SP-4-44-S

LIQUID PROPELLANTS
SAFETY HANDBOOK

Prepared by

SAFETY OFFICE

JOHN F. KENNEDY SPACE CENTER, NASA

April 1, 1965

LIST OF EFFECTIVE PAGES

Total number of pages in this publication is 102, consisting of the following:

Page No.		Issue	Page No.		Issue
Title		Original	2-1	through 2-19	Original
A		Original	2-20	BLANK	Original
i	through v	Original	3-1	through 3-21	Original
vi	BLANK	Original	3-22	BLANK	Original
vii		Original	4-1	through 4-7	Original
viii	BLANK	Original	4-8	BLANK	Original
ix	through x	Original	5-1	through 5-3	Original
1-1	through 1-22	Original	5-4	BLANK	Original

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TABLE OF CONTENTS

Section Page

I DESCRIPTION AND PROPERTIES OF LIQUID PROPELLANTS

TABLE OF CONTENTS (Continued)

II STORAGE FACILITIES

TABLE OF CONTENTS (Continued)

III STORAGE AND TRANSFER

TABLE OF CONTENTS (Continued)

Section Page

IV SPILLS, LEAKS, AND DECONTAMINATION

V PROPELLANT DISPOSAL

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

INTRODUCTION

PURPOSE

The purpose of this handbook is to familiarize operations personnel of the John F. Kennedy Space Center (KSC) with procedures and safety requirements for liquid propellants. It is written as a technical supplement to Safety Regulations, TSOP's, and Safety Plans for personnel involved in handling liquid propellants.

While liquid propellants should be handled with respect and understanding, this handbook should eliminate any possible unwarranted fears.

SCOPE

To fulfill the stated purpose, this handbook includes description and properties of liquid propellants, storage facilities, firefighting facilities, storage and transfer of liquid propellants, spills, leaks and decontamination, and disposal of liquid propellants.

RESPONSIBILITIES

The Director, KSC, is responsible through the Safety Office for establishing safety policies, criteria, and programs. The Safety Office, then, through its branches, establishes these policies, develops criteria, and promotes appropriate programs.

Safety is the responsibility - not only of supervisors - but of all personnel. It is an important part of each person's job, not a sideline. Since every job assignment requires that the work be done properly, efficiently - and safely - each person is responsible for operations under his control.

CHANGES AND REVISIONS

This handbook contains the latest information concerning liquid propellants utilized by the National Aeronautics and Space Administration at the Kennedy Space Center at the Merritt Island Launch Area as of the date of this publication. Changes will be issued periodically to keep the handbook current and accurate. Changes will consist of one or more new pages containing updated material. A new title page will be included with each Change, showing the latest effective date. These changes will be distributed to all persons issued a copy of the basic issue. When a Change is received, insert the new pages in their proper location, removing and destroying any superseded pages. It is the responsibility of each person to keep his copy up to date.

Each page containing changed material will have the word "Changed", followed by the Change date, at the bottom of the page opposite the page number. A change in the technical content of a text page will be indicated by a vertical black line in the outer page margin, extending the full depth of the changed text.

A List of Effective Pages ("A" page) at the front of each handbook lists all the pages in the handbook. A new List of Effective Pages will be included with every Change issued, listing every page, and indicating the pages included in the current Change. A cross-check on the status of the handbook can thus be made by referring to the latest List of Effective Pages.

Whenever the number of pages affected by the previous Changes, plus the pages affected by the current Change, total over 60 percent of the handbook, a Revision will be issued. A Revision is a complete new issue with all change dates and symbols deleted and all modified page, paragraph, figure and table numbers renumbered in their proper sequence. When a Revision is distributed to holders of copies, they should remove from the binders all previous pages, insert Revision pages in their place, and destroy the old pages.

COMMENTS AND SUGGESTIONS

Comments and suggestions from users of this handbook are welcomed and encouraged. It is hoped that all persons engaged in work involving microwave radiation will be continuously safety-conscious. A safety-conscious work force will observe conditions and practices which should be included in this handbook. Constructive criticism will improve its usefulness.

Comment sheets will be found at the back of the handbook. Fill out one or more of these sheets, describing your suggestion as completely as possible. Give your name, location, and organization so you may be contacted for additional information. Take or mail the comment sheet to the Safety Office (S). All comments, suggestions and criticisms will be given the fullest consideration, and will be incorporated into the handbook when deemed practical by the Safety Office.

SECTION I
DESCRIPTION AND PROPERTIES OF LIQUID PROPELLANTS

1-1 GENERAL

Liquid-propellant fuels and oxidizers are, in general, highly reactive. Consequently the propellants and their reaction products possess certain hazardous properties which must be fully understood by all who are required to handle them. So that these hazards can be recognized and understood, information on the properties of the propellant materials is included.

Unless otherwise specified, all temperatures are in degrees Fahrenheit.

1-2 ETHYL ALCOHOL

1-3 PHYSICAL PROPERTIES

Ethyl alcohol is a colorless liquid of pleasant odor. It is capable of being mixed in all proportions with water or ether with the following properties:

Boiling point (°F)	173
Freezing point (°F)	-174
Density of liquid at 68°F (lb/gal)	6.6
Specific gravity of vapor relative to normal air	1.59
Critical temperature (°F)	470
Critical pressure (psig)	913
Critical density (lb/gal)	2.3
Vapor pressure (psig): at 68°F	0.9
at 104°F	2.6
Viscosity at 68°F (centipoises)	1.2
Flash point (°F)	
Closed cup	55
Open cup	70
Autoignition temperature (°F)	700
Flammability (or explosive) limits in air at 68°F (% by volume):	
Lower	3.3
Upper	19.0
Threshold limit	1000 ppm (1900 mg/cu m)

1-4 CHEMICAL PROPERTIES

All of the alcohols are excellent solvents. The chemical composition of ethyl alcohol (ethanol, grain alcohol) is C_2H_5OH. Combustion of the alcohols differs from the combustion of the hydrocarbons in that the alcohol flames are difficult to see in daylight. The alcohols are moderately flammable and water soluble. Ethyl alcohol will burn, once lighted, even though diluted to less than 50 percent concentration in water.

1-5 PHYSIOLOGICAL EFFECTS

The alcohols used as propellants have several toxic properties that contribute tc hazards: they irritate sensitive tissues, they are fat solvents, and when absorbed into the body they cause a depression of the higher brain centers.

The greatest danger from ethyl alcohol is the likelihood of consumption as a beverage by uninformed persons. The consumption of propellant alcohol must be avoided because of the poisonous compounds used to denature it.

Ethyl alcohol in the liquid form can irritate eyes and to a lesser degree, skin. In high concentrations the eyes and respiratory passages may be irritated by the vapor.

1-6 FURFURYL ALCOHOL

1-7 PHYSICAL PROPERTIES

Furfuryl alcohol is a clear, amber-colored, mobile liquid. All of the alcohols have characteristic odors. The following is a list of physical properties of furfuryl alcohol:

Boiling point (°F)	338
Freezing point (°F)	-26
Density of liquid at 68°F (lb/gal)	10.7
Specific gravity of vapor relative to normal air	3.38
Vapor pressure (psia): at 68°F	0.1
at 104°F	0.1
Viscosity at 68°F (centipoises)	
Flash point (°F)	
Closed cup	--
Open cup	167
Flammability (or explosive) limits in air at 68°F (% by volume):	
Lower	1.8
Upper	16.3
Threshold limit	50 ppm (200 mg/cu m)

1-8 CHEMICAL PROPERTIES

Furfuryl alcohol is the only one showing a tendency toward instability. It forms water-insoluble products with darkening of the solution upon exposure to heat, atmospheric oxygen or acidic atmospheres or upon standing for long periods of time. The final result is a solid mass. This tendency can be reduced by use of an inert gas blanket, stabilizers, and sheltered storage.

1-9 PHYSIOLOGICAL EFFECTS

Furfuryl alcohol has the lowest threshold limit value of any of the alcohols mentioned. While it has a low volatility, toxic concentrations can build up when ventilation is inadequate. Like other alcohols, it has a depressant action on the central nervous system. It is more irritable to the respiratory tract than the other alcohols.

1-10 ANHYDROUS AMMONIA

1-11 PHYSICAL PROPERTIES

At atmospheric temperatures and pressures, ammonia is a pungent, colorless vapor. The following is a list of physical properties of anhydrous ammonias:

Boiling point (°F)	-28
Freezing point (°F)	-108
Density of liquid at boiling point (lb/gal)	5.7
Specific gravity of vapor, relative to normal air	0.6
Critical temperature (°F)	270
Critical pressure (psig)	1620
Critical density (lb/gal)	2.0
Vapor pressure (psig): at 68°F	110
at 104°F	211
Viscosity (centipoises): at	
boiling point	0.26
68°F	0.15
Autoignition temperature (°F)	1200
Flammability (or explosive) limits in air at 68°F (% by volume):	
Lower	16.1
Upper	26.8
Threshold limit	50 ppm (35 mg/cu m)

Ammonia is very stable and is not shock sensitive. It is thermally stable at temperatures as high as 900°F, above which disassociation to nitrogen and hydrogen begins.

Ammonia is soluble in water, alcohol, ether and many other solvents.

1-12 CHEMICAL PROPERTIES

Anhydrous ammonia is highly reactive, is alkaline in nature, and is a reducing agent. Concentrations of 16 to 27 percent burn in air. Ammonia reacts with organic or inorganic acids and forms white fumes in the presence of acid vapors. Most ammonia corrodes copper, tin and zinc and many alloys, particularly copper alloys.

The chemical composition of anhydrous ammonia is: NH_3.

1-13 PHYSIOLOGICAL EFFECTS

Ammonia has caustic properties in either liquid or vapor form. The liquid is cold and highly volatile.

Liquid ammonia, because of its low temperature and caustic properties, can cause damage to the skin or eyes. The vapor is irritating to the skin, eyes and respiratory tract. Most people can detect the odor at levels below the threshold limit. Some irritation has been observed at levels not much greater than the threshold limit value, and at around 400 ppm throat irritation is common. A level of 700 ppm and over is hazardous to life in one-half hour. Concentrations above 10,000 ppm (1 percent) are usually irritating to wet skin, and chemical burns of the skin may occur rapidly at vapor concentrations above 3 percent.

1-14. ANILINE

1-15 PHYSICAL PROPERTIES

Freshly distilled aniline is a clear, slightly oily liquid. After extended storage, it gradually turns through deepening shades of yellow to dark brown. This color change does not adversely affect its use as a propellant. The following is a list of physical properties of aniline:

Boiling point (°F)	364
Freezing point (°F)	21
Density of liquid at 68°F (lb/gal)	85
Specific gravity of vapor relative to normal air	3.2

Critical temperature (°F)	798
Critical pressure (psig)	755
Critical density (lb/gal)	2.8
Vapor pressure (psia): at 120°F	0.05
at 180°F	0.42
Viscosity at 68°F (centipoises)	4.43
Flash point (°F)	
Closed cup	160 to 168
Open cup	195
Autoignition temperature (°F)	980 to 1420
Threshold limit	5 ppm (19 mg/cu m)

1-16 CHEMICAL PROPERTIES

The chemical composition of aniline (aniline oil and aminobenzene) is: $C_6H_5NH_2$ minimum purity 99.8 percent.

Aniline is mildly alkaline and reacts with moderately concentrated strong mineral acids to form colored compounds. With dilute mineral acids, notably hydrochloric and sulfuric acids, it forms water-soluble salts. Aniline is hypergolic with fuming nitric acids. It is considered noncorrosive but slowly attacks nonferrous metals and some organic materials. This effect is due both to water content of commercial aniline and to its mild basic properties.

Aniline is soluble in ether, alcohol and most organic solvents. It is only slightly soluble in water (3.2 percent by volume at 68°F).

Aniline is a stable material under normal conditions. It does not decompose at its boiling point or when exposed to high environmental temperatures for long periods.

1-17 PHYSIOLOGICAL EFFECTS

Aniline readily penetrates intact skin and is only moderately volatile. It causes the oxygen-carrying pigment in the blood, hemoglobin, to change to a methemoglobin; thus, the ability of blood to transport oxygen to tissues is reduced in aniline poisoning.

Cyanosis, the most common symptom of aniline poisoning, is characterized by a bluish tinge which results from inadequate oxygenation of tissues. The location of the blue color depends on the route of entry of the compound into the body. When the liquid has penetrated the skin, the area of contact will sometimes appear cyanotic. When the compound has been swallowed or inhaled, and also in some cases of skin penetration, the bluish appearance will be generalized but may not be apparent in other than eyelids, lips, oral membranes and fingernail beds. In addition to cyanosis, which is important in detecting aniline absorption, this poisoning causes headache, weakness, difficult breathing, convulsions and psychic disturbances. The number of these effects and their severity will vary with the amount of the compound absorbed; in mild cases, only weakness or headache may be noticed.

1-18 ETHYLENE OXIDE

1-19 PHYSICAL PROPERTIES

Ethylene oxide is a gas at room temperature and a clear, colorless, mobile liquid at lower temperatures. It has a characteristic ether-like odor that is irritating in high concentrations. Ethylene oxide has the following physical properties:

Boiling point (°F)	51
Freezing point (°F)	-168
Density of liquid at boiling point (lb/gal)	7.4
Specific gravity of vapor relative to normal air	1.5
Critical temperature (°F)	383
Critical pressure (psig)	1028
Critical density (lb/gal)	2.7
Vapor pressure (psia):	
At 0°F	4.3
At 40°F	11.5
At 80°F	27.0
At 120°F	55.0
Viscosity at boiling point (centipoises)	0.28
Flash point, open cup (°F)	0.
Autoignition temperature (°F)	804 to 1060
Flammability (or explosive) limits	
In air at 68°F (% by volume):	
Lower limit	3
Upper limit	100
Threshold limit	50 ppm (90 mg/cu m)

1-20 CHEMICAL PROPERTIES

The vapor of ethylene oxide is flammable in all proportions above 3 percent ethylene oxide by volume. It is a reactive material, forming addition compounds with water, alcohols, amines and organic and mineral acids. Ethylene oxide can polymerize in the presence of such materials as pure anhydrous chlorides of iron, tin and aluminum, oxides of iron, aluminum and magnesium, the alkali metal hydroxides and acids; often with violence and always with the liberation of heat. Liquid ethylene oxide must be diluted with 22 times its volume of water before it becomes nonflammable.

Ethylene oxide is completely soluble in water at 50°F, but at higher temperatures it reacts with water, most alcohols and amines, ammonia, and organic and mineral acids. Of the natural gases, only butane is appreciably soluble in liquid ethylene oxide.

Liquid ethylene oxide, when pure, is stable. Materials such as the anhydrous chlorides of iron, tin and aluminum, oxides of iron and aluminum, alkali metal hydroxides, and acids, however, catalyze the polymerization of ethylene oxide.

1-21 PHYSIOLOGICAL EFFECTS

Liquid ethylene oxide does not irritate the skin but, because of its rapid volatilization, may cause local cooling and possible freezing of splashed skin areas. Aqueous solutions of ethyl oxide, however, are highly irritating to the skin and may sensitize it. Exposure to moderate-to-high concentrations of ethylene oxide vapor can cause irritation to the eyes and respiratory tract. Repeated exposure to lower concentrations can cause chronic respiratory irritation, anemia and some damage to liver and kidneys.

1-22 LIQUID FLUORINE

1-23 PHYSICAL PROPERTIES

Fluorine is a yellowish gas over a wide range of temperatures and pressures. It has a characteristic pungent halogen odor and is irritating to the respiratory tract with the following properties:

Boiling point (°F)	-306
Freezing point (°F)	-363
Density of liquid at boiling point (lb/gal)	12.6
Specific gravity of gas relative to normal air	1.3
Critical temperature (°F)	-200
Critical pressure (psig):	
At - 300°F	7
At - 250°F	153

At - 200^{0}F	794
Viscosity at boiling point (centipoises)	0.24
Threshold limits	0.1 ppm (0.2 mg/cu m)

1-24 CHEMICAL PROPERTIES

Propellant fluorine is essentially 100 percent pure F_2, containing only traces of oxygen, nitrogen and hydrogen fluroide (HF). It is the strongest oxidizing agent and one of the most reactive materials known. Under proper conditions, fluorine reacts with practically every element or compound known, exceptions being some of the inert gases such as helium and completely fluorinated compounds such as carbon tetrafluoride.

Fluorine reacts with nearly all materials instead of dissolving in them, but it is completely miscible with liquid oxygen (LOX) and liquid nitrogen.

Unconfined fluorine is stable to shock, heat, and electrical spark. Containers of fluorine, however, must not be subjected to shock or heat, as a violent reaction is possible.

1-25 PHYSIOLOGICAL EFFECTS

In either liquid or gaseous state, fluorine is highly corrosive to all body surfaces. The liquid is very cold and can freeze parts of the body that come in contact with it.

Fluorine's low boiling point makes it unlikely that the liquid will come into contact with the body, but if this accident should occur, skin injuries resembling burns will follow; these are likely to be severe, deep and slow in healing. Exposure to fluorine gas is a more likely accident. High concentrations of the gas can cause severe skin burns as well as severe damage to the eyes. The gas is highly irritating to the eyes and to the upper and lower respiratory tract. Pulmonary edema is a possible consequence of gas inhalation. Pulmonary edema occurs when the lung spaces fill with fluid, reducing the lungs' ability to transport oxygen. A person may breath an atmosphere containing a dangerous concentration without serious discomfort at the time but hours later (sometimes as much as a day), become severely ill. The color of the fumes is not a reliable index of the degree of toxic hazard. The initial symptoms of poisoning - irritation of the eyes and throat, cough, tightness of the chest, and nausea - are slight and may not be noticed. Some hours later, severe symptoms begin; their onset may be sudden and precipitated by exertion. Coughing, constriction in the chest, and difficult breathing develop. Cyanosis (a blue tinge to the mucous membranes of the mouth, eyelids, lips and fingernail beds) may follow. Persons showing these symptoms are in great danger. In milder cases, there may be signs of bronchitis with cyanosis; in others, nausea, abdominal pain and vomiting. Repeated exposure to the gas may cause chronic pulmonary damage and the deposition of fluoride in bones and teeth.

1-26 HYDRAZINE

1-27 PHYSICAL PROPERTIES

Hydrazine is a clear, oily liquid with an odor similar to that of ammonia. It is a stable liquid under the extremes of heat and cold in long-term storage. It will freeze, but upon freezing it contracts, so there is no damage to storage vessels. Hydrazine has the following physical properties:

Boiling point (°F)	236
Freezing point (°F)	35
Density of liquid at 68°F (lb/gal)	8.4
Specific gravity of vapor relative to normal air	1.1
Critical temperature (°F)	716
Critical pressure (psig)	2120
Critical density (lb/gal)	1.9
Vapor pressure (psia):	
At 40°F	0.07
At 80°F	0.31
At 120°F	1.04
At 160°F	2.9
Viscosity at 68°F (centipoises)	0.97
Flash point, open cup (°F)	100 to 126
Autoignition temperature (°F)	518
Flammability (or explosive) limits	
In air at 212°F (% by volume):	
Lower limit	4.7
Upper limit	100
Threshold limit	1 ppm (1.3 mg/cu m)

1-28 CHEMICAL PROPERTIES

Propellant-grade hydrazine contains a minimum of 97 percent hydrazine, N_2H_4, the remainder being primarily water.

Hydrazine is a strong reducing agent, weakly alkaline and very hygroscopic. It will react with carbon dioxide and oxygen in air. Exposure of hydrazine to air on a large surface (as on rags) may result in spontaneous ignition from the heat evolved by its oxidation with metallic oxides or other oxidizing agents. Hydrazine decomposes on contact with some metals, including iron, copper, molybdenum and their alloys and oxides.

Freezing does not affect the chemical properties of hydrazine. Thermal decomposition begins at about 320°F, but if hydrazine is permitted to remain in contact with catalysts such as copper, molybdenum or iron oxide, decomposition may occur at room temperatures. Liquid hydrazine is stable to shock. Hydrazine vapor can be exploded by a spark or flame if it is within the flammable limits.

1-29 PHYSIOLOGICAL EFFECTS

At normal temperatures, hydrazine is a clear, mobile, hygroscopic liquid with moderate volatility. The liquid is mildly alkaline and caustic to human tissue.

If spilled on the skin or in the eyes, liquid hydrazine can cause severe local damage or burns and can cause dermatitis. Additionally, it can penetrate skin to cause systemic effects similar to those produced when the compound is swallowed or inhaled. If inhaled, the vapor causes local irritation of eye and respiratory tract and systemic effects. On short exposure, systemic effects involve the central nervous system. Resultant symptoms include tremors; on exposure to higher concentrations, convulsions and possibly death follow. Repeated exposures may cause toxic damage to the liver and kidneys (interstitial nephritis), as well as anemia.

1-30 HYDROCARBONS

1-31 PHYSICAL PROPERTIES

The RP fuels are clear liquids ranging in color from water-white to a very pale yellow. The following is a list of physical properties of RP-1:

Boiling range (°F)	350 to 525
Maximum freezing point (°F)	-40
Density of liquid at 68°F (lb/gal)	6.7 to 6.8
Vapor pressure (psia):	
At 50°F	- -
At 100°F	- -
At 150°F	- -
At 200°F	- - - -
Viscosity at 68°F (centipoises)	110
Autoignition temperature (°F)	- -

1-32 CHEMICAL PROPERTIES

RP fuels may be described as high-boiling kerosene fractions. Hydrocarbon fuels react only under the strongest oxidizing conditions or at extremes of pressure and temperature. They are flammable, however, and their vapors form explosive mixtures with air.

Hydrocarbons are insoluble in water. They are soluble in many organic solvents and are, themselves, excellent solvents for many organic materials. They are chemically stable and insensitive to shock. They show good thermal stability over a wide range of ambient storage temperatures, but exposure to high temperatures accelerates the formation of gum and sediment.

1-33 PHYSIOLOGICAL EFFECTS

The hydrocarbon fuels vary in volatility according to their composition. They are fat solvents, which accounts for their skin-irritating properties. Their toxicity depends partly on their content of aromatics.

After more than momentary contact, hydrocarbon fuels can cause scaling and fissuring of skin and, probably rarely, blistering. Inhaling the aliphatic hydrocarbons can cause a narcosis, but because of the fuels' low volatility these effects are unlikely except in closed spaces with inadequate ventilation. The main danger comes from accidentally swallowing them; while not especially toxic by this route, gasping while swallowing or aspiration from improperly induced vomiting can introduce the liquid into the lungs, and pulmonary edema may ensue. Fuels with a high aromatic content are much more toxic. Exposure to benzene can cause toxic effects on blood-forming tissues and on blood.

1-34 LIQUID HYDROGEN

1-35 PHYSICAL PROPERTIES

High-purity liquid hydrogen is a transparent, colorless, odorless liquid. When observable, it is usually boiling vigorously because of its low boiling point, and when exposed to the atmosphere it creates a voluminous vapor cloud. It is stable to all types of mechanical shock and impact and has the following physical properties:

Boiling point (°F)	-423
Freezing point (°F)	-435
Density at -423°F: liquid (lb/gal)	0.59
vapor (lb/ft^3)	0.083 (1.02 times heavier than air at 32°F)
Density at 32°F, gas (lb/ft^3)	0.0056 (14.5 times lighter than air at 32°F F)

Autoignition temperature (^{o}F)	1075
Flammability limits in air, by volume (H_2 gas)	4.0 to 74.2%H_2
Viscosity at -423^{o}F (micropoises)	140
Critical temperature (^{o}F)	-400
Critical pressure (psia)	188
Vapor pressure (psig): -433^{o}F	-12.8
-423^{o}F	0
-420^{o}F	9.0
-402^{o}F	147.3

The density of liquid hydrogen decreases from 0.59 pound per gallon at its boiling point (-423^{o}F) to 0.45 pound per gallon at -405^{o}F, where the vapor pressure is 120 psia.

1-36 CHEMICAL PROPERTIES

Hydrogen (H_2) exists as a gas at atmospheric temperatures and pressures. It is colorless, odorless, and tasteless. It is the lightest of all elements and diffuses rapidly through porous materials and through some metals at red heat. The thermal conductivity of hydrogen gas at atmospheric temperature and pressure is about seven times greater than for air.

Liquid hydrogen is noncorrosive; it will form combustible mixtures with oxidizers. When allowed to evaporate, it becomes highly combustible with air over a wide range of mixtures.

All known substances are essentially insoluble in liquid hydrogen. Helium is possibly soluble to the extent of 1 percent.

Liquid hydrogen is chemically stable. Because of its low boiling point, it is physically stable only when stored under suitable conditions. When stored in properly designed containers, the 24-hour evaporation rate may be as low as 1.5 percent, or lower, for a 1,000-gallon container.

Hydrogen in either liquid or gaseous form will react violently with strong oxidizers; it will ignite very easily with oxygen and spontaneously with fluorine and chlorine trifluoride.

As with most cryogenic fluids, the effect of low temperature on material properties is extremely important. At liquid-hydrogen temperatures, mild steels and most ferrous alloys lose ductility and become brittle. Also, the severe temperature changes that will occur can cause stress concentrations that must be taken into account in designing equipment.

1-37 PHYSIOLOGICAL EFFECTS

Hydrogen is not toxic in the usual sense. The liquid has a very low temperature, so serious "burns" can result when skin or other tissues come into contact with the liquid or with pipes and valves containing the liquid. The gas can exclude oxygen and cause asphyxiation. Cold hydrogen vapors can also "burn" the skin.

Liquid hydrogen is invariably accompanied by a certain amount of hydrogen gas. Since the gas is extremely flammable, a serious fire hazard always exists when hydrogen-gas vapors are in the area. When no impurities are present, hydrogen burns in air with an invisible flame. Hydrogen-air mixtures containing as little as 4 percent or as much as 74 percent hydrogen by volume are readily ignited. Hydrogen-oxygen mixtures are flammable over a range of 4 to 94 percent by volume.

1-38 HYDROGEN PEROXIDE

1-39 PHYSICAL PROPERTIES

High-strength hydrogen peroxide is a clear, colorless liquid, slightly more viscous than water with the following physical properties:

	Concentration of H_2O_2 (% by weight)			
	70	80	90	100
Boiling point (°F)	258	271	286	302
Freezing point (°F)	-40	-13	11	31
Density of liquid at 68°F (lb/gal)	10.8	11.2	11.6	12.1
Critical temperature (°F)	- -	- -	- -	855
Critical pressure (psig)	- -	- -	- -	3130
Vapor pressure (psia):				
At 68°F	.11	.07	.05	.03
At 104°F	.37	.26	.17	.10
At 140°F	1.05	.76	.52	.33
At 176°F	2.62	1.96	1.38	.93
Viscosity at 68°F (centipoises)	1.23	1.26	1.26	1.25
Threshold limit			1 ppm (1.4 mg/cu m)	

When a hydrogen-peroxide solution is chilled, it is supercooled far below its true freezing point. As the solution freezes, a slush forms, becoming thicker as the temperature decreases. During the freezing process, crystals of hydrogen peroxide in higher concentration than the solution are deposited. This separation of the solid phase lowers the peroxide concentration of the solution and lowers the freezing point of the remaining liquid. Final solidification takes place at -67°F. Solutions of more than 65 percent contract on freezing and will not burst containers.

1-40 CHEMICAL PROPERTIES

Propellant-grade hydrogen peroxide is 52 to 100 percent pure H_2O_2 by weight. The following data pertain to propellant hydrogen peroxide over 52 percent in concentration but not necessarily to the less hazardous and less critical grades of lower strength.

Hydrogen peroxide, a monopropellant and an active oxidizing agent, is an energy-rich material which can decompose, yielding water (steam), oxygen and heat. It does not burn but vigorously supports combustion because of the oxygen it liberates when decomposing. Owing to its strong oxidizing nature, it can ignite many organic materials - wood, cotton waste, etc. High-strength hydrogen peroxide reacts under certain conditions with many organic compounds, such as carbonyl compounds and phenolics. It is hypergolic with hydrazine. It decomposes rapidly on contact with many inorganic compounds, such as potassium permanganate and ferrous sulfate. When decomposed by catalysts, it generates heat rapidly. If completely decomposed, solutions stronger than 67 percent hydrogen peroxide by weight generate enough heat to raise the temperature of the solution to its boiling point and then to convert all the decomposition products into vapor. Stronger solutions, therefore, produce superheated vapors whose temperature depends upon the concentration of the peroxide and the characteristics of the confining equipment. Concentrated hydrogen peroxide solutions are weak acids.

Hydrogen peroxide is miscible with water. Thus, reactivity can be quickly reduced by dilution with a large number of water-soluble organic liquids, such as alcohols, glycols, acetates, acids and ketones. It is nearly insoluble in petroleum,ether, toluene, styrene, carbon tetrachloride, chloroform, kerosene, fuel oil and gasoline. Many organic liquids, both soluble and insoluble, can form explosive mixtures with hydrogen peroxide.

Pure hydrogen peroxide in properly passivated containers decomposes at a very slow rate. In an aluminum shipping drum of 300 pounds capacity under normal storage conditions at about 70 degrees, less than 1 percent of the hydrogen peroxide decomposes in a year; in larger tanks, the loss is as low as 0.1 percent per year. If stored in containers of unsuitable material or if contaminated, hydrogen peroxide can decompose very rapidly, releasing large amounts of heat and gas.

The decomposition rate of hydrogen peroxide increases with temperature, approximately doubling for each temperature rise of 15 degrees. This progressively faster decomposition generally results in the complete decomposition of the hydrogen peroxide before the true boiling point is reached. Near the boiling point, the rate is very rapid and, if the container is not well vented, an explosion can result.

Hydrogen peroxide solutions are insensitive to detonation by shock and impact. Uncontaminated hydrogen peroxide is not likely to explode as a result of impact. However, when organic solvents such as ketones, alcohols and glycols are added, the resulting solution becomes shock-sensitive.

The contamination of hydrogen peroxide with dirt, rust, cigarette ashes, etc. accelerates its decomposition rate, resulting in possible runaway decomposition and rupture of the container.

The decomposition of hydrogen peroxide at an accelerating rate, as evidenced by increasing gas evolution and temperature, may be brough under control by adding 1 pound of 85 percent phosphoric-acid solution (in water) for each 100 gallons of hydrogen peroxide solution. Mixing is not necessary because the turbulence will disperse the stabilizer.

After being stabilized, and if the decomposition subsides, hydrogen peroxide may be stored in aluminum containers until consumed or otherwise disposed of. This solution must not be used in applications involving catalytic decomposition chambers, because the stabilizer will poison the catalyst.

1-41 PHYSIOLOGICAL EFFECTS

Contact with liquid, mist or vapor produces irritant effects. When the liquid touches the skin, there is a burning sensation and the affected areas are bleached. Prolonged contact can cause burns if one continues to wear permeable clothing contaminated with the compound. Inhaling the vapor irritates the respiratory tract and may result in burning of the nose and throat, running of the nose and coughing. The vapors may also irritate the eyes; symptoms are burning and watering. Exposure to high concentrations of a mist or aerosol of hydrogen peroxide (e.g., as a result of liquid decomposition), if not washed away promptly, can result in delayed but severe damage to the eyes.

1-42 NITRIC ACIDS

1-43 PHYSICAL PROPERTIES

The nitric acids (HNO_3) are fuming liquids varying from colorless to reddish brown, depending upon the amount of dissolved nitrogen oxides contained. Vapors from these acids have a characteristic pungent odor. Since the composition of the fuming nitric acids is variable, all values of physical constants listed are approximate:

Type	Specific gravity at 60°F		Melting point (°F)	Bubble point (°F)	Vapor Pressure at 160°F (psia)	Viscosity at 70°F (centipoises)	Density at 68°F (lb/gal)
	Min.	Max.					
I	1.511	1.525	-45	186	-5.6	0.863	- -
IA	1.511	1.525	-45	186	-5.6	- -	- -
III	1.564	1.575	-57	150	2.6	- -	- -
IIIA	1.564	1.575	-57	150	2.6	- -	12.6

1-44 CHEMICAL PROPERTIES

The fuming nitric acids are highly corrosive oxidizing agents and will vigorously attack most metals. They react with many organic materials, spontaneously causing fire. In rare instances, on gross contact with certain materials (e.g., hydrazine) and when spontaneous ignition is delayed because of degraded materials, an explosion may occur. Nitric acids are soluble in water in all proportions, however, there is an accompanying evolution of heat and oxides of nitrogen. Unless the acid is added slowly to water, the large amount of heat released when it dissolves may cause splattering.

The nitric acids will react with sea water, releasing large quantities of nitrogen oxides which are toxic. These chemicals are hygroscopic. The following is a listing of the chemical composition of fuming nitric acids:

	(% by weight)				
Type	Nitrogen dioxide (NO_2)	Water (H_2O)	Nitric acid (HNO_3)	Solids as nitrates	Hydrogen fluoride inhibiter
I	0.5 max.	2.0 max.	97.5	0.10 max.	- -
IA	0.5 max.	2.0 max.	96.8	0.10 max.	0.7 ± 0.1
III	14 + 1.0	1.5 to 2.5	82.4 to 85.4	0.10 max	- -
IIIA	14 ∓ 1.0	1.5 to 2.5	81.6 to 84.8	0.10 max.	0.7 + 0.1
IIIB	14 ± 1.0	1.5 to 2.5	81.6 to 84.8	0.04 max.	0.7 ± 0.1

1-45 PHYSIOLOGICAL EFFECTS

Fuming nitric acids are highly corrosive liquids and very hazardous on contact with the body. Type III acids (RFNA) contain oxides of nitrogen in solution which are readily released into the atmosphere. On contact with a variety of materials (such as organic compounds, many metals, and wood) nitric acids produce additional fumes of nitrogen oxides, of which the most dangerous is nitrogen dioxide.

Because the liquid is highly corrosive, skin and eyes can be severely burned unless the acid is immediately removed. Another serious hazard in handling fuming nitric acid is the inhalation of toxic vapors, especially nitrogen dioxide. The chief danger from acute poisoning is the development of pulmonary edema. Repeated exposure to these fumes at low concentration levels may cause ulceration of the nose and mouth, wearing down and decay of teeth, and chronic irritation of the entire respiratory tract.

1-46. NITROGEN TETROXIDE

1-47. PHYSICAL PROPERTIES

At room temperatures, nitrogen tetroxide is a heavy brown liquid, its color coming from the nitrogen dioxide content. As temperature is lowered, the color becomes lighter owing to the equilibrium shift of nitrogen dioxide to nitrogen tetroxide. The fumes are yellowish to reddish brown, depending on the temperature, and have a characteristic odor. The following is a list of the physical properties of nitrogen tetroxide:

Boiling point (°F)	70.1
Freezing point (°F)	11.84
Density at 68°F (lb/gal)	12.08
Specific gravity of gas at 70°F, 1 atmosphere	3.2
Viscosity at 70°F, 1 atmosphere (centipoises)	0.413
Critical temperature (°F)	316.8
Critical pressure (psig)	1445
Critical density (lb/gal)	4.67
Vapor pressure (psig) at:	
32°F	-9.6
70°F	-0.1
90°F	10
100°F	16
120°F	34
140°F	59
160°F	97
Threshold limit	2.5 ppm (9 mg/cu m)

Nitrogen tetroxide is very stable at room temperature. In water it reacts to form nitric and nitrous acids. The nitrous acid decomposes, forming additional nitric acid and evolving nitric oxide (NO). At 302 degrees F it begins to dissociate into nitric oxide and free oxygen, but upon cooling it reforms into nitrogen tetroxide. Dry nitrogen tetroxide (less than 0.1 percent water equivalent) may be stored in low-pressure carbon steel containers, since the vapor pressure at 140 degrees F is only 74 psia and the corrosivity at this water content is negligible for an idefinite period.

1-48 CHEMICAL PROPERTIES

The oxidizer referred to as nitrogen tetroxide is actually an equilibrium mixture of nitrogen tetroxide and nitrogen dioxide. It is sometimes referred to as dinitrogen tetroxide, nitrogen peroxide or liquid nitrogen dioxide. Purity of propellant nitrogen tetroxide is a minimum of 99.5 percent by weight. It contains no more than 0.1 percent water equivalent.

Nitrogen tetroxide is a corrosive oxidizing agent. It may react with combustible materials and is hypergolic with unsymmetrical dimethylhydrazine (UDMH). It is not sensitive to shock, heat or detonation. It is nonflammable with air, but it can support combustion.

1-49. PHYSIOLOGICAL EFFECTS

Nitrogen tetroxide in liquid form is corrosive to body tissues. It volatilizes readily, giving off yellowish to reddish-brown fumes containing a mixture of nitrogen tetroxide and nitrogen dioxide. Most discussions of the toxicity of these fumes identify the mixture as one or the other compound; likewise, calculations of atmospheric concentrations are normally made in terms of one compound or the other. It should be remembered, however, that the two oxides exist together in equilibrium.

Since the liquid is corrosive, severe burns of skin and eyes can result unless it is immediately removed. The inhalation of toxic vapors is normally the most serious hazard in handling nitrogen tetroxide. The main danger from acute poisoning is the development of pulmonary edema.

The color of the fumes is not a reliable index of degree of toxic hazard. Repeated exposure to these fumes at low concentration levels may cause ulceration of the nose and mouth, wearing down and decay of teeth and chronic irritation of the entire respiratory tract.

1-50 <u>LIQUID OXYGEN</u>

1-51 PHYSICAL PROPERTIES

High-purity liquid oxygen is a light-blue transparent liquid. Because of its low boiling point, it is usually boiling vigorously; uninsulated containers are usually frosted. Oxygen has no odor and has the following physical properties:

Boiling point (^{o}F)	-297.4
Freezing point (^{o}F)	-361
Density at boiling point (lb/gal)	9.527

Critical temperature (°F)	-181.1
Critical pressure (psig)	722.2
Critical density (lb/gal)	3.6
Vapor pressure (psig) at:	
-181.8°F	716
-200°F	480
-240°F	155
-280°F	29
-297.4°F	0
Viscosity at boiling point (centipoises)	0.19

Most common solvents are solid at liquid-oxygen temperatures. Liquid oxygen is completely miscible with liquid nitrogen and methane. Light hydrocarbons are usually soluble.

1-52 CHEMICAL PROPERTIES

The minimum purity of oxygen (O_2) is 99.5 percent. The major impurity is argon, with a trace of nitrogen. In either liquid or gaseous form, oxygen is a strong oxidizer which vigorously supports combustion. The violence of some reactions involving liquid oxygen may be attributed to the highly reactive oxygen-rich atmosphere surrounding the liquid.

Liquid oxygen is chemically stable. It is not shock-sensitive and will not decompose. At ordinary temperatures in properly designed containers, the 24-hour evaporation rate may be as low as 1.4 percent from a 450-gallon container, 0.4 percent from a 1,350- gallon container.

1-53 PHYSIOLOGICAL EFFECTS

If liquid oxygen spills on skin, injury resembling a burn will result. Liquid oxygen spills may cause high concentrations of oxygen gas on porous combustible materials such as clothing; this presents an extreme fire hazard to personnel. Oxygen gas will not cause toxic effects, but inhalation of very cold vapors may cause irritation of the upper respiratory tract.

1-54 UNSYMMETRICAL DIMETHYLHYDRAZINE (UDMH)

1-55 PHYSICAL PROPERTIES

UDMH is a clear, colorless liquid with a sharp ammoniacal or fishy odor characteristic of organic amines.

UDMH is not shock sensitive. It shows good thermal stability, even up to its critical temperature, 480 degrees. Some carbonization takes place at 700 degrees to 800 degrees and the liquid volume decreases upon cooling to ambient temperatures. The spontaneous decomposition temperature of UDMH in an atmosphere of nitrogen or helium has been determined to be 740 degrees to 750 degrees at 1 atmosphere, but decomposition does not become explosive up to at least 1112 degrees. The following is a list of the physical properties of UDMH:

Boiling point (°F)	146
Freezing point (°F)	-71
Density of liquid at 68°F (lb/gal)	6.6
Specific gravity of vapor relative to normal air	2.1
Critical temperature (°F)	480
Critical pressure (psig)	865
Vapor pressure (psia) at:	
0°F	0.3
40°F	1.0
80°F	3.1
120°F	8.4
Viscosity at 68°F (centipoises)	0.56
Flash point, closed cup (°F)	34
Autoignition temperature in air at 1 atmosphere (°F)	452 to 482
Flammability (or explosive) limits in air at 1 atmosphere (% by volume):	
Lower limit at: 77°F	2.3
302°F	1.8 ± 0.1 (approximately)
Upper limit at 77°F	80 (approximately)
212°F	88 to 96
302°F	98 ± 2
Threshold limit	9.5 ppm (1 mg/cu m)

1-56 CHEMICAL PROPERTIES

Propellant-grade unsymmetrical dimethylhydrazine (UDMH) is $(CH_3)_2NNH_2$ of 98 percent minimum purity. Its vapor reacts very slowly with air at ambient temperatures to form traces of several products, but this is not of practical significance in normal storage and handling. Carbon dioxide reacts with UDMH to form a salt, and extended exposure of UDMH to air or other carbon-dioxide-containing gases could lead to eventual salt precipitation. No formation of gums or other solids has been noted even after sustained storage under recommended conditions. The liquid is hygroscopic and mildly alkaline.

UDMH is completely miscible with water, hydrazine, diethylene-triamine, ethanol and most petroleum fuels.

1-57 PHYSIOLOGICAL EFFECTS

UDMH is a clear, mobile liquid of high volatility. It is mildly irritating to skin and eyes and can penetrate skin to cause systemic toxicity. The vapor causes eye and respiratory irritation as well as systemic effects. On short exposure, the dominant effect is stimulation of the central nervous system, manifested by tremors or convulsions. UDMH appears to be a more potent stimulant than hydrazine. The result of repeated exposure may be chronic poisoning, characterized by anemia. The question of liver damage, assumed on the basis of UDMH's chemical similarity to hydrazine, has not been completely resolved.

1-58 UDMH, UDMH/HYDRAZINE MIXTURE

1-59 PHYSICAL PROPERTIES

50/50 UDMH-hydrazine is a fuel blend consisting of approximately 50.4% hydrazine, 48.7% UDMH and 0.9% water and other soluble impurities determined by weight. The blend is a clear, colorless, hygroscopic liquid having a characteristic ammoniacal odor. When this blend becomes exposed to air, a fishy odor results in addition to the ammoniacal odor that is probably due to the air oxidation of UDMH. UDMH and hydrazine are mixed as a fuel mainly to overcome the instability and high freezing point of hydrazine. The following is a list of the physical properties of UDMH/hydrazine:

Boiling point (°F)	158.2
Freezing point (°F)	18.8
Density of liquid at 70°F (lb/cu ft.)	56.1
Critical temperature (°F)	634
Critical pressure (psia)	1696
Vapor pressure at 77°F	2.75
Viscosity at 77°F (centipoises)	0.91
Threshold limit	0.5 ppm

The UDMH/hydrazine mixture is insensitive to mechanical shock and vibration.

1-60 CHEMICAL PROPERTIES

The chemical formula of the UDMH-hydrazine blend is $(CH_3)_2NNH_2 + N_2H_4$. The 50/50 UDMH-hydrazine blend is hypergolic with oxidizers such as nitrogen tetroxide, white and red fuming nitric acids, hydrogen peroxide and chlorine trifluoride. It will ignite when in contact with some solid propellant formulations but with considerable delay.

The UDMH-hydrazine blend spread on a rusted metal surface in contact with air may generate enough heat to cause spontaneous ignition. Rust oxidizes hydrazine and may be a decomposition catalyst under certain conditions.

1-61 PHYSIOLOGICAL EFFECTS

UDMH may be absorbed through the intact skin, by inhalation of fumes, and by ingestion. Since UDMH is highly volatile, special precautions should be taken against liquid spills and other sources of vapor contamination, especially in closed areas.

Overexposure to UDMH may produce acute physiological effects similar to those produced by hydrazine. UDMH is irritating to the eyes and skin, but appears less so than hydrazine. However, UDMH can cause irritation of the mucous membranes of the eye, respiratory passages, lungs and gastrointestinal tract. Contact withthe eyes may cause immediate pain, tearing and redness of the conjunctiva; swelling of the lids may occur hours after the exposure.

Immediate symptoms of inhalation are chest pain, coughing, wheezing (similar to asthma), nausea and vomiting. If large amounts have been inhaled, pulmonary edema may occur.

The physiological effects of monomethylhydrazine (MMH) are the same as those for the other hydrazines withe one exception. It is doubtful that MMH will cause liver or kidney damage as do the hydrazines.

SECTION II
STORAGE FACILITIES

2-1 GENERAL REQUIREMENTS

2-2 LOCATION

Rocket propellants must be stored and handled in well ventilated areas remote from oxidizers and free from excessive heat and sparks.

2-3 WATER SUPPLY

The storage area shall be well supplied with a readily accessible flow of water. An outside, underground, looped system of mains, preferably cast iron, should be installed. Mains should be large enough to supply a flow of water for fire fighting of at least 2,000 gpm at adequate pressure. Where mains are provided, an adequate number of hydrants will be supplied from the mains.

Deluge-type safety showers should be provided for personnel and should be controlled by quick-opening valves capable of supplying large quantities of water under moderately high pressure (approximately 50 gpm). Cold water baths should also be provided at all operating stations. Hose connections are also necessary for flushing and cooling operations. If fog nozzles are installed for control of propellants, the local water supply may have to be supplemented by a pump to get the higher pressure necessary for efficient spray coverage.

2-4 ROADS

Adequate heavy-duty roadways are required in propellant storage areas, since the maximum tank truck load may be 40 tons. The roadways within the propellant storage areas shall be made of concrete rather than petroleum base surfaces. At least two access roads to each transfer and storage area are required, wide enough at each site to give adequate space for turning.

2-5 TEST COMPLEX

Ready storage for rocket propellant and oxidizers is located at the test complex. At least two men should always be assigned to any operation concerning the handling, transfer and storage of propellants. Safety showers shall be located in easily accessible places at the test complex near the propellant transfer and loading operations.

2-6 REQUIRED EXITS FROM OPERATING BUILDINGS

One properly located exit will suffice for small workrooms or cubicles (containing potentially explosive matter) having substantially constructed walls on three sides, providing personnel are limited to an absolute minimum required to perform a particular task.

Rooms in which more than eight persons work should be provided with additional exits upon the basis of one exit for each additional group of five persons (or fraction thereof). Exits should be at least 30 inches wide. Each 30 inches of width may be considered an additional exit. Where possible, exits should be no more than 25 feet away from employees and should lead directly outside rather than into a hall or another room. Arrangements that place a potentially explosive area between working personnel and exits should be avoided.

Exit doors in operating buildings will open outward and during operating hours will not be fastened with locks other than antipanic catches or other quick-releasing devices. Exit doors and escape routes will not be obstructed. Exit doors in buildings containing potentially explosive matter should be panel or flush type doors in pairs. Vision panels may be provided in each door where desirable, except where the using agency determines that the vision panel should be omitted for security reasons. Vision panels should be in the upper half of the door. The vision panel will be glazed with transparent, non-shatterable, noncombustible material or slow burning material of a type which is practically smokeless during combustion. In no case should the opening of the exit door be less than 30 inches wide by 80 inches high. All interior doors should open in the direction of flow of material.

2-7 FENCES

Entire storage areas shall be enclosed by an 8-foot galvanized chain link fence with three strands of barbed wire along the top. Entrance gates are provided where necessary. The fence should be inspected and maintained at regular intervals. No combustible materials, such as wood, should be used for constructing any part of the fence.

2-8 GENERAL CONSTRUCTION

Combustible materials will not be used in the propellant storage or handling structures, The roofing material may be corrugated asbestos. Conventional lightning protection is installed. No expansion joints are used in the concrete drain basins and all construction joints are sealed with cement mortar.

2-9 HEIGHT AND ROOF CONSTRUCTION

In general, single story buildings without basements are preferred in storage facilities.

Exterior walls and roof covering should be constructed of noncombustible materials. Storage tanks and propellant transfer systems may be protected by open side, steel frame buildings with sloped roofs of corrugated asbestos. Conventional petroleum-base roofing materials are prohibited. Such additional roofing materials as slate shingles or asbestos shingles are commonly used.

2-10 EXTERIOR WALLS

Exterior walls should be constructed of noncombustible materials. Structural framework of all storage buildings should be steel or masonry and should not contain wood. Sidings of brick, plaster, tile, concrete block, corrugated sheet asbestos, aluminum or steel, with proper protective coatings are normally used.

2-11 WEAK WALLS

Walls, except for specifically designed containment and protection purposes, should be as weak as practicable and constructed and supported to permit the venting of an internal explosion with the formation of a minimum number of large fragments.

2-12 VENTING AREA

When venting toxic propellants into the atmosphere, it is done through a stainless steel vent stack, located remote from the working or populated areas and discharging at least 50 feet above the highest operating level.

2-13 WINDOWS AND SKYLIGHTS

Material for windows and skylights shall be transparent, non-shatterable, slow burning plastic of a type which is practically smokeless when under combustion. Glazing with conventional glass presents the danger of falling and flying glass. The hazards may be reduced by covering such glass with wire mesh screening securely mounted on the inside. Windows in buildings in which mild explosion hazards exist should be large to provide for release of pressure in the event of an explosion, and the frame or sash should be of a suitable venting type. Nonshatterable type glazing is recommended. Skylights will not be used in buildings in an explosives hazard area.

2-14. WORKROOMS

Workrooms include space for an office with telephones, laboratory, and storage area. Locker rooms, a shower room, and toilets are included. Two sets of lockers are normally required to provide each man one locker for street clothes and one for work and safety clothing. Lockers for storing street clothing will be in a room separate from the lockers storing work and safety clothing. Spare protective equipment such as face masks, boots, gloves, suits, etc., are kept in the storage room. Workroom floors are normally concrete. The floors shall not be wood or rubberized material, since the danger of combustibility is increased when propellant is accidentally spilled.

Combustible materials, such as rags, and other extraneous materials will not be kept in a workroom or where propellant is stored but will be removed from the area promptly or disposed of. Good housekeeping is essential to minimize fire hazards and to provide a safe work area.

2-15 FIRE WALLS

Fire walls are designed to prevent the spread of fire from one side to the other. Firewall design and construction may vary with the type of construction of the building and its intended use. For the types of construction commonly encountered, firewalls should extend through the roof and walls of the buildings and should be constructed of noncombustible material. Openings in firewalls are held to the absolute minimum and those necessary openings are protected in accordance with the requirements of National Board of Fire Underwriters' Pamphlet No. 80, "Installation of Fire Doors and Windows."

2-16 OPENINGS IN FIRE WALLS

Openings are classed as A, B, C, D, E and F in accordance with the character and location of the wall in which they are situated. In each of the following classes, the minimum fire protection ratings are shown; however, doors, shutters or windows having higher ratings are acceptable.

Class A openings are in walls separating buildings or dividing a single building into fire areas. Doors for these openings have a fire protection rating of 3 hours and shall be installed on each side of the wall.

Class B openings are in enclosures of vertical communication through buildings (stairs, elevators, etc.). Doors for these openings have a fire protection rating of 1 or 1-½ hours.

Class C openings are in corridor and room partitions. Doors for these openings have a fire protection rating of 3/4 hour.

Class D openings are in exterior walls which are subject to severe fire exposure from outside the building. Doors and shutters for these openings have a fire protection rating of 1-½ hours.

Class E and F openings are in exterior walls which are subject to moderate or light fire exposure respectively from outside the building. Doors, shutters or windows for these openings have a fire protection rating of 3/4 hour.

2-17 FLOOR SURFACES

Floors in hazardous locations are constructed to facilitate cleaning and should have no cracks or crevices. Sub-floors and finished flooring should not wrinkle or buckle under operating conditions. Where washing is required, the entire construction must be capable of withstanding repeated applications of hot water or other compatible cleaners.

2-18 CONDUCTIVE FLOOR SURFACES

Conductive nonsparking floors are required where exposed materials readily detonated or ignited by sparks are present. Such floors are constructed of nonsparking material such as lead, conductive rubber or conductive flooring. This floor material is smooth and free from cracks and is of a type that will not develop surface separations, wrinkle or buckle under operational conditions. The electrical resistance measured between the ground and a 5 pound electrode in direct contact with 5 square inches of floor area will not exceed 250,000 ohms. Where conductive floors and shoes are required, the resistance between the ground and the wearer will not exceed 1,000,000 ohms; i.e., total resistance of conductive shoes on a person, plus the resistance of floor to ground.

2-19 OPERATING FACILITIES

2-20 STATIC ELECTRICITY

One of the more common occurrences of static electricity results when a person walks on a wool rug, picking up electrons and accumulating them on his body. When he touches a person with a lower potential, a discharge may result, shocking both persons. The circuit consisted of a source of electrons, the person on whom they first accumulated, and the person through whom they were discharged.

The generation of static electricity is not, in itself, a hazard. The hazard is created when charges are allowed to accumulate to the extent that an uncontrolled discharge occurs through, or in the presence of, a hazardous substance susceptible to ignition, such as a discharge of a spark across an air gap in the presence of highly flammable or explosive material. Personnel can collect a charge of static electricity by being in contact with moving nonconductive substances (blowing dust, certain types of clothing, etc.) or coming in contact with a mass that has been previously charged (transport vehicles, etc.).

Personnel must be particularly careful in the presence of explosive propellants in any form to discharge themselves or equalize their static electrical potential to that of the material to be handled, where hazards may exist.

The general method of eliminating or reducing the hazard from static is to provide an electrically continuous path to ground. This will allow the charges to dissipate as fast as they are generated. When all the objects concerned are conductive, grounding can be readily accomplished by electrically connecting all parts to a common ground conductor. Grounding exterior parts of containers alone does not necessarily eliminate all of the danger from static electricity, for in order to be completely effective, grounding must include the contents. Partial grounding or using conductors of insufficient strength or too high resistance may increase the static hazard by providing opportunities for discharge through an uncontrolled path to ground.

When personnel come into contact, or proximity of, ethyl alcohol, conductive floors are installed except where the hazards of dust-air or flammable vapor-air mixtures are eliminated by adequate housekeeping, dust collection, ventilation, or solvent recovery methods. Where conductive floors and shoes are required, table tops upon which exposed material is encountered should be covered with a properly grounded conductive material meeting the same requirements as those for flooring.

2-21 LIGHTNING PROTECTION

Approved lightning protection systems are the integrally mounted system and the separately mounted shielding system.

The integrally mounted system on wood frame construction with nonmetallic roof shall consist of air terminals, ridge cables, down conductors, and ground connections securely and electrically interconnected to form the shortest distance to ground.

The purpose of the air terminals is to intercept the electrical discharge at a safe distance above vulnerable and flammable parts of structures. The receiving points of the air terminals shall be placed high enough above the structure to eliminate danger of fire from the arc; the more flammable or explosive the conditions, the higher the point should be placed.

Fences surrounding liquid propellant storage areas shall be grounded for protection of personnel and explosive substances from the effects of a lightning strike on the fence or on power lines near or crossing fences. Fences shall be grounded on each side of each gate and at points 150 feet on each side of the point of power line crossings. Gates should be bonded to fences. Fences are normally grounded every 1000 to 1500 feet where they are located in isolated places, or at lesser distances as determined necessary to obtain adequate protection.

If the fence consists of wooden posts and horizontal metal stands only, down conductors shall be run the full height of the fence and securely fastened to each wire so as to be electrically continuous with the fencing.

2-22 FIXTURES AND EQUIPMENT

2-23 EMERGENCY SHOWERS

Work areas and storage rooms shall be provided with emergency showers. These easily accessible and clearly marked showers are controlled by quick-opening valves, so that liquid propellant can be quickly rinsed from the body. Fire blankets should be located near the showers. Special eyewash fountains or bubbler drinking fountains should be available for eye irrigation. Personnel showers shall be located in easily accessible places near transfer and storage equipment. The showers and eyewash fountains, shall be inspected periodically and before any propellant transfer operations.

2-24 SPRINKLER SYSTEMS

Automatic sprinkler systems are used where volatile fuels or oxidizers are loaded or stored. The mains leading to such systems shall be large enough to supply water at least 2,000 gpm at adequate pressure. Each sprinkler system shall be equipped with an audible warning device to alert personnel.

Deluge systems are installed in propellant storage and transfer areas where large volumes of water are immediately required. Machinery or operations in which there is a fire hazard should be equipped with hand-operated, quick-acting manually controlled deluge equipment in addition to an automatic device. The deluge system should be charged with steam, water, or chemicals (depending upon the character of the fire to be controlled). Such devices may be actuated by rate of rise, fixed temperature or a combination thereof. Where deluge system actuating controls contain electrical components, the controls will be placed in enclosures approved by the National Electric Code. Where two or more deluge systems are in the same fire areas, the water supply mains and the arrangements and size of the system riser will provide each system with enough water per head as determined by engineering studies of hazards involved. A device will be installed on the supply side of the system to actuate an audible warning device in affected operating areas should pressure failure occur. Operations protected by a deluge system should be stopped immediately if the system fails, and should not be resumed until adequate protection is provided.

2-25 ELECTRIC WIRING AND EQUIPMENT

The installation of electrical equipment in a rocket propellant handling and storage area will comply with the latest edition of the National Electrical Code.

An area does not become a "hazardous location for electrical equipment" within the meaning of the electrical code because of the mere presence of potentially explosive substances. Application of the code for "hazardous locations" is mandatory only where present or planned operations involve the possible presence (accidental or otherwise) of explosive vapors, etc. in explosive or ignitable concentrations or mixtures. It is often possible to locate much of the equipment in less hazardous or in safe areas and thus reduce the quantity of special equipment required and decrease the hazard.

Liquid propellant hazardous locations, as defined in the National Electrical Code, are Class I. (Flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures).

Equipment for use in hazardous locations, class I, as defined in the National Electrical Code, is tested by the Underwriters' Laboratories with respect to safety of operation in the presence of flammable mixtures of specific vapors or gases with air as follows:

Group A. Acetylene

Group B. Hydrogen or gases or vapors of equivalent hazard, such as manufactured gas

Group C. Ethyl ether vapors, ethylene or cyclopropane

Group D. Gasoline, petroleum, naphtha, benzene, butane, propane, alcohols, acetone, benzene, lacquer, solvent vapors, or natural gas

Motors for class I groups C and D locations, classified as "explosion-proof for operation in flammable gas atmospheres" are built on the wide-flange principle. These motors are not gastight but the long, machined metal-to-metal joints between shaft and flange are relied upon to cool the flame of an internal explosion below the ignition temperature of the surrounding gases. Conduit box is independently explosion-proof, terminal leads are sealed with approved sealing compound, and fan (where required) is of nonsparking alloy.

Primary and secondary overhead transmission lines in an explosives and fire hazard area shall be no closer to operating buildings than the height of the poles carrying the lines, but never closer than 50 feet. Lightning arrestors should be installed to protect electric services entering buildings.

The primary electric supply to an entire explosive area shall be so arranged that it can be cut off by switches at one or more central points away from the area. All wiring shall be through conduits.

Single phase electric handtools and other single phase portable electric equipment used in hazardous locations shall have all exposed noncurrent carrying metal parts grounded. Noncurrent-carrying metal parts of single phase electrical equipment (fans, typewriters, calculators, etc.) portable in the sense that they can be moved with a minimum of effort, require grounding only when lack of grounding will endanger exposed personnel.

Three-phase portable equipment such as motor-driven portable conveyors shall meet all requirements of the preceding paragraph except that the voltage may exceed 230 volts and the flexible cords shall be four-wire instead of three, with the fourth wire (green or other acceptable color identified) as the ground for the exposed noncurrent carrying metal frame or parts.

2-26 HEATING

Heating is necessary in a liquid propellant storage area to provide for hot showers and building heat. Liquid propellant handling areas generally are not heated because of the possible explosive ignition of volatile fuels.

2-27 UNIT HEATERS

Unit heaters are self-contained, automatically controlled heating appliances. They may include an integral fan for circulating air; the fan may be floor-mounted or suspended, intended for heating nonresidential space. A unit heater may be fuel-fired or may use steam, hot water or electricity. The heat to the unit heaters originates from an acceptable outside source and is required to meet all safety standards for use in a specific environment.

2-28 HEATING AGENT

Fuel oil, coal, natural or manufactured gases, and liquified petroleum gases may be used in both explosive and inert areas.

All these fuels introduce certain hazards when used in explosive and fire hazard areas. Incandescent particles capable of starting fires in many combustibles may be exhausted from boilers fired with any of these fuels. Coal presents a more severe hazard because particles from a coal fire are likely to retain their incandescence longer than those from oil or gas fires.

Fuel for boilerhouses should be stored at least 50 feet from the boilerhouses and no closer to the hazardous area than are the boilerhouses. Facilities such as low-pressure heating boilers servicing a single operating building shall be at least 100 feet from the operating building.

2-29 RADIATORS

Heating panels are used with systems equipped with heat exchangers utilizing steam which does not exceed 15 pounds gage pressure or hot water which cannot exceed 250 degrees F. Radiating panels and associated connections are installed with proper clearance between hot surfaces and woodwork and other combustibles.

2-30 TEMPERATURE CONTROL

Rocket propellants should be stored in dry, cool areas, and never in the sun. An environment as near optimum as possible for the particular type propellant will afford the safest storage condition. Sudden changes in temperature may damage airtight containers, or result in excessive condensation.

2-31 SPARK ARRESTERS

Motor vehicles or equipment employing internal combustion engines used within the vicinity of explosives or potentially explosive matter, are equipped with exhaust system spark arresters and carburetor flame arresters (approved air cleaners).

2-32 STEAM REDUCING VALVES

Where a reducing valve is used, a relief valve should be installed on the low pressure piping. The production of superheated steam from throttling reducing valves must be prevented by positive means. The use of a "water leg" or water column for control of steam pressure of 5 pounds or less is recommended. Where steam line pressures exceed 5 psi, a counterbalance or a rupture disc should be used in addition to installed pressure relief valves, if water legs are impractical.

2-33 VENTILATION

Buildings where fumes or vapor are formed shall be adequately ventilated, preferably at the source of the hazard. Exhaust fans through which flammable vapors or gases pass are required to be equipped with nonferrous blades (or casing lined with nonferrous material)and an approved motor as outlined in para. 2-25. The entire ventilating system is grounded electrically and bonded properly. The exhaust systems should be cleaned thoroughly and serviced on a regular schedule.

2-34 MAINTENANCE

When maintenance entails operations that might endanger employees in the vicinity, the area should be roped or fenced off. When overhead work is being done and employees must continue working immediately below, they shall be provided with hard hats or otherwise protected. Unfinished repairs or installations should be protected after working hours by roping or fencing the area to prevent access. Excavations should be further marked by red lanterns at night.

2-35 REPAIRS

Before repairing, adjusting or cleaning any power driven machinery, the control switch should be "locked out" and the machine conspicuously tagged to indicate the presence of maintenance men. Where a switch other than a knife switch is used, fuses should be removed from the circuit before repairing, adjusting or cleaning to avoid confusion as to whether the circuit is open. After repairs or adjustments are made, maintenance men should replace all guards, remove any spilled grease, oil, etc., and remove all tools, equipment, and spare parts from the machine area. Machines and floors should be cleaned of any dirt resulting from repairs.

When the use of portable grinders or other equipment results in dust, fragments, or flying objects, the operation should be enclosed by portable screen guards for protection.

2-36 WELDING AND CUTTING

Perhaps the most difficult hazard to control in cutting and welding is that of sparks setting fire to nearby combustibles. Wherever possible, cutting and welding should be done away from combustibles. Where combustibles are present, personnel with suitable fire extinguishing equipment, filter goggles, and protective equipment should be near the welder to control sparks.

2-37 FIREFIGHTING

2-38 GENERAL

Liquid propellant handling requires adequate and efficient firefighting facilities. Such facilities include special protective clothing and equipment, portable fire extinguishers and specialized firetrucks in addition to the normal fire protection facilities.*RP-1, liquid oxygen and liquid hydrogen ground storage tanking and rocket fueling; liquid hydrogen sampling; hypergolic igniter installation; F-1 day tests, and rocket launch.

2-39 FACILITIES

Firefighting facilities which will adequately support the specific liquid propellant operation must be available for immediate action. The following equipment will be assigned, as appropriate, to support liquid propellant operations; additional equipment will be available from the fire station on call.

A. Permanently mounted hose reels with 100 feet of 1-1/2 inch hose and adjustable nozzles

B. Permanently stationed carbon dioxide and dry powder extinguishers

C. Fixed foam system in the RP-1 area

D. Fixed water deluge systems in the liquid hydrogen, liquid oxygen, and RP-1 stroage tank areas

E. Crash trucks containing the following extinguishing agents and equipment

(1) 1,000 gallons of water

(2) 100 gallons of foam

(3) First aid firefighting extinguishers

*Operations requiring firefighting support include RP-1, liquid oxygen and liquid hydrogen ground storage tanking and rocket fueling; liquid hydrogen sampling; hypergolic igniter installation; F-1 day tests, and rocket launch.

(4) 50 feet of 2-1/2 inch hose

(5) Claw tool

(6) Metal cutting saw

(7) Trouble light with 50-foot extension cord

(8) Fire ax

(9) One self-contained breathing unit

F. One pickup truck containing:

(1) One "K" bottle containing 220 cubic feet of breathing air

(2) 100-foot extension hose with breathing mask

(3) Two 0.5 kilowatt auxiliary generators

(4) 100-foot electric extension cord

(5) 1,000 watt flood light

(6) Smoke ejector

(7) Three self-contained breathing units

(8) Two salvage covers

(9) First aid firefighting extinguishers

(10) Complete set of propellant handler's clothing

(11) Rocket propellant mask

(12) 100-foot nylon line

(13) Portable handlight

(14) Rescue harness

2-40 HAZARD DETECTOR EQUIPMENT

Adequate and reliable detection equipment is essential to decrease the likelihood of an unparalled disaster in handling millions of pounds of liquid propellants at a time.

Suitable detection instrumentation is of several different types due to the varied nature of the potential hazards. Two of the more important are propellant hazards and lightning.

Propellant hazards are of several different types: potential explosions of fuels and oxidizers, and containers exploding because of excessive pressure buildup. The extreme toxicity of MMH, UDMH, hydrazine, fluorine and nitrogen dioxide produces a severe physiological hazard. Also, in enclosed areas, an inert gas may displace atmospheric oxygen and cause suffocation. Each of these hazards requires different detection systems.

The following detection equipment is adaptable for use at the Merritt Island Launch Area (MILA). These are only the items considered state-of-the-art instrumentation.

2-41. HYDROGEN DETECTORS

Combustible gas detectors sample hydrogen by diffusion through a double walled sintered metal element. These sinters are supplied for general use in bronze, but sintered stainless steel is available and should be used on external instruments subject to salt air. A rain shield is also available. Hydrogen is catalytically converted by a hot-wire ac bridge circuit. The output of a solid-state amplifier depends on the amount of hydrogen in the atmosphere being tested. The output signal is a dc voltage and is routed to the control panel. These instruments are capable of continuous monitoring; they are stable, explosion-proof, and virtually maintenance free.

The gas detector is a solid state device utilizing a self-balancing constant temperature catalytic bridge. Its low-sensitivity threshold (0.05 percent hydrogen) makes it extremely satisfactory for use in detecting minor leakage fromvalves. This instrument could be used near the hydrogen lines at Launch Complex 39.

2-42. HYDRAZINE, UDMH, MMH, UDMH/HYDRAZINE, NITROGEN TETROXIDE DETECTORS

One such detector operates on the principle of a microfuel cell. When a hydrazine contacts the surface of the transducer, the hydrazine is oxidized, with a reduction occurring inside the cell at the cathode. This results in a current flow inthe external circuit which is linearly proportional to the amount of containment. In the case of nitrogen tetroxide, the reaction is similar, but in the opposite direction. The instrument sensitivity is 0.05 ppm; useful range is up to 100 ppm. The transducers must be removed for calibration every two to four weeks. This instrument is manufactured in fixed and portable models.

Another hydrazine detector operates on a thin-film sensing principle, wherein the film is coated with a sensitive material which reacts with the containment, causing a temperature change. This, in turn, changes the resistance of the film, unbalancing a bridge circuit an amount proportional to the amount of containment.

2-43 OXYGEN DETECTORS

Several types of oxygen detectors operate on the same basic principle; only one will be described. The oxygen detector operates on a thermomagnetic principle; oxygen is paramagnetic, while other common gases are diamagnetic. By warming the incoming sample, a gas flow is generated by convection. When a magnetic field is present, the rate of convection varies with the paramagnetism of the gas stream, causing temperature changes. In turn, this changes the resistance of the bridge circuit, unbalancing the bridge.

An instrument of this type is virtually maintenance free, because it need not be removed for calibration when the areas to be monitored are not in use. Atmospheric oxygen content is so constant that it is used as a calibration standard.

2-44 ULTRASONIC LEAK DETECTORS

The passage of a high pressure gas through a small opening generates ultrasonic sound, which can be used for leak detection. The amount of ultrasonic sound generated depends on the type of gas, pressure, and leak size. Ultrasonic leak detectors transform high frequency sound to the audio range.

These units can locate very small gas leaks despite rather high background noise. They are directional so that the leak can be located with some degree of accuracy. Each instrument is calibrated in terms of leak size and pressure. The detection distance is a function of the square root of the pressure and the square of the hole diameter.

The ultrasonic leak detector should be able to detect a 0.010-inch air leak at 10 psi at 35 feet. Detect in this case means an output double the ambient instrument noise. Oxygen would behave similarly; hydrogen and helium would be detected at a much greater distance (possibly twice as far).

Specifications for a typical unit are:

Power: 115 volts, 60 cycles

Output: 100 megacycles, 60 cycles

Sensitivity: Detect a 0.010 inch leak at 10 psi beyond 30 feet

2-45 FLAME DETECTORS

Flame detectors operate on several different principles: ultraviolet and infrared radiation, infrared television, and smoke detection. Each type is used in a particular case because of inherent advantages and disadvantages.

All flames emit infrared radiation at detectable wavelengths. Sunlight, which contains infrared, interferes in many of these regions; therefore, the selection of wavelengths to be monitored is important since reflected sunlight may create false alarms. Many flames, especially hydrogen, emit ultraviolet light. Sunlight does not contain an appreciable amount of ultraviolet at sea level so an ultraviolet system is less likely to trigger false alarms. However, its range of detection and sensitivity is more limited than that of infrared detectors. The third characteristic in emission is visible light, although a flame from a nearly pure hydrogen source is invisible.

One type flame detector can detect a match flame 16 feet away, and has a 30 degree angle of view. This detector can be placed in an explosion-proof case. The detector has a self-checking shutter which must report "flame/no flame" or a malfunction indication results.

An infrared television system has been developed using twin cameras. The image of one camera sensitive only to infrared is superimposed over a normal camera range. The normal camera detects only visible radiation. An alarm may be attached so that detection of an infrared image notifies the control center of a flame, the exact location of which is easily identified.

2-46 PYROTECHNICS FIRE DETECTION

This system senses smoke and fumes from burning carbonaceous material. These very sensitive units are for use in enclosed areas but are useless for detecting hydrogen flame.

2-47 THUNDERSTORM MONITORING DEVICES

When a thundercloud forms over the site to be monitored, the initial indication of the devices is a marked change of atmospheric potential gradient. An electrical current in the order of a microampere will flow into the atmosphere from grounded elevated conducting points when the potential gradient greatly exceeds fair weather values. This corona current can be used as a basis for an electrostatic warning alarm. A typical corona current sensing device (figure 2-1) may be applicable to areas and buildings for storage and handling of fuel or ordnance devices. The operation of the circuit is as follows: An elevated metal point is exposed on a mast and connected to a capacitor by an insulated wire. When a point discharge starts, the capacitor is gradually charged to a potential of approximately 80 volts. At this level, neon lamp NE 2H conducts and the capacitor discharges through the lamp and transformer. A voltage pulse is developed and applied to the bridge circuit. A positive pulse triggers the silicon controlled rectifier, regardless of the polarity of the point discharge. The rectifier remains conductive and provides a warning signal until the current is interrupted (manually or by a time-delay circuit).

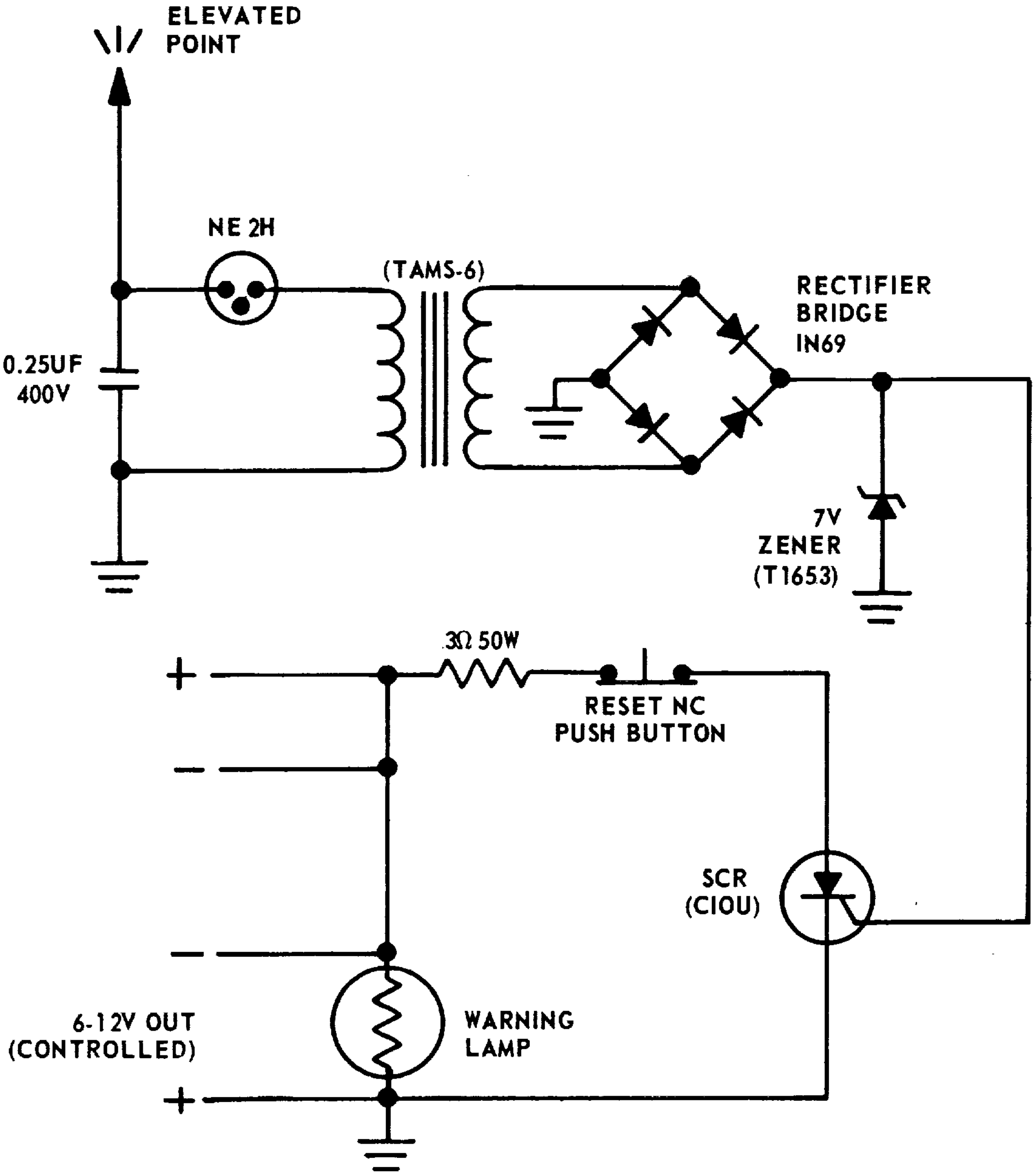


Figure 2-1. Circuit Diagram for Corona Current Detector

A somewhate more automatic corona current sensing device was also developed for the U.S. Air Force weather stations and control tower use. It operates on the same principle as the design shown in figure 2-1 but has two output channels. In one channel, relay contact closures for a repetitive alarm are supplied for a period up to one second for each instantaneous alert signal. From this, a warning signal may be initiated. The second channel is activated by the first and remains in the "alerted" position until a preset time has elapsed. It then resets automatically to the waiting position until another alert is initiated by the first channel.

2-48 SFERICS RECEIVERS

Sferic Pulse Amplitude Rate Spectrum Analyzer (SPARSA) is a ground-based passive sferics detector and direction finder which can continuously monitor sferics activity within a 200 mile radius. The sferics signals detected are electromagnetic radiation from the regions of atmospheric electrification associated with cumulonimbus cloud activity. The monitoring frequency of 500 kc insures that initial short length sferics activity is detected.

The antennas areFaraday-shielded, stick-shaped ferrite core loops which, when combined with the associated electronics, exhibit an azimuth acceptance angle of 5.7 degrees. These loops provide a maximum voltage output when the axis of the core is at right angles to the direction line to the source of the sferics signal. Minimum voltage output occurs when the antenna core axis is co-linear with the direction line. The directions of maximum or minimum antenna responses of the four-antenna combination of each receiver are spaced 45 degrees. The orientation of the antennas is shown in figure 2-2.

In the automatic mode, the outputs of the four antennas and their respective receivers are measured by an automatic control circuit. If no sferics signals are present, the turntable on which the antennas are mounted remains stationary. If sferics signals from the combined outputs of the four antennas are detected in excess of 20 pulses per minute,the control circuit causes the turntable to scan in eight steps of $\frac{\pi}{32}$ radians per step. The turntable dwells ten seconds after each step and recycles to the initial position on completion of the eight dwell period.

The scanning mode will continue as long as the total sferics activity exceeds the control circuit threshold. The scanning mode will start or stop in synchronism with an interval timer which may be set to correspond to the local standard time reference. In this way, time reference is provided for any data recording used.

The four antenna-receiver combinations are paired for 90-degree separation of the antenna axes. In figure 2-2, the four antennas are denoted by (a), (b), (c), and (d). The (a) and (b) antennas are paired as well as the (c) and (d) antennas. The (b) antenna output is compared in the acceptance angle circuits with the (a) antenna output and if less than the preassigned fraction of the (a) antenna output, the pulse will be accepted as originating from the direction line of the (b) antenna axis. The acceptance angle circuitry

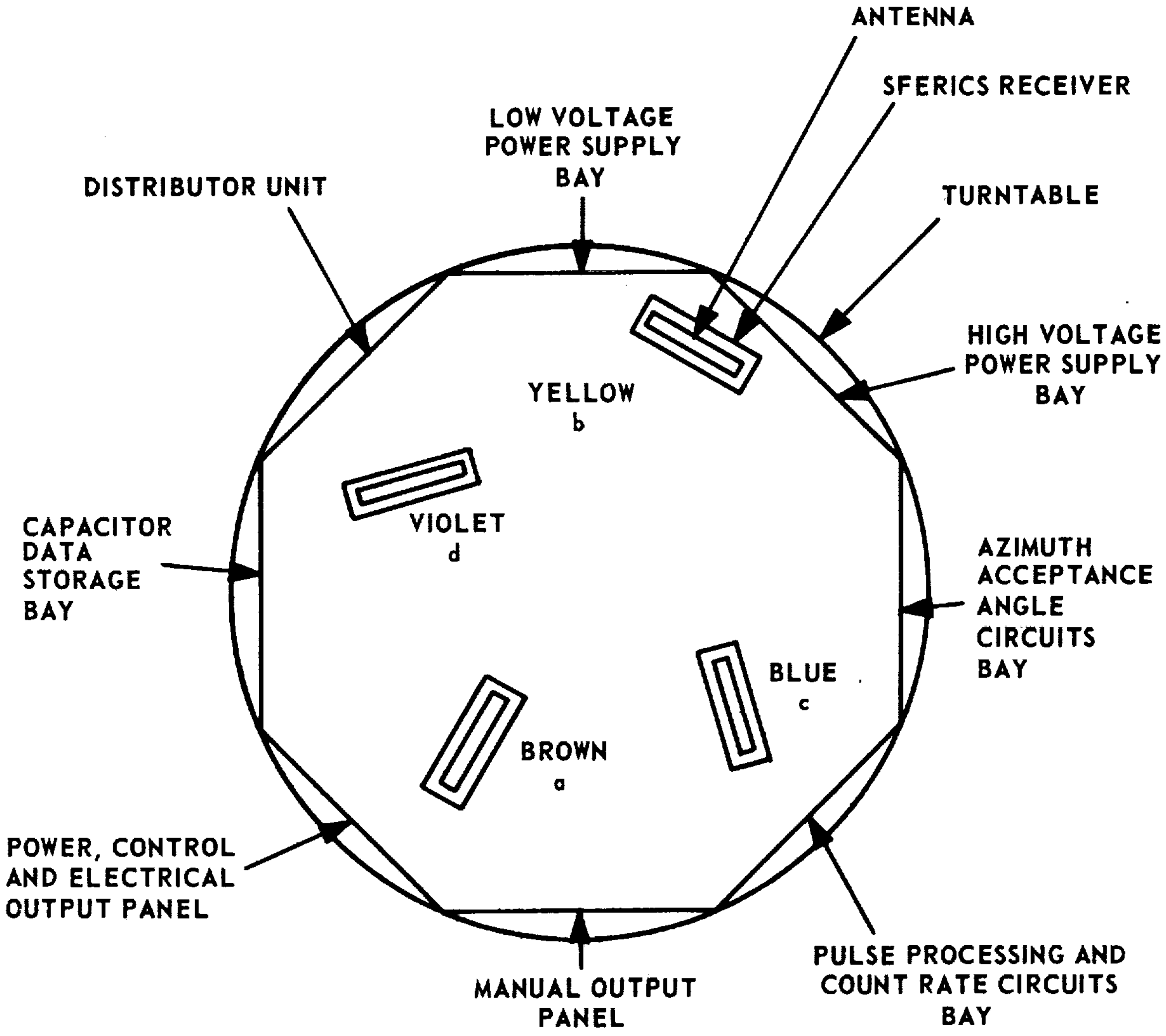


Figure 2-2. Sferic Pulse Amplitude Rate Spectrum Analyzer (SPARSA) System

also makes a simultaneous complementary comparison in which the (b) antenna output is used as the measure of the absolute magnitude of the sferic radiation burst and the (a) antenna output is measured to determine if its output is less than the preassigned fraction of the (b) antenna output.

Similarly the(c) and (d) antenna outputs are paired and selected. Sferics produced by a storm are therefore measured only when the acceptance angle of the appropriate antenna-receiver is aligned with the storm direction.

To minimize the distance effect on the detected pulses, the pulse processing circuits automatically set a variable amplitude counting threshold derived from the average maximum amplitude pulses produced in the corresponding acceptance angle azimuth sector. The counting threshold is one-fourth of the average maximum of the pulse amplitude distribution. Thus, it is claimed that the count rate from a particular source is independent of its range.

All gated pulses whose amplitude exceeds the threshold are then applied to a corresponding count-rate circuit. This circuit is basically a resistance-capacitance type in which the capacitor is used as the data storage element during the intervals between sampling. The final output of the SPARSA receiver is proportional to the sferics count rate in each azimuth sector or acceptance angle position.

Each antenna mechanically scans eight different azimuth sectors to form an octant: antenna (a) scans from 0 to 45 degrees, (d) from 45 to 90 degrees, (b) from 90 to 135 anc (c) from 135 to 180 degrees. Thus, if 360 degree coverage from one site is required, two SPARSA systems are needed.

Terminal strips are provided for connecting the SPARSA output to a recorder or/and a data display. A manual output is available by which each azimuth sector may be interrogated and a count rate indicated on a panel meter.

SECTION III
STORAGE AND TRANSFER

3-1 ALCOHOL

Methyl and furfuryl alcohol are usually contained in 55 gallon drums. Ethyl alcohol is shipped to Cape Kennedy by tank truck and transferred to a large steel storage tank in the alcohol storage area.

During storage or transfer, all containers, vehicles, and equipment associated with the handling and transferring of alcohols must be effectively grounded. Fuels and oxidizers must never be mixed in storage; violent explosion and fire could result. Alcohol-peroxide mixtures are highly explosive. Personnel should guard against contamination by wearing goggles, face shields, protective clothing and approved respirators. Spills must be cleaned up immediately; methyl alcohol is extremely flammable.

The hazards of ethyl alcohol are less severe than those of more toxic and explosive fuels. Leakage and spillage must be prevented. The primary hazard during transfer is fire.

Firefighting equipment, water, safety showers, and eyewash fountains shall be provided in the storage area. Furfuryl alcohol is one of the less hazardous propellants. However, safety in handling and transferring requires constant vigilance to preclude personnel contamination. This alcohol may easily splash in eyes, mouth and skin. Spillage creates vapors which can be inhaled. Contact in appreciable quantities can cause serious bodily harm.

All pumps, motors, lighting fixtures and other electrical devices used in the same area with methyl, ethyl and furfuryl alcohol should be approved explosion-proof types.

The alcohols may be stored in steel drums, glass carboys, or large vessels of steel or stainless steel. Aluminum may be used with methyl alcohol.

Ethyl and furfuryl alcohols are classed as flammable liquids; therefore, special precautions are necessary for transportation. Under no circumstances shall oxidizers and acids be transported with ethyl or methyl alcohol.

Methyl alcohol has a flash point lower than 100 degrees (closed cup) and is considered a "volatile flammable liquid." The major hazard associated with this liquid is fire. However, through vaporization, concentrations of vapors in air may build up to dangerous explosive limits. For this reason, transporting of this liquid must conform with regulations governing the type of vehicle and method of transportation required.

3-2 ANHYDROUS AMMONIA

Ammonia cylinders should be protected from the sun and weather. Storage tanks containing ammonia should also be shaded, unless the tank is so large that shading it is impractical. In that case, the storage tank shall be painted a light color, preferably white, to reflect sunlight. Buildings shall be of the open-side type, with steel framework and sloped roof.

Anhydrous ammonia must be handled with caution because it is a hazardous compound and is stored and shipped under pressure. Safe-handling procedures for pressurized containers are:

a. Do not drop or bump the containers; containers should never be subjected to abnormal mechanical shock.

b. Do not use slings or magnets when unloading cylinders. Do not use hooks on cylinders, but either hooks or fork trucks are suitable for portable tanks.

c. Do not slide or drag cylinders.

d. Do not use cylinders as rollers.

e. Do not remove valve caps until you are ready to withdraw ammonia.

f. Never heat a container or let it heat above 125 degrees F. Never store containers near sources (or potential sources) of heat such as electrical circuits or flammable substances.

g. Do not store containers in damp or corrosive atmospheres.

h. Report any container failure or accident promptly and in detail.

i. Do not ship leaking or damaged containers or ones which have been exposed to fire until the entire contents have been bled off. Bleeding off vapor instead of liquid will refrigerate the container rapidly and thus reduce its pressure.

j. Do not change markings or stampings on the containers for return shipment, Properly close the valves and replace plugs, caps, or covers.

Ammonia can be taken from bottle-type cylinders either as a liquid or a vapor. To take liquid ammonia from a bottle-type cylinder, the cylinder must be horizontal, butt end 2 inches higher than valve end, and valve outlet up. In this position, the dip tube is immersed in liquid ammonia, which may be withdrawn as required. The dip tube is a curved pipe, extending from the valve inlet to a point adjacent to the cylinder wall on the side opposite the valve outlet.

When ammonia vapor is needed in large quantities, liquid ammonia can be withdrawn from the cylinder and converted to vapor in a steam or electrically heated vaporizer with approved safety devices. Under no circumstances should cylinders be warmed directly by hot water, steam, or flame; this could rupture the cylinder. Also, great care must be exercised in manifolding two or more cylinders together. Valves on such an installation should never be closed unless the cylinders are reweighed immediately; even a slight temperature difference between cylinders will cause liquid flow from the warmer to the cooler container, overfilling the latter. If an overfilled cylinder is blocked off, a temperature rise may cause hydrostatic rupture.

A cylinder is considered empty when the pressure gage registers 25 psig or less and there is no condensation on the cylinder wall. At 25 psig, there is still ammonia in the cylinder, but the amount is negligible.

Ammonia is usually transferred by creating a pressure differential between the tank car and the storage tank.

The compressor method is the most common means of unloading single-unit tank cars and trucks. A compressor similar to those used in small, commercial ammonia-refrigerating systems is set up with its suction side connected to a vapor valve on the tank car. A liquid line from one or both liquid valves of the tank car runs directly to the liquid line of the storage tank. Oil contamination of the tank car is minimized by the installation of an oil separator on the discharge side of the compressor.

When the compressor is operating, the pressure inside the tank car is raised, and simultaneously the pressure inside the storage tank is reduced. This pressure differential moves the liquid ammonia from the car to the storage tank. During unloading, the differential should be approximately 30 psi. When the tank car is empty of liquid ammonia, the differential will drop 5 to 10 psi, and approximately 500 pounds of ammonia vapor will remain in the car (depending on final pressure).

When storing ammonia in main storage tanks, procedures for transferring from main storage to ready storage are basically the same.

3-3 ANILINE

Aniline is stored in fixed or mobile drums or tanks. Storage tanks, associated piping and fittings, pumping equipment, valves, etc. should be made of steel which meets individual construction specifications. Aniline is not corrosive to metals.

Aniline is a flammable liquid. However, with observance of general safety rules, there is little danger of fire when transferring aniline. Aniline has an autoignition temperature of approximately 1400 degrees and a closed cup flash point of 168 degrees. It is less flammable than kerosene but subject to the same handling precautions.

Storage tanks, pumps, and piping systems at the storage area must be properly grounded and all flanged joints bonded. Aniline is usually shipped in 55-gallon steel drums, which may be used for storage if the proper precautions are taken. These drums should be stored on a concrete base with a shed-type roof to protect them from the sun.

In the main storage area, storage tanks shall be surrounded by an earthen dike of sufficient height to hold 10 percent more than the maximum storage capacity. Buildings housing the storage tanks, drums and transfer system shall be of the open-side type, with sloped roof and steel framework. The buildings shall be properly grounded against static electricity and have an approved lightning-protection system.

The primary difference between main storage and ready storage lies in the quantity of aniline stored. The principles for main storage and handling areas shall be observed in the ready-storage area.

Transfer operations require at least two trained operators in attendance. All operating personnel must wear approved protective clothing and respiratory equipment.

3-4 ETHYLENE OXIDE

Due to the flammability, explosiveness and toxicity of ethylene oxide, buildings which store this propellant must be well ventilated to prevent vapor accumulation.

Tanks, lines, and other equipment used for ethylene oxide handling shall be thoroughly purged with nitrogen, methane, or other oxygen-free, inert gas to remove air. It is essential that ethylene oxide be kept in an oxygen-free atmosphere during all tank transfers.

This propellant is easily ignited at 0 degrees; it is flammable and its vapor is both toxic and explosive. All electrical equipment, motors, lights, and flashlights used where ethylene oxide is handled should be vapor-tight or explosion-proof. Static electricity is guarded against by providing bottom inlets to storage tanks and by properly grounding all equipment, tanks, columns, piping, and other metallic equipment. One of the ethylene oxide storage problems in Florida is the high daily average temperature. For this reason, the propellant is cooled below 86 degrees by a water sprinkling system.

Copper and other acetylide-forming metals (such as silver, magnesium, and their alloys) should not contact this propellant. Ethylene oxide reacts exothermally with such compounds as alcohols, amines, ammonia, and organic or mineral acids. Contamination should be avoided from such impurities as water, alkalies, metallic oxides and iron or aluminum salts to prevent polymerization or reaction.

Ethylene oxide containers shall never be used for any other item. Containers, lines, and other equipment used for handling ethylene oxide should be completely and thoroughly purged with nitrogen, methane, or other oxygen-free, inert gas to remove air. When a drum of ethylene oxide has been emptied, an inert gas pressure of 35 psig at 70 degrees should remain in the drum which should returned to the shipper.

Handling, transfer, and storage of ethylene oxide requires at least two operators. After all filling, vapor, and transfer connections have been properly made, all the inlet and outlet valves are properly set and checked. Cylinders and drums shall be emptied by inert gas pressure not exceeding 50 psig. (Gravity flow may also be used.) If gaseous ethylene oxide is required, the liquid is transferred from the drum into a vaporizer.

A tank car may be unloaded by either pumping or pressurization. The dome of an ethylene-oxide tank car is equipped with two down pipes with connections, a vent or vapor connection and a gaging and sample connection. All these outlets are equipped with ball-check or excess-flow valves as a safety precaution. If a valve or any connection is opened too rapidly, the ball-check valve immediately closes, cutting off the flow of liquid or vapor. A line carrying nitrogen or other inert gas is attached to the vapor or vent connection, and the pressure necessary for transfer of the oxide is maintained. As the relief valves on the tank car are set for 75 psig, the pressure used may range from 35 to 65 psig. If a centrifugal pump is used for transfer, an inert-gas pressure of 35 psig should be maintained in the tank car during unloading to force the liquid into the pump suction and to keep the vapor phase of the tank car in the nonflammable range.

3-5 LIQUID FLUORINE

Fluorine is the most powerful oxidizing agent known and will react with practically all organic and inorganic substances. The few exceptions are inert gases and metal fluorides. Fluorine reacts with all metals under elevated temperature and pressure. However, the formation of impermeable fluoride coatings on some metals produces materials satisfactorily for construction of containers. Material for liquid fluorine service must be initially treated with gaseous fluorine to form a thin fluoride film on the surface. The passivation procedures consist of slowly passing fluorine gas through the previously cleaned, dried, evacuated system. After 15 to 30 minutes the system is blanked off and working pressure of approximately 60 psig is applied for 12 to 24 hours. Metals most commonly used for fluorine storage tanks are monel or stainless steel. Monel is preferred, since it provides resistance up to 930 degrees.

Liquid fluorine is stored in three-shelled tanks. The innermost chamber contains the fluorine, the intermediate chamber contains liquid nitrogen and the outermost is evacuated of air and contains insulation. The workability of this system depends on the difference of the boiling points of liquid nitrogen (-320.44 degrees), and liquid fluorine (-306.55 degrees). The fluorine is kept loss-free by the boiling of liquid nitrogen. An alarm system is installed to monitor the nitrogen level. The storage system is designed to remain loss-free for 30 days with no additional liquid nitrogen. The outer and intermediate chambers are constructed of type 304 stainless steel. The liquid fluorine tank and the piping are of monel or 304 stainless steel. The entire storage area shall be enclosed by a wire mesh fence and kept locked when not in use.

Positive instant-acting safety showers shall be strategically located near the area where fluorine is handled. Fountain-type eye wash baths shall be provided.

Storage tanks shall not be exposed to fire, direct sunlight, direct heat or placed near steam lines. Buildings or shelters shall be provided for all storage tanks. All facilities shall be sited so the direction of prevailing winds is away from inhabited areas. Lighting and electrical fixtures shall be of the vaporproof type.

All materials and equipment used in handling fluorine must be free of dirt, grease, oxidation and moisture. Valves shall be disassembled and cleaned prior to use.

Adequate ventilation is essential for enclosed spaces. There shall be a minimum of 10 air changes per hour.

In handling liquid fluorine under pressure, remotely controlled valves should be used (preferably those operated by manually actuated extension handles passing through approved barricades). Double valving shall be used where large quantities of fluorine are handled.

Barricades of brick, concrete or steel plates are recommended to prevent the breakthrough of fluorine, flame or molten metal inthe event of system failure. Major storage facilities shall be surrounded by a concrete dike high enough to contain 10 percent more than the capacity of the storage vessels. The diked area should be constructed with a concrete floor.

Storage grounding cables shall be used between both the transferring vehicles and strategically located ground rods when liquid fluorine is transferred.

During all transfer and storage, personnel must wear protective clothing. Although no materials are known at present that will provide complete protection, impermeable gloves should be used to protect against fluorine and allow free movement of fingers. Clean neoprene gloves shall be worn when handling equipment which contains, or has recently contained, fluorine. This protects not only against fluorine but also hydrofluoric acid, which may be formed when escaping fluorine reacts with moisture in air and coats valve handles and other equipment.

Boots of approved protective materials are not manufactured commercially. A neoprene overboot should be selected which can be worn over regular safety footwear and is high enough to fit comfortably under the legs of protective trousers.

Vinyl-coated materials react violently with fluorine and should not be used. Neoprene jackets and trousers designed for quick removal are recommended. Full hoods shall be worn.

Gas masks and cartridge respirators shall not be relied on for protection against fluorine. Approved self-contained breathing apparatus with full face mask shall be used.

3-6 HYDRAZINE

This propellant is comparatively easy to handle once its chemical properties are thoroughly understood. Since rust oxidizes hydrazine and acts as a decomposition catalyst, the metals selected to contain this propellant shall be stainless steel, aluminum alloys, nickel, or nickel alloys.

Hydrazine storage consists of storage tanks, dikes, pump platform, truck transfer apron and safety equipment, which includes: storage tanks, sump tank (to receive water drainage and hydrazine spills), nitrogen padding system, pump, valves, grounding system, deluge system, safety showers, eyewash fountains, fire and washdown hose, alarm and sensor system.

The fuel tanks are revetted to protect other installations from damage in the event of an explosion. Ten-foot-high concrete dikes surrounding each storage tank shall contain the capacity of the storage tank plus twice this volume of water. Water is added to fuel spills by a deluge spray system or a fire hose to dilute the fuel and prevent fire and explosions. Access to the storage tanks is provided by permanently installed ladders over the dike walls. Fire retardant walls between the tanks are one foot higher than the tanks. Hydrazine storage area should have a roof over the pump platform but not over the hydrazine storage tanks because of the explosive and fire characteristics of this fuel.

A sump tank is needed to receive spills and drainage in the storage facility. A swing pipe outside the storage tank revetment is provided to drain uncontaminated water from the portion of the tank lying below grade and drained by a sump pump. Contaminated water in the sump tank resulting from a hydrazine spill is disposed of by chemical treatment or by incineration in accordance with the applicable maintenance operating procedure. When incineration is used, the spill will be transferred by tank truck to the contaminated hydrazine storage tanks in the propellants burner area.

Because of health hazards in fuel handling and storage, warning and caution signs will be posted throughout the storage area.

Operators shall be thoroughly indoctrinated in the fire, explosion and health hazards of handling hydrazine. They shall also be thoroughly familiar with the handling equipment and shall be able to repair and maintain it. At least two men are required when transferring hydrazine propellant.

A hydrazine alarm and detection system shall be provided to warn personnel when the concentration of the fuel blend in the air exceeds the threshold limit. All hydrazine storage vessels, pumps and piping systems must be properly grounded.

The electrical installation in transfer and storage areas shall conform to the National Electrical Code, Class I, Group D, Division 1 or 2, as applicable.

All hydrazine tanks shall be provided with a vapor-pressure relief valve of adequate size. The valve shall be set at a safe working pressure determined by tank materials and construction. The pressure-relief valve shall be connected to a fume vent system that will discharge the vapors away from the working area at a height of at least 50 feet.

3-7 HYDROCARBONS

The majority of hydrocarbon fuel arrives at the bulk storage plant by commercial tank semitrailer. It is transferred to bulk storage by the bulk plant pumping system. RP-1 fuel, however, arrives by railway tank car. The car seals are broken upon arrival and samples are taken for the chemical laboratory. If the fuel meets specifications, it is transferred to a fuel service trailer using a gas-powered portable pump and flexible hose. The fuel is pumped from the loading hatch of the railway car to the loading hatch of the service trailer, then transported to the liquid storage area and transferred to the bulk storage tanks utilizing both the service trailer pump and the plant pump.

Transfer of hydrocarbon fuels is usually accomplished from tank cars, tank trucks, or drums. All petroleum containers shall be kept closed when not in use.

Static electricity can be generated by the flow of petroleum from one container to another, or through a hose. In any transfer of petroleum, ground all equipment and transfer lines with screw clamps to prevent a static spark from causing an explosion or fire.

During the transfer of petroleum fuels, fire extinguishers shall be manned and ready for action. All operating personnel should know the exact loaction and operation of such equipment. The fire department should be notified of the operation, and transfer made only if they are standing by.

Personnel shall wear protective equipment. Face shields, flame-resistant coveralls, conductive safety shoes, etc., are required for all fuel handling. Approved respirators shall be worn in enclosed places or areas of high vapor concentration. All spills shall be promptly cleaned wiped and disposed of in a designated waste disposal area.

Fireproof storage buildings with approved explosion-proof lighting, wiring, switches, pumps, and motors shall be used for the storage and handling of fuels. The buildings shall be grounded for lightning protection.

3-8 LIQUID HYDROGEN

The liquid hydrogen facilities shall be constructed of noncombustible materials and adequately ventilated.

The electrical installation in transfer and storage areas shall conform to the National Electrical Code requirements for Class I, Group B, Division 1 or 2, as applicable.

All lines and equipment must be grounded to prevent accumulation of electricity.

An adequate water supply shall be provided for flushing, safety showers, and decontamination. Operational areas and storage sheds shall be provided with approved deluge safety showers, easily accessible, clearly marked and controlled by quick-opening valves. Facilities shall be provided to repair and decontaminate protective clothing and equipment. Safety equipment shall be periodically inspected.

All storage sites shall be properly drained to prevent damage to other areas, and prevent mixing of drainage with noncompatible materials. Drainage will not be permitted into an area where it might mix with an oxidizer.

When liquid hydrogen can evaporate into a confined area, the area shall be adequately ventilated to prevent an excessive concentration of gaseous hydrogen. Buildings shall be ventilated at the highest point so that hydrogen gas will not build up. Depending on the building location and construction, fans may be required. A combustion-detection and alarm system will analyze gas samples from all critical locations. Because hydrogen burns with a colorless flame, fire-detection and alarm system should also be installed.

Tanks, piping and equipment used in liquid hydrogen service must be kept clean and free of grease and oil. Surrounding areas shall be kept free of grease, oil and oily waste and other combustibles. Supervisors shall make periodic inspections to ensure good housekeeping.

Liquid hydrogen shall be stored in tanks of approved materials and construction. Storage tanks should be tested as required by ASME or ICC specifications for unfired pressure vessels. Materials used for pressure vessels operating at less then -20 degrees F should be inpact-tested in accordance with paragraph UG-84, Section VIII, "ASME Boiler and Pressure-Vessel Code." Storage tanks shall be vacuum-jacketed and insulated with a noncombustible material such as "Santocel", "Perlite" or equivalent, and free of grease and dirt. The vacuum space between the inner and outer shells shall be equipped with either a rupture disc or a pressure-relief device. The storage tank shall be equipped with an adequate vent line and a pressure-relief valve. The vents shall discharge to the outer atmosphere. Bottom outlets on storage tanks are recommended.

All lines between closed valves shall be equipped with pressure-relief valves. If relief valves are subject to freezing, the vessels and lines shall be equioped with rupture discs. All lines shall be carefully pressure - and leaktested periodically.

3-9 HYDROGEN PEROXIDE

Hydrogen peroxide is a powerful oxidizer. Avoid materials not compatible with hydrogen peroxide: iron, brass, bronze, magnesium alloys, lead, silver, lubricating oils, and pipe dope. All materials that will contact concentrated hydrogen peroxide must be chosen carefully. Storage tanks and pipelines should be of 99.6 percent aluminum. Pipe should be bent and flanged to avoid objectionable screw fittings. Gate valves are recommended and should contain 99.6 percent aluminum. Pumps should be of 435 aluminum or 316 stainless steel.

Surfaces in contact with hydrogen peroxide should be specifically treated by passivation prior to use to prevent excessive decomposition of hydrogen peroxide. Passivation consists of treating metal to form an oxide film. The hydrogen peroxide contacts this oxide film which serves as a layer between the hydrogen peroxide and the metal surface and prevents attack by the hydrogen peroxide on the metal. It also prevents the metal decomposing the hydrogen peroxide. The metal oxide is similar to a painted surface: as long as the film holds to the metal, the metal will not corrode.

Hydrogen peroxide must be stored in drums or tanks of approved design and construction.

Storage, transfer and test areas must be kept neat, clean and absolutely free of combustibles. All leaks and spills must be flushed away at once with large amounts of water. These areas must be inspected frequently; safety regulations must be enforced. Storage areas shall be washed thoroughly each week.

At least two trained operators shall be assigned to any operation involving the handling, transfer or storage of hydrogen peroxide. Personnel safety showers will be easily accessible and near storage and transfer equipment.

For head, face and body protection, permeable clothing of "Dacron" or "Dynel" fabric, when used with eye goggles, gloves and boots, normally gives adequate protection. For emergencies, vinyl coveralls, apron and hood may be added. The clothing must cover the operator's body and be adjusted to prevent drainage into gloves or boots.

Pumps of wrought or forged 300 stainless steel (304, 316, 321 and 347) - or aluminum alloys B356, 356 or 43 - that have a 300-series stainless-steel shaft, shall be used for pumping hydrogen peroxide. Cast stainless steel should be avoided because it is subject to chromium leaching, which seriously contaminates the propellant and hastens decomposition. Self-priming pumps should be used to ransfer hydrogen peroxide from tank cars or other tanks with top outlets. Stainless-steel mechanical seals with galss-filled "Teflon" and ceramic faces are recommended. Where used, packing should be in rings of either "Teflon" or "Vitrium", lubricated with a fluorinated hydrocarbon. Pump shafts should not be of aluminum; packing should contain no unsuitable materials. If packing is used, glands must not be over tightened; overheating could result in rupturing the gland.

Two types of drums are available: a double-head drum suitable for all freight shipment and a single-head drum suitable only for full carload and full truckload shipments. Drums must be marked "Wash leakage with water." Drum capacity is 30 gallons. Drums must be handled and stored with the bung up.

Tank cars have a dome containing a manhole, a vent with a porous-stone filter to exclude dust, a dip pipe for unloading, a fill connection and a burst disc designed to blow out at 45 psig pressure. The temperature of the hydrogen peroxide is measured by a thermometer or thermocouple in a protective aluminum tube inside the tank or fastened to the tank outside wall below the liquid level and insulated with glass wool. Pump unloading of these cars is recommended. The tank capacities for hydrogen peroxide are 4,000; 6,000; and 8,000 gallons.

For storage, horizontal tanks are preferred to vertical but the latter may be used. Normally, top inlet and outlet connections are used. All connections should be flanged. The tanks should have a large (18 to 20 inch) pressure-opening man-way and a filtered vent (2 inches or larger) on top. A temperature alarm also is recommended. The thermometer or thermocouple may be installed in the same way as on tank cars.

Tank cars, tank trucks and tanks may be unloaded by pumping, vacuum or pressurization with clean, dry nitrogen. The specified design pressure of the tank must not be exceeded. Filters and traps must be used to remove all impurities from the gas supply and to prevent feedback into the tank. Solid particles, as well as oil, vapors, etc. in the gas stream are contaminants which may cause hydrogen peroxide to decompose. After a tank is unloaded by pressure, the vent shall be opened at once. When pressure transfer is used on tanks, a line shall be attached to the safety vent and extended to the ground so that the vent may be opened to stop the flow in an emergency. Do not flush the tank after emptying it unless it is to be entered for inspection or repair.

3-10 NITRIC ACIDS

The fuming nitric acids are highly corrosive oxidizing agents and will vigorously attack most metals. Nitric acid must be stored in suitably housed drums or tanks of approved design, materials and construction. Storage, transfer, and test areas must be kept neat and free of combustibles. All leaks and spills must be flushed away at once with large amounts of water. These areas must be frequently inspected. An adequate water supply must be available for firefighting, flushing, decontamination, personnel showers and eye baths. Cold-water eye baths and approved safety-type personnel showers must be convenient for immediate use in emergency.

The following is a list of metals approved for use with fuming nitric acids:

Aluminum (types)	
New designation	Old designation
1060	BDIS, 99.6
EC	
1100	25
3003	35
3004	
6061	615
5052	525
5154	

Stainless Steel (types)
Designation
374
19-9DL
1-9DX
304 ELC
321
303
316

All other ferrous and nonferrous metals and their alloys are prohibited because they react with fuming nitric acid, producing toxic nitrogen oxides as well as failures from corrosion.

WARNING

When in contact with red fuming nitric acid, titanium metals and alloys of which titanium is a major constituent present the hazards of explosion and stress-corrosion cracking.

All storage tanks shall be of welded construction, and after fabrication should be properly stress-relieved. They shall not be equipped with bottom outlets but shall be of dip-leg design in which the inlet is about 3 inches above the bottom of a sump. They shall be equipped with pressure-relief valves and lines of adequate size and, where venting to the atmosphere is impractical, discharged into a fume-scrubbing system. Tanks shall have a high and low liquid level alarm system which also controls the pump motor. Because carbide precipitation occurs during the welding of stainless steel, the section of a stainless steel storage vessel most susceptible to corrosion failure is its welded area. This danger may be materially lessened by proper heat treatment of the vessel after fabrication. Since pumps, valves, etc., may be delivered without lubricants or packing, the approved packings and lubricants can be installed afterward, avoiding the need for removing existing materials and the hazard of leaving the wrong packings, etc., in the equipment.

In any operation relating to handling, transfer or storage of fuming nitric acids, at least two operators shall be present, and ready avenues of retreat for them should be available. In all handling operations, personnel shall wear approved protective clothing and respiratory safety equipment.

Hands and feet are always subject to contamination during handling of liquid propellants or propellant equipment. Gloves and boots that keep nitric acid off the skin must always be worn. The gloves should protect against nitric acid but allow free movement of fingers. A vinyl-coated glove meets these requirements. Since boots of approved protective construction materials are not commercially available, an overboot, designed to be worn over regular safety footwear and high enough to fit comfortably under protective trousers, is used. Boots of natural or reclaimed rubber may be used with reasonable safety if contamination is washed off quickly. They should be frequently inspected to detect flaws that might result in injury.

To protect head, face and body, an acid and fuel resistant protective suit of vinyl-coated fiberglass is suitable. Polyethylene clothing may also be worn. Fiberglass clothing impregnated with acid resisting plastic, such as "Teflon" and "Kel-F", or equivalent, is excellent for protecting handlers of nitric acid. The clothing must cover the entire body and be adjusted to prevent body contamination and keep leaked or spilled liquid acid from draining into boots or gloves. A hood of approved type must be worn to protect the head.

Whenever men are exposed for prolonged periods to nitrogen dioxide (released from fuming nitric acid) at concentrations greater than the threshold limit value, approved respiratory protection shall be worn. The canister gas mask does not provide adequate respiratory protection. Approved self-contained breathing apparatus will give the most reliable respiratory protection against gases or mists from fuming nitric acid.

The 11,000 gallon aluminum tanks are the most acceptable for permanent storage of nitric acid. Acid deliveries by tank car are in lots of approximately 8,000 gallons. All tanks in permanent storage are mounted on reinforced-concrete saddles over a reinforced-concrete drainage basin. The horizontal tank is commonly used. Nitric acid may be shipped in 55-gallon aluminum drums with a single bung on the side, but other containers of convenient size are used.

Nitric acid may be transported and stored in specially constructed semitrailers or trucks of various types and capacities. These units contain transfer equipment, vents and pressure-relief devices and instrumentation. Some trucks are equipped with a water system for safety showers.

3-11 NITROGEN TETROXIDE

This propellant is stable at ordinary temperatures; it exhibits only a reversible dissociation into nitrogen dioxide; therefore refrigeration is not required to keep it liquid. Special precautions to prevent it from freezing will be required when material is used below 12 degrees F. As nitrogen tetroxide shrinks on freezing, it will not damage lines and containers. Liquid nitrogen tetroxide can be stored safely in moderate-pressure vessels, from which there need be no loss by evaporation.

Liquid nitrogen tetroxide may be stored or transported in tank cars or cylinders and may be stored in bulk tanks. The storage tanks must be of approved design and materials.

Normal safety precautions in handling any toxic material should be strictly observed. Storage, transfer and test areas must be kept neat and free from combustibles, and frequently inspected. Precautions in handling liquid nitrogen tetroxide are similar to those for fuming nitric acid.

Although nitrogen tetroxide at ordinary temperatures and pressure is not corrosive to most common metals, the selection of metals depends on the oxidizer's moisture content. The following metals are suitable:

NO_2 moisture of 0.1% or less

Carbon steels
Aluminum
Stainless steels
Nickel
Inconel

Under wet conditions

Stainless steel (300 series)

Nonmetals

Ceramic (acid-resistant)
Pyrex glass
Teflon
Kel-F
Asbestos (cotton free)
Polyethylene (limited use)

Since hydrocarbon lubricants react with oxidizers, they must be avoided; the following lubricants, inert to strong oxidizers, may be used.

Fluorolube series

Nordcoseal-147 and DC2345

Teflon tape

Nitrogen tetroxide may be stored in stationary or mobile tanks or cylinders of approved materials. Equipment should be delivered without lubricants, packings or gaskets to avoid the possibility that the manufacturer has used a prohibited material. The approved materials may then be installed.

The tanks shall be tested according to the ASME "Boiler and Pressure Code." These tanks should be fabricated to withstand an internal pressure of at least 150 psig. Since nitrogen tetroxide does not present a particular serious corrosion hazard, the tank may be equipped with bottom outlets for transfer and cleaning. The tanks shall be equipped with rupture discs and pressure-relief valves set to vent at 75 psig.

Storage and mobile tanks must be equipped with both top-fill lines and fume-return pressure-balance lines. This design is necessary to keep the system closed during transfer and filling. The tanks shall also be equipped with liquid level gages and, if practical, a high and low level alarm system.

The bulk storage system shall be installed on a covered concrete base with an adequate drainage and decontaminating system. The design and construction of mobile tanks should comply with ICC regulations. This would avoid the use of low-pressure tanks which may be satisfactory for stationary storage but too light for safe handling in transit.

The protection required against the toxicity of nitrogen tetroxide is the same as for nitric acid (paragraph 3-10).

Transferring nitrogen tetroxide by pump is preferred because it considerably lessens the possibility of introducing moisture into the system. Nitrogen tetroxide may be transferred by the differential-pressure method, using dry compressed air (dew point 40 percent or lower) or a dry inert gas. The pumps shall be of approved material and may be of the centrifugal or positive-displacement type. Positive-displacement pumps are used whenever a high suction lift is required. Hoses shall be of approved materials and be designed for this service.

Pump-shaft seals may consist of either a mechanical seal of the proper construction materials or braided African blue asbestos packing, impregnated with approved lubricant. A seal-less pump with special bearings and impeller of stainless steel is recommended; as the design includes no exposed shafts, all shaft-seal problems are eliminated. All packing gland seals around shafts on pumps, valves, etc., shall be protected by polyethylene shields to prevent nitrogen tetroxide spraying on operators in case of failure.

Standard pressure gages of compatible materials shall be used in nitrogen tetroxide service. To minimize operator reading errors, all pressure gages used for a common purpose should have identical scales.

The propellant storage tanks shall be equipped with rupture discs and pressure-relief valves set to vent at 75 psig. When the tanks are so located that it is impossible to vent to the atmosphere, vent lines of adequate size shall be provided on the downstream side of the pressure-relief equipment and discharged into a fume-scrubbing system. Venting of tanks to the atmosphere must be done through a type 304 stainless steel vent stack, located away from the working area and discharging at least 50 feet above the highest operating level.

A nitrogen tetroxide detection and alarm instrument should be provided to warn personnel operating indoors when the concentration of nitrogen tetroxide in the air reaches the threshold limit. If natural ventilation is impossible or inadequate, down-draft ventilation should be provided.

Although nitrogen tetroxide at ordinary temperatures and pressure is not corrosive to most common metals, the selection of metals for this service should be governed by the oxidizer moisture content. The following metals are suitable:

NO_2 moisture of 0.1 % or less

Carbon steels
Aluminum
Stainless steels
Nickel
Inconel

Under wet conditions

Stainless steel (300 series)

Nonmetals

Ceramic (acid-resistant)
Pyrex glass
Teflon
Kel-F
Asbestos (cotton free)
Polyethylene (limited use)

3-12 LIQUID OXYGEN

Liquid oxygen is transferred and stored as a liquified compressed gas and must be stored in approved containers.

Metals used in liquid-oxygen equipment must be able to operate at extremely low temperatures. Ferrous alloys (except for the austenitic nickel-chromium alloys: 18-8 stainless steel and 9 percent nickel steel series) are too brittle for the low temperatures reached in the production and transfer of liquid oxygen.

The following are acceptable:

Stainless steel, series 18-8
Copper
Bronze

Brass
Monel
Aluminum
Everdur

Because of the strong oxidizing properties of oxygen and the extremely low temperatures encountered, few nonmetals are acceptable:

Teflon
Kel-F

Asbestos
Special silicone rubbers

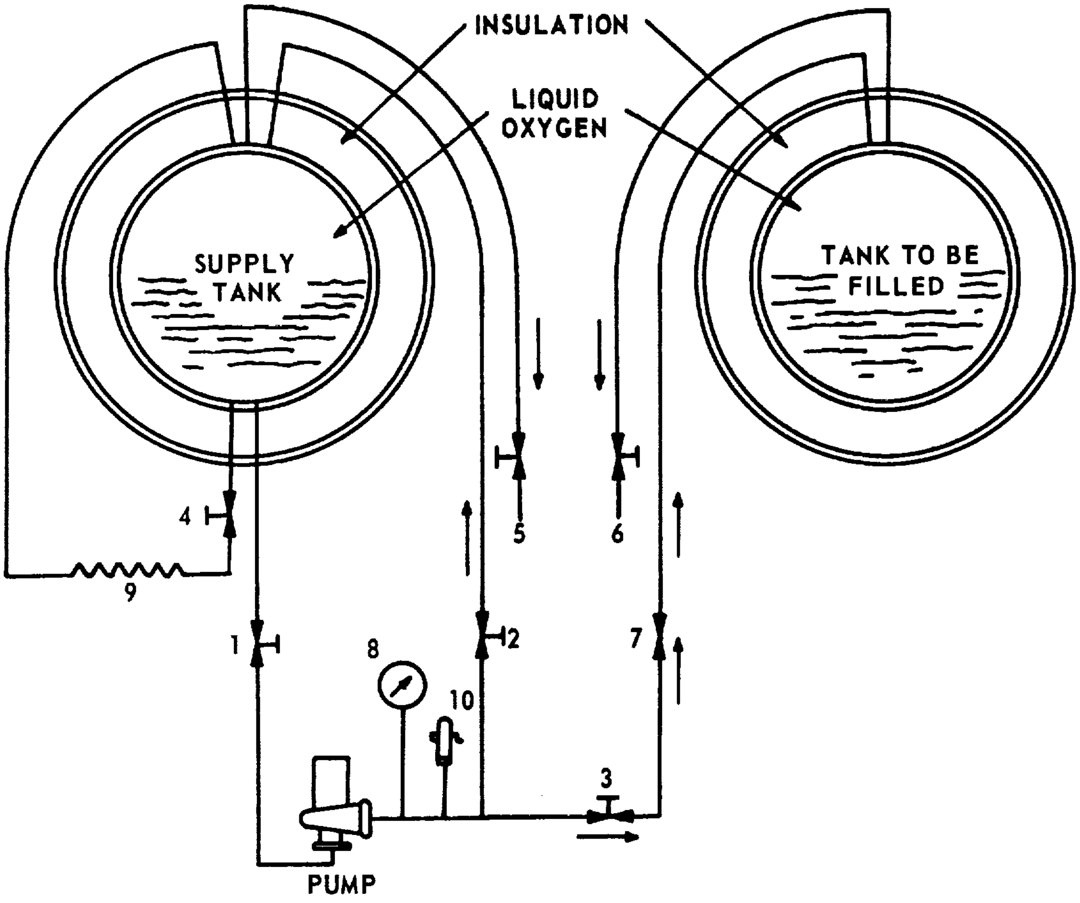
Since liquid oxygen is a powerful oxidizer, petroleum-base lubricants must not be used. Special lubricants such as the fluorolubes or the perfluorocarbons are used. Before use, tanks, containers, piping, etc., shall be degreased by washing with approved grease-removing solvents. Equipment taken out of service for maintenance or modification shall be inspected and degreased before being reused. Surrounding areas shall be kept free of grease, oily waste and all organic materials. Smoking, sparks and open flames shall not be permitted in storage areas. Supervisors shall make periodic inspections to ensure good housekeeping.

Liquid oxygen handling areas must be well ventilated to minimize gas concentration. Never dispose of the liquid in confined areas. A concentration of gaseous oxygen will contribute to the intensity of any fire.

When liquid oxygen is trapped in a closed system and refrigeration is not maintained, pressure rupture may occur. Oxygen cannot be kept liquid if its temperature rises above -181.8 degrees, regardless of the confining pressure. Liquid oxygen trapped between valves can cause the pipe or tube to rupture if the oxygen is not dumped or pressure-relieved by suitable devices. The loss of vacuum in vacuum-jacketed tanks can cause evaporation to increase and overload an inadequately designed venting system, raising pressure.

Liquid oxygen must be stored in stationary or mobile tanks of approved materials and construction. Storage and shipping drums used for other propellants are not to be used in this service. To ensure against defects in material or fabrication, the storage tanks should be tested as required by ASME or ICC specifications for unfired pressure vessels. Materials used for pressure vessels operating at temperatures less than -20 degrees should be impact-tested. Containers for the shipment, storage and transfer of liquid oxygen may be fabricated in accordance with any standard that meets pertinent structural requirements. Storage containers shall be vacuum-jacketed; the vacuum space may contain reflective insulation or powders. The insulated area between the inner and outer shells shall be equipped with either a rupture disc or a pressure-relief device, so that pressure cannot build and rupture the vessel. The storage tank shall be of welded construction and equipped with an adequate vent line and a pressure-relief valve, both discharging to the outside atmosphere. Bottom outlets on storage tanks are recommended, since they simplify the transfer system design and the selection of pumping equipment.

The following operating instructions for the liquid oxygen centrifugal transfer pump are a guide for safe, efficient operation. They are based on the premise that operating personnel are trained in general operation and handling of oxygen equipment. See figure 3-1.



1. PUMP SUCTION VALVE
2. PUMP PRIMING VALVE
3. PUMP DISCHARGE VALVE
4. PRESSURE BUILDING VALVE
5. BLOWDOWN VALVE
6. BLOWDOWN VALVE
7. CHECK VALVE
8. PRESSURE GAUGE
9. PRESSURE BUILDING COIL
10. SAFETY VALVE

Figure 3-1. Flow-Sheet, Liquid Oxygen Transfer

To start pump, close valve (3) and fully open primary valve (2) Gradually open the section valve (1) to admit liquid oxygen to the system, cooling the pump and piping. Allow two or three minutes for the system to cool.

Start pump drive motor. Shut down pump immediately if it does not take prime. Lack of prime can be identified by noisy operation of the pump and failure to build discharge in pressure gage (8). Allow liquid oxygen to stand in the pump and lines a few minutes.

Again try to start pump. If pump fails to take prime after repeating this procedure several times, the cause is probably insufficient subcooling at the pump suction. To increase subcooling, rapidly increase the gas phase pressure in the supply tank. If gas generated by normal evaporation and by cooling is insufficient, additional liquid must be vaporized by pressure building coil (9).

After the pump is operating properly, recirculating to the supply tank, gradually open valve (3) and close primary valve (2).

Once pump operation is normal, the liquid oxygen transfer pump requires no further adjustment. However, the pump should be stopped immediately for any of the following:

Liquid oxygen leakage
Gaseous oxygen leakage
Abnormal noisy operation
Graphite noseplate too hot
Oil or grease on surfaces around pump

Pump shutdown procedure:

Stop electric motor
Close pump suction valve (1)
Close pump discharge valve (3)
Open priming line valve (2)

Personnel handling liquid oxygen shall wear head and face protection including acid type goggles or a face shield, such as a nitrometer mask or hood. Flame-resistant clothing is not effective for use with liquid oxygen. If liquid oxygen is handled in an open system, an apron of approved material shall be worn. Respiratory protection is not required.

Organic or flammable substances must not contact liquid oxygen. Materials that can react violently with oxygen include oil, grease, asphalt, kerosene, cloth, wood, paint, tar and dirt. Mixtures of powdered organic materials and liquid oxygen may detonate.

3-13 UDMH, UDMH/HYDRAZINE

UDMH is transported by semitrailer tank truck or railroad tank car. Tank trucks are not authorized for use with hydrazine, except by special ICC permit. UDMH is frequently transported by truck in 55-gallon nonreturnable mild steel drums and stored until needed. No special procedures are needed for unloading sealed drums, if there is no leakage or loss of contents. Contact with leakage (liquid or vapor) should be avoided because of the toxic nature of the chemicals. Drums of UDMH should be kept sealed pending transfer.

The main storage tanks shall be designed, constructed and tested in accordance with the ASME code for unfired pressure vessels.

When the propellants are transferred, all storage vessels, drums, pumps, and piping systems must be properly grounded. UDMH and hydrazine are compatible with most common metals (except as noted in later paragraphs). Storage and shipping equipment may be of mild steel. There is no limitation on the use of UDMH with nickel, monel or types 303, 304, 316, 321 and 347 stainless steel or aluminum 1060,3003, 5052, 5154, and 6061. Aluminum is attacked to some extent by dilute aqueous solutions of UDMH, but no corrosion occurred when the concentrations contained a small percentage of water. UDMH typically contains about 0.1 percent water. Silver-solder or equivalent is satisfactory for brazing. Copper and high-copper alloys should not be used in UDMH transfer and storage equipment.

Hydrazine is a strong reducing agent, weakly alkaline and very hygroscopic. A film of hydrazine in contact with metallic oxides or other oxidizers may ignite. Hydrazine decomposes on contact with iron, copper, molybdenum and their alloys and oxides.

The use of monel, aluminum (type 40E), magnesium, or stainless steel containing more than 0.50 percent molybdenum, zinc, lead, copper and its alloys, and iron is prohibited in hydrazine transfer and storage equipment.

NOTE

> Aerozine 50 (50 percent nitrogen tetroxide, 50 percent UDMH) is a blend of hydrazine and UDMH. Therefore, when storing a blend of UDMH and hydrazine, the stricter procedures of hydrazine handling and storage apply.

Hydrazine or UDMH/hydrazine propellant must be stored apart from oxidizers, catalysts and sources of ignition such as electric spark or flame. All equipment must be grounded to prevent the generation of any static charge, and all electrical equipment shall be of the class and group recommended in the National Electrical Code.

Hydrazine can be stored in the drums in which it is received from the vendor. The drums shall be stored bung up on a concrete pad, preferably raised on racks for drainage of flush water. This also prevents collecting pockets of propellant (from leaks) under drums and minimizes rusting of chines. Combustible dunnage shall not be used.

Personnel handling UDMH or UDMH/hydrazine will wear plastic face shields, rubber or plastic wrist and arm protectors, and rubber-type aprons. If gross splashing is possible, an approved protective suit shall be worn. Approved items consist of rubber or rubberized clothing including neoprene, fiberglass impregnated with corrosion-resisting plastic (Teflon or equivalent) and vinyl coated cotton.

If the vapor concentration of hydrazine exceeds the threshold limit value (1 ppm) and it is necessary to work continuously in that atmosphere, approved respiratory protection shall be worn. A person cannot rely on smell to indicate the need for wearing respiratory protective devices. The gas mask should not be relied upon for protection in confined areas or in exposures to concentrations of hydrazine or UDMH vapors. Under such conditions, self-contained breathing equipment must be used.

Transferring hydrazine or UDMH/hydrazine blend between containers requires at least two persons.

Normal procedures for unloading drums from vehicles shall apply. Drums and containers shall be electrically bonded and grounded. Drums may be emptied by a self-priming pump (hand or motor drive) or by gravity flow; maintain a nitrogen atmosphere within the drum at slight positive pressure. This should always be done when a drum is only partially emptied and returned to storage. Before discarding empty drums, thoroughly flush them with water.

Main storage should be in isolated areas, and oxidants (nitric acid, hydrogen peroxide, halogens) should be kept out of the immediate storage area. Storage of the propellants should be maintained below the boiling point of UDMH (146 degrees F) is the maximum safe storage temperature. Horizontal or vertical cylindrical tanks are used for bulk storage. A slight positive pressure of nitrogen is maintained to prevent loss from air breathing, and to prevent the formation of an explosive mixture with air in the tank vapor space.

Each storage tank whose capacity is 1,000 gallons or more shall have a pressure-relief valve of adequate size and a rupture disc discharging either outdoors where no working areas can be contaminated (if this is possible) or to a scrubbing system.

Materials for seals,gaskets, and O-rings in UDMH/hydrazine service include nylon and Teflon. Lubricants and sealants for UDMH/hydrazine service include the polyglycol and silicone oils.

SECTION IV
SPILLS, LEAKS, AND DECONTAMINATION

4-1 GENERAL REQUIREMENTS

All personnel engaged in the handling and storage of propellants should be taught the nature of propellants and the general principles of safe conduct. Although the materials described can be handled safely when certain basic principles are known and followed, ignorance or carelessness can result in permanent injury or death. Because leaks and spills are possible, everyone working with propellants should be familiar with procedures of personnel and propellant decontamination.

All personnel should have preplacement and regular subsequent health surveillance examinations as may be required. The supervisor should check the general fitness of each member of the team daily.

To assure the removal of hazardous chemicals that may have contacted the body, operators should bathe and thoroughly scrub immediately after leaving the propellants handling area. A complete change of fresh clothes must be provided and discarded clothes sent to the laundry. The area and equipment must be kept free of all materials with which these chemicals may react. Smoking and eating while in the area must be prohibited, because handling food and tobacco often furnishes a means for the entry of poisonous materials into the body. It also may cause propellant contamination leading to possible violent chemical reactions.

4-2 ALCOHOL

Alcohol leaks and spills shall be kept to a minimum, since they present a great source of danger. Storage and transfer equipment must be inspected frequently, and any necessary maintenance must be performed at once. As water is the most effective flushing agent, an adequate supply must be available.

4-3 ANHYDROUS AMMONIA

A leak in ammonia connections or feed lines is detectable by odor. The exact location of the leak may be detected by allowing the fumes from an open bottle of hydrochloric acid, or from a sulfur dioxide aerosol container, to come into contact with the ammonia vapor, producing a dense, white fog. Other means of detecting leaks involve the use of moist phenophthalein or red litmus paper, which will change color in ammonia vapor. Sulfur papers are not recommended.

In the event of accidents involving spillage or leakage of anhydrous ammonia, the following procedure shall be used.

a. Evacuate all nonessential personnel.

b. All operating personnel shall be protected; the primary consideration being the use of approved self-contained respiratory protection.

c. Possible sources of ignition shall be eliminated.

d. The area shall immediately be deluged with water (fog or spray) to dilute the ammonia to a point where the hazards of fire, explosion and toxicity are eliminated.

e. If the defective container is located in an inhabited area and cannot be removed before most of the ammonia leaks out, the local police and fire authorities shall be advised of the possible hazards to health and the possibility of fire and explosion. An approved warning placard shall be posted in the vicinity of the accident, warning of the hazards of fire, explosion, and poisonous fumes.

If an accident occurs, the entire contents of any leaking container, tank or tank compartment shall be considered a total loss. The possibility of fire or explosion in a field recovery may result in damage far exceeding the value of the shipment. Leaking cylinders which cannot be made safe by tightening valves shall be dumped under large amounts of fresh, flowing water, and then be thoroughly washed and tested until no trace of ammonia fumes remains. Leaking tanks or tank compartments may be treated in one of the following ways:

a. Remove the defective tank to an uninhabited area and dump the contents, diluting with sufficient amounts of water.

b. Dilute the material, both at the site of the leak and through the top of the tank, until the hazards of fire, explosion and toxicity are eliminated.

4-4 ANILINE

Leaks and spills must be kept to a minimum since they present the greatest source of danger to personnel. Storage and transfer equipment must be inspected frequently, and any necessary maintenance must be performed at once. Aniline vapor may be present in toxic amounts where spills or leaks have occurred. Persons cleaning spills or leaks must be protected by full coverage suits, complete with hoods, gloves, and boots of the approved type. Self-contained breathing apparatus or air-line respirators, designed for use in high concentrations of aniline, shall be worn as directed.

4-5 ETHYLENE OXIDE

All polymeric wastes are water soluble and, as such, present no major problem. Spilled ethylene oxide shall be disposed of by diluting it with at least 22 times its volume of water. Should leaks or spills occur, only properly protected personnel should remain in the area. After a spill, the area must be thoroughly ventilated before cleaning. If ethylene oxide has spilled on a person's skin, allow it to evaporate.

Frequent inspections of equipment and vessels containing ethylene oxide should be made to detect or prevent leaks.

If there is any accident involving spillage or leakage of containers or tanks of ethylene oxide, the following precautions shall be taken:

a. Remove or minimize all possible sources of ignition

b. Immediately begin to flush the leakage with large quantities of water

c. Remove other cargo from the vehicle after it has been flushed with water

d. Protect operating personnel, respiratory protection being the first consideration

e. Post an approved warning placard in the vicinity of the accident telling of the hazards of fire, explosion and poisonous fumes

In the event of an accident, the entire contents of any leaking container, tank or tank compartment shall be considered a total loss, as recovery in the field is unsafe and uneconomical. Leaking or ruptured drums shall be dumped under large amounts of fresh, flowing water, thoroughly washed and tested until no trace of ethylene oxide fumes remains.

4-6 LIQUID FLUORINE

All areas containing fluorine under pressure shall be inspected for leaks at suitable intervals. Do not disconnect leaking cylinders from other equipment. Repair all leaks only after venting the fluorine. The use of filter paper moistened with potassium iodide solution or moist starch potassium iodide paper is a very sensitive means of detecting fluorine (down to about 25 ppm). The odor of fluorine is so strong that very low concentrations can be detected, but this is not a safe or reliable method of detecting lethal quantities.

Ammonium hydroxide (aqua ammonia) in a plastic squirt bottle should be used as a rapid qualitative test for the detection and location of small gas leaks. Ammonia hydroxide discharged from a squirt bottle in contact with fluorine produces a chemical smoke which is readily seen.

Should a truck transporting fluorine be involved in an accident, the following measures should be taken: The truck should be parked off the raodway if possible; in any event, flares and flags should be set out. Traffic should not be allowed to approach closer than 100 yards. Local police and fire authorities should be notified, but one man should stay with the truck.

In case of fire, the responding fire companies must be warned that fluorine is involved and that it will react violently with water. Dry chemical should be applied whenever possible. Water may be used to fight secondary fires.

4-7 HYDRAZINE

Should a leak result from a damaged drum, flush the spilled hydrazine away with water and transfer the remaining hydrazine to another drum. Flush areas and equipment contaminated with hydrazine immediately with large quantities of water. In addition, ventilate the area completely and thoroughly.

If, as a result of a shipping accident involving a truck transporting hydrazine, the hydrazine spills or leaks, all precautions prescribed for flammable liquids, e.g., removing flames, no smoking, etc., should be observed. Additional precautions should be taken against inhaling the vapors and spilling liquid on skin or eyes.

When drums are being shipped, the vehicle should be stopped, the motor turned off, and large quantities of water should be used to dilute the spillage. Leaking drums must be removed from the truck before it may proceed. The contents of leaking containers must be transferred to safe containers or safely disposed of.

When a cargo tank is involved, transport the vehicle to the nearest place where the contents of the tank can be disposed of with safety, meanwhile employing every available means to prevent any liquid from spilling or leaking onto the highway.

If the character of the leak makes further transport of the tank unsafe, remove the vehicle from the highway. Flush the leakage with large quantities of water, and dilute the tank's contents with fresh water (100 to 1 or more) before or while draining the contents into ditches or nonoxidizing absorbent materials. This is a reasonable practice if the operating personnel are wearing complete protective clothing and the accident occurs in an uninhabited area. Otherwise, flush the leakage with water, and devise some means of transferring the contents of the tank into safe containers by suitably protected personnel. In any event, as soon as immediate measures have been taken, local authorities should be notified of the fire, vapor, explosion and toxicity hazards.

4-8 HYDROCARBONS

Care must be taken to avoid spillage and constant vigilance must be exercised over the maintenance of facilities to prevent leakage. All spills and leaks must be immediately flushed away with large quantities of water or be absorbed by sand or dirt to be burned off elsewhere. Since water is the most effective and readily available decontaminating and flushing agent, an adequate supply must be available.

Should a person become contaminated due to leaks or spills, immediately remove clothing or shoes through which fuel has soaked. Wash fuel from skin at once with soap and water.

4-9 LIQUID HYDROGEN

Leaks and spills do not present a decontamination problem in the usual sense, since hydrogen vaporizes and diffuses rapidly in air. It will not form persistent explosive mixtures when allowed to evaporate in open unconfined areas. An explosive hazard exists when the hydrogen-air mixture is completely or partially confined. Such a mixture can explode.

The principal danger from a spill or leak is fire. There is no efficient means of decontamination other than rapid vaporization and dilution with air.

Any air will freeze solid if it comes into contact with a cold enough metal surface or with liquid hydrogen, thus creating a serious explosion hazard The solidified gases can also plug constricted areas such as valves and so cause a pressure failure.

4-10 HYDROGEN PEROXIDE

Spills of hydrogen peroxide may cause an immediate fire if they come into contact with combustible materials. Normally, if the area of spillage has been kept properly clean, there is no damage, and the hazard can be removed by diluting the hydrogen peroxide with water. Fires caused by spills can be extinguished with water. Chemical extinguishers such as foam or CO_2 are useless, because hydrogen peroxide releases oxygen which supports combustion even under a blanket of foam. Hydrogen peroxide itself does not burn.

Leaks must be kept under constant surveillance and washed with water until the container is emptied. If possible, the leaking container should be segregated from other containers.

Hydrogen peroxide that has been contaminated decomposes more rapidly; its container will show a rise in temperature. Decomposition may be retarded by adding 1 pound of stabilizer solution (6 percent phosphoric acid in water) for each 100 gallons of hydrogen peroxide. Stabilized hydrogen peroxide shall be so labeled. Gross contamination cannot be counteracted by any amount of stabilizer. If a container becomes contaminated, continuously check the temperature of the solution, and spray the outside of the tank with cooling water. Lay out fire hoses and prepare to dilute and dump the hydrogen peroxide. If the temperature continues to increase, connect the hose to a water source and dilute and discharge the tank's contents.

Contaminated drums can be detected first by temperature and pressure rises and then by the spewing forth of liquid from the vent. If temperature and pressure continue to rise, dump and dilute the contents as quickly as possible. Do not refill contaminated containers until they have been properly cleaned and passivated.

If an accident involves the spilling or leaking of hydrogen peroxide, deluge the spill with large quantities of water and run it off into ditches. Every effort must be made to keep the spillage from reaching organic material before it has been highly diluted with water. Because hydrogen peroxide is so sensitive to contamination, the contents of any ruptured container must be considered a total loss. Personnel must wear approved protective clothing during dumping. Keep flame, sparks and other sources of ignition away from the accident and dumping area.

4-11 NITRIC ACID

All personnel engaged in decontaminating nitric acid must wear full protective clothing and equipment. Water is the most easily used and the most readily available decontaminating agent. Do not use aqueous 5 percent solutions of caustic soda (sodium hydroxide, bicarbonate of soda, sodium carbonate and calcium carbonate) unless the water supply is limited because approximately 50 percent more nitrogen dioxide fumes are given off during treatment with these alkaline materials than with water. Concrete and asphalt contaminated with fuming nitric acids retain small amounts of acid in surface pores even though flushed with large quantities of water. The most practical decontamination procedures, therefore, are as follows:

a. When fuming nitric acid is spilled on concrete or other hard surfaces having a proper drainage system, neutralizing pit, and an adequate supply of water, complete flushing with water is sufficient.

b. For spills on concrete, asphalt or other hard surfaces in the field where an adequate water supply is not available and where drainage is impossible, spray the surface with a 5 percent solution of sodium bicarbonate or sodium carbonate until bubbling ceases.

c. For spills in enclosed areas, flush with large quantities of water. Spray the entire working surface with a 5 percent solution of sodium carbonate.

4-12 NITROGEN TETROXIDE

This oxidizer is a potent supporter of combustion. Cleanliness is an extremely important criterion when working with this chemical The high purity required prohibits the presence of solid particles in the storage system.

Since the odor of nitrogen tetroxide cannot be relied upon to indicate toxic concentrations, monitoring devices should be employed in work areas to warn of leaks. If an area is contaminated by spills or vapor leaks of nitrogen tetroxide or fire, the following procedure should be followed:

a Immediately evacuate exposed or affected personnel from the contaminated area and give treatment as necessary.

b. Allow only personnel protected by approved eye, body and respiratory protective equipment to enter or remain in the area.

c. Pump liquid from large pool spills into suitable containers, and transfer them to an approved disposal area.

d. Flush all surfaces exposed to the liquid with large quantities of water, making sure all washings are directed or drained to an area approved for acid disposal.

e. Ventilate the contaminated areas.

f. Wash contaminated surfaces (other than aluminum), from which gross contamination has been removed with sodium bicarbonate or sodium carbonate water solution and rinse with water as a final step in neutralization. The nitrogen tetroxide shall be disposed of by burning, or by dilution and neutralization, provided that the nitrate level is kept below acceptable values in the final disposal area.

To decontaminate equipment for maintenance, flush with large quantities of water, taking precautions as stated above. The use of alkaline solutions as neutralizing agents for aluminum equipment is prohibited, as the bases will attack aluminum.

4-13 LIQUID OXYGEN

Since oxygen is nontoxic, the primary danger from a spill or leak is a fire or explosion from high concentrations of oxygen gas in the presence of combustible materials. The danger of an oxygen enriched atmosphere in outdoor installations is very small. Although this condition is possible around indoor equipment, proper ventilation will minimize the danger.

4-14 UDMH, UDMH/HYDRAZINE

Approved masks shall be worn in the presence of UDMH/Hydrazine spills or leaks. When UDMH/Hydrazine blend is mixed with an equal weight of water, the temperature of the solution will rise to about 70 degrees; therefore, a large excess of water should be employed when it is used for disposal, firefighting, and other purposes. Small quantities, such as minor spills, can be disposed of most conveniently by flushing into sewers with large volumes of water. Copious water flushing is also recommended for personnel decontamination. Care must be taken that the waste does not drain into the waste disposal areas of oxidizers such as nitrogen tetroxide or the fuming nitric acids. Contact with such oxidizers will cause a hypergolic reaction.

SECTION V
PROPELLANT DISPOSAL

5-1 GENERAL REQUIREMENTS

The drainage systems of storage and test areas must be designed to preclude the interconnection of fuel and oxidizer drain lines. Contaminated material must be disposed of in accordance with carefully prepared plans and properly executed procedures to avoid contaminating adjacent or drainage basin areas. Mixing of drainage from flushing or washing of spills of fuel with those of oxidizers must be avoided until the spills or drainage have been adequately diluted or neutralized prior to disposal in accordance with the procedures outlined for each propellant.

5-2 METHODS

All operations requiring the handling of fuels and oxidizers should follow a predetermined plan. No one should be allowed in an area where these materials are kept in main, ready, or other storage unless he is accompanied by another authorized person; both should be outfitted with all necessary protective clothing and equipment.

Approved procedures must be followed in disposing of accidental spillage and in decontamination. Contaminated material must be disposed of in accordance with carefully prepared plans and by properly executed procedures to avoid contaminating adjacent or drainage basin areas.

5-3 ALCOHOL

Waste alcohol mixtures should not be allowed to enter drains or sewers where there might be danger of the ignition of vapor. Disposal may be accomplished by removal of the waste to a safe location in the disposal area, pouring the mixture on dry sand, earth or ashes; and cautiously igniting it. No more than 1,000 gallons should be burned at any one time.

5-4 ANHYDROUS AMMONIA

Should an accident occur, the entire contents of any leaking container, tank or tank compartment shall be considered a total loss, since the possibility of fire or explosion in a field recovery may result in damage far exceeding the value of the shipment. Leaking cylinders which cannot be made safe by tightening valves shall be dumped under large amounts of fresh, flowing water, thoroughly washed, and tested until no trace of ammonia fumes remains.

5-5 ANILINE

If spillage has occurred on soil, the area should be treated with a saturated solution of oxalic acid or hydrochloric acid. Approximately five parts of acid should be used for each part of aniline to be treated. The acid solution reacts with the aniline to form a white crystalline salt which can be swept into a container for burial in a waste disposal area where water supply contamination is improbable.

Treatment with acid solution (oxalic or hydrochloric) does not completely eliminate the aniline hazard. Salts formed should be swept and disposed of in the waste disposal area and the contaminated area washed with water. Contaminated top soil should be removed and hauled to a safe waste disposal area for burial.

The disposal area should then be marked properly. The hole left at the contaminated area where the spill occurred should be filled with uncontaminated soil.

5-6 ETHYLENE OXIDE

When it becomes necessary to dispose of ethylene oxide, it is preferable to do so as a vapor, venting to a safe location. The point of outlet should be equipped with an approved flame arrester. The vent line should be equipped with a connection for emergency purging with steam, nitrogen, or carbon dioxide to extinguish any fire occurring on the outlet side of the flame arrester.

Extreme care shall be taken to prevent the drainage system of an ethylene oxide storage area from becoming interconnected with that of an oxidizer storage area, as fire or explosion may result.

5-7 LIQUID FLUORINE

Small amounts of gaseous fluorine may be disposed of by slow venting. It may also be disposed of by a fluorine hydrocarbon air burner, scrubber and stack.

Small liquid fluorine spills shall be neutralized with sodium bicarbonate. Dry chemical type fire extinguishers using sodium bicarbonate are recommended for this purpose. This material not only neutralizes fluorine but assists in extinguishing secondary fires.

5-8 UDMH, UDMH/HYDRAZINE

Large quantities of hydrazine or UDMH or a blend of both may be disposed of by burning, preferably in an open metal pan completely away from any inhabited area or storage site. Burning shall be accomplished under proper supervision and safeguard. Usually, small quantities, such as minor spills, can be disposed of most conveniently by flushing into sewers with large volumes of water.

5-9 HYDROCARBONS

These fuels shall not be drained into, or disposed of, through drainage systems, creeks, rivers, or sources of drinking water.

When it becomes necessary to dispose of fuel which does not meet specifications, or is contaminated, it shall be sent to the waste disposal area and burned. Not more than 1,000 gallons shall be burned at one time. In addition, not more than one type of combustible liquid shall be burned at one time.

5-10 LIQUID HYDROGEN

Disposal does not present a problem since liquid hydrogen vaporizes and dilutes rapidly upon contact with air.

5-11 HYDROGEN PEROXIDE

Hydrogen peroxide is an exceptionally pure product and contains no contaminants that would cause surface water pollution or interfere with sewage. Its decomposition products are pure water and oxygen. However, strong hydrogen peroxide should be very thoroughly diluted before disposal to prevent strong reaction with organic materials and to prevent injury to fish life. Disposal takes place in a remote area set aside for hydrogen peroxide. The area comprises a pit free from organic vegetation and filled with water. Waste hydrogen peroxide is poured slowly into pit and, in addition, is sprayed with a stream of water to dilute contents. Protective equipment shall be worn during disposal.

5-12 NITROGEN TETROXIDE

Waste nitrogen tetroxide is disposed of by neutralization, by dilution, or by burning. Sodium bicarbonate or sodium carbonate water solution is used for neutralizing (except in the presence of aluminum). The waste nitrogen tetroxide is transported by truck to the contaminated nitrogen tetroxide storage tank. The contaminated material is pumped from the storage tank to the propellant burner for disposal. The propellant burner is designed to burn not less than 90 percent nitrogen tetroxide.

5-13 LIQUID OXYGEN

Disposal is not a problem since it vaporizes rapidly upon contact with air. As previously mentioned in paragraph 4-13, the danger of an oxygen-enriched atmosphere in outdoor installations is very small.

GLOSSARY OF TERMS

ACETATE

A salt or ester of acetic acid; cellulose acetate or one of its products.

ALKALI

A substance which dissolves in water to form an alkaline solution. Alkali are often spoken of as bases bust the term base has wider significance.

AMBIENT

The temperature or pressure of the surrounding medium.

ANHYDROUS

A term applied to oxides and salts to emphasize that the item does not contain water of crystallization or water of combination.

AUSTENITIC

Containing austenite or having the characteristics of austenite; a solid solution of carbon or iron carbide in iron.

AUTO-TEMPERATURE

The termperature at which a combustible mixture ignites without an external source of ignition.

BOILING POINT

The temperature at which a liquid boils. Under ambient conditions liquid changes from a fluid to a gaseous state.

CARBONAL

When carbon monoxide acts as a radical, as it appears to do in many reactions, it is referred as the carbon group.

CATALYSIS

The acceleration or retardation of a chemical by a substance which itself undergoes no permanent chemical change.

CAUSTIC

Destructive or corrosive to living tissue; an agent which burns or destroys living tissue.

CENTIPOISE

One-hundredth of a poise; normally a term used in measurements involving the viscosity of a fluid.

CORONA

The phenonomenon of air breakdown when the electric stress at the surface of a conductor exceeds a certain value. At higher values the stress results in a luminous discharge.

CRITICAL DENSITY

The density of a substance which is at its critical temperature and critical pressure.

CRITICAL PRESSURE

The pressure at which a gas becomes liquified at a critical temperature.

CRITICAL TEMPERATURE

The temperature above which a gas cannot be liquified.

CRYOGEN

A gas that has been cooled below its critical temperature, liquified, and stored at ambient pressure in insulated or refrigerated containers. An arbitrary temperature of minus 150 degrees Centigrade (-238 degrees Fahrenheit) has been chosen as the upper limit of the critical temperature of cryogenic gases.

CYANOSIS

Blueness of the skin and the mucous membranes due to insufficient oxygenation of the blood.

DERMATITIS

Inflammation of the surface of the skin or epidermis.

EDEMA

Pathological accumulation of fluid in the tissue spaces and serous sacs of the lungs; sometimes the term is restricted to such accumulation in tissue spaces only.

EXOTHERMAL

A condition accompanied by the release of heat.

EXPLOSIVE LIMITS

A concentration of a contaminant in air of a mixture that will propagate a flame. There is an upper limit of concentration above which the mixture will not propagate a flame.

FLAMMABLE LIMITS

The upper and lower vapor-volume concentrations of fuel in air that will propagate flame. Flammable limits in atmospheres other than air as so identified.

HALOGENS

A group consisting of the nonmetallic elements, fluorine, chlorine, bromide, and iodine.

HALOGEN ODOR

A strong, pungent odor, characteristic of iodine, bromide, chlorine, and fluorine.

HYDROCARBON

An organic compound such as acetylene or benzene, containing only carbon and hydrogen and often occurring in petroleum, natural gas, coal, and bitumens.

HYGROSCOPIC

Tending to absorb moisture; in the case of solids, without liquefaction.

HYPERGOLIC

The automatic ignition characteristic of certain oxidizers and propellants when mixed.

INTERSTITIAL

Occurring in the interstices between other structures, as the interstitial cells of Coelenterata, which are small, rounded embryonic cells occurring in the interstices between the columnar cells forming the ectoderm and the endoderm.

METHEMOGLOBIN

A transformed blood product from which oxygen cannot be removed, thus precluding blood oxygenation.

MISCIBILITY

The property enabling two or more liquids to mix when brought together and thus form one phase.

NARCOSIS

A state of unconsciousness produced by a drug; the production of a narcotic state.

NEPHRITIS

Inflammation of the substance of the kidney.

PASSIVATED

Rendered chemically passive; as iron or nickel treated with fuming nitric acid to create a passive surface.

PHENOLIC

A resin or plastic made by condensation of a phenol with an aldehyde and used especially for molding and insulating and in coatings and adhesives.

POISE

The unit of absolute viscosity of a fluid, signifying a force of one gram will maintain unit rate of shear of a film of unit thickness between surfaces of unit area. Otherwise one dyne-second per square centimeter.

POLYMERIZE

To change into another compound having the same elements in the same proportions but a higher molecular weight and different physical properties.

PULMONARY

Pertaining to the respiratory tract; the lungs.

PUNGENT

Caustic, stinging; causing a sharp or irritating sensation.

BIBLIOGRAPHY

Manual for Handling Missile Propellants. Pan American World Airways, Gyided Missiles Range Division, Patrick Air Force Base, Florida, 1 January, 1958.

The Handling and Storage of Liquid Propellants. AFM 160-39, Department of the Air Force, 1 April, 1964.

REDUCING AGENT

A substance which is capable of bringing about the chemical change known as reduction.

REDUCTION

Any process in which an electron is added to an atom or an ion. Three common types of reduction are the removal of oxygen from a molecule, the addition of hydrogen to a molecule, and the diminuition of the positive valence of an atom or ion.

SFERICS

An electronic detector of storms.

SYSTEMIC TOXICITY

The harmful effects of a toxic material as considered from a whole body viewpoint.

THRESHOLD LIMIT

Concentrations of airbourne contaminants to which most workers can be exposed during working hours (8 hours a day, 5 days a week) for prolonged periods, without adversly affecting their health. Comparable to the term maximum allowable concentration (MAC).

VISCOSITY

Internal friction due to molecular cohesion in fluids. The coefficient of viscosity is the value of the tangential force per unit area which is necessary to maintain unit relative velocity between two parallel planes unit distance apart. Viscosity varies inversely with termperature.

VOLATILE

Having a low boiling temperature at ordinary pressure.

ALPHABETICAL INDEX

ALPHABETICAL INDEX (Cont.)

ALPHABETICAL INDEX (Cont.)

ALPHABETICAL INDEX (Cont.)

APPROVAL

SP-4-44-S

LIQUID PROPELLANTS
SAFETY HANDBOOK

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