

# Naval Facilities Engineering Command

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Alexandria, Virginia 22332-2300

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## MAINTENANCE AND OPERATION OF PETROLEUM FUEL FACILITIES

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## FOREWORD

This manual establishes basic standards and procedures for development and conduct of maintenance programs designed to assure the readiness and dependability of Navy shore facilities which are sources of petroleum fuels for ships, aircraft and vehicles of all types.

Additional information or suggestions that will improve this manual are invited and should be submitted through appropriate channels to the Naval Facilities Engineering Command, (Attention: Code 1632), 200 Stovall Street, Alexandria, VA 22332-2300.

This publication cancels and supersedes **MO-230, Maintenance Manual Petroleum Fuel Facilities**, dated May 1977. It has been reviewed in accordance with the Secretary of the Navy Instruction 5600.16A and is certified as an official publication of the Naval Facilities Engineering Command.



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Assistant Commander for  
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## **ABSTRACT**

**This publication provides information about petroleum fuel facilities used throughout the Navy shore establishment. This manual specifically covers the nature of petroleum products, typical Navy fuel facilities/systems, environmental protection, and facility maintenance programs.**



## CHANGE CONTROL SHEET

Document all changes, page replacements, and pen and ink alterations posted in this manual.

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## CHAPTER 1. FUNDAMENTALS

1.0 OBJECTIVE. This chapter discusses authority and responsibility for maintenance of shore based fuel facilities. It also provides information on the general characteristics, types, and grades of petroleum fuel that may be found at fuel storage/handling facilities. The chapter concludes with discussions of fuel handling safety requirements and fuel quality.

### 1.1 INTRODUCTION

1.1.1 Purpose. This manual establishes basic standards and procedures for the maintenance of naval shore facilities involved in the receipt, storage, transfer, and issue of liquid petroleum fuels and lubricants. It is intended to document the maintenance guidelines necessary to prevent system shutdowns and fuel contamination and to decrease fire, spill, accident, and health hazards.

1.1.2 Scope. This manual presents general guidelines and, where possible, specific procedures to be followed in the maintenance of petroleum handling facilities. It covers both short-term maintenance routines and longer term, heavier maintenance that can be carried out by regular operating personnel or maintenance technicians. The text is directed toward systems, equipment, or structures that are considered representative of those which might be found in a typical fuel depot, terminal, or air station. There may be certain types of systems, equipment, or structures that are not covered. In such cases, maintenance personnel are urged to adapt the general principles presented to the particular problem at hand. Where necessary, the manual provides background information in areas such as fuel characteristics, the description of typical systems and equipment, and environmental protection to promote a better understanding of the maintenance procedures recommended. This information is not intended to establish new standards or to replace any existing standards for the construction or operation of naval fuel facilities. However, specific guidance on maintenance planning and execution is provided. Publications that provide additional information are described in Section 4.6.

1.1.3 Applicability. This manual is applicable to and has been structured to cover maintenance procedures for all petroleum fuel facilities ashore within the U.S. Navy.

#### 1.1.4 Responsibility.

1.1.4.1 Chief of Naval Operations (CNO). CNO is responsible for programming and budgeting the resources needed to acquire, operate, and maintain facilities under CNO command; and to establish and monitor the execution of related general policies, responsibilities, and procedures. To effectively carry out this mission, several naval systems commands provide assistance to CNO. They are Naval Facilities Engineering Command (COMNAVFACENGCOM), Naval Supply Systems Command (NAVSUP), Naval Air Systems Command (NAVAIR), Naval Sea Systems Command (NAVSEA), and Naval Space and Warfare Systems Command (SPAWAR). One of the most essential commodities in military operations is petroleum fuels. The safe, efficient handling of petroleum fuels on shore is primarily the responsibility of COMNAVFACENGCOM, NAVSUP, and NAVAIR.

#### 1.1.4.2 Naval Facilities Engineering Command

##### - COMNAVFACENGCOM Headquarters.

COMNAVFACENGCOM Headquarters (HQ) provides specialized or professional guidance and direction for the design, construction, maintenance, operation, repair, and alteration of public works and public utilities. This specifically includes petroleum fuel storage and dispensing facilities and supporting systems except where such responsibility has been assigned to another command, bureau, or office. In general, the COMNAVFACENGCOM HQ responsibility toward maintenance of petroleum fuel facilities consists of establishing sound, beneficial maintenance policies and providing technical guidance to resolve specific maintenance and repair problems. COMNAVFACENGCOM HQ is also available on request and in conjunction with the engineering field divisions to provide on-site surveys for upgrade and modernization of Petroleum, Oil, and Lubricant (POL) facilities.

##### - COMNAVFACENGCOM Engineering Field Divisions (EFDs).

COMNAVFACENGCOM EFDs are responsible for administration, technical survey, inspection, or interpretation required for execution of COMNAVFACENGCOM HQ technical programs within their assigned geographic areas. Except as otherwise provided in Navy regulations or other lawful directives, this responsibility specifically applies to maintenance of petroleum fuel facilities. In executing the duties described, COMNAVFACENGCOM EFDs are responsible for rendering assistance to cognizant naval activities as follows:

##### - Advise and assist the Activity

Commanding Officer in establishing and conducting effective new construction, maintenance, and repair programs for petroleum fuel facilities in accordance with COMNAVFACENGCOM HQ guidance and direction. Supplement and adapt this guidance and direction as appropriate to meet the specific requirements and capabilities of each individual activity.

- Schedule and conduct inspections, including the preparation of inspection reports, as required by NAVFAC MO-322.

- Assist local activities with the preparation of budgets, plans, specifications, solicitations of bids, awards of contracts, and inspections of work as required for major repair or replacement projects.

#### 1.1.4.3 Naval Supply Systems Command.

- NAVSUP. NAVSUP HQ is responsible for administration and management policies and methods of the Navy supply system, which includes petroleum fuel products. NAVSUP has responsibility for operating and maintaining all bulk fuel departments at Naval Supply Centers.

- Navy Petroleum Office. The Navy Petroleum Office (NAVPETOFF) is a naval activity directly under the cognizance of NAVSUP. The Commanding Officer of NAVPETOFF is also a Deputy Commander of NAVSUP for fuel management. The mission of NAVPETOFF is to provide technical direction for petroleum programs within the Navy, including facilities management and storage utilization, technical operation, quality surveillance, facility automation, oily waste handling and pollution abatement, fuel reclamation, and fuel facility design review; and to compute and promulgate bulk POL Positioned War Reserve Material Requirements (PWRMR).

NAVPETOFF has advisory responsibility for maintenance and operation of petroleum fuel facilities to ensure that an adequate supply and quality of bulk fuel exists. As an example, NAVPETOFF must concur before any major bulk storage tank or system is taken out of service or changed from one product to another. NAVPETOFF is also involved in all major changes in fuel specifications and coordinates with COMNAVFACENGCOM and NAVAIR regarding these changes.

NAVPETOFF coordinates with COMNAVFACENGCOM and NAVAIR on major changes in bulk fuel distribution that might have an effect on maintenance and operation of fuel facilities.

NAVPETOFF is also responsible for matters relating to the maintenance of POL facilities, ensuring that such operations and related maintenance programs of the NAVSUP-supported or financed petroleum stock points are economical and efficient and, in all respects, meet the requirements of military readiness. In addition, NAVPETOFF serves as technical advisor to the Fleet Commanders and Type Commanders on petroleum facility matters not directly under the control of the NAVSUP.

The NAVPETOFF Facilities Division responsibilities include:

- Conducting or taking part in inspections, modernization studies, and technical assistance visits.

- Administering the Preventive Maintenance Systems (PMS) Program at NAVSUP fuel terminals and providing technical advice on fuel system PMS to all other Navy activities.

- Providing design reviews on fuel-related facility projects.

- Analyzing and coordinating facilities planning for current and projected bulk storage programs.

- Providing advice on environmental and fuel reclamation matters.

- Assisting in the development of security, fire protection, and safety requirements for Navy fuel activities.

1.1.4.4 Naval Air Systems Command. NAVAIR HQ, in consonance with the major claimants, is responsible for the military readiness, maintenance, and safe operation of naval aircraft. Since fuel quality, safety, and ready availability of aircraft are so closely related to aircraft operation, NAVAIR HQ provides general guidance to the major claimants and the Activity Commanding Officers for the design, operation, and maintenance of ready issue aviation fuel tanks, aircraft fueling systems, and associated facilities. Fuel handling concepts, operating procedures, safety precautions, fuel quality specifications, and equipment design and system maintenance requirements are developed by NAVAIR and coordinated with COMNAVFACENCOM.

1.1.4.5 Naval Sea Systems Command. NAVSEA HQ is responsible for the military readiness, maintenance, and safe operation of all naval shipboard fuel systems.

1.1.4.6 Naval Space and Warfare Systems Command. SPAWAR HQ has responsibility for technical requirements associated with hazards from electromagnetic radiation and electrical systems and apparatus.

1.1.4.7 Individual Activities.

- Commanding Officer. The Commanding Officer of each Navy or Marine Corps activity is responsible for the fuel aboard his station or auxiliary activities under his command. Effective maintenance and safe operation of fuel

storage and handling facilities within the command are an inherent part of that responsibility.

- Supply Officer. The Supply Officer is responsible for budgeting, receipt, storage, accountability, issue, quality assurance, and environmental impact of petroleum products. The responsibility extends from point of receipt to point of issue, including the operation and maintenance of receiving systems, storage facilities, and shipping or dispensing systems.

Typically, the duties of the Supply Officer are carried out by a fuel department, division, or branch headed by a fuel management officer, who may be a military officer or a civilian. He in turn may be assisted by several Assistant Fuel Management Officers, who head the various branches of the fuel department. Within a large activity, separate branches may be established for subactivities that are geographically separated. Usually, a large bulk fuel storage depot is physically separated from the naval activity it serves and is therefore operated as a separate branch of the fuel department.

Separate branches may also be established for different functional groups within a given fuel department.

**EXAMPLES:**

- Fuel Operations Branch
- Security Branch
- Quality Control Branch
- Maintenance Branch
- Aircraft Fuel Delivery Branch
- Firefighting Branch
- Inventory Control Branch

Only the largest facilities have their own separate security, firefighting, and maintenance branches. Where maintenance branches exist, they may include a variety of trades such as pipe fitters, welders, machinists, electricians, carpenters, and heavy equipment operators. These organizations have capabilities for maintenance and repair work considerably above those where all work must be done by the fuel operators. In such cases, heavy maintenance and repair is usually done by the Public Works Department or by outside contractors.

In this regard, the interchangeable use of operating and maintenance personnel is encouraged by Naval Supply Systems Command Instruction 5312.7, which says in part, "Personnel with maintenance ratings should be trained, available, and utilized in fuel operations during peaks in operational workload. In like manner, fuel operating personnel should be trained and utilized to perform operational and preventive type maintenance during slack periods of operations." By application of this principle, a great deal of

preventive maintenance work can be done by fuel operators even though no regular maintenance personnel are on board.

- Public Works Officer. The Public Works Officer is responsible for performing corrective maintenance of fuel storage tanks, piping, receiving facilities, shipping facilities, waterfront structures, buildings, roads, electrical systems, fire protection systems, utilities, etc. that are associated with petroleum fuel facilities and, in the opinion of the Fuel Management Officer, are beyond the capability of his own personnel. He is also responsible for assisting the Fuel Management Officer in developing maintenance budgets and preparing estimates and recommendations for construction, maintenance, repair, and other projects required for continued operation of the fuel facility.

1.2 NATURE OF PETROLEUM PRODUCTS. The principal products to be received, stored, and issued at Navy petroleum facilities include burner fuels, diesel fuels, kerosenes, automotive and aviation gasolines, and jet fuels, as well as various lubricating oils, greases, and other related products. The following sections provide general information concerning the properties, types, and grades of petroleum products. More detailed information can be found in MIL-HDBK-201B, NAVAIR 06-5-502, MIL-HDBK-1022, and the respective product specifications.

1.2.1 General Characteristics. The following sections discuss the general characteristics and properties of the different fuel classes. These properties are summarized in Table 1.2.1.

1.2.1.1 Burner Fuels. Primarily used in boiler applications and of three main types:

- Distillate, both cracked and straight run
- Residual, cracked and straight run
- Blends of the preceding types.

- Viscosity. Varies greatly between grades. Heavier grades may require heating to maintain proper fuel flow during pumping or to provide good atomization in some burners.

- Flash Point. Relatively high flash points (degrees Fahrenheit) are desirable for safe handling and use. Minimum flash points are based on accepted practice. Flash points can be used to test fuel oils for contamination; a substantially lower flash point is a reliable indicator that a product has become contaminated with a more volatile product, such as gasoline.



PRODUCT	DENSITY	REID VAPOR PRESSURE	FLASH POINT	VISCOSITY
BURNER FUELS	API GRAVITY 15 <sup>o</sup> - 41 <sup>o</sup> API SPECIFIC GRAVITY 0.82 - 0.96	0	125 <sup>o</sup> F - 150 <sup>o</sup> F	35 - 10,000 SSU
DIESEL FUELS	API GRAVITY 35 <sup>o</sup> API SPECIFIC GRAVITY 0.84	0	100 <sup>o</sup> F - 140 <sup>o</sup> F	45 SSU
KEROSENE	API GRAVITY 41 <sup>o</sup> API SPECIFIC GRAVITY 0.82	0.5 psi	110 <sup>o</sup> F (min)	35 SSU
MOTOR GASOLINE	API GRAVITY 59 <sup>o</sup> - 65 <sup>o</sup> API SPECIFIC GRAVITY 0.72 - 0.74	7 - 9 psi Type I 12 - 14 psi Type II	-45 <sup>o</sup> F	31.5 SSU
AVIATION GASOLINE	API GRAVITY 70 <sup>o</sup> API SPECIFIC GRAVITY 0.70	7 psi (max)	-50 <sup>o</sup> F	30 SSU
JET FUELS	API GRAVITY 45 <sup>o</sup> API SPECIFIC GRAVITY 0.80	0 - 3 psi	-20 <sup>o</sup> F - 150 <sup>o</sup> F	32 - 50 SSU
LIQUIFIED PETROLEUM GAS (LPG)	SPECIFIC GRAVITY (GAS) 1.55 - 2.09	200 psi		

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TABLE 1.2.1  
PETROLEUM FUELS - PHYSICAL PROPERTIES

- Flammability. Because of their relatively high flash points, burner fuel oils are not flammable under ambient conditions. Precautions should be taken to avoid contamination of the fuel oil by more volatile products.

1.2.1.2 Diesel Fuels. Used to operate compression ignition engines in some ships, tugs, and landing craft; in auxiliary equipment aboard larger craft; in buses, heavy trucks, tractors, diesel locomotives, and stationary plants; and in other auxiliary equipment.

- Viscosity. The fuel oil is also the lubrication for the fuel injection system; therefore, its viscosity cannot be below the value specified for the system.

- Flash Point. Diesel fuel oils have relatively high flash points to permit safety in handling, storage, and burning.

- Pour Point. A fuel oil with a high pour point may require heating before use.

1.2.1.3 Kerosene. Used in space heating units, wick-fed lamps, bomb-type flares, cleaning tools, and machinery and as a vehicle for liquid insecticide sprays.

- Flash Point. Kerosene has a relatively high flash point to permit safety in handling, storage, and burning.

- Boiling Point. A good grade of kerosene is free of heavier products or high boiling point fractions that interfere with clean burning in lamps or complete atomization in turbine engines.

1.2.1.4 Gasoline, Motor. Used to fuel spark-ignition internal combustion engines that power motor vehicles, combat vehicles, and portable auxiliary power plants; it is also used as a fuel in gasoline pressure appliances such as field stoves and blow torches.

- Volatility. Gasoline requires a certain vapor pressure to ensure proper starting and accelerating qualities. Too high a vapor pressure may cause "vapor lock," which prevents fuel from reaching the engine. Distillation of gasoline is also important to determine the percentages of high and low boiling point fractions of the fuel. Boiling fractions that are too low can mean the fuel is too volatile and will cause vapor lock, while too much of the heavier fractions may not burn completely in the crankcase, which may indicate contamination of the fuel by fuel oil or other oils.

- Lead Content. Tetraethyl lead (TEL) is added to some gasolines as a knock inhibitor.

- Knock Value. Knock value is normally expressed as an octane number. Gasolines of inadequate knock value reduce power output and can cause overheating of the engine, lubrication failure, and burned pistons and cylinders.

1.2.1.5 Gasoline, Aviation (AVGAS). AVGAS is used as a fuel in aircraft reciprocating piston engines.

- Volatility. AVGAS is generally less volatile than automotive gasoline.

- Lead Content. AVGAS has a much higher lead content than automotive gasoline to increase anti-knock characteristics.

1.2.1.6 Jet Fuels. Jet fuels are used in aircraft turbine engines, ram jet engines, and other turbine-powered equipment.

- Flash Point. Some jet fuels (i.e., JP-4) have flash points as low as  $-20^{\circ}\text{F}$ ; therefore, they should be handled with caution.

- Lead Content. Jet fuels do not contain TEL or any other knock inhibitors.

- Cleanliness. Jet fuels must be kept free of contaminants since jet engines are susceptible to malfunctions from contamination.

1.2.1.7 Liquified Petroleum Gas (LPG). LPG consists primarily of propane and propylene with minor amounts of butane, isobutane, and butylene. The Navy uses LPG for heating, metal cutting, and brazing in dental laboratories, aboard ships, and in similar installations.

- Vapor Pressure. LPG is a vapor at atmospheric conditions. It is normally stored as a liquid at a pressure exceeding its vapor pressure of 200 psia.

- Odor. LPG is colorless, odorless, and non-toxic. It usually contains an odorizing agent that gives off a distinctive, pungent odor to help reduce the chance of explosion from undetected leaks.

1.2.1.8 Lubricating Oils. Lubricating oils are used in automotive and aircraft engines; they can be either petroleum based or synthetic. From the standpoint of operation, the most important properties of these oils are pour point, viscosity, viscosity index, and sulfur content.

1.2.1.9 Greases. Greases are used as lubricants in places where oils would run off. They are manufactured by combining petroleum and synthetic oils with metallic soaps to

produce a gel. Greases are produced for specific purposes and should be carefully selected to ensure the performance intended.

1.2.1.10 Related Products. There are petroleum products other than fuels, lubricants, and greases that are stored and issued in the field. Typical examples are corrosion-preventive compounds, solvents, and hydraulic fluids. Because of the wide variety of these products, a description of their properties and characteristics is omitted in this publication and should be obtained from their respective product specifications.

1.2.2 Types and Grades of Fuels and Lubricants. Any or all of the following grades and types of petroleum fuels and lubricants may be handled in a typical Navy petroleum facility.

1.2.2.1 Burner Fuels.

- Fuel Oil, ASTM D396-89 (formerly Federal Specification VV-F-815). Intended for use in oil-burner equipment.

Fuel oils come in the following grades:

- Grade No. 1. A light distillate used in vaporizing-type burners.

- Grade No. 2. A heavier distillate than grade No. 1, used in atomizing-type burners.

- Grade No. 4. A light residual or heavy distillate of moderate viscosity. While heavier than No. 2, it can be pumped and atomized at temperatures above its freeze point.

- Grade No. 5 (Light) and No. 5 (Heavy). These two grades differ only in viscosity. They can be pumped without being heated at temperatures above their freeze points.

- Grade No. 6. A high viscosity oil used mostly in commercial and industrial heating. It requires preheating in the storage tank to permit pumping and additional preheating at the burner to permit atomizing.

- Navy Distillate Fuel Oil. Navy distillate fuel oil, made to Specification MIL-F-24937, is being replaced by Diesel Fuel, Marine as burner fuel for steam-powered ships.

- Navy Special Fuel Oil. Navy Special Fuel Oil is a special blend of residual burner fuels still used in a few steam-powered ships. It is made to ASTM D396 (formerly

Specification MIL-F-859, Fuel Oil, Burner) and is much more viscous than Navy distillate fuel oil.

#### 1.2.2.2 Diesel Fuels.

- Diesel Fuel, Automotive. Automotive-type diesel fuels are made to Federal Specification VV-F-800, "Fuel Oil, Diesel," in three grades as follows:

- Grade DF-A (Arctic). This grade is formulated for use in areas where average temperatures are less than  $-25^{\circ}\text{F}$ .

- Grade DF-1 (Winter). This grade is intended for use in cold climates where the average ambient temperature does not fall below  $-25^{\circ}\text{F}$ .

- Grade DF-2 (Regular). This grade is formulated for use in all areas where ambient temperatures are  $0^{\circ}\text{F}$  or higher.

- Fuel Oil, Diesel Marine (F-76). Diesel fuel made to Specification MIL-F-16884 is designed for use at all temperatures above  $35^{\circ}\text{F}$  and as the principal burner fuel for steam-powered ships.

1.2.2.3 Kerosene. The only grade carried in the military supply system meets ASTM D3699-88 (formerly Federal Specification VV-K-211). However, kerosene prepared for use as a vehicle for liquid insecticides is a deodorized kerosene meeting Federal Specification VV-K-200.

#### 1.2.2.4 Gasoline, Motor.

- Federal Specification VV-G-1690B, "Gasoline, Automotive." Furnished in regular and premium grades, each grade being further subdivided into Classes A through E, depending on volatility (the more volatile classes being used in colder climates).

- Federal Specification VV-G-1690, "Gasoline, Automotive, Low Lead or Unleaded." Similar to VV-G-1690B except that the lead content is limited to 0.5 grams/gallon.

- Specification MIL-G-3056, "Gasoline, Automotive, Combat." A single grade of gasoline with two types furnished for use outside the continental United States. Type I is for use above  $0^{\circ}\text{F}$ . Type II is used in areas where the ambient temperatures are consistently below  $32^{\circ}\text{F}$ .

1.2.2.5 Gasoline, Aviation. Made according to ASTM 910-88 (formerly Specification MIL-F-5572) and graded by performance numbers as follows:

- 80/87. Dyed red.
- 100/130. Dyed blue or green.
- 115/145. Dyed purple.

1.2.2.6 Jet Fuels. Made in accordance with Specification MIL-T-5624, with the following grades:

- JP-4. Used in land-based jet aircraft and other turbine-powered equipment.
- JP-5. Used by the Navy for carrier-based jet aircraft because of its high flash point and fire safety characteristics.
- JP-7. A special kerosene-based, thermally stable, jet fuel used in high temperature jet engines that is made in accordance with MIL-T-38219.
- JP-8. A kerosene-based aviation fuel containing fuel system icing inhibitors and corrosion inhibitors that is programmed as a replacement for JP-4. Made in accordance with MIL-T-83133.

1.2.2.7 Lubricating Oils.

- MIL-L-17331, MS 2190, "Lubricating Oil, Steam Turbine." Intended for use in shipboard steam turbines, main engine reduction gears, and auxiliary machinery.
- MIL-L-9000, MS 9250, "Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel." A single grade lubricating oil with detergent additives intended for use in high output main and auxiliary engines.
- MIL-L-22851, "Lubricating Oil, Aircraft Piston Engine (Ashless Dispersant)." Intended as a crankcase oil in aircraft piston engines. The three types are as follows:
  - Type I is an additive concentrate.
  - Type II is a blend of 10% Type I and 90% Grade 1100 lubricating oil, conforming to MIL-L-6082.
  - Type III is a blend of 10% Type I and 90% Grade 1065 lubricating oil, conforming to MIL-L-6082.

1.2.3 Effects of Petroleum Products on Other Materials. Gasolines, jet fuels, and diesel fuels can dissolve oils and greases. They may cause deterioration of lubricants, sealants, packings, seals, gaskets, hoses, and other parts or equipment made of natural or synthetic rubber that come in contact with the fuels or their vapors. They can also attack gloves, boots, paint, and asphalt pavements that are not made of special solvent-resistant materials. Jet fuels, kerosenes, diesel fuels, and distillate burner fuels tend to loosen rust and mill scale from steel surfaces and thus contaminate the fuel. In addition, certain metals and metal compounds in contact with petroleum products can negatively affect the quality of these products or can themselves be affected by contact with petroleum. ASTM D130, "Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test," details one test that can be used to determine the effect petroleum fuels have on certain types of metal.

1.2.3.1 Zinc and Cadmium. Zinc and cadmium react with the acidic components of petroleum fuels to produce soluble and insoluble contamination of the fuel. The use of zinc and cadmium compounds and coatings, including galvanized materials, should be avoided in petroleum storage, distribution, and dispensing systems.

1.2.3.2 Copper and Copper Bearing Metals. Copper and copper bearing metals are highly susceptible to corrosion due to the sulfur and sulfur oxides present in petroleum products.

1.2.3.3 Aluminum. Aluminum in contact with petroleum fuels in the presence of salt and surface water is undesirable. Use of aluminum in contact with dry fuels in a petroleum storage, distribution, and dispensing system, i.e., downstream from a filter separator, is acceptable.

1.2.4 Effects of Petroleum on Human Health. Liquid petroleum fuels, their vapors, and some of the additive compounds they may contain are harmful to the human body. The principal hazards and precautions associated with petroleum fuels are summarized below.

1.2.4.1 Vapors. Vapors from all petroleum products are hazardous not only because they constitute a fire and explosion hazard but also because they are toxic to the human body. Since the vapors from petroleum products create the greatest threat to life, the characteristics of vapors must be clearly understood by all personnel handling these substances. All petroleum vapors are very dangerous if breathed continuously. Breathing in an atmosphere with as little as 500 parts of vapor per 1 million parts of air can cause a condition similar to severe alcoholic intoxication. Symptoms can include a brief initial state of excitement or exhilaration followed by disorientation, dizziness, nausea, unconsciousness, and death.

1.2.4.2 Toxicity. Petroleum fuel in contact with the human body can cause damage ranging from minor irritation to death. The seriousness of the damage depends on the type of fuel, extent of contact, duration of contact, and part of the body affected. The following paragraphs describe these potential situations.

- Fuel Oils, Diesel Fuels, Jet Fuels, and Kerosenes. These liquid petroleum fuels are harmful and irritating to the skin. Contact with them should be avoided. If contact with these petroleum fuels is made, wipe the affected area with a dry rag and wash it with soap and water. Do not use solvents or gasoline as cleaning agents.

Although these fuels are not poisonous, they must be kept out of the mouth, eyes, nose, ears, and open cuts. If this happens, obtain first aid immediately. If clothing becomes saturated with the liquid fuel, change as soon as possible. Prolonged wearing intensifies the irritation to the skin and increases the danger of fire.

- Gasoline and Naphtha-Based Fuels. Gasoline removes the protective oils from the skin and produces dryness, roughness, chapping, and cracking. Severe irritations or skin infection can follow this skin damage, which usually develops on the hands. Remove the gasoline with warm water and mild soap. If allowed to remain in contact with the skin, it will cause severe burns. If clothing becomes saturated with gasoline, remove it. Prolonged wearing only intensifies the irritation to the skin and poses the danger of fire. If gasoline comes in contact with the tender tissue of the eyes, wash them with liberal amounts of lukewarm water, administer first aid, and seek medical attention immediately. If gasoline is swallowed, it is exceedingly uncomfortable and can cause permanent damage to the digestive tract. Seek medical attention immediately.

- Fuel Additives. Fuel additives present the danger of toxic vapors and skin contamination. Extreme caution must be exercised in handling these substances.

- Tetraethyl Lead (TEL) and Tetramethyl Lead (TML) are additives used in aviation gasoline and some motor gasolines to improve the octane rating. Vapors from these additives are highly toxic. Direct contact with the concentrate from TEL/TML or its residue can result in serious permanent physical illness, brain damage, or death. No one should ever be permitted to enter a storage tank that has contained leaded gasoline without special safety equipment and complete instructions and training for its use.



A tank in use or having contained leaded gasoline must have the following warning stenciled above the manhole:

\*\*\*\*\*  
 \* CAUTION: THIS TANK HAS CONTAINED LEADED FUEL. DO NOT \*  
 \* ENTER TANK WITHOUT PERMISSION FROM FUEL OFFICER. \*  
 \*\*\*\*\*

- Fuel System Icing Inhibitor (FSII).

FSIIs also require special handling. Currently, there are two materials being used as FSIIs. Di-Ethylene-Glycol-Mono-Methyl-Ether (DIEGME) is currently the only approved FSII additive for use in JP-5 because of its high flash point. Ethylene-Glycol-Mono-Methyl-Ether (EGME) is the approved FSII material for use in both JP-4 and JP-8 fuels. Personnel involved in the handling and injection of these additives are advised to follow all guidance provided in the Material Safety Data Sheets, which includes wearing protective equipment and avoiding exposure by inhalation, injection, or skin/eye contact.

- Anti-Static Additive (ASA). Persons handling undiluted ASA must wear goggles to avoid any possibility of the product splashing into the eyes. In the event of eye contact, immediately wash the eye with water for 15 minutes and consult a doctor. Avoid repeated and prolonged skin contact and have facilities available for quickly removing any contamination from the skin with soap and water.

### 1.3 SPECIAL SAFETY REQUIREMENTS.

1.3.1 Static Electricity. Static electricity is the electrical charge caused by two different materials, especially non-conductive materials, rubbing together. In a petroleum fuel facility, static electricity can be created in many different ways. Some of the most common are listed below.

1.3.1.1 Splash Filling. Splash filling refers to the practice of filling a tank or other vessel through a short pipe in the top and allowing the incoming liquid to fall through the vapor space to the liquid surface below. While falling through the vapor space, a static charge builds up on the liquid surface. If the liquid is not a good conductor, the charge can build up until a spark is created that, in the presence of a low flash liquid like JP-4, would be disastrous. Although some fuels are better conductors than others and some contain anti-static additives, the safest thing to do is assume that the fuel is a poor conductor and avoid splash filling. Use bottom loading whenever possible. If top loading must be used, be sure the fill pipe extends to the bottom of the tank. In either case, reduce the entrance velocity to no more than 3 feet per second until the end of the fill pipe or bottom loading inlet is completely submerged.

1.3.1.2 Filters. Micronic filters, fuel monitors, and filter/separators, which are usually used to clean jet fuel, are the biggest generators of static electricity. These devices work by separating the fuel into very small drops and scrubbing the drops as they pass through to remove any dirt and water particles present. However, breaking down the fuel into such small drops creates a great amount of surface area upon which static charges can be generated. A spark from static charge buildup, in the presence of a low flash fuel, can cause an explosion.

The risk of explosion from filter-induced static buildup can be greatly reduced by the use of a relaxation tank or chamber. It has been learned that, if the fuel is in contact with the walls of the grounded system for a period of at least 30 seconds, the static charge that has been generated will dissipate, or relax. The fuel can then be pumped safely. The relaxation tank is inserted into the piping system when necessary to allow the fuel, at its established flow rate, to take at least 30 seconds to travel from the filter to the discharge point.

1.3.1.3 Pipe Flow. The flow of a liquid through a pipe creates a static charge on the surface of the liquid. As the liquid flows into the vessel being filled, the charge tends to break out at the top of the liquid and can cause a spark. The use of relaxation tanks and/or reduction in the fluid flow rate helps to alleviate the static charge buildup.

1.3.1.4 Other Factors. Many other factors contribute to the generation of static electricity in petroleum fuels.

- During filling operations, aircraft refuelers and commercial transports develop electrostatic charges. One reason for these high voltage buildups is the insulating effect of the rubber tires if the vehicle is not properly grounded and bonded to the servicing system.

- The movement of contaminants (rust, mill-scale, water, air, etc.) during settling in storage tanks ionizes the contaminants to produce a static charge. These charges build up around triggering points (gauging and sampling devices, flats, and swing pipes). If not discharged through the fuel to the wall of the tank (grounded), sparks can occur in the vapor space above the fuel.

- Personnel and clothing (wool, rayon, and synthetic materials) accumulate static electricity from normal body movement. These charges can be discharged through clothing, skin, or tools and equipment as they come in contact with components of the fuel system. Static charges accumulated on a person can be discharged by touching the cold, bare metal of the grounded equipment to be serviced with a warm metal object, such as a coin, before making any fuel connections.

This method places the human body at the same electrical potential as the equipment and reduces the chances of discharges (or sparking).

- Aircraft or service equipment can become electrostatically charged due to atmospheric conditions. In this case, the base weather service notifies the maintenance officer of the impending hazardous condition, such as a lightning storm. Subsequently, fuel handling operations must be temporarily discontinued.

1.3.1.5 Grounding and Bonding. The following sections are general descriptions of the methods used to prevent the buildup of electricity in fuel handling systems. For more detailed information, see Section 5.13.8.

- Grounding. Grounding is the connection of an electric conductor "to earth" using a ground conductor. This ensures that the connected equipment, truck, power system, etc. is at the same potential (voltage) as the earth or ground. The connection "to earth" is done by imbedding a conductive material, such as a ground rod, water service pipe, or gas service pipe, in earth. Once connected, static electricity, lightning, or other electrical currents will be directed to ground and dissipated in the earth.

- Bonding. Bonding is the permanent joining of metallic objects to assure electrical continuity and equal potential. This bonded system is then connected to a ground or "to earth" as previously described. Typically, the bond is made by using a bonding cable or jumper to allow electrical flow between the two metal objects, across a pipeline gap during repairs, etc. Bonding cables should be permanently welded to pipelines whenever possible in lieu of flange bolt connections.

### 1.3.2 Sparks and Open Flames.

1.3.2.1 Principles of Combustion. In order for a petroleum fire to occur, oxygen (air), petroleum vapor (within the explosive limits), and heat, a spark, or an open flame must all be present. If any one of these elements is missing, a fire will not occur. Since it is not practical to control the presence of oxygen, fires and explosions are prevented by controlling the amount of petroleum vapor and the sources of ignition present.

1.3.2.2 Sparks. In addition to electrostatic sparks, as discussed in 1.3.1, sparks caused by electrical currents are a major source of ignition in fuel handling operations. These sparks can be caused by connecting battery terminals, operating an electrical switch and arcing generator brushes, as well as from welding machine brushes, electric motors, and short circuits.

1.3.2.3 Open Flame. Open flames, fires, matches, cigarette lighters, and lighted smoking materials are obvious ignition sources. Additionally, standard electric light bulbs are fire hazards. If a bulb breaks, the filament can be hot enough to ignite petroleum vapors and cause a fire or explosion.

1.3.2.4 Fire Safety Precautions.

- Wear cotton or other non-static-producing clothing.
- Be sure all bonding and grounding connections are clean, unpainted, and in good condition.
- Do not begin fuel handling operation until all equipment is properly bonded.
- Do not use a chamois for filtering fuels as chamois filters increase the danger of static electricity.
- Never smoke within 100 feet of any fuel handling system.
- Do not use open fires, matches, cigarette lighters, oil lanterns, welding torches, heaters, blow torches or other open flames within 100 feet of any fuel handling operation. Do not carry "strike anywhere" matches or cigarette lighters in pockets.
- Never repair any fueling equipment during fuel handling operations.
- Use only drop lights and extension cords approved for use in hazardous locations.
- Discontinue fuel handling operations at the approach of electrical storms.
- Do not operate internal combustion engines within 100 feet of fuel handling operations unless the engines are essential to the operation and are equipped with spark-arresting mufflers and other safety equipment.
- Do not splash fill tanks, and avoid top filling whenever possible.
- Keep gauge tape in contact with the gauge hatch during gauging operations.
- Do not move other tank cars into the area during fuel loading or unloading operations.

- Keep all equipment and work areas neat, clean, orderly, and in good mechanical condition.
- Be certain that firefighting equipment and extinguishers are in good condition and readily available.
- Never use gasoline for cleaning floors, automobile parts, clothing, rags, etc.
- Never wash hands in fuels.
- Place oily waste and rags in self-closing metal containers. Empty containers frequently.
- Immediately remove any articles of clothing or shoes that have become soaked with fuels. This should be done in an area free from ignition sources.
- Discontinue fuel operations/maintenance if fuel is spilled, and do not resume until the spill is cleaned up.
- Do not allow fuel to accumulate in valve pits, pump room drains, or dike sumps.

#### 1.4 FUEL QUALITY.

1.4.1 Importance of Fuel Quality. Every type and grade of petroleum fuel or lubricant has been specially formulated to provide the most satisfactory and economical performance possible in the particular engine and under the operating conditions for which it was designed. Fuels or lubricants that have become contaminated can cause fires, explosions, loss of life, injury, and loss or damage to valuable aircraft, machinery, and equipment, which can result in a reduction in combat capability. Any product suspected of being contaminated must be reported to the testing laboratory for investigation and analysis.

#### 1.4.2 Common Contaminants and Their Sources.

1.4.2.1 Water. Water contamination in petroleum fuel may take one of three forms:

- Free water consists of relatively large drops of water which, if left undisturbed, will settle to the bottom of the container. In light products with low viscosity, free water settlement can be quite rapid, but in heavier or more viscous fuels, it takes longer. Some fuels contain anti-corrosive or cleaning agents called surfactants, which tend to prevent the settlement of free water.

- Dissolved water is water that is chemically combined with the fuel. In this state, the water is invisible, and the fuel appears to be clear; but a drop in temperature below the cloud point may cause the dissolved water to separate from the fuel in tiny droplets that remain in suspension and give the fuel a cloudy appearance.

- Emulsions are mechanical dispersions of oil and water having a frothy appearance. Emulsions can be very stable and hard to break. Separation may require special mechanical or chemical treatment.

Water contamination usually occurs during the transportation and storage of fuel. Examples of how water contamination can occur are:

- Marine Transportation. Cargo compartments of a tanker or barge may not be completely stripped of sea water ballast prior to loading.

- Tank Bottoms. Free water and emulsions settle out of the fuel and accumulate on the tank bottom. If this water is not completely removed because of tank design limitations or poor operating procedures, it will mix with the fuel during pumping operations.

- Tank Roofs. Free water can be introduced to the fuel through improper tank roof maintenance. Examples of this are failure to drain rain water off a floating roof tank, leaking roof seals on an open top floating roof, or a leaking cone roof tank.

- Underground Tanks, Pipes, and Fittings. Leaky underground tanks that are below the standing water table may take in water. Also, broken or leaking underground pipes can take in large amounts of rainwater run-off.

- Pipeline Operations. Slugs of water are sometimes used to separate two batches of different types of fuel.

1.4.2.2 Solid Matter. Types of solid matter contamination most prevalent in petroleum fuels are iron rust and scale, sand, and airborne dirt. The principal source of iron rust and scale is corrosion in pipelines, storage tanks, or other fuel containers. Sand and dirt are particularly serious in extremely sandy or dusty areas. They may accumulate around tank gauge hatches, tank manways, or other openings and enter the tank when the covers are removed. The presence of large amounts of particulate matter in fuel results in restricting or clogging of filter/separators, silting and plugging of fuel control units and nozzles, and scoring and wear of fuel system components by abrasion.

1.4.2.3 Other Fuels. The properties of a type or grade of fuel can be greatly changed by mixing it with another grade. Some causes of contamination between fuels are:

- Leaky bulkheads between cargo tanks.
- Leaky valve manifolds separating product systems.
- Use of common transfer piping for different products.
- Improper cleaning of a tank compartment or pipeline prior to changing product service.

1.4.2.4 Bacteria. Where petroleum fuels and water exist together, bacteria may exist in the area of interface. The bacteria live in the water and feed on the fuel. Only a small amount of water, such as a puddle in a tank bottom that cannot be drained, is required to support large colonies of these organisms.

Bacterial contamination usually appears as a brown, slime-like deposit that adheres to the inner surface of the fuel tank. This results in corrosion of fuel tanks, clogging of filters, and erratic operation of fuel quality indicating systems. Generally, bacteria contamination is most severe in high temperature/humidity climates.

1.4.3 Prevention of Contamination. The following are procedures that must be followed to prevent or reduce the possibility of fuel contamination from the sources previously discussed.

1.4.3.1 Water.

- Regularly drain and check all tanks, filter/separators, and equipment provided with manual drains. Drain them until a clean, bright, water-free sample is obtained. Tanks configured for circulation from the sump through a filter/separator need not be stripped.
- During flow operations, observe filter/separator and fuel monitor pressure gauges and be sure that both are functioning properly. Maintain a log to record differential pressure across the separator. Increasing differential pressure indicates a need to clean the filter.
- Ensure that regularly scheduled maintenance by both operating and maintenance personnel is properly performed.

- When it is possible to do so, fuels newly received by any means of transportation should be allowed to stand undisturbed in the receiving tank long enough to permit settlement of free water before the fuel is dispensed. Minimum settlement time is 2 hours for lighter fuels; heavier fuels should settle for longer periods of time. Refer to MIL-HDBK-200F for further details. After the settling period, the tank should be gauged for bottom water; any bottom water found should be removed.

- New bottoms for vertical, cylindrical tanks should slope downward from the shell at a uniform slope of 1 inch vertically to 20 inches horizontally to a bottom sump at the center. For tanks to be operated with filter circulation systems, the main suction line should terminate 4 inches from the bottom of the center sump. Non-circulating, above-ground tanks should be equipped with a frost-proof water draw-off valve at the shell with a 1 inch connection from the bottom of the sump. For non-circulating underground tanks, the sump connection should be appropriate for the type and size of sump pump used.

Horizontal tanks with filter circulating systems should slope downward toward the suction end at a slope of 1 inch vertically to 60 inches horizontally. Non-circulating horizontal tanks should slope downward away from the suction end at a 1 inch to 60 inch slope with a sump pump connection at the low end.

Older, above-ground tanks may have steel bottoms that are flat or crowned up at the center. When the tank is full, the bottom may develop low spots in which water accumulates. When such tanks are available for entry during cleaning or repair, they should be inspected for signs of water pockets; additional sumps and draw-off connections should be added where necessary, and when economically feasible, to make it possible to remove all bottom water.

All tanks should be gauged daily for bottom water, and any bottom water found should be promptly removed. Refer to Section 5.3.5, "Product Sampling," for further instructions.

- Tank roofs, seals, and fittings of all types should be maintained in good, weather-tight condition. Drains from floating roofs in open-top floaters should be equipped with a flexible connection from the low point of the roof to a shell connection near the bottom of the tank.

- Steam coils that are suspected of leaking should be hydrostatically tested at 1-1/2 times the normal working pressure.



- Filter/separators should be installed in aviation gasoline and jet fuel systems at the following points:

- In bulk receipt delivery lines to storage.
- At discharge of bulk tanks and ready-issue tanks.
- Between bulk tanks and ready-issue tanks.
- In circulating lines from ready-issue tanks.
- At the final issue point except where noncorrosive pipe and fittings are used.

- Jet fuel, kerosene, diesel fuel, and No. 1 and 2 burner fuels may develop a cloudy appearance with a drop in temperature. This is known as temperature haze. Circulation through a filter/separator usually removes the haze from jet fuels that have been cleaned of surfactants. The other fuels often contain surfactants that prevent the filter/separator from working by forming a film on the coalescing surfaces of the separator. There are several methods for removing the haze from kerosene, diesel fuels, or burner fuels, including:

- Allowing the product to stand undisturbed until the haze settles out.
- Circulating the product through a clarifier or clay filter.
- Circulating the product through two filter/separators in series.
- Underground tanks that are suspected of leaking should be tested using a temperature-controlled, hydrostatic stand-pipe test. Underground piping that is suspected of leaking should be isolated and hydrostatically tested in accordance with the procedures of Section 5.2.6.

An alternative means of testing for leaks in tanks and/or piping systems is by a patented process called Tracer Leak Detection. It involves injecting a volatile chemical concentrate, or tracer, into the tank or pipe. If the liquid leaks out of the tank or pipe, the tracer chemical escapes from the product by evaporation and diffuses into the soil. The tracer is then detected by drawing air from the soil with a vacuum pump and performing a chromatographic analysis of the air sample. The geographic EFD can provide further details on this system.

#### 1.4.3.2 Solid Matter.

- Brush away or remove any accumulated dirt or sand around fill covers, manholes, and other covered openings before removing them.

- Whenever tanks, piping, or equipment are open for construction, repair, or inspection, insist that they be protected against entry of dirt and foreign objects. Normally, closed tank openings not required to be open for ventilation or access should remain closed. Open ends of pipe should be capped with temporary closures. Openings in equipment such as pumps and meters should be sealed by temporary closures.

- Do not operate any fuel handling equipment unless all filters, monitors, strainers, screens, and nozzle spout caps are properly installed and in place.

- Never remove any filter, strainer, or screen for any purpose, except for cleaning or maintenance. Always replace the filter or screen immediately after cleaning.

- Notice and report to the proper authority any unusual operating condition.

- Observe water that is drained from refueler and filter/separator sumps and report any unusual accumulation of foreign matter.

- The inside of new pipe should be carefully inspected for loose scale, dirt, or rust. Any that is observed should be removed by brushes, swabs, plugs, or pigs before the new pipe is installed in the system.

- A new pipeline system should be thoroughly flushed out by circulating the product at higher than normal velocity until the discharge is clear of solid matter. Temporary strainers installed at strategic points to remove trapped matter will help. If the system design permits, a cleaning and gauging pig should be run through the new piping before it is put into service.

- When scale and rust are loosened by the penetrating action of a new grade of fuel, the tank or pipe involved should be thoroughly mechanically or chemically cleaned before the fuel is introduced. Even if a good cleaning job is done, loosened scale or rust can continue to appear in the product for several weeks after starting the new operation. Accordingly, extra precautions such as more frequent sampling, circulating of product, temporary use of strainers, frequent cleaning of strainer baskets, and use of cleaning pigs should be taken.

- Where loose scale from the inside of open top floaters is a persistent problem, consideration should be given to coating the inside of the shell with an epoxy or similar coating that is resistant to the solvent action of petroleum and to mechanical abrasion.

- Be certain that any replacement parts or equipment items, such as hoses, packings, gaskets, O-rings, seals, and pipe compounds, are made of materials that will not affect or be affected by the fuels with which they may come into contact.

#### 1.4.3.3 Other Fuels.

- Be sure that newly arrived products were not contaminated during shipment. Take frequent samples and, if possible, do not ship or use a product until test results are confirmed.

- Do not begin a transfer operation until the markings of all needed equipment items have been checked and found to agree.

- Use separate pipelines and equipment for each product.

- Pipelines should never be used for more than one type and grade of fuel.

- Provide separate receiving and distribution pipelines for each product type within a facility.

- Do not use common piping systems for incompatible products, and do not depend on valves to separate products as they may leak.

- To reduce the chance of fuel contamination due to human error, clearly label and color-code tanks, valves, pipelines, and pumps to indicate the type or grade of product they contain or control. (See Section 1.4.3.5.) Be sure that system flow diagrams are available to all operators. Use arrows to indicate the direction of product flow within the pipe.

- Changes in tank products should be approved in advance by NAVPETOFF.

1.4.3.4 Bacteria. Bacteria need pools of free water in the fuel to exist. Therefore, eliminate the water as outlined previously (Section 1.4.3.1), and the bacteria will not be able to survive. FSIIIs are helpful in controlling bacteria because they contain bacteria-killing agents and because they keep any free water present dispersed throughout the fuel.

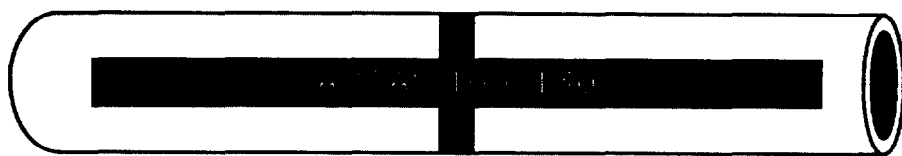
1.4.3.5 System Identification. Clear identification of petroleum systems and equipment by product type and grade is essential to operational safety and to product quality protection. MIL-STD-161F, "Identification Methods for Bulk Petroleum Systems Including Hydrocarbon Missile Fuels," establishes standards for identification of military fuel facilities. For ready reference by petroleum facility operations and maintenance personnel, the following information has been taken from that standard.

- The standard is intended to apply to petroleum fuel piping and storage tanks, including tank truck and tank car loading and unloading connections, storage tank valves, pump manifolds, cross country pipelines, tanker connections, and where desired by local authorities, cars and tank trucks.

- Petroleum piping should be painted No. 17875 white gloss with lettering enclosed in a No. 17038 black background. No. 13655 yellow should be used as the primary warning color for petroleum products. The identifying color is intended for use at appropriate places for identification only, not as a substitute for general-purpose, protective coatings, which are specified elsewhere.

- Markings should be applied by painting, stenciling, or adhering pre-printed sheets or films in accordance with MIL-D-8634, MIL-F-8799, or L-S-300.

- Product identification bands should be applied to petroleum piping as shown in Figures 1.4.1 and 1.4.2.



AVIATION GASOLINE -- ONE NARROW BAND



AUTOMOTIVE GASOLINES -- TWO NARROW BANDS



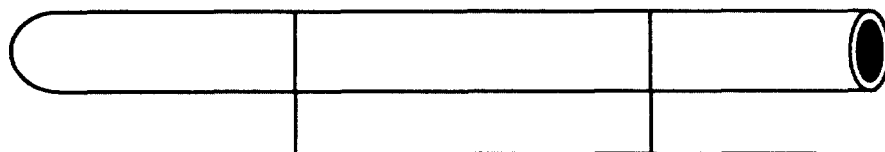
JET FUELS -- THREE NARROW BANDS



DISTILLATES -- FOUR NARROW BANDS



HEAVY FUEL (BLACK) OILS -- FIVE NARROW BANDS



AVLUBE	MIL-L-22851 TYPE 11
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LUBRICATING OILS -- SIGN

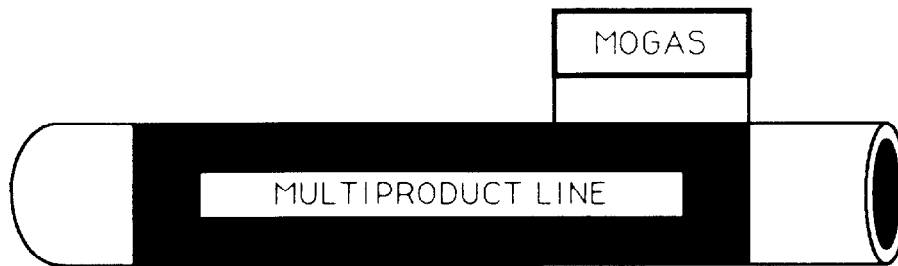
FIGURE 1.4.1  
PIPE IDENTIFICATION MARKINGS



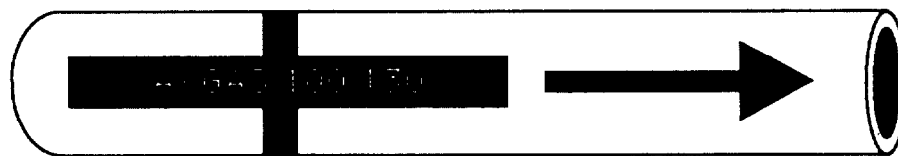
THERMALLY STABLE JET FUELS --  
WIDE BAND - NARROW BAND - WIDE BAND



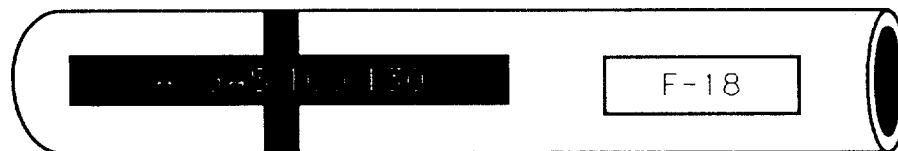
MISSILE FUELS -- 1 WIDE BAND - 1 NARROW BAND



MULTIPRODUCT LINES



DIRECTION OF FLOW



NATO SYMBOL MARKING

FIGURE 1.4.2  
PIPE IDENTIFICATION MARKINGS (CONT.)

## CHAPTER 2. TYPICAL NAVY FUEL FACILITIES/SYSTEMS

2.0 OBJECTIVE. This chapter provides general descriptions of typical fuel facilities and systems. It outlines the operation of the facility or system and provides references for its design.

### 2.1 PIERS/WHARVES.

2.1.1 Types of Piers. A pier is a structure that extends out from shore into navigable water and is designed for the berthing of vessels for repair, fueling, and other essential services. Typically, a structure is referred to as a pier if it is perpendicular or at an angle to the shore. If it runs parallel to the shore, the structure is called a wharf. However, for the purposes of this manual, all berthing structures will be referred to as piers.

Piers are used to provide either multi-purpose berths or special service berths. Those providing multi-purpose berthing are used to service different ship classes so that ships will have the option of utilizing one of several berthing facilities at a port. Special berths are provided when berthing arrangements and/or locations are required for fueling vessels, berthing vessels carrying explosives, or cleaning ship's bilges.

A pier dedicated to discharging fuel to storage or receiving fuel from storage is called a fueling pier. Fueling piers are equipped with pipelines for each type of fuel to be handled and/or stored at the site, as well as bilge and ballast lines. Stripper pumps (for emptying lines), protective hose racks, and small, hose-handling derricks are also necessary. Additionally, such piers provide freshwater, saltwater (for firefighting), electric power, telephone, and fire alarm services to berthed ships.

2.1.2 Structural Requirements. The structural design of fuel piers and wharves should be in accordance with MIL-HDBK-1025/1, "Piers and Wharves." The functional design should be in accordance with NAVFAC P-272, Definitive Drawings 1403995 through 1403999, "Non-Polluting Fuel Piers." The design of fuel piers should also comply with the U.S. Coast Guard oil pollution regulation, Chapter 33, Code of Federal Regulations, Part 154.

2.1.3 Piping Requirements. Petroleum piping on piers should include the following considerations. (Where existing installations do not comply, correction of the deficiencies should be considered.)

- Pipelines and equipment should be clearly marked to identify the grade of product being carried, as prescribed by MIL-STD-161F and summarized in Section 1.4.3.5.

- Pipelines should be used for one grade of fuel only, whenever possible.

- Multi-product lines, which are often used between bulk terminals, should be identified by sign or flag.

- All pipe, elbows, tees, etc. should be carbon steel with welded joints.

- Valves and similar fittings should be cast carbon steel with flanged ends. Military Handbook 201B recommends, "...that cast-iron valves, originally installed in place of steel valves at critical locations, such as at tanks or piers, should be replaced with steel valves when possible without interfering with the depot operation."

- Non-lubricated plug valves (also known as double block and bleed valves) should be installed along the waterfront for environmental protection and pipeline pressure testing purposes.

- Piping located beneath the deck of a multi-purpose pier is subject to corrosion and undetected leaks. It is difficult to inspect and maintain. It is preferable that piping be located above the pier deck.

- Each line should have a cast carbon steel double block and bleed valve near the point where it leaves the shore.

- Each line should have connections for draining when it is not in use. Piping that will not be used for 90 days should be drained and blanked off.

- A flexible connection must be provided between the ship and the fixed piping system. This connection may be a hose or a flexible marine loading arm with swivel joints (see Section 5.8). In either case, there should be enough slack or freedom of movement to allow for ship movement during the fueling operation.

- Each hose connection should have a drain connection on the ship side of the block valve so that the hose can be drained before it is disconnected.



- Hose connection or loading arm areas should be equipped with a spill containment structure having the following capacity:

- Three barrels if it serves one or more hoses or arms 6 inches or less inside diameter.

- Four barrels if it serves one or more hoses or arms larger than 6 inches but less than 12 inches inside diameter.

- Six barrels if it serves one or more hoses or arms 12 inches or larger inside diameter.

- Cast carbon steel check valves should be installed in unloading lines as close as practical to the hose connection.

2.1.4 Other Requirements. Other systems and equipment required for pier operations are:

- Fire protection system
- Communication system
- Pollution abatement equipment
- Personnel and equipment shelter
- Security fencing
- Bonding system
- Pier lighting equipment.

**2.2 OFF-SHORE MOORING FACILITIES.** Where it is not feasible to use piers to moor ships for fueling operations, off-shore moorings are used. These systems facilitate the receipt and discharge of fuel in cases where an activity is not geographically suitable for typical fueling operations or a tanker is too large for the body of water, as in the case of a super tanker, or the draft restrictions do not permit pierside loading/discharge of fuel.

2.2.1 Types of Off-Shore Moorings.

**2.2.1.1 Monobuoys (or Single-Point Moorings).** Monobuoys are used for deep water mooring of large tankers. They are mooring platforms that allow ships to swing freely while engaged in fueling operations. A ship tied to a pier can generate considerable tension on mooring lines when a stiff wind is blowing against the vertical surface of the ship. Monobuoys allow the ship to always be headed into the wind,

thereby reducing the strain on mooring lines. Figure 2.2.1 shows a monobuoy in operational mode. The buoy itself is a self-contained unit fixed to the ocean bottom by means of an anchor and/or pilings. A diesel-driven air compressor is located in the interior of the buoy; its purpose is to provide compressed air displacement for the float/sink hose. The product hoses are packed at all times, either with petroleum product or water, depending on the operational requirements.

The maintenance requirements for monobuoys can be quite extensive. Annual underwater inspections are required to determine the condition of the anchor chains, which attach the monobuoy to the bay/harbor floor. This highly corrosive environment necessitates an overhaul of monobuoys every 3 to 5 years. The monobuoy must be brought ashore for repair in these instances.

2.2.1.2 Multi-Point Moorings. Some commonly used types of moorings have several anchors and buoys that hold the ship in place during the fueling operations. They are called multi-point moorings. Once the ship is securely anchored in place, it connects with the undersea pipe system leading to shore, with the number of pipelines depending on the number of products to be handled at that mooring. At the mooring end of each pipeline is attached a fueling hose fitted with a valve and a marker buoy to enable the ship to locate and raise the hose for connection to the ship. Figure 2.2.2 illustrates a multi-point mooring system.

2.2.2 Design Requirements. The following references provide design requirements and more detailed information regarding off-shore mooring systems:

- NAVFAC DM-26.04, "Fixed Moorings"
- NAVFAC DM-26.05, "Fleet Mooring"
- NAVFAC DM-26.06, "Mooring Design, Physical and Empirical Data."

## 2.3 PIPELINES/PIPING SYSTEMS.

2.3.1 Use of Pipelines. Cross-country pipelines are generally the most economical method to move large quantities of fuel, both from a dollar viewpoint and a manhour viewpoint. Where possible, the Navy uses pipelines for liquid fuel transportation. In some cases, the Navy shares the use of commercially operated, common-carrier pipelines with other users. In other cases, the Navy enters into a long-term agreement with an outside contractor to construct and operate a pipeline from one point to another exclusively for use by the Navy. In still other cases, the Navy acquires the right-of-way, constructs the pipeline, and operates it with its own

2-5

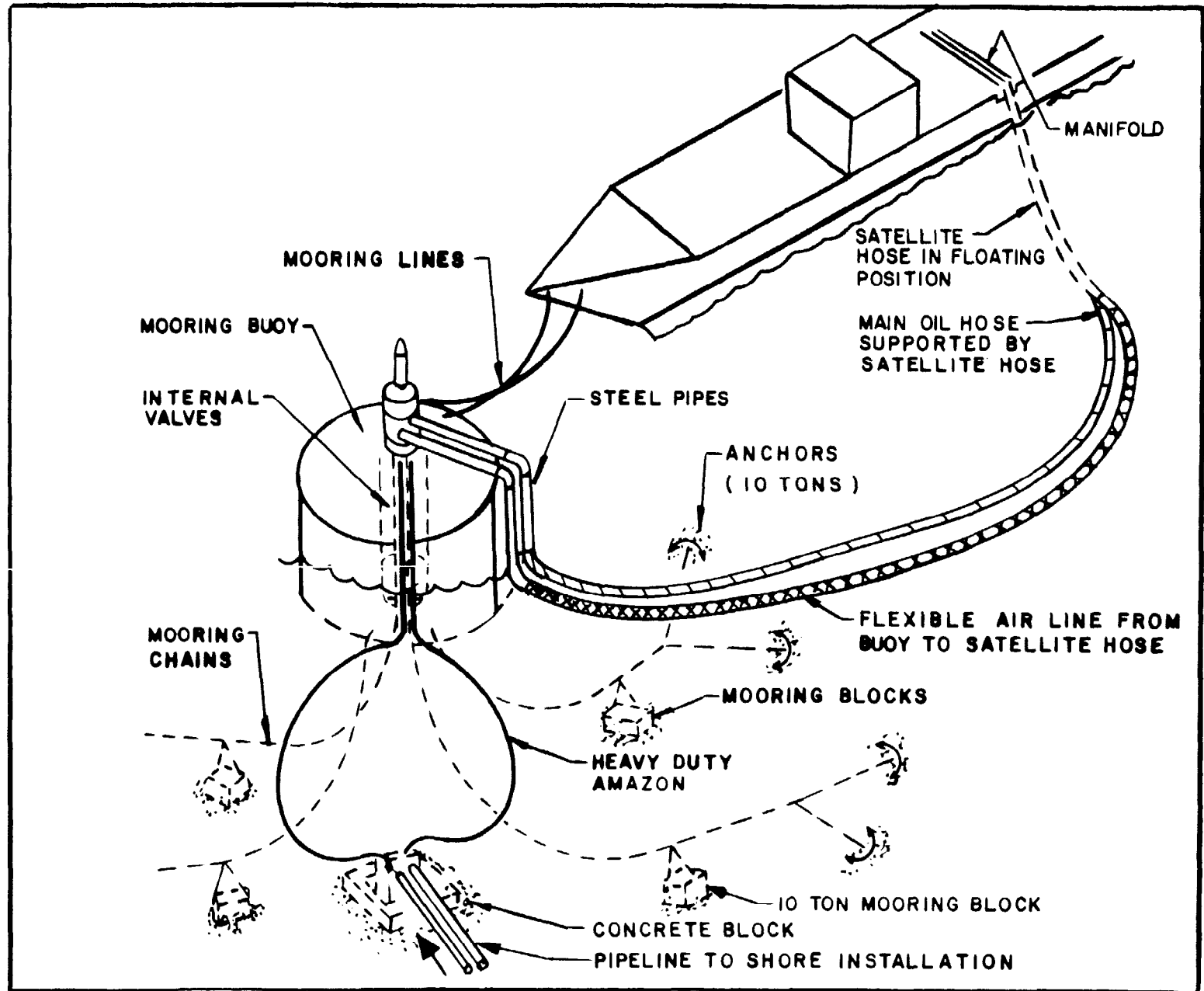


FIGURE 2.2.1

MONOBUOY IN OPERATIONAL MODE

2-6

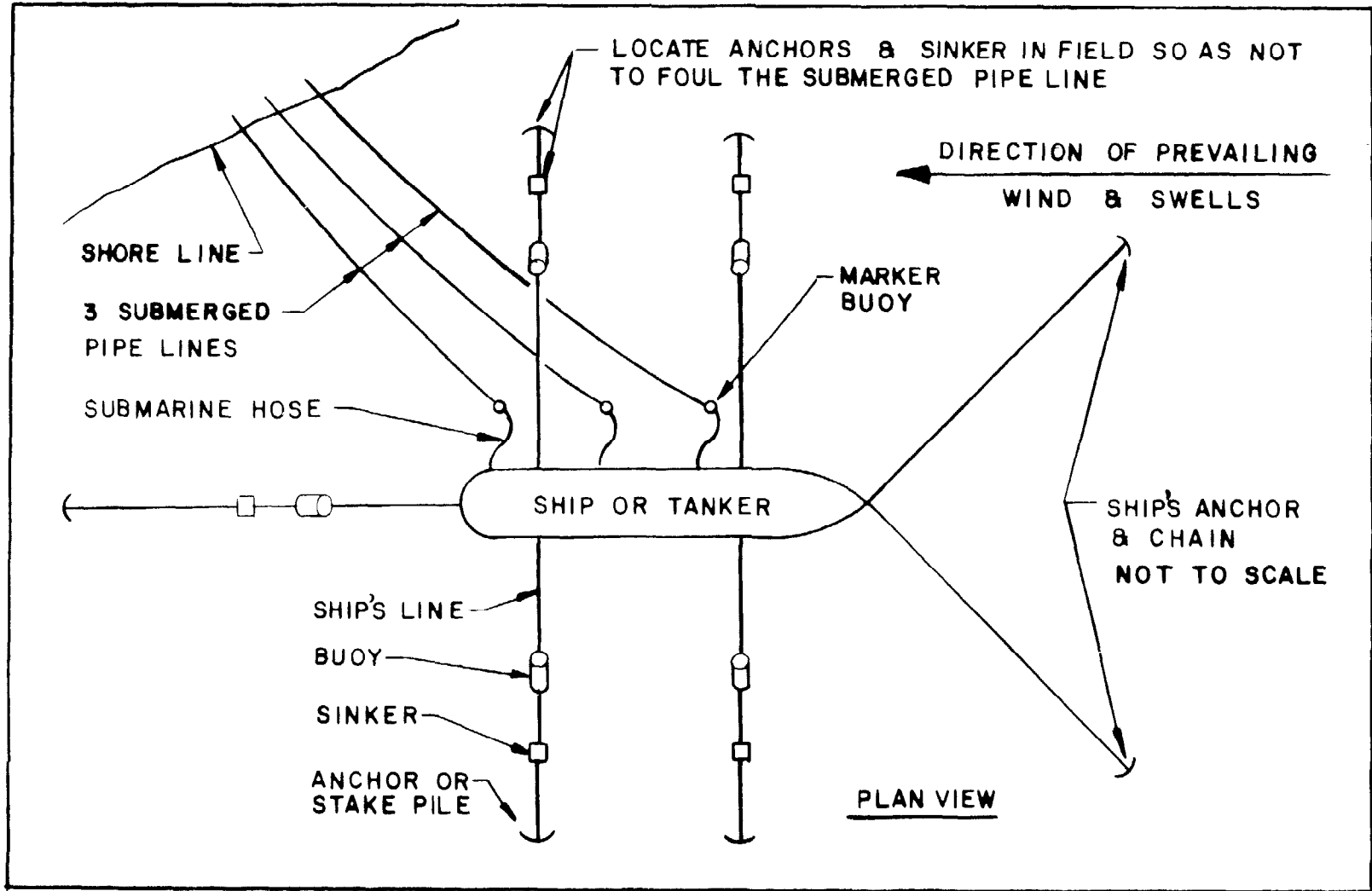


FIGURE 2.2.2  
MULTIPOINT OFF-SHORE MOORING

personnel; for example, the 93-mile pipeline connecting the Estero Bay, California, tanker terminal to the Naval Air Station, Lemoore, California.

In addition to being used for long distance, cross-country fuel transport, pipelines of many different lengths and sizes are used for all types of fuel relocation. The following paragraphs identify the main types of pipelines.

- Aboveground Pipelines. Current Navy policy is that, within the Continental United States (CONUS), pipelines will be installed above ground whenever possible to ease potential environmental concerns. A separate pipeline is provided at the facility for each kind of fuel specified for storage.

- Underground Pipelines. POL pipelines outside fuel terminals are laid underground whenever practical. This eliminates thermo-solar effects and provides additional protection against fire and other damages.

- Subaqueous Pipelines. In certain terrain, it is necessary to run a portion of a fuel distribution line underwater, as for a harbor crossing, through a marsh, etc. While the general design of subaqueous pipelines is somewhat analogous to that of the submarine pipeline used for offshore fueling, it follows more closely the design for underground piping.

- Submarine Pipelines. To receive or issue fuel from offshore moorings, one or more submarine pipelines are laid to the ship mooring point. The general layout of the submarine pipelines should be set up so that the lines fan out to present connections in line with the side of a ship moored in the fueling berth. Where fuel oil, diesel oil, and gasoline lines are provided, locate the fuel oil line in the center, with the gasoline line toward the bow mooring and the diesel oil line toward the stern mooring.

### 2.3.2 Pipeline Construction and Equipment.

2.3.2.1 Design. Piping design, materials, fabrication, assembly, erection, inspection, and pressure testing of intraterminal piping systems should be in accordance with ANSI Standard B31.3, "Chemical Plant and Petroleum Refinery Piping." Additional pipeline design, construction, operation, and maintenance guidelines are provided in Federal Regulation, Chapter 49, Code of Federal Regulations, Part 195, "Transportation of Liquids by Pipeline," as well as MIL-HDBK-1022, "Petroleum Fuel Facilities."

2.3.2.2 Pumping/Booster Stations. On long pipelines, it may be necessary to use pumps to move fuel to its destination. The pumps produce the system flow pressure to

overcome pipe friction losses and differences in elevation and static head along the pipeline. Booster stations are pumping stations located along the pipeline to sustain the fluid flow rate. Usually, centrifugal pumps are used at the pumping/booster stations to move the petroleum. Section 5.6 provides additional detail on pump types.

2.3.2.3 Pig Launching and Receiving Stations. Long pipelines are periodically cleaned by pipeline pigs, scrapers, and spheres propelled through the line by liquid pressure. Similar devices are also used to separate different batches of petroleum products. The use of pigs and scrapers is further detailed in Section 5.2.10.

## 2.4 TANK FARMS.

2.4.1 Design Requirements. Tank farms are intended to store operating and reserve fuel supplies. The types and sizes of storage tanks on a tank farm are determined by considerations of intended service, safety, economics, and locality. MIL-HDBK-1022, "Petroleum Fuel Facilities," and NAVFAC P-80, "Facility Planning Criteria for Navy and Marine Corps Shore Installations," provide specific tank design criteria along with criteria for the minimum distances between fuel storage tanks and other structures, such as buildings, railroads, roadways, or power lines.

2.4.2 Operations. The normal petroleum operations at a tank farm consist of the receipt, storage, and issue of liquid petroleum products. The volume and the type of products are governed by the mission of the activity and the nature of existing facilities. Some of the specific operations to take place are unloading and loading tankers, barges, tank cars, and tank trucks; making pipeline transfers; pumping from and into tanks; gauging; sampling; and maintaining records of inventories and operation of fuel dispensing systems.

2.4.3 Tank Types. The following paragraphs define some of the tank types to be found on a tank farm.

### 2.4.3.1 Storage Tanks.

- Cone Roof Tanks. The cone roof tank is the most commonly used fuel storage tank, primarily because of its low cost of construction relative to other designs. This type of tank is subject to breathing and filling losses; if the roof is not properly maintained in gas-tight condition, windage losses may result. The roof is coned toward the center of the tank with sufficient pitch to provide adequate drainage. Cone roof tanks may be used for storage of practically all grades of liquid petroleum products although they were originally designed for high flash point products. The military services have adopted the use of honeycomb aluminum internal pan

floaters in cone roof tanks in accordance with USAF AFM 88-15 (interim draft). These tanks offer the conservation and safe handling advantages of standard floating roof tanks without the disadvantages associated with the introduction of rain, snow, or sleet in open roof tanks. Figure 2.4.1 is a cutaway drawing of an internal pan floater tank.

- Floating Roof Tanks. A standard floating roof tank is designed to permit the roof to float on the surface of the liquid, rising or falling with changes in product levels. There is no vapor space. Consequently, with proper design of the deck and an effective closure (vapor seal) around the edge of the floating roof, breathing and filling losses are practically eliminated. Fire hazard is minimized because little vapor, if any, is present above the product level in the tank. There are two general types of floating roof tanks in use: the pontoon type and the double deck type. Floating roof tanks are best adapted for use with low flash point products. Geodesic domes are sometimes added to the tops of floating roof tanks in cold climates where accumulations of ice and snow can interfere with the proper operation of the roof.

- Concrete Tanks. Most underground concrete tanks at military installations are vertical cylinders with walls of prestressed concrete. Steel tension members are placed around the shell of the tank in a series of rings or a continuous spiral. The exterior of the tank shell is then protected with a second pour of concrete. Where concrete tanks are to be used for the storage of fuels heavier than diesel fuel, their interior surfaces are coated with a sodium silicate solution that fills the interstices of the concrete during the initial filling. Where concrete tanks are to be used for the storage of diesel and lighter types of fuel, the interior surfaces are normally provided with a coating system. Pits containing pumps and heaters may be located alongside an underground tank. Ladders or other means of access should be provided for the operator; safety rules require periodic landings to prevent a long fall and allow for resting. If ladders are to be used often, they should be replaced by stairs whenever possible.

- Steel Tanks. Steel tanks are commonly used for storage of nearly every kind of petroleum product. They may be installed either above or below ground and should be coated or uncoated. All underground tanks should now be of double-wall construction. Steel tanks in the smaller sizes of 500-barrel capacity or less may be horizontal or vertical, but sizes greater than 500-barrel capacity are, in most cases, vertical.

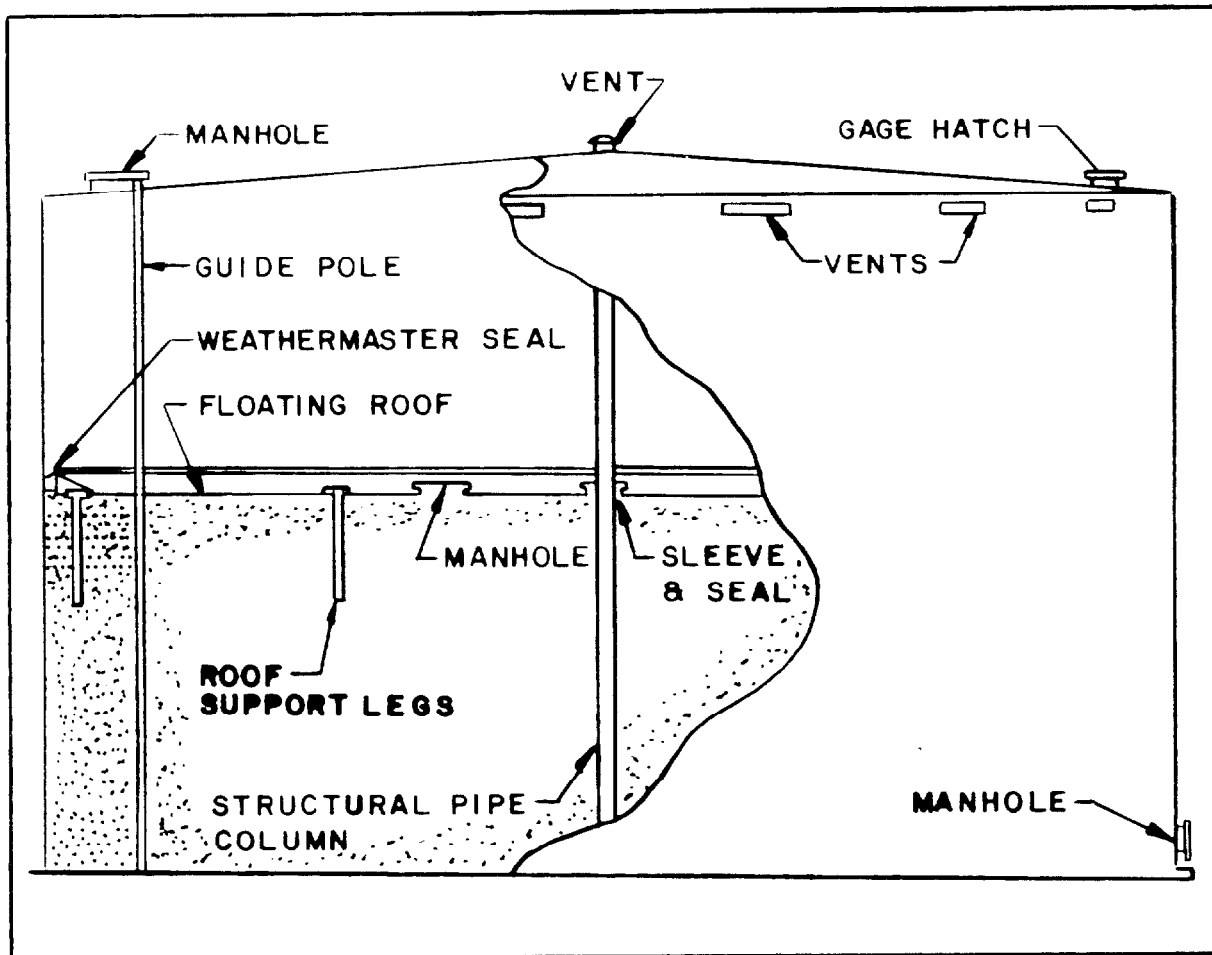


FIGURE 2.4.1

FIXED ROOF CONE TANK WITH INTERNAL PAN FLOATER



2.4.3.2 Ballast Tanks. Many types of tanks are provided for receiving ballast. They may be open or roofed, steel or concrete tanks. They are provided not only to receive ballast from ships but also to store ballast to be pumped back to ships when necessary. They are frequently used in conjunction with oil reclamation plants.

2.4.3.3 Surge Tanks. Surge tanks or shore receiving tanks are used when the flow rate is not constant or pumping is done over long distances. For example, a tanker discharging to a tank farm several miles away would pump into a surge tank near the pier. Shore booster pumps would then take suction on the tank and pump the product to the tank farm. The use of a surge tank ensures the booster pump of a constant supply of oil and allows for surges in the rate of tanker discharge.

2.4.3.4 Miscellaneous Tanks. Other types of tanks found at fuel storage installations include water tanks, buried service station tanks, drum filling storage tanks, drum filling plant surge tanks, cooker tanks at oil reclamation plants, burner fuel supply tanks, etc. The type of tank used for these purposes depends on the operation to be performed and the tanks available for use.

2.5 TANK TRUCK/RAIL CAR LOADING/RECEIVING FACILITIES. The following sections describe the basic types of tank truck/rail car facilities. More detailed information can be found in MIL-HDBK-1022, "Petroleum Fuel Facilities"; MIL-HDBK 201B, "Military Standardization Handbook, Petroleum Operation"; and NFPA 30, "Flammable and Combustible Liquids Code." This section does not address aircraft fueler loading/unloading facilities, which are covered in Section 2.6.

2.5.1 Loading Facilities. Fill stands are required for loading over-the-road tank trucks and/or rail cars used in the bulk transport of petroleum fuel. Regardless of whether the transport vehicle is a tank truck or a rail car, loading facilities should accomplish their mission using bottom loading to prevent the buildup of static charges created when splash-filling.

2.5.1.1 Tank Truck. A tank truck loading facility is one or more truck fill stands that dispense fuels to delivery trucks. Bottom loading stands should accommodate only one truck at a time, and they should be equipped with meters, strainers, overflow protection monitors, control valves, piping, and switches necessary for operation.

2.5.1.2 Rail Car. A rail car loading facility should provide railroad siding along each side of a loading island to accommodate six tank cars per side. A rail car loading facility may also be used for the disposal of sludge from storage tanks; however, for this purpose, a special sludge

transfer pipeline should be employed. Each stand should have all the necessary valves, piping, pumps, electrical control, meters, strainers, etc. for its proper operation.

2.5.2 Receiving Facilities. Fuel storage facilities not accessible by waterway or near a pipeline may be supplied by tank truck, rail car, or both. Further, facilities that use water or pipeline fuel deliveries as their primary source may use tank truck or tank car deliveries as a secondary source of supply or for deliveries of secondary fuels.

2.5.2.1 Tank Trucks. The receiving facility should be large enough to be capable of handling the entire daily fuel requirements in 8 hours. If the receiving station is at an activity with rail service, the station should be laid out so that it can also accommodate tank cars. Each unloading facility should be equipped with all hoses, valves, strainers, electrical controls, and self-priming pumps necessary for its proper operation.

2.5.2.2 Rail Cars. A rail car receiving facility unloads liquid petroleum products from rail cars. Each facility should be equipped with all valves, piping, pumps, controls, security fencing, lighting, etc. necessary for its proper operation. There should be one unloading connection per car with the number of connections being adequate to unload the daily requirements in an 8-hour period.

## 2.6 AIRCRAFT FUELING SYSTEMS.

2.6.1 Aircraft Truck Fueling Systems. Since refueler trucks offer the preferred method of refueling aircraft, aircraft truck refueling facilities are required to transfer fuel to the refueler trucks. The fueling equipment is located on concrete islands designed to provide fuel from one side only. Overhead truck fill stands are no longer authorized for any petroleum product.

All newly constructed and recently modified fill stands require two additional features:

- Containment curbs designed to hold the fuel that could accrue from a rupture of the largest refueler serviced.
- Self-monitoring, high-level shutoff ("Scully") systems with hand-held deadman control that close valves and/or stop pumps when fuel reaches sensors mounted in the tank being filled.

MIL-HDBK-1022, "Petroleum Fuel Facilities," and NAVFAC P-80, "Facility Planning Criteria for Navy and Marine Corps Shore Installation," provide additional guidance on the design of fill stands. Additional aircraft refueling design, operation,

and maintenance information can be found in NAVAIR 06-5-502, "Aircraft Refueling for Shore Activities," as well as NFGS 15486, "Aviation Fuel Distribution and Dispensing."

2.6.1.1 Equipment Requirements. Equipment at a truck fill stand for aviation fuel should include a filter separator, fuel monitor, relaxation chamber (or sufficient piping downstream of the monitor to ensure that fuel does not enter the tank being filled for at least 30 seconds), surge arrester, temperature compensated fuel meter, bonding cable, hose, and underwing nozzle with a product selectivity device and dead-man control.

2.6.2 Aircraft Direct Fueling Stations. Aircraft direct fueling stations provide outlets where aircraft can be fueled from a closed circuit fuel system as opposed to refueler trucks. While refueler trucks are the preferred method to fuel aircraft, direct fueling stations may be considered for:

- Carrier aircraft, including helicopters, when the mission dictates a continuing need for rapid turnaround without shutting engines down
- Cargo/transport aircraft with prescribed short ground times
- Patrol aircraft that require an average refueling of 2,500 gallons or more.

Aircraft direct fueling stations should be installed only when authorized by NAVFACENCOM HQ and NAVAIRSYSCOM HQ. NAVFACENCOM HQ (Code 04) and NAVAIRSYSCOM HQ (Code 4223) will provide technical assistance for the determination of the type and number of fueling stations.

Aircraft direct fueling systems utilize multi-arm pantographs with closed circuit nozzle assemblies. Cargo/transport aircraft may also be refueled from flush-type direct fueling stations located in the apron in conjunction with hose/pantograph trailers or trucks.

The fueling stations are usually arranged in rows between two taxi-ways with a fueling lane to accommodate an aircraft on each side of each station. See MIL-HDBK-1022 and P-80 for additional direct refueling facility design and arrangement criteria.

## 2.7 AUTOMOTIVE FUELING SYSTEMS.

2.7.1 General Requirements. Automotive fueling stations are required to dispense motor gasoline and diesel fuel to motor vehicles. The fueling facility provides separate facilities for each type and/or grade of fuel to be dispensed.

## 2.7.2 Equipment Requirements.

2.7.2.1 Piping. Piping and equipment should be in accordance with MIL-HDBK-1022, "Petroleum Fuel Facilities," and NFPA-30, "Flammable and Combustible Liquids" code. API Bulletin 1615, "Installation of Underground Gasoline Tanks and Piping at Service Stations," illustrates a typical installation layout.

2.7.2.2 Storage Tanks. Fuel is usually stored in underground, horizontal, double-wall steel or fiberglass tanks, at least one for each grade of fuel (see MIL-HDBK-1022).

2.7.2.3 Other Equipment. Automotive fuel facilities may also contain other items of equipment such as fuel dispensers, card/key locks, and vapor recovery systems. The TEC 21 system, a card-based fuel dispensing control and management system, is a specific example of the other types of equipment found at these facilities.

2.8 BASE UTILITY FUEL SYSTEMS. Some naval fuel facilities are required to receive, store, transfer, or dispense fuels for base utilities, such as heavy burner fuels for boiler plants and diesel fuels for diesel generating systems. Equipment for such services should be installed, maintained, and operated with the same regard for protection of fuel quality, protection of the environment, and safety of operation as for any other fuels.

2.9 BALLAST WATER HANDLING FACILITIES. Petroleum fuel facilities, which transfer fuel by barge or tanker or which fuel large ships, may require ballast water collection and treatment facilities to receive, collect, and treat oily ballast from cargo or fuel tanks.

2.9.1 Transfer Systems. Ballast transfer pipeline systems are installed either above ground or underground and extend from fueling piers to oily waste handling facilities.

Typically, the pipeline uses steel piping; however, when caustic liquids are involved, fiberglass pipelines are recommended. The pipe and fittings are made of reinforced fiberglass, fabricated specifically for high pressure and high temperature operation.

Where permanently installed ballast collection and treatment facilities are not provided, Ship Waste Offload Barges (SWOBs) and Waste Oil Rafts (DONUTs) can be used to collect and effectively treat ballast water to discharge standards. NAVFAC Manuals MO-909, "Oil Ship Waste Offload Barge," and MO-350, "Standard Operational Manual for the Waste Oil Raft," fully describe the use and operation of the Oil SWOB

and DONUT, respectively, for ballast water collection and treatment.

**2.9.2 Storage and Treatment Tanks.** Most storage tanks that receive sludge or contaminated fuel oil are equipped for settling out non-recoverable sludge by means of gravity separation. Within these tanks, the relatively light, free oil floats to form a layer of almost pure oil, while heavier free water and sludge settle to the bottom. Between these two layers is a layer of oil-water emulsions ranging from mostly water at the bottom to mostly oil near the top.

The minimum degree of treatment applied to ballast water involves settling only. This can be carried out in the ballast water tanks. Such tanks should be equipped with an oil-skimming device, a steam coil (for heating the tank contents), and an air coil (to provide gentle agitation). If a simple chemical treatment is effective, provision for injecting treating agents may be included.

Following the settling period, as much of the separated oil as possible should be skimmed before the settled water is released from the tank. Prior to discharge from the tank, the settled water should be tested for oil content to determine the best method of disposal. During discharge, the appearance of the water should be checked. Release of settled water should be stopped before the emulsion of oil-water interface is reached. A safe depth of settled water should be left in the tank when withdrawal is stopped. In some cases, a flow breaker may be installed in the discharge line so that flow will cease when the water level in the tank falls to a pre-determined level.

The fuel oil, which has been reclaimed from the ballast water during the collection and treatment process, should be blended with boiler fuel oil for use in shoreside boilers. However, it is important that quality assurance be performed on the reclaimed fuel oil to ensure that it meets the minimum requirements for shoreside boiler fuel. NAVFAC MO-911, "Utilization of Navy-Generated Waste Oils as Burner Fuel," and NAVSUPINST 4100.3B, "Fuel Reclamation," provide guidance for the blending of reclaimed oils with burner fuels for use in shore-based Navy boilers. Sludge accumulated during the collection and treatment of ballast water should be disposed of in accordance with applicable hazardous waste disposal procedures.

**2.9.3 Oil/Water Separators.** The water discharge from storage or settling tanks should pass through an API oil/water separator before being discharged into a water-course or passed on to other treatment processes. The separator should be constructed of reinforced concrete in accordance with NAVFAC DM-2.04, "Structural Engineering Concrete Structures." The separator should be proportioned in accordance with Chapter 5

of API, "Manual on Disposal of Refinery Wastes." Also see NAVFAC NFGS-11301, "Packed, Gravity Oil/Water Separator."

2.9.4 Chemical Injection Systems. In the oil separation process, chemicals are used to help break down the emulsions. These chemicals are pumped to the cooker tank through the chemical feed system. The chemical feed system has three basic elements:

- A dilution tank in which chemical solutions are prepared.
- A mixer that is used to mix the chemical solutions.
- A pump with an adjustable flow rate that pumps the solutions to the cooker tank. Following this final treatment, the ballast water should meet anti-pollution regulations and be acceptable for release into adjacent waterways.

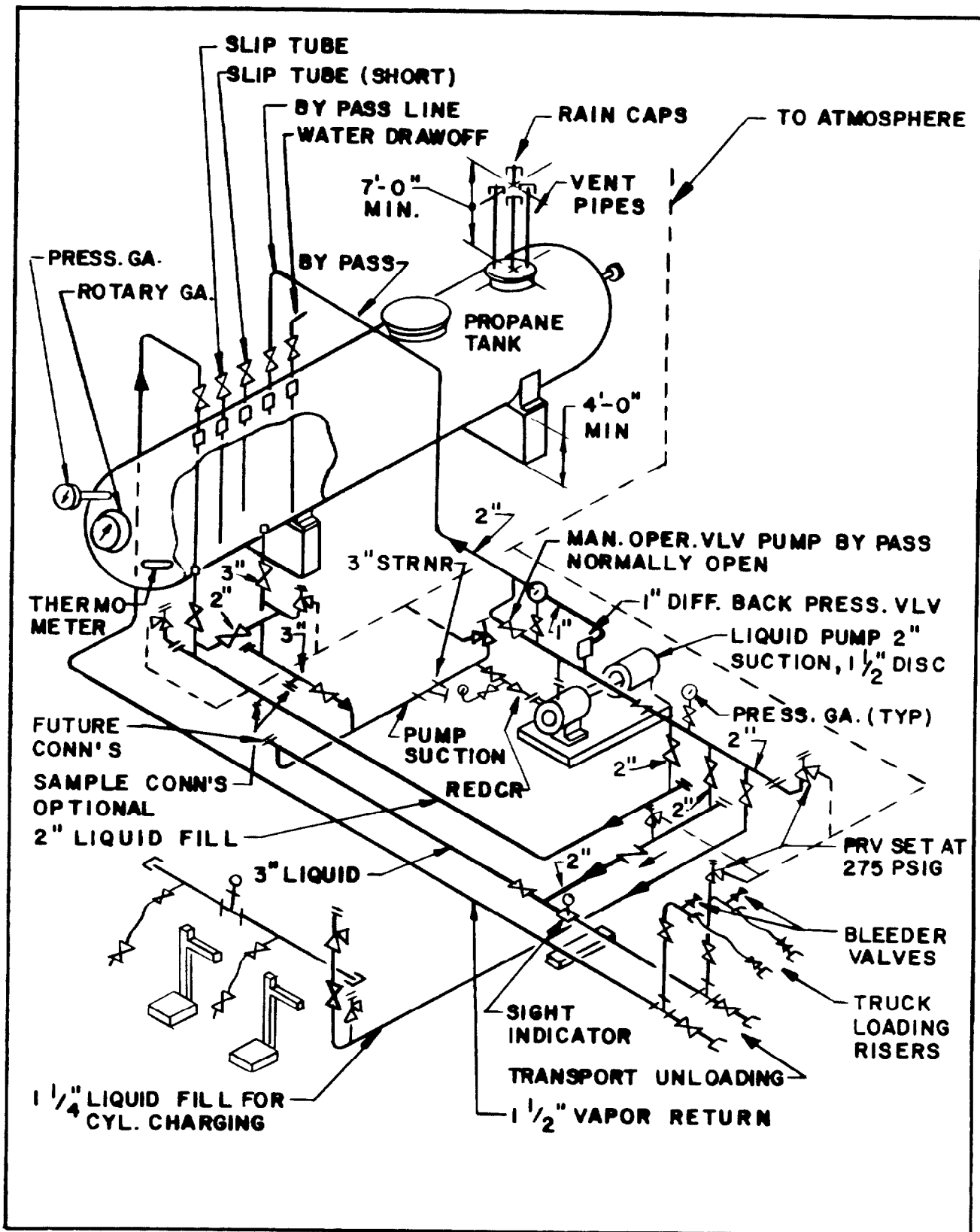
## 2.10 LIQUIFIED PETROLEUM GAS FACILITIES.

2.10.1 Types of Facilities. Liquefied Petroleum Gas (LPG) installations at naval shore facilities may include receiving, storage, distribution, and vaporizing facilities. Further, they may be associated with railroad, truck, or marine loading and unloading racks, or docks, depending on the operational requirements of the activity.

2.10.2 Facility Criteria. Refer to MIL-HDBK-1022, "Petroleum Fuel Facilities," for a complete listing of the applicable references for LPG facility criteria. The following is a partial listing of those standards:

- Standards for the storage and handling of LPG; NFPA 58, "Liquefied Petroleum Gases, Storage and Handling"
- Handbook of Fire Protection; NFPA 59, "Liquefied Petroleum Gases at Utility Plants"
- Design and construction of LPG installations; API Standard 2510, "Design and Construction of LP-Gas Installations at Marine and Pipeline Terminals, Natural Gas Processing Plants, Refineries and Tank Farms," and all standards referenced therein.

2.10.3 Equipment Requirements. LPG systems utilize basically the same types of equipment as standard petroleum systems. Typical LPG transfer/storage systems are illustrated in Figures 2.10.1 and 2.10.2.



**FIGURE 2.10.1**  
**TYPICAL SMALL VOLUME LPG FACILITY FOR TRUCKS & CYLINDERS**

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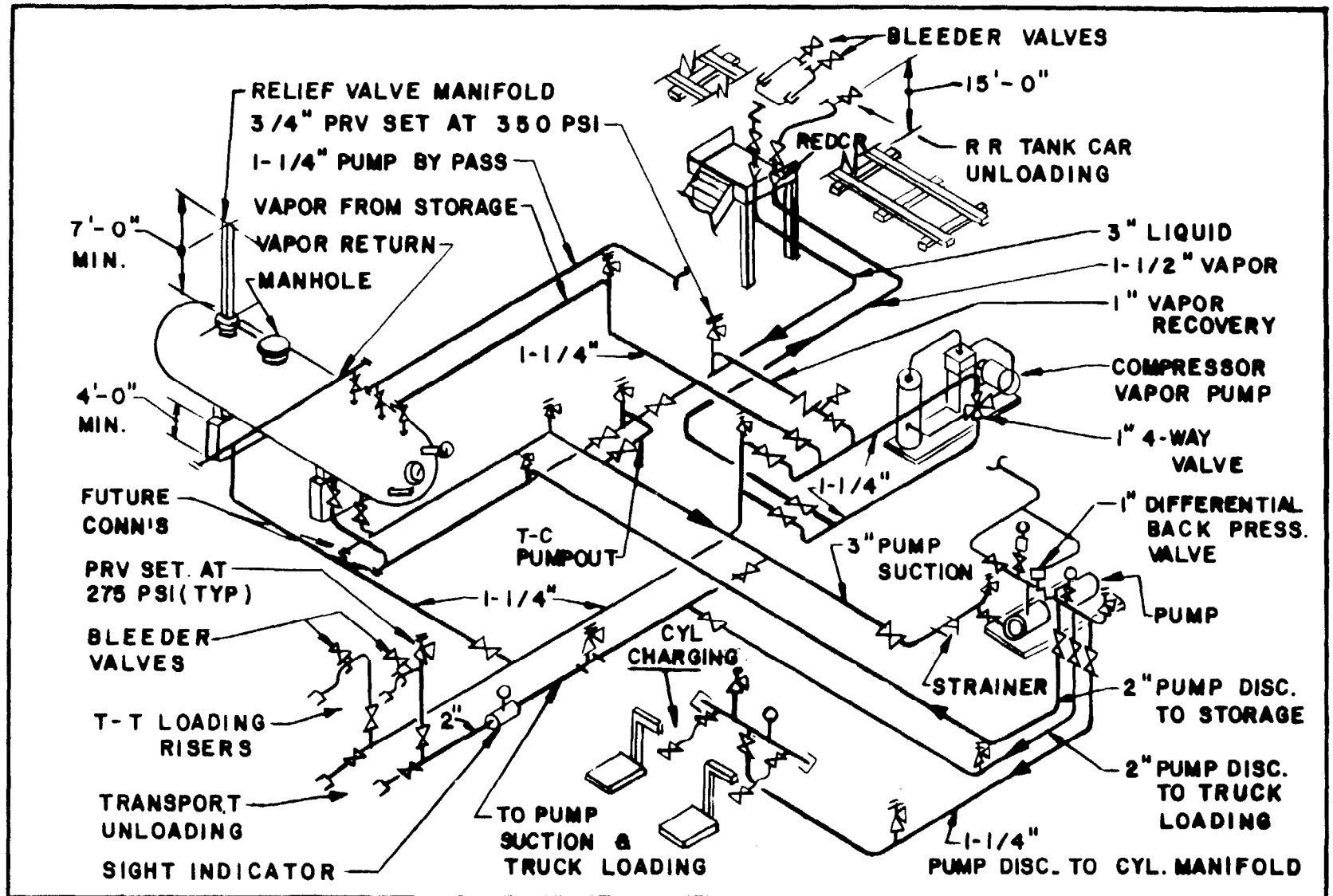


FIGURE 2.10.2

TYPICAL LPG VAPOR COMPRESSION SYSTEM FOR TANK CARS OR WATERBORNE DELIVERIES



## 2.11 FIRE PROTECTION SYSTEMS.

2.11.1 Scope. This section provides general background information about fire protection systems and equipment found in Navy fuel storage/handling facilities.

2.11.2 Classes of Fires. When a fire starts, the extinguishing method and agent used vary with the class of fire. Table 2.11.1 provides general fire fighting guidelines. Section 5.14 provides more in-depth coverage of the maintenance of fire protection systems. It is likely that any fire will involve material from more than one class.

### 2.11.3 Water Based Fire Fighting Systems.

2.11.3.1 Water Stream Systems. Water streams from hose nozzles or monitors are useful on petroleum fires only for cooling surfaces or equipment (for example, the shell of a tank that is adjacent to a fire). Since free oil will float on the surface of water, its usage may spread the fire unless it is carefully controlled and contained in dikes, drains, or similar enclosures. Water streams should be used on petroleum fires only under the direction of experienced fire fighters.

Either fresh or salt water may be used for fire fighting. Fresh water is preferred, if available, because it is less corrosive. Fire pumps usually take suction directly from an adjacent river or bay, but other common sources of water are public or private water distribution systems, reservoirs, wells, ponds, or special fire water storage tanks.

Water should be available in sufficient quantity and at the appropriate pressure for its intended purpose. Pressure is available from the residual pressure of the source system or from stationary fire pumps, elevated storage tanks, truck pumps, fire boats, or any combination of these.

2.11.3.2 Fog Systems. Fog systems employ special nozzles or heads, much like shower heads, that atomize the water into small drops before application to a fire. Fog systems require nozzle pressures of 100 psi or more to develop a very fine mist that flashes into steam in the heat of a fire. The combined cooling and smothering effect of water fog can protect fire fighters, structures, and equipment from petroleum fires and control the fire to the point that it can be extinguished by portable foam or a similar apparatus.

2.11.4 Halogenated Gas Systems. Halogenated gas systems are usually used in fighting fires caused by gaseous or liquid flammable materials, energized electrical circuits, and surface burning combustible solids, or when high value objects or processes need protection. Primarily, Halon 1301 and Halon 1211 are in general use in the United States today.

CLASS	TYPE OF MATERIAL	EXTINGUISHING AGENT OR ACTION	AFFECT	COMMENTS
A FLAMMABLE SOLIDS	WOOD, PAPER, CLOTH, PLASTICS, VEGETATION	WATER FOG	PRIMARY: COOLING SECONDARY: STEAM DISPLACES OXYGEN	ENSURE ELECTRICAL POWER SECURED
		CARBON DIOXIDE	DISPLACES OXYGEN	SMALL FIRES
B FLAMMABLE LIQUIDS	OIL, GASOLINE, KEROSENE, PAINT, GREASE	FOAM	OXYGEN STARVATION	BEST METHOD
		CARBON DIOXIDE	DISPLACES OXYGEN	EFFECTIVE IN SMALL, ENCLOSED AREAS
		WATER FOG	COOLING	WATER MAY FLOAT OIL AND SPREAD FIRE
C ELECTRICAL	MOTORS, CABLES, SWITCHBOARDS, DISTRIBUTION PANELS, TRANSFORMERS	SECURE POWER	BECOMES CLASS A FIRE: COMBAT WITH CARBON DIOXIDE TO DISPLACE OXYGEN	DO NOT USE WATER ON ELECTRICAL EQUIPMENT
D FLAMMABLE METALS	PHOSPHOROUS, SODIUM, ALUMINUM, MAGNESIUM	WATER	COOLING	UNLIKELY TO ENCOUNTER IN FUEL FACILITIES, EXCEPT FOR AIRCRAFT FUELING FACILITIES
		SAND IMMERSION	OXYGEN STARVATION	
	SODIUM	SAND IMMERSION	OXYGEN STARVATION	NO WATER

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TABLE 2.11.1  
SUMMARY OF FIRE CLASSES AND EXTINGUISHING AGENTS

Halon 1301 is generally used in total flooding or local application systems. Current Navy practice, per MIL-HDBK-1022, does not allow the installation of Halon systems for use at petroleum fuel facilities. Any Halon systems that are in use should be maintained in accordance with equipment technical manuals.

Halon 1211 is normally used in portable extinguishers which do not allow a significant concentration to develop when used. This is because Halon 1211 is toxic to people when concentrations exceed 4 percent. When discharged from the extinguisher, the Halon 1211 is in the form of a gas/mist which inhibits the chemical reaction of the fuel with oxygen.

**2.11.5 Foam Systems.** Foam solutions for fighting fires are specifically designed to extinguish Class B, flammable or combustible liquid fires. They can also be used safely on Class A fires; but because the foam solution contains over 94 percent water, it is not safe for use on Class C (electrical) fires. A foam solution is a mixture of one or several different types of foam concentrates with fresh or salt water. When foam is applied to a fire through special nozzles or chambers, it makes a frothy blanket of bubbles containing air or gas, which floats on the surface of the burning liquid. The foam extinguishes the fire by separating the air from the flammable vapor and containing the vapor.

**2.11.5.1 Chemical Foam.** Chemical foam is the oldest and least efficient foam. It is still used in some older Navy installations but is gradually being replaced. The water used may be fresh or salt and normally comes from the same source as that for the fire water system. In such cases, the fire water system should have enough capacity to satisfy the maximum capacity of the foam system, plus three or four cooling streams. Normally, a booster pump is required to supply enough pressure to operate the foam system.

The foam concentrate chemicals used in a chemical foam system are two separate dry powders called "A" powder and "B" powder. They are actually bicarbonate of soda and aluminum sulphate or some similar combination, plus a foaming agent. The chemicals are normally stored dry in sealed cans; but when very large quantities are required, they are in larger hopper-type bulk containers.

**2.11.5.2 Mechanical Foam.** Mechanical foam systems, also called air foam systems, use a single liquid chemical foam concentrate. Foam is formed just prior to the point of application by mixing the foam-water solution with air. Only a single foam solution pipe to each foam chamber or hydrant is required. The amount of foam concentrate injected into the water stream is automatically regulated by a mechanical foam proportioning system. This type of system can also be modified to use Aqueous Film Forming Foam (AFFF), or protein foam. AFFF

is preferable as it forms a more stable foam and creates a more permanent seal between air and the fuel.

2.11.6 Portable Extinguishers. Portable fire extinguishers are located throughout the fuel facility for quick access during a fire emergency. These fire extinguishers may be of the following types:

- Plain water or antifreeze solution, pump type
- Pressurized water (loaded stream) type
- Soda-acid and chemical foam type
- Carbon dioxide (CO<sub>2</sub>)
- Dry chemical
- Halon 1211.

Before using a portable fire extinguisher, be sure to read the instructions to verify that the extinguisher is the appropriate type for the class of fire occurring.

2.11.7 Other Fire Extinguishing Systems. Other systems present in fuel facilities to combat fires include:

- Fixed CO<sub>2</sub> flooding systems
- Dry chemical systems
- Sand
- Fire blankets
- Steam smothering systems.

## CHAPTER 3. ENVIRONMENTAL PROTECTION

3.1 INTRODUCTION. The Navy is actively committed to protecting and enhancing the quality of the environment by preventing and controlling pollution resulting from the use and operation of Naval petroleum fuel facilities.

Executive Order 12088 requires DOD to comply with environmental laws and regulations. There are several regulations that directly impact the handling and storage of petroleum products. The regulations include the following:

- Procedures for storage and handling
- Development and implementation of emergency plans
- Registration of underground storage tanks.

Individuals who violate environmental regulations may be subject to serious civil and criminal penalties, including fines and jail terms. For example, violations of Environmental Protection Act regulations may result in fines and/or mandatory jail sentences for owners and operators.

The Navy's environmental protection program is set forth in OPNAVINST 5090.1. This instruction should be used as the primary guide in dealing with all environmental matters. The organization assigned to assist Navy environmental shore activities is NAVFACENGCOM. Fuel facilities will usually deal with the NAVFACENGCOM EFD designated as the focal point for site-specific environmental assistance in their area. The NAVPETOFF also provides technical guidance related to environmental matters.

Some Navy environmental references on fuel operations are:

- |                   |  |
|-------------------|--|
| OPNAVINST 5090.1  | - Environmental and Natural Resources Protection Manual  |
| NAVSUPINST 4100.3 | - Fuel Reclamation Program   |
| NAVFACINST 6240.3 | - Department of the Navy Pollution Control Reports; Responsibilities and Guidance on Reporting of Oil Spills |
| NAVFAC P-908      | - Oil Spill Control for Inland Waters and Harbors  |

NAVPETOFFINST 4025.2- Handling, Storing, Recycling and/or  
Disposing of Contaminated Low Flash  
Petroleum Products

NAVFAC MO-911 - Utilization of Navy-Generated Waste  
Oils as Burner Fuel

3.2 OVERVIEW. This chapter provides information to help maintain compliance with environmental regulations. The chapter contains the following:

- A summary of each environmental law and regulation that applies to petroleum fuel facilities
- The applicable regulatory citation.

This chapter focuses on federal environmental regulations; however, many states and some local governments have enacted programs that are more stringent than federal requirements. EFDs will help determine specific requirements in their jurisdiction. Specific questions on any of the regulations in this chapter should be referred to your activity's Environmental Coordinator (EC) or EFD.

3.2.1 Environmental Programs. The following environmental programs are discussed in this chapter:

- Clean Air Act
- Clean Water Act
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) ("Superfund")
- Resource Conservation and Recovery Act (RCRA) (Hazardous waste management) including Hazardous and Solid Waste Amendment of 1984.
- EPA Underground Storage Tank (UST) Regulations
- U.S. Coast Guard Oil Spill Regulations.

Reference to the environmental laws and regulations governing these programs is taken from the Code of Federal Regulations (CFR), Chapters 40 (Protection of the Environment) and 33 (U.S. Coast Guard Rules).

### 3.3 ENVIRONMENTAL PROTECTION REGULATIONS.

3.3.1 Effects of Petroleum Fuels on the Environment. There are several ways in which petroleum products can affect the environment. Two of these pathways are more common and important than the others from an environmental protection point of view: air pollution and water pollution.

3.3.1.1 Air Pollution. The Clean Air Act will eventually be changed to control volatile organic compounds (VOC). VOC emission limits may require new vent and tank controls. Petroleum products, especially fuels with low flash points such as gasoline and JP-4, evaporate very easily. This property causes losses to the environment during transfer operations when the air inside a tank that contains some evaporated fuel is displaced or pushed out a vent (this is called working loss).

The same kind of evaporation loss occurs as an above-ground tank heats up on a sunny day and cools down during the night. Some of the air inside the tank is pushed out the vent as it heats up and expands during the daytime. Conversely, fresh air is pulled in as the tank cools at night (this is called breathing loss).

Other kinds of air pollutants (incompletely burned fuel, carbon monoxide, etc.) are generated by burning fuels in engines and boilers, especially when engines are improperly tuned or boilers are improperly fired.

3.3.1.2 Water Pollution. Most often, water pollution resulting from the storage and transportation of petroleum fuels is caused by accidental releases. Fuel and oil can be released not only to surface water such as rivers and streams but also to ground water (especially from leaking underground storage tanks and pipelines). The most common reasons for such releases are defective equipment or facilities and improper operation.

Many environmental protection laws passed in recent years directly affect petroleum fuel facilities. Federal, state, and local regulations under these laws have requirements that vary from place to place.

Activities should refer to the applicable instructions governing environmental regulations. The EFD for your activity can provide assistance in doing this.

3.3.2 Clean Air Act (Reference: 40 CFR Part 50 to Part 99). The Clean Air Act establishes emission limits for specific materials such as particulates and sulfur dioxide and permit requirements for sources of air pollution such as boilers and stacks. Source-specific permits can be issued by the state and/or local air quality control agencies. In general, requirements can be classified according to whether the source is stationary or mobile. Environmental requirements for these two types of pollution sources normally are regulated at the state and local level. Any unit or process that could produce air emissions may be subject to permit requirements. Permits may be required to construct, modify, or operate a source. Operating permits may include emission standards, operating conditions (including performance testing), and record-keeping requirements.

The Clean Air Act applies to petroleum fuel facilities as follows:

- The act establishes guidelines for the storage of petroleum products.
- Some tanks may be required to be equipped with an internal floating roof, an external floating roof, or closed vent (vapor recovery) system.

Many states, and some local governments, regulate a large number of toxic air pollutants. Check with your EFD to determine whether your facility is covered under any air toxins control programs.

3.3.3 Clean Water Act (Reference: 40 CFR Part 100 to Part 149). The Clean Water Act (formerly the Federal Water Pollution Control Act) regulates the quality of surface water in the United States.

Under the Clean Water Act, petroleum fuel facilities may be affected by the following requirements:

- National Pollution Discharge Elimination System (NPDES) permits for direct discharges to surface waters and for discharges to sewage treatment facilities.
- Spill Prevention, Control and Countermeasure (SPCC) plans for facilities having the potential to spill oil into navigable waters.
- Notification and cleanup of oil spills.
- Monitoring requirements.
- Controls on discharges from tanks.

If your activity wishes to discharge wastewater into any body of water, you will need an NPDES permit. These permits require a high degree of technical input and meetings with the state and/or local permitting agency. Contact your EC and geographic EFD for assistance in obtaining an NPDES permit prior to discharging to any body of water or Publicly Owned Treatment Works (POTW).

#### 3.3.3.1 Oil Spills.

- The Clean Water Act prohibits the discharge of oil into surface waters.
- If a spill occurs, contact the facility EC. The EC must immediately notify the National Emergency Response Center (800-424-8802).



- Facilities that have spilled, or have the potential to spill, oil into waters must prepare an SPCC plan covering the following:

- Facility drainage
- Bulk oil storage tanks
- Transfer operations and pumping
- Tank car and truck loading and unloading
- Oil spill reporting
- Oil spill containment and cleanup surveys
- Pollution abatement.

3.3.4 RCRA (Hazardous Waste Management); (Reference: 40 CFR Part 240 to Part 280). RCRA regulates the management of hazardous waste from the point of generation to its elimination or disposal. The RCRA program accomplishes the following:

- Defines which solid wastes are hazardous such as tetraethyl lead (TEL) (from leaded fuel tanks sludge), general ignitable wastes (flashpoint <141<sup>o</sup>F), waste with contaminant limits above criteria (i.e., mercury .002 mg/L, lead .05 mg/L)

- Establishes requirements for individuals who handle hazardous waste, including:

- Generators
- Transporters
- Treatment, storage, and disposal facilities.

3.3.4.1 Hazardous Waste Definition. Generating, collecting, storing, and disposing of hazardous waste are extremely complicated environmental issues (see OPNAVINST 5090.1, Chapter 11). A very general definition of hazardous waste is any discarded material (liquid, solid, or gaseous) that because of its quantity, concentration, or physical, chemical, or infectious characteristics, may pose a substantial hazard to human health or the environment when released or spilled. In addition to this general definition, the EPA and state regulatory agencies have classified certain substances as hazardous by definition (for example, TEL). Potential hazardous wastes of concern to fuel terminal personnel are slop fuels and tank bottom sludges. Due to the complicated nature of hazardous waste regulations, the storage or disposal of these substances, whether on-site or off-site,

should be coordinated with the local hazardous waste coordinator and the EFD office.

RCRA applies to petroleum fuel facilities as follows:

- Tank sludge bottoms from leaded gasoline and aviation fuel tanks contain TEL and TML, see Section 1.2.4.2. When disposed of, this sludge must be managed as a hazardous waste. Be very careful around this material; it is extremely dangerous. No one should enter a storage tank that has contained leaded fuels without special personal protective equipment (PPE) and proper training.

- In some states, used oil is regulated as a hazardous waste. Contact your EC or EFD to determine your state requirements.

3.3.5 CERCLA (The Superfund Program) (Reference: 40 CFR Part 300 to Part 302). CERCLA regulates response activities regarding the following:

- Releases of hazardous substances and oil
- Clean-up of sites contaminated by hazardous substances.

Under CERCLA, the U.S. Congress established the National Oil and Hazardous Substances Pollution Contingency Plan ("National Contingency Plan" or NCP). The NCP ensures that the requirements under the Clean Water Act and CERCLA are followed when oil or hazardous substances, respectively, are spilled. Petroleum facilities may be subject to the following requirements under CERCLA and NCP:

- Releases of oil must be reported to the National Emergency Response Center (NRC) by the EC, or EFD, for the facility; (operators should notify the EC).

- The NRC will designate an On-Scene Coordinator (OSC) to work with the facility or vessel and coordinate clean-up of the spill.

- Spills requiring marine salvage must be supervised by the OSC.

- Residues from the spill may be considered hazardous. Hazardous wastes must be sent to a permitted facility for treatment, storage, and disposal.

3.3.6 EPA Underground Storage Tank Regulations (Reference: 40 CFR Part 280). The UST regulations apply to tanks used to store or accumulate "regulated substances," including petroleum.

3.3.6.1 Applicability. UST regulations apply to any activity meeting the following criteria:

- The activity owns or operates an underground storage tank
- The underground tank stores a "regulated substance."

3.3.6.2 Definition of an Underground Storage Tank.

- Tank or tanks (including underground pipes connected thereto) which are used to contain an accumulation of regulated substances and the volume of which (including the volume of the underground pipes connected thereto) is 10 percent or more beneath the surface of the ground [40 CFR 280.10 (b)].

- Certain tanks are specifically excluded from regulation as USTs under federal regulations, including (but not limited to):

- Heating oil tanks for oil used on premises where stored (included in some states)
- Septic tanks
- Pipeline facilities under specific regulations
- Surface impoundments, pits, and ponds
- Storm water or wastewater collection systems
- Flow-through process tanks
- Storage tanks in basement or other vault-like places where tanks can be inspected.

3.3.6.3 Definition of a Regulated Substance.

- Any substance defined as a "hazardous substance" in CERCLA, except RCRA hazardous wastes.

- Petroleum, including crude oil or any fraction thereof that is liquid at standard conditions of temperature and pressure.

3.3.6.4 Compliance. The UST regulations affect operations that:

- Currently use a regulated underground storage tank

- Plan to install an underground tank in the future
- Currently have tanks in the ground (even if not in use).

3.3.6.5 Overview. The purpose of the UST portion of the Hazardous and Solid Waste Amendments of 1984 is to correct the serious problem of ground and ground water contamination caused by petroleum or hazardous waste leaking from underground tanks. The UST program requires that activities:

- Compile an inventory of tanks and notify appropriate state agencies
- Install leak detection and monitoring systems
- Notify state agencies of leaks and develop restoration programs to correct them.

#### 3.3.6.6 Notification Requirements.

- Notification is required for all USTs in the ground as of May 8, 1986, or brought into use after May 8, 1986.

- Notification forms are available from the state environmental protection agency. Specific notification requirements can be obtained from your EFD. Always check with the activity EC before completing notification forms.

- UST information required on notification form includes:

- Ownership
- Location
- Status
- Age
- Capacity
- Configuration
- Use.

### 3.3.6.7 Deadlines for Notifying State Agency.

- For newly installed tanks, owners must notify the designated state agency 30 days prior to installing the tanks.

- Owners of tanks currently in use were required to notify the designated state agency on or before May 8, 1986.

- Owners of tanks taken out of service after January 1, 1974, but remaining in the ground were required to notify the appropriate state agency by May 8, 1986.

- No notice is required for tanks taken out of service before January 1, 1974 (even if they are still in the ground).

3.3.7 United States Coast Guard (USCG) Oil Spill Regulations (Reference: 33 CFR Part 153 to Part 157). USCG regulations are intended to ensure that the proper steps are taken toward safe and efficient operations during emergency and non-emergency situations involving oil and hazardous substances. The following regulations apply only to marine petroleum fuel loading facilities:

- During an oil transfer, two-way voice communication must be maintained between the vessel and the facility, and the vessel must have a means of stopping the flow of oil.

- When transferring in a highly sensitive area, the vessel must be surrounded with oil containment material prior to transfer.

- When transferring in an area not meeting ambient air quality standard for ozone, the vessel's hydrocarbon vapors must be controlled.

- When discharging ballast, the ballast must be verified to be clean.

- When removing oil after a spill, the facility or vessel responsible must perform the following actions:

- Control the source of the discharge

- Minimize secondary pollution

- Dispose of waste in accordance with state and local requirements.

### 3.4 SPILLS, LEAKS, AND GENERAL RESPONSE.

3.4.1 Types of Leaks and Spills. There are many different types of spills that may occur at a petroleum fuel facility. A spill or "release" may occur due to any of the following:

- Leaking underground storage tanks
- Leaking above-ground storage tanks
- Pump failure
- Accidental occurrence (for example, a truck backing into a storage tank or a pipe)
- Operator error (a valve is left open)
- Spill during fuel transfer operations.

3.4.2 Typical Response Procedures. The following section discusses the most important aspects of response to a spill or leak of oil or hazardous substances. First, sources of information regarding detailed procedures are discussed. This is followed by descriptions of the duties of the EC during a spill event and procedures for containing a spill, notifying authorities, and cleaning up a spill. Available options for disposal of collected material are explained in the final section.

General safety precautions to follow in the event of a spill include the following:

- Always approach a spill from upwind.
- Do not touch any spilled material (avoid direct and indirect contact).
- Remove or extinguish all possible ignition sources (do not smoke!).
- Restrict access to the area affected by the spill.
- Do not touch any container unless all potential hazards are known.
- Do not approach if any unidentified fuming liquids or gases are present (due to chemical or physical reactions).

3.4.2.1 SPCC Plans. As mentioned in Section 3.3.3, the Clean Water Act requires petroleum fuels facilities that are near water and have aggregate above ground storage of 1320 gallons or more of oil (provided no single container has a capacity in excess of 660 gallons), or have a total underground storage capacity of 42,000 gallons or more to have an SPCC plan.

An SPCC plan is a manual for operating the facility in a way that decreases the possibility of a spill as well as a detailed design for handling any spills that do occur. This plan requires that necessary equipment not be taken off site. In other words, all equipment necessary for preventing spills and equipment used for cleaning up spills must be maintained on site at all times.

In addition to having the SPCC plan, a Spill Contingency Plan (SCP) is designed to aid the Navy On-Scene Coordinator (NOSC) in responding to spills. It should be prepared according to the Oil Spill Contingency Planning Manual (NEESA 7-029 Part II), which is available from EFD offices. The SCP contains details of the following aspects of spill response:

- Response procedures
- Base instruction that implements the SCP
- Spill response organization
- Site-by-site response plans (for potential spill sites at the facility).

The SCP also contains several other sections that provide important references in the event of a spill; these are listed below:

- List of contacts
- Available equipment
- Contracts
- Response centers
- Reports and documentation
- Sampling

- Disposal
- Dispersants
- Non-Navy spill response policies and

procedures.

The Fire Department at each facility should have copies of both the SPCC Plan and the SCP since it is responsible for assisting in any spill response and should be thoroughly familiar with the contents of these plans for the activity.

3.4.2.2 Facility Environmental Coordinator (EC)/Navy On-Scene Commander (NOSCDR). The identification and assessment of a spill are conducted by the facility EC or the NOSCDR. ECs/NOSCDRs are usually billeted under the Public Works Division. Their duties include the following activities:

- Assessing hazards to human beings and the environment
- Monitoring potentially hazardous situations
- Preventing the spread of hazardous substances
- Providing notification (both oral and written) to all appropriate agencies
- Ensuring that general safety precautions are followed by people responding to spill as well as by any bystanders.

When identifying a spill and assessing its potential impact, the EC should use any available information including help from shipping papers, placards, and labels on individual containers or tanks. Appropriate information includes the following:

```
*****
*                               WARNING                               *
*  DON'T FORGET:  When working around a flammable spilled      *
*  material, the possibility of a fire or an explosion must      *
*                               always be considered.           *
*****
```

- Identification of the spilled material
- Appearance and odor of pure material
- A statement of hazards involved and instructions for safe handling



- Emergency procedures and precautions
- Fire fighting procedures and precautions.

3.4.2.3 Containment. Spill containment response procedures are an essential part of controlling the flow of a spill, as well as controlling the size of the area eventually covered by a spill. However, operators should not try to contain spills that are very dangerous to them personally or to people in the immediate area of a spill. The EC should be contacted first; then operators may try to contain a major spill until the EC arrives to oversee containment and subsequent clean-up activities.

Stopping the flow of a release should be done safely and as soon as possible. This may be as simple as closing a valve or tightening a fitting or may involve temporarily plugging a leak.

When the leak cannot be stopped at the source, an artificial containing barrier should be set up to contain the spill or redirect its flow. On land, this may include diking, sandbagging, or allowing the spilled material to flow into a closed sump. Obviously, different containment equipment and procedures will be used on water; booms, flow guides, curtains, absorbers, and skimmers can be used to hold back such spills.

3.4.2.4 Contacting Appropriate Agencies. Notification regarding releases of oil or petroleum products is the responsibility of the EC. Operators should contact the facility EC immediately after they detect a spill or leak. The facility Fire Department should also be notified immediately if a potential for fire or explosion exists.

After receiving notice of a spill, the EC will immediately contact appropriate facility support services (for example, the Security and Fire Departments). The facility Security Department should be notified if evacuation of affected personnel or control of spectators is required. The NRC (described under CERCLA in Section 1.3.5) should then be notified as well as any other authorities identified in the SCP and SPCC Plan.

3.4.2.5 Clean-up. Clean-up procedures should be followed after a release has been contained. The facility EC should coordinate these activities.

3.4.2.6 Disposal of Contaminated Materials. Disposal procedures should be followed after a release has been cleaned up. The facility EC should coordinate these activities.

Every fuel facility has a requirement to respond to oil spills. The types of spill control equipment and quantities at each facility are set by the activity, validated by the EFD, and verified by the NOSCDR.

The Annual Allowance and Requirements Review (AARR) is an inventory by activity of COMNAVFACENGCOM-procured oil spill clean-up equipment and its condition. Verification of the inventory worksheets is required annually. Since it is the basis for developing and justifying the budget for funding initial outfitting and equipment replacement, care in completing each annual update is essential. The Naval Energy and Environmental Support Activity (NEESA) Port Hueneme, California, is assigned the responsibility for inventory management and reporting of oil spill equipment, oil spill equipment procurements, and emergency stock issues.

3.5 OIL SPILL RESPONSE. Basic step-by-step procedures to be followed in the event of an oil spill are as follows:

- Contact site EC/NOSCDR
- Contain spill according to directions of EC/NOSCDR
- Clean up spill under direction of EC/NOSCDR
- Complete survey to account for fuel loss on DD200 form.

3.5.1 Training. Specialized training in fire and spill control and oil skimmer use will provide greater detail on specific response and clean-up procedures.

3.5.1.1 Fire and Spill Control Drills. Fire and spill control drills will be addressed periodically, either during stand-up safety training or separately. In addition to this classroom training, actual fire and spill control drills will be conducted quarterly. These drills should be conducted by the facility Fire Department. At a minimum, the following will be addressed:

- Fire and spill reporting procedures
- Review of exit routes for employees and equipment
- Location and use of spill containment materials and equipment
- Location and use of fire fighting equipment and materials.

Selected personnel should receive instruction in the use of all fire fighting equipment available at the terminal. All fuel terminal personnel must be instructed in fire prevention and in basic fire fighting techniques. Refresher training supplemented by fire fighting practice will be held. Drills should include what actions have to be initiated to close valves, stop pumps, and contain spills. This is the first line of defense in containing any fire.

3.5.1.2 Oil Skimmer Training. There are two types of training programs in oil skimmer use. The first type provides on-site, hands-on and classroom training for oil spill personnel in the deployment, use, and retrieval of oil spill control equipment. This type of training is normally coordinated by the NOSC and NEESA. The need for this type of training should be pointed out to the local NOSC. The second type of training is directed toward facility personnel who operate and maintain the large DIP 3001 oil skimmer. This course is offered twice annually, once at NCBC Port Hueneme, California, and once at the Naval Station in Annapolis, Maryland. Requests to attend this course should be directed to NEESA. In addition to these forms of formal training, each facility should hold regular training sessions on how to deal with spills and how to deploy and use spill clean-up equipment and materials.

3.5.2 Dispersants vs. Coagulants. Dispersants are substances (such as soaps or surface agents) that break up oil slicks into smaller areas. Coagulants make oils spilled on water come together into clumps for easier retrieval. It is usually illegal to use dispersants when cleaning up oil spills. Consult the EC before using coagulants or dispersants on spilled oil.

3.5.3 Preventive Measures. The most effective way of controlling oil spills is by never letting them happen. Ensuring dike valves are closed, regularly inspecting equipment, replacing faulty or worn equipment, and general good housekeeping procedures are all measures that will help to prevent the occurrence of an oil spill.

## CHAPTER 4. FUEL FACILITY MAINTENANCE PROGRAM

4.0 OBJECTIVE. This chapter addresses types of maintenance and the personnel who perform it, the documentation required to successfully manage maintenance and inspections, and the development of a tailored maintenance plan for equipment and facilities at individual fuel depots and terminals. Instead of providing specific information for specific facilities or types of equipment, the chapter focuses on general maintenance and inspection concepts. It provides a guide for the development of a unique maintenance plan that can be tailored to the specifics of an individual shore activity. Further discussion of planned maintenance programs can be found in NAVFAC MO-321.

4.1 TYPES OF MAINTENANCE. Maintenance can be broken down into four categories that relate to the way the maintenance requirements are accomplished.

4.1.1 Preventive Maintenance. This category involves inspection and servicing of equipment at specified time intervals: this includes the day-to-day effort required to keep a facility, piece of equipment, or system functioning. The intent of preventive maintenance is to reduce equipment downtime by anticipating problems and taking necessary actions to prevent them. Preventive maintenance actions are usually low in cost and have minimal impact on the resources of ongoing fuel terminal operations. Preventive maintenance is often performed by operators rather than maintenance personnel. However, preventive maintenance should be formalized to meet specific maintenance standards and schedules. Although preventive maintenance usually requires little investment of material resources, it is very labor intensive. Therefore, managers should ensure that preventive maintenance is consistent with maintenance needs.

4.1.2 Predictive Maintenance. Predictive Maintenance involves equipment condition monitoring along with data tracking and trending to predict failures. Condition monitoring information is gathered from vibration monitoring, infrared imaging, oil and wear particle analysis, ultrasound detection, and other non-destructive testing. Predictive maintenance information is scanned, by computer analysis software or other methods, and potential problems are diagnosed. A technician tracks the severity of problems, orders necessary parts and schedules maintenance accordingly. Depending on the severity, equipment with problems can be scheduled for repairs during the next outage or taken out of service immediately. With this method, breakdown maintenance is avoided.

4.1.3 Corrective Maintenance. Corrective maintenance involves the planned replacement of material or components that have worn down or failed, causing a degradation of the ability of a system to operate at full capacity. This category includes maintenance efforts that are more involved than preventive maintenance. Corrective maintenance is nearly always accomplished by maintenance technicians rather than operators. Depending on the nature of the system and workload of the terminal, corrective maintenance may require expedited scheduling (Critical) , or it may be postponed for a long period of time with no significant impact on operations (Deferrable). Often, many small corrective maintenance efforts are planned at one time, thus minimizing total downtime of the system.

4.1.4 Breakdown Maintenance. Breakdown maintenance is implemented when there has been an unplanned material condition failure of a system. It is the most costly type to perform because it cannot be routinely planned. Maintenance personnel must react to breakdown situations immediately, interrupting other planned work. Proper spare parts or other materials may not be readily available, causing a need to substitute less adequate material or cannibalize some other system. Additionally, a system failure that results in the need for breakdown maintenance may cause fuel spills, fire, injury, delay in mission, or other major problems. Prevention of the need for breakdown maintenance is the goal of the maintenance program. If preventive and corrective maintenance are performed in a reasonable manner, breakdown maintenance can be minimized; however, it can never be eliminated.

4.2 PERSONNEL. Various personnel are involved in the maintenance of fuel facilities and equipment. Some of these personnel are associated directly with the fuel terminal or fuel department, while others belong to the shore activity public works organization or another Navy or contractor organization. The efforts of these organizations should be coordinated to ensure that all required maintenance and inspections are accomplished with minimal wasted or duplicated effort.

4.2.1 Fuel Operators. Fuel operators are assigned to operate fuel transfer and delivery equipment and are, therefore, a prime source of information on the condition of systems and the potential need for maintenance. Operators who are familiar with their systems can readily tell when systems are not performing normally. Additionally, operators are often assigned collateral responsibilities for preventive maintenance of particular elements of the fuel delivery system.

4.2.2 Fuel Maintenance Workers. Personnel in this category are assigned to the fuel terminal or fuel department and have a primary responsibility for fuel system maintenance. Depending on the size of the fuel operation and level of support available from public works, the number of fuel maintenance workers varies by activity. It is important to ensure coordination among fuel maintenance workers assigned to the fuel terminal or department and other maintenance personnel assigned to public works.

4.2.3 Public Works. Depending on the individual shore activity, public works support for the fuel terminal or fuel department is provided by a public works department or public works center. Public works personnel are normally responsible for all major maintenance and repair as well as periodic control inspections of fuel facilities. Additionally, depending on the capability of fuel department maintenance personnel, public works personnel may do all electrical work, welding, machining, and other maintenance tasks that exceed the skill or numerical capability of fuel maintenance workers. Responsibilities of public works personnel and fuel terminal maintenance personnel can easily overlap, thus leading to a duplication of effort; therefore, it is important that managers ensure all parties have a clear understanding of their responsibilities in fuel system maintenance.

4.2.4 Contractors. At some locations, operation and/or maintenance of the fuel system may be performed by contractor personnel. This tends to further confuse the delineation of responsibilities. The maintenance goal remains the same: to provide an acceptable level of maintenance at a reasonable cost.

4.2.5 Others. Periodically, functional experts, either government employees or contractor personnel, are required for specialized repair or inspection of fuel systems and components. They are normally involved in unique, non-repetitive projects, rather than normal, cyclic maintenance.

4.3 RECORDS AND REPORTS. Key to any good maintenance system is adequate documentation of items that must be maintained. The condition of these items must be described, and sufficient nomenclature must be provided to allow ordering of replacement parts. In addition, documentation of maintenance standards and frequencies is essential for planning, executing, and providing quality control of maintenance programs. Records and reports must be tailored to the individual terminal or fuel department, depending on its particular organization and maintenance responsibility. At a minimum, the following types of information should be documented.

4.3.1 Current Maintenance Records. Records should be kept in sufficient detail to document the following information:

- The identity of each major structure, equipment item, group of items, or system
- Current maintenance status of each, including unfunded deficiencies and uncompleted job orders
- Past maintenance history of each, including description and cost of major repairs or replacement
- Additional information, as required, for Annual Inspection Summary (AIS) input
- Recommendations for future programmed repairs or replacements, including estimates of funds or manpower requirements
- Schedules for future inspections, tests, or maintenance procedures where programmed or otherwise required.

4.3.2 Historical Records. Historical records are of particular importance in documenting original, as-built conditions of fuel systems and any subsequent modifications. They become the basis for future planned upgrades or changes. Likewise, original manufacturers' operating and maintenance manuals and parts lists should be preserved. They can be valuable for older equipment whose parts are hard to find. Additionally, historical records sometimes have considerable technical value; the knowledge of the complete maintenance history of a system or piece of equipment can aid in the identification and repairs of failures and the planning of the system/equipment replacements.

4.3.3 Requirements of Other Government Agencies. Records of tests and inspections of certain systems, structures, and equipment components may be required by other government agencies like the Coast Guard, the Environmental Protection Agency, and the Department of Labor. Chapter 3 provides additional information on environmental record-keeping.

4.4 SHORE FACILITY CONDITION INSPECTION SYSTEM. The Navy's shore facility inspection system is detailed in NAVFAC MO-322. The sections that follow provide an overview of key facility inspection issues.

4.4.1 Operator Inspection. In general, the term "operator inspection" refers to the routine examination, lubrication, and minor adjustment of equipment and systems to which a specific operator has been assigned. Additionally, operator inspection includes any effort by an operator to identify equipment or system problems that can be corrected through maintenance by either the operator or maintenance technicians. It is important that operator findings during routine operation,

examination, or inspection be formally documented when further corrective maintenance may be required. In a fuel depot or terminal, operators are most familiar with how equipment and systems should function; therefore, they are in the best position to know when systems or equipment are not operating normally and may need maintenance.

4.4.2 Preventive Maintenance Inspection. Preventive maintenance inspection is defined as routine examination, lubrication, and minor adjustment of equipment and systems not otherwise assigned to full-time operators. Like operator inspection actions, preventive maintenance inspection actions and findings should be fully documented so that follow-up action can be scheduled.

4.4.3 Control Inspection. Unlike the operator and preventive maintenance inspections that include some routine minor maintenance actions, control inspection refers only to scheduled examinations or testing to determine the material condition of a facility, piece of equipment, or system. Control inspections are normally accomplished by activity public works maintenance control or contractor personnel, rather than by operators or maintainers. The results of control inspections are the primary input to the AIS and are used to generate corrective maintenance job orders. In order to justify adequate maintenance and repair resources, it is extremely important that a well-documented control inspection program be established for the fuel depot or terminal. OPNAVINST 11010.34 series provides background and detailed guidance for preparing an AIS.

4.4.3.1 Frequency. The frequency of control inspections varies, depending on resources available to accomplish the inspections, criticality of the facility or system to be inspected, and age or condition of that facility or system. Appendix B of NAVFAC MO-322, Vol. 1, provides guidance on recommended minimum inspection frequencies.

4.4.3.2 Purpose. The primary purpose of control inspection is to identify and document facility maintenance and repair deficiencies. A secondary purpose is to ensure the adequacy of operator and preventive maintenance inspection efforts. Control inspection highlights inadequate and inconsistent levels of maintenance across all facilities, equipment, and systems of a given shore activity.

4.4.4 Specialized Inspection. A specialized inspection is a scheduled examination of systems or components that require specialized expertise or equipment to determine their condition. The specialized inspection program is administered by engineering field divisions of COMNAVFACENGCOM. Results of specialized inspections should be integrated with findings of the control inspection program in order to determine overall facility condition.



4.5 SPECIFIC MAINTENANCE ACTION PLAN. As discussed in Section 4.2, personnel from a fuel department or terminal, public works, and a contractor may all play a role in fuel system maintenance. The number of personnel in the organization and the physical plant size vary from activity to activity. However, regardless of who performs maintenance and how much maintenance is required, a site-specific maintenance action plan is essential to ensure the highest level of reliability for a given expenditure of resources. The plan must address specific equipment at the activity and specific personnel who will plan, execute, and manage maintenance actions. For each piece of equipment or system, the plan should list specific maintenance and inspection frequencies, areas to check, and any unique features. The plan can be automated on personal computers, or it may rely on schedule boards or cards. The mechanics of how the plans are developed and used depend on the physical plant and management philosophy of each activity. In any case, there must be a plan. The automated PMS program, available from NAVPETOFF, provides a good basis for such a plan. See para 4.6.17.

4.6 RELATED PUBLICATIONS, DIRECTIVES, AND PROGRAMS. Numerous DOD and Navy manuals and directives provide general and specific information that can be helpful to an individual shore activity in developing its specific maintenance action plan. Documents described in the following sections are the most significant references. All of these documents should be included in the library of publications at the activity, either by the public works or fuel terminal personnel. Additional references, including equipment manufacturers' catalogs and instruction manuals, should also be retained (depending on the needs of each activity).

4.6.1 DOD MIL-HDBK-201B, "Military Standardization Handbook, Petroleum Operations". This handbook provides general standards, procedures, and principles for both the operation and operational maintenance of military petroleum handling facilities. It is also intended as a guide for on-the-job training and indoctrination of new personnel. It is not intended to replace Navy Department regulations or operating instructions applicable to any specific facility.

4.6.2 DOD MIL-STD-457A. "Frequency for Inspection and Cleaning of Petroleum Fuel Operating and Storage Tanks". This standard establishes uniform criteria for determining the need for and frequency of interior inspection and cleaning of bulk fuel tanks used in storing and dispensing military petroleum fuels.

4.6.3 NAVFACENGCOM MO-117, "Maintenance of Fire Protection Systems". This publication established standard practices for

inspection, testing, and maintenance of fire protection systems at DOD installations. These practices and procedures are recommended to ensure the safety of personnel and property. The contents include foam, gaseous, and dry chemical extinguishing systems; and fire alarms, automatic sprinklers, and standpipe systems.

4.6.4 NAVFACENGCOM MO-306, "Maintenance and Operation of Cathodic Protection System". This publication establishes recommended practices for the inspection, maintenance, and repair of cathodic protection systems. It is intended for use by activity personnel in the maintenance of cathodic protection systems on facilities, such as underground fuel and water distribution systems, water tanks, and waterfront structures. The principles of operation of cathodic protection systems and the components of typical installations are described. A list of equipment required for both the scheduled inspection and the troubleshooting of improperly operating systems is given. Methods for performing scheduled inspections, performing preventive maintenance, and troubleshooting the systems are also described.

4.6.5 NAVFACENGCOM MO-307, "Corrosion Control". To be published.

4.6.6 NAVFACENGCOM MO-321, "Facilities Management". MO-321 presents the facilities management system for controlling resources utilized for real property maintenance and repair, as well as equipment maintenance, under the responsibility of public works departments. The manual emphasizes overall resource prioritization, work control, long-range planning, productivity, and contract impact on public works. MO-321 is the basic reference for developing a controlled maintenance system within an activity public works department. Where maintenance of fuel systems is accomplished by non-public works personnel, other publications may provide a better reference.

4.6.7 NAVFACENGCOM MO-321.1, "Maintenance Management of Shore Facilities for Small Activities". MO-321.1 presents a condensed and simplified version of the management principles outlined in NAVFACENGCOM MO-321, "Facilities Management"; MO-322, "Inspection of Shore Facilities"; and other related manuals for use at small shore activities. The described systems are basically the same systems promulgated in other facilities management manuals; however, they are adapted to the needs of a small activity that does not have the specialized staff positions, automated data processing equipment, or complex interrelationships that exist in medium and large sized public works departments.

4.6.8 NAVFACENGCOM MO-322, "Inspection of Shore Facilities". MO-322 prescribes the method for accurately identifying the backlog of facility maintenance and repair at a shore activity and quantifying its negative effect on mission

performance. MO-322 addresses procedures for performing control inspection, preventive maintenance inspection, and operator inspection.

4.6.9 MIL-HDBK-1022, "Petroleum Fuel Facilities". This handbook presents criteria to be used by qualified engineers in designing petroleum fueling and dispensing facilities. It describes basic requirements for five major issues: the design of piping systems, pumps, heaters, and controls; the design of receiving, dispensing, and storage facilities; ballast treatment and sludge removal; corrosion and fire protection; and environmental requirements.

4.6.10 NAVFACENGCOS Specification TS-09871, "Lining System, Interior, for Concrete Storage Tanks (for Petroleum Fuels)". This guide specification is intended for use in specifying the requirements for materials, surface preparation and methods of application of epoxy primer, polysulfide/vinylidene chloride copolymer latex blend with fabric reinforcement and precautions to safeguard health and safety while lining concrete tanks for storage of petroleum products.

4.6.11 NAVFACENGCOS Specification NFGS-09872, "Interior Coating Systems Used on Welded Steel Tanks (for Petroleum Fuel Storage)". This guide specification assists in specifying the requirements for coating systems for the interior of welded steel tanks used for petroleum storage. Options are given for coating the entire tank interior or simply coating the bottom and side-wall to the nominal 18 inch height when funds are short. This specification should not be used where there is severe general corrosion (metal thickness less than 1/8 inch) or where there are numerous holes all the way through the steel plate. Such tanks require more extensive repairs followed by the installation of a fiberglass-reinforced lining system. This system is described in guide specification 13661, "Fiberglass Reinforced Plastic Lining System for Bottoms of Steel Tanks (for Petroleum Fuel Storage)," which is discussed in Section 4.6.13 of this manual.

4.6.12 NAVFACENGCOS Specification NFGS-13219, "Cleaning Petroleum Storage Tanks with SOUTH DIV Revision 11/88". This guide specification covers the requirements for interior clean-up of concrete or steel tanks used for petroleum storage.

4.6.13 NAVFACENGCOS Specification NFGS-13661, "Fiberglass Reinforced/Plastic Lining System for Bottoms of Steel Tanks (for Petroleum Fuel Storage)". This guide specification covers a fiberglass-reinforced plastic lining system intended for use in lining the bottoms of severely corroded steel tanks in which all types of petroleum fuels are stored. The lining is for use in tanks where substantial amounts of steel have been lost by corrosion (up to one-half the original thickness

is lost, or an average of four or more pits 1/8 inch deep or greater occur within a 3 foot radius). The lining is also intended for use over concrete false bottoms in steel tanks.

4.6.14 NAVFACENCOM P-717.0, "Engineered Performance Standards for Real Property Maintenance Activities, Preventive/Recurring Maintenance Handbook". The handbook provides guidance for applying Engineered Performance standards to typical preventive maintenance tasks, including those required on fuel systems.

4.6.15 NAVAIRSYSCOM, NAVAIR 06-5-502, "Aircraft Refueling for Shore Activities". This technical manual provides information on fuel handling practices and equipment used in retail fuel operations at aviation shore activities.

4.6.16 NAVSUPSYSCOM PUB 558, "Fuel Management Ashore". This publication provides petroleum managers and operators with the necessary guidelines, general knowledge, and references to operate and maintain petroleum facilities.

4.6.17 NAVPETOFF Fuel Preventive Maintenance System (PMS). NAVPETOFF has developed an automated PMS program for fuel system equipment. The system is based on the Navy's 3M maintenance philosophy and is available to all interested activities. Contact NAVPETOFF Headquarters for further details.

## CHAPTER 5. MAINTENANCE

5.0 OBJECTIVE. This chapter provides preventive maintenance requirements and procedures for fuel facility systems and equipment. Additionally, troubleshooting guides and repair practices are described when necessary. The information contained in this chapter should be used in conjunction with applicable references and technical manuals to perform the identified maintenance actions.

5.1 GENERAL PROCEDURES AND SAFETY. The following guidance is recommended for performing maintenance on petroleum fuel-related equipment. Above all, proceed safely, as discussed both in Section 1.3 and in Section 5.1.4, and ensure that supervisors, operators, and customers are informed of scheduled maintenance and the possible need to interrupt service to perform troubleshooting or repair.

5.1.1 Inspection Technique While Secured. Using approved tag-out procedures, completely isolate the components in question, de-energize any electrical circuits, de-pressurize the system, and if necessary drain the system in accordance with proper environmental and disposal procedures. Before performing any maintenance actions in unventilated areas containing petroleum in the liquid and/or vapor state, be sure the work area has been certified as gas-free by a gas-free engineer. Note if excessive physical effort is required to move or cycle operating equipment. Use proper tools and wear protective clothing while working. If equipment is to be disassembled, refer to technical manuals. Secure and support detached piping and other system elements as required. Note conditions that indicate a need for component replacement or repair and proceed as directed.

5.1.2 Inspection Technique During Operation. Visually survey the equipment and adjacent area. Look for fluid puddles, fine mists, deteriorated coatings or joints, physical damage, and general site conditions. Use the sense of smell to detect petroleum vapor. Listen for unusual flow or mechanical noises. Record pressures, differential pressures, temperatures and flow rates, sight glass levels, and valve positions.

5.1.3 Returning System to Service. Ensure that measurement adjustments, torque, and tests during reassembly are as specified in reference or technical manuals. When equipment integrity has been verified to be in accordance with quality assurance instructions, complete the tag-out removal and prepare the equipment for service. Ensure that the valve

positions are returned to those previously recorded. When the system is in operation, compare the gauge readings to those previously recorded and ensure that flow is normal. If any lead wire seals or locking devices were disturbed, return them to the condition in which they were found.

Once gauges have indicated a return to normal operating parameters, record them on any charts used for trend analysis, or proceed as locally directed. Graphing pressures over time helps predict the life expectancy of filter elements. Graphs should remind maintenance personnel to verify that a ready stock of needed elements is available. Careful analysis of charts should also ensure that fuel quality is maintained or problems with filtration or delivery are detected prior to use in fuel-sensitive vehicles or aircraft.

**5.1.4 Major Safety Concerns.** Adhere to safety rules at all times and avoid complacency while performing repetitive maintenance actions that have been successfully completed in the past. Be vigilant. No guidance in this manual or any other manual and no oral instruction from supervisors or operators constitute permission for unsafe maintenance practice.

While inspecting, troubleshooting, or repairing fuel system components:

- Do not work on pressurized or operating equipment unless specifically required in a procedure.
- Use authorized tag-out procedures to prevent inadvertent operation of fuel transfer systems affected by the maintenance activities.
- Wear appropriate safety clothing such as hardhats and goggles.
- Use proper tools and lighting, including explosion-proof drop or extension lights.
- Be aware of adjacent operating or rotating machinery. Do not defeat safety interlocks, machinery guards, flange shields, or other automatic or passive safety devices.
- Be sure that all grounding/bonding connections are in place to prevent electrical sparking (see Section 5.13.8 for a full discussion of grounding).
- Do not attempt repair of electrical components in a wet environment while wearing wet clothing.

- Since fuel system equipment may contain or produce toxic, flammable, or explosive vapors, do not enter an enclosed, unventilated area of a fuel facility without ensuring that a proper check of the atmosphere has been taken by a gas-free engineer.

- Do not ignore small quantities of fuel that may accumulate near fuel system equipment low point drains or leaks. Immediately clean them with approved methods and dispose of residue in approved containers. Identify the source of any observed leaks.

- Do not allow smoking, welding, flame cutting, grinding, or metallic striking within 100 feet of open pipeline sections without proper clearance or authority.

- If you are working on pipelines in a remote location, leave information concerning your expected time of return and location with a designated individual.

- Note the location of fire protection, medical, and/or safety equipment.

The following publications more thoroughly discuss safety-related concepts and procedures:

- American Red Cross, Standard First Aid and Personal Safety Manual (Stock No. 321116)

- Cardio-Pulmonary Resuscitation (CPR) Training Manual, (Stock No. 321907); available from local chapters of the American Red Cross.

- API Bulletin 2511, "Precautionary Labels"

- OSHA 29 CFR 1910.151, "Medical Services and First Aid"

- OSHA 29 CFR 1926.20, .23 and .50, "General Safety and Occupational Health Provisions"

- 40 CFR, Part 1510.38, "National Oil and Hazardous Substances Pollution Contingency Plan"

- NAVSEA 0901-LP-230-0002, "Industrial Gases"

- NFPA 10, "Portable Fire Extinguishers"

- NFPA 30, "Flammable and Combustible Liquids Code"

- NFPA 49, "Hazardous Chemicals Data"

- NFPA 70, "National Electrical Code"

## 5.2 PIPING

5.2.1 Scope. This section provides general background information on petroleum piping systems, both above and below ground, and provides a description of common organizational level maintenance and troubleshooting associated with piping systems. It is intended to be used in conjunction with detailed technical information contained in manuals or operating instructions. Recommendations and guidance in the following subsections should be used to form the basis of a tailored maintenance plan for these items at your installation.

Additional information pertinent to piping systems for petroleum products can be found in the following references:

- MIL-HDBK-1022, "Petroleum Fuel Facilities"
- ANSI Standard B31.3, "Petroleum Refinery Piping"
- MIL-HDBK-201B, "Military Standardization Handbook for Petroleum Operations"
- NAVFAC MO-306, "Cathodic Protection"
- NAVFAC MO-307, "Corrosion Control"
- 49 CFR 195, "Minimum Federal Safety Standards for Liquid Pipelines"
- 33 CFR 156, "Oil Transfer Operations"
- MIL-T-52777, "Tank, Storage Underground Glass, Fiber Reinforced Plastic"
- A. O. Smith Inland, Manual No. 9600, "Engineering and Design Guide, Fiber Glass Reinforced Piping Systems."

### 5.2.2 Pipe Maintenance Concerns.

5.2.2.1 Pipeline Leaks. The principal causes of piping leaks are:

- External Corrosion. Natural elements such as water, sun, sea spray, snow, and windblown sand can, over time, deteriorate protective coatings and cause corrosion. Galvanic corrosion caused by improper or unprotected earth contact can contribute to localized corrosion. Where possible, regular visual inspections for rust, wear, or damaged coatings, followed by prompt repair, will minimize this problem. For underground piping, cathodic protection readings should be taken quarterly and permanently recorded.



- Internal Corrosion. Localized internal corrosion severe enough to cause leaks is caused by stagnant pockets of water, usually containing salts, at low points or dead ends in the piping system. This problem can be avoided by providing drain connections at low points, properly supporting pipes to avoid sagging, and eliminating dead ends. Pigging can also be used to sweep water from low points (see Section 5.2.10.1 for further discussion on pigging). The use of filter/separators and the frequent draining of water bottoms in tanks can also minimize the amount of water in the pipeline.

- Erosion. Internal mechanical wear can occur due to the abrasive nature of some fuels or abrasive contaminants swept along in the flow. This effect is most likely to occur over long periods of time at locations where the flow direction or velocity changes. The erosion of the wall thickness may become apparent after other damage or causes have weakened the pipe.

- Expansion and Contraction. Long runs of restrained piping can be over-stressed by thermal expansion or contraction caused by changes in ambient temperature, or in the case of heated products, by changes in the product temperature. The effects of expansion and contraction may be particularly severe where the piping is connected to fixed equipment (for example, at storage tanks or pumps). Expansion and contraction stresses can be avoided by removing unnecessary anchors or similar restraints from the piping, by installing expansion loops or joints at appropriate intervals, or by cold springing new pipe.

Cold springing is a method of reducing the stress in a pipe created by the difference between the pipe temperature and the operating temperature of the fuel flowing through the pipe. When the operating temperature is greater than the ambient pipe temperature, the pipe segment to be installed is cut shorter than the required length and stretched into contact at the joints. This pipe length is calculated with regard to the temperature induced elongation of the pipe. As the pipe expands due to the heat of the fluid flowing through it, the stresses on the pipe caused by the fluid flow are relieved. Care must be taken to ensure that the gaskets in the flanged joints are sufficiently compressed to prevent leakage. ANSI Standard B31.3, "Petroleum Refinery Piping", provides greater detail on the use of this method.

The slack loop method is used for preventing expansion stresses in underground pipelines. The slack loop method of installing a pipeline involves welding pipe segments into a series of long loops or "slack loops". When these pipes are lowered into the ditch, there is slightly more pipe than required. As the fluid flows through the pipeline, the pipe contracts as it cools, eliminating the slack while adding negligible tension to the pipe. If the temperature of the

fluid flowing through the pipeline is greater than the pipe temperature, cold springing the pipe should be performed rather than using the slack loop method.

In any situation where there is excessive movement of pipes, chronic misalignment of pumps, or similar equipment or chronic leaks at joints, the possible need for additional expansion joints should be considered. Consult a public works engineer for specific instructions before taking any action.

- Liquid Thermal Expansion. Leaks at joints, gaskets, and packings may be caused by thermal expansion of the product in the pipe. This is particularly the case with above-ground piping that is exposed to changes in ambient temperature. Thermal relief should be provided for sections of above-ground piping that can be isolated between two valves. Usually, a 3/4 x 1-inch spring-loaded relief bypass valve, set to relieve at 10 percent above the operating pressure of the system and piped around one of the line valves, is adequate. Consult with the public works mechanical engineer when determining the optimum relief settings for the local operating conditions. It is important that the final relief for the system return to that of an atmospheric (unpressurized) drain line, or storage tank, to prevent pressure buildups caused by relief valves connected in series.

- Inadequate Supports. Excessive deflection, misalignment, and over-stress of above-ground pipes can result from inadequate support. Supports or hangers must be structurally adequate, properly spaced, and adequately maintained.

- Mechanical Damage. Mechanical damage to pipelines can cause breaks, distortions, and leaks. Mechanical damage can be caused by the impact of vehicles, ships, or construction equipment, as well as ice, earthquakes, land slides, floods, or other acts of God.

- Hydraulic Shock. When the liquid flowing in the pipe is suddenly stopped, as by a quick-closing valve, part of the kinetic energy of the moving stream is converted to pressure waves that move through the liquid at speeds of over 4,000 feet per second. The effect, called hydraulic shock, is very much like slamming on the brakes of a freight train. Shock pressures can be reduced by decreasing the initial velocity of the liquid in the pipe or by increasing the time taken to close the valve. If operating conditions will not allow either of these remedies and shocks are persistent, the installation of shock arrestors should be considered.

Leaks can be caused by hydraulic shock in the piping system. Shock pressures can be four or five times the

normal working pressure of the system and can blow out gaskets and packings, break castings, or cause leaks at joints, especially expansion joints, because of movement of the pipe.

5.2.2.2 Product Contamination. Contamination of petroleum products by the pipe is caused by generalized corrosion of the inside of the pipe or by residues left on the pipe wall from a different grade of product or type of product additive. Internal corrosion can be prevented by the use of corrosion-inhibiting additives in the product.

Pipe walls can be cleaned of rust and scale or of the residues from other products by running pigs and scrapers through the pipe. Seriously fouled pipes can also be cleaned internally by washing them with mild acid and caustic solutions. Once clean, they can be coated with permanent protective coatings such as epoxies.

### 5.2.3 Criteria for Repair or Replacement.

5.2.3.1 General Considerations. In the event of an actual or potential leak in a petroleum piping system, the first consideration must be to prevent safety hazards and damage to the environment. Immediate steps must be taken to contain or recover any product lost through the leak (see Chapter 3). In each individual case, an experienced judgment must be made as to whether it is safe and economical to temporarily or permanently repair the leaking section of pipe. Applying lessons learned from determining the cause of a leak may prevent other sections of the piping system from sustaining similar leakage.

Consider some of the following items in evaluating repair methods for a pipe leak:

- Isolate pitting or general metal loss to the affected section. Prevent recurrence in other sections of the pipe system.
- Investigate the use of alternative methods of preventive maintenance such as improved coatings or cathodic protection.
- Evaluate consequences of future leaks with regard to safety, environmental damage, and service interruption impact.
- Perform a cost/benefit analysis to compare the cost of replacing the section of pipe with the cost of making continued spot repairs. Include additional operating benefits such as lower maintenance and increased plant performance accruing from replacement of the section of pipe.

5.2.3.2 Metal Thickness. One of the main contributors to pipe leakage is the loss of metal through internal or external corrosion of the pipe. Since there are no set criteria for determining the replacement of pipe as a factor of remaining wall thickness, each case must be individually studied to determine the proper method of repair and/or replacement. Current Navy criteria cites ANSI Standard B31.3 "Petroleum Refinery Piping," as the reference standard for initial pipe design and retirement thickness. This ANSI standard should be used as a general guideline for pipe repair or replacement.

5.2.4 Thickness Measurement. Because guidelines for pipe replacement are based upon metal thickness, it is necessary to be familiar with methods for measuring pipe wall thickness.

For above-ground piping that is out of service and has open ends, mechanical measurements can be made with such devices as transfer calipers, indicating calipers, depth gauges, pit gauges, hook gauges, and micrometers. Ultrasonic or x-ray techniques could also be used for above-ground piping, but ordinarily would not be necessary.

Underground piping poses a more difficult problem because it is not accessible for visible inspection or mechanical measurement. The usual practice is to spot-check the condition of the pipe by excavating at a few selected locations, inspecting the condition of the exposed sections, and making mechanical, ultrasonic, or x-ray measurements of the metal thickness. If serious corrosion is observed, more excavations and inspections should be made to determine its extent.

To select the proper places to excavate, two general methods can be used. The first is used when the least severe condition is expected. This method involves conducting a survey of pipe-to-soil electrical potentials. A potential survey requires the services of an experienced technician with the proper instruments. The methods and equipment required are described in MO-307. If the pipe is equipped with test leads, testing can be done on the surface with the pipe in service. The survey results should indicate the severity of possible corrosion and its approximate locations.

The second technique for measuring the wall thickness of underground pipes requires outside assistance and employs a self-propelled electronic scanner that moves through the bore of a pipe 6 inches in diameter or larger and records signals on a strip chart showing the profile of the pipe wall thickness. For most Navy pipelines, this method is more expensive than the potential survey and spot-check method described above (special scraper launch and retrieval barrels are necessary for inserting and removing the survey tool); thus, this method should not be used for pipelines less than 1 mile long. It

should, however, be used for submarine pipelines. A particular advantage to this method is that the survey can be carried out without removing the pipeline from service.

#### 5.2.5 Visual Inspection.

5.2.5.1 Regular Inspections. Visually inspecting piping systems for signs of defects should be a continuous process carried out by all personnel while physically sighting the system. Visual inspection should include the pipe itself, or the ground around it if the pipe is not visible, as well as fittings, flanges, joints, insulation expansion devices, supports, and hangers. Examine all equipment and fittings for:

- Signs of leaks
- Misalignment
- Excessive movement
- Physical damage from outside forces
- Broken or missing parts
- Loose nuts, bolts, etc.
- Damaged supports
- Deterioration of coatings/corrosion
- Noise or vibrations coming from equipment
- Pipelines offset from their normal position on the pipe support.

Report any abnormal condition to a supervisor before attempting any corrective actions.

5.2.5.2 Pipeline Patrols. Visual inspection of cross-country pipelines requires special consideration. In many cases, such pipelines cross remote areas where access is difficult. Regular surface and air patrols are required to detect signs of leaks, breaks, or surface conditions that may pose a threat to the pipeline. It is recommended that air patrols, if used, be supplemented by surface patrols, either on foot, mounted, or in surface vehicles. MIL-HDBK-201B recommends that pipeline patrols be made on irregular schedules (to discourage sabotage and pilferage). The current regulation, 49 CFR 195, "Minimum Federal Safety Standards for Liquid Pipelines," requires that the operators of liquid pipelines inspect the surface condition on or near each pipeline at intervals no longer than 2 weeks.

5.2.5.3 Inspection of River Crossing. Under 49 CFR 195, river crossings under a navigable waterway that are part of a cross-country pipeline system must be inspected to determine and record the condition of the crossing at intervals of not longer than 5 years. A double block and bleed (non-lubricated plug) valve should be installed at each end of water crossings.

5.2.6 Pressure Testing. To ensure the integrity of a piping system, pressure testing should be conducted to verify that the system is able to function to its design parameters. 49 CFR Part 195 details the requirements for hydrostatic testing of petroleum pipelines. Before conducting pressure tests, the impact of a rupture or failure of a piping system during the test must be thoroughly considered. In some cases, the benefits of a pressure test may be outweighed by the potential problems if the system fails.

5.2.6.1 Test Scheduling. Pressure testing should be scheduled in accordance with the maintenance plan of the individual facility. Pressure testing is usually conducted by specially trained personnel on an annual basis. Since facility personnel may be called upon to assist in the testing procedure, manpower planning is important.

5.2.6.2 Pressure Test Procedures/Guidelines. API RP No. 1110 provides general guidelines for developing pressure test procedures; however, each facility should develop its own tailored pressure test, addressing the following areas:

- The system to be tested should be isolated from other systems or equipment during the test.
- System components such as atmospheric tanks, float operated devices, meters, expansion joints, instrument systems, hoses, valves, and relief valves that are not designed to withstand the test pressure must be removed or isolated from the system.
- If slip blinds between flanges are used for isolation, they must be heavy enough to withstand the test pressure without buckling or bulging.
- Before the test fluid is introduced, any devices that will interfere with complete drainage of the system, such as orifice plates, must be removed.
- Drains must be provided at all low points in the system.
- Bleeder vents must be provided at all high points in the system. Bleed all air from the system before starting the test.

- Dependable and readily accessible control valves or other devices must be provided between the source of pressure and the system being tested.
- An automatic relief valve or other device set to relieve the pressure before the system is over-pressurized must be provided.
- All relief valves and drains must discharge to a safe and environmentally approved receptacle.
- Reliable, calibrated pressure gauges of the proper range must be installed and watched carefully during the test.
- For prolonged test periods, particularly for exposed pipelines, reliable thermometers should be installed at intervals throughout the system and watched carefully during the test. Changes in test fluid temperature can dramatically influence the test pressure.
- Reliable and constant communications should be provided for all observers. In the event of a leak or failure, pressure must be rapidly removed from the pipeline.
- The test pressure should be held at 125 percent operating pressure for 4 hours on observable pipelines and 110 percent operating pressure for 4 hours on non-observable pipelines (per 49 CFR Part 149 and NAVFAC NFGS 15486).

In addition to the above basic guidelines, the test procedure should comply with the applicable federal, state, and local environmental regulations as well as the safety concerns discussed in Section 5.1.4. Additional pressure testing information can be found in ANSI STD B31.3, "Chemical Plant and Petroleum Refinery Piping."

5.2.6.3 Operational Pressure Tests. Effective pressure tests of operating pipelines can be made if shut-down periods of approximately 12 hours or more are available. The line is shut down with a locked-in pressure, which is determined by the Public Works Engineering Group. Normally, there will be some drop in pressure as the product cools. After the fuel's temperature stabilizes, further pressure drops beyond a set limit indicate the line probably has a leak, which must be investigated. Many variables affect the fall-off of pressure after the temperature stabilization. Variables such as ambient temperature change, character of fluid in line, length and enclosed volume of pipe string, valve leakage, and terrain elevation should be considered in determining the existence of pipe leaks.

In long pipelines through areas of varying elevation, an approximation of a leak location can be made by observing the pressure drop at a gauge at the low point of the line. Continue the test until the pressure declines to a steady reading. Convert the final pressure gauge reading to feet of head of the fuel in the line. Assuming that the pressure gauge is at a lower elevation than the leak, the head of liquid measured indicates the vertical height (in feet) of the leak above the pressure gauge. With a contour map, it is possible to approximate the location of the leak based on the difference in elevation along the pipeline.

**5.2.7 Pipeline Repairs.** A repair, no matter how small, should not be taken lightly. Some correctly performed repairs may only hide the underlying cause and not solve the problem, leading to an eventual catastrophic failure. For this reason, supervisors should track repairs and establish a trend indicating when excessive repairs are required on pipeline sections. Management decisions may be necessary before further resources are expended on a failure-prone line.

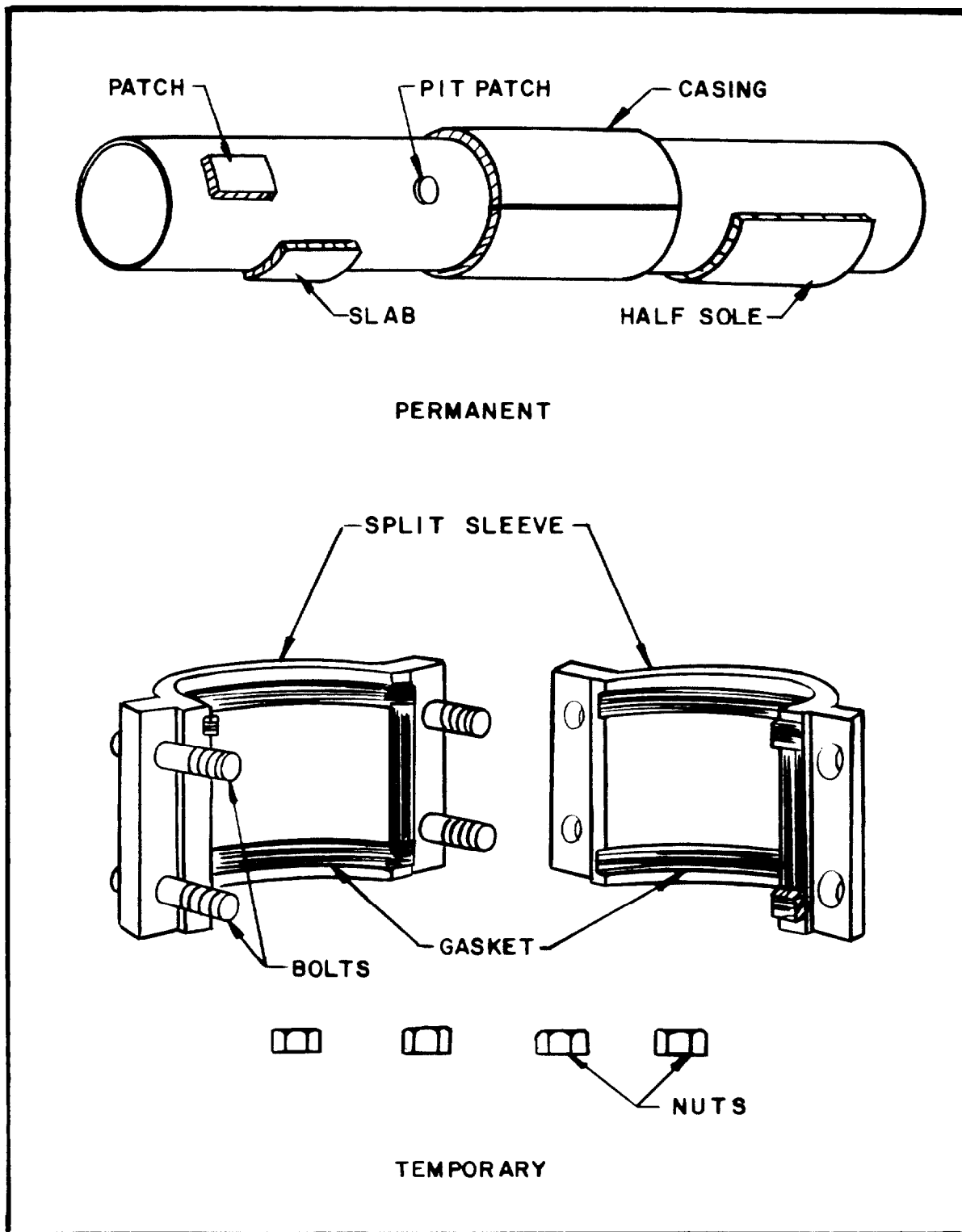
**5.2.7.1 Corrosion Pit Repair.** Corrosion pits (on the outside of a pipe) that have not yet penetrated the wall, can be repaired by filling the pit with epoxy putty to a level approximately flush with the surrounding surface. This patch is then shielded with a 1/4 inch steel plate shaped to fit the pipe curvature plus a 1/2 inch extension beyond the boundary of the corrosion pit. After the epoxy has cured, weld the steel patch in place using a continuous fillet weld. Follow the instructions of a gas-free engineer to ensure that no safety rules are violated. Preserve the patch with an appropriate coating.

Do not try to fill the pit area with weld material because the arc may strike through the reduced thickness pipe wall and start a leak and dangerous fire.

**5.2.7.2 Pipeline Leak Repairs.** Leak repairs are more difficult to handle because of the hazard involved. The first thing to do is to stop the leak. This can be done temporarily by bolting on a U-bolt split or clamp sleeve as illustrated in Figures 5.2.1 and 5.2.2, respectively. When the area has been cleaned of flammable or combustible liquids and vapors, the patch or sleeve can be permanently welded in place.

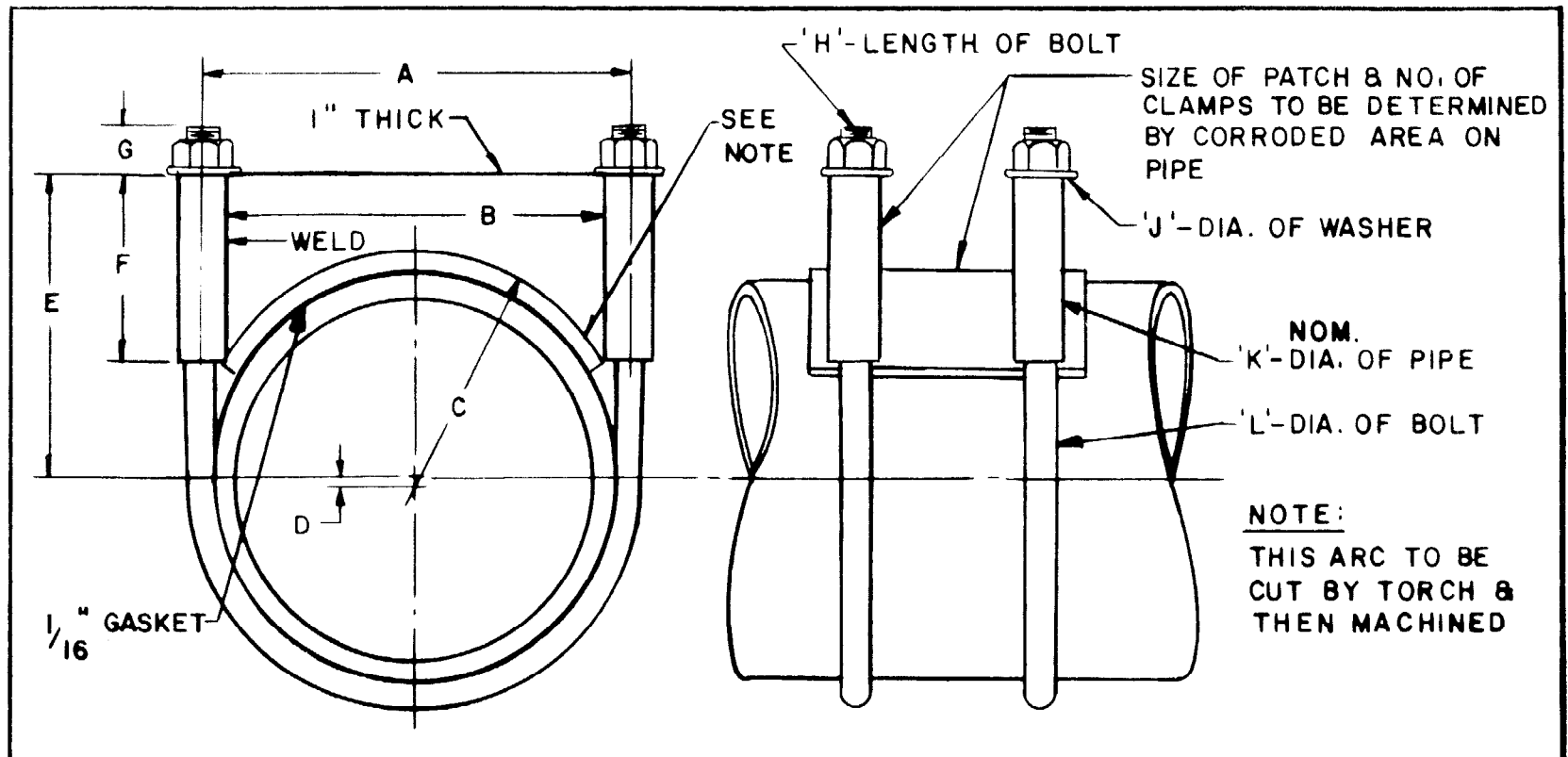
Each repair must be individually assessed to plan a repair that is safe and effective as well as cost effective. Experienced pipe repair personnel can often arrive at creative solutions with minimal impacts on pipeline availability. In any case, the area must be cleaned of spilled petroleum prior to any repair. In accordance with NAVFAC TS-02202, "Earthwork for Utilities," excavate and remove saturated earth and replace it with clean, dry sand. If the clamp is tight and holding and the pipe is completely filled, it can be welded in place





**FIGURE 5.2.1**  
**PIPELINE REPAIR METHODS**

5-14



SCHEDULE OF DIMENSIONS

PIPE SIZE	A	B	C	D	E	F	G	H	J	K	L	THREAD LENGTH
6"	7 1/2	6 3/16	3 37/64	1/16	6 1/8	4	1 1/2	27-1/32	7/8	1	7/8	2"
8"	9 1/2	8 3/16	4 3/4		7 9/16	5	1 1/2	33-1/16	7/8	1	7/8	2"
10"	11 3/4	10 3/32	5 7/8		8 3/4	5 1/2	1 3/4	39-1/2	1	1 1/4	1	2 1/4"
12"	13 3/4	12 3/32	6 7/8		9 3/4	6	1 3/4	44-5/8	1	1 1/4	1	2 1/4"

FIGURE 5. 2. 2  
PIPE REPAIR CLAMP SPECIFICATIONS

without taking the pipe out of service. Otherwise, arrangements must be made to empty, flush, and gas-free the pipe before any more work can be done. Employ the services of a gas-free engineer, who will use a combustible gas indicator to ensure that the area is safe for hot work.

The repair of underwater pipe involves the same general procedures and precautions described above, except that the work must be performed by qualified divers or from within a dry enclosure.

5.2.7.3 Pipeline Replacement. The decision to replace a section of an active pipeline implies that the line must be taken out of service, drained, flushed, and made safe for hot work. In the case of long, cross-country lines, this can be a major and very expensive problem.

If replacement is required, take the line out of service. Drain the line as completely as possible, being careful not to spill the drained product. After draining, flush the line with clean, fresh water if possible, and drain again. The water may now be contaminated with oil, so it should be drained into a safe receptacle and disposed of in accordance with proper environmental standards. Clean the work area and test it with a combustible gas indicator. The inside of the pipe may still contain combustible liquid or vapors. Make the first cuts into the pipe with a mechanical pipe cutter or hacksaw, not by burning. Once the inside of the pipe has been tested and proven gas-free, hot work of the new section may proceed. Protect the open ends of the existing pipe and the work area by installing removable plugs in the open ends. Remove them before the new section is secured in place.

The need to take long lines out of service can be avoided by a process called "hot tapping." This should only be undertaken by experienced personnel equipped with the necessary special tools and fittings. With this procedure, flanged nipples are welded to the outside of sound portions of the carrier pipe, two at each end of the section to be replaced. Gate valves are installed on the flanges. A power-driven tapping machine is inserted through the open gate, and a hole is cut through the wall of the carrier pipe in the bore of the nipple. The cutter is then removed, and the gate valve is closed. One nipple at each end is used as the connection for a temporary bypass around the section of carrier pipe to be replaced. In the other, nearest the cutoff point, a plug is installed. The product then flows through the bypass and the bad sections can be cut out and replaced without interruption of service. Many variations of this procedure are possible.

5.2.8 Expansion Joints. There are various types of expansion joints that include the use of sliding or rotating joints between mating parts sealed with gaskets, packings and

glands. The principal objective of inspection and maintenance procedures for expansion joints is to prevent leaks and mechanical failure due to improper application or installation.

Figure 5.2.3 shows a slip-type expansion joint with a packing and packing gland. The joint should be lubricated occasionally with a pressurized grease gun to prevent leaks and to allow free movement of the joint. Pump grease in until it comes out around the edges of the joint. If the joint leaks, tighten the gland in small increments. If the leak persists, re-pack it. If a joint leaks persistently, it may be misaligned.

Figure 5.2.4 shows a metallic, bellows-type joint. This type of joint can fail because of inadequate alignment guides or, more likely, because of fatigue failure of the metal bellows. If this happens, the joint must be replaced.

An option to expansion joints is the use of expansion loops. Expansion loops are formed by a series of 90° bends in the pipe supported either horizontally or vertically. They allow for the relative movement of pipe sections while maintaining a contiguous pipe string. The major maintenance requirement involves inspection of the supports as discussed in Section 5.2.12. Personnel should also check for cracks in the pipewall in the area of the bends due to excessive motion.

5.2.9 Flanges. In most oil piping systems larger than 2 inches, connections at valves, pumps, tanks, manifold, hoses, and other equipment are made with flanges. In older installations, cast iron, flat-faced flanges rated at 125 or 250 psi may be found on many valves and pumps. In new construction, forged steel, raised-face, weld-neck flanges of appropriate pressure ratings are preferred. These steel flanges have a 1/16 inch raised section around the center hub, which is the contact area for the gasket. This raised-face flange causes the outer edges around the bolt pattern to have a slight gap.

Do not install a steel raised-face flange against a cast iron, flat-faced flange. When the bolts are tightened, the cast iron may shear or crack around the unsupported outer edge. Flat-faced steel flanges are available for this purpose, or the raised portion of the face of a raised-face flange can be machined off to form a continuous flat face to mate with the cast iron.

5.2.9.1 Flange Gaskets. Gaskets for petroleum should be composition ring, 0.0625 inches thick, of one piece, factory cut, resistant to the effects of hydrocarbon fuels, and manufactured of fire-resistant materials (in conformance with NFGS 15486). Gaskets of flat-faced, cast iron flanges should be full face gaskets; they should extend across the entire flange area to the outside of the bolt circle. Gaskets for

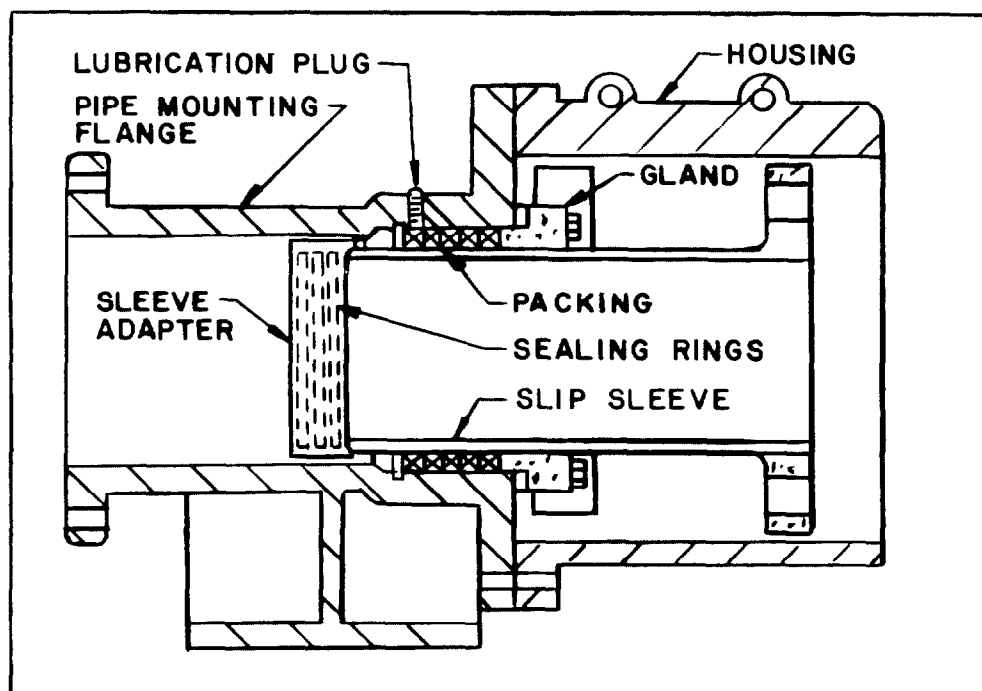


FIGURE 5.2.3  
SLIDING TYPE EXPANSION JOINT

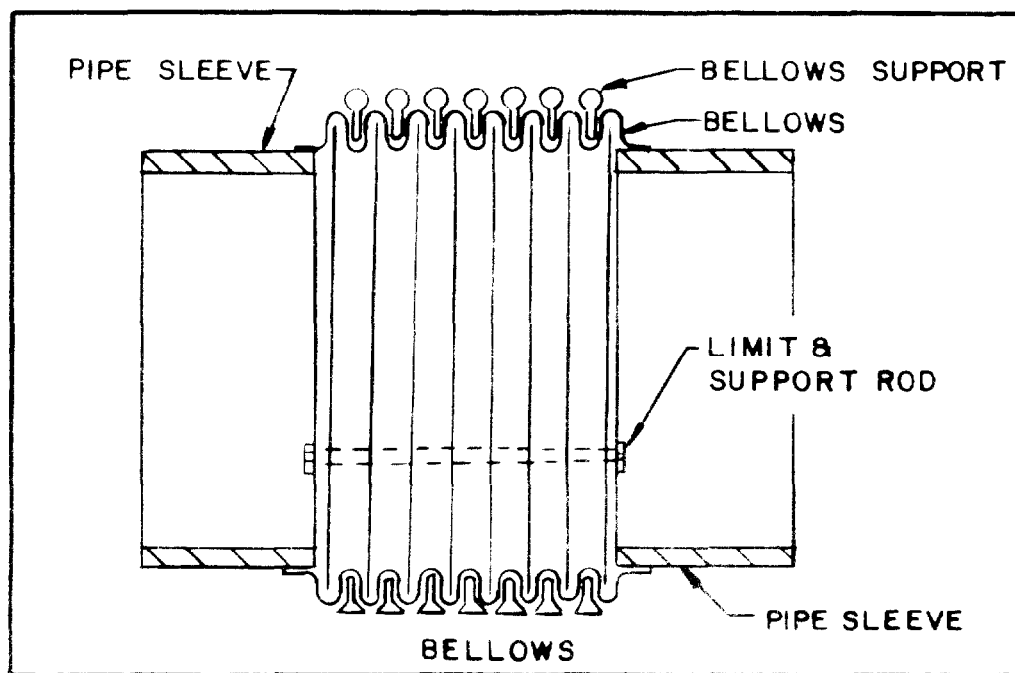


FIGURE 5.2.4  
BELLOWS TYPE EXPANSION JOINT

raised-face flanges should be ring gaskets that do not extend beyond the raised area of the flange face. Gaskets from disassembled joints should not be reused. For higher temperatures or pressures, spiral wound, metallic gaskets should be used.

5.2.9.2 Flange Bolts. Flange bolts for service up to and including 300 psi and 400°F must be carbon steel machine bolts in accordance with ASTM Specification A-307, Grade B, with cold pressed, hexagonal nuts conforming to ASTM Specification A-563. Nuts and bolts that are worn, corroded, bent, cracked, or otherwise defective should be replaced.

The sequence of tightening bolts is important in getting a tight joint. First, tighten all the bolts hand tight. Second, use a wrench to lightly tighten two bolts on diametrically opposite sides of the bolt circle. Third, lightly tighten two more bolts on opposite sides of the circle, 90° from the first two. Proceed by stages to tighten all bolts in the same manner. When the system comes up to operating pressure and temperature, tighten the bolts again in the same sequence.

5.2.9.3 Flange Inspection. Inspection of flanges, replacement of gaskets, or insertion of slip blinds requires that the flanges be spread apart. This can be a tricky job that can cause personnel injury or damage to the flanges if it is done with improper tools. A ratchet-type flange spreader, which locks into the bolt holes of the flange, is recommended for this purpose. If there is a frequent requirement for changing slip blinds on certain flanges, permanent jack screws should be installed.

5.2.10 Cleaning. The cleaning of pipeline runs should be a regular maintenance action with frequency determined by the observance of increased product contamination. Known events, such as the failure of an upstream strainer or transfer of dirty petroleum products, should trigger immediate pipeline cleaning.

5.2.10.1 Cleaning Scrapers and Pigs. The regular use of scrapers and pigs to clean the inside of the pipe is an important part of the regular maintenance routine for most cross-country pipelines. The frequency of pigging is governed by the nature of the products shipped. For example, if a pipeline carries only one grade of fuel containing an anti-corrosive additive, it may only be necessary to pig the line annually. More frequent cleaning would be indicated by observing the amount of contaminants pushed out by the pig.

Pipelines, either in multi-product service or not protected by a corrosion inhibitor, require more frequent cleaning. Some special products like crude oils, heavy fuel oils, and lubricating oils require more frequent pigging

because they tend to leave waxy coatings on the wall of the pipe. These build up and reduce the effective capacity of the pipe or, conversely, increase the pumping horsepower necessary to maintain a given flow rate.

To use this method, pipelines must be equipped with a pig launching station at the discharge end of the pump station. A receiving station, equipped with a manifold system to recover the pig, is located in the pipeline prior to a subsequent pumping station. Figures 5.2.5 and 5.2.6 illustrate pig launching and pig receiving stations, respectively.

The pigs are launched by diverting the main flow from the pump through the pig launching barrel. As the pig clears the barrel, a warning system, usually electric, indicates that the pig has left the barrel and is in the main line. When the pig approaches the receiving station, a warning device alerts personnel to its arrival. Since the pig sweeps the line, a sand-trap-blow-down connection is required at the receiving station to remove solids from the pipeline to prevent them from entering the storage tanks.

5.2.10.2 Chemical Cleaning. Situations may arise where it becomes necessary to change the service of an existing piping system, say, from heavy burner fuel oil to JP-5, where special cleaning is required to protect the quality of the new product. In such cases, chemical cleaning may be used. Chemical cleaning might also be used to prepare a pipe for a permanent interior coating such as an epoxy.

Chemical cleaning is a specialized procedure that should be undertaken only by experienced personnel. The process may involve the use of both acid and caustic solutions, which must be handled with great care to avoid injury to personnel, damage to systems or equipment, and damage to the environment. When the cleaning is finished, the cleaning agents must be neutralized and completely removed from the system before it can be used again.

In addition to chemical cleaning, techniques are available for mechanically cleaning the inside of existing pipes. Sand blasting, shot blasting, and high pressure water jets are examples.

5.2.11 Interior Coating. The practice of coating the interior of new steel pipelines before construction as a means of protecting the product in the pipe from contamination is well established. Epoxy coatings are the most commonly used, most frequently for aviation jet fuel service. However, the Navy does not normally use internally coated steel pipe. Navy practice is to use either aluminum, stainless steel, or fiberglass-reinforced plastic wherever non-ferrous piping is required, such as beyond the filter-separator of aircraft refueling stations.



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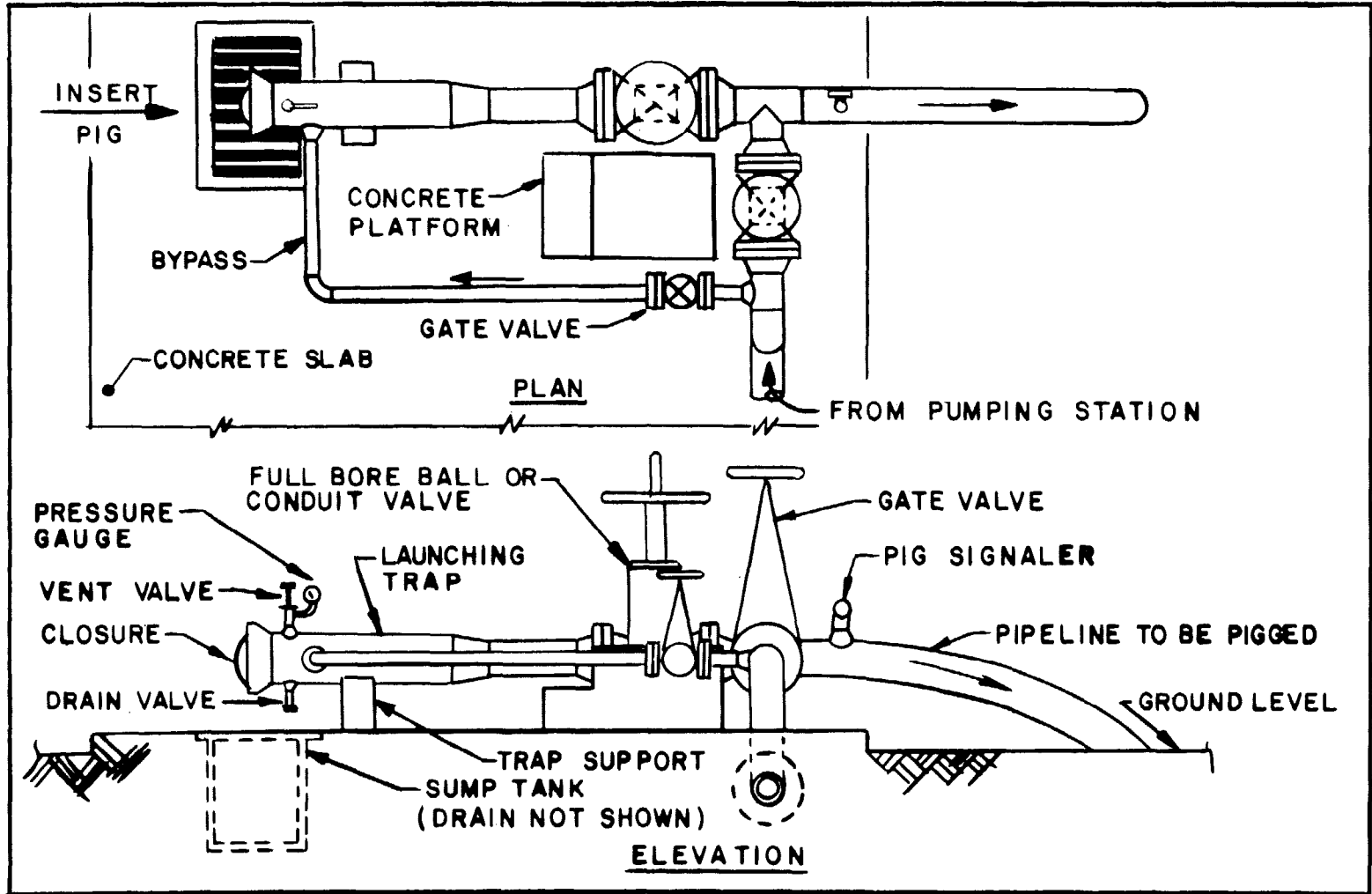


FIGURE 5.2.5

PIG OR SCRAPER LAUNCHING TRAP

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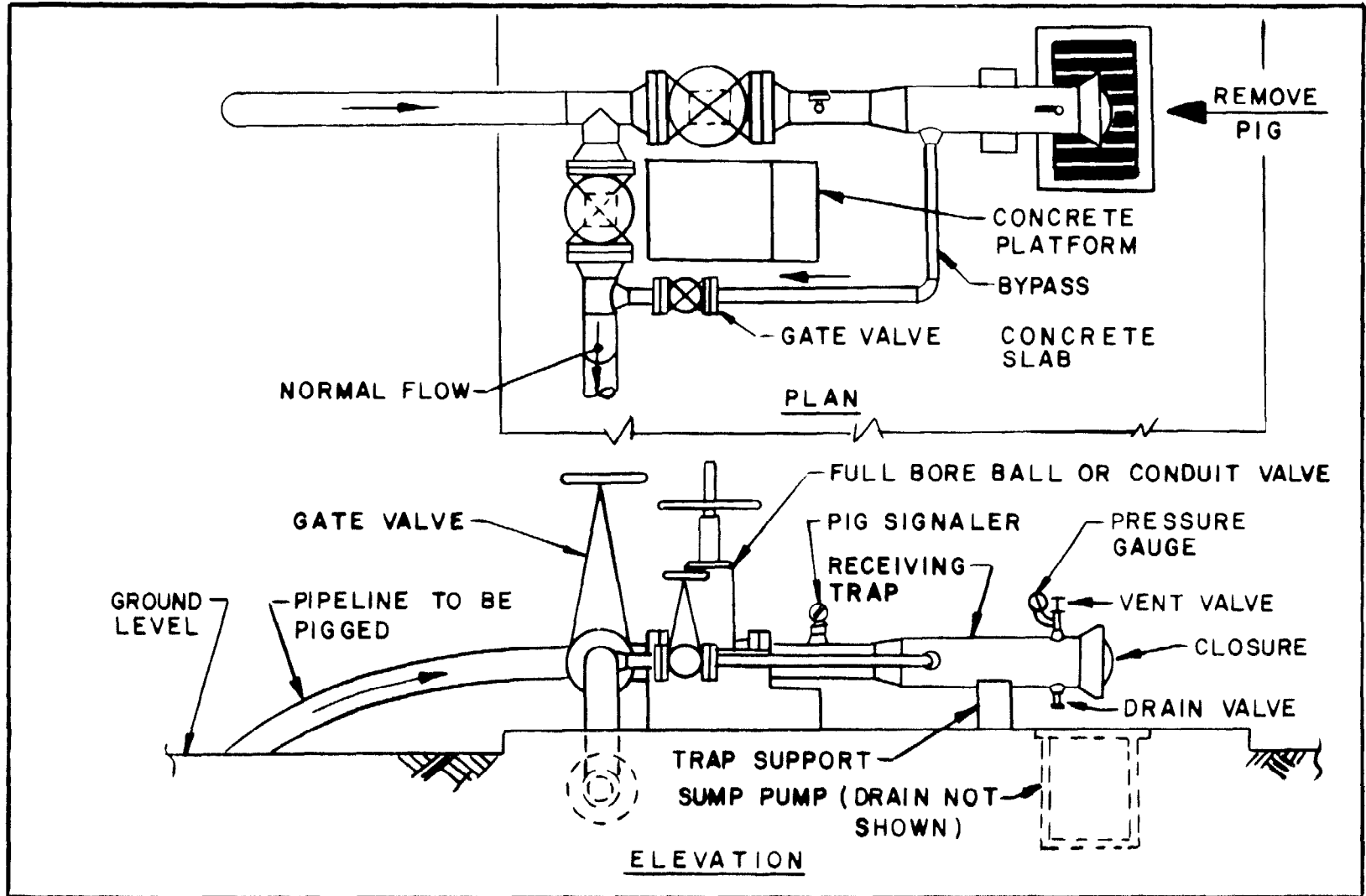


FIGURE 5.2.6

PIG OR SCRAPER RECEIVING TRAP

Application of internal coatings to existing pipes is rarer and more difficult but has been done successfully. The work involves specialized methods and equipment and is expensive. It should not be undertaken unless it is known that the pipe to be coated, presumably older pipe, has a lengthy remaining life expectancy.

Another, perhaps more practical, method for lining existing pipes is the use of moderately flexible plastic tubing pulled inside the old steel pipe. The outside diameter of the new tubing must be less than the inside diameter of the old pipe. The tubing is supported by filling the void between the two pipes with cement mortar pumped in under pressure. There is a reduction in the cross-section of the finished pipe, but this may be offset by an improved friction factor, which increases the fluid flow rate.

**5.2.12 Pipeline Supports.** Above-ground piping systems require support in order for the system to function properly. One function of a pipe support is to maintain proper pipe-to-pump or pipe-to-tank alignment. Without this alignment, the pump would require constant maintenance for realignment and replacement of bearings. Extreme care should be taken when removing a pipe support near the location of pumps and equipment. Some supports located near pumps and equipment are designed to keep any loading from being transmitted from the pipe system to the pump or equipment connections. This loading can cause damage to the equipment, such as cracking, misalignment, and eventual failure.

There are many types of supports available. Proper selection and location are determined by engineering calculations. However, supports may be required for a temporary maintenance situation, such as pipe replacement, or at the break in a pipe. Ensure that temporary supports are constructed in a sturdy and safe manner, allowing for the same conditions for which permanent supports are designed. Consult an engineer if in doubt that adequate support is provided.

The supports should be visually inspected for cracks, corrosion, misalignment, missing parts, and damage on a yearly basis. Most supports have rollers designed to accommodate movement of pipelines due to hydraulic shock or thermal effects. Exposure to weather and lack of lubrication can immobilize the rollers and rapidly wear the wall of the pipe, causing leaks. Where this condition exists or is expected, weld to the pipeline a rolled plate with an inside radius that matches the outside pipe wall curvature. Ensure that the length of this plate extends at least 1 foot beyond expected movement and wraps around the pipe at least 90 degrees. This shoe will absorb the wear mentioned previously. Generally, 1/4 inch thick plate is adequate. Spring supports serve the same function. Inspect both regularly for freedom of movement. Sight along the runs of pipe and observe the patterns of

deflection between successive supports. Investigate any excessively deep deflection for inadequate or ineffective support. Lack of deflection could indicate a tension stress on the pipe that could lead to cracks or ruptures.

#### 5.2.13 Fiberglass Pipe.

5.2.13.1 Uses of Fiberglass. Fiberglass pipe offers an alternative to steel and aluminum pipe. It is lightweight, noncorrosive, yet strong enough to be used in petroleum pipelines. Because of its light weight, installation is faster and less expensive. Life-cycle maintenance costs are also reduced, and alignments are less critical. One drawback of using fiberglass pipe is that it is less resistant to abrasive fluids.

To reduce the risk of static discharge in fiberglass pipes, double-walled pipe may be installed. The inner or carrier pipe contains a conductive additive in the pipe resin to attract the static charge. A conductive bonding strap which links the inner and outer pipe walls allows the static charge to flow to the outer pipe wall. The static charge increases in the outer shell until it discharges harmlessly to the surrounding soil. Since the outer pipe shell is in direct contact with the soil rather than with the fluid, the shell may contain fiberglass fibers without the conductive material.

5.2.13.2 Fiberglass Pipe and Fitting Connections. The primary method used for joining fiberglass pipe is the bell and spigot. The end of the pipe is tapered while the fitting end is belled in order to accept the tapered end of the pipe. The joint is secured by using an adhesive designed to meet the pipeline specifications. Threaded and bonded, grooved, and high pressure connections are also available, but the bell and spigot joints are the most commonly used.

5.2.13.3 Fiberglass Pipe Flanges. Flanges are used to connect fiberglass pipes to pumps, valves, or equipment. The fiberglass flanges are usually flat-faced and, if mated with a raised-face flange, require the use of a ring to close the gap. Check with facility engineers to order the proper type of gasket material since not all gaskets are compatible with fiberglass flanges. Use washers on both sides of flange joint bolt holes.

5.2.13.4 Service and Maintenance. Some basic guidelines should be followed when using fiberglass pipe and fittings.

- Avoid excessive bending. This could impose undue stresses on the pipe.

- Adequate protection should be provided where mechanical damage could occur from vehicular collision and improper use (for example, piping used as foot holds or hand holds).

- Valves or other heavy equipment should be supported independently of the pipe. Check with facility engineers if a question arises about support requirements.

- If the pipe is to be buried, special considerations are necessary. Backfill must not contain sharp rocks, heavy boulders, large solid clumps of dirt, or frozen lumps in cold weather. Backfill as soon as possible to avoid the chance of damage. Check with facility engineers for proper burial depths.

- Fiberglass pipe systems require visual inspection similar to that described in Section 5.2.5, "Visual Inspection."

- Fiberglass pipe can be used in new pipelines as a replacement for steel pipe, whether by section or in complete systems. The type, grade, pressure rating, and size must be determined by facility engineers before installation.

### 5.3 STORAGE TANKS.

5.3.1 Scope. This section provides general background information on petroleum fuel storage tanks and provides a description of common organizational level maintenance and troubleshooting associated with this equipment. It is intended to be used in conjunction with detailed technical information contained in manuals or operating instructions. LPG tanks are unfired pressure vessels and, as such, all inspection and repairs relating thereto fall under the cognizance of NAVFAC MO-324, "Inspection & Certification of Boilers & Unfired Pressure Vessels". Recommendations and guidance in the following subsections should be used to form the basis for a tailored maintenance plan for these items at your installation.

Additional information regarding petroleum storage tanks can be found in the following references:

- MIL-HDBK-1022, "Petroleum Fuel Facilities"
- NAVFAC MO-306, "Cathodic Protection"
- NAVFAC MO-307, "Corrosion Control"
- MIL-STD-457A, "Frequency for Inspection and Cleaning of Petroleum Fuel Operating and Storage Tanks"
- NAVFAC NFGS 13219, "Cleaning Petroleum Storage Tanks"

- API RP 2015, "Cleaning Petroleum Storage Tanks"
- API RP 2015A, "A Guide for Controlling the Lead Hazard Associated with Tank Entry and Cleaning".

5.3.2 Major Safety Concerns. Petroleum storage tanks can be safely cleaned and maintained by following proper procedures and enacting adequate safety precautions. Without the constant application of these safeguards, injury, death, or property damage will result from fire, explosion, oxygen deficiency, or the presence of toxic materials. No tank should ever be entered until it is properly certified "gas free" or adequate breathing apparatus is provided.

5.3.2.1 Fire or Explosion. Fuel, air, and heat must all be present for fires or explosions to occur. Further, the mixture of hydrocarbons and air can only be ignited if the fuel-to-air ratio is within the explosive range. Refer to Section 1.3.2 for more detailed information on preventing petroleum fires.

5.3.2.2 Oxygen Deficiency. All petroleum storage tanks are usually oxygen deficient due to the displacement of air by hydrocarbon vapors. Therefore, no one should enter a petroleum storage tank without wearing approved air supply apparatus unless the tank has been ventilated to meet the air/oxygen content standards of API RP 2015 or other standards as may be specified.

5.3.2.3 Toxic Materials. Section 1.2.4 of this manual describes the harmful effects of the various petroleum products and fuel additives.

### 5.3.3 Tank Cleaning

5.3.3.1 Objective. Storage tanks must be cleaned periodically in order to:

- Prevent fuel contamination from dirt, rust, scale, sludge, bacteria, deteriorated tank linings, or other foreign material that may accumulate in the tank.
- Prepare the tank for a change in product service.
- Make the tank safe for physical entry by personnel for inspection, repair, or alteration work.
- Make the tank safe for hot work such as welding or burning.
- Prepare the interior surface of the tank for protective coating.

5.3.3.2 Frequency of Cleaning. Petroleum storage tanks should be cleaned as often as necessary to maintain required product quality as determined by routine sampling and testing procedures. In addition, tanks should be cleaned as often as needed by operational demands for repairs, alterations, or product changes.

5.3.3.3 Preparation of Tank for Cleaning. The first step in preparing a petroleum storage tank for cleaning is to test the sludge to see if it is hazardous waste. This will allow for the implementation of proper cleaning procedures for the type of sludge present. Next, pump out as much of the fuel as possible using existing installed pumps. Any remaining fuel will be removed using portable pumps. All pumps used should be air operated, double diaphragm type with an exhaust outside the tank. If electric or gas-driven engines must be used, they should be located at least 50 feet upwind of the exposed manhole. Electrical connections should be made using explosion-proof hook-ups.

Following removal of the fuel, all tank valves and connections should be removed, and all flanges should be blanked off to ensure that no vapor or fuel is introduced into the tank while personnel are in or around the tank. On underground tanks where pipelines, etc. may be buried, close off the lines at the nearest exposed connection. API RP 2015B, "Cleaning Open-Top and Covered Floating Roof Tanks," provides additional guidance for preparing floating roof tanks for cleaning.

Before beginning to vapor-free the tank, one last physical inspection of the work area should be made by the safety and tank crew supervisors. This inspection ensures that:

- All preparations have been properly made.
- All required equipment and protective clothing are on the job and in working order.
- All personnel have been properly instructed.
- All hazards have been identified, and appropriate safety precautions have been taken.

5.3.3.4 Vapor-Freeing the Tank. After removing all of the liquid without physically entering the tank, the next step is to remove the vapor from the tank. Three basic methods are available to free a tank of hydrocarbon vapors: mechanical ventilation, steam ventilation, and natural ventilation.

- Mechanical ventilation is the safest of the three methods. It uses equipment such as eductors or fans to

draw vapors up through top man-ways or force air into the tank through bottom man-ways.

- Steam ventilation is accomplished by pumping high temperature steam into the tank. This is an effective ventilation method, but it has serious limitations, including generating static electricity, forming a vacuum from steam condensation, and being a relatively slow process.

- Natural ventilation simply consists of opening all man-ways, hatches, etc. and letting the air out. This process can be aided by a wind sail to direct air into or out of the open manholes. This method is not practical for underground tanks, is considered unsafe for tanks having contained gasoline or JP-4, and takes longer than other methods.

5.3.3.5 Gas-Free Engineering. Once the tank has been emptied of fuel and vapors, it must be certified as safe for personnel entry by a gas-free engineer. NAVSEA 56470-AA-SAF-010 prescribes the regulations and procedures applicable to confined or enclosed space entry and work as well as the minimum mandatory requirements for establishing and administering a gas-free engineering program. These regulations and procedures apply to all naval shore activities, military and civilian personnel, and contractor personnel working at naval facilities. API RP 2015, "Cleaning Petroleum Storage Tanks," and RP2015A, "A Guide for Controlling the Lead Hazard Associated with Tank Entry and Cleaning," provide additional guidance for ensuring a tank is vapor-free and safe for personnel entry.

5.3.3.6 Initial Cleaning. After the tank has been certified as gas-free, initial cleaning procedures from outside the tank can begin. Ventilation and vapor testing by a gas free engineer should continue throughout the operation to detect any dangerous concentrations of petroleum vapors released during the cleaning process. If the concentrations rise to 50 percent of the lower explosive limit, cleaning operations are to be halted until the ventilation process removes the vapors and makes the area once again gas-free.

Tank cleaning is accomplished by directing water-hose streams through the open hatch or man-way to remove rust, scale, dirt, sludge, and fuel residue and flush it to the pump-out connections or water drawoffs. Again, it is recommended that the pumps used to draw off this water be air-driven, double diaphragm types. Also, be sure that the hose nozzles are electrically bonded to the tank.

5.3.3.7 Completing Tank Cleaning. Following the initial cleaning process, ventilation is continued, and vapor readings are taken to determine if the tank is safe for entry. NAVSEA 56470-AA-SAF-010 and API RPs 2015 and 2015A provide



specific tank entry guidance and safety equipment requirements, but generally, workmen are not permitted to enter a tank where petroleum vapor concentrations are greater than 20 percent of the lower explosive limit. When this criterion is satisfied, the cleaning crew can enter the tank and begin removing the remaining sludge. If the vapor concentrations rise to 20 percent of the lower explosive limit, personnel must exit the tank immediately and not re-enter until the air ductors have restored the air to acceptable limits.

- Routine Cleaning. Routine cleaning means the removal of all liquid, sludge, dirt, scale, and rust from the interior surfaces of the tank. This degree of cleaning is usually satisfactory for protection of product quality, most changes in product service, preparation for tank inspection, and cold work. It is not acceptable for preparation of a tank for hot work or coating application. A tank cleaned in this manner would normally be vapor-free, but not necessarily lead-free.

- Preparation for Hot Work or Coating Application. For a tank to meet safety and surface quality standards for hot work and/or coating application, it must be both vapor-free and lead-free (refer to API RP 2105 for further information). All surfaces that are to be treated should be free of all traces of petroleum, lead, or sludge that might contaminate the work area. Wire brushing, scraping, or brush sand blasting are the primary methods used to achieve this result. These methods of cleaning may also be necessary to prepare a tank that previously contained a heavy petroleum product for clean product service.

5.3.3.8 Disposal of Sludge. Upon completion of the tank cleaning process, the resultant sludge and sediment must be analyzed to determine if it is hazardous waste before it is removed. Depending on the construction of the tank, sludge may be removed through one of several methods. The simplest and most commonly used method is to sweep and wash the sludge into piles, then shovel it into buckets, and remove it from the tank.

The sludge may then be disposed of in accordance with applicable Federal, state, and local environmental regulations.

- Lead-free Sludge. Because toxic lead is absent, the disposal problem is simplified. Typical disposal methods include:

- Blending with other petroleum fuels
- Incineration
- Reprocessing

- **Leaded Sludge.** Leaded sludge is a hazardous waste and must be disposed of in accordance with the Resource Conservation and Recovery Act (RCRA), 40 CFR, Parts 260 through 270; and applicable state and local regulations. Chapter 3 provides additional information on the required procedures for the handling of hazardous waste. The Navy is committed to ensuring the proper handling and disposal practices for all hazardous wastes. Be sure to address any questions to the EFD, Environmental Branch.

5.3.4 Inspection of Tanks. Petroleum storage tanks are subject to external and internal inspections to ensure that the fuel meets the appropriate quality standards. (The maximum interval between inspections should not exceed the schedule in Table 5.3.1.) LPG tanks are unfired pressure vessels and, as such, all inspection and repairs relating thereto fall under the cognizance of NAVFAC MO-324, "Inspection & Certification of Boilers & Unfired Pressure Vessels".

5.3.4.1 Methods of Inspection. The methods used for inspection of atmospheric storage tanks may include the following:

- Visual examination
- Physical measurement
- Hammer testing
- Drilling and sampling
- Vacuum box testing
- Pressure testing
- Ultrasonic thickness measurement
- X-rays.

The most appropriate method of inspection for any particular tank will be determined by the objective of the inspection, the type of tank, and the materials of construction.

5.3.4.2 Safety Precautions. A tank that is to be internally inspected should be clean, gas-free, and lead-free before the inspection. If it is not, all safety precautions, including the use of protective clothing and breathing apparatus must be strictly followed by tank inspectors.

TYPE OF SERVICE	INTERNAL COATING	FILTER/SEPARATOR IN INLET OR CIRCULATING PIPING	MAXIMUM INSPECTION INTERVAL (YEARS)	
			VISUAL	PHYSICAL ENTRY
Operational Storage (Aviation Fuel)	No	No	1	3
		Yes	2	4
	Yes	No	2	4
		Yes	3	6
Bulk Storage (Aviation Fuel)	No	No	Not Required	3
		Yes		4
	Yes	No		4
		Yes		5
All Other Petroleum Fuel Tanks: As Required (indicated by product sampling data)				

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TABLE 5.3.1  
INTERNAL INSPECTION FREQUENCIES

5.3.4.3 Inspection Tools. The following are typical of the tools and equipment that should be available for complete tank inspection:

- Hand Tools

- |                        |                       |
|------------------------|-----------------------|
| - Crayon               | - Paint               |
| - Depth gauge          | - Pipe tap            |
| - Drill and drill bits | - Plumb bob           |
| - Hook gauge           | - Portable lights     |
| - Inside calipers      | - Pipe plugs          |
| - Inspector's hammer   | - Square              |
| - Knife                | - Steel rule          |
| - Level                | - Straight edge       |
| - Magnet               | - Thin-bladed scraper |
| - Notebook             | - Wrench              |
| - Outside calipers     |                       |

- Special equipment

- |                    |                  |
|--------------------|------------------|
| - Camera           | - Trepanning saw |
| - Ladders          | - Vacuum box     |
| - Penetrant dye    | tester           |
| - Scaffolds        | - Vacuum pump.   |
| - Surveyor's level |                  |

5.3.4.4 External Inspections. Visual inspections of the external surfaces of storage tanks and their associated equipment should be a continuous process. Personnel should report any evidence of leakage, corrosion, coating deterioration, or structural damage whenever it is observed. Routine external inspections at specific intervals should also be employed.

- All platforms, ladders, and stairways should be inspected for signs of corrosion, inadequate supports, missing handrails, missing bolts, rivets, etc. Any defects or hazards noted should be marked and reported.

- Foundations should be inspected for excessive settling or water buildup at the tank base. Any voids should be filled and sealed. If settling is a problem, re-grading may be necessary.

- External piping connections should be examined for leakage, misalignment, distortion, or other signs of stress on the pipe. Nozzles and flanges should be examined for the same defects.

- The tank shell of above-ground tanks should be inspected for signs of leaks, cracks, distortion, buckling, or corrosion.

- Fixed roofs of above-ground tanks should be inspected for corrosion or structural defects. Methods used can include visual, hammering, cutting, ultrasonic, or radiation inspections.

- Floating roofs should be inspected for pools of liquid fuel or stains from evaporated fuel on the pan. Seals should be examined for wear and deterioration, and all mechanical parts should operate freely. Drains should be tested to see that they run freely and control valves operate properly. All accessory equipment, such as self-leveling stairs and anti-rotating devices, should be inspected and tested for proper operation. Always use a combustible vapor indicator to verify the atmosphere is safe for personnel entry.

5.3.4.5 Internal Inspections. Inspection of storage tank interiors is accomplished by visual and physical entry inspections. Visual inspections are taken from the man-way opening to ensure that the tank is safe to enter, i.e., there are no physical hazards present, such as loose beams or fittings that could fall on personnel below. Once the tank is deemed safe for entry, personnel may enter the tank to conduct specific inspection and testing procedures. Proper tank entry procedures, as detailed in Section 5.3.3, should always be followed.

- Tank Shell Inspections. The interior of the tank shell should be inspected for corrosion, physical damage, and cracking. Particular attention should be paid to the tank shell/tank bottom merger area (as it is highly susceptible to corrosion in low spots where water has collected, usually identified by discoloration of the bottom surface), and the interior location of any leaks identified by internal inspection. The shell should also be inspected for cracks, particularly near fittings and in the heavy plates near the bottom. Magnetic particle inspection is especially useful in locating suspected cracks.

- Bottom Inspection. Tank bottom inspection is especially important because bottoms are subject to corrosion on both the internal and external surfaces. The interior tank bottom should be inspected for corrosion with particular attention paid to the areas under equipment or pipe supports in the tank that are generally subject to heavy corrosion.

The bottom plate thickness can be measured by drilling holes through the plate and measuring the thickness with a gauge. The hole is repaired by either filling it in with a threaded plug or welding a patch over the hole. When the necessary equipment and technicians are available, ultrasonic or radiographic measurements can be taken. Since ultrasonic measurements may be made when only one side of a tank is accessible, it is the preferred method of inspecting tanks.

API RP 2207, "Preparing Tank Bottoms for Hot Work," is the recognized standard to prepare for hot work on tank bottoms. In summary, do not perform hot work on a tank bottom for any purpose unless the area underneath has been opened and tested vapor-free. To test for vapor under the bottom, drill several holes through the bottom plates in the area in question. Test each one individually with the combustible vapor indicator. If any one tests more than 4 percent of the Lower Explosive Limit (LEL), as might very well happen with a leaky bottom, the material under the bottom must be cleared of petroleum liquids or vapors before it is safe to work. It may be possible to purge the area with nitrogen or carbon dioxide or to flush it out with water. If this method is used, there is a danger that the vapors or liquid has just been moved to another place. The first application of heat may generate more vapors and create a hazardous condition. It is much safer to remove enough of the bottom by cold cutting to allow complete removal of any liquid, vapor, or saturated material beneath. Cover the area with clean dry sand and test again for vapor before starting hot work.

In tanks constructed of concrete or lined with concrete or an organic lining, inspection is mostly limited to visual examination for cracks, deterioration, or surface defects. Hammering, scraping, or picking that would damage the lining material must be avoided. Defects as might be indicated by wet spots, blisters, or delamination should be marked, cut out, and re-surfaced. A high voltage, low current holiday detector as used for inspecting pipeline coatings can also be used on organic tank linings.

- Bottom Testing. If a storage tank has or is suspected of having leaks, they can be located by any of the following methods:

- For tanks in service, the existence of a leak can be confirmed by putting a water bottom in the tank. A steady loss of water will identify the leak.

- A vacuum box tester can be used with a soap solution to identify a leak.

- A clay dam can be formed around the outside bottom edge of the tank. The tank is filled with about 6 inches of water, and a slight air pressure is applied under the tank. Air bubbles rising in the water will identify any leaks in the tank.

- Internal Drain Line Inspections. Internal drain lines in floating roof tanks should be carefully inspected for corrosion damage or internal blockage. Movable joints should operate freely. Seals and packings in the joints should be

inspected and lubricated or replaced if necessary. Stop chains, guides, supports, etc. should be in place and in good condition.

- **Internal Accessories.** Other internal accessories such as pumps, floating suctions, and gauges should be thoroughly cleaned, inspected, and overhauled as required as part of the internal inspection. The cathodic protection system, when used, can be examined, tested, and repaired at this time as well. Refer to NAVFAC MO-306 for specific information.

5.3.5 Product Sampling. In addition to routine inspections, representative sampling and testing of the products and bottoms within the tanks should be performed. The particulate content of these samples, either taken downstream from the tank prior to any filtration or in accordance with ASTM Method D-270, "Sampling of Petroleum and Petroleum Products," will indicate the necessity of inspecting and/or cleaning the tanks.

The maximum interval between product sampling should be as follows:

- Operating tanks (ready issue) in aviation fuel service - 30 days
- Active bulk storage tanks in aviation fuel service - 30 days
- Inactive bulk storage tanks in aviation fuel service - 180 days after the new product has been put in the tank
- All other types of tanks for petroleum fuels and lubricants, as frequently as required for the particular product and service by Military Handbook - 200, "Quality Surveillance Handbook for Fuels, Lubricants and Related Products"
- In all cases, more frequent sampling may be required by other operational considerations. The quality of all samples taken should be considered an indication of the condition of the storage tank.

### 5.3.6 Repair of Tanks.

5.3.6.1 Repair/Replacement Criteria. Repair or replacement of steel tanks is made necessary by some form of damage to the tank. While this damage can be the result of over-pressure, fire, explosion, or foundation damage, it usually is caused by the loss of metal from the steel tanks by corrosion. The two principal factors in analyzing the need for

tank repair or replacement due to corrosion are the rate of metal loss and the maximum acceptable amount of metal loss. LPG tanks are unfired pressure vessels and, as such, all inspection and repairs relating thereto fall under the cognizance of NAVFAC MO-324, "Inspection & Certification of Boilers & Unfired Pressure Vessels".

The rate of loss for a particular tank can be predicted by keeping and comparing records of metal thickness measurements for two or more consecutive inspections. The remaining thickness at any future time can then be projected.

The amount of acceptable metal loss for some parts of the tank is easy to determine. For an above-ground tank, the roof plates and rafters are acceptable so long as they are safe to walk on and keep the weather out. The point at which they become unsafe is largely a matter of judgment and should be determined through evaluation by a public works structural engineer. It should be well before anyone actually steps through a plate or before the roof collapses under a snow load.

The bottom plates, if properly supported on the foundation, need only resist the internal liquid pressure. As long as there are no leaks, they are acceptable. However, it is necessary to determine whether the bottom plates will last until the next inspection, which may be 4 or 5 years away. If the predicted life of the plates is less than the time until the next inspection, early replacement should be considered.

The minimum allowable thickness for tank shells is more complicated than it is for bottoms. It is determined by the height and diameter of the tank, the allowable stress for the steel used in construction, and the type of joint. Minimum design thicknesses for newer welded tanks are included in API 650. Older welded and riveted tanks no longer have applicable API codes. Good engineering judgment should be applied to the maintenance of these tanks as long as they remain in service.

Once the tank has been cleaned and vapor-freed, the damaged areas of the tank can be abrasive blasted or hand cleaned to bare metal, and hot or cold repairs can be made as necessary.

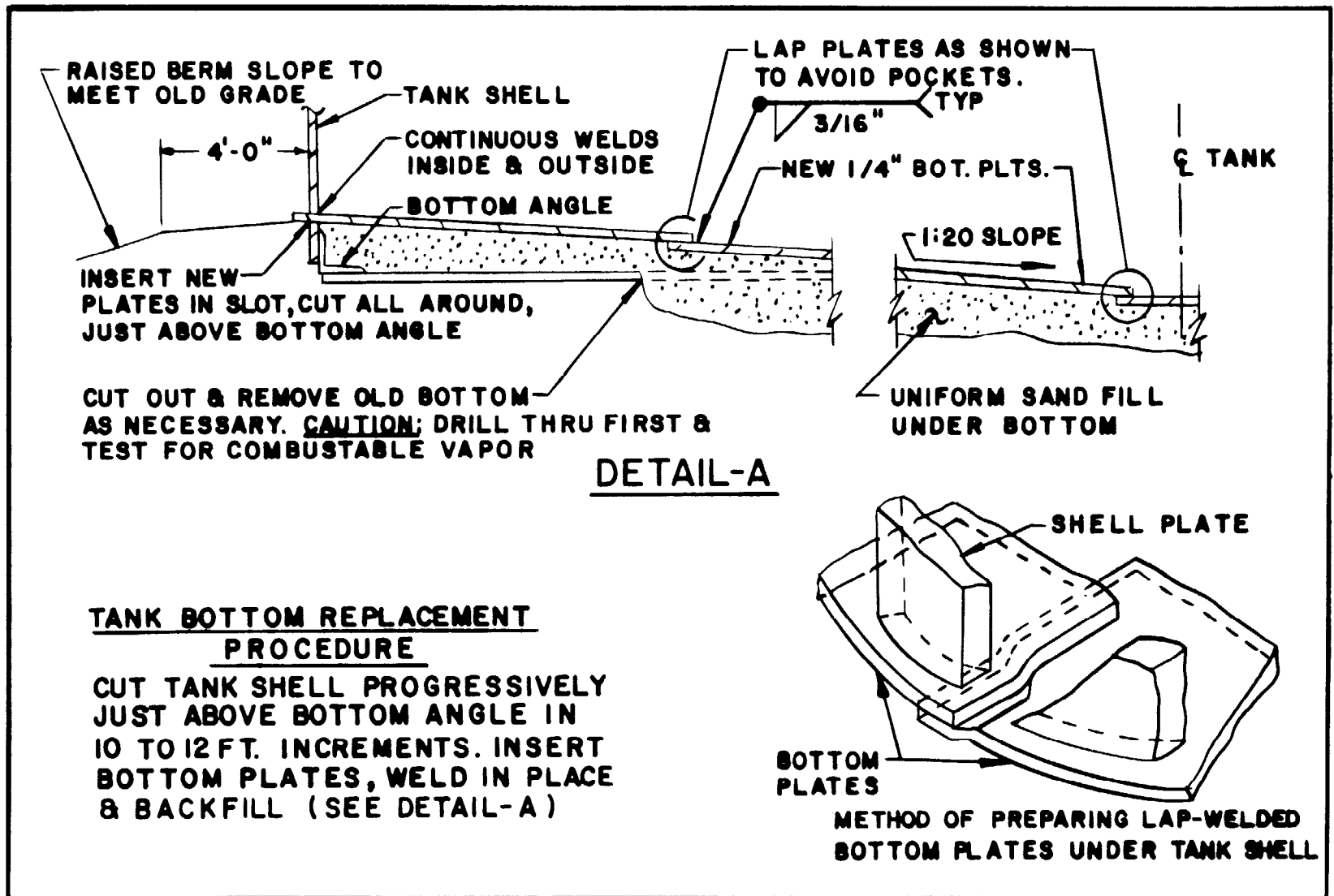
5.3.6.2 Bottom Replacement. Replacement of the tank bottom is the most commonly required major repair for storage tanks. The preferred method for bottom replacement of large storage tanks is to cut out the existing bottom center and slope the new bottom downward toward the sump located near the center. Column bases, if any, must be adjusted for the new bottom elevations. Figure 5.3.1 illustrates this method.

It should be emphasized that all welding at petroleum fuel facilities should be accomplished by a certified welder. Requirements are outlined in API STD 1104, "Welding of Pipelines and Related Facilities."

Before burning through any bottom-plates, drill a hole and test the area below for combustible vapor. Do not



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FIGURE 5.3.1

TANK BOTTOM REPLACEMENT-CONED DOWN BOTTOM

perform any hot work until the combustible vapor indicator shows the vapor concentration to be below 4 percent of the LEL. Repeat the precaution in each new area to be cut.

Laying concrete over an existing steel bottom is not recommended as a substitute for replacement or major repair of the bottom.

5.3.6.3 Rivets and Seams. Leaking rivets and seams on the exterior of riveted tanks are a constant source of problems. Backwelding or welding half-pipes over the row of rivets can be used with some success; however, both are very expensive repair methods. Epoxy repair putties and similar materials can also be used.

5.3.7 Interior/Exterior Coatings. Coatings are used both on the interior and exterior walls of storage tanks to prevent corrosion of the walls due to bottom water and/or soil contact. MO-307, "Corrosion Control," when published, will provide extensive detail on the types and uses of protective coatings.

Two of the most commonly used interior coatings are the Urethane System and the Fiberglass Reinforced Plastic (FRP) Lining System. The Urethane System, detailed in NAVFAC NFGS-09872, "Interior Coatings for Welded-Steel Tanks (Petroleum Fuel Storage)," employs a multi-layered polyurethane coating of the tank interior. This system should not be used where severe corrosion has reduced the tank metal thickness to less than 1/8 inch or where there are numerous holes all the way through the steel plate. In these cases, the FRP Lining System (see NAVFAC NFGS 13661, "Fiberglass Reinforced Plastic Lining System for Bottoms of Steel Tanks (for Petroleum Fuel Storage)," should be used.

#### 5.3.8 Tank Fittings.

5.3.8.1 Vents. Storage tanks must be equipped with vents to permit the passage of air and vapor in or out of the tank in order to prevent excessive pressure or vacuum buildup. The vents must be carefully sized for the operating conditions of each tank. API RP 2000, "Guide for Venting Atmospheric, and Low - Pressure Storage Tanks," provides recommended safe vent capacities.

There are two principal types of vents for atmospheric storage tanks: open vents and pressure vacuum vents, also called breather valves.

- Open vents consist of nothing more than a weather hood and bird screen to protect a free opening into the tank. As long as the vent is properly sized for the pumping rate into or out of the tank, the only required maintenance is to ensure that the openings are clear of obstructions such as bird nests, insect nests, and trash. Open vents should also be equipped

with flame snuffers, which should normally be open and free to operate. Open vents are normally used on fixed roof tanks containing diesel fuels, burner fuels, kerosene, JP-5 jet fuel, or lubricating oil.

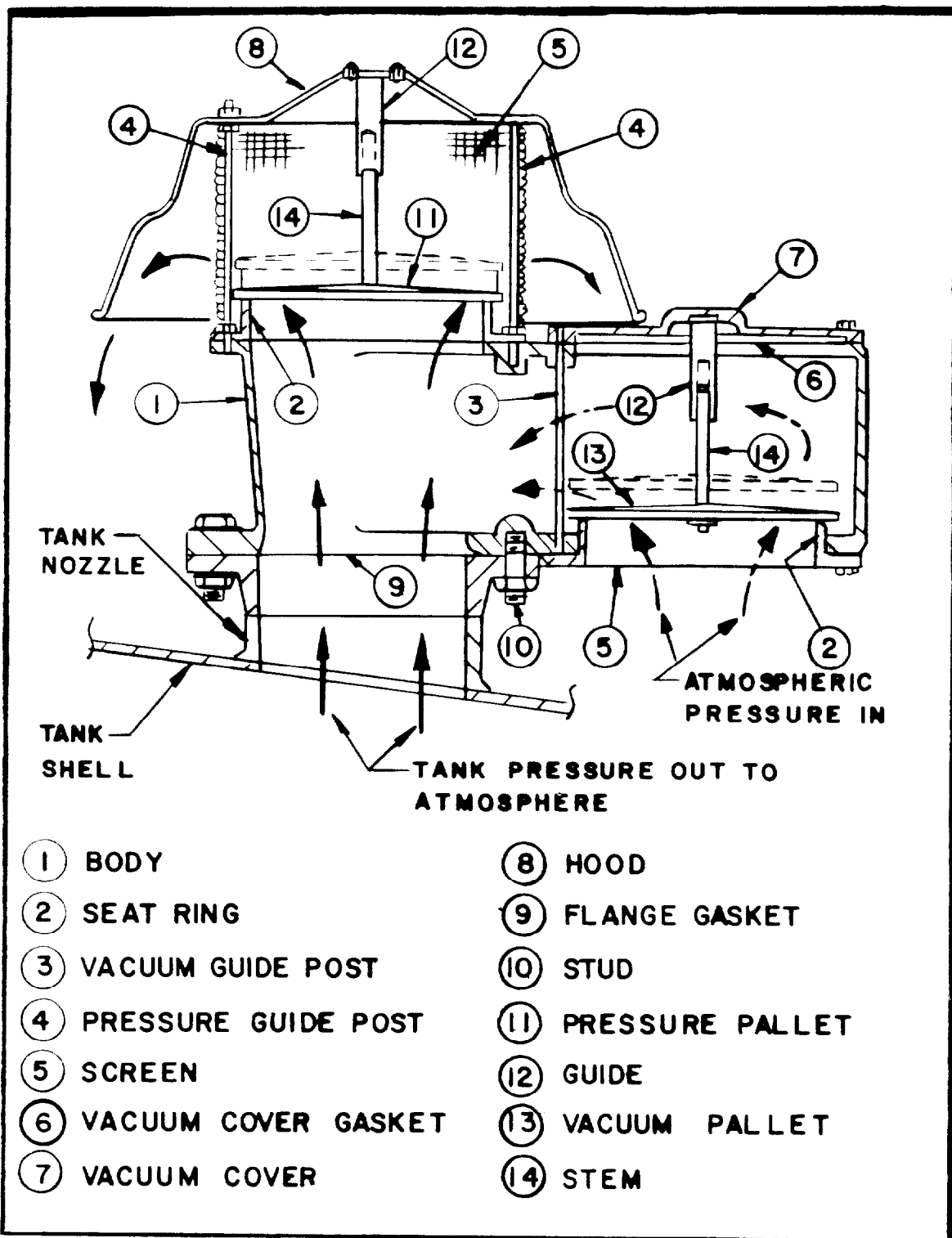
- Pressure vacuum vents are more complicated because they contain moving parts that can malfunction. Figure 5.3.2 shows a cross-section of a typical pressure vacuum vent. There are many variations of the details of construction, but most have the same basic elements. The flow of air or vapor in or out of the tank is controlled by valve-like devices consisting of a pallet and a seat. One controls the flow out of the tank (pressure), and the other controls the flow in (vacuum). The amount of pressure or vacuum required to open or close the valve is determined by the weight of the pallet and its area. Some have weights that can be adjusted in order to change the tank operating pressure.

A serious problem, such as the complete collapse of a tank, can occur if the vent fails to open when it should. Even a small pressure, such as an ounce or two per square inch over the large area of a tank roof and shell, can be destructive. The main objective of maintenance procedures for pressure vacuum vents is to make sure that they operate freely. Breather valves were originally designed as vapor conservation devices; however, they are no longer important for this purpose in view of the increased usage of floating roof tanks for volatile fuels like gasoline and JP-4 jet fuel.

Specific maintenance procedures are as follows:

- Remove the covers and inspect the pallets. Operate them by hand to see that they open freely.
- Be sure the weights are correct for the intended tank operating pressure.
- Clean and lubricate the stems and guides.
- In freezing weather, check frequently to see that pallets are not frozen shut.
- Re-grind pallets and seats that are corroded or worn. Use a fine grinding compound and light oscillating motion.
- Replace deteriorated seals, warped pallets, or broken parts.
- Remove bird and insect nests.

5.3.8.2 Flame Arrestors. Flame arrestors are designed to prevent external flame from entering the fuel tank through a vent opening. The device itself is a bank of finely



**FIGURE 5.3.2**  
**PRESSURE-VACUUM VENT-CROSS SECTION**

spaced, corrugated metal plates that divide and cool any flame attempting to enter the vent. Flame arrestors are installed under the vents of all volatile fuel (gasoline or JP-4 jet fuel) storage tanks except floating roof tanks and tanks equipped with breather vents. They should also be installed under open vents on tanks storing products with flash points of less than 100°F or tanks that are spaced closer than COMNAVFACENGCOM spacing standards, reference MIL-HDBK-1022, "Petroleum Fuel Facilities."

Flame arrestor maintenance is important because flame arrestors significantly reduce the vent capacity of the tank. Also, they are prone to clogging with dirt or frozen moisture. Maintenance of flame arrestors requires removing the cover, pulling out the arrestor bank, and removing any dirt, corrosion, ice, liquid, insect nests, trash, etc. that might block the vent above. It is important to check flame arrestors for freezing, especially during the early part of freezing weather.

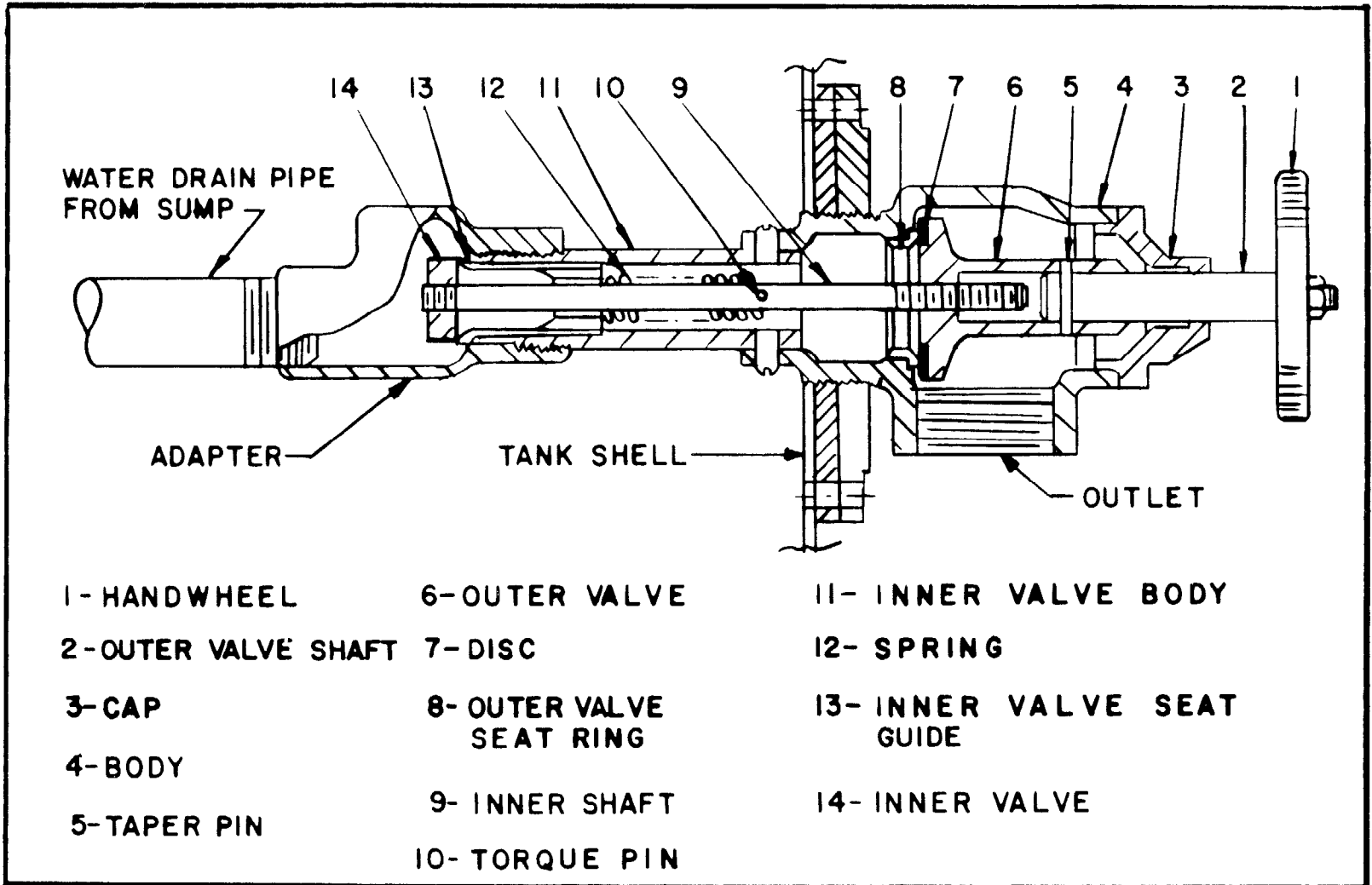
5.3.8.3 Water Draw-Off Systems. Water draw-off valves or systems are used to drain bottom water out of storage tanks to prevent product contamination and tank damage due to corrosion. Typically, this is done through the use of the non-freezing valves shown in Figure 5.3.3.

As seen in the figure, a non-freezing valve consists of an inner valve and an outer valve. When both valves are open, water or fuel can be drained from inside the tank. When the inner valve is closed, the outer valve can be opened, and any water or oil outside the inner valve can be drained out. It is this feature that prevents freezing. Outer valve bodies should always be drained and closed after each use.

The main objective of maintenance work is to be sure that the valve and its packings, if any, do not leak; that the valve and its packings work freely; and that the valve body is intact. Water draw-off valves should be removed from the tank, inspected, and repaired whenever the tank is out of service. Some valves are made so that the outer valve can be removed for inspection or repair while the tank is in service.

Water draw-off systems in existing underground tanks usually employ a low capacity sump pump to withdraw bottom water. These are usually vertical turbine pumps, but there are some older ones that actually have the entire pump, motor and all, located at the bottom of a well that extends through the tank from top to bottom. The maintenance procedure for sump pumps is the same as for other pumps described in Section 5.6.

5.3.8.4 Swing Lines and Floating Suctions. Present Navy policy calls for the replacement of swing lines and floating suction. Bottom sumps are used to remove the fuel from the tank and circulate it through a filter/separator to



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**FIGURE 5.3.3**  
NON-FREEZING WATER DRAW-OFF VALVE

remove contaminants. Any swing lines or floating suctions still in use, however, must be maintained properly.

Maintenance of these items involves ensuring that the joints move freely; and cables, floats, and operating mechanisms are in good working order. When the tank has been emptied and cleaned, the swing lines and floating suctions can be inspected, lubricated, and repaired.

5.3.8.5 Heating Coils. Many petroleum storage tanks in heavy fuel or lube oil service are equipped with heating coils or heaters to warm the fuel for transfer operations. Typically, these heaters are steam fueled. The main problem associated with these heaters is internal corrosion of the coils due to the presence of condensate in the heater coils or tubes. Depending on the type of heater used, this corrosion can lead to oil in the heating system or water in the fuel, either of which is undesirable.

To avoid this, steam coils should be shut off at the tank connections, both inlet and outlet, when not in use. Inactive coils should be plugged or removed from the tanks. New coils should be sloped to ensure complete drainage of condensate.

The flow of steam to coil should be controlled by an automatic temperature-regulating valve to prevent overheating the fuel in the tank. The action of the regulating valve should be observed and checked against a thermometer to be sure that it controls the tank temperature within a safe range, usually not over 150°F for No. 6 burner fuel oil.

5.3.8.6 Fuel Level Controls. Petroleum storage tanks are equipped with automatic devices to monitor and control the fuel level within the tank. These devices include:

- Gauging devices to provide local or remote readings of the tank pump. Typically, these gauges are float or similar devices that display the tank volume visible at eye level from the ground immediately outside the tank. Gauges for remote reading systems are used much less frequently and require the use of signal transmitters and microprocessors.

- High level alarms to ensure the tank is not overfilled. Typically, two alarms are used. One alarm will set off an audible alarm signal at the tank filling station when the petroleum level reaches 95 percent of the tank capacity. The second alarm, set to actuate at 98 percent of the tank capacity, will set off both audible and visual alarms as well as shut down the product supply pumps.

- Low level alarms to shut down the product transfer pumps, which may be taking suction from the tank.

Maintenance for these devices consists of ensuring the accurate calibration of the gauges and alarm settings. Signal transmitters and other controls should be kept in proper working order.

#### 5.3.9 Floating Roofs/Pans.

5.3.9.1 Floaters and Pans. Open top floating roof tanks are subject to the accumulation of rain and snow on the roof. If rain or snow is allowed to build too much, the weight can cause the roof to sink. Open top floaters must be checked regularly, and accumulated water or snow should be removed during and/or after each storm.

To drain water from the floating roof, various hose or flexible pipe configurations can be used, or the water can be allowed to drain directly down through the stored product and removed by the bottom sump or draw-off valve.

Snow and ice removal is more troublesome and laborious, but it must be done in bad storms; otherwise, the roof may sink. The shells of some open top tanks in snow country have been fitted with bolted doors at various levels to facilitate snow removal; otherwise, snow has to be hoisted over the top of the shell, regardless of the height of the roof.

Where either snow or rain accumulations are a serious problem, installation of a weather cover should be considered.

5.3.9.2 Rim Seals. Major repairs to floating roof rim seals not involving hot work have been accomplished with the tank in service. Because of the potentially dangerous accumulation of vapors above the roof during the repair work, such procedure is not recommended except in an extreme emergency. It is much safer to vapor-free the tank before undertaking major repairs to the seal.

#### 5.4 FILTERS, FILTER SEPARATORS, AND RELAXATION CHAMBERS.

5.4.1 Scope. This section provides general background information about filters, filter separators, and relaxation chambers and describes common organizational level maintenance and troubleshooting associated with this equipment. It is intended to be used in conjunction with detailed technical information found in manuals or operating instructions. Recommendations and guidance in the following subsections should be used to form the basis for a maintenance plan tailored to these items at your installation.



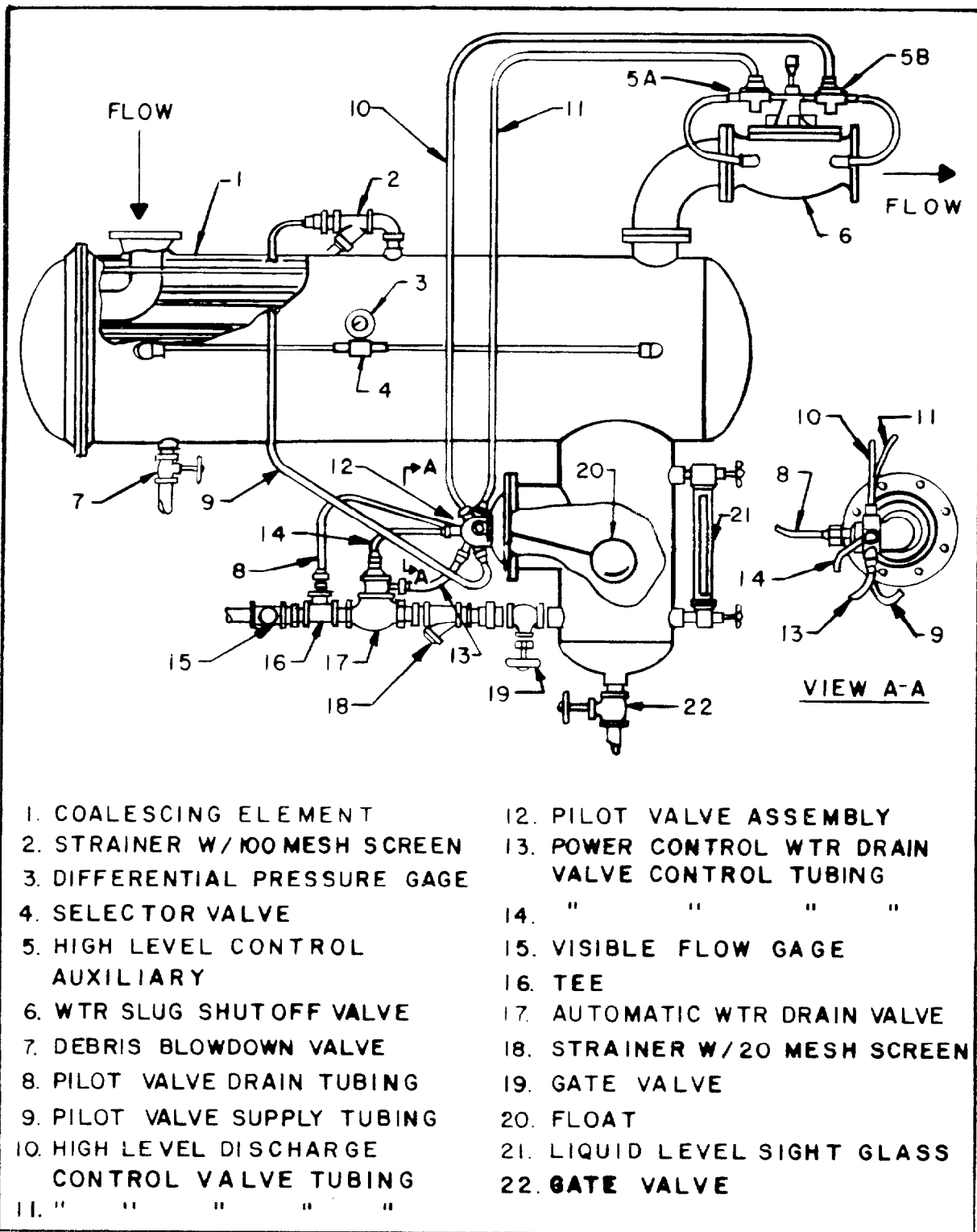
Additional information pertinent to filters, filter separators, and relaxation chambers can be found in the following references:

- MIL-HDBK-1022, "Petroleum Fuel Facilities"
- NAVAIR 06-5-502, "Aircraft Refueling for Shore Activities"
- NAVFAC NFGS 11301, "Packed, Gravity Oil/Water Separator"
- MILSPEC MIL-M-81380, "Monitor, Contamination, Fuel Dispensing Systems"
- MILSPEC MIL-F-8901, "Filter/Separator Liquid Fuel and Filter Coalescer Element; Fluid Pressure, Inspection Requirements and Test Procedures for."

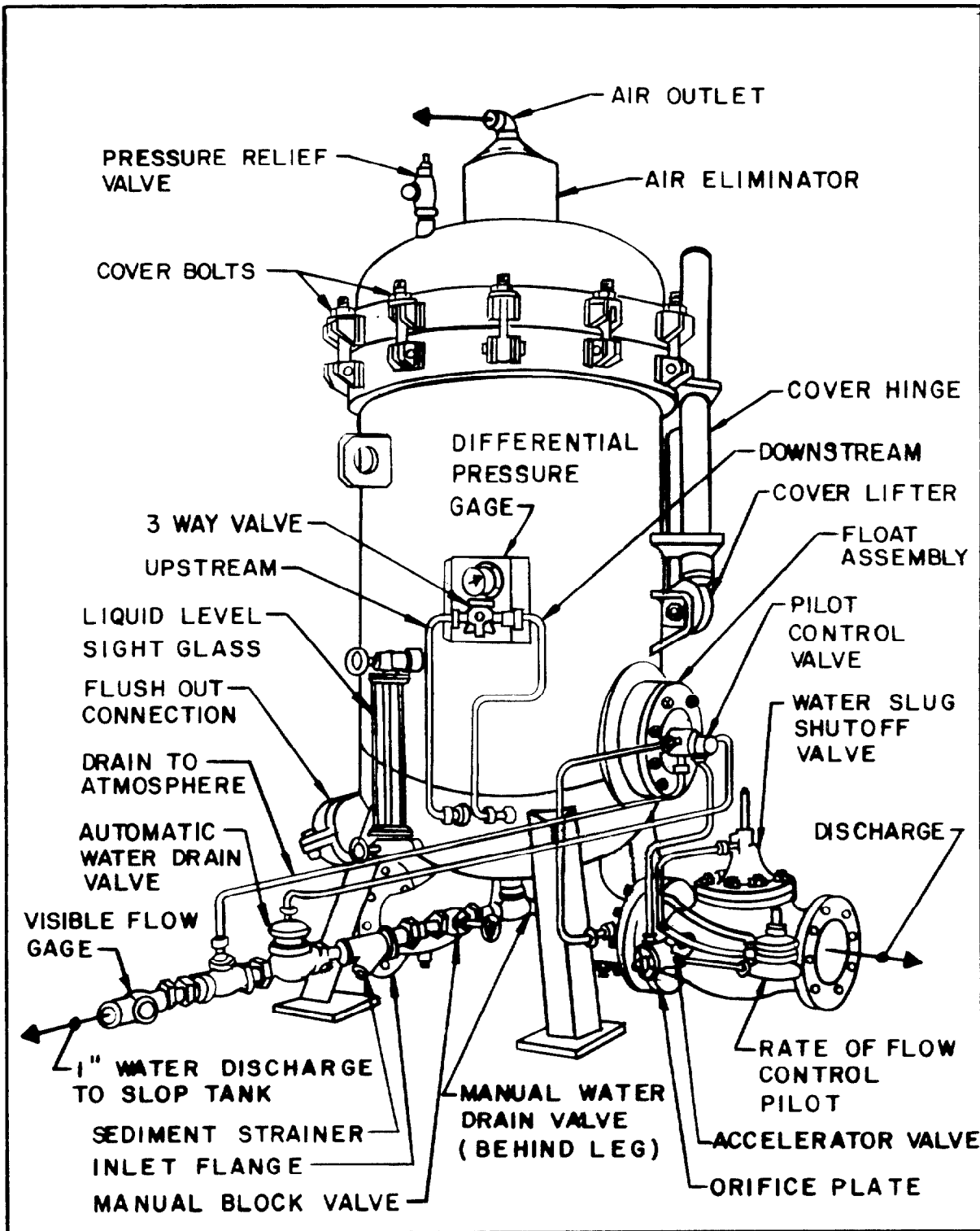
5.4.2 Filter/Separators. Filter/separators are filters with special elements capable of removing solids and separating and removing water. Filter/separators are used at truck fill stands, on mobile refueling equipment, on most fixed/hydrant fueling systems, and on portable fueling systems. Except where noncorrosive pipe and fittings are used, they must be located in bulk receipt delivery lines to storage tanks, at discharge from storage tanks and service tanks, between storage tanks and service tanks, in circulating lines from service tanks, and at the point of final discharge.

5.4.2.1 Description. Filter/separators contain cylindrical elements that cause very small drops of free water to join together into drops that are large enough to settle out. This process is called "coalescing." The same element that causes coalescing also filters out all but the very finest solid matter. One-stage filter/separators allow enlarged drops of water to settle out through gravity after one pass through the coalescing element. Two-stage filter/separators contain a second set of elements, called "separator elements," that allow the fuel to pass through without the water drops while filtering out solid matter. Filter/separators may be equipped with any or all of the following equipment, as illustrated in Figures 5.4.1 and 5.4.2:

- Air eliminator
- Pressure relief valve
- Differential pressure gauge
- Liquid level sight glass
- Cover lifter



**FIGURE 5.4.1**  
**HORIZONTAL FILTER/SEPARATOR &**  
**PRINCIPAL ACCESSORIES**



**FIGURE 5.4.2**  
**VERTICAL FILTER / SEPARATOR**  
**AND PRINCIPAL ACCESSORIES**

- Automatic water drain valve
- Explosion-proof electric heaters and tracers in water sump and water drain piping
- Water slug shutoff valve and rate-of-flow control valve.

5.4.2.2 Maintenance. Manual drains on filter/separators should be regularly opened until a clean, bright, water-free sample of fuel is obtained. The filter elements have a life span of about 3 years but require earlier replacement if any one of the following conditions occur:

- The pressure drop across the filter elements exceeds 20 psi.
- The combined pressure drop across filter elements and system fuel monitor elements exceeds 25 psi.
- The filter/separator graphic plot turns downward, indicating a rupture.
- The filter/separator graphic plot fails to increase after an extended period, indicating either ruptured elements or improper installation.

During filter element changes, the second stage water separator elements (see Figure 5.4.3) should be tested for their ability to repel water. If the element "wets" rather than repels water in "beads," it should be washed with warm water, thoroughly rinsed, and tested again.

5.4.3 "Hay-Pack" Water Separators. Hay-pack water separators were originally adapted from other applications for use in removing large amounts of water and dirt from light fuels such as aviation gasoline. The active agent in these separators uses filter packs of hay, straw, or excelsior made of wood fiber. They are not as good as the more modern multiple element filter/separator and are not approved as substitutes for filter/separators in Navy jet fuel systems. In addition, replacement filter packs are becoming increasingly difficult to obtain. Kits are available to convert some of them into multiple-element filter/separators.

Maintenance of hay-pack water separators consists of replacing the fiber packs when fuel quality begins to visually deteriorate, fuel flow slows, or back pressure increases. As the supply of packs is reduced, maintenance personnel should investigate conversion of the separator into a multiple-element filter/separator.

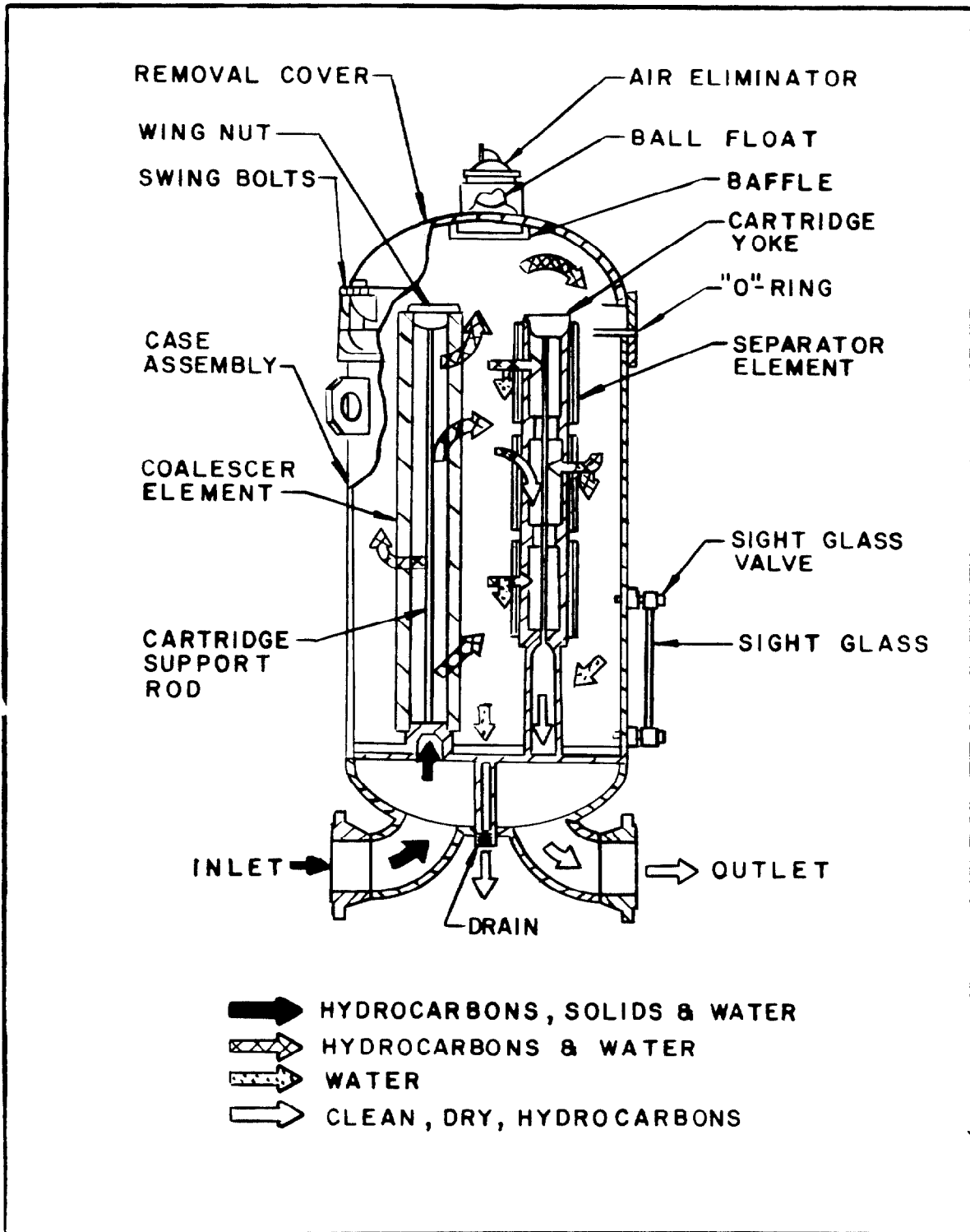


FIGURE 5.4.3  
 VERTICAL TWO STAGE FILTER /SEPARATOR  
 TYPICAL SECTION AND FLOW DIAGRAM

5.4.4 Fuel Quality Monitors. Fuel quality monitors are usually installed downstream of filter/separators near the point of final discharge (such as a truck fill stand, hose cart, refueler loading station, or aircraft fueling station). They are filters with special elements designed to reduce and eventually stop the flow of fuel when the amount of contaminants, either solids or water, exceeds the acceptable limit.

5.4.4.1 Description. Fuel quality monitors contain filter elements that consist of a cylindrical stack of disk elements with small clearances between disks (see Figure 5.4.4). The fuel flows from the outside through the small passages into the hollow center. As solid contaminants collect in the passages, the pressure differential increases. The filter elements are designed so that an increase in pressure differential causes the passages between the disks to close and shut off the flow. When the disks are exposed to water, they swell, close the passages, and reduce or stop the flow.

5.4.4.2 Maintenance. Fuel quality monitors with manual drains should be regularly opened until a clean, bright, water-free sample of fuel is obtained. The monitor elements have a life span of 3 years but require earlier replacement if any one of the following conditions occur:

- The pressure drop across the monitor elements exceeds 20 psi.
- The combined pressure drop across monitor elements and system filter/separator elements exceeds 25 psi.
- The fuel quality monitor graphic plot turns downward, indicating a rupture.
- The fuel quality monitor graphic plot fails to increase after an extended period, indicating either ruptured elements or improper installation.

Whenever fuel quality monitor elements require replacement, filters, filter/separators, and strainers located upstream from the monitor should be inspected for contamination. If contamination is found, its source must be identified and stopped.

5.4.5 Micronic Filters. Micronic filters are used mainly to remove dirt particles and impurities from engine fuels and lubricants. They are available in all types and sizes with a wide variety of replaceable elements.

5.4.5.1 Description. Micronic filters differ from filter/separators mainly in the type of elements used and the general absence of accessories. There are no coalescer elements, and the filter elements are usually designed to

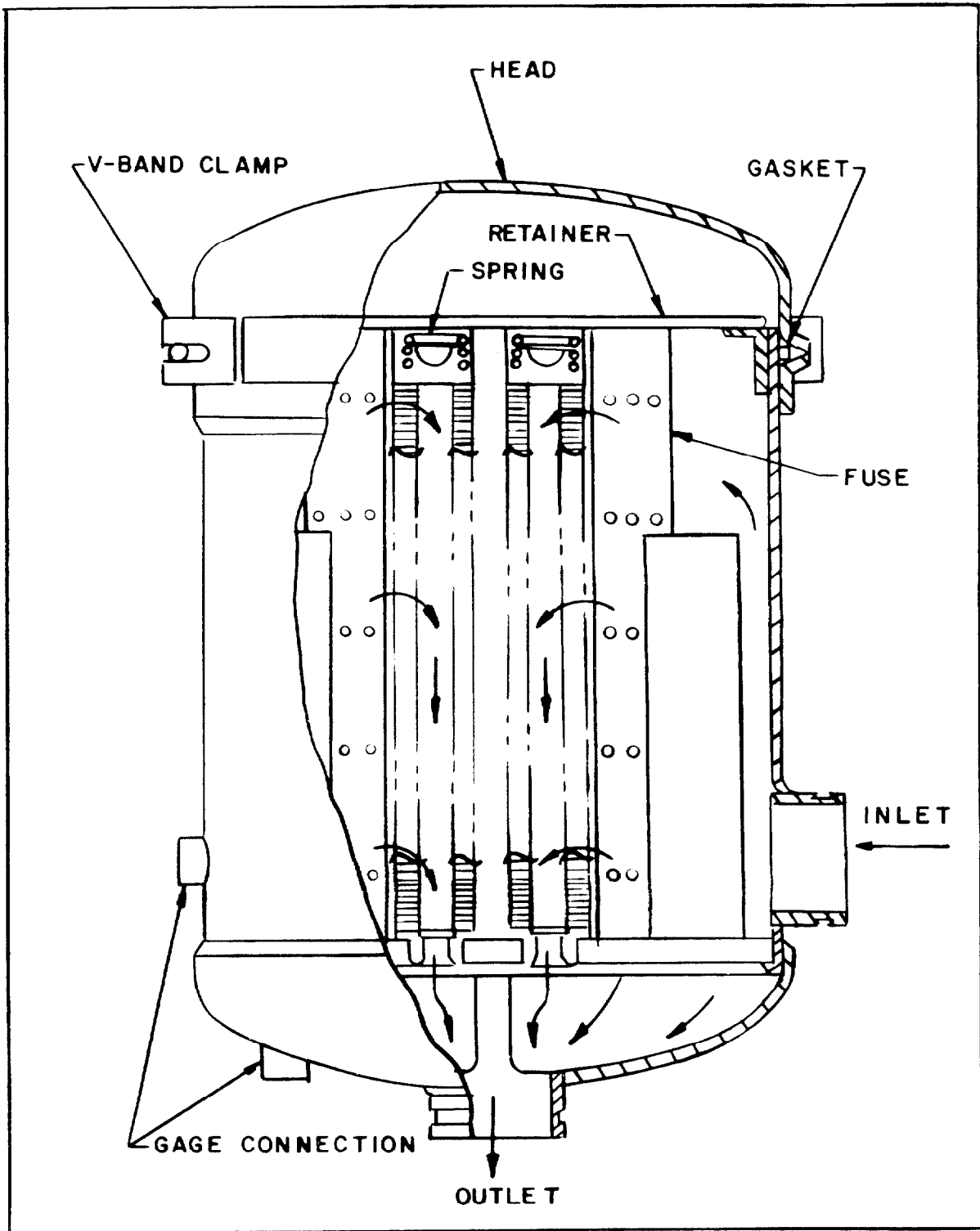


FIGURE 5.4.4  
FUEL QUALITY MONITOR

remove only coarser particles, usually 10 microns or larger. They also remove larger amounts of free water, but that is incidental to their main function of removing dirt. Most micron filters have one or more manual drains to remove water and to allow the condition of the fuel being filtered to be observed (see Figure 5.4.5).

5.4.5.2 Maintenance. The frequency of micron filter element replacement depends on the operating conditions, including the characteristics of the fuel being filtered, fineness of filtration required, and quantity of fuel filtered in a given period. The following considerations, combined with the experience garnered at each individual installation, should be used as a guide for element replacement:

- Replace elements when they or the filtered fuel becomes visibly dirty or discolored.
- Monitor differential pressure. Readings of 25 psi or more usually indicate dirty filter elements.
- Replace elements when the differential pressure gauge suddenly drops at normal flow, indicating a breakthrough.
- Monitor in-service duration. Filter elements that have been in service for 24 months or more should be inspected for chemical and/or physical deterioration.
- If drains are present, they should be opened on a regularly scheduled basis (as directed by the technical manual) until a clear fuel sample is obtained.

5.4.6 Relaxation Chambers. Relaxation chambers are used in petroleum handling operations to dissipate static electricity in the fuel created by pipe flow and/or filtering. As stated in Section 1.3.1.2, if petroleum fuel is held in contact with the walls of a grounded system for at least 30 seconds, the static charge present will dissipate, reducing the potential of fire or explosion.

5.4.6.1 Description. A relaxation chamber is basically a tank inserted into the pipeline between a filter/separator and the discharge point. It ensures that the fuel has a relaxation time of at least 30 seconds prior to discharge.

5.4.6.2 Maintenance. Maintenance requirements for relaxation chambers are relatively minor. A relaxation chamber should be kept free of bottom water accumulation through the use of a low point drain attached to the chamber. When the relaxation chamber follows a filter/separator in the pipeline, draining should be a very infrequent action.



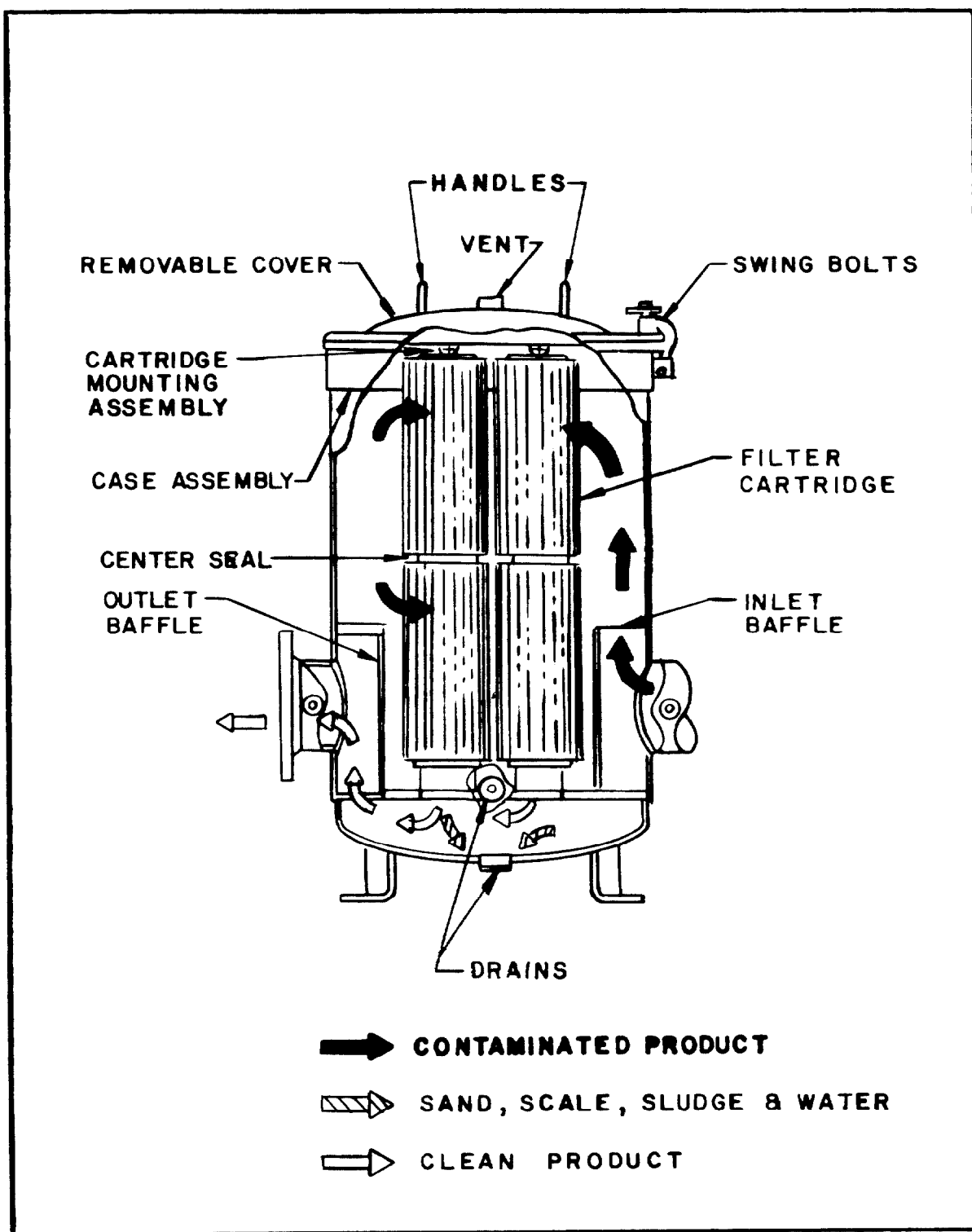


FIGURE 5. 4. 5  
MICRONIC FILTER

Relaxation chamber venting systems should be working properly. The vents used are the same as those used on petroleum storage tanks.

The chamber's grounding system should be periodically tested to ensure proper conductivity.

Finally, if the relaxation chamber is equipped with a relief valve, the valve should be properly calibrated.

## 5.5 STRAINERS.

5.5.1 Scope. This section provides general background information about strainer installations and describes common organizational level maintenance and troubleshooting associated with strainers. It is intended to be used in conjunction with detailed technical information found in manuals or operating instructions. Recommendations and guidance in the following subsections should be used to form the basis for a maintenance plan tailored for these items at your installation. Additional information pertinent to strainers can be found in the following references:

- MIL-HDBK 201B, "Military Standardization Handbook for Petroleum Operations"
- NAVPERS 10788-B, "Principles of Naval Engineering"
- NAVEDTRA 105240E1, "Machinist's Mate 3 and 2."

5.5.2 Description. Strainers are used to remove large particles from liquid streams. They protect system components such as filters, meters, and pumps from mechanical damage by large pieces of debris. Strainers are extremely helpful in new systems that contain relatively large amounts of construction debris and in incoming lines from ships and barges that are often sources of heavy contaminants. Large particles are removed by the strainer basket, which is usually made of stainless steel wire mesh. Mesh size may vary from 20 to 100 strands per inch, depending on the characteristics of the fuel and the purpose of the strainers. Strainer baskets may be supplemented by insertion of cloth bags during periods of expected contamination.

5.5.3 Maintenance. Dirty strainer baskets can be washed (using air jets or pressurized liquid streams) and reused as long as they are not ruptured or otherwise damaged. Gum or tar can be removed by soaking baskets in a high flash point fuel, such as kerosene.

Strainers should be installed with a shutoff valve on the inlet and outlet. These valves should be closed, and the strainer body should be drained out before removing the cover.

Some strainers, such as pipeline strainers that are in continuous service and require frequent cleaning, have special liquid connections with an auxiliary pump that can be used to flush out the basket while the unit is in service. Dirty fuel and debris are drained into a slop tank and disposed of in accordance with proper environmental directives.

Duplex strainers have two bodies and baskets with a two-way selector valve between them. With this arrangement, one can be cleaned while the other remains in service (see Figure 5.5.1).

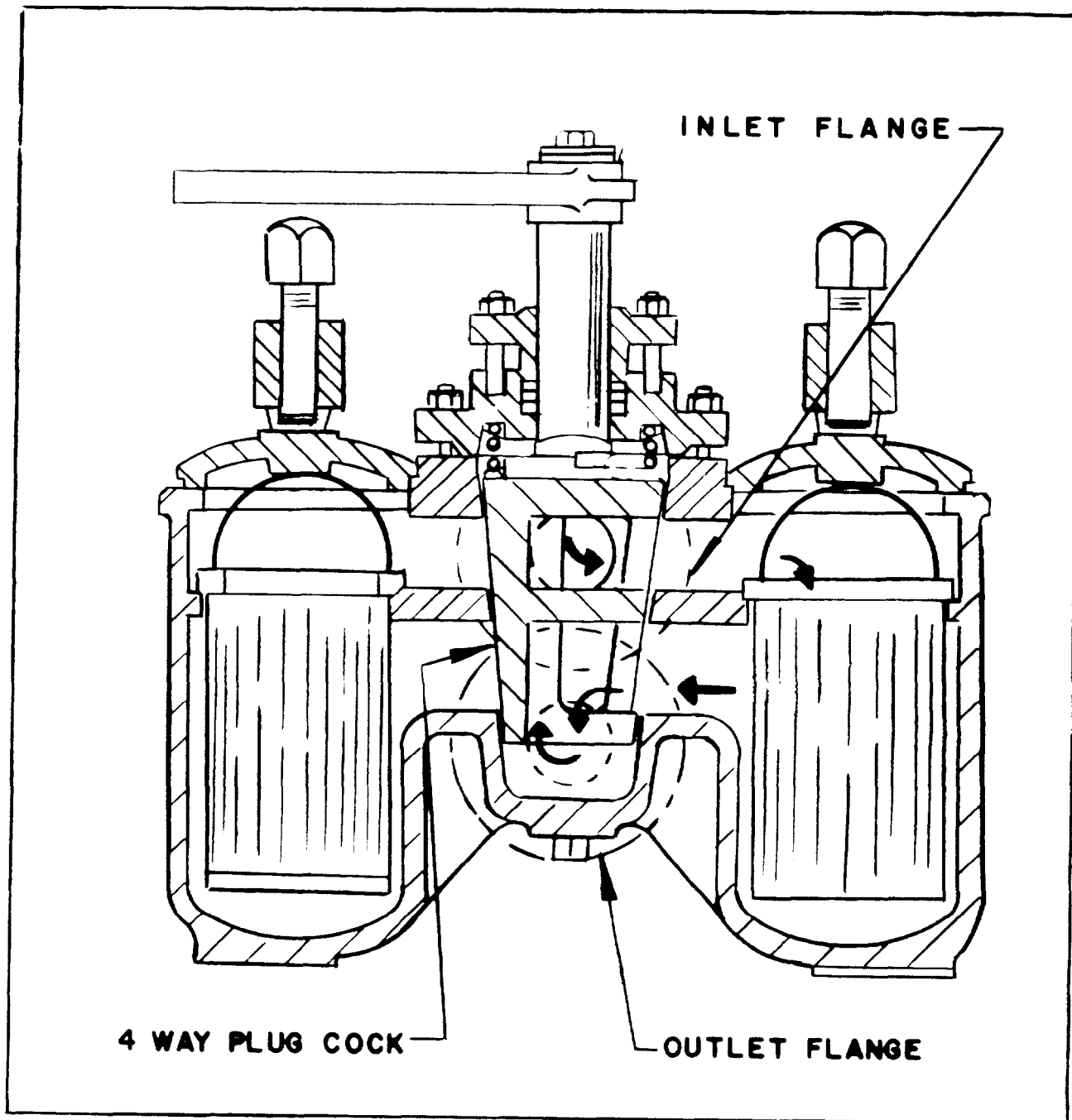
Strainers should be regularly inspected to keep them clean and unrestricted and to safeguard the equipment they protect. The proper cleaning interval must be developed by experience with each individual installation and trend analysis established through observation of differential pressure gauges (sometimes installed on the inlet and outlet side of a strainer). The condition can also be determined by taking frequent samples from the bottom drain.

Unexpected accumulations of particles, tar, paper, or other foreign matter are an indication of severe contamination and should be brought to the attention of supervisors or end-point users. Such instances should trigger an inspection of filter/separators or other upstream fuel system components to locate the source. Downstream components should also be checked for accumulation of particles too small to be trapped by the strainer and for damage caused by contaminants.

## 5.6 PUMPS.

5.6.1 Scope. This section provides general background information on pumps used in petroleum facilities and describes common organizational level maintenance and troubleshooting associated with pumps. It is intended to be used in conjunction with detailed technical information contained in manuals or operating instructions. Recommendations and guidance in the following subsections should be used to form the basis for a maintenance plan tailored for these items at your installation. Additional information pertinent to pumps can be found in the following references:

- API STD 610, "Centrifugal Pumps for General Refinery Service"
- MIL-P-13386, "Pumps, Centrifugal, Multi-Stage, Vertical"
- MIL-P-176908, "Pumps, Rotary, Power Driven"



**FIGURE 5.5.1**  
**DUPLEX STRAINER COMPONENTS**

- MIL-P-21214, "Pumps, Centrifugal, Vertical Sump"
- MIL-HDBK-201B, "Petroleum Operations."

#### 5.6.2 General Maintenance Requirements for Pumps.

5.6.2.1 Specific Procedures. MIL-HDBK-201B outlines some basic criteria that may indicate the need to perform minor maintenance or overhaul on a pump. Minor maintenance such as repacking, packing adjustment, or coupling alignment can normally be performed by operators while the pumps are still installed in the system. These functions must be accomplished with care since improper adjustment can cause severe damage to the pump.

In addition to the general maintenance guidelines specified in Section 5.1, the following practices should be observed during pump maintenance operations:

- Feel the pump during operation and note any excessive vibration or heat radiating from the bearings, packings, or seals that may indicate necessary maintenance actions. Also, listen for unusual flow or mechanical noises.

- After the pump is secured, note any excessive physical effort necessary to hand rotate the pump, scraping noises, or varied resistance to rotation.

- Inspect mounting bolts, the foundation, and hardware for cracks.

5.6.2.2 Troubleshooting of Common Pump Problems. Proper operation and maintenance of pumps are essential to the function of most fuel facilities. In many cases, when pumps do not operate properly, the cause may be a system condition that is not directly associated with the pump itself. Table 5.6.1 summarizes some of the more common pump operating problems and their possible causes. The following paragraphs describe the problems in more detail.

- No Fuel Delivered. Lack of fuel flow can be caused by any of the following problems:

- Empty Storage Tank. This is an obvious but sometimes overlooked possibility, especially with small underground tanks.

- Pump Not Primed. Centrifugal pumps will not work unless the impeller is completely immersed in liquid. For this reason, they are not suitable for applications such as unloading trucks or tank cars or where the liquid level in the storage tank is below the pump suction. To prime a pump, open

PROBLEM	POSSIBLE CAUSES
NO FUEL DELIVERED	Empty storage tank Pump not primed Speed too low Insufficient NPSH Discharge head too high Impeller casting broken Wrong direction of rotation
FLOW RATE OR PRESSURE BELOW NORMAL	Air leaks in suction piping or stuffing box Pump speed reduced Insufficient NPSH Restricted discharge piping Variation in storage tank liquid level Air in piping Air or vapor pockets in suction piping
MOTOR OVERLOAD	Lack of pressure drop in discharge piping Increase in liquid viscosity or specific gravity Internal defects in pump Low voltage Irregular frequency
EXCESS NOISE OR VIBRATION	Inadequate NPSH Misaligned, worn, or bent shaft or bearings Relief valve chattering Hydraulic shock

TABLE 5.6.1  
PUMP TROUBLESHOOTING CHART

the vent cock or plug in the top of the volute and add liquid under a positive head into the suction connection until fluid flows from the vent.

- Pump Speed Too Low. If the motor speed is too low, the pump may not develop enough pressure to deliver fuel. Have an electrician check that the motor voltage is not too low and that all three phases (for three-phase motors) are energized. Check the speed with a tachometer if necessary and compare the speed with nameplate data or the technical manual.

- Insufficient Net Positive Suction Head (NPSH). NPSH is the net positive pressure working at the pump suction flange to push the liquid into the impeller, rotor, or piston of the pump, taking into account such factors as atmospheric pressure, altitude correction, static head, friction loss, and liquid vapor pressure. If there is insufficient NPSH available, the pump will deliver at less than rated capacity or possibly not at all. Possible causes are that the piping is too small, the pump is too far from the storage tank, the suction lift is too high, the fuel vapor pressure is too high, or a clogged strainer or other restriction exists in the suction system.

- Discharge Head Too High. If there are severe restrictions in the discharge system or if the discharge point is elevated too far above the pump, the pump may not be able to deliver fuel.

- Impeller Casting Broken. Even though impellers are keyed to the drive shaft, there have been cases where the impeller bound up on the inside of the volute and broke around the hub.

- Wrong Direction of Rotation. This is rare, but it can happen with a new pump or a replaced or rewired motor. The direction of rotation in three-phase power systems can be changed by changing the motor lead connection. Most pump casings have an arrow on them to show the proper rotation, but even these have been known to be reversed.

- Flow Rate or Pressure Below Normal. Reduced performance of a pump can be caused by any of the following conditions:

- Suction Piping Leaks. Air leaks in the suction piping or stuffing box on the suction side will reduce pump output.

- Reduced Pump Speed. Low voltage or an open phase in the electrical system can cause lower than normal pump speed.

- Restricted Discharge Piping. If the discharge pressure is normal or above normal but the flow rate declines, it is a sign that there is a restriction in the discharge piping. This could be caused by dirty filters, a partially closed valve, or a fuel quality monitor that is restricting flow.

- Internal Wear in the Pump. Excessive clearances between parts such as the wear rings of a centrifugal pump, the piston rings or valves of a reciprocating pump, or the rotors or vanes of a rotary pump, will cause a reduction in discharge pressure and flow rate.

- Storage Tank Liquid Level. The head of liquid in the storage tank adds to the pressure developed by the pump in the system. The added head pressure is reduced as the level in the tank drops. The head of liquid in a tank containing 40 feet of liquid at 0.82 specific gravity is about 14 psi. At 5 feet, the head is less than 2 psi, and the system pressure is reduced accordingly.

- Air in Piping. If air is introduced into the system from some outside source, such as a positive displacement pump used to defuel trucks, there will be a reduction of flow while the slug of air passes through.

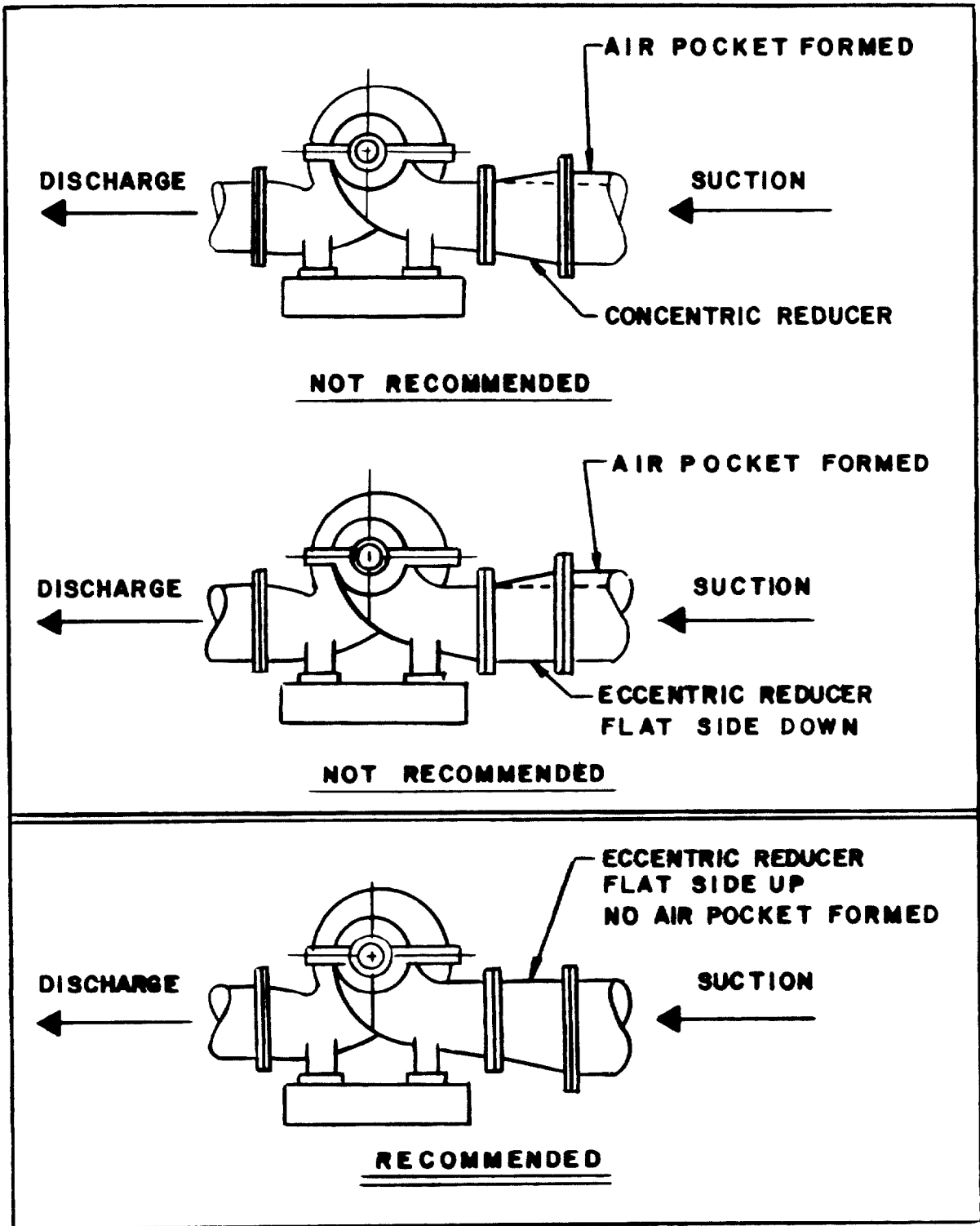
- Air or Vapor Pockets in Suction Piping. Air or vapor pockets in the suction piping can cause a reduction or complete stoppage of flow. Figure 5.6.1 shows how air or vapor pockets can be formed by improper installation of reducers. Suction piping should be flat on top, as shown in Figure 5.6.1, or slope gently but uniformly upward toward the storage tank.

- Motor Overload. Motor overload is indicated by tripped circuit breakers, blown fuses, or high motor temperature. It may be caused by:

- Insufficient Pressure Drop in the System. Centrifugal pumps are selected so that the performance curve is compatible with the system curve of flow rate versus pressure drop. If a centrifugal pump, designed to pump against fairly high system pressure drops, is switched to a system with a much lower pressure drop, the flow rate tends to increase, and the horsepower demand tends to increase accordingly. When the power demand exceeds the circuit protection rating, the breakers trip. A temporary solution is to increase the system pressure by throttling a valve in the discharge piping.

This will increase the pressure and decrease the flow rate and motor horsepower demand. Never attempt to throttle a pump by closing a suction valve. If the change in service is to be





**FIGURE 5.6.1**  
**AIR POCKETS IN SUCTION PIPING**

permanent, the problem can be corrected by cutting down the impeller diameter. This will permanently reduce the flow rate and power demand.

- Liquid More Viscous or of Greater Specific Gravity Than the Design Liquid. A pump operating at a given capacity has a greater power demand if the viscosity or specific gravity of the product being pumped is increased. If this is a permanent condition, a more powerful motor is required.

- Stuffing Boxes Too Tightly Packed. Slightly loosen the packing gland, but be alert for leakage.

- Misalignment. Check pump and motor alignment and adjust as required. Check casing for distortion or signs of excessive stress from connected piping.

- Low Voltage. Low voltage or irregular frequency of an AC power system can cause motor overload. Either can commonly happen when power is supplied by a small local generating plant that is not a part of a larger power supply grid.

- Excess Noise and Vibration. Excess noise or vibration can be caused by the following:

- Inadequate NPSH. Inadequate NPSH can cause the liquid to flash into vapor. Bubbles of vapor passing through the pump sound like gravel or marbles banging around in the pump. The collapse of the vapor bubbles is the cause of cavitation.

- Worn, bent, or misaligned shaft or bearings.

- Chattering relief valve with a spring setting that is too low.

- Hydraulic shock from improper design or valves that close too fast.

- Pressure and Vacuum Gauges. In analyzing most of the troubles described in the previous paragraphs, much time and trouble can be saved by the use of high quality pressure and vacuum gauges to establish the operating condition. Pressures and vacuum gauge readings that are too low for the system probably indicate air leaks in the suction piping or worn internal parts such as wear rings, vanes, or gears or leaking packings. Pressures that are too high for the pump design, usually associated with low flow rate or no flow, indicate too much resistance in the discharge system. Low discharge pressure and very high flow for a centrifugal pump may indicate a potential motor overload. High vacuum on the

suction side with no or low flow indicates restricted suction piping or too high of a suction lift and a potential vapor lock.

5.6.2.3 Routine Preventive Maintenance. Most of the problems described in the preceding paragraph are caused by conditions outside the pump itself. They might be due to an improper installation or altered application of the pump. Most types of pumps used in fuel systems are ruggedly constructed and, with reasonable care, will give many years of trouble-free service. Some items that should be included in a regular maintenance program are as follows:

- Operator Inspection. When the pump is running, look, listen, and feel for anything unusual such as leaks, hot bearings, vibration, loose parts, or strange noises.

- Cleanliness. Keep all foreign objects and material away from the pump. Wipe all surfaces clean. Keep spare parts in their original packages and protect them from dirt and corrosion.

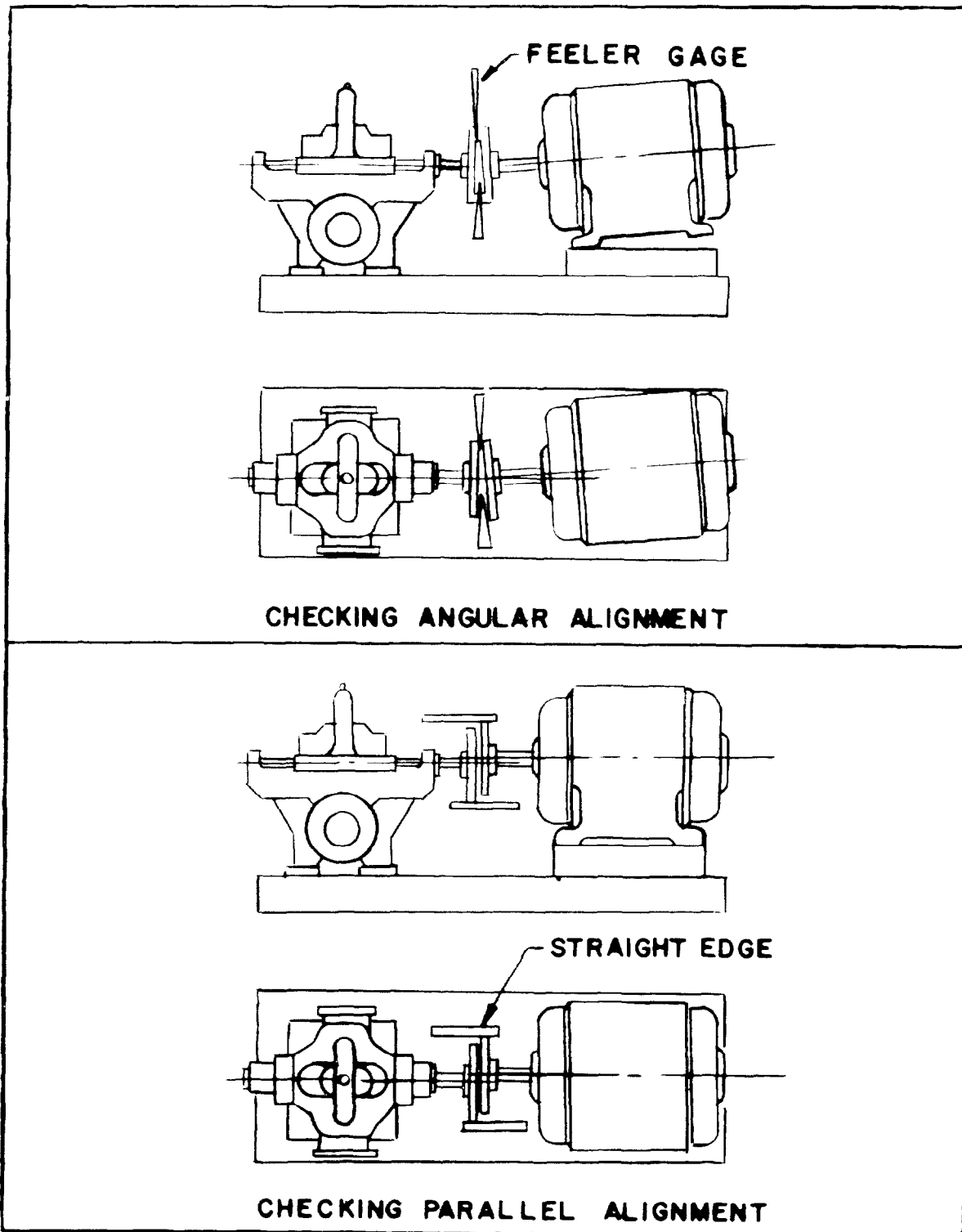
- Lubrication. If the pump is oil-lubricated, keep the oil cups full. Be sure that oil rings are free and passages are open and clean. Fill grease cups or pressure-type fittings using only lubricants of the type recommended by the manufacturer.

- Reduction Gears. Reduction gears, found on rotary pumps, may require periodic oil changes (as recommended by the manufacturer). Check the oil level and quality between changes.

- Strainers. If the strainer is equipped with a bottom drain valve, open it and check for dirt. Remove and clean the basket in accordance with operating experience and scheduled maintenance.

- Coupling and Shaft Alignment. If there is vibration, hot running, excessive bearing, or packing or seal wear, there may be an alignment problem. Check to see if the pump and motor base bolts are tight. Disconnect the piping flanges and watch for movement that would indicate excessive piping strain. Figure 5.6.2 illustrates the basic alignment procedure for pump shaft couplings. Follow the coupling manufacturer's instructions for each particular make and type.

- Stuffing Boxes. Stuffing boxes with packing rings are supposed to drip slightly for cooling and lubrication. Damage to the packing or shaft may result if they are over-tightened. Tighten them only when the pump is running.



**FIGURE 5.6.2**  
**PUMP SHAFT COUPLING ALIGNMENT**

- **Mechanical Seals.** Mechanical seals do not usually require much attention if properly installed and cooled. If they do fail (which might be caused by cooling stream failure, dirt, or a defective part), they have to be replaced. Leaking seals may indicate other problems, such as bearing failure or shaft misalignment, which can cause shaft movement and vibration that, in turn, cause seal faces to leak.

- **Coupling Guards.** The Occupational Safety and Health Administration (OSHA) requires guards on rotating parts such as couplings, set screws, keys, gears, pulleys, and belts. Ensure they are securely mounted.

**5.6.3 Gear Pumps.** Gear pumps are positive displacement rotary pumps that can use a variety of mechanisms to trap a volume of liquid and move it in the desired direction. Gear pumps use gears, screws (worm gears), or lobes to carry out this function. Figure 5.6.3 shows a variety of gear pumps.

All types of rotary pumps have the ability to handle high viscosity fluids under conditions for which centrifugal pumps are not suited. The rotary type exhibits the constant flow characteristics of the centrifugal pump and the positive discharge feature of reciprocating pumps. Gear pumps are self-priming and have constant discharge volume, regardless of their fluid suction pressure. Relief valves are required on discharge piping and are sometimes provided inside the pump to recirculate fluid from the discharge to the suction of the pump if the discharge valve is shut.

**5.6.3.1 Description.** Gear, screw, or lobe pumps use a set of interlocking, close tolerance gears or lobes to move fluid. A driver gear is connected directly to the pump shaft and drives an idler gear. Each gear is closely fitted in the pump housing and is subject to wear if run at high speeds or used to pump fluids with poor lubricating properties. Fluid enters the tooth space and is carried along the casing to the outlet. This same principle is followed with rotary screw and lobe pumps. Screw pumps may have one driver and one, two, or no idlers.

A gear pump usually has a mechanical seal to prevent leakage along the shaft and roller or ball bearings that are cooled and lubricated by the fluid being pumped. In some cases, the bearings may be located in the casing but separated from the fluid by mechanical seals and may have a separate means of cooling and lubrication.

**5.6.3.2 Maintenance.** Because of the close tolerance in gear pumps, they exhibit reduced capacity as they wear and will require an overhaul to restore original capacity. Section 5.6.2.2 covers troubleshooting and should be followed when performance or leakage problems arise. In addition, follow all

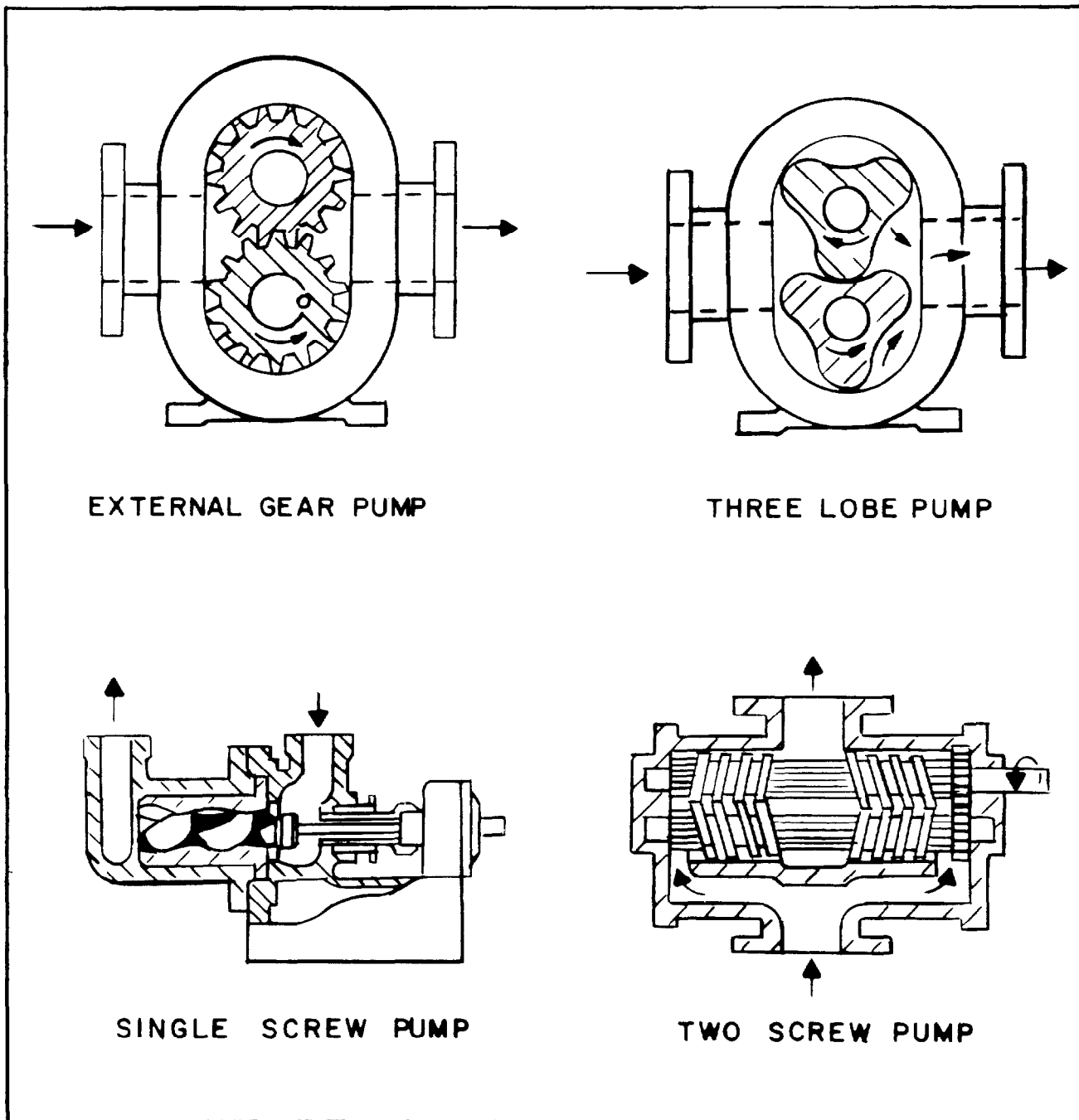


FIGURE 5.6.3  
GEAR PUMP VARIETIES

applicable general maintenance and safety requirements and refer to the applicable pump technical manual.

**5.6.4 Diaphragm Pumps.** Diaphragm pumps are positive displacement, reciprocating pumps used for low pressure, contaminated systems. Diaphragm pumps can run dry for indefinite periods without damage, or they can pump the most abrasive fluids, such as settling tank sludge, with little wear on pump parts. Figure 5.6.4 is a cross-section of a typical diaphragm pump.

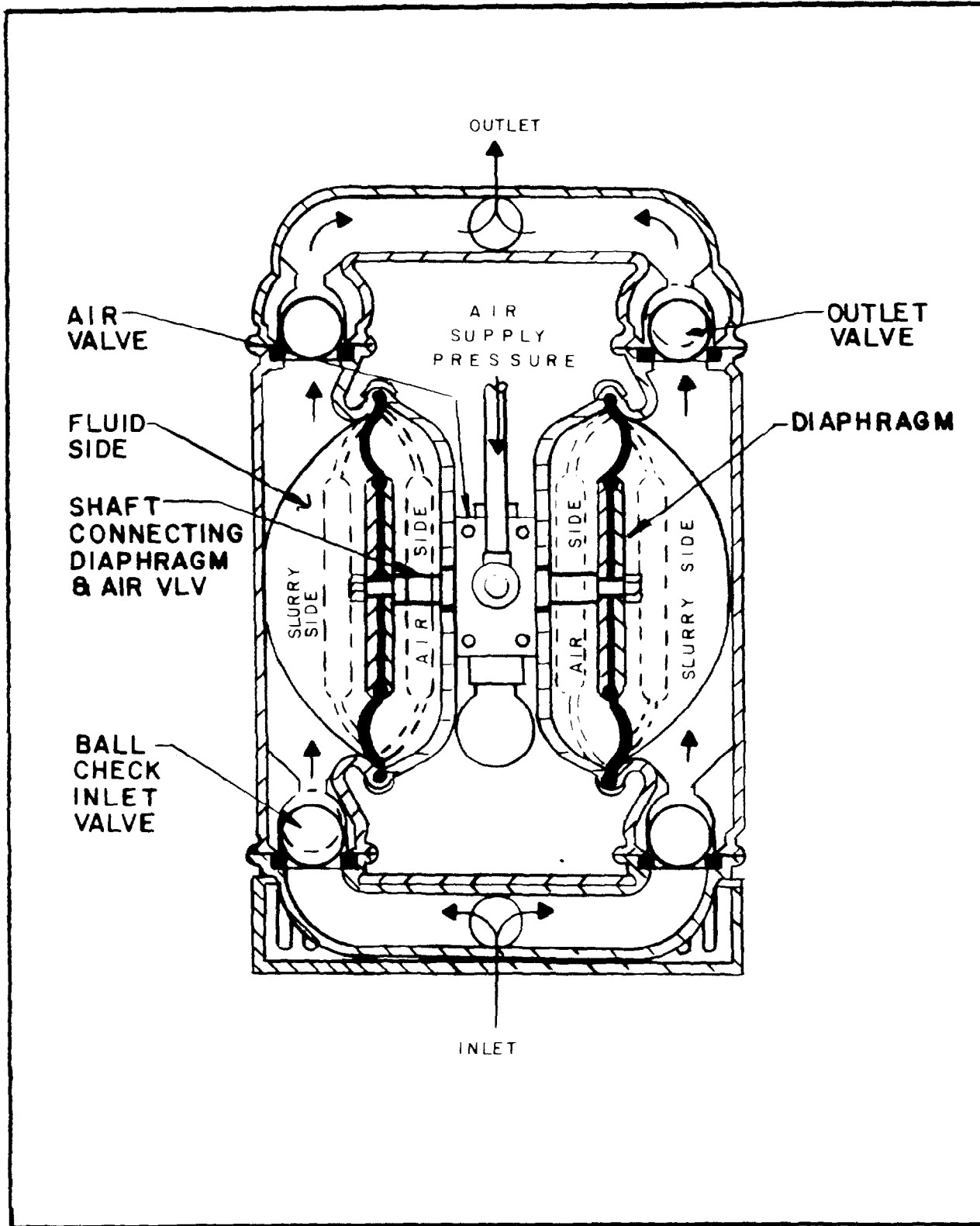
**5.6.4.1 Description.** A diaphragm pump operates by directing compressed air to the backside of a diaphragm through an air control valve. Fluid is pushed out of the liquid chamber through a check valve as the diaphragm is pulled in by a shaft that is connected to the pressurized diaphragm. The suction created draws fluid into the liquid chamber through the pump inlet check valve. When the pressurized diaphragm reaches its limit of stroke, an air valve shifts the air supply to the opposite diaphragm and vents the air from the side at its limit. This cycle continues as long as the air supply is maintained.

**5.6.4.2 Maintenance.** Diaphragm pumps require very little maintenance. Most parts in each pump can be replaced if they are found to be defective. Problems associated with diaphragm pumps are usually manifested by a reduction in capacity, indicating a check valve or diaphragm problem or a failure of the air valve. These problems cause the pump to short stroke or stop operating.

Section 5.6.2.2 covers troubleshooting and should be followed when problems do arise. As always, consult the pump technical manual and follow all applicable general maintenance and safety requirements.

**5.6.5 Centrifugal Pumps.** A centrifugal pump moves fluid by increasing the velocity of the fluid and transforming that energy into pressure by reducing the velocity. The centrifugal pump utilizes the throwing force of a rapidly revolving impeller. The liquid is pulled in at the center (or eye) of the impeller and is discharged at the outer rim of the impeller. Figure 5.6.5 shows the flow-path through a typical single stage, single suction, centrifugal pump.

By the time the liquid reaches the outer rim of the impeller, it has acquired considerable velocity. The liquid is then slowed down by traveling through the volute, where the diameter is increasing. As the cross-sectional area of the volute increases, the velocity decreases, causing the pressure to increase.



**FIGURE 5.6.4**  
**DIAPHRAGM PUMP CROSS SECTION VIEW**



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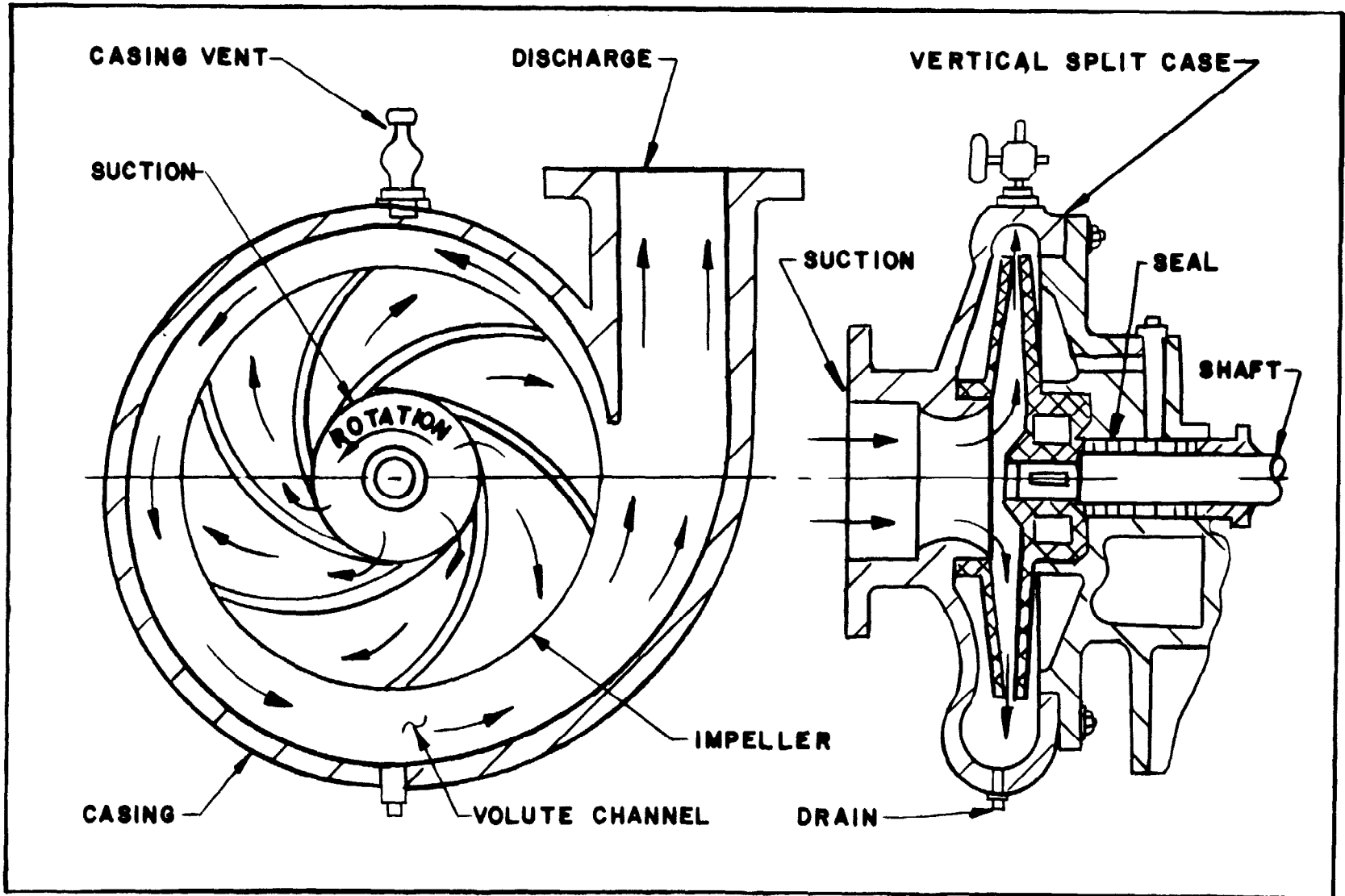


FIGURE 5.6.5

SINGLE SUCTION CENTRIFUGAL PUMP SECTIONAL VIEW

5.6.5.1 Description. API STD 610, "Centrifugal Pumps for General Refinery Service," is the new Navy standard for centrifugal pumps. The following discussion applies to centrifugal pumps conforming to this standard.

The casing for the liquid end of a pump with a single-suction impeller is made with an end plate that can be removed for inspection and repair of the pump. A pump with a double-suction impeller is generally made so that one-half of the casing may be lifted without disturbing the pump.

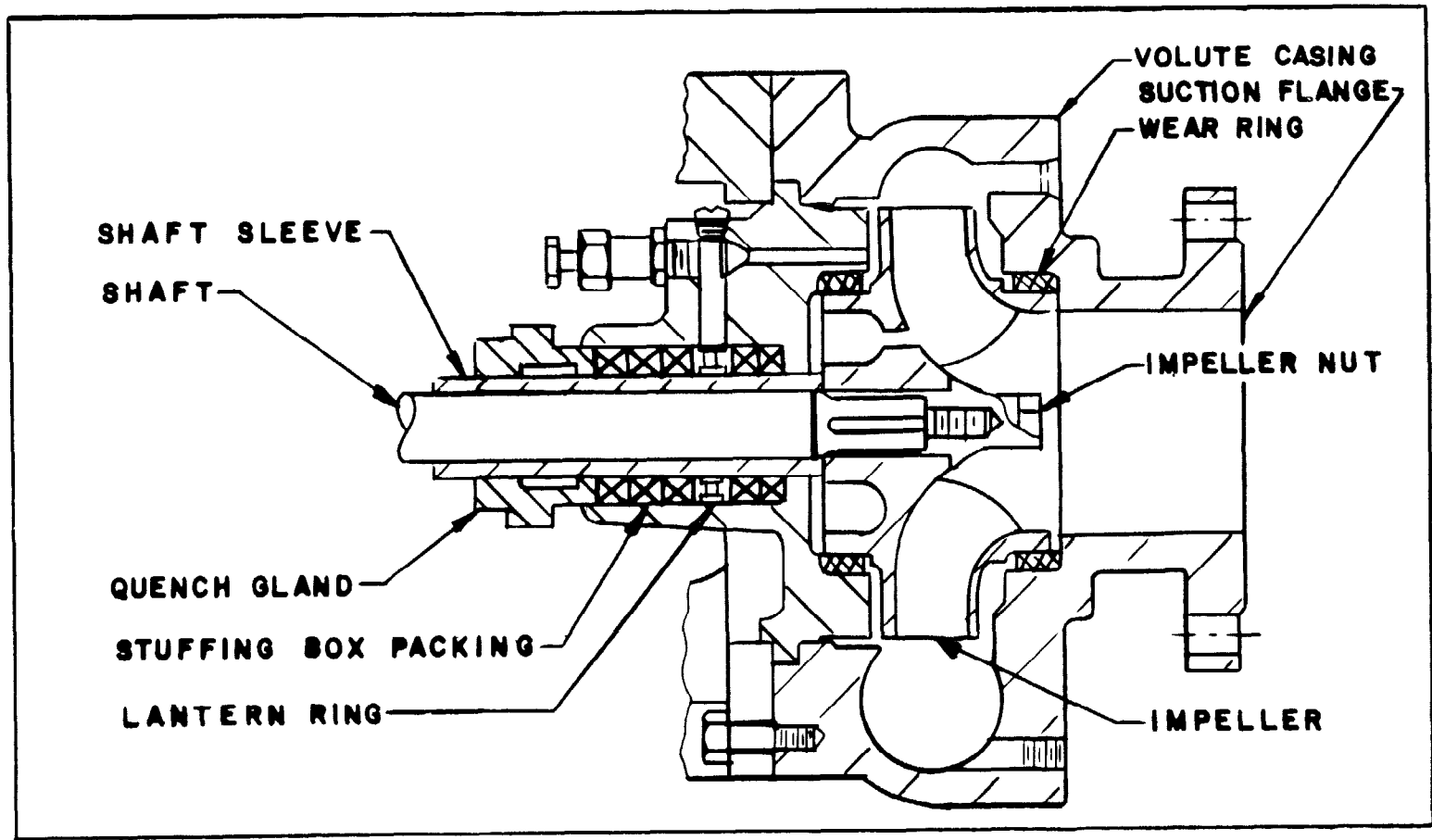
Since the impellers rotate at a very high speed, they must be carefully machined in order to minimize friction, and they must be balanced to avoid vibration. To minimize leakage between the discharge side and the suction side of the pump casing, close radial clearance must be maintained between the outer hub of the impeller and the part of the pump casing in which the hub rotates.

Because of the high rotational speed of the impeller and the necessarily close clearance, the running surfaces of both the impeller hub and the casing at that point are subject to relatively rapid wear. To eliminate the need for renewing an entire impeller and pump casing solely because of wear in this location, centrifugal pumps are designed with replaceable wearing rings. One ring, the impeller wearing ring, is attached to the hub of the impeller and rotates with the impeller; a matching ring, the casing wearing ring, is attached to the casing and is stationary. Wearing rings can be seen in Figure 5.6.6.

Some small pumps with single-suction impellers are made with a casing wearing ring only. In this type of pump, the casing wearing ring is fitted into the end plate.

In many centrifugal pumps, the shaft is fitted with replaceable sleeves. The advantage of using sleeves is that they can be replaced more economically than the entire shaft. Shaft sleeves are illustrated in Figures 5.6.6 and 5.6.7.

Recirculating lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound when the discharge is entirely shut off. Seal piping (liquid seal) is also installed to cool the shaft and the packing, to lubricate the packing, and to seal the joint between the shaft and the packing against air leakage. A lantern ring (spacer) is inserted between the rings of the packing in the stuffing box. Seal piping leads liquid from the discharge side of the pump to the annular space within the lantern ring. The web of the ring is perforated so that water can flow in either direction along the shaft, between the shaft and the packing.



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**FIGURE 5.6.6**  
**STUFFING BOX WITH PACKING**  
**CROSS SECTIONAL VIEW**

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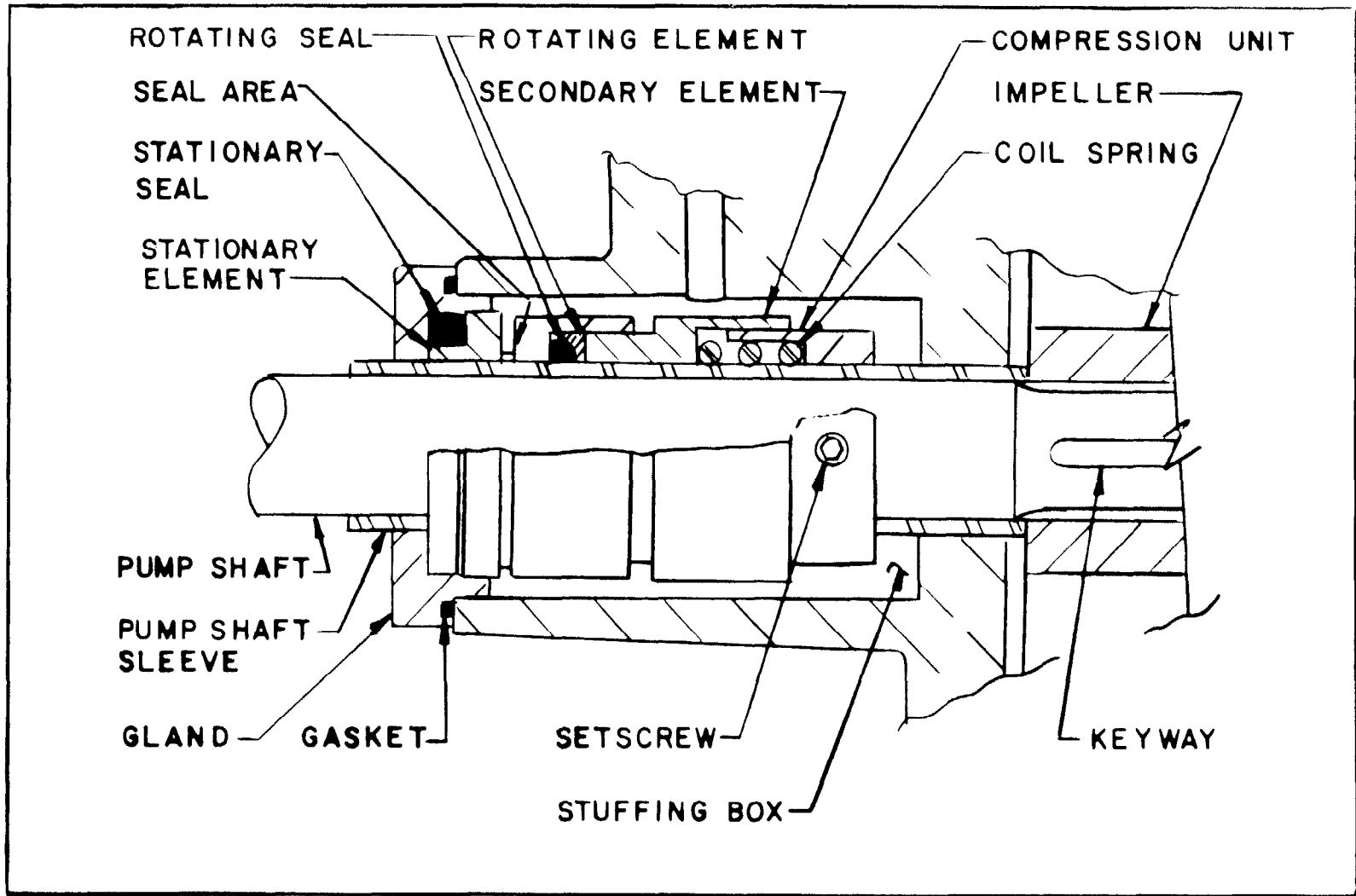


FIGURE 5.6.7

STUFFING BOX WITH MECHANICAL SEAL CROSS SECT. VIEW

Mechanical seals instead of packing are used in a variety of centrifugal pumps. one type of mechanical seal is shown in Figure 5.6.7. Spring pressure keeps the rotating seal face snug against the stationary seal face. The rotating seal and all of the assembly below it are affixed to the pump shaft. The stationary seal face is held in place by the seal gland and packing ring. A static seal is formed between the two seal faces and the sleeve. System pressure within the pump assists the spring in keeping the rotating seal face tight against the stationary seal face. When the seals wear out, they are simply replaced. New seals should not be touched on the sealing face because body acid and grease can cause the seal to prematurely pit and fail.

Bearings support the weight of the impeller and shaft and maintain the position of the impeller, both radially and axially. Some centrifugal pumps have a built-in bearing lubrication system, complete with lube oil and flow indicators. Other bearings are grease-lubricated with grease cups and vent plugs constructed in the housing to allow for periodic lubrication.

The power end of a centrifugal pump may be either a steam turbine or, more commonly, an electric motor. As a rule, high-pressure centrifugal pumps are direct drive; that is, the impeller rotates at the same RPM as the turbine. However, some low-pressure centrifugal pumps have reduction gears installed between the turbine and the impeller.

5.6.5.2 Maintenance. Centrifugal pumps are very dependable when properly maintained. Packing adjustment and motor lubrication are usually the only maintenance items that may be required during operations. Mechanical seals also require maintenance but, if properly installed on a true shaft, give long, reliable service. Frequent trouble with these seals is usually traceable to shaft vibration, wear, or improper installation. It is most important that the seal faces be protected against contact with skin, grease, or metal particles. Further troubleshooting guidelines are found in Section 5.6.2.2. Refer to the applicable technical manual for specific maintenance procedures, and follow all applicable general maintenance and safety requirements.

5.6.6 Rotary Vane Pumps. Rotary vane pumps are positive displacement rotary pumps that use either a swinging vane or a sliding vane to trap a segment (specific volume) of fluid and move it in the desired direction.

5.6.6.1 Description. The rotary vane pump consists of a cylindrically bored casing with a suction inlet on one side and a discharge outlet on the other side. A rotor, smaller in diameter than the cylinder bore, is driven about an axis that is off center and above the centerline of the

cylinder to provide minimum clearance at the top and maximum clearance on the bottom.

The rotor carrier vanes, which move in and out as the rotor turns, seal against the face of the cylinder bore to provide pumping volume. The vanes trap fluid on the suction side and carry it to the discharge side, where a gradually reduced volume forces the fluid out the discharge line. The vanes may swing on pivots, or they may slide in slots in the rotor. Vane type pumps are shown in Figure 5.6.8.

5.6.6.2 Maintenance. Rotary vane pumps are similar to gear pumps in that they are designed with very close tolerances on the rotating parts. However, as the vanes wear, they will slide further out of the rotor and minimize any reduction in capacity due to wear. This requires that rotary vane pumps be inspected after a predetermined number of operating hours to ensure continued performance. Periodic but infrequent replacement of the vanes should be expected. For other problems, refer to the applicable pump technical manual and follow all applicable general maintenance, troubleshooting, and safety requirements.

5.6.7 Reciprocating Pumps. Reciprocating pumps are positive displacement pumps that use a piston moving back and forth in a cylinder to move a segment of fluid in the desired direction. Reciprocating pumps are low volume but are sturdy and can handle contaminated fluids and very viscous and sludgy materials. A steam-powered reciprocating pump is illustrated in Figure 5.6.9.

5.6.7.1 Description. A reciprocating pump uses a set of pistons or plungers, cylinders, valve assemblies, and mechanical control linkages. On the suction stroke, the piston moves out, causing pressure in the pump cylinder to drop and the suction valve to open, which permits the fluid to flow into the cylinder. On the discharge stroke, the piston reverses direction toward the cylinder head, causing pressure to increase in the cylinder, the suction valve to shut, and the discharge to open, causing flow.

The capacity of the pump is determined by the volume displaced by the piston on one stroke and the frequency of the strokes. The discharge pressure is determined by the viscosity of the fluid being pumped and the back pressure created in the discharge piping. The power end of a reciprocating pump may be either a steam piston/cylinder arrangement or an electric motor.

One of the characteristics of a reciprocating pump is the cyclical variation of discharge flow and pressure. By using pumps with two or more cylinders and varying the timing on each cylinder, smoother discharge flow will be produced.

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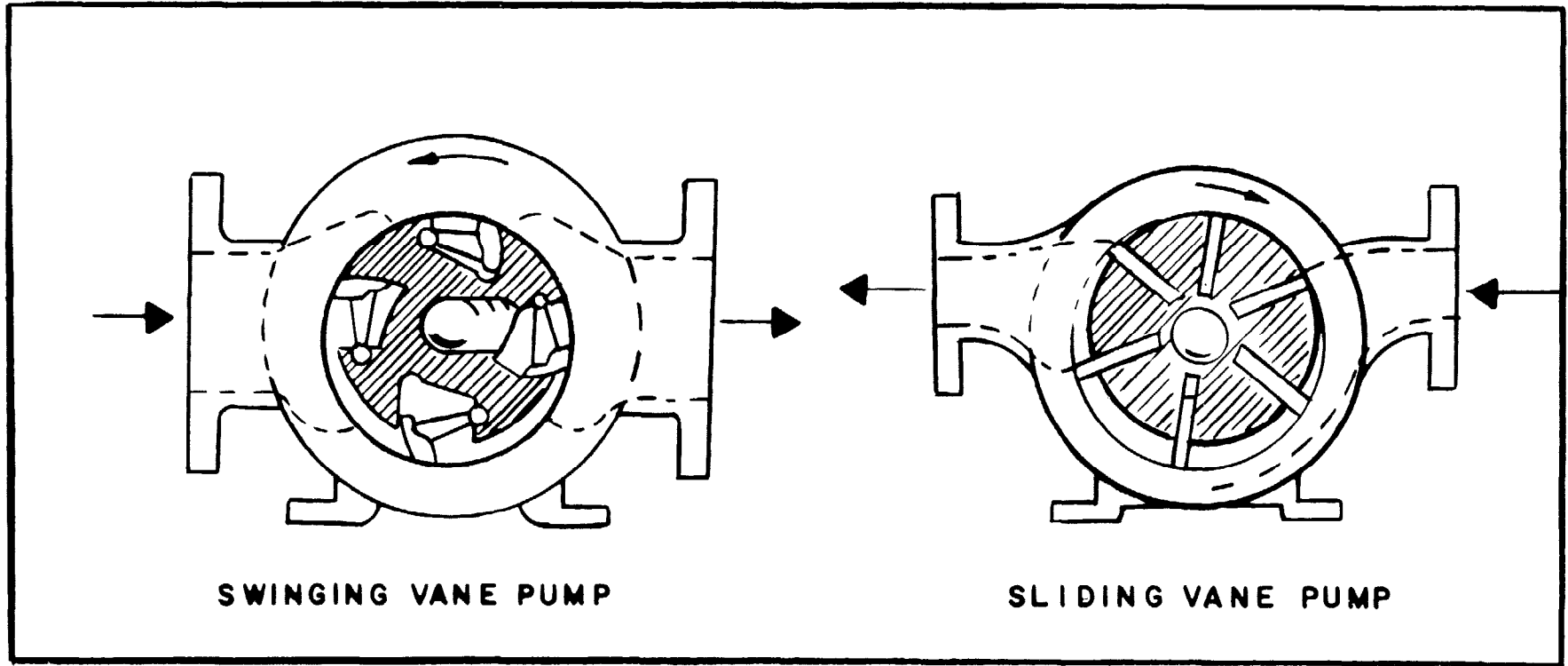
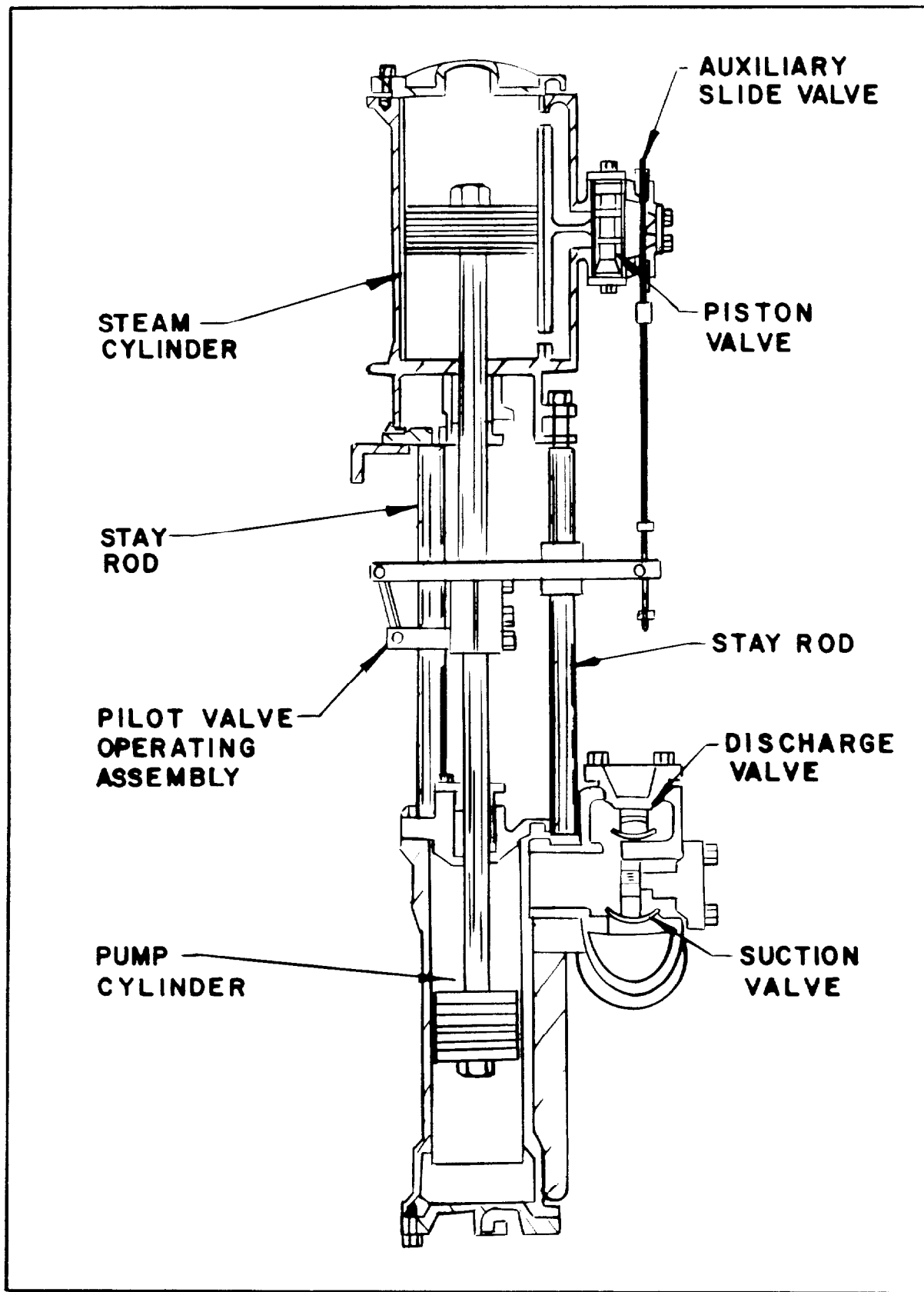


FIGURE 5.6.8

ROTARY VANE PUMP VARIETIES



**FIGURE 5. 6. 9**  
**STEAM POWERED RECIPROCATING PUMP CUTAWAY VIEW**



5.6.7.2 Maintenance. Reciprocating pumps are simple in design and operation but have components requiring maintenance attention. The nature of the fluids pumped would indicate the possibilities of high abrasive wear on suction valves, discharge valves, cylinder linings, and piston rings, as well as fouling of all fluid passage ways by contaminants. Steam-driven pumps have mechanical control assemblies that are prone to wear and require periodic adjustment to ensure that a full stroke is maintained by the piston. The reciprocating motion, with its constant change in direction, can induce vibration, loading on pipes and supports, and wear in valves from near-constant motion. Internal disassembly and inspection is recommended on a periodic basis as determined by operating hours. Look for worn seals, shafts, rings, linkages, erosion in valve seats, pitting in the cylinder walls, and excessive free play.

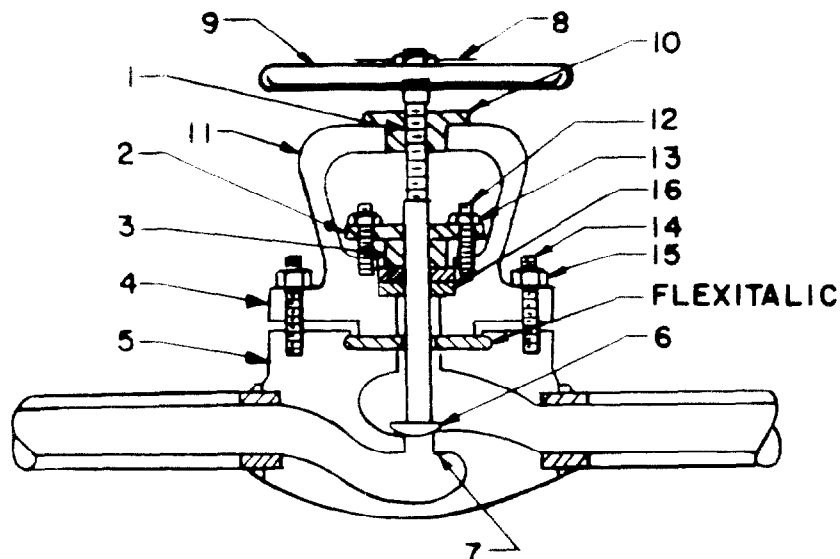
For other guidance, follow the general maintenance inspection and repair recommendations earlier in this chapter and in the applicable technical manual.

## 5.7 VALVES.

5.7.1 Scope. This section provides general background information on the various types of valves found in petroleum systems and provides a description of common organizational level maintenance and troubleshooting associated with valves. Additional information pertinent to valves and associated equipment can be found in the following references:

- MIL-V-12003, "Valve, Plug, Cast Iron or Steel"
- MIL-V-23611, "Valve, Ball"
- MIL-V-18434, "Valves, Gate, Globe, and Angle"
- MIL-HDBK-1022, "Petroleum Fuel Facilities"
- MIL-HDBK-201B, "Petroleum Operations."

5.7.2 General Maintenance Requirements. Valves that have been in constant service over long periods of time eventually require gland tightening, repacking, or a complete overhaul of parts. If it is detected that a valve is not controlling the fuel flow as intended, the valve should be dismantled, and all parts should be inspected. All defective parts must be repaired or replaced. Any time a valve is dismantled, packing gaskets, seals, etc. should be replaced. Figure 5.7.1 provides a checklist of items recommended to maintain valves.



- |  |  |
|--|--|
| <p>1- STEM &amp; STEM THREADS- REMOVE BURRS &amp; PAINT. CLEAN WITH RAGS OR CROCUS CLOTH, DO NOT PAINT</p> <p>2- STRONGBACK /PACKING RETAINER- CLEAN WITH WIRE BRUSH &amp; USE A LIGHT SILICONE SPRAY LUBRICANT</p> <p>3- GLAND- CLEAN WITH RAGS OR CROCUS CLOTH, DO NOT PAINT. (INTRNL)</p> <p>4- VALVE BONNET- CLEAN WITH WIRE BRUSH; PAINT</p> <p>5- VALVE BODY- SAME AS ITEM 4</p> <p>6- VALVE DISC- INSPECT FOR CUTS CRACKS &amp; REPORT ABNORMALITIES TO SUPERVISOR. THIS COMPONENT IS VITAL FOR THE SAFE &amp; PROPER OPERATION OF A SYSTEM. BLUE THE DISC &amp; CHECK FOR PROPER SEATING SURFACE.</p> <p>7- VALVE SEAT- INSPECT FOR CUTS &amp; CRACKS &amp; REPORT ABNORMALITIES TO SUPERVISOR. THIS COMPONENT IS VITAL FOR THE SAFE &amp; PROPER OPERATION OF A SYSTEM.</p> <p>8- VALVE ID. TAG- ENSURE TAG IS READABLE. REPLACE WHEN REASSEMBLING.</p> | <p>9- VALVE HANDWHEEL- CLEAN WITH WIRE BRUSH; DO NOT PAINT.</p> <p>10- STEM BUSHING -S/A ITEM 9</p> <p>11- YOKE - S/A ITEM 4</p> <p>12- GLAND STUD- ENSURE AT LEAST ONE BUT NOT MORE THAN FOUR THREADS ARE VISIBLE; CLEAN WITH WIRE BRUSH; DO NOT PAINT.</p> <p>13- GLAND STUD NUT- CLEAN WITH WIRE BRUSH; ENSURE NUT 'RUNS' FREELY ON STUD. PRESERVE WITH A LIGHT SILICONE LUBRICANT.</p> <p>14- BODY BONNET STUD- S/A IT. 12</p> <p>15- BODY BONNET STUD NUT- S/A ITEM 4</p> <p>16- GLAND STUFFING BOX -USE CORRECT STYLE SIZE &amp; ENSURE PACKING IS CUT PROPERLY. THE STYLE REFERS TO SERVICE OF VALVE &amp; TEMPERATURE OF LIQUID.</p> |
|--|--|

**NOTE:** ON ALL THREADS, A SILICONE LUBRICANT SHOULD BE APPLIED TO PREVENT SEIZING & TO RETARD RUST & CORROSION

**FIGURE 5.7.1**

**VALVE MAINTENANCE CHECKOFF DIAGRAM**

5.7.2.1 Common Valve Problems. There are several valve maintenance problems common to many valves, regardless of type, size, or design. These are outlined below.

- When a valve will not complete its full stroke or exhibits excess leakage if closed, dirt or foreign matter may be trapped between the valve seat and the seating surfaces of the valve disk. It may also mean that the seats are eroded or damaged. If this problem is due to damaged parts, replace these parts in accordance with the specific valve technical manual. If the problem is due to dirt or an eroded seat, clean the valve as directed by the valve technical manual and lap the seat and disk as described in Section 5.7.2.4 of this manual.

- If the valve is leaking at joints or connections, the joint may simply be loose. If tightening the flange bolts or connection does not stop the leakage, clean the flange surfaces on the valve and piping to remove dirt or foreign matter that may be trapped on the joint faces, install a new gasket, and tighten the connection.

If leakage is observed in the stem packing area, tighten the gland nuts. If leakage is still observed or the gland nuts cannot be tightened any further without binding the valve stem, repack the valve as described in Section 5.7.2.3.

5.7.2.2 Spotting-In or Blue Checking Valves. The method used to visually determine whether the seat and the disk of a valve make good contact with each other is called spotting-in or blue checking. A thin coat of Prussian blue is evenly applied over the entire machined surface of the disk. The disk is then inserted into the valve and rotated one quarter turn with light, downward pressure. For gate valves, insert the gate into the valve and press it firmly into the seat. The Prussian blue will adhere to the valve seat at those points where the disk makes contact. A correct blue check will leave an unbroken, uniform circle on the valve seat. The circle should be on the lower portion of the valve seat and should not be excessively wide or high on the seat. On the gate valve, the blue circle should also be unbroken and of uniform thickness.

After the condition of the valve seat has been checked, the disk should be cleaned, and a thin, even coat of Prussian blue should be applied to the seat. The disk or gate is then pressed into the valve as described above. When removed, the blue ring on the disk should again be unbroken and uniform. On gate valves, the ring should be offset to the low side of the gate seating surface but should rise to a concentric position as the valve gate and seat wear.

If the blue ring is broken in any way, the disk and seat are not making proper contact, and action should be taken to correct the fit, such as lapping the valve seat and disk as described in Section 5.7.2.4 or replacing the seat and disk.

5.7.2.3 Repacking Valves. If the stem and packing of a valve are in good condition, stop packing gland leakage by tightening the packing. Be careful, however, to avoid excessive thread engagement of the packing gland studs and tightening old, hardened packings, which could cause the valve to seize. Subsequent operation of such a valve may score or bend the stem.

Valve repacking involves removing the old packing, inspecting and cleaning the valve stem and gland, and installing new packing. Adding new packing is not difficult but should be done in accordance with the applicable valve technical manual or the references listed under Section 5.7.1 of this manual.

5.7.2.4 Lapping of Valve Seats. If bluing occurs or inspection of the valve shows small irregularities in the valve seat, the valve seat and disk may be lapped to remove these irregularities. Lapping involves applying a small amount of grinding or lapping compound to the face of the disk or the lapping tool and grinding this against the seat to smooth out the irregularities. Lapping is usually done on globe, gate, and some check valves; however, the seats in larger globe or gate valves are replaceable, as are the seats in all ball and butterfly valves.

5.7.2.5 Flow Mark. To ensure that valves are aligned properly with fluid flow direction, some valves such as globe, stop check and check valves, are marked with flow marks on the body of the valve. Consult the system diagram and valve technical manual prior to installing these types of valves in the system. Installing a check valve against the flow direction usually results in complete obstruction of the flow.

5.7.3 Motor Operators. Motor operators are used to remotely position various types of valves. Gate, ball, butterfly, and plug valves in on-off service are often operated by electrically driven operators, which must be considered as an integral part of the valve for maintenance. Air- and hydraulic-powered operators are available, but they are rarely found in petroleum terminals.

5.7.3.1 Description. Most of the electric operators in petroleum service are driven by small electric motors through a rather complex arrangement of gears, using limit switches and controls. They imitate the human action of rotating a handwheel or handle but can generally change the position of the valve faster. The controls and limit switches

are necessary to prevent damage to the system due to hydraulic shock or damage to the valve through mechanical impact.

5.7.3.2 Maintenance. Routine, preventive maintenance should include cycling infrequently operated valves monthly, lubricating the valve operator, and adjusting the valve packing. The applicable equipment technical manual should be consulted before any maintenance is performed. Many valve operators are exposed to weather and require preservation and moisture-proof seals for stem and cable penetration. They should be inspected regularly. Limit switches are especially susceptible to damage from the environment. A stuck or rusted switch can render an otherwise operable valve dysfunctional.

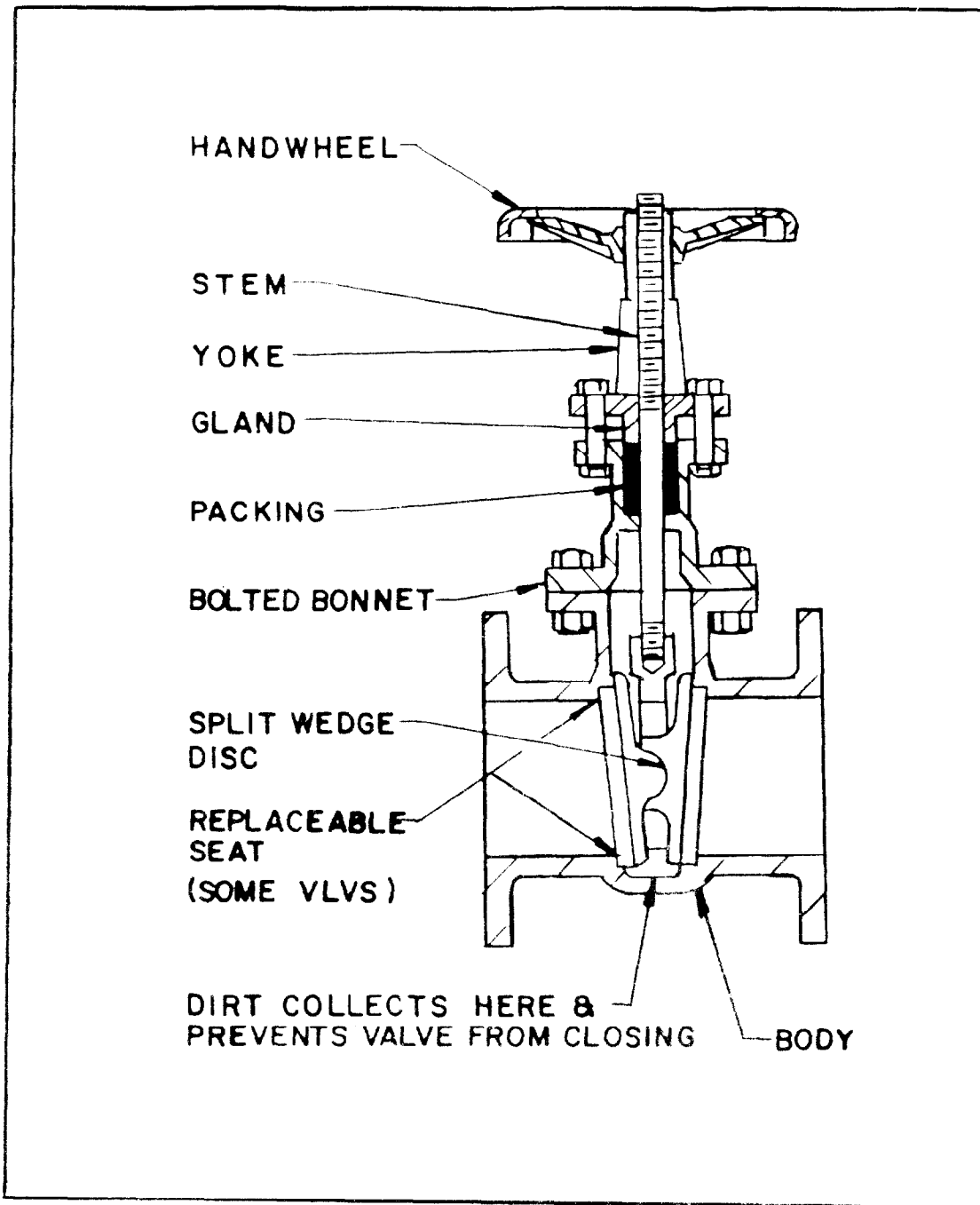
If the valve motor does not start, follow the requirements of the valve technical manual. Normal maintenance recommendations include inspecting the connections in the controller and terminal box, fuses or circuit breakers, terminals at the source of power, voltage at motor terminals, and motor insulation resistance to ground and resistance between phases. Obtain the assistance of a qualified electrician, if necessary, to correct any deficiencies. If the motor overheats, it may be overloaded, be operating at an improper terminal voltage, or have a short circuit. See Section 5.13.5.2 for detailed information on motor failures.

Other conditions or malfunctions with motor-operated valves include mechanical problems such as limited valve travel despite an operable motor or excessive noise or vibration during operation. These malfunctions indicate a failure of the drive system or a sheared pin or key, which may have been caused by a stuck valve. All drive parts (including gears, clutches, and the valve stem) should be inspected and replaced if necessary.

5.7.4 Gate Valves. Gate valves are primarily used to start or stop fluid flow. These valves should be either fully opened or completely closed. They should not be used to throttle flow. When fully open, the fluid flows through the valve in a straight line with very little resistance or turbulence.

5.7.4.1 Description. Gate valves are so named because the wedge-shaped part that stops flow through the valve acts somewhat like the opening or closing of a sliding gate. When the valve is wide open, the gate is fully retracted into the valve body, leaving an opening for flow through the valve the same size as the pipe in which the valve is installed. Figure 5.7.2 shows the internal parts of a typical rising stem gate valve.

5.7.4.2 Maintenance. Gate valve maintenance can be either preventive or corrective and can range from a periodic inspection to a complete overhaul of the valve. The repair of



**FIGURE 5.7.2**  
**GATE VALVE CUTAWAY VIEW**

gate valves, other than routine renewal of packing, is generally limited to refinishing the valve seat and disk surfaces. The procedures for both repacking and lapping are covered in Section 5.7.2. However, with gate valves, the seat and gate cannot be lapped against each other. Lapping the seat requires special tools such as a lapping disk that is inserted into the valve and rotated against one seat at a time. The gate is lapped by placing it on a lapping block with lapping compound and moving the disk in a figure eight pattern. This motion prevents the removal of too much material from one area of the gate being lapped or cutting a groove into the gate.

5.7.5 Globe Valves. Globe valves are extensively employed when throttling of fluid flow or positive shutoff is required. They are not normally used for on-off service because of the large pressure drop through the valve. Globe valves that are used for isolation should not be throttled since this can erode the seating surfaces and cause leakage. Likewise, throttle valves should not be used for positive shutoff since they may leak. While still requiring adequate support, globe valves are able to absorb higher structural loadings than gate valves.

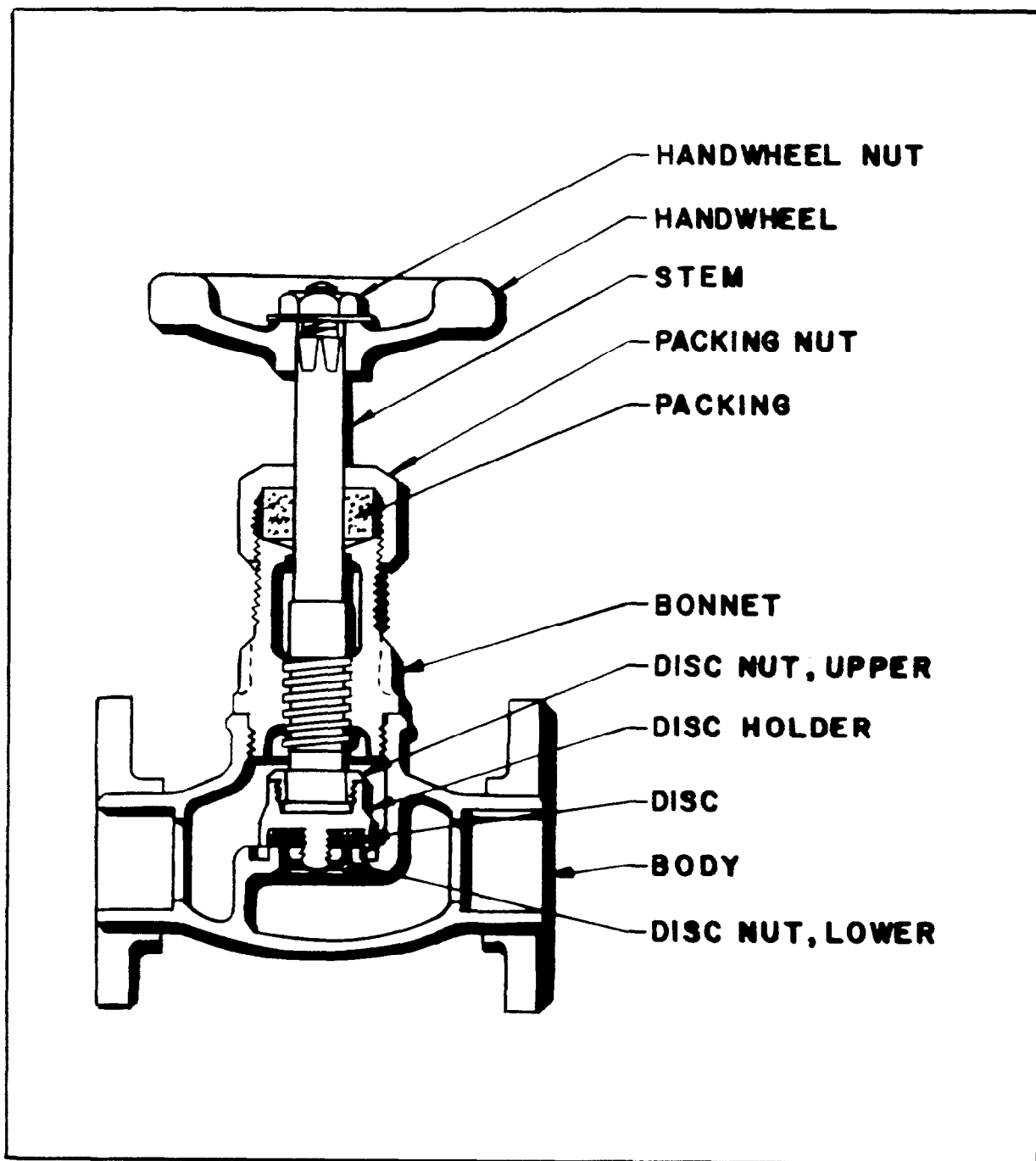
5.7.5.1 Description. The seats in the globe valve are parallel to the direction of flow, the disk is brought down directly on the seat, and the seating force is provided through the valve stem. Some globe valves have a backseating feature so they can be repacked under full line pressure when fully open. Figure 5.7.3 shows a cross-section of a typical globe valve.

5.7.5.2 Maintenance. Follow all applicable general maintenance requirements and safety concerns as directed in the valve technical manual and in Section 5.1.

5.7.6 Ball Valves. Properly designed and constructed ball valves are relatively simple and dependable for on-off petroleum service. Ball valves are generally not used for throttling. The valve can be fully closed by a quarter turn of the handle and does not require lubrication. Ball valves make extensive use of synthetic materials like Teflon for seats and seals.

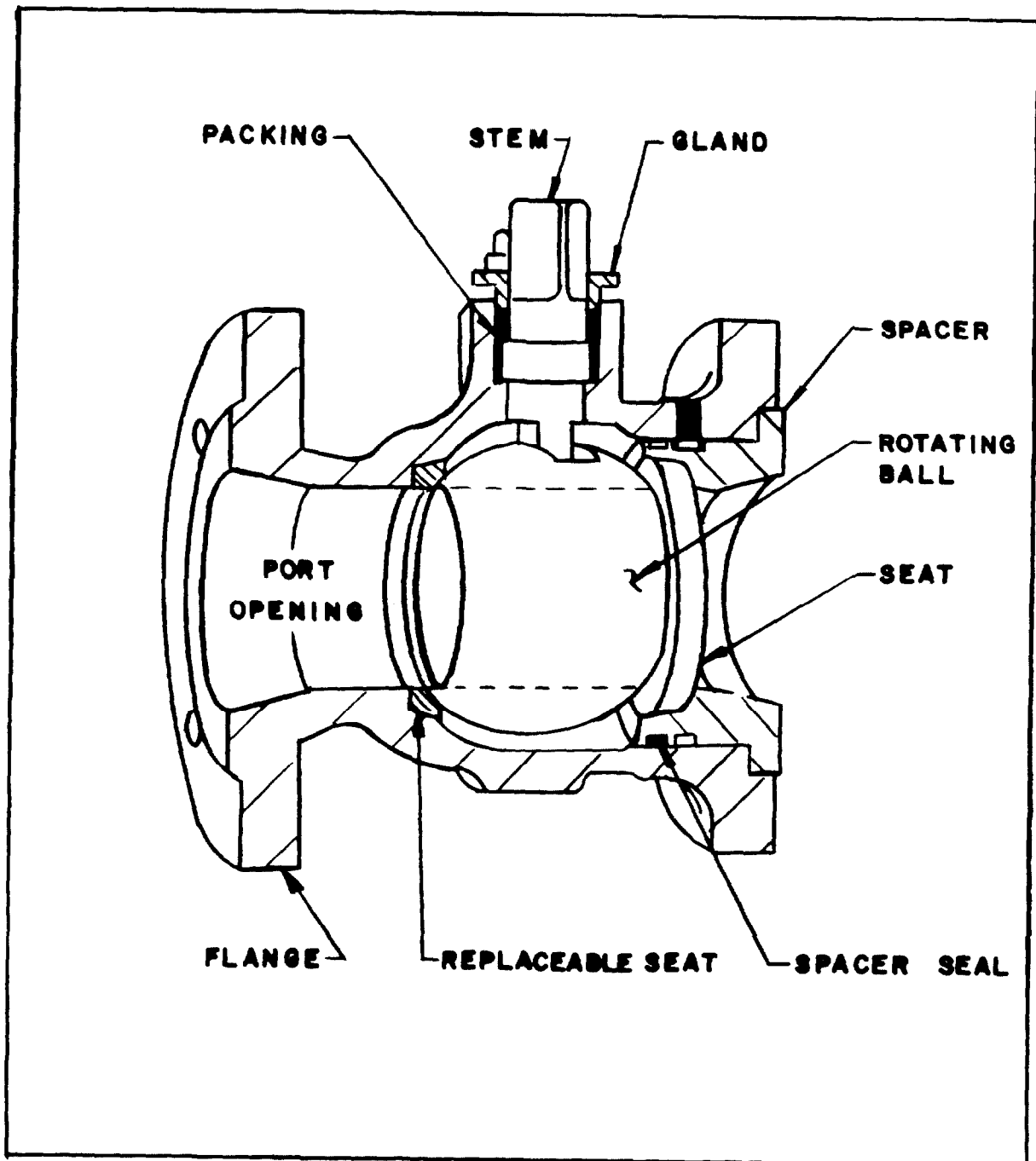
5.7.6.1 Description. Ball valves use a rotating element with a hole through the center. When the hole is aligned with the bore of the pipe, flow is allowed. When it is turned 90° from the bore of the pipe, flow is stopped. In most designs, liquid pressure tends to force the ball against the pliable seat material, forming a seal. The hole in the ball is usually the same diameter as the pipe and offers virtually no resistance to flow. Figure 5.7.4 shows a typical ball valve.

5.7.6.2 Maintenance. The simple design of the ball valve requires very little maintenance. All maintenance on ball valves should be accomplished with the valve completely



**FIGURE 5.7.3**  
**GLOBE VALVE CUTAWAY VIEW**





**FIGURE 5.7.4**

**BALL VALVE CUTAWAY VIEW**

isolated since the design of the ball valve does not isolate the packing or stem seals from fluid pressure.

Maintenance should be performed on the valve when there is leakage past the closed valve (as observed by increasing downstream pressure or flow from tell-tale drains or when the valve becomes difficult to operate). Maintenance generally consists of renewal of the packing or valve stem seals and renewal of the seats and ball, if required.

Regardless of the maintenance required, follow the applicable general maintenance requirements and safety concerns as directed in the valve technical manual, Section 5.1 of this manual, and any applicable references in Section 5.7.1.

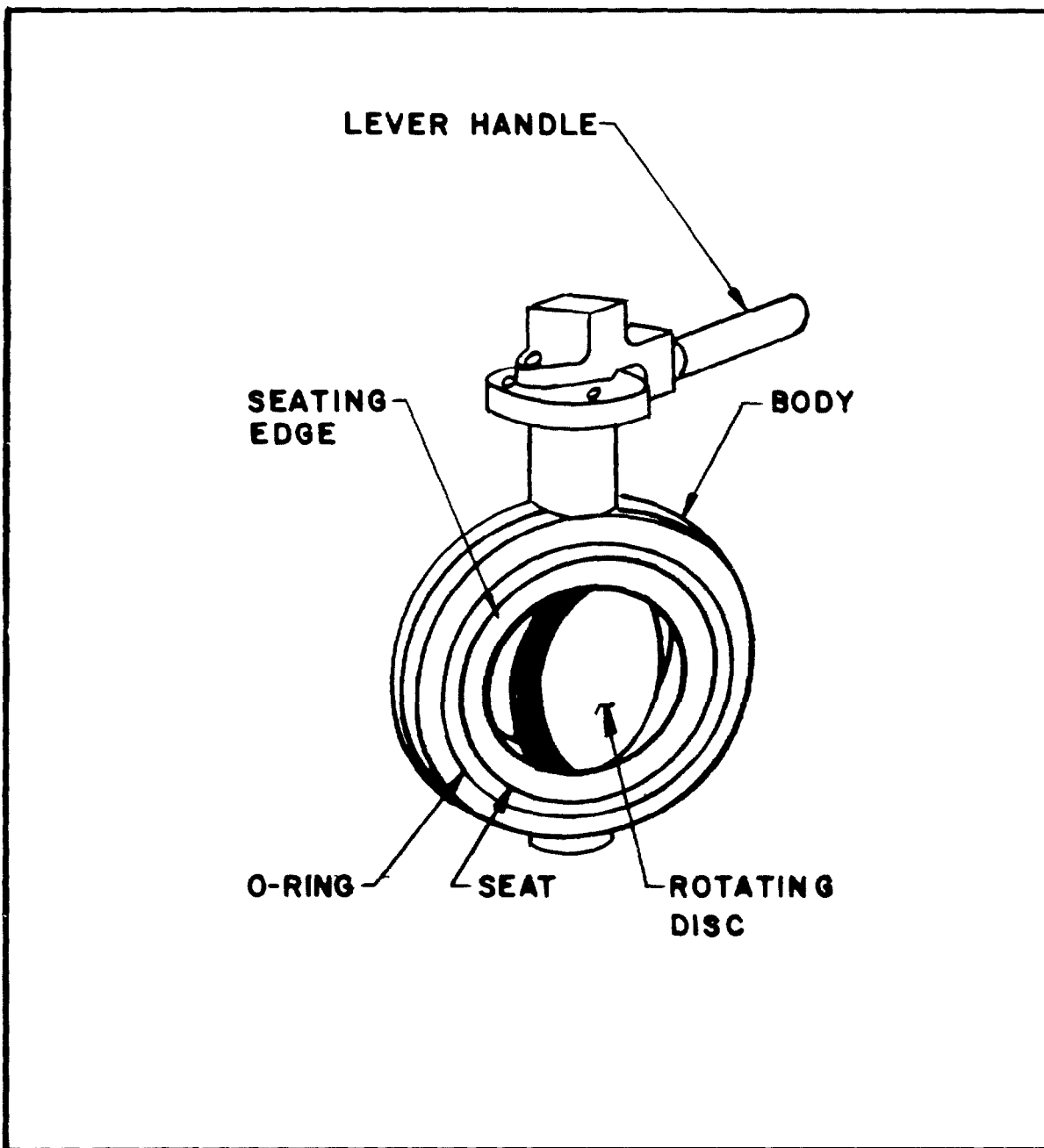
**5.7.7 Butterfly Valves.** A butterfly valve is a variation of a ball valve that uses a flapper disk instead of a ball. Butterfly valves are used for on-off flow control services as well as throttling. They generally should not be used where complete stoppage of flow or isolation is required. Butterfly valves are less expensive than other valves for initial installation, but life-cycle costs, coupled with the need for back-up valves to ensure positive isolation, limit their usefulness in petroleum applications.

**5.7.7.1 Description.** Butterfly valves are similar in design to ball or plug valves, varying mainly in the disk design, as shown in Figure 5.7.5. The benefits of these valves are that they are light in weight, are relatively small, are quick acting, and can be used for throttling.

The seats in butterfly valves are usually made of a resilient material that seals the stem, although packing is usually added to provide a positive seal.

**5.7.7.2 Maintenance.** Since the design and construction of butterfly valves are relatively simple, the maintenance requirements are also simple. Most often, a valve can be returned to service by replacing the seat. Since the resilient seat is held in place by mechanical means, neither bonding nor cementing is necessary. Because the seat is replaceable, the valve seat does not require lapping, grinding, or machine work.

Prior to replacing the seat, inspect the circumference of the rotating disk to ensure that imperfections do not score the new seat. Carefully file or grind any rough edges, but do not remove the curvature of the disk edge. Follow the applicable general maintenance requirements and safety concerns as directed in Section 5.1 of this manual, the valve technical manual, and any applicable references in Section 5.7.1.



**FIGURE 5.7.5**  
**BUTTERFLY VALVE**

5.7.8 Lubricated Plug Valves. A complete understanding of the operation principles of lubricated plug valves is important because many thousands of them are used in naval fuel systems and because they require constant maintenance attention. Lubricated plug valves use heavy, specialized grease under high pressure, instead of a flexible seat, to form the seal between the plug and the body. If properly maintained, these valves give a dependable, tight seal; however, they will leak if the grease reservoirs become empty or lose pressure.

Lubricated plug valves are not authorized for new construction and should be replaced by another type when they are no longer serviceable.

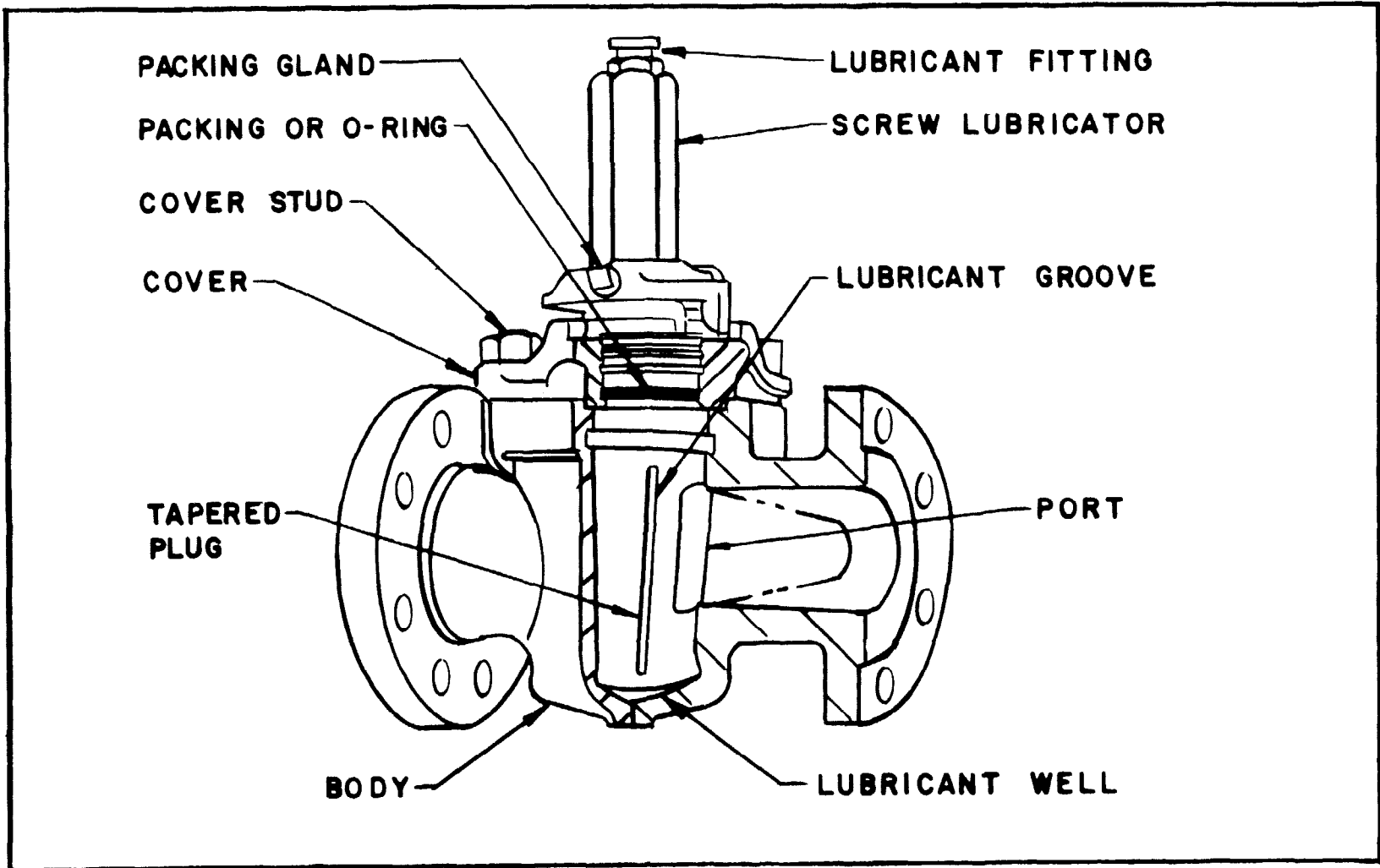
5.7.8.1 Description. A lubricated plug valve is similar in design to a ball valve; however, the rotating element is a conical plug with a port (hole) through it. The valve can be opened or closed by a quarter turn of the handle. However, it differs from a ball valve through the inclusion of a lubricant fitting and packing gland that forces the lubricant through the plug body. The lubricant flows through the sides and the bottom of the plug to form the seal and is prevented from escaping around the top by an O-ring. Figure 5.7.6 illustrates a cutaway section of a typical lubricated plug valve.

The specialized grease serves two other functions. Direct, metal-to-metal contact would prevent rotation of the plug without excessive effort. The grease forced out the bottom provides the lift necessary to break the direct metal contact while the grease surrounding the plug ensures the seal. Additionally, the grease acts as a lubricant for rotating the plug.

5.7.8.2 Maintenance. Lubricating the plug valves is the primary maintenance required, and if completed as scheduled, little else should be necessary. Ordinary petroleum-based grease is not used for plug valves, as it is soluble in fuels and would contaminate them. Be sure that the grease applied to these valves matches the valve vendor's specification and that it is compatible for use with all petroleum products expected to pass through the valve.

The grease is available in two forms: semi-solid sticks, which are manually inserted; and bulk, which is packaged in tubes or cans and forced in by a grease gun. Sticks are longer lasting but require more time and care to apply. For a valve that may accept either type, preference should be based on the considerations of each activity. A large number of valves can be lubricated by a hand grease gun or a powered service cart or vehicle using the bulk grease. Stick packing may be more advantageous for remote sites and a smaller number of plug valves.

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**FIGURE 5.7.6**

**LUBRICATED PLUG VALVE CUTAWAY VIEW**

The force needed to rotate the valve is a key determinant of the state of the valve. This force may be excessive when the packing grease supply is low and the plug body has been ground into the valve seat. This is corrected by adjusting the packing gland bolt or screw until additional lubricant lifts or unseats the plug with an audible "click" or "pop." Guard against over-adjustment. Excessive lift will allow the lubricant to wash away, breaking the seal.

Experience indicates that lubricated plug valves that are regularly used should be maintained weekly. Where there is a grease reservoir, as with the screw-type lubricator, the lubricator should be tightened to insert more grease and increase the pressure. More grease is added only as the reservoir becomes empty.

Irregularly used valves should be lubricated quarterly or before each use, whichever comes first. If a valve will not turn, it probably needs lubrication. Do not force it. A properly operating valve requires about 50 pounds of force to rotate.

Stick lubricants are usually applied in a screw-type lubricator. The steps to follow when applying this type of lubricant are:

- Remove the lubricator.
- Insert a new stick of lubricant in the lubricator.
- Replace the lubricator.
- Tighten the lubricator until all of the lubricant goes into the valve or there is sufficient pressure.
- If all of the lubricant is forced into the valve, keep repeating the process until there is sufficient pressure. A large diameter valve that has not been recently lubricated may take a dozen or more sticks. If possible, operate the valve during lubrication to distribute the lubricant.
- Always leave the screw lubricator fully extended and full of lubricant.

Lubricated plug valves that do not maintain a tight seal probably have been scored by dirt, galled, worn, or otherwise damaged. If the damage is slight, it can be corrected by lapping the plug into the seat. This should be done as described in Section 5.7.2.4.

If the valve operator, such as a worm gear operator, has grease fittings, lubricate it as scheduled using a hand gun with conventional lithium-based grease.

**5.7.9 Non-Lubricated Plug Valves.** Non-lubricated plug valves are similar to lubricated plug valves, except that they achieve their closure by forcing a resilient seal against the seat through a variety of mechanisms among several makes of valves. They need no lubrication, and some of them are among the most dependable and maintenance-free valves available.

**5.7.9.1 Description.** Non-lubricated plug valves are similar in design to lubricated plug valves. They do not have the parts that are required for lubrication and have replaceable resilient seats. Plug valves are quick acting and relatively small. They are not designed for throttling flow.

**5.7.9.2 Maintenance.** Since non-lubricated plug valves require no lubrication, they are virtually maintenance-free. If a valve exhibits leakage, the seat should be replaced in accordance with all applicable general maintenance requirements and safety concerns detailed in Section 5.1 of this manual, the valve technical manual, and any applicable references in Section 5.7.1.

**5.7.10 Check Valves.** Check valves are designed to prevent back flow and allow fluid transfer in only one direction in the piping systems. Check valves should conform to API Standard 6D.

**5.7.10.1 Description.** Swing check valves use a disk that is attached to the valve body by a pinned hinge and is shut by gravity during a no-flow condition. The differential pressure caused by flow allows the valve to open. A swing check valve is shown in Figure 5.7.7.

A lift check valve uses a disk and seat similar to that of a globe valve; however, there is no stem attached. The valve is opened when pressure under the seat overcomes the pressure on top of the disk and pushes open the valve. Pressure on top of the disk can be supplemented by a spring or other means.

**5.7.10.2 Maintenance.** Check valves require very little maintenance. However, they may require lapping or seat and disk replacement if back-leakage occurs. Swing check valve seats are lapped following the same procedure used for gate valves. Lift check valves are lapped in the same manner as globe valves.

Irregular flow through the check valve can cause the valve disk to chatter or hammer against the valve seat. This is often a cause of premature or excessive wear of the valve seat. If this condition occurs, the pipe upstream should be

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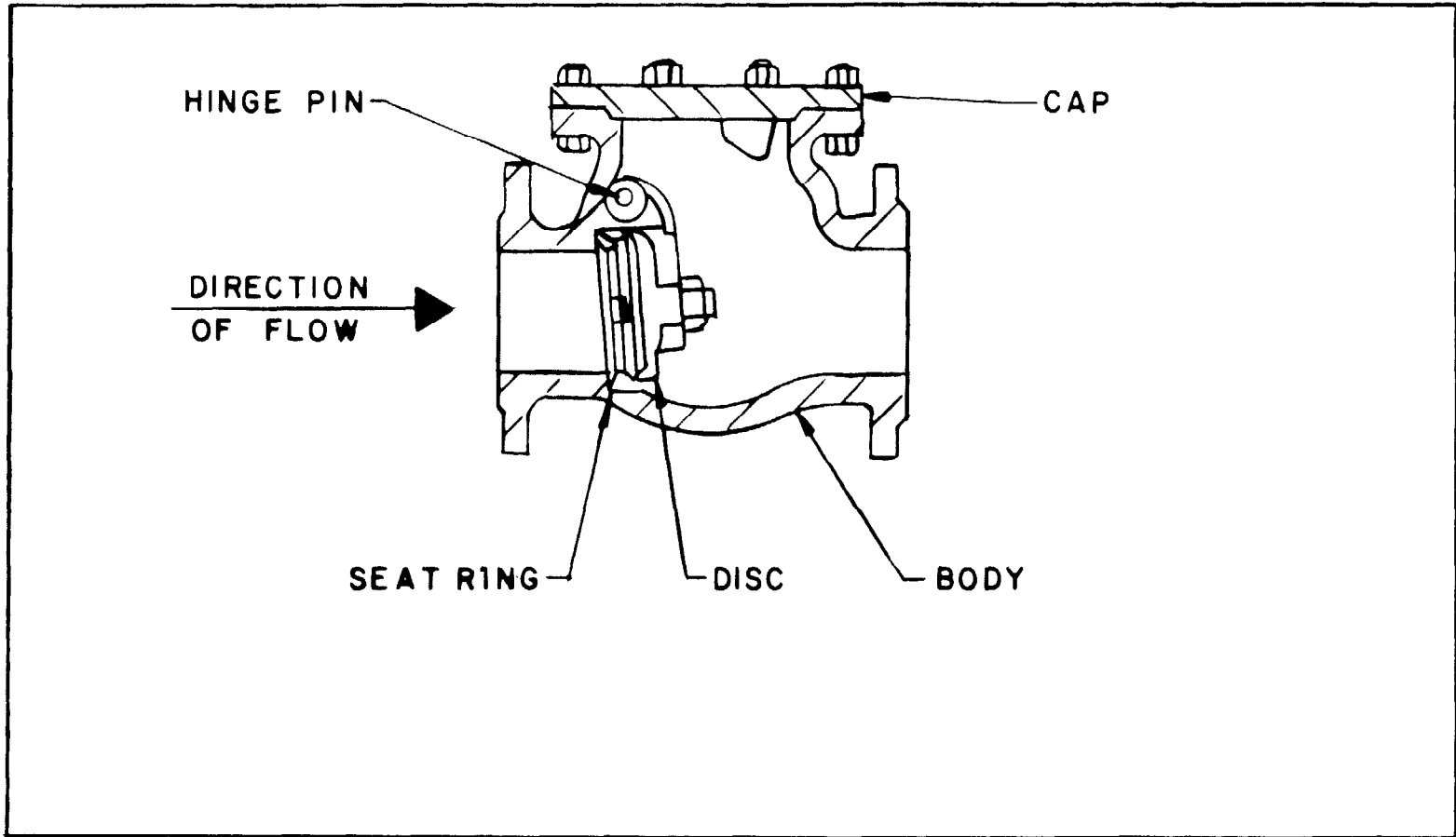


FIGURE 5.7.7

SWING CHECK VALVE CROSS SECTIONAL VIEW



checked for blockages or debris; also, the equipment supplying or regulating the pressure or flow may require maintenance.

The proper positioning of the valve, with reference to the horizontal, is very important to ensure proper check valve operation. Since the downward force of gravity is necessary for proper operation, a check valve installed upside down or on any angle away from horizontal may not function as intended. Ensure markings on the valve body are understood and followed during valve installation.

**5.7.11 Flow Control Valves.** Flow control valves are used to control or regulate petroleum product flow by use of differential pressure across a diaphragm to open or close a valve. Diaphragm-operated valves are useful in numerous applications. With various combinations of pilot arrangements, they can be made to operate as remote operated shutoff, pressure reducing, pressure relief, back pressure, excess flow, check, and automatic two-stage shutoff valves such as those used for truck loading. One valve design can do all of these things with minor installation differences.

Nearly every aircraft fueling system's filter/separator has a combination water slug shutoff and flow rate control valve, and an automatic water drain valve; these are diaphragm-operated valves.

**5.7.11.1 Description.** The valve is operated by the difference in pressure between the main valve body beneath the diaphragm and the pressure in the cover chamber above the diaphragm (see Figure 5.7.8). The pressure above the diaphragm is supplemented by a spring so that, if the fluid pressures above and below the diaphragm are equal, the spring will close the valve. If the pressure above the diaphragm is reduced, as by opening the cover chamber to atmosphere, the greater pressure below will cause the valve to open. The pressure differential between the upstream and downstream sides of the diaphragm is caused by the pressure drop of flow through the valve. The pressure drop has to be high enough, about 2-1/2 pounds, to overcome the force of the spring to allow full opening of the valve.

In the case of filter/separators, a float-operated pilot valve is arranged so that it introduces higher pressure to the cover chamber and closes the valve when there is too much water in the sump. Similarly, when the rate-of-flow pilot senses too much pressure drop, as with excess flow, it lets enough pressure into the cover chamber of the main valve to partially close it (called modulating the valve), until the flow rate is reduced to an acceptable level. Electrically controlled solenoid pilot valves can also be used to control opening or closing of the main valve from a remote point through relatively simple wiring.

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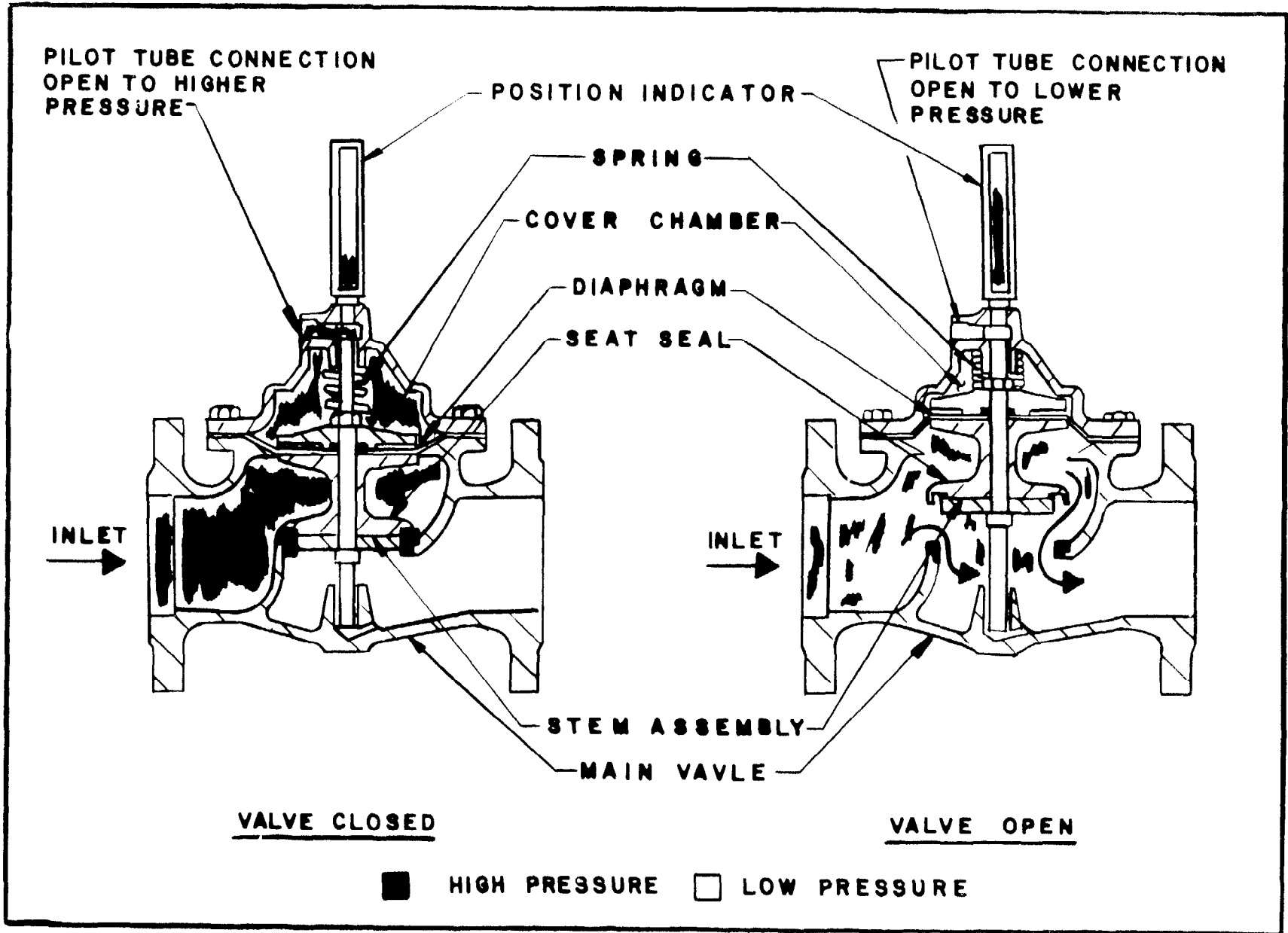


FIGURE 5.7.8

DIAPHRAGM FLOW CONTROL VALVE CROSS SECTION

Other pilot system accessories may include accelerator control valves (to control the speed of operation), manual pilot controls (to permit manual control of the main valve), and pilot strainers (to protect the pilot system from dirt).

5.7.11.2 Maintenance. Diaphragm-operated control valves are generally dependable and trouble-free. The principal source of trouble is dirt or frozen moisture in the small pilot tubing or valves. A strainer in the liquid supply to the pilot system is recommended. When pilot strainers are first installed, they should be inspected and cleaned once a week, but the frequency of inspection may be reduced as observation of the strainer contamination indicates. Valves should be observed during operation to determine whether they respond to system conditions as intended. A position indicator on top of the valve is helpful. If the valve does not work properly, remove and clean the pilots and pilot tubing.

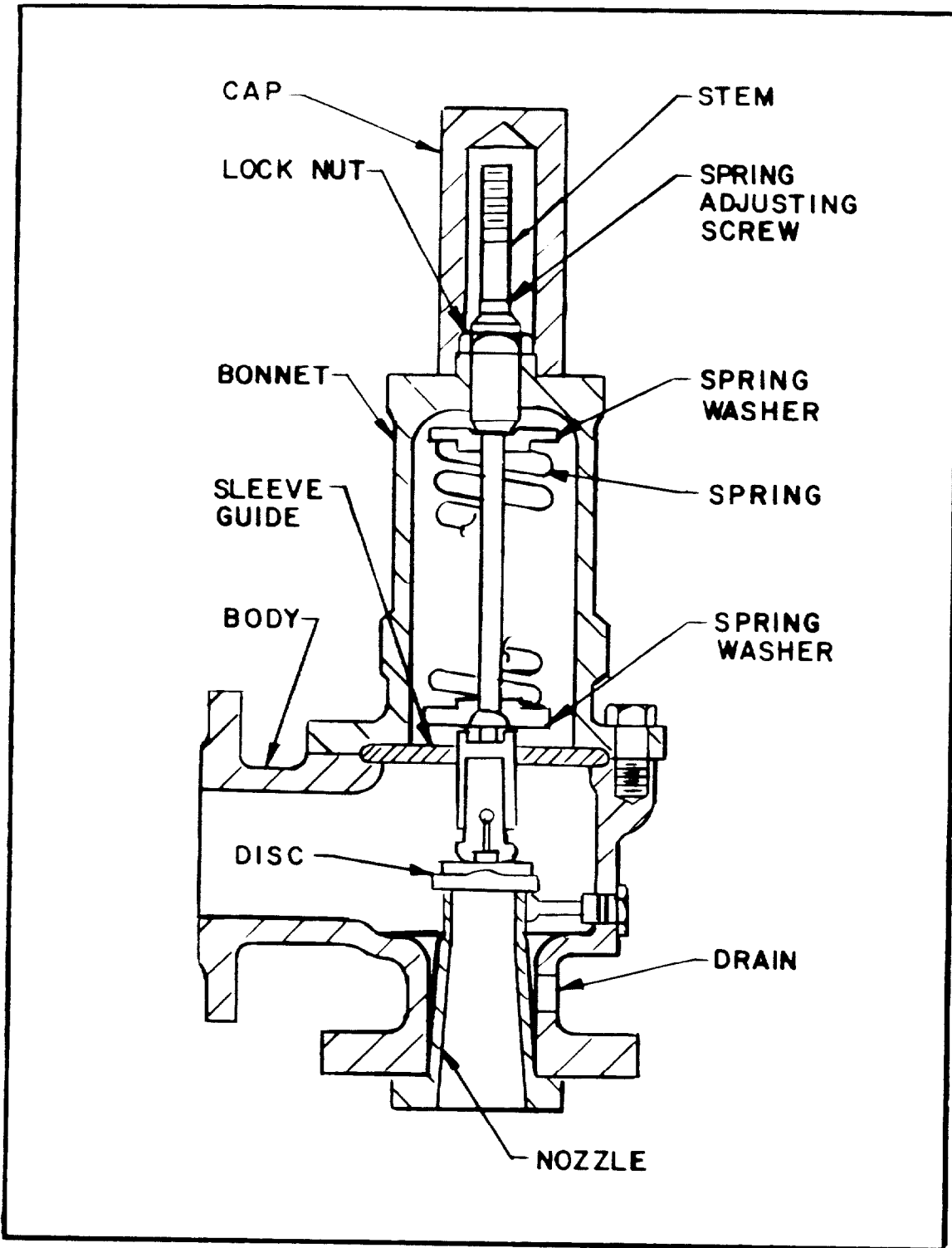
If the valve is installed with the direction of flow and the pilot system is clean but the valve will not open, the diaphragm may be ruptured. If the flow is reversed, failure to close may also indicate a ruptured diaphragm. Replacement of the diaphragm is relatively simple. Follow the manufacturer's instructions for the particular make of valve, and complete the test in a shop environment if possible.

Since proper operation requires overcoming spring force to open the valve, a valve that cycles rapidly or does not maintain the expected flow or pressure may have a defective spring.

5.7.12 Pressure Relief Valves. Relief valves are automatic valves used on system lines and equipment to prevent inadvertent over-pressurization. Most relief valves simply lift (open) when the fluid/vapor pressure increases above a preset value and reset (shut) when the pressure drops down to below the lift pressure.

In petroleum fuel facilities, pressure relief valves are used to prevent over-pressurizing critical systems, such as aircraft fuel systems. They are used to prevent damage to pumps, particularly positive displacement pumps, when working against a closed discharge. They are also used to avoid system leaks and damage caused by thermal expansion. Figure 5.7.9 shows a cross-section of a typical pressure relief valve which might be used for these purposes. In some cases, pressure relief bypass valves may be built into positive displacement pumps.

5.7.12.1 Description. The construction and operation of a pressure relief valve is similar to that of a globe valve in a normally closed state. To open, the pressure on the disk must exceed the opposing force from a pre-calibrated spring



**FIGURE 5.7.9**  
**PRESSURE RELIEF VALVE CROSS SECTIONAL VIEW**

surrounding the valve stem. The calibrated spring and associated adjustment mechanism replace the handwheel and yoke commonly found on an ordinary globe valve.

5.7.12.2 Maintenance. Maintenance should be limited to manual lifting (if required by the component technical manual) and adjusting of the set relief pressure. In nearly all such valves, the relief pressure can be adjusted within the pressure range of the spring by turning an adjusting screw on top. Use pressure gauges to determine the set valve opening pressure and adjust the pressure as necessary. After adjustment, set the lock nut and replace the cap and seal. Tag the valve to indicate the adjusted set pressure and the date it was set. If the pressure is above or below the acceptable range for the relief valve, replace the spring.

Testing of the relief valve upon initial installation in a system should be done with extreme care and caution since it involves raising the pressure in the system above normal operating pressure. If the relief valve fails to open during a test, the system could be easily over-pressurized. Alternatively, the valve may be taken to a test bench and set. This may be preferable to risking over-pressurization of the system. When maintenance is being performed on a relief valve, the system in which it is installed should have another means of over-pressure protection or should be vented to atmosphere to prevent pressure buildup.

Since pressure relief valves are for system and personnel protection, technical manual procedures and maintenance requirements must be followed verbatim. In addition, follow all applicable general maintenance requirements as directed in Section 5.1 of this manual and any applicable references in Section 5.7.1.

5.8 SWIVEL JOINTS, LOADING ARMS, AND PANTOGRAPHS. Most other components of fuel systems are fixed in place and can accommodate only very small relative displacement without affecting service. However, either the source or the receiver and sometimes both are mobile, and the connection between the two requires the use of hoses, loading arms, and pantographs. Hoses are covered in Section 5.11. Loading arms and pantographs, covered here, are in effect hose replacements, offering the flexibility of a hose with the durability of piping. Swivel joints, also discussed in this chapter, supply the freedom of movement necessary to allow movement between fuel source and receiver, while ensuring a tight seal. Most maintenance requirements for these items arise from the rough handling that they receive.

5.8.1 Scope. This section provides general information about swivel joints, loading arms, and pantographs and describes common organizational level maintenance and

troubleshooting associated with these items. It is intended to be used in conjunction with detailed technical information contained in manuals or operating instructions.

Additional information pertinent to swivel joints, loading arms, and pantographs can be found in the following references:

- MIL-HDBK 201B, "Petroleum Operations"
- NAVAIR 06-5-502, "Aircraft Refueling for Shore Activities"
- MIL-HDBK-1022, "Petroleum Fuel Facilities."

5.8.2 General Maintenance Requirements. Seals on swivel joints, loading arms, and pantographs are in constant need of maintenance from being in constant motion and being forced beyond a normal range of motion. In addition, the movable joints require periodic lubrication and, less frequently, replacement of packings, seals, or O-rings. As with hoses, nozzles, and pressure regulators, care must be taken to ensure that grounding or bonding wire is not damaged during maintenance or allowed to deteriorate.

Loading arms and pantographs are treated roughly during refueling operations. Since they are hose replacements, consideration should be given to inspecting and monitoring them with the care given to hoses. Operators, who perform most of the preventive maintenance, must be alert for leaks, wet spots, erratic mechanical operation, and excessive force while transferring fuel. Inspections are to be conducted in accordance with NAVAIR 06-5-502.

5.8.3 Loading Arms and Swivel Joints. Loading arms use sliding tubes with seals or packings that elongate to close the distance between the supply line and tank car or tank truck. Leaks in these seals are a major problem. Side impact against the sliding or fixed portion of the arm can cause flat spots, allowing a gap in the seal between the loading arms and providing opportunities for leakage. If repacking the seal does not stop the leak, check for scoring or flat spots caused by side impact.

The swivel, or swing, joint attaching the arm to supply piping is also a source of leaks, especially if the arm is subject to stress when it mates to the tank or coupling adapter. A program of periodic lubrication and inspection will ensure longer swivel joint life, since a fully lubricated joint will not allow dirt to enter. However, if seals continue to leak despite lubrication and seal replacement, the entire joint must be replaced and the reason for the recurring failures should be identified. Common causes for failure are inadequate support for the arm and excessive motion beyond the range expected of the joint. Fully stocked kits are usually

available to complete seal or joint renewal. The manufacturer's technical manual will provide more detailed information.

5.8.4 Pantographs. Pantographs are most often used in aircraft fueling facilities, either from fixed fuel system skids or on mobile refuelers. They have a number of swivel joints and one or more caster or dolly wheels to assist movement from the stowed to transferring position. The focus of their maintenance centers around the care of the joints, with lubrication being the primary preventive maintenance requirement. Most pantographs have a sufficient number of swivel joints to prevent excessive strain. If leaks persist after replacement of suspect seals or O-rings, there may be dirt or other foreign matter in the bearing. In that case, replacement of the joint is necessary. Refer to the manufacturer's technical manual for more detailed information such as the correct grade of lubricant and suggested maintenance frequency. One possible source of strain on joints is standing on the arms of the pantograph. Operators and maintenance personnel should discourage the practice.

The other area of required maintenance for pantographs is its accessory equipment, such as emergency break-away devices, deadman controls, and ventura/control valve pressure adjustments. Refer to NAVFAC NFGS 15486, "Aviation Fuel Distribution and Dispensing," for detailed information regarding the operation of this equipment.

5.9 NOZZLES AND REGULATORS. When the end user of a fuel product is an aircraft, extra precautions are necessary to ensure that the fuel reaches the aircraft through a safe and clean connection. Fueling nozzles and regulators provide the last means of filtration as well as assurance against pressure surges, thus preventing damage to fuel-sensitive systems and engines. In most cases, it is readily apparent to the fueling personnel when problems exist with the equipment. When problems are discovered, the fueling operation is halted, the suspect item is removed from service, and replacement equipment is attached.

As static electricity charges are inherent in fueling, an important consideration for both of these items is to ensure that operators and maintenance personnel inspect for deterioration of grounding straps, clamps, or other metal-to-metal contact. Such deterioration can result in a static-induced explosion or fire.

5.9.1 Scope. This section provides general background information about fueling nozzles and regulators. The pressure regulators discussed here apply only to those integral with fuel delivery systems at the end point. More extensive coverage of pressure regulator valves, including theory of operation, is found in Section 5.6.13.

5.9.2 Pressure Nozzles. According to NAVAIR 06-5-502, aircraft fueling nozzles require daily inspection to ensure against leaks and provide uncontaminated fuel. The nozzle is equipped with 60 mesh or finer wire mesh screen to trap particulates from the hose. Additionally, the leak resistance of the poppet valve is to be tested daily against full pump pressure. Any unusual conditions found during this test indicate that repair is necessary and the nozzle and hose should be removed from service. The inspection should also include the condition of the dust cap at the aircraft adapter end. Storage racks should also be inspected periodically to identify and correct conditions that allow moisture or dirt to accumulate in the nozzle. Dust caps or covers must be attached to all stowed nozzles.

During use, care must be taken to prevent minor damage to the seating or coupling surfaces of the nozzle by careless handling that increases the likelihood of leaks. The internal construction of a pressure fueling nozzle is shown in Figure 5.9.1. Regardless of use or condition, each nozzle is to be removed from service weekly and sent to a designated shop for inspection, repair, and analysis of contents impinged upon the mesh screen. In removing the nozzles from service, an audit trail is necessary to trace the problem to its source. Follow local procedures in tagging and reporting these problems. Other actions performed in the repair shop include tests of nozzle interlocks to prevent discharging fuel when not properly connected, seating adjustment of the poppet valve, cleaning of mesh screens with acetone to remove fuel gum, and blow-down with compressed air. The operation of the manual valve crank assembly is also checked for smooth and positive motion on a special test bed. The manufacturer's technical manual should be consulted for specific test requirements.

5.9.3 Pressure Regulators. A hose-end pressure regulator is a spring-operated valve that is used to prevent pressure surges from reaching the aircraft fuel system. The valve spring operates against delivered fuel pressure. When the spring is overcome and compressed by excessive fuel pressure, the valve restricts flow until pressure is returned to the set point. The operating pressure of the regulator is predetermined by the spring selection. This parameter is not adjustable unless a different spring is inserted in the body. A cutaway view of a typical hose-end pressure regulator is included as Figure 5.9.2. The most commonly used regulator pressure set point is 45 psig; however, regulators with 35 and 25 psig set points are in use. This pressure should be maintained at a flow rate of up to 300 GPM.

As indicated in NAVAIR 06-5-502, the pressure regulator should be checked for proper operation weekly. Since no part of the regulator other than the regulator body is accessible or has failure or maintenance indicators, the following procedure is recommended. Subject the regulator-nozzle assembly to a



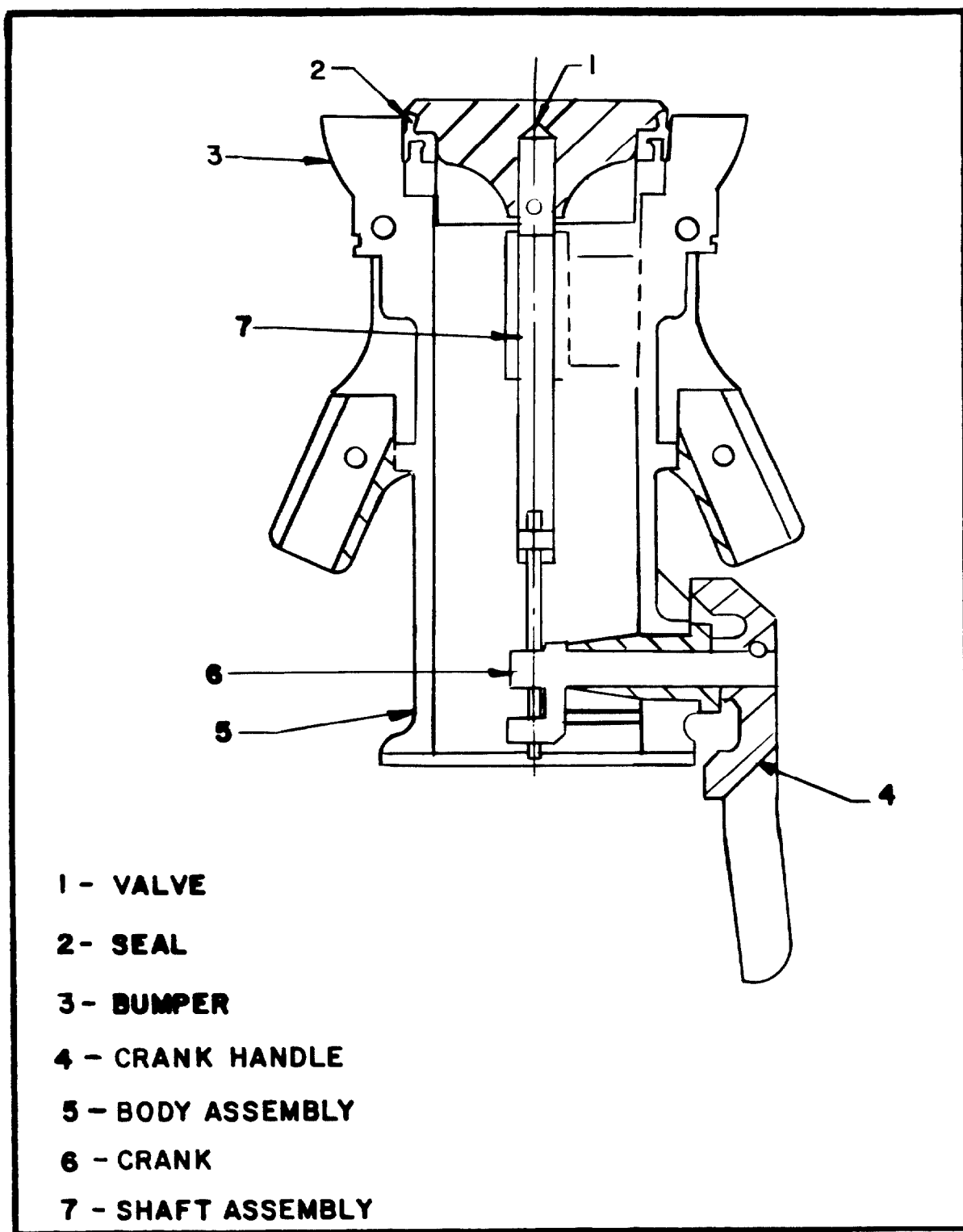
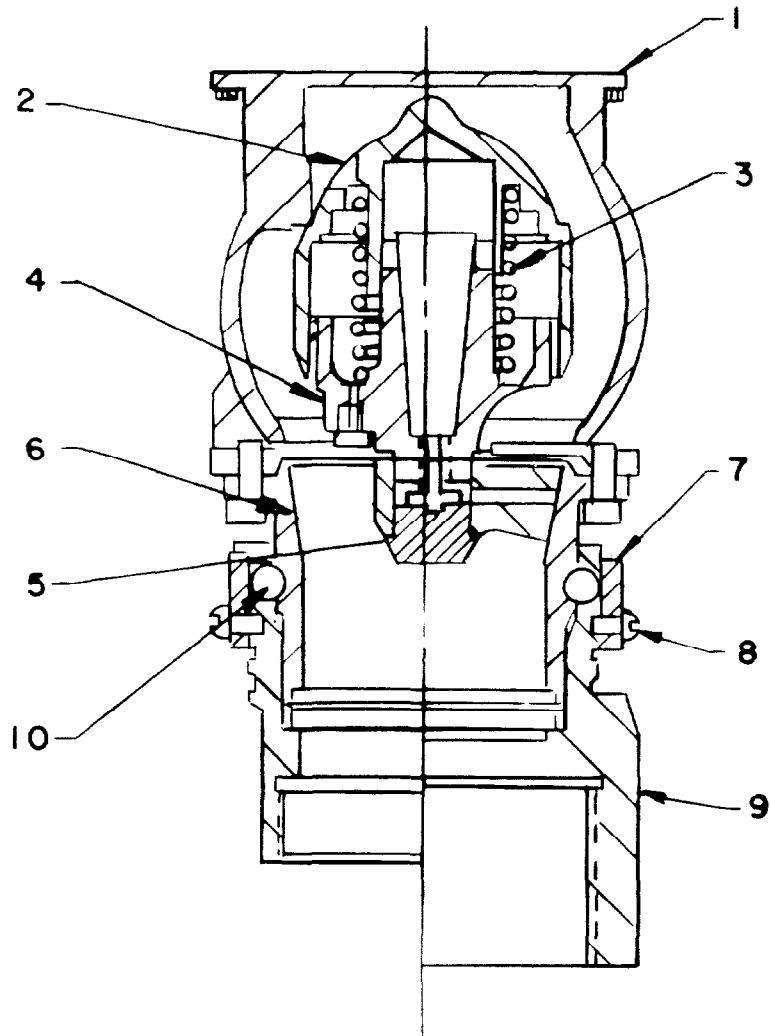


FIGURE 5.9.1  
PRESSURE FUELING NOZZLE CROSS SECTION



1 - BODY, OUTLET

2 - PISTON

3 - SPRING

4 - PISTON GUIDE

5 - RETAINING SCREW

6 - ADAPTER, SWIVEL

7 - SLEEVE, BALL RET.

8 - WIRE, LOCK

9 - SWIVEL HOUSING

10 - BALL BEARING

**FIGURE 5.9.2**

**PRESSURE REGULATING VALVE & QUICK DISCONNECT COUPLER  
CUTAWAY VIEW**

daily circulation check by attaching the nozzle to an adapter that allows recirculation of the fuel to the suction side of the pump. At the end of the recirculation period, attach an approved pressure gauge to the sampling connection of the nozzle. Compare the gauge reading to that specified in the manufacturer's technical manual for the spring in use. If the reading falls outside the tolerance, remove the regulator from service and send it to repair.

At the repair shop, a recirculation test loop is used to check the ability of the regulator to sustain the pressure at varying flow rates. A diagram of a typical test loop is provided as Figure 5.9.3. Caution should be used in operating this test loop since JP-5 or other flammable liquids are used in the system. The test is performed in two steps. First, elevated pump pressure is applied to both sides of the regulator to check for leaks. Second, increasing flow is established using a pressure higher than the set point, and the downstream pressure is recorded as a function of flow rate. Refer to the manufacturer's technical manual for more detail.

## 5.10 PRESSURE GAUGES AND METERS.

5.10.1 Scope. This section provides general information about pressure gauges and metering devices, and describes common organizational level maintenance and troubleshooting associated with them. It is intended to be used in conjunction with detailed technical information contained in manuals or operating instructions. Recommendations and guidance in the following subsections should be used to form the basis for a maintenance plan tailored for these items at your installation. Additional information for pressure gauges and meters can be found in the following references:

- National Institute of Standards and Technology, Handbook 44, "Specifications Tolerances and Other Requirements for Weighing and Measuring Devices"
- MIL-HDBK-1022, "Petroleum Fuel Facilities"
- MIL-HDBK 201B, "Military Standardization Handbook for Petroleum Operations"
- ASME 40.1 (formerly MIL-GG-G-76E), "Gauges - Pressure Indicating Dial Type - Elastic Element."

### 5.10.2 Pressure Gauges.

5.10.2.1 Pressure Gauge Description. Pressure gauges include Bourdon tube, bellows, and diaphragm gauges. In a Bourdon tube pressure gauge, the pressure acts inside a hollow, flattened tube called a "Bourdon spring tube" (see Figure 5.10.1). Pressure inside the tube tends to straighten it,

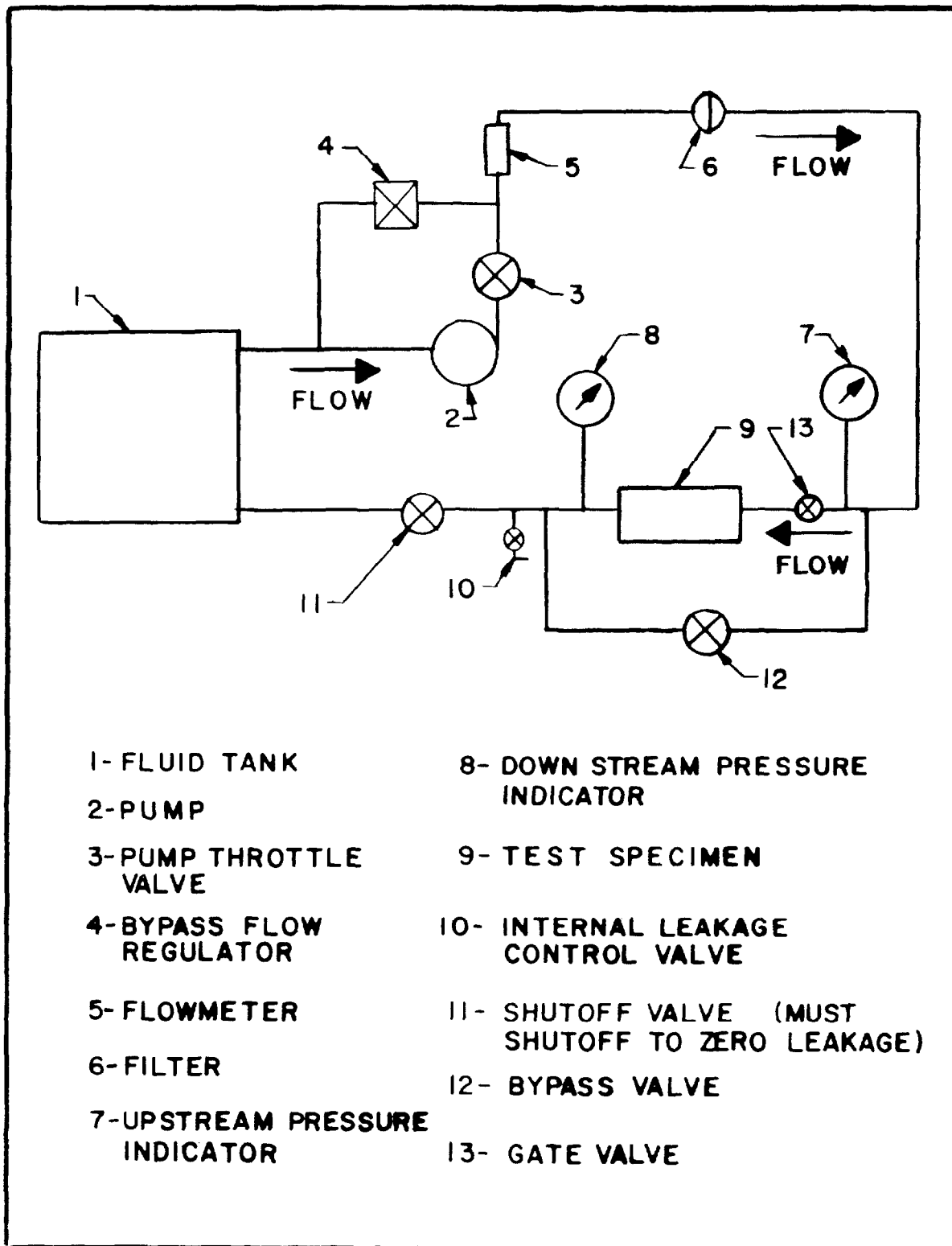
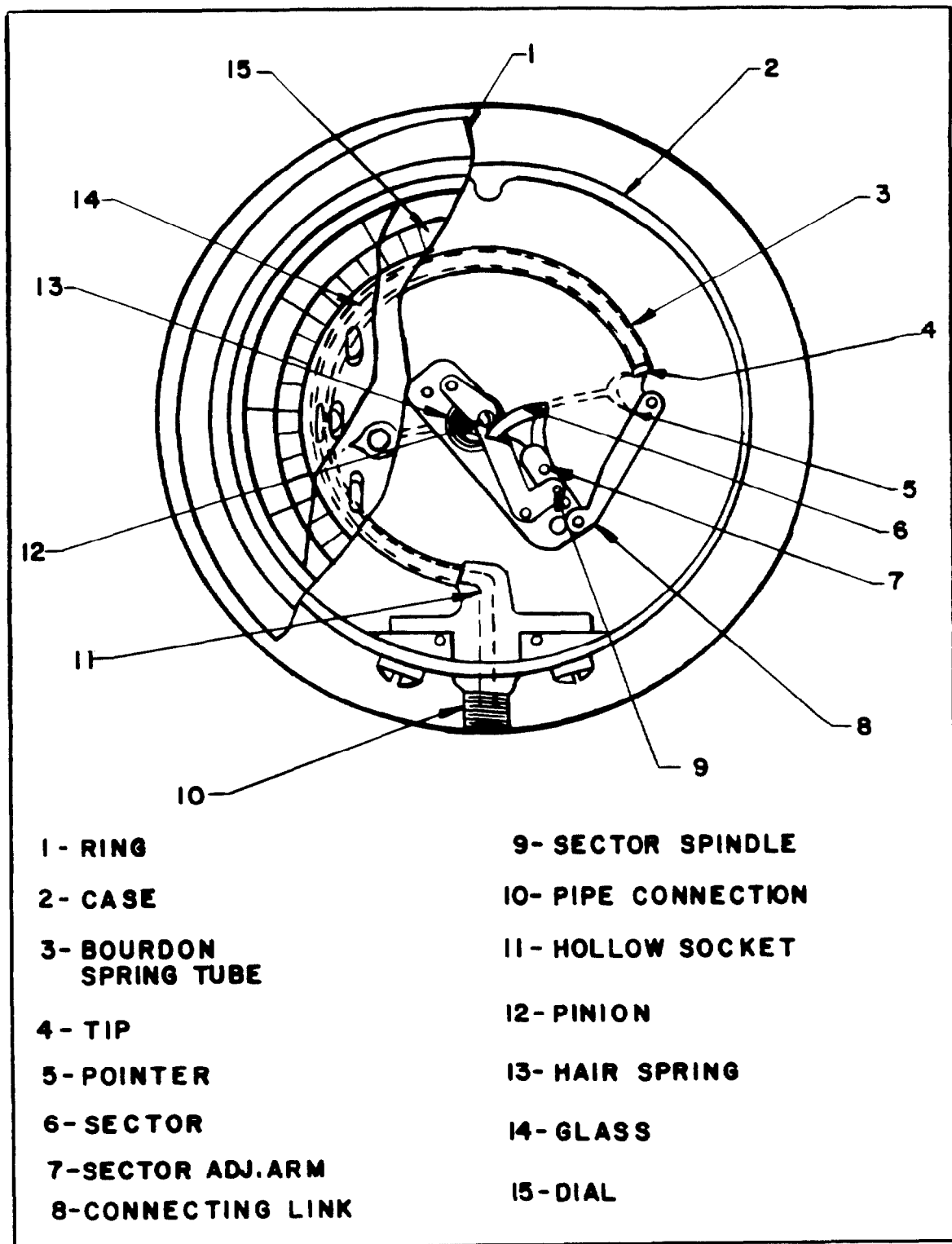


FIGURE 5.9.3

TYPICAL RECIRCULATING PRESSURE REGULATOR TEST LOOP DIAG.



**FIGURE 5.10.1**

**PRESSURE GAGE BOURDON TUBE MECHANISM**

moving the lever and gear system and rotating the pointer. There are four common types of Bourdon tube gauges: simplex, vacuum, compound, and duplex. The simplex gauge is used for measuring the pressure of steam, air, water, oil, and similar fluids or gases. The vacuum gauge measures the absence of atmospheric pressure and indicates vacuum in inches of mercury. The compound gauge measures vacuum to the left of the zero point and pressure to the right of the zero point. The duplex or differential pressure gauge consists of two independent mechanisms within the same case. It has two inputs and pointers that operate independently to indicate a pressure drop between the inner side and outer side of strainers and filters.

A bellows gauge is generally used to measure pressures below 15 psig. When pressure increases in the sensing line to a bellows gauge, the bellows expands and operates a system of gears and levers that are connected to the pointer. When the pressure to the bellows gauge decreases, the bellows contracts, returning the pointer toward its zero point.

Diaphragm gauges are very sensitive and give reliable indications of small differences in pressure. The gauge mechanism consists of a tough, pliable, neoprene rubber membrane connected to a metal spring that is attached by a simple linkage system to the gauge pointer. One side of the diaphragm is exposed to the pressure being measured, while the other side is exposed to the atmosphere. When pressure is applied to the diaphragm, it moves the pointer to an increasing reading on the dial. When the pressure is lowered, the diaphragm moves the pointer back toward the zero point.

5.10.2.2 Pressure Gauge Maintenance. Gauges are delicate and sensitive measuring devices that require exact calibration. It is unlikely that any calibration will be done with the gauge in its normal location. At a regular interval, the gauge should be properly isolated and removed to a metrology or calibration lab to ensure its continued accuracy.

Gauges are subject to damage from excessive pressure, vibration, corrosive environment, metal fatigue, or abuse. Gauges suspected of such damage should be removed from service and tested as soon as possible. Cracked or abraded dial glasses should be noted for replacement as the glass forms a seal against the environment.

Sometimes an inoperative or inaccurate gauge is caused by damage to the tubing connecting the gauge to its pressure source or to the petcock valve isolating the tubing at the pipe. For liquid pressure gauges, leaks are indicated by fine mists or droplets under the tubing or gauge, since the fluid itself drives the gauge-sensing element. For pressurized gas-handling systems such as air, applying a soapy water solution to a suspected leak source yields bubbles if a leak is present. Small leaks in vacuum tubing are identified by

covering a suspected leak with a nonporous plastic film or Teflon tape while the gauge is observed. If there is a leak, gauge pressure will change significantly when the tape is applied.

The attachment of the tubing to the gauge is a common source of leaks. Wrapping Teflon tape around the threads of the connection often seals the leak.

5.10.3 Meters. Meters are installed in fuel-receiving or delivery lines to measure the bulk fuel quantity flowing through the line. Since fuel delivery quantities are normalized to 60°F for accuracy, some meters can compensate for fuel temperature differences. Positive displacement meters are installed for use in lines serving aircraft, ground vehicles, or small boats, while turbine meters are acceptable for long-duration, steady-state transfers.

5.10.3.1 Meter Description. Positive displacement meters measure flow by an analog conversion of the motion of a transverse rotating vane through a calibrated set of gears driving a counter register. Turbine meters operate in a similar fashion except that they substitute an axially aligned rotor for the vane. Clearances between the rotor and housing allow some slippage; this type of meter is less accurate. To maintain accuracy and protect meter movement, flow control devices and strainers are installed upstream of the meter. A means of adjustment and a card- or key-activated electronic tap may be attached to the meter, allowing automatic accounting of fuel deliveries to identified end users. Some meters provide a preset fuel delivery total that may be used to slow the fuel flow to a predetermined rate, thus avoiding hydraulic shock when the preset fuel total is approached.

5.10.3.2 Meter Maintenance. Although the meter is mechanically simple, the associated electronics, controls, and adjustments cause the meter to require assistance for most maintenance actions beyond calibration.

Calibration can be accomplished by attaching a portable volumetric prover, a calibrated master meter, or a pipeline prover and adjusting the meter to coincide with the acceptable standard. Refer to the technical manual for the specified frequency and procedure.

If the strainer inspection is not otherwise covered, the strainers installed upstream from the meter should be inspected on a regularly scheduled basis in accordance with the technical manual. Section 5.5 of this manual provides additional guidance.

5.11 HOSES. Almost all components of fuel systems are fixed and hard mounted. The exceptions are hoses commonly used to connect sources of fuel supply to the fuel facility's customers. Because of their flexible construction, hoses are subject to damage not seen in other fuel system components. Since hoses are often used in environmentally sensitive areas, this damage can lead to leaks that are bound to bring unwanted attention to the facility and its function. Great care must be exercised in maintaining these hoses.

5.11.1 Scope. This section provides general background information about hoses used in petroleum service for shore-based facilities and describes common organizational level maintenance and troubleshooting associated with hoses. It is intended to be used in conjunction with detailed technical information contained in manuals or operating instructions.

Additional information pertinent to petroleum hose use and maintenance can be found in the following references:

- MIL HDBK 201B, "Petroleum Operations"
- MIL-HDBK-1022, "Petroleum Fuel Facilities"
- NAVAIR 06-5-502, "Aircraft Refueling for Shore Activities"
- MILSPEC MIL-T-83973, "Hydrant Hose."

5.11.2 General Maintenance Requirements. Most maintenance on hoses results from physical damage during use. For petroleum hoses, the following guidance is recommended.

5.11.2.1 Inspection Techniques. Visually survey the hose. Observe the hose's general condition and look for fluid puddles, fine mists, physical damage such as jacket abrasion or deformation, and deteriorated joints. Use the sense of smell to detect petroleum vapor. Look for improper hose handling that may overstress the hose by stretching, relative movement, or kinking. Mark the location of suspected damage for later inspection, and remove the hose from service as soon as possible.

5.11.2.2 Common Inspection Points. The following items should be included in the inspection procedure for hose.

- Outer Jacket. Inspect the outer jacket for cuts, gouges, tears, abrasion, bulges, blisters, chemical damage, or cracks that may be caused by exposure to the sun. Spot tears and cuts that do not go through to the reinforcement can be patched or covered.



- Carcass. The carcass comprises middle layers of the hose between the jacket or cover and the interior lining. The carcass contains the wire and fiber reinforcement that gives the hose its strength. If the jacket is intact, the carcass is not visible; but kinks, flat spots, or bulges indicate that the carcass has been damaged. Mark any such defects that are observed.

- Nipples and Flanges. Nipples and flanges should be examined for signs of leaks, slippage at the joint with the hose, cracks, or similar defects.

- Interior Lining. Wipe the inside with a clean swab or cloth to find signs of deterioration. Visually inspect the lining with a flashlight as far in from each end as possible.

- Hose Markings. Markings indicating manufacturer, class of service, last date tested, and safe working pressure should be visible. Their absence is an indication of excessive wear or abuse and should alert personnel to other problems.

5.11.2.3 Causes of Hose Damage. Most petroleum hoses are designed to absorb heavy use. However, careless use or abuse can contribute to premature failure.

- Improper Hose Service Application. Use only hoses specifically manufactured for oil service and so marked. These hoses, which are classified as Class I by the Rubber Manufacturer's Association (RMA), are satisfactory for petroleum fuels, including gasoline, with an aromatic content of 30 percent or less. Highly aromatic gasolines or solvents require RMA Class II or Class III hoses.

- Abrasion. Avoid damage to the outer jacket caused by dragging the hose across piers, decks, or pavement. Lift the hose with a crane, or carry it on dollies or rollers.

- Kinking or Crushing. Most Oil Suction and Discharge (OS&D) hose has metal wire reinforcement in the carcass. The reinforcement can be permanently deformed or broken if the hose is kinked or crushed. Never lift a hose by the middle with the ends hanging down.

- Sling Damage. Because of their weight, hoses may suffer exterior damage from single rope slings. Use belt slings, saddles, or bridles. Protect the hose with pieces of old hose, wood, or canvas.

- Over-Pressure. Hoses can be damaged by internal pressures in excess of design pressure. Standard hoses are designed for a working pressure of 150 psi and 600 psi minimum bursting pressure. Most transfer pumps do not

develop more than 100 psi at the hose; but shock waves, which might be caused by use of a quick-closing valve, could cause much higher surge pressures. If this is a problem, remove the quick-closing valves or install surge suppressors. If normal system operating pressures are marginally close to the hose working design pressure, install pressure relief valves. Overpressure is not normally a problem with aircraft fueling hose because of the lower pressure limitations of aircraft fuel systems.

- Ship Movement. Sufficient slack must be provided in the hoses and supporting gear to allow for the rise or fall of the ship as it loads or unloads, the range of the tide, and fore and aft and sideways movements of the ship due to changes in wind or current or the wakes of passing vessels.

- Deterioration When Not in Use. Many hoses spend more of their service life in a stowed condition than in actual use. Stowed hoses should be laid flat and uniformly supported. They should be protected from the sun and weather, drained completely, and flushed out with fresh water before storage.

- Physical Damage by Excessive Pull. A hose can be damaged by actions such as moving a vehicle or aircraft with the hose connected.

5.11.2.4 Hose Testing. The following is a test procedure for existing hose suggested by the RMA:

- Test fluid may be water or liquid petroleum with a flash point of 110<sup>o</sup>F or more. Kerosene, JP-5, or no. 2 burner fuel is acceptable, but gasoline, JP-4, or air should not be used. If petroleum is used as the test medium, the test should be conducted in a place where contamination of adjacent waters will not occur if there is spillage.

- Provide blind flanges, nipples, valves, pressure gauges, and pumps of appropriate size and rating for the test to be performed.

- Lay the hose out flat and straight, uniformly supported.

- Fill the hose with test fluid, expel all air, and raise the pressure to 10 psig.

- Hold the pressure for at least 5 minutes. During that interval, measure the length of the hose, end-of-rubber to end-of-rubber. Record the measured length as original length.

- If the hose is maintaining 10 psig, raise the pressure to 1 1/2 times the rated working pressure of the system and hold for 15 minutes. At that time, examine the hose and fittings for leaks, bulges, distortions, or other signs of weakness. Again, measure the length as described above. Record the measurement as test pressure length.

- Calculate the elongation as a percentage of original length versus test pressure length. For new hose, the maximum allowable test elongation for the new hose is 7.5%. If the test elongation of a used hose exceeds twice that amount, or 15%, it is an indication that there is a serious internal weakness and the hose should be retired.

5.11.3 Tanker and Barge Hoses. This hose, also known as a Oil Suction and Discharge (OS&D) hose, is generally of heavy construction with flanged couplings and a reinforced hose body. Its relatively high weight per foot makes it susceptible to mechanical damage and leakage from improper handling. As a result, the following requirements are set.

5.11.3.1 Maintenance Requirements. Coast Guard Oil Pollution Regulations, otherwise known as 33 CFR Part 151 to Part 156, require that oil transfer hose whose inside diameter is more than 3 inches be tested and inspected annually. A proper test requires that the hose "not burst, bulge, leak, or abnormally distort under static liquid pressure at least as great as the relief valve setting (or maximum pump pressure when no relief valve is installed) plus any static head pressure of the system in which the hose is used...."

The visual inspection requirement states that the hose shall "have no loose covers, kinks, bulges, soft spots, and no gouges, cuts or slashes that penetrate the hose reinforcement," and that it "have no external and, to the extent internal inspection is possible with both ends open, no internal deterioration...."

5.11.3.2 Criteria for Hose Replacement. Replacement of OS&D hose is a matter to be determined by experienced judgment; however, any of the following conditions would indicate that the hose should be removed from service:

- It fails the pressure test.
- It exceeds or approaches the allowable pressure test elongation.
- The jacket is cut, torn, worn, etc. to the point that reinforcement is exposed.
- The hose is kinked or crushed to the point that the minor outside diameter (that is, the smallest diameter at the point of damage) is 30 percent less than normal.

- There is serious crazing or cracking of the jacket due to sunlight exposure.

- Large pieces of the interior lining are separating or blistered.

- The hose is generally stiff or dried out, and a bending test reveals that the reinforcement is exposed or deteriorated.

5.11.3.3 Hose Markings. After a pressure test and prior to use, ensure that OS&D hose is stenciled or otherwise permanently marked to indicate:

- Manufacturer's trademark or identification

- Rated working pressure

- Class of service as follows:

- Class I, oil and gasoline up to and including 30 percent aromatic content.

- Class II, gasoline up to and including 50 percent aromatic content, such as no-lead or low-lead, high octane gasoline.

- Class III, 100 percent aromatic solvents such as xylene or toluene.

- Pressure and date of last hydrostatic test.

5.11.4 Underwater Hoses. Underwater hoses must have a working pressure of 225 psig or more and a suction vacuum of 20 inches of mercury. They are similar in construction to OS&D hoses but may have additional chafing gear covering some sections of hose. External reinforcements may also be added to prevent kinking due to tidal motion when they are used in oil transfer service in offshore moorings. Experience has shown that some sections of the underwater hose consistently wear more than others. Hose life can be extended by periodically changing the position of individual sections in the hose string. Ensure that the proper stainless steel bolts and monel nuts are used to reassemble the string.

U.S. Coast Guard requirements state in 33 CFR Part 156 that underwater hoses are to be tested every 2 years. It is recommended that, when equipment is available to lift buoys, anchors, chains, and other offshore mooring equipment, an effort be made to schedule hose inspection and testing concurrently, regardless of the duration since the last test. Work on the mooring systems can cause additional strain and wear on the hoses.

5.11.5 Tank Truck/Tank Car Hoses. These hoses are similar in construction to those used in tanker and barge service. The hose end attached to the tank truck or tank car should be equipped with a dry-break coupling or nozzle. Since these hoses are subject to the same physical and environmental conditions as OS&D hose, it is recommended that they be inspected and tested annually as described in this section. Hose sheds and racks are usually provided at loading and unloading facilities. They should be used to protect and extend the life of the hose.

5.11.6 Aircraft Fueling Hoses. The other classes of hose described in this section deliver products whose purity is not assured or finely maintained. This is not true of aircraft fueling hose. Fuel flowing through this hose may have already been filtered and metered and is intended for engines not tolerant of fuel contamination. Safe arrival of the aircraft is dependent on fuel delivered through these hoses. In addition, they are subject to the same environmental and physical hazards as OS&D hoses but are of lighter construction. These factors combine to cause aircraft fueling hose to be a major maintenance concern.

5.11.6.1 Cause of Premature Failure. In addition to previously stated modes of failure, the following are considerations:

- Overpressure. Most aircraft fueling systems limit pressures far below working pressure of fueling hose. However, thermal expansion in a closed hose may cause excessive pressures if relief valves are not present.

- Improper Storage. When possible, aircraft fueling hose should be protected against continuous exposure to sun and weather. Hose that is not in current use should be drained, flushed, and laid flat in a cool, dark location in large, loose, uniformly supported coils.

- Abrasion on Pavement. Aircraft fueling hose in continual use can be repeatedly dragged across abrasive pavements in fueling areas. This scars the surface of the outer jacket and allows moisture into the reinforcing fabric. The result is eventual fabric rot.

5.11.6.2 Inspection and Testing Criteria. NAVAIR 06-05-502 states:

Hose should be thoroughly inspected over its entire length, with special emphasis close to the nozzle and near the connection at the opposite end, where the hose should be pressed around its entire circumference in a test for soft spots. Be alert for blisters and wet spots. Any exposed hose reinforcement material is cause for hose replacement because exposed fabric provides a source for water to enter, migrate,

and ultimately rot the fabric. Inspect the area around the hose end couplings for slippage (evidenced by misalignment of hose and couplings and/or scored or exposed areas). Pressure testing of hose above 100 psi or one and a half times the normal pressure is not recommended because such practice may actually weaken the hose and be the cause of subsequent ruptures during aircraft fueling operations.

In addition, operators should be instructed to examine the hose assemblies for leaks or defects during each use and to take corrective action appropriate for the conditions observed. Current NAVAIR criteria provide for accomplishment of a detailed preventive maintenance check sheet on a daily basis, or more often if it is determined necessary on a local basis.

Hose pressure testing is performed daily using a filled hose under full pump pressure. Periodic pressure tests of the type discussed earlier in this section should be scheduled as directed by the fuels management officer.

5.11.6.3 Criteria for Hose Replacement. The criteria for replacement of aircraft fueling hose are similar to those outlined for tanker and barge hose. The hose should be replaced if there is any sign of bubbles or weeping or if the outer cover is worn away sufficiently to expose the fabric. An important additional consideration is any evidence of deterioration of the interior liner that can be detected by particles of rubber in strainer screens, which might cause contamination of the fuel. Any hose where this condition is suspected should be immediately replaced.

5.11.6.4 Preparation for Use of New or Out-of-Service Hose. NAVAIR 06-06-502 details the hose pickling process used to place a new hose in service or return one to use after an extended period of lay-up. Basically, the goal of pickling is to remove plasticizers, talc, and mica from the hose and reduce the gum and particulates transported with the fuel. Even a new hose should be thoroughly inspected. Because of the inspection and pickling process, such hoses will not be available for use for a minimum of 4 days after receipt.

## 5.12 LANDSCAPING.

5.12.1 Dikes and Mounds. An above-ground petroleum storage tank is normally surrounded by an earth, concrete, or steel enclosure designed to contain any fuel that may be spilled during operation of the tank or by tank or piping failure. Underground tanks are normally covered with earth mounds for physical protection. In addition, dikes or containment areas are used for underground tanks in locations where a spill might affect the environment or endanger adjacent property.

5.12.1.1 Utilization Criteria. Every above-ground petroleum storage tank having a capacity of more than 660 gallons must be surrounded by a dike capable of holding 100 percent of the tank capacity. Tanks with a capacity of more than 10,000 barrels must have an individual dike for each tank. Groups of tanks smaller than 10,000 barrels each but with a total capacity of no more than 15,000 barrels may be surrounded by a single dike. The tanks should be subdivided by drainage channels to prevent spills from endangering adjacent tanks within the dike.

5.12.1.2 Construction. Typically, the dike will be constructed of earth using 12 inches of clay or similar impervious material on the top, the inside slope, and the dike basin. The top of the dike should have a flat surface at least 3 feet wide. The slopes should not be greater than 1 1/2 feet horizontal to 1 foot vertical. Slopes should be protected against erosion by covering the clay surface with 2 to 3 inches of graded crushed stone or blast furnace slag bound together with hot liquid asphalt. If earth dikes are not feasible, concrete retaining walls or steel enclosures may be used (see Fig 5.12.1).

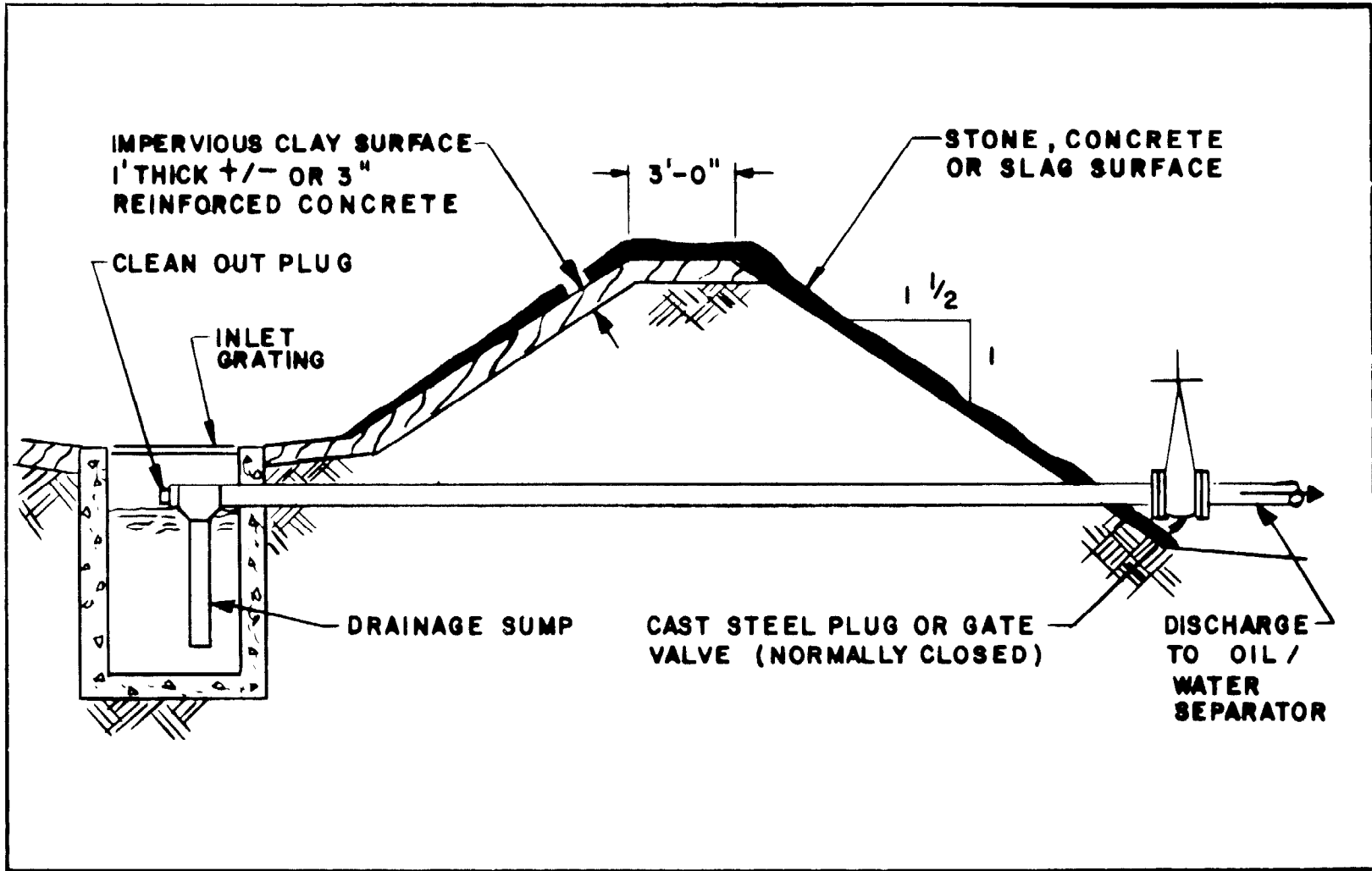
To prevent erosion of the outside wall, densely rooted, local vegetation may be planted, or thin coatings of concrete reinforced with wire mesh may be applied.

5.12.1.3 Maintenance. The dikes and basins must be continually inspected and maintained to prevent the accumulation of water, control erosion, and eliminate unwanted vegetation. The slopes should be dressed occasionally to replace eroded material and prevent further erosion.

5.12.2 Vegetation Control. While vegetation may be used to control erosion on the outside of the dike, it is not permitted on the inside slope or top of the dike because of the potential fire hazard. To decrease maintenance in these areas, it is recommended that a non-selective soil sterilant conforming to environmental regulations be applied to prevent vegetation from growing. Approved weed killers can also be used to prevent unwanted vegetation growth. Vegetation outside immediate working areas should be trimmed regularly so that it does not exceed 4 inches in height. Brush, trash, leaves, and similar combustible material should not be allowed to accumulate.

5.12.3 Drainage. Petroleum handling and storage areas where a spill might occur are required to have closed drainage systems to contain the spill and return the fluid to storage. They also require drains to remove accumulated rain water, natural seepage, or fire water that may be pumped in during an emergency. These systems are essential to the safe operation of the facility and the prevention of pollution. Drainage systems may include pipes, valves, ditches, sluice

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**FIGURE 5.12.1**  
**TYPICAL EARTH DIKE WITH DRAIN**



gates, sump pumps, oil/water separators, manholes, catch basins, etc., all of which must be maintained in clean working order at all times.

Drainage inside the dike is achieved by the slope of the basin surface or by a system of drainage ditches. In either case, interior drainage should be away from the tank leading to one or more sump pumps. The drainage is carried through the dike wall by a discharge pipe fitted with some type of a control valve operable from outside the dike. The discharge pipe should then lead to an oil/water separator.

5.12.3.1 Maintenance. Drain valves or similar control devices should be kept closed at all times except when actually in use under supervision. Tank fields should be drained as frequently as required to keep them in a clean, dry, accessible condition. Regular drainage of water from tank fields is part of the maintenance function.

Records must be kept of each time tank fields are drained into a body of navigable water without passing through a treatment system.

Treatment equipment, such as oil/water separators, must be cleaned as often as required to maintain an acceptable level of effluent quality. See the appropriate section of this chapter for further information regarding the maintenance of the specific piece of equipment.

5.12.4 Roadways and Walkways. Roadways and walkways refer to all routes of travel regularly used for vehicles or pedestrians for operation of the petroleum fuel facility, including exterior bridges, ramps, stairs, catwalks, parking areas, etc. required for access to the facilities. Materials of construction may include concrete, steel, timber, asphalt, gravel, cinders, earth, shells, etc.

5.12.4.1 Maintenance. Roadways and walkways must be maintained in level, smooth, structurally sound condition, free from defects, and safe for passage by the intended traffic at all times.

Surface defects such as potholes and cracks must be patched promptly when they occur. Replace washouts promptly. Keep drains clear of obstructions at all times. In freezing weather, remove snow as it accumulates, and apply sand and salt.

Maintain safety railings, barricades, handrails, stairways, etc., where required in sound, safe structural condition. Protect all structural materials from corrosion or weathering by application of appropriate protective coatings. Maintain all traffic signs, painted markings, reflectors, etc. legible.

### 5.13 ELECTRICAL SYSTEMS.

5.13.1 Scope. This section is intended for use by fuel facility maintenance personnel to accomplish general maintenance and minor repairs to common fuel system electrical equipment. Typically encountered systems/equipment will be described, general background information will be provided, and normal maintenance and minor repair requirements will be defined. The section will not address shore facility primary distribution (transformers, switchgear, transmission lines), building interior secondary circuits, or common exterior security lighting. Instead, it will focus on petroleum-specific electrical requirements. In general, coverage will be from the disconnect or breaker downstream through the petroleum equipment. More detailed information on shore facility general electrical maintenance is covered in NAVFAC MO-116, MO-200, MO-201, and MO-204. Additional information pertinent to petroleum facility electrical systems theory, design, installation, and maintenance can be found in the following references:

- API RP 540, "Recommended Practice for Electrical Installation in Petroleum Processing Plants"
- API RP 2003, "Protection Against Ignitions Arising Out of Static, Lightning and Stray Currents"
- NFPA 70, "National Electrical Code"
- NFPA 77, "Static Electricity"
- NFPA 78, "Lightning Protection Code."

5.13.2 Hazardous Areas. Electrical systems and equipment located in hazardous environments, such as around petroleum facilities, are subject to special precautions for their operation, inspection, maintenance, and repair. It is essential that operations and maintenance personnel understand these hazards and use the appropriate safety equipment, procedures, and replacement parts necessary to preserve life and property.

When electrical equipment and explosive petroleum vapors exist in the same area, there is a serious hazard of fire and explosion. Recognizing this fact, the National Fire Protection Association (NFPA) has established the following definitions and rules concerning the classification of hazardous areas in petroleum fuel facilities:

- Class 1, Division 1. A Class 1, Division 1, location is a location (1) in which hazardous concentrations of flammable gases or vapors exist under normal operating conditions; or (2) in which hazardous concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which

breakdown or faulty operation of equipment or processes might release hazardous concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment.

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

Typical locations within fuel facilities that can be defined as hazardous and, therefore, require explosion-proof apparatus are:

- Indoor areas such as pump rooms (even though adequately ventilated) that contain pumps, meters, bleeders, or withdrawal fittings
- Indoor areas with similar equipment that are unventilated
- Outdoor areas such as pump pads or blocks with similar equipment
- Truck and tank car loading and unloading stations
- Piers and wharfs where fuel is loaded or unloaded
- Areas surrounding above-ground storage tanks and within diked areas surrounding tanks
- Pits and depressions adjacent to or within any hazardous area or containing piping, valves, or fittings that convey hazardous materials
- Aircraft fueling stations
- Vehicle gasoline dispensing stations.

Figures 5.13.1 through 5.13.4 show the various limits and classifications of areas that are considered hazardous in typical POL facilities and must be equipped with explosion-proof apparatus.

The hazardous area limits shown in the diagrams must be considered as minimum requirements and, in practice, are often exceeded. For example, wherever possible, it is good practice to exclude all electrical equipment from within diked areas surrounding tanks. It is also good practice to install explosion-proof equipment in any area adjacent to fueling stands or loading racks where spills might occur and where prevailing wind direction or topography might direct an accumulation of hazardous vapors toward electrical apparatus. As an example of this practice, aircraft fueling aprons are considered by some authorities to be hazardous areas anywhere within 200 feet of a fueling point.

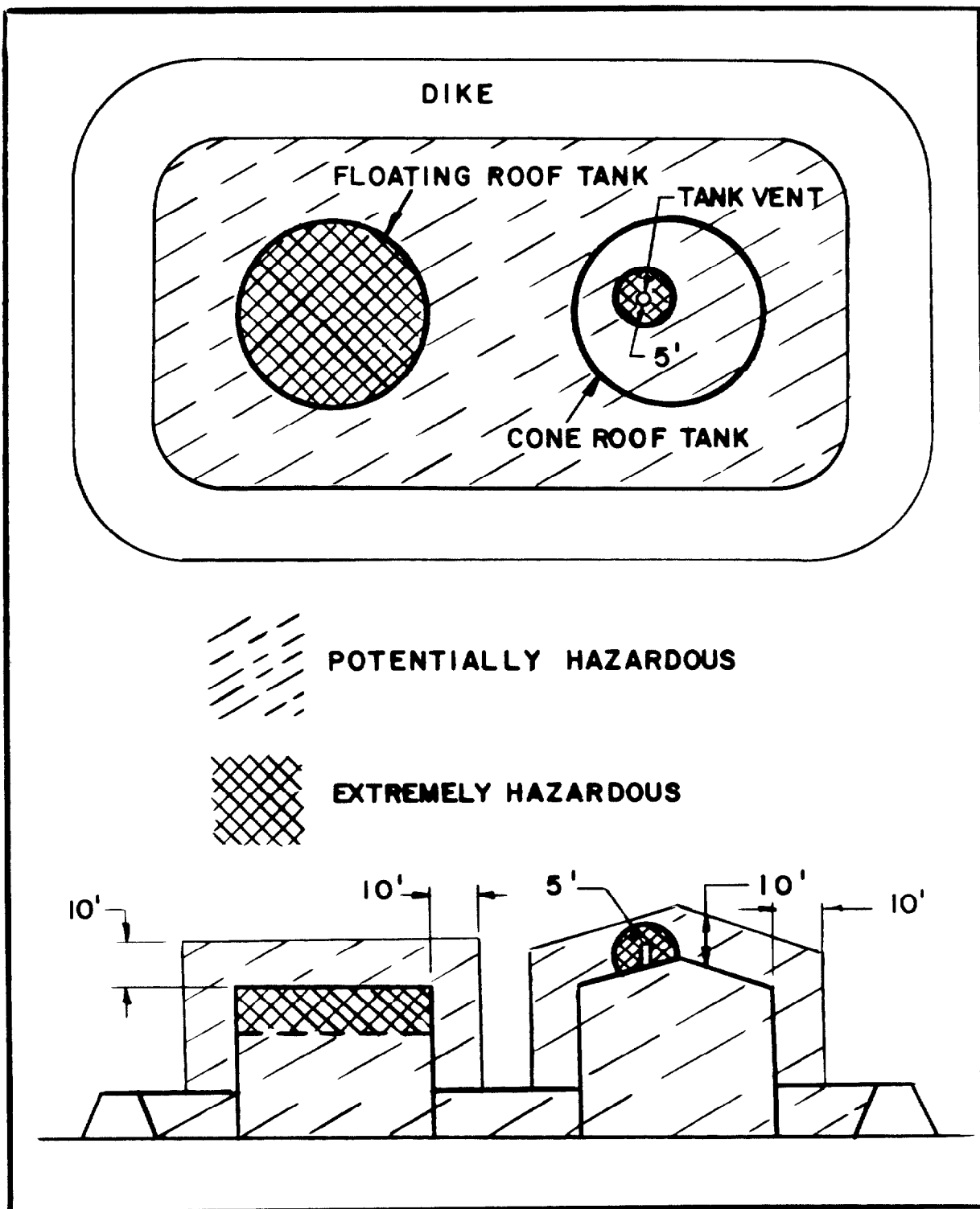
#### 5.13.3 Electrical Explosion-Proof Equipment Areas.

Electrical installations and equipment for petroleum facilities must be approved for use in hazardous areas. Therefore, NFPA National Electrical Code-approved "explosion-proof apparatus" is required for this equipment. By definition, this equipment is enclosed in a case capable of (1) withstanding an internal explosion; (2) preventing internal sparks, flashes, or explosions from igniting external gas or vapor; and (3) operating at an external temperature low enough to prevent ignition of a flammable atmosphere.

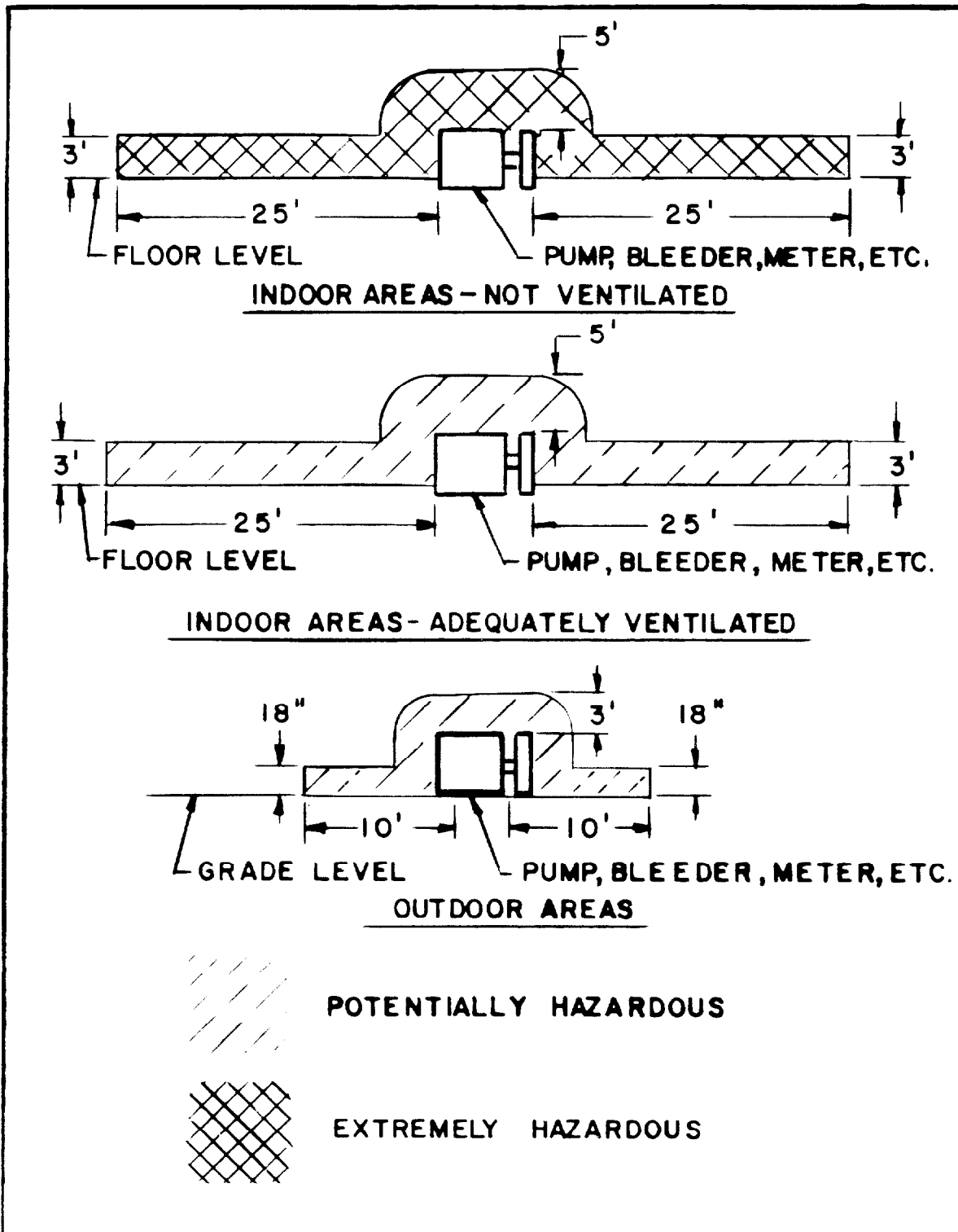
A common misconception is that explosion-proof equipment is such because it is gas-tight. The requirement, however, is not that enclosures be gas-tight, but that they be designed and manufactured with enough strength to contain an explosion and prevent the escape of flame or heat that could ignite surrounding atmospheres. Figure 5.13.5 illustrates the design of explosion-proof equipment.

In general, any electrical equipment that can produce an arc or spark in its normal operation, or whose surface temperature exceeds 80 percent of the ignition temperature of the nearby petroleum product, must be explosion-proof in both Division 1 and Division 2 locations. Furthermore, in Division 1 locations, all junction boxes, pulling elbows, flexible connections, and fittings must be explosion-proof. Figure 5.13.6 shows typical equipment arrangements for hazardous areas.

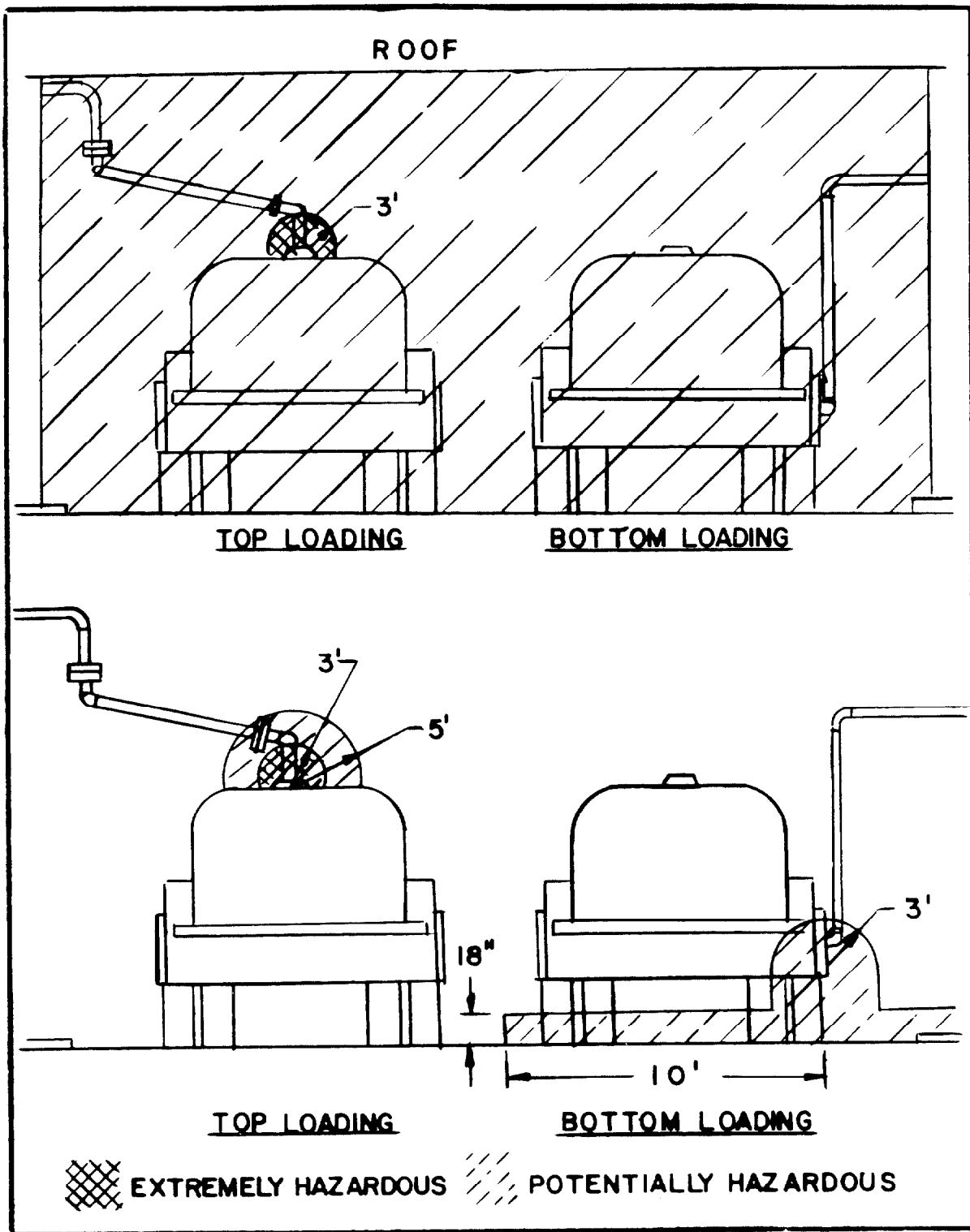
Seals must be provided in conduit and cable systems to prevent the passage of gases, vapors, or flames from one portion of an electrical installation to another. Seals also prevent large amounts of explosive gases or vapors from accumulating, thereby confining explosive pressure.



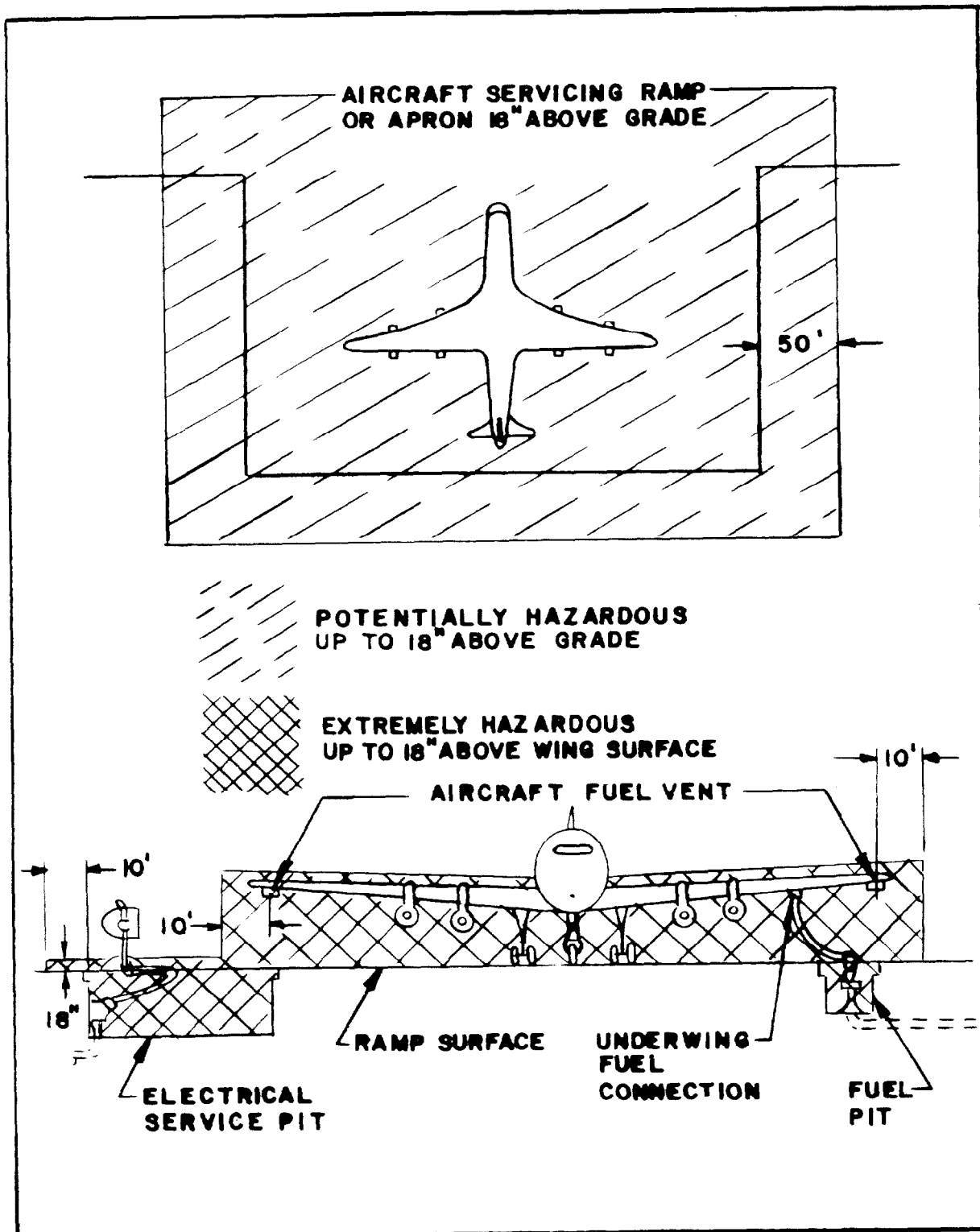
**FIGURE 5.13.1**  
**HAZARDOUS AREAS-TANK STORAGE**



**FIGURE 5.13.2**  
**HAZARDOUS AREAS - PUMPING EQUIPMENT**

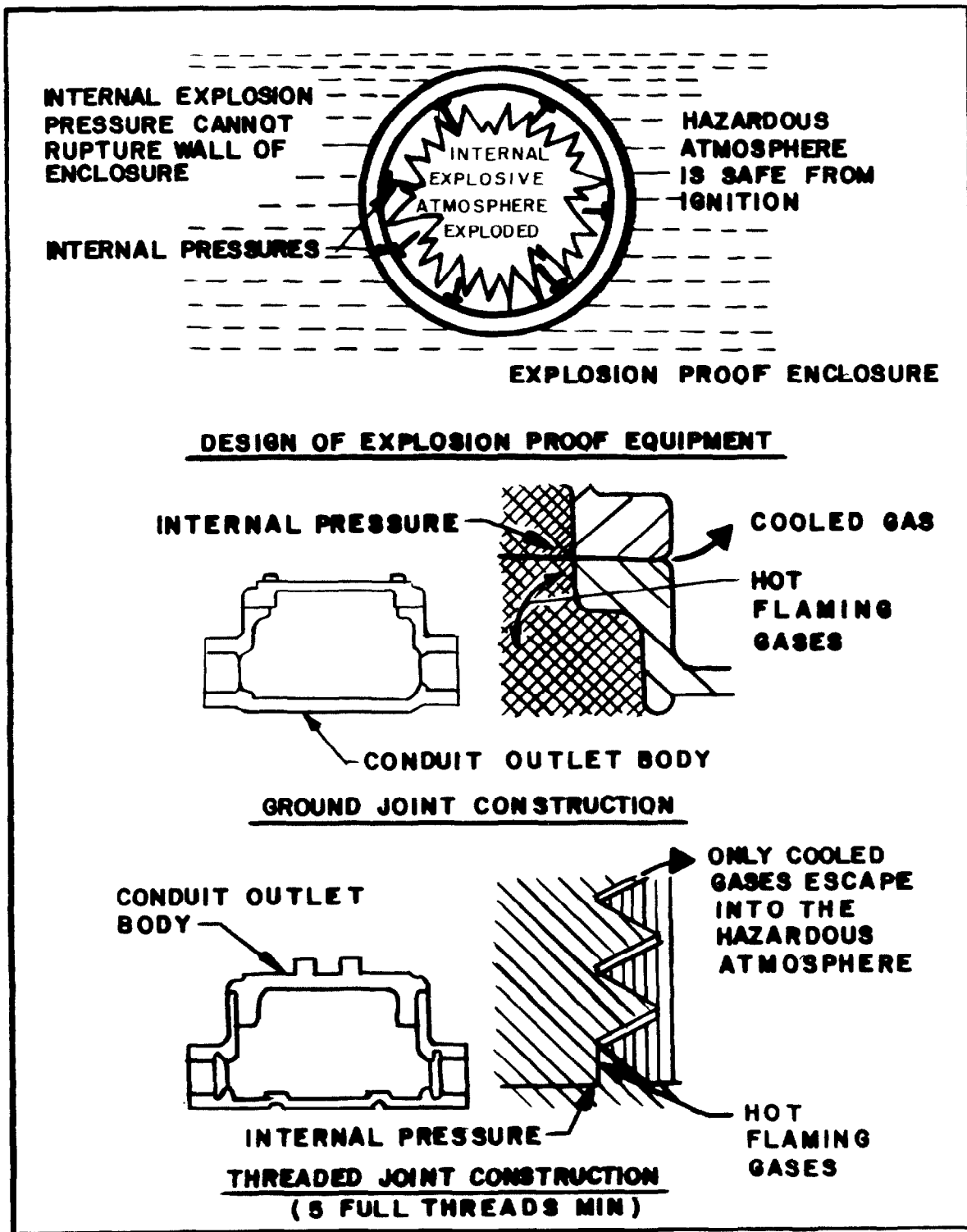


**FIGURE 5.13.3**  
**HAZARDOUS AREAS- TRUCK LOADING FACILITIES**

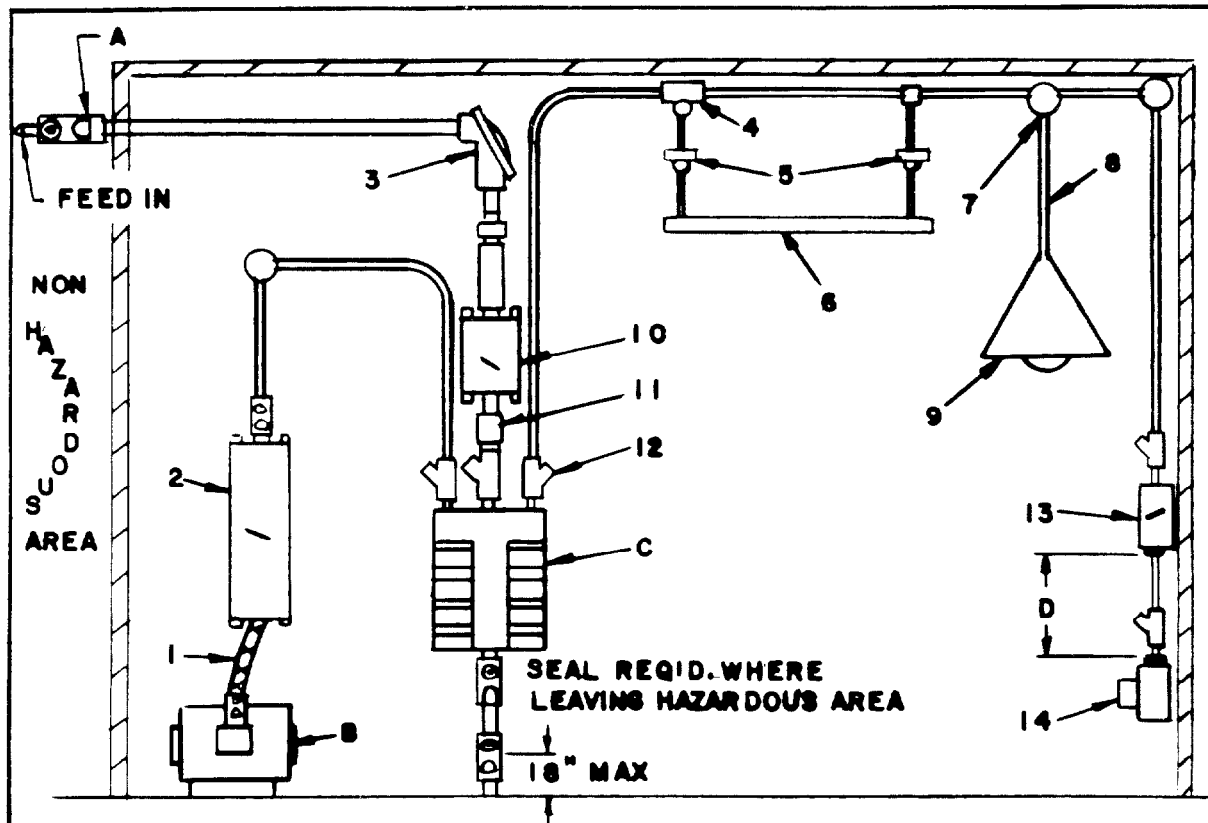


**FIGURE 5.13.4**  
**HAZARDOUS AREAS - AIRCRAFT FUELING STANDS**





**FIGURE 5.13.5**  
**DESIGN OF EXPLOSION PROOF EQUIPMENT**



ALL EQUIPMENT, DEVICES, & FITTINGS MUST BE APPROVED FOR CLASS I, DIVISION 1, GROUP D LOCATION

A- SEAL EITHER SIDE OF PARTITION. NO COUPLING OR OTHER FITTING BETWEEN SEAL & BOUNDARY.

B- SEAL IN MOTOR FRAME

C- PANELBOARD TERMINAL COMPARTMENT SEALS INTEGRAL WITH PANEL.

D- IF LESS THAN 36", REQUIRES ONLY ONE SEAL.

- |   |                                   |
|---|-----------------------------------|
| 1- FLEXIBLE COUPLING                    | 8- FLEXIBLE HANGER SUPPORT        |
| 2- COMBINATION MOTOR/STARTER            | 9- MERCURY VAPOR LIGHTING FIXTURE |
| 3- PULLING ELBOW                        |                                   |
| 4- FLANGED JUNCTION FITTING WITH CANOPY | 10- CIRCUIT BREAKER               |
| 5- SWIVELS                              | 11- CONDUIT UNION                 |
| 6- FLUORESCENT LIGHTING FIXTURE         | 12- CONDUIT SEALING FITTING       |
| 7- FIXTURE HANGER                       | 13- LIGHT SWITCH                  |
|   | 14- RECEPTACLE                    |

**FIGURE 5.13.6**  
TYPICAL EQUIPMENT ARRANGEMENTS FOR HAZARDOUS AREAS

Figure 5.13.7 depicts hazardous internal vapors ignited by turning on a switch, but the fire being contained between the two seals. Seals must be installed in each run of conduit entering or leaving any enclosure containing switches, fuses, circuit breakers, relays, or other devices that may produce arcs, sparking, or high temperatures.

In no case should seals be placed more than 18 inches from an arcing device in an explosion-proof enclosure, and such seals must be in every conduit run that leaves a hazardous area. In Division 1 areas, seals should also be used with enclosures that house terminals, taps, and splices when the conduit is 2 inches or larger. In Division 1 and 2 areas, rigid conduit with threaded joints must be used between the seal and the explosion-proof enclosure. Threadless connections are not flame-tight and cannot be used.

Further, in Class 1, Division 1, locations containing explosive gases or vapors, lamps must be enclosed in explosion-proof fixtures. In all classes of hazardous locations, pendant fixtures must be suspended by either flexible hangers or rigid conduit stems not over 12 inches long. Longer stems can be used if they are permanently braced within 12 inches of the fixture.

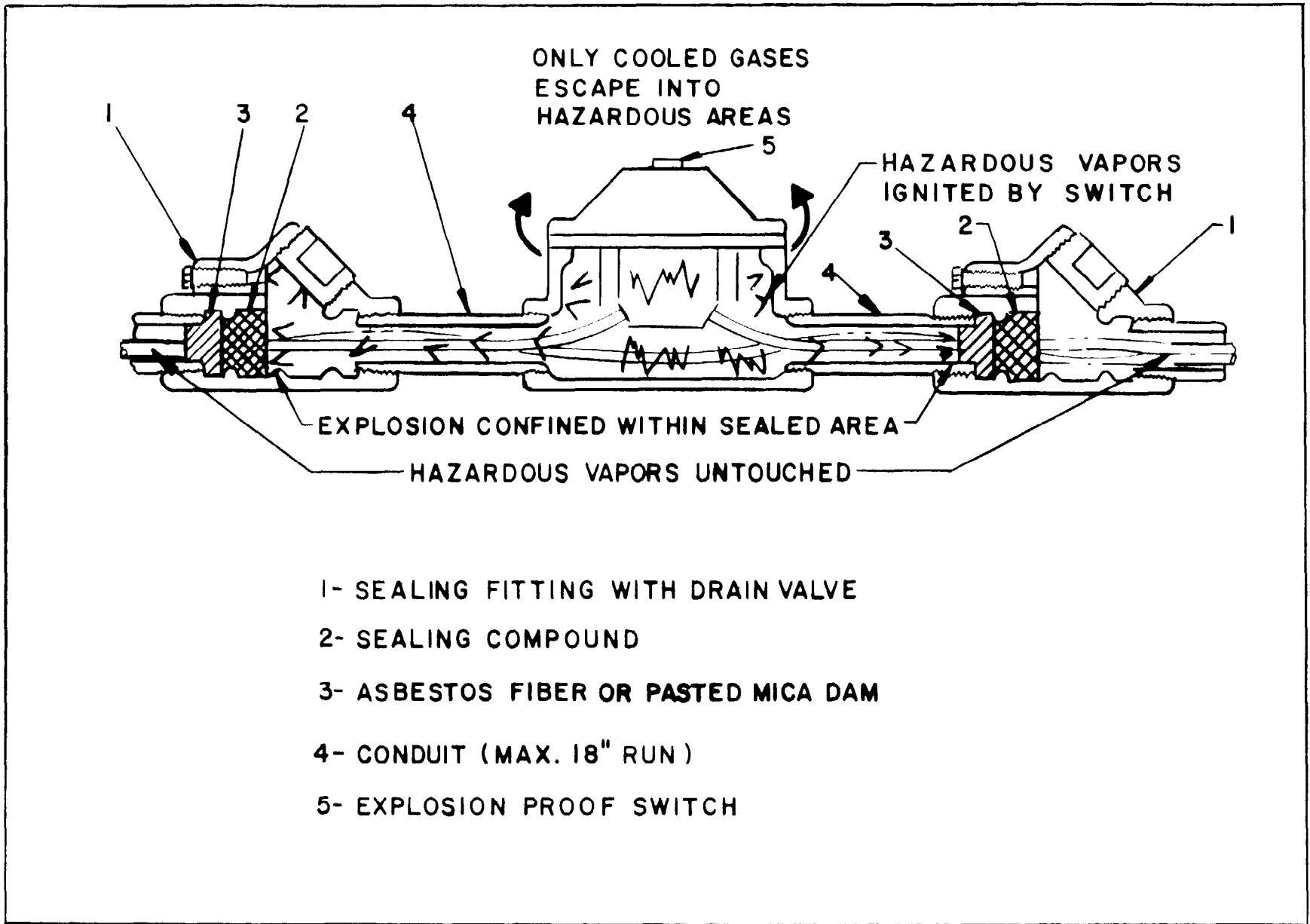
In Class 1, Division 2, locations, fixed lighting fixtures need not be explosion-proof if lamp surface temperatures do not exceed 30 percent of the ignition temperature of the vapors involved. In practice, however, where gasolines, jet-fuels, or kerosene is in use, it is prudent to use explosion-proof lighting equipment.

5.13.4 Maintenance of Electrical Equipment. The electrical maintenance of fuel facilities is generally carried out by public works electricians or by outside contractors. However, certain minor repairs and items of routine maintenance can be performed by fuel operators and maintenance personnel. The following paragraphs describe these maintenance activities.

- If a fuse is blown or circuit breaker is tripped, locate the cause of trouble before replacing or resetting. Never oversize fuses, replace them with solid links, or try to hold a circuit breaker closed against an overload or fault.

- A switch or circuit breaker enclosure that feels warm to the hand should be reported to qualified personnel, who should check for internal conditions and for circuit overloading.

- Since the purpose of explosion-proof equipment is to prevent the ignition of hazardous materials, every effort must be made to ensure the effectiveness of the equipment for the protection of personnel and property.



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FIGURE 5.13.7  
CONFINEMENT OF EXPLOSIVE GASES UTILIZING CONDUIT SEALING FITTINGS

- Bolted cover equipment should be inspected to ensure that all bolts are in place and tight. Machined surfaces must be free of paint, dirt, rust, or grease and should be free from damage or deformity. Screwed cover devices or screwed fittings need at least five full threads of metal-to-metal contact.

- Breathers must have free passages, and drain fittings should be periodically operated to prevent condensation and corrosion within the apparatus.

- Seal fittings must be checked for proper location and condition. Seals broken during maintenance or repair or seal fittings that show evidence of physical damage or cracks must be replaced.

- When replacing bulbs in explosion-proof lighting fixtures, care must be taken to reassemble the fixture correctly. Do not increase the wattage above the original rating in any explosion-proof lighting fixture. (Increased wattage produces excessive surface temperatures, which can cause vapor ignition.)

- The use of portable electric tools, equipment, lamps, etc. in hazardous areas should be restricted. If such use is necessary, only approved receptacles, cord plugs, and devices should be used. The housing of any portable equipment must be clearly stamped with a nameplate or legend indicating that it is approved for hazardous areas.

5.13.5 Major Safety Concerns. Electrical maintenance personnel must always be aware of the inherent hazards in petroleum transfer systems they maintain. Electrical energy is an obvious hazard in all electrical systems/equipment. What may not be so obvious are the numerous mechanical hazards that exist, especially rotating machinery. It is the responsibility of all maintenance personnel to observe safety regulations and procedures, properly use all appropriate safety equipment, and ensure completed work is safe and reliable.

#### 5.13.5.1 Safety Precautions.

- Do not service or adjust equipment alone. Under no circumstances should any personnel reach into or enter any live equipment enclosure for servicing or adjusting equipment, except as directed by an approved procedure and only then in the presence of someone capable of rendering aid. Personnel working with or near live circuits or high voltages should be trained in modern methods of cardio-pulmonary resuscitation.

- Keep away from live circuits. Do not replace components or make adjustments inside any equipment while it is energized, except as directed by an approved technical manual

or procedure. Use only one hand if it is necessary to reach into or adjust live equipment/circuits. Always use the approved tag-out procedure to prevent electrical circuits from becoming unexpectedly energized during maintenance.

- Be aware of environmental hazards. Avoid sparking/arcing in ignitable atmospheres by using special tools, clothing, and explosion-proof drop lights/extension cords and maintaining adequate grounds. Ensure safe air quality and adequate ventilation before working in any questionable environment such as tanks, vaults, service pits, underground locations, enclosed spaces, any oxygen displaced atmospheres, or especially after fire extinguishing agents have been dispensed (e.g., CO<sub>2</sub>, Halon). Have the atmosphere certified safe by a gas-free engineer before entering to perform any work (see Section 5.3.3.5). Avoid breathing or contact with hazardous chemical compounds and irritants often encountered in the maintenance environment such as gasoline, kerosene, diesel fuel, cleaning solvents, silicones, fiberglass, asbestos, insulating oils, carbon dust, PCBs, PVCs, and combustion by-products. Always follow the approved disposal methods for these and any other waste materials.

- Do not defeat any safety devices such as power disconnects or deadman switches except as directed by an approved technical manual. Make certain to fully restore the safety device before returning equipment to normal service. Do not use current safety devices (circuit breakers or fuses) more than once. Do not use main disconnects as ON-OFF switches to energize or de-energize equipment. Always use tested components of the correct value, size, type, and specification and replace and install them in accordance with applicable codes.

- Use the National Electrical Code rules as guidelines to ensure safety of the finished work.

- Refer to the publications listed in Section 5.1.4 for additional safety information.

#### 5.13.6 Electric Motors.

5.13.6.1 Definitions and General Descriptions. An electric motor is a device that converts electrical energy into mechanical energy. Figure 5.13.8 shows the simple elements that demonstrate the basic principles of motor operation. Electric motors of sizes ranging from under one horsepower (HP) to several hundred HP are in use in petroleum facilities. They drive pumps, valve operators, meters, and tools, providing reliable and effective force. Figure 5.13.9 is a cutaway of a typical electric motor.

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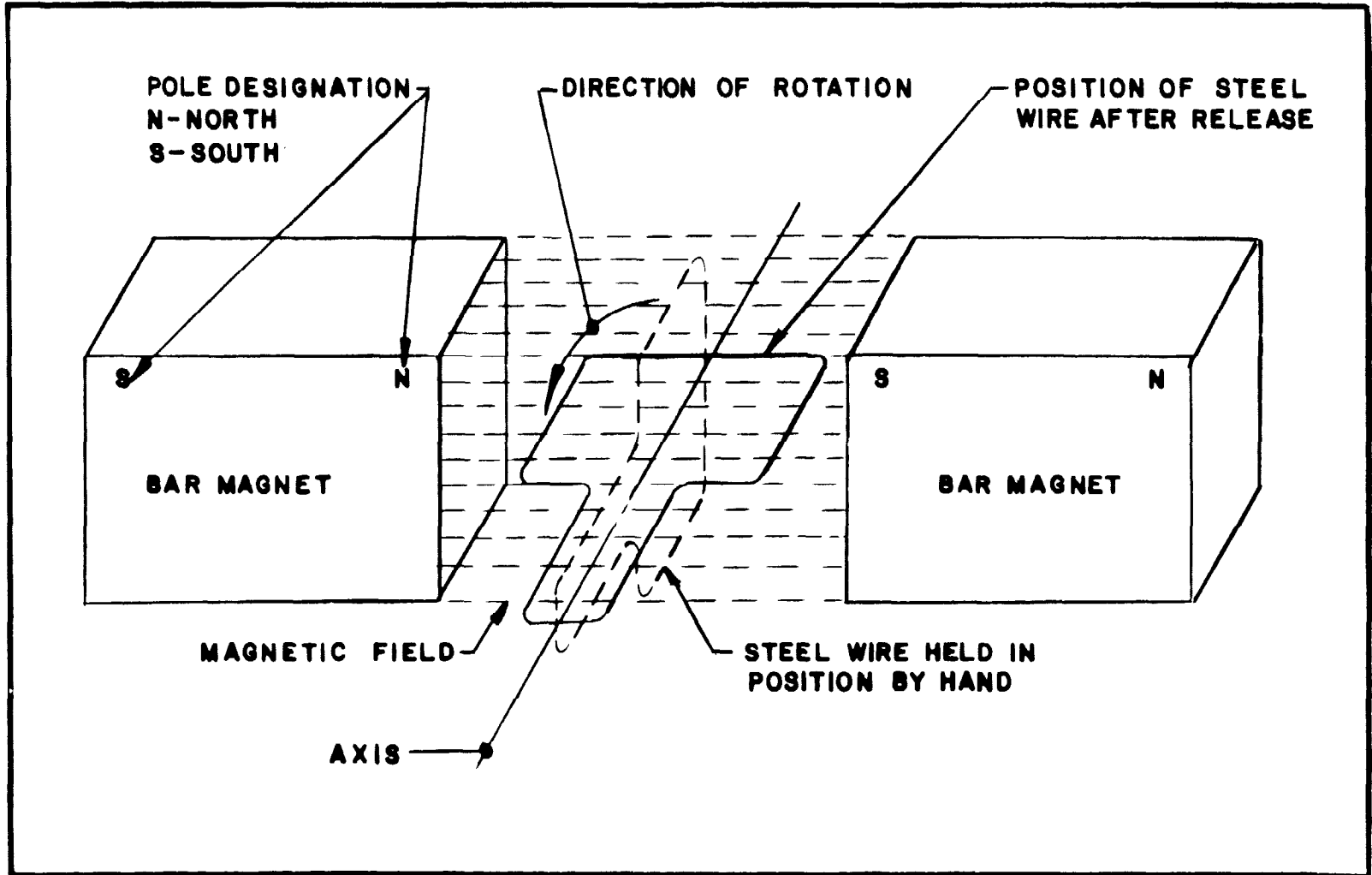
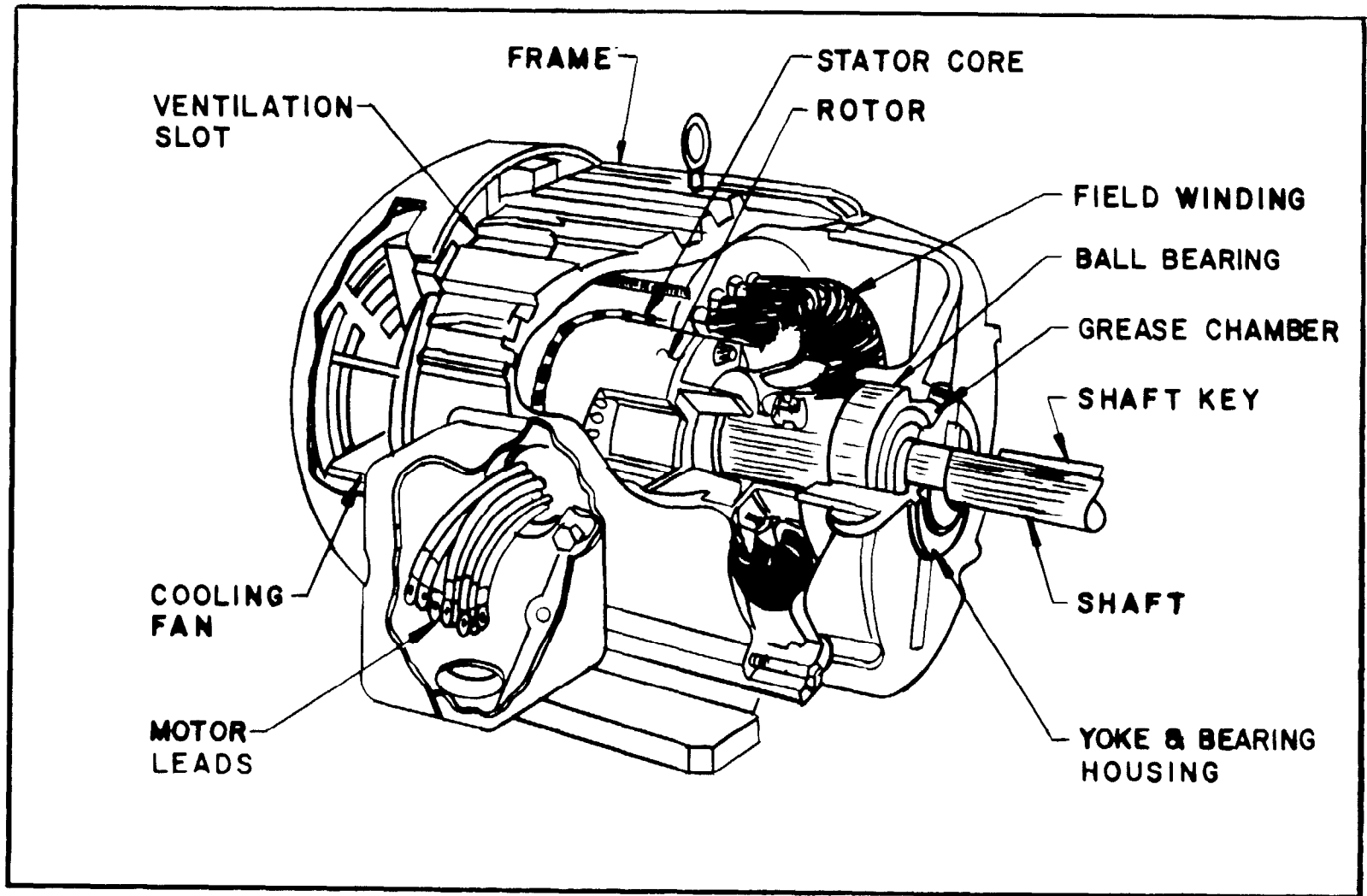


FIGURE 5.13.8

BASIC PRINCIPLE OF MOTOR OPERATION

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**FIGURE 5.13.9**  
**TOTALLY ENCLOSED FAN-COOLED MOTOR**



#### 5.13.6.2 Common Electric Motor Problems.

- Alignment. Misalignment and vibration are major causes of motor failure. Failure to tightly dowel both the motor and driven machines to a common base may result in shifting of the motor or driven machine. Mechanical loads (such as from pipelines connecting to pumps) also cause the driven machine to move. Therefore, motor alignment should be periodically checked, and the alignment should be adjusted as required.

- Overheating. The temperature of a motor will rise during operation. Anything that restricts air circulation through the ventilation passages of the motor will cause it to overheat. For example, lint, blown grass and weeds, dirt, dust, and snow impede the passage of air through the motor. Further, the presence of oil in the coils, either from bad seals or over-lubrication, can increase the problem. If the motor is in an enclosed space, such as a pit or small room without ventilation, the surrounding air temperature will quickly rise and will not be able to cool the motor, thereby causing it to overheat.

- Moisture Control. Moisture causes motor coil insulation to lose its insulating properties. The more moisture, the less insulating value. Enough moisture will cause windings to short circuit and the motor to fail.

Moisture can enter a totally enclosed or explosion-proof motor as it "breathes" in moisture-laden air. This can cause condensation on the motor coils after the motor shuts down. Motors that are operated every day will usually be hot enough to evaporate any moisture which has entered with the air. If possible, motors should be run periodically to prevent moisture buildup. If it is not possible to run the equipment or if a motor has been left standing in the weather for a long period, the insulation level should be checked by a qualified person before the motor is energized. If lower than acceptable levels are found, heaters or heat lamps should be used to dry the windings.

In addition, motors that are left standing in moist atmospheres are subject to bearing rust. The shafts on motors with oil bearings should be turned at least once per month, and those with grease bearings, once every 3 months. A motor that has been immersed in water can be disassembled, washed in clean fresh water, steam-cleaned, and bake-dried using electric heaters and infrared heat lamps. If the immersion has been in salt water, the bearings should be replaced. After cleaning and drying, a coat of insulating varnish should be applied to all windings. The windings should then be tested for their insulation value before reassembly.

Some large motors are equipped with strip heaters that come on when the motor is turned off. These heaters should have a pilot indicator to show that they are working and should be periodically checked to be sure they have not burned out.

Another method to prevent moisture buildup or to remove moisture from motor windings is to continuously apply a voltage of between 5 and 7-1/2 percent of the nominal motor voltage to the windings. This will circulate enough current to prevent condensation and remove moisture. This procedure should only be accomplished by qualified personnel.

- Improper Lubrication. Over-lubrication of motor bearings can be as harmful as under-lubrication. Motors used in a dirty environment should be lubricated every 9 to 12 months. Typically, after 18 months of use, the oil held by the soap in the grease has been used, and the grease must be replaced. The lubricating grease should be of a type recommended by the motor manufacturer. Technical manuals for the specific motor being lubricated will detail the exact lubrication procedures to be followed.

On oil-lubricated bearings, use only the proper non-detergent oil. Detergents cause the oil to penetrate the seals, damage the motor windings, and create ventilation problems.

- Insect and Rodent Control. Insects, rodents, snakes, and other small animals can cause damage to motor windings. Suitable screens should be installed on open motors to prevent pest attack.

- Voltage Imbalance in Three-Phase Supply Systems. This is usually caused by large, single-phase loads being put on a three-phase system. A motor operating with imbalanced voltage can fail because of excessive temperature increases. Loose connections and transformer malfunctions can also cause voltage unbalances. Line voltage should be checked periodically. If more than a 1 percent imbalance is found, it should be reported to the public works office or other agency supplying power to the facility.

- Low Voltage. Motors subjected to low voltage supply also tend to overheat. As the voltage decreases, the current increases, and it is the current that produces heat. Again, frequent monitoring of the system voltage will warn of the condition. Voltage that drops below 5 percent of the nameplate rating should be reported for correction.

- High Voltage. High voltage can also cause motor burn-out. A voltage of more than 10 percent above the nameplate rating causes magnetic saturation of the iron in the motor stator, which causes current and temperature to rise.

Because of closer design tolerances, newer motors are more susceptible than older equipment to over-voltage damage. Submersible pump motors are especially prone to over-voltage damage. Again, a voltage check that shows 5 percent or more over-voltage must be reported.

- Lightning. Much motor damage occurs from lightning strikes. The coils of a motor are vulnerable to the high voltage traveling wave caused by lightning. If lightning arrestors are installed on the distribution system to protect rotating equipment, the ground connections from these arrestors should be carefully inspected and maintained. Secondary arrestors can be installed at each feeder and tap and at each important motor controller to provide extra protection in areas subjected to frequent lightning storms. These arrestors should always be mounted externally to the starters and should never be installed within hazardous areas.

Short Cycling. This is the act of repeatedly starting a motor within a short time period. When a motor that has reached its normal operating temperature is subjected to frequent re-starts, the motor will become overheated very quickly. Faulty control devices such as pressure switches, flow switches, and thermostats can cause short cycling, as can on and off conditions occurring too frequently.

- Loose Connections. Loose electrical connections in starters and motor terminal housings, especially where aluminum cable is used, can also cause overheating.

5.13.6.3 Preventive Maintenance Checks and Inspections. In accordance with the inspection procedures and guidelines presented in Section 5.13.4, the following physical inspection and maintenance items should be observed regularly:

- Enclosures and Air Passages. Examine external and internal cleanliness, structural support, corrosion, mechanical damage, moisture, obstructed air passages, free air circulation, and damaged internal parts.

- Bearings. Inspect for proper lubrication, overheating, excessive vibration, noise, moisture, dirt, and correct end play.

- Windings and Electrical Insulation. Look for dirt, moisture, lubricant deposits, insulation deterioration (overheating, cracking, brittleness, odor, abrasion), loose wedges, and motor lead condition. Insulation resistance testing should be done by qualified personnel.

- Air Gap. There should be uniformity in all quadrants of the air gap between the rotor and stator to within 10 percent tolerance.

- Starter. Look for loose iron and rubbing.
- Rotor. Identify any loose or broken bars and overheating.
- Brushes. Examine for proper seating, good connections, wear, chipped toes and heels, cracked brush holders, and pigtails.
- Commutators and Collector Rings. Check for roughness, wear, high or low bars, proper undercutting of mica, roundness, eccentricity, sparking, and neutral position adjustment of brushes.
- Space Heaters. Look for proper operation, loose connections, high resistance readings.

5.13.6.4 Instruments for Motor Inspection. The following is a minimum suggested list of instruments for electric motor maintenance and inspection. These instruments will enable a maintenance technician/inspector to perform thorough electrical tests, check alignments, and measure vibrations:

- Portable indicating ammeter
- Portable indicating voltmeter
- Megohmmeter (500-volt hand-crank type)
- Hand revolution counter
- Spring balance (0 to 20 lb scale)
- Thermometers (centigrade)
- Portable analyzer or multipurpose testing instrument (volts AC; DC; ohms)
- Hook-on ammeter (voltmeter)
- Phase-sequence indicator, portable
- Vibration indicator (hand type)
- Dial indicator and magnetic mount.

5.13.6.5 Troubleshooting and Fault Isolation. A large number of motor problems actually are the result of failures in the control circuit or improper alignment of either motor components or the motor with connected apparatus.

Table 5.13.1 is provided as an aid to effective inspection, recognition of unsatisfactory motor conditions or performance, and determination of the most desirable corrective action to be taken.

#### 5.13.7 Motor Controllers.

5.13.7.1 Definitions and General Descriptions. Any device that starts or stops a motor, changes a motor's speed, or reverses its rotation is classified as a motor controller.

Basically, a motor controller is a switch that may be operated by manual or electrical means.

- Manual Motor Controller. A manual motor controller or manual "starter" is a motor switch that is operated by a mechanical linkage from a toggle handle or pushbutton (provided as part of the unit).

- Magnetic Motor Controller. A magnetic motor controller or starter is one in which the starter action is initiated automatically by a separate pilot device or switch, called a "control device." Control devices are divided into two groups: momentary contact devices and maintained contact devices. Figure 5.13.10 shows typical applications of momentary and maintained contact control devices.

Motor controllers are further classified as "across-the-line" starters or "reduced-voltage" starters. Across-the-line starting means that the controller applies full voltage to the motor terminals upon closing. This type of starting is the most common and is used where full voltage starting torque may be safely applied to the driven machinery and where the resulting current surge is not objectionable.

Where high surge current (which causes line voltage fluctuations) or high torque starting is objectionable, reduced-voltage starters are employed. Higher voltage motors (above 600 volts) are almost always controlled by reduced-voltage starters.

Motor controllers (or motor starters) also function to protect the motors that they control. Protection against over-current damage is usually provided by a current actuated, built-in relay. These relays, sometimes referred to as "heaters," are of three basic types:

TABLE 5.13.1

## ELECTRIC MOTOR TROUBLESHOOTING CHART

## INDUCTION MOTORS

<u>TROUBLE</u>	<u>CAUSE</u>	<u>REMEDY</u>	
MOTOR WILL NOT START	Overload control trip	Wait for overload to cool. Try starting again. If motor stalls or does not start, check all the causes as outlined below.	
	Power not connected	Connect power to control, and control to motor. Check clip contacts.	
	Faulty (open) fuses	Replace fuses.	
	Low voltage	Check motor-nameplate values with power supply. Also check voltage at motor terminals with motor under-load to be sure wire size is adequate.	
	Wrong control connections	Check connections with control wiring diagram.	
	Loose terminal-lead connection	Tighten connections.	
	Driven machine locked	Disconnect motor from load. If motor starts satisfactorily, check driven machine.	
	Open circuit in stator winding	Check for open circuits.	
	Short circuit in stator winding	Check for shorted coil.	
	Winding grounded	Test for grounded winding.	
	Bearings stiff	Free bearings or replace.	
	Grease too stiff	Use special lubricant for special conditions.	
	MOTOR NOISY	Motor running single-phase	Stop motor, then try to start. It will not start on single phase. Check for "open" in one of the lines or circuits.
		Electrical load unbalanced	Check current balance.
Shaft bumping (sleeve-bearing motors)		Check alignment, and condition of belt. On pedestal-mounted bearing, check cord play and axial centering of rotor.	
Vibration		Driven machine may be unbalanced.	
Air gap not uniform		Center the rotor and if necessary replace bearings.	
Noisy ball bearings		Check lubrication. Replace bearings if noise is persistent and excessive.	
Loose punchings, or loose rotor on shaft		Tighten all holding bolts.	
Rotor rubbing on stator		Check the rotor and replace bearings if necessary.	
Objects caught between fan and end shields	Disassemble motor and clean it. Any rubbish around motor should be removed.		

TABLE 5.13.1 (Continued)

MOTOR NOISY (CONT.)	Motor loose on foundation	Tighten holding-down bolts. Motor may possibly have to be realigned.
	Coupling loose	Insert feelers at four places in coupling joint before pulling up bolts to check alignment. Tighten coupling bolts securely.
MOTOR AT HIGHER THAN NORMAL TEMPERATURE OR SMOKING	Overload	Measure motor loading with ammeter. Reduce load
	Electrical load unbalance (fuse blown, faulty control, etc)	Check for voltage unbalance or single phasing. Check for "open" in one of the lines or circuits.
	Restricted ventilation	Clean air passages and windings.
	Incorrect voltage and frequency	Check motor-nameplate values with power supply. Also check voltage at motor terminals with motor under full load.
	Motor stalled by driven machine or by tight bearings	Remove power from motor. Check machine for cause of stalling.
	Stator winding shorted	Cut out coil or rewind.
	Stator winding grounded	Test and locate ground.
	Rotor winding with loose connections	Tighten, if possible, or replace with another rotor.
Belt too tight	Remove excessive pressure on bearings.	
	Motor used for rapid-reversing service	Replace with motor designed for this service.
MOTOR BEARINGS HOT	Wrong grade of grease	Flush existing rease and add proper grade of grease.
	Insufficient grease	Remove relief plug and regrease bearing.
	Too much grease	Remove relief plug, and let motor run. If excess grease does not come out, flush and relubricate.
	Foreign material in grease	Flush bearings, relubricate; making sure that new grease is clean.
	Bearings misaligned	Align motor and check bearing-housing assembly. See that races are exactly 90° with shaft.
	Bearings damaged (corrosion, etc.)	Replace bearings.
	End shields loose or not replaced properly	Make sure end shields fit squarely and are properly tightened.
	Excessive belt tension or excessive gear side thrust	Reduce belt tension, or gear pressure, and realign shafts. See that thrust is not being transferred to motor bearing.
	Bent shaft	Straighten shaft.

**TABLE 5.13.1 (Continued)**

<b>HOT SLEEVE BEARINGS</b>	Insufficient oil	Add oil. If oil supply is very low, drain and flush before refilling.
	Foreign material in oil or poor grade of oil	Drain oil, flush, and relubricate using industrial lubricant recommended by motor manufacturer.
	Oil rings rotating slowly or not rotating at all	Oil too heavy; drain and replace.
	Rings bent or otherwise damaged in re-assembling	Replace rings.
	Ring out of slot (oil-ring retaining clip out of place)	Adjust or replace retaining clip.
	Motor tilted too far	Level motor or reduce tilt and realign, if necessary.
	Motor tilted, causing end thrust	Level motor, reduce thrust, or use motor designed for thrust.
	Defective bearings or rough shaft	Replace bearings. Resurface shaft.
<b>WOUND ROTOR MOTOR PROBLEMS:</b>	Wires to control too small	Use larger cable to control.
<b>ROTOR RUNS AT LOW SPEED WITH EXTERNAL RESISTENCE CUT OUT</b>	Control too far from motor	Bring control nearer motor.
	Open circuit in rotor circuit (including cable to control)	Test by ringing out circuit and repair.
	Brushes sparking	Adjust commutation.
	Dirt between brush and ring	Clean rings and insulation assembly.
	Brushes stuck in holders	Use right size brush.
	Incorrect brush tension	Check brush tension and correct.
	Rough collector rings	File, sand, and polish.
	Eccentric rings	Turn in lathe or use portable tool to tune up rings, without disassembling motor.
	Excessive vibration	Balance motor.
	Current density of brushes too high (overload)	Reduce load (if brushes have been replaced, make sure they are of the same grade as originally furnished). Check shaft for straightness.
<b>SYNCHRONOUS MOTORS</b>		
<b>TROUBLE</b>	<b>CAUSE</b>	<b>REMEDY</b>
<b>MOTOR WILL NOT START</b>	Faulty connection	Inspect for open or poor connection.
	Open circuit one phase	Test, locate, and repair.
	Short circuit one phase	Open and repair
	Voltage falls too low	Reduce the impedance of the external circuit.
	Friction high	Make sure bearings are properly lubricated. Check bearing tightness. Check belt tension. Check load friction. Check alignment.



TABLE 5.13.1 (Continued)

MOTOR WILL NOT START (CONT.)	Field excited	Be sure field-applying contact is open and field-discharge contact is closed through discharge resistance.
	Load too great	Remove part of load.
	Automatic field relay not working	Check power supply to solenoid.
	Wrong direction of rotation	Check contact tips. Check connections. Reverse any two main leads.
FAILS TO PULL INTO STEP	No field excitation	Check circuit connections. Be sure field-applying contact is operating. Check for open circuit in field or exciter. Check exciter output. Check rheostat. Set rheostat to give rated field current when field is applied. Check contacts of switches.
	Load excessive	Reduce load Check operation of unloading device (if any) on driven machine.
	Inertia of load excessive	May be a misapplication - consult manufacturer.
MOTOR PULLS OUT OF STEP OR TRIPS BREAKER	Exciter voltage low	Increase excitation. Examine exciter as shown in dc motors. Check field ammeter and its shunt, to be sure reading is not higher than actual current.
	Open circuit in field, and exciter circuit	Test with magneto and repair break.
	Short circuit in field	Check with low voltage and polarity indicator and repair field.
	Reversed field coil	Check with low voltage and polarity indicator and reverse incorrect leads.
	Load fluctuates widely	See Motor "hunts" below.
	Excessive torque peak	Check driven machine for bad adjustment, or consult motor manufacturer.
	Power fails	Reestablish power circuit.
	Line voltage too low	Increase if possible. Raise excitation.
MOTOR "HUNTS"	Fluctuating load	Correct excessive torque peak at driven machine or consult motor manufacturer. If driven machine is a compressor, check valve operations. Increase or decrease flywheel size. Try decreasing or increasing motor field current.
STATOR OVERHEATS IN SPOTS	Rotor not centered	Realign and shim stator or bearings.
	Open phase	Check connections and correct.
	Unbalanced currents	Loose connections. Improper internal connections.

TABLE 5.13.1 (Continued)

ONE OR MORE COILS OVERHEAT	Short circuit	Cut out coil as expedient (in motors up to 5 hp); replace coil when the opportunity arises (rewind).
FIELD OVERHEATS	Short circuit in a field coil Excessive field current	Replace or repair. Reduce excitation until stator current is at nameplate value.
ALL PARTS OVERHEAT	Overload	Reduce load or increase motor size. Check friction and belt tension, or alignment.
	Over- or underexcitation	Adjust excitation to nameplate rating
	No field excitation	Check circuit and exciter.
	Reverse field coil	Check polarity and, if wrong, change leads.
	Improper voltage	See that nameplate voltage is applied.
	Improper ventilation	Remove any obstruction and clean out dirt.
	Excessive room temperature	Supply cooler air.

## DC MOTORS

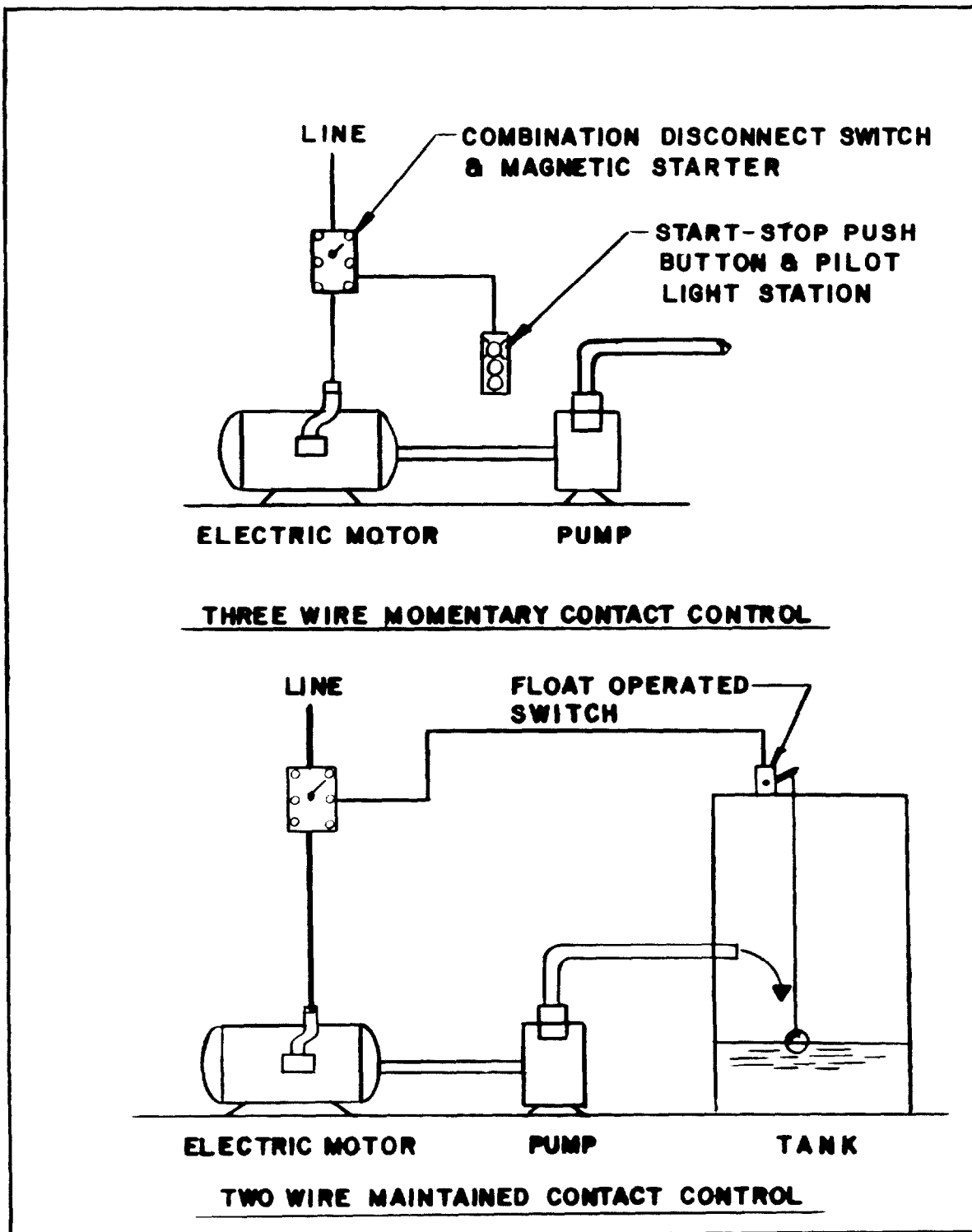
<u>TROUBLE</u>	<u>CAUSE</u>	<u>REMEDY</u>
MOTOR WILL NOT START	Open circuit in control  Low terminal voltage Bearing frozen  Overload Excessive friction	Check control for open starting resistor, open switch, or burned fuse. Check voltage with nameplate rating. Recondition shaft and replace bearing. Reduce load or use larger motor. Check lubrication in bearings to make sure that the oil has been replaced after installing motor. Disconnect motor from driven machine, and turn motor by hand to see if trouble is in motor. Strip and reassemble motor; then check part by part for proper location and fit.
MOTOR STOPS AFTER RUNNING SHORT TIME	Motor is not getting power	Check voltage at the motor terminals; also clips, and overload relay.
MOTOR ATTEMPTS TO START BUT OVERLOAD	Motor is started with weak or no field  Motor torque insufficient to drive load	If adjustable-speed motor, check rheostat for setting. If correct, check condition of rheostat. Check field coils for open winding. Check wiring for loose or broken connection Check line voltage with nameplate rating, larger motor, or one with suitable characteristic match load.

**TABLE 5.13.1 (Continued)**

MOTOR RUNS TOO SLOWLY UNDER LOAD	Line voltage too low	Check and remove any excess resistance in line, connections, or control.
	Brushes ahead of neutral Overload	Set brushes on neutral. Check to see that load does not exceed allowable load on motor.
MOTOR RUNS TOO FAST UNDERLOAD	Weak field	Check for resistance in shunt-field circuits. Check for grounds.
	Line voltage Brushes back of neutral	Correct high-voltage condition. Set brushes on neutral.
SPARKING AT BRUSHES	Commutator in bad condition Eccentric or rough commutator	Clean and reset brushes. Grind and true commutator, also undercut mica.
	Excessive vibration	Balance armature. Check brushes to make sure they ride freely in holders.
	Broken or sluggish acting brushholder spring	Replace spring, and adjust pressure to manufacturer's recommendations.
	Brushes too short	Replace brushes.
	Machine overloaded Short circuit in armature	Reduce load, or install larger motor. Check commutator, and remove any metal particles between segments. Check for short between adjacent commutator risers. Test for internal shorts in armature and repair.
BRUSH CHATTER OR HISsing NOISE	Excessive clearance of brushholders	Adjust holders.
	Incorrect angle	Adjust to correct angle.
	Incorrect brushes for the service	Get manufacturer's recommendations.
	High mica Incorrect brush-spring pressure	Undercut mica. Adjust to correct value.
MOTOR WILL NOT COME UP TO SPEED	Excessive load	Decrease the load. Check operation of unloading device (if any) on driven machine.
	Low voltage Field excited	Increase voltage. Be sure field-applying contactor is open, and field-discharge contactor is closed through discharge resistance.
POOR COMMUNICATION	Insufficient brush-spring pressure	Adjust to correct pressure, making brushes ride free in holders.

**TABLE 5.13.1 (Continued)**

ONE BRUSH TAKES MORE LOAD THAN IT SHOULD	Unbalanced circuits in armature	Eliminate high resistance in defective joints by inserting armature or equalizer circuit or commutator risers. Check for poor contact between bus and bus rings.
EXCESSIVE SPARKING	Poor brush fit on commutator	Sand in brushes, and polish commutator surface.
	Brushes binding in the brushholder	Remove and clean holders and brushes with solvent (nontoxic). Remove any irregularities on surfaces of brushholders or rough spots on the brushes.
	Insufficient or excessive pressure on brushes	Check and set brush arm for correct pressure (varies with motor design)
	Brushes off neutral	Set brushes on neutral.
SPARKING AT LIGHT LOADS	Paint spray, chemical, oil or grease or other foreign material on commutator	Use motor designed for application. Clean commutator, and provide against foreign matter. Install an enclosed motor designed for the application.
FIELD COILS OVERHEAT	Short circuit between turns or layers.	Replace defective coil.
COMMUTATOR OVERHEATS	Brushes off neutral, or overload	Adjust brushes.
	Excessive spring pressure on brushes	Reduce load or increase motor size. Decrease brush-spring pressure but not to the point where sparking is introduced
GROOVING OF COMMUTATOR	Brushes not properly staggered	Stagger brushes.
BRUSHES WEAR RAPIDLY	Rough commutator	Resurface commutator and undercut mica.
	Excessive sparking	Make sure brushes are in line with communicating fields.
ARMATURE OVERHEATS	Motor overloaded	Reduce load to correspond to allowable load.
	Motor installed in location where ventilating is restricted	Arrange for free circulation of air around motor.
	Armature winding shorted	Check commutator, and remove any metallic particles between segments. Test for internal shorts in armature and repair.



**FIGURE 5.13.10**  
**DIAGRAM OF MOMENTARY & MAINTAINED CONTACT**  
**MOTOR CONTROL DEVICES**

- Bimetallic. A resistance wire heater is connected in series with each lead to the motor. As the load current increases, the heat generated in the wire increases. The increased heat causes a metal strip composed of two dissimilar metals (bimetallic) to deflect. When the metal strip or element deflects sufficiently, it acts to open a switch (relay), which is wired in series with the motor or the motor starter coil.

- Solder-Ratchet. This type has a cylinder containing an alloy that melts when excessive current flows in a wire wrapped around the cylinder. The wire is in series with the motor. When the alloy (solder) melts, it releases a shaft that opens a switch (relay) wired into the motor circuit or the motor starter coil circuit.

- Magnetic. This type employs a magnetic element similar to a circuit breaker, which has adjustable, instantaneous trip settings or adjustable time-delay settings. Magnetic relays are often used to protect larger motors.

Magnetic motor starters also offer low voltage protection due to the nature of their construction. When voltage drops below the rating of the starter coil, it no longer holds the contacts of the starter closed, and the motor circuit is broken. If the starter has three-wire, or "momentary contact" control, it cannot be re-energized except by someone actuating the "start" pushbutton. If, on the other hand, the control circuit is two-wire or "maintained contact," it will automatically re-start when the voltage level is restored because the control device remains closed.

#### 5.13.7.2 Maintenance and Inspection of Control Equipment and Devices.

- Protection From Damage. Dirt is a principal cause of electrical motor control failure. Accumulations of normal atmospheric dust particles, lint, chemicals, metallic particles, and oil mists or vapors will cause insulation failures, overheating, arcing, and sluggishness of moving parts due to friction. Every maintenance schedule should include a thorough, systematic cleaning of motor control apparatus. Standard practice should include removal of dirt by means of vacuum or by blowing with compressed air. The use of non-metallic vacuuming equipment is preferable to a compressed air system because excessive pressure from compressed air may embed sharp dirt particles in insulating materials. Oil must be removed with cloth and suitable solvents.

Humidity and moisture can cause metal parts to oxidize and change contact surface resistance. Moisture and dirt can cause insulating materials to break down and can form a current path to ground, resulting in a short circuit, equipment damage, and personnel injury. In large controllers

which are not in frequent use, electric heating strips should be installed to evaporate any moisture that may collect. This is preferable to the use of drain hoses, which can easily become clogged.

Control devices operate at high speeds and with some mechanical shock. Vibration or unwanted movement of parts due to loose mounts or connections will cause other parts to become loosened. Routine inspection and tightening of all bolted parts will prevent hours of unnecessary repair work.

Electrical controls, when operating normally, do so with a minimum of resistance. Tight or hard moving parts generally indicate misalignment or corrosion of a moving part. Frequently operated equipment will not develop resistance except through misalignment or excessive wear. These conditions should be corrected by replacing the offending part, not by lubricating the part as lubricants collect dust, abrasives, and metallic particles that cause additional wear and can break down insulations. Infrequently operated equipment can develop rust or oxide deposits on moving parts. Good practice dictates that all electrical equipment be periodically operated and checked to avoid such conditions and ensure that the equipment will work when needed.

- Contact Surface Maintenance. Contacts in motor control devices may require considerable maintenance, depending on the frequency of their operation. Every time contacts open or close, they are subjected to both mechanical wear and electrical burning. Contact material gradually disappears; because of this, contact pressure decreases, which increases resistance and causes overheating. Some adjustment is possible, but eventual replacement is necessary. Contact pressure can also be reduced by overheated or damaged contact springs. For proper operation of both the motor control equipment and the motor, contacts and springs should be inspected periodically and replaced when wear appears.

Contacts should always be replaced in pairs to ensure proper life of the replaced parts.

Contact surfaces should be kept clean. Copper surface contacts form an oxide, which is a poor conductor. While frequent operation usually keeps the surface clean enough, infrequently operated equipment should be periodically cleaned with a fine file or sandpaper. Do not use emery cloth as it is an electrical conductor. Silver contacts are generally self-cleaning and need not be filed or sanded unless they are very rough or deeply pitted. It is not necessary or even desirable to have entirely smooth surfaces. Surfaces with a roughness comparable to a medium sandpaper are considered to be in good condition.

- Terminal and Connector Tightness. Vibration and expansion or contraction due to temperature changes can loosen terminal connections. Loose connections can cause equipment and conductor overheating and damage. Whenever a controller is opened for inspection or service, all terminals should be checked for tightness.

- Electro-Magnetic Coil Inspection. The force required to open or close a relay, contactor, or motor starter solenoid is provided electro-magnetically by the operating coil. These coils are generally designed to operate when the voltage applied to them reaches 85 percent of the rated voltage. Coils are expected to withstand 110 percent of rated voltage without damage. Coil operating voltages should be periodically tested at the coil terminals; over-voltages increase operating temperature, shorten coil life, and cause mechanical damage while under-voltage causes sluggishness and inability to close properly against the contact springs. In any case, checking coil voltage against coil rating can prevent equipment damage and needless shutdowns.

The current drawn by an AC coil is much greater at the "open gap" state than at the "closed gap" state of the magnetic solenoid circuit. The coil can withstand the momentary high current during a normal operating cycle. However, when the air gap is artificially maintained by purposely holding the solenoid open or by accidental mechanical blockage, the coil current can become excessive and damaging. Corrosion or even large dirt particles in the solenoid air gap can cause elevated currents in the coil. If voltage is too low to close the solenoid, it will also cause excessive current to flow.

An AC, electromagnetic coil should be reasonably quiet; if it chatters, either the pole faces are not seating properly, or the coil voltage is too low.

- Thermal Relay Application. Thermal relays protect motors and their controllers from overload and momentary surges. They do not protect against short circuits. They are usually operated by a heating device or heater; that is, when a current that exceeds the rated current passes through the circuit, the heater will act to trip the thermal relay. These heaters are sometimes adjustable through a narrow range but are usually made with different current ratings. When possible, motor starters with thermally operated overload relays should be located near the motor to be protected so that the ambient temperature of both are nearly equal. If the ambient temperatures are different, some compensation must be made.



Heaters should always be comparable to the full load nameplate ampere rating of the motor to be protected. In general, the heater rating should be 120 percent of the nameplate rating.

- Maintenance of Control Devices. Control devices, such as pushbuttons, flow switches, pressure switches, float switches, limit switches, and pilot lights should be frequently checked by operation of the devices. Periodic internal inspection, cleaning, and terminal tightening should be included in all maintenance schedules. Particular attention should be given to the condition of wiring within the devices since a short or ground on these control wires can result in an unwanted motor operation, which might cause injury or property loss. All pilot lights, visual operating devices, targets, glow lights, and ground detectors should be maintained in operating condition. Pilot lights and wiring to indicating devices should always be checked before assuming that trouble has occurred in equipment.

Pressure switches, temperature switches (thermostats), and temperature transmitters should be calibrated periodically against pressure gauges and thermometers.

Where possible, flow switches should be calibrated against flow meters.

Float switches and level transmitters and receivers should be calibrated periodically against a manual gauging of the tank or vessel in which they are installed.

5.13.8 Grounding and Bonding. Proper control of unwanted or stray electrical charges is important for petroleum facilities. Lightning and static charges are a potential ignition source for fuel vapors. Stray currents contribute to corrosion of many metals and affect more than just electrical components. The control of unwanted electrical charges will reduce maintenance workload.

The following are publications and their sources that provide additional information on materials, methods, and standards regarding the correct inspection and maintenance of grounding, bonding, and static electricity suppression systems:

- ANSI Standard 142, "Recommended Practice for Grounding Industrial and Commercial Power Systems"

- ANSI - C2, "National Electrical Safety Code"

- API RP 2003, "Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents"

- API RP 540, "Recommended Practice for Electrical Installations in Petroleum Processing Plants"

- API Bulletin 1003, "Precautions Against Ignition During Loading of Tank Truck Motor Vehicles"

- NFPA Standard 70, "National Electric Code"

- NFPA Standard 77, "Static Electricity"

- NFPA Standard 78, "Lightning Protection Code"

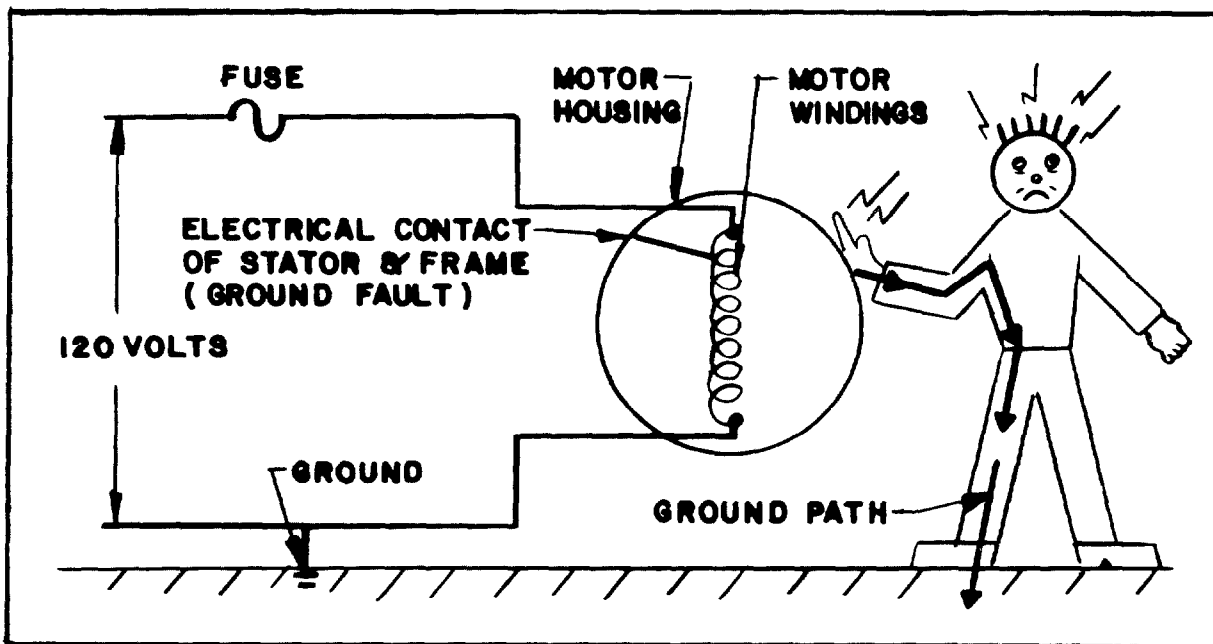
- NAVFAC MO-307, "Corrosion Control."

5.13.8.1 Grounding and Bonding of Electrical Power Systems and Equipment. In addition to providing the means of completing an electrical circuit, grounds are necessary to suppress the dangerous levels of random electrical energy that present a constant hazard at fuel facilities. A primary objective of grounding is to ensure that all connected equipments and conductors are at the same electrical potential as the earth, i.e., ground.

Electric power systems and equipment are grounded by connecting metallic parts (e.g., conduits, motor frames, equipment enclosures) to earth through a low resistance conductive path. The electro-mechanical connection of the metallic parts of a grounding system is known as "bonding."

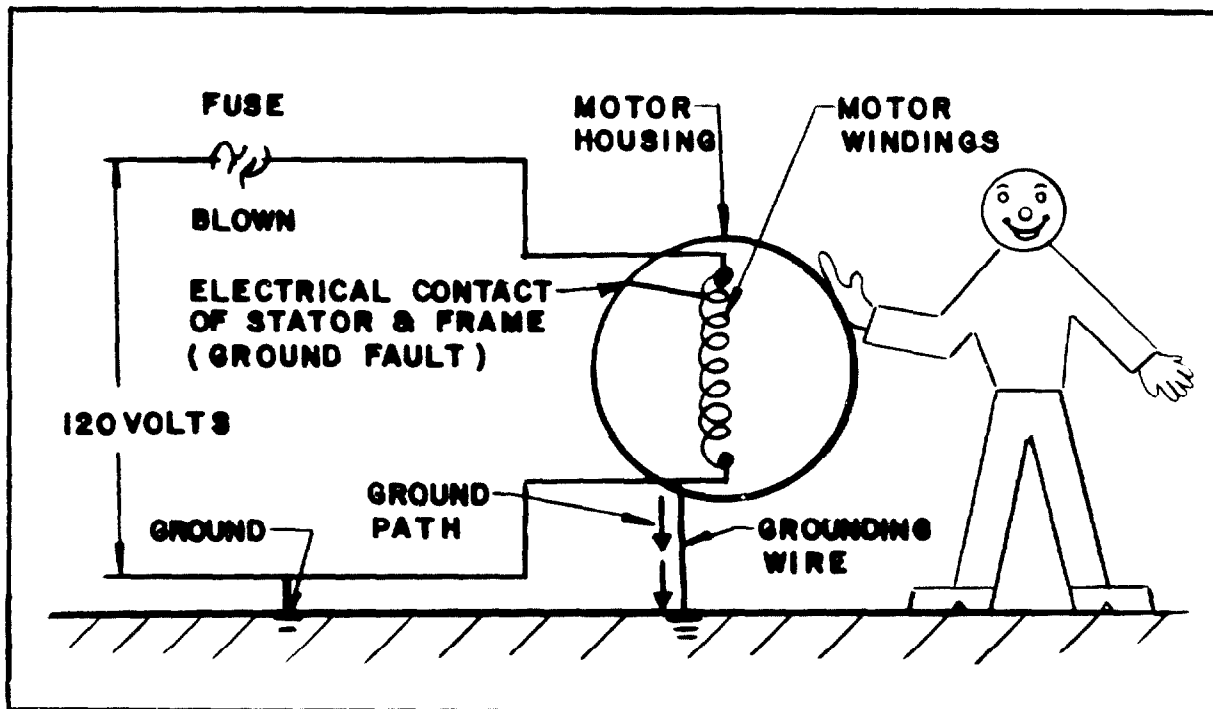
The objective of bonding is to create a very low resistance electrical connection of components that does not exceed the measured resistive limit of the grounding system. A reliable mechanical connection is also required in order to avoid increased resistance or loss of the ground connection due to vibration, heat-cool cycles, or physical impacts. The actual bonding of the grounding system to the earth is accomplished by making the appropriate connection to an available grounded structure, i.e., a buried water service pipe. When these are unavailable, a suitable ground rod must be driven into the ground at a depth sufficient to contact moist soil and achieve the required conductivity.

Equipment grounding protects personnel from electrical shock in the event of a system fault. Figure 5.13.11 shows a motor that has developed such a fault; in this case, an insulation ground fault. Because the motor frame is not grounded, the protective device (fuse or circuit breaker) feeding this motor will be unable to detect this unsafe condition. An individual touching this frame may present a lower resistance path to ground and receive a 120 volt shock. Shocks of as little as 120 volts can be fatal.



**FIGURE 5.13.11**

**UNGROUNDING MOTOR HOUSING**



**FIGURE 5.13.12**

**GROUNDING MOTOR HOUSING**

In Figure 5.13.12, the identical conditions occur as in Figure 5.13.11, except that the motor frame is grounded. With a grounded motor, the protective device will detect the unsafe condition and disconnect the circuit. Obviously, the higher the equipment operating voltage, the more serious the electrical shock hazard. All electrical codes and standards of good practice require that exposed metal parts of electrical equipment be properly grounded.

**5.13.8.2 Grounding of Fuel Handling Equipment.** Static electric charges and electric currents from lightning can cause stray currents to flow in tanks, tank trucks, pipelines, hose nozzles, and other fuel handling equipment. Such equipment must be properly bonded throughout each system and properly grounded in order to prevent such stray currents and charges from producing arcs (sparking) and causing serious explosion hazards.

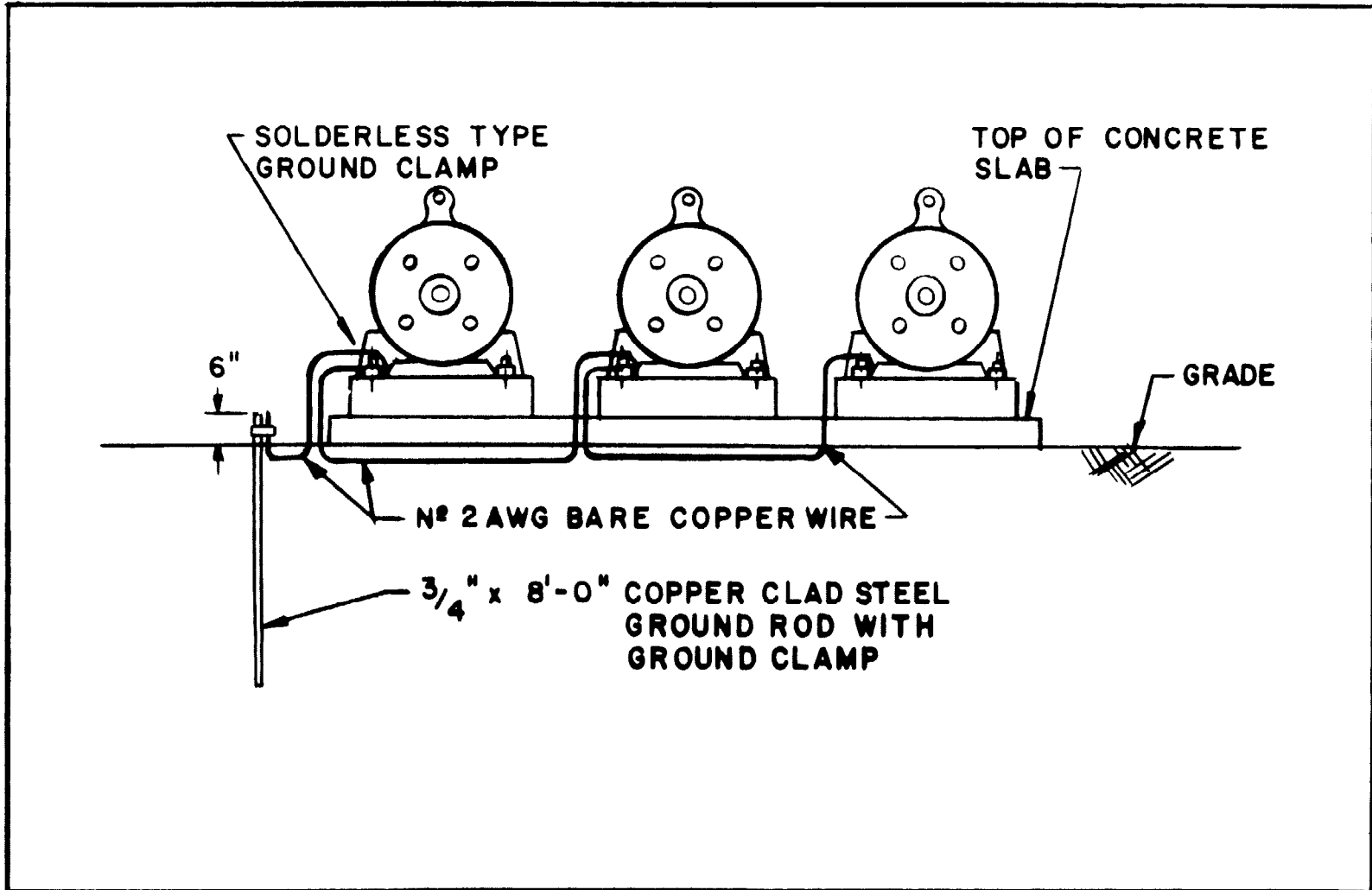
When jet fuel or other distillates are pumped at a high flow rate from a nozzle into a tank that is insulated from the ground, a static charge will be produced in the tank. If the nozzle is grounded and happens to be brought near the tank after the latter has become charged, there will be a discharge from the tank to the nozzle, causing a spark. If a proper mixture of air and vapor exists, an explosion is very likely to result. The most effective remedy is to make sure that the receiving tank and the nozzle are effectively bonded.

Static charges accumulate on automotive vehicles when they are in motion, particularly at high speed in dry weather. Potentials up to 25,000 volts have been measured between a gasoline-truck body and ground. It is for this reason that tank trucks and tank cars should always be grounded and bonded to fill stands before any fuel is handled. Many installations have ground detecting relays, which must detect that the equipment is properly grounded and bonded before they will allow pumps to start or solenoid valves to open. The simplest installations are quite often furnished with a cable connected to a ground rod, which can be easily clamped to the truck or tank car being filled.

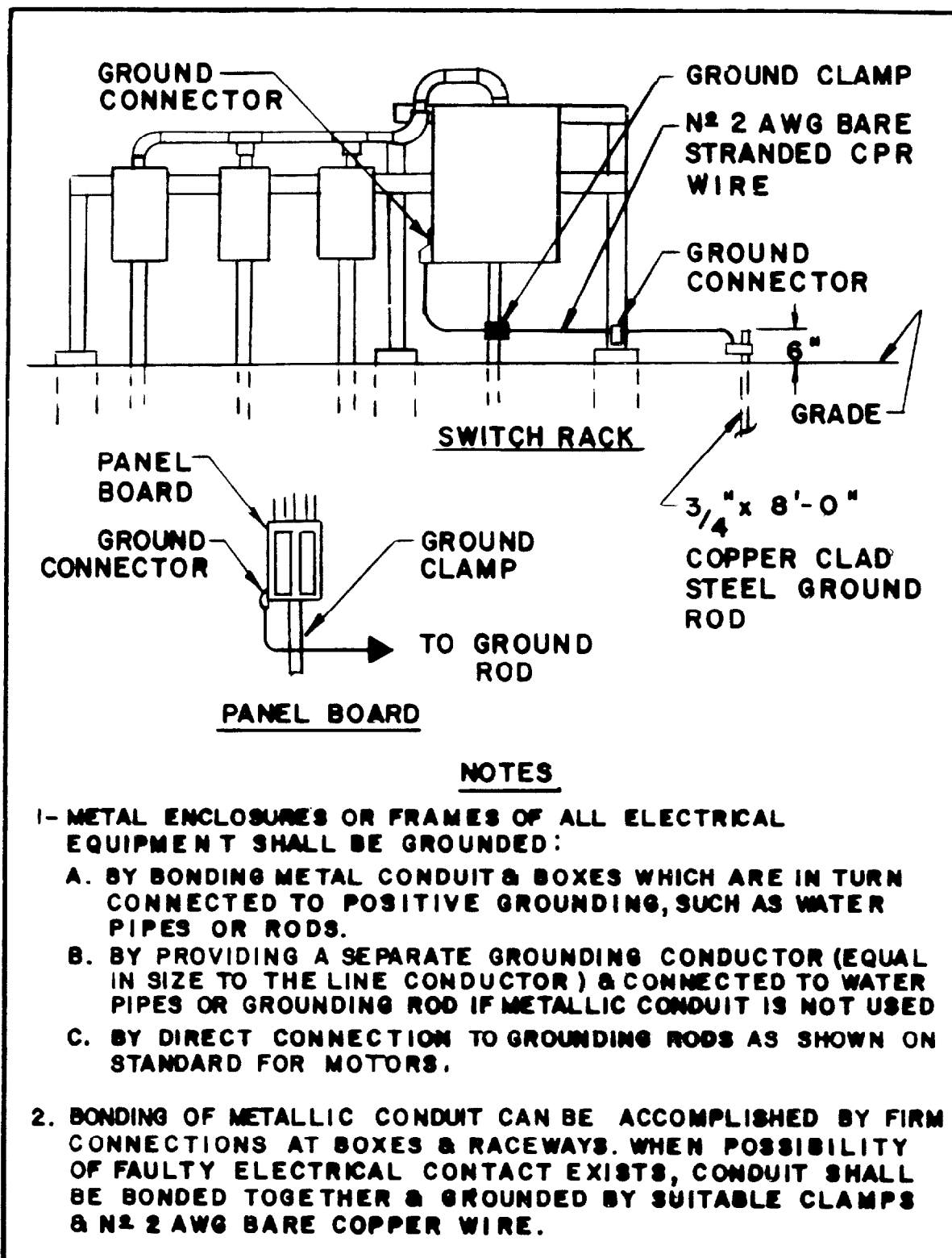
Figures 5.13.13 through 5.13.21 show typical applications of grounding and bonding of petroleum handling equipment and should be studied thoroughly for similarities at any given facility. Additionally, Section 1.3 provides further information concerning static electricity.

**5.13.8.3 Preventive Maintenance of Grounding Systems.** Primarily, the maintenance of grounding systems and bondings is a function of regular and diligent inspection. Additionally, resistance measurements of the grounding circuits should be taken and recorded at every inspection interval. This is necessary because a ground conductor, connection, or circuit may appear to be in perfect condition; however, internal

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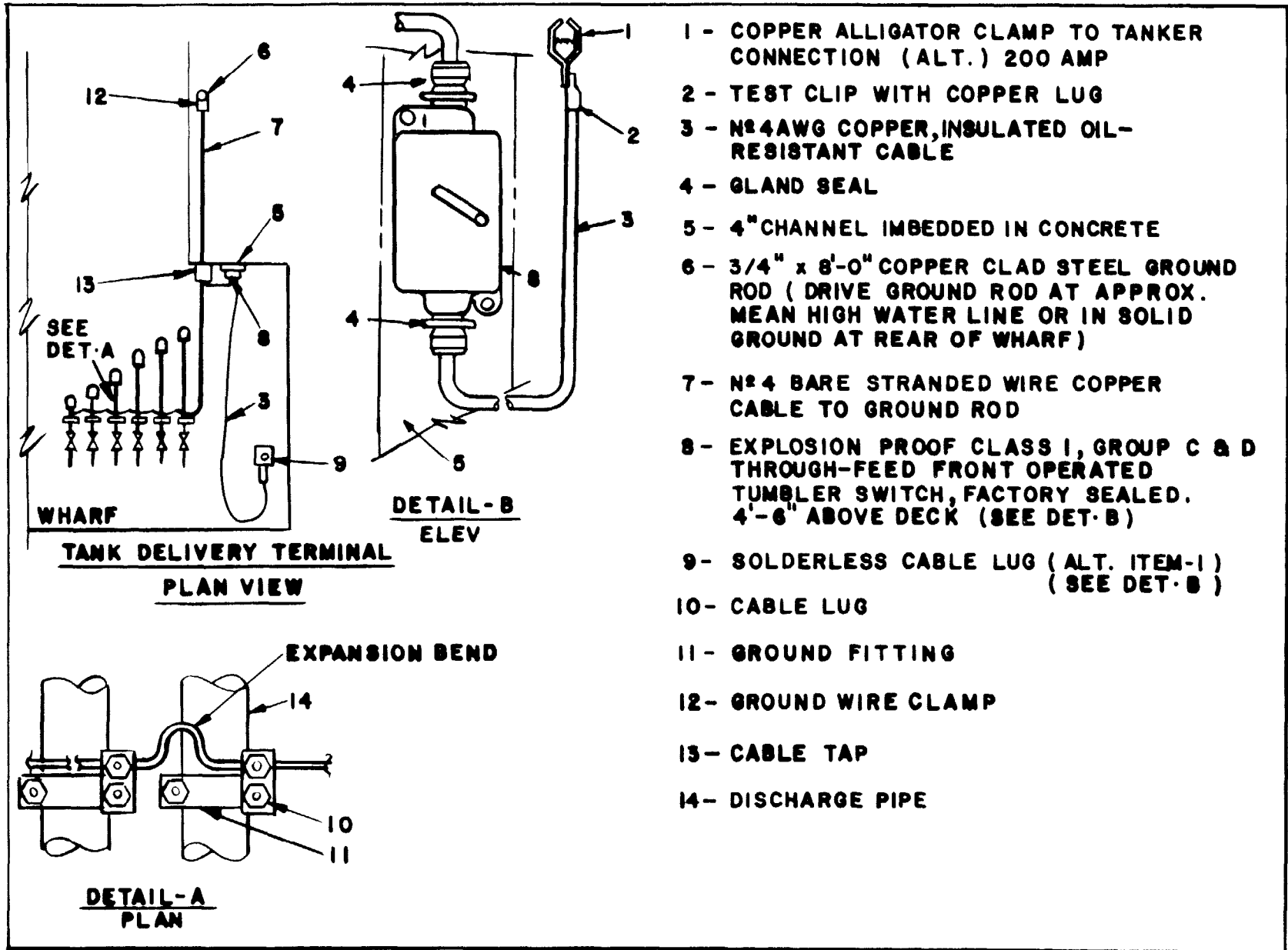


**FIGURE 5.13.13**  
**GROUNDING & BONDING ELECTRICAL MOTORS**



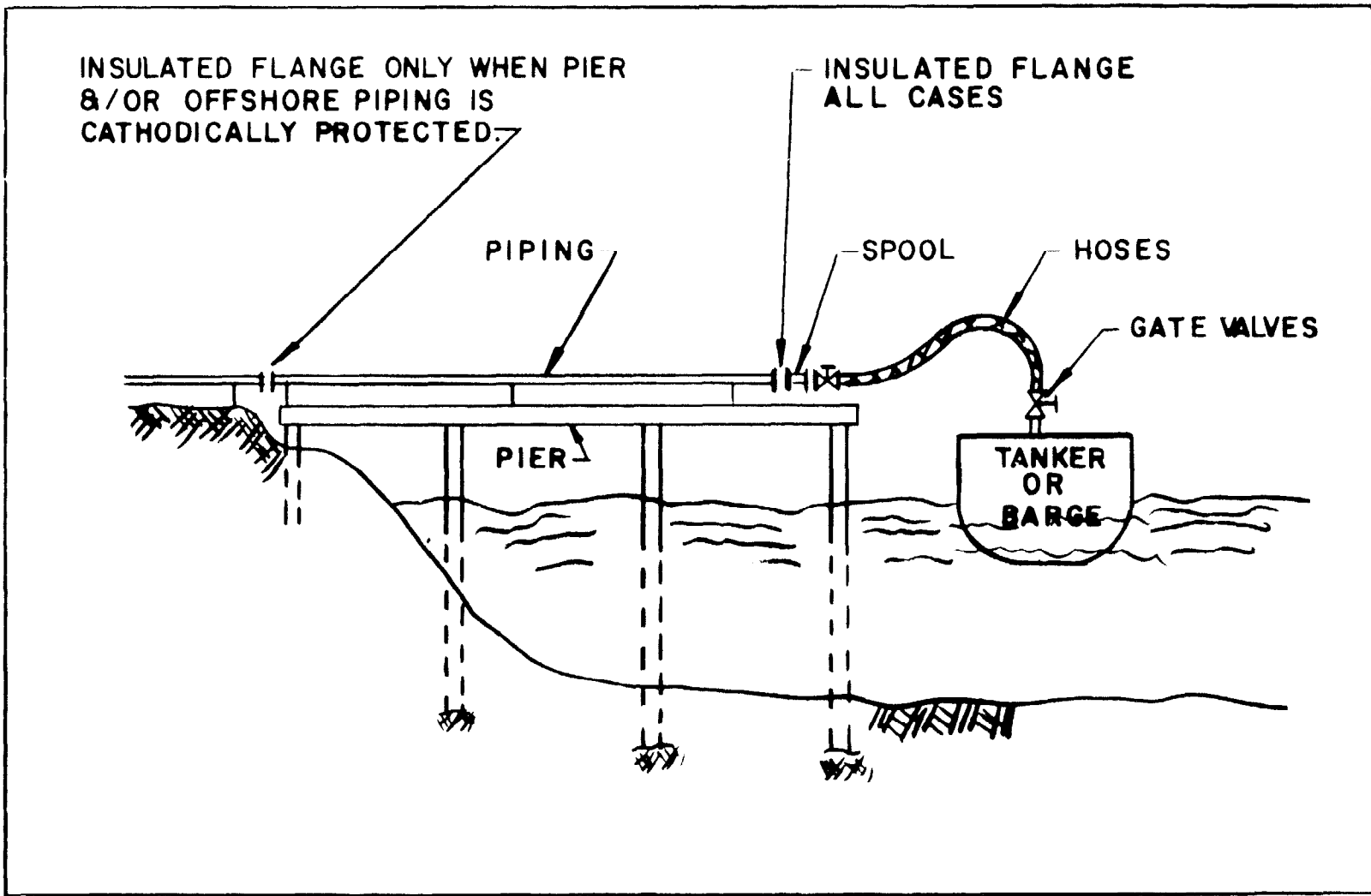
**FIGURE 5.13.14**  
**GROUNING & BONDING SWITCH RACKS & PANEL BOARDS**

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**FIGURE 5.13.15**

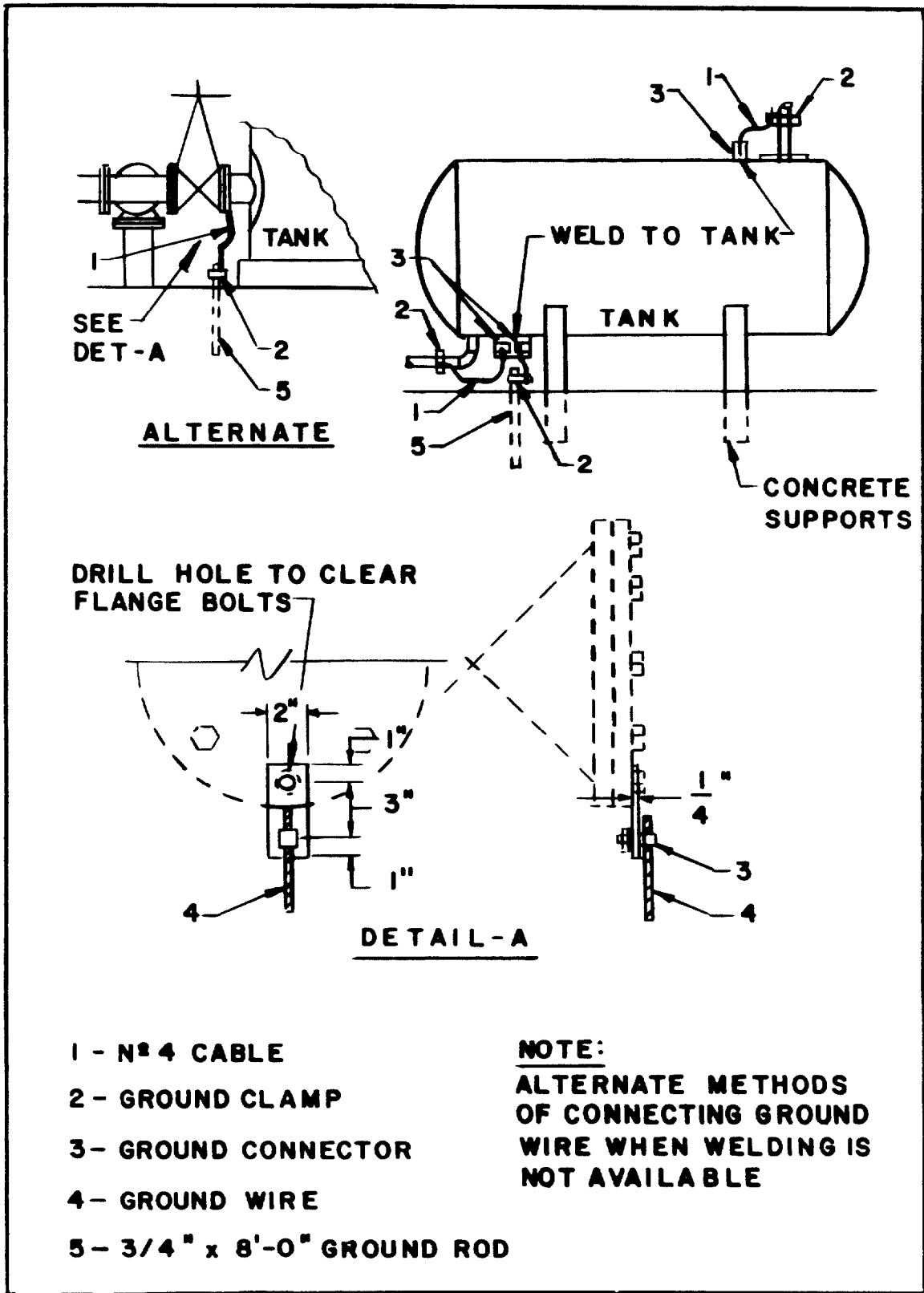
**GROUNDING & BONDING TANKERS & BARGES**



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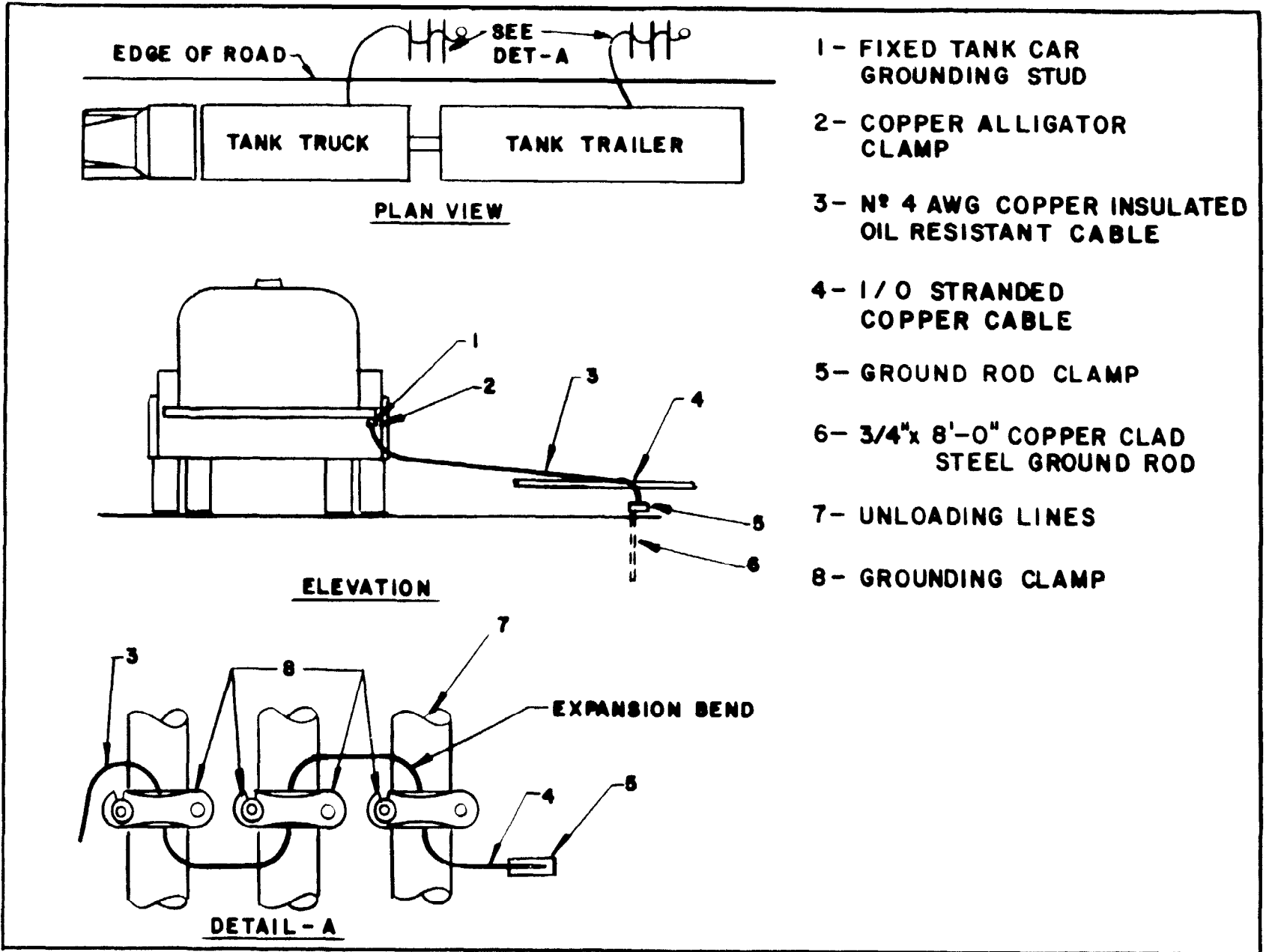
**FIGURE 5.13.16**  
**GROUNDING AND BONDING TANKERS AND BARGES**





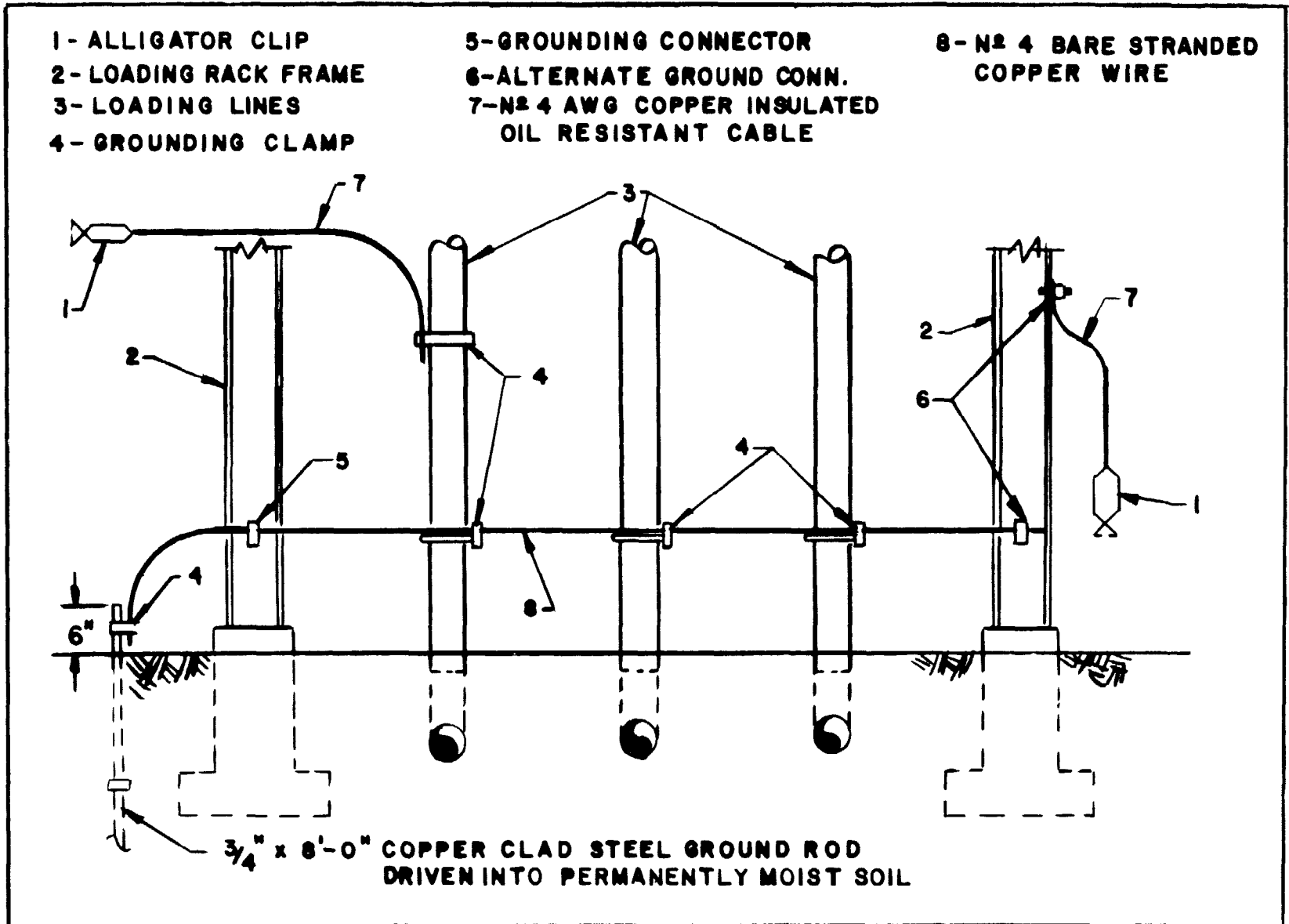
**FIGURE 5.13.17**  
**GROUNDING ABOVE-GROUND STORAGE TANKS**

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**FIGURE 5.13.18**

**GROUNDING & BONDING TANK TRUCK UNLOADING FACILITIES**

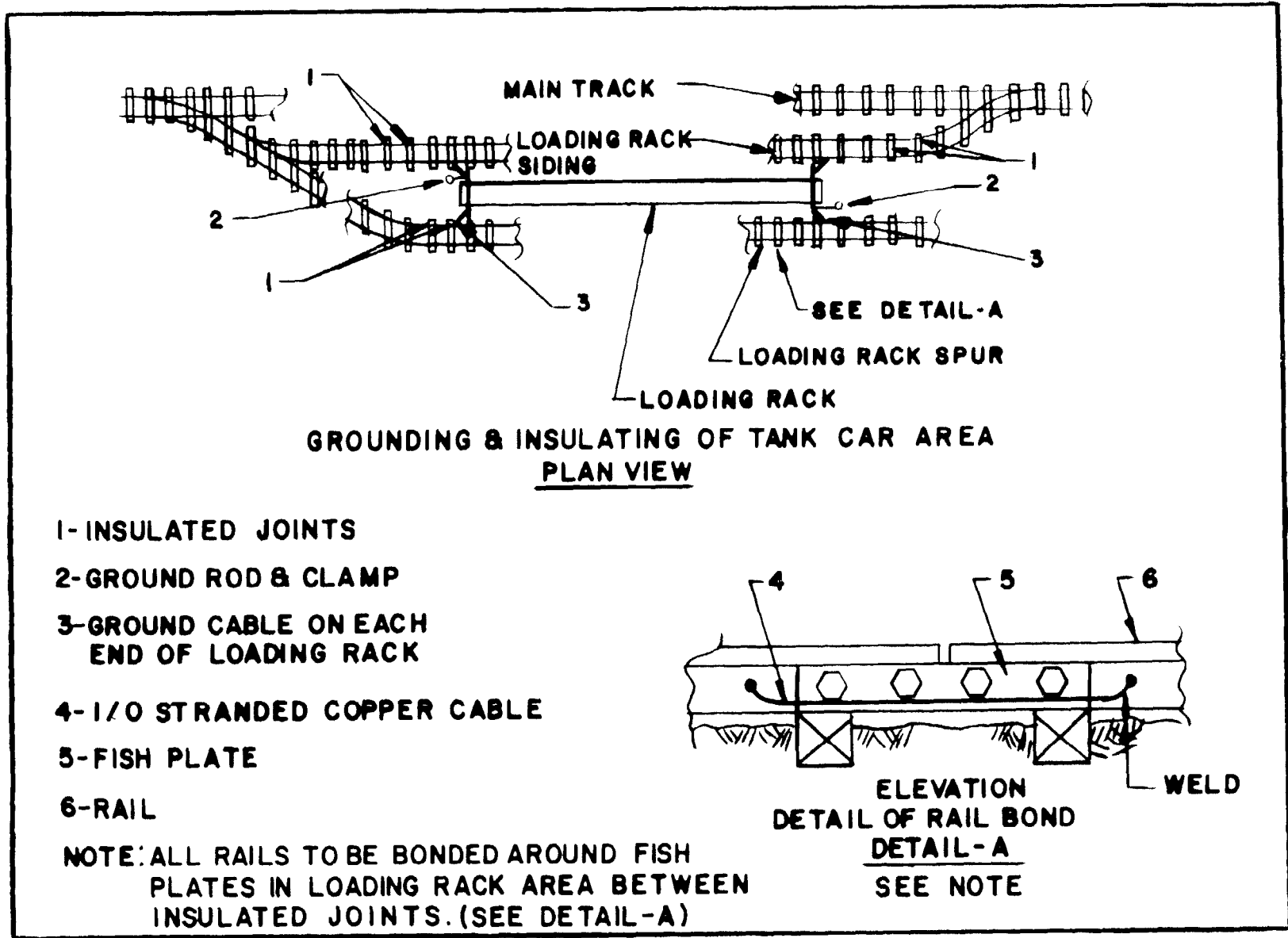


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FIGURE 5.13.19

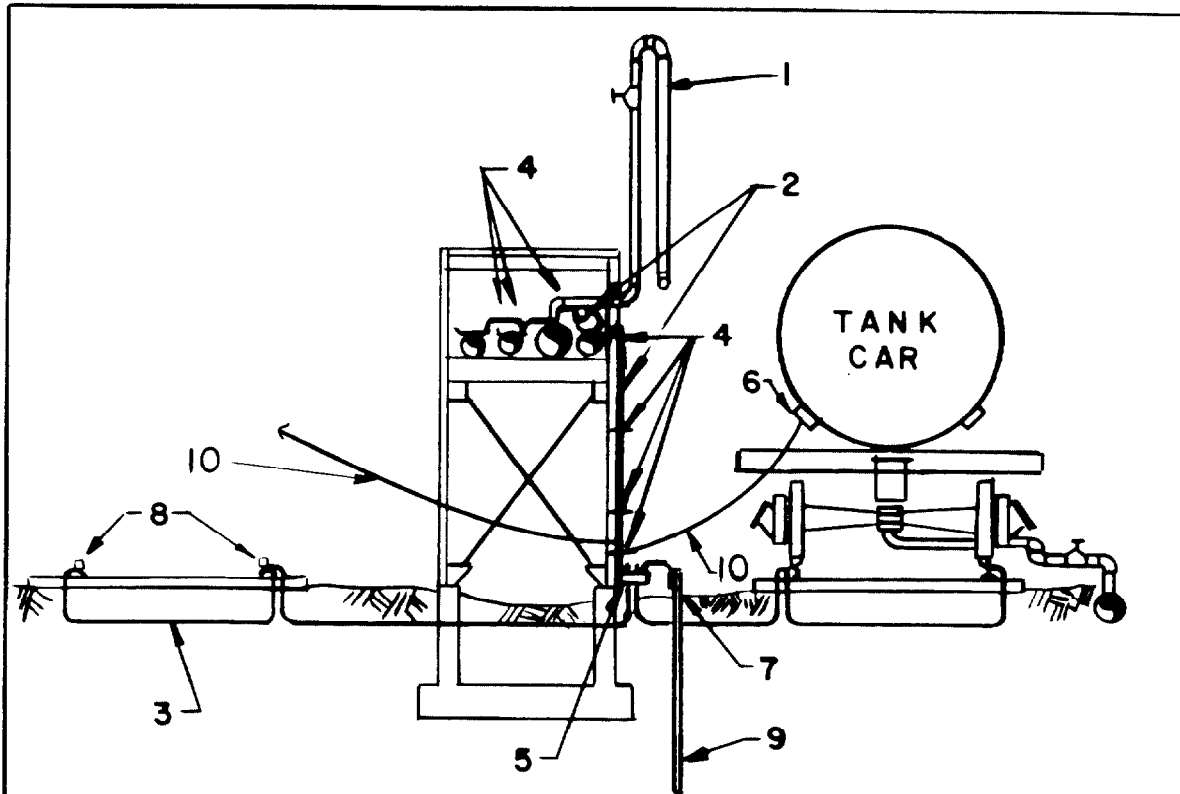
GROUNDING AND BONDING TANK TRUCK LOADING RACKS

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**FIGURE 5.13.20**

**GROUNDING & BONDING TANK CAR LOADING & UNLOADING FACILITIES AT BULK TERMINALS**



- 1 - LOADING ARM
- 2 - 1/0 STRANDED COPPER CABLE (CONTINUOUS)
- 3 - 1/0 STRANDED COPPER CABLE
- 4 - GROUNDING CLAMP
- 5 - GROUND CONNECTOR
- 6 - COPPER ALLIGATOR CLAMP
- 7 - GROUND ROD CLAMP
- 8 - RAIL CONNECTION
- 9 - 3/4" x 8'-0" COPPER CLAD STEEL GROUND ROD
- 10 - N# 4 AWG COPPER INSULATED OIL RESISTANT CABLE

**FIGURE 5.13.21**  
**GROUNDING & BONDING TANK CAR LOADING & UNLOADING**  
**FACILITIES AT BULK TERMINALS**

corrosion, oxidation of contacting surfaces, insulation breakdown, or other hidden defects might have seriously degraded conductivity. Regular checks of circuit resistance can uncover circuit degradation before a hazardous condition develops.

Connections to ground should be periodically tested with an ohmmeter, using as a reference a 5/8 inch copper weld rod driven in the earth to contact damp soil. The resistance between the reference and the connection being tested should not exceed 25 ohms for grounds for electrical systems, equipment, and apparatus; and 10,000 ohms for static grounds from petroleum handling equipment. Be certain to use the correct test equipment and methods according to the environmental hazards that may be encountered and the appropriate equipment technical manuals, code specifications, or technical directives.

Be sure to apply adequate corrosion protection to connections, as required, since lack of corrosion protection is frequently the cause of ground circuit degradation. Adequate corrosion control may consist of various shielding, wrapping, taping, coating, or material selection methods to protect the ground integrity of conductors and bonds against degradation from petroleum products, acids, alkalies, salts, ultraviolet light, soil organisms, rodents, physical impacts, vaporous chemicals, oxidation, or weather. Use these materials in accordance with MO-306, instructions provided by the materials manufacturers, the equipment technical manual, the code specification, or the technical directive. Any required repair beyond the capability of operators or maintenance personnel should be reported to cognizant authority.

## 5.14 FIRE PROTECTION

5.14.1 Scope. This section provides maintenance information and instructions for fire protection systems and describes fire fighting systems that are normally found at a fuel facility. It is not intended to cover specialized apparatus such as fire boats or similar specialized equipment that would be associated with a fire department or to provide detailed fire fighting theory and practice.

At installations large enough to have their own fire departments, much of the testing and inspection that comprises fire protection system maintenance may be done by fire department personnel rather than fuel facility personnel. In any case, when possible, testing and inspection of fire fighting systems should be carried out under the supervision of an experienced fire fighter. Fuel facility personnel should still ensure that all fire protection systems have adequate maintenance coverage and that splitting of responsibilities

between fire department and fuel facility personnel does not allow items to escape maintenance.

Many factors contribute to the prevention of fires. Some, such as design practice, are beyond the scope of this manual. However, knowledge of the elements of combustion and sources of these elements provide a large measure of fire safety as does maintenance and readiness of fire suppression systems. References detailing design and operation information for fire protection systems in relation to petroleum facilities can be found in NAVSUP P-558, "Fuel Management Ashore," and NAVFAC DM-8, "Fire Protection Engineering." Specific maintenance actions for fire protection systems are covered in NAVFAC MO-117, "Maintenance of Fire Protection Systems and in NFPA 10, "Portable Extinguishers."

#### 5.14.2 Water-Based Fire Fighting Systems Maintenance.

5.14.2.1 Water Supply System. Assurance of an adequate supply of water should be one of the primary objectives of fire system maintenance. Some suggestions to include in an effective maintenance program are:

- If the primary supply is from a public or private main, run an annual flow test to establish the available flow and pressure at your connection.
- For other sources of supply such as ponds, bays, or rivers, inspect the intakes for obstructions, cleanliness of intake screens and strainers, and operation of valves and gates. Start and prime the pumps and observe and record pressure at full flow.
- Where water supply comes from standpipe or tanks, test and record water levels once each week. Continual changes in levels indicate leaks or backflow.
- Protect all exposed piping and storage tanks from freezing. Where this is not possible, ensure that the water is continually circulated or that the lines are drained.
- Debris and sediment may accumulate in the piping systems and cause dangerous restriction in volume, decreased pressure, and clogged nozzles during use. Semi-annual flushing of all hydrants is highly recommended.
- If installed drain lines permit, water in idle systems such as piping, pump casings, tanks, or similar components should be sampled for contamination.

5.14.2.2 Fog Systems. Nozzles are exposed to the weather and require monthly inspection and maintenance. Look for corrosion and debris clogging or deflection of the spray pattern, and apply a light coat of silicone grease to the

nozzle. Some heads are threaded onto a standing pipe or portable extension and contain an internal strainer accessible once the head is removed. Perform similar preservation and inspection for blockage or debris and ensure that the head is securely tightened. Fog systems should be set off annually. In some locations, such as a warehouse or office, this cannot be done because the release of water from a sprinkler system would cause a great deal of damage. Short of full-scale operation, there are usually test connections or bypasses so the control elements can be tested without setting off the main system. Observe the spray pattern and, where installed, adjust the pattern with the screw centered axially in the fog head. Ensure lines supplying the fog heads are drained or protected prior to the arrival of cold weather.

5.14.2.3 Drainage Systems. Around tank farms or other structures where large amounts of fire fighting water may be used, inspect installed drainage monthly to ensure accumulated, water-floating, flammable liquids are not dammed by debris, leaves, sand, or building materials blocking drain access.

5.14.2.4 Pumps. Most fire pumps are centrifugal pumps that operate on the same principles and with the same maintenance procedures as those described in Section 5.6. They may be driven by electric motors, internal combustion engines, or steam turbines. Maintenance recommendations for electric motors are covered in Section 5.12. Pump maintenance procedures are basically the same as described for petroleum pumps in Section 5.5. As the following list outlines, fire pumps require special consideration at some installation where they are only operated intermittently.

- Pumps should be turned over by hand daily and test operated weekly. During testing, use available discharges to allow the pumps to be operated at or near rated capacity for 15 minutes.

- Operate engine- or turbine-driven pumps until normal operating temperatures are reached.

- Verify the condition of the oil sump level, strainers, fuel tanks, storage batteries, and associated equipment prior to and after operation.

- During operation, monitor and record discharge pressure, estimated flow rate, relief valve operation, and oil, fuel, and coolant gauge readings. Check for leaks.

- Ensure any remote or automatic start devices are operable.



- Ensure all valves are cycled and reset for normal operations prior to completion of the check.
- During cold weather, protect pumps from freezing or continually circulate water.
- Ensure pump rooms are clean and free from loose material.

5.14.2.5 Hydrants and Valves. Hydrants provide ready access to large volumes of fire fighting water despite various environmental and locational constraints. Figure 5.14.1 illustrates a hydrant designed for cold climates. Recommended maintenance and inspection procedures are listed below.

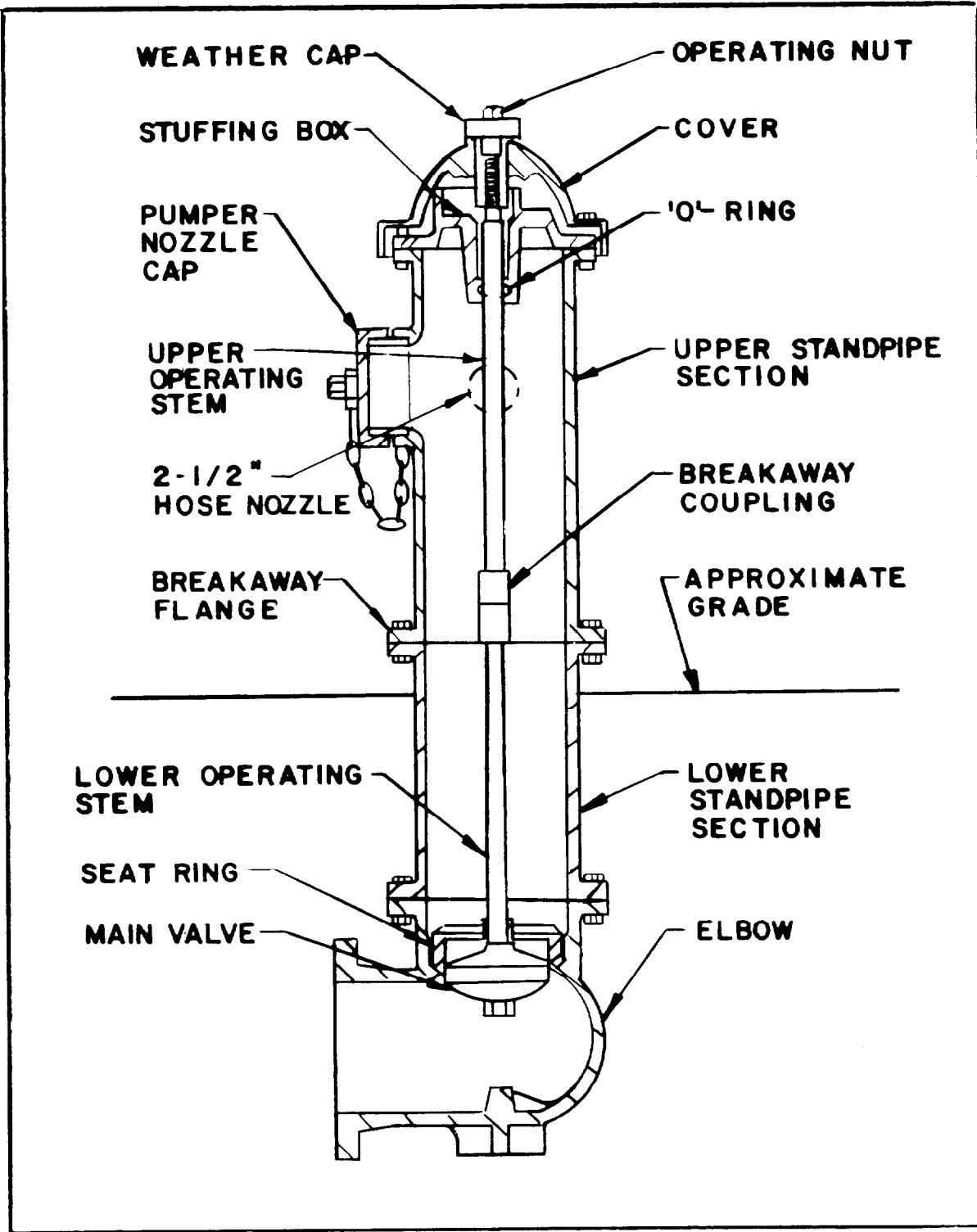
- Perform a monthly general inspection to ensure that the hydrant is well preserved, has not been tampered with or damaged, and is unobstructed. If vehicle damage is suspected, install guard posts.

- Remove nozzle caps to check the condition of threads and couplings. Clean and lubricate with silicone grease as necessary.

- Open the valve twice each year to flush the firemain. Firemain valves should receive periodic inspections to ensure proper operation and correct valve position indicator response. All valves should be cycled each month with caution taken to ensure that no system is activated or fire fighting agent is accidentally applied. Further guidelines on valve maintenance and troubleshooting are contained in Section 5.7.

5.14.2.6 Corrosion Protection. Most underground firemains are cast iron pipe, which has reasonably good corrosion resistance in ordinary soils and in fresh water service. Mains in salt water fire service, and those exposed to aggressively corrosive soils or to a marine environment such as under or on a pier, may be subject to corrosion damage. Protection can be achieved by coating and cathodic protection as described in MO-306 and MO-307. The interior of steel storage tanks or standpipes used for fire water service are also subject to corrosion damage, which can be controlled by interior coatings and cathodic protection. Under certain conditions, extinguishing agents can increase corrosion problems, especially some foam agents and dry chemicals.

5.14.2.7 Fire Hose. Fire hose is usually constructed with an outer jacket of woven fabric protecting an inner lining of rubber. Most hoses fail because of natural deterioration during storage caused by mildew, ozone (exposure to the sun), weathering, and excess heat. A hose in actual use is also subject to mechanical damage during handling, exposure to oils and chemicals, and fire damage. An effective program for the maintenance of fire hose should include the following items:



**FIGURE 5.14.1**  
**FROST-PROOF FIRE HYDRANT**

- Hose should be stored in a covered, weather-tight hose shed, adequately supported to prevent physical distortion during storage. The hose shed should have louvers and ventilators to allow free circulation of air.

- Hose should be thoroughly cleaned and dried before being stored.

- Hose jackets made of natural fibers can be treated against mildew. Hose jackets made of synthetic fibers such as nylon are not subject to mildew damage.

- Hose should be removed from storage once each quarter and restored in a different position to avoid permanent distortion of the jacket or lining.

- Hose should be hydrostatically tested annually at 200 psi, held for not less than 5 minutes. During the test, examine threads and couplings for signs of damage or movement. Stencil the hose with the test date and pressure.

- Hose sheds should be maintained in sound, weather-tight condition. Wooden and metal sheds should be kept painted to avoid weathering, rot, or corrosion damage. All hose sheds should be clearly marked to identify their purpose and contents. Maintain hinges and latches on doors in good operating condition. Keep ventilators and louvers open and free from obstruction. Inspect monthly to ensure that all nozzles, tools, wrenches, spanners, adapters, etc. are in place.

#### 5.14.3 Foam Systems.

5.14.3.1 Chemical Foam. Maintenance of chemical foam system valves, piping, and equipment such as those described in Figure 5.14.2 should follow that for similar components discussed earlier in this chapter. The foam agent should be inspected as follows:

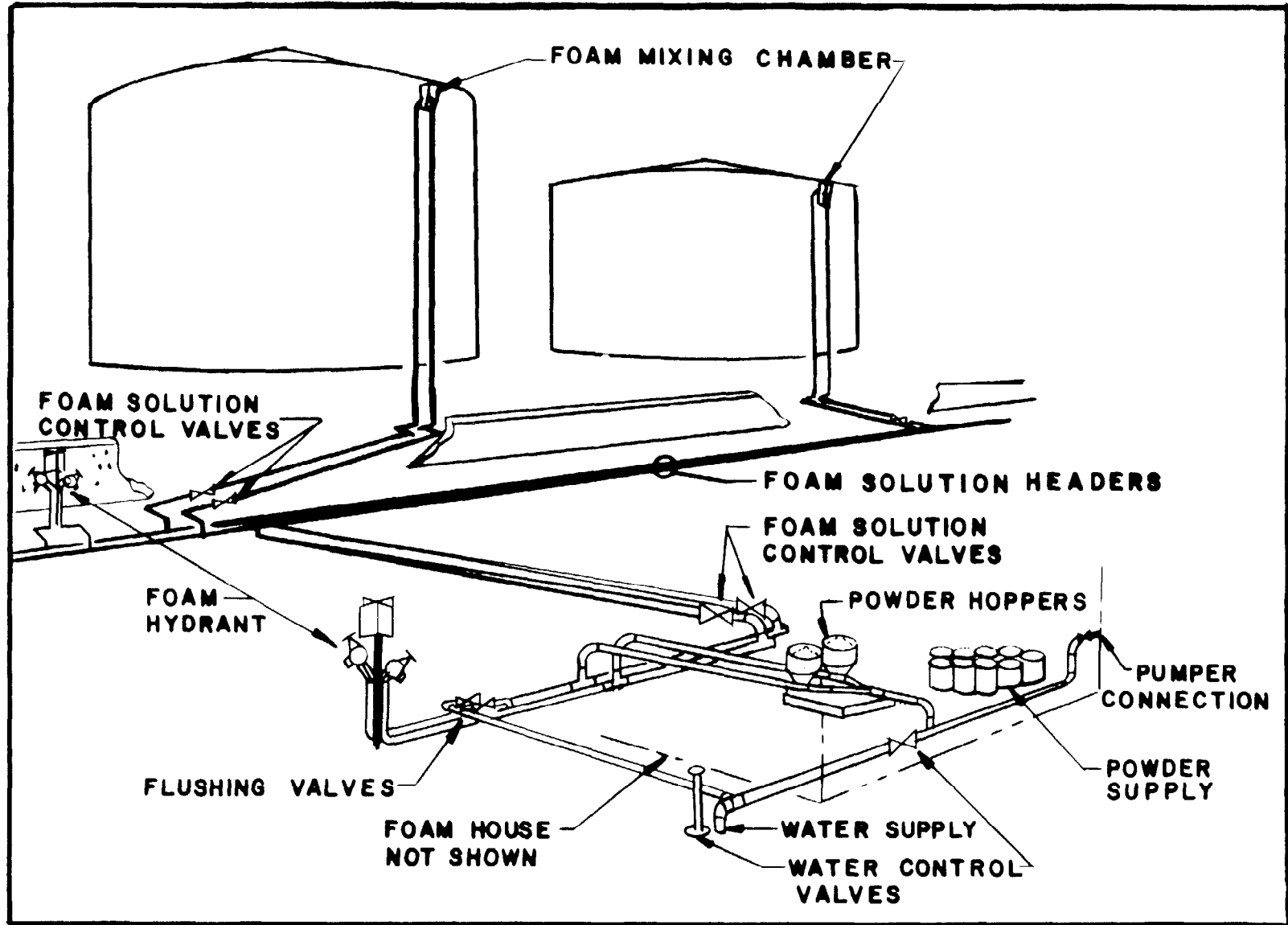
- Inventory the amount of "A" and "B" powder on hand in bulk or cans.

- Replace any cans that are broken, leaking, or badly corroded.

- Be sure that cans in storage are clearly marked and segregated between "A" and "B" powder.

- On a random basis, open and sample about 2 percent of the cans. Take samples from the top and bottom of bulk storage hoppers. Inspect for caking of the powder due to dampness, which would prevent it from running freely, and for particulate contamination.

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**FIGURE 5.14.2**

**CHEMICAL FOAM SYSTEM FOR STORAGE TANKS**

It is also recommended that the foam solution piping be flushed with fresh water and completely drained after each use or test.

5.14.3.2 Mechanical Foam. The following maintenance actions are recommended for mechanical foam concentrate:

- Check quantities in cans, drums, and foam tanks.

- Once a year, take samples of liquid foam concentrate. Inspect samples for signs of excessive sludge formation or other deterioration. Samples can be sent to the supplier's laboratory for analysis and report of condition.

- Take steps to eliminate changes in storage temperature of liquid foam concentrates. Liquid foam concentrate should not be stored at temperatures above 120°F, and it should not be stored for more than 2 months above 80°F. "Regular" liquid foam concentrate freezes at about 20°F. It cannot be used when frozen but can be carefully thawed and is effective thereafter. "Cold" foam freezes at -20°F and "Deep Cold" freezes at -40°F. Aqueous Film Forming Foam (AFFF) has approximately the same temperature limitations as "regular" liquid foam concentrate.

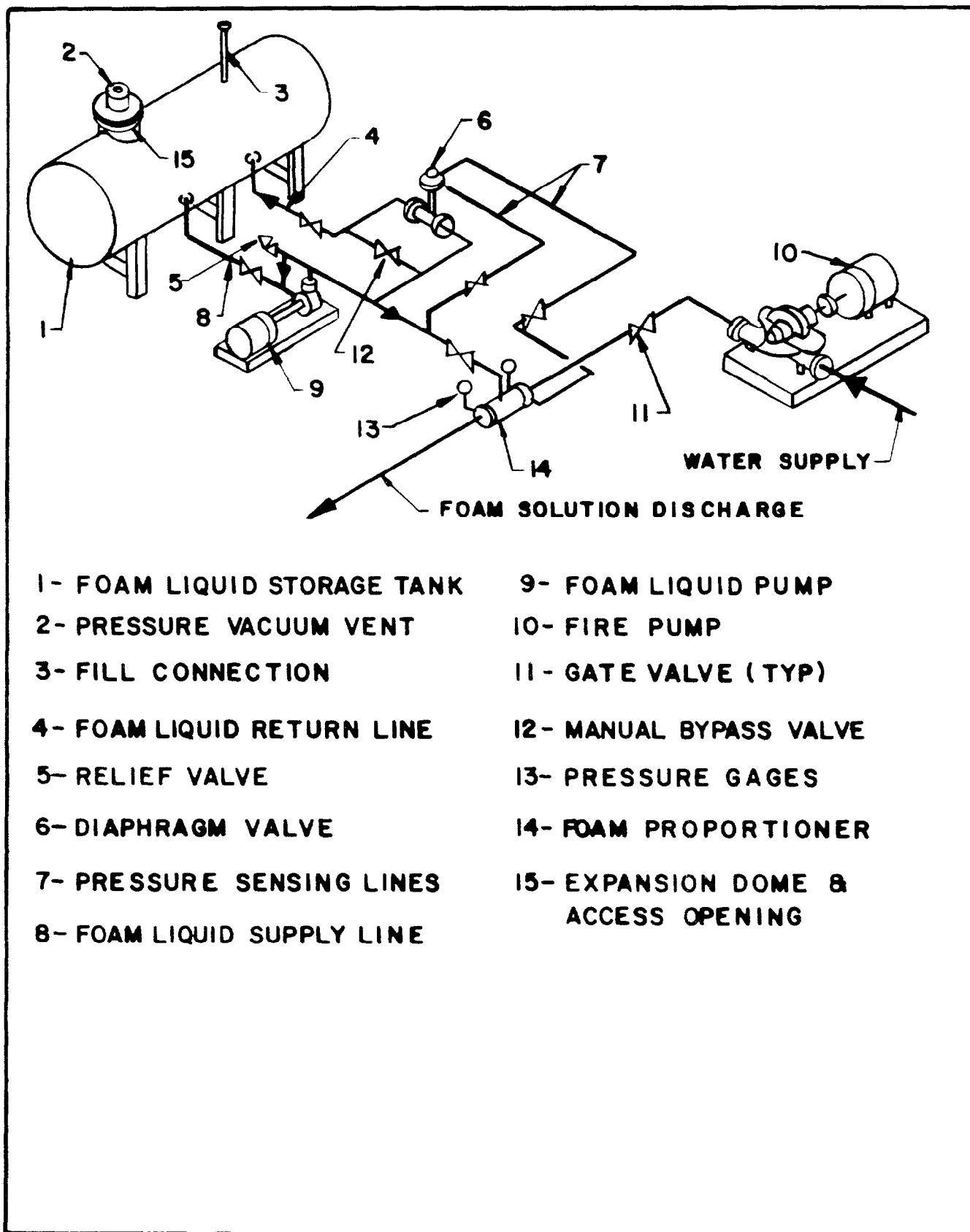
- Inspect all storage containers and connected piping for leaks and corrosion.

5.14.3.3 Foam Proportioner System. The quality of the foam applied during a fire is governed by the ability of the proportioners to correctly measure and mix the foam concentrate with the water, as described in the previous subsections. Figure 5.14.3 shows a mechanical foam proportioning system that might be used to protect a large installation. Note that there is a separate pump for the liquid foam concentrate. The following maintenance actions are recommended to ensure the ability of the proportioner to produce effective foam:

- Inspect proportioning systems once each month for physical damage, missing parts, leaks, corrosion, or deterioration.

- If the system has a liquid foam concentrate pump, operate it once every 3 months, bypassing the proportioner and returning liquid concentrate to the storage tank.

- Every 3 months, test operate all valves and clean strainers.



**FIGURE 5.14.3**  
**MECHANICAL FOAM PROPORTIONING SYSTEM**

- Each year, test operate the foam proportioner and obtain a sample at a hose station. This sample is used with a calibrated refractometer to ensure that the proper proportion of foam concentrate to water is achieved by the proportioner. If not, the proportioner, nozzles, and tank must be inspected.

- Every 5 years, run a full-scale foam-making test on the entire system.

- On chemical systems, inspect hoppers every 3 months for dirt, obstructions, and similar defects. Test operate vent levers and valves.

5.14.3.4 Foam Solution Piping. Many older foam systems are inoperable because the foam solution piping to storage tanks and hydrants is full of leaks from interior and exterior corrosion. As most systems are of the dry pipe type, internal corrosion of pipe can be prevented by completely flushing with clean, fresh water and draining after each use or test. External corrosion can be prevented by coatings and cathodic protection as described in MO-306 and MO-307. An annual hydrostatic test of the system at 150 psig held for 30 minutes is recommended to locate leaks. During the test, disconnect foam risers from storage tanks and blank flange to prevent damage to the tanks from the test pressure. Test operate, clean, and lubricate all system valves and hydrants as necessary.

Chemical (dry powder) foam systems that are found to have extensive leaks should be replaced by mechanical (liquid) systems where continuous protection is considered necessary.

5.14.3.5 Foam Makers and Foam Chambers. Once a year, inspect all foam makers and foam chambers to see that they are free from obstructions, damage, or deterioration. Pay particular attention to air intake screens on foam makers and diaphragms on foam chambers.

5.14.3.6 Portable Equipment. Portable equipment such as hoses, nozzles, pick-up tubes, liquid or powder cans, and hoppers should be stored in sheds or cabinets. Foam hose should be inspected every 3 months using the same inspection procedure used for water hose.

5.14.3.7 System Markings. All foam systems, equipment, and valves should be clearly marked to indicate their individual purpose. Every foam pump house should have a diagram of the proportioning and distribution system. All valves should be marked by individual signs to indicate their function, such as "FOAM TO TANK #97."

#### 5.14.4 Portable Extinguishers.

##### 5.14.4.1 Portable Extinguisher Inspection.

Inspection of fire extinguishers should be carried out on a continual basis, with maximum intervals determined by the nature and degree of hazard involved. Some operations, like fueling an aircraft, should not be undertaken by the operator until he/she has observed that fire extinguisher(s) are in place and ready for instant use. In other cases, at a remote, unmanned pump house for example, inspection of fire extinguishers might be scheduled on a weekly or monthly basis, depending on the circumstances.

The inspector should check the following items:

- The extinguisher is in its assigned location.
  - Visibility and access to the extinguisher are not obstructed.
  - Seals and tamper indicators are not broken.
- If there is a question, proceed as directed in the next section.
- Pressure gauges on the charge are in the safe operating range.
  - The extinguisher cylinder, hose, and nozzle are undamaged and in good condition.
  - The extinguisher is properly marked as to type and use.
  - The maintenance tag is current.

##### 5.14.4.2 Portable Extinguisher Maintenance.

Unscheduled maintenance should be carried out at the discovery of any of the following:

- Inspection deficiencies
- Partial or complete discharge of the expelling or extinguishing charge
- Evidence of tampering
- Mechanical damage or leaks
- Exposure to abnormally hot or cold temperatures, or to corrosive materials or atmosphere.

In addition to routine inspections described above, scheduled maintenance is recommended for various types of fire extinguishers at the intervals prescribed. In all cases, the



extinguisher should be carefully examined, filled, and tested by experienced repair personnel. The following procedures should be followed for the various types of extinguishers:

- Plain Water or Antifreeze Solution, Pump Type. Once each year, test operate the pump, empty the extinguisher, and recharge it.

- Pressurized Water (Loaded Stream) Type. Once each year, discharge the contents, recharge and pressurize the extinguisher with compressed air to not more than the pressure rating of the extinguisher. Hydrostatic test every 5 years.

- Soda-Acid and Chemical Foam Type. Once each year, discharge the contents and recharge the extinguisher. Hydrostatic test it every 5 years.

- Carbon Dioxide (CO<sub>2</sub>). Every 6 months, weigh the extinguisher and recharge it when the weight loss exceeds 10 percent of the weight specified on the label. Hydrostatic test it every 5 years.

- Dry Chemical. Replace the expelling gas charge and test for leaks whenever, for any reason, the pressure gauge goes below the normal operating range. Every 5 years, completely discharge the extinguisher and replace both the expelling and extinguishing charges. Hydrostatically test the extinguisher every 10 years.

- Halon 1211. Disassemble and maintain in accordance with manufacturer instructions on an annual basis. Prior to disassembly, fully discharge the extinguisher to check the operation of the discharge valve and pressure system. Tag or label the extinguisher to indicate the date of maintenance and the person performing the maintenance. Recharge in accordance with manufacturer instructions.

#### 5.14.5 Miscellaneous Extinguisher Systems.

5.14.5.1 Fixed CO<sub>2</sub> Flooding Systems. Fixed CO<sub>2</sub> systems should be inspected in a manner similar to portable CO<sub>2</sub> bottles. Each bottle should be securely mounted with a remote activation trigger attached. This trigger and the associated evacuation alarm and ventilation trip should be tested every 6 months, followed by a determination of net weight of CO<sub>2</sub> remaining. Temporarily secure individual CO<sub>2</sub> bottle valves while performing this check. Be sure to return the system to normal operation once the check has been completed.

5.14.5.2 Dry Chemical Systems. The powders, such as potassium bicarbonate, used in dry chemical systems are susceptible to moisture absorption and caking, especially in damp locations. Every 6 months, the storage cylinder should be

opened for inspection. If the powder is lightly caked, break the clumps apart with a clean wooden stake or similar item. If the powder resists this attempt, replace the powder. Inspect the extinguisher for evidence of activation or tampering. If any powder has entered the hose, check to ensure the hose is unclogged, and drain the powder. Check to see that the gas charge cylinder is sealed and in place, and record the inspection on the attached tag.

5.14.5.3 Sand. Sand is useful for containing and smothering small petroleum fires. Ensure the sand, usually stored in buckets, is not contaminated and the container is accessible and secured.

5.14.5.4 Fire Blankets. Fire blankets should be intact; without holes, cuts, or tears; and stored in a weather resistant, clean, dry, marked enclosure. Inspect the material condition monthly.

5.14.5.5 Steam Smothering. In specialized, enclosed application, steam can suffocate a fire. After properly de-energizing the system, inspect the system monthly to ensure all nozzles are unobstructed, free from corrosion, and not worn or misshapen. Check to see that a sufficient steam supply is available and that residual condensate is not accumulating in the piping leading to the devices. Ensure that the operation of remote activation devices and alarms is satisfactory. Line the system up for proper operation at the conclusion of maintenance procedures.

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