the use of hot element electrical heaters in areas where there is a possibility of flammable vapor occurrence.

NFPA 30A §7-3 specifies the areas to be classified and the type of classification (see also Table 2-2). In general, the entire area within a pit and areas up to 46 cm (18 inches) above grade and 0.9 m (3 feet) horizontally from the edge of a maintenance pit should be classified as Class 1, Division 2. The extent of other classified areas within a maintenance facility should be in conformity with the requirements presented in Table 2-3.

The design deviations, if any, should be discussed with the transit system's A&E firm, insurance carrier, and local fire department. It is necessary to comply with all regulations and local code requirements.

2.4.2 Ventilation

Ventilation requirements for repair garages are contained in NFPA 88B for ***gasoline*** and ***flammable liquids*** and should be followed. This NFPA document suggests proper heating equipment, installation practices and ventilation requirements for such facilities. In general, the NFPA 88B standard does not prohibit the use of overhead (> 2.5 m (8 ft.) above the floor) suspended unit heaters for these facilities. Also, the ventilation requirements of §6-3 of NFPA 30A should be included in the design.

The restrictions on the use of heating equipment are indicated in NFPA 30A §8-4. This section specifies the following:

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> *8-4 Heat producing appliances using gas or oil fuel may be installed in the lubrication or service room where there is no dispensing or transferring of Class I liquids, including the open draining of automotive **gasoline** tanks, provided the bottom of the combustion chamber is at least 18 in. (46 cm) above the floor and the heat producing appliances are protected from physical damage.*
>
> *8-4.1 Solid fuel stoves shall not be permitted in any lubrication room or service room.*

The heating system combustion air inlet should be at least 46 cm (18 inches) above the floor and be interlocked with a building ventilation system that provides air flow of 0.23 m^3/min/sq. m (0.75 cfm/sq. ft.) of the floor area. The number of air changes per hour suggested by this standard is only modestly greater than exhaust rates provided in many current diesel facilities. The requirement for removal of vapors accumulations from floor level and low level exhaust from maintenance pits at 12 air changes per hour should also be noted.

2.4.3 Structural/Mechanical

Water drainage from the maintenance areas should be collected and passed through a water/oil separator. This is necessary since other fluids such as engine oil, transmission fluids and coolants could be handled in this service location. If these oils are spilled, they must be separated from any runoff water that drains from the area.

However, since alcohol fuels and coolants will mix in all proportions with water and will not be separable from the water without special distillation equipment, these fluids should be captured and not allowed to enter any sewer or drainage system, and their disposal should follow EPA procedures set forth in 40-CFR EPA, § 260 through 299: Hazardous Waste. The release of ***flammable liquids*** into a sewer system is prohibited by NFPA-30.

2.4.4 Other Requirements

The requirements for fire protection and control in a facility using or processing ***flammable*** and ***combustible*** liquids are indicated in §5-6, NFPA 30. These same requirements should be assumed applicable to a bus maintenance facility also. Automatic sprinklers may be required if the maintenance facility is more than one story in height or beneath another occupancy, depending on total floor area.

Flammability of alcohols is high. They will burn over a wide range of mixtures and methanol can ignite and burn within the fuel tank. Special flame arresters are required to be located in the neck of methanol fuel tanks to prevent ignition of fuel within the tank by outside sparks or flames. Ethanol has a lower ***flammable*** range and will not burn within the fuel tank.

Standard procedures and firefighting equipment should be used for alcohol fires. Dry powder, Halon™, CO_2 (Carbon Dioxide) and ARF (Alcohol Resistant Foam) extinguishers work well with alcohol fires. Water will extinguish such fires but the burning liquid methanol will have to be diluted with more than 5 parts of water before the flame can be extinguished. The use of water spray in front of the fire to act as a curtain will provide a fire radiation barrier that will facilitate firefighters in approaching a fire. Flames may be nearly invisible and difficult to detect in daylight.

It is necessary for the people who work daily with the alcohol fuel buses to realize the different ways in which these fuels must be handled—when compared to conventional ***diesel fuel*** or ***gasoline***. Familiarity with conventional diesel and ***gasoline*** procedures may lead workers involved in maintenance and service operations into conducting similar activities that would be dangerous with alcohol fuels. Personnel protection and work practices by maintenance personnel need to be modified to minimize potential inhalation and dermal exposures. These include use of safety goggles and impermeable (e.g., nitrile) elbow-length gloves whenever fueling a bus or opening fuel lines for maintenance.

2.5 BUS FUEL SYSTEM

Because of the corrosiveness of alcohol fuels, the materials chosen for use in the bus fuel tanks, fueling lines, fuel pump, and fuel filters should be selected with care to assure compatibility with methanol and ethanol fuels. Recommended materials can be obtained from the engine manufacturer (such as in the Detroit Diesel Methanol Engine Installation Manual, January 1991). These include the use of stainless steel or Teflon for the fuel lines, and nickel plated, stainless steel, or brass fittings.

Lubricating oil must provide adequate engine lubrication while minimizing formation of deposits where the two liquids come into contact, such as on cylinder walls and inside the fuel injector. Special lubricating oils having lower ash percent than diesel engine lubricating oils are required. In addition, a special additive is needed to ***neat*** methanol fuel to improve the lubrication property and ensure maximum engine performance and durability.

A cooler is needed in the fueling return line to the fueling tank to keep the alcohol fuel below its boiling point [337 K (148 °F) for methanol and 351 K (173 °F) for ethanol]. Also, a special dry break fuel filler neck should be installed, as well as a means for grounding (earth) of the bus during the fueling process.

2.6 PERSONNEL TRAINING

The safe operation of any transit facility using alcohol powered buses will depend very strongly on the level of training given to various personnel throughout the facility as well as on the commitment to safety from management. Safety consciousness can only be achieved by providing continuous training for all personnel (including management). Training programs should be developed to include all personnel who will be directly or indirectly involved in the maintenance, operation, fueling or storage of the buses. The following individuals (at a minimum) should be provided with formalized training:

- Fuelers;
- Bus Operators;
- Mechanics;

- Supervisors;
- Upper Management; and
- Building Occupants.

The different topics that should be covered in a training program will depend on the skill level and nature of responsibility of the personnel being training. Table 2-4 shows a matrix of types/topics of training and the category of personnel. The information in this matrix should be used as a guide to determine the minimum training to be provided.

In general, the type and level of training to be provided to personnel in a transit system using alcohol fuel buses are similar to those provided in a ***gasoline*** fueled bus operation. However, the training should be modified, where needed, to recognize the following fuel specific issues.

1. Methanol vapors are toxic and irritate exposed skin. Hence, handling the fuel should be performed by persons wearing gloves and eye protection wear. Human exposure to vapors (both inhalation and physical) should be minimized.

2. Alcohol fuels are very ***flammable*** and the fire may not be easily visible. Proper training in fire prevention, detection and control should be provided.

Training in all areas identified in Table 2-4 can be accomplished in a variety of ways. In-house training is probably the most cost-effective way to provide training to employees, provided a training department exists within the organization. If proper in-house technical information is not available, Train-the-Trainer courses are available from government agencies and private training companies. The Federal Transit Administration offers one such course entitled "Instructor's Course in Alternative Fuel Safety." This type of training can also be used to reinforce in-house trainers' technical training material so that it can be passed on to the transit property employees.

Insurance and utility companies are also a source for training material. These training courses are generally given at specific locations but can also be brought to the transit property. A transit agency should check with its insurance company or the company supplying its fuel.

Record keeping is an important part of any training program. The type of training provided, the date, and number of hours taken are all critical data should there be an accident. Copies of training records should be included in employees' personnel files.

Table 2-4
Training Topics for Various Personnel

Training Topics	Fuelers/ Mechanics	Building Occupants	Bus Operators	Emergency Response Personnel	Local Groups	Manage-ment	Utilities
Physical/Chemical Properties of the Fuel	✓	✓	✓	✓		✓	✓
Safe Handling/Fueling Procedures	✓		✓				
Emergency Notification Procedures	✓	✓	✓			✓	
Emergency Evacuation Procedures	✓	✓	✓	✓	✓	✓	
Fire Detection/Suppression Features	✓	✓	✓	✓		✓	✓
Vehicle/Facility Safety Features	✓		✓	✓		✓	
Safe Repair/Maintenance Procedures	✓					✓	
Licenses/Permits Required/Certification	†		†			‡	‡
Fire Prevention	✓	✓	✓			✓	
Emergency Preparedness Drills	✓		✓	✓	✓	✓	✓

† If Applicable ‡ As Required

Maintenance records of equipment failures become very important when trying to isolate and identify equipment problems. Every failure, no matter how small in nature, should be recorded and, if possible, investigated to determine why the failure occurred. If needed, the manufacturer should be called in to offer technical assistance.

Fire drills should be conducted on a regular basis and records maintained and made available for inspection by fire department and/or safety personnel. Deficiencies in the evacuation of a building or any problems with alarm/detection equipment should be documented and forwarded to the appropriate person for corrective action. OSHA regulations require that fire drills be conducted on a regular basis.

Fire alarm systems as well as fire suppression systems installed in the facility and on the buses should be inspected on a regular basis and conform to the manufacturer's requirements and/or local codes, if any. In addition to the regular inspections, periodic testing of this equipment may also be required. NFPA standards should be consulted to determine exact testing procedures and inspection intervals. Records of these inspections and tests should be kept on the premises. Additional information is included in Section 2.2.6 of this document, "Maintenance of Safety Equipment."

Personnel required to receive safety training on the chemical/physical properties of ***alcohol fuels*** should receive basic information on the potential dangers associated with a release of the fuel or its vapors. The information contained in Section 2.1, "General Properties," should be included in the training.

Fire prevention should be practiced whether or not ***alcohol fuel*** buses are used. Good housekeeping and the proper storage of ***flammable*** and ***combustible*** materials are essential in order to provide for a safe workplace for employees. Strict enforcement of "no smoking" policies, adequate ventilation, and the use of personal protective and safety equipment will go a long way to eliminate the potential for a problem.

Local fire department, police, and emergency medical service personnel should also receive training on the location of all safety controls, the hazards associated with ***alcohol fuels,*** and any special information on the systems installed.

2.7 EMERGENCY PREPAREDNESS

The establishment of an Emergency Response Action Plan constitutes an important part of facility safety management for the handling, storing, or dispensing of hazardous/***flammable*** materials such as ***alcohol fuels.*** The Emergency Response Action Plan must be a **written document** which addresses the following issues.

1. Identification of emergencies (detection and classification).

2. Action times required, their implementation sequence and the time duration within which to initiate different actions.

3. Notification procedures and a notification list which should include both internal (i.e., transit agency) and external (fire service, ambulance, police) contacts.

4. Evacuation procedures and required training to implement emergency procedures.

5. Location and type of safety systems (both in the facility and on the bus).

6. Event suppression or management actions which should include personnel rescue, fire suppression strategies, evacuation of personnel, and protection of property as yet unaffected.

OSHA's personnel protection regulations require the employer to have an "Employee Emergency and Fire Prevention Plan" (29 CFR §1910.38). Specifically, 29 CFR §1910.38 requires the inclusion of the following items, as a minimum, in the plan:

OSHA

29 CFR §1910.38 Employee Emergency and Fire Prevention Plan

(i) *Emergency escape procedures and emergency escape route assignments;*

(ii) *Procedures to be followed by employees who remain to operate critical plant operations before they evacuate;*

(iii) *Procedures to account for all employees after emergency evacuation has been completed;*

(iv) *Rescue and medical duties for those employees who are to perform them;*

(v) *The preferred means of reporting fires and other emergencies; and*

(vi) *Names or regular job titles of persons or departments who can be contacted for further information or explanation of duties under the plan.*

The transit system should comply with the provisions of OSHA regulations and incorporate these requirements in its ***system safety*** plan.

Because of the potential impacts of an alcohol spill and ignition incident, it is important that the transit agency work closely with the local emergency response agency to develop a joint notification and action implementation plan.

Emergency preparedness drills involving the transit property, fire department, emergency medical services and police should be conducted to test the effectiveness of the Emergency Response Action Plan. This will help in minimizing unnecessary damage by familiarizing response personnel with the safety equipment installed. In areas where the transit system operates in more than one jurisdiction, drills should be rotated so that all jurisdictions have a chance to participate. Emergency plans should clearly identify which agency is in charge of the incident prior to an actual emergency in order to eliminate unnecessary delays.

These emergency exercises should be followed up with a critique. If problems are identified, additional training may be needed or the Emergency Response Action Plan may need to be revised.

Transit employees must be familiar with their agency's Emergency Response Action Plan so they can implement it as soon as an alarm is sounded. This response may include staffing fire command stations, removing buses from other parts of the facility, or helping in the evacuation of the facility.

Depending on the location of the alcohol facility, local civic groups, school boards, and local businesses should be made aware of any emergency action plans which could affect them in a major alcohol spill incident. In addition to providing training to the fire, police, and emergency medical services, the local fuel supplier should be included in emergency preparedness.

Chapter 3
Alternative Fuel Facility System Safety Process

3.1 SAFETY REQUIREMENTS

The purpose of this section is to assist transit agencies in implementing a program to identify and resolve potential safety issues that may occur over the lifetime of the system. Such a program will assist in the development of a proactive safety assessment that allows for the identification and resolution of potential safety issues during the planning, design, construction, and operation of the transit system. This section identifies the important elements of a safety/***hazard*** assessment technique, by which a transit authority can conduct a ***risk*** assessment to address design issues when standards/codes do not provide the necessary definitive guidance or when a transit authority wishes to consider alternative designs.

A ***system safety*** program, discussed in Section 3.2, should be instituted during the system planning/design phase and continue throughout the system construction, renovation, operation and disposition of a facility used for the maintenance, fueling and/or storage of transit vehicles fueled with alternative fuels. The ***system safety*** program should emphasize the prevention of accidents by identifying and resolving ***hazards*** in a systematic manner in accordance with the Hazard Resolution Process elaborated in Section 3.3.4.

3.2 SYSTEM SAFETY PROGRAM

A ***system safety*** program should be implemented to identify and resolve ***hazards***. The transit authority should provide for the development of a System Safety Program Plan (SSPP) to assist in implementing and documenting that program. The SSPP should identify the responsibilities of all parties for implementing a ***system safety*** program.

The SSPP should:

- Have as its objective, to provide for the safety of passengers, employees, the public, and equipment.

- Encompass all system elements and organizations within the transit system.

- Identify the safety roles and responsibilities of all organizational elements, and require accountability.

- Designate one individual with the responsibility for the safety of the system who has clearly defined roles and responsibilities established through a written policy.

- Establish a safety program that contains a ***hazard*** resolution process including the procedures necessary to identify and resolve ***hazards*** throughout the system's life cycle.

- Ensure transit authority management's commitment and approval, in the form of a signed policy, for allocation of resources required to maintain a high level of safety.

The individual identified to carry out the safety program should clearly have the authority to insure its implementation and should report directly to top management.

The SSPP should be developed during the planning/design phase of the alternative fuel transit facility and maintained current throughout the facility system's life cycle. The SSPP should be prepared in general accordance with the requirements of MIL-STD-882C, Task 102 or equivalent. The SSPP should, as a minimum, identify the scope of the ***system safety*** program activities including those discussed previously.

3.3 HAZARD IDENTIFICATION AND RESOLUTION PROCESS

A ***hazard*** analysis should be performed on all facility modifications and new construction projects. This analysis should be initiated by defining the physical and functional characteristics of the alternative fuel vehicle and facility system to be analyzed. These characteristics should be presented in terms of the people, procedures, facilities, and equipment which are integrated to perform a specific operational task or function within a specified environment.

3.3.1 System Definition

The first step in the ***hazard*** resolution process is to define the physical and functional characteristics of the system to be analyzed. These characteristics are presented in terms of the major elements which make up the system: equipment; procedures; people; and environment. A knowledge and understanding of how the individual system elements interface with each other are essential to the ***hazard*** identification effort.

3.3.2 Hazard Identification

The second step in the ***hazard*** resolution process involves the identification of ***hazards*** and the determination of their causes.

There are four basic methods of ***hazard*** identification that may be employed to identify ***hazards***. These methods are:

- data from previous accidents (case studies) or operating experience;
- scenario development and judgement of knowledgeable individuals;
- generic ***hazard*** checklists; and
- formal ***hazard*** analysis techniques.

When identifying the safety ***hazards*** present in a system, a major concern is that only a portion of the total number of system ***hazards*** has been identified. Therefore, every effort should be made to identify and catalog the whole universe of potential ***hazards***.

There are several ***hazard*** analyses techniques that should be considered to assist in evaluating potential ***hazards*** and documenting their resolution. These techniques include a Preliminary Hazard Analysis (PHA), Subsystem Hazard Analysis (SSHA), System Hazard Analysis (SHA) and Operational and Support Hazard Analysis (O&SHA). These analyses should be conducted in general accordance with MIL-STD-882C, Tasks 202 (PHA), 204 (SSHA), 205 (SHA) and 206 (O&SHA), or equivalent, respectively.

3.3.3 Hazard Assessment

The third step in the ***hazard*** resolution process is to assess the identified ***hazards*** in terms of the severity or consequence of the ***hazard*** and the probability of occurrence of each type of ***hazard***. This should be accomplished in general conformity with the criteria outline in MIL-STD-882C, Paragraphs 4.5 and 4.6 or equivalent.

3.3.4 Hazard Resolution

After the ***hazard*** assessment is completed, ***hazards*** can be resolved by deciding to either assume the ***risk*** associated with the ***hazard*** or to eliminate or control the ***hazard***. The ***hazard*** reduction precedence is as follows:

- Design to eliminate or control the ***hazard***.
- Add safety devices.

- Provide warning devices.
- Institute special procedures and training.
- Accept the ***hazard***.
- Eliminate the use of the system/subsystem/equipment that creates an unacceptable ***hazard***.

Various means can be employed in reducing the ***risk*** to a level acceptable to management. Resolution strategies or countermeasures in order of preference are:

Design to Eliminate Hazards. This strategy generally applies to acquisition of new equipment or expansion of existing systems, however, it can also be applied to any change in equipment or individual subsystems. In some cases, ***hazards*** are inherent and cannot be eliminated completely through design.

Design for Minimum Hazards. A major safety goal during the system design process is to include safety features that are ***fail-safe*** or have capabilities to handle contingencies through redundancies of critical elements. Complex features that could increase the likelihood of ***hazard*** occurrence should be avoided. Changes may be made to an existing design to control the known ***hazard***.

Safety Devices. Known ***hazards*** which cannot be eliminated or minimized through design may be controlled through the use of appropriate safety devices. This could result in the ***hazards*** being reduced to an acceptable ***risk*** level. Safety devices may be a part of the system, subsystem, or equipment.

Warning Devices. Where it is not possible to preclude the existence or occurrence of an identified ***hazard***, visual or audible warning devices may be employed for the timely detection of conditions that precede the actual occurrence of the ***hazard***. Warning signals and their application should be designed to minimize the likelihood of false alarms that could lead to creation of secondary hazardous conditions.

Procedures and Training. Where it is not possible to eliminate or control a ***hazard*** using one of the aforementioned methods, safe procedures and/or emergency procedures should be developed and formally implemented. These procedures should be standardized and used in all test, operational, and maintenance activities. Personnel should receive training in order to carry out these procedures.

Hazard Acceptance/System Disposal. Where it is not possible to reduce a ***hazard*** by any means, a decision must be made to either accept the ***hazard*** or dispose of the system.

Risk assessment estimates (Tables 3-1, 3-2 and 3-3) should be used as the basis in the decision-making process to determine whether individual facility, system or subsystem ***hazards*** should be eliminated, mitigated, or accepted. ***Hazards*** should be resolved through a design process that emphasizes the elimination of the ***hazard***.

3.3.5 Follow-up

The last step in the ***hazard*** resolution process is follow-up. It is necessary to monitor the effectiveness of recommended countermeasures and ensure that new ***hazards*** are not introduced as a result. In addition, whenever changes are made to any of the system elements (equipment, procedures, people, and/or environment), a ***hazard*** analysis should be conducted to identify and resolve any new ***hazards***.

This process should include full documentation of the ***hazard*** resolution activities. The effectiveness of the countermeasures should be monitored to determine that no new ***hazard***s are introduced. In addition, whenever substantive changes are made to the system, analyses should be conducted to identify and resolve any new ***hazards***.

3.4 SAFETY PRINCIPLES

The following safety principles should be observed in the transit system operating alternative fuel vehicles (See Tables 3-1, 3-2, and 3-3 for the definition of undesirable and unacceptable ***hazards***):

1. When the system is operating normally there should be no unacceptable or undesirable ***hazard*** conditions.

2. The system design should require positive actions to be taken in a prescribed manner to either begin system operation or continue system operation.

3. The safety of the system in the normal operating mode should not depend on the correctness of actions or procedures used by operating personnel.

4. There should be no single point failures in the system that can result in an unacceptable or undesirable ***hazard*** condition.

5. If one failure combined with a second failure can cause an unacceptable or undesirable ***hazard*** condition, the first failure should be detected and the system shall achieve a known ***safe state*** before the second failure can occur.

6. Software faults should not cause an unacceptable or undesirable ***hazard*** condition.

7. Unacceptable ***hazards*** should be eliminated by design.

Table 3-1
Risk Assessment

Frequency	*Hazard* Category			
	I–Catastrophic	II–Critical	III–Marginal	IV–Negligible
A–Frequent	IA	IIA	IIIA	IVA
B–Probable	IB	IIB	IIIB	IVB
C–Occasional	IC	IIC	IIIC	IVC
D–Remote	ID	IID	IIID	IVD
E–Improbable	IE	IIE	IIIE	IVE

IA, IIA, IIIA, IB, IIB, IC	Unacceptable
IIIB, IIC, ID	Undesirable (allowable with agreement from Authority having jurisdiction)
IVA, IVB, IIIC, IID, IIID, IE, IIE	Acceptable with notification to the Authority having jurisdiction
IVC, IVD, IIIE, IVE	Acceptable

Table 3-2
Frequency Categories

Frequency	Definition of Term
A–Frequent	***MTBE*** is less than 1,000 operating hours
B–Probable	***MTBE*** is equal or greater than 1,000 operating hours and less than 100,000 operating hours
C–Occasional	***MTBE*** is equal or greater than 100,000 operating hours and less than 1,000,000 operating hours
D–Remote	***MTBE*** is equal or greater than 1,000,000 operating hours and less than 100,000,000 operating hours
E–Improbable	***MTBE*** is greater than 100,000,000 operating hours

Table 3-3
Hazard Categories

Hazard	Definition of Term
I–Catastrophic	Death, system loss, or severe environmental damage
II–Critical	Severe injury, severe occupational illness, major system or environmental damage
III–Marginal	Minor injury, minor occupational illness, or minor system or environmental damage
IV–Negligible	Less than minor injury, occupational illness, or less than minor system or environmental damage

8. Maintenance activities required to preserve specified ***risk*** levels (Table 3-1) involve the elimination of unacceptable or undesirable ***hazard*** conditions during maintenance. These should be prescribed to the individual responsible for ***system safety*** during the design phase. These maintenance activities should be minimized in both the frequency and in the complexity of their implementation. The personnel qualifications required to adequately implement these activities should also be identified.

3.5 VERIFICATION AND VALIDATION

The design and implementation of all ***safety critical*** hardware and software elements of the system as identified in the ***hazard*** resolution process should be subjected to verification and validation. The objective of this verification and validation activity should be to verify that all ***safety critical*** elements have been designed and implemented to achieve safe operation and to verify the level of safety achieved.

The verification and validation process should include:

1. The identification of all factors upon which the assurance of safety depends. Such factors should be directly associated with the design concept used.

2. The identification of all ***safety critical*** functions performed by the system.

3. Analyses demonstrating that all dependent factors are satisfied and that each ***safety critical*** function is implemented in accordance with safety principles. Each facility used for storing, maintaining and/or fueling alternative fuel vehicles should, in addition to the above, exhibit a calculated Mean Time Between Hazardous Events ***(MTBHE)*** of 100 million system operating hours or greater. ***System safety*** documentation should support this calculation and substantiate the methodology used to arrive at the result.

Glossary

Approved Acceptable to the "authority having jurisdiction."

Authority Having Jurisdiction The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

Autoignition Temperature The temperature at which a flammable concentration of vapor will ignite in the absence of an external ignition source. (Ignition effected by a hot surface rather than by an open flame or spark.)

Biomass Plant material, vegetation or agricultural waste used as a fuel.

Cetane Number A measure of the tendency of a fuel to cause engine knock in a diesel engine. The scale is based on a comparison of the knock tendency of the fuel in question to that of two reference fuels, cetane and alpha-methylnaphthalene. Cetane, which has good compression ignition properties, is assigned a value of 100. Alpha-methylnaphthalene, which has very poor compression ignition qualities, is assigned a value of zero. Fuels with high cetane numbers tend to have low octane numbers and vice versa.

Chemical Formula The chemical composition. Methanol and ethanol are pure substances with a definite formula. Natural gas, commercial propane, gasoline, and diesel fuel have variable compositions.

Combustible Capable of igniting and burning.

Denatured To render unfit to eat or drink.

Diesel Fuel Diesel fuel is the most common fuel for heavy duty engines and therefore a standard of comparison for other, alternative fuels.

Fail-Safe A characteristic of a system or its elements whereby any failure or malfunction affecting safety will cause the system to revert to a state that is known to be safe.

Flammability Limits The range of fuel vapor concentrations in a fuel-air mixture over which burning can occur. Below the lower flammability limit there is not enough fuel to burn. Above the higher flammability limit there is not enough air to support combustion.

Flammable Easily ignited and capable of burning rapidly.

Flammable Liquid A liquid having a flash point below 100 °F (37.8 °C) and having a vapor pressure not exceeding 40 psia (2,068 mm Hg) at 100 °F (37.8 °C) shall be known as a Class I liquid.

Flash Point The temperature below which the liquid does not produce sufficient vapors for immediate ignition by an external ignition source. If a flammable substance is not above its flash point, it must be heated to the flash point before ignition can occur.

Fuel Energy Value The amount of energy contained in the fuel. Fuel heating values are either listed as Higher Heating Values (HHV) or Lower Heating Values (LHV), depending on whether the latent heat of vaporization of the water formed from the combustion of the fuel is considered available. If it is, then the higher or gross heating value is used; if it is not then the lower, or net, heating value is used.

Gasoline In this report gasoline refers to 87 octane unleaded gasoline.

Hazard An existing or potential condition that can result in an accident.

Heat of Vaporization The amount of heat energy necessary to vaporize one unit mass (e.g., a kilogram) of liquid fuel. For comparison, the latent heat of vaporization of water is 2550 kJ/kg..

Listed Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Neat Not diluted.

Octane Number A measure of the tendency of a fuel to cause engine knock in a spark-ignited engine. The scale is based on a comparison of the knock tendency of the fuel in question to that of two reference fuels, isooctane and n-heptane. Isooctane, which has good knock resistance, is assigned a value of 100. Nheptane, which has very poor knock resistance, is assigned a value of zero. Fuels with high octane numbers tend to have low cetane numbers and vice versa.

PSI, PSIG, and PSIA Pounds per square inch, pounds per square inch gauge, and pounds per square inch absolute, respectively.

Reactive Tending to participate readily in chemical or physical reactions.

Reid Vapor Pressure The pressure exerted by vapor in equilibrium with its liquid at 100 °F. This parameter is generally used to compare the relative volatility of liquids.

Relative Fuel Vapor Density The density of the fuel vapor compared to air. Thus, on this scale, air equals 1.00.

Risk A measure of the severity and likelihood of an accident.

Safety Critical A designation placed on a system, subsystem, element, component, device, or function denoting that satisfactory operation of such is mandatory to mitigation of unacceptable and undesirable hazards as defined in Table 3-1.

Sources of Ignition Devices or equipment that, because of their modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable vapor-air mixtures when introduced into such a mixture or when such a mixture comes into contact with them and that will permit propagation of flame away from them.

Spark Ignition Energy The minimum spark size required to ignite the most flammable vapor-air mixture under the most favorable conditions. The details of the test apparatus used can easily account for a factor of two variation in the experimental results. Note also that a typical two-cell flashlight produces about 2000 mJ of energy per second, so the ignition energies listed represent very small amounts of energy.

System Safety The application of engineering and management principles, criteria, and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle.

Vapor Pressure The pressure, measured in psia, exerted by a volatile liquid as determined by ASTM D 323, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method).*

Ventilation Ventilation is for the prevention of fire and explosion. It is considered adequate if it is sufficient to prevent accumulation of significant quantities of vapor-air mixtures in concentrations over one-fourth of the lower flammable limit.

Volatile Evaporating readily at normal temperatures and pressures.

Volume Fuel with Same Energy This is the ratio of the volumetric energy content of the fuel to that of gasoline or diesel fuel. Numerically, this is the ratio of the LHV in MJ/L for the fuel to the lower heating value of gasoline or diesel fuel in MJ/L.

List of Acronyms

A&E	Architectural and Engineering
ACH	Air Changes per Hour
ADA	Americans with Disabilities Act, 1990
AFI	Alternative Fuel Initiative
AMFA	Alternative Motor Fuels Act of 1988
ANSI	American National Standards Institute
ARF	Alcohol Resistant Foam
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
BOCA	Building Officials and Code Administrators (Chicago, IL)
CFR	Code of Federal Regulations
CNG	Compressed Natural Gas
CSA	Canadian Standards Association
DVE	Diesel Volume Equivalent
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 1992
ESD	Emergency Shutdown
FM	Factory Mutual
FTA	Federal Transit Administration of the United States Department of Transportation
LFL	Lower Flammability Limit
LHV	Lower Heating Value
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas

MTBE	Mean Time Between Events
MTBHE	Mean Time Between Hazardous Events
NEC	National Electrical Code
NFPA	National Fire Protection Association
NGV	Natural Gas Vehicle
O&SHA	Operational and Support Hazard Analysis
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration (of U.S. Dept. of Labor)
PHA	Preliminary Hazard Analysis
ppm	Parts Per Million
SHA	Support Hazard Analysis
SSHA	Subsystem Hazard Analysis
SSPP	System Safety Program Plan
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
TWA	Time-Weighted Average
U.S. DOT	United States Department of Transportation
UFL	Upper Flammability Limit

Glossary of Graphic Symbols

Information

OSHA — Occupational Safety & Health Administration Logo

National Electrical Code Logo

NFPA® — National Fire Protection Association Logo

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