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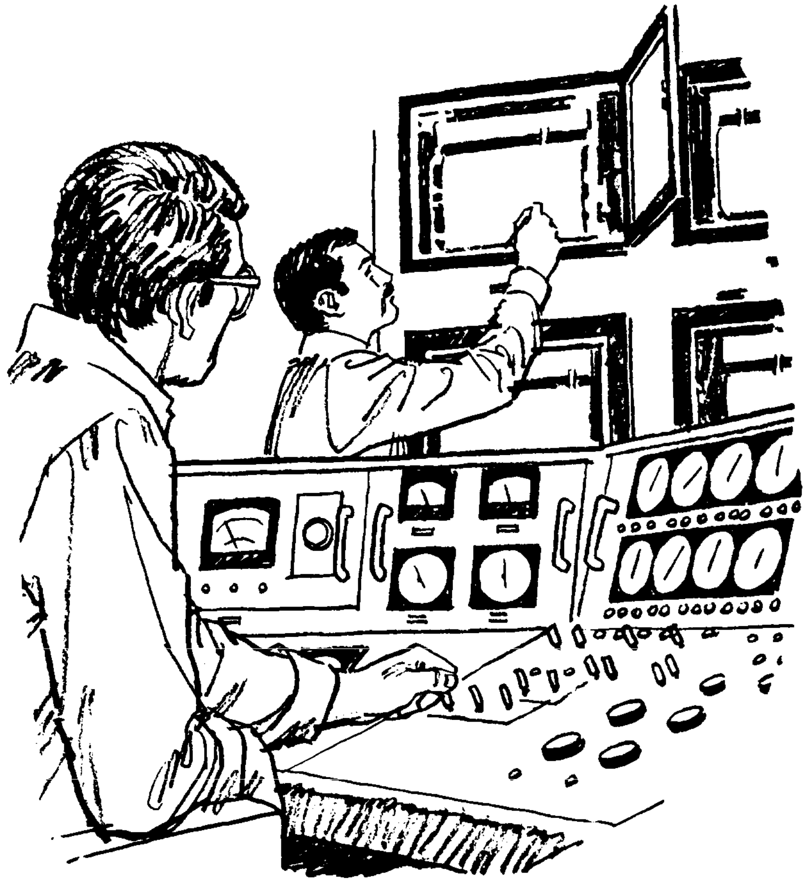

MAINTENANCE OF *Steam, Hot Water & Compressed Air* DISTRIBUTION SYSTEMS

NAVFAC MO-209
January 1989

SN 0525-LP-001-3540

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ABSTRACT

This manual is directed to operators and supervisors who actually perform and supervise operations and maintenance work. The manual is divided into eight chapters with chapter one covering definitions and responsibilities. Chapter two deals with basic inspection, testing, and reporting procedures. Chapter three covers steam distribution systems, while chapter four covers high temperature water distribution systems. Chapter five deals with compressed air distribution systems. Chapters six and seven cover instruments and controls and piping and associated equipment, respectively. Chapter eight covers steam traps. In general, this manual provides guidelines for maintenance and operation of steam, hot water and compressed air distribution systems.

FOREWORD

This publication provides information on the maintenance of steam, hot water and compressed air distribution systems.

For maximum benefit, this manual should be used i.n conjunction with equipment manufacturers' manuals, parts Lists and drawings. In case of conflict, manufacturers' recommendation on use, care. operation, adjustment and repair of specific equipment should be followed. This man Tc l is a general guide which establishes standards for the operators, mechanics, and supervisors who are responsible for carrying out operations and maintenance functions.

Additional information concerning procedures, suggestions, recommendations or modifications that will improve this manual are continually invited and should be submitted through appropriate channels to the Commander, Naval Facilities Engineering Command, (Attention: Code 165), 200 Stovall Street, Alexandria, VA 22332-2300.

This publication cancels and supersedes NAVFAC MO- 209 of March 1966 and any changes thereto. It has been reviewed and approved in accordance with the Secretary of the Navy Instruction 5600.16A and is certified as an official publication of the Naval Facilities Engineering Command.

C. M. MASKELL
Captain, CEC, U. S. Navy
Deputy Commander for
Public Works

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SAFETY SUMMARY

All work around steam, high temperature water or compressed air presents a hazardous situation which can result in serious injury or death. Performance without injury is a sign of conscientious workmanship and planned supervision Therefore, safety is a primary consideration when operating, inspecting or maintaining any of the distribution systems addressed in this publication.

The first essential action is to read and understand all Navy and manufacturers' publications associated with the systems and equipment being used in your activity. Each manual explains safe and accepted ways of installation, startup, operation, inspection, maintenance, removal and shutdown. If you do not understand what you have read, DO NOT attempt to perform the intended task; get guidance from your supervisor.

The following safety rules need to be emphasized:

GENERAL

All personnel should be trained and qualified in cardiopulmonary resuscitation (CPR).

All personnel should wear safety shoes.

All personnel should wear clothing appropriate to the job being performed. Eliminate loose clothing which can get caught in machinery.

Wear hardhats when required.

All personnel should wear eye and ear protection prescribed for the task being performed.

Report all injuries, even if they seem to be minor.

DO NOT WORK ALONE. At least one other person should be on hand to provide assistance, if needed.

Always use the correct tool for the job.

PREVENT STEAM AND HIGH TEMPERATURE WATER BURNS! Make sure Isolation valves are closed before opening or removing equipment for fittings.

Prevent skin raptures and sensory injuries when working with compressed air. Close isolation valves before working on lines or fittings.

Follow lookout and tagout procedures prescribed for the power plant.

Be aware many boiler room surfaces are HOT.

Current and accurate drawings of various mechanical systems are essential for operational safety of the plant.

ELECTRICAL WORK

Do not wear jewelry, including rings. bracelets, necklaces or wrist watches.

Do not wear jackets with metal zippers.

Do not take short cuts. The steps recommended by a manufacturer usually have a margin of safety built into them.

Do not try to connect meters to circuits unless you are qualified. Wait for an electrician.

Wear rubber gloves, and be sure that they are inspected and air tested on a regular basis.

Always use insulated tools and grounded equipment. NEVER USE screwdrivers or other tools with metal shanks extending through the handle.

Always use tags and lockouts on circuits being worked on.

WARNINGS AND CAUTIONS

Warning and cautions appear in Navy and manufacturers 'manual. A CAUTION refers to a situation which, if not observed, may cause errors in data, damage to equipment or injury to personnel. A WARNING is a situation which, if not observed may cause loss of data, destruction of equipment or mutilation or death to personnel.

The cautions which appear in NAVFAC MO-209 have been repeated here for emphasis and reinforcement of their need to be observed explicitly. The numbers in parentheses at the end of the caution indicate the page on which the caution appears; for example, (4-15) refers to page 4-15.

Never stand or sit on aluminum jackets. Severe damage to the insulation will result. (3-5)

Long lines which have been encased in a Gilsonite type moisture barrier should be given consideration before shutdown. Shutdown presents the possibility of cracking the barrier when the line contracts. (3-16)

Where modifications have been made to the original configuration of the system or where metering or other devices protrude from the piping, shutdown may not be possible. Inspect entire line to insure that especially where clearances are minimal contraction will not cause bending, damage or breakage to piping and protrusion. (3-16)

Never operate a pump for more than a few minutes with the discharge valve closed; continued operation without water circulation causes the pump to overheat. Where system conditions require possible recirculation line on the discharge side of the pump to bypass approximately 10 percent of the rated flow. This line discharges back to the suction tank, preferably below water level. (4-21)

Never control water delivery by throttling the suet on valve, or cavitation may be the result. Cavitation, which is the formation of partial vacua in a flowing liquid, reduces the availability net ~ositive suction head. Also the sudden condensation of the vapor bubbles resulting from cavitation erodes the rotor and casing. (4-21)

Never permit the pressure drop through the strainer to exceed the normal operating value recommended by the manufacturer. (4-22)

Do not use gaskets thicker than 1/64 inch. The halves of the casing will be held too far apart, which permits leakage around the wearing rings. (4-28)

When employing a Bourdon gauge to measure steam pressure, use a gauge siphon or water leg to ensure that hot steam does not come in contact with the tube. (6-1)

On steam meter installations make sure the connecting pipes between the meter and the primary element are filled with condensate before placing the meter in service. (6-21)

Mercury is poisonous. Avoid breathing mercury vapor. Avoid repeated skin contact which may cause serious skin irritations. Keep mercury in clean dark containers with plastic bottle caps. Mercury dissolves many metals. (6-23)

CHAPTER 1. DEFINITIONS AND RESPONSIBILITIES

1 OPERATION. Operation includes startup, normal operation, emergency operation and shutdown of plant equipment. Good operation is safe, reliable and economical. Operators and operator supervisor are responsible for safe and efficient operation of equipment. Follow these basic rules of good operation.

All operators should be thoroughly familiar with the equipment and systems which they operate. Carefully study drawings, diagrams, instruction manuals, special operation procedures and emergency procedures. Know the location, method of operation and function of all valves, switches, electrical controls and other control devices.

Perform work assignments in a safe manner in accordance with approved safe operating procedures. Use available protective safety clothing and equipment.

Operate equipment and systems economically, safely and reliably.

Teamwork and cooperation are essential.

Be alert and concentrate on the work. Errors and forgetfulness can cause serious personnel injuries and costly damage to the equipment.

2 CASUALTY CONTROL Casualty control includes the prevention, minimization and correction of operational and emergency casualties to plant installations. Sound design, careful inspection and effective organization and training of plant personnel are part of a casualty control program. Casualty control is the responsibility of all plant personnel.

(a) The responsibilities of the operators are:

(1) Operating the plant equipment in a safe reliable manner.

(2) Handling emergencies and casualties effectively per approved procedures,

(3) Reporting immediately to their supervisors any equipment defects or operation deficiencies.

(b) The responsibilities of the maintenance personnel are:

(1) Maintaining the equipment in good condition at all times

(2) Making quick effective repairs when casualties occur

(c) The responsibilities of the supervisory and engineering personnel are:

(1) Selection of competent personnel,

(2) Preparation and supervision of adequate personnel training program,

(3) Preparation and supervision of an adequate plant maintenance, housekeeping and inspection program.

(4) Plant installations competently designed and installed

(5) Preparation and supervision of safe, reliable and economic normal operating procedures.

(6) Preparation and supervision of necessary emergency and casualty procedures, including training personnel in these procedures

(7) Preparation and procurement of training aids, system diagrams and manufacturers' manuals for training and guiding operating and maintenance personnel.

(8) Preparation and supervision of an adequate periodic test and inspection program for all plant safety devices, fire fighting equipment and other emergency equipment

3 OPERATOR MAINTENANCE. Operator maintenance is the necessary routine, recurring maintenance work performed by the operators to keep the equipment operating at its designed capacity and efficiency.

3.1 Responsibilities. The operator is actually the most important member of the maintenance team. A well-informed and responsible operator should perform the following duties:

(a) Keep equipment in service for maximum periods.

(b) Detect any flaws so that equipment is removed from service in time to prevent serious damages.

(c) Perform minor repairs on equipment removed from service to minimize outage time.

3.2 Duties. Everyone in the operating chain should be aware of the following conditions:

(a) Cleanliness. Dirt is the principal cause of equipment failure and should be removed immediately by the operator.

(b) Lubrication. Any two surfaces brought together develop friction. When not properly lubricated the surfaces wear one another down, change clearances and cause equipment breakdowns.

(c) Temperature Change. Any unusual temperature change which the operator cannot correct should be reported immediately to the plant supervisor. When the temperature of a piece of equipment rises rapidly, immediately shut down.

(d) Loose Components. Vibration is a major source of equipment failure. Equipment not properly secured vibrates, causes an unbalance, vibrates further and compounds the problem. In making rounds, the operator should put his hand on the bearing, touch the fan housing and feel the motor casing. If any unusual sound is heard, vibration felt or motion seen, take steps to correct the condition.

4 PREVENTIVE MAINTENANCE. Preventive maintenance is a system of routine inspections of equipment recorded for future reference on inspection records. Its purpose is to anticipate and prevent possible equipment failures by making periodic inspections and minor repairs in advance of major operating difficulties.

4.1 Responsibilities. Preventive maintenance (PM) is the responsibility of both operators and specified maintenance crews. The operator is expected to perform as much maintenance as possible, which is controlled by technical ability, availability of tools and time. Specifically assigned maintenance crews work on equipment requiring no operator where the work to be done is beyond the scope of the operator.

4.2 Scheduling. Scheduling preventive maintenance is the responsibility of the plant supervisor. Maintain a record card for each major piece of equipment with entries of the MP schedule, inspections and operation. See NAVFAC MO-322, INSPECTION OF SHORE FACILITIES, for more detailed information.

5. BREAKDOWN MAINTENANCE. Breakdown maintenance is the emergency repair of inoperable equipment by operators or maintenance crews. The plant and maintenance supervisors are responsible for emergency repairs. The Utility and Maintenance Shops should develop a coordinated plan to efficiently handle emergency breakdowns.

CHAPTER 2. BASIC PROCEDURES

Section 1. INSPECTION

1 IMPORTANCE OF INSPECTION. Inspection is important. Its purpose is to locate and identify existing or potential equipment deficiencies so corrective maintenance can be planned and initiated. The benefits of a well-organized inspection program include the following points:

Equipment deficiencies are detected in their early stages of development.

Breakdowns and unscheduled maintenance are reduced.

Maintenance costs are reduced.

Production costs are reduced by fewer breakdowns. Compared to production loss costs, inspection costs are negligible.

2 OPERATOR INSPECTION. Operator inspection is the periodic inspection of equipment by the operators. Operators should be given instructions regarding their responsibilities. Each operator should make a daily check of equipment and report to supervisors all deficiencies found, such as the following problems:

Inadequate lubrication

Excessive vibration and noise

Abnormal temperatures and pressures

Capacity reduction

Leaks

3 PREVENTIVE MAINTENANCE INSPECTION. Preventive maintenance inspection (PM) is the periodic inspection of important unattended equipment and systems. It also includes inspection of operator-attended equipment when the operator lacks the time or training to do it. The PM inspector shall report breakdown immediately to the supervisor. Any deficiencies found shall be reported to the manager of the Inspection Branch, or equivalent, through the inspectors' supervisor.

4 CONTROL INSPECTION. Control inspection consists of periodic inspections and/or tests of equipment to determine the physical condition of the equipment. The objectives of control inspections are:

To provide for inspection of all equipment not covered by the operator or PM inspection.

To assure adequacy of operator and PM inspection.

5 REFERENCE. For additional information on inspection, refer to NAVFAC MO-322, Inspection of Shore Facilities.

Section 2. INSPECTION SCHEDULING

1 FREQUENCY.

1.1 Guide. Inspection schedules are necessary for all equipment items requiring periodic inspections. To determine the frequency of inspection, ask the following questions:

Will the failure of this tern interfere with an essential operation?

Does the item have a high cost or a long lead time for replacement?

Will failure endanger life and/or property?

Will failure of this item result in high energy losses and costs?

If all of these questions are answered YES, the item must have frequent inspection. If the answer to the questions are a combination of YES and NO, less frequent inspection is required. If the answer to all the questions are NO, little or no inspection is required.

1.2 Basis of Frequency. Consult manufacturers' publications, operating division personnel, and the other chapters of this manual when establishing inspection frequencies. Frequency may be established on a calendar basis such as monthly, quarterly, or semiannually. On a seasonal basis such as after every 1.000 hours of operation.

1.3 Maximum Frequency. Inspection of items should not be scheduled more frequently than required to assure normal operating efficiency. Most items should be-inspected at least once a year.Exceptions to the requirement for annual inspection may be made for direct buried distribution systems, storage systems, high towers and similar items where it is operationally impracticable or unfeasible to make internal or external inspection, or where personnel performing the inspection would be subject to great personal hazard.

1.4 Replacement of Parts upon Breakdown. On certain types of low-cost or inaccessible items, replacement of the item at the time of breakdown may be more economical than periodic inspections.

1.5 Adjustment in Frequency. Occasionally few deficiencies are found during the scheduled inspection of some items. When this occurs consider less frequent inspections. Or when the same deficiency is reported after each inspection of a particular item, inspect more frequently. Determine the frequency of inspection so that emergency calls and service work are kept to a minimum.

2. TIME ESTIMATES. The time normally required to make a careful examination of an item depends on the following considerations:

Tools or equipment the inspector may need

Time required for making sketches or written descriptions of any deficiency found.

Travel time from one item to the next.

Size of item

3 ROUTE PREPARATION. The inspection route pertains to the geographical location of the facilities to be inspected. Generally the inspection route should require a minimum of travel between the inspected facilities.

4. REFERENCE. Refer to NAVFAC MO-322, Inspection of Shore Facilities, for more information on inspection scheduling.

Section 3. TESTS, SURVEYS AND REPORTS

1. OBJECTIVES. Utilities surveys are detailed reviews of the maintenance, operation and management of utility systems. The surveys are made by specially trained engineers and utility managers. Utilities surveys have two main objectives:

To make immediate savings through changes which require little or no expenditures of funds;

To identify savings by making changes which may require further study and/or a seizable investment in new facilities.

2. FREQUENCY. All major activities in each district should be surveyed on a continuing basis.

3. PREPARATION. A representative will visit the activity approximately a month before the survey to discuss the on-site logistics and to make advance preparations. The representative will explain the program, what its objectives are, how the survey is to be conducted and what results can be expected. The survey team requires the following :

Engineers, supervisors, electricians, pipefitters and other specified personnel to be present during the survey period

Data, curves, reports, diagrams, studies, records, contracts and other information to be available during the survey period.

4. SURVEY PROCEDURE. Each survey requires about 4 weeks. Each member of the four-member team spends 1 week at the activity being surveyed as follows:

(a) First week: The electrical engineer visits the station.

(b) Second week: The mechanical engineer on distribution and utilization visits the station.

(c) Third week: The mechanical engineer on plant operation makes a survey.

(d) Fourth week: The utility manager goes into general management areas and consolidates the individual reports prepared by the three preceding team members.

5. REPORTS.

5.1 Format. Formal survey reports a ways include the following items:

(a) A standard preface

(b) Recommendations which are broken down into two general groups :

(1) General recommendations proposed for immediate accomplishment

(2) The remaining recommendations for further study and consideration for future accomplishment

5.2 Recommendations. Recommendations cover the following areas:

(a) Electrical generation and distribution

(b) Steam distribution and utilization

(c) Plant operation

(d) General utility management

6. REFERENCE. Refer to NAVFAC MO-322, Inspection of Shore Facilities, for additional information on utilities surveys.

Section 4. TOOLS AND SPARE PARTS

1. INVENTORY. All maintenance activities should have adequate but not excessive stocks of equipment spare parts and maintenance tools. Lack of an essential repair part prolongs a short repair job into a long shutdown and costly production loss. Lack of adequate tools increases maintenance shutdown and production loss time periods.

2 INVENTORY CONTROL. Stocks of tools and spare parts should be maintained at or above specified minimum inventories. Items should be reordered promptly when stocks decrease to the specified order points. Periodic physical inventories should be made to check the stock quantities indicated by the record system.

3. TOOLS. The tools required for maintenance activities are determined by the type and size of equipment to be maintained. A properly equipped maintenance activity should have the following shop tools and equipment :

Small lathe	Impact wrenches
Medium lathe	Tube rollers
Power drill press	Turbin bolt wrenches
Electric and/or air drill	Sling chain and hoists
Meggers and electrical test sets	Mauls and axes
Pipe-threading machine	Pipe cutters and dies
Hydraulic press	Drills and tabs
Gas and electric welding outfits	Shaper
Large pipe wrenches	Metal saw

4 REPAIR PARTS. The operation and maintenance supervisors should review the manufacturers' list of recommended spare parts for all new equipment and should prepare a list of parts to be purchased and stocked. This list should be reviewed periodically and items added or deleted as necessary. The stock of repair parts should be adequate but not excessive. Stocked parts should be stored in a clean, dry area. They should be adequately identified by tags and their storage location noted on the spare parts lists.

CHAPTER 3. STEAM DISTRIBUTION

Section 1. APPLICATIONS AND SYSTEMS

I HEAT TRANSMISSION. Steam conveys heat energy to distant points. The amount of heat that steam can transmit depends on its temperature and pressure. Saturated steam temperature depends on steam pressure. The total heat content of a pound of steam increases with a rise In pressure, from atmospheric pressure (14.7 psia) up to about 410 psig. Above 410 psig, the total heat of steam decreases as pressure increases. Direct buried conduit systems shall be installed, maintained, and repaired in accordance with the Manufacturer's Approved Brochure and NAVFAC Guide Specifications NFGS-15705, Underground Heat Distribution Systems (Prefabricated or Pre-Engineered Types). Systems shall have a Letter of Acceptability issued by Federal Agency Committee on Underground Heat Distribution Systems. The Letter of Acceptability is signed by representatives of federal agencies participating in the committee and stating that the supplier's system is approved for use for the site ground-water conditions, operating temperature, and soil classification(s) indicated. Shallow concrete trench systems shall be installed in accordance with NFGS-15751, Heat Distribution System Outside of Buildings (Concrete Shallow Trench Type). As energy costs continue to rise, proper operation, maintenance and repair becomes more and more cost effective to implement in an expeditious manner. Engineering Field Divisions shall assist and Activities shall assure that efficient operation and timely maintenance of steam distribution systems are performed. The Power Principles Video Training Program shall provide further assistance to all concerned.

2 STEAM DISTRIBUTION SYSTEM. Consumers may be located in several buildings or a group of buildings where steam is required for space heating and/or process work. For purposes of this manual, a steam distribution system consists of the following equipment:

Steam piping required to transport steam from a central steam generating plant to consumers

Piping required to return condensate to the generating plant

Equipment, instrumentation, and related facilities required to serve the above described purposes

3 SUPPLY PRESSURE. Steam supply systems are categorized as either low-pressure systems or high-pressure systems.

3.1 Low-Pressure Steam. Low-pressure steam, O to 15 psig, is used for space heating (unit heaters, radiators, connectors, heating coils, or other steam heating devices), snow melting, cooking, and domestic hot water heating. It is distributed from a central plant or mechanical room to a multiple building installation. The advantages of low-pressure vice high pressure steam are:

Small distribution losses, due to the relatively low temperature of the steam

Smaller losses and trouble from leakage, traps, and venting

Simplified pressure reduction at buildings

Substitution of standard cast iron fittings

Less maintenance

3.2 High-Pressure Steam. High-pressure steam, above 15 psig, is used for industrial purposes, process work, hospital uses, laundry machinery, and dry cleaning. For extensive outside distribution, high-pressure steam at or above 100 psig is commonly employed. Figure 3-1 illustrates a schematic flow diagram of a steam distribution system. In this system, steam is generated at 100 psig in a central steam generating station and then distributed to consumers. The diagram shows conversion of high-pressure 100-psig steam to 40-psig low-pressure steam for hospital uses. Reduction to 5-psig steam for space heating purposes is also shown. Steam for laundry machinery, however, is used at 100-psig pressure. System components such as valves, traps, pressure reducing valves, pumps, and other required equipment are considered in following chapters. The main advantages of high-pressure steam vice low pressure steam distribution are:

Smaller pipe sizes

Availability for purposes other than heating

More flexibility in design for velocity and pressure drops

4 DISTRIBUTION ROUTE. The piping route for steam distribution systems is selected to obtain the minimum possible distance from the central generating station to the demand centers. The following factors affect selection of the route (for additional factors refer to NAVFAC DM-3, Design Manual, Mechanical Engineering):

Characteristic of the location

Future growth

Basements or crawl spaces available for piping

Existing tunnels or trenches available for the system

Aboveground obstructions, such as rivers or roads

Underground obstructions, such as piping or rock

Soil Corrosivity

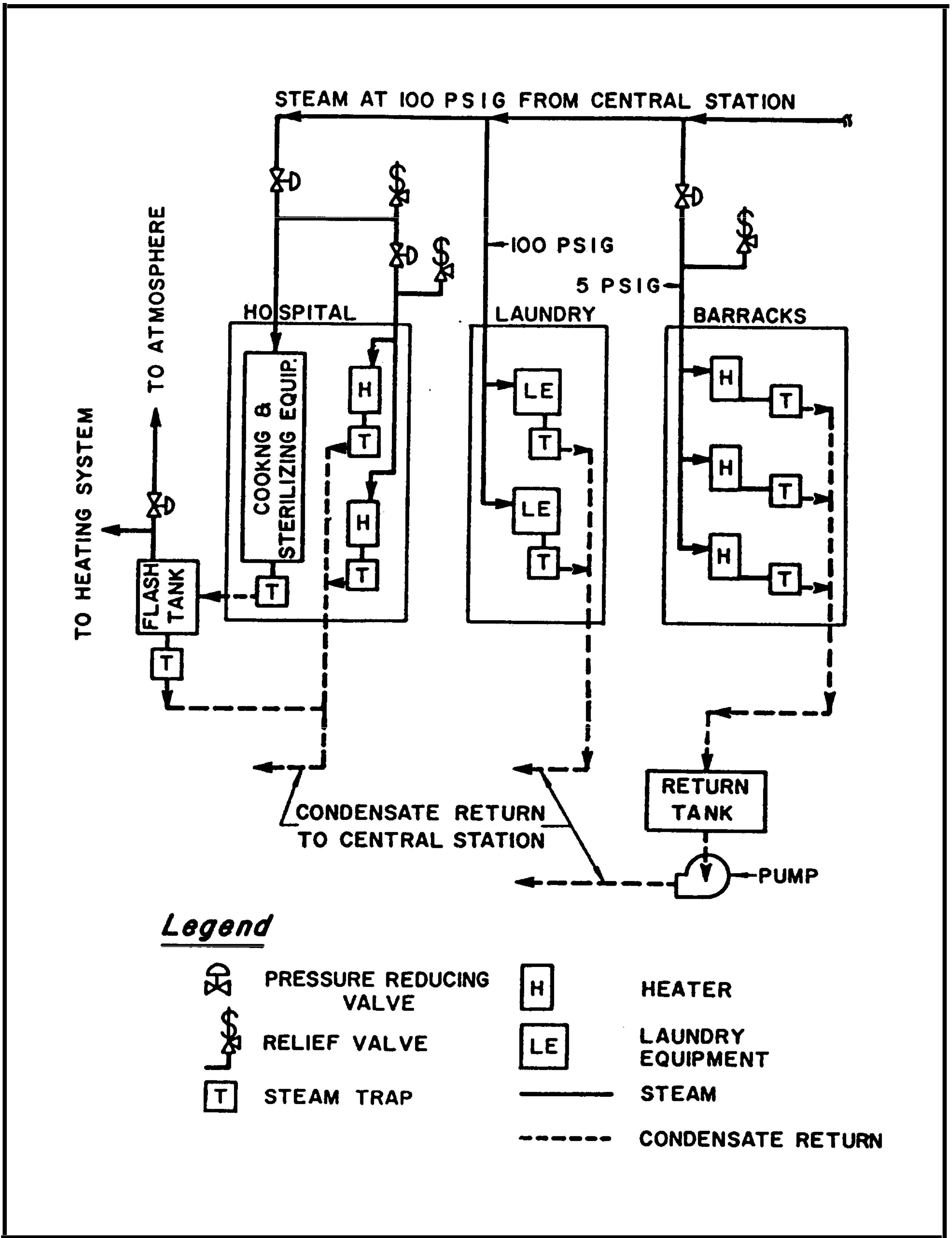

FIGURE 3-1. Schematic Flow Diagram of a Typical Steam Distribution System

Section 2. STEAM DISTRIBUTION METHODS

1 TYPES OF DISTRIBUTION SYSTEMS. Two main systems are used for distribution of steam: aboveground distribution systems and underground distribution systems. The decision to select an aboveground system or an underground system depends on the following factors:

Permanent against temporary use

High water table ground conditions

Degree of hazard (as when the overhead piping may cause a potential danger to aircraft or other operations)

2 ABOVEGROUND DISTRIBUTION SYSTEMS. Aboveground distribution systems shall be selected whenever practical. Due to their ease in detecting when and where maintenance is required, NAVFAC prefers this type of installation. With proper maintenance, this type of system is the most energy efficient and cost effective.

2.1 Advantages of Aboveground Systems. The main advantages of using aboveground vice underground distribution systems are:

Lower initial cost

Less maintenance

Easy detection of failure

Higher continuous operating efficiency

Longer life

Reduced external corrosion

2.2 Distribution Lines. Distribution lines usually consist of aboveground conduits supported as follows:

Low Elevations. For aboveground systems installed at low elevations, the conduits are supported on concrete pedestals, steel frames, or treated wood frames. Supports are spaced 10 to 15 feet on centers depending on pipe size.

High Elevations. At higher elevations aboveground, conduits may be supported on wood, steel pipe, H-section steel poles with crossarms, or steel frameworks fitted with rollers and insulation protection saddles.

Long Spans. When long spans are required, conduits are supported by cable suspension with supports up to 50 feet on center.

2.3 Pipe Covering.

CAUTION

Never stand or sit on aluminum jackets. Severe damage to the insulation will result.

Aboveground piping is covered with insulation (refer to chapter 7) and then furnished with a protective covering of one layer of impregnated roofing felt and an aluminum jacket. This covering provides protection against weather and mechanical damage. The felt is applied with longitudinal and circumferential seams lapped not less than 4 inches and secured with stainless steel staples. The aluminum jackets, longitudinally corrugated for strength, are not less than 0.017-inch thick. The longitudinal and circumferential seams are lapped not less than 2 inches. Jackets are secured with aluminum strips or with stainless steel sheet metal screws set on not more than 5-inch centers on the longitudinal and circumferential seams.

2.4 Road Crossings. Road crossings are often made by transition to an underground system which usually serves as an expansion loop.

2.5 Elevation Clearance. Conduits may be located as little as 12 inches or as much as 22 feet above grade. The clearance above roadways is from 14 to 16 feet for automobile and truck traffic. For railroad crossings the clearance is 22 feet above grade.

2.6 Pitch of Aboveground Steam Lines. Steam lines are pitched down at a minimum of 3 inches per 100 feet of length in the direction of steam flow. Often counterflow of condensate within the steam pipe will occur in a portion of a pipeline because of steam flow reversal in a loop system. In these cases, that portion of the pipe is pitched a minimum of 6 inches per 100 feet and pipe diameters are increased by one standard pipe size. Increasing the flow area reduces the steam velocity in the pipe and prevents retention of condensate and water hammer.

3 UNDERGROUND DISTRIBUTION SYSTEMS. Underground distribution systems shall only be used where local conditions prohibits the use of above-ground systems; for example, when an above-ground system would create a hazard to aircraft or other operations. Underground systems are more costly to install and more difficult to maintain than the above-ground systems. Justification, stating the conditions which prohibits the use of above-ground systems is required on all MCON and special projects involving steam distribution systems. This includes repair by replacement type projects where the existing distribution systems are underground.

3.1 Advantages of Underground Systems. The main advantages of using underground distribution systems follow.

They are a less vulnerable target.

They do not interfere with aboveground traffic.

They are less unsightly.

The piping is protected from freezing when buried below the frost line.

3.2 Soil Characteristics. The following soil characteristics determine the type of conduit system used.

Permeability. This characteristic is influenced by the elevation of the water table in the ground. See NAVFAC DM-3, Design Manual. Mechanical Engineering; and NAVFAC DM-7.2, Design Manual, Foundations and Earth Structures for field permeability tests.

Soil Corrosivity. When metal casings are used as underground conduits, the corrosivity of the soil is an important consideration. Soil properties such as resistivity, pH, aeration, and the presence of certain soil bacteria can influence the corrosivity of the soil. Other factors such as the presence of stray electrical currents in the ground can affect the corrosion of buried structures. The requirement for cathodic protection should be based upon past experience in the specific location being considered if possible. If underground corrosion has been a problem, then either relocate the system to a less corrosive site, use an above ground system, or use cathodic protection to control corrosion. If there has been insufficient experience in the specific location being considered, then soil corrosivity as determined through a corrosion survey of the site can be used to make a preliminary assessment of soil corrosivity. Soil resistivity can be used as a general guide for determining the need for cathodic protection. Where soil resistivity is less than 10,000 ohms per cubic centimeter, cathodic protection will probably be necessary to prevent premature system failure. Detection of stray electrical currents in the ground should be determined through a corrosion survey of the site. Procedures for performing a corrosion survey of the site are given in NAVFAC DM-4, Design Manual, Electrical Engineering.

Soil Stability. NAVFAC DM-7.2, Design Manual, Foundations and Earth Structures, provides criteria for determining soil stability.

3.3 Factors Affecting Installation. Several factors may affect an underground installation, including the following situations:

Possibility of surface runoff seeping into a backfilled trench and percolating down at a greater rate than the draining capability of the ground below the system

Areas where pending may occur

Permeability of the ground below the system

3.4 Pitch of Underground Steam Lines. To provide easy drainage, steam lines are pitched down at a minimum of 3 inches per 100 feet of length in the direction of steam flow. Where the ground" surface slopes in a direction opposite to the steam flow in the pipes, the underground lines are generally stepped up in vertical risers at drip points in manholes and then pitched down to the next drip point. This method is also used for very long horizontal runs to keep the line within a reasonable range of elevations. For counterflow conditions, refer to paragraph 2.6.

3.5 Conduit Systems. Conduit systems are single or multiple pipe systems totally enclosed in a waterproof structure. The piping is firmly supported . and anchored, but is free to expand and contract following temperature changes without damaging the insulation or casing. Necessary pipe supports, guides, anchors, expansion joints, and fittings are provided (refer to chapter 7). Conduit systems are designed to permit drainage of the conduit in place and to permit drying of the insulation if the system is flooded. This is especially important in areas of heavy rainfall and where the water table is likely to be high for several days. Conduit systems are classified as A or B types, depending on the following criteria.

(a) Class A Sites and Systems. These systems include any site where water, or the water table, is expected to be above the bottom of the conduit at any time. In this system, there is always a possibility for saturated ground above any part of the conduit structure.

(b) Class B Sites and Systems. These systems include any site where water, or the water table, does not rise above the bottom of the system. The Class B sites are usually areas where the soil is coarse grained, which facilitates drainage.

3.6 Class A Conduits. Class A conduits are used exclusively in Class A sites. They must satisfy the following requirements:

(a) Water tightness as determined by the field air pressure test (refer to section 4 of this chapter)

(b) Free air passage suitable for drying the insulation if it becomes wet

(c) Designed to permit air pressure testing at any time (refer to section 4)

(d) Capability of being drained in place, if required

(e) Capability to withstand 20-psig air pressure applied between the insulation and outer casing, 3.6.1 End and Gland Seals. Seals are used to prevent water infiltration where the conduit runs through walls, as at manholes and entrances to buildings. End seals are used when there is no longitudinal movement of the pipe, as at terminal ends of conduits inside manholes, pits, or building walls. End seals consist of a steel bulkhead plate welded to the pipe and conduit. Figure 3-2 illustrates an end seal. When the pipes can have longitudinal movement, gland seals are used to prevent water infiltration. Gland seals consist of a packed stuffing box and gland follower mounted on a steel plate welded to end of conduit. End seals or gland seals are equipped with drain and vent openings located diametrically opposite on the vertical centerline of the seal. Telltale vents, located at the top of the seal, are never less than 1 inch in diameter and must provide a free passage to the airspace between the insulation and the conduit walls (refer to paragraphs 3.6.2 and 3.6.3). Drain connections (l-inch minimum diameter) are located at the bottom of the seal.

3.6.2 Type A-1, Cast Iron Conduits. These units are prefabricated at the factory in standard length sections. They consist of pipe(s) individually covered with premolded or preformed pipe insulation of proper thickness, (refer to chapter 7), and a cast iron conduit casing. The insulated pipe is supported within the metallic casing in such a way that a continuous annular space (l-inch minimum) is provided for the entire length of the system, between the outer surface of the insulation and the inner surface of the exterior casing. This provides adequate continuous airspace for venting and draining. An extension of bare pipe is left at each end of the section for welding in the field. After welding, joint closures are made by applying insulation to the pipe and then using a solid sleeve or mechanical joint for the conduit. In other types of installations the conduit is furnished with flanged ends to make the joint closures. Figures 3-3 and 3-4 illustrate a solid sleeve joint and a standard mechanical joint, respectively. Piping is pitched by the slope of the trench bottom. Supports and anchors are designed to permit complete drainage of the casing in place and to allow freedom of airflow.

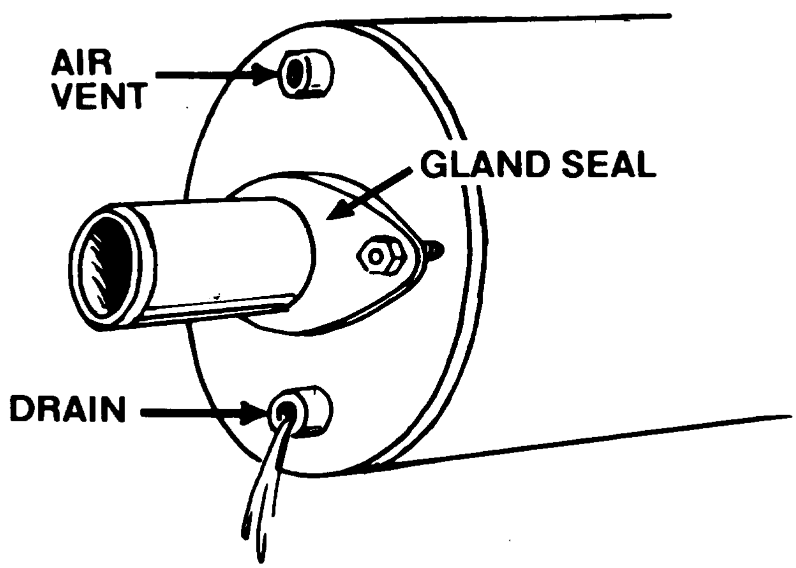

FIGURE 3-2. Conduit End Seal

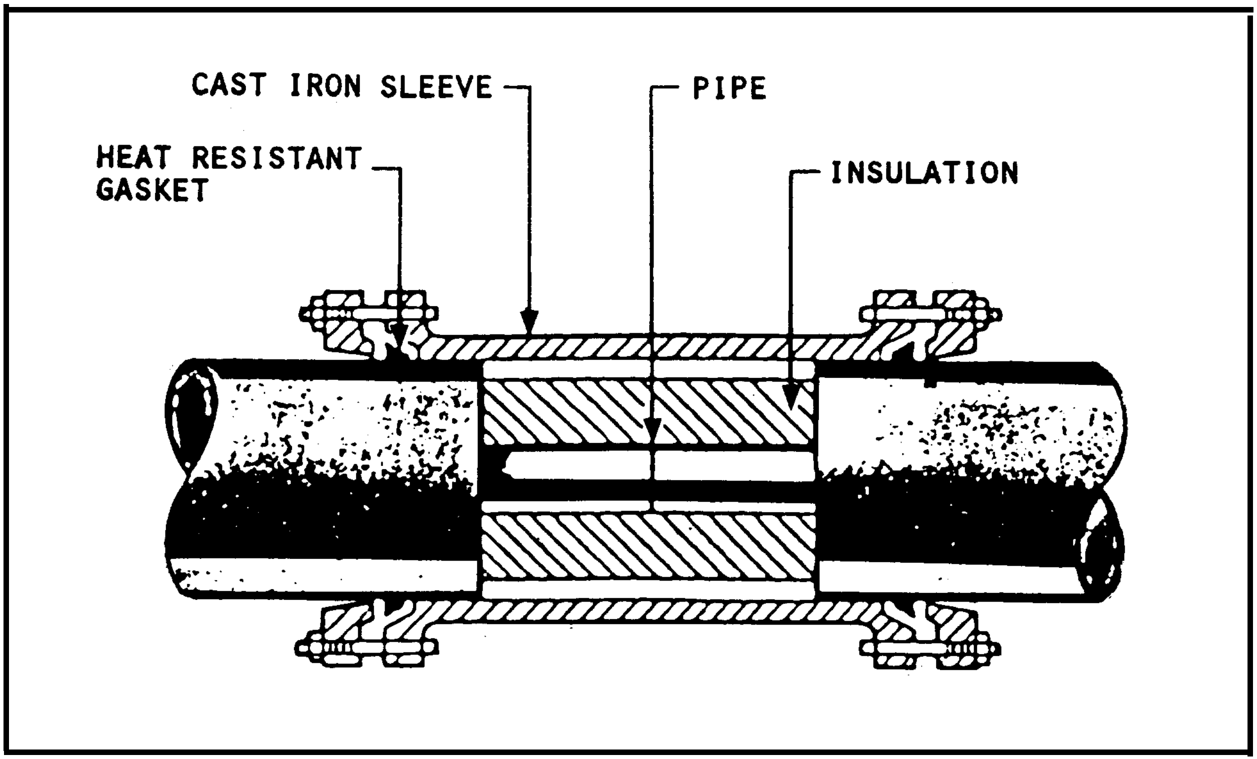

FIGURE 3-3. Solid Sleeve Joint

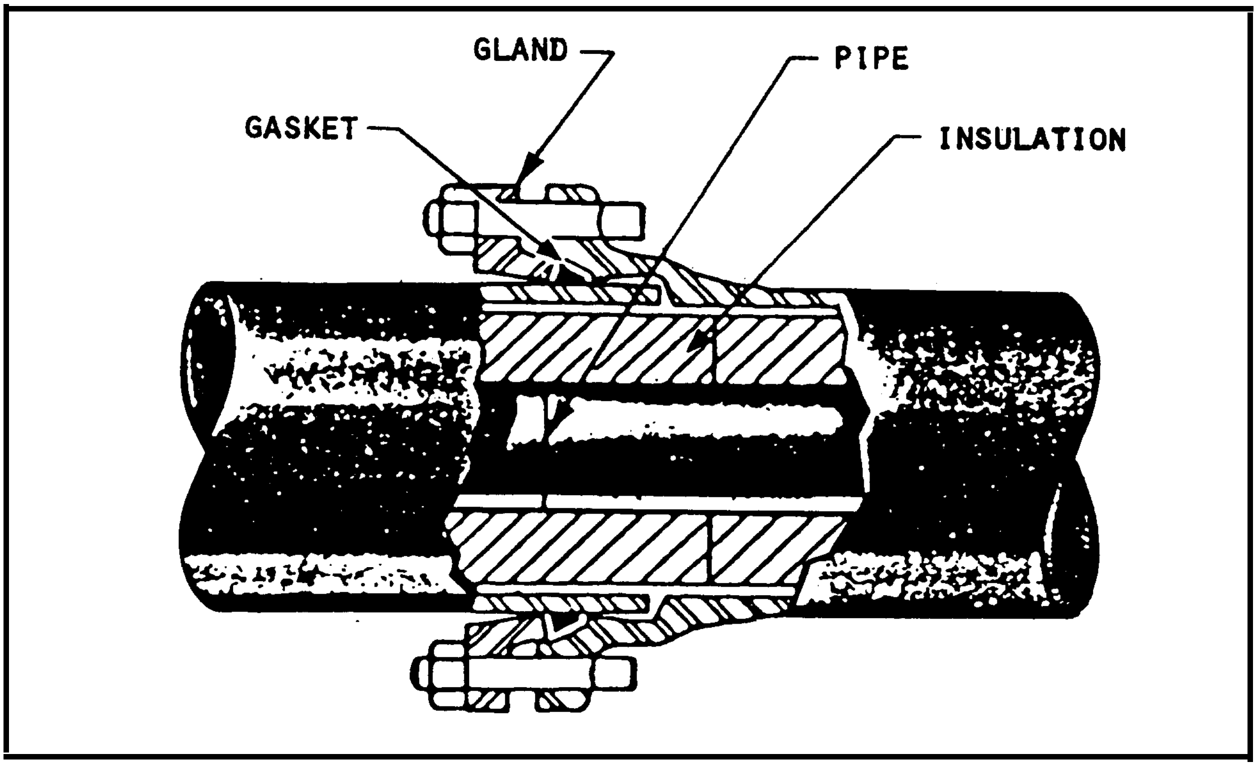

FIGURE 3-4. Standard Mechanical Joint

3.6.3 Type A-2, Steel Casing Conduits. Steel casing sections are units completely insulated and coated, prefabricated at the factory in unit sections of standard length (usually 21 feet). The sections are shipped from the factory with an extension of bare pipe at each end for field welding. Pitching of the pipe is provided by the slope of the trench bottom. Sections are composed of the following items.

(a) Pipe(s) for either a single or a multiple pipe installation.

(b) Layer of premolded or preformed insulation of the required thickness (refer to chapter 7).

(c) Open mesh cloth insulation jacket.

(d) Intermediate pipe supports. These supports are designed to permit free expansion or contraction of the pipe without damage to the insulation Also, they allow free air circulation and drainage from one end of the system to the other.
pipe insulation and the inner surface of the exterior metallic casing for the entire length of the system.

(e) Annular airspace (l-inch minimum) between the outer surface of the

(f) Zinc or other corrosion-resistant coated steel casing.

(g) Hiqh temperature melting point asphalt or coal tar coating. This is a waterproof-coating with low permeability which neither softens nor flows at temperatures below 220°F.

(h) Asphalt saturated asbestos felt wrapping.

(i) Reinforcing end collars welded at the factory to each end of the conduit section.

3.6.4 Configurations of Steel Casing Conduits. Steel casing conduits are of two types: corrugated steel conduits and spiral welded steel conduits.

3.6.5 Corrugated Steel Conduits. These sections have helically corrugated, zinc-coated, steel conduits with spiral seams welded to ensure a waterproof pressure-tight casing. The conduit is designed for strength to prevent deformation in service. The insulation on the pipe(s) at each end of the conduit sections is usually protected with a heavy asbestos felt cap wired on. The insulation caps are permanent and remain in place when the pipe and conduit joints are made. Joint closures are made by welding the bare ends of the pipes. After welding and testing for leaks, insulation is applied to the pipe. Finally, a connector band or coupling, which fits snugly over the reinforcing end collars, is welded airtight. After welding, waterproofing similar to that of the section is applied.

3.6.6 Spiral Welded Steel Conduits. This is a smooth steel conduit with spiral joints of the lockseam welded type. The steel sheets used for this type of conduit are heavier than those used for corrugated steel casings. The end connections of the conduit can be made with or without sleeves. In the latter case, the ends are reinforced to an adequate thickness and beveled for field welding. When welding sleeves are used, they are of a thickness at least equal to that of the conduit.

3.7 Class B Conduits. Class B conduits are used in Class B sites. They must fulfill the following requirements.

(a) They must be watertight as determined by a laboratory water-tightness test applied to a test length of conduit of the same construction as used in the field (refer to section 4).

(b) They must have a free air passage suitable for drying out the insulation if it becomes wet.

(c) They must be capable of being drained in place, if required.

3.7.1 Type B-1, Tile Conduit. Tile conduits consist of a continuous reinforced concrete slab furnished with an internal base drain and provided with vitrified-clay-tile sidewall blocks, fittings, and arches. The pipes enclosed within the conduit are supported by rigid metal frames securely anchored, equipped with steel bars and cast iron rollers. An annular airspace (l-inch minimum) is provided between the outer surface of the pipe insulation and the inner surface of the tile for the entire length of the system.

3.7.2 Type B-2, Concrete Trench. Concrete trenches usually consist of cast-in-place bottom and sides covered with a precast top slab in lengths not exceeding 3 feet. The concrete is generally reinforced with 10-gauge welded wire fabric. The conduits may be square or rectangular in cross section with varying dimensions according to its use. Pipe supports, insulation, air-spaces, and expansion joints are as described for tile conduits (paragraph 3.7.1). Trenches permit complete drainage of the system and free expansion and contraction of the pipes without damage to the insulation (refer to chapter 7 for details). All joints are sealed with portland cement and an application of creosote primer and coal tar enamel. The coal tar is of a type which neither softens nor flows at temperatures below 220°F.

3.7.3 Piping Expansion and Contraction. Expansion and contraction of the piping is provided by expansion loops or offsets installed within the conduit between anchor points. In restricted spaces mechanical expansion joints are often provided (refer to chapter 7 for details).

3.8 Walking Tunnel. A walking tunnel is a conduit sufficiently large to permit personnel walking through it for inspection or repairs. They are relatively high in construction cost when compared with smaller conduits. In congested areas or where additional facilities must be accommodated (such as water systems, electric lines, or telephone lines), they are often justified. Piping is stacked vertically on one side of the tunnel. The means for supporting the pipes are similar to those described previously. The tunnel is waterproofed by adequate sealing.

3.8.1 Drainage. To drain water infiltrated into the tunnel through sealing failure or leaks in the service lines, a shallow trench is used. The tunnel floor is conveniently sloped to drain the water into the trench which runs along one wall of the tunnel. The trench bottom is sloped longitudinally to a point of disposal. Often, the trench bottom is below a sewer making gravity drainage impossible. In this case, a sump pit with facilities for pumping the water is provided. A float controlled drainage pump, steam or electrically driven, is used.

3.8.2 Construction. Tunnels are built of reinforced concrete, brick, or other suitable materials and are membrane waterproofed. They have provisions for ventilation and are adequately lighted to facilitate. maintenance. Moisture resistant electric fixtures are generally used.

3.9 Manholes. Manholes are constructed of reinforced concrete not less than 6-inches thick. Monolithic pours are used for the bottom and sides, and, where possible, the sides extend at least 4 inches above the finished grade. The top is commonly a steel cover of a cast slab of the same strength and thickness as the manhole. Figure 3-5 shows a section of conduit in a trench before backfilling. Adequate space is provided in manholes for inspection and repairs. The depth, however, is usually limited to 6 feet or less.

3.9.1 Ventilation. Manholes are provided with vents to obtain quick and effective ventilation and remove any dangerous gases that might otherwise

accumulate. A so, ventilation helps to carry away moisture that could collect in appreciable quantities. A two-pipe ventilation arrangement is furnished as follows:

(a) One pipe has its lower end at an elevation of 12 inches from the bottom of the manhole, projects through the manhole top, and ends not less than 18 inches aboveground.

(b) The other pipe ends flush with the inside face of the manhole top, projects through it, and ends not less than 18 inches aboveground, where possible.

(c) Both pipes are 4-inch size or larger and the aboveground ends are equipped with mushroom heads.

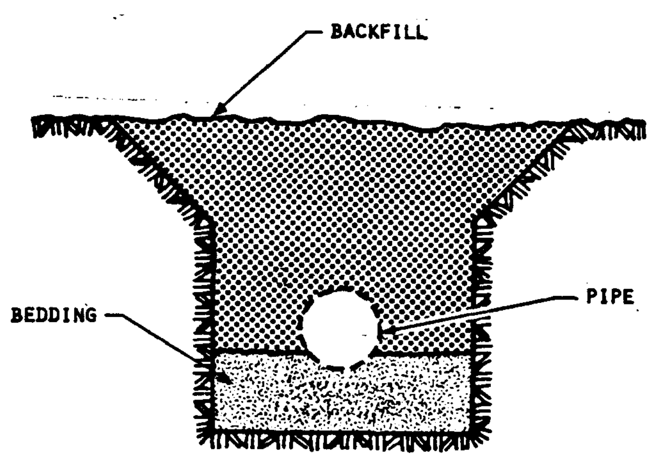

FIGURE 3-5. Cross Section of Conduit Trench

3.9.2 Waterproofing. Watertightness is an important requirement in manhole construction. Manholes are provided with an extra-heavy cast iron frame and a waterproof cover, not less than 24 inches in diameter. The bottom is waterproofed by placement of a waterproof membrane between the concrete slab and the earth, and the membrane is continued up the outer sides for at least 1 foot. The exterior surface of the sides is coated with creosote primer and coal tar. Conduit seals are provided for all types of conduits at manholes entrances.

3.9.3 Ladders. All manholes 3-feet deep or more are furnished with side-rail ladders fastened to the wall for safe and easy access. The ladder consists of round steel rungs not less than 3/4-inch thick and uniformly spaced, approximately 15 inches between centers. The highest rung of the ladder is generally within 6 inches of the street surface.

3.9.4 Drainage. In locations where the manhole bottom is above a nearby sewer, the manhole can be drained by gravity to the sewer though a backwater trap. If no sewer is available or the manhole bottom is below the sewer, water removing equipment is necessary. A sump in the bottom of a manhole can be drained by a motor operated pump or a steam ejector. The electrical installation is heatproof and moistureproof.

4 CONDENSATE RETURN. In steam distribution systems that use ferrous condensate return lines, it is customary to provide a separate conduit for the insulated condensate return piping. This is done because the return piping is often subject to corrosion which makes its life considerably shorter than the life of the steam pipes. When nonferrous condensate return lines are used, they are enclosed with the steam lines in the same conduit. In such cases, the condensate return lines are insulated when required by economic considerations.

5 PIPING. Steam distribution systems generally use black steel pipe. The condensate return lines can be extra strong wrought iron, extra strong steel, or copper. Joints for steel piping are usually welded, except those in manholes, which may be flanged. Copper piping is provided with brazed joints. For information on valves, fittings, and associated equipment refer to chapter 7.

Section 3. OPERATION OF STEAM DISTRIBUTION SYSTEMS

1 STARTUP INSPECTION. Before placing a new steam distribution system in service, or after a major overhaul to an existing system, check the following i terns.

(a) Make sure the system meets requirements set forth in the specifications.

(b) See that applicable tests, as described in NAVFAC TR-733, Heat-Traced System for Polar Regions (Latest Revision), have been satisfactorily completed.

(c) Ensure that all installation, repair, and cleanup work is completed. This includes cleaning and flushing the piping system.

(d) Make sure that conduits and passages are free from obstructions and are tight.

(e) Make sure insulation is correctly installed, dry, and in good condition.

(f) Make sure all auxiliary equipment is correctly installed and ready for operation.

2 SYSTEM STARTUP. Before starting up the system notify the steam generating station and the steam consumers. Prepare a starting schedule and supply it to all interested parties so that adequate provisions may be made. For new direct buried conduit and concrete shallow trench systems ensure that procedure included in the system supplier's product brochure are followed.

2.1 Startup Procedure. Startup of steam distribution lines which lead to facilities and processing areas should be done in a slow, bleed-type manner, especially where lines have been shut down for only a short period of time. The high-pressure, hot steam mixing with residual low-pressure, cold condensate can cause violent reactions which may result in burst joints and damaged piping, fittings, and metering devices. Where bypass lines have been installed at valve stations, the valve should be left closed and the bypass line opened during startup. Once pressure has equalized on both sides of the valve," then open the valve and close the bypass line. This action will prevent possible warpage damage to the valve. Continue with the following procedure.

(a) Open all manual vents.

(b) Place steam traps in service by opening the isolating valves. Trap bypass valves, when provided, may be opened during startup to speed up the discharge of air and condensate. They must be closed, however, when the system is in normal operation.

(c) Before placing the steam lines in service, warm up the piping slowly by passing a small amount of steam. Valves 8 inches in size and larger are usually provided with a small bypass valve for this purpose. If no bypass valves are available, crack open the required main valves. To bring a cold steam line to operating temperature, a considerable amount of steam must be condensed. The amount depends on the size of the line and the time required for the warmup. Make sure condensate drains freely during the warmup period, as this will reduce the possibility of water hammer.

(d) After pressure is equal on both sides of the valve, open main valves fully and close bypass valves, if provided.

(e) Check trap operation. Close bypass valves as soon as dry steam starts discharging through the valves.

(f) Check manually operated vents. When all air has been released and steam is being discharged, close manual vents.

(g) Start operation of the draining equipment (pumps, steam ejectors) in sump pits and manholes.

2.2 Warmup Precautions. During the warmup period, check for the following conditions:

(a) Action of expansion joints or loops

(b) Action of supports, anchors, guides, and hangers

(c) Proper drainage of condensation from drip points

3 NORMAL OPERATION. Control and regulate the use of steam at the points of usage, when possible, to prevent frequent warming and cooling of the main distribution system. Make certain steam traps are working properly, discharging only condensate and air. Ensure correct operation of associated equipment, such as pumps, pressure reducing stations, valves, traps, strainers, and auxiliary equipment, which are addressed elsewhere in this manual. Check operation of automatic air vents to see that the air accumulated in the high points of the system is being discharged. Check operation of draining equipment (pump, steam ejectors) in sump pits and manholes. Make sure manhole vents are unrestricted, and tunnels and trenches are kept dry and properly ventilated. In operation, there is always a certain amount of leakage from piping or infiltration through conduit seals. If ventilation is not adequate, the enclosed air becomes saturated with moisture which can produce corrosion. In underground conduits of reinforced concrete construction, the steel may be corroded by moisture infiltration. Once corrosion starts, the process is hastened because the expansive force of the ferrous oxide, resulting from the corrosion of the steel, breaks away the concrete surface. This exposes more metal, and the process keeps on at an accelerated rate. In aboveground systems, make sure the following criteria are met.

(a) Supporting structures do not settle or shift in position.

(b) Insulation covering maintains its mechanical and watertight protection.

(c) Insulation remains dry and in good physical condition.

4 SYSTEM SHUTDOWN. The principal reason for a shutdown is energy conservation; a secondary reason is for maintenance. Because of steam

monitoring for various needs the entire year, the shutdown of a complete system is impractical. However, there is usually the possibility to shut down sections or individual lines of the system. When a shutdown involves individual facilities, it is necessary to shut down the distribution piping to the facility, not just the facility, if there is to be any significant energy savings. The heat loss of piping through radiation and convection result in an energy loss of considerable measure.

4.1 Shutdown Procedure. Before shutting down the system, notify the steam generating station and the steam consumers. Then continue with the following shutdown procedure.

(a) Slowly close main valves.

(b) Crack open manual vent valves to relieve the pressure. The time required to bring down the pressure depends on the amount of throttling of the vent valves.

(c) Check operation of steam traps. When the system steam pressure is too low for proper operation of the traps, open the bypass valves for direct drainage of the condensate.

(d) Keep drain and vent valves wide open to ensure the lines drain properly.

(e) Keep draining equipment in service to eliminate any water resulting from infiltration in underground systems.

4.2 Shutdown of Piping.

CAUTION

Long lines which have been encased in a Gilsonite type moisture barrier should be given consideration before shutdown. Shutdown presents the possibility of cracking the barrier when the line contracts.

CAUTION

Where modifications have been made to the original configuration of the system or where metering and other devices protrude from the piping, shutdown may not be possible. Inspect entire line to ensure that, especially where clearances are minimal, contraction will not cause bending, damage, or breakage to piping and protrusion.

Shutdown of steam distribution piping does not require any unusual methods. After selecting the line to be shut down, close the valving to prevent steam from entering the line. Allow the line to cool, then open all drain fittings in the line to rid the line of condensate. Repair or replace all valves, traps, strainers, and other fittings that are known to be in need of maintenance.

4.2.1 Maintenance. While a steam distribution line is shutdown, maintenance of the piping and fittings should be performed. Although not all inclusive, the following is a listing of suggested action areas.

(a) Repair or replace traps known to be malfunctioning.

(b) Bench test traps which are in need of inspection.

(c) Insert traps at points known to require a trap but do not have one.

(d) Where appropriate, change type of trap to one more effective.

(e) Remove scale, dirt, flaking, and other residue from strainers.

(f) Replace damaged or worn strainer screens.

(g) Lubricate valve stems and replace dried packing.

(h) Inspect and repair entrainment separators.

(i) Inspect and repair pipe joints, expansion joints, and elbows.

(j) Inspect, repair, and calibrate any in place metering devices.

(k) Inspect and repair or replace sump pumps in pits and manholes.

4.2.2 Development of Internal Corrosion. The development of corrosion during a shutdown period is a possibility, but only if the lines and fittings are not properly and continually maintained. There are two basic types of chemicals used for preventing condensate corrosion, neutralizing inhibitors and filming inhibitors. Adding the selected amines to the boiler water counteracts corrosion. Adding filming amines prevents corrosion in piping that is in good condition, but the Navy does not sanction the use of filming amines and specifically prohibits their use for cold-iron support. If scaling and flaking are prevalent, a neutralizing inhibitor is required. The most comonly used neutralizing inhibitors are amines such as morpholine, cyclohexylamine, and diethylaminoethanol (DEAE). Channeling in drain lines, caused by the presence of oxygen, can be reduced by the addition of cyclohexylamine as a boiler-water additive. Because of their differing vapor-to-liquid ratios, two or more of the neutralizing amines may be used together to provide highly effective neutralization programs for complex systems. The choice of additives is a matter of judgment.

4.2.3 Safe Usage of Amines. Special caution must be observed when using live steam in humidification systems. Problems have been experienced with additives such as morpholine and DEAE. Special care should be observed where steam may be in direct contact with food. Under the Code of Federal Regulations (Title 21, Section 173.310), boiler-water additives may be safely used in the preparation of steam that will contact food under the following conditions.

(a) The amount of additive does not exceed that required for its functional purpose, and the amount of steam in contact with food does not exeed that required to produce the intended effect in or on the food.

(b) The compounds are prepared from substances identified below and are subject to the limitations prescribed:

Cyclohexylamine - Not to exceed 10 ppm in steam, and excluding use of such steam in contact with milk and milk products

DIethylaminoethanol - Not to exceed 15 ppm in steam, and excluding use of such steam in contact with milk and milk products

Morpholine - Not to exceed 10 ppm in steam. and excluding use of such steam in contact with milk and milk products -

Octadecylamine - Not to exceed 3 ppm in steam, and excluding use of such steam in contact with milk and milk products

5 EMERGENCY PROCEDURES. Repair all piping leaks as soon as possible. If leaks cannot be repaired with the system in service, make arrangements for a shutdown. Often the defective line can be isolated by closing sectionalizing valves while maintaining the service to affected consumers with steam supplied through an alternate route by means of a loop closure. A loop closure is a closing link of distribution piping that permits the flow of steam through two or more routes.

6 CASUALTY PLANNING. Piping system operators should be familiar with the location and arrangement of the piping system, valves, associated equipment, and controls. Give definite instructions on emergency procedures to operators. Schedule and carry on periodic fire drills, inspections, and other emergency procedure tests. Train operators in the use of available fire fighting and emergency draining equipment.

Section 4. MAINTENANCE OF STEAM DISTRIBUTION SYSTEMS

1 INSPECTION AND MAINTENANCE. Trouble-free service and piping system reliability is promoted by proper operating procedures, including the following requirements:

(a) Proper Operating Temperatures and Pressures. Do not operate piping systems beyond their normal pressure and temperature ratings except during emergency conditions and under careful observation.

(b) Normal Makeup. Watch closely the makeup requirements in the generating plant. If the required makeup increases noticeably, investigate the distribution system for possible leaks.

(c) Correct Operation. Follow operating procedures as described in section 3 of this chapter. Make sure the piping system is always drained of condensate and adequately vented. Check the operation of expansion joints or loops. Make sure that supports, hangers, anchors, and guides adequately support and guide the pipes.

(d) Ventilation and Draining. Make sure that manholes and conduits of underground systems are always well ventilated and drained.

(e) Cathodic Protection. Follow manufacturer's instruction for the proper operation of cathodic protection systems. Take rectifier readings monthly and make Structure-to-Electrolyte potential readings quarterly as described in paragraph 2.4.5. Report inconsistent readings to your supervisor or EFD (Code 102) immediately.

2 PREVENTIVE MAINTENANCE INSPECTION. Piping systems should be inspected with a frequency that depends on the particular installation and type of service given. Inspection schedules and actions adequate for average installations are presented in the following paragraphs.

2.1 Monthly Inspection of Aboveground Systems. Check for the following conditions:

(a) Leaks

(b) Damage to insulation

(c) Abnormal pressures and temperatures

(d) Abnormal pressure drops

(e) Condition of steam traps, strainers, and moisture separators.

(f) Vibration

(g) Correct operation of associated equipment such as steam traps, pumps, pressure and temperature controllers, strainers, and auxiliaries,

2.2 Yearly Inspection of Aboveground Systems. Inspect the following items.

(a) Inspect piping. Check for corrosion, leakage, loose joints, damaged or missing supports.

(b) Inspect condition of insulation. Check for damaged protective jacket.

(c) Check for settling or shifting in position of poles, hangers, or other supporting members. This is determined by checking the grade of the lines.

(d) Inspect valves for leakage, corrosion, defects in stems, packing glands, handwheels, bodies, flanges, and gaskets.

(e) Inspect valve and meter pits. Check for clogged vents, structural damage, missing covers, and accumulations of dirt and debris.

(f) Inspect condition of flanged fittings. Leaks should be repaired as soon as possible; otherwise, wire drawing of flanges and damage to the insulation may occur. Leaks cause a loss of treated water with consequent increase in the makeup requirements.

(g) Condition of expansion joints.

(h) Condition of anchors, hangers, guides, and supports.

(i) Condition and calibration of pressure reducing stations.

(j) Setting of relief and safety valves.

(k) Condition and calibration of instruments.

(1) Condensate return piping. Check for siqns of corrosion caused by corrosive gases, chiefly carbon dioxide and oxygen, dissolved in the - condensate. Refer to chapter 6 for details on condensate return piping.

2.3 Hydrostatic Tests. Test the system with water pressure following major repairs involving pipe welding or making up joints. This should be done before applying the insulation. Use a water pressure equivalent to one and one-half times the distribution supply pressure. Hydrostatic tests should be held for a minimum of 4 hours.

2.4 Inspection of Underground Systems. The scheduling and procedures presented for aboveground systems also apply to underground systems. In addition, paragraphs 2.4.1 through 2.4.5 give information relative to underground systems specifically.

2.4.1 Nitrogen Monitoring System. This is a system developed for field testing of leaks in underground conduits. It consists of pressurizing the airspace of the casing with nitrogen, a commercially available inert gas. When no leaks are present, the nitrogen pressure is maintained fairly constant. Should a leak develop, a pressure drop will be produced, which is detected by a control system installed for that purpose.

2.4.2 Consideration should be given to installing alarm systems within the air space of conduit systems which is based on time domain reflectrometer technology. Such alarm systems can signal the presence of a leak, record the location, and log the time of the first sensing of the leak. These alarm systems can be retrofitted into existing underground heat distribution systems as well as installed in new installations,

2.4.3 Infrared Thermography will assess the overall performance of buried distribution systems by measuring the varying intensities of thermal radiation at the surface of the ground. Infrared radiation video sensing systems identify and record ground surface temperatures. These findings are then interpreted by applying knowledge of buried distribution systems to identify and analyze the results. Thermography is an effective tool for performing maintenance by identifying problem areas without excavation.

2.4.4 Metallic Casings (Class A Systems). Look for evidence of leakage as indicated by pending, erosion, or settlement of areas near piping. Weekly checks of telltales will indicate the presence of leaks in the inner pipe by the discharge of steam. Telltales are installed in the casing and carried to aboveground level. When a leaking main is put out of service for some time, any appreciable leakage will soak the insulation.

(a) Drying of Insulation. Systems may become wet because of improper handling during installation, subsequent inner pipe or casing failure, or floods . For that reason they must be dryable, and the inner pipe insulation must be capable of withstanding boiling such as would occur with a failure of the inner pipe. To dry the insulation proceed as follows:

(1) Remove the drain and vent plugs and drain any water accumulation from the conduit.

(2) Place lines in operation. This will apply heat to the insulation through the inner piping, helping the drying process.

(3) Circulate pressurized air through the conduit airspace. Inject the air through a vent located at the high end of the run and force the water out of the lower end. The rate of ventilation should not beless than 2 cubic feet per minute, nor higher than that producing an air linear velocity of 500 feet per minute in the airspace. The average air velocity is determined by dividing the cubic feet per minute at atmospheric pressure by the area of the ventilated air passages, expressed in square feet. The area is taken in a plane at right angles to the centerline of the pipe. In any case, the required air pressure at the inlet end of the conduit should not be higher than 20 psig, and the resulting air velocity should not be high enough to damage the insulation by either impact or erosion.

(4) While drying the insulation, place a cool mirror at the exhaust point for a short time at appropriate intervals. Locate the mirror so that it may show maximum clouding caused by moisture. Shut down the air occasionally to allow it to heat up in the conduit.

(5) Continue the drying process for not less than 48 hours. In any case, do not stop until the mirror shows no visible clouding.

(b) Field Air Pressure Test for Casing Watertightness. Proceed as follows:

(1) Make sure that the system is dry.

(2) With the lines in operation, apply air pressure to the space between the conduit and pipe until obtaining 20 psig. If the system is reasonably watertight, this pressure should hold for at least 2 hours without requiring any additional air supply.

(3) During the. test, examine all accessible joints for leaks by applying a solution of soap and water. Apply the soapy lather after wire brushing the joints.

(4) Mark leaks, if any. Make repairs after releasing the air pressure, and test again.

(5) Leaks can be detected using SF6 tracer gas For a complete discussion of methodology, see NEESA 32-015, Location of Leaks in Pressure Testable Direct Burial Conduits - Operator's Manual.

2.4.5 Class B Systems. When conduit leaks are suspected, perform the following procedure before putting the line back in service.

(a) Permit all drainable water to drain back to manholes by loosening the manhole glands as required.

(b) If appreciable moisture is observed, put the line in service by turning on the steam. This will raise the temperature of the piping, evaporating the moisture which is then released through the pipe ends in the manholes.

(c) Emergency conditions may require digging down to the conduit, or to one of the sealing strips, to install a temporary vent until permanent repairs can be carried out. This releases steam, preventing the buildup of excessive pressures which may result in the failure of the conduit or the sealing strips.

(d) Drying of Insulation. Use same procedure as described in paragraph 2.4.2(a) for metallic casings. The rate of forced ventilation should be limited to 2 cubic feet per minute during a 48-hour period. Allow a maximum air pressure of 12 inches water gauge anywhere in the conduit airspace.

(e) Odorization Test. One method often used to detect leaks is known as the odorization test. This test consists of introducing properly odorized air under pressure into the airspace cavity of the conduit through a conveniently located vent. With all other vents and drains closed, leaks can be located by the odor of the escaping air.

(f) SF6. Refer to paragraph 2.4.2.b(5).

2.4.6 Tunnels and Manholes. Mechanical ventilization is often provided for tunnels to remove obnoxious gases that might accumulate, to carry away moisture saturated air, and to facilitate maintenance through better ambient conditions for 'workmen. Mechanical ventilation can be provided permanently by exhaust fans installed in the generating plant to create a slight negative draft in the tunnel. Atmospheric air enters the tunnel through the manhole vents, circulates through the tunnel, and is discharged to the atmosphere by the exhaust fans. Often temporary ventilation is obtained by fans arranged to force air into the manholes. Perform inspections according to the following schedules,

(a) Monthly Inspection. Inspect manholes and check operation of the draining equipment.

(b) Quarterly Inspection. Inspect and tighten the packing of conduit gland seals. The friction caused by the movement and the heat conducted from the pipe shortens the life of the packing. Repack the gland before a defective packing permits water to enter. Gland seals on lines that are frequently turned on and off require more maintenance than those installed on lines operating on longer cycles. The inspection frequency depends on the particular installation.

(c) Yearly Inspection. Make a general overhaul of sump pumps and team ejectors after the heating season. Inspect manholes for water leaks and check condition of ladders, waterproof covers, electrical fixtures and installation, and vents. Check supports, guides, expansion joints, and all auxiliary equipment.

2.4.7 Inspection of Cathodic Protection Systems. Consult specific instructions furnished by the manufacturer or designer of the system for the particular installation. NAVFAC MO-306, Maintenance and Operation of Cathodic Protection Systems and)40-307, "Cathodic Protection Systems Maintenance" give specific guidance for the inspection and maintenance of cathodic protection systems. In general, the following inspection schedules apply:

* Impressed current Systems: Read and record rectifier settings and outputs monthly. Record information on NAVFAC Form 9-11014/17B. Notify EFD (Code 102) if inconsistent readings are observed.

* Galvanic Anode and Impressed Current Systems: Make Structure-to-Electrolyte Potential readings at selected test points quarterly. Record information on NAVFAC Form 9-11014-17B. Notify EFD (Code 102) if inconsistent readings are obtained.

3 OVERHAUL AND REPAIRS. Paragraphs 3.1 through 3.4 contain instructions for overhauling and repairing equipment as indicated by periodic inspections, or as required by breakdowns.

3.1 Maintenance of Main Lines and Conduits. Proceed as follows:

(a) Make necessary repairs as recorded during periodic inspections performed in accordance with the preventive maintenance program.

(b) Repair all piping leaks immediately by tightening loose connections, tightening or repacking valve glands and conduit seal glands, replacing gaskets, and welding or replacing defective parts or sections.

(c) Repair the coatings and coverings that protect metallic conduits as necessary. If the area to be recoated is small, a standard asphalt blanket patch cut to cover the required area may be used. The patch is heated with a torch and trowelled over the damaged area. For larger areas, the following procedure may be used.

(1) Obtain a canvas blanket of adequate size to be used as a form around the casing. Nail a piece of 2-inch by 2-inch wood to both ends of canvas to provide a better handhold.

(2) Coat inside surface of canvas with grease or oil.

(3) Pour hot asphalt on top of the conduit, letting it flow down around the bottom. While pouring, keep shifting the blanket up and down around the conduit to prevent asphalt from sticking to the blanket. This method will permit covering the low two-thirds of the conduit.

(4) Complete the covering by pouring hot asphalt on top of the conduit and smoothing with trowel and torch.

(5) Finish by wrapping the repaired area with 30-pound roofing felt.

(d) Replace damaged insulation.

(e) Repair leaks in metallic conduits by caulking, peening, or welding. Replace defective sections, if required.

(f) Provide and maintain effective water drainage of the system.

(g) Use proper gasket material of correct design for the fluid pressure and temperature service conditions.

(h) Perform suggested corrosion control techniques.

(i) Repair or replace supports, hangers, guides, expansion joints, and auxiliary equipment as required.

(j) Stop water leaks in the floor and walls of tunnels and conduits (refer to paragraph 3.3(a)).

(k) Use clean, uniform backfill for pipe trenches of underground systems. Do not use frozen fill, sod, cinders, or large stones. Backfill the trench simultaneously on both sides of the conduit to prevent unequal or unbalanced side pressures. Backfill in layers 6-inches thick up to 6 inches above top of conduit. Protect traffic crossings with timbers until the fill settles.

3.2 Maintenance of Cathodic Protection Systems. General maintenance procedures for cathodic protection systems are found in NAVFAC MO-306, Maintenance and Operation of Cathodic Protection Systems and MO-307, “Cathodic Protection Systems Maintenance. Make repairs or replacements as required after periodic inspections. Refer to manufacturer’s instructions for information on maintaining specific installations and equipment.

3.3 Maintenance of Manholes. Make repairs as recorded during periodic inspections of maintenance program.

(a) Water leaks. Stop water leaks in the floor and walls. For concrete manholes, proceed as follows:

(1) Chip out the porous area using a cold chisel and a hammer. This will expose sound concrete facilitating patch bonding.

(2) Plug holes or cracks with a quick setting cement mortar or with a putty made of calcium chloride and water.

(3) If water enters through the manhole floor, first clean the floor, removing accumulated silt. If the floor is generally sound, except for the joints at the wall or isolated cracks, proceed as indicated in (1) and (2) above. If the concrete of the floor shows general porosity, pour a new floor.

(b) Repair ladders as required.

(c) Repair electrical installation and fixtures if necessary,

Section 5. STEAM TRAP MAINTENANCE PROGRAM

1 MAINTENANCE PROGRAM. Steam traps, like all other components of utility systems, have a structured maintenance program to ensure system integrity, energy conservation, and cost reduction. The program must be well planned and conscientiously implemented.

1.1 Trap Replacement. The economic comparison between losing steam and repairing or replacing steam traps can be estimated. The difference in costs of a neglected system and a regularly maintained system can also be estimated. As traps wear with age, the steam used to make a trap function increases approximately 3 pounds per year for the first 3 years. After that, it can increase by as much as 8 pounds per year. The following empirical formula is the result of a study at the Navy Post Graduate School, Monterey, CA. It may be used as a guide for optimum time for trap replacement.

$$\text{Time in service (years)} = \frac{\text{Cost of trap replacement (\$)}}{11.3 \times \text{Cost of steam (\$/Mlb)}}$$

For example, if a trap costs $250 to replace and steam costs $10 per pound to produce:

$$\text{Time} = \frac{\$250}{11.3 \times \$10} = 1.5 \text{ years}$$

This formula illustrates that a relatively small quantity of steam lost each hour can make frequent trap replacement economical. Experience and discretion must be used when determining trap replacement. Replacement time depends a great deal upon the trap type and design.

1.2 Continuous Maintenance. Industry experience has shown that in a system which is without a planned program, between 10 and 50 percent of the traps may be malfunctioning at any one time. In a system which produces 300 million pounds of steam per year at a total cost of $3 million, approximately 75 percent of the cost is fuel (a direct variable cost). A 1 percent improvement in the efficiency of the system through steam trap inspection and maintenance could save over $20,000 a year in fuel costs.

1.2.1 Program Establishment. The following steps should be followed in setting up an effective program of steam trap inspection and maintenance.

(a) Baseline Survey. The initial survey provides or verifies records of steam trap location and type, provides a steam trap map, determines the baseline condition of the trap inventory, and checks installation and use for misapplication. Refer to figure 3-6 for an example of a format that could be used during a baseline survey of steam traps.

(b) Establish System Standards. Standards for types, sizes, and installation of traps eliminate misapplication, reduce inventory and system costs, and provide a basis for budgeting and trap replacement planning.

(c) Training. As a formal program is established, the people involved in operation, inspection and maintenance, energy conservation, and engineering must be trained and indoctrinated in the goals of the program.

STEAM TRAP BASELINE SURVEY

DATE:____________ AREA/MAP NO.:____________ INSPECTOR:____________

Tag No.	Bldg/Grid Location	Mfg, Model	Size	Location Description	Installation/ Service Description	O-Oper. F-Failed	Priority for Action/Remarks 1-Immed. 2-Schedule 3-Backlog

FIGURE 3-6. Example Baseline Survey Form

d) Equipment. Proper equipment for inspection pays for itself in improved ap uptime and savings in manpower.

(e) Establish Inspection Schedules. A balance between the cost of inspection and potential savings in operational costs must be achieved.

(f) Accurate Records. Records that are easy to keep, which induce accurate entries, and support the program are a must.

(g) Improve Condition of the System. A longer range, but integral, objective in establishing a formal program is to bring the condition of the steam traps to a level where inspection and maintenance are routine money-makers rather than an uphill battle.

For a detailed description for implementing of each of the steps, refer to Steam Trap User's Guide, UG-0005, April 1985, Naval Civil Engineering Laboratory, Port Hueneme, CA.

2 TRAP INSPECTION. The cost of steam lost through a leaking trap in one day can exceed the cost of a new trap. If a trap is not discharging condensate at its designed rate, the reduction in efficiency of the steam-using equipment can waste more money in one day than the cost of the trap. Good inspections that pinpoint problem traps for early repair or replacement are important. While the trap is the focus of the inspection, external conditions of the trapping station should be inspected as well. Supports, bracing: insulation, external leaks, and corrosion should receive attention from the inspector during each trap inspection. The following paragraphs describe inspection schedules, safety precautions, methods of inspection, trap failure, troubleshooting, and inspection reports and records.

2.1 Inspection Schedules. The frequency of steam trap inspections should be based upon the condition of the system, age of the traps, and percentage of traps found to be faulty in a baseline survey. A general guide for continuing inspection frequencies after the baseline survey is as follows:

Trap Failure Rate	Inspection Frequency
over 10%	monthly
5- 10%	every 2 months
less than 5%	every 3 months

2.1.1 One manufacturer recommends inspection frequencies based on system pressure as shown:

Pressure	Inspection Frequency
0 - 30 psi	Annual
30 - 100'	Semiannual
100 - 250	Quarterly or monthly
over 250	Monthly or weekly

2.1.2 More thorough but less frequent inspections are more effective than frequent inspections of the same equipment. The primary goal in scheduling inspections is to achieve a balance between the cost of inspection and steam loss and integrity of the system. Exposed traps should be monitored daily during freezing weather. Also, traps serving critical process equipment should be monitored frequently.

2.2 Safety Precautions. The following personal safety precautions are recommended.

Steam lines, traps, and steam equipment are HOT. Follow all safety rules for working where burns are potential.

Wear protective clothing and safety gear (hardhat, goggles, gloves) when appropriate.

Steam valves should be opened or closed only by authorized personnel.

Always wire valve closed and attach DO NOT OPEN tag before working on or removing traps and strainers.

Always isolate the steam trap from steam supply and pressurized return live before opening the trap for inspection or repair.
Always isolate a strainer from pressurized system before opening.

Never touch a steam trap with bare hands.

For strainer blowdown, wear gloves and a face shield. Catch discharge in a bucket.

2.3 Inspection Methods. The basic methods of inspecting traps are visual observation, sound detection, and temperature measurements. Visual observation is the easiest and least costly method of checking trap operating condition, but none of the methods provide a cure-all for trap troubleshooting. Any one method can give misleading results under certain conditions. The best inspection is obtained by using a combination of two methods. A quarterly steam trap program report is required from the EFDs based on their assessment and verification that a viable steam trap maintenance program exist at the activity level. Procedures for the three methods are covered in paragraphs 2.3.1 through 2.3.4. The application of these methods in routine inspections and in troubleshooting traps that may be failing is covered in paragraphs 2.4 through 2.4.3 and 2.7 through 2.7.3.

2.3.1 Visual Observation. Observing the discharge from a trap is the only positive way of checking its operation. This can be accomplished simply by having a atmospheric vent downstream of the steam trap. Refer to figure 3-7.

Flash steam is the lazy vapor formed when hot condensate comes in contact with the atmosphere. Some of the condensate reevaporates into a white cloud appearing as steam mixed with the discharging hot water.

Live steam is a higher temperature, higher velocity discharge than flash steam and usually leaves the discharge pipe in a clear flow before it condenses to a visible cloud of steam in the atmosphere.

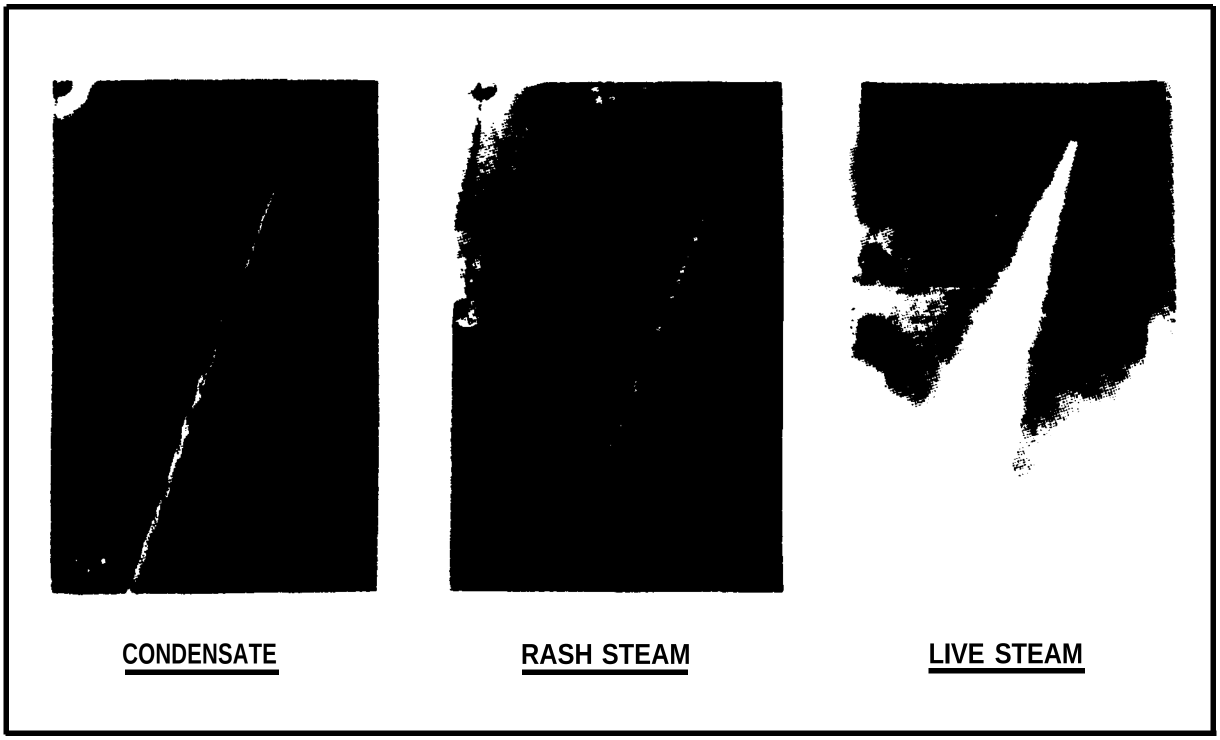

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FIGURE 3-7. Difference Between Flash Steam and Live Steam

The following descriptions apply to visual observation.

(a) If the trap discharges to a closed condensate return system, it must have a slaved test discharge pipe open to the atmosphere installed downstream of the trap.

(b) A properly operating trap will discharge condensate and flash steam as it cycles. Some types of traps (inverted bucket, disk) have an intermittent discharge, others (float, F&T) should have a continuous condensate discharge, and certain types (thermostatic) can be either. The presence of a continuous live steam discharge is a problem. The lack of any discharge also indicates trouble.

(c) Inspectors should realize that when a trap is under a fairly heavy load the discharge produces considerable flash steam. A faulty trap may be losing a significant amount of live steam that cannot be detected. In a condensate discharge of, for example, 100 lb/hr a loss of 10 lb/hr of live steam will not be visually detectable. This relatively small loss can amount to the cost of a new trap in 2 to 3 months. Therefore, if a trap is suspected of being faulty, always check your visual inspection with another method.

(d) A basic part of visual inspection is determining if the trap is cold or hot at operating temperature. One method is to squirt water on the trap top and observe its reaction. The water will not react on a cold trap, but will bubble and bounce on a hot trap.

2.3.2 Sound Detection. Listening to traps operate and judging performance and potential malfunction are convenient inspection methods when working with a closed condensate return system. Experience is required, but much can be derived from the sounds made, or not made, by traps while operating. The following descriptions apply to sound detection.

(a) By listening carefully to steam traps as they cycle, a judgment can be made whether they are operating properly or not. An inspector can hear the mechanisms working in disk, inverted bucket and piston traps. Modulating traps give only flow sounds which are hard to detect if the condensate load is low. However, the performance of a suspected trap should be cross-checked visually or by temperature measurements since a trap that does not cycle may be either failed open or under a heavy condensate load.

(b) Simple equipment can be effective, such as industrial stethoscopes or a 2-foot length of 3/16-inch steel rod in a file handle. They are used simply by placing the probe end on the trap bonnet and your ear against the other end.

(c) If there are a large number of traps or situations where traps are congested or close to other equipment generating noise, ultrasonic listening equipment is warranted. These instruments have earphones, are equipped with probes, and allow selection of sound frequency bands. High frequencies are sensitive to flow noise, and low frequencies are sensitive to mechanical sounds.

2.3.3 Temperature Measurements. Diagnosing trap condition from temperature differences between upstream and downstream pipes is the least reliable inspection method. It can be useful in combination with visual or sound inspection as long as the potential ambiguities are recognized. Equipment types range from sophisticated infrared meters, to simple thermometers and heat sensitive markers. A contact thermocouple thermometer is recommended.

2.3.4 Measurements Technique. File contact points on the pipe clean. Take temperature measurements immediately adjacent, no more than 2 feet, on either side of the trap. The readings should be in the ranges shown in table 3-1 for the pressures in the supply and discharge/return lines. Interpretation of the temperature readings requires knowledge of the line pressures. For example, a supply line at 150 psig with temperature of 340°F, and a return line at 15-psig with temperature of 230°F, indicate a properly operating trap.

2.4 Inspection Procedures.

2.4.1 Data Preparation. Before beginning routine periodic inspections, the trap inventory should be current, steam trap maps of buildings and exterior areas should be prepared, and traps tagged with stainless steel tags for permanent identification. Inspectors should be provided with effective and convenient equipment. The use of two different colored tags is one method for identifying cold traps for investigation: and failed or faulty traps for maintenance and repair. A suggested equipment list follows and is illustrated in figure 3-8:

Carrying pouch and belt

Clipboard with trap lists and trap maps

TABLE 3-1. Normal Pipe Temperatures at Various Operating Pressures

Steam Pressure (psig)	Pipe Surface Temperature Range (°F)
0 (atmosphere)	212
15	225-238
30	245-260
100	305-320
150	330-350
200	350-370
450	415-435
600	435-465

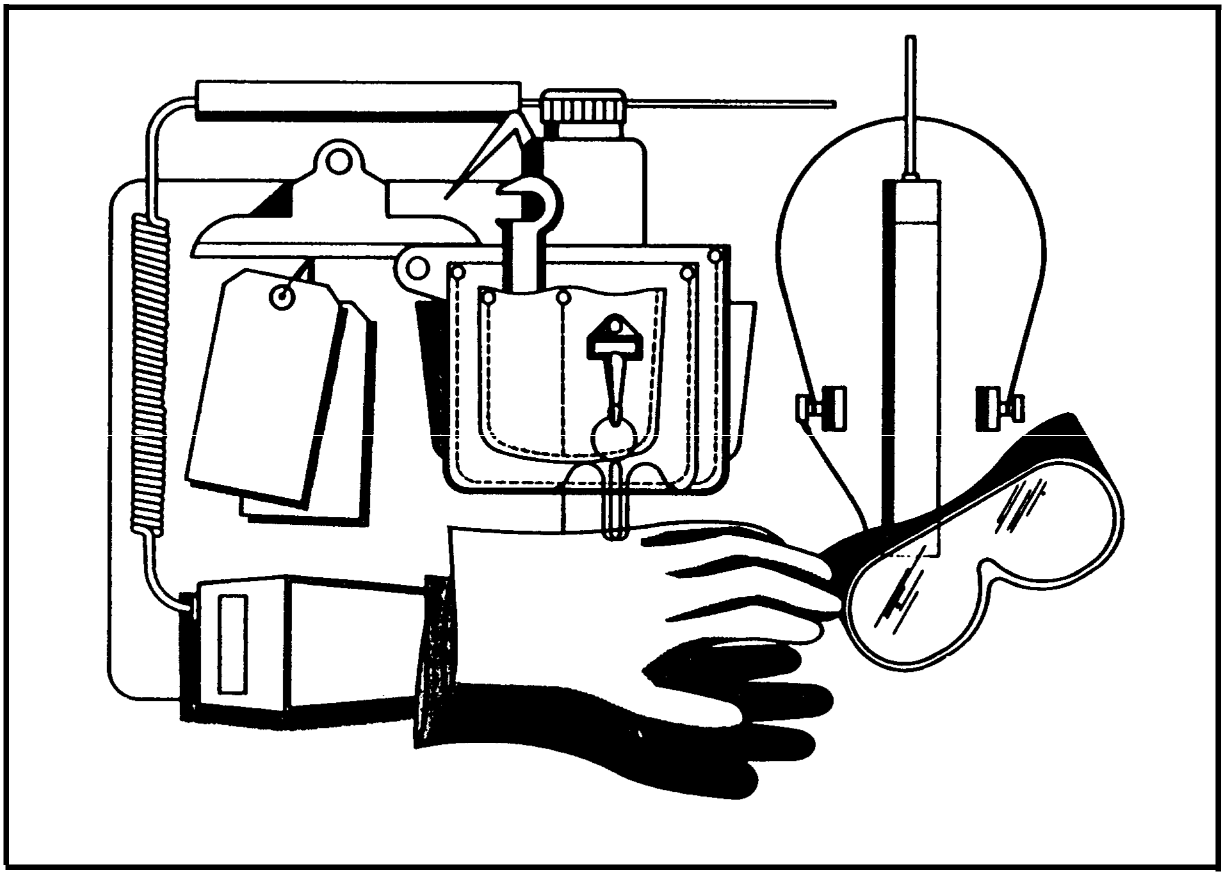


FIGURE 3-8. Steam Trap Inspection Equipment

Maintenance requirement tags (yellow and white)

Valve wrench

Water squeeze bottle

Ultrasonic sound detector

Thermocouple thermometer

2.4.1 Description of Test procedure (see figure 1):

First close Valve (l). Then close valve (2), as this prevents back feeding of steam from the condensate header. Open valve (3). Valve (3) is part of the test "T" which has been installed previously for testing the steam trap. If steam blows out of test T, this is an indication that trap is malfunctioning. If only condensate drips out, this indicates that the trap is functioning properly (Note that a small amount of flash steam could come out). Then open valve (4). If steam blows out of valve (4) under pressure, it means the trap is holding steam and that there was steam up-stream of the trap during test.

After the tests are complete, open (2), close (3), close (4) and slowly open (1) for normal operation.

Note that there is no longer a by-pass around the steam trap. All valves should be ball requiring 1/4 turn from fully open to fully closed. All valves should have round handles instead of bar handles for safety. Clothing could catch on a bar handle and accidentally open the valve. The test "T" end pipe and the end pipe for valve (4) should point down to the ground or in another safe direction.

2.4.2 Check-off List. The following is a summary of steps for routine inspections that apply the methods outlined in paragraph 2.3.

(a) For All Traps:

Is steam on?

Is trap hot - at operating temperature?

Net test for signs of a hot trap. Squirt a few drops of water on trap. Water should start to vaporize immediately. If it does not, this indicates a cold trap.

Tag cold traps with a yellow tag for maintenance check to determine if it is a system or trap problem.

Blow down strainer.

(b) Sound Check Hot Traps:

Listen to trap operate.

Check for continuous low pitch condensate flow.

Check for continuous high pitch steam flow.

Check for intermittent flow.

Is trap cycling?

Note mechanical sounds.

(c) Visually Check Traps That Sound Abnormal:

Close valve to return line.

Open discharge valve.

Observe discharge for normal condensate and flash steam.

Observe discharge for live steam.

Observe discharge for continuous or intermittent operation.

(d) Temperature Check if Necessary:

Clean spots upstream and downstream of trap for measuring temperature.

Record supply line pressure

Measure supply line temperature.

Record return line pressure.

Measure return line temperature.

Tag failed traps with white tag for either replacement or shop repair.

(e) Check External Conditions:

Supports and braces

Insulation

Corrosion

Leaks

2.4.3 Inspection for Misapplication. Inspectors should be aware of and inspect for the following potential misapplications and installation problems.

Trap installed backwards or upside down.

Traps located too far away from the equipment being serviced. Piping runs are too long.

Traps not installed at low points or sufficiently below steam-using equipment to ensure proper drainage.

Traps oversized for the conditions. Oversized traps allow live steam blowthrough.

More than one item of equipment served by one trap. Group trapping is likely to snort circuit one item due to differences in pressure and other items will not be properly drained.

The absence of check valves, strainers, and blowdown cocks where required for efficient operation.

Trap vibration due to insecure mounting.

Bypass line with valves open. If a bypass is necessary, it should be fitted with a trap.

Condensate line elevation is so high that the steam pressure cannot lift the condensate through the trap. Traps do not lift condensate; inlet steam pressure does.

Inverted bucket traps and float and thermostatic traps, which are susceptible to freezing.

Thermostatic and disk traps that are insulated. These traps must emit heat to function.

Disk trap with excessive backpressure; therefore, a differential pressure that is too low for the trap to operate properly.

Determine accessibility of trap for inspection and repair.

Ensure trap is located below drip point whenever possible.

Check whether trap is close to the drip point.

2.5 Trap Failures. By failing closed, there is a backup of air and condensate that floods the equipment. Flooding prevents the equipment from performing its heat transfer function. By failing open, air, condensate, and steam continue through the trap into the condensate system. This pass-through wastes steam and affects heat transfer equipment by excessive pressures and temperatures in the return lines. Major causes of trap failure are residue buildup and wear. Industry has found the combination ball-float and thermostatic steam traps to be the most reliable and cost effective. The thermostatic part of the trap is to pass condensate should the ball-float fail closed, and to release air on initial start-up.

(a) Residue. Dirt, rust, and foreign particles can build up in steam traps, because when the valve is closed the trap body forms a natural pocket. Dirt pockets should be installed on all steam header drip legs and the strainers should be opened periodically for blow-down. Strainers, whether installed before the trap or included in the body of the trap, should have blowdown cocks installed. Installed, operating strainers are one of the most important protections for traps, but are only as good as their care. Figure 3-9 shows typical trap installations with strainers and blowdown valves. The following conditions should be checked.

All strainers should be blown down every inspection.

Residue between the seat and disk may cause a trap to fail open; residue buildup in the trap body may cause a trap to fail closed.

Piston impulse traps, disk traps, and orifice traps have small holes and should have a fine mesh strainer.

(b) Wear. Wear of internal parts, linkages, and seals will cause trap failures. Failure can be in either the open or closed position. The following are some typical wear conditions.

(1) When the mating surfaces of valves and valve seats wear out, there is a tendency for an initial leak to enlarge by a process called wire-drawing, which shows up as a small gully worn across mating surfaces. Valves that are partially open because of residue lodged between the valve and seat can initiate wire-drawing, since high-speed steam will follow the condensate and cut the mating surfaces.

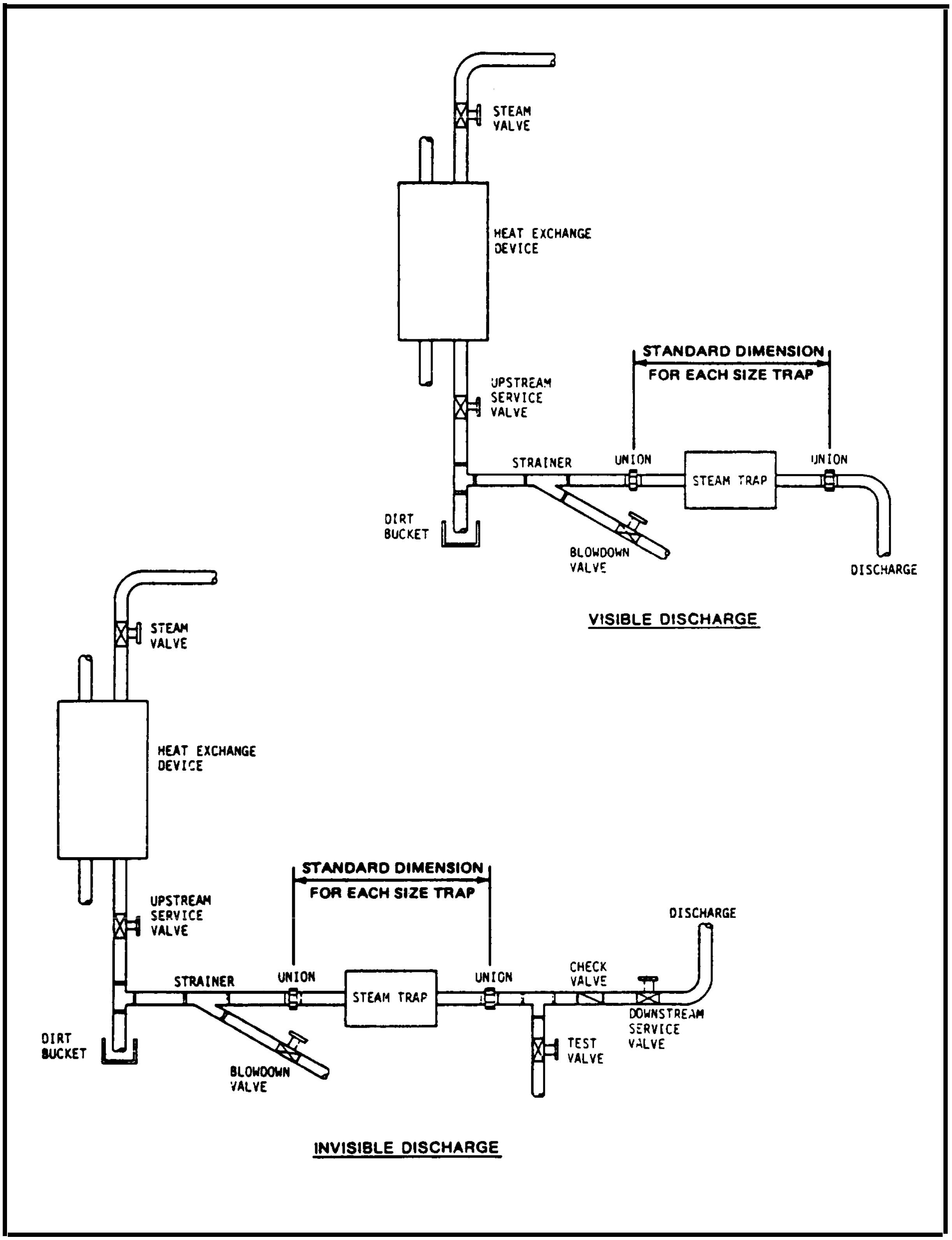


FIGURE 3-9. Typical Steam Trap Installations

(2) Cast iron and steel traps often have their valve seat loosened by the erosive effect of flashing condensate. This results in large leaks.

(3) Continuous operation and excessive use cause links, levers, pins, pivots, and elements to change shape and malfunction due to wear.

(4) If trap failure persists and a comprehensive inspection indicates that failure is not due to residue buildup or wear, the inspector may determine the problem to be system troubles rather than trap malfunction.

2.6 Troubleshooting.

2.6.1 Identification. During periodic inspections, inspectors have many traps to inspect. Fast identification of a faulty or failed trap is important. If the nature of the problem can be identified, so much the better. Economical, cost-effective inspection, though, depends on identifying problem traps with the least expenditure of labor. Correction of the problems can be scheduled in a consolidated, planned, efficient manner by the shops.

2.6.2 Diagnostics. Troubleshooting begins with the knowledge of trap operations and combines the methods of inspection with a familiarity with trap misapplications and potential failures that are discussed in this chapter. Table 3-2 outlines the basic indicators of normal operations and problems for the various types of traps.

2.7 Inspection Reports and

cords.

2.7.1 Inspection Log. An example inspection log is shown in figure 3-10. This log is intended to report results of periodic inspections and is a temporary record. The log does not repeat data contained in the steam trap inventory record.

2.7.2 Permanent Records. Permanent inspection and repair records are an important element in the inspection and maintenance program. The record provides information needed to identify chronic problem areas, develop life cycles costs, and generally aid in upgrading the steam system. Inspection report data should be transferred from the inspection log to the permanent record. The following data should be included in the permanent record:

Trap identification and location

Date initially installed

Scheduled inspection frequency

Date of last inspection

Date and description of last repair

2.7.3 Manual Records. If automation of the permanent trap records is not feasible, an alternative system that can be used is an index card system.

TABLE 3-2. Troubleshooting Steam Traps

Type Trap	Normal Operation	Problem Indication	Possible Cause/ Action
All types	Trap hot under operating conditions. Discharge mixture of condensate and flash stream. Cycling open/close depending on type of trap. Relatively high inlet temperature.	Visual Inspection Live steam discharge; little entrained liquid.	Failed open.
			Replace or overhaul trap.
		Condensate cool; little flash stream.	Holding back condensate.
			Check trap for dirt or inoperative valves.
		No discharge.	Failed closed; clogged strainer; line obstruction.
			Replace or overhaul trap; clean strainer; clear line.
		Leaking steam at trap.	Faulty gasket.
			Replace gasket.
		Temperature Measurement High temperature downstream.	Failed open.
			Replace or overhaul trap.
		Low temperature upstream.	Failed closed, clogged strainer, line obstruction.
			Replace or overhaul trap. Clean strainer; clear line.

TABLE 3-2. Troubleshooting Steam Traps (Continued)

Type Trap	Normal Operation	Problem Indication	Possible Cause/ Action
lost and F&T	Continuous discharge on normal loads. May be intermittent on light load.	Sound Inspection Noisy; high pitch sound.	Steam flowing through; failed open.
			Replace or overhaul trap.
	Constant low pitch sound of continuous flow.	No sound.	Failed closed.
			Replace or overhaul trap.
Thermo-static	Discharge continuous or inter-mittent depending on load, pressure, type. Constant low pitch sound of continuous or modulating flow,	Same as for float trap above.	
Inverted bucket	Cycling sound of bucket opening and closing. Quiet steady bubbling on light load.	Steam blowing through.	Failed open.
			Replace or overhaul trap.
		No sound.	Failed closed.
			Replace or overhaul trap.
		Discharging steadily; no bucket sound.	Handling air; check again in 1 hour.
			Clear vent or re-place trap.
		Discharging steadily; bucket dancing.	Lost prime.
			Add prima or re-place trap.
		Discharging steadily; bucket dancing after priming.	Failure of internal parts.
			Replace or overhaul trap.

TABLE 3-2. Troubleshooting Steam Traps (Continued)

Type Trap	Normal Operation	Problem Indication	Possible Cause/ Action
		Discharging steadily; no bucket sound.	Trap undersized.
			Determine correct size and replace trap.
Disk	Intermittent discharge.	Cycles faster than every 5 seconds.	Trap undersized or faulty.
			Replace trap.
	Opening and snap-closing of disk about every 10 seconds.	Disk chattering over 60 times/ minute or no sound.	Failed open.
			Replace or overhaul trap.

Each trap has its own index card with identifying and inventory data entered. The card is carried by the inspector during inspections and the observations are entered. One index card may allow room, front and back, for 10 to 12 inspections. Data must then be compiled manually from hundreds or thousands of cards to identify trends: to compile costs, and to pinpoint possible system problems. A manual system is much less effective than a temporary inspection log with data being entered into a report-generating computer system.

3 STEAM METERING. Steam metering is done principally to determine the efficiency of a steam system. The data collected from metering can aid in determining the feasibility of modifications or the effectiveness of energy conservation actions.

3.1 Metering Considerations. Steam is difficult to measure. It is a high temperature, compressible fluid with virtually no lubricating properties. Because of pressure and temperature fluctuations, the specific volume of the fluid changes. Most meters manufactured are capable of metering steam with reasonable accuracy. However, the various advantages and disadvantages of individual meters will affect the choice of meter selection for a particular application. The following items are for consideration.

(a) Pressure in a steam line fluctuates with demand and decreases in proportion to the distance from the central plant. PRESSURE COMPENSATION IS ESSENTIAL.

STEAM TRAP INSPECTION LOG

DATE: ____________ INSPECTION: ____________

TRAP I.D.	LOCATION	OPERATING	INSPECTION REPORT	REPAIR PRIORITY

FIGURE 3-10. Example Inspection Log

(b) Temperature compensation is recommended if there is any chance of metering superheated steam. Superheating can occur in a variety of situations: downstream of malfunctioning desuperheaters, downstream of pressure reducing stations. and downstream of certain piping configurations.

(c) Installation must be to ASME standards and/or manufacturer's specification. One of the most common metering errors is that the meter is placed where it is convenient, not where it should be. IF THERE IS NO SUITABLE LOCATION FOR THE METER, THE PIPING SHOULD BE RECONFIGURED.

(d) Inspect the meter site. Do not rely on drawings to establish line size and operating pressure. Commonly, meters are ordered for a pipe size listed in mechanical drawings. Then, when the true size of the line is discovered, the meters are made-to-fit. Similarly, boiler plants often operate at a pressure lower than designed.

(e) Maintenance. A steam meter, like any other piece of equipment, must be maintained. Bearings wear, orifices erode, and data recording equipment must be periodically resealed. A steam meter left to operate without regular maintenance cannot be trusted to give reliable results.

3.2 Meter Types. Steam meters are categorized into three main types: differential pressure, turbine (figures 3-11 and 3-12), and vortex shedding (figure 3-13). Since each type has advantages and disadvantages, the comparisons shown in table 3–3 can be considered before selection.

3.2.1 Orifice Meters. Orifice plate meters operate on a differential pressure principle. A differential pressure (DP), proportional to the steam flow, is measured across a knife-edged orifice plate (figure 3-14). DP varies as a function of the square of the flow. The following items are characteristics of orifice meters.

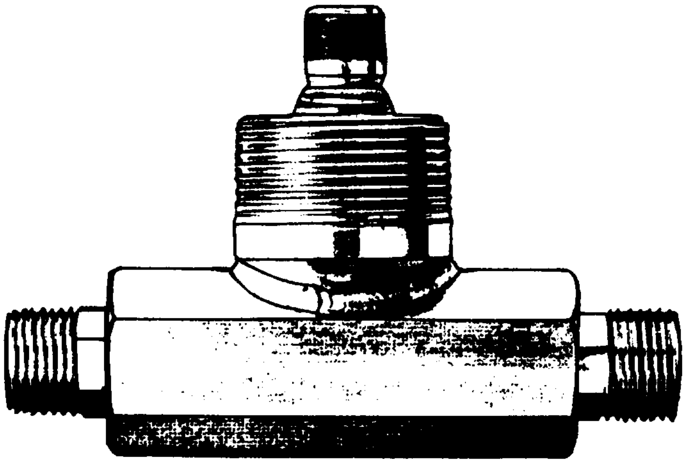
(a) Accuracy. Accuracy within the specified flow range is %1 percent full scale, but turndown ratio is limited, typically 3:1.

(b) Sizing. Sizing is critical because the differential pressure is small and the limited turndown ratio requires an accurate estimate of flow range.

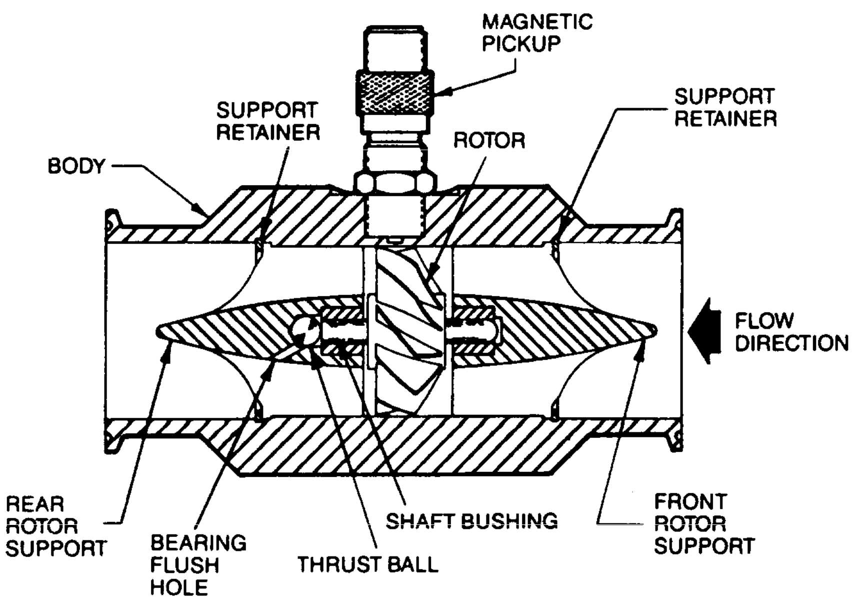
(c) Calibration. Calibration is relatively simple and accurate. It can be performed with a manometer and utilizes standard procedures familiar to most instrument technicians.

(d) Maintenance. Erosion of the knife edge is inevitable and replacement of the orifice is periodically required. Seasonal changes in flow may require change of the orifice to maintain accuracy within the flow range.

(e) Output. Orifice type meters typically output a pneumatic signal to a mechanical ring balance. The mechanical system is relatively crude and difficult to calibrate. Pressure compensation is also difficult. Another type DP transmitter converts the pneumatic signal to an electric analog signal that will drive strip chart recorder or data logger. This type transmitter is easily pressure compensated.



EXTERIOR VIEW



SECTION VIEW

FIGURE 3-11. Turbine Flowmeter

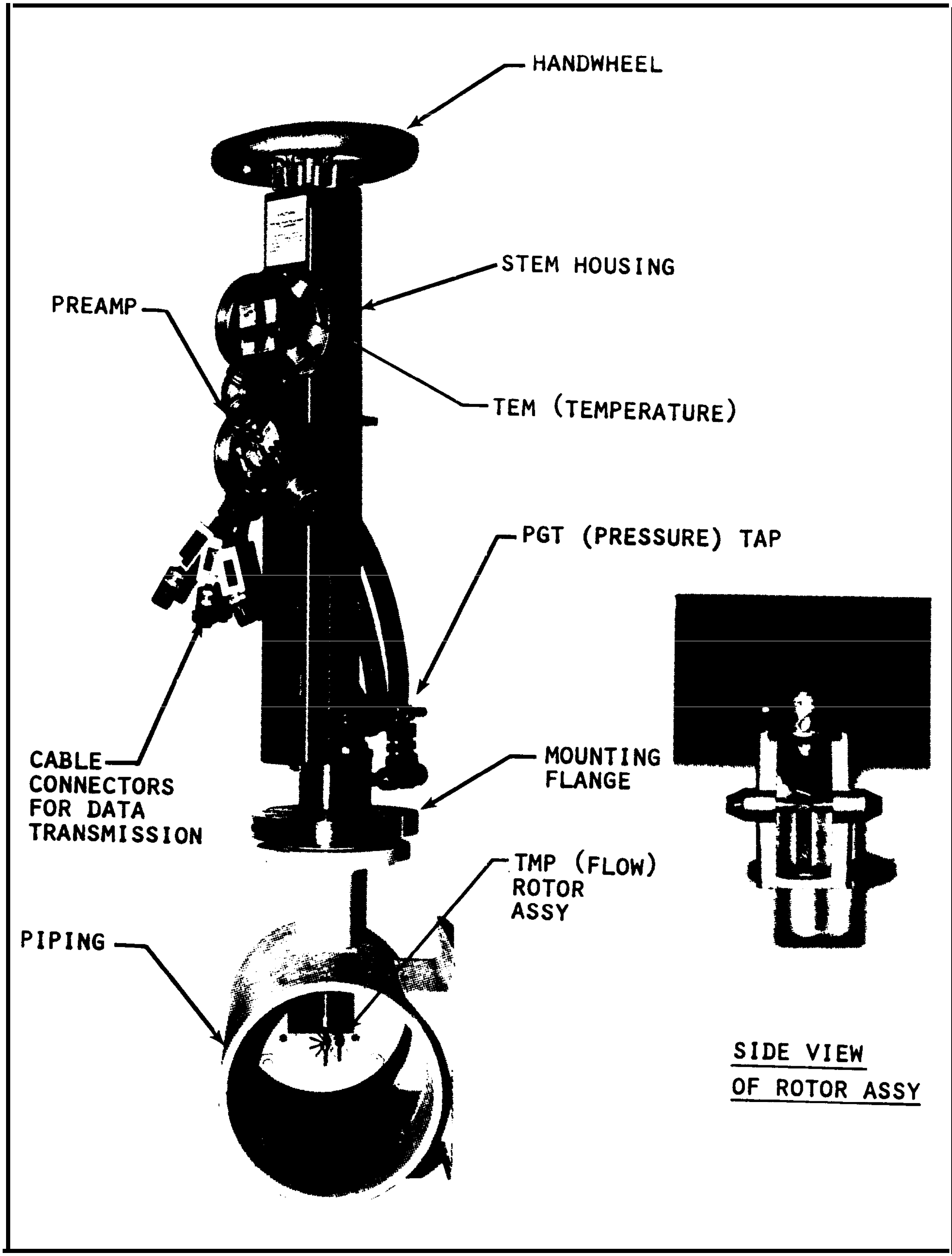


FIGURE 3-12. Insertion Turbine Meter Assembly

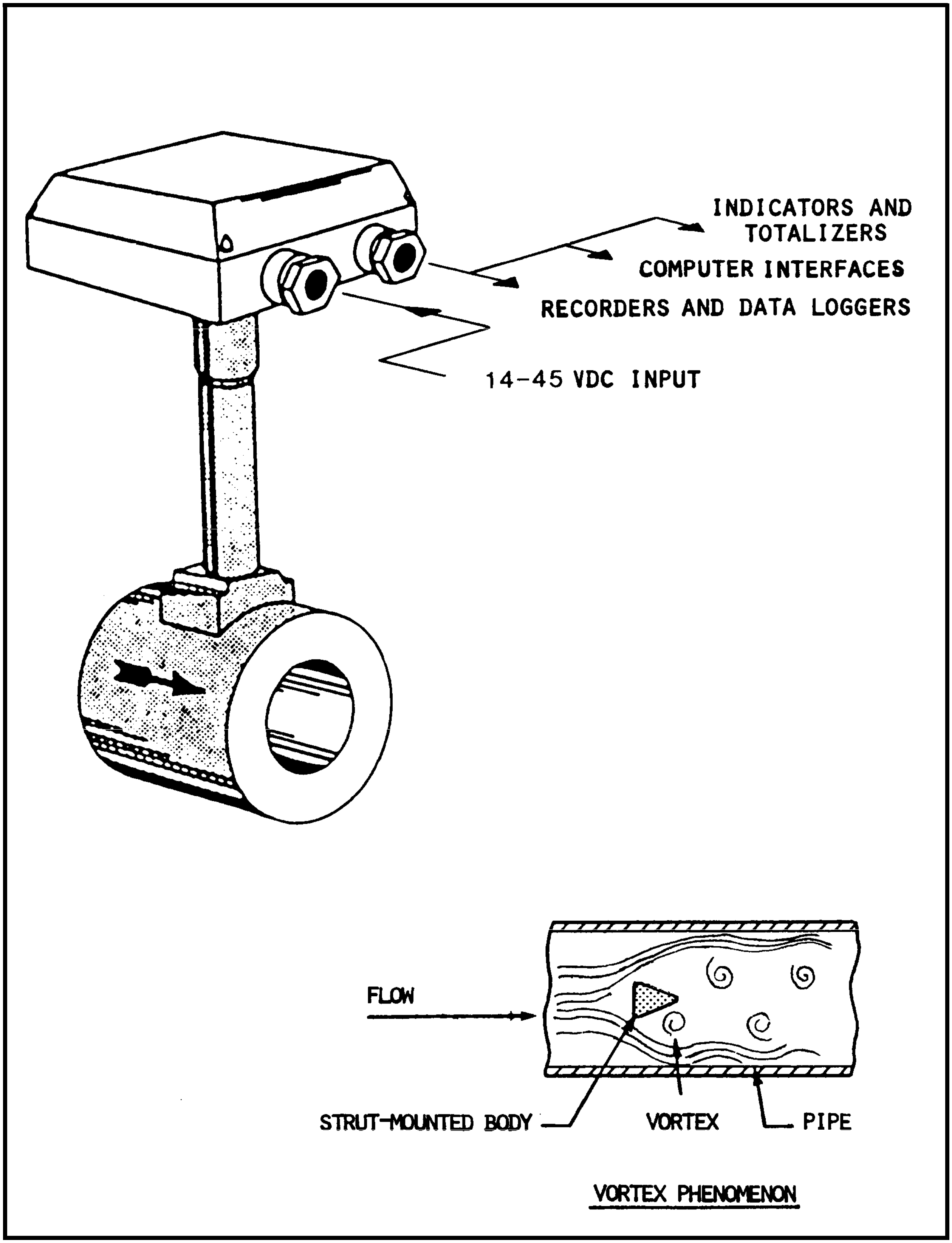


FIGURE 3-13. Vortex Shedding Flowmeter

TABLE 3-3. Comparison of Meter Types

Characteristic	Orifice	Vortex	Turbine
Rangeability	3:1	8:1 to 15:1	25:1
Accuracy drift	Gradual drift as erosion occurs	No significant drift	No significant drift until catastrophic failure
Installation	Steam system must be secured	Steam system must be secured	Can be hot tapped
Service	Steam system must be secured	Steam system must be secured	Can be serviced without securing steam system
Calibration	Can be performed in field	Manufacturer	Manufacturer

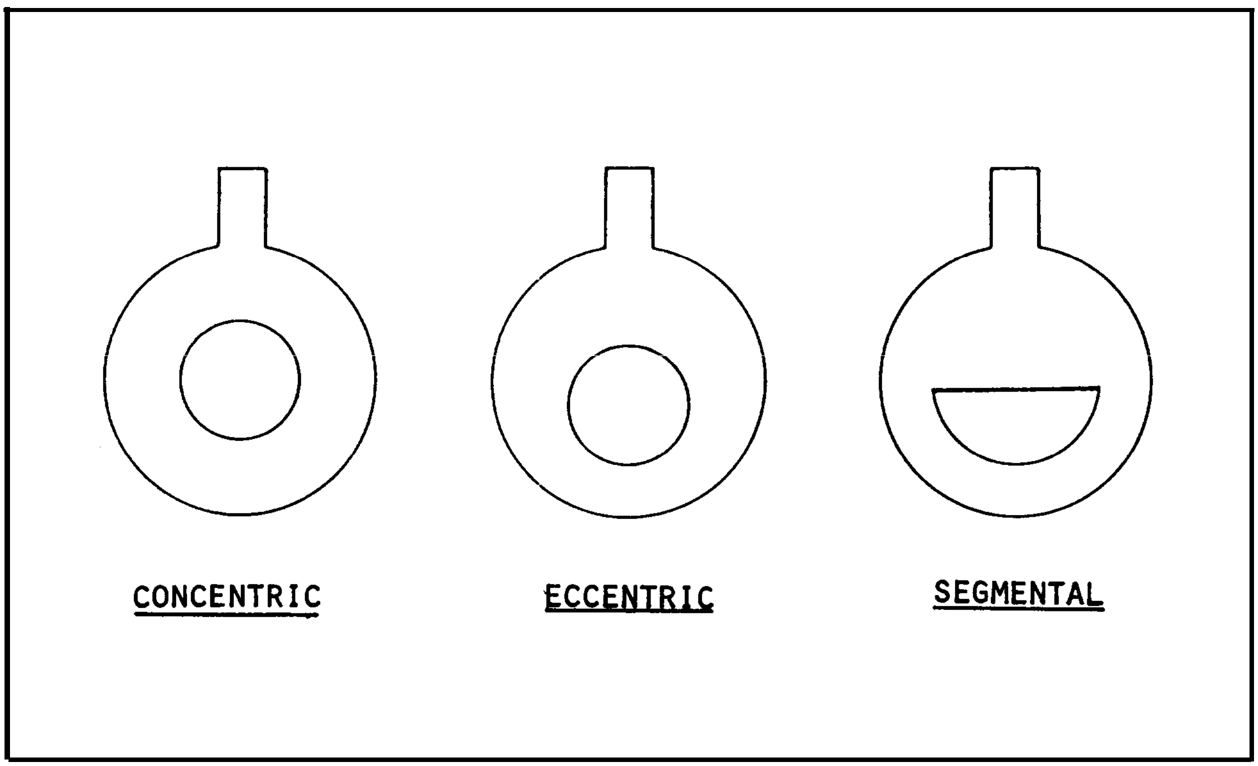


FIGURE 3-14. Types of Orifice Plates

(f) Installation. Shutdown of the steam system at installation, and each time the orifice plate is checked or replaced, is necessary. An upstream straight pipe run of 10 to 30 diameters is required.

3.2.2 Pitot Tubes. The pitot tube, which is limited to single point measurements, is another type of DP meter. Pitot tubes sense two pressures at the same time, impact and static. An impact tube is open ended and has a 90° bend at the bottom; a static tube is straight, closed at the bottom, with a slot in the side. The tubes may be mounted separately or combined coaxially as shown in figure 3-15. Pressure taps are connected to a manometer where the pressure differential is indicated. It is common installation practice to weld a coupling to a pipe and insert the probe through the coupling. Pi tot tubes have a minimum pressure drop and are low in cost, free of moving parts, and easy to install, but are susceptible to being plugged by suspended matter in the fluid.

3.2.3 Insertion Turbine Meters. Fixed and insertion turbine meters (figures 3-11 and 3-12) measure velocity of steam in a pipe with a rotor inserted at the critical point in the flow profile. The critical point represents the average flow velocity. The following items are characteristics of insertion turbine meters.

(a) Accuracy. Accuracy within the turndown ratio of 25:1 is typically %1 percent. The turndown ratio is significantly better than differential pressure meters.

(b) Sizing. Sizing is less critical than differential pressure meters because of wide rotor range and ease of installation.

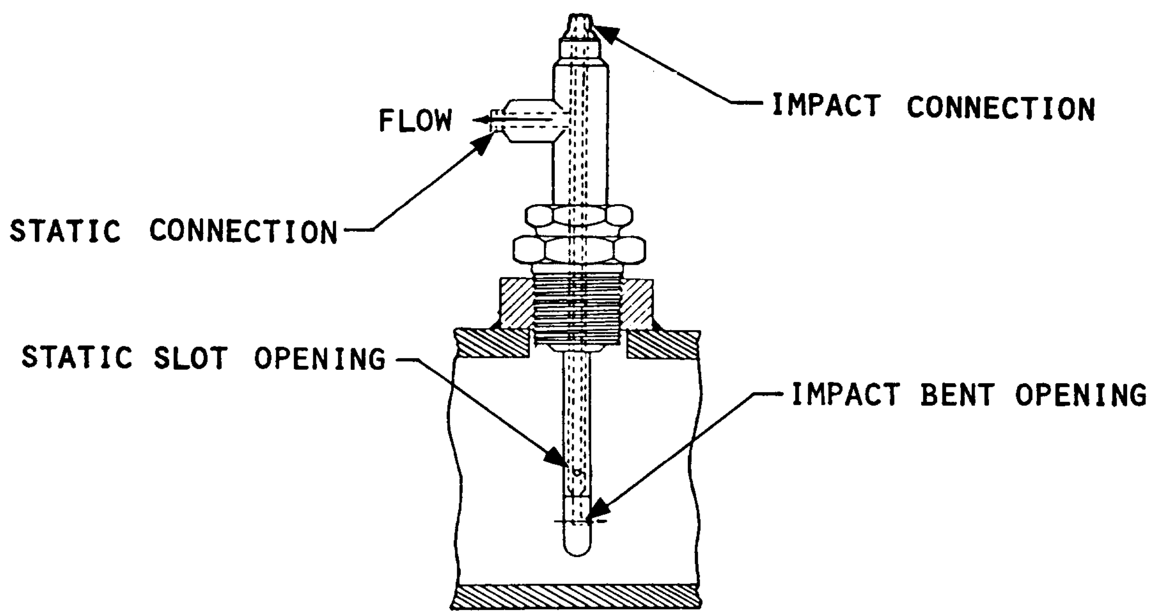


FIGURE 3-15. Pitot Tubes Mounted in a Single Casing

(c) Calibration. Calibration of the turbine rotor is performed by the manufacturer. The rotor cannot be calibrated by the user. Meter electronics require initial scaling and resealing each time a rotor is replaced. Scaling information is provided by the manufacturer.

(d) Maintenance. Required routine maintenance is the replacement of the turbine rotor each 6 months to 1 year, or when a failure occurs. Failure will be catastrophic: occurring within 30 minutes or less. Maintenance is performed only in the event of a failure.

(e) Output. The turbine meter outputs an analog signal (4-20mA), which can be recorded on a strip chart recorder or data logger, and a digital signal (10V peak-to-peak) in the range of 0-1,500 Hz. Pressure and temperature compensation are integral to the unit.

(f) Installation. The insertion turbine meter can be installed by a hot tapping procedure, without securing the steam system. Maintenance can be performed without interruption of steam service. An upstream straight pipe run of 10 diameters is required.

3.2.4 Vortex Shedding Meters. Vortex shedding meters operate by measuring oscillator vortex shedding frequency for flow around an object in the flow stream (figure 3-13). The following-items are characteristics of vortex shedding meters.

(a) Accuracy. Accuracy is typical %1 percent full scale with a turndown between 8:1 and 15:1, depending on flow rate and pipe size.

(b) Sizing. Sizes are available up to 8 inches. The velocity of steam in the pipe must be relatively high, possibly requiring a pipe size reduction before and after the meter.

(c) Calibration. The vortex shedding meter is calibrated by the manufacturer.

(d) Maintenance. There are no moving parts. Therefore, after initial setup maintenance is unnecessary unless component failure occurs.

(e) Output. Output is digital from the meter to transmitter. The transmitter converts the digital meter signal to an analog signal that is compatible with either a strip chart recorder or a data logger.

(f) Installation. Installation requires securing the steam system to install the meter between two flanges in the steam line If velocities are not sufficient for the vortex meter, the size of the pipe upstream and downstream of the meter must be reduced to increase velocity. The vortex meter is extremely sensitive to swirl or abnormalities in the flow profile, and the meter may require up to 40 diameters downstream of an obstruction or change in direction of the steam line. An upstream straight line pipe run of 10 to 20 diameters is required.

3.2.5 Acoustical Meters. Two types of ultrasonic meters are used to measure flow rate., Doppler meters and time-of-travel meters. The Doppler meter is based on a transducer signal of known frequency sent into the fluid. A pulse reflected off of solids, bubbles, or any discontinuity is received by another transducer in the form of a frequency shift. The frequency shift is proportional to the velocity of the liquid. Time-of-travel meters have transducers mounted at 45° to the direction of flow. Since the speed of the signal between the transducers varies, a time-differential relationship proportional to the flow is obtained by transmitting the signal alternately in both directions. To minimize signal scatter and absorption in time-of-travel meters, the liquid must be relatively free of entrained gas or solids.

3.2.6 Vibrating Meters. Mass flow can be measured by taking advantage of the Coriolis force. One type of meter uses a sensor housing with a U-shaped tube. The flow tube is vibrated up and down at its natural frequency by a magnetic device contained inside the tube. The resistance to change in direction by the liquid flowing in and out of the tube during the vibration cycle causes the tube to twist. The amount of twist is directly proportional to the mass flow rate. Attached sensors feed this data for processing to an electronic conversion unit. A voltage proportional to mass flow rate results in a digital readout.

Section 6. PRESSURE REDUCING STATIONS

1 PRESSURE REDUCTION. Steam is generally distributed at pressures substantially higher than required for consumer uses. Pressure reducing stations are employed to lower high-pressure steam down to the working pressure of the system. Low-pressure steam can then be safely used for heating purposes or for process work.

2 REDUCING STATION COMPONENTS. A pressure reducing station may consist of a pressure reducing valve, pressure regulating valve, relief valve, strainer, auxiliary valves, and pressure gauges (figure 3-16).

2.1 Pressure Reducing Valve. This is the primary valve of the pressure reducing station. Its main purpose is to reduce the incoming steam pressure to a safe level below the rupture point of the equipment served. These valves can be either self-operated or pilot-operated; single-seated or double-seated; spring-loaded or weight-lever operated.

2.1.1 Pilot-Operated Valves. These valves may be operated by either internal or external pilot valves. The unit consists of a small pilot valve and a piston or diaphragm actuated main valve. In operation, the controlled pressure governs the movement of the small pilot valve, which develops a variable loading pressure that depends upon the controlled pressure. The loading pressure then controls the movement of the main valve. The control fluid used by the pilot valve may be compressed air, steam, or it may be the controlled fluid itself. Figure 3-17 illustrates a pressure reducing valve with an external pilot valve. The controlled fluid enters the chamber below the pilot valve diaphragm through the control pipe and develops an upthrust which is balanced by the adjusting spring. This determines the position of the pilot valve. The fluid enters the pilot valve through pipe A. The amount of fluid passing through is determined by the position of the pilot valve. The bleed port restricts the fluid flow from the pilot which builds pressure under the main valve diaphragm and opens the main valve against the pressure of the main spring. In operation, delivery pressure feeds back through the control pipe to the pilot diaphragm. As this pressure approaches a balance with the thrust of the adjusting spring, the pilot throttles the loading pressure. In turn, the main valve takes a position established by the loading pressure where just enough fluid flows to maintain the set delivery pressure. The set delivery pressure can be changed as required by changing the compression of the adjusting spring.

2.1.2 Valve Seating. Single-seated valves are used for deadend service, where pressure must be maintained during no-flow periods. This type of valve can be closed tightly. Balanced seating valves require smaller forces to operate since the pressure acts on both sides of the disk. They do not close tightly. Some valves are V-ported to provide throttling in the early stages of opening and closing.

2.1.3 Valve Loading. Self-operated pressure control valves may be either spring-loaded or weight-loaded. The controlled pressure can be adjusted by changing the spring compression or by changing the lever position of the weight. In spring-loaded valves, the setting can be locked, which prevents operating trouble. The setting of weight-loaded valves is more easily

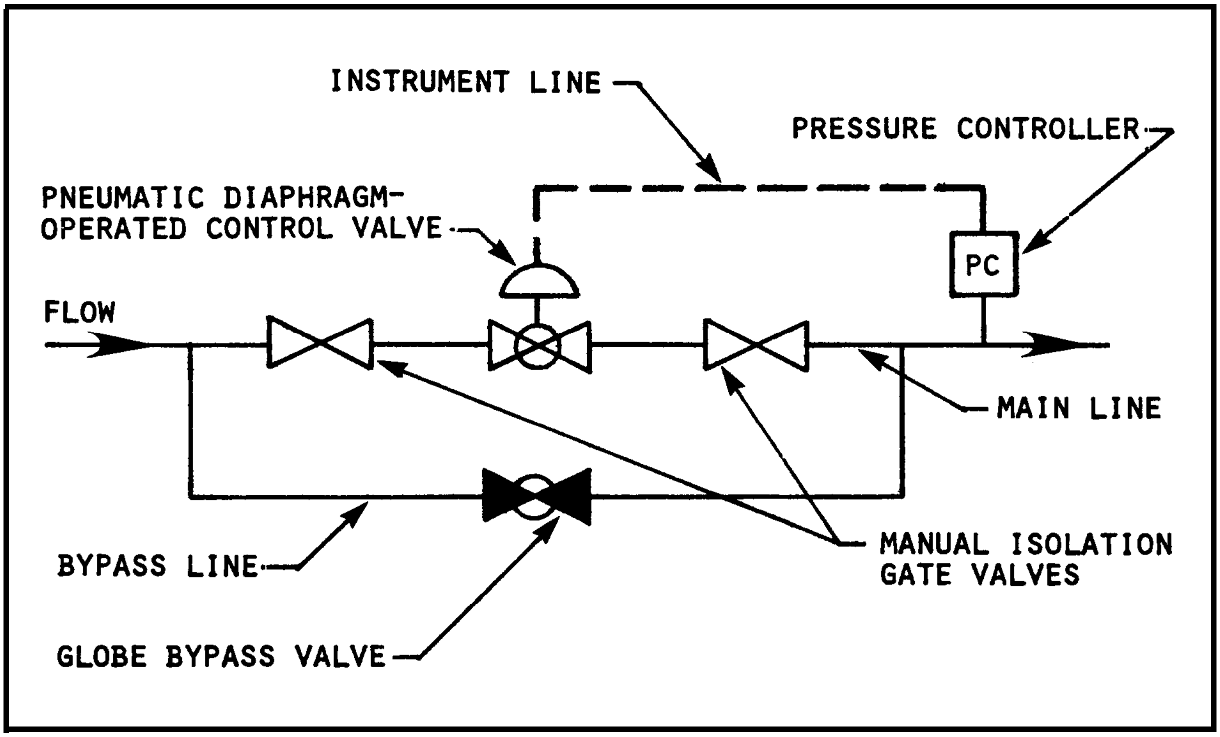


FIGURE 3-16. Typical Pressure Reducing Station Configuration

tampered with, as when unauthorized persons shift the position of the weight on the lever.

2.2 Pressure Regulating Valve. This is the secondary valve of the pressure reducing station. Its main purpose is to control and maintain the pressure required by the steam-using equipment. Pressure regulating valves are of the same construction as pressure reducing valves.

2.3 Relief Valve. This valve is used to protect low-pressure lines and steam-using equipment from overpressure should the pressure reducing valve fail to operate.

2.4 Strainer. Strainers are installed ahead of pressure reducing or pressure regulating valves. Strainers are used in piping systems to remove foreign material from the fluid. Loose dirt, rust, scale, or other loose foreign matter may cause malfunctions and costly damage if allowed to enter vital equipment. The screen of a strainer is usually constructed of a thin sheet of bronze, monel, or stainless steel. The screen or basket can be removed for cleaning. In some strainers a blowoff valve is provided to permit blowing out foreign material while in service. Figure 3-18 illustrates a pipe line strainer furnished with a connection for a blowoff valve.

2.5 Auxiliary Valves. Isolating gate valves are provided to remove from service pressure reducing and pressure regulating valves. In large installations, or where a continuous supply of steam must be assured, pressure reducing stations are provided with bypass valves installed parallel to the

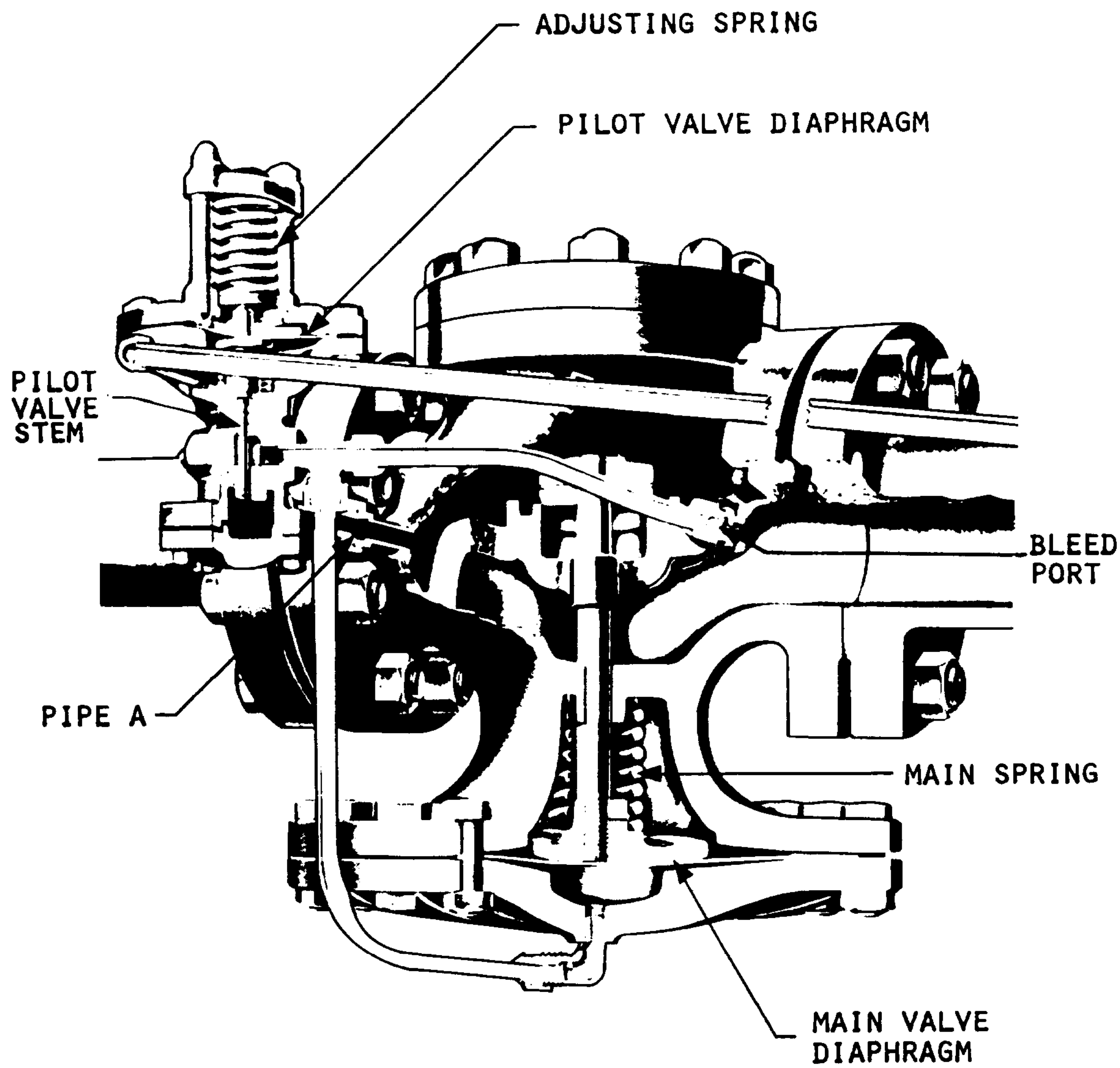


FIGURE 3-17. Pilot-Operated Pressure Reducing Valve

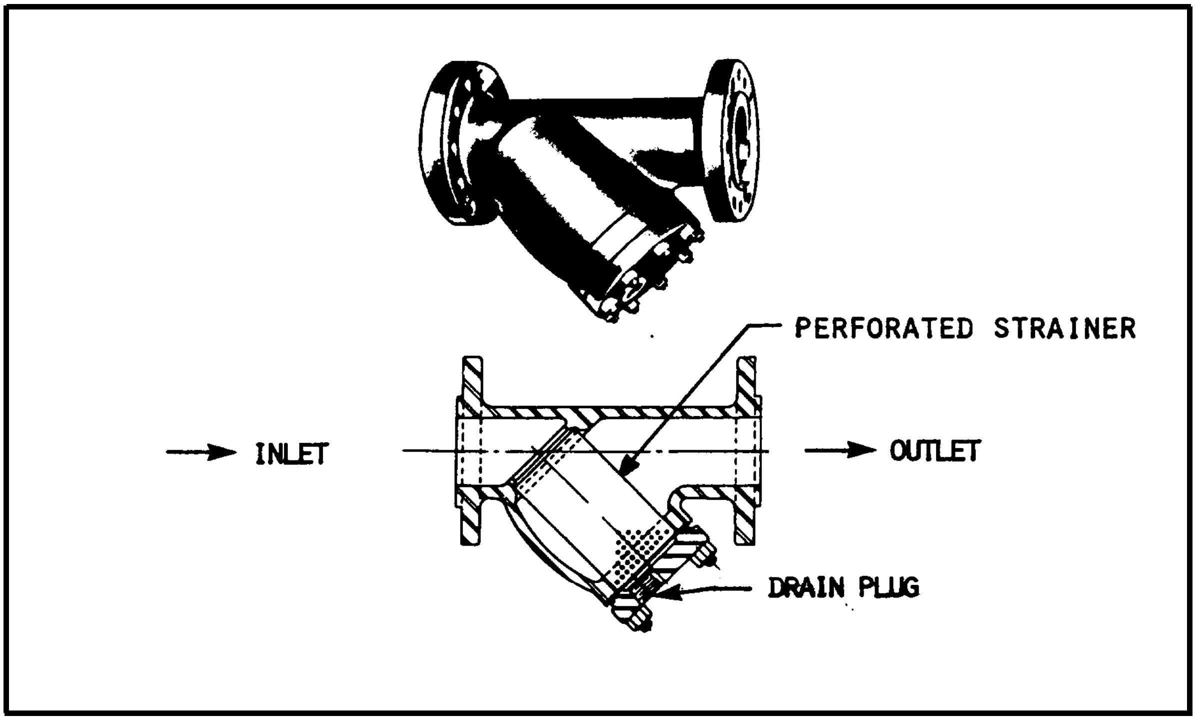


FIGURE 3-18. Pipeline Strainer With Section View

pressure reducing and pressure regulating valves. Bypass valves should be of the globe type to permit manual regulation, and they are usually half the size of the pressure reducing or regulating valves.

2.6 Pressure Gauges. Pressure gauges should be installed on the high- and low-pressure side of the pressure reducing station to facilitate supervision of the operation.

3 INSTALLATION.

3.1 Two-Stage Reduction. When making a two-stage reduction, the size of the pipe on the low-pressure side of the valve is usually increased to provide for the expansion of steam. This permits a more uniform steam flow velocity. The valves are sometimes separated by a distance of about 20 feet to reduce excessive hunting action of the first valve. Usually, where the steam distribution pressure exceeds 50 psi, the pressure reducing valve is installed near the connection between the main distribution line and the consumer system, followed by the pressure regulating valve and a relief valve. Double-ported, pilot-operated valves should be installed for large capacities, especially for inlet pressures above 125 psi. Because double-ported valves will not shut off completely on no-load demand, single-seated valves must be used for such service. Reducing valves should be selected to operate fairly open, with ratings and reduction ratios as recommended by the manufacturer. A strainer and condensate drain should be installed ahead of the pressure reducing valve. When the reduction ratio is more than 15 to 1, the reducing valve should be installed with increased outlet or expanding nozzle to provide for the increased volume of steam resulting from the reduced pressure.

For distribution pressures below 50 psi, the pressure regulating valve may be omitted.

3.2 Dual Valve Installations. In relatively large installations with steam requirements above 3,000 pounds per hour, and where variations in steam demand are likely to occur, a dual valve installation is used. This installation consists of two reducing valves installed in parallel, sized to pass 70 and 30 percent of maximum flow. The larger valve should be set at a slightly reduced pressure so that it will remain closed as long as the smaller valve can supply the demand. This prevents wire-drawing of seats and valves of large reducing valves operating at very low loads. For example, if a total of 40,000 pounds of steam per hour are required, the larger valve would be sized for 0.70 x 40,000, or 28,000 pounds per hour; the smaller one would be sized for 0.30 x 40,000, or 12,000 pounds per hour.

4 INSPECTION AND MAINTENANCE OF PRESSURE REDUCING STATIONS In addition to the procedures addressed in chapter 6, sections 2 and 3, perform the following operations.

Report any malfunction in the operation of any instrument of gauge.

Protect gauges from violent pressure fluctuations by throttling the gauge needle valve or by installing snubbers.

Clean gauge glasses as required for ease of reading.

Ensure steam lines are drained of condensate.

Blow down all strainers and clean strainer baskets at regular intervals, as required.

Allow only authorized and trained personnel to repair, calibrate, or adjust pressure reducing stations.

CHAPTER 4. HIGH TEMPERATURE WATER DISTRIBUTION

Section 1. APPLICATIONS AND SYSTEMS

1 SCOPE Direct buried conduit systems shall be installed, maintained, and repaired in accordance with the Manufacturer's Approved Brochure and NAVFAC Guide Specifications NFGS-15705, Underground Heat Distribution Systems (Prefabricated or Pre-Engineered Types). Systems shall have a Letter of Acceptability issued by Federal Agency Committee on Underground Heat Distribution Systems. The Letter of Acceptability is signed by representatives of federal agencies participating in the committee and stating that the supplier's system is approved for use for the site ground-water . conditions, operating temperature, and soil classification(s) indicated. Shallow concrete trench systems shall be installed in accordance with NFGS-15751, Heat Distribution System Outside of Buildings (Concrete Shallow Trench Type). Hot water can be distributed more efficiently and cost effectively than steam. For this reason hot water should be utilized over steam wherever feasible. Engineering Field Divisions shall assist and activities shall assure that operation and maintenance of hot water distribution systems are performed. The Power Principles Video Training Program shall provide further assistance to all concerned.

2 HTW HEAT TRANSMISSION. High temperature water (HTW) is an alternate medium to steam for conveying heat to customers located some distance from the generating plant. HTW can be efficiently generated and distributed, easily controlled, and accurately measured. It is distributed in a closed system from the generating plant to customers within a radius of 6 miles; although, with booster pumps-this distance can be extended. The system experiences little energy loss except for line heat losses of 3°F to 8°F per mile of distribution piping.

3 HTW DISTRIBUTION SYSTEMS.

3.1 <u>Definition</u>. An HTW distribution system consists of the following equipment:

(a) Piping to transport high temperature supply water from a central HTW generating plant to consumers;

(b) Piping to return the high temperature water to the generating plant;

(c) Equipment, instrumentation, and related facilities to safely and efficiently accomplish these tasks.

3.2 <u>Types of HTW Distribution Systems</u>.

(a) <u>Low Temperature Water System (LTW)</u>. A hot water heating system operating with a pressure of approximately 30 psig and a maximum temperature of 250°F.

(b) <u>Medium Temperature Water System (MTW)</u>. A hot water heating system operating at temperatures of 350°F or less, with pressures not exceeding 150 psig. The usual supply temperature is approximately 250 to 325°F.

(c) High Temperature Water System (HTW). A hot water heating system operating at temperatures over 350°F and pressure of approximately 300 psig. The usual maximum supply water temperature is 400 to 450°F.

(d) Selecting type of Hot Water Distribution System. Systems must maintain adequate pressure and temperature and assure uniform flow of water to customers. Hot water generators consist of natural circulation boilers or forced circulation boilers. Since hot water distribution systems are more efficient than steam distribution systems, they should be selected whenever practical. The lower the temperature required the more efficient the system should operate due to the lower temperature differential between the hot water and piping's external temperature. Lower temperature systems are less costly to construct as well. All projects calling for the replacement or new installation of a heating system shall include a life cycle economic analysis of steam vs LTW, MTW, and HTW distribution systems, and justification, stating the conditions which prohibits the use of above-ground systems on all MCON and special projects. This includes repair by replacement type projects where the existing distribution systems' are steam and/or underground. The following factors will be among those considered in the analysis:

(1) Economic advantage of thermal storage of the hot water system in sizing of equipment such as boilers, pumps, and piping.

(2) Operation and maintenance costs of hot water distribution system versus steam distribution system.

(3) Customer requirements of temperature or pressure served more economically by steam or hot water.

(4) Replacement or renovation of existing plant and distribution system compared with construction of new plant and/or distribution system. Comparison to be on a life cycle basis.

(5) Prevalence of skilled steam plant or hot water plant operators in area, especially in remote locations.

(6) Complexity of controls and ability of steam to maintain varying or constant temperature conditions through the assigned or existing heat transfer equipment.

3.3 Heat Storage Capacity. A useful characteristic of HTW systems is the large heat storage capacity. This property gives the system a thermal fly-wheel effect which permits-close temperature control and more rapid response to changing load demands. In fact, the system acts as an accumulator of the heat generated and helps equalize the heating load on the boilers. Table 4-1 shows a comparison of the heat storage capacity of water and steam for different pressures and temperatures. The variations of density and volume of HTW with changes in temperature are shown in table 4-2.

3.4 Temperature Differential. To take full advantage of the high heat content of HTW, distribution systems are designed for the largest temperature

TABLE 4-1. Heat Storage Comparison of HTW and Steam

Saturated Temperature (°F)	Absolute Pressure (psia)	Total Heat Content (Btu/ft')		Heat Content Ratio HTW/ Steam
		HTW	Steam	
250	29.82	12,852	84.22	152.6
260	35.43	13,378	99.23	134.8
270	41.86	13,910	116.35	119.5
280	49.20	14,430	135.77	106.3
290	57.56	14,946	157.73	95.17
300	67.01	15,449	182.44	84.68
310	77.68	15,950	210.18	75.88
320	89.66	16,446	241.19	68.19
330	103.06	16,930	275.76	61.39
340	118.01	17,411	314.18	55.42
350	134.63	17,878	356.76	50.10
360	153.04	18,342	392.29	55.70
370	173.37	18,803	455.73	41.26
380	195.77	19,251	513.10	37.52
390	220.37	19,685	575.73	34.21
400	247.31	20,116	644.55	31.21
410	276.75	20,545	719.82	28.54
420	308.83	20,949	802.07	26.09
430	343.72	21,350	891.76	23.94
440	381.59	21,750	989.48	21.98
450	422.6	22,170	1,095.79	20.23

TABLE 4-2. Density and Volume Variations of HTW With Temperature

Saturated Temperature	Density (lb/ft')	Spec. Volume ft'/lb
70	62.30	0.01606
250	58.82	0.01700
260	58.51	0.01709
270	58.24	0.01717
280	57.94	0.01726
290	57.64	0.01735
300	57.31	0.01745
310	56.98	0.01755
320	56.66	0.01765
330	56.31	0.01776
340	55.96	0.01787
350	55.59	0.01799
360	55.22	0.01811
370	54.85	0.01823
380	54.47	0 .0183b
390	54.05	0.01850
400	53.65	0.01864
410	53.25	0.01878
420	52.80	0.01894
430	52.36	0.01910
440	51.92	0.01926
450	51.50	0.01940

difference between the supply and the return water consistent with economical considerations. The amount of heat extracted from a given amount of water effects the temperature differential between the supply and the return water. The greater the temperature difference, the more heat obtained per unit of water. Higher heat extraction permits cutting down the flow rates, which reduces the size requirements of the distribution pipes and pumps, and the pump horsepower. The usual temperature differential range for an HTW system is 100°F to 150°F. A maximum differential of 200°F is practical with forced circulation boilers. For natural circulation boilers, a maximum differential of 250°F is considered practical.

4 EXPANSION TANKS. All HTW systems require expansion tanks to allow for variations in the system water volume caused by temperature changes. Volume expansion is not based on cold water conditions because that extreme variation only occurs when starting up cold. Rather, the tank is sized to handle changes in water volume resulting from normal load changes. In general, the following factors are considered in sizing a tank.

Sludge and suction space at the bottom of the tank. From 6 to 9 inches of elevation are reserved for this purpose.

Reserve storage of not less than 30 seconds supply to all pumps connected to the tank.

Space for water expansion due to temperature changes. This depends on the supply and return temperature limits, and on the total amount of water in the system.

Space for operation of level alarms and overflow. Normally, l-foot depth is reserved for this purpose.

Space pressurization above the overflow level. When steam pressurization is used, this space amounts to 20 percent of the volume reserved for water expansion.

The ratio of diameter to length is kept to 3.5 approximately, with a minimum tank diameter of 6 feet.

4.1 Expansion Tank Connections. The following connections are usually provided for expansion tanks.

Draining and filling connections used to completely drain the tank or to fill it with water after a shutdown.

Supply piping for steam pressurized tanks. The boiler water should be fed horizontally below tank water level through independent pipe leads from each boiler.

Pump suction connections usually provided with vortex eliminators.

Safety valves for protection against overpressure.

Blowoff connections to rapidly remove large quantities of water resulting from volume expansion when starting up a system, to reduce water concentration, and to aid in the removal of sludge.

Overflow connections.

Connections for thermometers, pressure gauges, water gauge glasses, level controls, and alarms for proper operation and control.

5 PRESSURIZATION. The design boiler pressure must be high enough to produce saturated water at a temperature substantially above the design supply water temperature. This is required to prevent a flashing of water into steam should the system flow pressure drop. The temperature difference, 20°F to 30°F approximately, can be obtained by cooling the water below the saturation temperature before it enters the circulation system pump. Additionally, the expansion tank of a steam pressurized system is usually located about 16 feet above the boiler outlet header, and this additional head provides a safe margin above the saturation temperature. The two basic methods of system pressurization that are used to keep the HTW in its liquid state are the steam cushioned system, and the inert gas pressurized system.

5.1 Steam Cushioned System. In this system, the steam present at saturated water temperature conditions in the expansion tank is used directly to impose a pressure cushion. The elevation of the tank above the circulation system pump provides the required head to prevent flashing of the supply high temperature water.

5.2 Inert Gas Pressurized System. In this system an inert gas, usually nitrogen, is used in the expansion tank to impose a pressure higher than the maximum saturated pressure of the high temperature water. The expansion tank can be located at floor level. When an inert gas is used to pressurize the system, the expansion tank is generally connected to the main return line and no circulation takes place in the tank. Compressed air is never used for pressurization because absorption of oxygen by water would occur with unacceptable corrosion of the metallic elements of the system.

6 PUMPING SYSTEMS. Two main pumping systems that are in use as a result of the different pump arrangements are the combined pumping system and the separate pumping system.

6.1 Combined Pumping System. In this system the same pumps are used to circulate water through both the HTW generators and the system. In general, these systems are used where the circulation rate in a single distribution system is fairly constant, and heat load capacities do not exceed 31,500,000 Btu per hour. Figure 4-1 illustrates a steam pressurized HTW combined pumping system. Combined pumping systems are generally provided with the following equipment.

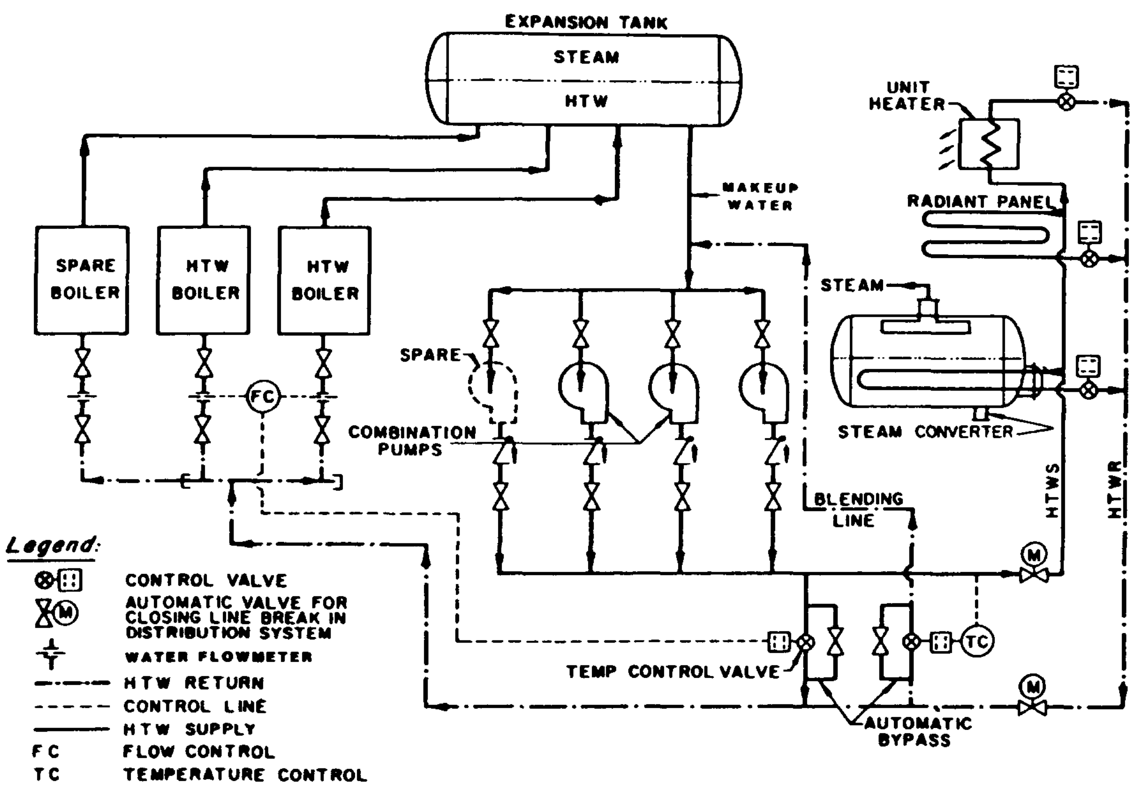


FIGURE 4-1. Steam Pressurized HTW Combined Pumping System

(a) Automatic Bypass Control Valve. This valve is installed at the discharge of the combination pumps, bypassing the distribution system, and is activated by the boiler inlet waterflow rate. The purpose of the valve is to ensure minimum required boiler circulation at all times, regardless of load conditions. The valve is provided with a manual bypass.

(b) Temperature Control Valve. This valve is installed in the blending line to the suction of the combination pumps. Its purpose is to cool water entering the pumps, below the point at which flashing may occur. Also, it serves to regulate the HTW supply temperature by mixing the hot water from the expansion tank with a portion of the cooler high temperature water return. The valve is furnished with a manual bypass.

(c) Water Flowmeters. These meters are provided for measurement of waterflow to each boiler inlet piping so that all boiler flows can be equalized.

(d) Automatic Closing Valves. These valves are provided to isolate the using end of the system should a major break occur in the supply or return main. In such a case, the automatic bypass control valve referred to in (a) above operates to direct the discharge water from the combination pumps to the boiler inlet. This maintains the required waterflow through the HTW generators and prevents tube burnout.

(e) Pressure Differential Switch. This switch is installed across the pump suction and discharge headers to terminate firing when the pressure differential falls below a preset minimum. Often, a minimum flow switch in each flowmeter is used instead, which terminates firing when insufficient water flows through the boiler.

(f) Combustion Control Interlocks. The pump starters are interlocked with the combustion control to prevent boiler operation without pump operation.

6.2 Separate Pumping System. In these systems, water is circulated through the boiler by individual boiler recirculation pumps, while separate circulating pumps circulate the water through the distribution system. This is a more flexible arrangement which assures circulation through the boiler Independently of the water circulation through the distribution circuit. Figure 4-2 illustrates a nitrogen pressured HTW separate pumping system. Separate pumping systems are used for the following conditions:

Where heat loads vary greatly and adequate flow cannot be obtained under minimum load conditions

Where it is desirable to operate a distribution system for short periods independently of the boilers

Where several zoned distribution systems are required, each with its own set of system circulating pumps

Where the heat load is over 31,500,000 Btu per hour and the system is economically justified

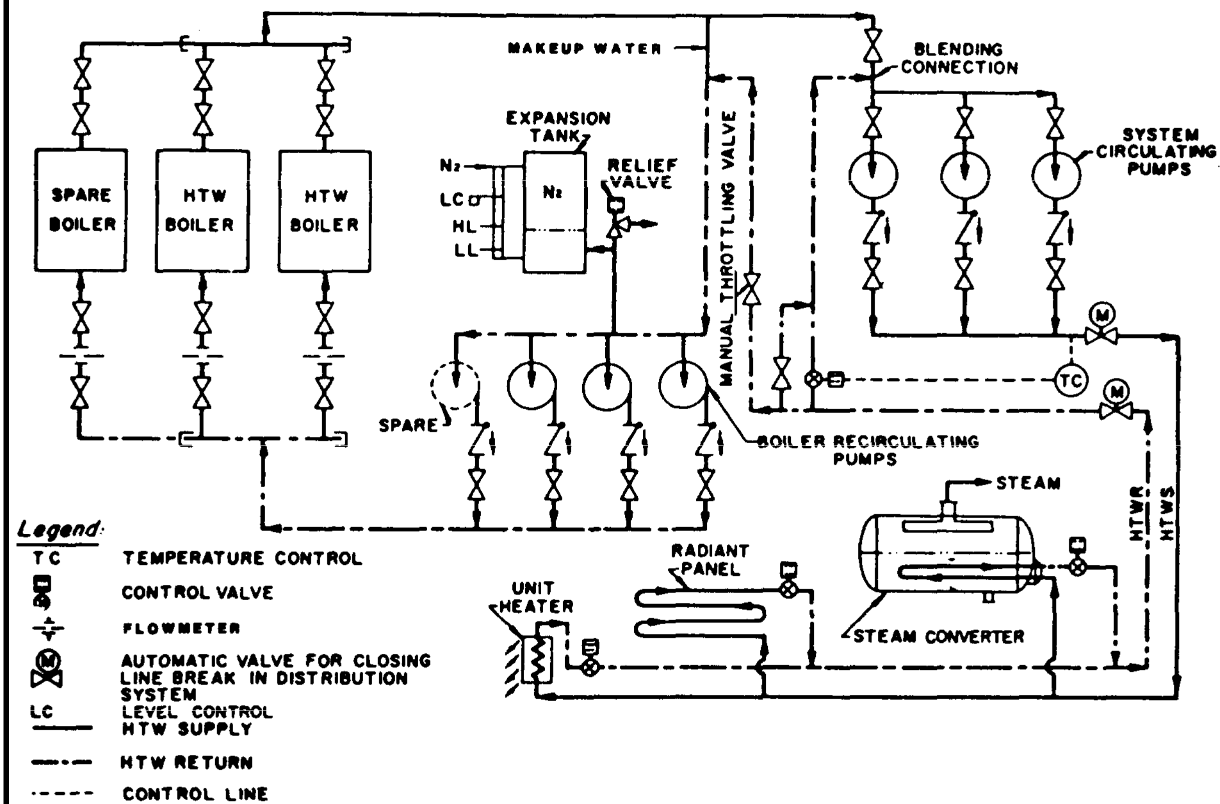


FIGURE 4-2. Nitrogen Pressurized HTW Separate Pumping System

Where it is mandatory that a boiler circulating system be isolated from the distribution system

6.3 Alternate Equipment. Separate pumping systems are usually provided with the following equipment.

(a) Temperature Control Valve. This automatic valve is installed in the blending line to the suction of the system circulation pumps. It serves the same purpose described for combined systems in 6.1(b) above. The valve is furnished with a manual bypass. The purpose of the manual throttling valve, which is installed in the return line supplying the boiler recirculation pumps, is to create a pressure drop, thereby facilitating operation of the temperature control valve.

(b) Automatic Closing Valves. These are motor operated valves provided to isolate the using end of the system should a major break occur in the supply or return mains. They are set to close when the waterflow exceeds a predetermined value.

(c) Water Flowmeters. These meters are used for the same purpose described in 6.1(c) above for combined pumping systems.

(d) Minimum Flow Switch. A minimum flow switch is incorporated in each boiler flowmeter to terminate firing when the waterflow drops below a safe level.

(e) Combustion Control Interlocks. The starting switches of the boiler recirculation pumps are interlocked with the combustion control of all boilers to prevent boiler operation without pump operation.

6.4 Zoning. When economically justified, zoning arrangements of the distribution circuits are provided where various groups of buildings with different requirements of temperature, pressure, and flow must be served. This is generally the case when hospitals, laundries, airports, and kitchens have to be supplied from the same distribution system. In those cases, separate circulation pumps are used for each zone, which permits independent regulation of the flow, pressure, and temperature for each group of related consumers. The zone temperature is controlled by an individual temperature control valve through the blending connection for the zone. This permits maintaining a constant supply temperature to each zone of a distribution system and at the same time holding a constant expansion tank pressure. The net result is higher economy and flexibility.

Section 2. HIGH TEMPERATURE WATER DISTRIBUTION METHODS

1 TYPES OF DISTRIBUTION METHODS. HTW distribution methods are similar to those described for steam distribution systems. No provisions are needed: however. for the disposal of drip line condensate as in a steam distribution system.

1.1 Distribution Route. In HTW distribution circuits, the circulating pumps maintain positive circulation in the closed piping system at all elevations. This permits laying the supply and return lines following the general contour of the land. However, prior to selecting a route for the HTW distribution system, a thorough evaluation of the location and economic factors should be made. A discussion of these factors is found in Section 2 of NAVFAC DM-3.8, Design Manual, Exterior Distribution of Utility Steam, High Temperature Water (HTW), Chilled Water (CHW), Fuel Gas, and Compressed Air.

1.2 Freezing. To prevent freezing should the system be out of operation, the distribution pipelines are normally buried below the frost line.

2 ADVANTAGES OF HTW DISTRIBUTION SYSTEMS. The major advantages associated with the use of HTW distribution systems are listed below.

(a) Low Water Makeup Requirements. HTW systems are completely closed circuits and very little water is consumed. The most significant water losses in normal operation are system leakage through pump glands and valve packings. Water can be lost also through vents or blowoffs because of changes of volume when starting a cold system. Minimum makeup water requirements result in reduced feedwater treatment, and boiler blowdown is seldom necessary.

(b) Lack of Corrosion. Since the water is recirculated in a closed system, neither corrosion nor scaling occurs. The system is always filled with noncorrosive treated water.

(c) Small Distribution Lines. High temperature differentials permit the use of relatively small distribution lines throughout the system.

(d) No Traps or Pressure Reducing Value Stations Required. HTW systems do not have traps, drips, or pressure reducing stations. HTW systems can meet the need for several temperature levels without reducing the pressure of the heating medium, as required in steam distribution.

(e) Low Transmission Heat Losses. Smaller distribution lines have smaller diameters, which result in lower heat losses than those that occur in comparable steam systems.

(f) High Thermal Efficiency. The closed recirculation system operates at a high thermal efficiency because: first, all the heat not used by consumers or not lost through pipe radiation is returned to the boiler plant; and second, the heat loss in boiler blowdown is practically eliminated. High boiler efficiencies are obtained by the elimination of sudden changes in firing rates which tend to produce poor combustion and high stack gas temperatures. This is possible because of the thermal flywheel effect resulting from the large heat storage capacity of HTW. The system acts as an accumulator of the heat generated and helps equalize the heating load on the boilers.

(g) Negligible System Losses. The system is closed and is under constant pressure at all times, which eliminates flashing.

(h) Simplified Distribution System. HTW distribution lines can follow the natural land contours (refer to paragraph 4.1). This and the elimination of traps, pressure reducing valves, and condensate return pumps makes for a simplified system.

(1) Flexibility. HTW can be used directly at full temperatures for space and process heating or indirectly through converters to produce low-pressure hot water or steam.

(j) Ease of Operation and Control. Ease of operation and control is facilitated by:

Simplification of valves and fittings.

Absence of traps, pressure reducing valve stations, and condensate return pumps.

Feedwater treating equipment of simple design.

Central pump location. Pumps are installed in the central heating plant and are not dispersed throughout the system.

Uniform temperature is as easily maintained in normal operation as during peak loads.

(k) Safety of Operation. Water leaking from an HTW line rapidly expands to atmospheric pressure, causing a refrigerating effect; the leaking water is further cooled by evaporation. This permits holding the hand within 1 or 2 feet of a small leak without being burned. Also, the amount of HTW at saturation temperature that can pass through an opening in a given time is about one-half the amount of steam which could pass through the same opening.

3 REFERENCE DESIGN SPECIFICATIONS. Design standards and recommendations for HTW distribution systems are contained in NAVFAC DM-3, Design Manual, Mechanical Engineering; and NAVFAC DM-3.8, Design Manual, Exterior Distribution of Utility Steam, High Temperature Water (HTW), Chilled Water (CHW), Fuel Gas, and Compressed Air.

Section 3. OPERATION OF HTW DISTRIBUTION SYSTEMS

1 OVERVIEW. Operating procedures for HTW and steam distribution systems are similar. Although HTW systems do not have traps, condensate pockets, pressure reducing valve stations, or condensate return pumps, high points in the system must be vented periodically to relieve air accumulation.

2 STARTUP INSPECTION. Before placing a new HTW distribution system in service, or after a major overhaul to an existing system, make sure the following requirements are fulfilled.

(a) System meets all applicable requirements as listed In approved specifications.

(b) Applicable field tests have been satisfactorily completed.

(c) All installation, repair: and cleanup work is completed, including cleaning and flushing of heat carrier pipes.

(d) All conduits and passages are free of obstructions and are tight.

(e) All insulation is correctly installed, dry, and in good condition.

(f) All auxiliary equipment is correctly installed and ready for operation. Auxiliary equipment, including pumps, strainers, drains, vents, and expansion joints, is discussed in chapter 6 of this manual.

(g) HTW generators and accessory equipment are ready for operation.

3 SYSTEM STARTUP. Before starting up the system, notify the HTW generating station and the HTW consumers. Prepare a starting schedule and supply it to all interested parties so that adequate preparations may be made.

3.1 Startup Procedure for Combined Pumping Systems. Proceed as follows to start a cold system.

(a) Make sure that proper water level is carried in the system expansion tank.

(b) Open inlet and outlet valves for the HTW generators, expansion tank, and distribution system.'

(c) Open water inlet valve to combination pumps.

(d) Open pump vents until all air is released; then close vents.

(e) Start the pumps, then slowly open the discharge valve. Check pumps and drives for any abnormal condition such as excessive vibration, noise, or unusual temperature. Check lubrication.

(f) Check and adjust waterflow through HTW generators until all boiler flows are equalized at a correct value.

(g) Vent air from headers and high points in the system.

(h) Recheck limit and safety controls; then ignite the HTW generators. Slowly heat the HTW generators' refractory and the system water. During this period, maintain combustion controls on manual operation; do not change to automatic control until after reaching operating pressure-

(i) As the system heats, the system water expands. This may cause the water in the expansion tank to reach a higher than permissible level. In this case, blowdown as required.

(j) Check operation of the temperature control valve in maintaining system water temperature by recirculating return water through the blending line.

(k) Check operation of the automatic bypass valve in maintaining proper flow through the HTW generators.

3.2 Startup Procedure for Separate Pumping Systems. The startup procedures for a separate pumping system are similar to those for a combined pumping system, except for the following differences.

(a) During the warmup period, circulate all water returned from the system through the HTW generator. No return water should go directly to the expansion tank.

(b) After the system water reaches a temperature of 200°F, circulate all water through the boiler and none through the distribution system. This permits raising the pressure in the expansion tank to normal operating conditions with a minimum firing rate.

(c) After reaching operating pressure, circulate water through the distribution system at approximately 25 percent of normal rate.

(d) As the return water temperature drops, increase the firing rate as required to maintain operating pressure in the expansion tank.

(e) Follow the above described procedures while increasing flow rate through the distribution system as the return water temperature continues to rise. This will establish normal operating conditions.

3.3 Warmup Precautions. While the system Is being warmed up, check the following conditions:

(a) Performance of expansion joints or loops.

(b) Performance of hangers, supports, guides, and anchors.

(c) Free expansion of headers and piping in the expected directions and in the proper amounts. If any restrictions are noted, shut down the system and provide proper clearance.

4 NORMAL OPERATION. While the system is in operation, check the following equipment.

(a) Water Hammer. Severe shock to piping and equipment may occur if cold water is injected into HTW lines too rapidly and without precaution. This must be remembered when placing idle pumps and circulating lines in operation.

(b) Blending. When possible, use bypass valves to blend cold water with hot water; allow sufficient time to heat the equipment valve. If no bypass valves are provided, slowly open main valves to permit gradual blending until temperatures are stabilized; then open as required.

(c) Vents. Check vents and see that any air accumulated in the high points of the system is discharged.

(d) Draining Equipment. Check operation of draining equipment (pumps, steam ejectors) in sump pits and manholes.

(e) Manholes, Tunnels, and Trenches. Make sure manhole vents are unrestricted, and tunnels and trenches are kept dry and properly ventilated.

(f) Aboveground Systems. Make certain that supporting structures do not settle or shift position. Insulation covering must maintain its mechanical and watertight protection, and insulation must remain dry and in good physical condition.

5 SYSTEM SHUTDOWN. Notify the generating plant and the HTW consumers before shutting down the system. When shutting down, proceed as follows:

(a) Shut down the HTW generator.

(b) Keep the water circulating through the HTW generator until inlet and outlet water are at the same temperature.

(c) Close inlet water valve of HTW generator.

(d) Close outlet water valve of HTW generator. Open bypass valve of outlet valve to relieve the pressure until water in generator has cooled; then close bypass.

(e) If line is to be drained to sewers and the water temperature is higher than permitted by local ordinances, make provisions to cool the water in a sump or by other means.

(f) When aboveground systems are used in cold climates, drain the lines to prevent freezing if the system is to be out of service for a prolonged period of time.

(g) If system is to be drained, keep drain and vent valves wide open to maintain the lines in a dry condition.

(h) In underground systems, keep draining equipment in service to remove any filtration water.

6 EMERGENCY PROCEDURES.

(a) Leaks. Repair all piping leaks as soon as possible. If leaks cannot be repaired with the system in service, make necessary arrangements for a shutdown. Often, the defective line can be isolated by closing segregating valves.

(b) Water Hammer. In case of water hammer resulting from the opening of a valve, close the valve immediately until the indications stop. Use a bypass valve, if provided, for blending purposes. If no bypass is provided, very slowly open the valve to permit gradual blending until temperatures are stabilized; then open as required.

7 CASUALTY PLANNING. Make certain piping system operators are familiar with the location and arrangement of piping system, valves, associated equipment, and controls. A map of the area served, showing the location of distribution piping and equipment and consumers, is very useful and should be available to operators. These maps are usually made in sections and are extended as new areas are served. Give definite instructions on emergency procedures to operators. Schedule and carry out periodic fire drills, inspections, and other simulated emergency procedure tests. Train operators in the use of available fire fighting and emergency draining equipment.

Section 4. MAINTENANCE OF HTW DISTRIBUTION

1 MAINTENANCE PROCEDURES. Maintenance procedures for HTW distribution system do not differ significantly from those for steam distribution systems. The following categories of maintenance inspections and tests should use the same procedures as applicable from section 4 of chapter 3:

Operator Inspection and Maintenance

Preventive Maintenance Inspections

Monthly Inspection of Aboveground Systems

Yearly Inspection of Aboveground Systems

Preventive Maintenance Inspection of Underground Systems

Tests

Overhaul and Repairs

Inspection and Maintenance of Cathodic Protection Systems on Underground Systems

1 PUMPS FOR HTW SYSTEMS.

1.1 Pump Requirements. Combination pumps are used in HTW combined pumping systems to circulate water through both the HTW generators and the system. The pump must provide the total head required to circulate water through the complete circuit served. The head must overcome pressure drops through valves, fittings, piping in the distribution system, and heat consumers. It must also overcome pressure drops through HTW generators. Water pressure at any point in the distribution system may be calculated as: expansion tank pressure, plus static pump suction head, plus head developed by the pump, minus line pressure drop up to the point under consideration, minus difference in elevation (static head) between the pump and the point considered. Figure 4-3 illustrates a pump of the type used in HTW pumping systems.

1.1.1 Pump Head. The required pump head may range from 60 to 250 feet of water above the HTW generator pressure, depending on the size and complexity of the system. The pumps are normally designed with a fairly flat head characteristic curve, to obtain a nearly constant head through the complete load range. This is important for parallel operation of pumps. The drop between shutoff pressure and that corresponding to maximum operating flow should not exceed 15 percent of the shutoff pressure (zero flow condition).

1.1.2 Pump Type. Pumps are of the centrifugal type, usually of single-stage design. For systems with a high total head, a cost evaluation is usually made to determine the convenience of using additional single-stage booster pumps against the use of multistage units. Pump casings may be of cast iron for pressures below 150 psig; higher pressures may require cast steel construction. Pump internal components are usually made of stainless steel. Deep stuffing boxes should be used for sealing, with from five to nine packing rings; or a mechanical type seal may be furnished. Adequate bearing and gland cooling water systems must be provided, and drains should be visible.

1.1.3 Pump Location. Pumps are usually located in the flow line of the system, below and near the expansion tank. This helps in maintaining the highest possible net positive suction head (NPSH). The pump head should not exceed 80 percent of the available NPSH in a plant arrangement.

1.2 Circulation Pumps. These pumps are used in HTW separate pumping systems to circulate water through the distribution system. Water is circulated through the HTW generator by individual boiler recirculation pumps. Circulation pumps are the same type as the combination pumps described above.

1.3 Boiler Recirculation Pumps. These pumps are used in HTW separate pumping systems to circulate high temperature water through the boilers. The design is similar to circulation pumps. Their characteristics, however, depend on the design of the boiler served.

1.4 Makeup Feed Pumps. These pumps deliver makeup water from the storage tank or from a feedwater heater to the expansion tank. The pumps are usually of the electrically driven, plunger type; the capacity depends on the time required to fill the expansion tank from the lowest to the highest permissible operating level. For a steady heating load, pumps may be started manually.

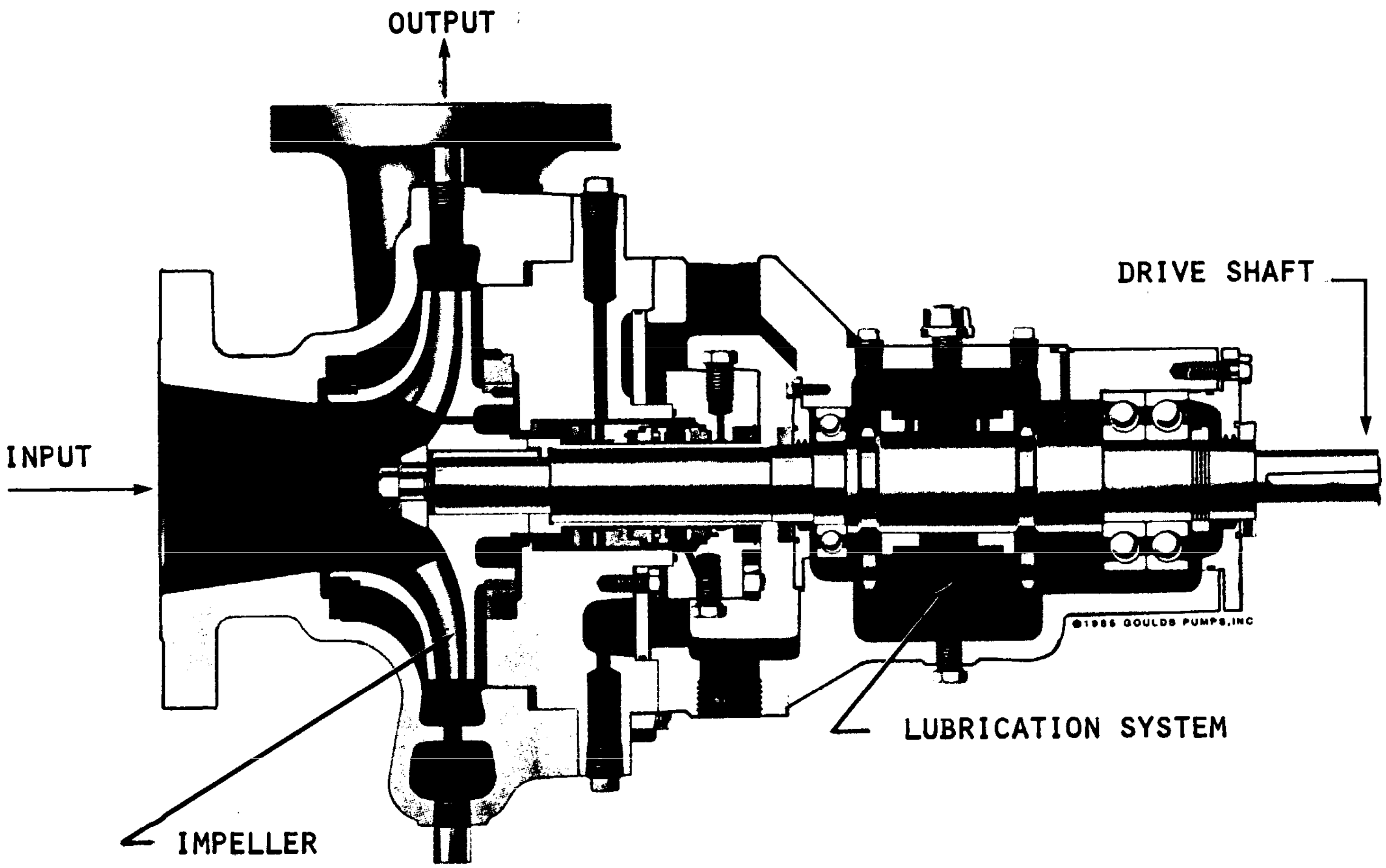


FIGURE 4-3. HTW Centrifugal Pump

When the load fluctuates, automatic starting and stopping by means of level control is usually employed.

1.5 Filling and Emergency Pump. Often, the size of the makeup feedwater pump is inadequate to fill the system in a reasonable time. A cold water filling pump, with a capacity ranging from 100 to 200 gpm, is used in those cases to fill the system. This pump delivers cold water from the treated cold water tank to the expansion tank; connections are also made to the boiler and pipe lines for filling purposes. When used for emergency feeding, or as a standby for the makeup pump, suction must also be connected to the feedwater heater or to the storage tank. For emergency makeup, the pump should be sized to discharge stored makeup water into a boiler circulating system to feed one boiler for approximately 10 minutes at full steaming capacity. This will make up for steam lost in the lowest set safety valve on the expansion tank in the event it is stuck open.

2 CONDENSATE RETURN. The following practices are important in the operation of condensate return systems.

(a) Ensure the maximum amount of condensate is returned to the central boiler plant. This practice saves heat and reduces makeup water requirements. In turn, both the investment costs for water treatment equipment and the costs of treating makeup water are reduced.

(b) Condensate losses should be minimized. Losses of condensate lead to increased costs for makeup water. Poorly operating traps may waste steam, causing losses which must be replaced by makeup water to the boilers. Boiler blowdown operations should be reduced to the minimum required to control solids in boiler water within specified limits. Excessive blowdown results in heat waste and requires additional makeup water to replace that lost through blowdown.

(c) To avoid possible contamination, condensate from some sources should be discarded rather than returned. If such condensate is to be discharged into a terra cotta or concrete sewer, it should first be piped through a cooling basin or sump, or a proper arrangement should be used to lower its temperature. This will prevent damage to the sewer. Do not return condensate from any source likely to produce contamination, such as: pickling tanks, electroplating baths, decreasing equipment, or open steam cookers.

(d) Monitor system regularly for acid corrosion. In general, condensate is pure water with no salts or causticity. However, carbon dioxide (CO_2), which enters the boiler system with the feedwater, carries over with the steam and dissolves in the condensate, making it acidic. Also, oxygen often leaks in at pipe connections and glands. Acid corrosion caused by CO_2 usually results in grooving or channeling along the bottom of the pipe, or in a uniform thinning of the metal. This produces initial failure at threaded joints where the piping is thin and where stress may accelerate the attack. This condition exists just after the traps of hot water generators or radiators. Oxygen corrosion is characterized by general pitting over the circumference of the pipe.

(e) corrosion can be minimized by the following methods:

(1) Proper Operation. Since carbon dioxide and oxygen are the main offenders, any operating method that reduces the content of carbon dioxide and/or oxygen will reduce the corrosive effects. Operate nonaerating heaters at the temperatures, pressures, and ratings recommended by the manufacturer for proper release of noncondensible gases (mainly CO_2 and oxygen).

(2) External Treatment. Different types of pretreatment of makeup water may be required, as for example: lime-soda softening, hot lime zeolite softening, acid-cycle softener, and the salt splitting process. The choice of any of these methods depends on the economics of the individual case and the characteristics of the available water. All types reduce the quantity of CO_2 or bicarbonate fed to boilers, thus reducing return line corrosion.

(3) Internal Treatment. Corrosion of return piping can be controlled by the use of amines. Amines are chemical compounds that raise the alkalinity of the water. Some of the simpler types are soluble and volatilize from boiler water. Amines inhibit corrosion by protecting the surface of the metal, as well as by raising the pH (increasing the alkalinity) of the condensate. In the concentrations required for protection of condensate piping, amines do not affect nonferrous metals, are nontoxic, and are stable at temperatures approximating 765°F.

2.1 Condensate Return Systems. Condensate may return to the boiler plant by gravity or by the use of mechanical means.

2.1.1 Gravity Return. In gravity return systems, condensate returns to the boiler under its own hydraulic head. The elevation of the steam-using units above the boiler waterline must be sufficient to overcome pressure drops caused by flow, as well as operational pressure differentials.

2.1.2 Mechanical Return. Condensate pumps are used to return condensate from a building or group of buildings to the boiler plant. Figure 4-4 illustrates a typical condensate return unit. The unit consists of a receiver with a water gauge, a motor driven centrifugal pump, and a float control. The pump operates intermittently under the action of the float control switch.

3 OPERATION OF HTW PUMPS. Perform the following procedures for HTW pump operation.

3.1 Startup Inspection. When starting a new unit, or after a general overhaul, make sure the following requirements are fulfilled.

(a) All installation, repair, and cleanup work is completed.

(b) Installation is tested for leaks.

(c) Unit is aligned.

(d) Unit is lubricated with an approved lubricant.

(e) Pump is turned over by hand to make sure that it is free.

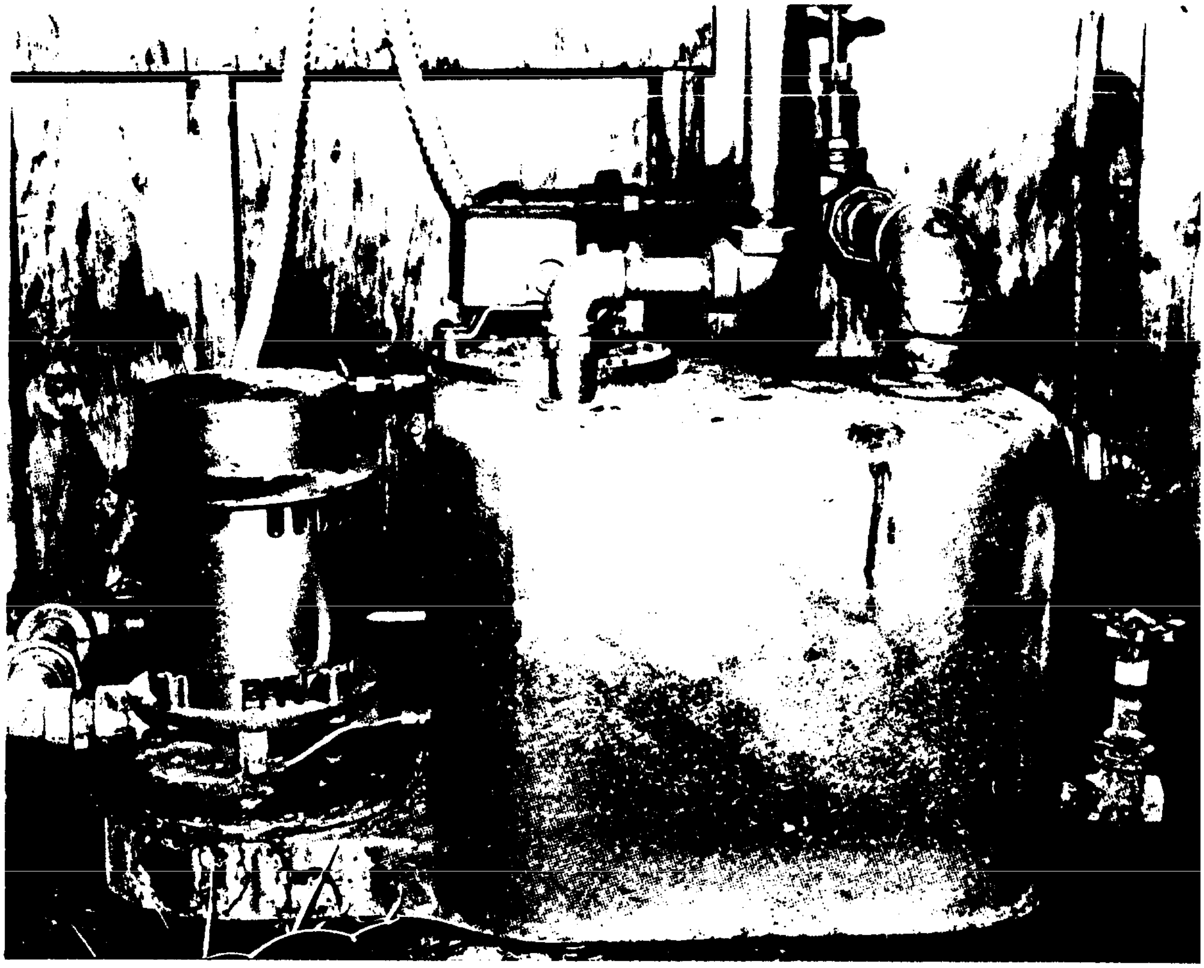


FIGURE 4-4. Condensate Return Unit

(f) Rotation is checked and, if required, corrected.

(g) Adequate bearing cooling water is supplied to bearing jackets at proper pressure and temperature.

(h) Cooling water is supplied to stuffing box jackets at proper pressure and temperature. A flow of 2 gpm is sufficient.

(i) All valves are closed.

3.2 System Startup. Proceed as follows:

(a) Open vent valves on top of pump casing.

(b) Open the suction valve slowly. When water flows to the pump under pressure, as is usual, the water will fill the pump, expelling trapped air through the vents.

(c) Supply water to lantern rings, if provided.

CAUTION

Never operate a pump for more than a few minutes with the discharge valve closed; continued operation without water circulation causes the pump to overheat. Where system conditions require possible operation of the pump with no effective water discharge, provide a recirculation line on the discharge side of the pump to bypass approximately 10 percent of the rated flow. This line discharges back to the suction tank, preferably below water level.

(d) After the pump is full of water, start the pump with the discharge valve closed to reduce the starting load on the drive. When the pump is up to speed, close the vents and slowly open the discharge valve to obtain required delivery.

(e) Make sure the bearing oil rings, if so fitted, turn freely. They may be observed through the oil holes in the bearing caps. If the rings are not operating properly, shut down the pump and correct as required.

3.3 Normal Operation. The following considerations are important in operation.

CAUTION

Never control water delivery by throttling the suction valve, or cavitation may be the result. Cavitation, which is the formation of partial vacuum in a flowing liquid, reduces the available net positive suction head. Also, the sudden condensation of the vapor bubbles resulting from cavitation erodes the rotor and casing.

(a) Output Control. The delivery of centrifugal pumps can be controlled by changing the speed, or by throttling the discharge. Normally, the pumps are driven at constant speed and the delivery is controlled by throttling the discharge, either manually or automatically.

(b) Pump Characteristics. Centrifugal pumps deliver a determined flow at a given pressure (head) when operated at a constant speed If the system head increases abnormally, pump delivery will decrease rapidly, following its characteristic curve. A clogged line, a defective valve, or wrong operating procedures are common causes of head increase in a system. Investigate and correct immediately, if required.

CAUTION

Never permit the pressure drop through the strainer to exceed the normal operating value recommended by the manufacturer.

(c) Strainers. Clean strainers, if provided, at established intervals as recommended by the specific manufacturer. When starting a new system, strainers require frequent cleaning until the system is free from foreign matter.

(d) Parallel Operation. Pumps operating in parallel should have similar characteristic curves in the operating range. If that is not the case, the pump that develops the greatest head will pump most of the water. This condition may be corrected by throttling the discharge valve until the head developed by the pump is reduced to the required value. A better solution is obtained by installing a calibrated orifice in the pump discharge line after the valve. The orifice is designed to decrease the pump head as necessary, which permits operation with a fully open discharge valve.

(e) Stuffing Box Adjustment. Tighten stuffing boxes evenly to prevent excessive leakage, but do not overtighten. Excessive friction can overheat and damage the pump shaft or shaft sleeve and the packing. Set the gland loose enough to allow a trickle of water leakage through the stuffing box. This lubricates and cools the packing which prevents it from overheating and scoring the shaft or shaft sleeve.

(f) Lubrication. When oil rings are used for lubrication, make sure that oil level is maintained, as specified by manufacturer, and that the rings keep turning. Use only the amount and type of oil approved by the manufacturer for the service intended. Regulate bearing cooling water, if used, to maintain oil within safe operating limits. If the bearing is overcooked, atmospheric moisture may condense in the bearing housing, contaminating the oil. If there is no specific information from the manufacturer, consider a maximum operating temperature of 150°F for babbitted sleeve bearings and 180°F for antifriction bearings. Drain oil periodically with a frequency depending on the type of operation. Flush out bearings with gasoline or kerosene, then add new oil. Use clean tools and cloths; do not use waste materials. When grease-packed, antifriction bearings are used, be sure not to over grease the bearings as this may result in overheating. Usually, antifriction bearings should be packed-one-third full with a proper grade of bearing grease. For average operating conditions, add 2 or 3 ounces of grease at intervals of 3 to 6 months. Use a safety fitting or remove drain plug when adding grease to prevent overgreasing.

(g) Irregular Performance. Watch for any abnormal pump operation. Check bearing temperatures, pressure gauges. and flow indicators periodically, and compare with normal operating conditions. Observe stuffing boxes to see that sufficient water leaks through the stuffing box for proper cooling and lubrication. Watch for abnormal noise, overheating, and vibrations. Check anchor bolts for tightness; loose bolts may cause vibration and misalignment.

(h) Noise. A crackling noise may indicate excessive suction lift. A rumbling noise is usually caused by irregular discharge conditions, as when a pump operates at low capacity or beyond its discharge rating.

(i) Water Hammer. Water hammer results from a sudden change in velocity of a liquid column. Avoid water hammer by starting the pump with its discharge valve closed, then slowly open the valve after the pump starts. When stopping, close the discharge valve slowly before stopping the pump. In some installations, pumps stop and start suddenly. If water hammer conditions seem dangerous, a slow-opening and slow-closing check valve should be installed. This permits a gradual increase of flow when starting and a gradual decrease when stopping.

3.4 System Shutdown. Proceed as follows when taking a pump out of service.

(a) Close the discharge valve before stopping the drive. This permits gradual reduction of the load on the driving unit, and protects the pump casing from possible damage caused by water hammer, especially in high-pressure operation. It also protects the check valve from possible water hammer action.

(b) Stop the driving unit.

(c) Close valves supplying water to seal cages (lantern rings), if so fitted.

(d) Close suction valve.

(e) Drain the pump to prevent damage, if the pump is to be out of service for an appreciable period of time and there is a possibility of freezing weather.

4 OPERATION OF CONDENSATE RETURN UNITS. Observe the following procedures for the operation of condensate return units.

4.1 Startup Inspection. When starting a new unit or after a general overhaul, check for the following conditions.

(a) Make sure all installation, repair, and cleanup work is completed.

(b) Test installation for leaks. See that all pipe connections are tight.

(c) See that pump and motor are lubricated with an approved lubricant.

(d) Turn pump shaft by hand to make sure it rotates freely.

(e) See that adequate electrical supply of correct frequency and voltage is available.

(f) See that switches, starters, and protective devices are adequate and are correctly installed.

(g) Ensure that condensate return valves and boiler feed valves are open. The pump does not operate until receiver water level is high enough to close float switch.

(h) Close starting switch momentarily to check motor rotation. Correct, if required.

4.2 System Startup. Proceed as follows to put a pump in service

(a) Close motor disconnect switch. Start the motor by closing the starter.

(b) Observe whether the float switch starts and stops the pump when the water reaches the desired levels in the receiver.

4.3 Normal Operation.

(a) Output Control. Pump delivery is governed by the float switch control. Operation depends on water level in the receiver.

(b) Strainers. In new installations, clean strainers daily until no accumulation of foreign matter is observed. Establish a maintenance inspection program to ensure strainers are cleaned at intervals as recommended by the manufacturer.

(c) Stuffing Boxes. Check packing gland adjustment.

(d) Lubrication. Follow the procedures described in ‘lubrication of HTW pumps.

(e) Irregular Performance. Check any indication of irregular operation, such as abnormal temperature, pressure, vibration, and noise. Operation of new equipment should be closely watched.

4.4 System Shutdown. Proceed as follows when taking a return unit out of service.

(a) Open pump control switch when no return condensate is available or required for boiler feeding. If the unit is to be out of service for overhaul, open the motor disconnect switch.

(b) Close condensate return valves (inlet to the receiver) and boiler feed valves. This should be done only after the boiler is cool and does not require additional water.

(c) If the unit is to be out of service for an appreciable period during freezing weather, drain the pump and receiver to prevent damage.

5 MAINTENANCE OF PUMPS. HTW pumps and condensate return pumps are generally of the centrifugal type and their maintenance procedures are similar.

5.1 Inspection and Maintenance. Never run a pump dry; waterflow is required for lubrication and cooling of internal surfaces. Never throttle the pump suction for flow regulation or cavitation may result. Never operate a centrifugal pump continuously with a closed discharge, or overheating and seizing may result. Operate pumps at least once a week; do not have a unit standing idle for prolonged periods. Check stuffing box conditions; always permit sufficient water leakage for cooling and lubrication. After the packing has been in service for some time, it may require tightening to prevent excessive water leakage. Tighten gland nuts evenly to prevent tilting a gland, which could score the shaft or shaft sleeve.

5.2 Preventive Maintenance Inspection.

(a) Daily. Inspect for the following conditions.

(1) Check for abnormal water pressure, temperature, and flow conditions.

(2) Check for abnormal vibration, noise, and overheating.

(3) Check for too much or too little packing leakage.

(4) Check for hot stuffing box.

(5) Check for hot bearings.

(b) Semiannually. Inspect for the following conditions:

(1) Check alignment of pump and drive at normal operating temperature.

(2) Check shaft or shaft sleeve for scoring.

(3) Replace packing when excessive tightening of the gland is required to keep leakage within limits. Occasionally, packing replacement is necessary if the packing becomes hard and tends to score the shaft.

(4) Drain oil from oil lubricated bearings; clean, flush, and refill with new oil.

(5) Check lubrication of grease-lubricated bearings. Do not over grease. Saponification of the grease may occur if water infiltrates past the bearing shaft seals. This condition may be readily noticed as it gives the grease a whitish color. Replace grease if saponified.

(c) Yearly. Dismantle the pump for a complete inspection and overhaul using the following procedure.

(1) Remove rotor. Inspect for wear, corrosion, and erosion. Remove any deposit or scaling.

(2) Check wearing clearances according to manufacturer's instruction. Generally, wearing ring clearances should not exceed 0.003 inch per inch on the diameter of the wearing rings.

(3) Clean the water seal piping and inspect and clean the seal cages. Inspect and clean stuffing boxes and replace packing.

(4) Check shaft and shaft sleeves for scoring, corrosion, or wear at seals. See if shaft is straight. Check deflection by turning shaft between lathe centers; maximum permissible runout should be from 0.003 inch to 0.006 inch, depending on pump speed. (The lower the speed, the larger the permissible runout of the shaft.)

(5) Check impellers for corrosion, erosion, or excessive wear. Remove foreign matter in the impellers.

(6) Measure bearings for wear. If no specific information is available, allow 0.002-inch clearance per Inch or fraction thereof of shaft journal diameter, plus 0.001 inch. For thrust bearings of the sleeve and collar type the maximum desirable axial float should be 0.016 inch.

(7) Check condition of foot valves and check valves. Check valve operation is particularly important as it protects the pump from water hammer when the pump stops.

(8) Inspect and clean suction and discharge strainers.

(9) Calibrate pressure gauges, thermometers, and flowmeters. Check to see that any breakdown or restricting orifices, which may be used for recirculation or venting, are clean and unobstructed.

5.3 Maintenance. Repair or replace defective parts following yearly inspection.

(a) Wearing Rings Replace wearing rings when they are worn to twice the original clearance, or if the leakage reduces the capacity, head, and efficiency of the unit.

(b) Gland Packing. Replace the entire packing of the stuffing boxes; "never add a ring or two to the existing packing. When repacking a stuffing box furnished with a liquid seal, remove the seal cage (lantern ring) to take out the packing behind it. Count the number of rings before and after the seal cage so that it can be replaced exactly in its previous position. The water-seal passage must line up with the seal cage. Before repacking, inspect the shaft and shaft sleeve for scratches. A scratch where the shaft contacts the packing will quickly ruin the packing. Use only packing material of the type recommended by the pump manufacturer for the intended service. Usually, pumps intended for general service use a high grade of soft, square, asbestos packing, impregnated with oil and graphite. Metallic packings are often furnished for pumps designed for high temperature boiler feed service. Hardened steel shaft sleeves should be furnished when using metallic packing. If bronze sleeves are furnished, use a soft grade packing. When repacking, cut each ring to the proper length so that the ends come together but do not overlap. Place succeeding rings in the stuffing box with joints staggered about 90°. Place one ring in the stuffing box at a time; then tamp it with a metal ring or suitable tool until seated firmly before putting in the next ring. After the correct number of rings are in place, set the gland to hold the packing. Do not press the packing too tight; this may result in burning the packing and cutting the shaft or shaft sleeve. The stuffing box is not packed right if packing friction prevents turning the rotor by hand. However, if a new pump packed with metallic packing has been stored for a great length of time, it may be necessary to apply leverage to free the rotor. When restarting a pump, it is well to have the packing gland finger tight only. All leakage must flow along the shaft to lubricate the packing and prevent overheating.

(c) Mechanical Seals. A mechanical seal consists of two primary parts, a stationary sealing face and a rotating sealing face attached to the shaft and in contact with the stationary face. The close, lapped clearances between the two faces prevent leakage of liquid out or air in. Mechanical seals are precision products and should be treated with care. Follow manufacturer's instructions for maintenance procedures. If specific information is unavailable, perform the following procedure.

(1) Clean each part by washing in a suitable solvent.

(2) Check for defective or damaged seal faces, (nicks, cracks, or scratches, especially those running transversely across the face). Replace seal faces, if required, or relap on a lapping plate.

(3) Replace defective or damaged shaft seal rings. Shaft seal rings should have a push-fit over the shaft. If clearance is excessive, leakage will result.

(4) Replace defective springs.

(5) Replace defective spring retainer, or relocate as required.

(6) Correct seal lubrication, if necessary.

(7) Remove shaft burrs that may damage shaft seal rings.

(d) Alignment. Check alignment by placing a straight edge over top and sides of the two halves of the coupling. Also, measure the space between the two halves with a thickness gauge, at four points 90° apart. All measurements should be equal. Correct misalignment by using shims under the pump or motor as required. Alignment must be correct after the foundation bolts have been thoroughly tightened. Misalignment is often caused by pipe strain. See that suction and discharge piping is properly supported to relieve strains on pump. Faulty alignment causes excessive wear of bearings, shaft, and packing, and produces noise and vibration.

(e) Metallizing. Worn shaft sleeves may be replaced, or they may be rebuilt to size by welding or metallizing. In the metallizing process, new surface metal in wire form is automatically drawn through a special gun to a nozzle. In the nozzle, the wire is melted in an oxygen-gas flame and sprayed by a blast of compressed air which carries the metal to the previously prepared surface. Particles mesh on this surface to produce a coating. The air blast keeps the sprayed surface cool, eliminating risk of warpage or distortion.

CAUTION

Do not use gaskets thicker than 1/64 inch. The halves of the casing will be held too far apart, which permits leakage around the wearing rings,

(f) Gaskets. The gasket placed between the upper and lower halves of the pump casing usually consists of a strong, l/64-inch thick, oiled paper, cut to shape. Asbestos gaskets l/64-inch thick may be used.

5.4 Flood Damage Maintenance. In general, no liquid should enter the casing of a pump which has sealed joints and is connected to suction and discharge piping. Usually, flood maintenance is only concerned with servicing the bearings, packings, and coupling. Dismantle the bearings and inspect them for any rusted or badly worn surfaces. If rust or worn surfaces appear, replace the bearing. Dismantle and clean oil or grease lubricated couplings. Lubricate with an approved lubricant. Disassemble couplings of the pin and rubber bushing type; replace worn parts; clean and reassemble. If liquid or foreign matter has entered the pump, open the pump and make a complete inspection.

CHAPTER 5. COMPRESSED AIR DISTRIBUTION

Section 1. APPLICATIONS AND SYSTEMS

1 COMPRESSED AIR USES. Compressed air is a form of power which is very useful in both military and industrial applications. “It is of particular advantage in applications that require intermittent power a some distance from its source, as the air pressure can be maintained near y constant during work intervals. Compressed air uses fall into one of three categories: power service, process service, or control purposes.

Power Service. In this application compressed a r either moves something or exerts a force. Examples of power service uses are pneumatic tool operation, air lifts, clamps, and cylinders.

Process Service. Compressed air used in this application becomes a part of the process itself. An example is the use of compressed air in a combustion process. Compressed air provides oxygen for the combustion process, and in turn it becomes a part of the combustion products and is no longer identifiable as air.

Control Purpose. Extensive use is made of compressed air to govern and/or regulate various equipment by monitoring pressure or flow rates of some substance. A pneumatically controlled combustion system is an example of such an application.

2 COMPRESSED AIR DISTRIBUTION SYSTEM. Compressed air distribution systems consist of the following equipment:

Piping required to transport the compressed air from a central compressor plant to the consumers

Equipment, instrumentation, and related fat' lit es required to accomplish the above described purpose safely and efficiently

3 SUPPLY PRESSURE. Compressed air is distributed at low, medium, or high pressures. It must be dry and free of oil, dust. or other contaminants. Refer to NAVFAC MO-206, Operation and Maintenance of Air Compressor Plants, for methods of producing compressed air and removing moisture, oil, dust, and other contaminants.

3.1 Low-Pressure Compressed Air Systems. These systems provide compressed air at pressures up to 125 psig. When several air pressures are required within that range, the plant is usually designed for the highest pressure, pressure reducing stations supplying the lower pressures as required. Typical low-pressure applications follow.

Application	Pressure (psig)
Air motors, crane drives, and starting motors for, internal combustion engines	70- 125
Shops	80- 100
Laundries and dry cleaning plants	75 - 100
Starting aircraft jet engines [1]	85
Instrumentation and control	15- 50
General service (tools, cleaning, painting)	40 - 90
Sootblowing for HTW generators and steam boilers	100- 120

[1]Medium-pressure compressed air may also be used for this purpose.

3.2 Medium-Pressure Compressed Air Systems. These systems provide compressed air within the range of 126 to 399 psig. Such systems are not extensive and are generally provided with individual compressors located near the load. Typical applications for medium-pressure applications follow.

Application	Pressure (psiq)
Starting diesel engines	100 - 399
Hydraulic lifts	145 - 175
Retread tire molds	175 - 200

3.3 High-Pressure Compressed Air Systems. These systems provide compressed air within the range of 400 to 6,000 psig. To minimize the hazards that exist with higher pressures and capacities, separate compressors are used for each required pressure. However, for systems at 3,000 psig that also require relatively small amounts of air at a lower pressure, but above 400 psig, air may be supplied in the higher value for the main system and reduced to the lower pressure for small branches provided that safety relief valves are used. Examples of high-pressure applications follow.

Application	Pressure (psiq)
Torpedo workshop	600 and 3,000
Ammunition depot	100, 750, 1,500 and 4,500
Catapults	1,500
Mind tunnel	3,000
Testing laboratories	6,000

4 AIR RECEIVERS. Air receivers are tanks installed in the compressor plant that serve as reservoirs for the storage of compressed air. Air receivers permit meeting peak demands in excess of compressor capacity and act as pulsation dampeners on reciprocating compressor installations. They also separate, collect, and drain moisture, oil, and dirt from the system air. Figure 5-1 shows a typical air receiver.

4.1 Secondary Air Receivers. Long distribution lines that are marginally sized may occasionally require secondary receivers located near a point of heavy demand. Where peak demands are of relatively short duration, this additional storage capacity located near the consumer avoids excessive pressure drops in the line.

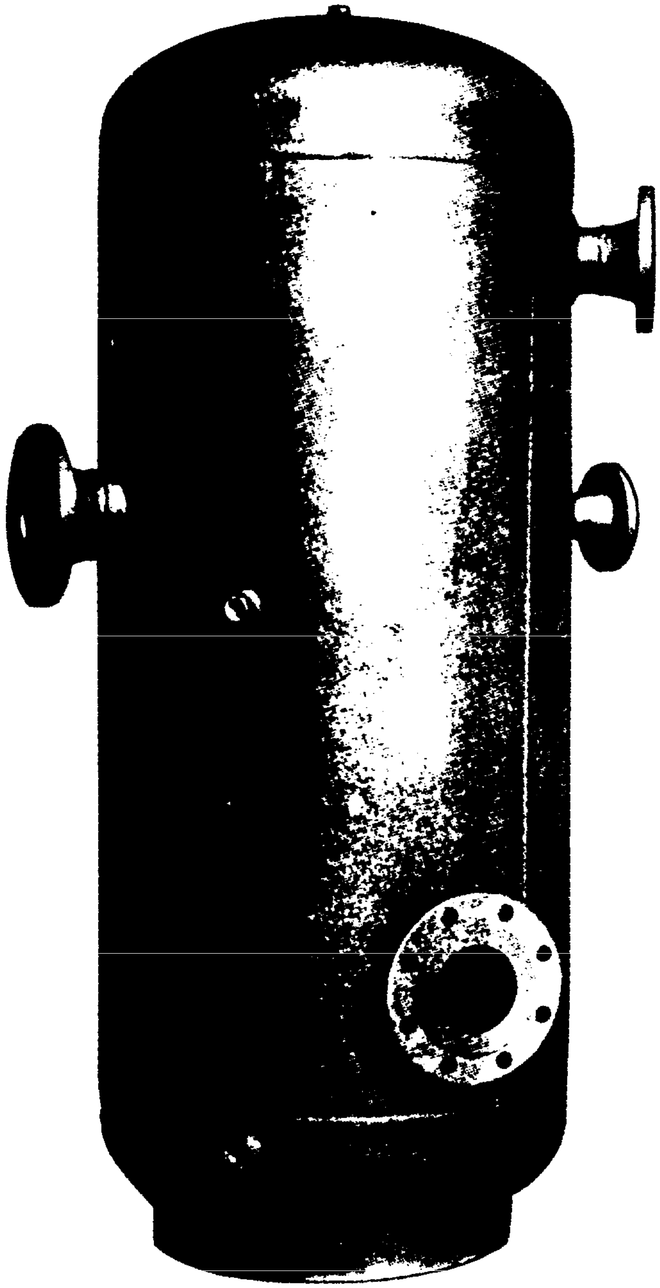


FIGURE 5-1. Air Receiver

4.2 Inspection and Certification of Air Receivers. Technical and administrative procedures for inspection and certification of air receivers are contained in NAVFAC MO-324, Inspection and Certification of Boilers and Unfired Pressure Vessels. This manual also provides test and inspection schedules and damage reporting procedures.

(a) Standard Vessels. An Unfired pressure vessel is a closed vessel in which internal pressure is above atmospheric pressure, and the pressure is obtained from an external source. Safe operation of these vessels requires adherence to the inspection frequencies and guidelines of MO–324, Inspection and Certification of Boilers and Unfired Pressure Vessels.

(b) Non-Standard Vessels. Vessels not designed and constructed according to the rules of the American Society of Engineer's Boiler and Pressure Vessel Code (ASME B&PV Code) are considered non-standard vessels. Because most contract inspectors are licensed to inspect according to the ASME B&PV Code they will not certify non-standard vessels as safe for operation. Therefore, the procurement of non-ASME B&PV Code is discouraged. When certification of non-standard vessels must be accomplished, NAVFACENGCOM certified Inspectors should be employed. Repair of non-standard vessels is prohibited. The inspection of non-standard vessels shall proceed in the same manner as outlined in MO-324.

Section 2. COMPRESSED AIR DISTRIBUTION METHODS

1 TYPES OF AIR DISTRIBUTION SYSTEMS. Compressed air is delivered to consumers by either aboveground or underground piping systems. In many instances, however, life cycle economics have found that small air compressors at the source are more feasible than a compressed air distribution system.

2 DISTRIBUTION ROUTE. The minimum distance between the central compressor plant and the consumers is the preferred routing for a compressed air distribution system; however, as with heat distribution systems, other factors affect the final selection of a route. These factors include the following i terns:

Characteristics of the location

Future expansion

Basements or crawl spaces available for piping

Aboveground obstructions such as rivers or roads

Underground obstructions such as piping or rock

Soil Corrosivity

2.1 Secondary Systems. Generally, a separate system supplies each air service; however, economic considerations may justify installing additional compressors to supply air to minor branch systems.

3 SELECTION OF ABOVEGROUND OR UNDERGROUND DISTRIBUTION SYSTEMS. The decision whether to use aboveground or underground piping shall be based on the life cycle economics. The advantages of each system are as follows:

Above-ground	Underground
Lower first cost	Less vulnerable target
Less maintenance	Less obstruction to aboveground traffic
Easy detection of failure	Less unsightly
Higher continuous operating efficiency	Freeze protected when buried
Longer life	

3.1 Other Factors. The following considerations may have an important influence on the final decision of which system to employ.

Permanent versus temporary use

Existence of a high water table

Degree of hazard (for example, the potential danger that overhead piping may cause to aircraft operations)

Annual ownership, operation, and maintenance costs

4 ABOVEGROUND DISTRIBUTION SYSTEM. An economic analysis will, in most instances, demonstrate the advantages of an aboveground system. Other requirements, such as temporary use or certain operating and local restrictions, may dictate their use. Aboveground systems are less costly to

operate and maintain. The following considerations apply in the design of aboveground distribution systems.

(a) Spans. The maximum spans between pipe supports for straight pipe runs depend on pipe size. Maximum spans for steel pipe and rigid copper tubing are shown "in tab' e 5-1.

(b) Pipe Supports Pipes are usually held in place by U-shaped or similar type clips firmly secured to support structures. The support structures may be walls columns, brackets, concrete pedestals, steel frames, or treated wood frames. Clips fit closely around the pipe; however, sufficient clearance is permitted to allow for longitudinal movement during. normal expansion and contraction. At anchor points, the pipe is firmly clamped to the structure. The hangers are rigid or braced, if necessary, where piping hangs from ceiling beams. This reinforcement prevents "whipping" of the pipe should a break occur while the line is under pressure.

(c) Elevation Clearance. For distribution outside buildings, aboveground overhead lines may be located as little as 12 inches or as much as 22 feet above grade. The clearance above roadways is from 14 to 16 feet for automobile and truck traffic. For railroad crossings, the clearance is 22 feet above grade. The minimum height for installations at low elevations should be sufficient to clear surface water.

(d) Pitch of Aboveground Lines. Air lines are pitched down a minimum of 3 inches per 100 feet of length, in the direction of airflow, to low points where the condensate is collected.

TABLE 5-1. Maximum Span for Pipe

Diameter (inches)	Std. #t. Steel Pipe 40 s (feet & inches)	Copper Tube Type K (feet & inches)
1/2	5'-0"	3'-9"
3/4	5'-9"	4'-3"
1	6'-6"	5'-0"
1 -1/2	7'-6"	5'-9"
	8'-6"	6'-6"
2-1/2	9'-3"	7'-3"
3	10'-3"	7'-9"
3-1 /2	11'-0"	8'-3"
4	11'-6"	9'-0"
5	12'-9"	10'-0"
6	13'-9"	10'-9"
8	15'-6"	
10	17'-0"	
12	18'-3"	

(1 inch = 0.3048 m)

(e) Drip Legs. The low line points are provided with drip legs equipped with scale pockets and automatic drain traps. When accessible, scale pockets may have a manual drain valve instead of an automatic drain trap. Drip legs are located at:

Low points

Bottom of all risers

Every 200 to 300 feet for horizontally pitched pipe

(f) Counterflow of Condensate. Where pipes must be sloped upward, causing condensate to run in a direction opposite to airflow, the pitch of the pipe is increased to a minimum of 6 inches per 100 feet.

5 UNDERGROUND DISTRIBUTION SYSTEM. Selection of the route for an underground distribution system involves consideration and evaluation of the following equipment.

(a) Walking Tunnel. A concrete tunnel containing piping for miscellaneous services may also be used to house compressed air pipes.

(b) Trenches. A concrete trench used for miscellaneous service pipes may be designed to include air lines.

(c) Manholes. Access to underground conduit for inspection, repair, and ventilation of service piping is provided by manholes.

(d) Direct Burial. Direct burial is the method most commonly used for compressed air distribution lines. Because this type of construction generally lowers the air temperature causing additional condensation, it is important that the piping be properly pitched to collect condensation at drip legs. Drip legs can be located in building basements; however, manholes may be required at low points of long distribution systems to house moisture traps. Corrosion control by cathodic protection may be required depending on soil corrosivity.

(e) Pipe Covering. Buried compressed air lines generally require no insulation. However, they should be shop coated, wrapped: tested, and handled in accordance with NAVFAC Specification 34Y (Latest Revision), Bituminous Coating for Steel Surfaces.

(f) Pitch of Underground Systems. Air lines are generally pitched down a minimum of 3 inches per 100 feet of length, in the direction of airflow, to provide easy drainage of condensate.

(g) Drip Legs. Refer to section 2, paragraph 4(e). In horizontally pitched buried pipes where traps are inaccessible, drip legs are located at intervals of not over 500 feet.

(h) Counterflow of Condensate. Refer to section 2, paragraph 4(f).

6 PIPING.

6.1 Piping Design. When practical, pipelines distributing compressed air to numerous branches or service outlets in a large area should form a closed loop. This maintains maximum pressure at branches and outlets and provides two-way distribution to consumers. The use of a closed loop equipped with conveniently located segregating valves permits a partial shutdown of the system for inspection or repairs. Generally, provisions are made for bleeding each part of a loop between segregating valves. The loop pipe should be of sufficient size to prevent an excessive pressure drop at any outlet regardless of the direction of airflow around the loop. Branches shall be at the top of the main to prevent carryover of condensate and foreign matter.

6.2 Piping Materials.

6.2.1 Low-Pressure and Medium-Pressure Systems. Black steel pipe in appropriate thicknesses conforming to pipe Schedule 40, ASTM A 53 or A 120 is used in these systems and is joined preferably by welding. For special conditions, stainless steel pipe and copper tubing with appropriate fittings are also used. Connections to removable equipment are always flanged, except when using small threaded pipe. In all cases, pipes, fittings, and valves shall be in accordance with NAVFAC Specification 21Y (Latest Revision), Steam Power Plant, Heating, and Ventilating Equipment and Piping; and ANSI/API 510-1983, Pressure Vessel Inspection Code - Maintenance, Inspection, Rating, Repair, and Alteration.

6.2.2 High-Pressure Systems. Seamless steel pipe conforming to ASTM A 53 or A 120, with Schedule determined in accordance with ANSI/API 510-1983, is commonly used for high-pressure air systems. Except in very small sizes, butt welded fittings are employed. Screw fittings, when used, have their ends sealed by fillet welds and exposed pipe threads covered with weld. Unions are of the forged steel ground joint type. When economic considerations dictate its use, small systems may employ stainless steel pipe with special fittings to assure a continuous supply of high quality air. Shore activities, particularly torpedo workshops, frequently require copper tubing, Silver-brazed, bronze fittings and valves, and bronze unions with steel ring nut, plastic ring gasket, and silver-brazed ends are used with copper tubing. Pipes and fittings shall comply with NAVFAC Specification 21Y (Latest Revision), Steam Power Plant, Heating, and Ventilating Equipment and Piping; and ANSI/API 510-1983, Pressure Vessel Inspection Code - Maintenance. Inspection, Rating, Repair, and Alteration.

6.3 Valves. Refer to chapter 6 for description and application of the different types of valves used in air distribution systems. Globe valves used in high-pressure horizontal air lines should be installed so that the stem projects horizontally. This prevents restrictions to line drainage which could be caused by the elevated valve seat. If the valve must be installed with the stem in the vertical position, or when the valve interferes with line drainage, a drain connection for the pocketed space should be provided.

6.4 Expansion and Contraction. Expansion and contraction of pipes carrying compressed air is normally not a serious problem. However, consideration must be given to failure of an aftercooler which would allow air at elevated temperatures to enter the system and cause thermal expansion. Piping in the immediate vicinity of the air compressors can also be hot enough to warrant careful checking of flexibility. Wherever possible, expansion is controlled by a change in direction of pipe runs or by the use of expansion bends and loops. In low-pressure systems, various types of corrugated pack-less type expansion joints or slip-packed joints can be used.

7 REFERENCE DESIGN SPECIFICATIONS. Consult NAVFAC DM-3.5, Design Manual, Compressed Air and Vacuum Systems; and NAVFAC DM-3.8, Design Manual, Exterior Distribution of Utility Steam, High Temperature Water (HTW), Chilled Water (CHW), Fuel Gas, and Compressed Air, for design standards of compressed air distribution systems. NAVFAC Guide Specification-15411 contains detailed guidance on construction and components of these systems.

Section 3. COMPRESSED AIR PLANTS

1. COMPONENTS OF AN AIR COMPRESSOR PLANT. Air compressor plants are used to provide an adequate quantity of compressed air at sufficient pressure to the various points of application. The main components of an air compressor plant are the air compressor, the auxiliary equipment, and the controls. NAVFAC MO-206 provides detailed operation and maintenance procedures of compressed air plants.

2. AIR COMPRESSOR. The air compressor is the heart of a compressed air plant. Compressors are used to increase the pressure of the air from Initial conditions (air intake) to the discharge conditions (air discharge). Compressors may be used as vacuum pumps as well. A vacuum pump has an intake that is below atmospheric pressure and usually compresses to no higher than atmospheric pressure. The main type of air compressors are positive displacement and dynamic. The manufacturer's technical manual should provide detailed operating and maintenance of the compressor.

2.1 Positive Displacement Compressors. There are two basic types of positive displacement compressors. In one, the air is compressed as the volume of the enclosed space is reduced. In the other, a definite quantity of air is trapped and transferred from the suction intake to the discharge port without reducing its volume. The pressure increase is caused by backflow into the casing when the discharge port is uncovered. Example of the first type are the reciprocating compressors, rotary sliding vane compressors, and rotary liquid piston compressors. An example of the second type is the rotary twin-lobe compressor.

2.2 Dynamic Compressors. Dynamic compressors operate by imparting velocity and pressure to the admitted air, through the action of a rapidly spinning impeller or rotating vanes. The main types of dynamic compressors are the centrifugal and the axial compressors.

3. AUXILIARY EQUIPMENT. The following auxiliary equipment is required for the proper operation of an air compressor plant.

3.1 Air Intake Filters. Filters prevent the admission of atmospheric dust to the air compressor.

3.2 Silencers. Silencers reduce objectionable compressor suction noise.

3.3 Intercoolers and Aftercoolers. Intercoolers are used between consecutive stages of compression to remove the heat of compression. Aftercoolers are installed on the compressor's discharge lines to remove the heat of compression after compression is completed. They are effective in removing moisture and oil from the compressed air as well.

3.4 Separators. Separators remove and collect the entrained water and oil precipitated from the air.

3.5 Traps. Traps drain condensed moisture and oil from separators, intercoolers, aftercoolers, receivers, and distribution piping.

3.6 Air Receivers. Air receivers are tanks wherein compressed air is discharged and stored. They help to reduce pulsations in the discharge line and provide storage capacity to meet peak demands exceeding the capacity of the compressor.

3.7 Air Dryers. Air dryers remove moisture that might condense in air lines, air tools, or pneumatic instruments.

3.8 Safety Valves. Safety valves are used in a compressed air or gas system. They must open rapidly and fully so that excessive pressure buildup can be relieved immediately to prevent damage or destruction of the system components. Safety valves are found In interstages, air receivers, and between a positive displacement compressor and any shutoff valve.

4. CONTROLS. Control systems for air compressors vary from the relatively simple to the extremely sophisticated. The simpler control systems, through the use of sensors, monitor the performance of the equipment and through the use of lights and/or audible signals alert an operator that some variable is outside the normal operating range. Most systems automatically initiate a shutdown procedure under certain conditions to prevent equipment damage. With increasing use of remote, unattended compressor installations, the demand for the highest degree of protection and reliability has brought about many advancements and lessened the need for operator involvement. Many controls systems provide a completely automatic sequence for starting, operating, and shutdown of compressors. The more advanced control systems are able to optimize equipment efficiency by controlling one or more variables to obtain a specified level of performance.

Section 4 OPERATION OF COMPRESSED AIR DISTRIBUTION SYSTEMS

1 SAFETY PRECAUTIONS.

1.1 Explosion Hazards. Although compressed air at all pressures can be dangerous, high-pressure systems are especially so. Serious explosion possibilities exist in compressed air systems whenever high-pressure air is suddenly admitted into pockets or dead ends which are at or near atmospheric pressure. The air temperature in the confined space is increased to the ignition point of any flammable material that may be present. This autoignition or diesel action has been the cause of serious explosions that resulted in loss of life and complete destruction of facilities. Such an explosion can create shock waves that travel throughout the compressed air system and may possibly cause explosions at remote points. Under such conditions, a small quantity of oil residue, or even a small cotton thread, may be sufficient to cause ignition.

1.2 Preventive Measures. As a safeguard against explosions in high-pressure compressed air systems, a number of precautions should be taken.

(a) Use of Slow-Opening Valves. These valves are used in pocketed spaces such as lines to gauges and regulators to prevent a sudden pressure rise in these spaces.

(b) Elimination of Flame Arrestors. Flame arrestors. sometimes used to prevent flame propagation in pipelines, should not be installed in high--pressure air systems as they may create additional hazards.

(c) Pipe Coloring. High-pressure air lines are identified with a painted light gray band and adjoining light green arrowhead pointing in the normal flow direction. These markings are placed on high-pressure air lines at each point where piping enters or emerges from a wall and immediately adjacent to all valves, regulators, check valves, strainers, and other components

(d) Location of Equipment. High-pressure air storage and dryer cylinders are isolated from other facilities as a precaution against damage that could result from the rupture of the cylinders.

(e) System Tests. Before putting a high-pressure compressed air system into operation, the required testing of DM-3.5, Design Manual, Compressed Air and Vacuum Systems, must be accomplished by competent personnel with an engineer responsible for safety.

2 STARTUP INSPECTION.

Before placing a new compressed air distribution system in service, or after a major overhaul to an existing system, make sure the following requirements are fulfilled.

(a) System meets all applicable requirements as stated in the approved specifications.

(b) Applicable field tests, as described in NAVFAC DM-3.5, Design Manual, Compressed Air and Vacuum Systems, and section 3, paragraph 1.2 have been satisfactorily completed.

(c) All installation, repair, and cleanup work is completed, including cleaning and flushing of compressed air pipelines. This is especially important in high-pressure air systems where any grease, oil: lint, or flammable material left in the pipe may constitute an explosion hazard.

(d) The system is tight, properly supported, and in good operating condition.

(e) All auxiliary equipment, such as strainers, moisture separators, valves, and pressure reducing stations, is correctly installed and ready for operation.

3 SYSTEM STARTUP. Before placing the distribution system in service, notify the central compressor plant and the compressed air consumers. Provide a startup schedule to all involved organizations together with specific procedures to be followed in the event of an emergency

3.1 Startup Procedure. Proceed as follows:

(a) Make sure that proper air pressure is carried in the air receiver of the compressor plant-

(b) Drain receiver of accumulated condensate, if any.

(c) Check automatic drain of air receiver for proper operation.

(d) Make sure air relief valve and air receiver pressure gauge are in good operating condition and are properly calibrated.

(e) Slowly open main air valve located at the air receiver outlet pipe.

(f) Place in service the automatic drain traps located in the drip legs. Check operation of the traps. Where manual drain valves are used, throttle the valves until moisture is drained; then close valves.

(g) Slowly open main air inlet valve of the secondary air receiver, if provided.

(h) Make sure air relief valve and pressure gauge of the secondary air receiver are in good operating condition and are properly calibrated. -

(i) Drain secondary air receiver of accumulated condensate.

(j) Check automatic drain of secondary air receiver for proper operation.

(k) Slowly open branch air valves, as required. In high-pressure systems special-care should be taken when admitting air to a-pocketed space to prevent explosion hazards (refer to section 3, paragraph 1.1 and 1.2).

(1) Place in service pressure reducing stations and moisture separators, as required.

3.2 Precautions. While placing the distribution system in service, check for the following:

Action of expansion loops or bends

Action of supports, anchors, guides, and hangers

Proper drainage of condensate from drip legs

4 NORMAL OPERATION. While the system is in operation, perform the following tasks.

(a) Check operation of moisture separators and automatic drain traps. Open manual drain valves periodically to rid the system of condensate.

(b) Clean strainers regularly and maintain dehumidifiers in a free and clean condition

(c) Make sure manhole vents are unrestricted, and tunnels and trenches are kept dry and properly ventilated.

(d) Check operation of draining equipment in manholes.

(e) Make certain the air distribution system is free from leaks. Refer to table 5-2 for amount and cost of air leaks, which is based on 50 cents per 1,000 cubic feet, For costs other than 50 cents per 1,000 cubic feet, multiply the cost in the table by K/50, where K is the actual cost in cents per 1,000 cubic feet. Air distribution systems can be checked for leaks by one of the following methods:

By listening for the sound of air leaks

By conducting a no load test on weekends (with all air users shut down, measure airflow with meters)

Soap test

By conducting a static pressure test (Refer to chapter 5, section 5 or NEESA 16-3015, Evaluation of Compressed Air System Losses, for additional information.)

(f) In aboveground systems, ensure supporting structures do not settle or shift position.

5 SYSTEM SHUTDOWN. Notify the central compressor plant and the compressed air consumers before shutting down the system. The shutdown procedure is as follows:

(a) Close main air valves slowly.

(b) Crack open bleed valves to relieve the pressure. The time required to bring the pressure down depends upon the amount of valve throttling,

(c) Check operation of the automatic drain traps. When the air pressure is too low for proper operation of the traps, open manual drain valves for direct drainage of condensate.

(d) Relieve air pressure in secondary air receivers by opening manual drain valves. This will also permit draining moisture condensate and sediment accumulated in the tanks.

(e) In underground systems, keep draining equipment in service to remove any water that may infiltrate into the manholes.

6 EMERGENCY PROCEDURES. Repair all piping leaks as soon as possible. Refer to table 5-2 for a quick estimate of the amount and cost of air leaks. The defective line can be isolated for repairs by closing segregating valves. Often the service can be maintained to affected customers through an alternate route by means of a loop closure.

7 CASUALTY PLANNING. Make certain operators are familiar with location and arrangement of piping systems, valves, associated equipment, and controls. A map of the area served, showing the location of the distribution piping, equipment, and consumers, is very useful and should be available to operators. Give operators definite instructions on emergency procedures. Schedule periodic practice fire drills, inspections, and other emergency procedure tests. Train all opertors in the use of available fire fighting and emergency draining equipment.

TABLE 5-2. Amount and Cost of Air Leaks[1]

	Size of Hole (inches)									
	1/64		1/32		1/16		1/8		1/4	
Air Press. (psig)	Air Losses (cfm)	Cost Per Month $	Air Losses (cfm)	Cost Per Month $	Air Losses (cfm)	Cost Per Month $	Air Losses (cfm)	Cost Per Month $	Air Losses (cfm)	Cost Per Month $
50	0.146	3.15	0.594	12.80	2.37	51.00	9.42	203.50	37.8	815.00
60	0.169	3.65	0.682	14.75	2.73	59.00	10.9	235.50	43.5	940.00
70	0.192	4.15	0.773	16.70	3.09	65.50	12.3	265.50	49.4	1,065.00
80	0.214	4.60	0.864	18.65	3.46	74.50	13.8	298.00	55.2	1,190.00
90	0.237	5.10	0.955	20.60	3.81	82.00	15.3	330.50	61.1	1,330.00
100	0.260	5.60	1.05	22.70	4.19	90.50	16.8	363.00	66.9	1,445.00
110	0.279	6.00	1.14	24.60	4.55	98.00	18.2	393.00	72.8	1,570.00
120	0.305	6.60	1.23	26.55	4.93	106.50	19.6	423.50	78.6	1,695.00
130	0.325	7.00	1.33	28.70	5.28	114.00	21.1	455.50	84.5	1,825.00
140	0.351	7.60	1.41	30.45	5.64	122.00	22.4	484.00	89.7	1,935.00
150	0.370	8.00	1.51	32.60	5.98	129.00	23.8	515.00	95.5	2,060.00
175	0.429	9.25	1.72	37.15	6.89	149.00	27.4	590.00	110.0	2,375.00
200	0.494	10.65	2.00	43.20	7.93	171.00	31.6	680.00	127.0	2,745.00

1Airflow is based on nozzle coefficient of 0.64. Costs assume a continuously pressurized system.

Section 5. MAINTENANCE OF COMPRESSED AIR DISTRIBUTION SYSTEMS

1 INSPECTION AND MAINTENANCE. Piping system reliability and trouble-free service are promoted by proper operating procedures to include:

(a) Proper Ratings. Do not operate piping systems beyond their normal pressure and capacity ratings, except during emergency conditions and under close observation.

(b) Correct Operation. Follow operating procedures as described in section 3 of this chapter. Make certain piping system is always drained of condensed moisture and free of oil and dirt.

(c) Piping Supports. Ensure supports, hangers, anchors, and guides adequately support and guide the pipes. Check operation of expansion joints or bends.

(d) Ventilation and Draining of Manholes. Ensure manholes of underground systems are always well ventilated and drained.

(e) Cathodic Protection. Follow manufacturer's instructions for operation of cathodic protection systems, if provided. Take rectifier readings monthly and make Structure-to-Electrolyte potential readings quarterly as described in paragraph 2.4.5. Report inconsistent readings to your supervisor or EFD (code 102) immediately.

2 PREVENTIVE MAINTENANCE INSPECTION. Inspect piping systems with a frequency appropriate for the particular installation and type of service given. The following inspection schedules are considered adequate for average installations.

2.1 Monthly Inspection of Aboveground Systems. Inspect for the following i terns.

(a) Leaks. It is very important that air distribution lines be kept free from leaks. A l/16-inch hole on an air line carrying compressed air at 100 psig pressure wastes approximately 2,200,000 cubic feet of air per year if operated continuously. This approximates the entire output of a 500 cubic feet per minute compressor operating during nine 8-hour days.

(b) Moisture and Dirt. Check traps, strainers. and dehumidifiers for proper operation according to manufacturers' recommendations and operating environment.

(c) Abnormal Pressures. Insufficient pressure may indicate excessive leakage, line obstructions preceding the using station, clogged strainers, defective compressor operation or controls, or improper operation of pressure reducing stations. Excessive pressures may indicate malfunctioning of the compressor control, improper setting or defective operation of the air receiver safety valve, or malfunctioning of pressure reducing stations.

(d) Excessive Pressure Drops. An overloaded pipeline or an obstructed line will show an excessive pressure drop.

(e) Vibration. Vibration may be caused by inadequate or defective supports, and/or improper anchorage.

(f) Corrosion. The external surfaces of air lines should be protected by corrosion-proof paint or by adequate covering.

(g) Operation of Associated Equipment. Ensure correct operation of associated equipment, such as moisture traps, strainers, pressure reducing stations, dehumidifiers, and auxiliary equipment, which are addressed elsewhere in this manual.

2.2 Yearly Inspection of Aboveground Systems. Inspect the following items.

(a) Check for corrosion, leakage, loose joints, and damaged or missing supports of piping systems.

(b) Settling or shifting of poles, hangers, or other supporting members. This can be determined by checking the grade of the lines.

(c) Check valves for leakage, corrosion, defects in stems, packing glands, handwheels, seats, bodies, flanges, and gaskets.

(d) Valve pits for clogged vents, structural damage, missing covers, and accumulation of dirt and debris.

(e) Condition of flanged fittings.

(f) Condition of expansion joints, if any.

(g) Condition of hangers, guides, supports, and anchors.

(h) Condition of traps, strainers, dehumidifiers, and moisture separators.

(i) Condition and adjustment of pressure reducing stations.

(j) Setting of relief and safety valves.

(k) Condition of air receivers.

(1) Condition and calibration of instruments.

2.3 Inspection of Underground Systems. The applicable instructions in paragraph 2.2 are also valid for inspections of underground systems. Refer to information on inspection of steam distribution systems (ignore instructions regarding insulation and telltales).

3 HYDROSTATIC TESTS. Test the distribution system with water pressure following major repairs involving pipe welding or making up joints.

4 OVERHAUL AND REPAIRS. Refer to chapter 3, section 4, paragraphs 3.1 through 3.4.

Section 6 . EVALUATION OF LOSSES IN COMPRESSED AIR SYSTEMS

1 COMPRESSED AIR SYSTEM LEAKS. Leakage of compressed air is a problem at industrial installations and if uncorrected, will result in significant monetary losses. Leakage can result from corrosion in underground piping, damaged joints, and defective fittings and valves. A relatively simple test has been devised which will rapidly and economically determine whether a distribution line is leaking and if so, the magnitude of the losses.

2 TEST METHOD. This test requires that a segment of a compressed air distribution line be pressurized, sealed, and checked by use of a pressure gauge to determine if the line is leaking. If there is no pressure decrease, there is no leakage. If the pressure does decrease, a leak is indicated. The amount of leakage can be determined and a graph prepared that will determine the loss at operating pressure.

3 TEST EQUIPMENT. The equipment is very simple and relatively inexpensive:

Pressure gauge

Stopwatch

4 TEST PRECAUTIONS. This test will produce valid results as long as the relationship between pressure and flow rate is linear. Assuming a sonic exit velocity, the relationship will be linear as long as the ratio of the atmospheric pressure to the line pressure exceeds the critical pressure ratio of 0.53 for gases. Thus, to ensure maximum accuracy, test data should not be used if the pressure gauge registers less than 20 psig.

5 TEST PROCEDURES. The following steps must be performed to complete a pressure decay test.

(a) Obtain scale drawings of the section to be tested. Verify drawings in the field and calculate the volume of the section to be tested.

(b) Install a pressure gauge at a convenient location.

(c) Secure all loads the line supplies.

(d) Isolate the line from the compressed air system.

(e) Immediately begin taking readings at the pressure gauge but do not try to start the moment the valve is closed. Observe the pressure gauge and begin timing when the pointer passes a convenient mark. Example: On a 100-psig system, wait for the pressure gauge to reach 95 psig before starting the stopwatch.

(f) Note the time at convenient pressure intervals (5 or 10 psi increments). Continue data recording until 20 psig is reached.

(g) Calculate Q from equation 5.1(a).

(h) On graph paper, plot Q on the Y axis and P on the X axis.

(i) Using linear regression, calculate the equation for the best fitting straight line and solve for $Q_{nominal}$. ($Q_{nominal}$ is defined as normal operating pressure.)

5.1 Test Formula. In determining the air losses, use the following mass loss formula.

(a)

$$Q = \frac{35.852\ V}{(T+460)(t_f - t_i)}(P_i - P_f)$$

Where: Q = volumetric airflow (scfm)
V = volume of tank, ft^3
T = temperature, °F
P = pressure, psig
t = time, minutes
i = initial
f = final

(b) Although the regression equation can be calculated by hand, the calculations are quite laborious. It is strongly recommended that an inexpensive hand-held calculator with statistics capability or an in-house computer program be used as the information can then be rapidly and accurately calculated.

5.2 Example. The following example illustrates the pressure decay test procedure.

(a) A section of 10-inch compressed air line is suspected of leakage. The line is located on drawings and verified by a field inspection. Using an engineering scale and the drawing, the length of line is found to be 1,000 feet. Calculating the volume of the line:

$$V = \frac{\pi d^2 l}{4} = \frac{1}{4}\pi \times \left(\frac{10.75\text{ in}}{12\text{ in/ft}}\right)^2 \times 1{,}000\text{ ft}$$

$$V = 630.3\ ft^3$$

(b) A pressure gauge is installed on the line at an outlet valve, and all loads on the line are secured. With a person watching the gauge, the line is isolated from the central air distribution system.

(c) The pressure gauge, which had indicated 96 psig, begins to fall immediately. When the gauge reaches 90 psig, the stopwatch is started. Time is recorded at 10-psi intervals as shown in table 5-3. (A stopwatch with a lap counter makes this easier.)

(d) Assuming an ambient temperature of 68°F, the losses can be calculated for each pressure interval, using equation 5.1(a). Results are shown in table 5-4.

(e) The data can be plotted as shown in figure 5-2 to determine how well the test data fits a straight line. Although test data from an actual test will normally be offset from a straight line to some degree, severe deviations will require that the test be repeated.

TABLE 5-3. Pressure Test Data

Pressure (psig)	Time (min:sec)
90	0:00
80	10:42
70	23:17
60	38:34
50	58:56
40	87: 28
30	135:01

TABLE 5-4. Calculation of Losses

Pressure (psig)	Average Pressure (psig)	Time (min:sec)	Time (rein)	Loss (scfm)
90--80	85	10:42	10.70	40
80-70	75	23:17	23.28	34
70-60	65	38:34	38.57	28
60-50	55	58:56	58.93	21
50-40	45	87:28	87.47	15
40-30	35	135:01	135.02	9
30-20	25	277:40	277.67	3

(f) Applying linear regression to the data:

X = avg press.
Y = loss
Y = mX+b

yields the equation: Q = 0.62 P - 12.75.

Losses at operating or nominal pressure (96 psig) are calculated:

Q_{96} =O.62 (96) - 12.75 Q_{96} = 47 scfm

At a cost of 50 cents for 1,000 cubic feet of compressed air, this represents: $12,350/year (dollar figure will vary based on facility costs for compressed air).

6 CORRECTIVE MEASURES. $Q_{nominal}$ represents the loss in the compressed air system at operating conditions, assuming a constant pressure over the length of pipe in question. This value, taken with the activity's cost to produce compressed air, can be used to develop projects to repair or replace sections of compressed air line.

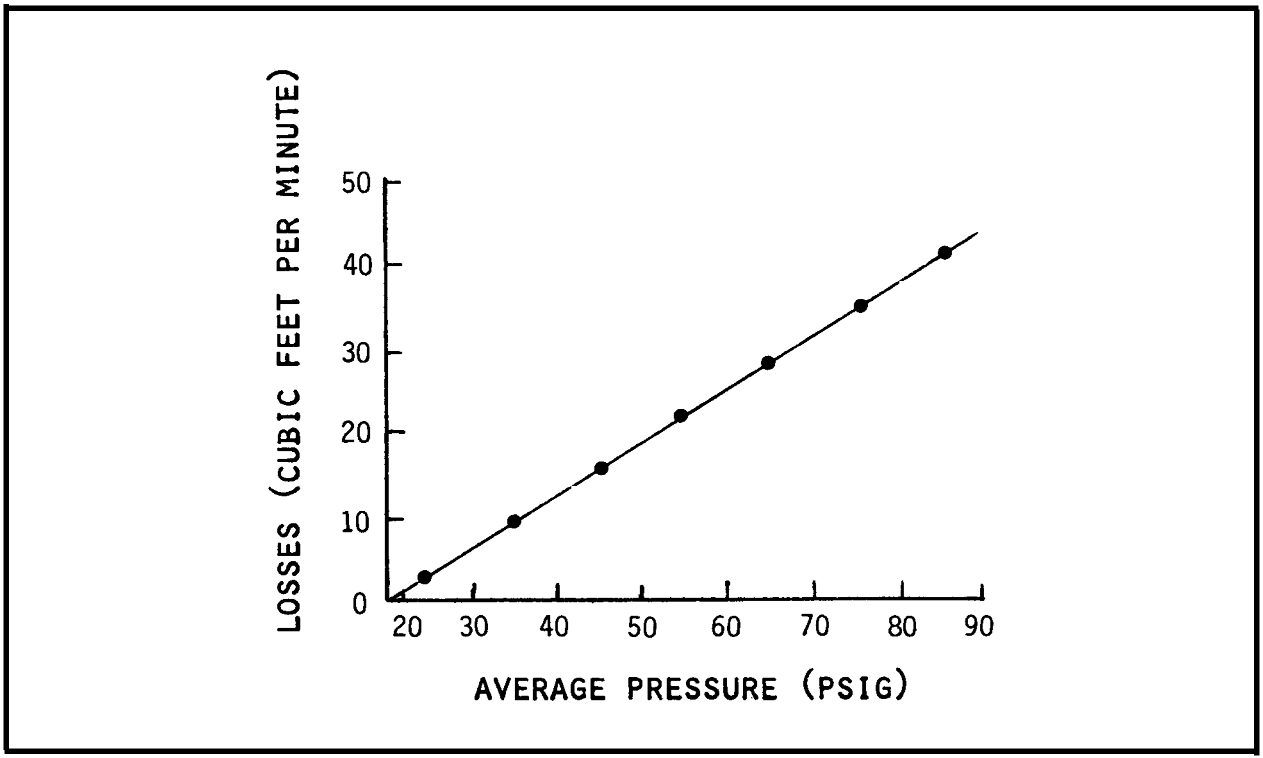


FIGURE 5-2. Loss (cfm) vs Pressure (psig)

CHAPTER 6. INSTRUMENTS AND CONTROLS

Section 1. MEASUREMENT AND CONTROL OF FLUIDS

1 IMPORTANCE OF MEASUREMENT AND CONTROL. Efficient and safe operation of a distribution system requires measuring and controlling flows, temperatures, and pressures of the fluids handled. Several types of Instruments and controls are used for that purpose, as described in the following paragraphs. The amount and type of instruments and controls used depends on the complexity and importance of the installation.

2 INDICATING INSTRUMENTS. These instruments give Immediate information on fluid condition for purposes of regulation and control, and warning of unusual conditions, such as abnormal pressures, temperatures, or flows. Pressure gauges, thermometers, and flowmeters are the indicating instruments most commonly used in distribution systems.

2.1 Indicating Pressure Gauge.

CAUTION

> When employing a Bourdon gauge to measure steam pressure, use a gauge siphon or water leg to ensure that hot steam does not come into contact with the tube.

The more common type of pressure gauge is the Bourdon type, whose Internal mechanism is illustrated in figure 6-1. The measuring element of the Bourdon type gauge is a thin-walled, oval-shaped tube bent into an arc. The tube is closed at one end and connected to the pressure source at the other. The oval-shaped tube changes its shape with a change in pressure resulting in the following conditions.

(a) When the pressure within the tube Increases, the oval cross section tends to become circular.

(b) The above action causes the tube to straighten. This is similar to the action of a paper tube toy which is normally curled until air pressure is applied to the opening.

(c) The movement of the free end of the Bourdon tube is transmitted through a toothed gear sector and pinion to a pointer which indicates the pressure on a uniformly graduated dial.

2.2 Pressure Snubbers. Pressure snubbers are sometimes used to protect the gauge from damage to the mechanism by cushioning shock and pulsation. A gauge cock must be Installed next to the gauge, and provisions are often made for the Installation of a test gauge for testing purposes.

2.3 Thermometers. These instruments are used to measure the temperature of fluids. There are principally three types: liquid, analog, and digital.

2.3.1 Liquid Thermometers. The more common type of liquid thermometer consists of a capillary glass tube from which air has been removed. The upper

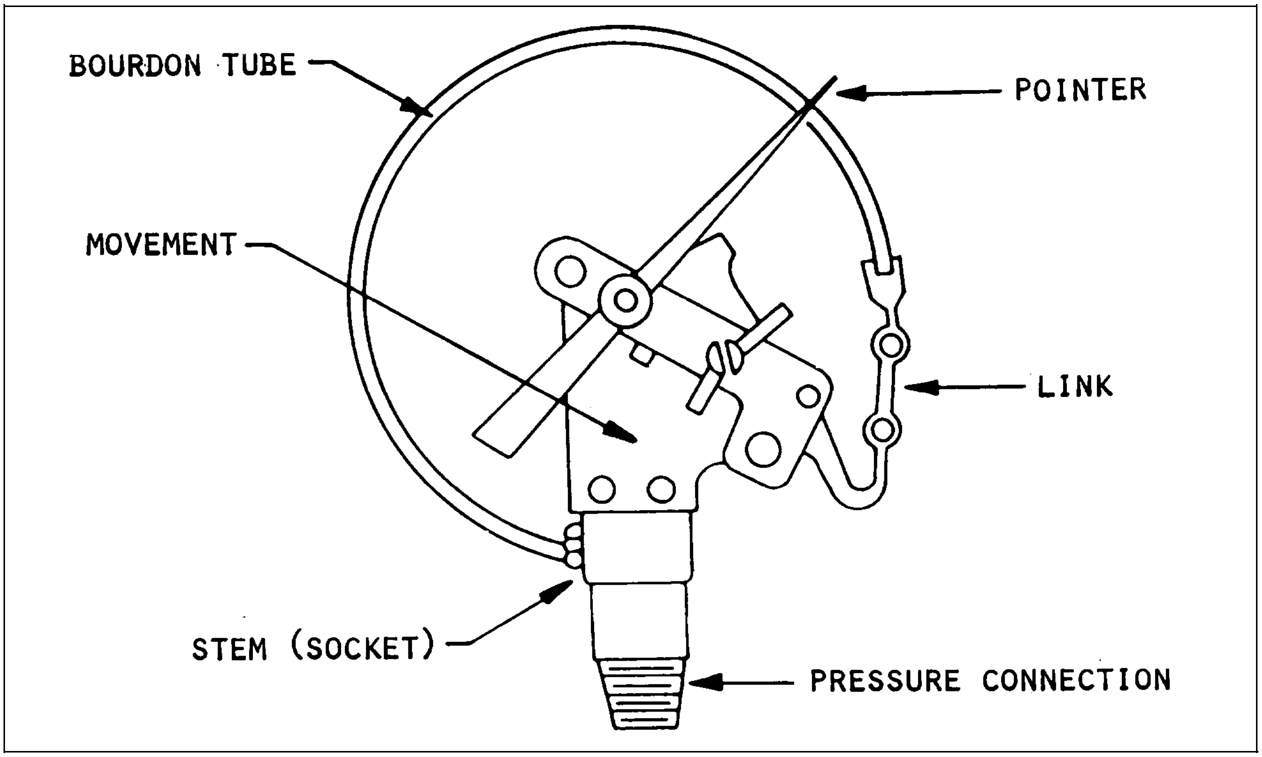


FIGURE 6-1. Internal Mechanism of a Bourdon Type Pressure Gauge

end of the tube is closed and the other end is expanded into a bulb filled with a suitable liquid, such as mercury or alcohol. When the bulb is heated, the liquid expands and rises in the tube. The reverse is true when the bulb is cooled. In each case, the displacement of the liquid through the tube is proportional to the temperature. Divisions marked in the tube, or on an adjacent surface, indicate the degrees of temperature. Industrial thermometers are made in armored and unarmored styles, and in straight, angle, and oblique stem styles. Figure 6-2 illustrates a straight stem industrial thermometer.

2.3.2 Analog Thermometers. Analog thermometers use a thermocouple or platinum resistance temperature detector (RTD) with a cable type probe and a meter which has a pointer and a graduated dial for reading the temperature in either Fahrenheit or Celsius. Field analog thermometers have self-contained power sources and are hand-carried. Figure 6-3 illustrates an analog thermometer.

2.3.3 Digital Thermometers. Digital thermometers use a thermocouple or platinum RTD with a cable type probe and a digital LED or LCD readout in either Fahrenheit or Celsius. Digital thermometers have self-contained power sources and have the advantages of holding the last reading for viewing later and changing the precision desired between whole degree and one-tenth of a degree readings. Some digital pyrometers utilize infrared sensing for temperature measurement. Figure 6-4 illustrates a typical digital thermometer.

2.4 Flowmeters. Flowmeters are instruments that measure the rate of flow of a fluid. Flowmeters are categorized into the following general classifications: differential pressure, positive displacement, velocity, and

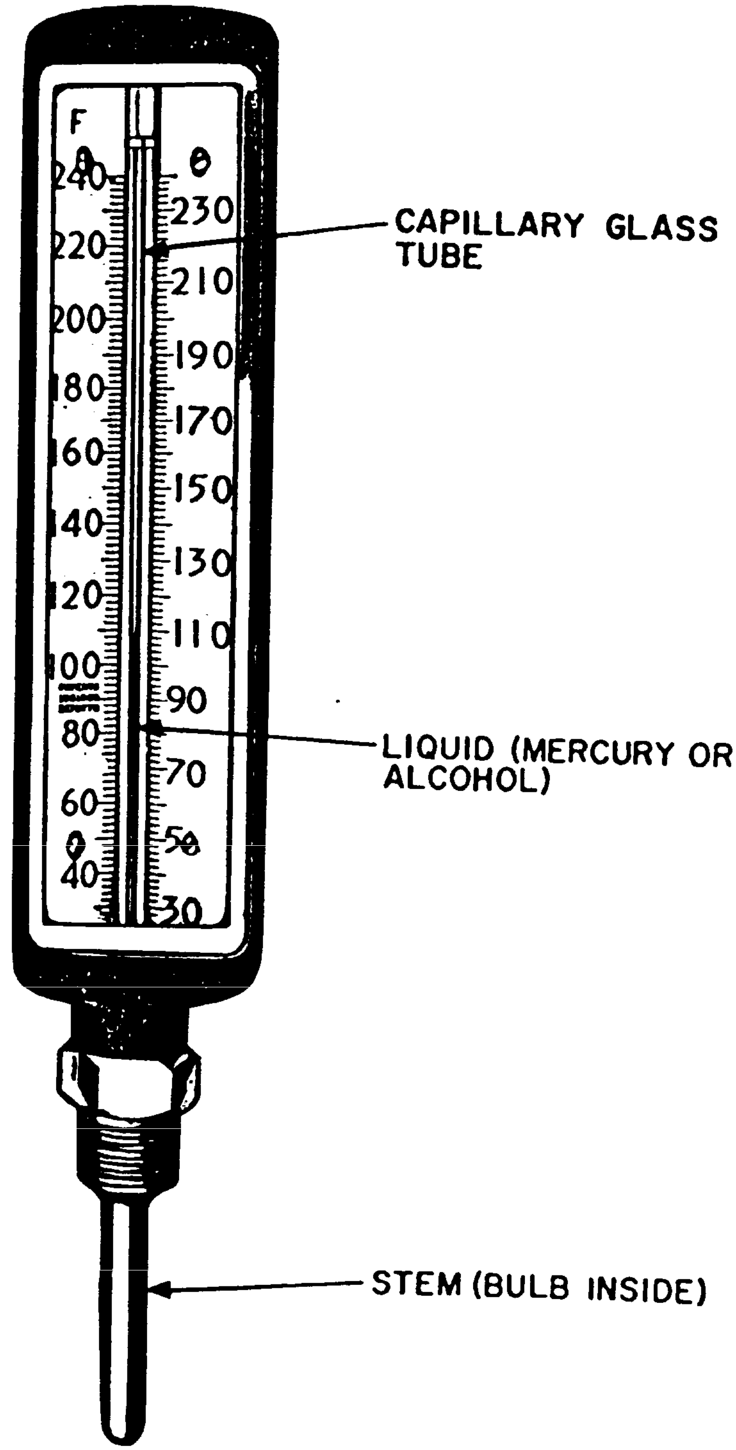


FIGURE 6-2. Straight Stem Industrial Thermometer

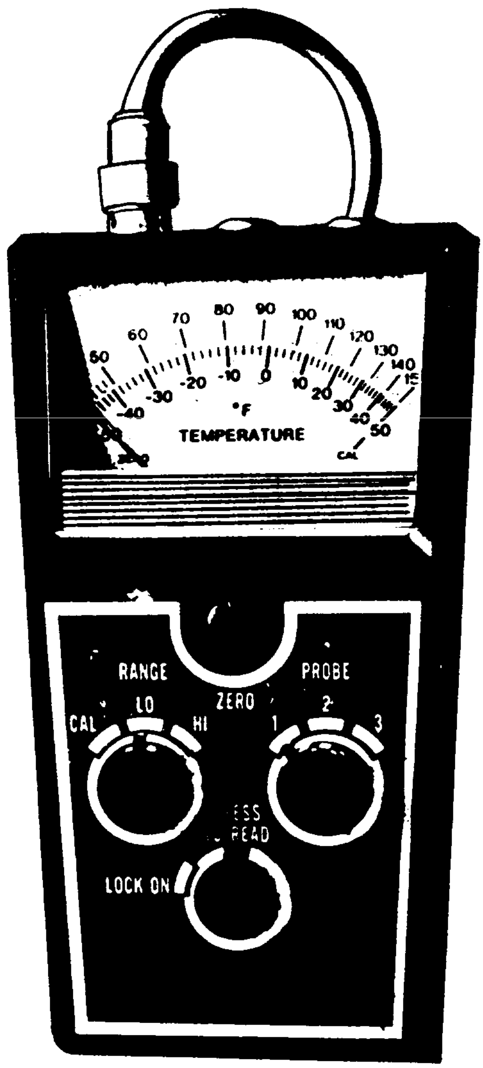


FIGURE 6-3. Analog Thermometer

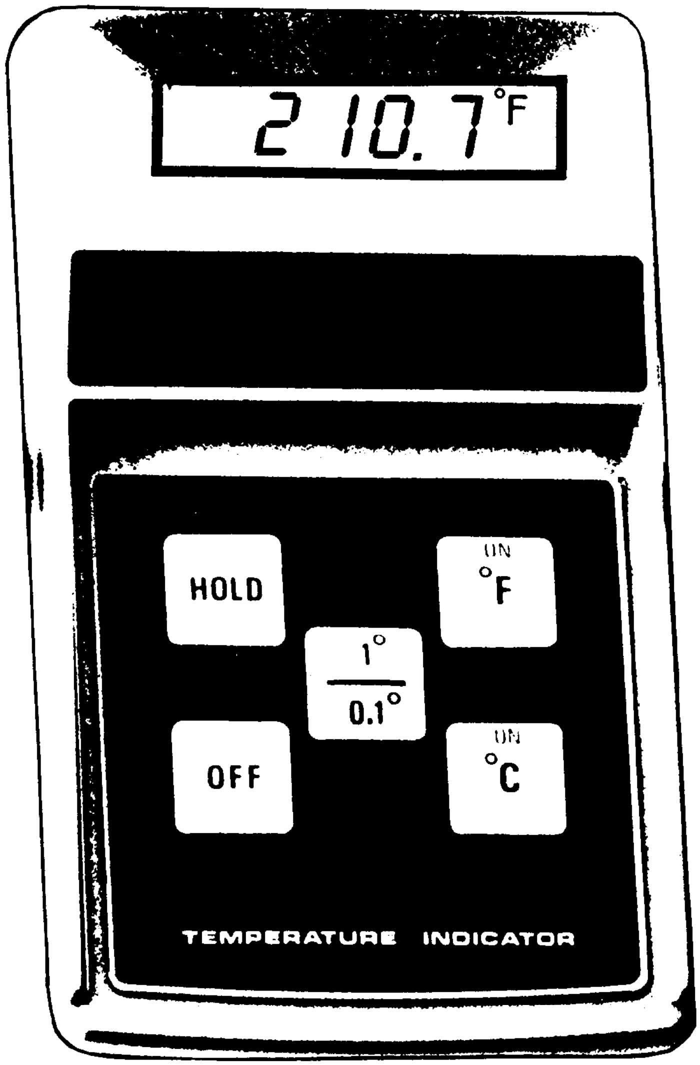


FIGURE 6-4. Digital Thermometer

mass meters. Table 6-1 lists the meters associated with each of the general classifications. The most common meters used in association with the subject areas of this manual are: orifice meters, turbine meters, and vortex shedding meters.

2.4.1 Orifice Meters. Orifice meters are the most widely used flowmeters. A specified size and shape of hole is made in a flat metal plate to create the orifice. Most orifices are a concentric shape, but eccentric, conical, and segmental shapes are used. The constriction of the orifice creates a pressure differential on across the plate, which is sensed by pressure taps on each side. Orifices are popular because they have no moving parts and an increase in pipe size does not cause a significant increase in cost of the orifice meter.

2.4.2 Turbine Meters. A turbine meter is positioned within the pipe and consists of a multibladed rotor mounted perpendicular to the fluid flow. Electric impulses are sensed by a magnetic pickup, photoelectric cell, or gears in direct relation to the rotational speed. The sum of electrical impulses over a given period of time is in direct proportion to flow volume. The addition of a tachometer to measure the rotational speed of the rotor will determine the flow rate. Turbine meters can be of the insertion type which allow tapping of the distribution pipe and insertion of the meter without interference to the fluid flow or system shutdown.

2.4.3 Vortex Meters. Vortex meters take advantage of the fact that eddies or vortices are formed downstream of a bluff object placed in a fluid flow. The frequency of the vortex shedding is in direct proportion to the flow velocity of the fluid through the meter. The major components of the meter are: a bluff body mounted across the column of flow, a sensor to generate electrical impulses as vortices are detected, and a signal amplification transmitter which functions in proportion to the flowrate. Vortex meters are easily installed into the pipeline without special tools or complicated procedures.

3 RECORDING INSTRUMENTS. Where a continuous record of the changing conditions of a fluid is required (such as pressure, temperature, and flow), recording instruments are usually employed. They provide information that can be analyzed to determine current operating performance of the system, to

TABLE 6-1. Classifications and Types of Flowmeters

Differential Pressure	Positive Displacement	Velocity	Mass
Orifice Venturi tube Flow tube Flow nozzle Pitot tube Elbow-tap Target Variable area	Piston Oval gear Nutating disk Rotary vane	Turbine Vortex shedding Electromagnetic Sonic	Coriolis Thermal

suggest future improvement. and to indicate needed maintenance or repairs. Also, they provide means to keep records that can prove invaluable in determining the causes producing abnormal operation of the system.

3.1 Pressure Recorders. Pressure recorders generally use a low-pressure diaphragm or a tube of oval cross-section wound in a helical or spiral coil shape. The diaphragm or coil end is connected to a pen arm, directly or through link and levers; the other end is connected to the pressure source. The pen records upon a chart which is driven by spring wound clockwork, a synchronous electric motor, or a battery drive. The operating principle is the same as for the Bourdon tube.

3.2 Temperature Recorders. A common type of temperature recorder consists of a thermal system including a bulb, capillary tubing, and a helical coil. The system may be filled with gas, vapor, or liquid. In operation, temperature changes at the bulb cause pressure changes in the medium filling the system. The pressure changes actuate the helical coil (measuring element), which through the pen arm, records the pressure changes in terms of temperature. The pen is attached at the free end of the helical coil through proper linkage and records on a chart. A rotating assembly, operated by clockwork or by a synchronous electric motor, is used to mount the chart. A temperature recording is shown in figure 6-5 as part of a flowmeter.

3.3 Flow Recorders. Recording flowmeters are often provided with integrating mechanisms that totalize the amount of flow during a given period of time. The principle of operation follows.

(a) A primary element produces a localized pressure drop in the fluid. The flow rate is always proportional to the square root of the pressure drop.

(b) A secondary element, consisting of a U-tube mercury manometer, receives the signal from the primary element. In operation, the localized pressure drop created by the primary element in the pipe is transmitted to the U-tube through the low- and high-pressure connections.

(c) The differential pressure acting on the mercury causes the float in the float chamber to rise or fall following the variations in the flow through the primary element.

(d) Motion of the float is transmitted through suitable linkage to the pen arm shaft that records rate of flow on the chart.

(e) The chart is mounted on a rotating assembly driven by a clockwork mechanism or by a self-starting synchronous motor as shown in figure 6-6.

(f) Check valves in the high- and low-pressure chambers prevent loss of mercury in case of:

- Overload conditions
- Flow reversal
- Violent fluctuations in flow

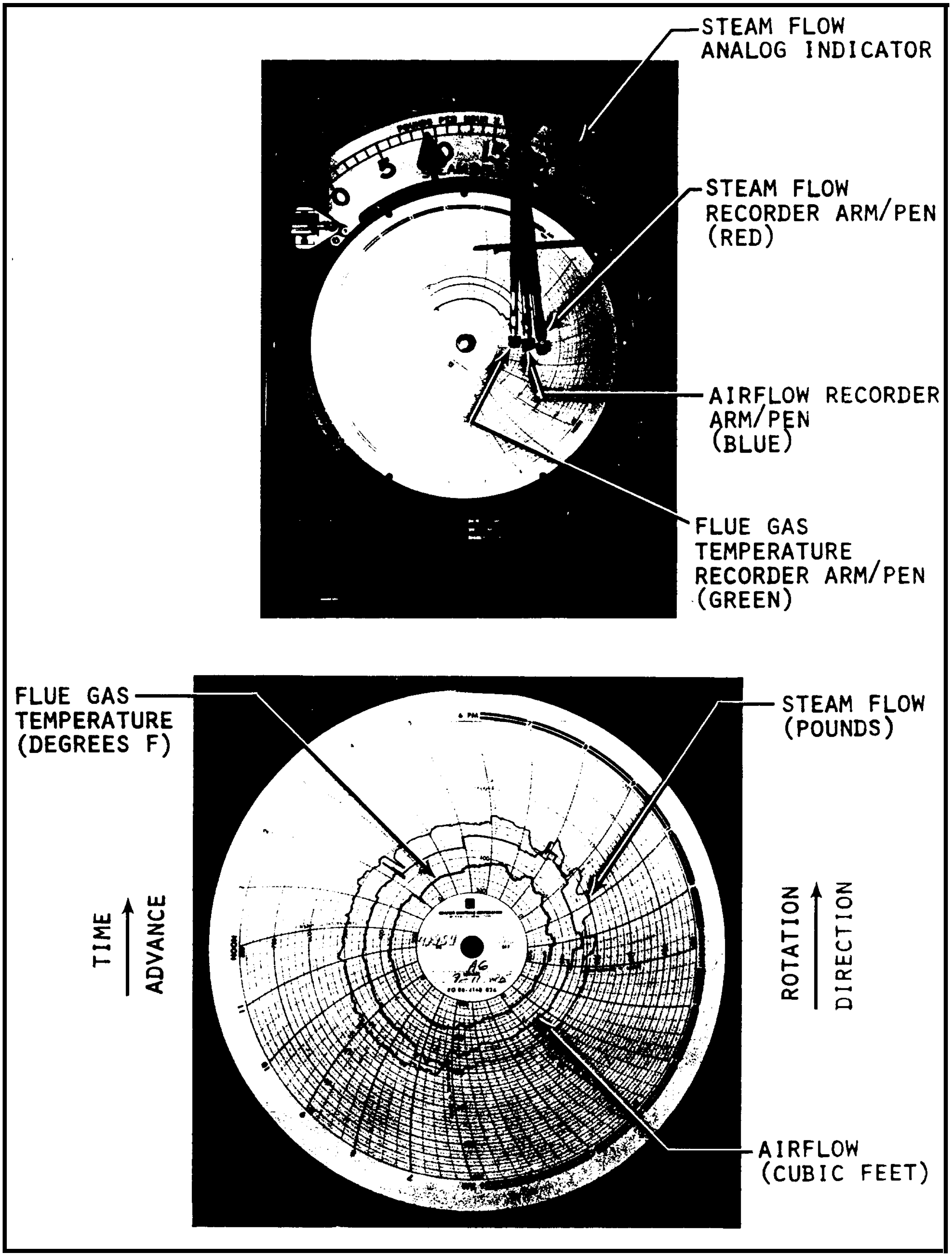


FIGURE 6-5. Typical Steam Flowmeter in Boiler Plant

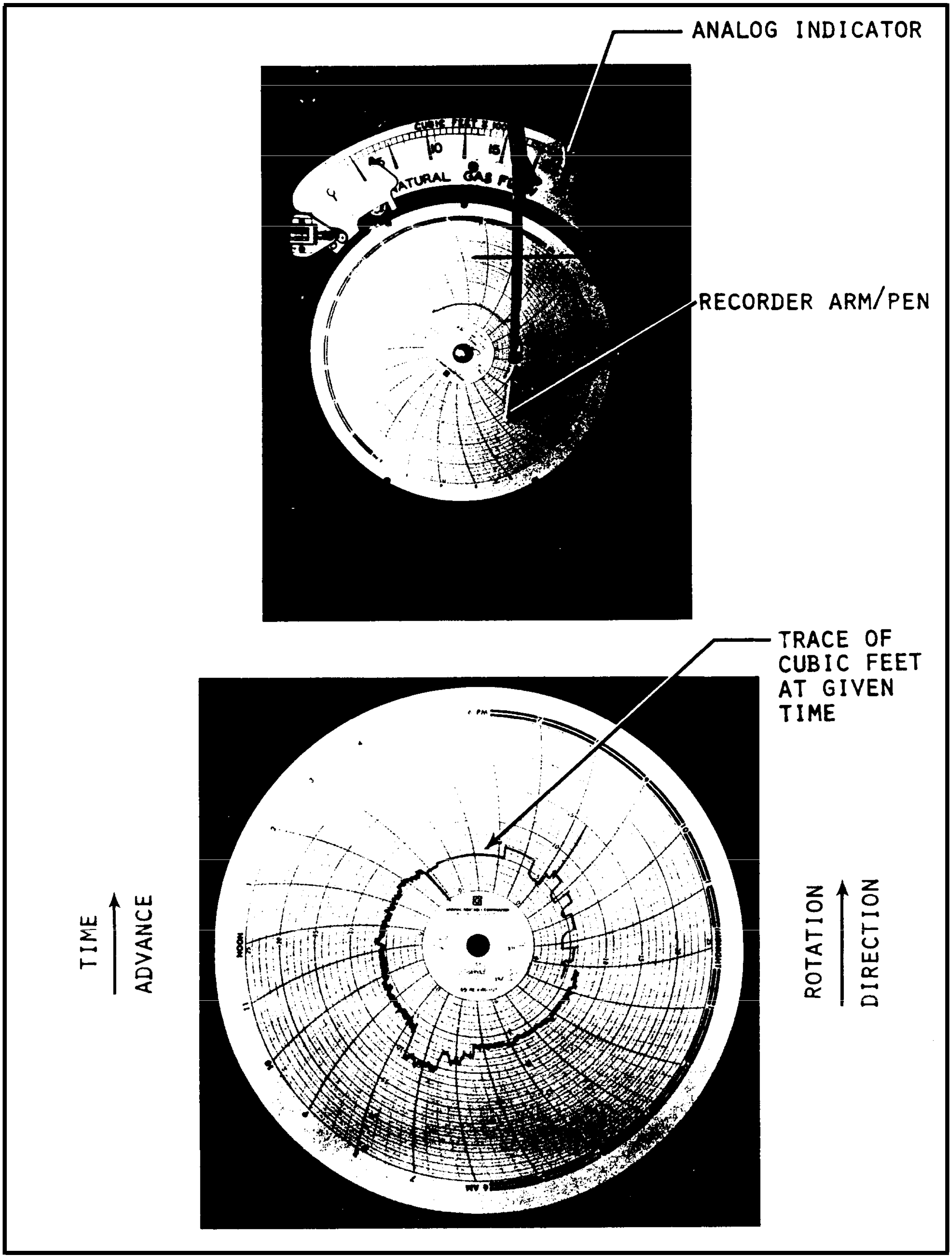


FIGURE 6-6. Typical Natural Gas Flowmeter in Boiler Plant

(g) An adjustable damping restriction permits making any adjustments required to dampen violent fluctuations and give a steady reading. The adjustments can be made without interfering with the operation of the flowmeter.

3.4 Microprocessor Instrumentation The types of recorders described in paragraphs 3.1, 3.2, and 3.3 are still be in use in many installations, but they are rapidly being replaced by recording instruments that are microprocessor driven. Electronic sensors in the metering equipment transmit signals with the aid of amplifiers to strip chart recorders (figure 6-7) and data loggers (figure 6--8). Microprocessor driven recorders are more accurate, easy to calibrate, and safer than older mechanical traps.

3.5 Btu Meters. The Btu meter is a special type of meter generally used in HTW generating stations of more than 20 million Btu per hour output. The meter is used to integrate heat flow in the system. One component of the meter measures the instantaneous temperature difference between the flow and return lines, usually recording these temperatures at the same time. Simultaneously, another component. measures the instantaneous rate of water flow in the return line, by means of an orifice or venturi tube. The Btu meter obtains the instantaneous products of the temperature difference and flow, and integrates them. The result of the multiplication and integration is the heat energy delivered to the system, or removed by the heat consumer across which the meter is connected. The flowmeter component usually records the flow at the same time. Btu meters have also been electronically linked to recorders and data loggers.

4 CALIBRATION. It is important that the operator be cognizant of the scales and ranges for which the gauges are calibrated. Typical calibrations follow.

- Pressure Gauges. Pressure gauges and pressure recorders are generally calibrated in pounds per square Inch (psi), inches of water (in. WG) or inches of mercury (in. Hg), depending on the pressure range and kind of fluid being measured.

- Temperature Gauges. Thermometers and temperature recorders are usually calibrated in degrees Fahrenheit (°F).

- Flowmeters. Flowmeters are ordinarily calibrated in pounds per hour (lb/hr), gallons per minute (gpm), or cubic feet per minute (cfm).

- Btu Meters. Btu meters are usually calibrated in Btu's per hour.

- Instrument Characteristics. Instrument range should be such that under normal conditions of operation, the Indicating pointer display will remain at midrange. Variations in operating conditions should occur within the middle third of the range. Instruments should be self-compensating and should not be affected by external changes in temperature or pressure.

5 TELEMETERING. Telemetering is used when the conditions of the installation require a central supervisory control system. This permits remote indication, recording, and/or control of the system fluid conditions.

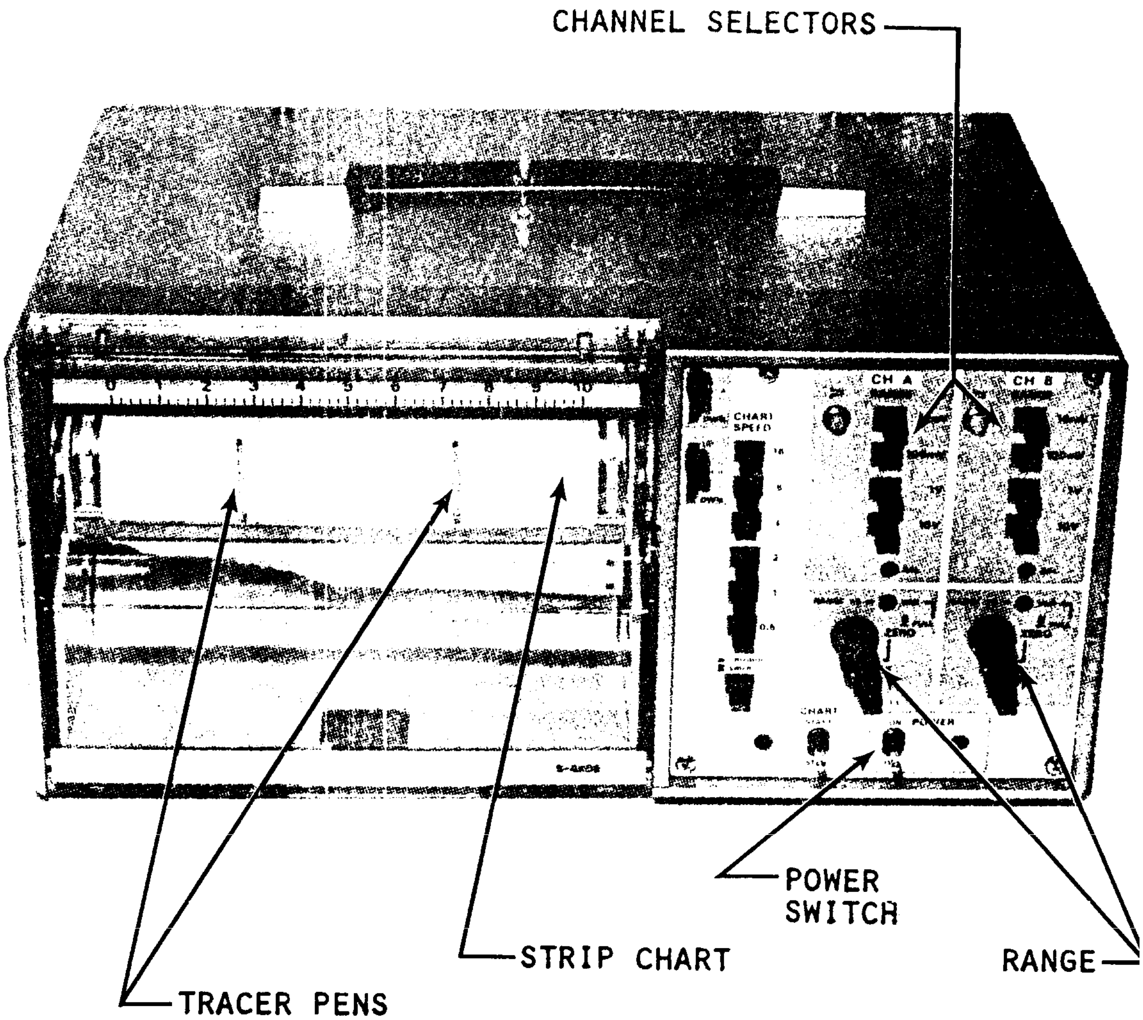


FIGURE 6-7. Strip Chart Recorder

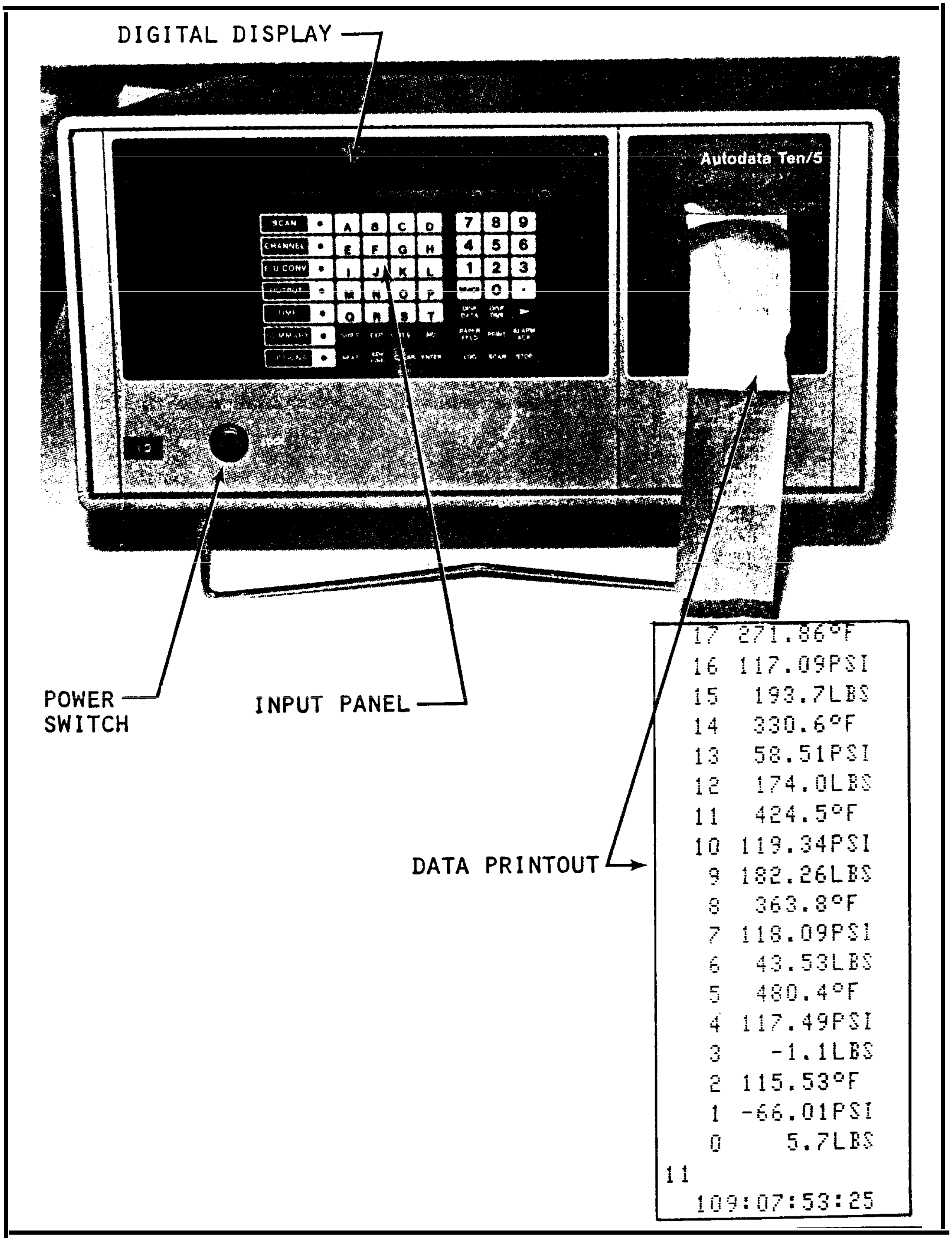


FIGURE 6-8. Data Logger

5.1 Pneumatic. Figure 6-9 illustrates a schematic diagram of a pneumatic (air operated) signal transmitter. The transmitter is used to generate an output signal air pressure proportional to the reading of the measuring instrument. The output signal, therefore, is related to pressure, temperature, or flow as measured by the measuring element installed in the line. When used in control systems, means are provided for changing the setting and response sensitivity of the equipment.

5.2 Solid State. Pneumatic transmitters are being replaced wherever possible by solid state transmitters, as shown in figures 6-10 and 6-11. Solid state transmitters are much more reliable, have no moving parts, are easily changed, are more sensitive, and require less space.

6 AUTOMATIC CONTROLS. Automatic controls, when compared with manual control, present a number of advantages, including:

- Elimination of human errors.
- Fastest and most accurate response to changing conditions.
- Predetermined pattern of operation.
- Release of operating personnel from routine assignments. Operators can be engaged in more productive duties.

The types of automatic controls generally used in a distribution system are described in the following paragraphs.

6.1 Pressure Controls. Pressure controls are used for two main purposes: first, to maintain a substantially constant pressure in one part of a system regardless of pressure variations, within the range limits, of the other part of the system; and second, to maintain a definite pressure differential between two points and control the fluid flow. In either case, the fluid pressure upstream of the control is always higher than the control pressure. Pressure controls consist of three elements:

(a) A pressure sensing device

(b) A regulating valve that controls the passage of the fluid

(c) A connecting element between the pressure sensing device and the valve

The pressure control may be of the self-operated type, consisting of a device which operates a regulating valve directly; or it may be of the pilot-operated type, operating the regulating valve through a pilot or relay valve; or the valve may be operated following the signal air pressure from a pressure transmitter. Figure 6-12 illustrates a typical self-operated, spring-loaded pressure regulator valve. In this type valve, the controlled pressure is applied to the top chamber over the diaphragm and the diaphragm movement is directly transmitted to the control valve through the valve stem.

6.1.1 Typical Operating Principle. In operation, an increase in the fluid controlled pressure pushes the diaphragm against the resistance of the spring;

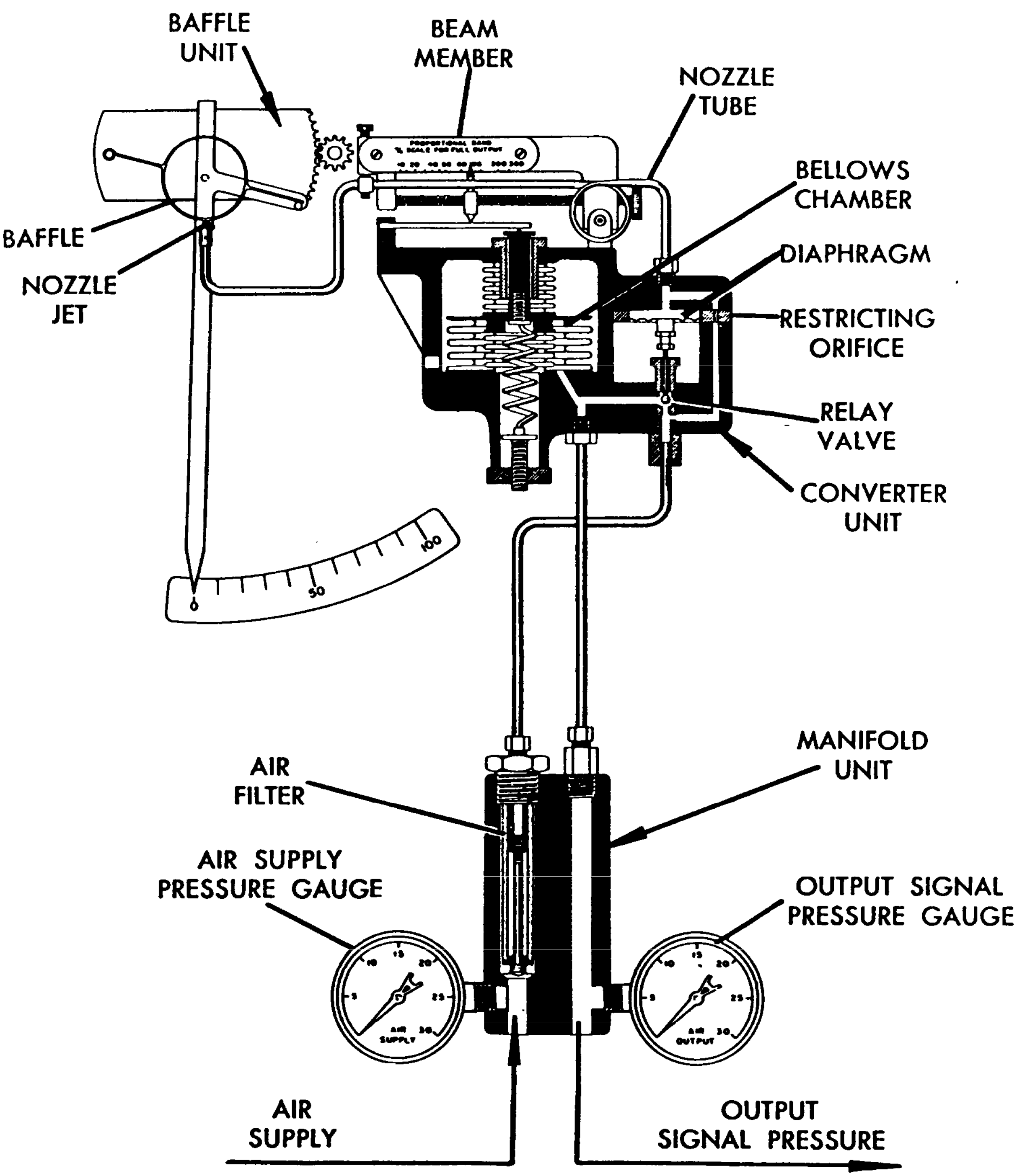


FIGURE 6-9. Schematic Diagram of a Pneumatic Transmitter

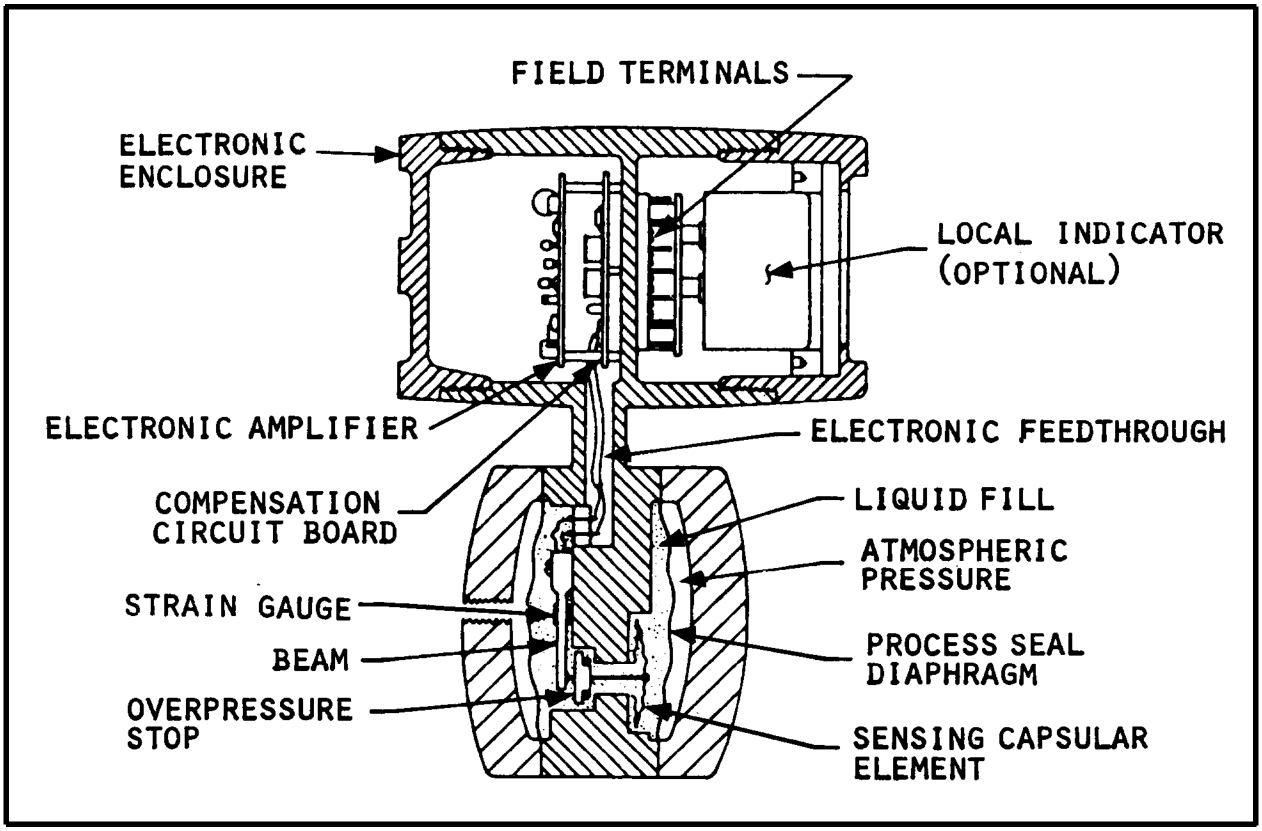


FIGURE 6-10. Section View of Electronic Pressure Transmitter

this closes the valve until the spring force balances the thrust exerted through the valve stem by the diaphragm. The reverse is true for a decrease in the fluid controlled pressure. The controlled pressure can be adjusted by changing the spring compression. When this type of valve is used for remote control, signal air pressure from a pneumatic transmitter is applied in the top chamber over the diaphragm.

6.1.2 Valve Seating Arrangements. Valves can be of the single-seated type or of the balanced type. Single-seated valves are used for dead-end service, where a pressure must be maintained during no-flow periods. This type of valve can be closed tightly. Balanced valves require smaller forces to operate since the pressure acts on both sides of the disk. They do not close tightly. Some valves are V-ported to provide throttling in the early stages of opening and closing.

6.2 Temperature Controls. These controls are used to maintain a substantially constant temperature in one part of the system, regardless of load fluctuations. Permissible variations must be within the range of the equipment.

6.2.1 Temperature Control Components. A temperature control has three basic elements which include a temperature sensing device (temperature bulb); a regulating valve, generally actuated by a bellows, to control the passage of the heating or cooling fluid; and necessary capillary tubing connecting the temperature bulb with the bellows. The temperature bulb, capillary tubing, and bellows system are filled or partly filled with liquid, gas, or a

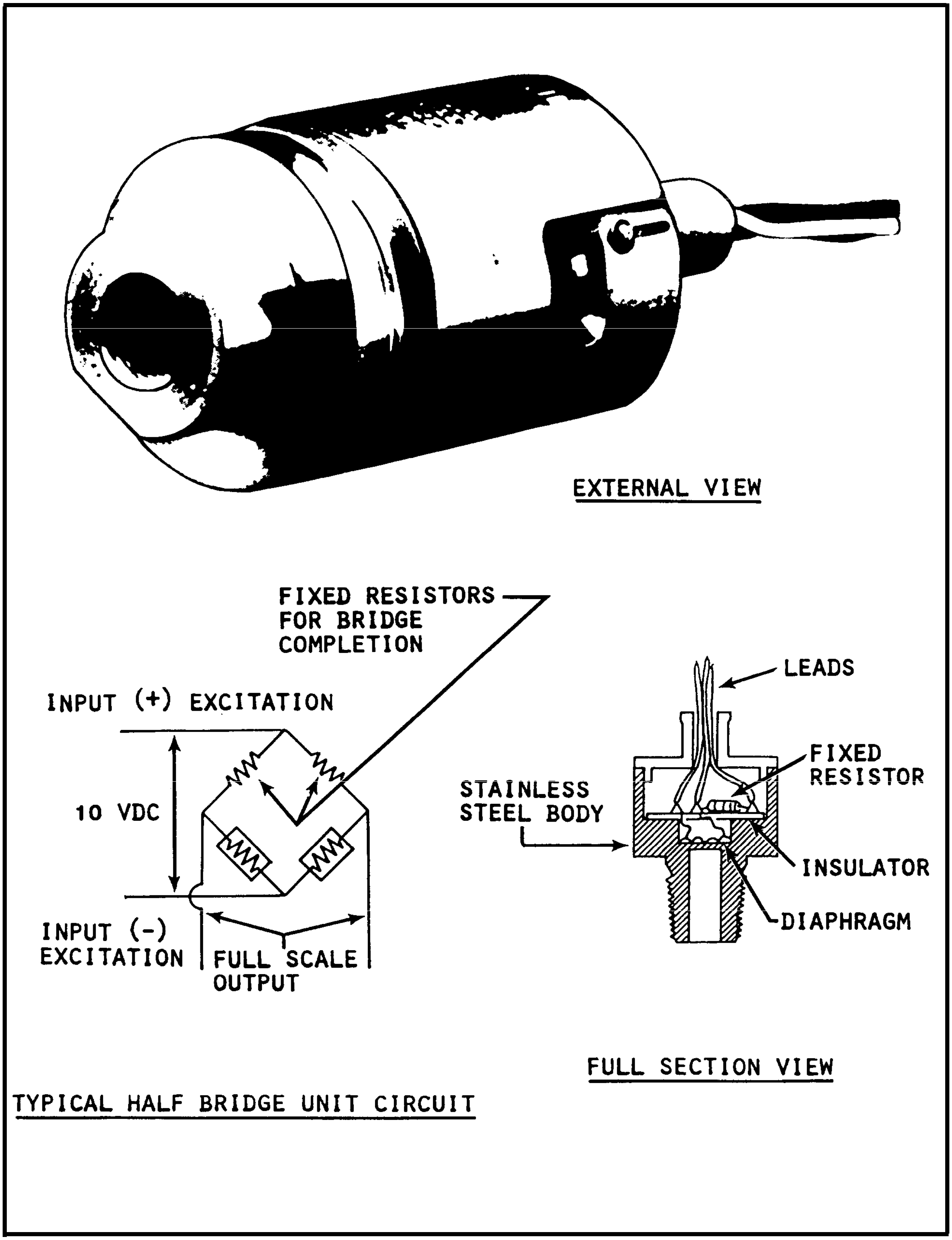


FIGURE 6-11. Solid State Transmitter

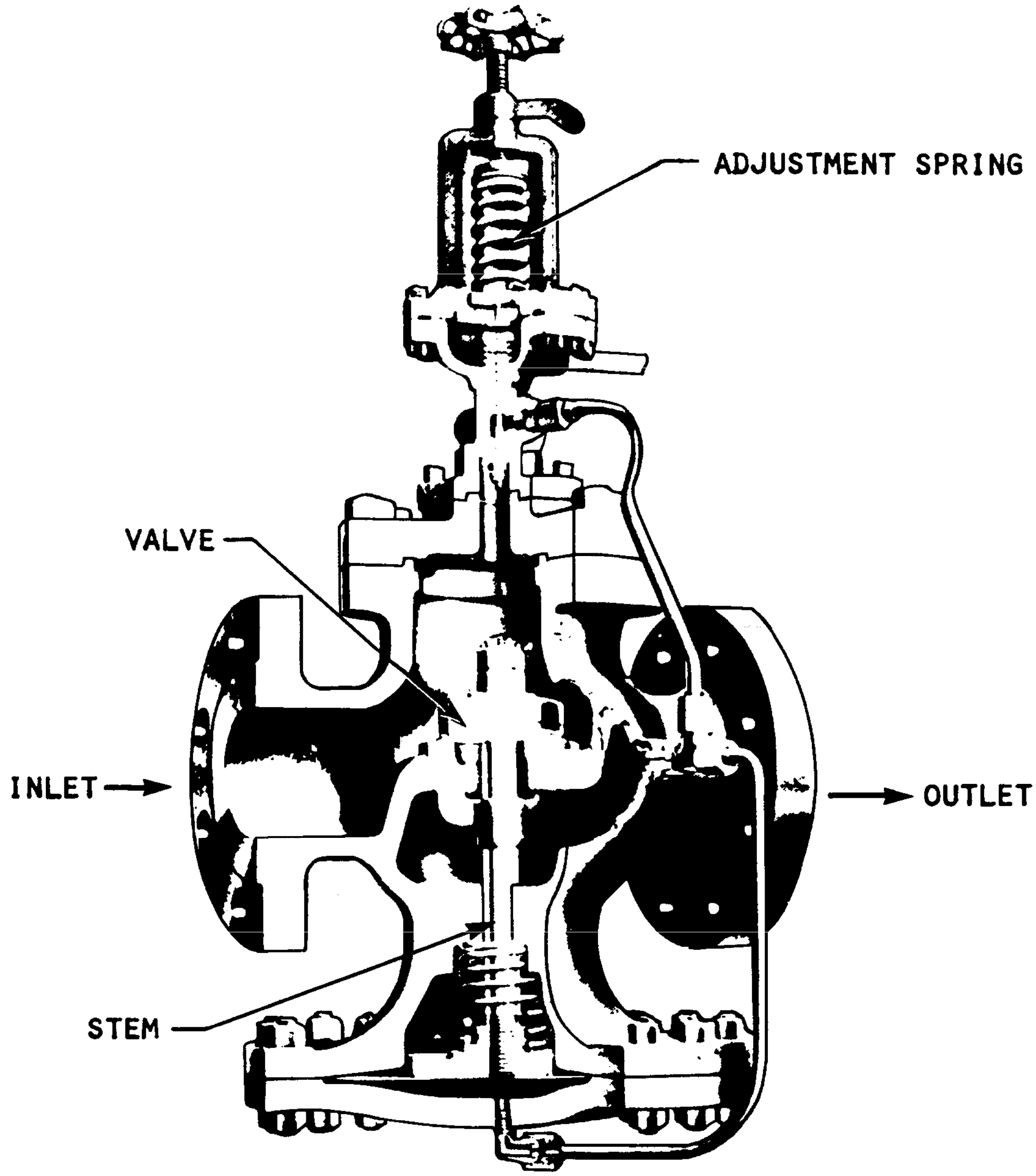


FIGURE 6-12. Pressure Regulator Valve

combination of liquid and vapor. In operation, temperature changes at the bulb produce expansions or contractions of the medium filling the system, which in turn causes expansion or contractions of the bellows. The movement of the bellows is transmitted to the valve disk by means of the valve stem. The expansion movement of the bellows is opposed by an adjustable compression spring. The controlled temperature can be adjusted by changing the spring compression.

6.2.2 Remote Control. Remote control of temperature may be affected by a diaphragm-operated valve similar to that shown in figure 6-13. With this type of valve, signal air pressure from a pneumatic transmitter is applied in the top chamber over the diaphragm. The air loading pressure changes in relation to temperature changes of the controlled medium, thereby operating the valve to control the flow as required.

6.3 Moisture Control. Energy conservation, prevention of pipe corrosion, and reduction of insulation deterioration are possible by remote sensing of damaged insulation. This is possible through wiring embedded in the insulation surrounding a pipe. When moisture comes in contact with the embedded wire, the electrical conductivity of the wire is changed. this change is sensed and transmitted to a central monitoring station. The distance to the disruption Is displayed to maintenance personnel on a video display and on a strip recorder simultaneously (figure 6-14). This timely method of immediate detection of a remote insulation break minimizes a disruption of service normally associated with location and repair efforts.

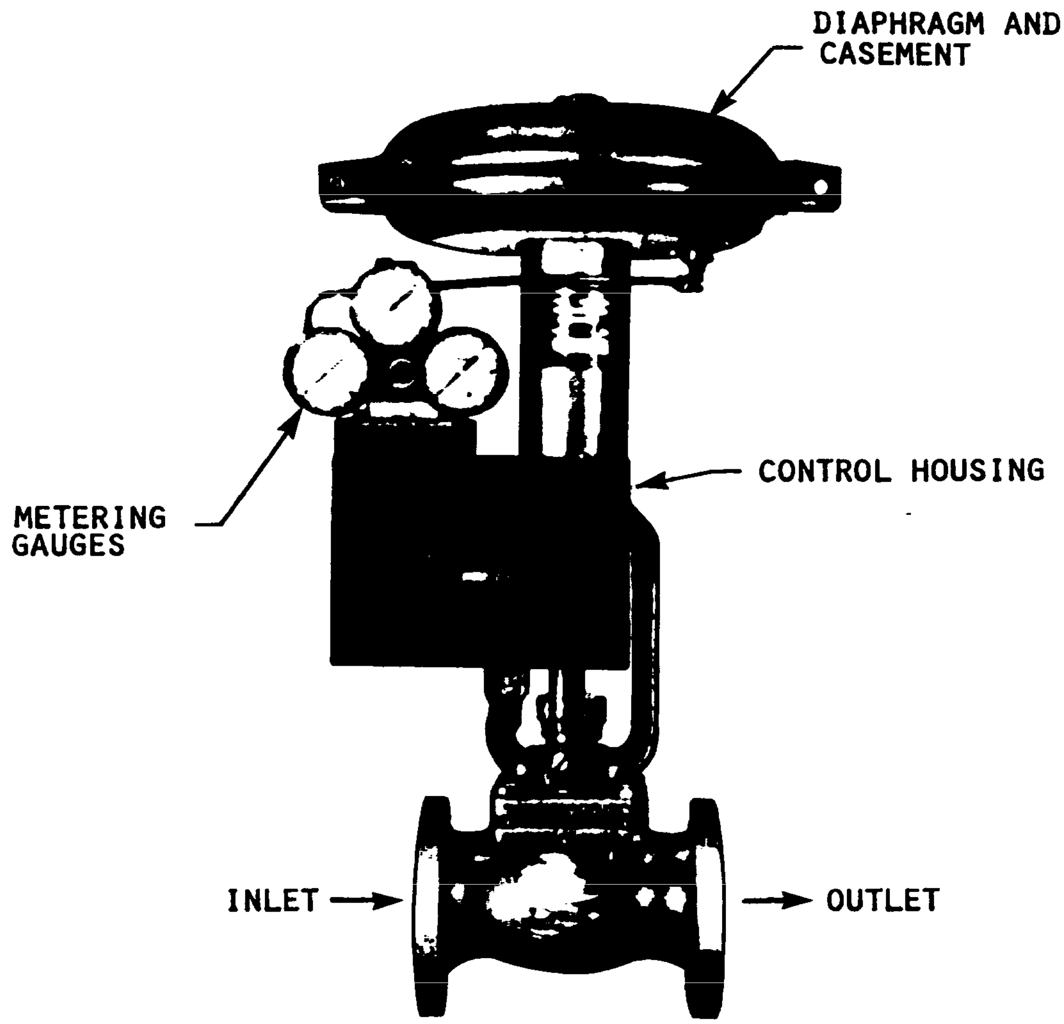


FIGURE 6-13. Diaphragm-Operated Valve

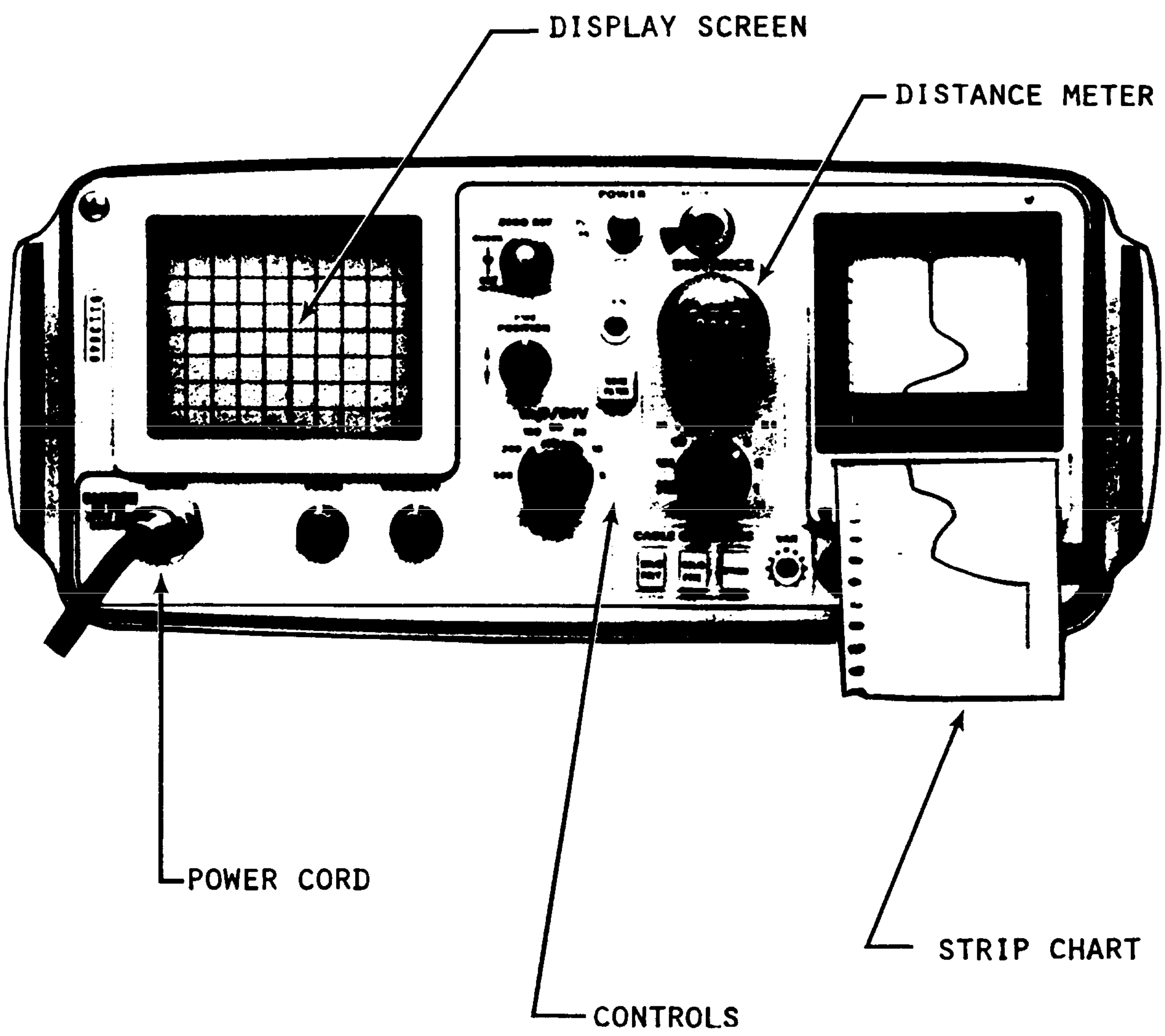


FIGURE 6-14. Video Display/Strip Recorder

Section 2. OPERATION AND MAINTENANCE OF INSTRUMENTS

1 INSTRUMENT USAGE. The proper use and care of instruments are important factors in their reliability and life span. Perform the following procedures for the care of instruments.

(a) Report any malfunction in the operation of any instrument or gauge.

(b) Wind hand-wound chart drives of recording instruments with 24-hour movements at the same time each day; wind those with 7--day movements at the same time each week.

(c) Protect gauges from violent fluctuations by throttling the gauge needle valve or by installing snubbers.

(d) Clean gauge glasses as required for ease of reading.

CAUTION

On steam meter installations, make sure the connecting pipes between the meter and the primary element are filled with condensate before placing the meter in service.

(e) Protect flowmeters that operate on the principle of differential pressure by not placing them in service unless there is pressure and flow in the metered pipeline. Remove the meter from service before shutting down the pipeline. This type of flowmeter is placed in service as follows:

(1) Open equalizing valve.

(2) Open low-pressure shutoff valve slowly.

(3) Close equalizing valve.

(4) Open high-pressure shutoff valve slowly.

(f) To take a differential pressure flowmeter out of service, or when checking the zero adjustment, close high- and low-pressure shutoff valves and open equalizing valve. Consult manufacturer's instructions for recommended procedures.

2 PREVENTIVE MAINTENANCE OF INSTRUMENTS. Only authorized and trained personnel should repair, calibrate, or adjust instruments. The following paragraphs present maintenance inspection routines adequate for average installations.

2.1 Daily Inspection of Instruments. Inspect all accessible instruments and gauges for defects such as leaks, cracked or broken glass, bent pointers, loose connections, changed terminals, broken wiring, or any other obvious faults. Report any defects immediately.

2.2 Yearly Inspection of Instruments. Make a thorough inspection of all instruments and gauges for corrosion, deposits, binding, and mechanical defects. Check the following items:

- Ruptured or distorted pressure parts
- Incorrect calibration or adjustment
- Leaks in piping or meter
- Plugged internal passages
- Loose pointers
- Broken balance-arm screws
- Broken or loosened linkages
- Broken or damaged adjustment assemblies
- Dirt or foreign material
- Binding of moving parts
- Dirty gauge movements
- Linkage pins binding
- Defective gauge glass gaskets
- Gauge valve packing leaks
- Badly worn pins or bushings
- Mercury separation in thermometers
- Temperature bulbs damaged by overheating
- Plugged piping or tubing; loose connections
- Mercury contamination
- Defective floats
- Operation of clockwork mechanism and integrator
- Secondary element electronics
- Sensors
- Coating of electrodes
- Capacity of instrument still sufficient for system

3 MAINTENANCE OF INSTRUMENTS. Repair or replace defective parts as required after the yearly inspection; for example:

(a) Replace distorted Bourdon tube assemblies which have been subjected to overpressure.

(b) Replace temperature bulbs which are swollen as a result of excessive temperature.

(c) Replace all gauge movement linkages, pins, and bushings which have lost motion caused by wear.

(d) Replace or repair broken adjustment assemblies.

CAUTION

> Mercury is poisonous. Avoid breathing mercury vapor. Avoid repeated skin contacts which may cause serious skin irritations. Keep mercury in clean dark containers with plastic bottle caps. Mercury dissolves many metals.

(e) Clean dirty mercury by straining through chamois cloth.

(f) Repair all leaks in piping or meter.

(9) Repair or replace defective floats.

(h) Replace defective gaskets.

(i) Rod out all plugged or partly plugged pipeline connections.

(j) Clean out the meter connecting piping by blowing down with the operating fluid.

(k) Lubricate only those parts which the manufacturers' instructions state require lubrication. Use recommended lubricants.

(1) Replace all corroded, bent, or otherwise defective parts.

(m) Check calibration of all instruments and gauges.

4 TEST AND CALIBRATION OF INSTRUMENTS.

4.1 Thermometer Calibration. Calibrate thermometers weekly by comparing readings with those of a glass-stemmed, standardized laboratory thermometer. Locate the bulb of the instrument and the laboratory thermometer in a heated bath which is agitated to ensure uniform heating within range of thermometers. Take readings as the temperature rises. Correct the instrument under test by means of the adjusting screw or by displacing the scale as required. After making the corrections, repeat the calibration. Be careful not to subject the instrument to temperatures above its designed maximum. See paragraph 4.4 for calibration of electronic temperature measurement instruments.

4.2 Pressure Gauges. Pressure gauges can be calibrated by comparing readings with those of a test gauge of known accuracy. Laboratory test gauges are usually accurate to 1/4 of 1 percent of the pressure range. Never use test gauges as service gauges. A convenient pressure source for gauge testing is an air supply of adequate pressure. Install an air filter ahead of the connection to the gauges to obtain clean air during the test. Often, a deadweight tester is used for calibration purposes. The deadweight tester is a precision built hydraulic unit for obtaining basic pressure standards. It consists of a manually operated oil pump assembly where a piston supports a weight platform. A valved connection is made from the oil pump to the gauge being tested. In operation, calibrated deadweights are placed on the weight platform and the pump is manually operated until the platform is freely supported by the piston. The oil pressure developed, which is shown on the dial of the gauge being tested, must correspond with the pressure stamped on the calibrated deadweights. To adjust the pointer, remove the bezel ring and glass plate, or the snap ring on plastic cases, and move the pointer by turning its micrometer adjustment until it is brought to the nearest possible agreement over the desired range. The pointers of some type of gauges can be adjusted from the back without removing the cover. Refer to paragraph 4.4 for calibration of electronic pressure measurement instruments.

4.3 Flowmeters. Flowmeters are generally calibrated by means of a water column. The purpose of the calibration is to make sure that the pressure differential caused by the passage of the fluid through the primary element is indicated correctly by the meter. During the test the pressure differential is artificially produced by means of a water column, by placing on the high--pressure side of the meter body a pressure equal to the differential which should be produced by the primary element under actual flow conditions. The details of the procedure vary for the different makes of flowmeters and the manufacturer's instructions should be closely followed. See paragraph 4.4 for calibration of electronic flow measurement instruments.

4.4 Electronic Components. Operator calibration of most electronic components consists of zeroing, span adjustments, resistor replacement, or module replacement. Most electronic components associated with metering are factory calibrated and must be returned for calibration or exchange. Unless specific calibration instructions are explained in the equipment manual and a qualified electronics technician is available, contact the manufacturer before attempting calibration.

Section 3. OPERATION AND MAINTENANCE OF CONTROLS

1 INSPECTION BEFORE STARTUP OF CONTROLS. Before placing a new control system in service, or after an overhaul, make sure the following prestartup requirements are fulfilled.

(a) Installation, repair, and cleanup work completed.

(b) Installation tested for leaks.

(c) Approved drawings, diagrams, and manufacturers' instruction manuals available to the operators for study and reference. Operators must understand the control equipment and control systems.

(d) Clean, dry, compressed air at proper pressure available for operation of pneumatic controls.

(e) Correct electric power supply available for electrical and electronic components.

(f) Controlled devices shut down, bypassed, or controlled manually.

(g) All control components installed, tested, and adjusted, as per manufacturer's instructions.

(h) All piping and tubing blown out, cleaned, and filled with normal operating fluid at normal temperature.

(i) All air vented and removed from liquid filled systems.

(j) All wiring circuits correctly and securely connected.

2 STARTUP OF CONTROLS. Proceed as follows:

(a) When controls are used for regulating steam flow, slowly warm the line and drain the condensate before placing the regulating valves in operation.

(b) Blow down strainers and moisture separators, if provided.

(c) Adjust instrument air pressure reducing valves to obtain correct instrument air supply pressure.

(d) Place controllers in service using the approved procedures as outlined in the manufacturers' manuals.

(e) Adjust controllers to obtain the required control pressure, temperatures, or flow.

3 NORMAL OPERATION OF CONTROLS. Blow down strainers and clean the baskets at regular intervals, or as required, depending on the type of installation. Condensate from air filters and moisture separators should be blown once per shift. Adjust the controllers as required to obtain correct pressures, temperatures, and flows.

4 SHIJTDOWN OF CONTROLS. Before turnoff of a controller or control system for repairs, inspect the installation, observe the operation, and list all necessary repair work. Transfer from automatic to manual control and remove the controller from service.

5 EMERGENCY PROCEDURES. Repair all leaks as soon as possible. In case of a controller failure, change from automatic to manual control. Remove the controller from service and make necessary repairs.

5.1 Pneumatic Controls. In case of defective or erratic operation of pneumatic control systems caused by oil and/or water in the instrument air supply, investigate the following conditions.

- Condition of Instrument Air Compressors. Compressors should be maintained in good condition to minimize oil carryover with the air.
- Rate of Oil Feed to the Compressors. Oil feed rate should be the minimum required for adequate lubrication. Use type and quantity of oil recommended by the manufacturer.
- Carbon Rings. Investigate possible use of carbon ring or carbon cylinder liner compressors which do not require cylinder lubrication.
- Aftercoolers, Separators, and Driers. Check operation of the equipment. Investigate possible installation of additional equipment for moisture removal.

5.2 Electronic Controls. Proceed as follows when erratic or erroneous operation is contributed to electronic control equipment.

- Inspect system by sections to isolate the faulty equipment.
- Inspect all wiring and connections for defects.
- Troubleshoot suspected equipment for malfunction.
- Repair or replace components according to manufacturer's manual.

6 CASUALTY PLANNING. The operators should be familiar with the arrangement and location of controllers, valves, and associated equipment. Provide the operators with manufacturers' instruction manuals and diagrams. Schedule and carry on periodic drills to change rapidly and safely from automatic to manual control, and from manual control to automatic. The operators must be capable of heating the system safely and efficiently on either manual or automatic control. Give operators definite instructions on emergency procedures.

7 INSPECTION AND MAINTENANCE OF CONTROLS. Report any malfunction in the control systems. Only authorized and trained personnel should repair, calibrate, or adjust controls. Look for leaks. Retighten glands if required. Perform the following procedure after every 8 hours of operation of pneumatic control systems.

(a) Blow the settling chambers in the compressed air piping.

(b) Drain compressed air receiver.

(c) Drain moisture from filter housings.

8 PREVENTIVE MAINTENANCE INSPECTION OF MECHANICAL CONTROLS. The following paragraphs present inspection routines adequate for average installations.

8.1 Daily Inspection of Controls. Observe operation of controls for proper functioning, check leaks, and stop stuffing box leaks as soon as possible.

8.2 Yearly Inspection of Controls. Once a year, or more often if required, dismantle regulating valve and control mechanism. Clean system components and inspect for wear, corrosion, erosion, pitting, deposits, leaks, and mechanical defects. Check all safety devices and warning signals for correct operation and possible defects. Check setting, adjustment, and operation of controls. Check operation of safety devices.

9 MAINTENANCE OF CONTROLS. Repair or replace defective parts as required after the yearly inspection. Perform the following maintenance work as required.

- Examine regulating valve stem and replace or metalize it if necessary. Change or regrind valve plug and seat if required. Change valve to smaller size if excessive cutting indicates an oversize valve. Check valve positioner and spring adjustment. Repace stuffing box .

- Clean, inspect, and test needle, pilot, poppet, reducing, and transfer valves. Replace defective parts.

- Observe condition of bellows and diaphragms. Replace if defective.

- Replace gaskets.

- Replace badly worn linkage pins and bushings. Do not paint these parts.

- Clean air filter. Replace air filter cartridges.

- Repair all leaks. Rod out piping connections when necessary.

- Vent out air from liquid filled systems.

- Use caution when installing, connecting, or disconnecting capillary tubing to protect it from dents or kinks. Any restriction to the flow of the liquid, gas, or vapor in the tube causes defective operation of a temperature controller.

- One person should be responsible for the adjustments and calibrations of the control system components. Two or more persons, if working without coordination, may produce a poorly adjusted control system.

- Repairs of electronic equipment should be performed by a qualified electronics technician and only in accordance with manufacturer's instructions.

CHAPTER 7. PIPING AND ASSOCIATED EQUIPMENT

Section 1. THERMAL INSULATION AND FREEZE PROTECTION

1 INSULATION. A thermal insulating material resists the flow of heat through it and is used in heat distribution systems for the following purposes:

- To prevent heat loss
- To prevent condensation of steam in steam lines
- To maintain desired fluid temperatures
- To protect personnel from high temperatures, as in manholes and pits

1.1 Economic Studies. With fuel and material costs soaring over the past several years. previous standards of insulation thickness have been discarded in favor-of much higher values. As an example, in 1962 a 24-inch steam line at 1,050°F required 5.5 inches of insulation. On the basis of 1973 costs, the requirement was 6.0 inches of insulation; however, when costs at the midlife of the insulation were taken as a basis, the thickness requirement had increased to 9.5 inches. Most commercial plants have adopted the midlife cost method on the assumption that fuel and other costs will continue to increase. The number of factors involved in energy management complicates the selection of optimum insulation thickness and usually requires a comprehensive study of insulation thickness economics. The Thermal Insulation Manufacturers Association provides guidance for such studies.

1.2 Selection of Insulation Material. In discussing insulating materials, the "k' factor or thermal conductivity of the material must be understood. The k factor is the amount of heat, in Btu/hour that flows through a slab of insulation l-foot square, and l-inch thick when one face is 1°F hotter than the other. K factors for insulation typically vary from about 0.25 to over 1.00 depending upon the material and the temperature. The heat flow in Btu's per hour per square foot is equal to k times the temperature difference ("F) divided by the thickness (inches). In commercial applications, a low k factor is of fundamental importance in selecting an insulation material. However, in most applications, the final material selection may entail some compromise of the k factor in favor of other properties. Insulation strength is of obvious importance if the insulation must withstand dropping, stacking, impacts, or vibration. However, when strengthening agents are added, this normally results in additional heat conduction paths and the k factor is increased. The same would be true should insulation stiffness be a required property. The binders or spacers that must be added to the insulation result in a higher k factor. The same considerations generally hold true when resistance to moisture, dimensional stability, or fire resistance are required properties.

1.3 Insulation Properties. Table 7-1 lists common types of insulations with their maximum temperatures, k factors, and density. Other properties are listed below.

(a) Calcium Silicate. This is a molded insulation with a usable temperature range of 100°F to 1,200°F. Flexural strength is approximately

TABLE 7-1. Insulation Properties

Material	Max Temp °F	Density lb/ft^3	k Factors
Glass wool (organic binder) cements and fillers	400	0.5 -3	0.35 @ 300°F
Processed Gilsonite[1]	460	40-44	0.6 to 0.8
Cellular glass	800	7.5 - 9	0.55 @ 300°F; 1.04 @ 800°F
Felted glass fiber (no binder)	1,000	4.5	0.35 @ 300°F; 0.71 @ 800°F
Calcium silicate	1,200	11 -13	0.42 @ 300°F; 0.60 @ 700°F
Mineral fiber fill (rock, slag, or glass)	1,200	10 - 12	0.26 @ 100°F; 0.65 @ 600°F
Expanded silica (perlite)	1,500	4 -13	0.33 @ 0°F; 1.13 @ 1,000°F
Mineral fiber fill (rock & slag)	1,800	16 - 24	0.59 @ 400°F; 0.75 @ 1,000°F
Mineral fiber fill (rock, slag, or glass)	1,800	24 - 30	0.55 @ 200°F; 0.80 @ 600°F
Alumina/silica ceramic fiber	2,300	3 -12	0.31 @ 300°F; 0.82 @ 1,000°F

*Used for underground insulation

70 lb/in^2 and compressive strength is about 100 lb/in^2 for a 5 percent deformation.

(b) Expanded Silica. This is another molded insulation having a temperature range from O to 1,500°F. In addition to its compressive strength of approximately 100 lb/in^2 at a 5 percent deformation, it is water resistant.

(c) Mineral-Fiber. This is available in rigid or flexible blanket form. Cutting and mitering are accomplished easily in the field.

(d) Glass Compounds. This is a versatile material available in many forms such as blankets, semirigid sheets, and cylindrical shapes. Maximum usable temperatures vary depending on the additives required to obtain the specified properties.

(e) Processed Gilsonite. This is a loose, bulk Insulation consisting of hydrocarbon with a high resin content. When used to insulate hot pipe, it forms three zones around the pipe: fused, sintered, and unconsolidated. The material in direct contact with the pipe melts and fuses to the wall providing a dense waterproof coating. It remains plastic enough, however, to allow for normal expansion and contraction of the pipe. The sintered zone provides a water resistant barrier with insulating qualities. The outer zone retains its processed form which provides the pipe with additional insulation and its load-bearing characteristics.

(f) 85 Percent Magnesia. This is no longer made due to the asbestos content, but is still found in some plants on older lines.

(9) Alumina-Silica Ceramic Fiber. This is a material with multiple applications that can be processed into blankets, strips, cloth, paper, and solid shapes. Some varieties withstand temperatures in the 2,300°F to 2,600°F range.

1.4 Insulation Thickness. Lacking an economic analysis of the specific plant, table 7-2 contains suggested minimum thickness of insulation in relation to nominal pipe diameter and dry thermal conductivity. The k factor listed in the table is for a mean temperature of 200°F. The k factor for calcium silicate should be assumed as 0.40 for use with this table. In underground systems, the k factor for the insulation is often assumed to be 0.40 regardless of its actual value. Insulation thickness for condensate return piping installed in separate conduits should not be less than 1 inch. Condensate return piping installed in the same conduit with the steam piping need not be insulated. Condensate return piping in manholes, however, should be insulated with insulation of the same material and thickness required for steam piping of the same size.

TABLE 7-2. Minimum Pipe Insulation Thickness

Thermal Conductivity k[1]	Nominal Pipe Diameter (inches)									
	1/2 to 2	2-1/2	3	3-1/2	4	5	6	8	10	12
0 to 0.35	1.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.5
0.40	1.5	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	3.0
0.45	1.5	2.0	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.5
0.50	2.0	2.5	2.5	2.5	2.5	2.5	3.5	3.5	3.5	4.0
0.55	2.0	3.0	3.0	3.0	3.0	3.0	4.0	4.0	4.0	4.5
0.60	2.5	3.5	3.5	3.5	3.5	3.5	4.5	4.5	4.5	5.0
0.65	2.5	4.0	4.0	4.0	4.0	4.0	5.0	5.0	5.0	5.5
0.70	3.0	4.5	4.5	4.5	4.5	4.5	5.5	5.5	5.5	6.0

[1]For Intermediate k factor, use the k factor nearest. For example: for k=0.385 use 0.40.

1.5 Underground Conduit System. Insulation for underground systems should conform to the DOD adopted ASTM C-552, Specification for Cellular Glass Block and Pipe Thermal Insulation. Pipe insulation should be a nonconductor of electricity, verminproof, rot resistant, and noncorrosive to the pipe when wet. All piping, flanges, valves, field joints, and fittings should be insulated with the same material and equal thickness as the insulation of the adjoining pipe. A continuous annular space (l-inch minimum) is commonly provided between the outer surface of premolded or preformed pipe insulation and the inner surface of the exterior casing. This provides an adequate air passage for venting and draining.

1.6 Exposed Piping. All exterior pipes, valves, flanges, and fittings exposed in manholes or exposed aboveground should be covered with insulation. The insulation should be waterproofed and covered for protection with an aluminum jacket.

1.7 Installation. Insulation should be installed in such a manner that it will not be damaged by pipe expansion or contraction. Metal bands or straps used to hold insulation in place should be of stainless steel. Wire should not be used for this purpose. With prefabricated casings containing molded or preformed insulation already in place around the piping, special installation procedures may be required and precautions must be taken to ensure the insulation is kept absolutely dry.

1.8 Maintenance. Maintenance of insulation includes prompt repair of damaged surfaces, repainting and waterproofing, tightening bands, and repairing protective covering. Make certain that fluid temperatures do not rise above the safe limit for the material used. Unnecessary and expensive heat losses will occur if insulation removed for repairs is not promptly replaced.

2 FREEZE PROTECTION. When the heat distribution system is to be shut down for a significant period of time during freezing weather, all steam lines, condensate lines, high temperature water (HTW) lines, and compressed air lines and equipment should be protected from freezing by completely draining the system. Occasionally, installations are provided with tracing systems to prevent freezing during shutdowns of short duration. In those cases, the system need not be drained, as the tracing system will maintain the water temperature above the freezing point (32°F).

3 TRACING. Either steam or electrical tracing systems are available.

3.1 Steam Tracing. Where a source of low- or medium-pressure steam is available, small diameter steam lines, called steam tracers, are installed beside the pipelines to maintain the water temperature above the freezing point during short duration shutdowns. The tracing lines are provided with traps for condensate drainage. The condensate can be either reinfected into the condensate return system or disposed of, depending on economic considerations.

3.2 Electric Tracing. Where an adequate source of steam is not available, or economic considerations dictate its use, electric tracing is employed. Tracing is provided by flexible electric heating cables wrapped around the pipelines, valves, and fittings. Electric tracing cable normally consists of twin resistor wires accurately positioned in high dielectric refractory material. At one end of the cable, the two wires are joined together within a waterproof end-cap, and at the other end power leads are connected to the tracing leads within a waterproof junction.

Section 2. THERMAL EXPANSION OF PIPES

1 OVERVIEW. The length of a pipe increases as temperature rises; for example, when a piping system is taken to operating temperatures from a cold condition. Table 7-3 shows the expansion of steel, wrought iron, and copper pipe per 100 feet of length for different temperature changes. From the table, it may be noted that a steel pipe of 100 feet in length expands 2.88 inches when the temperature changes from 0°F to 360°F (a temperature change of 360°F) . If this movement is restricted in any manner, for example, by pipe anchors, equipment connections, or Inflexible changes of direction, the full strength of the expanding pipe will be exerted against the restriction. In the case cited, this force, for a 12-inch pipe, would equal 232,000 pounds. If not properly relieved, such expansion can damage or cause failure of pipe-lines and equipment. The elongation of a lengthy heating line is conveniently handled by expansion loops and bends, and expansion joints. Where possible, piping systems should be designed to provide for expansion of branch lines inside buildings to prevent any effect on mains.

2 EXPANSION LOOPS AND BENDS. Whenever possible, it is better to provide for pipe expansion by changing the direction of pipe runs, or by using expansion bends or loops. Expansion loops are factory fabricated and may be furnished in sections to facilitate handling and delivery. They absorb the pipe expansion by introducing U-type or Z-type loops in the pipeline, and they do not require maintenance.

3 EXPANSION JOINTS. Expansion joints are commonly used where space restrictions prevent the use of expansion loops and bends. Expansion joints must be installed only in accessible locations to facilitate maintenance. The following are examples of the usual types of expansion joints:

- The mechanical slip joint
- The bellows type joint
- The flexible ball joint

3.1 <u>Mechanical Slip Joint</u>. Mechanical slip joints consist of a female member which slides over a male member, while the joint is kept tight by means of packing. The packing may be the semiplastic type, injected into the packing space by means of a built-in packing gun (plunger and cylinder assembly); or the coil type, installed in a conventional stuffing box. Mechanical slip joints require periodical lubrication, usually supplied through special lubrication fittings. When used, maximum traverse of piping should be limited to less than 8 inches. Figure 7-1 Illustrates a mechanical slip joint that uses semiplastic packing.

3.2 <u>Bellows Type Joint</u>. The bellows type joint, illustrated in figure 7-2, absorbs pipe expansion and contraction by the flexing of a metal bellows. The joint consists of a corrugated thin-walled tube of an appropriate metal (generally stainless steel) clamped between flanges. The pipes should be supported and guided in such a way that misalignment is reduced to a minimum. Also, external tie rods with limit stops are usually provided to protect the joint against overtravel. Some types of joints have rings to help the corrugations in resisting the fluid pressure. Bellows or corrugations for

TABLE 7-3. Pipe Expansion per 100 Feet of Length With Temperature Changes

Temperature (°F) (1)	Expansion in Inches for Different Materials		
	Steel (2)	Wrought Iron (3)	Copper (4)
0	0	0	0
20	0.148	0.180	0.238
40	0.300	0.350	0.451
60	0.448	0.540	0.684
80	0.580	0.710	0.896
100	0.753	0.887	1.134
120	0.910	1.058	1.366
140	1.064	1.240	1.590
160	1.200	1.420	1.804
180	1.360	1.580	2.051
200	1.520	1.750	2.296
220	1.680	1.940	2.516
240	1.840	2.120	2.756
260	2.020	2.300	2.985
280	2.180	2.470	3.218
300	2.350	2.670	3.461
320	2.530	2.850	3.696
340	2.700	3.040	3.941
360	2.880	3.230	4.176
380	3.060	3.425	4.424
400	3.230	3.620	4.666
420	3.421	3.820	4.914
440	3.595	4.020	5.154
460	3.784	4.200	5.408
480	3.955	4.400	5.651
500	4.151	4.600	5.906

[1]Expansion in inches per 100 feet length of pipe, from 0°F to pipe temperature shown in column (l).

absorbing vibrations or mechanical movements to ambient temperatures may be made of copper or other materials suitable for the job conditions. A maximum travel of 4 inches should be allowed for this type of joint.

3.3 Flexible Ball Joints. Ball joints consist of four main components:

(a) The casing or body that holds the gaskets and ball

(b) The ball itself, which fits inside the casing

(c) The inner and outer gaskets, installed between the ball and the casing, to provide a seal

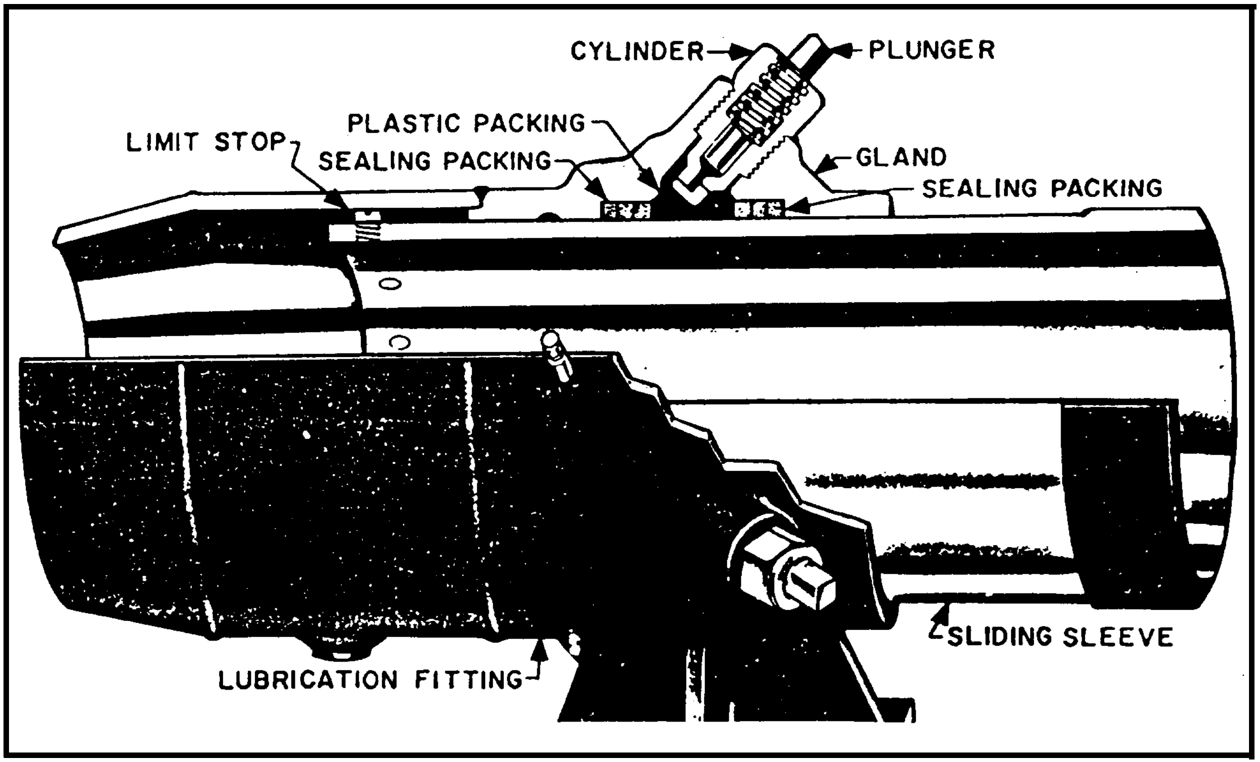


FIGURE 7-1. Mechanical Slip Joint

(d) A retaining flange to hold the gaskets and ball in the casing

In construction, the pipe end of one of the two pipes being coupled is connected to the joint casing; the other pipe end is connected to the ball. The ball is a hollow fitting that has two ends. One end is shaped externally like a ball, and fits inside the casing. The other end is cylindrical in shape and can be threaded, flanged, or adapted for welding to the pipe. Because of the flexible articulation, ball joints can accommodate movements in two or more planes simultaneously, as well as permitting twisting or torsional rotation of the pipe, and angular movement.

4 INSPECTION AND MAINTENANCE OF EXPANSION LOOPS AND BENDS. No specific maintenance is required for expansion loops and bends other than inspection for alignment. The following general inspection procedures are used for ordinary piping:

(a) Checking for leaks

(b) Inspecting supports

(c) Making certain that operating conditions do not exceed temperature and pressure ratings

5 INSPECTION AND MAINTENANCE OF EXPANSION JOINTS.

5.1 Inspection and Maintenance of Mechanical Slip Joints. Once a year, inspect for signs of erosion, corrosion, wear, deposits, and binding. Repair

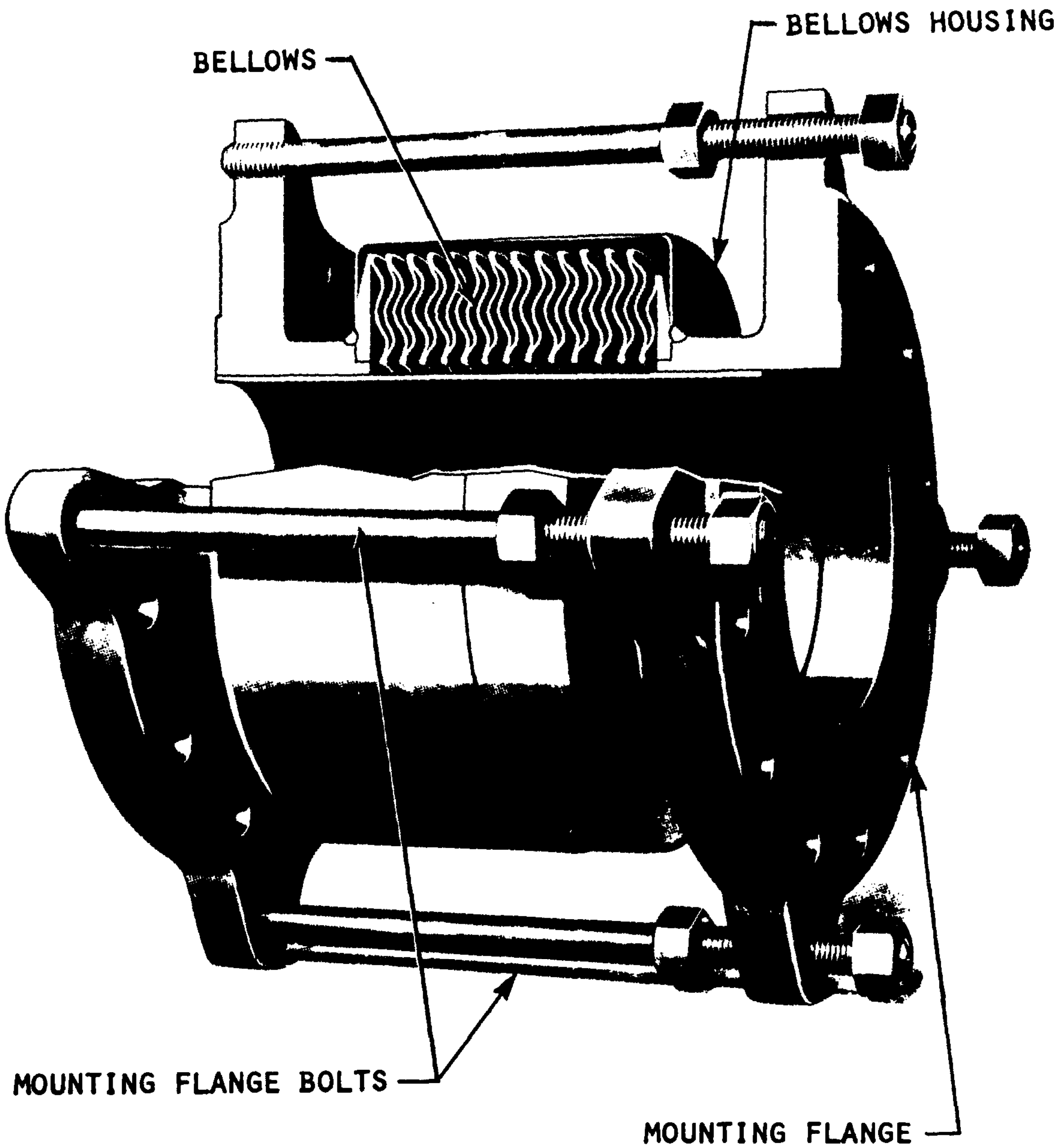


FIGURE 7-2. Bellows Type Joint

or replace defective parts as required. The following items are the main points to consider during inspection and maintenance of slip joints.

(a) Alignment. Check alignment at least once a year.

(b) Packing. Adjust or replace packing, as required, to prevent leaks and assure a free working joint. In the gun-packed type of joint, the addition of a few plugs of plastic packing (depending on the size of the joint) is all that is required. This can be done while in operation. The frequency depends on the operating conditions and type of joint used. In conventional gland-packed joints, the gland nuts must be evenly tightened until signs of leakage disappear, especially during the first few days after the packing is put into service. After the initial adjustment, the packing requires only periodic inspection. It is very important to immediately stop any leaks through the packing glands; otherwise, leaks may cut channels in both the packing and the slip. The frequency of packing replacements depends on the operating conditions. When replacing old packing, the joint must be taken out of service.

(c) Travel. Check the flange-to-flange distance of the joint once a year, first when cold and then when hot, and compare with the travel limits shown in the manufacturer's data. If slip travel has changed, it may indicate a shift in the anchorage and/or pipe guide. The source of the problem should be located and corrected.

(d) Lubrication. Lubricate slip joints every 6 months, using the correct quantity, type, and method of lubrication recommended by the manufacturer for the service conditions.

5.2 Inspection and Maintenance of Bellows Type Joints. Inspect joint annually for alignment, fatigue, corrosion, and erosion. Check travel between cold and hot conditions and compare with manufacturer's instructions. In case of failure, the bellows section must be replaced.

5.3 Inspection and Maintenance of Flexible Ball Joints. Usually no lubrication is required with this type of joint as there is little frictional wear. External takeup is provided for adjustment if necessary. Replace gaskets as required. The frequency of gasket replacement depends on the operating conditions.

Section 3. VALVES AND FITTINGS

1 VALVES. Valves are used in heat conveying systems and in compressed air distribution lines for the following purposes:

- To stop the flow of the medium
- To control the flow of the medium
- To prevent flow reversal
- To prevent excess pressure

1.1 Gate Valves. A gate valve basically consists of a body and a disk that slides across the flow path and shuts it off. Gate valves are used in lines where unrestricted flow is important, since with the valve fully open, a straightway flow area is provided through the valve. They should not be used for flow regulation or throttling service; when so used, the gate may vibrate and chatter, with subsequent damage to the seating surfaces. Throttling also causes erosion of the lower edge of the seat rings. Gate valves are properly used as stop valves. They are built in the following four different types, according to the variations in their stem or gate construction.

(a) Outside Screw Rising Stem and Yoke. In this type of valve (refer to figure 7-3) the stem rises while the handwheel remains in the same level. The position of the disk is indicated by the position of the stem. The exposed threads of the stem should be protected from damage and corrosion.

(b) Nonrising Stem. Here the stem rotates in the bonnet and is threaded to the disk. Wear on the packing is reduced but the stem is exposed to the fluid passing through the valve.

(c) Wedge Disk. The gate of this type of valve is a solid wedge that slides between tapered seats.

(d) Double Disk. The gate here consists of two separate disks with a spreader mechanism between them. While the valve is being closed, the disk spreader contacts the bottom of the valve body and forces the disks apart against parallel-faced seating rings.

1.2 Globe Valves. The globe valve is so called because of its globular outline. As illustrated in figure 7-4, there is a directional change as flow travels through a globe valve, which results in greater frictional resistance. Globe valves are used for throttling purposes and flow regulation. They may have plug or disk type valves and seats. The disks can be of metal or composition. Metal disks are appropriate for throttling service; composition disks, however, are not recommended for this service because of the severe cutting action which may damage the disk face. Globe valves placed in a horizontal steam line should be installed with the stem in a horizontal position, to prevent collection of condensate in the valve and line. Flow direction through the valve depends on the service intended. In feed lines, the valve is installed so that-the pressure acts under the disk; a loose disk in that case will not act as a check to prevent flow. On open-end and drain lines, however, some engineers recommend that globe valves be

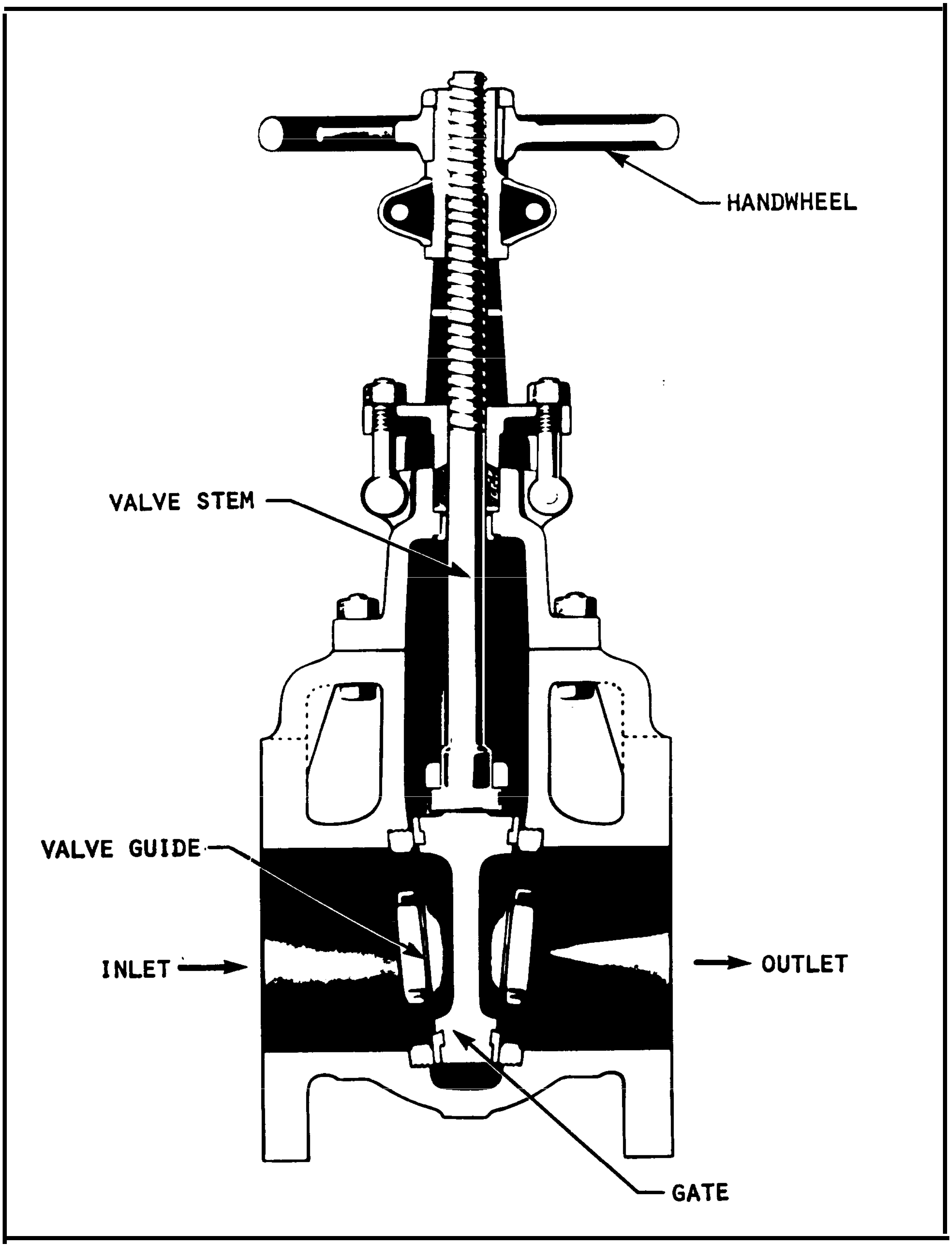


FIGURE 7-3. Rising Stem Gate Valve

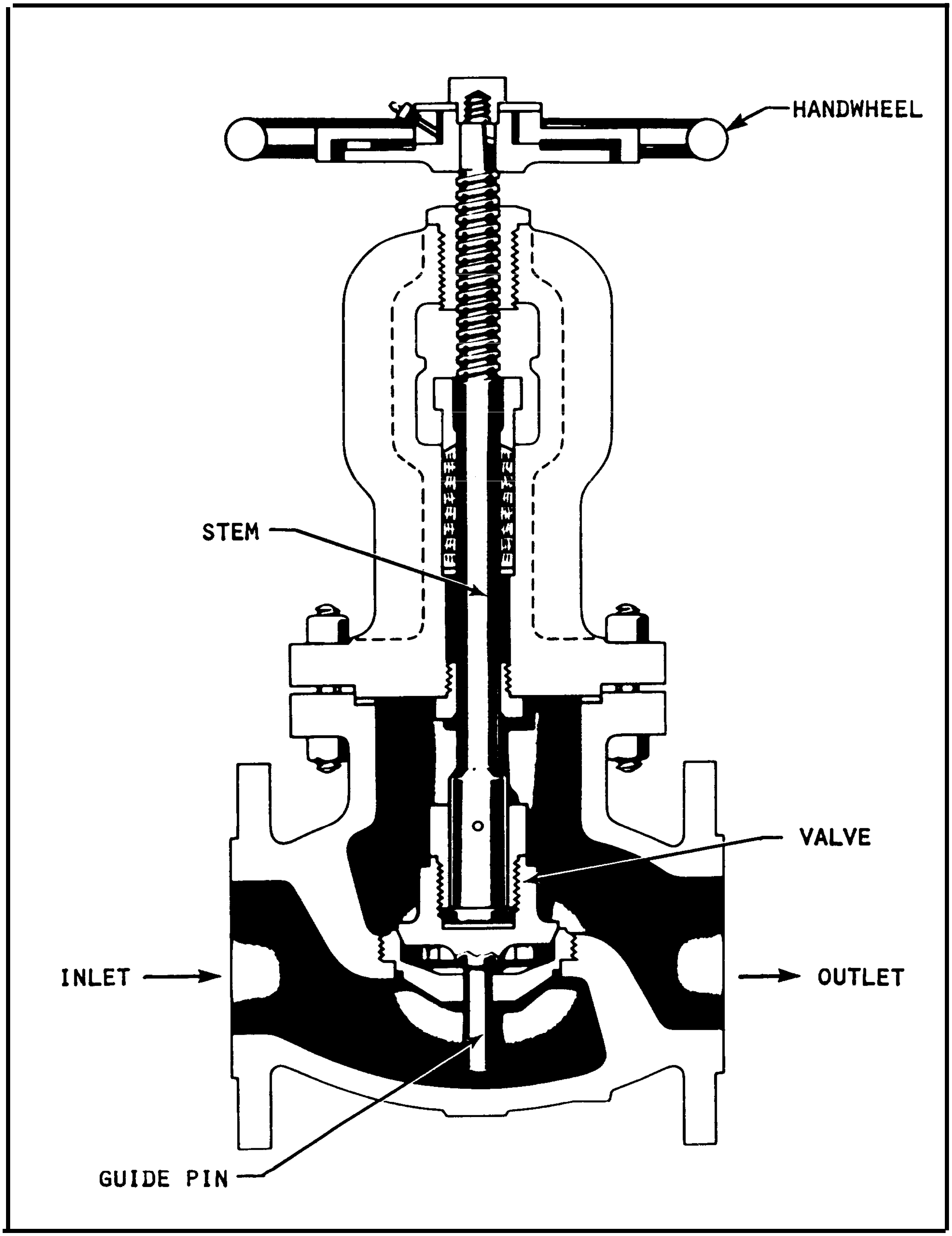


FIGURE 7-4. Globe Valve

installed with the pressure on top of the disk. Drain valves with pressure under the disk may vibrate open if not tightly closed. In high temperature steam applications, valves should be installed so that the pressure is above the disk. This will eliminate leakage of the steam.

1.3 Angle Valves. In this type of valve the fluid leaves at an angle of 90° from the direction of the entering fluid. Construction and operating characteristics are similar to those of globe valves. Angle valves are mainly used for convenience in the installation arrangements, as when a 90° turn in the fluid direction is required. Their use eliminates an elbow and reduces the number of joints.

1.4 Check Valves. Check valves are used to prevent flow reversal of the fluid in a line. A Swing-check type of valve is illustrated in figure 7-5. The flow of liquid through the swing-check valve is almost straight in its direction, being comparable to that of the gate valve. In the lift-check valve, there is a directional change as flow travels through the valve, similar to the flow through globe valves. In operation, both types of valves have the fluid entering below the seat which lifts the disk and permits the flow. When flow ceases, the disk's weight causes it to close against the seat. Any flow reversal shuts the valve tightly. Operation is automatic.

1.5 Relief Valves. Relief valves are designed to open automatically to prevent pressure in the lines or in pressure vessels from increasing beyond safety operating limits. They can be used with liquids or gases, including steam. The main difference between a safety valve, used to protect boilers from overpressures, and a relief valve is that the latter requires about 20 percent overpressure to open wide, while the safety valve opens wide at a set pressure. In operation, the relief valve starts to close as the pressure drops, and shuts off at approximately the set pressure. The discharge pipe from a relief valve should be positioned to avoid injury to personnel when discharging. Also, the installation should be designed to prevent the discharge end from getting plugged with ice during freezing weather. Relief valves should not be oversized. Oversizing will prevent the valve from opening sufficiently, causing hunting and wire-drawing, with consequent service trouble and heavy replacement costs.

2 OPERATION OF VALVES. Perform the following procedure.

(a) Close valves tightly, by hand only. Do not employ a wrench or persuader. Some large sized valves have impact wheels to help in closing and opening.

(b) Open and close valves slowly. This helps prevent water hammer in water systems. In steam systems, it permits slow warming of the lines. In compressed air systems, especially those of high-pressure design, this is required to reduce hazards and prevent surges.

(c) Before operating large gate valves, use small bypass valves, when possible, to equalize pressure on both sides of the gate.

(d) Often a closed valve leaks, due to foreign matter trapped between the seat and disk. This is sometimes eliminated by opening and closing the valve several times to flush out the deposits.

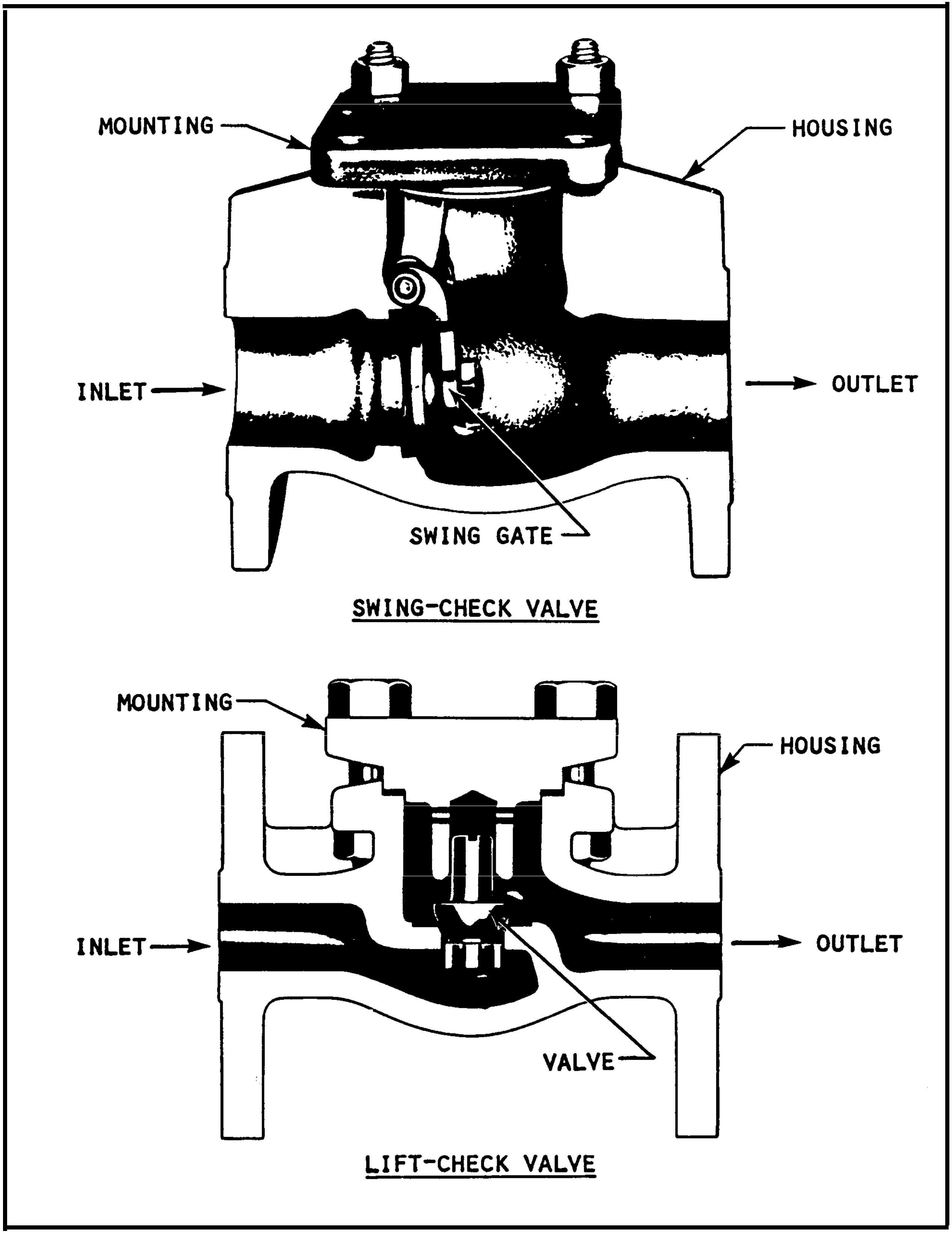


FIGURE 7-5. Check Valve

(e) Maintain fluid pressure and temperature within the valve rating.

(f) Do not jam valve shut while hot, or binding may result when the valve cools.

(g) Do not jam valve open while cold. Valve may bind open when hot. This is prevented by closing the valve one-fourth turn after it is wide open.

3 INSPECTION AND MAINTENANCE OF VALVES. Perform the following procedures.

(a) Monthly. Inspect for leaks and damage to insulation. Check for defective operation.

(b) Quarterly. Operate any valve which has not been used frequently. This will prevent sticking. Lubricate exposed threads and valve stem gearing.

4 PREVENTIVE MAINTENANCE INSPECTION OF VALVES. Perform the following inspections.

(a) Quarterly. Loosen and lift the packing follower. Lubricate the packing with graphite-bearing oil or grease. Replace packing followers and tighten as required to prevent packing leakage without causing binding.

(b) Yearly. Disassemble and clean the valve, and Inspect the following i terns:

- Valve leaks
- Damaged seats and disks: wear, wire-drawing, and grooving
- Deposits of foreign matter
- Lodging of foreign matter between disk and seat
- Scoring and pitting
- Worn out, corroded, or damaged stems, disks, and seats
- Damaged insulation
- Defective parts
- Damaged gaskets
- Packing condition

5 PREVENTIVE MAINTENANCE INSPECTION OF RELIEF VALVES. Perform the following inspections.

(a) Monthly. Inspect for leakage through the valve which may indicate defective seats or lodged scale. Make sure exhaust piping is in good condition, adequately supported, and valve discharge cannot endanger personnel.

(b) Quarterly. Test setting point using a calibrated test gauge. Readjust setting if necessary by changing the spring compression.

(c) Yearly. Dismantle the valve and look for the following:

- Damaged seats
- Lodging of foreign matter between seat and feather
- Corrosion, erosion, worn out or defective parts
- Distortion caused by uneven tightening of bolts
- Deposits of foreign matter
- Defective installation of exhaust piping
- Damaged gaskets
- Damaged seats and feathers: wear, wire-drawing, and grooving

6 MAINTENANCE OF VALVES. Perform the following maintenance procedure.

(a) Repair leaks by tightening loose connections and packing glands. Repack glands and repair or replace defective parts. Never reuse old packing, even if it looks satisfactory.

(b) Repair damaged insulation. Be sure to use insulating material of the proper type required for the service.

(c) Paint exposed valves for protection against external corrosion. Do not paint the stem. Exposed stem threads of gate valves of the rising stem type should be protected by a piece of thick rubber hose placed over the stem.

(d) Repair valve seats and disks by lapping with a grinding compound to a smooth, even finish, removing as little metal as possible. The disk seating surfaces may be coated with Prussian blue and lowered against the seat to check the fit. The valve is tight when a good, continuous contact is obtained. To remove cuts and scratches, it may be necessary to use a valve reseating machine or lathe. Avoid removing too much metal.

(e) Replace worn out, corroded, or damaged stems, disks, and seats.

(f) Remove and discard old packings. Clean the stuffing box. Clean inside of valve bonnet and other parts, removing all dirt and scale.

(9) Remove and discard old gaskets. Replace gasket of proper size and quality for the service intended.

(h) Estimate the cost of extensive valve repairs. Installing a new valve is often less expensive than repairing an old one.

7 MAINTENANCE OF PRESSURE RELIEF VALVES. Make necessary repairs or replacements after the yearly inspection of paragraph 5(c). Check the setting

point after reassembling the valve. If the valve does not close tightly after it has popped and has relieved considerable fluid, it is hanging up because the blowdown adjustment is probably too low. Blowdown should be set between 2 and 4 percent of the set popping pressure. If the valve chatters, the probable cause is low blowdown adjustment, or excessive back pressure caused by defective installation.

8 BRANCH VALVING AND CONNECTIONS. Takeoffs from supply and return mains to buildings are usually taken at the top of the lines. These branch connections are located at fixed points of the mains, at or near anchor points, to prevent movement. Valves are not required at each takeoff where a branch is short. Where the branches are of considerable length, however, or where several buildings are served, takeoffs should be provided with valves. When the length of the branch requires provision for expansion, the expansion loop or joint is commonly located inside the building.

9 FITTINGS. Fittings are used to provide bends in pipelines, branches, and connections; to seal pipes; and to attach fixtures.

(a) Steam Distribution. Welded construction is preferred for steam distribution for the following reasons:

- Construction is faster.
- There are no joints that may leak and cause trouble.
- There are no projections to interfere with coverings.
- Less material is required for an overall system.

(b) HTW Distribution. Screwed joints are not permitted; welded joints are used throughout the system. Flanged joints are kept to a minimum.

(c) Compressed Air Distribution. Refer to chapter 5 of this manual.

10 REFERENCE DESIGN SPECIFICATIONS FOR FITTINGS.

- For steam supply and condensate return consult NAVFAC Specification 21Y (Latest Revision), Steam Power Plant. Heating, and Ventilating Equipment and Piping; and ANSI/API 510-1983, Pressure Vessel Inspection Code - Maintenance. Inspection, Rating, Repair, and Alteration, for minimum design requirements of distribution systems.
- High Temperature Water. See references listed in this paragraph.
- Compressed Air. NAVFAC Specification 21Y applies. Also, ANSI/API 510-1983, Section 2, “Industrial Gas and Air Piping”; and Section 8, “Gas Transmission and Distribution Piping Systems.”

11 MAINTENANCE OF FITTINGS. The following items should be checked.

(a) Leakage. Check all flanged fittings, elbows, and tees twice a year for leakage and any loosening of bolts. If leaks are permitted for an extended period of time in heat distribution systems, wire-drawing of flanges and damage to insulation may result. Also, a substantial loss of treated water is likely to occur. Refer to chapter 5 of this manual for estimated losses caused by air leaks.

(b) Making Up Flanges. See that flanges are properly matched before Inserting the bolts when making up a flange. Do not drift the two flanges at the point at which they match; rather, use proper adjustment of the pipe guiding arrangement for the purpose. Replace leaking gaskets; use size and gasket material adequate for the pressure, temperature, and kind of fluid handled. It is convenient to dress a gasket with a mixture of graphite and oil (or water) before installation. This will facilitate disassembling the joint when so required. After making up the flange, tighten the bolts evenly without damaging screw threads. After the line is up to operating temperature, retighten the bolts, if required. to take up any bolt elongation caused by temperature increase.

Section 4. ANCHORS, HANGERS, AND SUPPORTS

1 APPLICATION. Anchors, hangers, and supports are used to carry the weight of pipes, valves, and fittings, as well as the weight of the contained fluid. When combined with expansion joints and bends, they control and guide pipe expansion. Common functions of anchors, hangers, supports, and guides include:

- Supporting the full unbalanced pressure of the fluid
- Resisting the strains caused by expansion and compression of the piping
- Supporting the weight of piping, valves, fittings, and fluid
- Eliminating or minimizing vibration and shock

2 ANCHORS.

2.1 Construction. Anchors used in underground pipe installations commonly consist of a steel plate welded to both the pipe and the conduit. The other end of the steel plate is embedded in concrete blocks sufficiently large to provide a firm anchor. The concrete may also be cast with the pipe in place; however, in either method it is important that the concrete extends beyond the trench walls and floor into the firm, undisturbed ground. At higher elevations where difficulty may be experienced in obtaining adequate rigidity of piping supports, the end of the steel anchors used to secure the pipes to the poles may be guyed to concrete deadmen by wire ropes and turnbuckles. The wire ropes should be installed parallel to the pipeline in both directions.

2.2 Reference Design Specifications. Anchors appropriate for distribution systems should be designed in accordance with NAVFAC Specification 21Y (Latest Revision), Steam Power Plant, Heating, and Ventilating Equipment and Piping.

3 HANGERS AND SUPPORTS.

3.1 Construction. For aboveground systems at lower elevations, concrete pedestals, steel frames, or treated wood frames are used. The spacing may be 10 to 15 feet on center, depending on pipe sizes. At higher elevations, aboveground pipelines may be supported on wood, steel pipe, H-section steel poles with crossarms, or steel frameworks fitted with rollers and insulation saddles. Excessive spacing between hangers will allow the line to sag. In a steam line, this permits the collection of condensate which impairs the performance of the system.

3.2 Long Spans. When long spans are necessary, cable-suspension or catenary systems may be used with supports up to 50 feet on center.

3.3 Underground Conduits. Approved manufacturers' standard supports should be used for underground conduits.

3.4 Reference Design Specifications. Supports for distribution system pipelines should conform to requirements specified in NAVFAC Specification 21Y (Latest Revision), Steam Power Plant. Heating. and Ventilating Equipment and Piping.

4 INSPECTION AND MAINTENANCE OF ANCHORS, HANGERS, AND SUPPORTS.

4.1 Anchors. Inspect anchors quarterly for corrosion, breakage, and shifting. Ensure that anchors are holding and that walls and footings near anchors do not show distress cracks. Make certain that bolts, turnbuckles, wire ropes, and other stressed members give no sign of impending failure. Anchor shifting may cause pipe misalignment and bending of expansion joints. If an anchor has shifted, take the line out of service and properly secure the anchor. Make necessary adjustments or repairs to the expansion joints and guides.

4.2 Hangers and Supports. Inspect hangers and supports quarterly. Check for corrosion, wear, and failed parts. Make certain that all supports are in line with the piping and tracking true; that supporting rollers turn freely; that each hanger is carrying its share of the load; and that there are no signs of imminent failure of any stressed member. Repair or replace defective parts as required. Line sags caused by misalignment can often be cured by simple hanger adjustments.

CHAPTER 8. STEAM TRAPS

Section 1. TRAPS DESCRIPTION

1 PURPOSE OF TRAPS. Steam traps are automatic mechanical devices which drain condensate, remove air and noncondensable gases from the system, and stop the passage of live steam through the drain lines. Accumulation of condensate seriously affects the performance of steam distribution lines by decreasing the capacity for heat transmission. Also, condensate may produce water hammer which can result in burst pipes, blown gaskets, or personal injury. Water hammer is the result of a slug of condensate being pushed by the steam and forcefully hitting the walls of the steam conduit. A layer of air or gas is comparable to a layer of ground cork insulation. Air in steam considerably lowers the temperature of the mixture, thus reducing the capacity for heat transfer; also, air slows the rate at which steam can get into the equipment. Air and some noncondensable gases, mainly carbon dioxide, may produce corrosion of the ferrous parts of the system.

2 CONSTRUCTION. Steam traps should conform to Federal Specification WW-T-696 (Latest Revision), Traps, Steam, and Air. Traps have the following components:

(a) A vessel to collect condensate

(b) An opening through which condensate is discharged

(c) A valve to close the opening

(d) Adequate mechanisms to operate the valve

(e) Inlet opening to the vessel for condensate admission

(f) Outlet opening for condensate discharge

3 PIPING FOR TRAPS. Drip piping to traps should be of the same weight and material as the drain piping. Traps may be discharged through a check valve into a pumped condensate line if the pressure differential through the trap is adequate. Preferably, however, a discharge line from a trap should run separately to a gravity condensate return main or to a nearby flash tank. The discharge piping from a trap should be pitched down, at a minimum of 3 inches per 100 feet (0.25 percent), to the collection tank of a condensate pump set, or to a gravity return. This slope is not required, however, when there is sufficient pressure in the steam line to overcome the friction and static head in the discharge line. If it is impractical to return drips to a condensate system, they may be drained as waste to a sewer. When the temperature of the drains exceeds sewer limitations, the condensate must be cooled in a sump or by other means. Some traps are provided with a built-in strainer. When this is not the case, a strainer should be installed ahead of the trap to act as a catch-pocket of pipe scale, sediment, and foreign materials. For testing convenience, trap installations should include a tee and test valve in the discharge line to check trap action. When it is required to ensure continuity of service, a three-valved bypass should be installed around the trap. This permits drainage of the line when the trap is out of service for repairs.

4 CLASSIFICATION. All steam traps do not function in the same manner, but all traps operate using basic physical laws. Steam traps are grouped into three major classifications which are based on function. The functions are sometimes mixed to provide combination type steam traps. The three classifications are as follows:

(a) Mechanical - operates using the difference in density between condensate and steam

(b) Thermostatic - operates using the difference in temperature between steam, condensate, and air

(c) Thermodynamic - operates using the difference in kinetic energy between flowing steam and condensate

5 TRAP TYPES. Within each classification there are types of traps. Table 8-1 lists the types of traps associated with each classification.

6 MECHANICAL TRAPS. The function of mechanical traps is based on the fact that low density steam will travel above the higher density condensate when both fluids are in a common container, such as a conduit.

6.1 Bucket Traps. Bucket traps can be of the open top or the inverted type. Both use the difference between the density of steam and condensate for their operation. Upright bucket traps are now rare and seldom ever installed (refer to figure 8-l). Upright bucket traps which fail are usually replaced by inverted bucket traps (refer to figure 8-2). Cooled condensate is not required to operate traps which release condensate at steam temperature. When the trap is first installed and steam Is turned on, the inverted bucket is down and the valve is wide open. Condensate and air enter under the bell or inverted bucket and flow through the discharge orifice. After all the condensate and air are removed, steam reaches the trap and floats the bucket, closing the valve. When condensate and air enter the trap, the bucket loses its buoyancy and drops. This opens the valve and the condensate and air are discharged until the steam again floats the bucket, closing the valve. Normal failure may be either open or closed.

TABLE 8-1. Types of Steam Traps

Mechanical	Thermostatic	Thermodynamic
Upright bucket	Bimetallic	Orifice plate
Inverted bucket	Thermal expansion	Venturi nozzle
Float	Bellows	Piston impulse
	Float and thermostatic	Disk

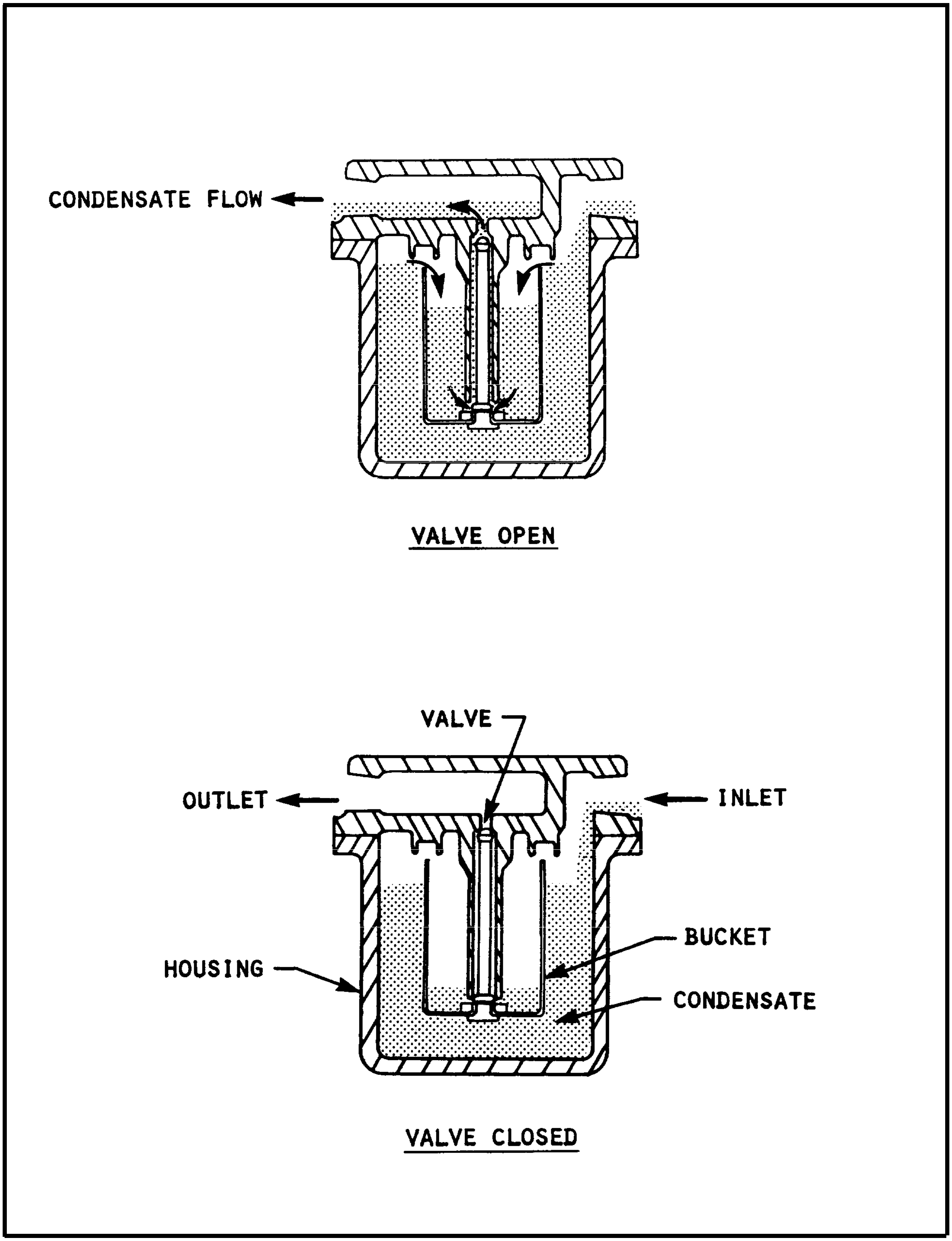


FIGURE 8-1. Upright Bucket Trap

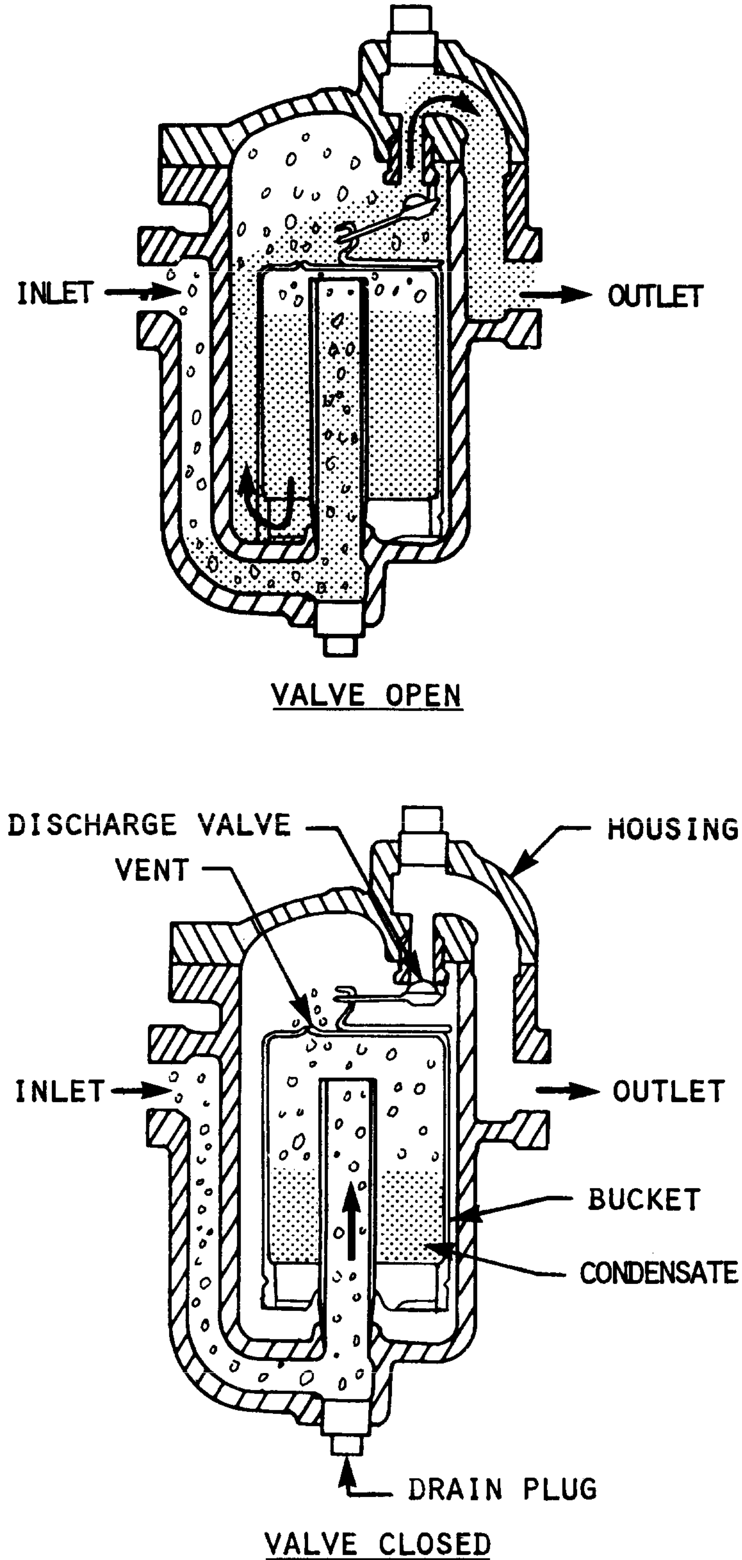


FIGURE 8-2. Inverted 8ucket Trap

6.2 Float Traps. Float traps usually consist of the following parts (refer to figure 8-3):

- Float
- Connecting rod
- Valve
- Casing
- Inlet
- Outlet

As condensate enters the inlet of a float trap, the condensate level in the trap rises. When condensate rises above the outlet opening, the preadjusted float rises and opens the trap valve releasing the condensate. The trap is designed so that the condensate level never drops below the level of the outlet valve while the trap is operating. This ensures that the lighter density live steam can never escape through the outlet.

7 THERMOSTATIC TRAPS. Since steam contains more heat energy than the condensate, the heat of the steam can be used to control the operation of a steam trap. Thermostatic traps are most useful for removal of air or noncondensable gases, especially during startup.

7.1 Bimetallic Trap. The operation of a bimetallic steam trap is based on a bimetallic element which changes shape with changes in temperature. Movement of the bimetallic element controls a valve that releases air and condensate. The basic bimetallic trap is only sensitive to changes in temperature and needs to be adjusted to the pressure range in which it will be operating. To prevent the loss of live steam, or a buildup of condensate, manufacturers use several different valve and bimetallic element shapes and sizes. These designs allow the bimetallic steam trap to respond better to changes in its operating conditions. Bimetallic steam traps normally fall closed. Refer to figure 8-4 for an illustration of a bimetallic steam trap.

7.2 Thermal Expansion Steam Trap. The thermal expansion type steam trap operates over a specific temperature range without regard to changes in pressure. The thermal element may be a wax, a plastic, or a special liquid. This thermal element is used because it has a high expansion rate when subjected to a small increase in temperature. The thermal element is sealed off from direct contact with the condensate and steam. When condensate is flowing through the trap the valve would be fully open. With a slight rise in temperature up to the saturation temperature, the thermal element would dramatically expand closing the valve and preventing loss of live steam. Almost any operating pressure can be selected over which to open and close the valve by selecting the corresponding saturation temperature at which the thermal element will dramatically expand. Thermal expansion steam traps normally fail open. (Refer to figure 8-5.)

7.3 Bellows. The more common design for low-pressure heating systems is the bellows or diaphragm trap (refer to figure 8-6). The bellows element has corrugations and may be filled with a liquid, such as alcohol, water, or a mixture of both. When heated by steam around the bellows, the liquid inside the bellows begins to vaporize. This forces the bellows to expand since there is a greater pressure inside than outside the bellows. Bellows can be used at varying pressures because when there is steam in the trap body outside the bellows, there is steam within the bellows. When there is condensate in the

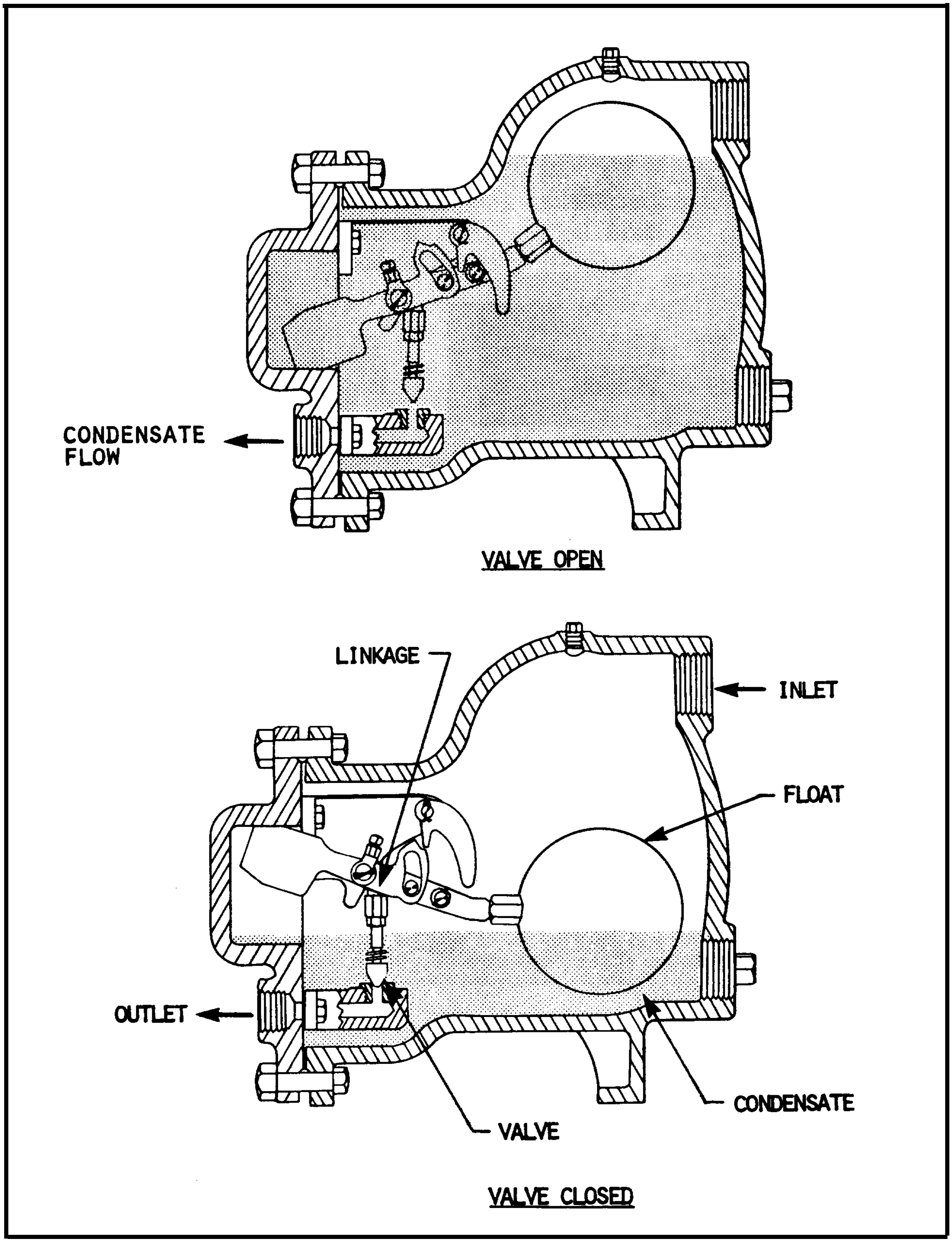


FIGURE 8-3. Float Trap

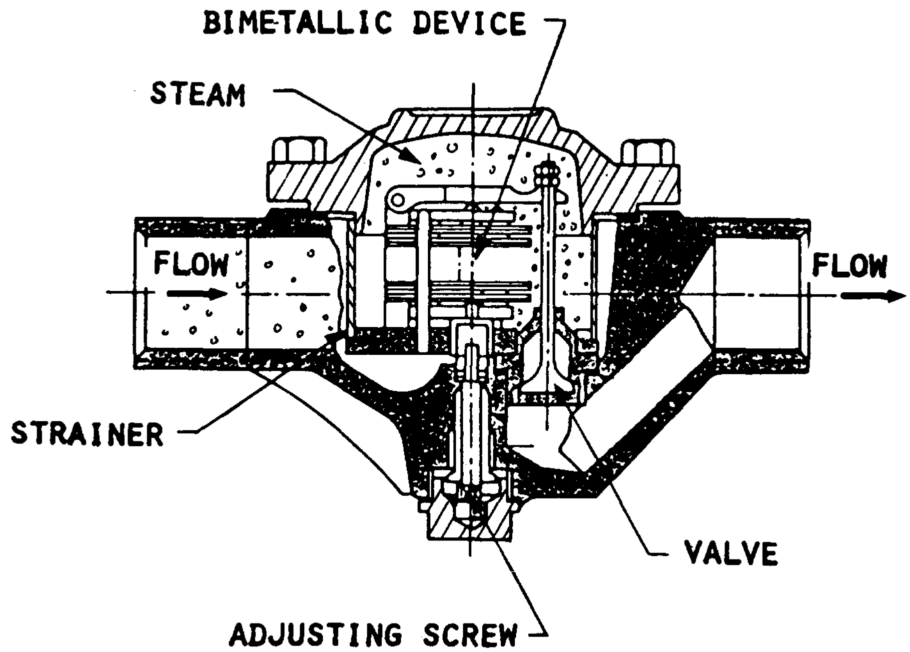


FIGURE 8-4. Bimetallic Steam Trap - Closed Position

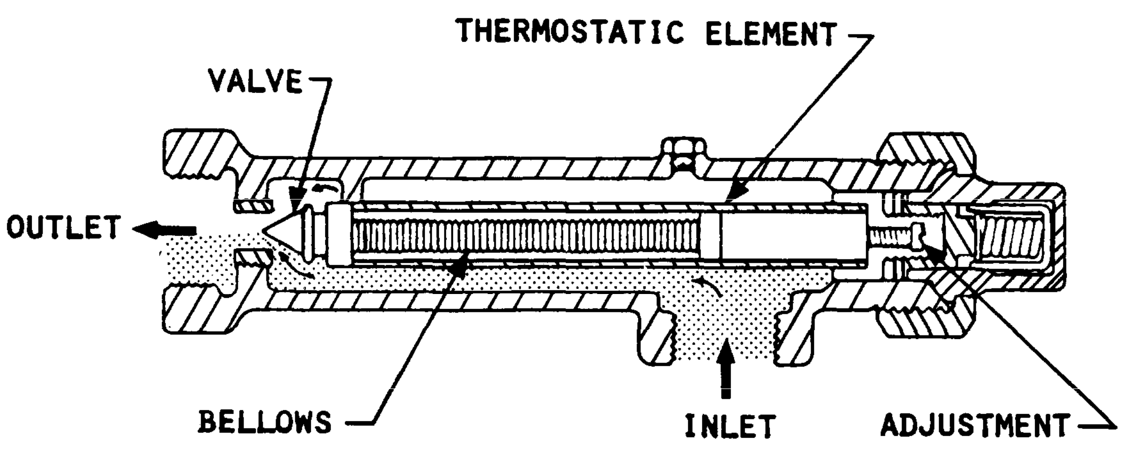


FIGURE 8-5. Thermal Expansion Steam Trap - Open Position

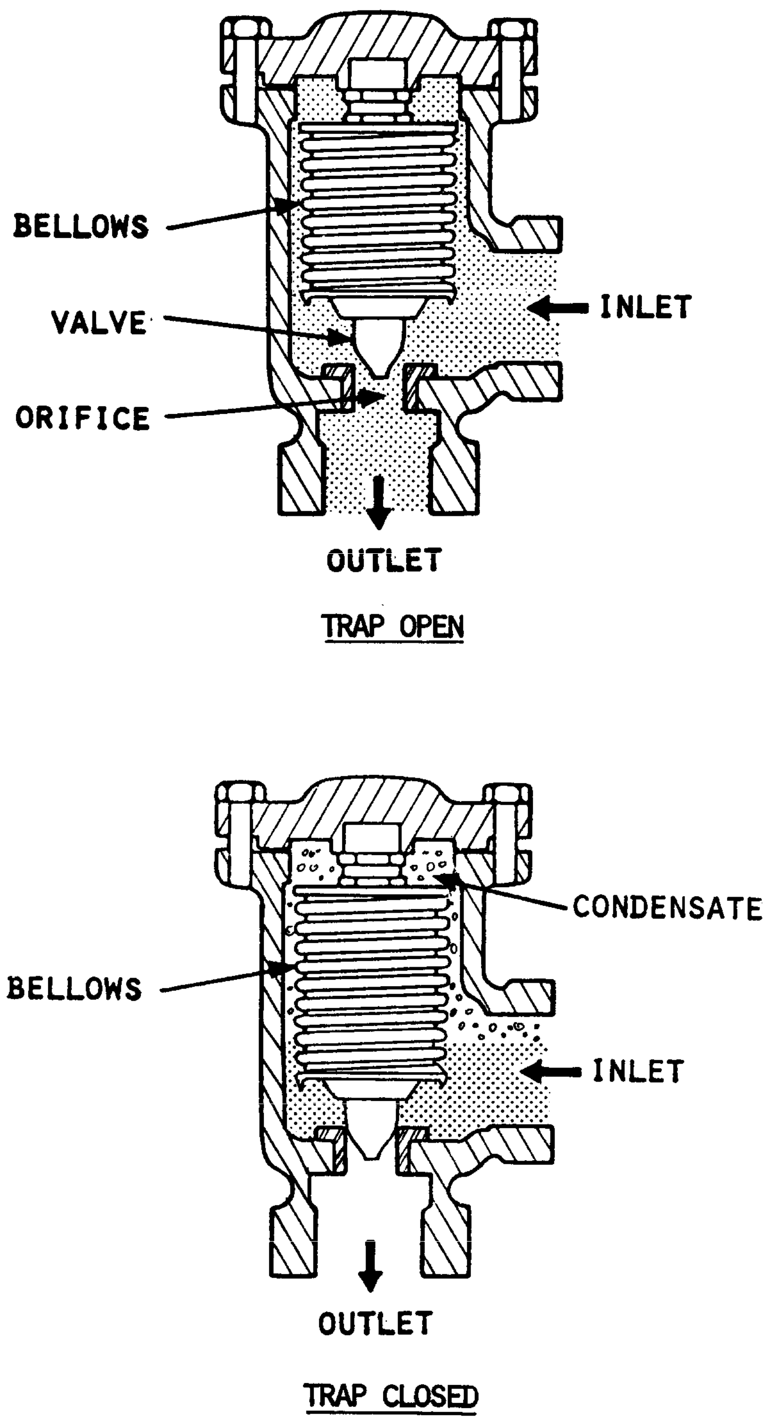


FIGURE 8-6. Bellows Trap

body, depending upon its pressure and temperature, there may be condensate or steam within the bellows. The bellows action is a combination of temperature and pressure, since lower pressures allow water to boil at lower temperature. If a bellows trap is taken apart while hot, the bellows may continue to expand and destroy itself. If a bellows trap is exposed to superheated water, the fill will completely vaporize, achieving much greater pressure inside the bellows than it is designed for, causing the bellows element to distort or rupture. If bellows are subjected to water hammer, their ridges flatten from a semicircle to a sharp crease, which will cause failure. When a bellows breaks, it loses its vacuum and expands. This pushes the valve into the seat stopping any condensate flow. Diaphragm capsules are similar in action to bellows. Bellows and diaphragm steam traps normally fail closed.

7.4 Float and Thermostatic Trap. This trap also depends for its operation on the difference in density between the steam and the condensate. In operation, condensate that collects in the trap body gradually raises the float, thus opening the discharge valve through a lever mechanism. After the condensate is discharged, the float drops, closing the valve and preventing the passage of steam. Air and noncondensate gases are relieved through a thermostatic vent. The thermostatic vent consists of a bellows and valve assembly. (Refer to figure 8-7.) The chamber inside the bellows is filled with a liquid, or has a small amount of volatile liquid, such as alcohol. In operation, the liquid expands or vaporizes when steam contacts the expansive element. The pressure developed expands the element and closes the valve, preventing the passage of steam. When relatively coo? condensate or air contacts the element, the vapor condenses or the liquid contracts, thus decreasing the pressure and opening the valve which permits the air and condensate to flow. The discharge from this type of trap is intermittent. A cooling leg of 3 or 4 feet should be provided ahead of the trap. Some thermostatic elements employ metal diaphragms in place of bellows; but the operating principle is identical. Float and thermostatic traps normally fail closed.

8 THERMODYNAMIC TRAPS. Thermodynamic traps operate using the differences in the flow energy, velocity, and pressure of steam and condensate. Trap design also takes into account the difference in the pressure drop between steam and condensate flowing through an orifice or venturi.

8.1 Orifice Plate Trap. When a gas or vapor passes through a restriction, it expands to a lower pressure beyond the restriction. Drilling a small hole in a plate is the equivalent of slightly opening a valve. (Refer to figure 8-8.) An orifice trap operates on the principal of continuously removing condensate from the steam line. This continual condensate removal allows the orifice trap to use a smaller diameter outlet than other types of steam traps which operate on an open-close-open-close cycle. Thus, the potential loss of live steam during system startup, or when the trap has failed open, is less for an orifice trap than for other types of steam traps. The mass flow rate of steam is much less than that of condensate, cutting down the potential loss of live steam during normal operation. Since they are always open, the mode of failure of an orifice trap would be closed if clogged with debris.

8.2 Venturi Nozzle Trap. Placing a short section of smaller inside diameter pipe between two sections of pipe creates a venturi nozzle. (Refer to figure 8-9.) The nozzle trap is based on the two-phase flow principle. Steam

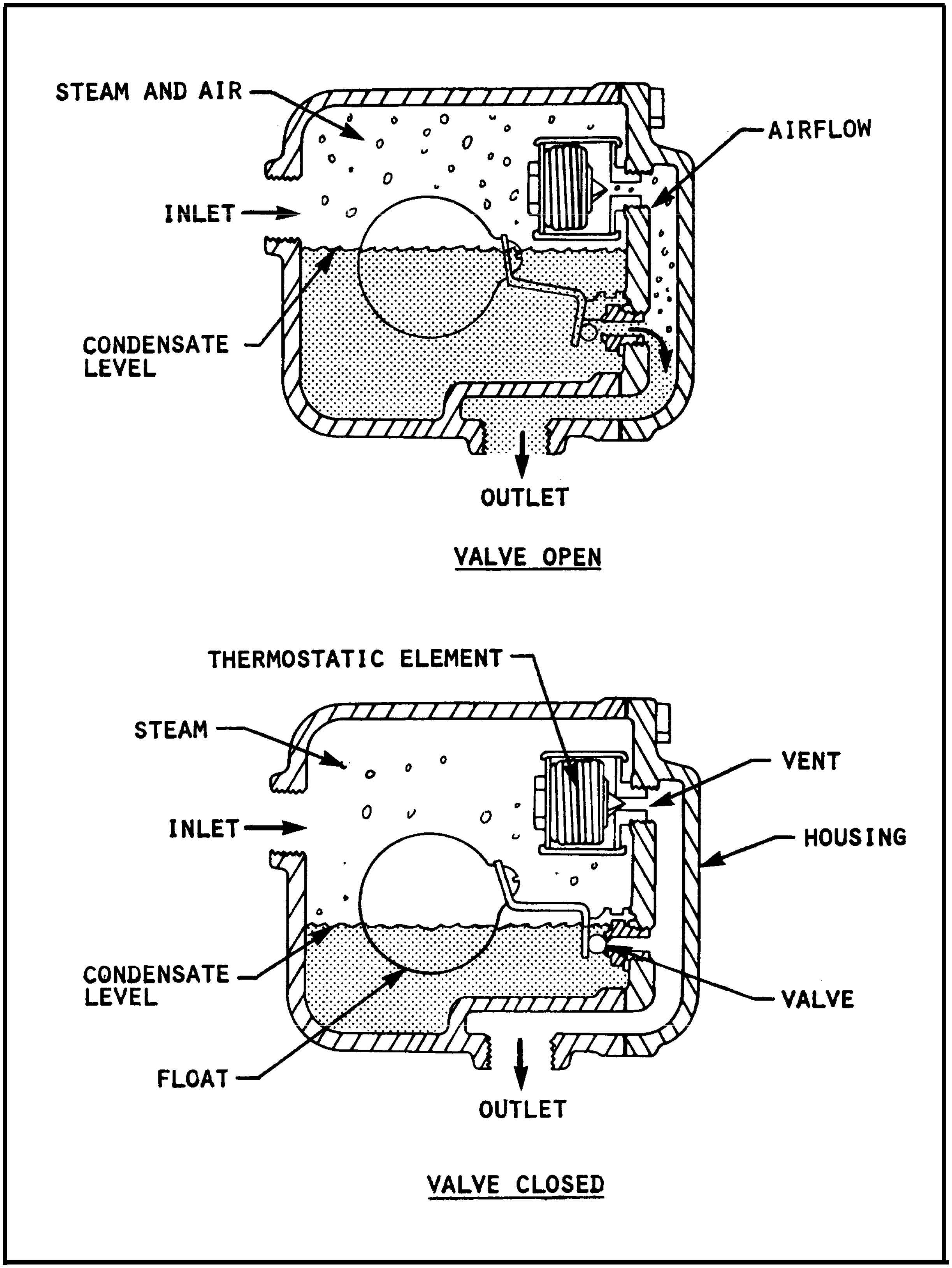


FIGURE 8-7. Float and Thermostatic Trap

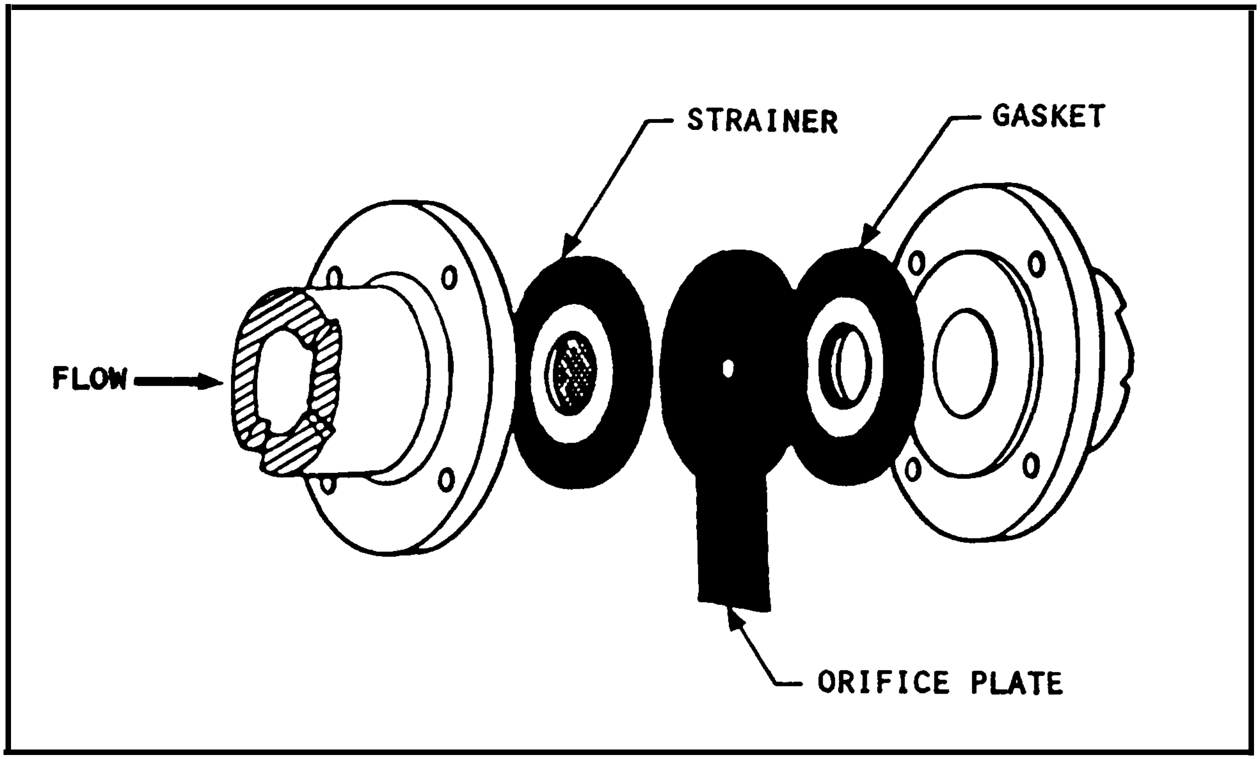


FIGURE 8-8. Orifice Plate Trap

will pass through the nozzle approximately 25 times faster than condensate, but the denser condensate impedes the flow of the steam. Therefore, the steam must push any condensate through the nozzle first before the steam can pass through. If the line becomes clear of all condensate, steam will pass through the nozzle, but the steam loss is negligible before more condensate forms to be pushed through the nozzle. The nozzle trap is normally installed downstream of a strainer which prevents particles from clogging the orifice of the nozzle. The venturi nozzle is palm size, has no moving parts, and comes in three standard pipe sizes: one-half, three-quarters, and one inch.

8.3 Piston Impulse Trap. The first thermodynamic operating trap is the piston impulse style. (Refer to figure 8-10.) The piston impulse style valve lifts to expose a relatively large seat area for cool condensate. As the condensate heats up and approaches steam temperature, some flows by the piston opening around a disk on the piston valve and flashes into steam. The flash steam at a pressure between Inlet and discharge is pushing against a relatively large flange area on top of the disk and pushes the valve down and closed. Steam in the flash or control chamber prevents more steam from entering the trap until it condenses. Once closed, the trap will not open until steam in the control chamber cools and condenses and incoming condensate blocks steam from flowing into the control chamber. When the steam in the control chamber condenses, the pressure above the piston drops allowing the valve to open. Air or noncondensable gas flows out the center vent hole in the piston. If blocked by dirt, the trap becomes airborne and nonfunctioning. Normal trap failure may be open or closed.

8.4 Disk Trap. The disk trap consists of only three parts: body, cap, and disk. The disk is the only moving part. (Refer to figure 8-11.) In

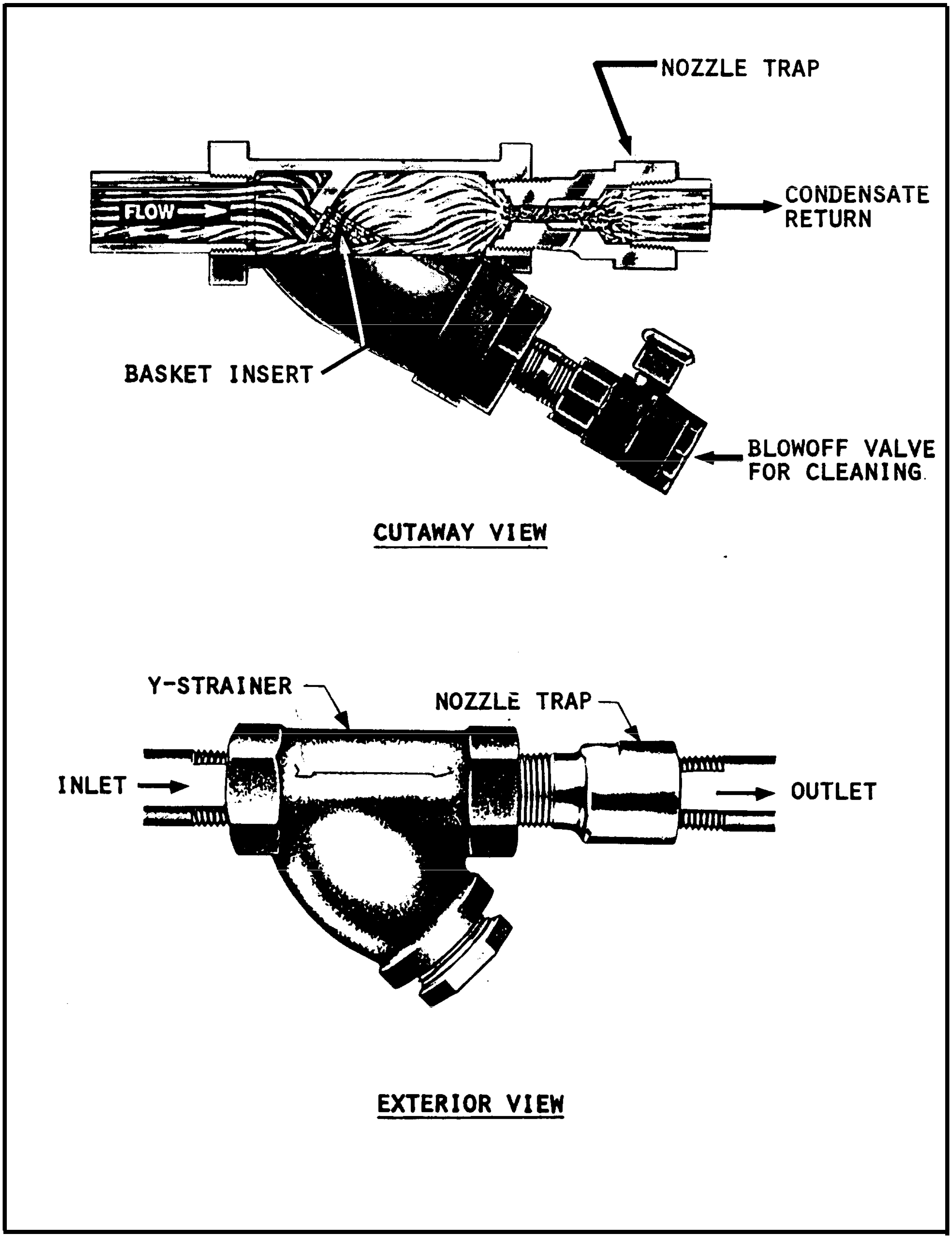


FIGURE 8-9. Venturi Nozzle

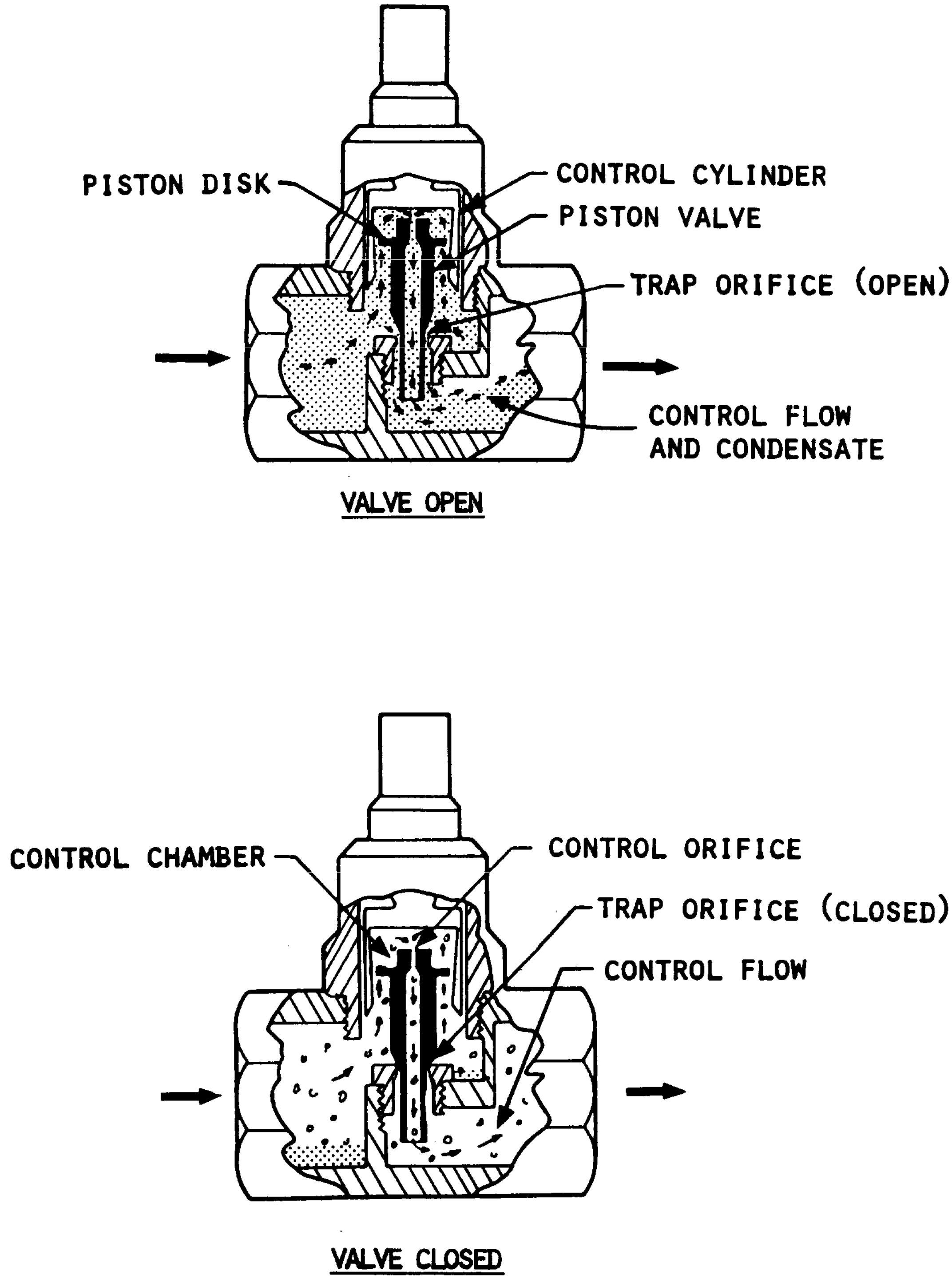


FIGURE 8-10. Piston Impulse Trap

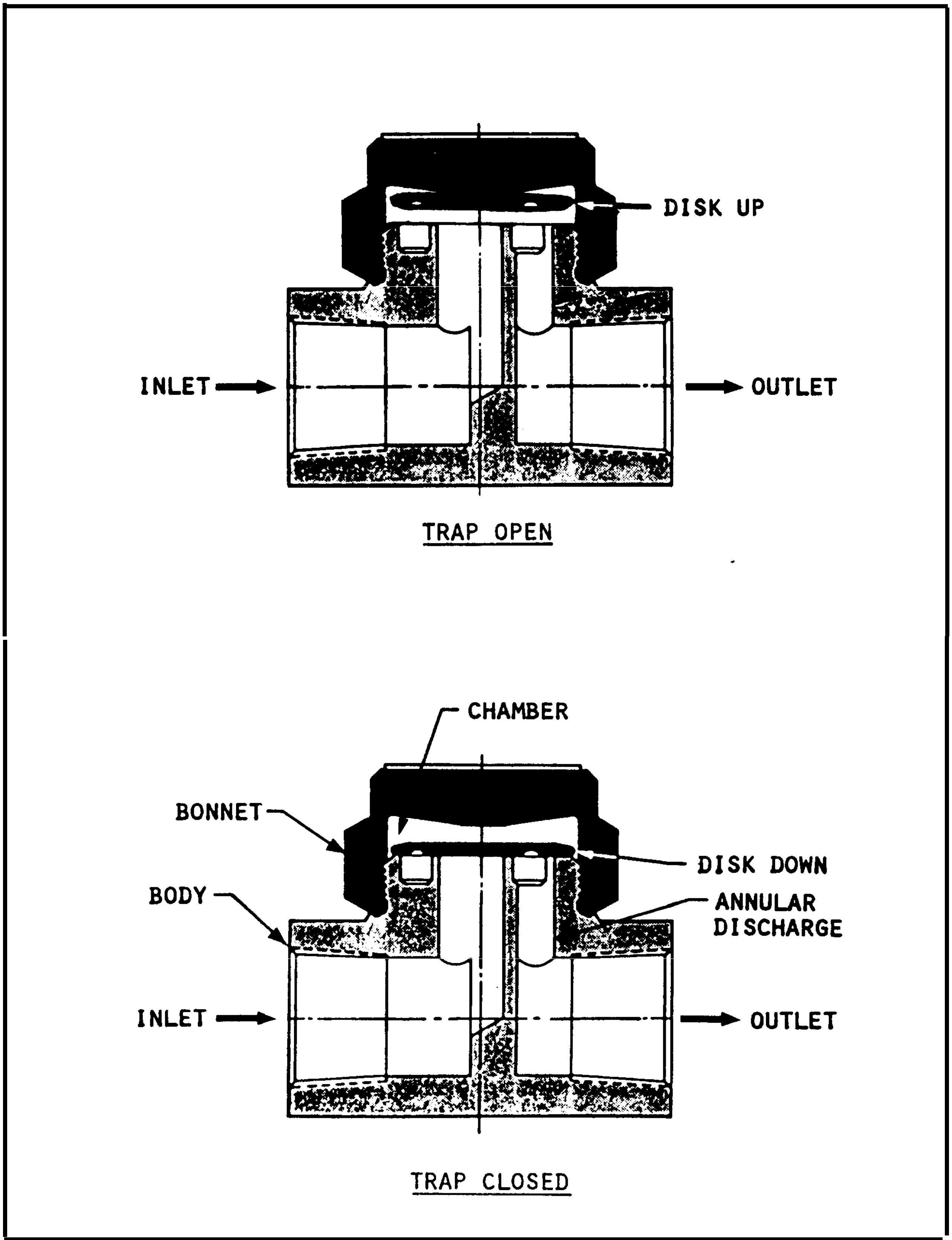


FIGURE 8-11. Disk Trap

operation, pressure in the inlet orifice forces the disk off the seating surfaces, allowing condensate to flow through the outlet. The chamber above the disk can hold steam or flash which causes an intermediate pressure. That Intermediate pressure, between the inlet and outlet, pushing on the top surface of the disk forces the disk down, closing the orifice. As the steam in the chamber condenses, the pressure in the chamber drops and the disk is once again forced up by the higher pressure in the inlet orifice, allowing the condensate to escape through the outlet. The disk trap is essentially time cyclic, dependent on the condensate forming in the chamber above the disk. Disk traps normally fail closed.

9 TRAP OPERATING CHARACTERISTICS AND SELECTION. Table 8-2 describes steam trap operating characteristics. Table 8-3 illustrates the relationship of trap type to application.

TABLE 8-2. Steam Trap Operating Characteristics

Characteristics	Bellows Thermostatic	Bimetallic Thermostatic	Disk	F&T	Inverted Bucket
Method of operation (discharge)	Continuous	Semimodulating	Intermittent	Continous	Intermittent
Operates against back pressure	Excellent	Poor	Poor	Excellent	Excellent
Venting capability	Excellent	Excellent	Good[3]	Excellent	Fair
Load change response	Good	Fair	Poor to good	Excellent	Good
Handles dirt	Fair to good	Good	Poor	Poor to good	Excellent
Freeze resistance	Excellent	Excellent	Good	Poor	Poor[5]
Water hammer resistance	Poor	Excellent	Excellent	Poor	Excellent
Handles startup loads	Excellent	Fair	Poor	Excellent	Fair
Suitable for superheat	Yes	Yes	Yes	No	No
Condensate subcooling	5°F to 30°F	50°F to 100°F	Steam temperature	Steam temperature	Steam temperature
Usual failure mode	Closed*	Open	Open'	Closed	Open

[1]Can be intermittent on low loads.
[2]Can fail open due to wear.
[3]Not recommended for very low pressure.
[4]Can fail closed due to dirt.
[5]May be insulated for excellent resistance.

TABLE 8-3. Steam Trap Selection Guide

Application	Special Considerations	Primary Choice[1]	Alternate Choice
Steam Mains and Branch Lines	Energy conservation Response to slugs of condensate Ability to handle dirt Variable load response Ability to vent gases Failure Mode (open)	Inverted bucket Thermostatic in locations where freezing may occur	Float and thermostatic
Steam Separators	Energy conservation Variable load response Response to slugs of condensate Ability to vent gases Ability to handle dirt Failure Mode (open)	Inverted bucket (large vent)	Float and thermostatic Thermostatic (above 125 psig)
Unit Heaters and Air Handling Units	Energy conservation Resistance to wear Resistance to hydraulic shock Ability to purge system Ability to handle dirt	Inverted bucket (constant pressure) Float and thermostatic (variable pressure)	Float and thermostatic (constant pressure) Thermodynamic (variable pressure)

Thermostatic traps should be used in any application where freezing temperatures may occur.

TABLE B-3. Steam Trap Selection Guide (Continued)

Application	Special Considerations	Primary Choice	Alternate Choice
Finned Radiation and Pipe Coils	Energy conservation Resistance to wear Resistance to hydraulic shock Ability to purge system Ability to handle dirt	Thermostatic (constant pressure) Float and thermostatic (variable pressure)	Thermostatic
Tracer Lines	Method of operation Energy conservation Resistance to wear Variable load performance Resistance to freezing Ability to handle dirt Back pressure performance	Thermostatic	Thermostatic
Shell and Tube Heat Exchangers	Back pressure performance Gas venting Failure mode (open) Resistance to wear Resistance to hydraulic shock Ability to purge system Ability to handle dirt Ability to vent gases at low pressures Energy conservation	Inverted bucket with large vent (constant pressure) Float and thermostatic (variable pressure)	Thermostatic
Process Air Heaters	Energy conservation Ability to vent gases Ability to purge system Operation against back pressure Response to slugs of condensate Method of operation	Inverted bucket	Float and thermostatic Thermodynamic
Steam Kettles:			
Gravity Drain	Energy conservation Resistance to wear Resistance to hydraulic shock Ability to purge system Ability to handle dirt	Inverted bucket	Thermostatic
Siphon Drain	Energy conservation Resistance to hydraulic shock Ability to vent air at low pressures Ability to handle air startup loads Ability to handle dirt Ability to purge system Ability to handle flash steam	Thermostatic	

Section 2. MOISTURE SEPARATORS AND DRIP LEGS

1 MOISTURE SEPARATORS. Various types of blowdown and inline separators are used in distribution lines to separate entrained water, oil, and particles from steam, compressed air, or gases. (Refer to figures 8-12, 8-13, and 8-14.) All moisture separators use the principles of a vortex and centrifugal force to separate the moisture from steam or gas. As steam enters a separator, the design of the inlet or stationary baffle vanes cause the steam to swirl in a cyclone-like vortex against the the walls of the vessel. The increasing velocity of the vortex causes centrifugal force to deposit the moisture on the walls of the vessel. The moisture then drops to the bottom of the separator and is eliminated through a trap or directly into a drain line. Once entrainment has been eliminated, clean, dry steam flows through the center of the vortex to an outlet and back into the flow line. NAVFAC MO-206, Operation and Maintenance of Air Compressor Plants, addresses the usage and maintenance of moisture separators.

2 DRIP LEGS. Drip legs are provided to collect condensate from steam lines and compressed air lines. The condensate is generally removed by traps, although manual drain valves are often used for compressed air lines. Drip legs are usually located at low points, at the bottom of all risers, and at intervals of not over 200 feet for horizontally pitched pipes where traps are accessible. In buried underground pipe installations, where the traps are inaccessible, drip legs are usually located at intervals of not over 350 feet.

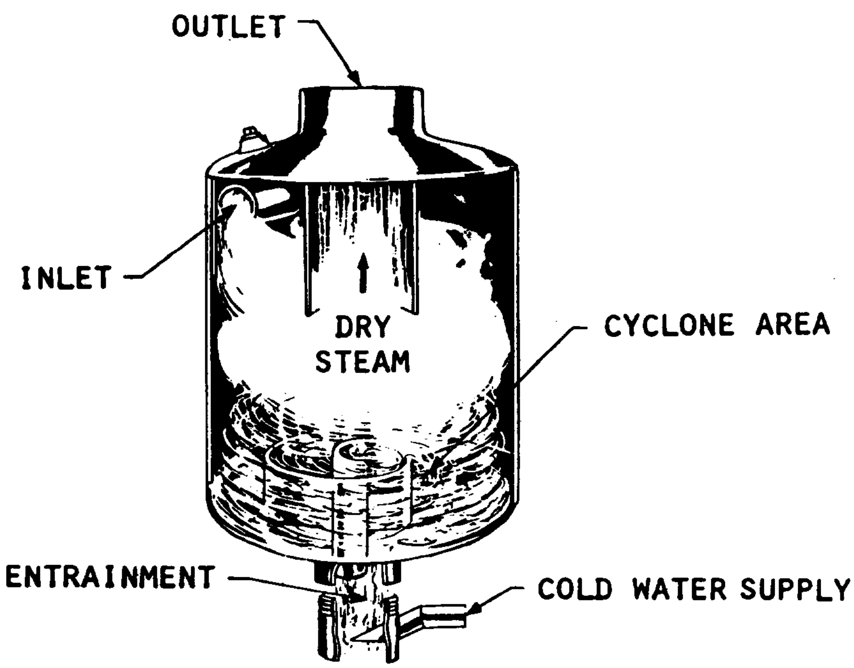


FIGURE 8-12. Moisture Separators - Downdraft

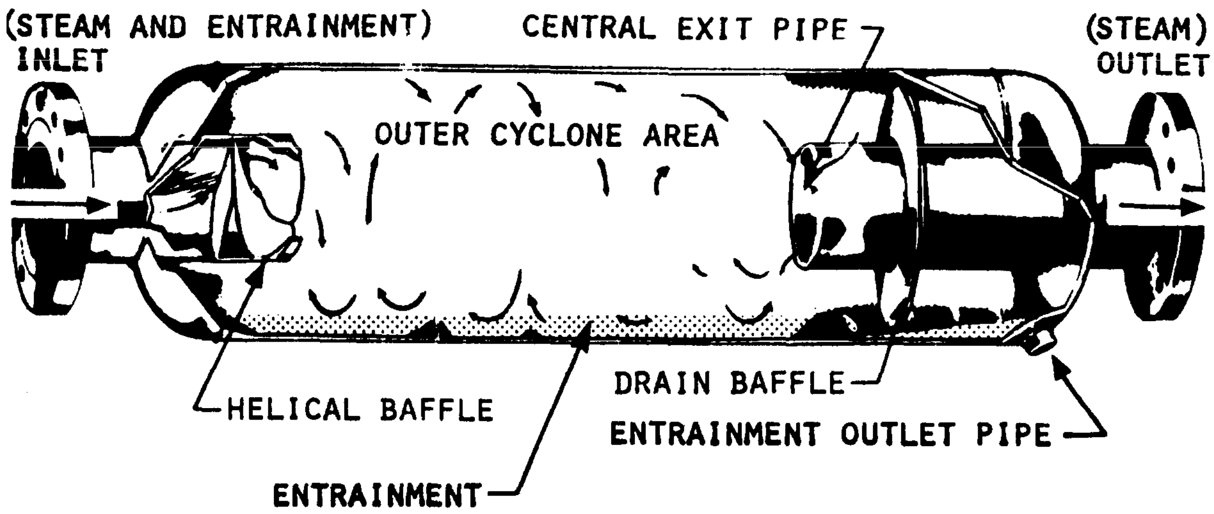


FIGURE 8-13. Moisture Separators - Inline Horizontal

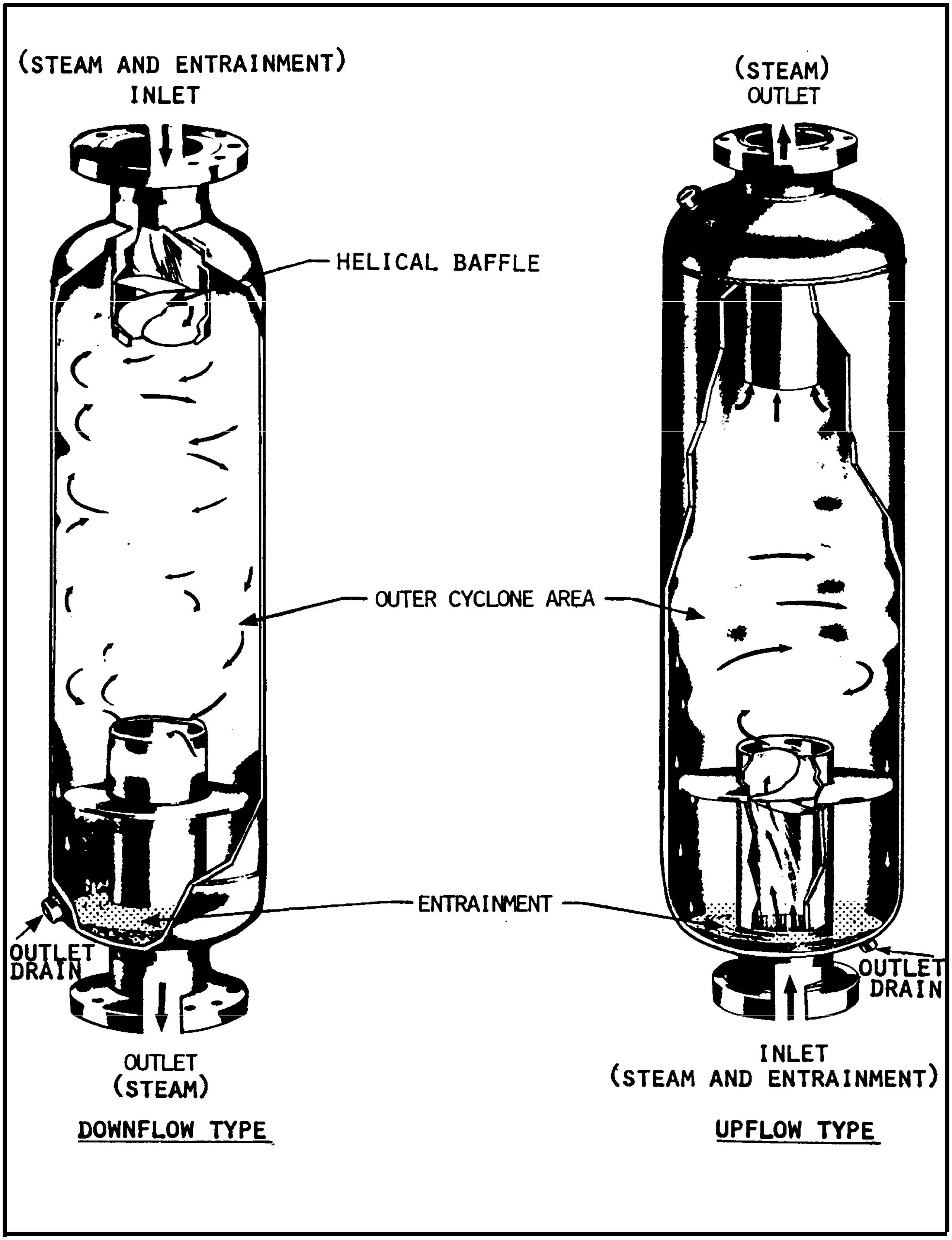


FIGURE 8-14. Moisture Separators - Inline Vertical

Section 3. SYSTEM UPGRADE

1 PURPOSE OF SYSTEM UPGRADE. The maintenance of a steam distribution system may occasionally require the installation of additional sections of lines and traps for system upgrade. Do not sacrifice efficient trapping solely for the sake of standardization with fewer types, but rather determine the advantages against easier maintenance and greater longevity.

2 TRAP LIMITATIONS. Federal Specification WW-T-696 (Latest Revision), Traps, Steam. and Air, covers a number of commonly used steam traps. The following limitations are provided for consideration when selecting the type of trap to use.

(a) Bucket trap.

- Trap will not operate where a continuous water seal cannot be maintained.
- Must be protected from freezing.
- Air handling capacity not as great as other type traps.

(b) Ball float trap.

- Must be protected from freezing.
- Operation of some models may be affected by water hammer.

(c) Disk trap.

- Not suitable for pressures below 10 psi.
- Not recommended for back pressures greater than 50 percent of inlet pressure.
- Freeze proof when installed as recommended by manufacturer.

(d) Impulse or orifice trap.

- Not recommended for systems having back pressure greater than 50 percent of the inlet pressure.
- Not recommended where subcooling condensate 30°F below the saturated steam pressure is not permitted.

(e) Thermostatic trap.

- Limited to applications where condensate can be held back and subcooled before being discharged.
- Operation of some models may be affected by water hammer.
- Diaphragm and bellows types are limited to applications of 300 psi and 425°F maximum.

(f) Combination float and thermostatic trap.

- Cannot be used on superheated steam systems.
- Must be protected from freezing.
- Operation of some models may be affected by water hammer.

3 SIZING TRAPS. The following factors affect the accuracy of trap sizing.

(a) The unavoidably large range in condensate load for many steam services.

(b) The wide variance in operating pressure and differential pressure.

(c) The uncertainty of trap capacity because of error In estimating condensate temperature. Sizing errors can offset most of the system savings provided by trapping. Traps that are too small cause condensate to back up. Oversized traps allow live steam through. Along with selection of the proper type of trap, correct sizing is the Important step in establishing trapping standards for the system. In setting up standards, a review of past practices against current results may avoid repeating errors in sizing. To determine the correct size trap, perform the following requirements;

- Calculate or estimating the maximum condensate load.
- Determine the operating pressure differential and the maximum allowable pressure.
- Select a safety factor.
- Size the type of trap from manufacturers' capacity tables.

3.1 Condensate Load. The amount of condensate generated by items of equipment can generally be obtained from equipment manufacturer's literature. For most all applications, formulas, tables, and graphs are available in steam trap manufacturers' brochures for calculation of condensate loads. Table 8-4 provides formulas for simplified estimating of condensate loads as shown In table 8-5.

3.2 Pressure Differential. One element of trap capacity is the difference in pressure between the supply line and condensate return. If the trap discharges to the atmosphere, the differential pressure will be the supply pressure. For sizing traps, the maximum steam operating pressure is used. Frequently, traps are installed with the outlet connected to a return system, which is under some pressure. The trap must operate against this pressure, plus a static head, if the trap is required to lift the condensate to a return at a higher level. Table 8-6 gives examples of the reduction in trap capacity caused by this back pressure. This must be considered when sizing traps.

3.3 Safety Factor. The safety factor is a multiplier applied to the estimated condensate load. Trap ratings are based on maximum discharge capacity; that is, continuous flow ratings. Factors vary from 2:1 to 10:1 and are influenced by the operational characteristics of the trap, and accuracy of

TABLE 8-4. General Formulas for Estimating Condensate Loads

Application	Pounds/Hour of Condensate
Heating water	$\frac{GPM}{2}$ x temperature rise ‘F
Heating fuel oil	$\frac{GPM}{4}$ x temperature rise ‘F
Heating air with steam coils	$\frac{CFM}{900}$ x temperature rise ‘F
Heating: pipe coils and radiation	$\frac{A \times U \times \Delta T}{L}$ A = area of heating surface, ft^2 u = heat transfer coefficient (2 for free convection) AT = steam temperature - air temperature, ‘F L = latent heat of steam, Btu/lb

TABLE B-5. Estimating Condensate Loads

INSULATED STEAM MAIN Pounds/Hour of condensate per 100 linear feet at 70°F (at 0°F, multiply by 1.5)						
Steam Pressure (psig)	2	4	6	8	10	12
10	6	12	16	20	24	30
30	10	18			40	46
60	13	22	32	41	51	58
125	17	30	44	55	68	80
300	25	46	64		103	122
600	37	68	95	124	154	182

TABLE 8-6. Percentage Reduction in Steam Trap Capacity

Inlet Pressure (psig)	Back Pressure (percent of inlet pressure)		
	25%	50%	75%
10	5%	18%	36%
30	3%	12%	30%
100	o	1 0%	28%
200	o	5%	23%

the estimated condensate load, pressure conditions at the inlet and outlet, and the configuration of the installation design. If the condensate load and pressure conditions can be accurately determined, the safety factor used can be low, which helps avoid oversizing. When experience with the steam system and equipment, and thoughtful engineering of trap sizing are applied, safety factors in the range of 2:1 to 4:1 are adequate. When sizing from manufacturers' capacity ratings, make sure the ratings are based on flow of condensate at actual temperatures rather than theoretical rates or cold water flow tests.

4 INSTALLATION GUIDELINES. The following guidelines can be used for optimum location and correct installation during system upgrade.

- Install unions on either side of the trap to a standard overall dimension, to allow for easy servicing and replacement, and to provide upstream and downstream service valves.

- A test discharge with valve is usually installed after the trap in return condensate systems.

- Inlet and outlet piping to a trap should be equal to or larger than the trap tappings. All unused inlet and outlet ports must be plugged. When using thread sealant tape, at least one thread is left exposed on the outside to ensure that none of the tape is cut off on the inside and carried into the trap.

- Since the use of cast iron traps is restricted to a working pressure of 250 psig or less, consider the use of nonrepairable stainless steel traps where applicable.

- Normally all lines slope in the direction of flow. Improper pitch may result in pockets of condensate which contribute to damage by water hammer. If the return line slopes up, install a check valve upstream of the trap.

- Install traps using the markings which indicate the direction of flow. Orient float, thermostatic, bucket, and disk traps to take full advantage of gravity for effective operation.

- If the upstream side of a trap has a lower pressure because the steam valve is modulated closed, Install a vacuum breaker on the trap to allow atmospheric pressure into the body of the trap, which allows a positive pressure to cause flow through the trap.

- Float and thermostatic traps are widely used in low-pressure heating systems because they are effective in removing all condensate. Ratings of float and thermostatic traps have a considerable safety factor.

- Bimetallic traps are resistant to damage by water hammer and allow unrestricted discharge of air on startup, but are poor in handling air and noncondensables after startup.

- Thermostatic traps are inexpensive for low-pressure applications and allow air and noncondensables to escape on startup. These characteristics, along with typical sizes from 1/2 to 2 inches, make the thermostatic trap useful for comfort heating systems.

- Inverted bucket traps are especially suited to situations where water hammer may be a problem. Since they require a water seal to operate, inverted buckets are subject to freezing in outdoor applications. Because they have a moderate air handling ability, they are recommended for unit heaters where there is no modulation of steam pressure.

- Traps discharging into relatively high-pressure areas, such as a return line higher than the trap level, may reverse and destroy weaker parts of the mechanism.

- Contrary to manufacturer’s claims, bucket, float, and thermostatic traps may freeze in outdoor installations when the steam is throttled and insufficient heat is available.

- Do not insulate thermostatic and disk traps because they must give off heat to function properly. To ensure adequate opportunity for heat transfer, do not insulate 18 inches of pipe adjacent to the trap inlet. Inverted bucket traps may be insulated since they do not need to lose heat to function.

- Do not introduce condensate from a high-pressure steam system into the return lines of a lower-pressure system unless the return lines are of an adequate size. The high-pressure condensate will flash and occupy more volume than it did as condensate. Traps associated with the low-pressure system will be prevented from operating properly. Discharging high-pressure condensate into a cooler low-pressure return system may cause water hammer.

- A lifting steam trap is nonexistent. Condensate rises to a return system only if there is sufficient pressure behind it to overcome the static head.

- Balance pressure thermostatic traps may be destroyed if there are long runs of pipe between the source of the condensate and the trap.

- Traps that are undersized for the pressure drop and condensate load do not effectively remove condensate from the system. To drain properly, traps must be placed sufficiently below the system. Traps without sufficient air handling capacity lead to air blockage and prevent the proper operation of heating and other steam operated equipment. Steam traps should be located as close to the source of the condensate load as is practical.

APPENDIX

ABBREVIATIONS AND ACRONYMS

APPENDIX

ABBREVIATIONS AND ACRONYMS

Btu	British thermal unit
cfm	Cubic feet per minute
CHW	Chilled water
CO_2	Carbon dioxide
CPR	Cardiopulminary resuscitation
DEAE	Diethylaminoethanol
DP	Differential pressure
F&T	Float and thermostatic
ft^3/lb	Cubic feet per pound
gpm	Gallons per minute
HTW	High temperature water
Hg	Mercury
Hz	Hertz
lb/ft^3	Pounds per cubic foot
lb/hr	Pounds per hour
LCD	Liquid crystal display
LED	Light emitting diode
mA	Milliampere
NPSH	Net positive suction head
$_pH$	Acid/alkaline content level
PM	Preventive maintenance
ppm	Parts per million
psi	Pounds per square inch,
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
RTD	Resistance temperature detector
Scfm	Standard cubic feet per minute
WG	Water gauge

REFERENCES

REFERENCE - 1

REFERENCES

1. NAV\FAC DM-3, Design Manual, Mechanical Engineering.

2. NAVFAC DM-3.5, Design Manual. Compressed Air and Vacuum Systems.

3. NAVFAC DM-3.8, Design Manual. Exterior Distribution of Utility Steam, High Temperature Water (HTW), Chilled Water (CHW). Fuel Gas. and Compressed Air.

4. NAVFAC DM-4, Design Manual. Electrical Engineering.

5. NAVFAC DM-7.2, Design Manual, Foundations and Earth Structures.

6. NAVFAC MO-206, Operation and Maintenance of Air Compressor Plants.

7. NAVFAC MO-307, Cathodic Protection Systems Maintenance.

8. NAVFAC MO-322, Inspection of Shore Facilities.

9. NAVFAC MO-324, Inspection & Certification of Boilers & Unfired Pressure Vessels.

10. NAVFAC TR-733, Heat-Traced System for Polar Regions (Latest Revision).

11. NAVFAC Guide Specification - 15411.

12. NAVFAC Specification 21Y (Latest Revision), Steam Power Plant. Heating, and Ventilating Equipment and Piping.

13. NAVFAC Specification 34Y (Latest Revision), Bituminous Coating for Steel Surfaces.

14. NEESA 18-3015, Evaluation of Compressed Air System Losses.

15. NEESA 32-015, Location of Leaks in Pressure Testable Direct Burial Conduits - Operator's Manual.

16. ANSI/API 510-/1983, Pressure Vessel Inspection Code - Maintenance, Inspection. Rating, Repair and Alteration.

17. ASTM C-552, Specification for Cellular Glass Block, and Pipe Thermal Insulation.

18. Federal Specification WW-T-696 (Latest Revision), Traps, Steam, and Air.

19. Steam Trap User's Guide, UG-0005, April 1985, Naval Civil Engineering Laboratory, Port Huneme, CA.

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