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MILITARY HANDBOOK

EXTERIOR DISTRIBUTION OF UTILITY STEAM, HIGH TEMPERATURE WATER (HTW), CHILLED WATER (CHW), FUEL GAS, AND COMPRESSED AIR

NO DELIVERABLE DATA REQUIRED BY THIS DOCUMENT

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ABSTRACT

This handbook provides basic, yet comprehensive, design guidance and technical data for exterior distribution piping systems. Services supported by these systems include: utility steam supply, High Temperature Water (HTW), Chilled Water (CHW), cooling or condensing water, fuel gas, and compressed air to various buildings and other facilities. This handbook also contains data covering return systems for condensate, water, and other spent services. Additional design data includes information on loads and fluid conditions, fluid characteristics, and distribution site locations. Factors governing tests for field permeability, soil resistivity, soil stability, and water conditions, information on distribution pipe sizing, valves and supports, distribution methods, and piping specifications and codes are provided. Material included also covers ownership, operations, and maintenance cost variables associated with permanent or temporary sites.

FOREWORD

This military handbook has been developed from an extensive evaluation of Shore Establishment facilities, surveys of new materials availability and construction methods, selections from the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies and the private sector. MIL-HDBK-1003/8 uses and references design data standards established and validated by national professional societies, associations, and technical institutes. Deviations from this criteria, in planning, engineering, design, and construction of Naval shore facilities, cannot be made without prior approval of NAVFACENGCOM HQ Code 04.

Design methods and practices cannot remain static any more than the naval functions they serve or the technologies used. Accordingly, recommendations for improvements to this document are encouraged and should be furnished on the DOD Form 1426 provided inside the back cover to Naval Facilities Engineering Command, Chesapeake Division, Code 406, Washington Navy Yard, Washington, DC 20374, telephone (202) 433-3314.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCED DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

MECHANICAL ENGINEERING CRITERIA MANUALS

CRITERIA MANUAL	TITLE		PREPARING ACTIVITY
DM-3.01	Plumbing Systems		PACDIV
MIL-HDBK-1003/2	Incinerators	(proposed)	SOUTHDIV
DM-3.03	Heating, Ventilating, Air Conditioning, and Dehumidifing Systems		WESTDIV
DM-3.04	Refrigeration Systems for Cold Storage		SOUTHDIV
DM-3.05	Compressed Air and Vacuum Systems		HQTRS
DM-3.06	Central Heating Plants		NEESA
MIL-HDBK-1003/7	Fossil Fuel Power Plants	(proposed)	NEESA
MIL-HDBK-1003/8	Exterior Distribution of Utility Steam, HTW, CHW, Fuel Gas and Compressed Air		CHESDIV
DM-3.09	Elevators, Escalators, Dumbwaiters, Access Lifts, and Pneumatic Tube Systems		WESTDIV
DM-3.10	Noise & Vibration Control for Mechanical Equipment (Tri-Service)		ARMY
MIL-HDBK-1003/11	Diesel-Electric Power Plants	(proposed)	SOUTHDIV
MIL-HDBK-1003/12	Boiler Control Systems	(proposed)	NORTHDIV
MIL-HDBK-1003/13A	Solar Heating of Buildings and Domestic Hot Water		CESO
DM-3.14	Power Plant Acoustics (Tri-Service)		ARMY
DM-3.15	Air Pollution Control Systems/Boilers and Incinerators (Tri-Service)		ARMY
DM-3.16	Thermal Storage Systems		HDQTRS
MIL-HDBK-1003/17	Industrial Ventilation		NEESA
MIL-HDBK-1003/18	Central Building Automation Systems		ARMY
MIL-HDBK-1003/19	Design Procedures for Passive Solar Buildings		CESO

Note: Design manuals, when revised, will be converted to military handbooks and listed in the military handbook section of NAVFAC P-34.

EXTERIOR DISTRIBUTION OF UTILITY STEAM, HIGH TEMPERATURE WATER (HTW), CHILLED WATER (CHW), FUEL GAS, AND COMPRESSED AIR

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Section 1: INTRODUCTION

1.1 Scope. Data and criteria in this handbook apply to exterior design of distribution piping systems for supplying certain central generating plant services to various buildings and facilities and for returning such spent services to the plants.

1.2 Cancellation. This handbook cancels and supersedes NAVFAC DM-3.08 of July 1981.

Section 2: PLANNING FACTORS

2.1 Types of Exterior Distribution Systems. Types of exterior distribution systems are described in paras. 2.1.1 through 2.1.5.

2.1.1 Steam and Condensate. Steam and condensate systems supply heat in the form of steam from central steam generating plants. Several buildings, building groups, or ship berthing facilities may be supplied with steam for domestic hot water and for space heating. Heating equipment using steam may include unit heaters, radiators, convectors, heating coils, and other devices. Process equipment using steam may include hot water heaters, laundry machinery, cleaning and plating tanks, kitchen equipment, and other devices. Condensate is returned to the central plant whenever possible.

2.1.2 High Temperature Water. High Temperature Water (HTW) Systems circulate high temperature water which supplies heat from a central heating plant to several buildings for space heating and process work and returns the water to the central plant (refer to NAVFAC DM-3, Mechanical Engineering). HTW systems operate at 260° F (127° C) or higher. Related systems such as Medium Temperature Water (MTW) systems operating between 200° F (93° F) to 259° F (126° C) and Low Temperature Water (LTW) systems operating below 200° F are frequently utilized. These systems are considered in the same general category, and material shall be selected to the same specifications as for HTW systems, except that Reinforced Thermalsetting Resin Plastic (RTRP) pipe is acceptable for LTW distribution systems.

2.1.3 Compressed Air. Compressed air systems supply compressed air from a compressor plant to docks, shops, hangars, and other structures (refer to the NAVFAC DM-3 series).

2.1.4 Chilled Water. Chilled Water (CHW) systems circulate chilled water from a central refrigeration plant to several buildings for space air conditioning (refer to NAVFAC DM-3 series) and returns the water to the central plant.

2.1.5 Cooling or Condensing Water. Cooling or condensing water systems distribute cooling water from a central source (such as a bay, stream, or cooling tower) to several facilities for condensing steam or refrigerants, for cooling water jackets, or stuffing boxes. The water is then returned to the source (cooling tower) or sent to waste in once-through systems (refer to NAVFAC DM-3 series).

2.1.6 Fuel Gas. Fuel gas systems distribute fuel gas for fuel gas burning operations.

2.2 Loads and Distribution System Locations. For approximate conditions, see Table 1.

2.2.1 Requirements for Individual Facilities. The actual loads and conditions are determined from the design of each building and facility. Refer to P-272 (Part 1), Definitive Designs for Naval Shore Facilities, as guidance for preliminary estimates of requirements. The facility layout, design, and geographic factors will further define requirements.

Table 1
Distribution Loads and Fluid Conditions

[illegible]	Use	Capacity	Fluid Pressure, psig, Vacuum, in Hg Temperature, Degrees F	Demand Factors[1]	Comments
Steam	Auxiliary power.........	Determined by heat balance............	Boiler steam....	1.0.................	Feedwater and fuel-oil heating
	Heating and snow melting..	See criteria in DM-3.03............	2 to 10 psig....	1.0[2] for heating radiation, 0.8[2] for ventilation.........	....
	Waterfront demands.......	See criteria in DM-25.021...........	150 psig maximum	1.0 single berths 0.8 multiple berths	High purity steam for nuclear ships..
	Process........	Laundry............	100 psig........	0.65................	7 hr/day, 5 days/week, normally.
		Kitchen............	10 to 40 psig...	1.0................	2-8 hr/day, 7 days/week, normally.......
		Bakery.............	10 psig.........	1.0................	8 hr/day, 5 days/week, normally.
		Dry cleaning........	70 psig.........	0.65................	....
		Hospital...........	40 to 60 psig...	0.65................	....
		Laundry HW..........	5 to 45 psig....	0.65................	7 hr/day, 5 days/week, normally.
		Domestic HW: DM-3.01.	5 to 45 psig....	0.65................	....
	Refrigeration..	Tons x steam rate/ton................	Boiler steam pressure 26-28 in. Hg. vacuum	1.0................	Turbine-driven centrifugal compressor.....
		Tons x steam rate/ton	12 in Hg........	1.0................	Absorption machine........
Condensate return.....	Distribution loss..........				
	Boiler feed....	Losses: Condensate Blow Down or Blow Off: Determined by amount and analysis of makeup. Process depends on usage. Distribution 10 percent.........	20 to 60 psig...	1.0 for continuous operation of condensate pumps...... 1.5 to 3 for intermittent operation of condensate pumps.	Check economics of returning condensate.....
Hot Water (supply and return)	Heating and snow melting..	Same criteria as for steam.............	10 to 100 psig..	....	....
	Process........	....	Same as for steam..........	Same as for steam...	
Chilled water supply and return	Refrigeration..	gpm = $\frac{12{,}000 \text{ Btu/ton} \times \text{tons}}{500 \times (t_s - t_r)}$[3]	Supply: 42 degrees F to 45 degrees F. Return: 52 degrees F to 60 degrees F. Pressure depends on friction & static heads..	1.0[2]................	....
Condenser water......	Refrigeration..	3 gpm/ton...........	Supply 85 degrees F. Return 105 degrees F	1.0................	....
	Power system...	gpm = $\frac{\text{steam lbs/hr} \times 950 \text{ Btu/lb}}{500 \times (t_s - t_r)}$[3]	Pressure depends on friction & static heads..	1.0................	See NAVFAC DM-3 series.........
Fuel Gas....	Process fuel gas burners...	....	....	....	See NAVFAC DM-3 series.........
Compressed air	Low pressure medium pressure high pressure	....	....	....	See NAVFAC DM-3 series.........

1/ Demand factors are to be applied to total connected loads.

2/ Values shown are approximate. Actual Demand Factor is a site-specific determination and is based on actual load diversification.

3/ t_s = Water supply temperature; t_r = water return temperature.

2.2.2 System Load Demand Factors. For demand factors, see Table 1.

2.2.3 Aboveground and Underground Systems. When selecting a system, factors to consider are: permanent versus temporary use, high-water table corrosiveness of soil for underground systems, cost, and degree of hazard (refer to para. 3.2.6.6).

2.2.4 Distribution Routes. Select the most direct routes, avoiding all obvious obstacles where possible.

2.2.4.1 Aboveground Piping Routes. Aboveground systems are generally lower in life-cycle costs but are less convenient in areas of heavy traffic. Consider blockage of access to areas for future development along with vulnerability to damage and acts of vandalism or sabotage.

2.2.4.2 Buried Piping Routes. Select routing to allow for proper drainage of the system. Manholes and provision for piping expansion must be considered in space allocation. Consider minimum separation of parallel piping runs where temperatures in the runs vary widely. Consider cover and drainage provisions for manholes.

2.2.5 Economic Studies. Refer to NAVFAC P-442, Economic Analysis Handbook, for procedures in life-cycle cost analyses. Economic studies for all piping system types must include life-cycle (owning, operating, and maintenance) costs. For prefabricated/pre-engineered underground systems, perform the economic analysis, developing costs from heat loss data provided in NFGS-15705, Underground Heat Distribution System (Prefabricated or Pre-Engineered Types). For concrete shallow trench systems, use the procedures in CEGS-15709, Heat Distribution Systems Outside of Buildings Concrete Shallow Trench Systems. The first consideration shall be an aboveground system, which, in most cases, will be economically advantageous to the Government. Another consideration will be whether or not the facility is permanent or temporary. Provide a separate economic analysis for the selection of an insulation system among those allowed in NFGS-15251, Insulation for Exterior Piped Utilities.

2.2.5.1 Annual Owning, Operating, and Maintenance Costs. Consider the following:

a) Base selection of the distribution system and route on the results of life-cycle economic analyses of alternatives. Esthetics shall be considered within the limits of the Station Master Plan.

b) Operation and maintenance costs depend on the type of system design and past experience with various systems.

2.2.5.2 Steam Versus HTW Distribution. For criteria on steam versus HTW distribution, refer to NAVFAC DM-3.06, Central Heating Plants. Some advantages and disadvantages of each system type are summarized on Table 2.

Table 2
Advantages and Disadvantages of Steam and High Temperature Hot Water Distribution Systems

STEAM SYSTEM	HOT WATER SYSTEM
STEAM SYSTEM ADVANTAGES 1. Smaller return pipe sizes are required. 2. Pumping costs for maintaining circulation are lower. Motor size is fraction of that required for water, as is operating time in some cases. 3. Maintenance costs are lower. The small difference of pressure under which the system components operate reduces wear and maintenance expense to a minimum. 4. When the condensate is repeatedly recycled through the boiler and system, makeup water requirements and corrosion are negligible, and equipment life is lengthened. **STEAM SYSTEM DISADVANTAGES** 1. Larger supply piping sizes are required. 2. Larger expansion loops, joints and swing connections are required. 3. Convectors and radiators must be installed in a pitched position. 4. Additional specialty items such as traps, lifts and in some cases pressure-reducing valves are required. 5. Condensate systems fail frequently, causing significant losses of heat. Reference: ASHRAE, 1980 Systems Handbook, Ch. 13.	**HOT WATER SYSTEM ADVANTAGES** 1. Fast, uniform response to instantaneous load changes using minimum pipe sizes. 2. Piping may be installed level or at any pitch. 3. Smaller supply pipe sizes are used. 4. Forced circulation provides, in the total water mass, the desirable inertia effect which helps to diversify system load requirements contributing to uniform input at fuel burners. 5. Requires fewer specialty items. 6. Permits practical air elimination to minimize corrosion and maintenance. 7. Resetting of system supply water temperature to meet changing loads permits more efficient energy usage. **HOT WATER SYSTEM DISADVANTAGES** 1. Larger motor sizes are required for circulating pumps. 2. Larger return pipe sizes are required. 3. Expansion tanks and air vents are required. 4. More maintenance is required due to increased equipment wear caused by longer operating times. 5. More intricate controls may be required, to compensate for areas with frequent load variations, in order to keep system in balance. Reference: ASHRAE, 1980 Systems Handbook, Ch. 15.

2.2.5.3 High-Pressure (above 50 psig) (344.5 kPa) Steam Versus Low-Pressure (0 to 15 psig) (0 to 103.4 kPa) Steam Distribution. Compare costs of higher pressure pipe, valve, and fitting standards against lower pressure standards plus costs of pressure reducing stations in selecting the most economical system. Low pressure steam may not require full-time boiler operator attendance. Medium-pressure steam systems, 15 to 50 psig (103.4 - 344.5 kPa), if operationally adequate, shall also be considered. End-use temperature requirements of terminal equipment must be met by the system selected.

Section 3. GENERAL DESIGN FACTORS

3.1 Distribution Site Location. Fluid distribution site locations shall be according to the following:

3.1.1 Location Factors. For location factors for each system, see Table 3.

3.1.2 Subsurface Explorations. When buried steam or hot water systems are specified, a thorough investigation of ground and water conditions shall be made. The procedure indicated in NFGS-15705 is applicable to most prefabricated piping systems. When concrete shallow trench systems are specified, the criteria of CEGS-15709 shall be used for prefabricated piping systems covered in this handbook.

3.1.2.1 Time of Year. Make the survey at a time of year when the highest water table is expected to exist, if possible. Exploration methods indicated in the NAVFAC DM-7 series, Soils and Foundations, are to be followed.

3.1.2.2 Test Explorations. Make test explorations (borings or test pits) at least every 100 ft (30.5 m) along the line of a proposed system. If changes in stratification are noted, the boring spacings should be decreased so an accurate horizontal soil profile may be obtained.

3.1.2.3 Groundwater Conditions. Extend all explorations 5 ft (1.53 m) below the expected elevation of a system to determine groundwater conditions (refer to NFGS-15705).

3.1.2.4 Special Ground Considerations. Give particular attention to the following conditions:

a) The possibility that the ground below a backfilled piping system may not be able to absorb runoff that has seeped into it.

b) Areas where ponding may occur, either along a sloping surface or in low flat areas.

c) The permeability of the ground below the system (refer below).

TABLE 3
Location Factors for Each Distribution System

Item	Determine the Following
Load centers........	Maximum demand load of system. (See criteria in Table 1 and ascertain requirements of all facilities.) Distance from generating plant. Basements or crawl spaces under buildings available for piping. Location of entry of system to load center structure. Location or need of meters for billing purposes. Future expansion.
Route...............	Existing piers, tunnels or trenches available for system. Aboveground obstructions, such as rivers, lakes, roads, railroads, structures, etc. Belowground obstructions, such as tunnels, trenches, piping, rock, storage tanks, etc. Location of expansion loops, joints and manholes. Master Plan. (See DM-1.)
Site................	For above and underground systems: Ground contours along route. For underground systems: Borings every 100 ft along route (See Par 3.1.2) - longer for larger projects. Absorption test (See Par 3.1.2.5) Resistivity test (See Par 3.1.2.7) Stability of soil (See Par 3.1.2.8) Water table survey made at time of highest levels if possible, or modify by judgment based on local data. Maximum, normal, and minimum groundwater levels. Frost level. Location of distribution line drainage and venting.
Coordination........	Installation of other related distribution systems and manholes. Interference with electric distribution lines and manholes. Interference with water supply and fire extinguishing systems. Interference with sanitary and storm sewers and manholes. Interface with communications systems. Interference with ground drainage lines, catch basins, and manholes. Interference with fuel distribution piping systems. Interface with other gas supplies such as argon, nitrogen and carbon dioxide used in industrial process work. Excavation and backfill. Landscaping.
Cooperation.........	Local rules and regulations (permits, tests, approvals, etc.).
Hazards.............	See DM-1 for criteria.
Unit costs..........	Excavation of soil and rock and of landfill. Piping material. Piping insulation or covering. Pipe conduit. Construction of manholes. Construction of expansion loops and field joints.
Local labor.........	Availability and costs.
Local material......	Availability and costs.

3.1.2.5 Permeability Tests. Perform field permeability tests as follows:

a) Space field permeability tests (percolation) along the line of a trench at intervals of approximately 100 ft (30.5 m). When available information indicates uniform subsurface conditions, longer intervals may be allowed for larger projects.

b) Dig holes approximately 1 ft^2 (.093 m^2) to a depth of 2 ft (620 mm) below the approximate bottom of a trench.

c) Fill each hole with water to the bottom elevation of the planned trench.

d) After the water has completely seeped away, immediately refill each hole with water to the same depth.

e) If it requires 20 minutes or less for the water to drop 2 in (51 mm), consider the soil dry; otherwise, consider it as saturated at times.

3.1.2.6 Test Results. Use test results as follows:

a) If the soil is saturated, no further tests are required. Class A underground conduit systems for wet soils must be used.

b) If the soil is dry, as defined above, permeability test holes shall be deepened an additional 3 ft (920 mm) to determine if the water table is within 5 ft (1.53 m) of the trench bottom (refer to NFGS-15705 for site classification criteria).

3.1.2.7 Soil Resistivity. Considerations for soil resistivity are as follows:

a) Take soil resistivity readings along the conduit line (in accordance with Table 3).

b) A cathodic protection system is required to protect metallic piping systems and manholes. This applies to all sites where soil resistivity is less than 30,000 ohms per cubic centimeter (ohm-cm), where stray direct currents can be detected underground, or where underground corrosion, due to local soil conditions, has been found to be severe.

3.1.2.8 Soil Stability. During the above survey, observe and note the soil stability. Refer to NAVFAC DM-7 series for criteria. Note areas of unstable soil on the site plans depicting the distribution route.

3.1.3 Site Classification. Base selection of the conduit system type on the underground water conditions at the project site as defined in NFGS-15705 for Class A, B, C, or D application corresponding to underground water conditions ranging from severe to mild, respectively. The Federal Agency Committee on Underground Heat Distribution Systems has reviewed and approved systems by suppliers. Each system is defined in the brochure approved by the Committee. No system may be installed without prior approval as given in the brochure. The letter of certification contained in the conduit system brochure stipulates the approved site classification. A system approved for higher classification shall be acceptable for use in lower classifications. For example, Class A is acceptable for Classes B, C, and D, etc. The project designer is responsible for accomplishing the following prior to project bidding:

a) Define site conditions for underground water classification (A, B, C, or D), soil corrosiveness, soil pH if less than 5.0, and potential soil load bearing problems.

b) Determine the general layout and essential characteristics of the system such as system media, maximum operating temperature and pressure, location and design of manholes, and branch runouts. The interface detail of the system at manhole walls shall be provided by the system supplier.

c) Design special elements of the system as required.

d) Calculate the maximum heat loss per lineal foot of the conduit in accordance with the procedures outlined in NFGS-15705.

3.1.4 Reinforced Thermosetting Resin Plastic (RTRP) Pipe. RTRP pipe is normally supplied under Military Specification MIL-P-28584 A, Pipe and Fittings, Glass Fiber Reinforced Plastic for Condensate Return Lines, when used for condensate systems. This pipe is suitable for service pressures up to 150 psig (1,034 kPa) and temperatures up to 200° F (93° C). Above 200° F the pressure rating drops off rapidly. At 250° F (121° C) the pressure rating is 125 psig (861.3 kPa) and drops to 45 psig (310.1 kPa) at 270° F (132° C). These ratings are for hot water. Live steam cannot be tolerated, although RTRP pipe may be used for vented gravity condensate lines as well as for pumped condensate lines. RTRP pipe is acceptable at Class B sites (refer to para. 3.1.3). It is recommended for Class A sites, as permitted in para. 2.1.2, due to its low cost and long service life. Procure and install RTRP condensate piping in accordance with NFGS-15705. Special care must be taken in the design of steam drip connections to protect the RTRP piping from live steam from failed traps. Insulate condensate piping only when a life-cycle cost analysis indicates a payback in energy savings, or where needed for personnel protection (manholes, for example).

3.2 Service and Loads. Determine from Section 2 the services, such as steam, high temperature water, hot water, chilled water, compressed air, fuel gas and others, required for each load center or building, the load demands for each service, and the capacity of a source or central plant for each service. Refer to Section 2 for fluid conditions inside service lines, for sizing pipes for these conditions, and for the required capacities.

3.2.1 Alternate Routes. Refer to Master Plan and consider system routing and size to accommodate future construction.

3.2.2 Pressure Drop. Determine the pressure drop per 100 ft (30.5 m) from the total allowable pressure drop and ultimate length of a line. Note the maximum flow between each load center and size the different pipeline sections accordingly.

3.2.3 Obstacles. From field survey, note all obstacles for each route.

3.2.4 Future Loads. Refer to Master Plan and consider system routing to accommodate future construction.

3.2.5 Distribution Circuits. Select a circuit which is economical, easy to operate, balance and control, and is suitable for a particular project terrain. Note that types easiest to balance and control are those where pressure and temperature differences are fairly constant between equipment supply and return branches.

3.2.6 Route Types. Run distribution piping through buildings, aboveground, or underground and below piers.

3.2.6.1 Through Buildings. Select the route considered technically and economically best justified; make full use of building piers, underpiling spaces, basements, crawl spaces, and attics, including connecting corridors between buildings, existing tunnels, and concrete trenches. However, high pressure fuel gas, steam, and HTW piping inside buildings should be routed to comply with federal and local fire and life safety codes. Gas piping shall comply with American National Standards Institute (ANSI) Standard ANSI B31.8, Gas Transmission and Distribution Piping Systems; B31.2, Fuel Gas Piping; and National Fire Protection Association (NFPA) Standard NFPA 54-84, National Fuel Gas Code. Steam, condensate, and compressed air lines shall comply with ANSI B31.1, Power Piping.

3.2.6.2 Exterior Steam Distribution. Use NFGS-02714, Exterior Steam Distribution, for all steam distribution piping on building exteriors, aboveground piping supports, piers (pedestals), and poles exposed to the weather, and for all steam piping on piers and under piers, in tunnels, and in manholes. Use CEGS-15709 for piping in trenches.

3.2.6.3 Aboveground Overhead Piping. Locate piping as low as 1 ft (305 mm) or as high as 22 ft (6.7 m) above the ground surface. A 16-ft (4.9 m) clearance is required for automobile and truck traffic, and a 22-ft (6.7 m) clearance for railroad cars.

3.2.6.4 Buried Piping. For buried piping routes, the following criteria apply:

a) Compressed Air and Gas Piping. Compressed air and gas piping generally require no insulation, but they should be shop coated, wrapped, tested, and handled in accordance with provisions of NFGS-15612, Gas Distribution Systems; NFGS-15411, Compressed Air Systems (Non-Breathing Air Type); and NFGS-09809, Protection of Buried Steel Piping and Steel Bulkhead Tie Rods. Provide for testing of coverings by electrical flow detectors (spark test).

b) Minimum Cover. Protect all buried piping and conduits by laying them under a minimum cover of 24 in (610 mm). However, buried piping under railroads, roads, streets, or highways shall be protected against possible external damage due to superimposed car or truck traffic or due to changes in ground contours. Pipes shall be below the frost line. Casings may be needed where there is no frost.

c) Other Hazards. When piping must be laid where it will be subjected to hazards such as earthquakes, washouts, floods, unstable soils, landslides, dredging of water bottoms, and other categorically similar conditions, protect it by increasing pipe wall thickness, constructing intermediate supports or anchors, using erosion prevention, covering pipes with concrete, adding seismic restraints for above-grade piping, or implementing other reasonable protection.

d) Manholes. Select manhole locations in accordance with NFGS-15705. Details of piping and design of manholes are the responsibility of the project designer. Manholes are required where vertical offsets in steam piping are required to conform to grading requirements. Manholes accommodate the required steam main drip traps and any block valves needed. Manholes are usually provided at all major branch line connections and at drip traps on compressed air lines.

e) Tunnels. Construct tunnels for underground routes with a walkway minimum height of 76 in (1.93 m) and clear width of 36 in (920 mm), with piping stacked vertically on one side, and with enlarged zones for crossovers and takeoffs. Label all pipes and conduit. Provide enough room to reach all flange bolts, to operate tools, and to operate or to replace any component. Run a drainage trench along one wall to a point of disposal, such as a storm sewer or a sump pit, with an automatic drainage pump driven by an electric motor or steam jet. Install all electrical systems in rigid metal conduit. Identify and separate by voltage class. Tunnels shall be well lighted and ventilated. Use moisture resistant electrical fixtures. Tunnels may be built of reinforced concrete, brick, or other suitable structural materials and shall be membrane waterproofed.

3.2.6.5 Condensate Return Cost. For criteria on condensate return costs, refer to NAVFAC DM-3 series.

3.2.6.6 Choice of Route. Except in congested and vulnerable areas, choose aboveground routes for heat distribution systems. Otherwise, adapt site conditions to comparative advantages of going above or underground as stated below:

Aboveground	Underground
Lower first cost	Less heat loss on hot lines 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	Less heat gain in chilled and condenser water piping

3.2.6.7 Piping Layouts. The project designer is responsible for determining location of expansion bends, loops and joints, anchors, takeoffs, isolation valves, and drip points. The project designer is also responsible for locating all manholes, takeoffs, isolation valves, and drip points. The system designer is responsible for the initial location of anchors, expansion bends, loops, and joints. The system designer is also responsible for the final location and the design of these features to fit actual field conditions. Plan and position piping layouts as follows:

a) Determine what lines between the same points should be parallel to each other (such as supply and return) or be separated (such as steam from chilled water). The minimum clearance between pipe conduits in the same trench shall be 6 in. (150 mm).

b) Determine locations of expansion bends or loops, anchors, takeoffs, and drip points. In non-pre-engineered/prefabricated heat distribution systems, the project designer is responsible for determining location of expansion bends, loops and joints; anchors; takeoffs; isolation valves; and drip points. In pre-engineered/prefabricated heat distribution systems, the project designer is responsible for locating all manholes, takeoffs, isolation valves and drip points. Initial location of anchors, expansion bends, loops and joints shall be by the system designer. Final location and design of these features shall be by the system supplier to fit actual field conditions.

c) Lay out piping on a scaled contour map of the site and on a profile drawing along the route, locating all obstructions and interferences, such as streams, roads, railroads, buried tunnels, concrete trenches, sewers, drainage piping, water piping, electrical conduits, and other service piping.

3.2.6.8 Underground. Use only approved and certified conduit systems for steam, condensate and HTW, and procure and install in accordance with the requirements of NFGS-15705. The Federal Agency Committee for Underground Heat Distribution Systems approves and certifies the various types of conduit systems, i.e., drainable and dryable (pressure testable), sectionalized, prefabricated (non-pressure testable), and poured-in-place granular insulation type conduit systems. Concrete shallow trench systems may be used only if the soil characteristics set forth in CEGS-15709 are met. In this case, design and specify the system in accordance with CEGS-15709.

3.3 Insulation. Insulation shall be evaluated for all piping systems with the potential for significant thermal losses. These include steam, condensate, HTW, MTW, LTW, and CHW piping. Use NFGS-15250, Insulation of Mechanical Systems, for CHW, LTW and special applications requiring insulation of fuel gas and compressed air piping systems. Use NFGS-15251 for above-grade steam, HTW, MTW, LTW, and condensate return piping systems. (Alternately, NFGS-15250 may also be used for these above-grade piping systems.) Aluminum jackets and organic felt shall be used as specified in NFGS-15250 and NFGS-15251. Use NFGS-15705 for underground heat distribution piping insulation. Insulation materials shall not contain asbestos.

3.4 Miscellaneous Criteria. Anchor or guy exterior distribution systems to withstand the wind velocity specified for design of structures (refer to NAVFAC DM-2 series, Structural Engineering).

Section 4. SPECIFIC PIPING DESIGN FACTORS

4.1 Fluid Characteristics. Refer to paras. 4.1.1 through 4.1.5 for fluid characteristics.

4.1.1 Steam. Refer to Keenan and Keyes, Thermodynamic Properties of Steam.

4.1.2 Condensate. Refer to the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Fundamentals Handbook and ASHRAE Systems Handbook for the economics of returning condensate.

4.1.3 High Temperature Water, Medium Temperature Water and Low Temperature Hot Water. Refer to ASHRAE Fundamentals Handbook and ASHRAE Systems Handbook.

4.1.4 Compressed Air. For data on compressed air, refer to NAVFAC DM-3.05, Compressed Air and Vacuum Systems.

4.1.5 Fuel Gas. Refer to ANSI B31.2.

4.2 Distribution System Piping.

4.2.1 Equivalent Lengths of Piping. To the straight lengths of pipe along a pipeline route, add equivalent lengths for valves and fittings as indicated in Table 4.

4.2.2 Sizing of Distribution Piping. Size distribution piping in accordance with paras. 4.2.2.1 and 4.2.2.2.

4.2.2.1 Steam Piping. Design considerations shall be as follows:

a) Steam Flow Charts. For pressures of 30 psig (206.7 KPa), 50 psig (344.5 kPa), 100 psig (689.4 kPa), and 150 psig (1033.5 kPa), see Figures 1 through 4. These charts show weight-rate pressure drop and velocities of saturated steam in Schedule 40 steel pipe. By selecting all pipe sizes on an optimum pressure drop, the total pressure drop of a pipeline may be estimated from an equivalent length, irrespective of pipe size. The charts are based on the rational flow formula (Darcy) shown below. For higher pressures, refer to Crocker and King, Piping Handbook.

b) Rational Flow Charts. The simplified rational flow formula (Darcy) is used for compressible fluids for all pressures:

EQUATION: $$P_{100} = W^2 \frac{(0.000336f)\ v}{d^5} = C_1 \times C_2 \times v \qquad (1)$$

WHERE:

P_{100} = pressure drop per 100 ft. of equivalent length of pipe (psi)

$C_1 = W^2 10^{-9}$ (for values, see Figure 5)

$C_2 = \dfrac{336000f}{d^5}$ (for values, see Table 5)

W =rate of flow, pounds per hour (pph) (.454 KGH)
f =friction factor
d =inside diameter of pipe (in)
v =specific volume of fluid ($ft.^3$ per lb) at average pressure

c) Velocities. (See Table 6.)

EQUATION:

$$V = \frac{3.06W}{d^2R} \quad (2)$$

WHERE:

V = velocity of flow (fpm)
R = density (pcf)

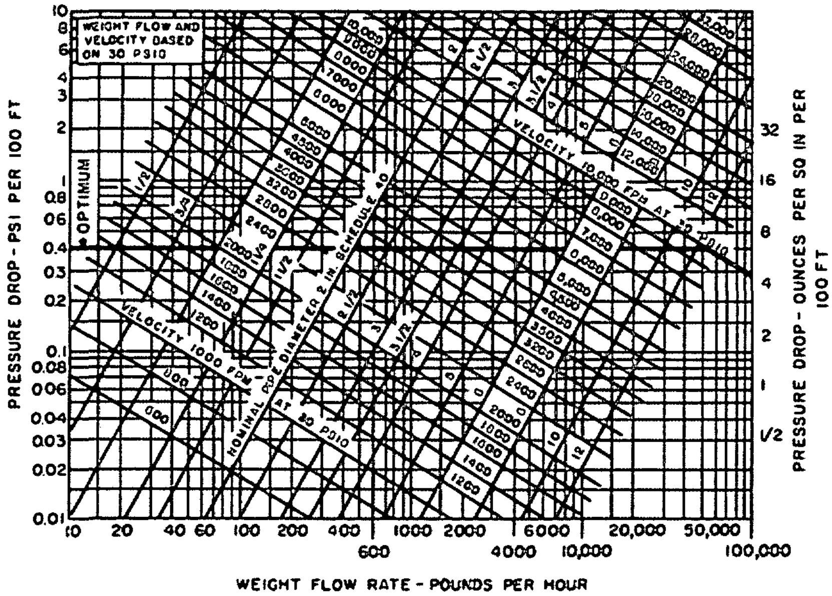
d) Steam Distribution Pressures. Steam pressure shall be governed by the highest pressure needed by the equipment served at the most remote location as well as by an economic analysis of the feasible systems, including pressure considerations. The advantages of a low pressure system (under 15 psig) (103.4 kPa) are low distribution loss, lower losses and less trouble from leakage, traps, and venting, simplified pressure reduction at buildings, standard steel fittings, and low maintenance. The advantages of high pressure distribution, over 50 psig (344.5 kPa), are smaller pipe sizes, availability of steam for purposes other than for heating, and more flexibility in velocities and pressure drops.

e) Selection of Valve Types. Install double-ported, pilot-operated valves for large capacities, especially for inlet pressures above 125 psig (861.3 kPa). Double-ported valves will not shut off completely on no-load demand; therefore, single-seated valves must be used for such services. Do not install reducing valves on the basis of pipe sizes because oversized valves do not give satisfactory service. Select valves to operate generally fully open, with ratings and reduction ratios as recommended by the manufacturer. Install a strainer and condensate drain ahead of the pressure reducing valve. Because the volume of steam increases rapidly as the pressure is reduced, a reducing valve with increased outlet or expanding nozzle is required when the reduction ratio is more than 15 to 1. Provide cutout valves to isolate the pressure reducing valve to permit maintenance. Where the resulting superheated steam temperature is objectionable to the process on the low pressure side or the temperature-use limit of the equipment has been exceeded, a desuperheater must be used to lower the steam temperature to that for saturation. A manual bypass is to be provided for emergency operation when the pressure reducing valve is out of service. A pressure gauge shall be provided on the low pressure side. Where steam requirements are relatively large, above approximately 3,000 pounds/hour (1364 kg/hr), and subject to seasonal variation, install two reducing valves in parallel, sized to pass 70 percent and 30 percent of maximum flow. During mild spring and fall weather, set the larger valve at a slightly reduced pressure so that it will remain closed as long as the smaller valve can supply the demand. During the remainder of the heating season, reverse the valve settings to keep the smaller one closed, except when the larger one is unable to supply the demand.

Table 4
Representative Equivalent Length in Pipe/Diameter Ratio (L/D) For Various Valves and Fittings[1]

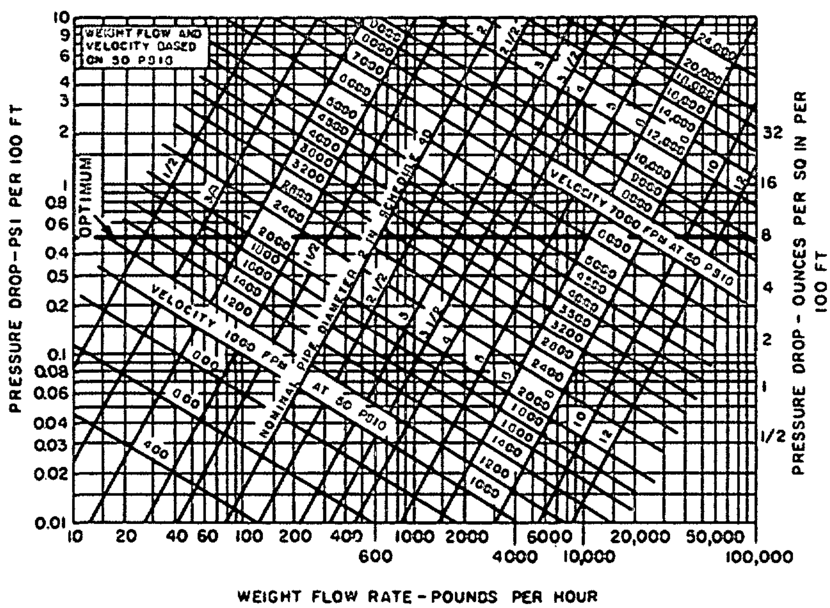
ITEM	DESCRIPTION OF PRODUCT		EQUIVALENT LENGTH IN PIPE LENGTH/DIAMETER RATIO (L/D)
Valves:			
Conventional globe	With no obstruction in flat, bevel or plug type seat.	Fully open	340
	With wing or pin guided disc.	Fully open	450
Y-pattern globe	With stem 60 degrees from run of pipe line.	Fully open	175
	With stem 45 degrees from run of pipe line.	Fully open	145
Conventional angle	With no obstruction in flat, bevel or plug type seat.	Fully open	145
	With wing or pin guided disc.	Fully open	200
Conventional wedge, disc, double disc, plug or gate.		Fully open	13
		Three-quarters open	35
		One-half open	160
		One-quarter open	900
Pulp stock gate		Fully open	17
		Three-quarters open	50
		One-half open	260
		One-quarter open	1,200
Conduit pipe line gate		Fully open	3[2]
Butterfly 6-inch and larger		Fully open	20
Conventional swing check		0.5[3]... Fully open	135
Clearway swing check		0.5[3]... Fully open	50
Globe lift check or stop-check		2.0[3]... Fully open	Same as conventional globe
Angle lift check or stop-check		2.0[3]... Fully open	Same as conventional angle
Foot valves	With strainer and poppet lift-type disc.	0.3[3]... Fully open	420
	With strainer and leather-hinged disc.	0.4[3]... Fully open	75
In-line-ball check	2.5 vertical and 0.25 horizontal	3...... Fully open	150
Straight-through cocks	Rectangular plug port area equal to 100% of pipe area.	Fully Open	18
Three-way cocks	Rectangular plug port area equal to 80 percent of pipe area (fully open).	Flow straight through	44
		Flow through branch	140
Fittings:			
90 degrees standard elbow			30
45 degrees standard elbow			16
90 degrees long radius elbow			20
90 degrees street elbow			50
45 degrees street elbow			26
Square corner elbow			57
Standard tee	With flow through run.		20
	With flow through branch.		60
Close pattern return bend			50

1/Legitimate for all flow conditions except in laminar flow range where Reynolds number is less than 1000.
2/Exact equivalent length is equal to the length between flange faces of welding ends.
3/Minimum calculated pressure drop in psi across valve to provide sufficient flow to lift disc fully.
Note: For additional data see DM-3.05.



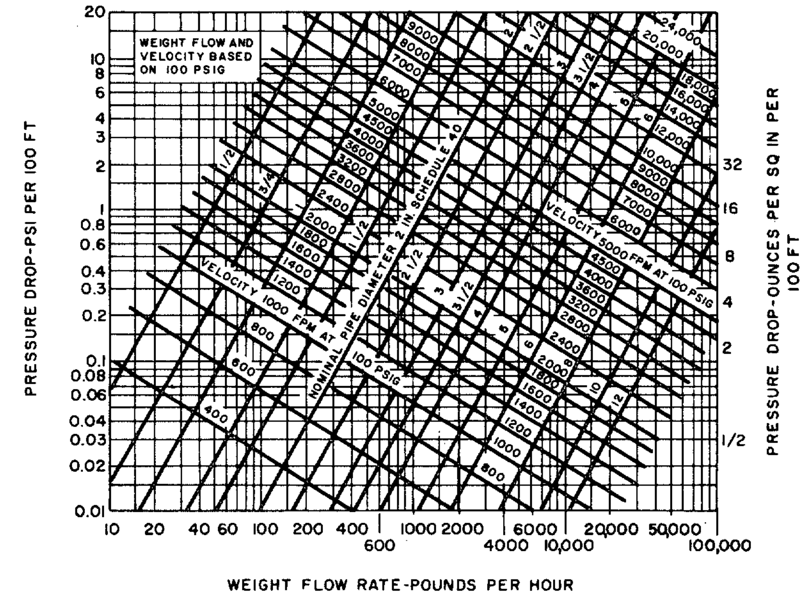
(MAY BE USED FOR STEAM PRESSURES FROM 23 TO 37 PSIG WITH AN ERROR NOT EXCEEDING 8 PERCENT) BASED ON MOODY FRICTION FACTOR WHERE FLOW OF CONDENSATE DOES NOT INHIBIT THE FLOW OF STEAM.

Figure 1
Chart for Weight-Flow Rate
and Velocity of Steam (30 psig) (206.7 kPa)



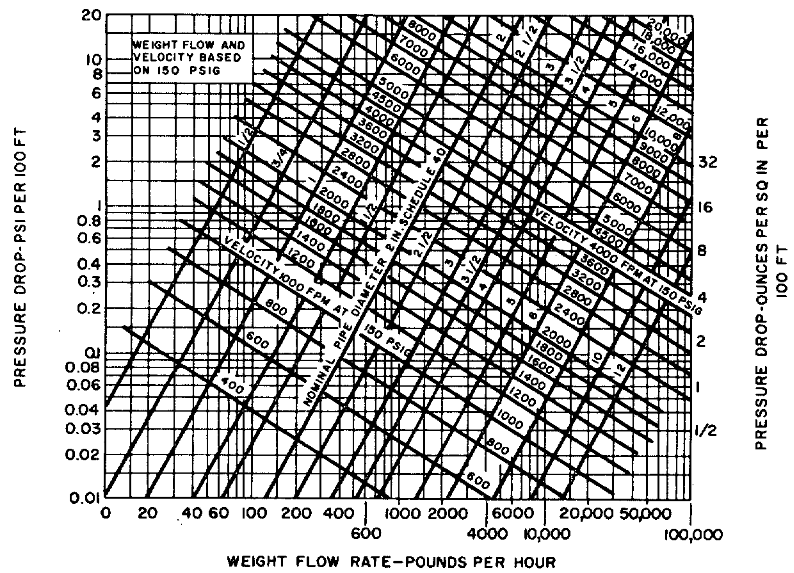
(MAY BE USED FOR STEAM PRESSURES FROM 40 TO 60 PSIG WITH AN ERROR NOT EXCEEDING 8 PERCENT) BASED ON MOODY FRICTION FACTOR WHERE FLOW OF CONDENSATE DOES NOT INHIBIT THE FLOW OF STEAM.

FIGURE 2
Chart for Weight-Flow Rate
and Velocity of Steam (50 psig) (344.5 kPa)



(MAY BE USED FOR STEAM PRESSURE FROM 85 TO 125 PSIG WITH AN ERROR NOT EXCEEDING 8 PERCENT) BASED ON MOODY FRICTION FACTOR WHERE FLOW OF CONDENSATE DOES NOT INHIBIT THE FLOW OF STEAM

Figure 3
Chart for Weight-Flow Rate
and Velocity of Steam (100 psig) (689.4 kPa)



(MAY BE USED FOR STEAM PRESSURES FROM 127 TO 180 PSIG WITH AN ERROR NOT EXCEEDING 8 PERCENT) BASED ON MOODY FRICTION FACTOR WHERE FLOW OF CONDENSATE DOES NOT INHIBIT THE FLOW OF STEAM.

FIGURE 4
Chart for Weight-Flow Rate
and Velocity of Steam (150 psig) (1033.5 kPa)

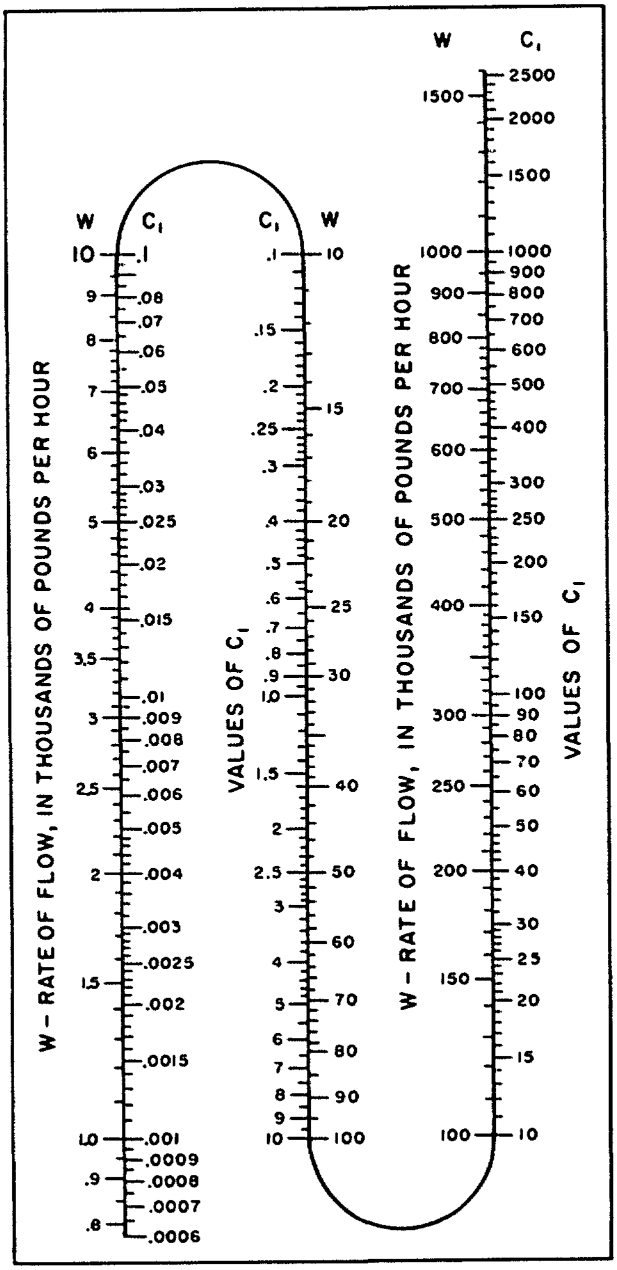


FIGURE 5
Values of C_1, Flow Factor in Equation 1

TABLE 5
Values of C_2, Flow Factor in Equation 1

Nominal pipe size (in)	Schedule no.	Value of C_2
1/8	40 s	7 920 000.
	80 x	26 200 000.
1/4	40 s	1 590 000.
	80 x	4 290 000.
3/8	40 s	319 000.
	80 x	718 000.
1/2	40 s	93 500.
	80 x	186 100.
	160	4 300 000.
	xx	11 180 000.
3/4	40 s	21 200.
	80 x	36 900.
	160	100 100.
	xx	627 000.
1	40 s	5 950.
	80 x	9 640.
	160	22 500.
	xx	114 100.
1-1/4	40 s	1 408.
	80 x	2 110.
	160	3 490.
	xx	13 640.
1-1/2	40 s	627.
	80 x	904.
	160	1 656.
	xx	4 630.
2	40 s	169.
	80 x	236.
	160	488.
	xx	899.
2-1/2	40 s	66.7
	80 x	91.8
	160	146.3
	xx	380.0
3	40 s	21.4
	80 x	28.7
	160	48.3
	xx	96.6
3-1/2	40 s	10.0
	80 x	37.7
4	40 s	5.17
	80 x	6.75
	120	8.94
	160	11.80
	xx	18.59
5	40 s	1.59
	80 x	2.04
	120	2.69
	160	3.59
	xx	4.93
6	40 s	0.610
	80 x	0.798
	120	1.015
	160	1.376
	xx	1.861
8	20	0.133
	30	0.135
	40 s	0.146
	60	0.163
	80 x	0.185
	100	0.211
	120	0.252
	140	0.289
	xx	0.317
	160	0.333
10	20	0.039 7
	30	0.042 1
	40 s	0.044 7
	60 x	0.051 4
	80	0.056 9
	100	0.066 1
	120	0.075 3
	140	0.090 5
	160	0.105 2
12	20	0.015 7
	30	0.016 8
	s	0.017 5
	40	0.018 0
	x	0.019 5
	60	0.020 6
	80	0.023 1
	100	0.026 7
	120	0.031 0
	140	0.035 0
	160	0.042 3
14	10	0.009 49
	20	0.009 96
	30 s	0.010 46
	40	0.010 99
	x	0.011 55
	60	0.012 44
	80	0.014 16
	100	0.016 57
	120	0.018 98
	140	0.021 8
	160	0.025 2
16	10	0.004 63
	20	0.004 21
	30 s	0.005 04
	40 x	0.005 49
	60	0.006 12
	80	0.007 00
	100	0.008 04
	120	0.009 26
	140	0.010 99
	160	0.012 44
18	10	0.002 47
	20	0.002 56
	s	0.002 66
	30	0.002 76
	x	0.002 87
	40	0.002 98
	60	0.003 35
	80	0.003 76
	100	0.004 35
	120	0.005 04
	140	0.005 73
	160	0.006 69
20	10	0.001 41
	20 s	0.001 50
	30 x	0.001 61
	40	0.001 69
	60	0.001 91
	80	0.002 17
	100	0.002 51
	120	0.002 87
	140	0.003 35
	160	0.003 85
24	10	0.000 534
	20 s	0.000 565
	x	0.000 597
	30	0.000 614
	40	0.000 651
	60	0.000 741
	80	0.000 835
	100	0.000 972
	120	0.001 119
	140	0.001 274
	160	0.001 478

NOTE.--The letters s, x, and xx in the columns of Schedule no. indicate Standard, Extra Strong, and Double Extra Strong pipe respectively.

TABLE 6
Reasonable Velocities for Flow of Steam in Pipes

Condition of Steam	Pressure (psig)	Service	Reasonable Velocity[1/] (fpm)
Saturated....	Vacuum.......	Turbine exhaust....	Up to 18,000
	0 to 25......	Heating............	4,000 to 6,000
	25 and up....	Steam distribution.	6,000 to 10,000
	125 and up...	Underground steam distribution......	Up to 20,000
Superheated..	200 and up..	Boiler and turbine leads............	7,000 to 20,000

[1/]Velocities should be below those which would produce excessive noise or erosion.

f) Safety Valves. One or more relief or safety valves must be provided on the low pressure side of each reducing valve in case the piping and equipment on the low pressure side do not meet the requirements of the full initial pressure. The combined discharge capacity of the relief valves shall be such that the pressure rating of the lower pressure piping and equipment will not be exceeded. For special conditions, refer to ANSI B31.1 and ASHRAE Systems Handbook.

g) Takeoffs from Mains. Takeoffs from mains to buildings shall be located at the top of and at fixed points of the mains, at or near anchor points. When a branch is short, valves at each takeoff are unnecessary. When the branch is of considerable length or where several buildings are served, takeoffs shall have valves. A 45° takeoff is preferred; 90° takeoffs are acceptable. Branch line slope of 1/2 in (12.6 mm) shall be used for lines less than 10 ft (3.05 m) in length and should be 1/2 in per 10 ft (3.05 m) on branch lines longer than 10 ft.

4.2.2.2 Condensate Returns. Condensate returns are preferred if owning and operating costs of such a system are less than that of using and treating raw water for makeup. Factors favoring condensate return are: high area concentration of steam usage, restriction on condensate disposal, high raw water treatment costs, water treatment space unavailable, high cost of raw water, and high cost of fuel for feedwater heating. Design considerations shall be as follows:

a) Return Piping. Size condensate trap piping to conform with 30 to 150 lbs/in^2 (206.7 to 1,033.5 kPa) steam piping in accordance with Tables 7 and 8 and interpolate these for other pressures.

b) Discharge Piping. Size discharge piping from condensate and heating pumps in accordance with pump capacities, which may be between one to three times the capacity of steam system branch which they serve, depending on whether continuously or intermittently operated.

c) Common Pump Discharge Mains. Size common pump discharge mains to serve the sum of their capacities. Use the Hydraulic Institute Pipe Friction Manual for steel pump discharge pipe sizing of new clean steel pipe, 6 ft per second (fps) (1.83 m/s) maximum velocity, and a correction factor of 1.85 to provide for increased pressure drops when the pipe becomes dirty and rough with age. Friction plus static heads shall not exceed the pump characteristics of standard pump and receiver units.

4.2.2.3 HTW Piping. High temperature water piping shall be as follows:

a) Sizing Piping. Use pipe friction charts in ASHRAE Fundamentals Handbook. These charts are based on the rational flow formula using clean pipe. A reasonable average velocity is approximately 5 fps (1.53 m/s). The minimum allowable velocity is 2 fps (.61 m/s).

b) Venting and Draining. For methods of venting high points of distribution lines, refer to NAVFAC DM-3.03, Heating, Ventilating, Air Conditioning, and Dehumidifying Systems. Piping must have drainage means at low points.

TABLE 7
Return Pipe Capacities for 30 psig (206.7 kPa) Steam Systems[1]
(Capacity Expressed in lbs/hr)

	Drop in pressure (psi per 100 ft in length)				
Pipe size (in)	1/8	1/4	1/2	3/4	1
3/4	115	170	245	308	365
1	230	340	490	615	730
1-1/4	485	710	1,025	1,290	1,530
1-1/2	790	1,160	1,670	2,100	2,500
2	1,580	2,360	3,400	4,300	5,050
2-1/2	2,650	3,900	5,600	7,100	8,400
3	4,850	7,100	10,300	12,900	15,300
3-1/2	7,200	10,600	15,300	19,200	22,800
4	10,200	15,000	21,600	27,000	32,300
5	19,000	27,800	40,300	55,500	60,000
6	31,000	45,500	65,500	83,000	98,000

The above table is based on steam at pressure of 0 to 4 psig.

TABLE 8
Return Pipe Capacities for 150 psig (1,033.5 kPa) Steam Systems[1]
(Capacity Expressed in lbs/hr)

Pipe size (in)	Drop in pressure (psi per 100 ft in length)					
	1/8	1/4	1/2	3/4	1	2
3/4	156	232	360	465	560	890
1	313	462	690	910	1,120	1,780
1-1/4	650	960	1,500	1,950	2,330	3,700
1-1/2	1,070	1,580	2,460	3,160	3,800	6,100
2	2,160	3,300	4,950	6,400	7,700	12,300
2-1/2	3,600	5,350	8,200	10,700	12,800	20,400
3	6,500	9,600	15,000	19,500	23,300	37,200
3-1/2	9,600	14,400	22,300	28,700	34,500	55,000
4	13,700	20,500	31,600	40,500	49,200	78,500
5	25,600	38,100	58,500	76,000	91,500	146,000
6	42,000	62,500	96,000	125,000	150,000	238,000

[1]The above table is based on steam at pressure of 1 to 20 psig.

4.2.2.4 Chilled Water Piping. Use the standards of the Hydraulic Institute, Pipe Friction Manual for sizing new clean pipe, unless water is renewed annually, in which case a correction factor of 1.41 for pressure drop is also to be used. For recommended velocities, refer to NAVFAC DM-3 series.

4.2.2.5 Condenser Water Piping. Use the standards of the Hydraulic Institute Pipe Friction Manual for pipe sizing, multiplying the pressure drop by a factor of 1.85 to correct for the increase of pipe roughness with age. For recommended velocities, refer to NAVFAC DM-3 series. No correction faction is required for RTRP pipe.

4.2.2.6 Fuel Gas Piping. Apply criteria in NAVFAC DM-3.01, Plumbing Systems, for sizing pipe inside buildings. Use Figure 6 for low volume flow rates and Figure 7 for high volume flow rates in sizing distribution piping. Using these figures will simplify design of piping by indicating required diameter, maximum rate of flow, permissible pressure drop, initial pressure, or final pressure when the rest of these values are known. These charts are based on the Weymouth formula for rate of flow in cubic ft of gas per hour. The chart is based upon the following conditions: gas at 60° F (15.5° C) and specific gravity of 0.60, with air = 1.0.. Exterior distribution piping usually stops 5 ft (1.53 m) outside of buildings.

4.2.2.7 Compressed Air. For criteria on distribution piping, refer to NAVFAC DM-3.05.

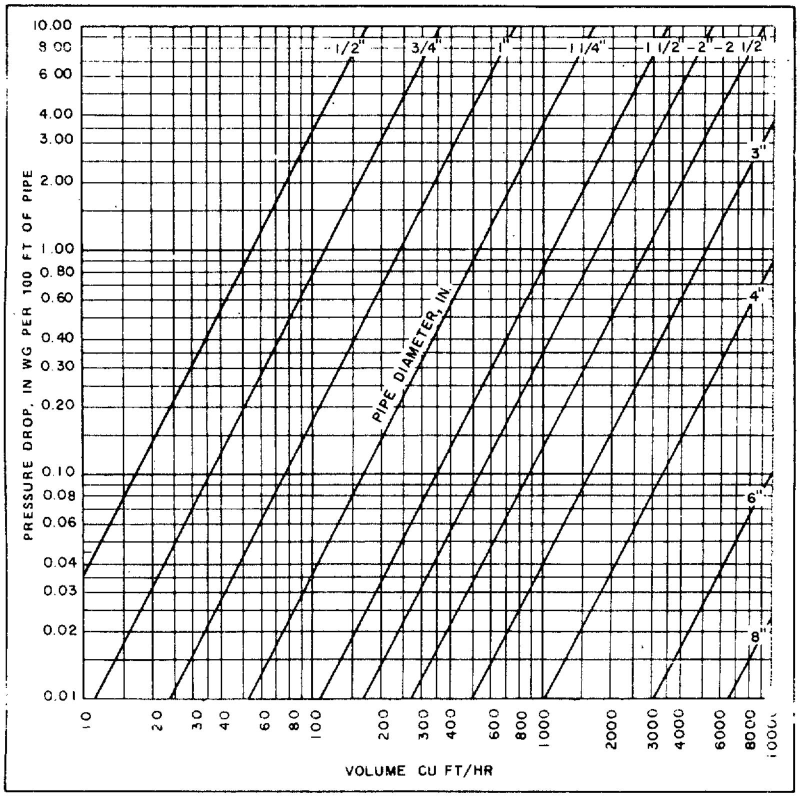


FIGURE 6
Low Volume Flow Rate Fuel Gas Chart (10 to 10,000 CU FT/HR)
(.283 to 283 m^3/hr)

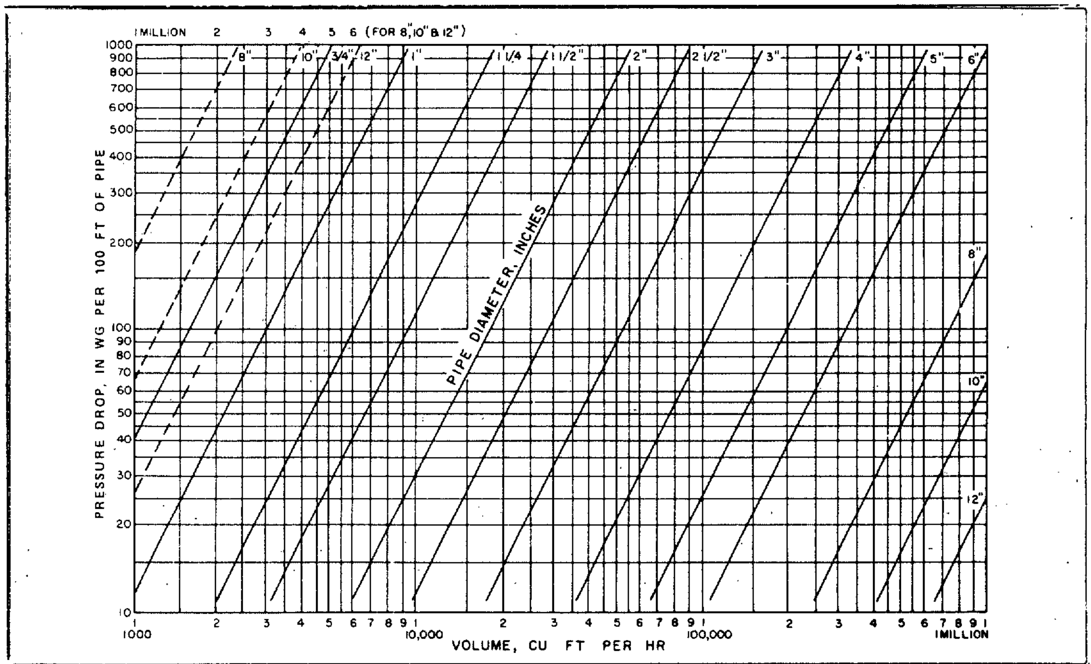


FIGURE 7
High Volume Flow Rate Fuel Gas Chart (1,000 to 1 million CU FT/HR)
(28.3 to 28,300 m^3/hr)

4.2.3 Piping Specifications and Codes. Piping specifications and codes are described in paragraphs 4.2.3.1 through 4.2.3.4.

4.2.3.1 Steam Supply and Condensate Return. Piping shall conform to ANSI B31.1, except for underground prefabricated or pre-engineered type systems, in which case the entire system shall conform to NFGS-15705. If a plastic pipe condensate return system is used, it also shall conform to NFGS-15705.

4.2.3.2 High Temperature Water, Medium Temperature Water, and Low Temperature Hot Water. Piping specifications and codes shall be as follows, except for underground prefabricated or pre-engineered types, in which case the entire system shall conform to NFGS-15705:

a) Piping. HTW metallic piping (450° F maximum) (232° C) and medium temperature water metallic piping shall conform to ANSI B31.1.

b) Joints. Use welded joints throughout. Threaded joints are not permitted. Hold flanged joints to a minimum and use ferrous alloy gaskets in such joints. Avoid the use of copper and brass pipe.

c) Valves. All valves shall have cast steel bodies with stainless steel trim (no bronze trim). All valves shall be capable of being repacked under operating pressures. Use gate valves only as shutoff or isolation valves.

4.2.3.3 Fuel Gas and Compressed Air. Piping shall conform to ANSI B31.1; ANSI B31.2; and ANSI B31.8. Provide excess-flow (earthquake) shutoff valves in gas supply piping outside of each building served in earthquake zones I and II. In addition, flexible connections shall be provided. Gas piping and appurtenances from point of connection with existing system to a point approximately 5 ft (1.53 m) from the building shall conform to NFGS-15612.

4.2.3.4 Chilled and Condenser Water. Use Schedule 40 steel pipe in 10-in (254 mm) sizes and smaller, and use 1/2-in (127 mm) wall thickness steel pipe for 12-in (305 mm) size and larger. RTRP pipe and PVC pipe are also acceptable. RTRP pipe and PVC pipe are available in 2-in through 12-in (51 mm - 305 mm) pipe sizes.

4.2.4 Thermal Expansion of Steel and Copper Pipe. Pipe expands with temperature increases, such as between installation and operating temperatures, as indicated in Table 9. Provisions must be made for the control of expansion in any piping system where thermal expansion is a factor. Wherever possible, provide for expansion of pipes by changes in direction of pipe runs.

4.2.4.1 Branch Lines. Where practicable, branch line piping should be designed to provide for expansion inside buildings. Expansion control of branch lines should be designed so as to have no affect on mains.

TABLE 9
Pipe Expansion in Inches Per 100 ft (30.5 m) of Length for Temperature Shown

Change in Temperature (degrees F)	Material	
	Steel	Copper
0	0	0
10	0.075	0.111
20	0.149	0.222
30	0.224	0.333
40	0.299	0.444
50	0.374	0.556
60	0.449	0.668
70	0.525	0.780
80	0.601	0.893
90	0.678	1.006
100	0.755	1.119
110	0.831	1.233
120	0.909	1.346
130	0.987	1.460
140	1.066	1.575
150	1.145	1.690
160	1.224	1.805
170	1.304	1.919
180	1.384	2.035
190	1.464	2.152
200	1.545	2.268
210	1.626	2.384
220	1.708	2.501
230	1.791	2.618
240	1.872	2.736
250	1.955	2.854
260	2.038	2.971
270	2.132	3.089
280	2.207	3.208
290	2.291	3.327
300	2.376	3.446
310	2.460	3.565
320	2.547	3.685
330	2.632	3.805
340	2.718	3.926
350	2.805	4.050
360	2.892	4.167
370	2.980	4.289
380	3.069	4.411
390	3.156	4.532
400	3.245	4.653
410	3.334	4.777
420	3.423	4.899
430	3.513	5.023
440	3.603	5.145
450	3.695	5.269
460	3.785	5.394
470	3.874	5.519
480	3.962	5.643
490	4.055	5.767
500	4.151	5.892
520	4.342	6.144
540	4.525	6.396
560	4.715	6.650
580	4.903	6.905
600	5.096	7.160
620	5.291	7.417
640	5.486	7.677
660	5.583	7.938
680	5.882	8.197
700	6.083	8.460
720	6.284	8.722
740	6.488	8.988
760	6.692	9.252
780	6.899	9.519
800	7.102	9.783
820	7.318	10.056
840	7.529	10.327
860	7.741	10.598
880	7.956	10.872
900	8.172	11.144
920	8.389	11.420
940	8.608	11.696
960	8.830	11.973
980	9.052	12.253
1,000	9.275	12.532
1,100	10.042	13.950
1,200	11.598	15.397

4.2.4.2 Expansion Bends. Except for RTRP pipe, bends are to be factory fabricated as follows:

a) Loop Sections. Loops may be furnished in sections to facilitate delivery and handling.

b) Anchors. A reasonable distance between anchors for expansion loops is 200 ft (61 m) for a 125-psig (861.3 kPa) steam system. Expansion is usually kept at about 6 in (150 mm) between anchors.

c) Cold Springing. Cold springing may be used in installations, but no design stress relief shall be allowed for it. For credit permitted in thrust and moments, refer to ANSI B31.1.

4.2.4.3 Expansion Joints. Install expansion joints only where space restrictions prevent the use of other means. When necessary to use, expansion joints shall be in an accessible location and shall be one of the following types:

a) Mechanical Slip Joint. An externally guided joint designed for repacking under operating pressures. Maximum traverse of piping in expansion joints is to be held under 8 in (203 mm).

b) Bellows Type Joint. These joints on steel pipe shall be used for thermal expansion with stainless steel bellows, guided and installed according to manufacturer's instructions. Bellows or corrugations for absorbing vibrations or mechanical movements at ambient temperatures shall be made of copper or other materials suitable for the job conditions. A maximum travel of 4 in (102 mm) shall be allowed for this type. RTRP expansion joints may be polytetrafluoroethylene bellows type.

c) Flexible Ball Joints. These joints shall be installed according to manufacturer's instructions.

4.2.4.4 Flexibility Analysis. Refer to Section 6 of ANSI B31.1 for expansion and flexibility criteria and allowable stresses and reactions.

4.2.4.5 Stress Analysis. For methods of analyzing stresses in piping systems, use piping handbooks and publications of pipe and pipe fitting manufactures. These manufacturers also supply calculation forms and charts. Keep calculated pipe stresses under those allowed by ANSI B31.1.

4.2.5 Insulation of Piping Systems. Insulation design for underground heat distribution piping shall conform to NFGS-15705. Applicable sections of NFGS-15250 shall be used for other systems.

4.2.5.1 Insulation Thickness. Insulation thicknesses indicated in NFGS-15250 and NFGS-15251 are suitable for most geographic locations. However, in locations where extreme annual temperatures occur, the project designer shall evaluate different thicknesses of insulation. Final selection shall be based on an economic analysis in accordance with paragraph 2.2.5.

4.2.5.2 Jackets. Insulation jackets in waterfront or other locations subject to flooding shall be designed to drain; they shall not be watertight.

4.2.6 Drainage Provisions. Drainage provisions must conform to requirements listed in para. 4.2.6.1.

4.2.6.1 Pitch. The surrounding terrain and piping application will both affect the pitch of piping as follows:

a) Horizontal Piping. Pitch horizontal steam piping down at a minimum of 2-1/2 in (64 mm) per 100 ft (30.5 m) of length in the direction of steam flow.

b) Underground Piping. Pitch horizontal piping down toward drain points (unless otherwise noted) a minimum of 2-1/2 in per 100 ft. Where the ground surface slopes in the opposite direction to steam piping, step up underground piping in vertical risers at drip points in manholes and pitch them down to the next drip point. Use this method for all very long horizontal runs, aboveground or below ground, to keep piping within a reasonable range of elevations, with reference to the ground surface.

c) Counter-Flow Conditions. Where counter-flow of condensate within the steam pipe may occur in a portion of a pipeline because the stepped construction cannot be built or because of steam flow reversal in a loop system, pitch that portion up in the direction of steam flow a minimum of 6 in (152 mm) per 100 ft and increase pipe diameter by one standard pipe size.

d) Compressed Air and Fuel Gas Lines. Pitch compressed air and gas piping as for steam piping (refer to item a) above).

e) Pumped Water Pipe. Pitch pumped water pipes (condensate, HTW, MTW, LTW, CHW, or condenser water) up or down in direction of flow at a minimum slope of 2-1/2 in per 100-ft length. Place drain valves at all low points and vents at high points.

4.2.6.2 Drips and Vents. Drips and vents shall be as follows:

a) Drip Legs. Provide drip legs to collect condensate from steam piping and compressed air piping for removal by automatic moisture traps or by manual drain valves for compressed air piping when practicable. Drip legs shall be at low points, at the bottom of all risers, at intervals of approximately 200 - 300 ft (61 - 91.5 m) for horizontally pitched pipe where a trap is accessible, and not over 500 ft (152.5 m) for buried underground pipe systems. On gas piping, drip legs are not usually required where dry gas is provided. Where there is moisture in the gas, drip legs and sediment traps shall be provided in accordance with NFPA 54-84. Automatic traps are not utilized.

b) Water Piping. Vent piping, especially high-temperature water piping, at distribution piping high points.

c) Fuel Gas Piping. Provide capped dirt traps in vertical risers upstream of gas-burning devices.

4.2.6.3 Condensate Systems. Condensate systems shall be as follows:

a) Furnish a complete system of drip traps and piping to drain all steam piping of condensate from drip legs. Drip piping to traps shall be the same weight and material as the drained piping. Drip traps must conform to the material and performance requirements of Federal Specification WW-T-696D(1), Traps, Steam and Air.

b) Preferably, a condensate line from a trap shall be run separately to a gravity condensate return main or to a nearby flash tank (Refer to ASHRAE Systems Handbook for flash tank details and specific trap applications. Also, refer to Naval Civil Engineering Laboratory UG-0005.). However, a trap may be discharged through a check valve into the pumped condensate line if pressure in the trap discharge line exceeds the back pressure in the pumped condensate line during standby time of an intermittently operated pump. If the pumped condensate line is RTRP pipe, a condensate cooling device, similar to that shown in Figure 8, shall be installed to limit temperature of the condensate entering the line to less than 250° F (121° C).

c) Traps shall be selected using a safety load factor no greater than 2. The condensate load shall be indicated on design drawings and may be determined for aboveground lines by using Table 10. The condensate load for underground distribution lines is determined from maximum heat loss as indicated by the design and in NFGS-15705. With the tight safety load factor for sizing traps, an alternate method of expelling gasses during warmup is required. To this end, all strainers shall have blowdown valves which will also be used for controlled warmup.

d) Pitch discharge piping down a minimum of 3 in (76 mm) per 100 ft (30.5 m) to the collection tank. This applies where a condensate pump set or reliance upon a gravity return is used. An exception to this "rule-of-thumb" exists when there is sufficient pressure in a steam line to overcome its friction and static head, whether the line is level or pitched up. Trap-discharge line shall not be RTRP pipe nor shall the trap discharge connect to an RTRP pipe by direct connection. Connections to pumped condensate lines of RTRP pipe shall be through a condensate cooling device as depicted in Figure 8. This system provides a cooling tank and difuser, plus a temperature of condensate returned to a pumped RTRP condensate line to less than 250° F (121° C).

e) If it is not justifiable to return drips to a condensate system, they may be drained as waste to a sewer. If the temperature exceeds sewer limitations, condensate must be cooled in a sump or by other means. Disposal of condensate from steam systems along the waterfront or under piers warrants special consideration and shall be determined on a case-by-case basis.

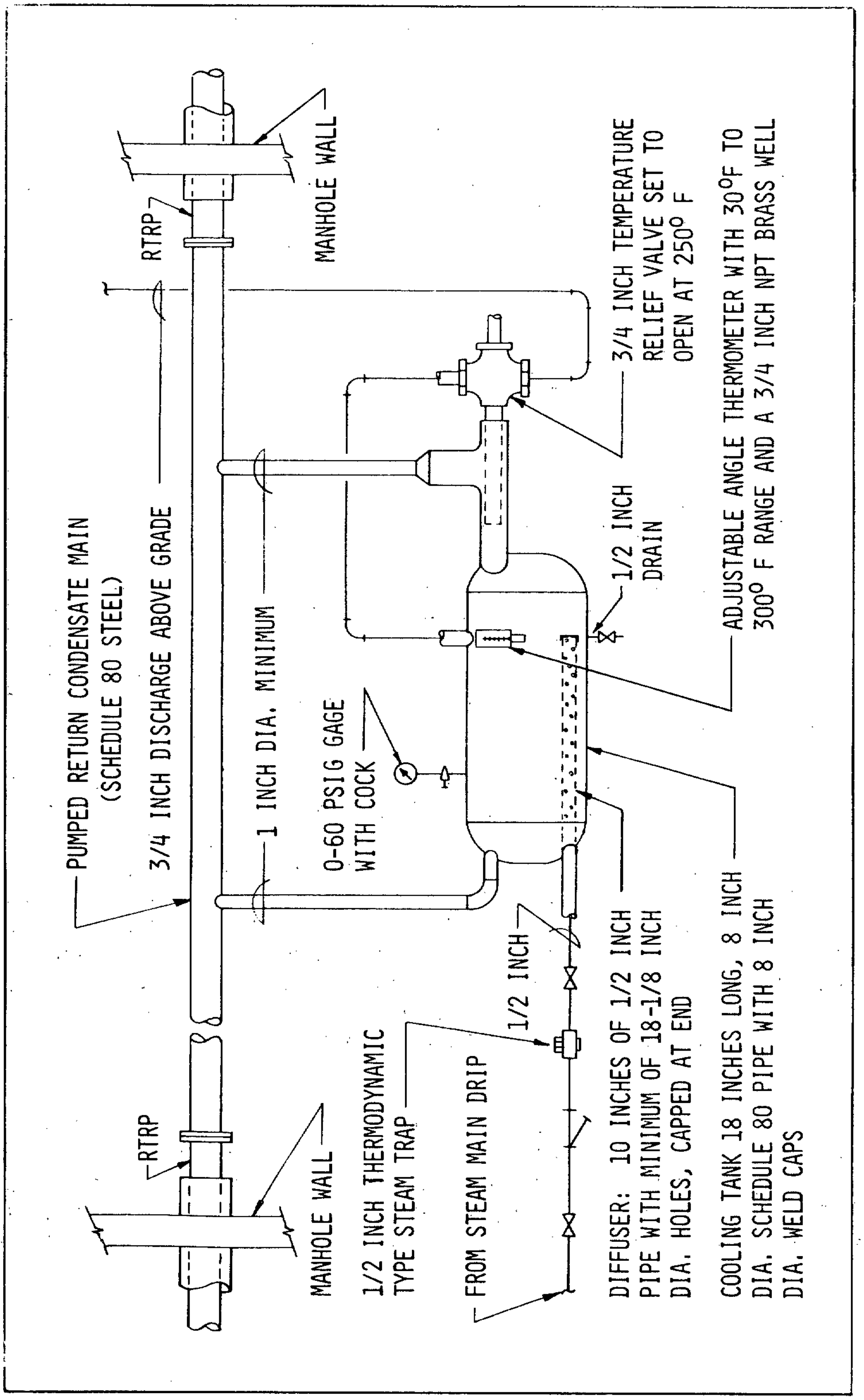


FIGURE 8

Protective Arrangement for RTRP Pipe

TABLE 10
Condensate Loads from Aboveground Heat Distribution Piping
(Pounds Per Hour Per 100 Linear Feet)

Steam Pressure (psig)	Steam Line Size (inches, diameter) 2	4	6	8	10	12
10	6	12	16	20	24	30
30	10	18	25	32	40	46
60	13	22	32	41	51	58
125	17	30	44	55	68	80
300	25	46	64	83	103	122
600	37	68	95	124	154	182

4.2.7 Pipe Anchors. Anchors shall comply with the criteria in paras. 4.2.7.1 through 4.2.7.5.

4.2.7.1 Location. Locate anchors for non-pre-engineered/prefabricated systems at takeoffs from mains and other necessary points to contain pipeline expansion. If possible, anchors are to be located in buildings, piers, tunnels, and manholes with suitable access.

4.2.7.2 Specification. Design and locate anchors in accordance with ANSI B31, Codes for Pressure Piping.

4.2.7.3 Strength. Design anchors to withstand expansion reactions. With expansion joints, the additional end reactions due to internal fluid pressure shall be considered and add end reactions due to spring rate of the joint.

4.2.7.4 Guying. Anchors for elevated aboveground systems shall consist of wire rope guys running from embedded concrete deadmen to pipe saddles welded to the pipe and secured to the vertical support(s). Guy in both directions. Guys may be located on the diagonal to also serve as sway bracing.

4.2.7.5 Embedding. In underground concrete tunnels, the ends of structural steel shapes anchoring a pipe may be embedded in the tunnel walls or floors.

4.2.8 Supports. Pipe supports shall conform to ANSI B31.

4.2.8.1 Low Elevations. For aboveground systems at low elevations, defined as lower than 5 ft (1.53 m) above grade or the working surface, use and space concrete pedestals, steel frames, or treated wood frames as required, depending on pipe sizes.

4.2.8.2 High Elevations. At higher elevations aboveground, support pipelines on wood, steel pipe, H-section steel, reinforced concrete, prestressed concrete poles with crossarms, or steel frameworks fitted with rollers and insulation saddles (see Figure 9). Details of design will vary depending on site conditions.

4.2.8.3 Long Spans. When long spans are necessary, cable-suspension or catenary systems may be used.

4.2.8.4 Underground Conduits. Supports for underground conduits shall be approved types of manufacturers' standard designs.

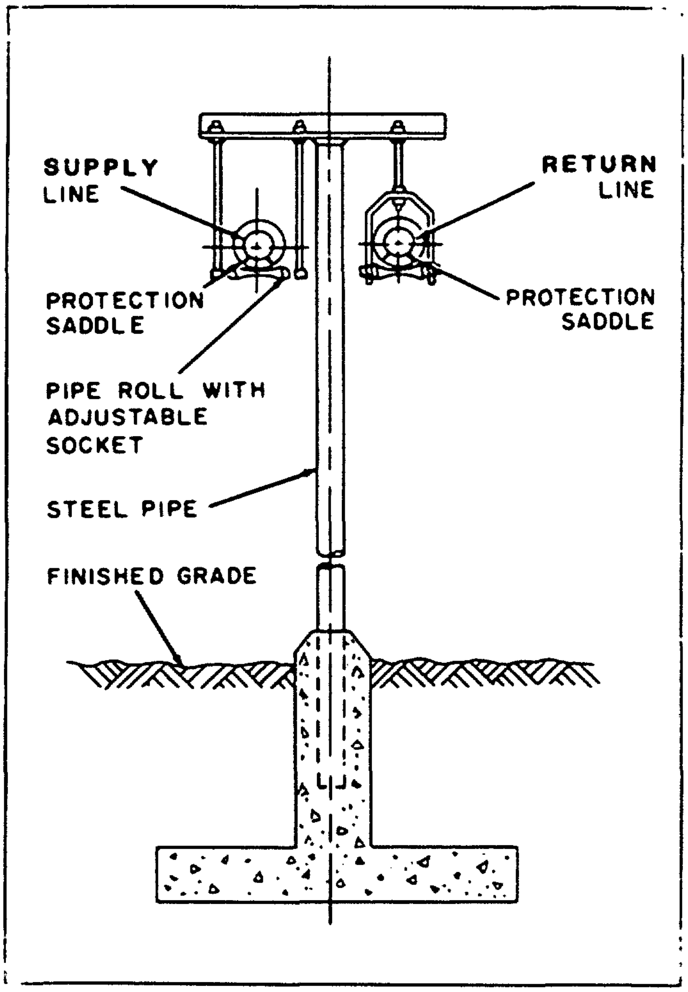


FIGURE 9
Typical Aboveground Pipe Supports

REFERENCES

American National Standards Institute Standards (ANSI), 1430 Broadway, New York, NY 10018.

ANSI B31	Codes for Pressure Piping
ANSI B31.1	Power Piping
ANSI B31.2	Fuel Gas Piping
ANSI B31.8	Gas Transmission and Distribution Piping Systems

American Society of Heating and Air Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE., Atlanta, GA 30329.

ASHRAE	Fundamentals Handbook
ASHRAE	Systems Handbook

Corps of Engineers Guide Specification, available from the United States Army Corp of Engineers, Waterways Experiment Station, Attn: Publications and Distribution Service Branch, Post Office Box 631, Vicksburg, MS 39180.

CEGS-15709	Heat Distribution Systems Outside of Buildings Concrete Shallow Trench Systems

Criteria for Underground Heat Distribution Systems, Building Research Board Technical Report No. 66, 1975, 2101 Constitution Avenue, Washington, DC 20418.

Federal Specifications, available from the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120; telephone (Autovon DOD only) 442-3321; Commercial: (215) 697-3321.

WW-T-696D(1)	Traps, Steam and Air

Military Specifications, available to all parties, free of charge, from the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120; telephone: Autovon (DOD only) 442-3321; Commercial: (215) 697-3321.

MIL-P-28584 A	Pipe and Fittings, Glass Fiber Reinforced Plastic for Condensate Return Lines

National Fire Protection Association Standard (NFPA), Batterymarch Park, Quincy Park, MA 02269.

NFPA 54-84	National Fuel Gas Code

NAVFACENGCOM Design Manuals and P-Publications Department of Defense activities may obtain copies of Design Manuals and P-Publications from the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120. Department of Defense activities must use the Military Standard Requisitioning and Issue Procedure (MILSTRIP), using the stock control number obtained from NAVSUP Publication 2002.

Other Government Agencies and commercial organizations may procure Design Manuals and P-Publications from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

DM-1 series	Architecture
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DM-3.01	Plumbing Systems
DM-3.03	Heating, Ventilating, Air Conditioning and Dehumidifying Systems
DM-3.05	Compressed Air and Vacuum Systems
DM-3.06	Central Heating Plants
DM-7 series	Soils and Foundations
P-272 (Part I)	Definitive Designs for Naval Shore Establishment
P-442	Economic Analysis Handbook

NAVFAC Guide Specifications are available to all parties, free of charge, from the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120, Telephone: Autovon (DOD only): 442-3321; Commercial: (215) 697-3321.

NFGS 02714	Exterior Steam Distribution
NFGS 09809	Protection of Buried Steel Piping and Steel Bulkhead Tie Rods
NFGS 15250	Insulation of Mechanical Systems
NFGS 15251	Insulation for Exterior Piped Utilities
NFGS 15411	Compressed Air Systems (Non-Breathing Air Type)
NFGS 15612	Gas Distribution Systems
NFGS 15705	Underground Heat Distribution System (Prefabricated or Pre-Engineered Types)

Pipe Friction Handbook, Hydraulic Institute (HI), 712 Lakewood Center North, 14600 Detroit Avenue, Cleveland, OH 44107.

Piping Handbook, 5th Edition, Crocker and King, McGraw-Hill Book Company, Inc., New York, NY 10036.

Steam Trap Users Guide, UG-0005, Naval Civil Engineering Laboratory, copies are available from National Technical Information Service, Operations Division, 4285 Port Royal Road, Springfield, Virginia 22161; telephone (703) 487-4650; ADA 156351, 1-800-336-4700.

Thermodynamic Properties of Steam, Keenan and Keyes, Hill and Moore. J. Wiley & Sons, NY, Copyright 1969, Library of Congress Catalog, Card No. 68-54568.

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PROJECT NO.
FACR-0199

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER
MIL-HDBK 1003/8

2. DOCUMENT TITLE EXTERIOR DISTRIBUTION OF UTILITY STEAM, HIGH TEMPERATURE WATER, CHILLED WATER, FUEL GAS & COMPRESSED AIR

3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS *(Street, City, State, ZIP Code)*

4. TYPE OF ORGANIZATION *(Mark one)*

- [ ] VENDOR
- [ ] USER
- [ ] MANUFACTURER
- [ ] OTHER *(Specify)*: ______
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- [ ] AE
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