UFC 3-430-09
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UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR MECHANICAL UTILITY DISTRIBUTION

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EXTERIOR MECHANICAL UTILITY DISTRIBUTION

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Change No.	Date	Location

This UFC supersedes UFC 3-430-09, dated 16 January 2004 and UFC 3-430-01FA, dated 25 July 2003.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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TABLE OF CONTENTS

FIGURES

TABLES

CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Unified Facilities Criteria (UFC) provide common requirements and general criteria for the design of exterior mechanical distribution systems including steam, heating water, chilled water, and compressed air for Department of Defense (DoD) facilities.

1-2 INCORPORATES, REISSUES, AND CANCELS.

This document is a revision and update of UFC 3-430-09 *Exterior Mechanical Utility Distribution*. The Military Handbook format contained in UFC 3-430-09 is being converted into UFC format as part of this revision. It incorporates UFC 3-430-01FA *Heating and Cooling Systems Distribution* and UFC 3-430-09N *Exterior Mechanical Utility Distribution* (already archived). The natural gas distribution has already been pulled from these two UFCs and is its own separate UFC (UFC 3-430-05 *Natural Gas and Liquefied Petroleum Gas [LPG] Distribution Pipelines*). Once this UFC is published, UFC 3-430-01FA will be archived.

1-3 PURPOSE AND SCOPE.

This UFC provides criteria and requirements for the design and construction of economical, efficient, and environmentally acceptable distribution piping systems for heating, cooling, and compressed air plants. The scope of this UFC covers exterior distribution piping up to 5 feet from the buildings envelope. This document does not constitute a detailed technical design, maintenance, or operation manual. This document includes any new advancements for mechanical utility distribution, if applicable. The mediums used in these distribution systems, as defined by the DoD, include:

- Chilled Water Systems
- Chilled Water/Glycol Mixture Systems
- High temperature hot water (HTW) 351°F to 450°F (177°C to 232°C)
- Medium temperature hot water (MTW) 251°F to 350°F (122°C to 177°C)
- Low temperature hot water (LTW) Maximum of 250°F (Maximum of 121°C)
- High pressure steam systems over 15 psig (over 103 kPa)
- Low pressure steam systems up to 15 psig (up to 103 kPa)
- Condensate return systems up to 200°F (up to 93°C)
- Compressed Air

Non-Government standards form the foundation of criteria requirements as represented in MIL-STD-3007G (General Requirements, figure 1). Refer to MIL-STD-3007G as DoD policy authority to adopt non-government standards (NGS).

1-4 APPLICABILITY.

This UFC follows the same applicability as UFC 1-200-01, paragraph 1-3, with no exceptions.

1-5 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-6 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-7 ARCTIC AND SUBARCTIC CONSTRUCTION.

In addition to this UFC, refer to the UFC 3-130-05, *Arctic and Subarctic Utilities* for thermal considerations with utilities in cold regions.

1-8 GLOSSARY.

Appendix B contains acronyms, abbreviations, and terms.

1-9 REFERENCES.

Appendix C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 PLANNING FACTORS

2-1 TYPES OF EXTERIOR DISTRIBUTION SYSTEMS.

Applicable Unified Facilities Guide Specifications (UFGS) related to exterior distribution systems are covered in paragraph 2-2.

Types of exterior distribution systems are as follows:

2-1.1 Steam and Condensate.

These 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/or for space heating. Heating equipment using steam includes unit heaters, radiators, convectors, heating coils, and other devices. Process equipment using steam includes hot water heaters, laundry machinery, cleaning/plating tanks, kitchen equipment, and other devices. Steam driven equipment including chiller and compressor applications. Condensate is returned to the central plant.

2-1.2 Hot Water.

System circulates hot water which supplies heat from a central heating plant to several buildings for space heating, domestic hot water, and process work, and returns the water to the central plant. HTW systems operate at 351 degrees Fahrenheit (°F) (177 degrees Celsius [°C]) and higher; MTW systems operate between 251°F (121°C) to 350°F (177°C); and LTW systems operate at or below 250°F (121°C).

Material must be selected to the same specifications as for High Temperature Water systems, except that reinforced thermosetting resin plastic (RTRP) piping may be used for LTW distribution systems which have maximum of 150 psig (1034 kilopascal (kPa)) at 200°F (93°C).

2-1.3 Compressed Air.

System supplies compressed air from a compressor plant to docks, air start systems, shops, hangars, and other structures. Refer to UFC 3-420-02 for designing low pressure compressed air systems.

2-1.4 Chilled Water.

System circulates chilled water from a central refrigeration plant to several buildings for space cooling or process cooling and returns the water to the central plant.

For cooling systems which require low chilled water fluid temperatures where glycol /water mixtures are necessary, follow applicable regulatory guidance. Size pumps and heat exchangers to account for glycol’s increased viscosity and decreased heat transfer efficiency.

2-1.5 Cooling or Condensing Water.

System distributes 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 typically returned to the source (cooling tower).

2-1.6 Geothermal Distribution Piping.

For geothermal distribution piping systems see UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*.

2-2 UFGS RELATED TO DISTRIBUTION SYSTEMS.

The following UFGSs are for use in the design of the exterior distribution systems discussed in this UFC:

2-2.1 UFGS 09 97 13.28 Protection of Buried Steel Piping and Steel Bulkhead Tie Rods.

UFGS 09 97 13.28 covers the requirements for exterior protection tape wrapping systems.

2-2.2 UFGS 22 14 29.00 Sump Pumps.

UFGS 09 97 13.28 covers the requirements for automatic, electric-motor-driven, centrifugal, wet-pit and submersible sump pumps.

2-2.3 UFGS 23 05 48.19 Seismic Bracing for Mechanical Systems.

UFGS 23 05 48.19 covers the requirements for the seismic protection of mechanical equipment, ductwork, building piping, and exterior utilities.

2-2.4 UFGS 23 07 00, Thermal Insulation for Mechanical Systems.

UFGS 23 07 00 covers field-applied exterior piping insulation, insulation requirements for exterior distribution piping including aboveground piping, underground piping, piping on piers, piping under piers, piping in trenches on piers, piping in tunnels, and piping in manholes.

2-2.5 UFGS 33 60 02 Aboveground Heat Distribution System.

UFGS 33 60 02 covers the requirements for insulated aboveground heat distribution systems (hot water systems to 420°F (216°C) and steam systems to 250 psig (1.72 MPa).

2-2.6 UFGS 33 61 13 Pre-Engineered Underground Heat Distribution System.

UFGS 33 61 13 covers the requirements for an insulated underground heat distribution system and/or condensate return system of the pre-engineered type, for steam and high temperature hot water up to 450°F (230°C).

2-2.7 UFGS 33 61 13.13 Prefabricated Underground Hydronic Energy Distribution.

UFGS 33 61 13.13 covers the requirements for prefabricated underground distribution system for chilled water, low temperature hot water (less than 200°F [95°C]) or dual temperature water. Show the design for the entire piping systems on project drawings.

2-2.8 UFGS 33 61 13.19 Valves, Piping, And Equipment in Valve Manholes.

UFGS 33 61 13.19 covers the requirements for valves, piping and equipment in valve manholes that form a part of an underground distribution system.

2-2.9 UFGS 33 61 14, Exterior Buried Preinsulated Water Piping.

UFGS 33 61 14 covers the requirements for exterior buried factory-prefabricated preinsulated water piping, including hot domestic water piping, recirculating hot domestic water piping, chilled water piping, chilled-hot (dual-temperature) water piping, and hot water piping from heat exchangers. Show the design for the entire piping systems on project drawings.

2-2.10 UFGS 33 63 13, Exterior Underground Steam Distribution System.

UFGS 33 63 13 covers the requirements for Contractor designing and providing exterior buried factory-prefabricated preinsulated or pre-engineered preinsulated steam and condensate piping systems and hot water piping systems for Class A, B, C, and D ground water conditions including concrete pipe anchors exterior of manholes, interface with each manhole, and the watershed to aboveground piping.

2-2.11 UFGS 33 63 13.19 Concrete Trench Hydronic and Steam Energy Distribution.

UFGS 33 63 13.19 covers the requirements for heat distribution systems of the concrete trench type for water systems from 150°F to 450°F (66°C to 232°C) and steam systems up to 250 psig (1.72 MPa).

2-2.12 UFGS 33 63 14, Exterior Buried Pumped Condensate Return.

UFGS 33 63 14 covers the requirements for Contractor designing and providing exterior buried factory-prefabricated preinsulated pumped condensate (hot water) return piping systems suitable for installation in Class A, B, C, and D ground water conditions, including piping in manholes, plastic piping systems, and related work. Use the plastic carrier piping only for sizes 2, 3, 4, 5, 6, 8, and 10 inches (50, 80, 100, 125, 150, 200, and 250 mm). Thus, the connecting system piping must be of equal size or increased to the next size of the plastic carrier piping. This UFGS also covers Contractor's responsibilities which include the following:

- Design.
- Provide exterior buried factory-prefabricated preinsulated pumped condensate (hot water).
- Provide plastic piping systems for Class A or Class B ground water conditions including concrete pipe anchors exterior of manholes, interface with each manhole, and the watershed to aboveground piping.

Show the design for the buried piping, the manholes, the piping within manholes, and the piping not in approved prefabricated conduit or pre-engineered systems on project drawings. The Contractor designs and provides direct buried factory-prefabricated preinsulated piping in a conduit or pre-engineered insulated piping system, including concrete piping anchors exterior of manholes, interface with each manhole, and the watershed to aboveground piping.

2-2.13 UFGS 33 63 16, Exterior Shallow Trench Steam Distribution.

UFGS 33 63 16 covers the requirements for exterior shallow trench heat distribution systems, including concrete trench, manholes, piping, pipe anchors, pipe supports, interface with each manhole and watershed to aboveground piping. The specification covers system components for working pressure of 150 psig (1034 kPa) steam at 366°F (186°C) and 125 psig (862 kPa) condensate at 250°F (121°C) or hot water at 450°F (232°C). Show the design for the entire piping systems and shallow concrete trench systems on the project drawings.

2-2.14 UFGS 33 63 23, Exterior Aboveground Steam Distribution.

UFGS 33 63 23 covers the requirements for exterior aboveground steam and condensate (hot water) piping systems: exposed to the weather exterior of buildings and supported on pedestals or poles; on piers, under piers, and in trenches on piers; and in tunnels, in manholes, and related work. The UFGS also covers buried factory-prefabricated preinsulated steam and condensate piping under roads. The specification covers system components for working pressure of 150 psig (1034 kPa) steam at 366°F (186°C) and 125 psig (862 kPa) condensate at 250°F (121°C).

2-2.15 Compressed Air Piping System.

UFGS 22 15 26.00 20 *High and Medium Pressure Compressed Air Piping* relate to compressed air systems. Show the design for the entire piping systems on project drawings.

2-3 DISTRIBUTION LOADS AND SYSTEM LOAD DEMAND FACTORS.

For approximate conditions, refer to Table 2-1.

Table 2-1 Distribution Loads and Fluid Conditions

Fluid	Use	Capacity	Fluid Pressure, Vacuum, Temperature	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 UFC 3-410-01	2 to 10 psig (14 to 69 kPa)	1.0 2/ for heating radiation, 0.8 2/ for ventilation	---
	Waterfront demands	See criteria in UFC 4-150-02	150 psig (1034 kPa) maximum	1.0 single berths 0.8 multiple berths	High purity steam for nuclear ships
	Process	Laundry	100 psig (689 kPa)	0.65	7 hr/day, 5 days/week, normally
		Kitchen	10 to 40 psig (69 to 276 kPa)	1.0	2-8 hr/day, 7 days/week, normally
		Bakery	10 psig (69 kPa)	1.0	8 hr/day, 5 days/week, normally
		Dry Cleaning	70 psig (483 kPa)	0.65	---
		Hospital	70 psig (483 kPa)	0.65	---
		Laundry Hot Water	5 to 45 psig (34 to 310 kPa)	0.65	7 hr/day, 5 days/week, normally
		Domestic Hot Water: UFC 3-420-01	5 to 45 psig (34 to 310 kPa)	0.65	---
	Refrigeration	Tons x steam rate/ton	Boiler steam pressure 26-28 in Hg (88-94 kPa). Vacuum	1.0	Turbine-driven centrifugal compressor
		Tons x steam rate/ton	12 in Hg (41 kPa)	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 4/	20 to 60 psig (138 to 414 kPa)	1.0 for continuous operation of condensate pumps 1.5 to 3 for intermittent operation of condensate pumps	
Hot Water (supply and return)	Heating and snow melting	Same criteria as for steam	10 to 100 psig (69 to 689 kPa)	---	---
	Process	---	Same as for steam	Same as for steam	
Chilled Water Supply and Return	Refrigeration	*gpm=* *<u>12,000 Btu/ton x tons</u>* *500 x (t_s - t_r) 3/*	Supply: 42°F to 45°F (6°C to 7°C) Return: 52°F to 60°F (11°C to 16°C) Pressure depends on friction and static heads	1.0 2/	---
Condenser Water	Refrigeration	*3 gpm/ton*	Supply 85°F (29°C). Return 105°F (41°C)	1.0	---
	Power System	*gpm=* *steam x 950 <u>lbs/hr Btu/lb</u>* *500 x (t_s - t_r) 3/*	Pressure depends on friction and static heads	1.0	
Compressed Air	Low pressure medium pressure high pressure	---	---	---	

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.
4/ "Distribution 10 percent" is an estimate that can be used for the losses in the condensate return system when sizing the condensate receiver. It is assumed that losses in the condensate return typically occur in the steam traps in the condensate return system. The losses in the steam traps can be calculated in order to establish a more accurate estimate, but typically the estimate of 10% will be used.

2-3.1 Requirements for Individual Facilities.

The actual loads and conditions are determined from the design of each building and facility. The facility layout, design, and geographic factors will further define requirements.

2-3.2 System Load Demand Factors.

For demand factors, refer to Table 2-1.

2-4 SYSTEM SELECTION GENERAL.

When designing a heating or cooling distribution system, the designer must first select two critical items: media type and system type.

2-5 DISTRIBUTED MEDIA SELECTION.

2-5.1 Connecting to an Existing System.

Almost all heating and cooling distribution systems will be connected to an existing central distribution system. In this case, the designer most often designs for the media to which it is being connected-HTW, MTW, LTW, steam/condensate, or chilled water.

2-5.2 Installation of New System.

When no existing system is present, the designer must select the system that is most appropriate for the Government. High temperature hot water and steam/condensate systems are the most common types of distribution systems currently used on military installations. However, a new system must only use the temperatures and pressures necessary to meet the requirements of the installation. For example, the use of high pressure steam sterilizers or steam kettles at several facilities may require the use of a high pressure steam or HTW system. However, it is typically much more cost effective (on a first cost and life cycle cost basis) to use a low or medium temperature hot water distribution system whenever possible and to incorporate standalone high pressure/temperature systems where required. The lower maintenance costs, safer operation, longer life of systems, and simpler system controls for hot water systems often offset the costs of larger piping required.

2-6 SYSTEM TYPES.

When selecting a distribution system, the designer must determine which system types apply to a particular medium. The designer must also exclude systems which are not appropriate for a particular site or for which the Government has no interest. Examples of this are locating aboveground systems in non-industrial areas where the installation is sensitive to the aesthetic appearance of the area or routing concrete shallow trench systems through drainage swales or flood plains.

2-6.1 Heat Distribution Systems in Concrete Trenches (Chapter 5).

This system is a buried system with its removable concrete cover installed at grade and will typically be used for HTW, MTW, and steam/condensate systems. In rare instances, it may also be used for chilled water and LTW in the event no plastic piping is installed in the same trench as high temperature (greater than 250°F [121°C]) piping systems. Experience has shown that if insulation of a high temperature system is compromised, temperatures can increase to such a level and cause damage to the plastic piping.

2-6.2 Pre-engineered Underground Heat Distribution Systems (Chapter 6).

This system is designed for higher pressure and temperature applications. The two types of pre-engineered systems are the drainable-dryable-testable (DDT) type which is used for high pressure steam/condensate, HTW, and MTW at any type of site and the water spread limiting (WSL) type which is used only for steam/condensate systems in bad and moderate sites. HTW and MTW supply and return lines may be provided in a single casing; however, steam and condensate lines must always be provided in separate casings because condensate lines typically last less than half as long as the steam line and are easier to replace when in a separate casing.

2-6.3 Prefabricated Underground Heating/Cooling Distribution System (Chapter 7).

This system is designed for lower temperature and pressure applications. It is typically used for LTW, chilled water, or combination LTW/chilled water systems.

2-6.4 Aboveground Distribution System (Chapter 8).

This system may be used for HTW, MTW, steam/condensate, and LTW systems, and for chilled water systems where freezing is not a concern.

2-7 SYSTEM SELECTION.

The system type selected will be based on the type of media that is distributed.

2-7.1 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. 3-9.6.4.

2-7.2 Distribution Routes.

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

2-7.3 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. Consider emergency vehicle access as required for the aboveground distribution routing.

Consider aboveground distribution systems for use in lieu of underground systems because of generally longer life and lower maintenance and use wherever operations and local conditions permit.

2-7.4 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.

2-7.5 High Temperature Water and Steam/Condensate Systems.

The order of preference for system types for high temperature and high pressure systems are:

1. Aboveground Distribution System. This is the least expensive system and historically requires the lowest maintenance and operating costs. However, the safety and aesthetics of an aboveground system are not always desirable and must be accepted by the Government.
2. Heat Distribution Systems in Concrete Trenches. This is the most dependable of the buried distribution systems. The piping is totally accessible through removable concrete covers, the piping does not come in contact with the soil, and ground water is drained away from the piping system to low point drains. Except in rare instances, utilize this system if aboveground is not acceptable with the Government.
3. Pre-engineered Underground Heat Distribution System. This type of buried distribution system is the last option due to very short system lives which are typically caused by poor drainage, poor corrosion protection, and improper installation. Instances where it would be used would be when aboveground is not acceptable with the Government or when drainage swales and high ground water prevent the installation of a concrete trench system.

2-7.6 Low Temperature and Chilled Water Systems.

The order of preference for system types for hot water, chilled water or combination hot/chilled water are:

1. Aboveground Distribution System. This is the least expensive system and historically requires the lowest maintenance and operating costs. However, the aesthetics of an aboveground system are not always desirable and must be accepted by the Government. In addition, aboveground systems are typically not used for chilled water because of potential freezing problems in colder climates and heat gain in warmer areas.

2. Prefabricated Underground Heating/Cooling Distribution System. This buried distribution system is relatively inexpensive and dependable. The non-metallic casing materials provide excellent protection from corrosion and the lower temperatures and pressures allow the system to operate for extended periods of time. It is an excellent application for chilled water since the system is installed underground, limiting the amount of heat gain to the system.

2-7.7 Economic Studies.

Refer to National Institute of Standards and Technology (NIST) Handbook 135, entitled *Life Cycle Costing Manual for the Federal Energy Management Program*, for procedures in life-cycle cost analyses. Economic studies for all piping system types must include life-cycle (owning, operating, and maintenance) costs. For plastic piping systems which require special tools or methods for installation, these costs shall also be included in the life-cycle cost analysis. For prefabricated/pre-engineered underground steam or hot water systems, perform the economic analysis, developing costs from heat loss data provided in Appendix A A-1. For concrete shallow trench systems of greater than 500-feet (152.5 m) length, use the additional procedures outlined in para. 2-7.11 and modify UFGS 23 07 00 accordingly. Consider first an aboveground system, which, in most cases, will be economically advantageous to the Government. Also consider 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 UFGS 23 07 00.

2-7.8 Annual Owning, Operating, and Maintenance Costs.

Consider the following:

- Base selection of the distribution system and route on the results of life-cycle economic analyses of alternatives. Consider aesthetics within the limits of the Station Master Plan.
- Operation and maintenance costs depend on the type of system design and past experience with various systems.

2-7.9 Steam Versus High Temperature Water Distribution.

For criteria on steam versus high temperature water distribution, see list below:

a. Economic advantages of central storage of the HTW system sizing of equipment such as boilers, pumps, and piping

b. Operation and maintenance costs of HTW distribution system versus steam distribution systems

c. Pressure and temperature requirements provided economically by steam or HTW

d. Cost of replacement or renovation of existing plant and distribution system compared with construction of new plant and distribution system compared with construction of new plant and/or distribution system. A comparison will be on a life cycle cost basis. The analysis must indicate a system change is economical before change is made.

e. Prevalence of skilled plant operators in the area. This is critical in remote locations. HTW system operators require more skill to make the system operate efficiently.

f. Complexity of controls and ability if system to maintain fluctuating or constant temperature conditions through the assigned or existing heat transfer equipment.

2-7.10 High-Pressure (above 50 psig) (345 kPa) Steam Versus Low-Pressure (0 to 15 psig) (0 to 103 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. If operationally adequate, consider medium-pressure steam systems, 15 to 50 psig (103 to 345 kPa). End-use temperature requirements of terminal equipment must be met by the system selected.

2-7.11 Insulation for Shallow Trench Systems Which Exceed 500 Feet.

If the estimated distribution line length exceeds 500 feet (152.5 m), determine the required insulation thickness as follows and edit UFGS 23 07 00 as required.

2-7.11.1 Heat Loss Formula.

For concrete shallow trench systems, perform the economic analysis with heat losses calculated using the following equation:

Equation 2-1. Heat Loss Formula

$$Q = \frac{2*\pi*(T_f - T)}{\frac{ln(r_p/r)}{K_p} + \frac{ln(r_i/r_p)}{K_i} + \frac{1}{h_a*r_i}}$$

Where:

r = inside radius of pipe (one half of id), feet (meter)
r_p = outside radius of pipe (one half of od), feet (meter)
r_i = radius of insulation (one half of od), feet (meter)
T_f = temperature of fluid, °F (°C)
T = temperature of ambient, °F (use 75), °C (use 23.9)
*K_p = steel pipe thermal conductivity, Btu-in/(hr)(sq-ft) (°F), W/m*K*
*K_i = Insulation thermal conductivity, Btu-in/(hr)(sq-ft) (°F), W/m*K*
Q = Pipe heat lost, Btu/hr (ft. of pipe), W (meter of pipe)
h_a = outside film coefficient still air, 2.0 Btu/(hr)(sq-ft) (°F), 11.36 W/m^2*K
π = mathematical constant equal to 3.14159

2-7.11.2 Heat Loss and Cost Relationship.

To optimize the costs the designer must calculate the total owning and operating cost of different sections of the system. The five steps of this approach for determining the owning and operating costs listed below. To determine the optimal piping insulation the designer may utilize the following approach. The minimum insulation thickness must comply with ASHRAE 90.1. For the minimum insulation thickness and each increase in nominal insulation thickness, calculate the heat loss and its associated energy cost. Once the first cost premium is no longer recouped in a Life-Cycle Cost Analysis. At that point the optimal piping insulation thickness has been determined and is the thickest pipe insulation where the first cost premium was recouped in the life-cycle cost analysis. This insulation thickness will be utilized on the design drawings or within the specifications.

a. Step 1: After the general layout of the system has been made and the site and application conditions have been determined, size the system carrier piping assuming a 2 percent heat loss from the supply line at maximum flow.

b. Step 2: Select one particular type of system configuration which is relatively low in first cost and is approved for use with the site and application conditions identified, to use as a model in making the economic analysis.

c. Step 3: Determine separately, for each section of the system, the installed cost per foot of the system configuration with utilizing the optimal insulation thickness for each section. A section can be considered as any portion of the system in which the conditions that affect heat loss are similar - for example, pipe size, tunnel shape, cover type. The cost of all components, other than valve vaults called for in the selected system must be included in the cost estimate.

d. Step 4: Determine the annual owning cost per foot of each section of the system with utilizing the optimal insulation thickness for each section, using Equation 2-2.

e. Step 5: Calculate the heat loss per linear foot separately for each pipe in each section of the selected model system, utilizing the optimal insulation thickness for each section, using applicable calculation procedures in para. 2-7.11.1.

Equation 2-2. Annual Owning Cost per foot/meter

$$Owning\ Cost\ (\$\ per\ ft.-year) = \left(\frac{Installed\ Cost\ (\$\ per\ ft.)}{*\ Series\ Present\ Worth\ Factor}\right)$$

$$Owning\ Cost\ (\$\ per\ meter - year) = \left(\frac{Installed\ Cost\ (\$\ per\ meter)}{*\ Series\ Present\ Worth\ Factor}\right)$$

** = The series present worth factor is the reciprocal of the capital recovery factor.*

The series present worth factor can be obtained from any set of interest tables, given the annual interest rate (or rate or return) and the number of years over which the cost is to be amortized (that is, the economic life of the item). Use an economic life of 25 years and a discount rate as published in National Institute of Standards and Technology (NIST) Handbook 135, entitled Life Cycle Costing Manual for the Federal Energy Management Program.

CHAPTER 3 GENERAL DESIGN FACTORS

3-1 GENERAL.

Some aspects of a heating or cooling distribution system design are similar regardless of the system type. These aspects are covered in this chapter.

3-2 DESIGN RESPONSIBILITIES FOR UNDERGROUND PRE-ENGINEERED HEAT DISTRIBUTION SYSTEMS.

The project designer is responsible for accomplishing the following:

- 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.
- 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 must be provided by the system supplier.
- Design special elements of the system as required.
- Calculate the maximum heat loss per lineal foot of the conduit.

3-2.1 Design by Project Engineer.

The project designer must indicate on project drawings the exterior steam and condensate piping systems aboveground, the manholes, piping within manholes, and piping not in approved conduit systems. The project designer must establish the system design parameters of the entire underground piping system, such as site classification, general layout, essential characteristics of the system, and specially designed elements of the system. The project designer is responsible for sizing the pipe, establishing the piping elevations, identifying the piping right-of-way, obstructions, and utilities (plan and profile) within 25 feet (7.62 m) of the center line of the right-of-way, and every area within 25 feet (7.62 m) of the center line that must be avoided; for example, paved areas and buildings. The project designer is also responsible for the location and sizing of manholes, the design of concrete manholes and the piping and equipment layout of manholes including valves, fittings, traps, expansion joints (when required), and manhole drains.

3-2.2 Design by System Supplier.

The construction Contractor must design and provide buried factory-prefabricated preinsulated piping in a conduit or pre-engineered insulated piping system. It is intended that the supplier provide the details of design for his system. The design will address expansion loops, bends, offsets, concrete pipe anchors outside of manholes, interface with each manhole, and the watershed to aboveground piping. When prefabricated steel manholes are indicated, the system supplier is responsible for the structural design of the manhole and the manufacture of the complete manhole, including installation of valves, fittings, and other equipment as specified herein and indicated on the project drawings. The Contractor is responsible for the design, fabrication, and installation of the underground piping system within the system design parameters established by the project designer.

3-3 DISTRIBUTION SITE LOCATION.

Fluid distribution site locations must be according to the following:

3-3.1 Location Factors.

For location factors for each system, refer to Table 3-1.

3-3.2 Subsurface Explorations.

When a concrete trench or a buried steam or hot water system is specified, a thorough investigation of ground and water conditions must be made. Employ a licensed civil (geotechnical) engineer familiar with ground water conditions at the site to establish the classification. In the absence of existing definitive information on soil types and groundwater conditions, make a detailed site classification survey. Upon completion of the survey, classify each exploration point as A, B, C, or D on the basis of the criteria presented in Table 3-2 and Table 3-3. The worst ground water condition encountered between adjacent manholes determines the class of the system to be installed between adjacent manholes. Conduct this survey within the guidelines specified in paras. 3-3.2.1 through 3-3.2.12. When concrete shallow trench systems are specified, use information covered in this UFC.

3-3.2.1 Timing of Survey.

Conduct the survey after the general layout of the system has been determined. Survey will cover the entire length of the proposed system, and will be made by a geotechnical engineer. The geotechnical engineer will be a registered professional engineer with a minimum of three years of experience in the field of soil mechanics and foundation design. This engineer must also be familiar with the local soil conditions.

3-3.2.2 Time of Year.

Make the survey at a time of year when the highest water table is expected to exist, if possible. If this is not possible, correct water table measurements on the basis of professional judgment and local knowledge, to indicate conditions likely to exist at the time of year when the water table is at its highest point. It may be necessary to dig test pits at the worst locations to investigate the soil for evidence of high water table. Follow exploration methods indicated in the UFC 3-220-01 *Geotechnical Engineering*.

Table 3-1 Location Factors for Each Distribution System

Item	Determine the Following
Load Centers	Maximum demand load of system (See criteria in Table 2-1 and ascertain requirements of all facilities.) Distance from generating plant 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, and structures. Belowground obstructions, such as tunnels, trenches, piping, rock, and storage tanks. Location of expansion loops, joints, and manholes Master Plan (Refer to UFC 1-200-01)
Site	For above and underground systems: Ground contours along route For underground systems: Borings every 100 feet (30.5 m) along route (refer to para 3-3.2.4) Permeability test (refer to 3-3.2.7) Resistivity test (refer to para 3-3.2.9) Stability of soil (refer to para 3-3.2.11) Water table survey made at time of highest levels if possible, or modify by judgement 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 communication 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 and tests approvals)
Hazards	For hazards associated with the proposed utility distribution system location, coordinate with points of contact or base personnel familiar with the site. Designer shall also perform a survey of the site to determine any additional hazards which will require being accounted for in the utility system design.
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

Table 3-2 Unified Soil Classification System

<table>
<tr><th colspan="4">Field Identification Procedures (Excluding particles larger than 3 inches [76 mm] and basing frictions on estimated weights)</th><th>Group Symbols</th><th>Typical Names</th><th>Permeability When Compacted</th></tr>
<tr><td rowspan="8">Coarse Grained Soils More than half of material is larger than No. 200 sieve size*</td><td rowspan="4">Gravels More than half of coarse fraction is larger than No. 4 sieve size**</td><td rowspan="2">Clean Gravels (Little or no fines)</td><td>Wide range in grain size and substantial amounts of all intermediate particle sizes</td><td>GW</td><td>Well graded gravels, gravel-sand mixtures, little or no fines</td><td>Pervious</td></tr>
<tr><td>Predominantly one size or a range of sizes with some intermediate sizes missing</td><td>GP</td><td>Poorly graded gravels, gravel-sand mixtures, little or no fines</td><td>Very Pervious</td></tr>
<tr><td rowspan="2">Gravels With Fines (Appreciable amount of fines)</td><td>Non-plastic fines (for identification procedures see ML below)</td><td>GM</td><td>Silty gravels, poorly graded gravel-sand-silt mixtures</td><td>Semipervious to Impervious</td></tr>
<tr><td>Plastic fines (for identification procedures see CL below)</td><td>GC</td><td>Clayey gravels, poorly graded gravel-sand-clay mixtures</td><td>Impervious</td></tr>
<tr><td rowspan="4">Sands More than half of coarse fraction is smaller than No. 4 sieve size**</td><td rowspan="2">Clean Sands (Little or no fines)</td><td>Wide range in grain sizes and substantial amounts of all intermediate particle sizes</td><td>SW</td><td>Well graded sands, gravelly sands; little or no fines</td><td>Pervious</td></tr>
<tr><td>Predominantly one size or a range of sizes with some intermediate sizes missing</td><td>SP</td><td>Poorly graded sands, gravelly sands; little or no fines</td><td>Pervious</td></tr>
<tr><td rowspan="2">Sands With Fines (Appreciable amount of fines)</td><td>Non-plastic fines (for identification procedures see ML below)</td><td>SM</td><td>Silty sands, poorly graded sand-silt mixtures</td><td>Semipervious to Impervious</td></tr>
<tr><td>Plastic fines (for identification procedures see CL below)</td><td>SC</td><td>Clayey sands, poorly graded sand-clay mixtures</td><td>Impervious</td></tr>
</table>

*The No. 200 sieve size is about the smallest particle visible to the naked eye.
**For visual classifications, the ¼” size may be used as equivalent to the No. 4 sieve size.

Unified Soil Classification System (continued)

Field Identification Procedures (Excluding particles larger than 3 inches [76 mm] and basing frictions on estimated weights)					Group Symbols	Typical Names	Permeability When Compacted
Fine Grained Soils More than half of material is smaller than No. 200 sieve size*	Identification Procedures on Fraction Smaller Than No. 40 Sieve Size						
		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)			
	Silts and Clays Liquid limit less than 50	None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock, flour, silty of clayey fine sands with slight plasticity	Semipervious to Impervious
		Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Impervious
		Slight to medium	Slow	Slight	OL	Organic silts and organic silty clays of low plasticity	Semipervious to Impervious
	Silts and Clays Liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Semipervious to Impervious
		High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays	Impervious
		Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity, organic silts	Impervious
Highly Organic Soils		Readily identified by color, odor, spongy feel and frequently by fibrous texture			PT	Peat and other highly organic soils	

*The No. 200 sieve size is about the smallest particle visible to the naked eye.

Table 3-3 Site Classification Criteria

Site Class	General Conditions Required for Such Classification	Conditions Found During Site Classification Survey That Are Indicative of the Class			
		Relative to Water Table Level	Relative to Surface Water Accumulation		
			Soil Types	Terrain	Precipitation Rates or Irrigation Practices in Area
A-Severe	Water table frequently above bottom of the system	Groundwater within 1 ft (305 mm) of bottom of system	Any	Any	Any
	Water table occasionally above the bottom of the system and surface water accumulates and remains for long periods in soil surrounding the system	Groundwater within 1 ft (305 mm) of bottom of system	GC, SC, CL, CH, OH	Any	Any
B-Bad	Water table occasionally above the bottom of the system and surface water accumulates and remains for short periods in soil surrounding the system	No groundwater encountered	GW, GP, SW, SP	Any	Any
			GM, SM, ML, OL, MH		
	Water table never above the bottom of the system, but surface water accumulates and remains for long periods in soil surrounding the system	No groundwater encountered	GC, SC, CL, CH, OH	Any	Equivalent to 3 inch (76.2 mm) or more in any one month or 20 inch (508 mm) or more in one year
C-Moderate	Water table never above the bottom of the system, but surface water accumulates and remains for short periods in soil surrounding the system	No groundwater encountered	GM, SM, ML, OL, MH	Any	Equivalent to 3 inch (76.2 mm) or more in any one month or 20 inch (508 mm) or more in one year
			GC, SC, CL, CH, OH	Any except low areas	Equivalent to less than 3 inch (76.2 mm) in any one month and to less than 20 inch (508 mm) in one year
D-Mild	Water table never above the bottom of the system and surface water does not accumulate and remain in soil surrounding the system	No groundwater encountered	GW, GP, SW, SP	Any	Any
			GM, SM, ML, OL, MH	Any except low areas	Equivalent to less than 3 inch (76.2 mm) in any one month and to less than 20 inch (508 mm) in one year

3-3.2.3 Exploration Considerations.

As a minimum, collect information on groundwater conditions, soil types, terrain, and precipitation rates and irrigation practices in the area of the system. Information on terrain and precipitation rates and irrigation practices may be obtained from available records at the installation. In addition, soil resistivity will be determined for the cathodic protection system design for Pre-Engineered Underground Heat Distribution System. The cathodic protection system shall meet the requirements of UFC 3-570-01 *Cathodic Protection*. For Army projects only: these projects require cathodic protection Center of Expertise (CX) review of the proposed design.

3-3.2.4 Test Explorations.

Information on ground-water conditions and soil types will be obtained through borings, test pits, or other suitable exploratory means. Make test explorations (borings or test pits) at least every 100 feet (30.5 m) along the line of a proposed system. If changes in stratification are noted, decrease the boring spacings so an accurate horizontal soil profile may be obtained. If a significant difference in underground conditions is found at adjacent exploratory points, additional explorations will be made between those points in order to determine more precisely where the change occurs. Upon completion of the survey, each exploration point will be classified on the basis of the criteria presented this UFC. The classification criteria are different for each system.

Determining ground-water conditions and soil types using test explorations (borings or test pits) and classification criteria are not required for the design of Prefabricated Underground Heating and Cooling Distribution Systems or Aboveground Distribution Systems. Though a site survey must be conducted for these distribution systems to ensure that actual site characteristics have been identified so that accurate plan and profile drawings can be generated.

3-3.2.5 Depth of Explorations.

Extend all explorations at least 5 feet (1.53 m) below the anticipated elevation of the bottom of the proposed system to determine ground water conditions.

3-3.2.6 Special Ground Considerations.

Give particular attention to the following conditions:

- The possibility that the ground below a backfilled piping system may not be able to absorb runoff that has seeped into it.
- Areas where ponding may occur, either along a sloping surface or in low flat areas.
- The permeability of the ground below the system (see below).

3-3.2.7 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 feet (30.5 m). When available information indicates uniform subsurface conditions, longer intervals may be allowed for larger projects.

b. Dig holes approximately 1 square foot (0.093 square meter) to a depth of 2 feet (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 inches (51 mm), consider the soil dry; otherwise, consider it as saturated at times.

3-3.2.8 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. The soil is dry, as defined above, deepen permeability test holes an additional 3 feet (920 mm) to determine if the water table is within 5 feet (1.53 m) of the trench bottom.

3-3.2.9 Soil Resistivity.

Considerations for soil resistivity are as follows:

a. Take soil resistivity readings along the conduit line (in accordance with Table 3-1.

b. On 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, a cathodic protection system is required to protect metallic piping systems and manholes. For Army projects only: these projects require cathodic protection Center of Expertise (CX) review of the proposed design.

3-3.2.10 Soil Corrosiveness Classification.

Have an licensed civil (geotechnical) engineer make the classification based on a field survey of the site carried out in accordance with recognized guidelines for conducting such surveys. For Army projects only: these projects require the cathodic protection CX to assist in the corrosiveness classification. Classify the soil at the site as corrosive or noncorrosive on the basis of the following criteria:

- Corrosive: The soil resistivity is less than 30,000 ohm-cm or stray direct currents can be detected underground.
- Noncorrosive: The soil resistivity is 30,000 ohm-cm or greater and no stray direct currents can be detected underground.

3-3.2.11 Soil Stability.

During the above survey, observe and note the soil stability. Use UFC 3-220-01 for criteria. Note areas of unstable soil on the site plans depicting the distribution route.

3-3.2.12 Soil Load-Bearing Capacity.

As a part of the project designer's survey, have an licensed civil (geotechnical) engineer investigate the load-bearing qualities of the soil in which the system will be installed. Identify the location and nature of potential soils problems. Depending on the nature of the problem, the designer may choose to reroute the line, use a combination of concrete shallow trench, direct buried, or aboveground low-profile systems, or elect to over excavate and replace with nonexpansive fill.

3-4 SITE CLASSIFICATION.

Base selection of the conduit system type on the underground water conditions at the project site as defined in Table 3-1, Table 3-2, and Table 3-3 for Class A, B, C, or D application corresponding to underground water conditions ranging from severe to mild, respectively. Guidance on each classification is provided below.

3-4.1 Class A, Severe.

The water table is expected to be frequently above the bottom of the system, or the water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system.

3-4.2 Class B, Bad.

The water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for short periods (or not at all) in the soil surrounding the system or the water table is expected never to be above the bottom of the system, but surface water is expected to accumulate and remain for long periods in the soil surrounding the system.

3-4.3 Class C, Moderate.

The water table is expected to never be above the bottom of the system, but surface water is expected to accumulate and remain for short periods in the soil surrounding the system.

3-4.4 Class D, Mild.

The water table is expected never to be above the bottom of the system and surface water is not expected to accumulate or remain in the soil surrounding the system.

3-5 ANALYZING SITE CLASSIFICATION FOR APPLICATION OF PRE-ENGINEERED UNDERGROUND SYSTEM.

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 is acceptable for use in lower classifications. For example, Class A is acceptable for Classes B, C, and D.

3-6 ANALYZING SITE CLASSIFICATION FOR APPLICATION OF SHALLOW CONCRETE TRENCH SYSTEM.

3-6.1 Soils.

3-6.1.1 Fine Grained Soils (Impervious).

The highest ground water level evident during the wettest period of the year must be a minimum of 1 foot (305 mm) below the lowest point of water entry into the concrete shallow trench system. The lowest point of entry is defined as the joint between the concrete trench wall and concrete trench bottom. The concrete trench bottom will be continuous with no openings. The above condition will ensure that constructability of the concrete shallow trench is practical and that potential infiltration of water into the shallow trench will be negligible. Open drainage ways, swales, or swampy/boggy areas will preclude use of a concrete shallow trench system because of groundwater level guidance in Table 3-3. The concrete shallow trench system must be rerouted or regraded to bring the concrete trench out of the unsuitable conditions. Have the licensed civil (geotechnical) engineer who performed the detailed site classification survey provide regrading instructions. The designer will ensure that the fill will remain stable and will not be subject to future wash-outs. If the specific site conditions are such that these alternatives are not viable, consider aboveground low profile or a direct buried system of the prefabricated or pre-engineered type for these areas.

3-6.1.2 Coarse Grained Soils (Semipervious/Pervious).

The ground water level during the wettest period of the year must be at least 1 foot (305 mm) below the lowest point of water entry into the concrete shallow trench system.

- Water table located 1 to 2 feet (305 to 610 mm) below lowest point of water entry. The criteria of para. 3-6.1.1 applies.
- Water table located 2 or more feet below lowest point of water entry: Concrete shallow trench systems with noncontinuous bottom (tunnel constructed of noncontinuous concrete bottom with openings provided in bottom at intervals of 4 feet (1220 mm) or more to permit drainage into the semipervious/pervious soils) may be used. Special considerations are required when the concrete shallow trench would traverse open drainage ways or swales where the water table would be less than 2 feet (610 mm) below the concrete trench bottom. The designer may elect to reroute the system, place fill to bring the system out of the unsuitable conditions, or provide a continuous bottom trench floor for this area of the site.

3-6.1.3 Swelling Soils (Material with High Swell Potential).

If the specific site conditions are such that these alternatives are not viable, consider aboveground low profile or a direct buried system of the prefabricated or pre-engineered type for those areas. Design the concrete shallow trench system in materials having high swell potential in accordance with para. 3-6.1.1. Soils having a liquid limit greater than 50 and a plasticity index greater than 25 require testing (consolidation swell) to determine the swell characteristics. When the results of the swell test indicate high swell potential, special considerations such as over excavation (width and depth) and replacement with non-expansive fill, under-trench drainage system or other methods of minimizing differential heave will be provided. The design of special features such as described above will be in accordance with instructions provided by the licensed civil (geotechnical) engineer who performed the detailed site classification survey. Design of joint spacing and joint details to accommodate movements will also be provided when required.

3-6.2 Settlement of Trenches.

Generally, settlement of concrete trenches will not be a problem since the unit load of the shallow trench system will be similar to the existing unit overburden load. Backfill adjacent to the concrete trench must be thoroughly compacted to prevent settlement which would create ponding. Positive slopes away from the concrete trench are desirable. Special care of backfill and compaction is required where the system crosses existing streets to preclude settlement and cracking of the roadway adjacent to the trench from repeated traffic loads.

3-6.3 Under-Trench Drainage Systems.

Use concrete trench subdrain systems as required. When subsurface conditions are of differing soil types, (fine grained and coarse grained) and those differing soil conditions will cause blocked drainage either horizontally or vertically adjacent to the concrete trench, provide subdrains to ensure drainage to prevent ponding or entrapment of water adjacent to the shallow trench system. Base the design of the subdrain system on the instructions provided by the licensed civil (geotechnical) engineer who performed the detailed site classification survey and classified each exploration point. Soils of low permeability and high moisture content (lean and fat clays [CL-CH]) must not require under-drains when the shallow trench system is designed to accommodate all anticipated inflow with systems or equipment such as direct connections to storm sewers or the use of dual sump pumps. Connect drainage system sump pump discharge pipes to storm sewer system where feasible. If not feasible, provide discharge to splash blocks on grade. When discharging to grade install the pump discharge line without a check valve to allow complete drainage of the discharge pipe to prevent freezing. Do not use under-trench drainage to alter ground water level to meet requirements of Table 3-3.

3-7 UTILITY INVESTIGATION.

All existing, concurrently constructed, and new utilities will be identified when located within 25 feet of the proposed distribution system routing. When the proposed routing crosses any utilities, burial depths will be determined. Utility locations and depths can be verified through base personnel familiar with utilities, base/post utility maps and by site visits. The designer is responsible for these site visits to verify locations of utility interferences and to coordinate all other construction items with the Government. In the event utility information is not available, utility location consultants may be procured who specialize in the location, identification, and depth determination of utilities. When interferences exist, details will be provided in the design to relocate utilities or modify system routing to avoid the interference.

3-8 REINFORCED THERMOSETTING RESIN PLASTIC (RTRP) PIPE.

RTRP pipe is suitable for service pressures up to 150 psig (1034 kPa) and temperatures up to 200°F (93°C). Above 200°F (93°C) the pressure rating drops off rapidly. At 250°F (121°C) the pressure rating is 125 psig (8612 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 piping as well as for pumped condensate piping.

RTRP pipe is acceptable at Class B sites (refer to para. 3-4). It is recommended for Class A sites, as permitted in para. 2-1.2, due to its low cost and long service life.

3-9 SERVICE AND LOADS.

Determine from Chapter 2 the services, such as steam, high temperature water, hot water, chilled water, compressed air, 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 Chapter 2 for fluid conditions inside service lines, for sizing pipes for these conditions, and for the required capacities.)

3-9.1 Alternate Routes.

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

3-9.2 Pressure Drop.

From the total allowable pressure drop and ultimate length of a line, determine the pressure drop per 100 feet (30.5 m). Note the maximum flow between each load center and size the different pipeline sections accordingly.

3-9.3 Obstacles.

From a field survey, note all obstacles for each route.

3-9.4 Future Loads.

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

3-9.5 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.

3-9.6 Route Types.

Run exterior distribution piping aboveground or underground.

3-9.6.1 Exterior Steam Distribution.

Use UFGS 33 63 23 for all steam distribution piping exposed to the weather, on building exteriors, aboveground piping supports, piers (pedestals), poles, and for all steam piping on piers and under piers, in tunnels and in manholes. Use UFGS 33 63 16 for piping in trenches. Use UFGS 33 63 13 for buried steam piping.

3-9.6.2 Aboveground Overhead Piping.

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

3-9.6.3 Buried Piping.

For buried piping routes, the following criteria apply:

- **Compressed Air Piping.** Compressed air generally require no insulation, but they must be shop coated, wrapped, tested, and handled in accordance with provisions of UFGS 09 97 13.28, *Protection of Buried Steel Piping and Steel Bulkhead Tie Rods*. Provide for testing of coverings by electrical flow detectors (spark test).
- **Minimum Cover.** Protect all buried piping and conduits by laying them under a minimum cover of 24 inches (610 mm). However, protect buried piping under railroads, roads, streets, or highways or due to changes in ground contours against possible external damage due to the superimposed car or truck traffic. Lay pipes below the frost line. Casings may be needed where there is no frost.
- **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, erosion prevention, covering pipes with concrete, adding seismic restraints for above-grade piping or other reasonable protection.
- **Manholes.** Select manhole locations in accordance with the following. Details of piping and design of manholes are the responsibility of the project designer. Design manholes to provide adequate space for maintenance, proper venting, and quick egress. 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 to be provided at all major branch line connections and at drip traps on compressed air lines.
- **Tunnels.** Construct tunnels for underground routes with a walkway minimum height of 76 inches (1.93 m) and clear width of 36 inches (920 mm), with piping stacked vertically on one side and 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 must be well lighted and ventilated. Use moisture resistant electrical fixtures. Tunnels may be built of reinforced concrete, brick, or other suitable structural materials, and must be membrane waterproofed.

3-9.6.4 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 in Table 3-4.

Table 3-4 Advantages for Aboveground and Underground Routes

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

3-9.6.5 Underground.

Use only approved and certified conduit systems for steam, condensate and HTW, and refer to UFGS 33 63 13, UFGS 33 63 14, and UFGS 33 61 14, respectively. The Federal Agency Committee for Underground Heat Distribution Systems approves and certifies the various types of conduit systems, that is, 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 this UFC are met. In this case, utilize UFGS 33 63 16.

3-10 EXPANSION COMPENSATION.

All expansion systems, loops, and bends will be sized in order to prevent excessive pipe stresses (due mainly from thermal expansion) from exceeding those allowed by the Power Piping Code, American Society of Mechanical Engineers (ASME) B31.1. Mechanical expansion joints are not recommended for absorbing system expansion. Mechanical expansion joints greatly increase the maintenance requirements of the distribution systems. In the unlikely event that expansion joints must be used, they must be placed in an adequately sized valve manhole. The designer is responsible for expansion calculations for Heat Distribution Systems in Concrete Trenches, Prefabricated Underground Heating/Cooling Distribution Systems, and Aboveground Distribution Systems. The designer is also responsible for the expansion and stress determinations in all the valve manholes, including the location of the equipment/pipe support locations. Even though the manufacturer is responsible for the expansion calculations for Pre-Engineered Underground Heat Distribution Systems, the calculations will be thoroughly reviewed by the designer at the shop drawing review. It is recommended that a three dimensional finite element computer program be used for determining system stresses. Many finite element software packages are available which operate on desktop computers. The temperature differential used in the stress analysis will be the maximum temperature of the media less the minimum temperature the system will encounter during a shutdown. All loops and bends will be sized based on zero percent cold springing. Cold springing effects lessen over time and are difficult to maintain in the event the system is ever cut, and therefore must not be included in the analysis. However, loops may be installed with cold springing as an added conservative measure.

3-11 INSULATION.

Evaluate insulation for all piping systems with the potential for significant thermal losses. These include steam, condensate, HTW, MTW, LTW, and chilled water (CHW) piping. Use UFGS 23 07 00, *Thermal Insulation for Mechanical Systems*, for CHW, LTW, special applications requiring insulation of compressed air piping systems. Use UFGS-33 60 02 for above-grade piping systems including: steam, HTW, MTW, LTW, and condensate return. Use aluminum jackets and organic felt as specified in UFGS 23 07 00. Use applicable guide specification UFGS 33 61 13, UFGS 33 63 13.19, and UFGS 33 63 23 for underground distribution piping insulation. Insulation materials must not contain asbestos.

3-12 MISCELLANEOUS CRITERIA.

Anchor or guy exterior above ground distribution systems to withstand the wind velocity specified for design of structures, refer to UFC 3-301-01.

3-13 SYSTEM LAYOUT PLAN/PROFILE.

All distribution systems require a layout plan and profile be provided by the designer.

3-13.1 Plan and Position Piping Layouts as Follows:

- Determine what lines between the same points will 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 must be 6 inches (150 mm).
- 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 must be by the system designer. The system designer determines the initial location of anchors, expansion bends, loops, and joints; the system supplier determines final location and design of these features to fit actual field conditions.

- 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, drainage piping, sewers, water piping, electrical conduits, and other service piping, within 25 feet (7.6 m) of the center line of the right-of-way and identify areas within 25 feet (7.6 m) of the center line that must be avoided. If sufficient right-of-way to accommodate pipe expansion cannot be identified and expansion joints are required, they must be specified and located with installation details noted on the drawings.
- Provide a log of soil conditions along the piping right-of-way which gives, as a minimum, soil type, soil resistivity and pH, bearing strength and unstable conditions, and indicate corrective work required.
- Provide details at building entries on the project drawings to show pipe elevation, floor elevation, building wall construction, and existing equipment.

3-13.2 Layout Plans will Include, but not be Limited to:

- System routing (including expansion loops and bends, manhole locations and anchor locations).
- Stationing numbering for the system (one dimensional coordinates from the point of origin of the distribution system).
- All utilities within 25 feet (7.6 m) of the system.
- All roads and buildings clearly labeled.
- Types of ground cover conditions (asphalt, concrete, seeding, and gravel).
- Show locations of erosion and sediment control items. Coordinate with erosion and sediment notes, details, and legend.
- Grade contour lines (new and existing).
- Label baselines to be used for project layout as ‘construction baseline’. Provide all layout dimensions sand clearances from the construction baseline to ensure accurate routing. Include horizontal control point locations and descriptions.

3-13.3 A Profile of the System will also be Drawn and, as a Minimum, Show:

- All system stationing numbering.
- Indicate structure tops, pipe or trench invert elevations, slopes, lengths, and diameters. Coordinate structure numbers with plan sheets. Reference plan sheets where pipes/structures are shown.
- System slope drawn to scale to all low points.
- Show and label new and existing grades and surface materials.
- Show and label all existing or new utility crossings at their actual burial depths.

3-14 FEDERAL AGENCY APPROVED SYSTEM SUPPLIERS.

The following list contains all approved system suppliers issued Federal Agency Letters of Acceptability for systems included in the UFGS 33 63 13, *Exterior Underground Steam Distribution System*:

3-14.1 Class A, B, C, and D Ground Water Conditions.

- Perma Pipe, Niles, IL
- Rovanco Pipe, Joliet, IL
- Pittcon Preinsulated Pipes, Inc., Syracuse, NY
- Nova Group, Inc., Napa, CA
- Thermacor Process, Inc., Fort Worth, TX

3-14.2 Class B, C, and D Groundwater Conditions.

- Thermal Pipe System, Media, PA

3-15 VALVE MANHOLES.

For all distribution systems, valve manholes will be designed by the project designer. A valve manhole is required for all buried system lateral connections, all below to above ground system transitions, all drain points (low points), all below ground valving, all trap stations, high points for vents of buried systems, and to minimize depth of buried systems. Distance between valve manholes varies with different applications. However, spacing must never exceed 500 feet (152.4 m) with Pre-Engineered Underground Heat Distribution Systems or Prefabricated Underground Heating/Cooling Distribution Systems to minimize excavation when searching for failures and to minimize effects of a failure. To enhance maintainability, avoid valve manholes deeper than 6 feet (1.83 meters).

3-15.1 Manhole Internals.

Layout of each manhole will be designed on a case by case basis.

3-15.1.1 Equipment/Valve Locations.

It is important to first layout, to scale, all manhole piping, insulation, valving (with stems upright 90 degrees or less from vertical), and equipment and then locate the manhole walls around these appurtenances to ensure adequate manhole size and room for maintenance personnel. One line diagrams of piping and equipment are unacceptable. See Figure A-2 for a typical manhole plan. Note that all valve manhole layouts have certain designer requirements in common. The designer will:

- Provide main line isolation valves in valve manholes to most efficiently minimize outages to buildings served by the distribution system. When installed, main line isolation valves will be located downstream of the building's service laterals.
- Provide lateral isolation valves within the valve manholes for all laterals runs.
- Locate all carrier pipe vents and drains needed within the manhole for proper system drainage of the main and lateral lines.
- Layout all valve manhole internals (valves and valve stems, pipe with insulation, access ladders, isolation flanges, and equipment) to scale to ensure adequate clearance has been provided for operation and maintenance within the manhole.
- Ensure no non-metallic piping is routed in the manholes (that is, as allowed with chilled water or condensate return systems) which also serves high temperature mediums that could damage the non-metallic piping. Damage to non-metallic piping is caused when manholes flood and the hot piping boils the flood water. Boiling water can exceed the allowable temperature of many nonmetallic piping materials. Because of this, the designer must transition to steel piping at the manholes.

3-15.1.2 Clearances.

Design will provide for clearance around piping and equipment in the manhole in accordance with Table 3-5.

Table 3-5 Valve Manhole Clearances

RECOMMENDED INTERNAL CLEARANCES					
MINIMUM DISTANCE INCHES (mm) FROM/TO	**O.D. OF PIPE INSULATION OR CONDUIT**	**END OF VALVE STEM OR BODY**	**ELEC EQUIPMENT**	**LADDER**	**BOTTOM OF TRAP STATION OR DRAIN**
WALL	18” (457 mm)	18” (457 mm)	-	6” (152 mm)	18” (457 mm)
FLOOR	24” (610 mm)	24” (610 mm)	36” (914 mm)	12” (305 mm)	12” (305 mm)
TOP OF MANHOLE	18” (457 mm)	12” (305 mm)	6” (152 mm)	6” (152 mm)	36” (914 mm)

Notes:

1. In addition to the clearances for the ladder indicated provide 24" (610 mm) around the ladder for maintenance access.
2. Provide 24" (610 mm) around sides of manhole drain to allow for cleaning of debris.

3-15.1.3 Access Ladders.

Access ladders will be required on all valve manholes greater than 3 feet (914 mm) in depth. Ladders will be welded steel and will consist of uprights and nonslip steps or rungs. Uprights will be not less than 16 inches (406 mm) apart and steps or rungs will be spaced no greater than 12 inches (305 mm) apart. Ladders will extend not less than 6 inches (152 mm) from the manhole wall and will be firmly anchored to the wall by steel inserts spaced not more than three 3 feet (914 mm) apart vertically. All parts of the ladders will be hot-dipped galvanized after fabrication in conformance with ASTM A 123. The top rung of the ladders must be not more than 6 inches (152 mm) from the top of the manhole. A typical valve manhole access ladder detail is shown in Figure A-3 in Appendix A.

3-15.1.4 Insulation.

Insulation for valves, fittings, field casing closures, and other piping system accessories in valve manholes will be of the same types and thicknesses as those provided in the distribution systems' guide specification. All insulation will be premolded, precut, or job fabricated to fit and will be removable and reusable. Insulation jackets will be provided for all pipe insulation in manholes and will comply with the requirements of the particular distribution system guide specification.

3-15.1.5 Isolation Flanges.

Isolation flanges will be provided when connecting to an existing cathodically protected heating or cooling distribution system or to prevent a new system's cathodic protection system from contacting an existing system. The isolation flanges will be installed in the valve manhole and a typical flange detail is shown in Figure A-4 in Appendix A.

3-15.1.6 Valve/Piping Supports.

Piping in valve manholes often will need supports within the manhole especially when larger valves or equipment are attached to the piping. These supports will be located on the manhole plans as determined by the designer's expansion compensation calculations for each manhole valving and equipment layout. Typical valve/piping support details are shown in Figure A-5.

3-15.2 Valve Manhole Construction.

Valve manholes will be field constructed of reinforced concrete conforming to the current criteria. Valve manholes will be constructed of 4,000 psi (27.58 MPa) minimum compressive strength concrete. Reinforcing bars will conform to ASTM A 615, grade 60. Typical reinforcing steel details and sizing are shown in Figure 3-1 and Table 3-6 respectively. Concrete floor slabs and walls will be of sufficient weight to prevent flotation in high water table areas. Floor slabs will be sloped to the drain which will be installed in the floor slab. Concrete wall sections will be not less than 8 (203 mm) inches thick and must meet anticipated load and soil conditions. Side walls will be constructed in a monolithic pour. Water stops will be provided at all construction joints. Do not locate valve manholes in roads or parking areas which create an inadequate amount of manhole ventilation and poor access.

Table 3-6 Valve Manhole Reinforcement Steel Sizes

VALVE MANHOLE REINFORCEMENT SCHEDULE							
MAXIMUM DIMENSION* (Imperial Size) Metric Size		**WALL REINFORCEMENT (Imperial Size) Metric Size**		**SLAB REINFORCEMENT (Imperial Size) Metric Size**			
OUTSIDE L1XW1	INSIDE L2XW2	HORIZONTAL	VERTICAL	BOTTOM PRINCIPAL	TOP** PRINCIPAL	BOTTOM SECONDARY	TOP SECONDARY
(9'4"X9'4") 2.74 m x 2.74 m	(8'0"X8'0") 2.44 m x 2.44 m	(#5@10") #16@254 mm	(#5@12") #16@ 305 mm	(#4@18") #13 @457 mm	(#5@10") #16@254 mm	(#4@18") #13 @457 mm	(#4@18") #13 @457 mm
(15'4"X15'4") 4.67 m x 4.67 m	(14'0"X14'0") 4.27 m x 4.27 m	(#5@6") #16@152 mm	(#5@10") #16@254 mm	(#4@18") #13 @457 mm	(#5@10") #16@254 mm	(#4@18") #13 @457 mm	(#4@18") #13 @457 mm

<u>Notes to the Designer</u>

* L1, L2, W1, AND W2 dimensions from Figure 3-1. Maximum depth (H1) for this table is 8'0" (2.44 m)

** Principal reinforcement will span the shorter dimension

Reinforced concrete design is based on the following:

1. Loads: 200 PSF (976 kg/m^2) surcharge adjacent to vault.
2. Soil properties: Moist = 120 pcf water table 2' (610 mm) below surface
   Saturated = 125 pcf (2002 kg/m^3) bearing cap. = 1500 psf (7320 kg/m^2) Min.
   Ko = .80

3-15.3 Valve Manhole Covers.

The valve manhole cover types discussed here are: raised solid plate, supported cover, and concrete.

3-15.3.1 Raised Solid Plate Covers.

Raised solid plate covers are preferred for HTW and steam/condensate systems installed in Pre-Engineered Underground Heat Distribution Systems. For shallow concrete trench systems, the raised solid plate cover’s raised feature will interfere with the trench's walkway function. When the valve manhole cover must remain flush with the trench top, the supported cover is the preferred type. For the raised solid plate cover, ventilation openings are provided around the entire perimeter below the raised top. The height of the valve manhole wall above grade (6 inches [152 mm], minimum) must be sufficient to prevent surface water entry. The solid plate cover assembly is removable. The cover, constructed of aluminum, also provides sectionalized access for inspection and maintenance. For site/facilities which the government requires the cover plates to be locked to prevent unauthorized access. Design shall include necessary equipment/devices to provide the necessary locking capabilities to meet the government requirements. The solid plate cover raised frame design and section, lifting lug, and handle details are shown in Figure 3-2 through Figure 3-8. Figure 3-9 contains notes for raised solid plate cover figures.

3-15.3.2 Supported Covers.

Supported covers may be used for any distribution system covered in this UFC. For Pre-engineered Underground or Prefabricated Underground Heat Distribution Systems, design the cover to be at least 6 inches (152 mm) above the surrounding grade. When used for concrete shallow trench systems, the finished top will be flush with the concrete trench top. Required grates or other structural members used for supporting covers to be made of corrosion resistant material such as galvanized steel. Details for the supporting cover are shown in Figure 3-10 through Figure 3-14. These details are designed for loadings up to 150 psf (732.4 kg/m^2) and must be re-evaluated for larger loadings. Other structural solutions for supporting the checkered plate are acceptable. The checkered plate cover (also referred to as diamond or embossed plate) as shown in Figure 3-14, will be installed over grating or other structural supports in most locations to minimize the influx of leaves and other debris. The checkered plate is attached to the grating and is removable.

3-15.3.3 Concrete Covers.

The use of concrete covers is discouraged, but, if used, they must be used with 4 ft x 4 ft (1.22 m x 1.22 m) aluminum doors for any distribution system covered in this UFC. Concrete covers must only be used if desired by the Government or if specific design conditions exist, such as below to aboveground system transitions. When used for Pre-engineered Underground or Prefabricated Underground Heat Distribution Systems, design the top of the concrete cover to be a minimum of 6 inches (152 mm) above the surrounding grade. When used for concrete shallow trenches, design the cover to be flush with the trench top. Concrete requirements for this cover are similar to those required for valve manhole construction. Concrete cover will be designed to support anticipated loadings. Figure 3-15 shows a typical concrete cover plan and Figure 3-16 provides construction details for this cover. The concrete cover detailed is designed for loadings up to 150 psf (732.4 kg/m^2). For greater loadings, the design must be re-evaluated. A disadvantage of concrete covers is the difficulty in providing ventilation. For concrete shallow trench systems, a single 6 inch (150 mm) gooseneck pipe will be used, as detailed in Figure 3-17, to allow steam to exit the valve manhole if a leak or excessive heat loss is present. Note that for shallow trench systems, the gooseneck will be installed off to one side of the valve manhole concrete top to minimize pedestrian traffic interference. For Pre-engineered Underground Heat Distribution Systems, two 6 inch (150 mm) goosenecks will be used. One will extend below the top as detailed in Figure 3-17. The other will be similar but will extend to within 8 inches (203 mm) of the valve manhole floor on the opposite side of the manhole.

3-15.4 Valve Manhole Drainage.

Drainage of water from the valve manhole is mandatory for the successful operation and longevity of buried heating or cooling distribution systems. There are three types of valve manhole drainage systems described below: gravity drainage, pumped drainage from a sump basin, and pumped drainage from the valve manhole.

3-15.4.1 Gravity Drainage.

The most cost effective and lowest maintenance system is gravity drainage to a storm drain when location, depth of existing storm drains, and local regulatory requirements allow this possibility. Drainage lines will be 6 inches (150 mm) in diameter minimum and will conform to the latest storm drain criteria and will be sloped at one percent, minimum. Valve manhole outlet will be a floor drain with back water valve or ball float to prevent storm water inflow from the storm drain (see Figure 3-18). Note that valve manhole drain outlets must be covered with a dome type strainer to minimize the accumulation of trash over the drain inlet. Also, the manhole floor will be sloped toward the drain.

3-15.4.2 Pumped Drainage from Sump Basin.

For pumped drainage, a duplex submersible pump system installed in a remote sump basin may be provided as indicated in Figure 3-19 and Figure 3-20. The sump basin will be located no more than 10 feet (3.05 m) from the valve manhole. Drainage from the valve manhole to the sump basin will be similar to drainage to a storm drain including the valve manhole floor drain (Figure 3-18). Discharge from the pumps can be routed to a splashblock at grade or to an adjacent storm sewer. The pump discharge to storm sewer shall include a gate valve and full flow check valve. The check valve shall be located between the gate valve and the pump. Design of the surrounding grade must ensure drainage away from the sump basin, valve manhole and concrete shallow trench (if used) when discharging to grade. A power pedestal complete with failure warning light will be provided with each basin as shown in Figure 3-21. A typical wiring diagram and sequence of operation are shown in Figure 3-22. See UFGS 22 14 29.00 *Sump Pumps* for sump pump requirements including electrical requirements. A specification for the sump basin system can be included in the applicable manhole or heat distribution section of the contract specification. The sump basin design has proven to operate well even in the colder climates of the upper tier states in the continental United States. It is also an excellent method to retrofit existing manholes that currently do not drain properly. The remote sump basin increases the life of the systems by removing the sump pump and pump controls from the hot, humid environment of the manhole. Also, pump maintenance will be done outside of the manhole. The pumps are easily disconnected and lifted to grade. The sump pumps used in the sump basin must incorporate the following design characteristics:

- Electrically driven.
- Duplex system with alternator.
- Dedicated electrical service.
- Submerged operation in 200°F (93°C) water.
- Entire pumping system capable of 200,000 cycles of operation in 200°F (93°C), 100% relative humidity environment.
- Permanently lubricated bearings.
- Bronze impeller.
- Monel shaft.
- Capable of passing 3/8 inch spheres.
- Screened inlet.
- Bronze housing.

3-15.4.3 Pumped Drainage from Valve Manhole.

Another means to pump water from the manhole is to locate the duplex sump pumps in the valve manhole. Typically, a 2 ft by 2 ft by 1 ft (610 mm by 610 mm by 305 mm) deep sump will be provided in a corner of the valve manhole. The duplex sump pumps will be installed to pump out of this sump. Typical valve manhole sump pump electrical arrangement is shown in Figure 3-23. The control panel with high level warning light will be mounted adjacent to the valve manhole at grade. This keeps the electrical panel out of the hot, humid environment of the manhole. The sequence of operation and wiring diagrams will meet the requirements of Figure 3-22. Pump discharge can be routed to a splash block at grade (similar to the sump basin discharge piping arrangement on Figure 3-19) or to an adjacent storm drain. When discharging to a storm drain, the pump discharge shall include a gate valve and check valve. Check valve shall be located between the gate valve and the pump. Electric sump pumps used in the valve manholes must incorporate the design characteristics listed in paragraph 3-15.4.2. Note that life of the pumps are typically shortened when installed in the hot and humid valve manhole environment.

3-15.5 General.

3-15.5.1 Valve Manhole Wall Penetrations.

A design must be provided for the distribution system wall penetrations. For a shallow trench system, the wall penetrations will typically be the same size as the inside dimension of the shallow trench connecting to the valve manhole. For shallow trench dimensions, refer to Chapter 5. Structural reinforcement must be designed around this opening. Drainage from the trench will then flow into the manhole. For Pre-engineered or Prefabricated Underground Heat Distribution Systems, sleeved openings will typically be provided with an expandable link-seal between the casing and the pipe sleeve as indicated on Figure 3-24. Structural reinforcement must be designed to avoid contact with the pipe sleeve and water stop to prevent grounding of the system's cathodic protection.

3-15.5.2 Waterproofing.

Waterproof membranes will be placed in or below the concrete bottom slab and continued up the outer sides to the top of the sidewalls in accordance with the valve manhole guide specification.

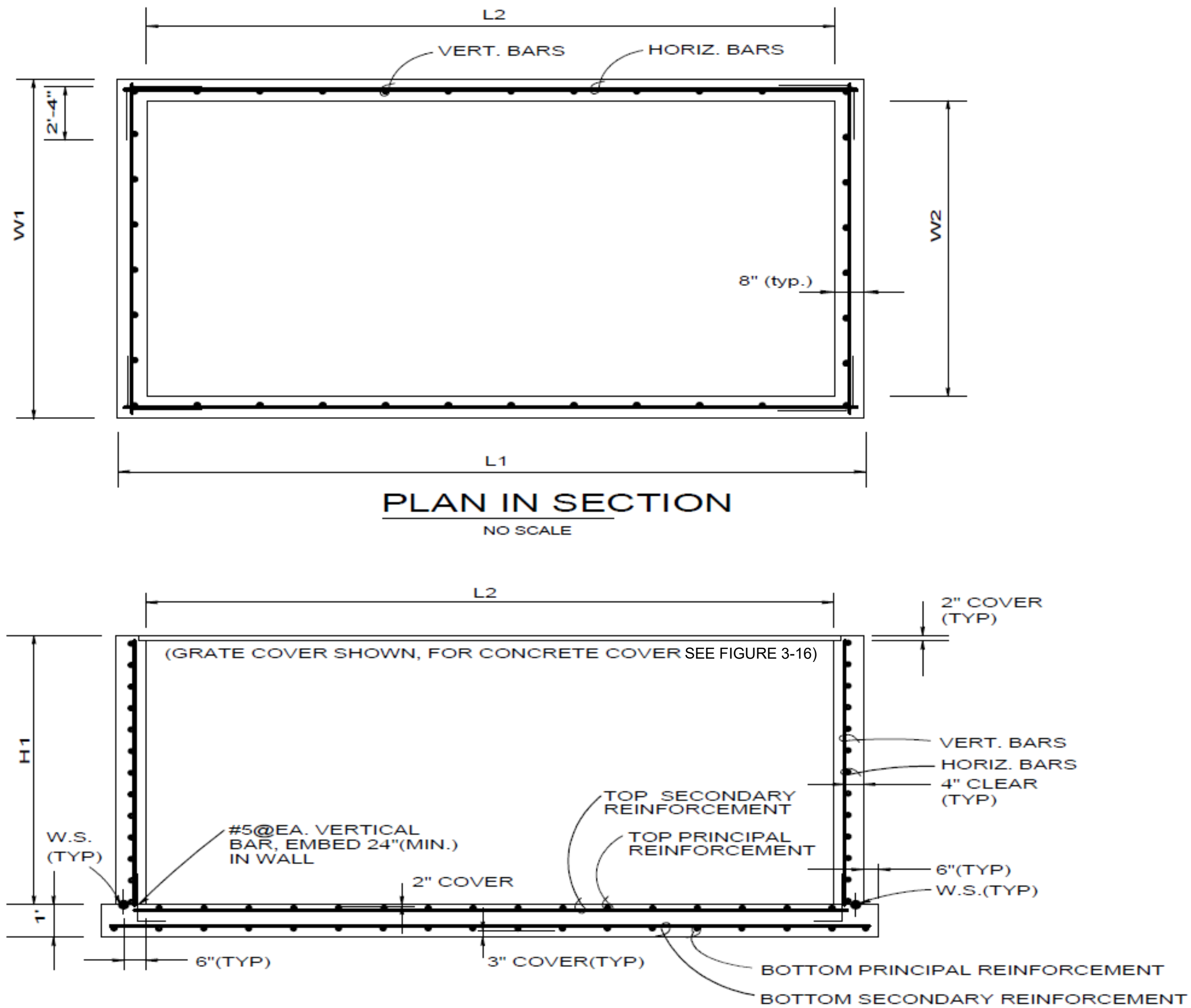
3-15.5.3 Pipe Anchoring Adjacent to Valve Manholes.

Regardless of the buried distribution system, pipe anchors are typically provided between 2 to 5 feet (0.61 to 1.52 m) of a manhole wall to minimize movement through the manhole. For piping which passes through valve manholes, anchoring on one side only is typically adequate. Anchoring piping on more than one side may restrict piping movement and overstress the piping in the valve manhole. Anchors will typically be provided as part of the distribution system and will not be embedded in the manhole wall. However, if the manhole is used to support an anchor, the manhole must be designed to withstand the forces exerted by the system. Expansion compensation stress calculation will always be conducted to ensure proper anchor locations throughout the distribution system. These calculations must also account for the expansion in the valve manholes.

3-15.5.4 Piping Materials in Valve Manholes.

Nonmetallic piping must not be used in the same valve manholes as piping carrying higher temperature media that could cause the temperature around the non-metallic piping to exceed the allowables and potentially cause permanent damage to the non-metallic piping. In addition, chilled water systems with polyvinyl chloride (PVC) carrier piping must never be installed in the same valve manhole with any heating system.

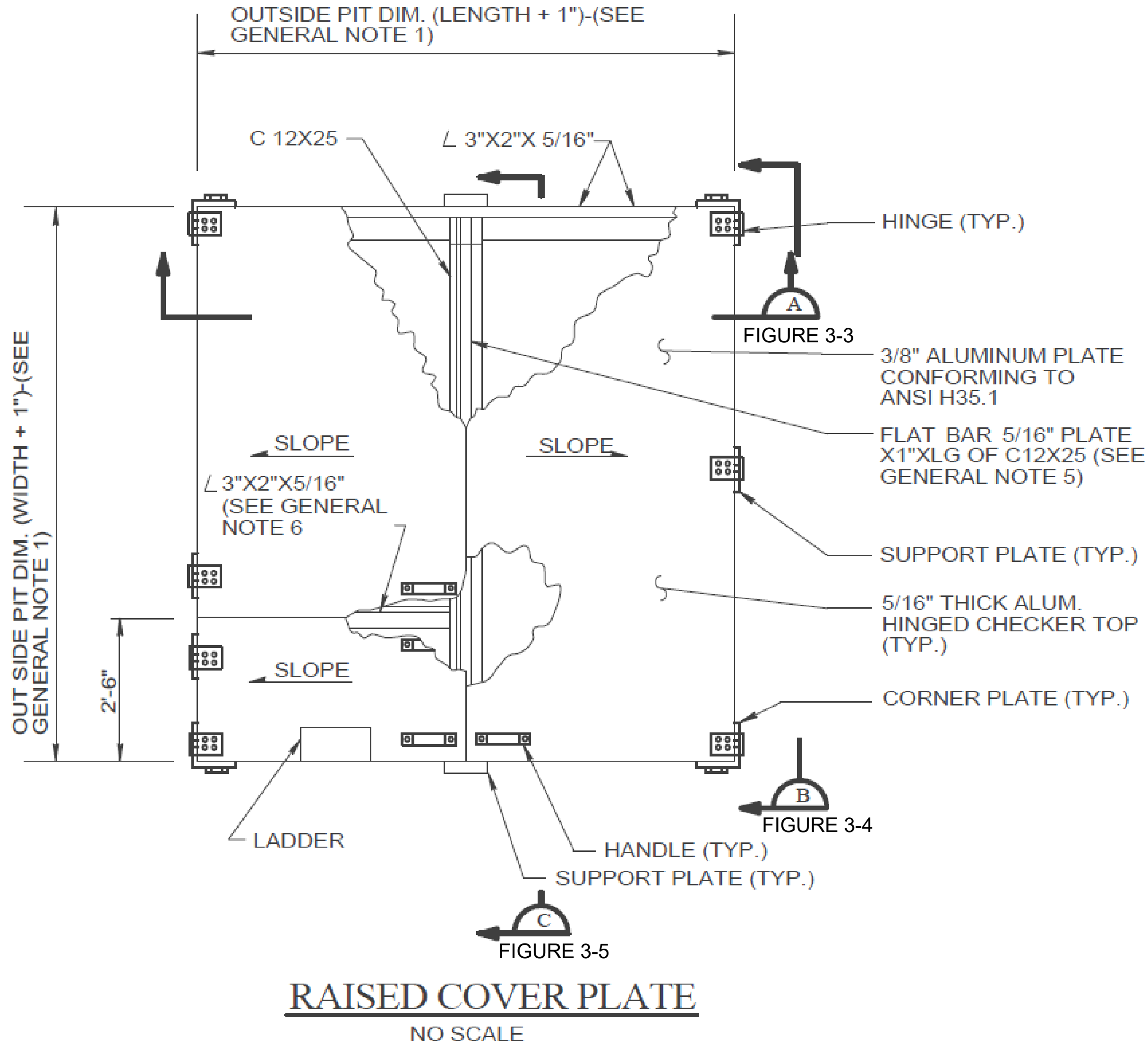
Figure 3-1 Valve Manhole Elevation and Section



Notes:

1. See Table 3-6 for reinforcement bar sizes.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
3. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
4. Imperial rebar #5 is equivalent to metric rebar #16.

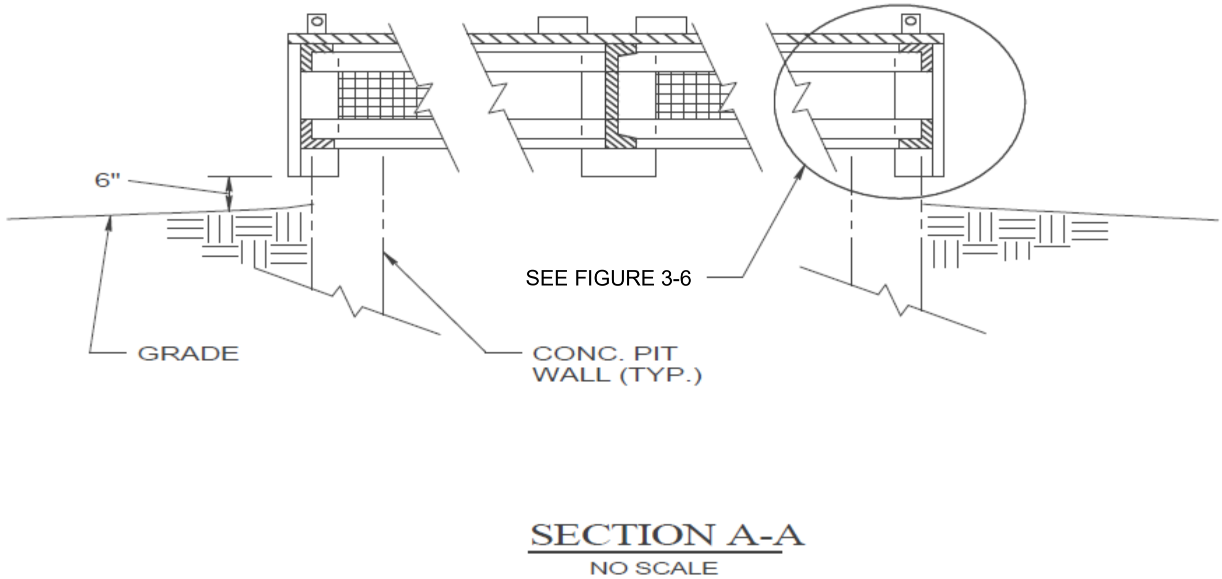
Figure 3-2 Raised Cover Plate Design



Notes:

1. For raised cover plate general notes see Figure 3-9.
2. Note to the Designer: Plate cover shown is designed for loadings up to 40 PSF (195 kg/m^2) when spacing between sidewall and center supports is less than 3'6" (1.07 m). loadings or spacings greater than these must be designed for on a case by case basis.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
4. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
5. Imperial channel member C12x25 is equivalent to metric channel member C310x37.

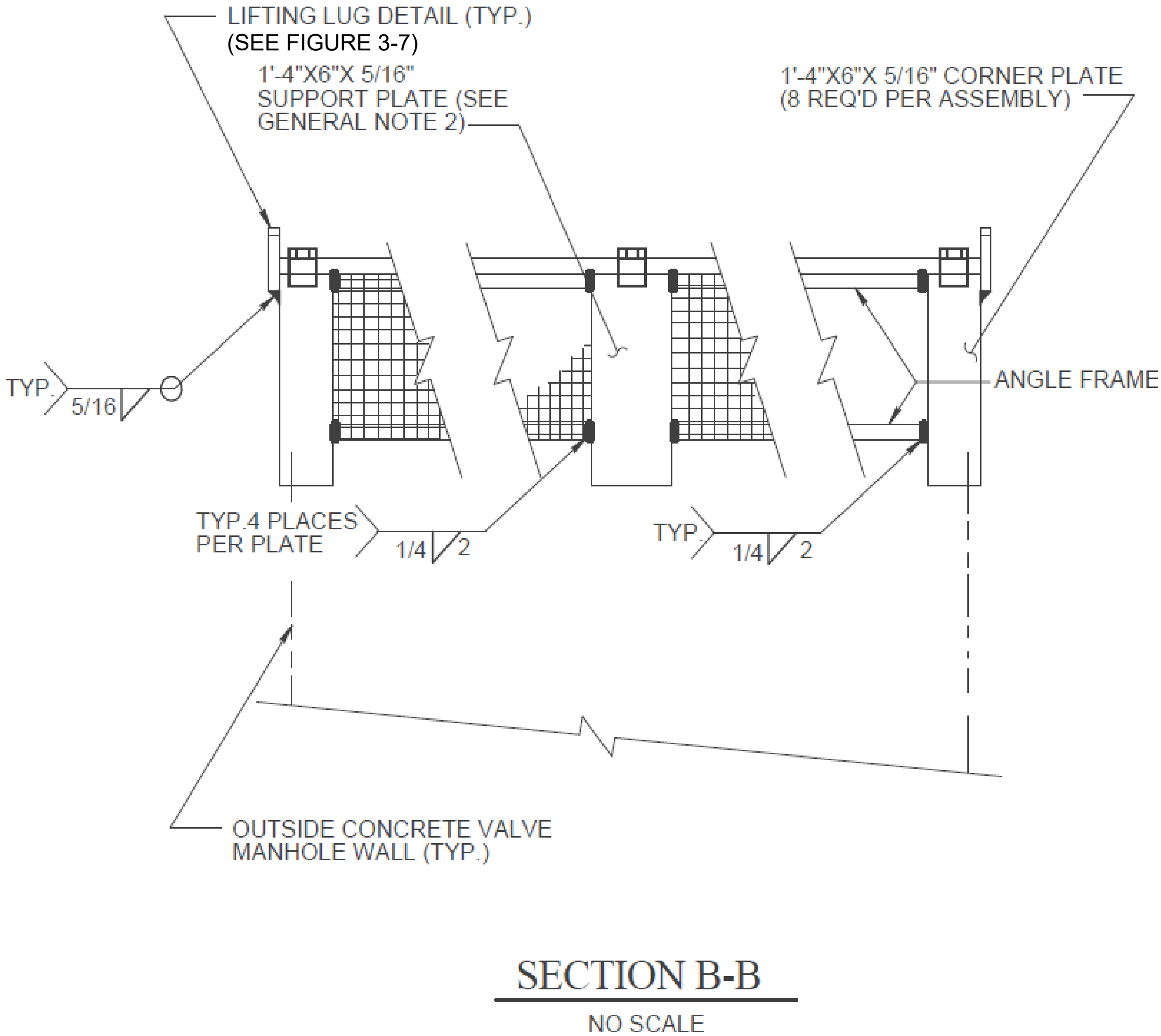
Figure 3-3 Section A-A of Raised Cover Plate



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

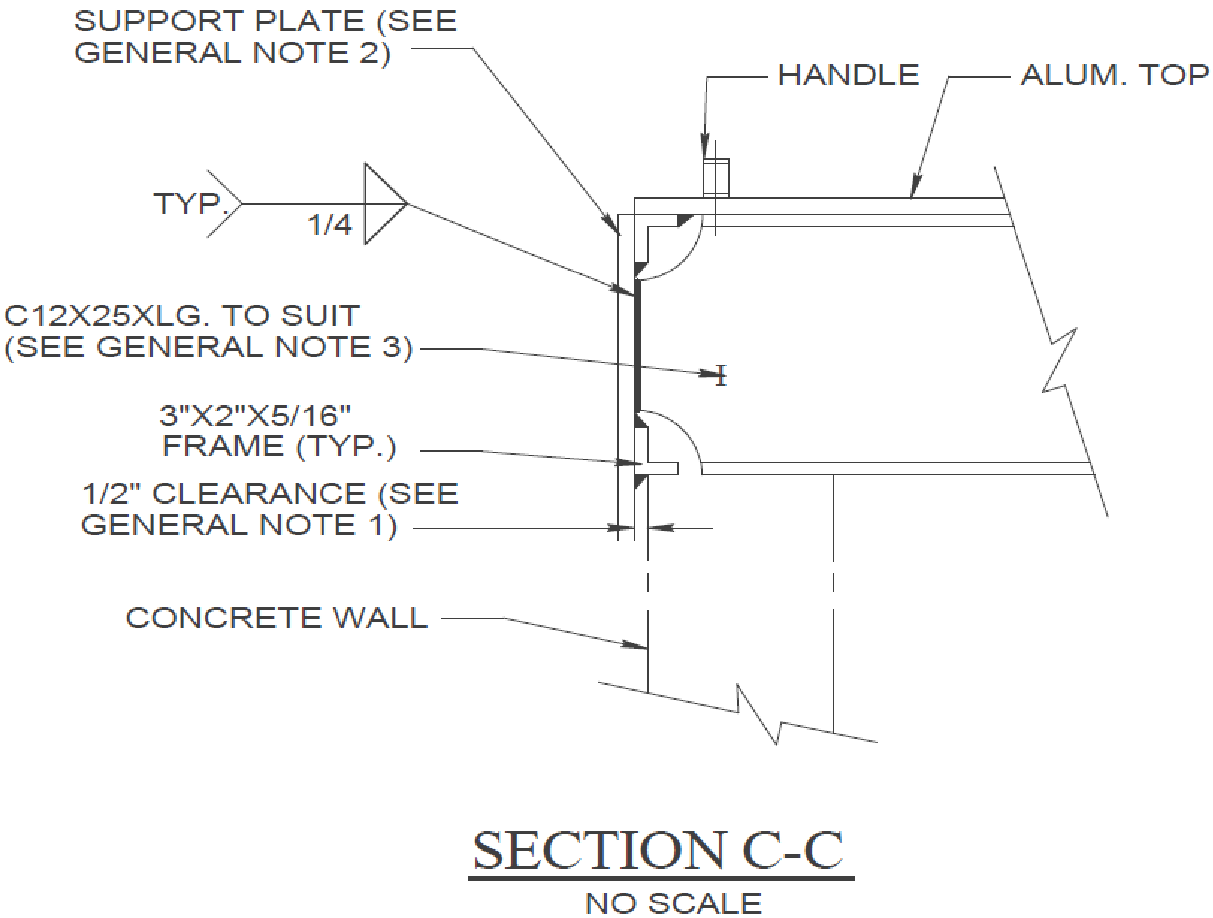
Figure 3-4 Section B-B of Raised Cover Plate



Notes:

1. For raised cover plate general notes see Figure 3-9.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
3. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.

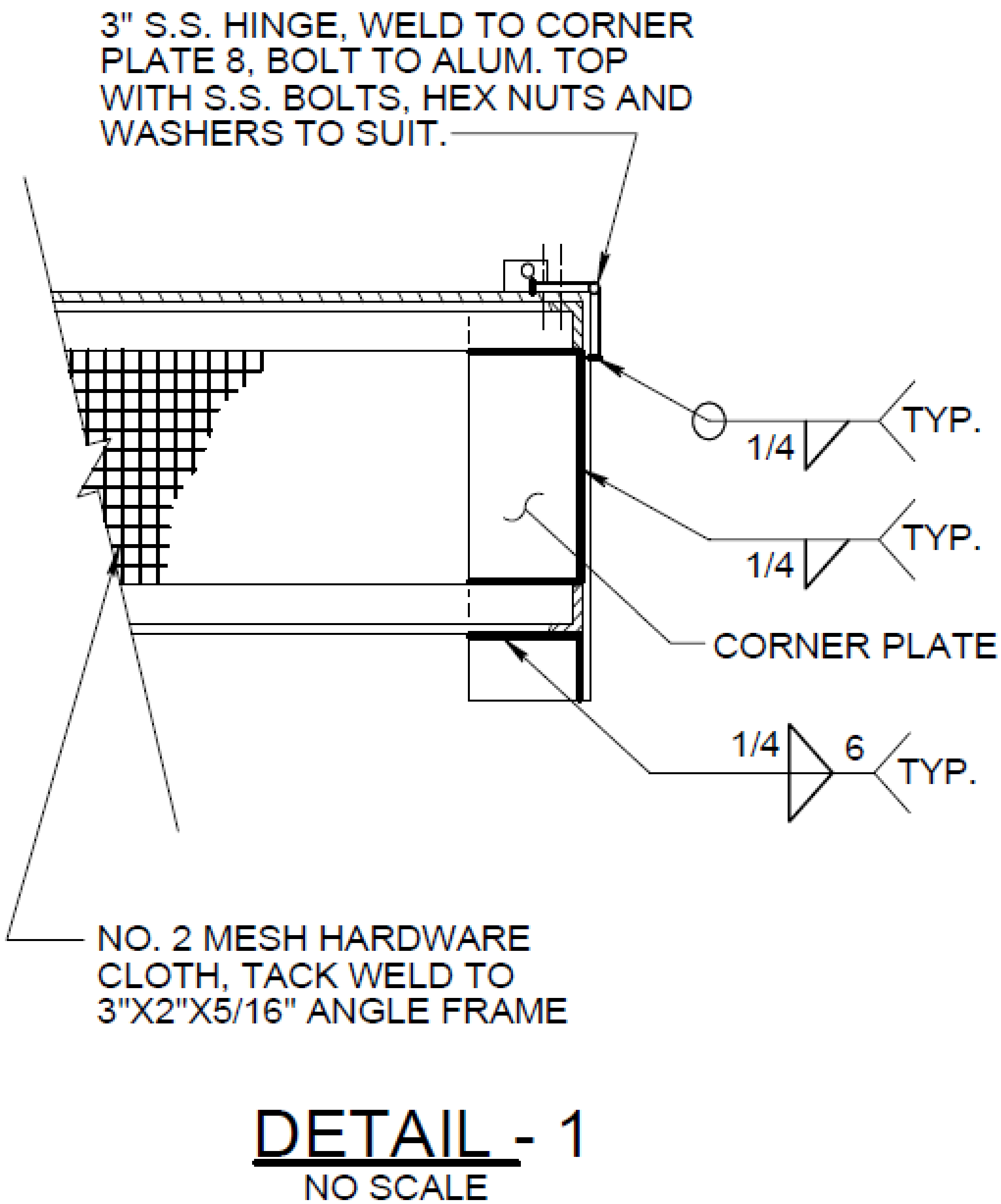
Figure 3-5 Section C-C of Raised Cover Plate



Notes:

1. For raised cover plate general notes see Figure 3-9.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
3. Imperial channel member C12X25 is equivalent to metric channel member C310x37.

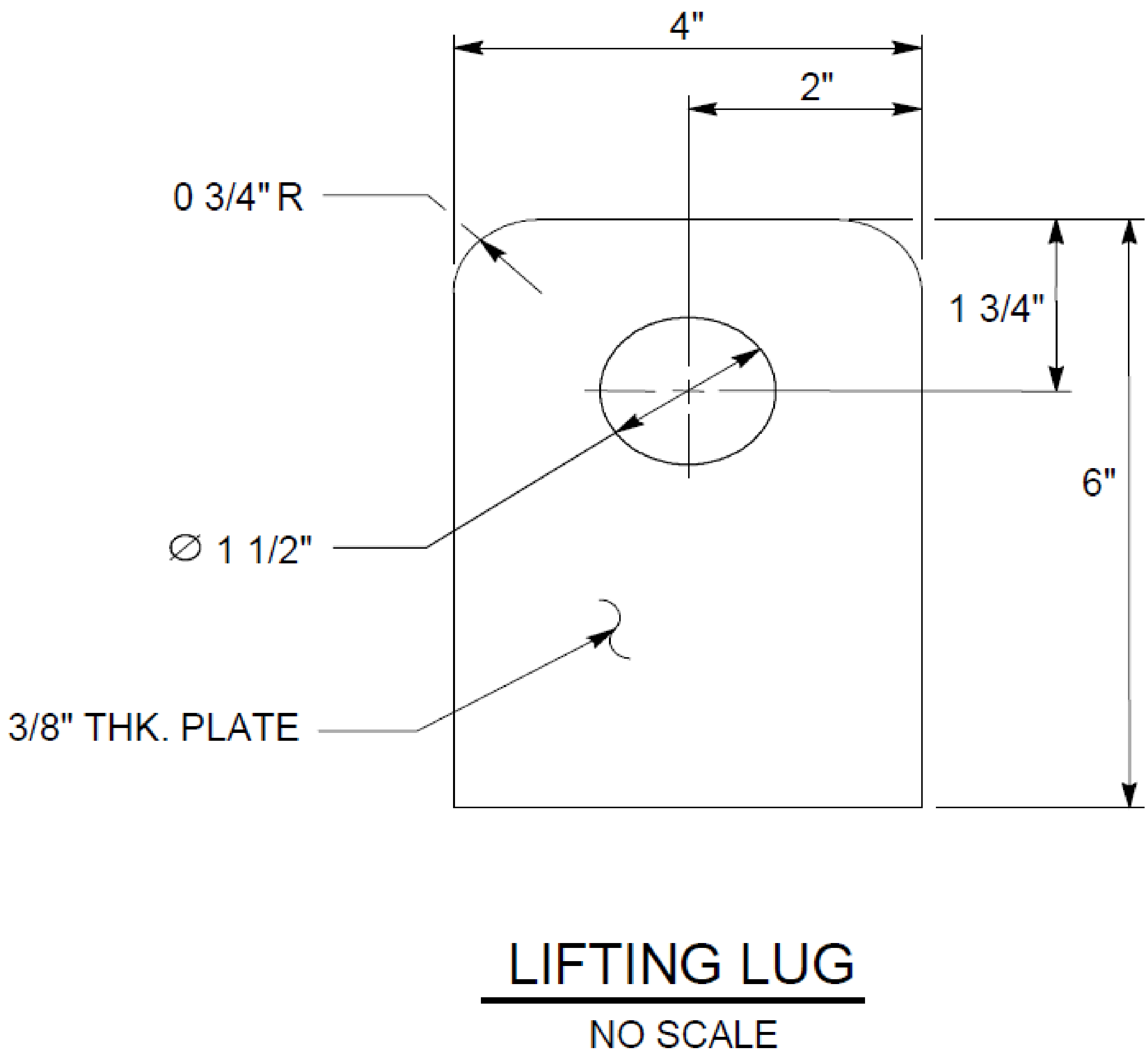
Figure 3-6 Detail of Raised Cover Plate



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

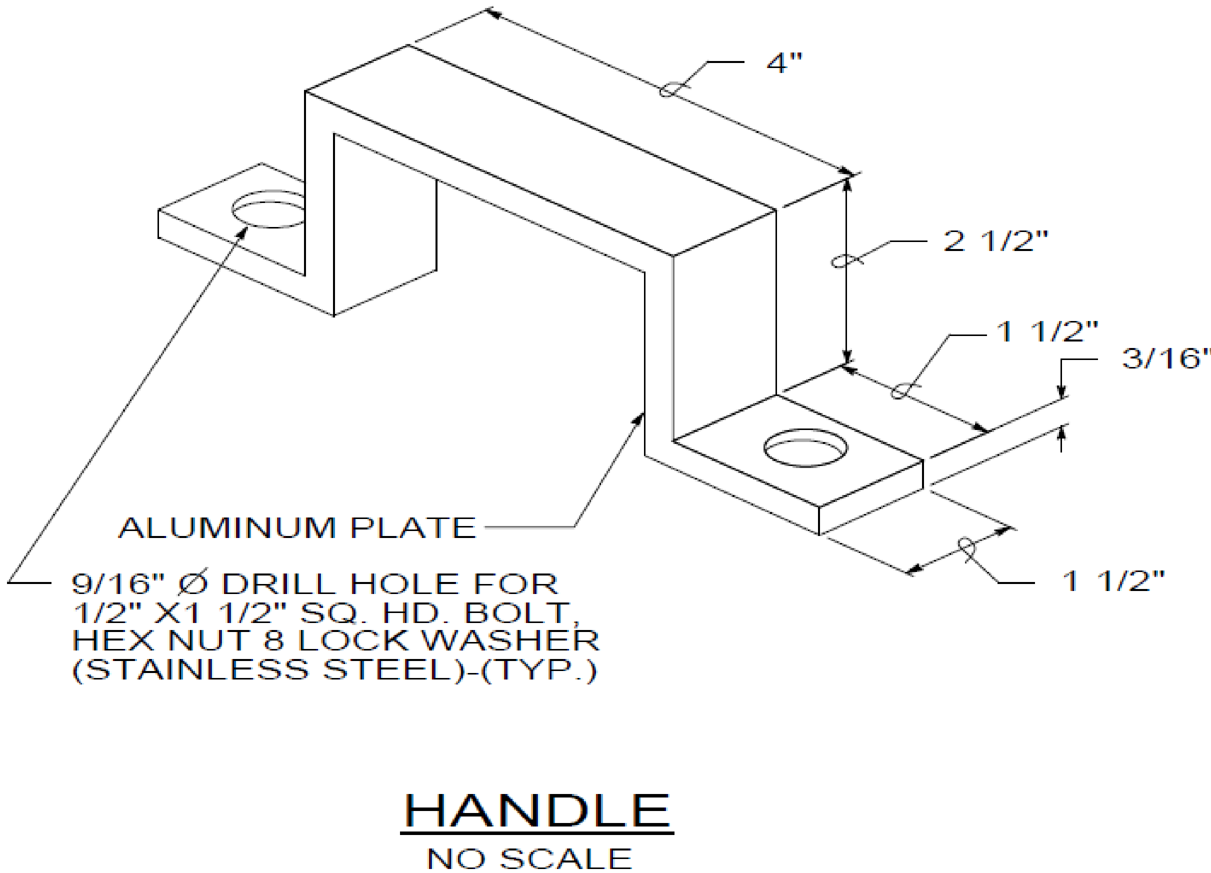
Figure 3-7 Lifting Lug Detail



Notes:

1. 4 lugs required per assembly.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

Figure 3-8 Handle Detail



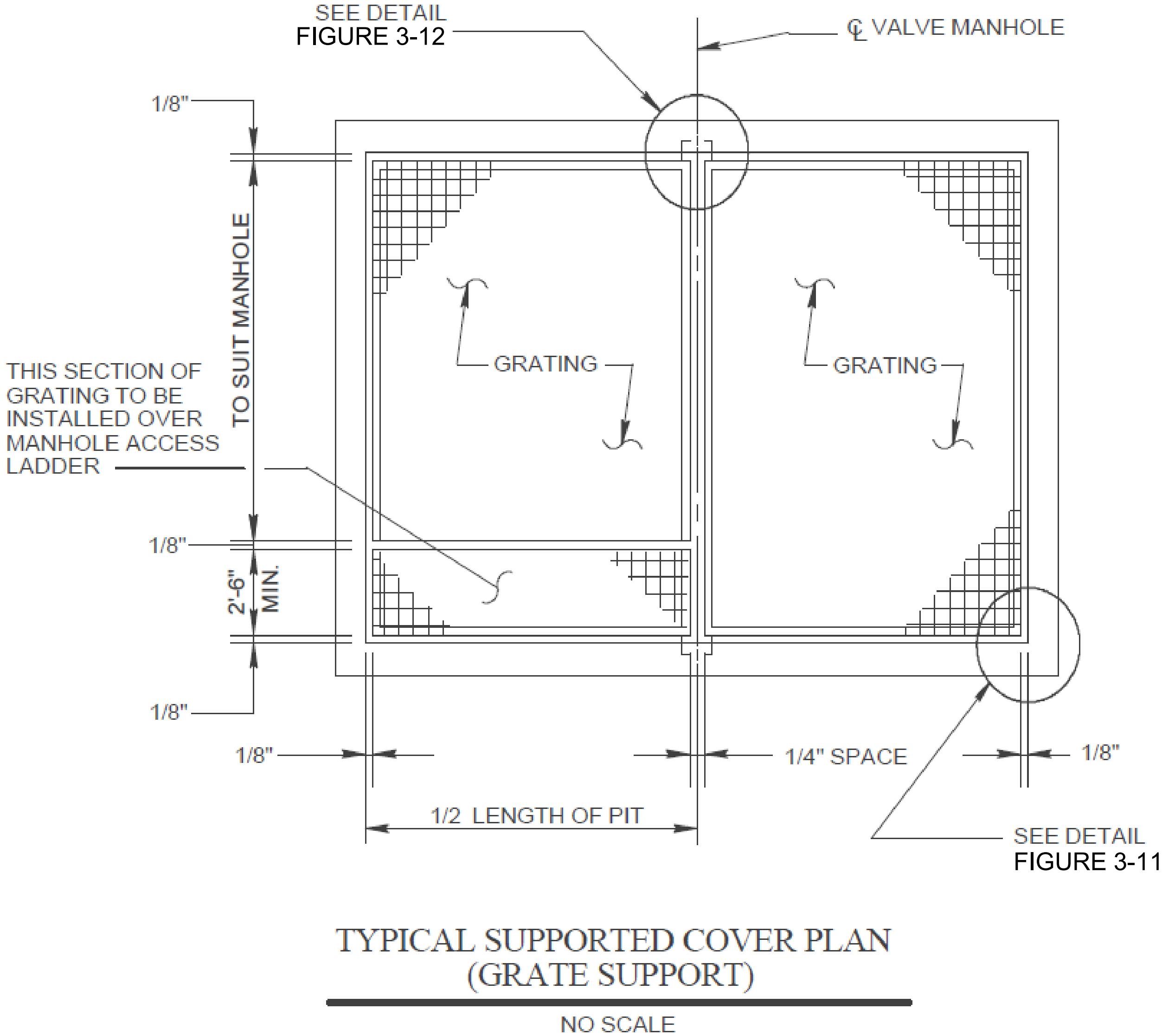
Notes:

1. 2 handles required, per hinged top, minimum 6 per pit cover assembly.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

Figure 3-9 General Notes for Raised Cover Plates

1. FIELD VERIFY OUTSIDE DIMENSIONS OF NEW MANHOLE BEFORE CONSTRUCTING MANHOLE COVER ASSEMBLY. ADD 1" (25.4 mm) TO OUTSIDE MANHOLE DIMENSIONS (TO ALLOW FOR CLEARANCE) TO DETERMINE INSIDE ASSEMBLY DIMENSIONS.
2. EACH SUPPORT PLATE MUST BE LOCATED HALFWAY BETWEEN CORNER PLATES AT 3 SIDES OF MANHOLE. 2 SUPPORT PLATES MUST BE LOCATED BETWEEN 2 SPLIT ALUMINUM CHECKER TOP AT ONE SIDE OF MANHOLE.
3. SUPPORT CHANNELS MUST BE C12X25XLG (C310X37XLG), TO EQUAL WIDTH OR LENGTH DIM. PLUS 1" (25.4 mm) TO SUIT INSIDE ASSEMBLY DIMENSION. THE CHANNEL MUST REST ON THE CONCRETE MANHOLE TOP AND THE ALUMINUM TOP MUST REST ON THE FLAT BAR PLATE.
4. CHANNEL SUPPORT, CORNER PLATES, SUPPORT PLATES, ANGLE FRAME HARDWARE CLOTH, AND LIFTING LUGS MUST BE HOT-DIPPED GALVANIZED BEFORE INSTALLATION ON VALVE MANHOLES.
5. FLAT BAR 5/16" (7.94 mm) THICK WELDED TO TOP OF C12X25 (C310X37) TO MAKE ALUMINUM CHECKER TOP SLIGHTLY SLOPED AS INDICATED. LOCATE FLAT BAR TO MATCH CHANNEL BEFORE WELDING.
6. ANGLE 3"X2"X5/16" (76.2 mm X 50.8 mm X 7.94 mm) WELDED TO C12X25 (C310X37).
7. 3"X2"X5/16" (76.2 mm X 50.8 mm X 7.94 mm) AT EACH END LENGTH MUST EQUAL HALF OF LENGTH OR WIDTH OF VALVE MANHOLE.

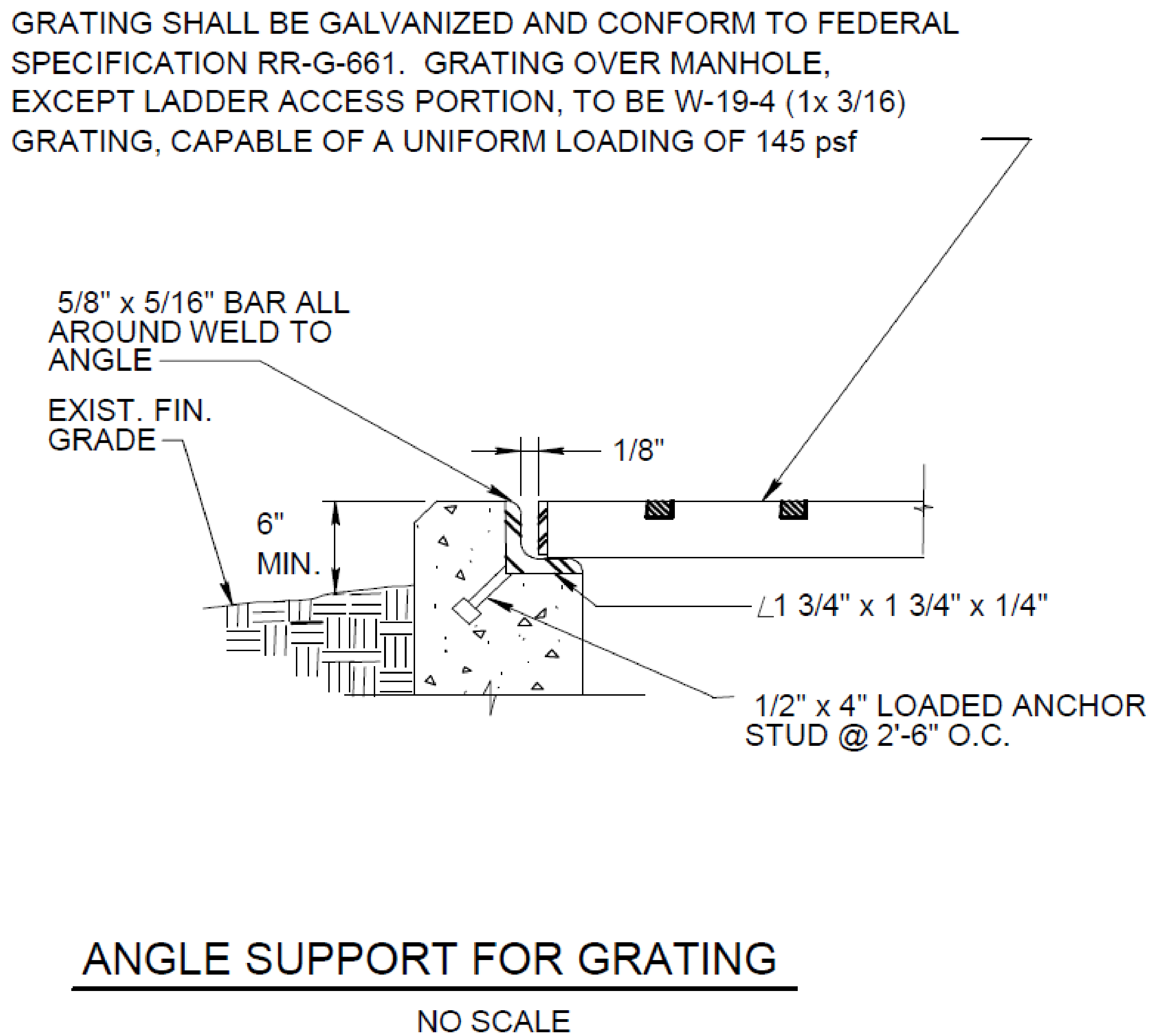
Figure 3-10 Typical Supported Cover Plan (Grate Support)



Notes:

1. Note to the Designer: Grates in Figure 3-10, Figure 3-11, and Figure 3-12 are for loadings up to 150 PSF (732.4 kg/m^2). Loadings greater than these must be designed for on a case by case basis.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
3. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.

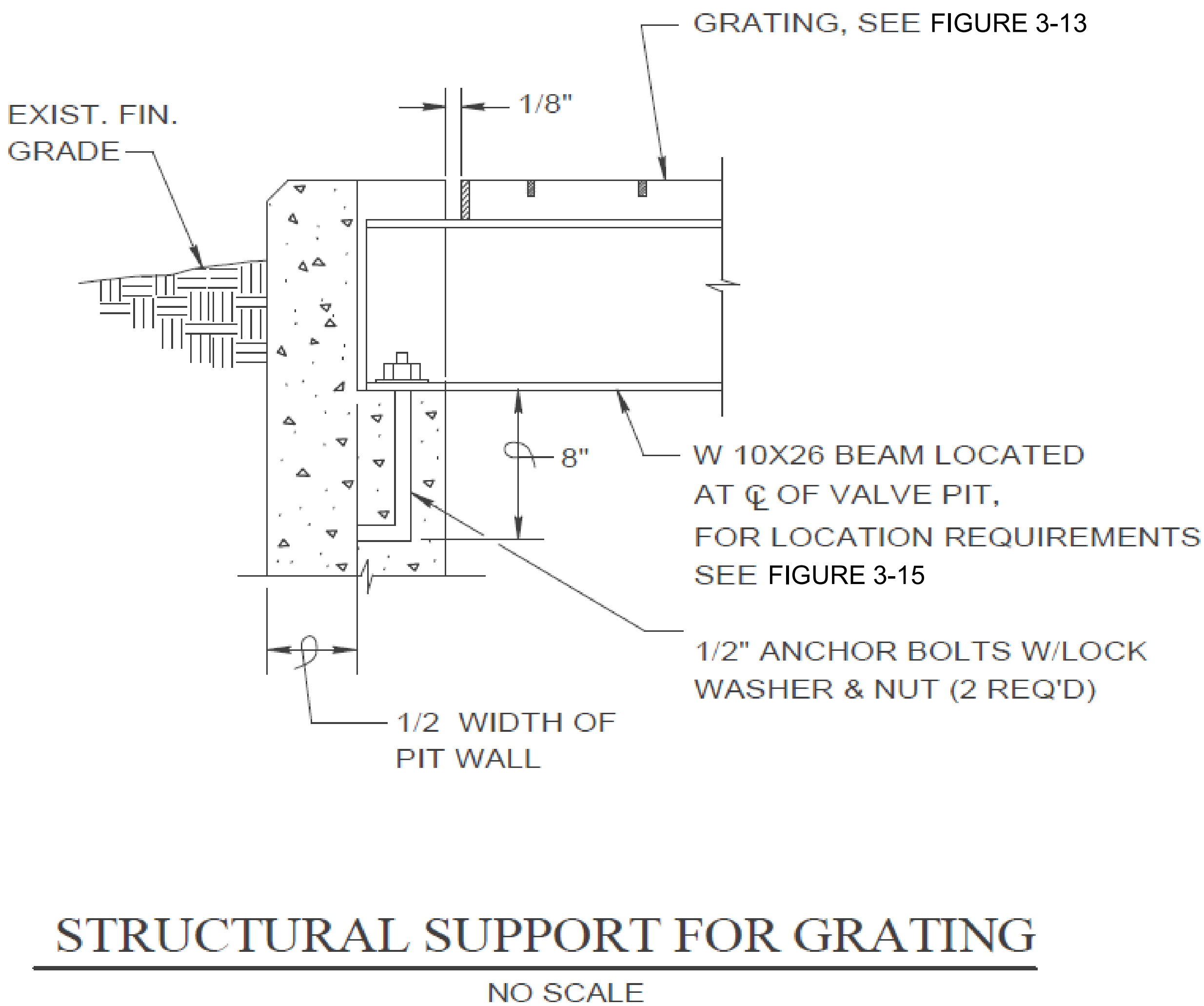
Figure 3-11 Detail of Angle Support for Grating



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
3. Imperial to metric conversion: PSF to kg/m^2 conversion factor is 1 PSF = 4.88 kg/m^2.
4. Imperial grating W-19-4 (1x3/16) is equivalent to metric grating W-30-102 (25x5).

Figure 3-12 Detail of Structural Support for Grating

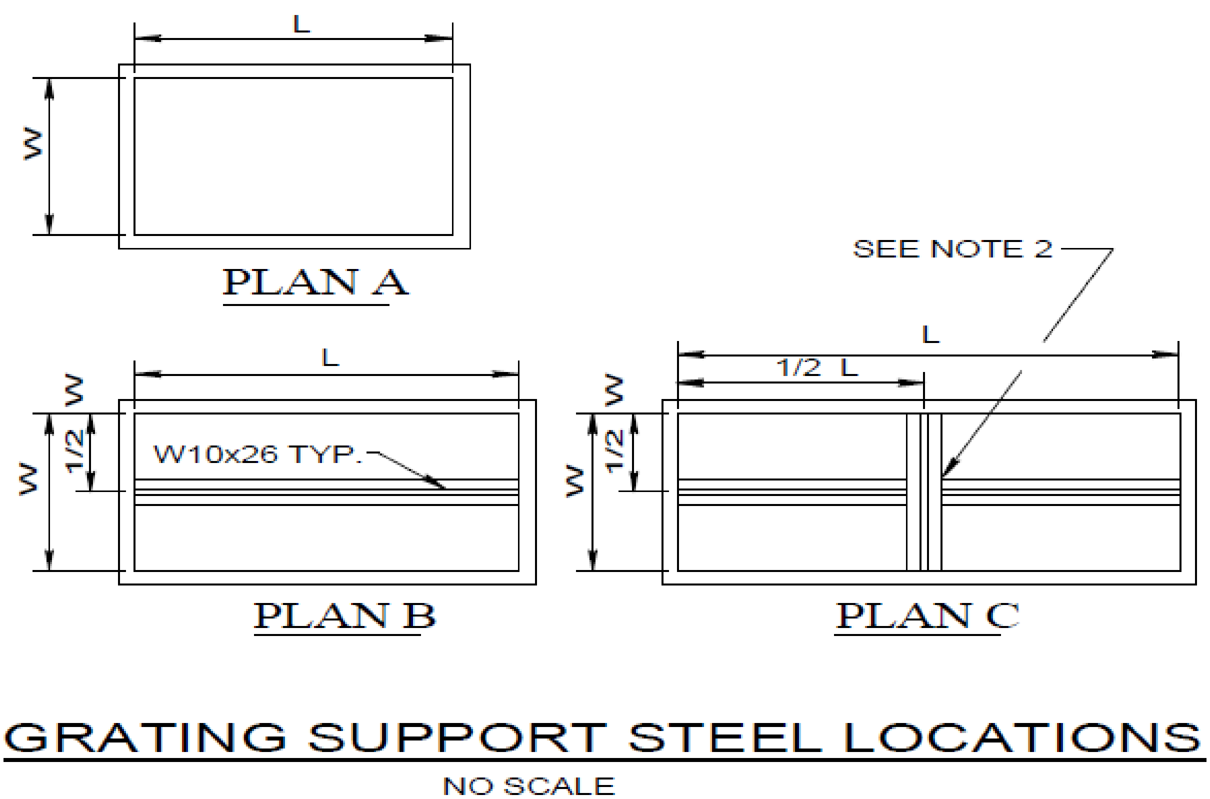


Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Imperial beam member W10x26 is equivalent to metric beam member W350x39.

Figure 3-13 Grating Support Steel Locations

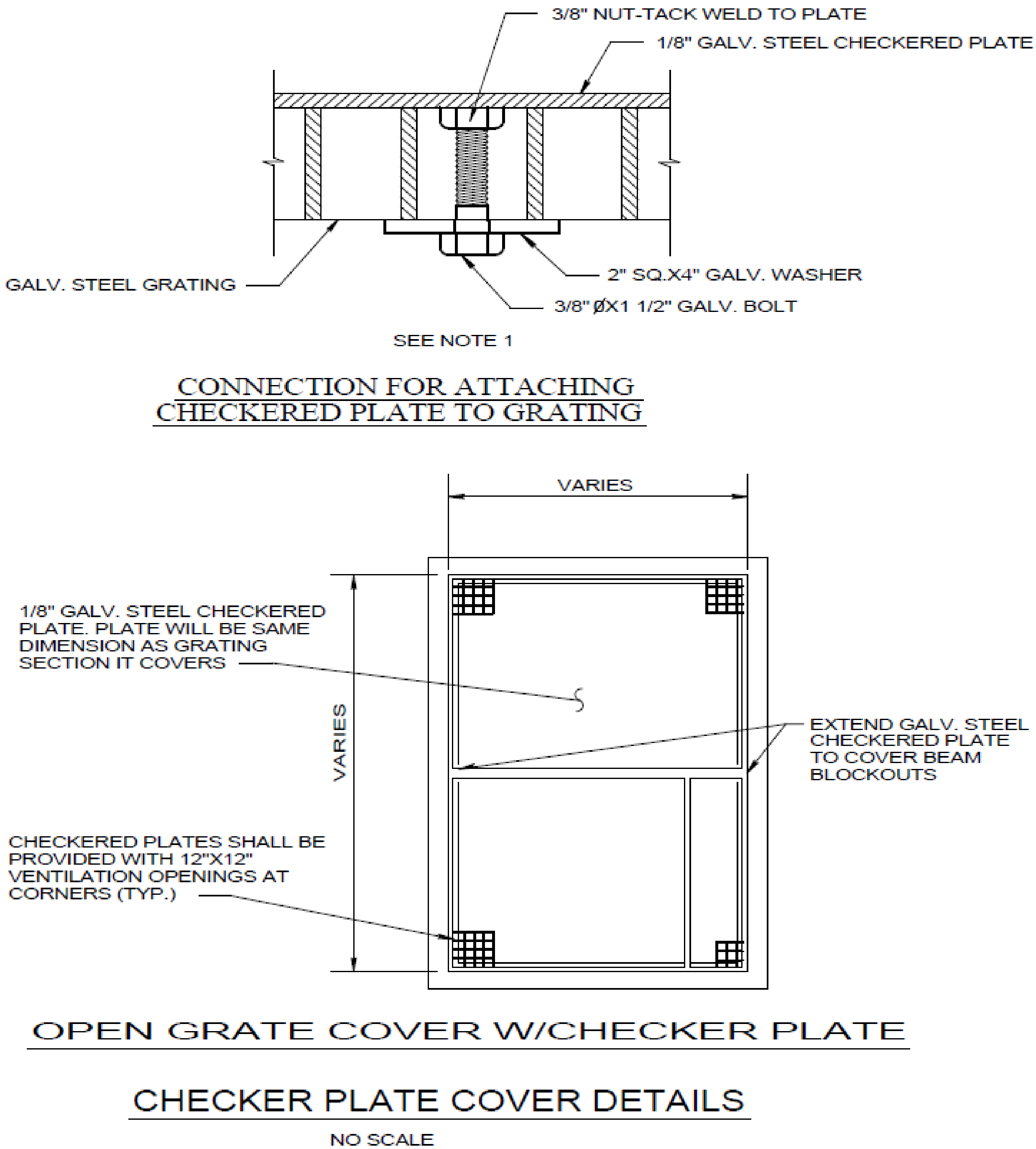
GRATING SUPPORT STEEL			
VALVE MANHOLE PLAN	W-WIDTH	L-LENGTH	REMARKS
A	4 FT (1.22 M) OR LESS	AS REQUIRED	ONE MEMBER REQUIRED
B	GREATER THAN 4 FT (1.22 M) NOT TO EXCEED 12 FT (3.66 M)	AS REQUIRED NOT TO EXCEED 12 FT (3.66 M)	ONE MEMBER REQUIRED
C	GREATER THAN 12 FT (3.66 M) NOT TO EXCEED 16 FT (4.88 M)	GREATER THAN 12 FT (3.66 M) NOT TO EXCEED 16 FT (4.88 M)	THREE MEMBERS REQUIRED



Notes:

1. For valve manhole with dimensions L & W greater than 16 feet (4.88 m) requires steel members and grating to be designed for uniform loading of 145 PSF (707.6 kg/m^2).
2. Intersection of steel members must be designed for loading and dimensions indicated.
3. Imperial beam member W10x26 is equivalent to metric beam member W350x39.

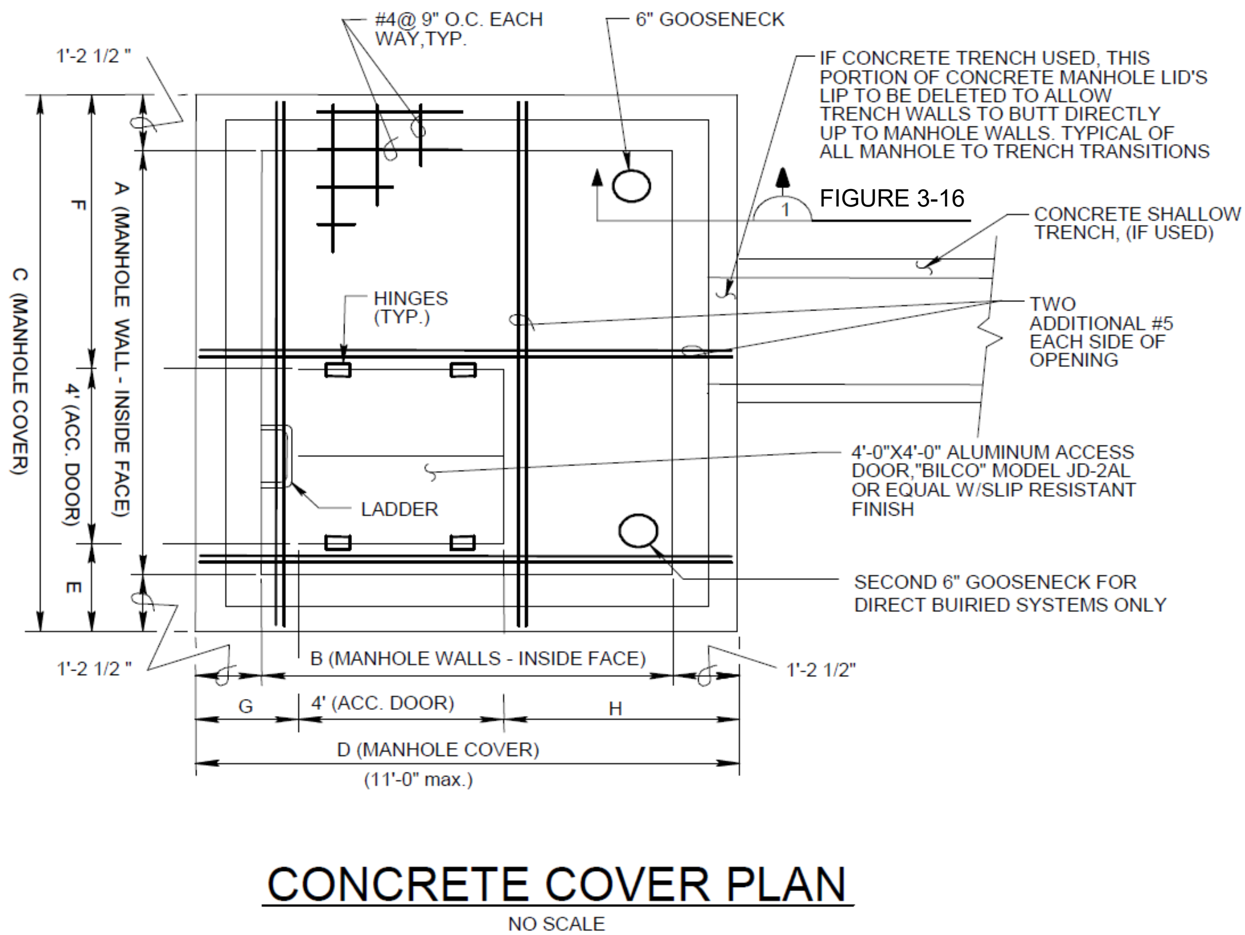
Figure 3-14 Detail of Checker Plate Cover



Notes:

1. Provide a minimum of 4 connections per panel. Connections must be 4 1/2" from edges of panels and 10" from ends of panels.
2. Spacing between panels and between panels and angles must be 1/4".
3. Note to the designer: Checkered plate to be used to cover grating in cold climates and areas where trash accumulation is a concern.
4. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

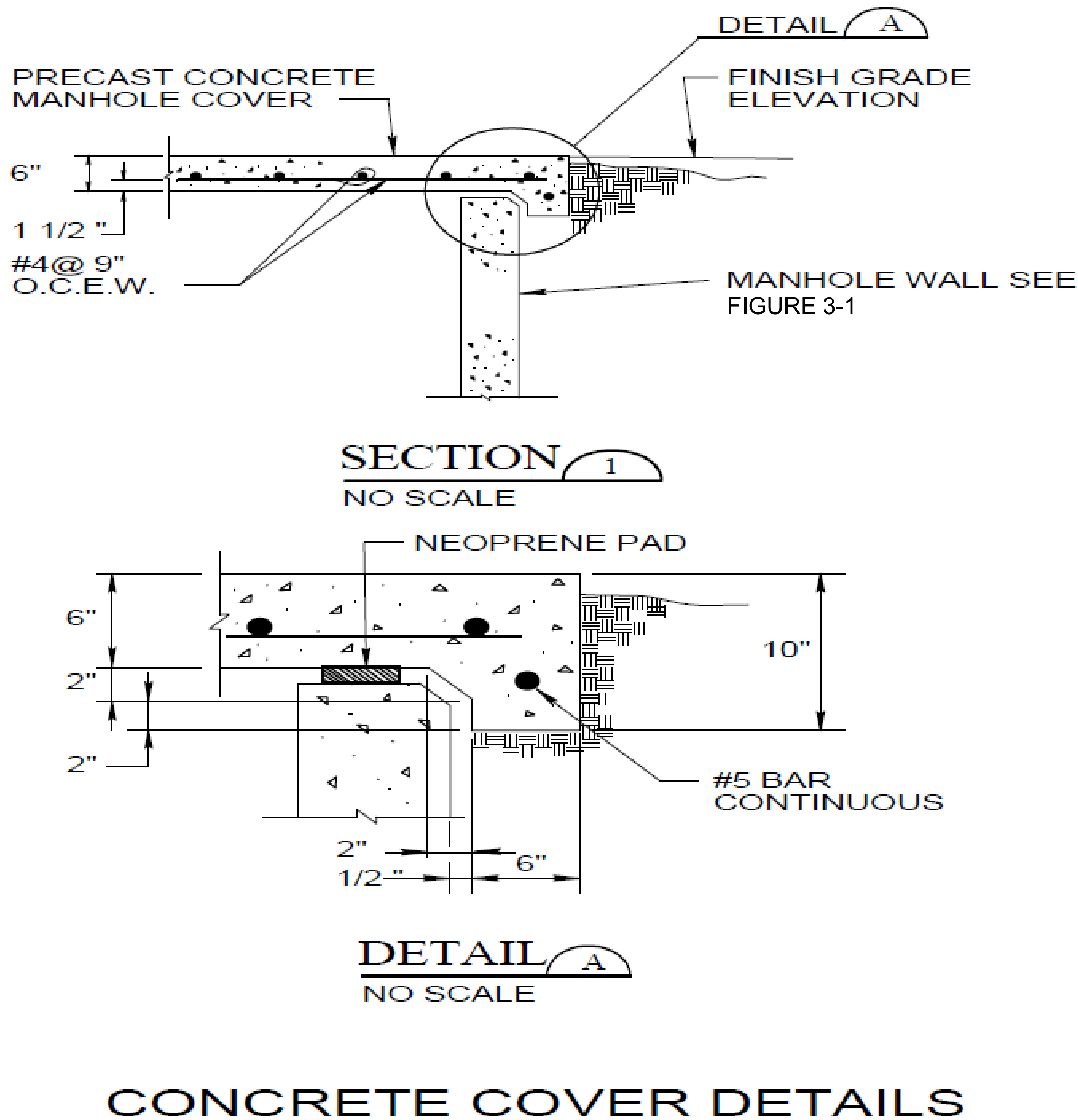
Figure 3-15 Typical Concrete Cover Plan



Notes:

1. Note to the Designer: Concrete cover detailed is designed for loadings up to 150 PSF (732.4 kg/m^2). Loadings greater than these must be designed for on a case by case basis.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
3. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
4. Imperial rebar #4 is equivalent to metric rebar #13.
5. Pipe sizes imperial to metric conversion: 6" = 150 mm.

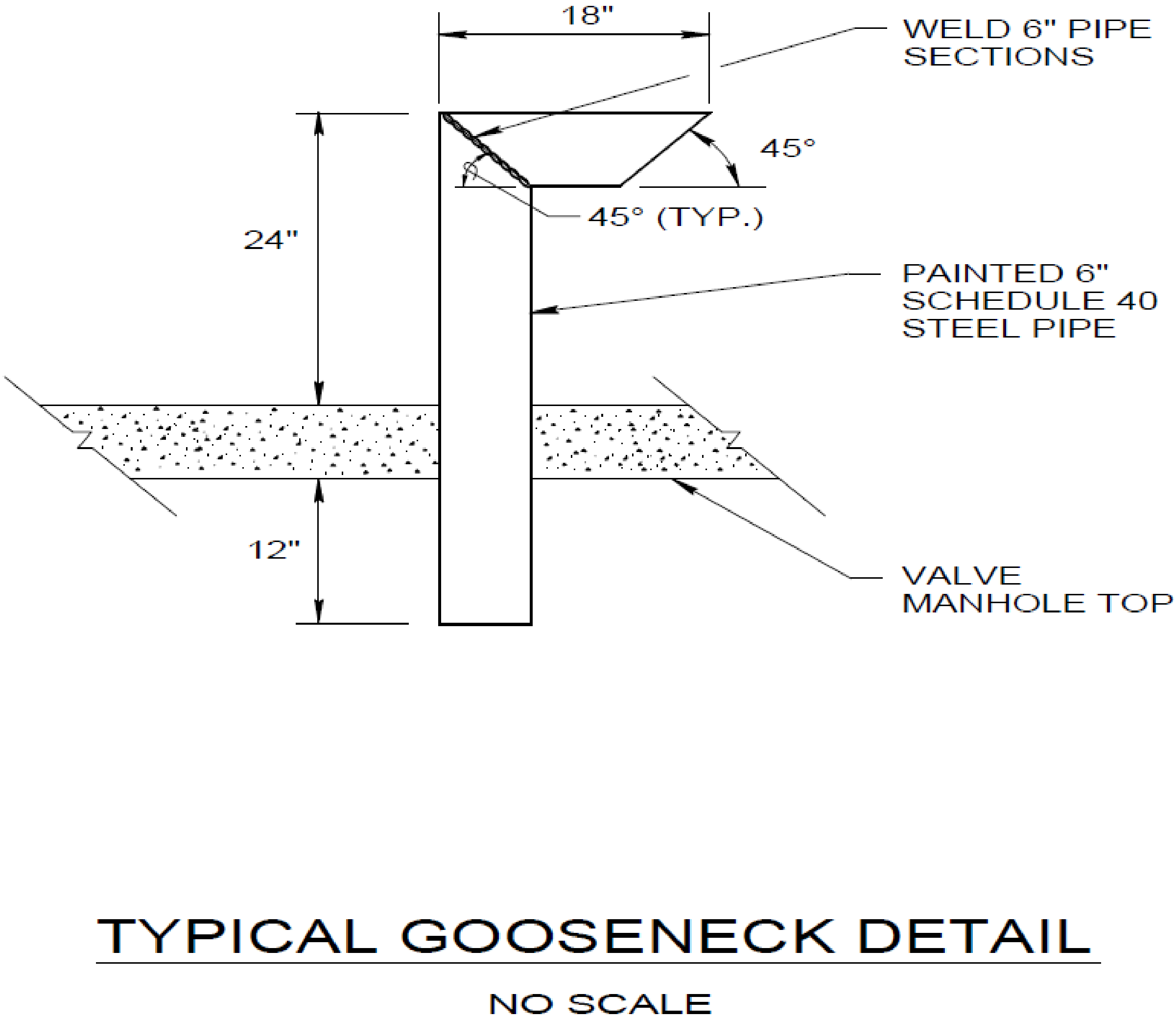
Figure 3-16 Concrete Cover Details



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Imperial rebar #4 is equivalent to metric rebar #13.
3. Imperial rebar #5 is equivalent to metric rebar #16.

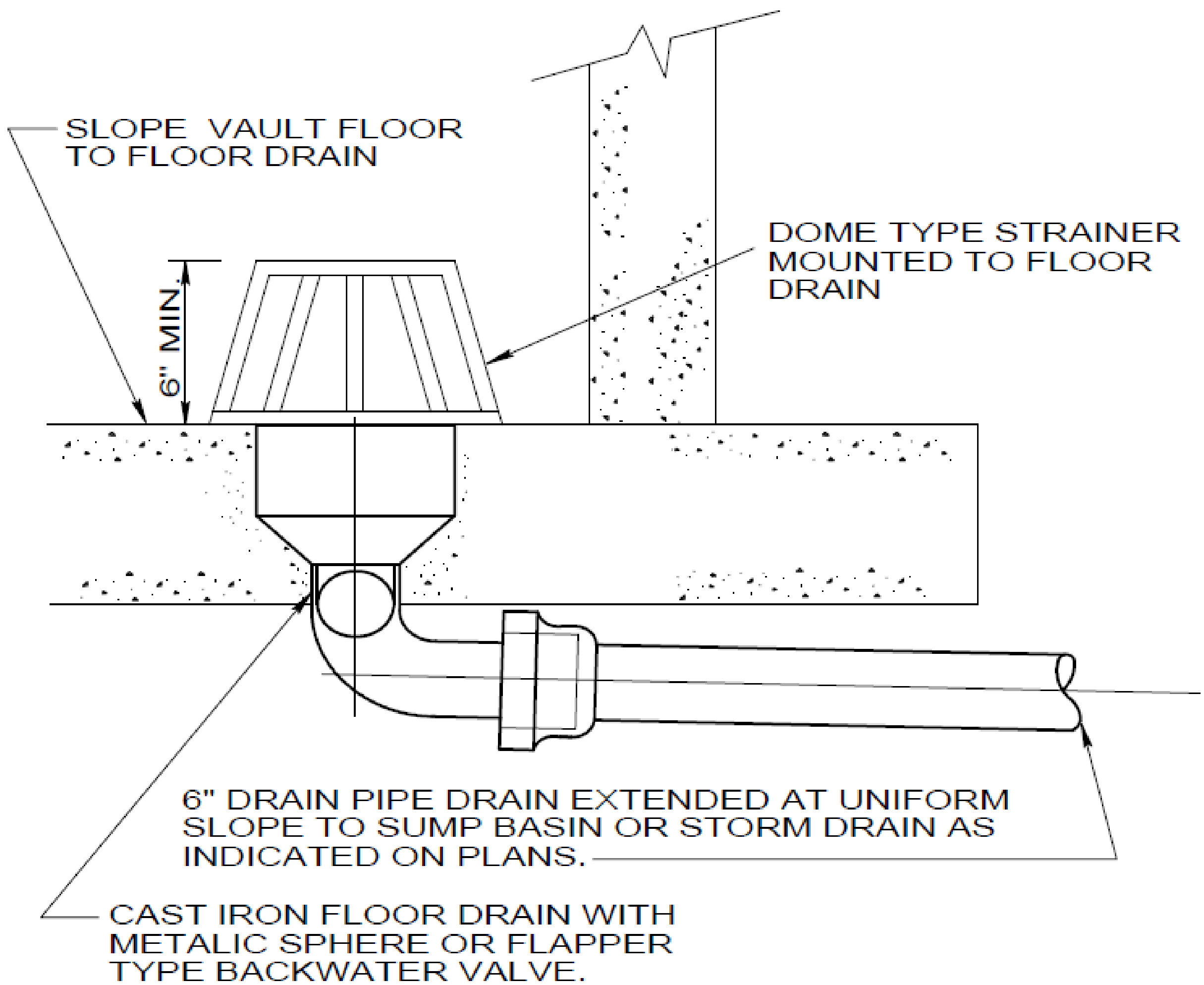
Figure 3-17 Gooseneck Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Pipe sizes imperial to metric conversion: 6” = 150 mm.

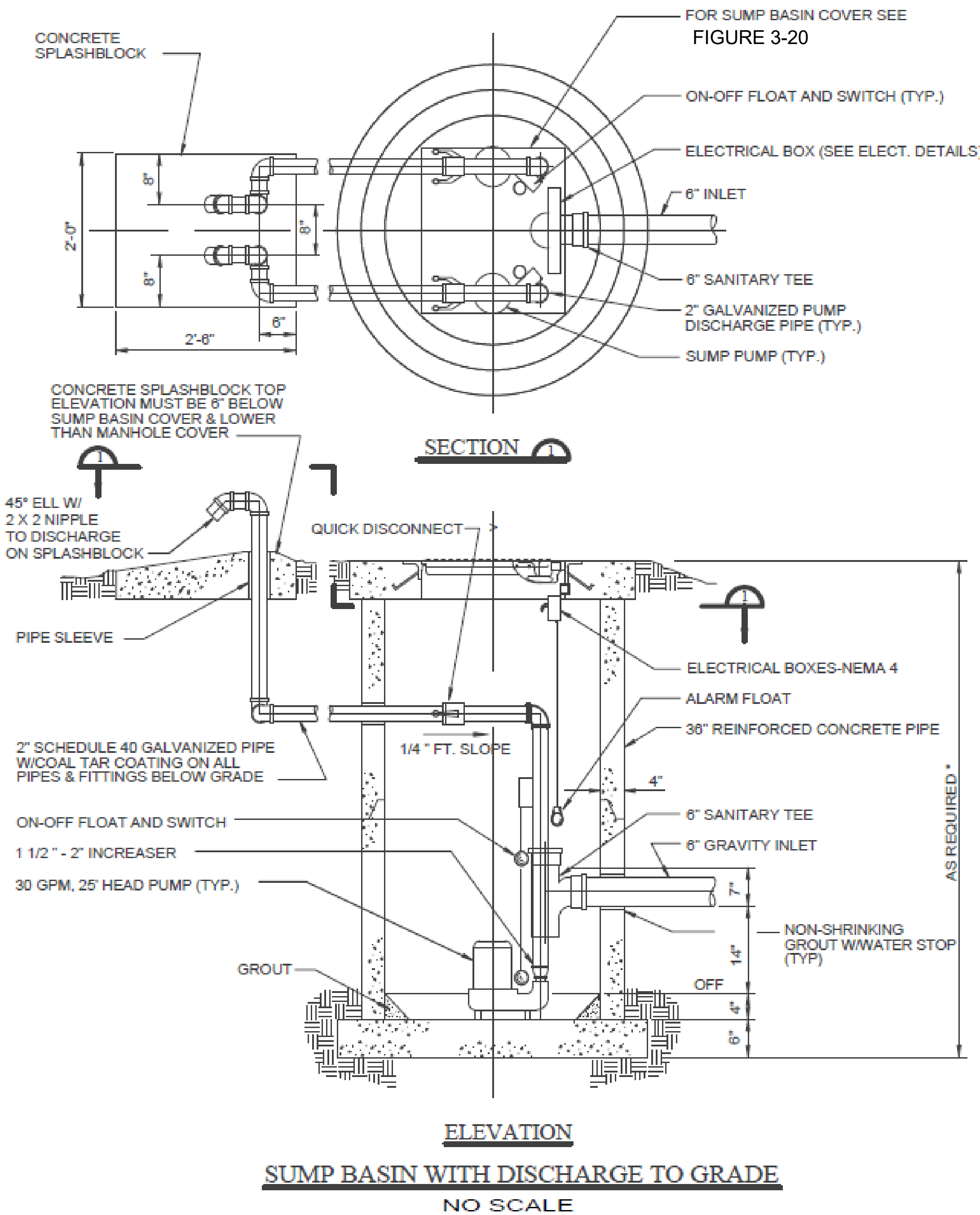
Figure 3-18 Valve Manhole Floor Drain Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Pipe sizes imperial to metric conversion: 6” = 150 mm.
3. When utilizing a flapper type backwater valve, the valves construction shall have an access port for maintenance or replacement of the flapper.

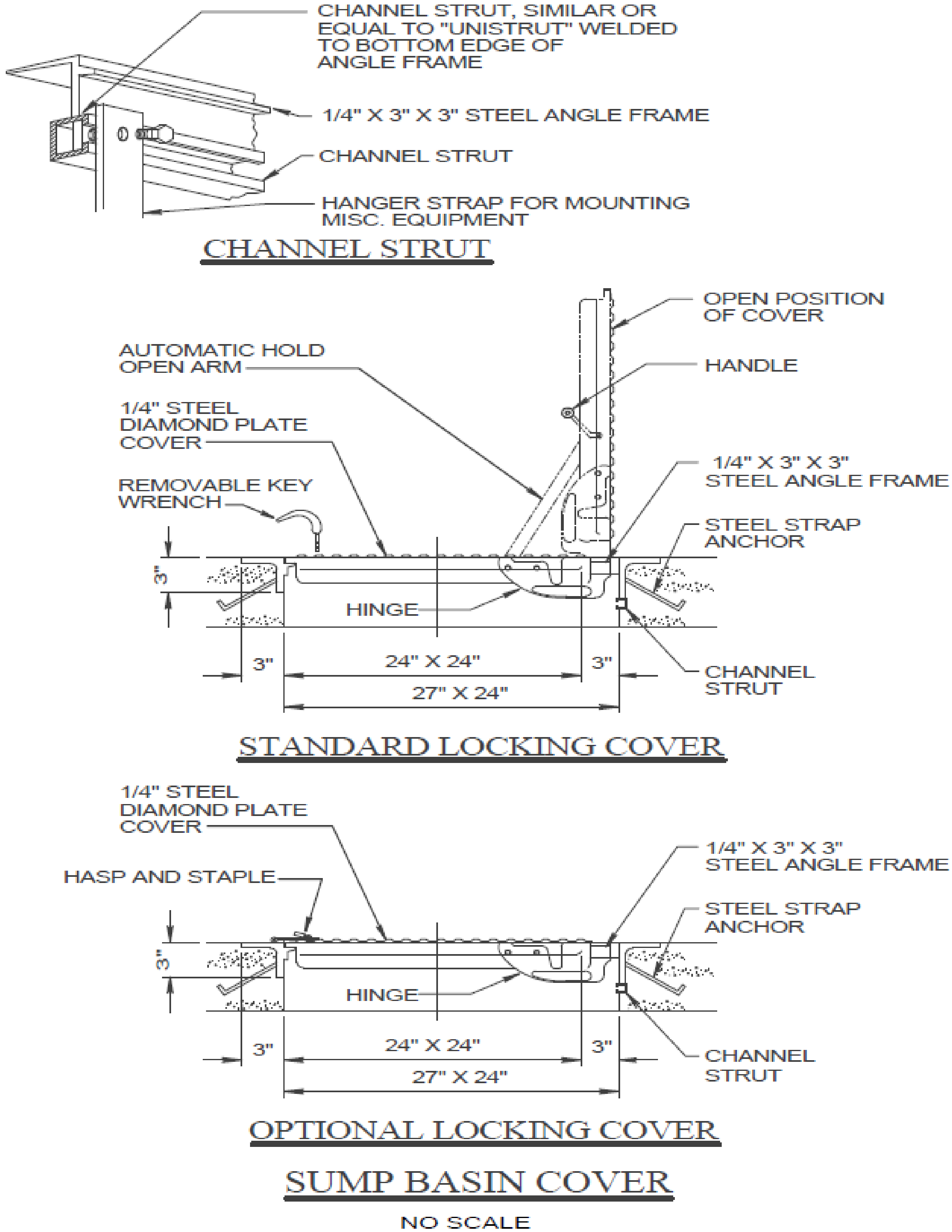
Figure 3-19 Remote Sump Basin



Notes:

1. Note to the designer: depth dependent on maintaining 1/8" / ft. slope from vault manhole outlet to the sump basin. Depth will be a minimum of 4' or a minimum of 1' deeper than design frost depth, whichever is greater.
2. See Figure 3-21 and Figure 3-22 for sump basin electrical design.
3. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
4. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
5. Pipe sizes imperial to metric conversion: 1-1/2" = 40 mm, 2" = 50 mm, and 6" = 150 mm.
6. Imperial 30 GPM, 25' Head is equivalent to metric units 113.7 LPM, 7.62 Meter Head.

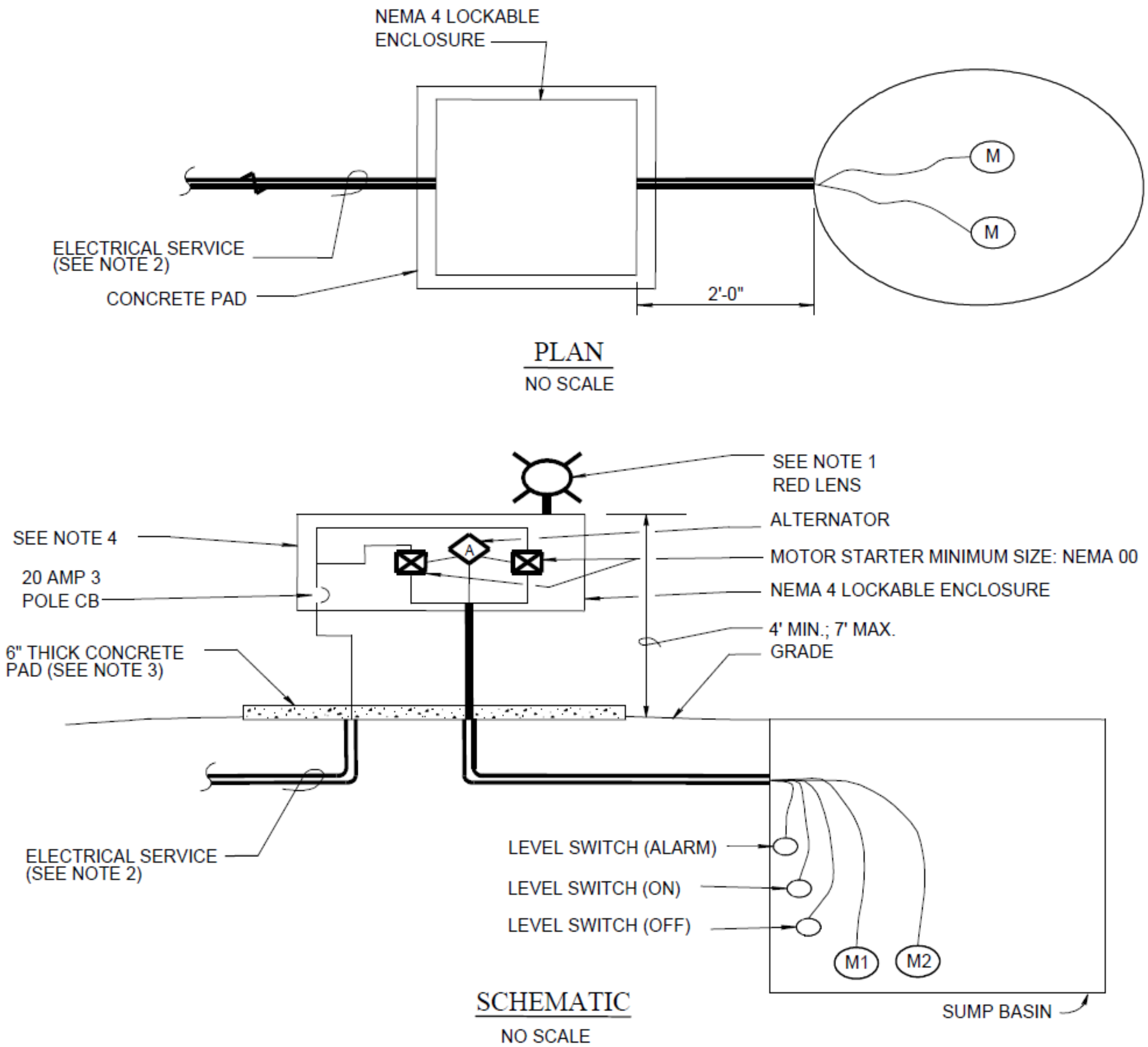
Figure 3-20 Sump Basin Cover Details



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

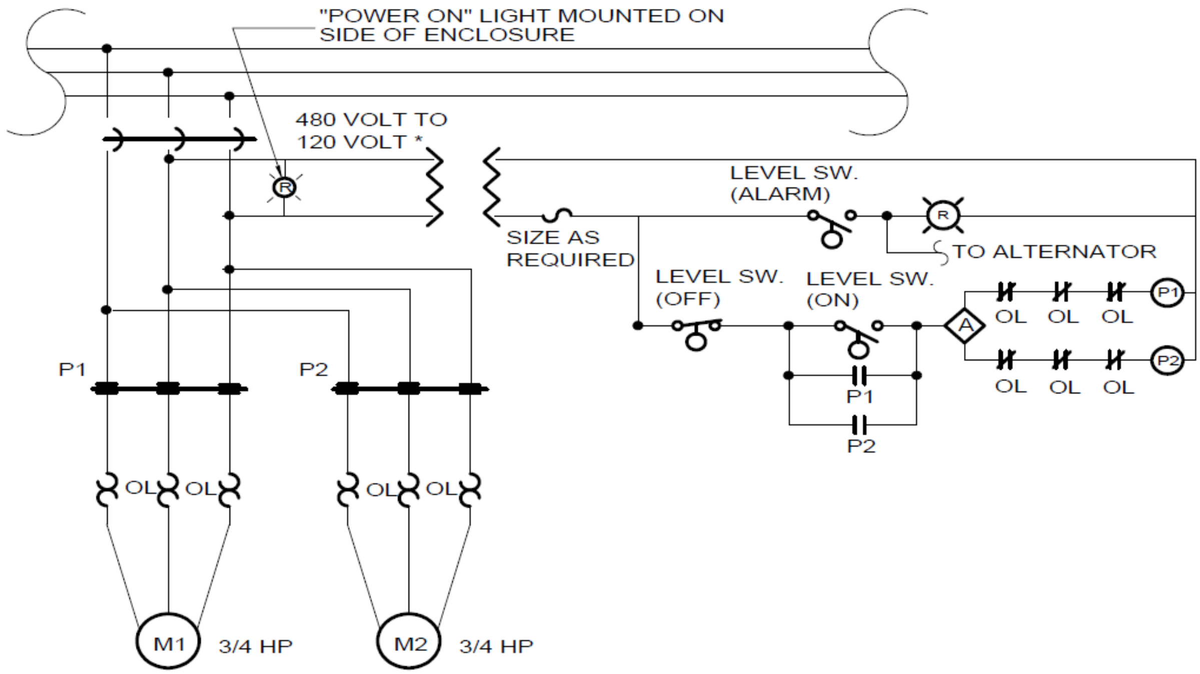
Figure 3-21 Sump Basin Electrical Details



Notes:

1. High water level alarm light. 120 volts, 75 watt sealed beam lamp, 60 flashes per minute. Federal signal model 27-S or approved equal. The lens must be red.
2. Above ground conduit feeding enclosure and all penetrations of concrete pad and sump basin wall will be made of rigid steel.
3. Concrete pad must extend beyond the enclosure at least 6" on all sides.
4. Provide sign with 2" (51 mm) high, 1/8" (3.2 mm) stroke, yellow letters, stating the following: "The circuit breaker must be left in the on position. This circuit provides power to the sump pumps on the underground heat distribution system. Failure to keep this circuit on will cause extensive and costly damage to the underground heat (steam) distribution system.".
5. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
6. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.

Figure 3-22 Sump Pump Wiring Diagram



SEQUENCE OF OPERATION:

THE ALTERNATOR SHALL OPERATE A PUMP UPON WATER LEVEL REACHING LEVEL SWITCH ON AND DEENERGIZE IT WHEN THE WATER LEVEL FALLS BELOW LEVEL SWITCH OFF. IT SHALL ALTERNATE PUMPS ON EACH SUCCESSIVE CLOSING OF LEVEL SWITCH ON. IF THE WATER CONTINUES TO RISE PAST THE ALARM LEVEL, THE RED LIGHT SHALL BE ENERGIZED AND THE LAG (SECOND) PUMP SHALL BE ENERGIZED.

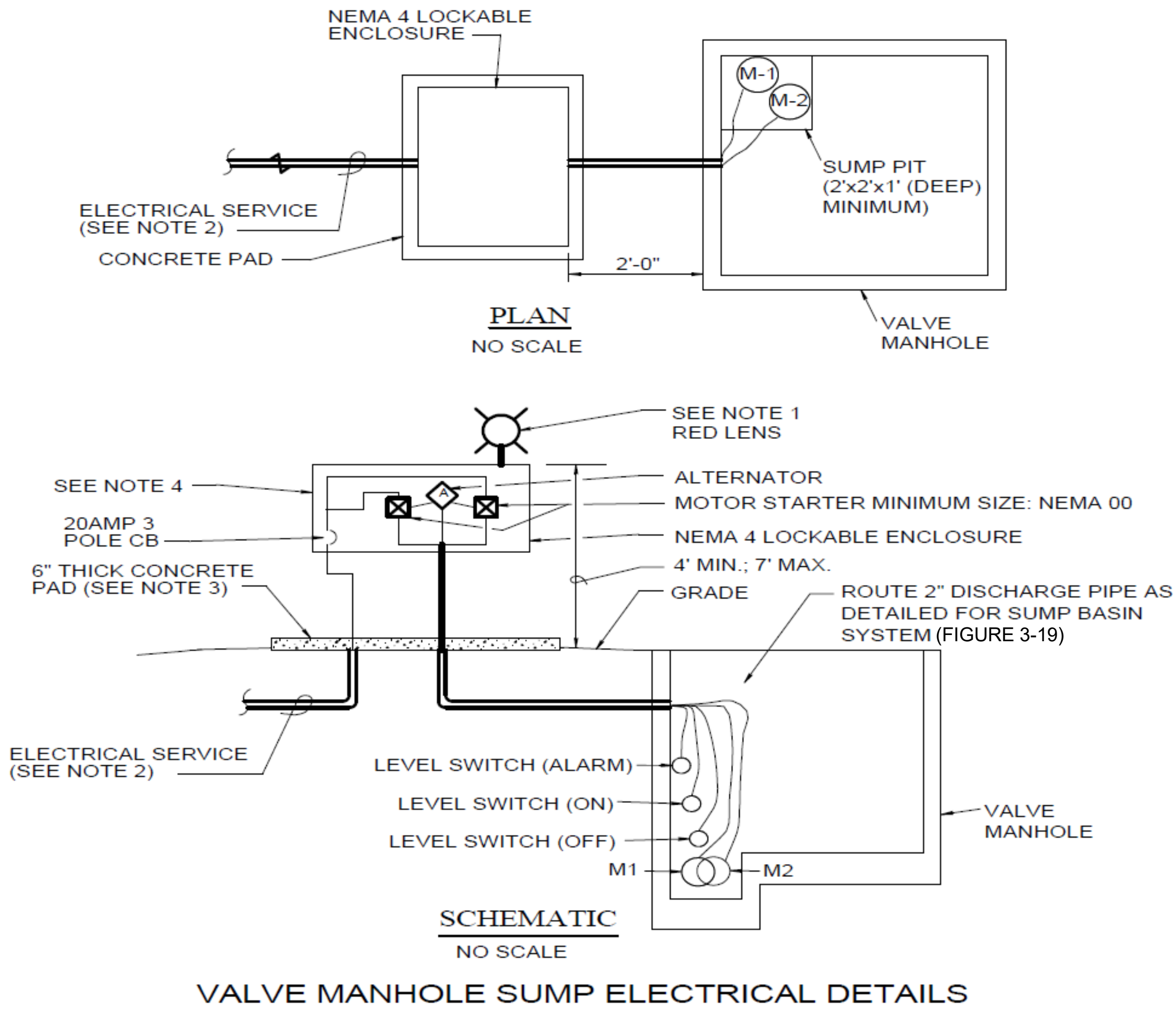
SUMP PUMP CONTROL-3 LINE DIAGRAM

NO SCALE

Note to the Designer:

Actual system voltage and horsepower requirements must be verified and detailed for each design.

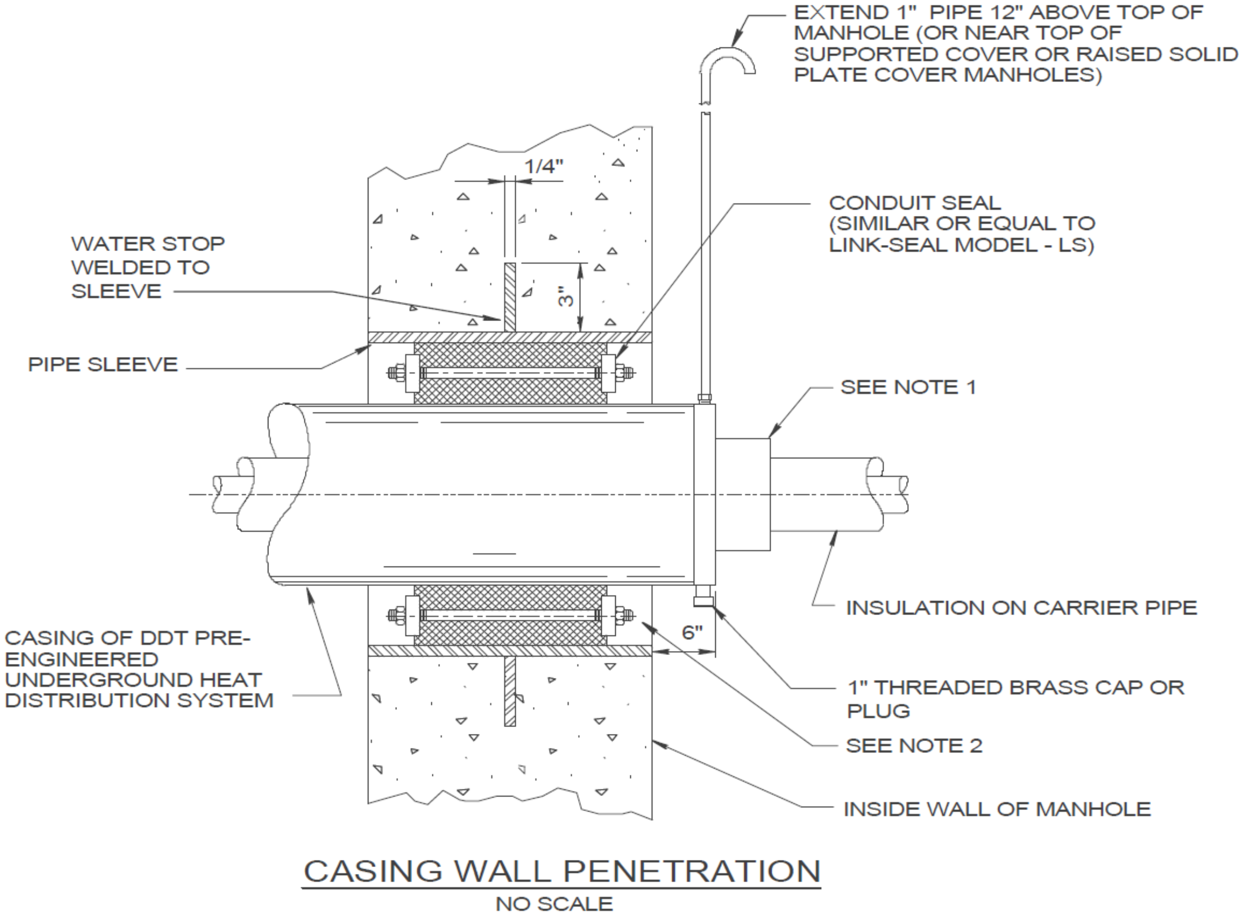
Figure 3-23 Valve Manhole Sump Pump Electrical Details



Notes:

1. High water level alarm light. 120 volts, 75 watt sealed beam lamp, 60 flashes per minute. Federal signal model 27-S or approved equal. The lens must be red.
2. Above ground conduit feeding enclosure and all penetrations of concrete pad and valve manhole wall will be made of rigid steel.
3. Concrete pad must extend beyond the enclosure at least 6" (152 mm) on all sides.
4. Provide sign with 2" (51 mm) high, 1/8" (3.2 mm) stroke, yellow letters, stating the following: "The circuit breaker must be left in the on position. This circuit provides power to the sump pumps on the underground heat distribution system. Failure to keep this circuit on will cause extensive and costly damage to the underground heat (steam) distribution system.".
5. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
6. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
7. Pipe sizes imperial to metric conversion: 2” = 50 mm.

Figure 3-24 Casing Wall Penetration Detail



Notes:

1. End seal or gland seal must be provided on all DDT pre-engineered bury systems inside manhole walls. Casing air space must be provided with drain plug and vent. Vent must have 1" (25 mm) pipe routed as indicated.
2. Inside diameter (ID) of sleeve must be determined after casing outside diameter (OD) has been verified. Generally, sleeve ID must be 5" (127 mm) more than casing OD. Verify with seal manufacturer.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

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CHAPTER 4 SPECIFIC PIPING DESIGN FACTORS

4-1 DISTRIBUTION SYSTEM MATERIAL SELECTION.

4-1.1 Steam System Material Selection.

- **Valves.** For high-pressure steam systems (125 psig [862 kPa] or greater), valves will be 300-pound class and will have welded or flanged ends. Steam valves at lower pressures will be 150-pound class with welded or flanged ends. Valves on trap stations, including the bypass valve, will be 150-pound class with threaded ends. Shutoff valves will be gate type.
- **Fittings.** All fittings in the steam distribution system, except as discussed for valves, will be welded except at equipment, traps, strainers, and items which require frequent removal. These items will be threaded or flanged.
- **Piping.** Steam piping will be carbon steel conforming to ASTM A 53, Grade B, Type E or S. Steam piping will be schedule 40 for piping 1-1/2 inches (40 mm) and larger. Steam piping will be schedule 80 for piping smaller than 1-1/2 inches (40 mm).

4-1.2 Condensate System Material Selection.

- **Valves.** Valves will be 150-pound class with welded ends. Valves on trap stations, including the bypass valve, will be 150-pound class with threaded ends. Shutoff valves will be gate type.
- **Fittings.** All fittings in the condensate distribution system, except as discussed for valves, will be welded except at equipment, traps, strainers, and items which require frequent removal. These items will be threaded or flanged.
- **Piping.** Condensate piping will typically be carbon steel conforming to ASTM A 53 schedule 80, Grade B, Type E or S.

4-1.3 MTW/HTW System Material Selection.

Piping specifications are as follows, except for underground prefabricated or pre-engineered types, in which case the design will include UFGS 33 63 13.

- **Valves.** All valves on MTW/HTW systems will be 300-pound class with welded or flanged ends. All valves must have cast steel bodies with stainless steel trim (no bronze trim). Shutoff or isolation valves will be gate type. Valve packings must be capable of handling the pressures and temperatures associated with MTW/HTW systems. All valves must be capable of being repacked under operational pressures.
- **Fittings.** All fittings on MTW/HTW systems will be welded. Threaded fittings 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. The only exceptions will be specialty equipment such as dielectric flanges used to isolate the piping system from a cathodically protected system.

- **Piping.** MTW/HTW piping will be carbon steel conforming to ASTM A53, Grade B, Type E or S. All piping will be schedule 40 except for welded pipe less than 1-1/2 inches (40 mm), which will be schedule 80.

4-1.4 Low Temperature Heating Water Material Selection.

- **Valves.** Typically, valves will be 150-pound class and will be located in the valve manholes. Ball valves provide a good means for line isolation. Utilize metallic valves as these are more durable than nonmetallic valves.
- **Piping.** The most common piping materials are steel, copper tubing, and RTRP (fiber- glass). However, do not include nonmetallic piping in the same valve manholes with MTW, HTW, and steam systems.

4-1.5 Chilled Water Material Selection.

- **Valves.** Typically, valves will be 150-pound class and will be located in the valve manholes. Ball valves provide a good means for line isolation. Utilize metallic valves as these are more durable than nonmetallic valves.
- **Piping.** The most common piping materials used for chilled water systems are steel, copper tubing, RTRP (fiber- glass) and, for CW only, polyvinyl chloride and polyethylene. However, do not include nonmetallic piping in the same valve manholes with MTW, HTW, and steam systems. Chilled water lines using PVC piping must be installed in separate valve manholes since PVC can be thermally damaged at relatively low temperatures. Outside the valve manholes, a minimum separation of 15 feet (4.57 m) must be maintained between pre-engineered underground MTW, HTW, and steam systems and PVC encased, prefabricated underground heating/cooling distribution systems to avoid thermal degradation of the PVC.

4-2 DISTRIBUTION SYSTEM PIPING.

4-2.1 Sizing of Distribution Piping.

Size distribution piping as follows:

4-2.1.1 Minimum Pipe Size.

For direct buried piping use minimum of 2-inch (50 mm) Schedule 80 pipe with all joints welded. For shallow trench system piping use minimum of 2-inch (50 mm) pipe with threaded end connections. Smaller pipe sizes and threaded joints are allowable in valve manholes.

4-2.1.2 Steam Piping.

The project designer must specify the design temperatures and pressures. The approved systems are suitable for temperatures to 450°F (232°C). If higher temperature systems are required, review manufacturers' approved brochures to determine the exceptions to the brochures to be made in the project specification relative to pipe material, pipe expansion, and valve classification. Design considerations are indicated in Table 4-1 and as follows:

4-2.1.2.1 Steam Distribution Pressures.

Steam pressure is 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 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 (345 kPa), are smaller pipe sizes, availability of steam for purposes other than for heating, and more flexibility in velocities and pressure drops

4-2.1.2.2 Selection of Valve Types.

Install double-ported, pilot operated valves for large capacities, especially for inlet pressures above 125 psig (862 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. Provide a manual bypass for emergency operation when the pressure reducing valve is out of service. Provide a pressure gauge 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 large 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.

4-2.1.2.3 Safety Valves.

Provide one or more relief or safety valves on the low pressure side of each reducing valve in case the piping and/or equipment on the low pressure side do not meet the requirements of the full initial pressure. The combined discharge capacity of the relief valves must be such that the pressure rating of the lower pressure piping and equipment will not be exceeded. For special conditions refer to ASME B31.1, American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Handbook - HVAC Systems and Equipment, and ASHRAE Handbook – HVAC Applications.

4-2.1.2.4 Takeoffs from Mains.

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

4-2.1.2.5 Steam Piping Sizing.

Pipe sizing is critical to proper operation of both the steam and the condensate return systems. There are several methods to size steam lines. One of the quickest and most popular methods is using pressure drop versus flow rate charts, which provide steam velocities based on the required flow and pressure drops. The ASHRAE Fundamentals Handbook, Chapter "Pipe Design", is a good source for these steam sizing tables. Reasonable velocities for various system pressure ranges are included in Table 4-1.

In addition, ensure the total pressure drop in the system will not be excessive. Steam pressure must be high enough to meet all special process requirements.

Table 4-1 Reasonable Velocities for Flow of Steam in Pipes

Condition of Steam	Pressure psig (kPa)	Service	Reasonable Velocity [1] fpm (m/s)
Saturated	Vacuum	Turbine exhaust	Up to 18,000 fpm (91.44 m/s)
	0 to 25 psig (0 to 172 kPa)	Heating	4,000 to 6,000 fpm (20.32 to 30.48 m/s)
	25 psig (172 kPa) and up	Steam distribution	6,000 to 10,000 fpm (30.48 m/s to 50.8 m/s)
	125 psig (862 kPa) and up	Underground steam distribution	Up to 20,000 fpm (101.6 m/s)
Superheated	200 psig (1.68 MPa) and up	Boiler and turbine leads	7,000 to 20,000 (35.56 m/s to 101.6 m/s)

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

4-2.1.3 Condensate Returns.

Pipe sizing is critical to proper operation of both the steam and the condensate return systems.

Design considerations are as follows:

4-2.1.3.1 Condensate Piping Sizing.

There are basically two types of condensate return systems used on central heating systems: the two pipe system (which uses steam pressure to force condensate back to the plant) and the three pipe, or pumped return, system. When sizing lines for these condensate return systems, Table A-7 in Appendix A will be used for guidance.

4-2.1.3.2 Return Piping.

Size condensate trap piping to conform with 30 to 150 psig (207 to 1034 kPa) steam piping in accordance with the ASHRAE Fundamentals Handbook, Chapter "Pipe Design" tables and interpolate these for other pressures.

4-2.1.3.3 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 the steam system branch which they serve, depending on whether continuously or intermittently operated.

4-2.1.3.4 Common Pump Discharge Mains.

Size pumps to move condensate to the central plant at the required head at 200°F. 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 feet per second (fps) (1.83 meter per second [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 must not exceed the pump characteristics of standard pump and receiver units.

4-2.1.4 HTW and MTW Piping.

Design considerations are as follows:

4-2.1.4.1 HTW and MTW Piping Sizing.

Use pipe friction charts in ASHRAE Handbook Fundamentals. 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 (0.61 m/s).

4-2.1.4.2 Venting and Draining.

Piping vents and drains will be located at all high and low points, respectively (see Figure 5-17).

4-2.1.5 Chilled Water Piping.

The most efficient method of determining pipe size for chilled water systems is to use head loss vs. flow rate charts such as those found in ASHRAE Fundamentals, Chapter "Pipe Design". These tables are based on 60°F (15.6°C) water so for chilled water pipe sizing there is little error introduced using these charts. Or 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.

Sizing of chilled water piping shall not exceed the maximum allowed flow rates indicated in ASHRAE 90.1.

4-2.1.6 Low Temperature Heating Water (LTW) Piping.

The most efficient method of determining pipe sizing for LTW systems is to use head loss vs. flow rate charts such as those found in ASHRAE Fundamentals, Chapter "Pipe Design". These tables are based on 60°F (15.6°C) and when using with LTW systems, these charts do introduce some error. However, the error is on the conservative side (the charts overstate the pressure drop of LTW).

4-2.1.7 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. No correction factor is required for RTRP pipe.

Sizing of condenser water piping shall not exceed the maximum allowed flow rates indicated in ASHRAE 90.1.

4-2.1.8 Compressed Air.

For criteria on distribution piping, refer to UFC 3-401-01, *Mechanical Engineering* and UFC 3-420-02, *Compressed Air*.

4-2.2 Piping Specifications and Codes.

Piping specifications and codes are as follows:

4-2.2.1 Steam Supply and Condensate Return.

Piping must conform to ASME B31.1, except for underground prefabricated or pre-engineered type systems which the design will include UFGS 33 63 13.

- If a separate pump condensate return system is used, the design will include UFGS 33 63 14.

4-2.2.2 Compressed Air.

Piping will conform to ASME B31.1.

4-2.2.3 Chilled and Condenser Water.

Piping will conform to ASME B31.9.

4-2.2.4 Medium and High Temperature Hot Water.

Piping will conform to ASME B31.1.

4-2.2.5 Low Temperature Hot Water.

Piping will conform to ASME B31.9.

4-2.3 Thermal expansion of steel and copper pipe.

Pipe expands with temperature increases (such as between installation and operating temperatures) as indicated in Table A-10 in Appendix A. Make provisions 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.

4-2.3.1 Branch Lines.

Where practicable, design branch line piping to provide for expansion inside buildings. Expansion control of branch lines must be designed so as to have no effect on mains.

4-2.3.2 Expansion Bends.

Bends are to be factory fabricated except for RTRP pipe.

- **Loop Sections.** Loops may be furnished in sections to facilitate delivery and handling.
- **Anchors.** A reasonable distance between anchors for expansion loops is 200 feet (61 m) for 125 psig (862 kPa) steam system. Expansion is typically kept at about 6 inches (152 mm) between anchors.
- **Cold Springing.** Cold springing may be used in installations, but no design stress relief is allowed for it. For credit permitted in thrust and moments, refer to ANSI B31.1.

4-2.3.3 Expansion Joints.

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

- **Mechanical Slip Joint.** An externally guided joint designed for repacking under operating pressures. Hold maximum traverse of piping in expansion joints under 8 inches (203 mm).
- **Bellows Type Joint.** Use these joints on steel pipe for thermal expansion with stainless steel bellows, guided and installed according to manufacturer's instructions. Make bellows or corrugations for absorbing vibrations or mechanical movements at ambient temperatures of copper or other materials suitable for the job conditions. A maximum travel of 4 inches (102 mm) is allowed for this type. RTRP expansion joints may be polytetrafluoroethylene bellows type.
- **Flexible Ball Joints.** Install these joints according to manufacturer's instructions.

4-2.3.4 Flexibility Analysis.

Refer to ASME B31.1 for expansion and flexibility criteria and allowable stresses and reactions.

4-2.3.5 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 ASME B31.1. In addition, software specifically for pipe stress analysis may be utilized for preforming piping stress calculations conforming to ASME B31.1

4-2.4 Insulation Thickness.

Insulation thicknesses indicated in UFGS 23 07 00 are suitable for most geographic locations. However, in locations where extreme annual temperatures occur, the project designer must evaluate different thicknesses of insulation. Make final selection based on an economic analysis in accordance with para. 2-7.7.

4-2.4.1 Jackets.

Design insulation jackets in waterfront or other locations subject to flooding to drain; they must not be watertight.

4-2.5 Draining Provisions.

Drainage provisions must conform to requirements listed below.

4-2.5.1 Pitch.

The surrounding terrain and piping application both affect the pitch of piping as indicated below.

- **Horizontal Piping.** Pitch horizontal steam piping down at a minimum of 2-1/2 inches (64 mm) per 100 feet (30.5 m) of length in the direction of steam flow.
- **Underground Piping.** Pitch horizontal piping down towards drain points (unless otherwise noted) a minimum of 2-1/2 inches (64 mm) in 100 feet (30.5 m). 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 also for all very long horizontal runs, aboveground or belowground, to keep piping within a reasonable range of elevations with reference to the ground surface.
- **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 inches (152 mm) per 100 feet (30.5 m) and increase pipe diameter by one standard pipe size.
- **Compressed Air Lines.** Pitch compressed air piping at a minimum of 2-1/2 inch (64 mm) per 100 feet (30.5 m) of length in the direction of flow.
- **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 inches (64 mm) per 100-foot (30.5 m) length. Place drain valves at all low points and vents at high points.

4-2.5.2 Drips and Vents.

Provide drips and vents as follows:

- **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. Locate drip legs at low points, at the bottom of all risers, and at intervals of approximately 200 to 300 feet (61 to 91.5 m) for horizontally pitched pipe where a trap is accessible, and not over 500 feet (152.5 m) for buried underground pipe systems.
- **Water Piping.** Vent piping, especially high-temperature water piping, at distribution piping high points.

4-2.5.3 Condensate Systems.

Condensate systems are as follows:

- Furnish a complete system of drip traps and piping to drain all steam piping of condensate from drip legs. Ensure drip piping to traps is the same weight and material as the drained piping.
- Preferably, run a condensate line from a trap separately to a gravity condensate return main or to a nearby flash tank. (Refer to ASHRAE Handbook - HVAC Systems and Equipment and ASHRAE Handbook – HVAC Applications for flash tank details and specific trap applications. Additionally, refer to Naval Civil Engineering Laboratory [NCEL] UG-0005, Steam Trap Users Guide.) 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.
- Select traps using a safety load factor no greater than 2. The condensate load must be indicated on design drawings and may be determined for aboveground lines by using Table 4-2. The condensate load for underground distribution lines is determined from maximum heat loss as indicated by the design. With the tight safety load factor for sizing traps, an alternate method of expelling gasses during warmup is required. To this end, all strainers must have blowdown valves which will also be used for controlled warmup.
- Pitch discharge piping down a minimum of 3 inches (76 mm) per 100 feet (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 must not be RTRP pipe nor the trap discharge connect to an RTRP pipe by direct connection.
- 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 to be determined on a case-by-case basis.

Table 4-2 Condensate Loads from Aboveground Heat Distribution Piping (Pounds Per Hour Per 100 Linear Feet)

Steam Pressure (psig)	Steam Pipe Size inches (mm), diameter					
	2 (50 mm)	4 (100 mm)	6 (150 mm)	8 (200 mm)	10 (250 mm)	12 (300 mm)
10 psig (69 kPa)	6	12	16	20	24	30
30 psig (207 kPa)	10	18	25	32	40	46
60 psig (414 kPa)	13	22	32	41	51	58
125 psig (862 kPa)	17	30	44	55	68	80
300 psig (2.07 MPa)	25	46	64	83	203	122
600 psig (4.14 MPa)	37	68	95	124	154	182

Notes:

1. Imperial to metric conversion: 1 lbs/hr = 0.454 kg/hr.
2. Imperial to metric conversion: 100 feet = 30.48 M.

4-3 PIPE SUPPORTS AND ANCHORS

4-3.1 Pipe Anchors.

Ensure anchors comply with the following criteria:

4-3.1.1 Location.

Locate anchors for non-pre-engineered/prefabricated systems at takeoffs from mains and other necessary points to contain pipeline expansion. If possible, locate anchors in buildings, piers, tunnels, and manholes with suitable access. The locations of anchors for underground piping must be provided no closer than 3 feet (1 m) nor further than 5 feet (1.5 m) from the piping entrance to the building. This is to minimize movement of piping to the building entrance.

4-3.1.2 Specification.

Design and locate anchors in accordance with ASME B31.1.

4-3.1.3 Strength.

Design anchors to withstand expansion reactions. With expansion joints, consider the additional end reactions due to internal fluid pressure, and add end reactions due to spring rate of the joint.

4-3.1.4 Guying.

Anchors for elevated aboveground systems must 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 serve also as sway bracing.

4-3.1.5 Embedding.

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

4-3.2 Supports.

Ensure pipe supports conform to ASME B31.1.

4-3.2.1 Low Elevations.

For aboveground systems at low elevations (defined as lower than 5 feet [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.

4-3.2.2 High Elevations.

At higher elevations above ground, 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. Details of design will vary depending on site conditions.

4-3.2.3 Long Spans.

When long spans are necessary, cable-suspension or catenary systems are allowed.

4-3.2.4 Underground Conduits.

Use approved types of manufacturers' standard designs supports for underground conduits.

4-3.2.5 In Trench.

Suspend pipes either from the walls or the tops of the walls. Do not support piping from either the floor of the trench or from the removable top. The pipe hanger design must provide for adequate system expansion and contraction.

4-3.2.6 Finish and Protection.

All noninsulated ferrous parts of the piping, piping support system, or equipment will be hot-dipped galvanized or primed with red oxide primer and painted with epoxy paint.

4-4 CONCRETE TRENCH DESIGN.

The concrete shallow trench will consist of poured concrete sides and floor, with removable tops. Portions of the floor may be omitted at locations outlined previously under course grained soils with water table 2 feet (610 mm) or more below lowest point of water entry.

4-4.1 Depth of Trench.

Ensure the depth of the concrete trench is sufficient to provide adequate protection to the piping system and slope the floor of the trench to provide adequate internal drainage, but in all cases not less than 6 inches (152 mm) from the bottom surface of the suspended pipe insulation to the floor of the trench. Ensure there is a minimum of 3 inches (76 mm) between the surface of the pipe insulation and the adjoining trench walls and a minimum of 4 inches (102 mm) between surfaces of adjacent pipe insulation.

4-4.2 Drainage of Trench.

Base the design on sound engineering practices which provide for drainage under all anticipated conditions. Consider the annual rainfall, water table, and other topographic conditions in the basis for the design. For those instances where natural drainage cannot be provided (storm water drainage system at least 2 feet [610 mm] below trench bottom at all times), provide a dual sump pump capability with failure annunciator.

4-4.3 Tops.

The tops of the concrete trenches will be removable by use of a portable lifting device such as a forklift or backhoe, and can also be used for sidewalks, if practical. Earth must not cover the tops. Covers will be close tolerance fit with a maximum gap tolerance build-up of 0.12 inch (3 mm) from all causes.

4-4.4 Details.

Design the Concrete Shallow Trench Heat Distribution System and show on the contract drawings. Use Figure 4-1 through Figure 4-11, Figure 5-2 through Figure 5-4, Figure 5-13, Figure 5-14, and Figure 5-16 as appropriate.

Provide the following information on the contract drawings for the concrete Shallow Trench System, as applicable: dimension on all runs of pipe; elevations of the pipe along the systems path; sizes of the pipe; location of all valves; location and details of all expansion loops, Z- and L-bends; location of pipe anchors; how changes in pipe direction are made; thickness of the insulation on the pipe; concrete trench details; final elevations of concrete trench; profile of trench showing all existing utilities; manhole dimensions; manhole cover details; how manhole is drained and vented where required; sump pump piping details; sump pump capacity; condensate pump capacity and details; include specific requirements for modification to existing; steam drip trap locations and capacity; steam pressure reducing valve capacity and details; and other pertinent information and details required to clearly show the intent of the Shallow Trench Heat Distribution System. Also indicate any obstructions in the path of the distribution system that the Contractor may have to work around.

4-4.5 Valve Manholes.

Extend valve manholes at least 9 to 12 inches (229 to 305 mm) above finished grade to prevent seasonal runoff from entering except where trench will be a pedestrian walk, in which case the vault cover will be flush with the trench covers.

4-4.6 Inspection Ports.

Where required, provide inspection ports at appropriate locations to enable the Government to observe drains or expansion at loops or locations requiring frequent (monthly) observation.

4-4.7 Crossing.

At all road and railroad type crossings, provide required slab thickness for railroad crossings and H-20 loading for street crossings. Review railroad track removal/replacement with respective authority and coordinate all activities. Road and rail crossing where maintenance of traffic is critical may be accomplished by jacking using an acceptable conduit/tunnel.

4-4.8 Precast Concrete Shallow Trench Options.

In addition to or in combination with a poured-in-place concrete shallow trench system, a precast or prefabricated shallow trench system consisting of precast concrete covers, concrete trench, or supports may be specified. If the designer selects this option, he must include special details and specification requirements of the precast system and the transition between the poured-in-place and precast system.

4-5 MANHOLES.

Guidance for manholes is shown below:

4-5.1 Drainage.

Provide sump pumps in manholes. Units typically discharge by buried piping to nearest storm sewer if possible. Where not economical to discharge to storm sewer, pumps are to discharge above grade to splash blocks. Plan discharge locations carefully so water will not be placed over tunnel tops, sidewalks, or other locations where water discharge would be problematic. Use sump pumps capable of passing 3/8-inch (12 mm) solid (sphere) minimum. Adjust float switches so the pumps start sequentially, reducing electrical line surge. Coordinate power requirements with electrical designer and provide tell-tale light above ground to indicate that power is available to sump pumps.

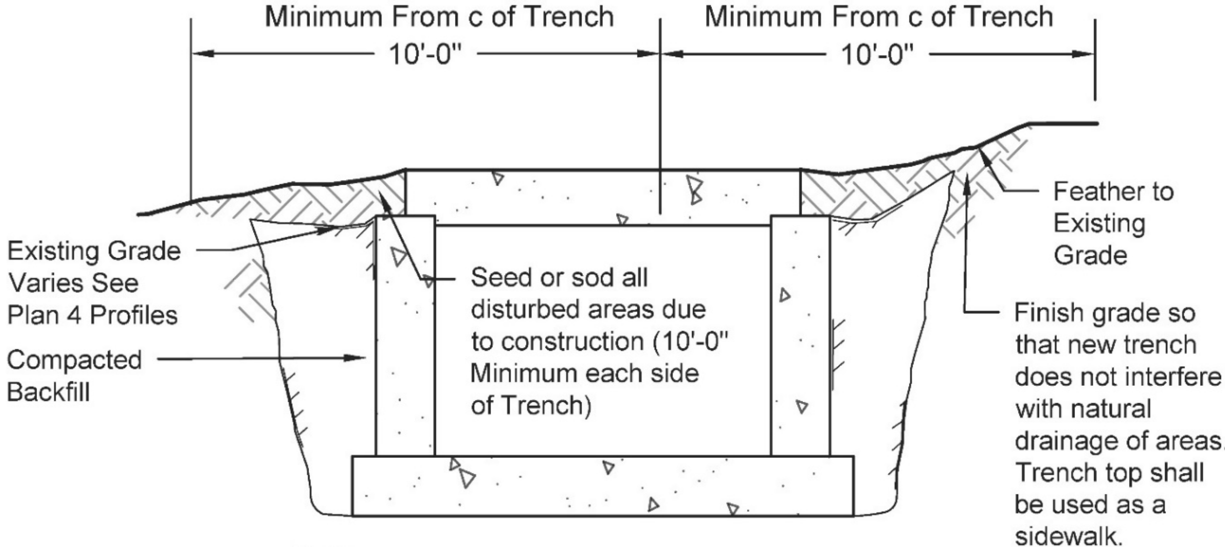
4-5.2 Waterproofing.

If portions of manholes are installed below the water table, waterproof that portion below the water table.

4-5.3 Pipe Entry.

Pipe entry, for buried pre-engineered systems piping, must be in accordance with Figure 4-12.

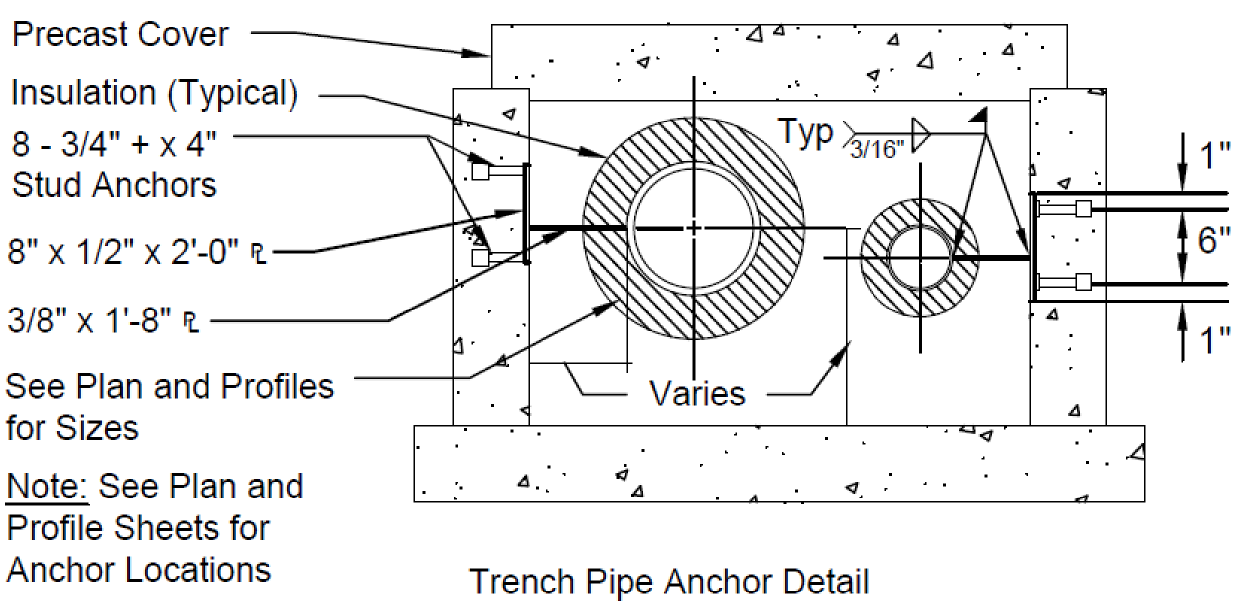
Figure 4-1 Concrete Shallow Trench Grading Section



Notes:

1. Trench floors must be sloped to provide continuous drainage to sump pumps in manholes. All pockets found in trench floor must be provided with a floor drain to the nearest manhole sump or the floor must be sloped to provide gravity drainage.
2. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.

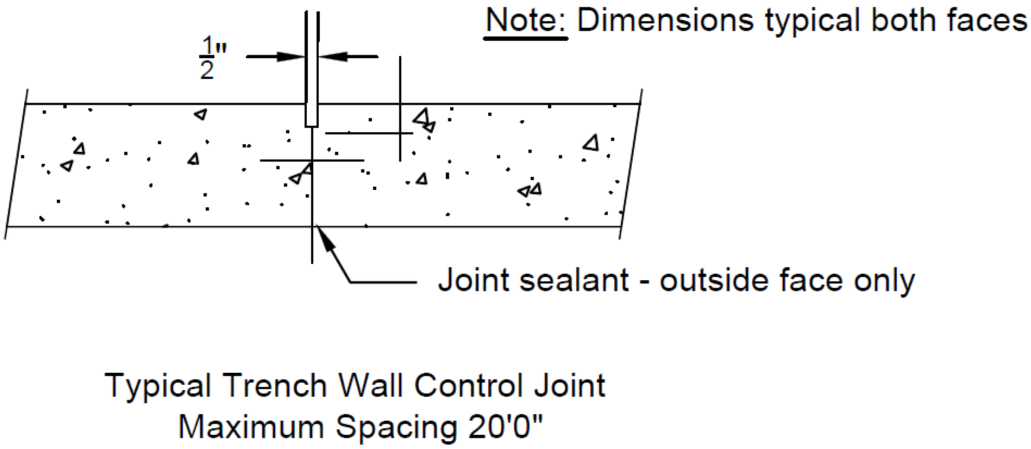
Figure 4-2 Trench Pipe Anchor Detail



Notes:

1. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

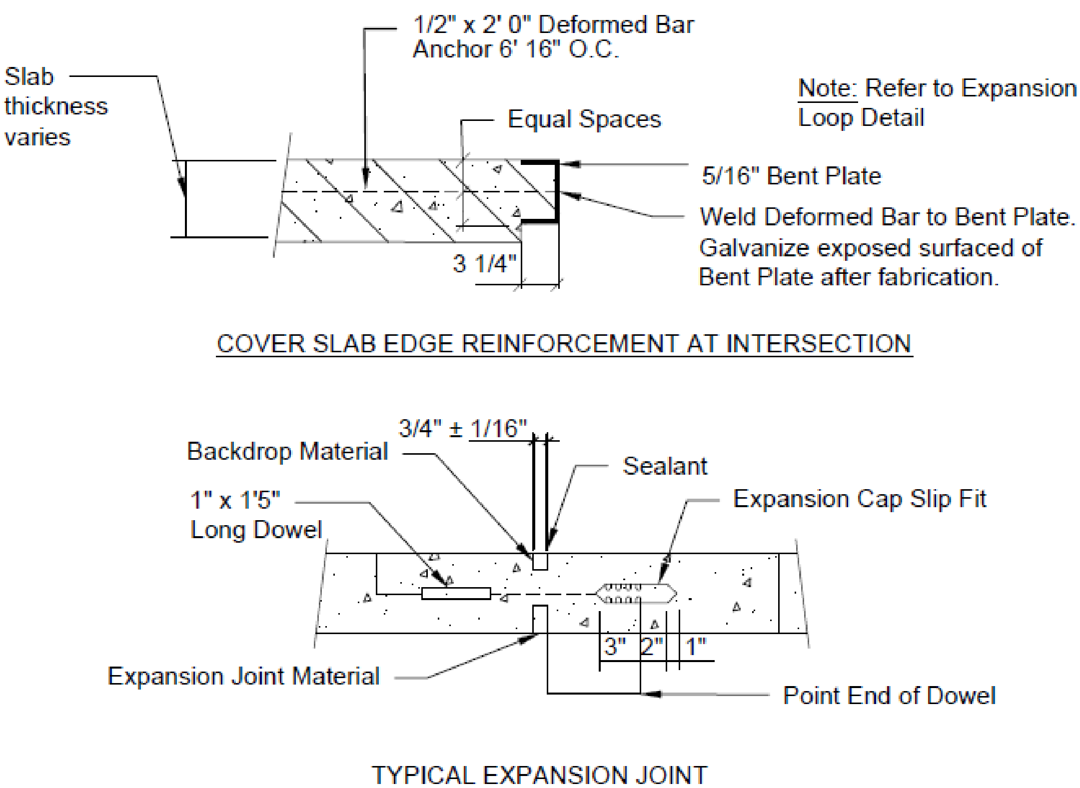
Figure 4-3 Typical Trench Wall Control Joint Detail



Notes:

1. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

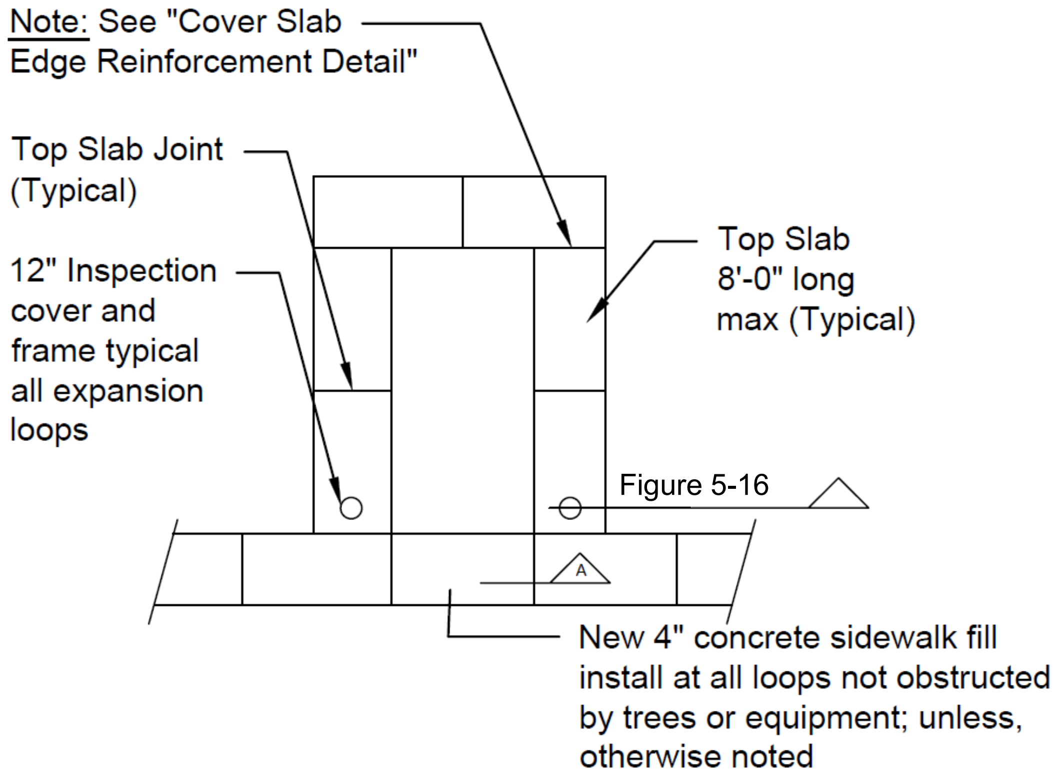
Figure 4-4 Cover Slab Edge Reinforcement at Intersection and Typical Expansion Joint Detail



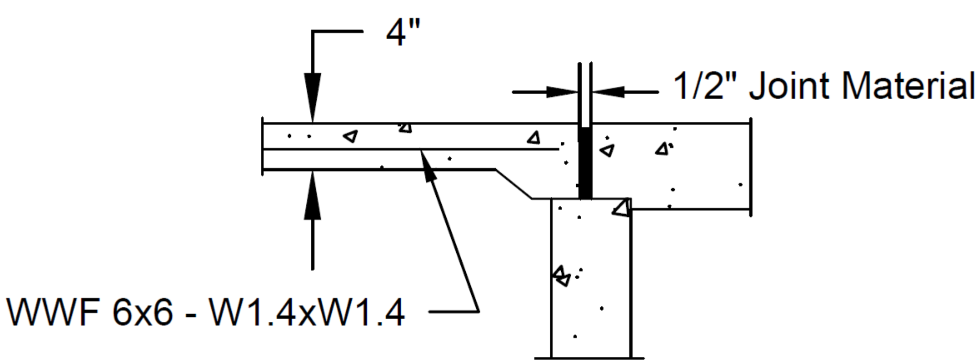
Notes:

1. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

Figure 4-5 Expansion Loop Cover Detail



EXPANSION LOOP COVER DETAIL

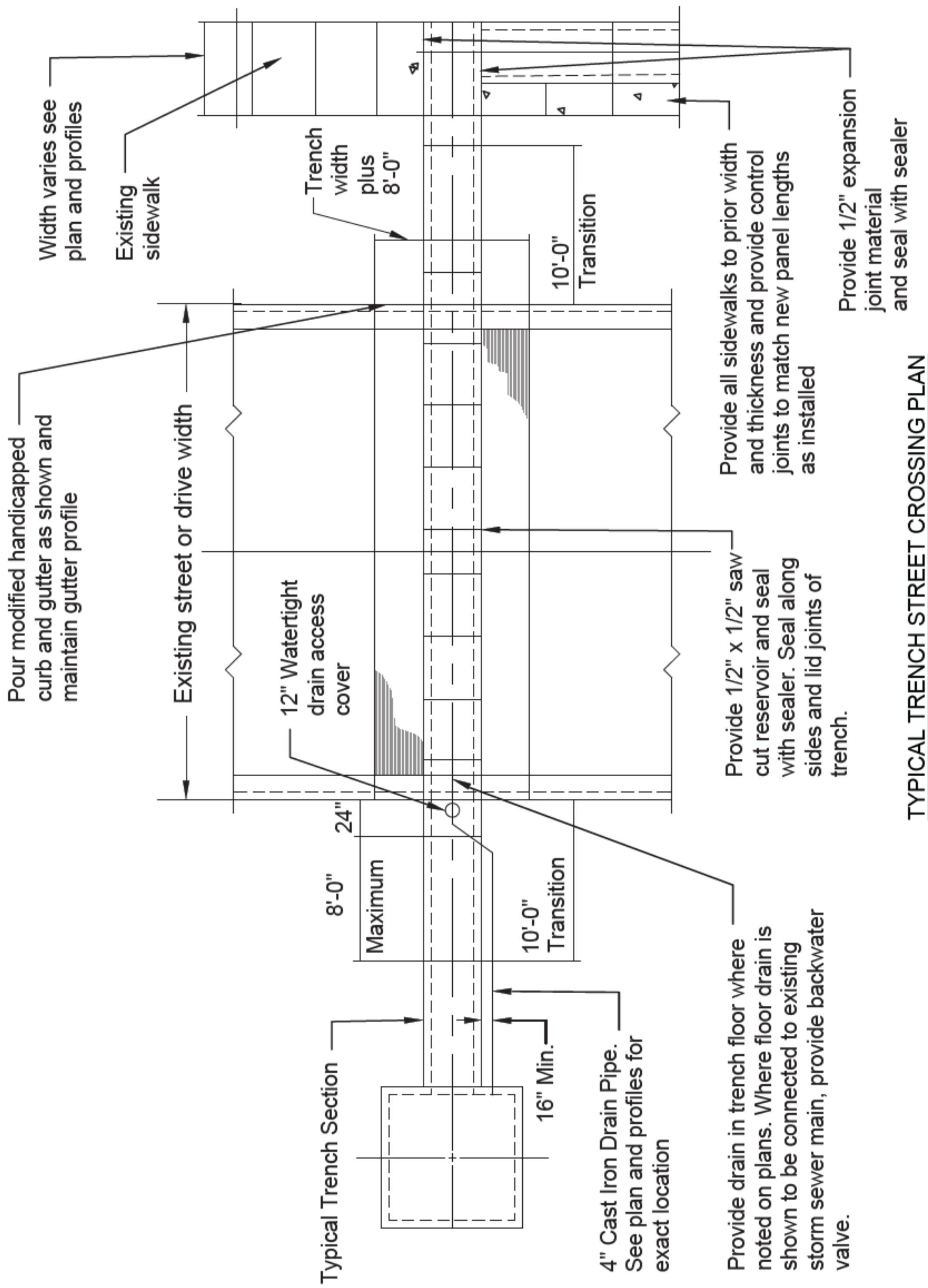


DETAIL A

Notes:

1. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
3. Imperial WWF 6x6 - W1.4xW1.4 is equivalent to metric WWF 102x102 - MW9xMW9.

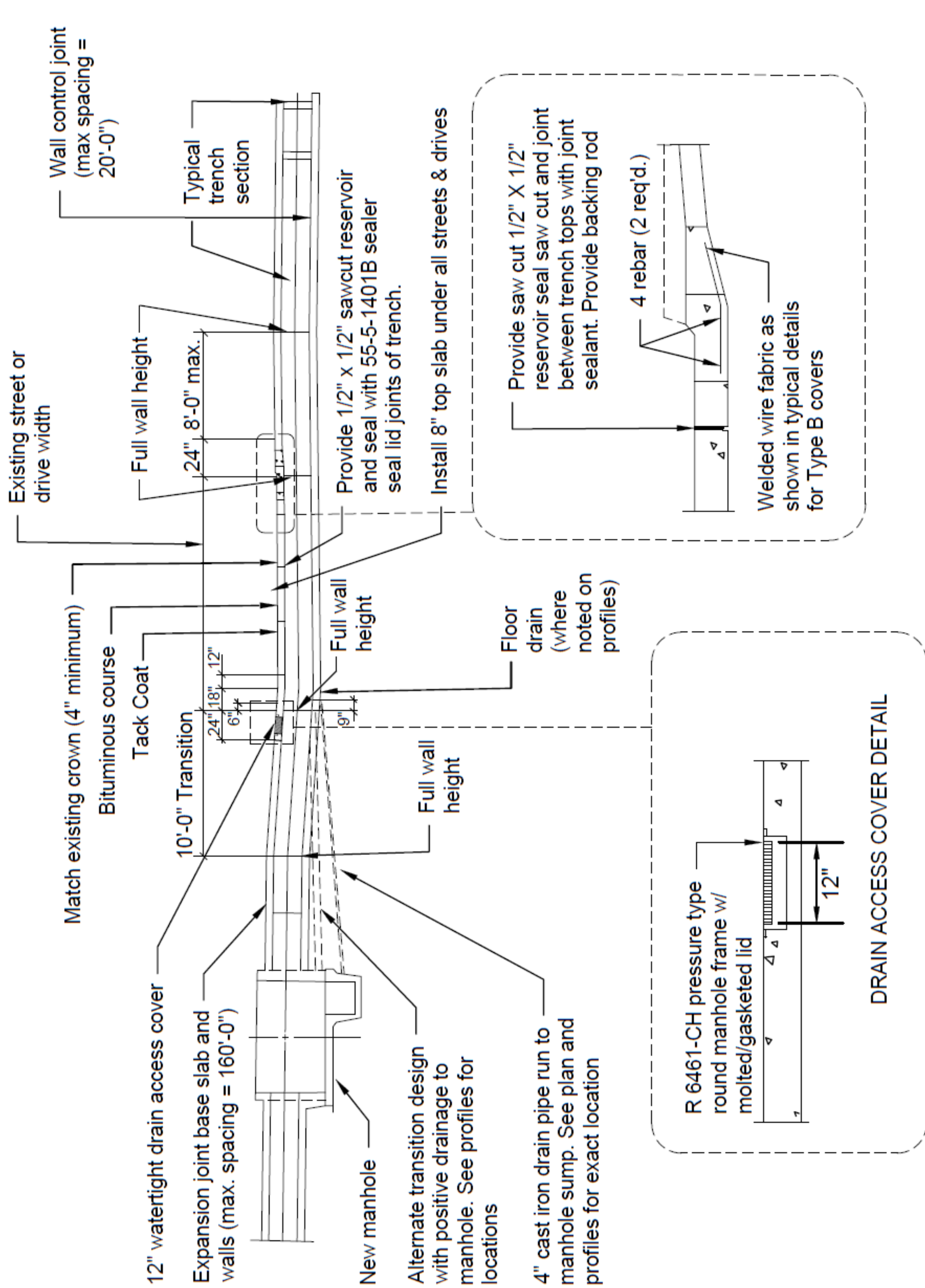
Figure 4-6 Typical Trench Street Crossing Plan Detail



Notes:

1. Precast panel length to be 8'-0" maximum 4'-0" minimum.
2. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
4. Pipe sizes imperial to metric conversion: 4” = 100 mm.

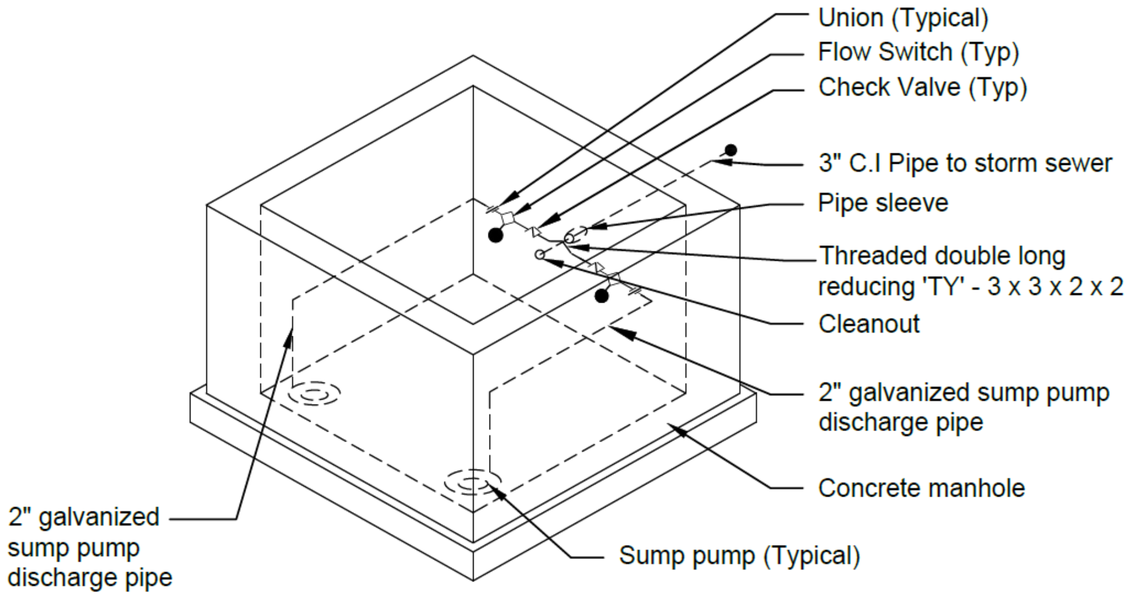
Figure 4-7 Typical Trench Street Crossing Section Detail



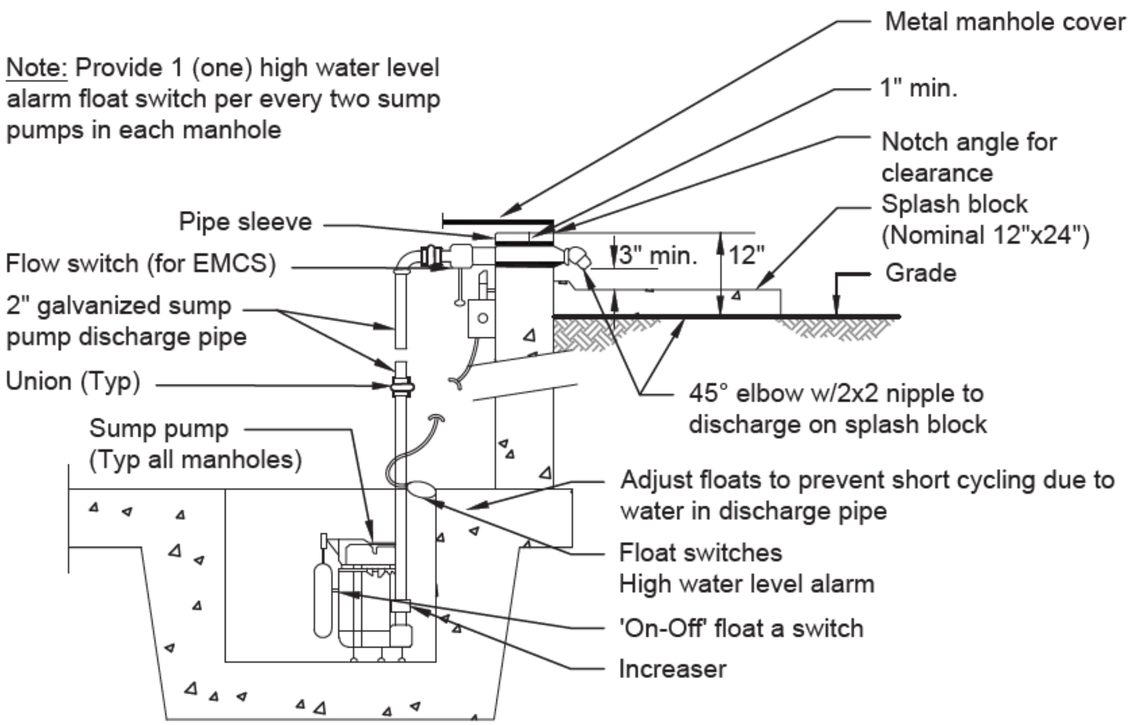
Notes:

1. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
3. Pipe sizes imperial to metric conversion: 4" = 100 mm.

Figure 4-8 Sump Pump Discharge Piping Details



TYPICAL SUMP PUMP PIPING TO STORM SEWER

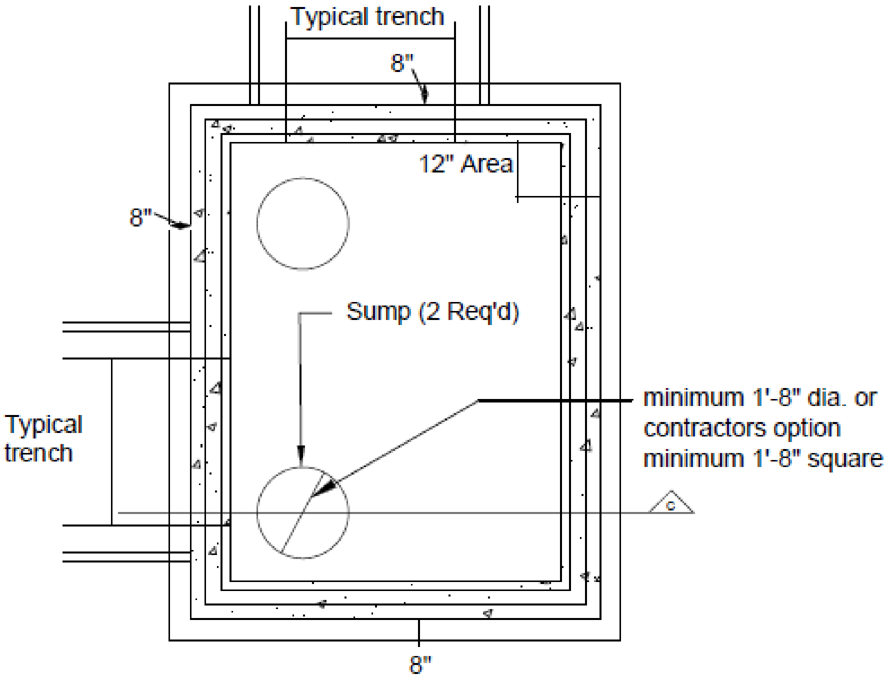


Typical Sump Pump Piping to Splash Block

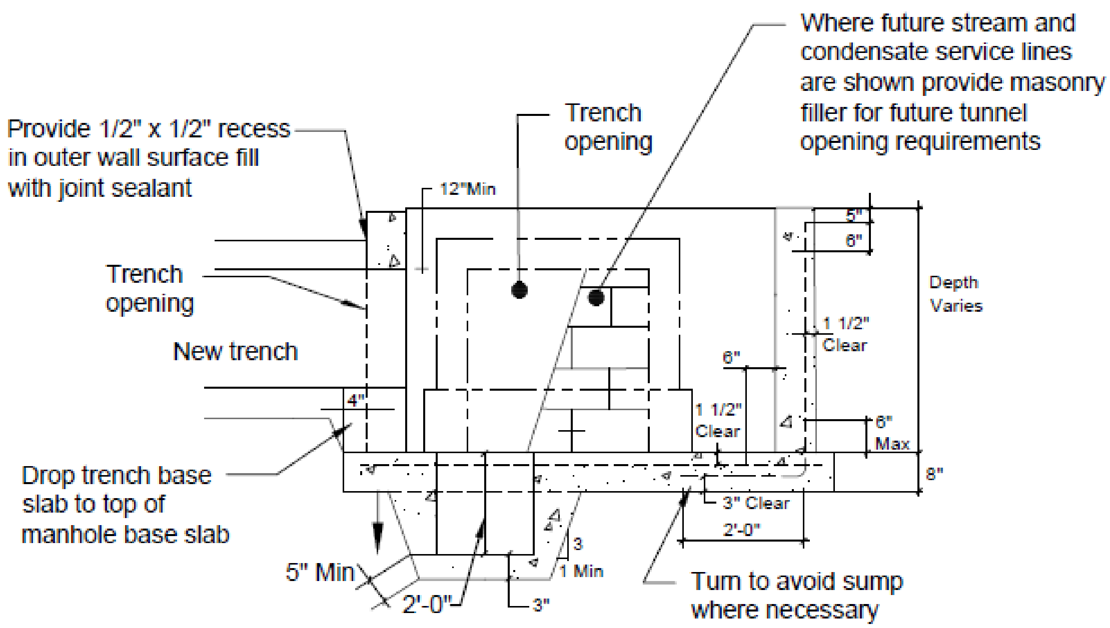
Notes:

1. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
3. Pipe sizes imperial to metric conversion: 2" = 50 mm, 3" = 80 mm.

Figure 4-9 Wall Reinforcing Detail and Typical Valve Manhole Detail



Plan
WALL REINFORCING DETAIL

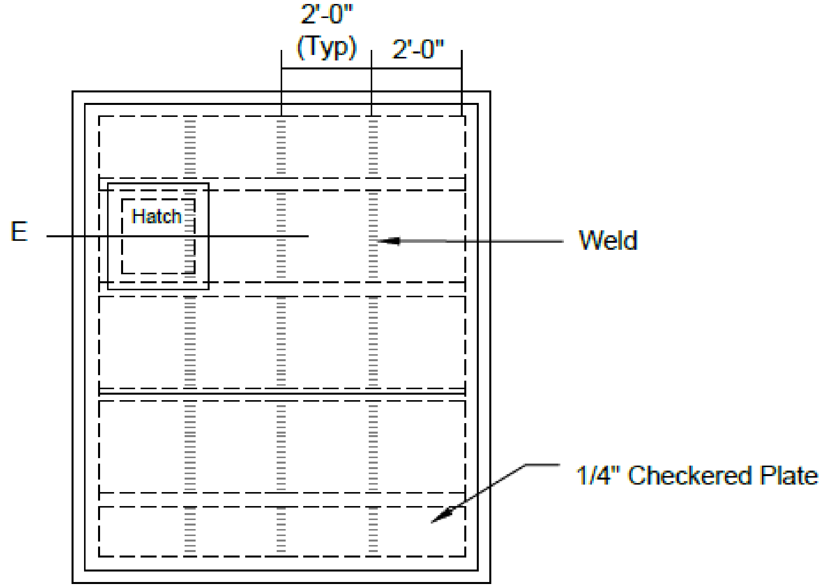


Section C
TYPICAL VALVE MANHOLE DETAIL

Notes:

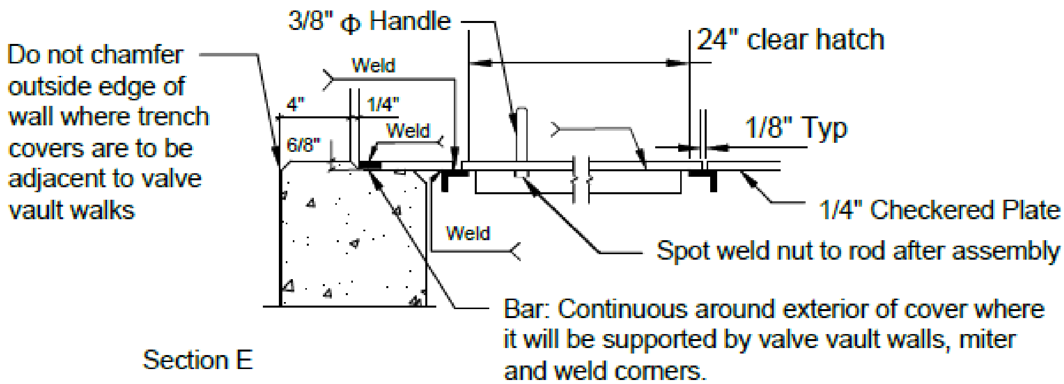
1. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

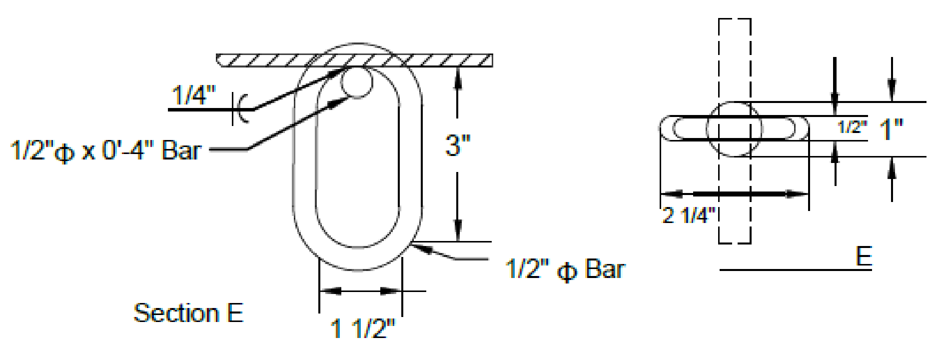
Figure 4-10 Valve Manhole Cover in Walks Detail



Plan

TYPICAL VALVE MANHOLE COVER IN WALKS



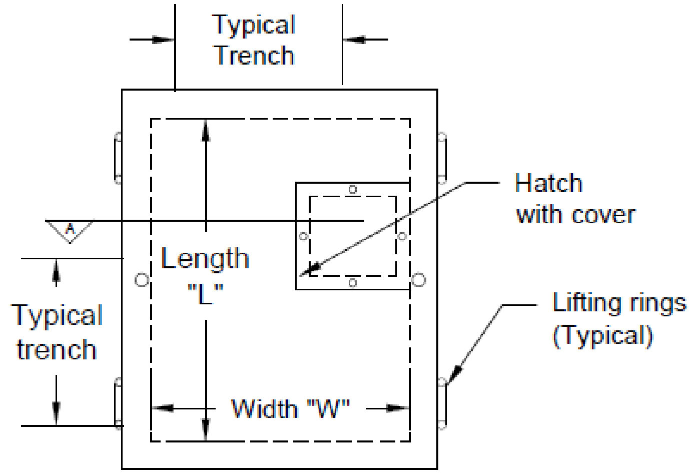


TYPICAL LIFTING DEVICE FOR VALVE MANHOLE COVER IN WALKS

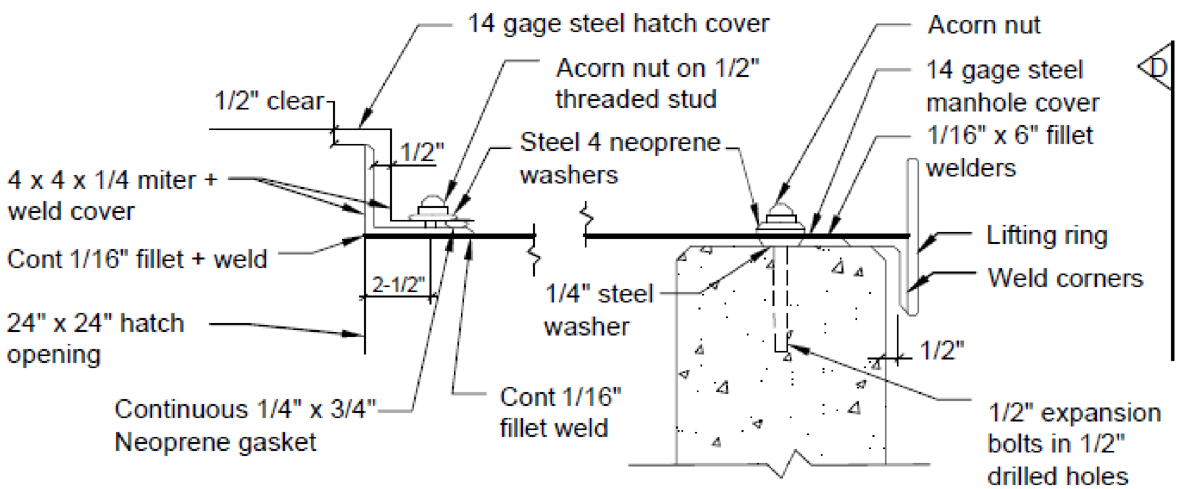
Notes:

1. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

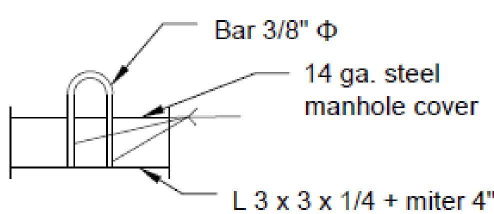
Figure 4-11 Typical Standard Valve Manhole Cover Detail



TYPICAL STANDARD VALVE MANHOLE COVER



Section A



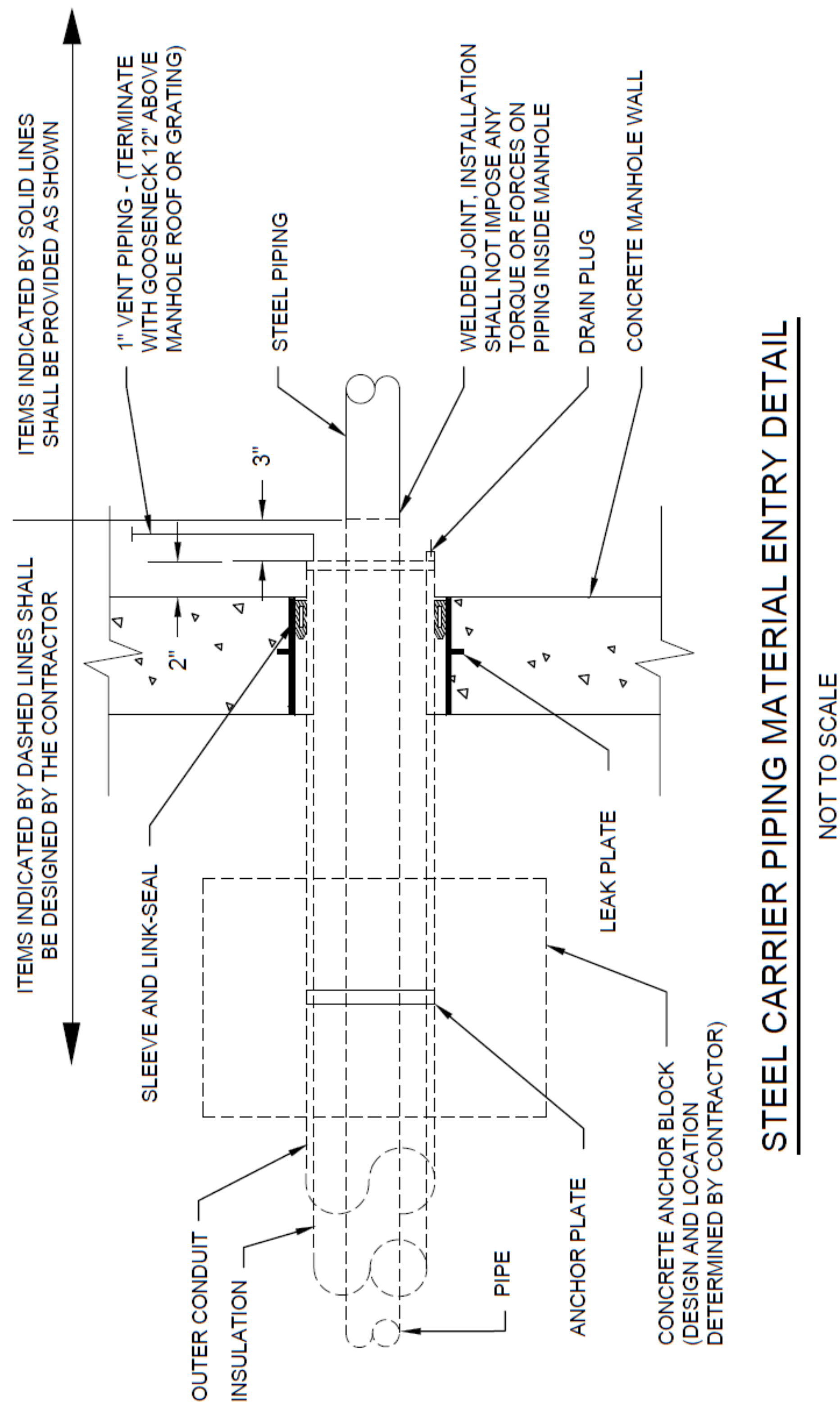
Section D

TYPICAL LIFTING RING

Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

Figure 4-12 Steel Carrier Piping Manhole Entry Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Pipe sizes imperial to metric conversion: 1” = 25 mm.

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CHAPTER 5 HEAT DISTRIBUTION SYSTEMS IN CONCRETE TRENCHES

5-1 GENERAL.

The concrete shallow trench is a system, which allows insulated carrier pipes to be routed underground but yet not have the piping in contact with the soil. The system also provides comparatively easy access for maintenance and repair by means of removable concrete tops. These exposed tops can be used as sidewalks since the system is installed at grade.

5-2 SYSTEM DESIGN.

The designer is responsible for conducting a site investigation, designing the distribution system plan and profiles, and designing the valve manholes, as described in Chapter 3. In addition, the designer will use details and descriptions presented here to design a concrete shallow trench system at a particular site.

5-2.1 Trench Systems - General.

5-2.1.1 Piping and Fittings.

All carrier piping and pipe fittings will be carbon steel and will be designed to satisfy the temperature and pressure requirements of the system. Materials will conform to the requirements in the guide specification.

5-2.1.2 Pipe Supports.

Pipe supports will typically consist of three types: free, guided, and anchor. All of these pipe supports will be mounted on channel supports mounted to the trench walls as detailed in Figure 5-1. Supports may be mounted by other means, such as on concrete pedestals, provided that paths for water flow are maintained. Table 5-1 provides guidance for the sizing of the channel supports. Note that the channels for anchor supports in the table are designed for more substantial loads than required for free and guided supports. The anchor support channel in this table is adequate for approximately 1,000 pounds force axially. The designer will determine axial force requirements at all anchor points and design the channels to accommodate these forces. Maximum distance between support channels must be as listed in Table A-9 in Appendix A. These spacings are applicable to long, straight runs of piping only and must be reduced at elbows, vertical risers, valving, and equipment. The actual spacings, in these instances, will be determined by analyzing the pipe stresses with the pipe stress analysis, as described in Chapter 3 and Chapter 4. There are other types of supports (such as roller type) that may also be used. However, all supports must be capable of withstanding the thermal stresses and forces exerted on them.

5-2.1.3 Clearances.

Clearances in the trench will be adequate to provide room for expansion, air movement, and a sufficient amount of access for cleaning and maintenance. There must also be a minimum of 4 inches (102 mm) clearance under the support channels to ensure ground water drainage along the trench floor. Figure 5-2 provides a trench cross-section, which corresponds to the Table 5-2 trench dimension schedule, which must be filled in by the designer.

5-2.1.4 Insulation and Jacketing.

Insulation will be selected in accordance with insulation thickness tables in the guide specification. These insulation thicknesses were developed using a life cycle cost analysis. All insulations used have passed the Federal Agency Committee's boiling test and are listed in the guide specifications. All insulation in the trench will be covered with jacketing material in conformance to the guide specification.

5-2.2 Trench Systems - Structural.

The concrete trench will be field constructed of reinforced concrete conforming to the current criteria. Trench walls and floors will be poured in place-they will not be precast. Trench tops will be poured in place or precast. Walls, floors, and tops will be constructed with 4,000 psi (27.58 MPa) minimum compressive strength concrete. Reinforcing bars will conform to ASTM A 615, grade 60. Wall, floor, and top thicknesses must be 6 inches (152 mm), minimum. However, thicker sections may be required to accommodate site specific loadings or to prevent flotation. Concrete trench floors must be sloped at a 1 inch in 20 feet (25.4 mm in 6.10 m) slope toward all low points to ensure proper drainage. Typical expansion or keyed joints and water stops must be provided at all construction joints and must be detailed as shown in Figure 4-4 and Figure 5-3. Trench reinforcing details will be provided and will be similar to the section shown in Figure 5-4. Note that actual concrete thicknesses and reinforcing bar sizes will be verified by the designer for each project. Trench corners will be constructed as detailed in Figure 5-5. Trench tops will be no longer than eight feet to allow easy removal and placement.

5-2.3 Trench Top Removal Devices.

The most common type of removal devices for the trench tops will be the sling type as detailed in Figure 5-6. Four lifting devices are required to lift a trench top. One set of lifting devices will accommodate all trench tops for each contract. In some instances, sling type lifting devices will not be convenient to use (for example when the trench top butts up against a parallel sidewalk or when the trench is routed through a parking area). In these instances, the designer must require coil inserts to be cast into the trench cover in four locations that will accommodate threaded lifting eye bolts. When not being used, threaded plugs are inserted into the coil inserts. Eye bolt lifting devices are detailed in Figure 5-7.

5-2.4 Road and Parking Lot Crossings.

Road crossing requirements will be designed on a case by case basis and must take into account pavement materials, soils, and frost characteristics of the design site. A typical road crossing is shown in Figure 5-8. Figure 5-9 details a concrete trench to curb and gutter system transition and Figure 5-10 details a concrete trench to drain pan system transition. In all instances, the crown of the road crossing will be matched and the thickness of the trench top will be designed to accommodate worst case loadings. Parking lot crossings typically will have the trench top exposed at grade as shown in Figure 5-11. Exposed tops allow for easier trench top removal over extended lengths of paved areas. If appearance of the crossing is critical, black pigments may be added to the concrete tops at the road crossing to match the surrounding pavement. In rare instances, the trench tops may be covered with asphalt surfacing, as detailed in Figure 5-12.

5-2.5 Sidewalk Intersections.

In the event the trench system intersects an existing sidewalk, the trench system will match the sidewalk as detailed in Figure 5-13.

5-2.6 Expansion Compensation.

Expansion loop and bend design is the responsibility of the designer, and is covered in Chapter 3. The expansion loop design is critical. Sufficient space needs to be provided in the expansion loop area to ensure that no pipe or insulation interference will occur due to pipe movement as shown in Figure 5-14. This detail indicates location of supports and also shows how the piping system will be offset to allow for expansion movement in the trench. Table 5-3 is a typical loop schedule, which corresponds to Figure 5-14. The locations of the supports in the expansion loops will be determined from the designer's piping stress analysis and then entered in Table 5-3. All piping stresses will be less than ASME B31.1 allowables for each application. The designer will require inspection ports be provided in the trench tops at each bend in the trench system routing for the purpose of observing pipe movement at the bends during system startup. The inspection port is similar to the access cover detailed in Figure 5-16, except the nominal diameter of the lid will be 12 inches (305 mm).

5-2.7 Sealants.

The trench will be sealed to minimize the influx of ground water. A 1/4 inch (6.4 mm) thick neoprene pad will be used between trench tops and tops of trench walls. The pad will have a minimum width of 2 inches (51 mm). All trench joints must be sealed with elastomeric sealants, which are available as a one or two component system. Asphaltic sealants have not performed as reliably for this application. The elastomeric sealant must be able to resist 50 percent total joint movement. The nonsagging type must be used for vertical joints. The self-leveling type must be used for trench top butt joints as shown in Figure 5-15. Other horizontal joints may be sealed with either type of elastomeric sealant, but the sealant used in trench bottoms must finish flush with the floor.

5-2.8 Vents and Drains.

Piping vents and drains will be located at all high and low points, respectively (see Figure 5-17). Piping drains will be provided in valve manholes only where access can be achieved and where system drainage is provided. Piping vents may be located anywhere in the trench piping system with an access cover provided in the trench top, as detailed in Figure 5-16 or with an aluminum access door shown in Figure 3-15.

5-3 GENERAL CONSIDERATIONS.

The designer will address these key areas to ensure a satisfactory shallow trench design.

g. The grading design will ensure ground water will not pond or sit over the trench. The trench will not be routed through existing flood plains, swales, or in areas where seasonal water accumulates. Another distribution system, preferably an Aboveground Distribution System (Chapter 8), would be used in these areas. In areas where seasonal ground water will cause a trench flotation problem, the design will include a subdrainage system along the trench if thickening of system walls and floor slabs to offset the buoyancy effect is not practical.

h. The trench floors will slope a minimum of 1 inch in 20 feet (25.4 mm in 6.10 m) toward valve manholes and the piping will parallel the trench floor. This will allow the trench to drain off all water that may enter. Drainage will then be provided from the valve manholes as described in Chapter 3.

i. Valve manholes must be spaced to minimize the depth of the trench system. Additional manholes may be less expensive than excessive trench depths to accommodate the slope while still keeping the trench tops at grade.

Table 5-1 Channel Support Schedule

LOCATION	PLATE	ANCHOR STUDS	ANGLE	CHANNEL	BOLTS
Free and Guided Supports	1/2" x 10" x 10"	4-1/2" x 4"	2" x 2" x 1/4" x 6" long	MC 6x15.3	1/2"
Anchor Supports	3/4" x 10" x 10"	6-5/8" x 4"	2" x 2" x 1/4" x 6" long	MC 8x22.4	3/4"

Notes:

1. Schedule for channel detailed in Figure 5-1.
2. Note to the Designer: Channels exceeding loadings indicated in this UFC must be designed for vertical and axial loadings encountered.
3. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
4. Imperial channel member MC 6x15.3 is equivalent to metric channel member MC 150x22.8.
5. Imperial channel member MC 8x22.4 is equivalent to metric channel member MC 200x33.9.

Table 5-2 Trench Dimension Schedule

Trench Dimension Schedule											
STANDARD TRENCH ITEM NO.	PIPE SIZES (INCHES)	A	B_1	B_2	C*	D_1	D_2	E*	F MIN.	Hw MIN.	W
					6”			6”			
					6”			6”			
					6”			6”			
					6”			6”			

Notes:

1. Notes to the Designer: Clearances based on the thickest insulation, if less insulation (lower “k”) is provided. Dimensions C, D, E, and F will be different than scheduled. However, overall trench dimensions must remain the same. C* & E* dimensions must be maintained throughout all straight sections of trench to allow proper clearances for expansion.
2. Schedule designations are associated with trench dimension section, Figure 5-2.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm

Table 5-3 Expansion Loop Schedule*

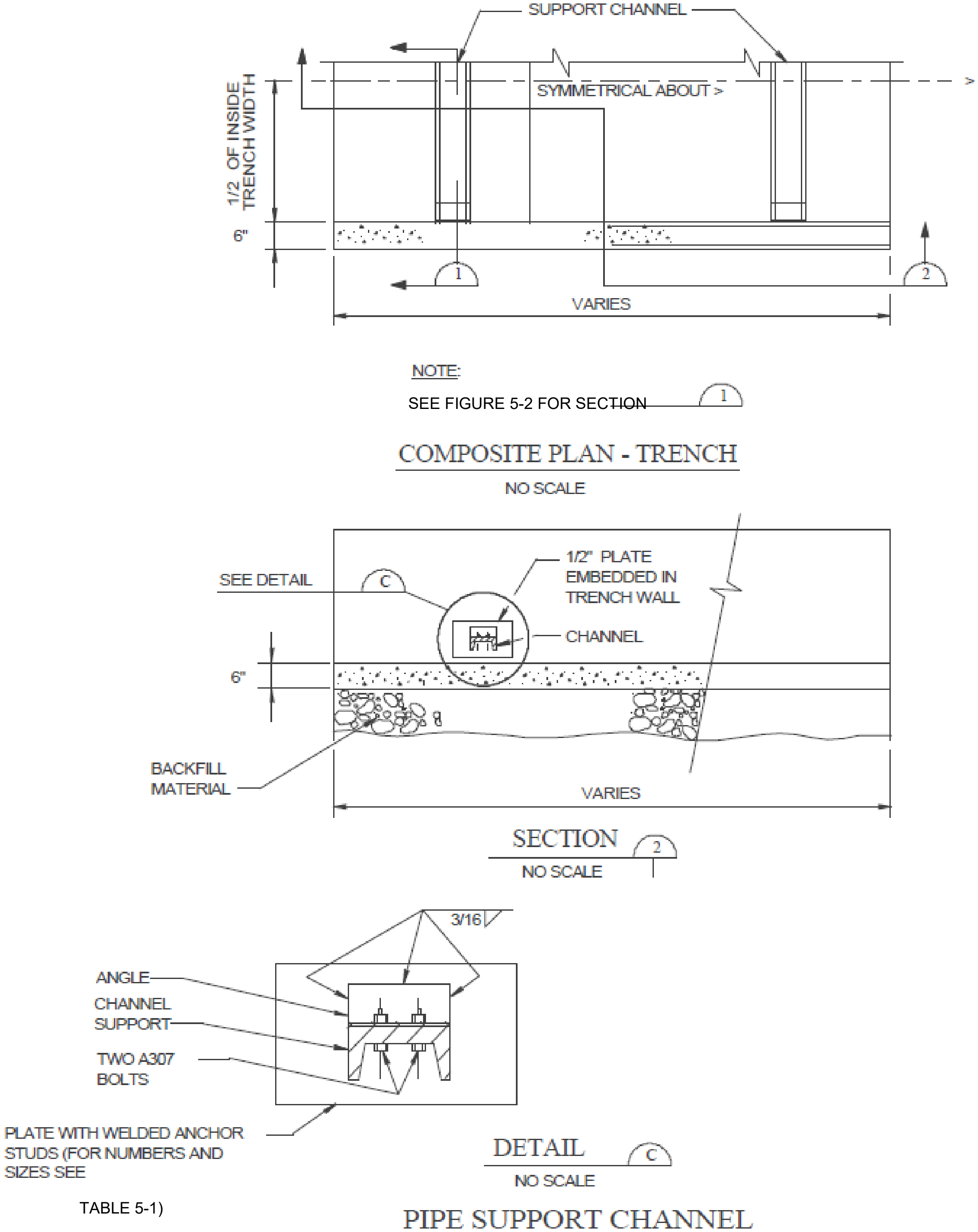
LOOP NAME	LINE SIZES	X	Y	YY	Z	ZZ	W	H	U	REMARKS

*See Expansion Loop Detail for Designations (Figure 5-14)

Note to the Designer:

If only one support is required along parallel leg of loop, ZZ =0. If only one support is required along perpendicular legs of loop, YY = 0.

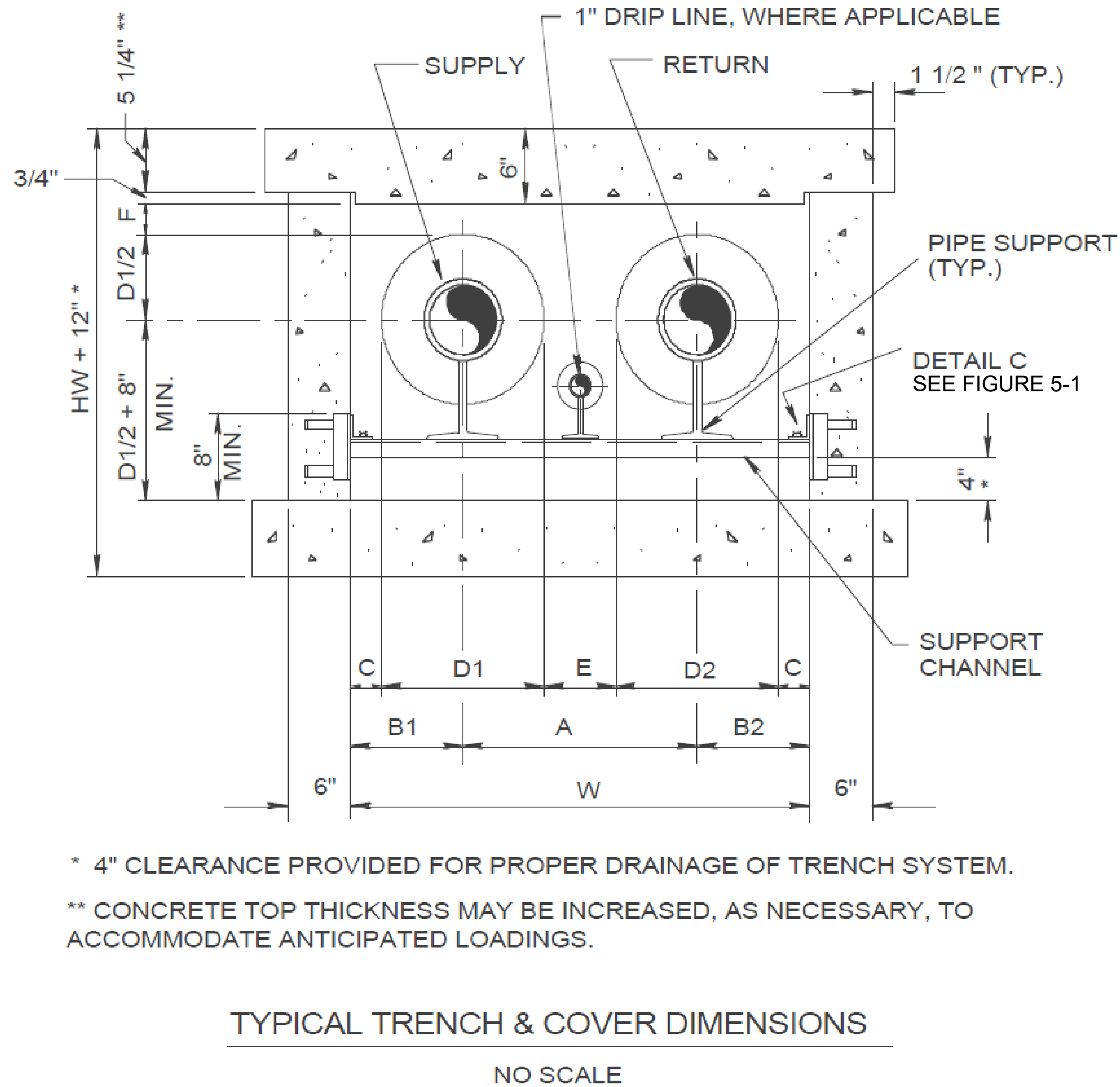
Figure 5-1 Pipe Support Channel



Notes:

1. The channel support may lay on top of the angle rather than being suspended below the angle and held on by bolts as shown. Placing the channel on top would allow the angle to support the channel and the bolts would hold the channel in position.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

Figure 5-2 Trench Dimension Section



Notes:

1. Dimension "HW" must be increased as necessary to accommodate the minimum trench bottom slope of 1" per 20 feet (25.4 mm per 6.10 m).
2. See Table 5-2 for trench dimension schedule.
3. Detail is section 1 from Figure 5-1.
4. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

Figure 5-3 Keyed Construction Joint Detail

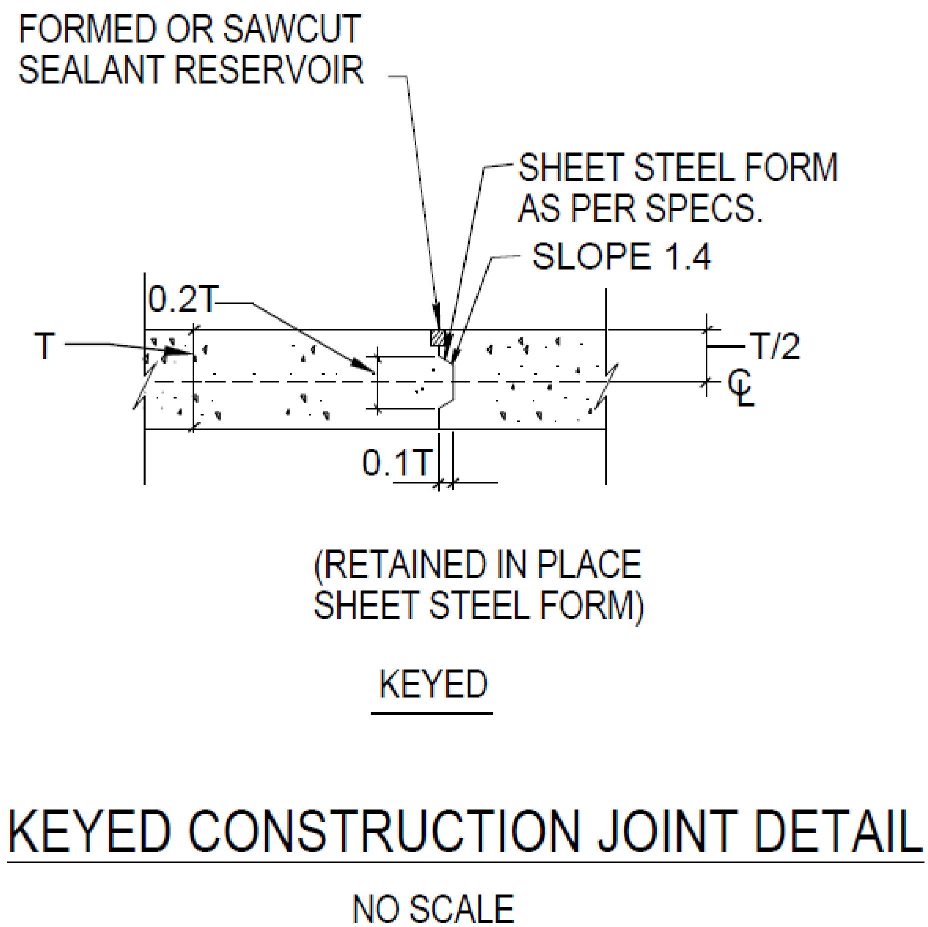
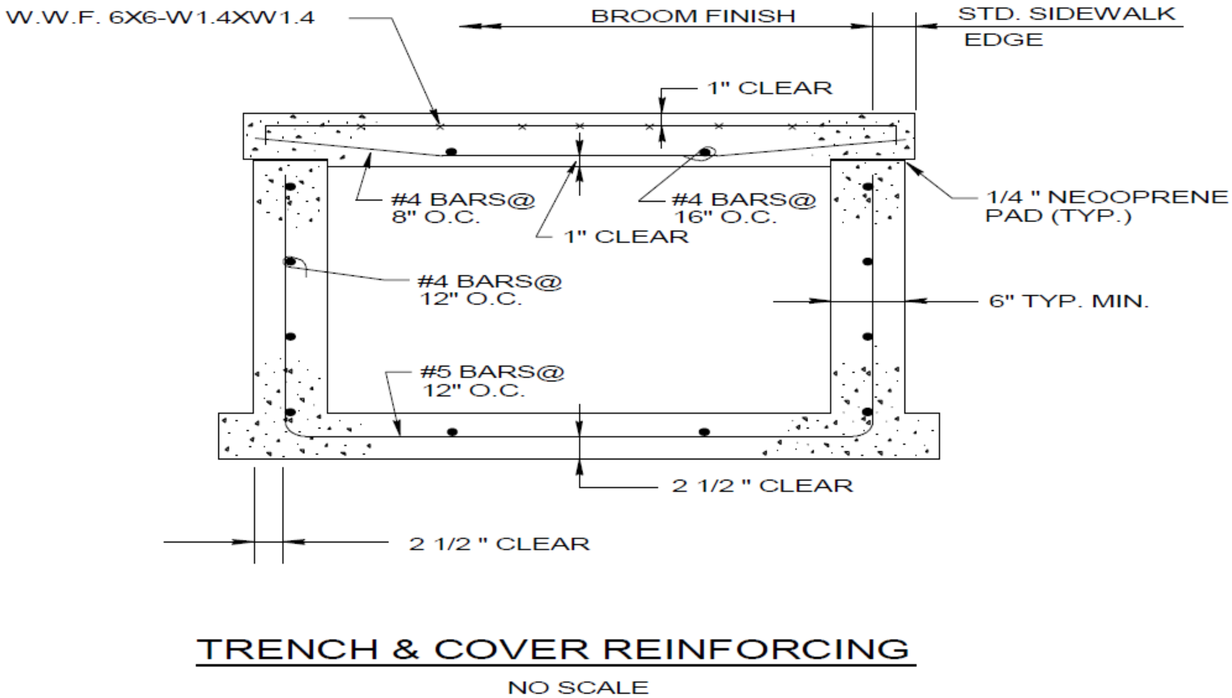


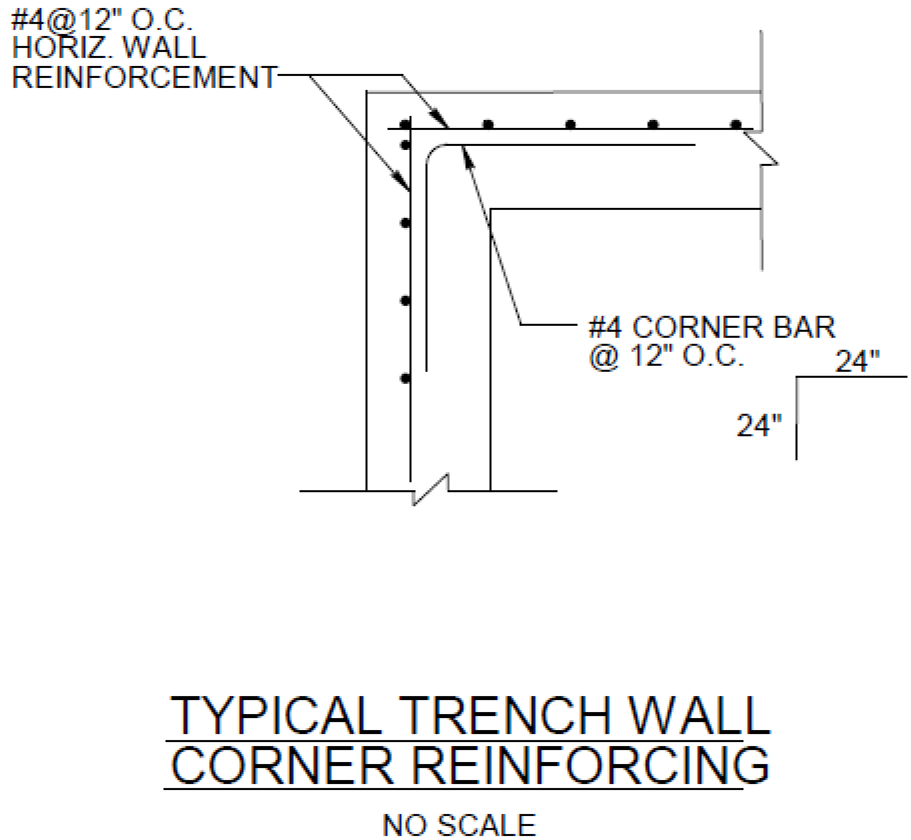
Figure 5-4 Trench and Cover Reinforcing Section



Notes:

1. See Table 5-2 for trench dimension schedule.
2. Note to the Designer: Trench reinforcement and concrete thickness must be determined by a structural engineer based on site specific loads and soil properties. Reinforcement shown is the minimum required.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
4. Imperial rebar #4 is equivalent to metric rebar #13.
5. Imperial rebar #5 is equivalent to metric rebar #16.
6. Imperial WWF 6x6 - W1.4xW1.4 is equivalent to metric WWF 102x102 - MW9xMW9.

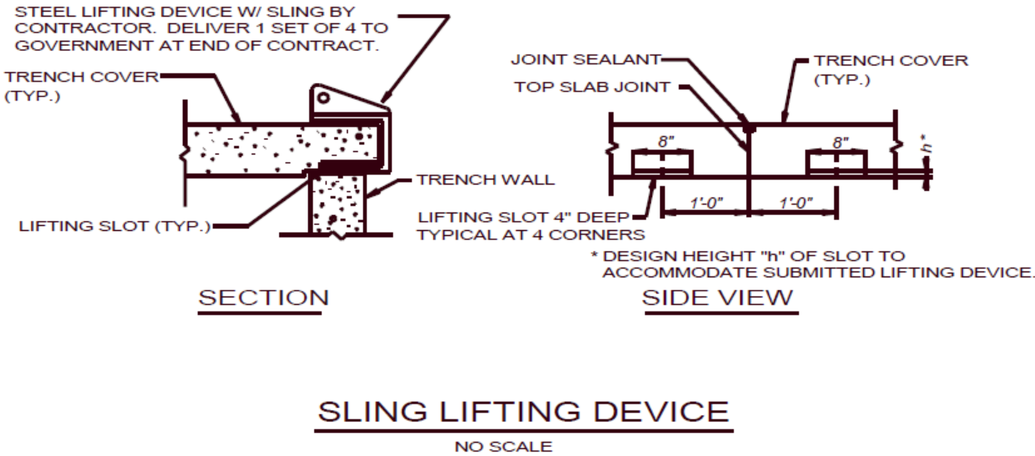
Figure 5-5 Typical Trench Wall Corner Reinforcing Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
2. Imperial rebar #4 is equivalent to metric rebar #13.

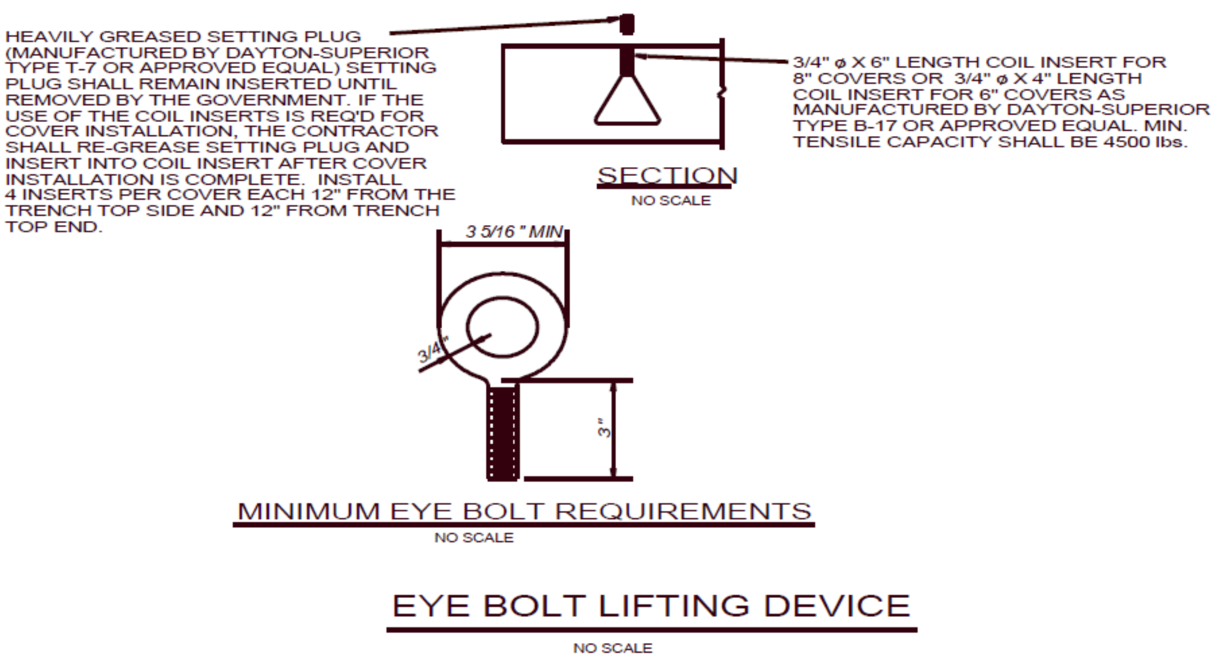
Figure 5-6 Sling Lifting Device



Notes:

1. Design of lifting device must satisfy ACI shear requirements along lifting slots.
2. Contractor must distribute load equally between the four lifting devices by using a strongback or approved equal.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
4. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.

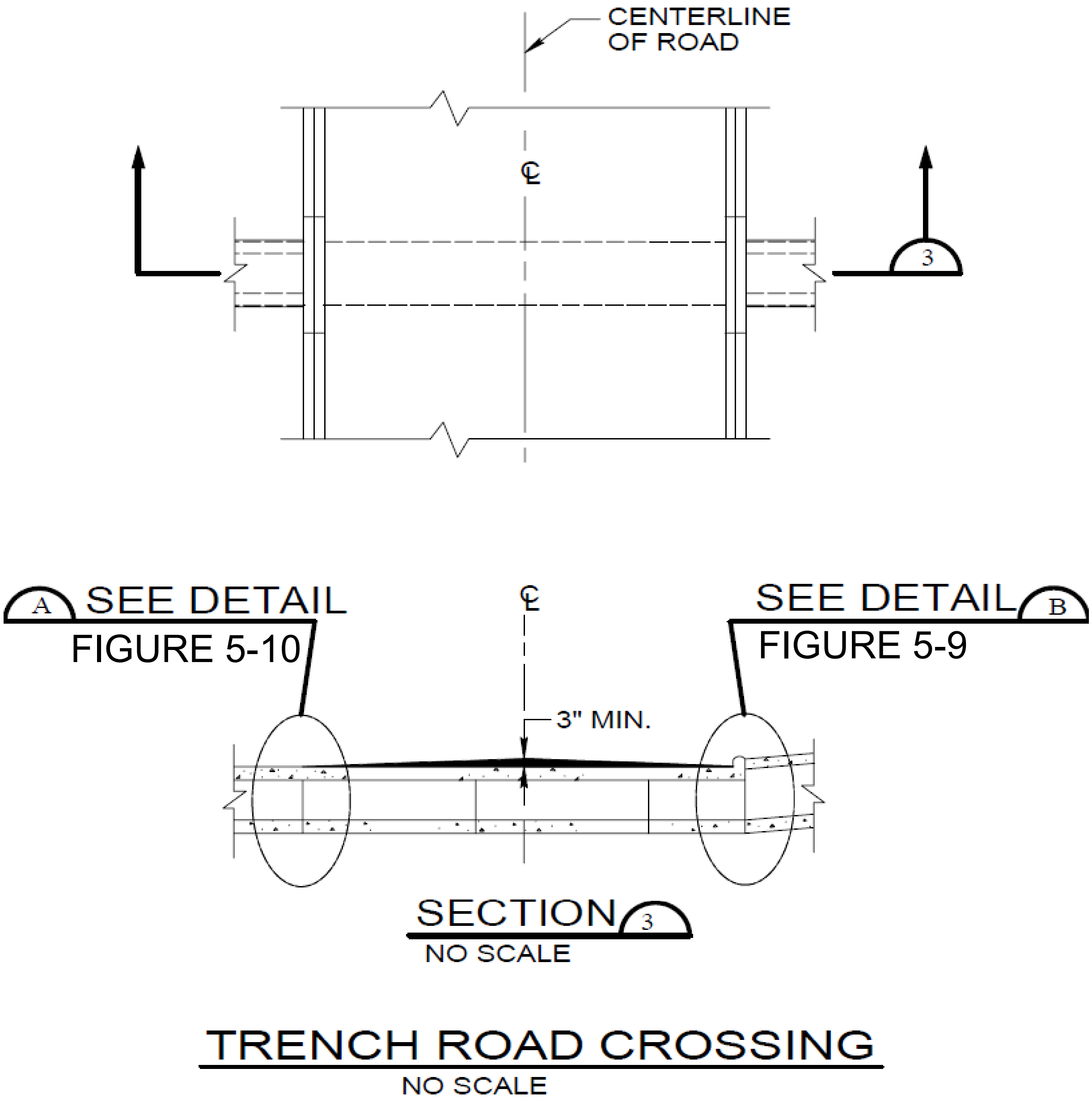
Figure 5-7 Eye Bolt Lifting Device



Notes:

1. Provide 1 set of 4 of each eye bolt type to government at end of contract.
2. Detail applies for trench covers at all road crossings, and at all parking lot crossings. Detail also applies to all trench covers that butt up to back of curbs, and any other areas that would restrict the use of the standard lifting devices. Lifting slots must be provided in all trench covers regardless of whether coil inserts are used or not.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
4. Imperial to metric conversion: Lbs to kg conversion factor is 1 lb = 0.454 kg.

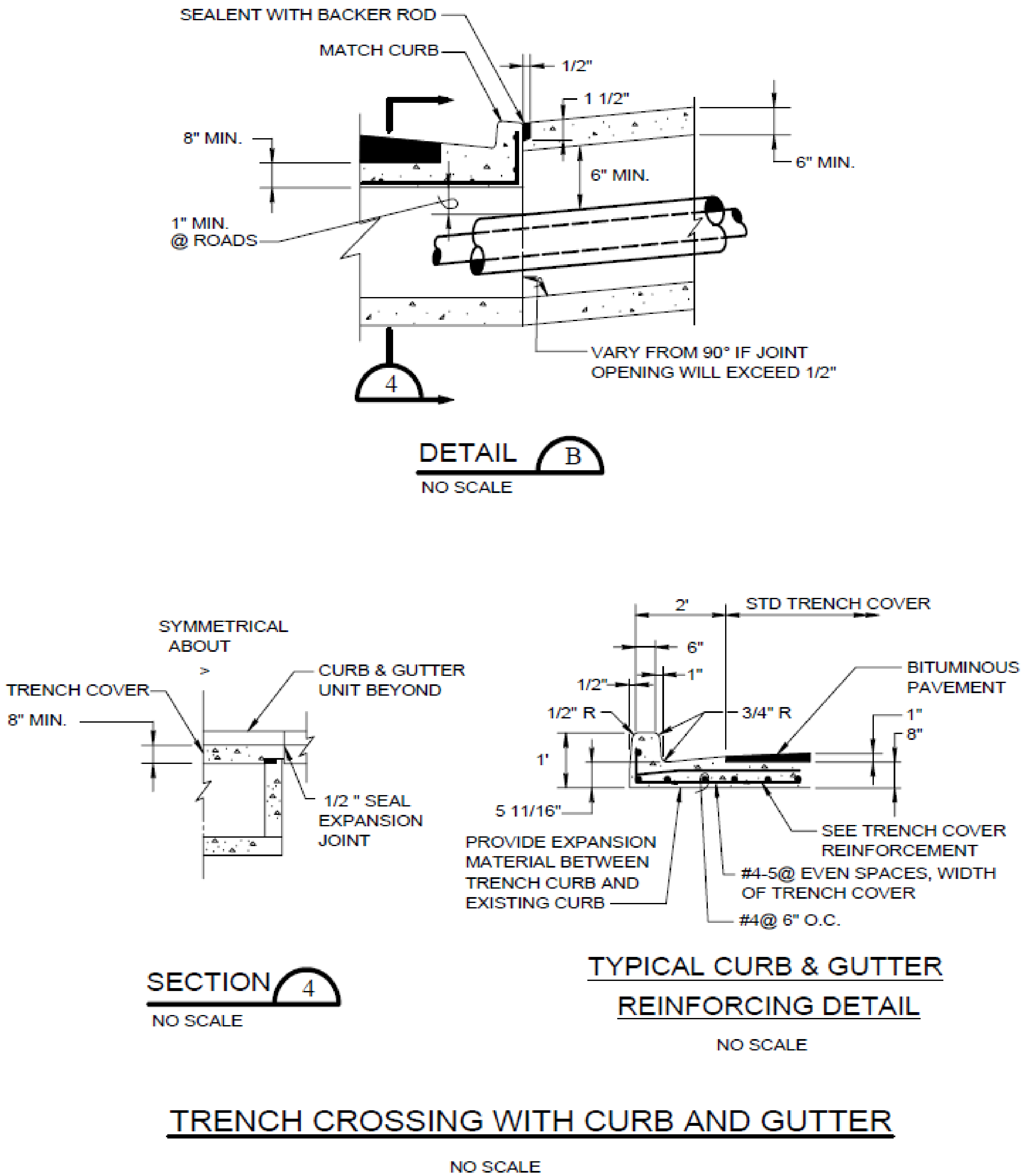
Figure 5-8 Typical Trench Road Crossing



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

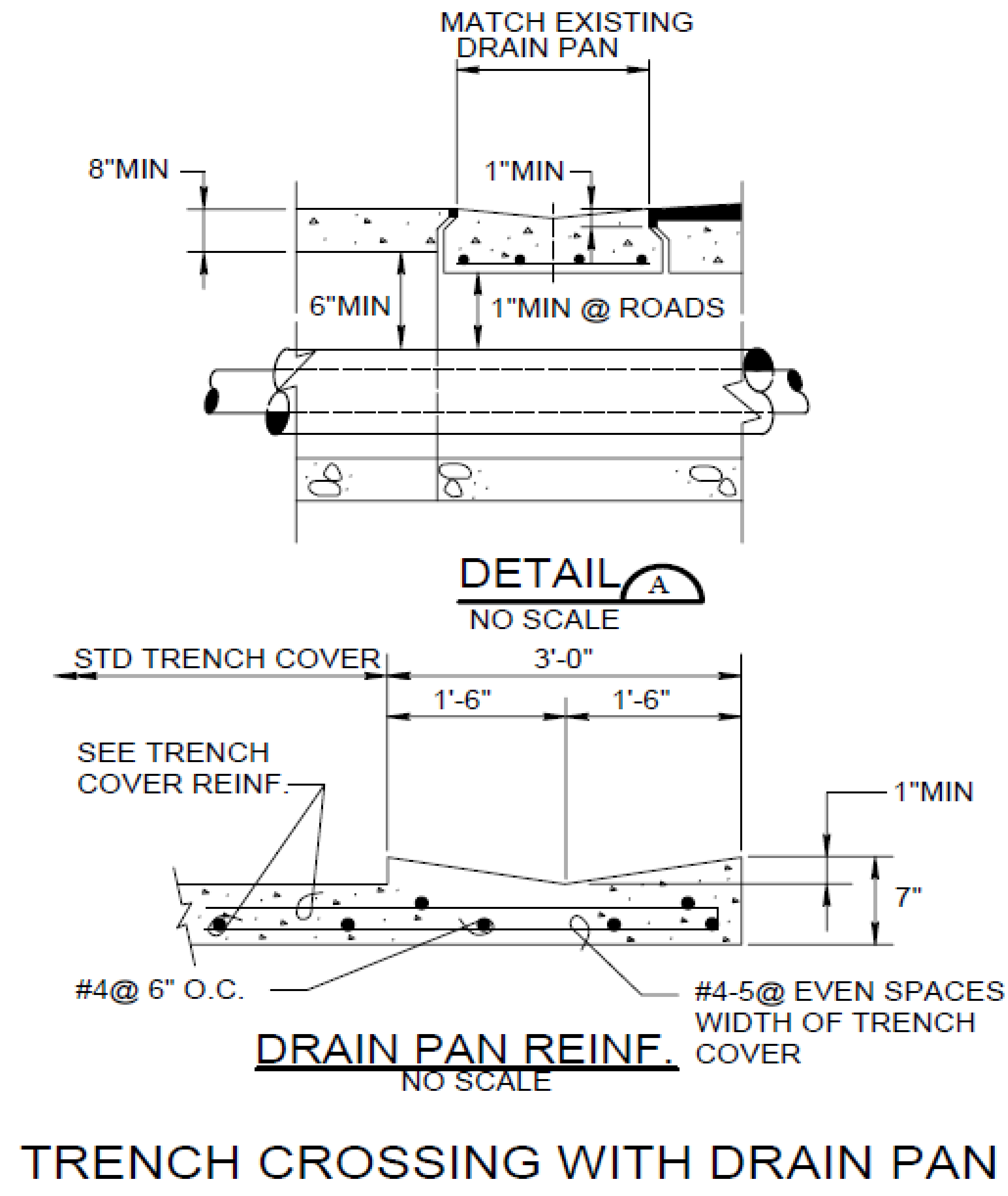
Figure 5-9 Trench Crossing with Curb and Gutter



Notes:

1. Note to the Designer: Trench concrete thicknesses and reinforcement shown must be verified for each design by the designer.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
3. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
4. Imperial rebar #4 is equivalent to metric rebar #13.
5. Imperial rebar #5 is equivalent to metric rebar #16.

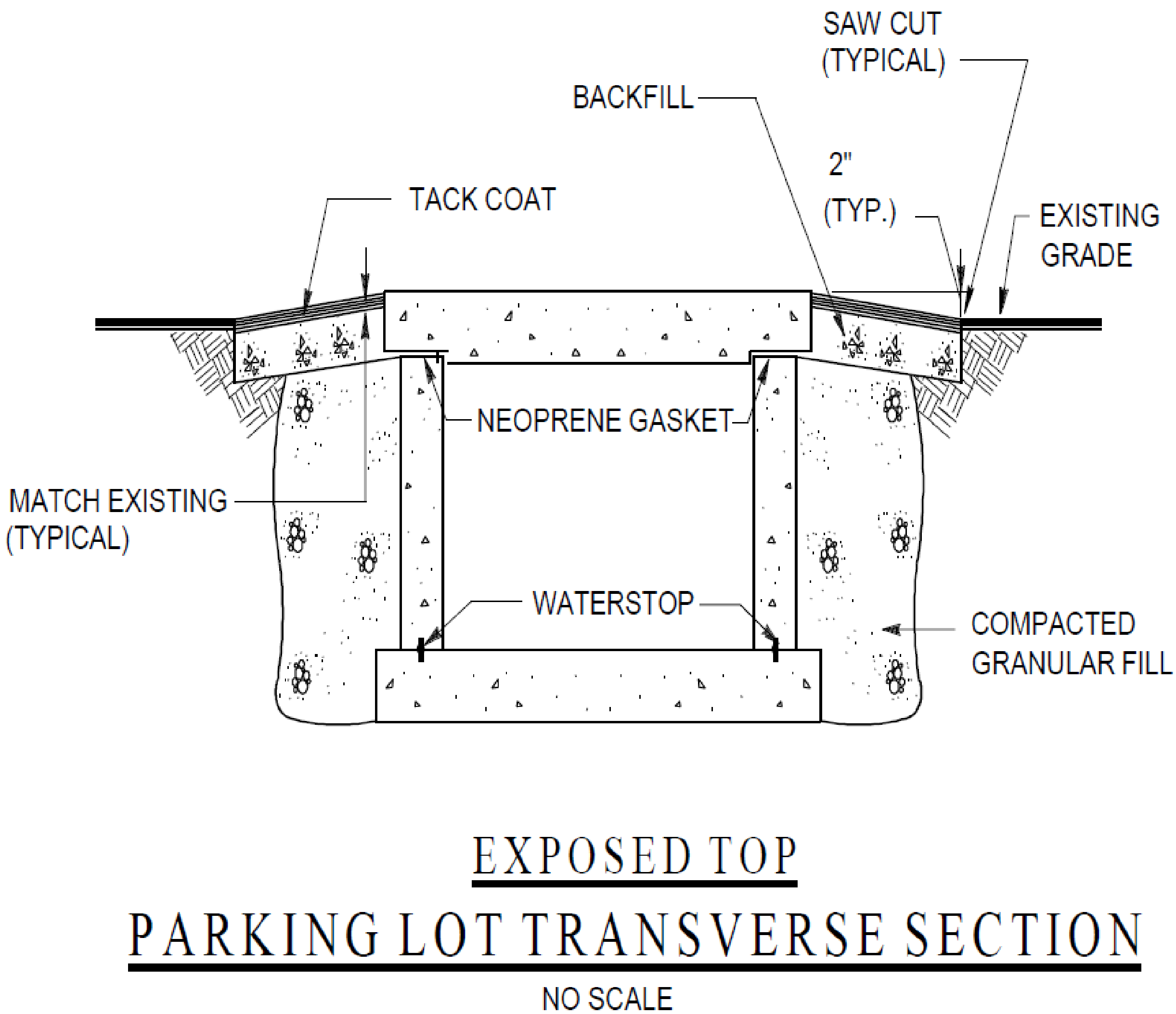
Figure 5-10 Trench Crossing with Drain Pan



Notes:

1. Note to the Designer: Trench concrete thicknesses and reinforcement shown must be verified for each design by the designer.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
3. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
4. Imperial rebar #4 is equivalent to metric rebar #13.
5. Imperial rebar #5 is equivalent to metric rebar #16.

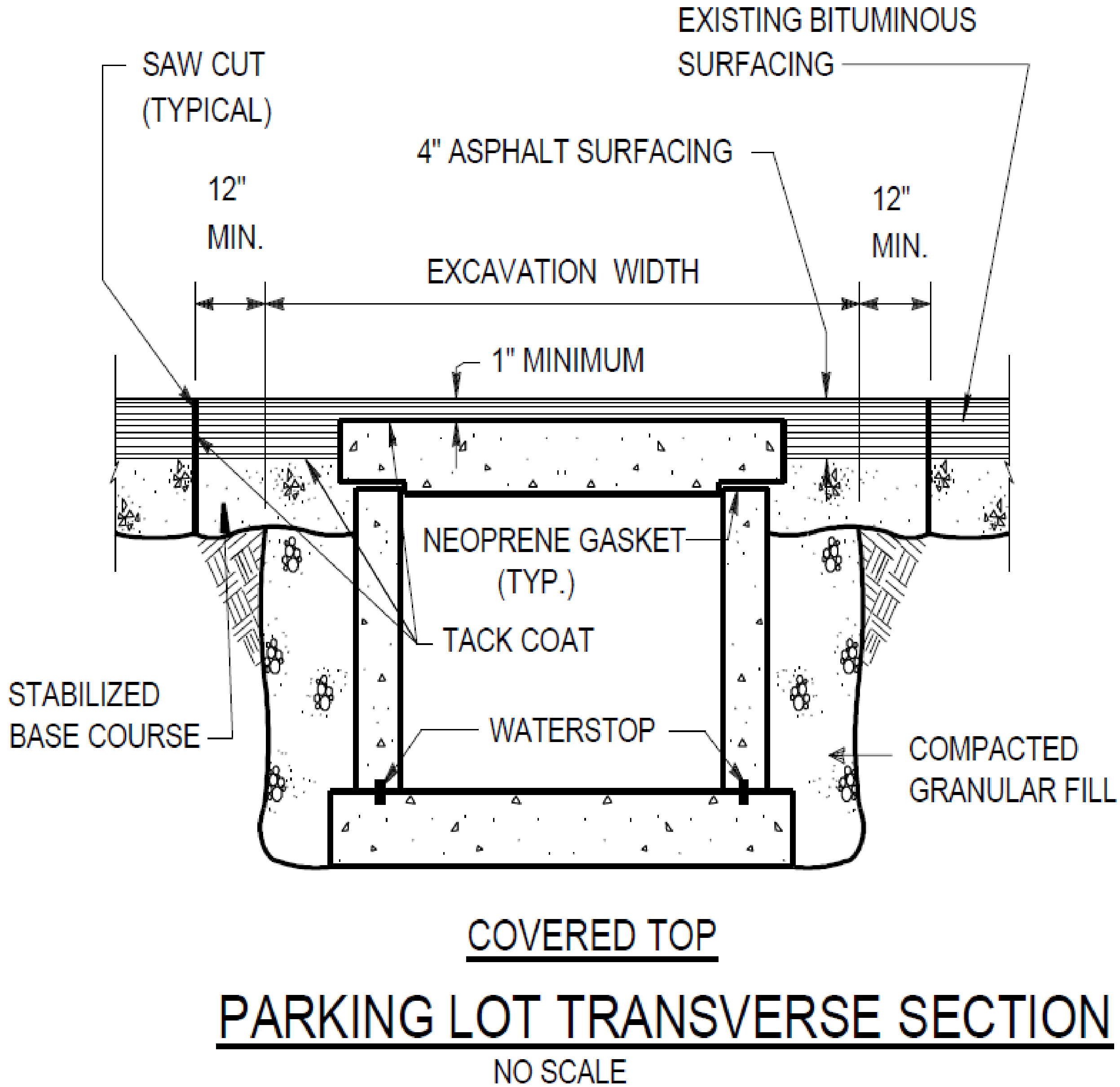
Figure 5-11 Parking Lot Crossing; Exposed Top



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

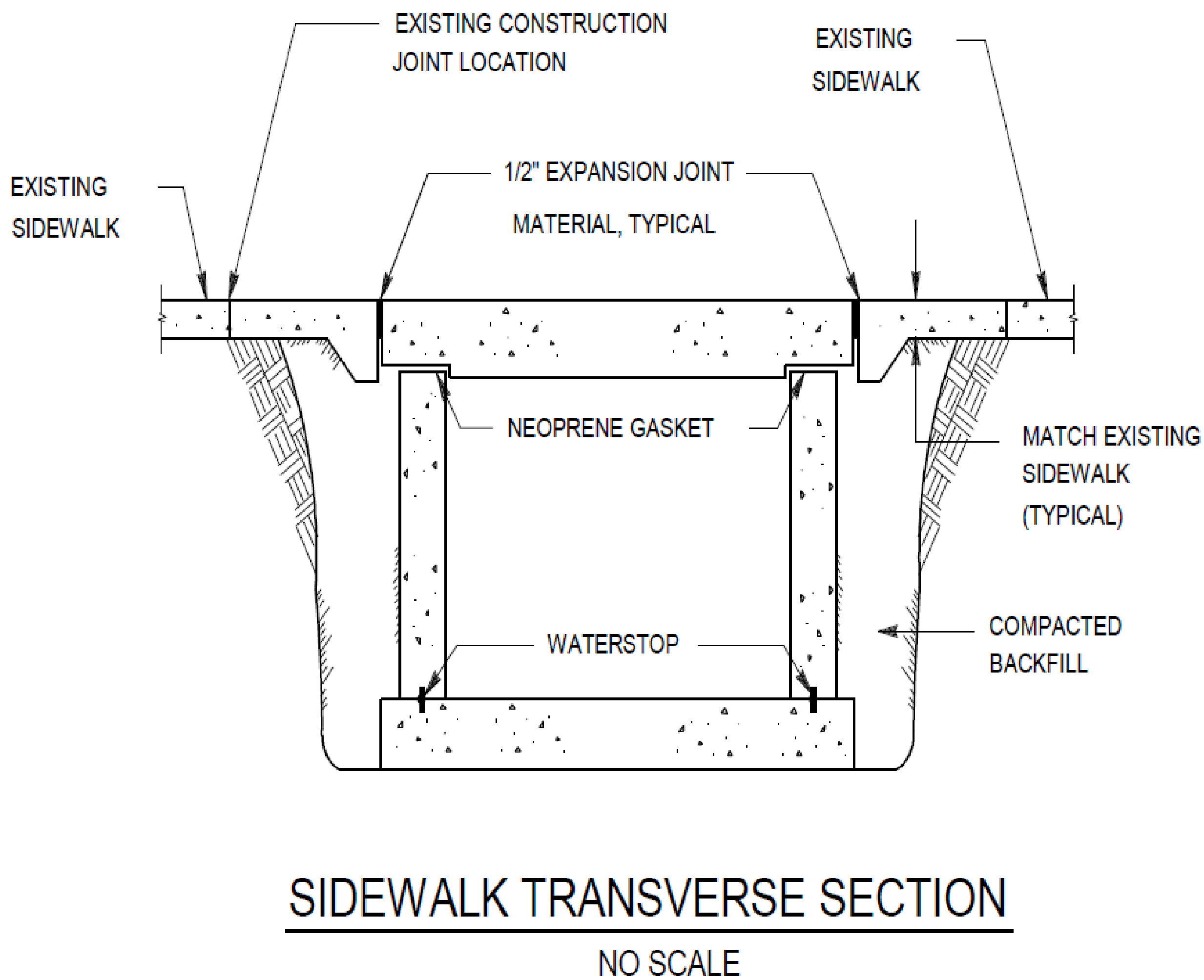
Figure 5-12 Parking Lot Crossing; Covered Top



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

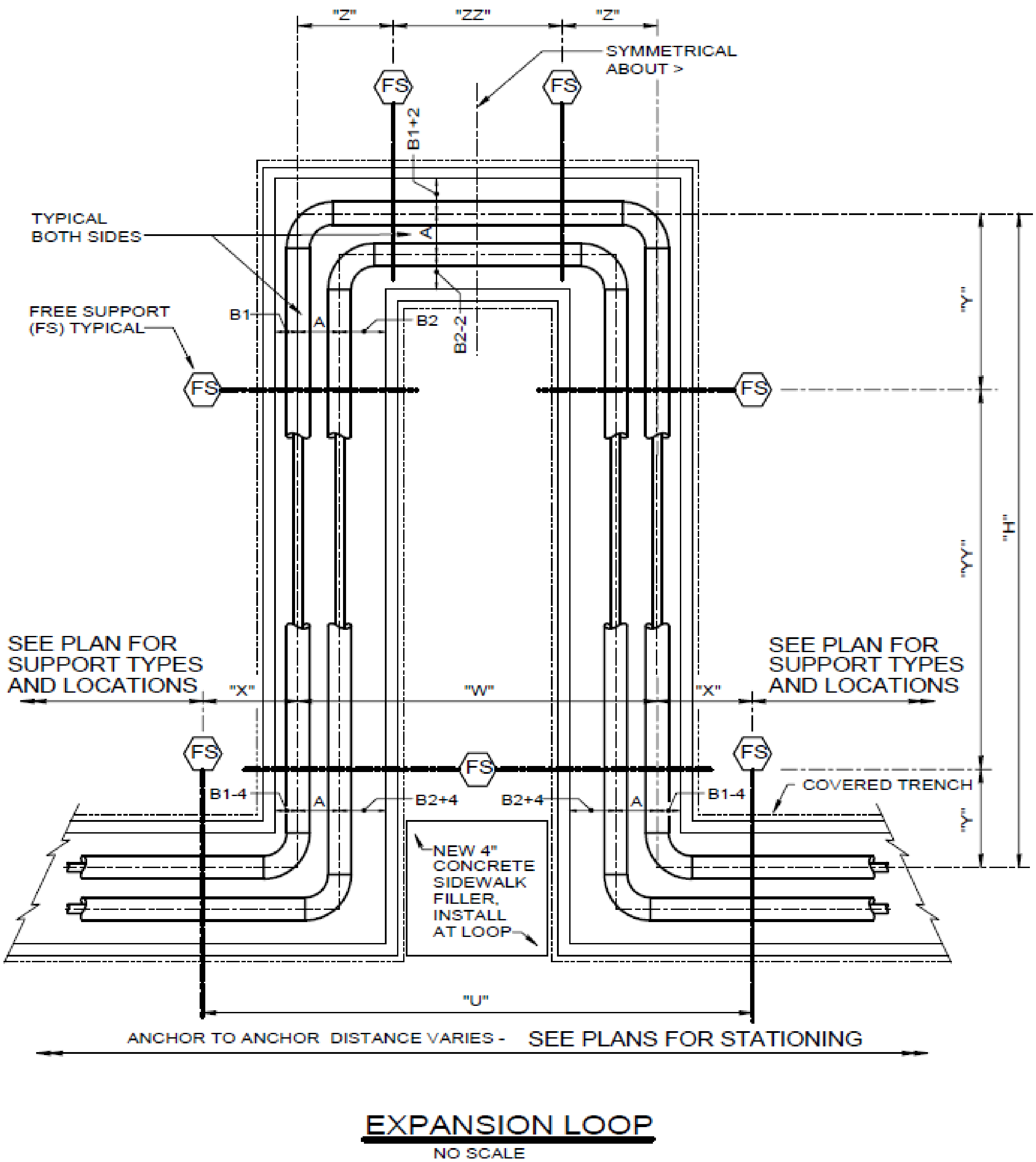
Figure 5-13 Sidewalk Transverse Section Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

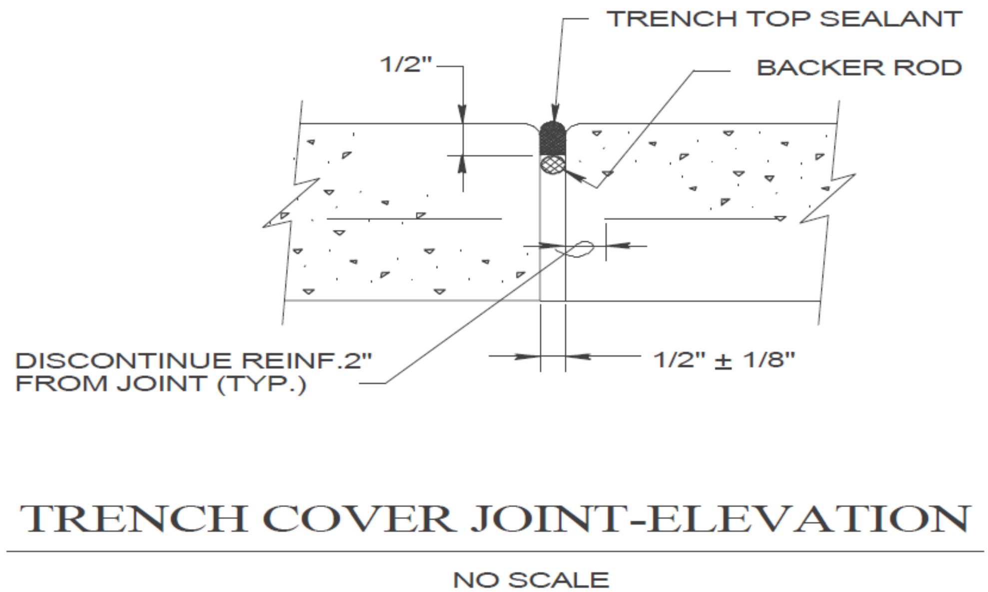
Figure 5-14 Expansion Loop Detail



Notes:

1. Dimensions A, B, and B2 are from the “Trench Dimension Schedule”, Table 5-2
2. Dimensions Z, ZZ, Y, YY, W, H, X, and U are from the “Expansion Loop Schedule”, Table 5-3
3. Note to the Designer: Between the first free support (FS) at the loop and the anchor, alternate free support and guide support (GS) to keep the piping system centered in the trench.
4. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

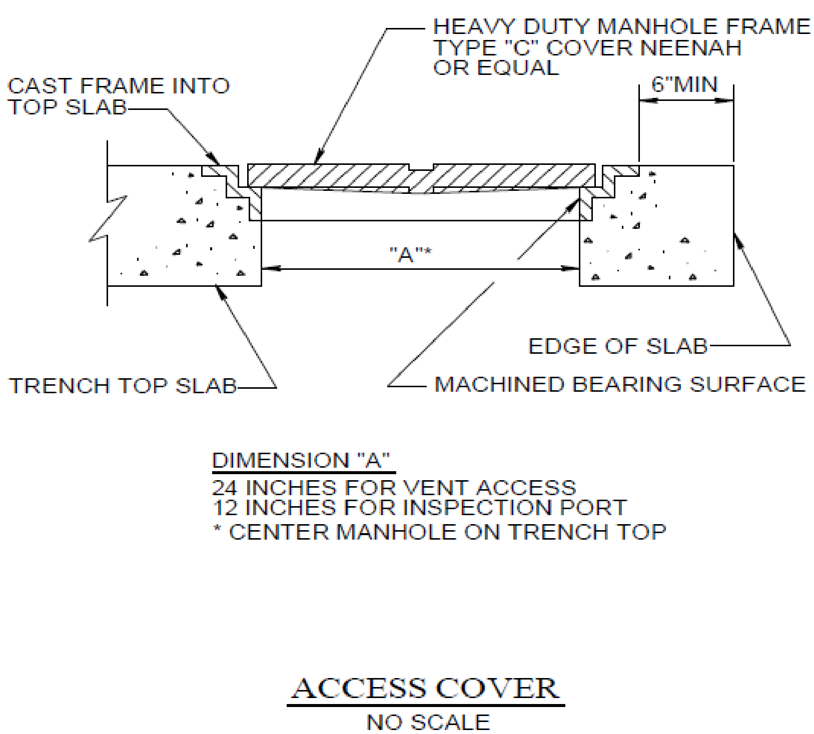
Figure 5-15 Trench Cover Joint Elevation



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

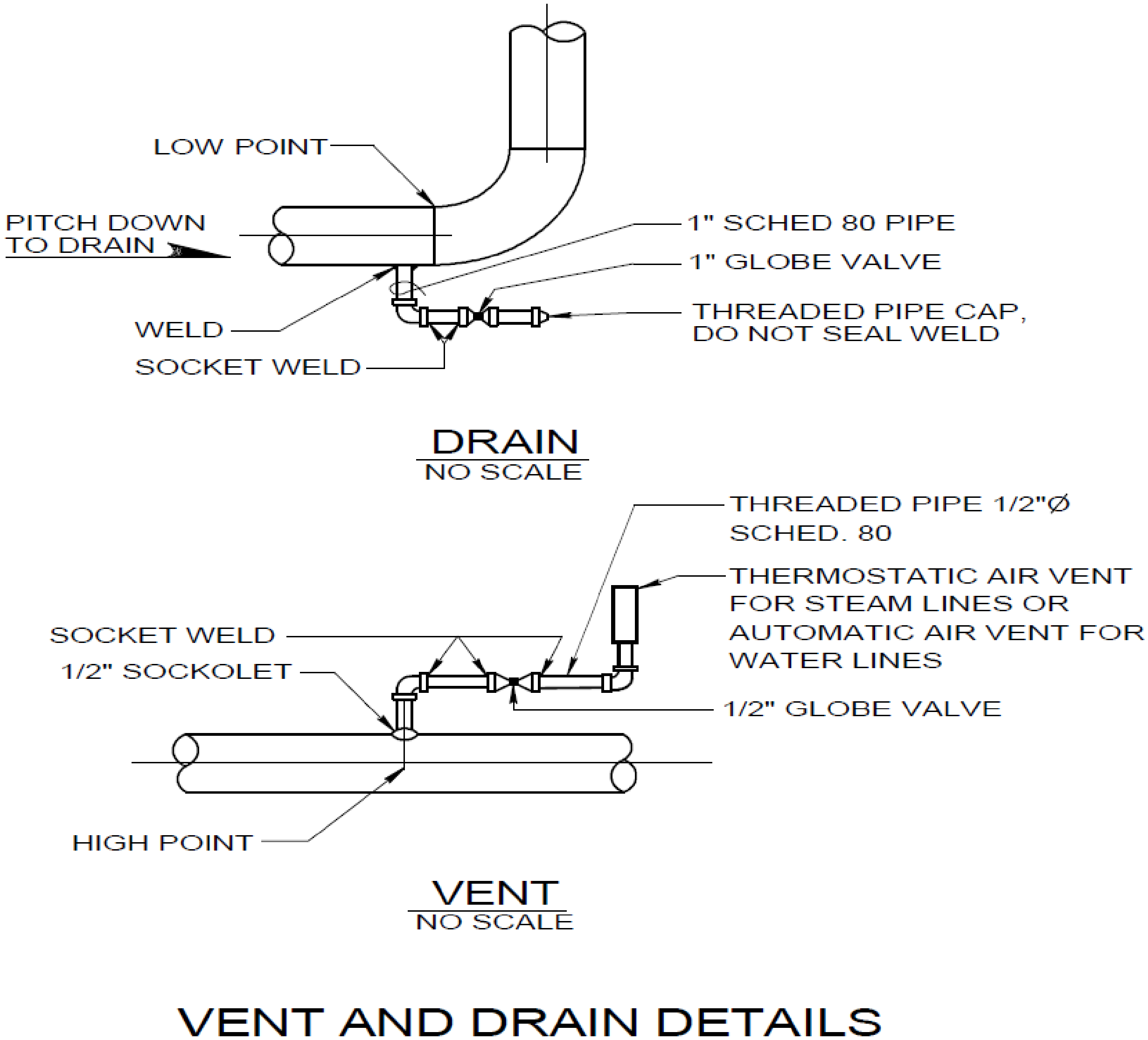
Figure 5-16 Access Cover Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

Figure 5-17 Vent and Drain Details



Notes:

1. Low points in all piping to be drained.
2. Pipe sizes imperial to metric conversion: 1/2” = 15 mm and 1” = 25 mm.

CHAPTER 6 PRE-ENGINEERED UNDERGROUND HEAT DISTRIBUTION SYSTEM

6-1 GENERAL.

Unlike Heat Distribution Systems in Concrete Trenches, which are totally designed by the designer, Pre-engineered Underground Heat Distribution Systems are designed by the system manufacturer. These pre-engineered systems are factory fabricated in lengths, which are transported to the site for field assembly. Other types of systems and materials are continuously being evaluated and will be included in guide specifications and this UFC when deemed acceptable. There are two types of these systems. The DDT type is allowed for severe, bad, and moderate site conditions. In severe sites allow only drainable-dryable-testable type systems. In bad and moderate sites allow DDT and WSL systems. These site conditions (or classifications) are described in detail in this UFC. Although the manufacturer is responsible for the pre-engineered system design, the project designer also has design responsibilities which include establishing the site, soil, and groundwater conditions, pipe sizes, proposed routing (including construction limits) estimated length, elevations, profiles of the system along with existing and finished earth surfaces and obstructions within 25 feet (7.62 m) of the system centerline including adjacent or crossing utilities. The project designer also provides information on location and design of manholes and entrances to buildings and manholes.

6-2 PROJECT DESIGNER'S RESPONSIBILITY.

6-2.1 Site Information.

As with all buried distribution systems, the site investigation is the responsibility of the designer. As described in Chapter 3, the designer will obtain soil borings, be responsible for designing the grading in the area, investigate all utilities for possible conflicts, and design for utility relocation as necessary. The designer must then determine the site conditions (severe, bad, or moderate) before a system type (DDT or WSL) is selected. The designer will then provide plans and profiles of the Pre-engineered system routing. The designer will show approximate slope of the system. 1 inch in 20 feet (25.4 mm in 6.10 m) is required to ensure drainage. This slope must be maintained in the entire system including through each leg of each expansion loop to ensure proper system drainage.

6-2.2 Valve Manholes.

The designer will design all valve manholes for the system as described in Chapter 3. The manholes will be no further apart than 500 feet (152.4 m) to minimize excavation if a leak in the system must be found. The manholes will also be provided at all high (vent) points and low (drain) points in the system. The valve manholes will include ground water drainage capabilities as explained in Chapter 3. Casing vents and drains will be included for maintenance of the casing air space in DDT systems as shown in Figure 6-1.

6-2.3 Insulation.

The insulation types used on the Pre-engineered Underground system will only be those that are listed in the guide specification. The insulation thickness tables in the guide specification will be used in determining required insulation thickness. These insulation thicknesses were developed using life cycle cost analyses.

6-2.4 Cathodic Protection.

The designer will be responsible for the cathodic protection design for all systems with coated steel casings. The cathodic protection system shall meet the requirements of UFC 3-570-01 *Cathodic Protection.* For Army projects only: these projects require cathodic protection Center of Expertise (CX) review of the proposed design. The designer must also require that dielectric flanges be provided to isolate the system's cathodic protection system from non-protected systems. These dielectric flanges must always be installed inside valve manholes.

6-2.5 Review.

The designer will provide a detailed review of the manufacturer's shop drawings to ensure the system meets the requirements of the contract. As a minimum, the following items are required in this review process:

- Carrier pipe size and thickness.
- Insulation thickness, type, and K-value.
- Casing material and thickness.
- Casing coating material and thickness.
- Verification of constant system slope to all low points (proposed elevations at all casing joints on submitted shop drawing layouts).
- Cathodic protection design.
- Manufacturer's system stress analysis.

6-3 MANUFACTURER'S RESPONSIBILITY.

6-3.1 Pre-Engineered Underground Heat Distribution System Design.

The manufacturer is responsible for the Pre-engineered Underground Heat Distribution System. This responsibility includes any or all of the following: insulation types, guided and anchor supports, end seals, casing and piping joint closure, casing type and thickness, and carrier pipe depending on the type of Pre-engineered Underground Heat Distribution System provided. There are two types of Pre-Engineered Underground Heat Distribution Systems. The drainable-dryable-testable system is a factory fabricated system, which includes a watertight outer protective casing of steel, an air space, and an insulated carrier steel pipe. Casing drains and vents are provided in end plates, which are installed in valve manholes. DDT systems can be used for any heating medium including MTW, HTW, high and low pressure steam, and condensate return and in any site condition (severe, bad, or moderate). The WSL systems is also a factory fabricated system, which includes an outer protective casing and an insulated carrier pipe. The system is fabricated in sections, which are independent from each other. Ground water or condensate, which leaks from or into one section, cannot travel into the next section. Field-assembly of the sections requires no welding; the sections are pushed together and are sealed with a system of couplings and seals. WSL systems can be used only in bad and moderate site conditions. The designer must determine the site conditions before a system type is selected. The site conditions will be considered severe, bad, or moderate based on the site investigation results. For DDT and WSL systems, steam and condensate lines must always be installed in separate casings, due to the corrosion problems associated with condensate return systems. Water systems may use just one casing for both supply and return pipes, although installing the pipes in separate casings is preferred by the Government because it is less difficult to isolate leaks. The tops of the casings will typically be buried between 2 and 6 feet (0.61 to 1.83 meters) below grade. However, note that excessive burial depths increase the installation and repair costs and must be avoided where possible.

Show the design for the belowground piping, the manholes, the piping within manholes, and the piping not in approved conduit systems on the drawings. The Contractor designs and provides buried pre-engineered insulated piping system including concrete pipe anchors exterior of manholes, interface with each manhole and building, and the watershed to aboveground piping.

6-3.2 Expansion Compensation.

The manufacturer is responsible for the system expansion compensation. A detailed stress analysis will be submitted for review as part of the contract requirements. The manufacturer will normally make use of expansion loops and bends to absorb system expansion in DDT systems. For WSL systems, field joints may be used to accommodate expansion. Except in rare instances, expansion joints will not be permitted.

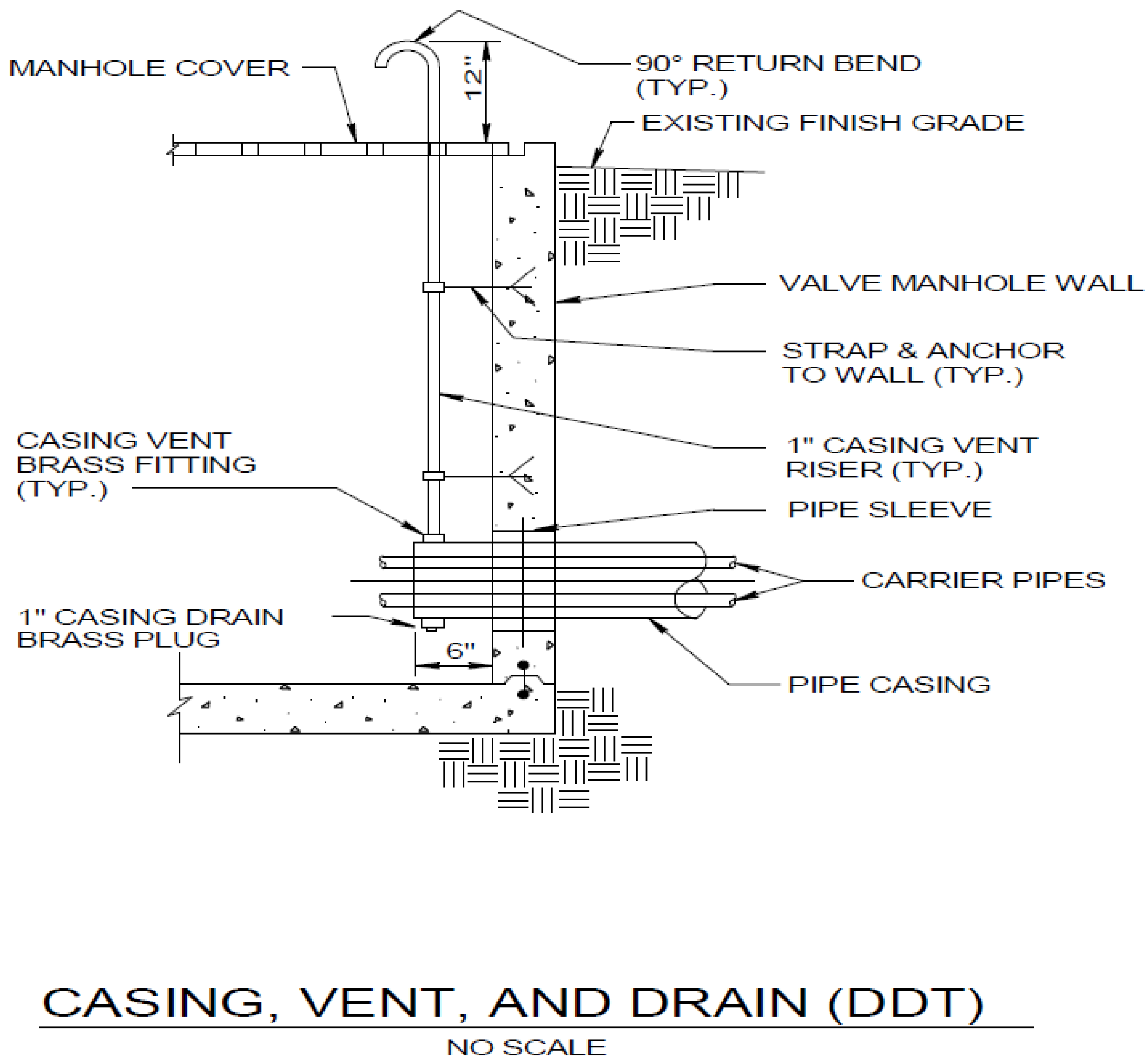
6-3.3 Pre-Engineered System's Representative.

The manufacturer is required to ensure that a qualified direct employee of the system manufacturer is present to guarantee proper installation when the following types of work are performed:

- Inspection, unloading and storage of materials.
- Inspection of trench prior to laying of casing.
- Inspection of concrete thrust blocks.
- Hydrostatic test of all service lines.
- Field joint closure work.
- Air test of casing.

- Coating patch work.
- Holiday test of casing coating.
- Initial backfill up to 10 inches (254 mm) above the top of the casing.
- Radiographic weld examination.
- Startup and operation tests.

Figure 6-1 Casing, Vent, and Drain (DDT) Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Pipe sizes imperial to metric conversion: 1” = 25 mm.

CHAPTER 7 PREFABRICATED UNDERGROUND HEATING/COOLING DISTRIBUTION SYSTEM

7-1 GENERAL.

This system is similar to Pre-engineered Underground Heat Distribution System (Chapter 6) because it is factory fabricated in lengths, which are transported to the site for field assembly. However, the system is not allowed for any high temperature water (greater than 200°F [93°C]) or steam/condensate systems. The project designer is also responsible for more of the overall design.

Show the design for the underground piping, the manholes, the piping within manholes, and the piping not in approved conduit systems on the drawings. The Contractor designs and provides buried factory-prefabricated preinsulated piping in a conduit including concrete pipe anchors exterior of manholes, interface with each manhole and building, and the watershed to aboveground piping.

7-2 SYSTEM DESIGN.

7-2.1 Site Information.

As with all heat distribution systems, the site investigation is the responsibility of the designer. The designer will obtain soil borings, be responsible for designing all grading in the area, and investigate all utilities for possible conflicts with the system. The designer will provide detailed design plans and profiles of the distribution system routings. The design will ensure a minimum slope of 1 inch in 20 feet (25.4 mm in 6.10 m) is maintained between valve manholes. The site information requirements are covered in detail in Chapter 3.

7-2.2 Valve Manholes.

The designer will design all valve manholes for the system as covered in Chapter 3. As with valve manholes for the Pre-engineered Underground Heat Distribution System, manhole spacing will not exceed 500 feet (152.4 m) and all manholes will have drainage capabilities. Also, all valves, flanges, unions, and couplings must be located within the manholes.

7-2.3 System Material Selections.

Although this system is manufactured in sections in a factory, the designer will specify all materials.

7-2.3.1 Piping.

The piping materials allowed are steel, copper tubing, RTRP, or PVC. RTRP piping cannot be routed through valve manholes with heating systems that could damage the RTRP. PVC piping cannot be routed in any valve manhole with any other heating system piping due to its comparatively low temperature tolerance.

7-2.3.2 Casing.

Allowed casing materials are PVC, polyethylene, or RTRP. Because these casing materials are susceptible to damage from high temperatures, they must be installed a minimum of 15 feet (4.6 m) from buried MTW, HTW, or steam systems to avoid plastic deformation and failures of the casing materials.

7-2.3.3 Insulation.

Insulation type for these systems is typically polyurethane foam. Open cell type insulations, such as fiberglass, mineral wool, or calcium silicate, are unacceptable for use with chilled water systems due to the tendency of condensation forming in these insulations. Insulation thickness will be specified in the guide specification.

7-2.4 Expansion Compensation.

The designer will perform expansion compensation calculations as covered in Chapter 3 and Chapter 4. When required, based on these calculations, sizes and locations of all expansion loops and bends, and any other expansion-compensating device, will be clearly shown on the contract drawings. The designer must provide expansion loop details.

CHAPTER 8 ABOVE GROUND DISTRIBUTION SYSTEMS

8-1 GENERAL.

Aboveground distribution systems have the lowest first cost and lowest maintenance costs of any distribution system described in this UFC and are completely designed by the project designer. This system is a good application for industrial areas and where water tables are high. Many installations, however, do not desire to have distribution piping above ground for aesthetic reasons.

Show the design for the aboveground piping, and the piping under roads on project drawings. The design includes manholes, the piping within manholes, (buried factory-prefabricated preinsulated piping in a conduit or pre-engineered insulated piping under roads), concrete pipe anchors, interface with each manhole, and the watershed to aboveground piping.

8-2 SYSTEM DESIGN.

8-2.1 Site Information.

The designer will determine information on the site. The designer will design all grading for the area and investigate all utilities for conflicts. The designer will provide detailed plans and profiles of the above ground distribution system routing. Although this system is aboveground, profiles will indicate system drain and vent points and also potential interferences between the concrete support piers and any buried utilities.

8-2.2 Piping and Fittings.

All carrier piping and pipe fittings will be carbon steel and will be designed to satisfy the temperature and pressure requirements of the system. Materials will conform to the requirements of the guide specification.

8-2.3 Pipe Supports.

The two most common types of aboveground distribution systems are low profile and high profile.

8-2.3.1 Low Profile System.

In this system, the distribution piping is mounted to concrete piers by means of pipe supports. Typically, the bottoms of the pipes are mounted no more than 4 feet (1.22 m) above grade except at road crossings, which incorporate high profile supports. Typical pipe supports including anchored, free, and guided pipe supports are mounted to the concrete piers. Spacing of supports in straight runs of piping will conform to the support spacing schedule in Table A-9 in Appendix A. Provide extra supports, as necessary, at pipe bends and risers. Requirements for concrete piers and pipe supports are included in the guide specification.

8-2.3.2 High Profile Systems.

High profile systems are routed high enough to cross roads and avoid obstructions. Typically the piping will be installed 14 to 16 feet (4.3 to 4.9 m) above grade. The system presented in this UFC uses 6-inch concrete-filled pipes embedded in concrete footings. Typical pipe supports including anchored, free, and guided pipe supports are mounted to the channels at the top of the support. Anchored type pipe supports are typically stabilized with guy cables. The designer for each pipe support application or support structure must size these to withstand the thermal stresses and forces exerted on them. Spacing of supports in straight runs of piping will conform to the support spacing schedule in Table A-9 in Appendix A. Extra supports will be added, as necessary, at pipe bends and risers. Concrete footings and high profile supports will conform to the requirements of the guide specification.

8-2.4 Insulation and Jacketing.

All piping on aboveground systems must be insulated and jacketed. Insulation thicknesses will be determined by insulation tables provided in the guide specification or ASHRAE 90.1 requirements, whichever is more stringent. Edit guide specification if ASHRAE 90.1 is more stringent. All insulation will be covered with a jacketing material in conformance with the guide specification.

8-2.5 Expansion Compensation.

Expansion loops and bends will be designed as described in Chapter 3. Expansion loops will be located to minimize impacts to ground level interferences such as trees and sidewalks. For horizontal expansion loops, pipe supports will be spaced less than the maximums listed in Table A-9 in Appendix A because of the extra bends and associated movement in the loops. In low profile systems, vertical expansion loops may be used as road crossings. Details will be provided indicating support types and locations throughout the loops and bends.

8-2.6 Vents and Drains.

Provide venting of all piping high points and draining of all low points to allow total drainage of the system. Vent and drain locations will be indicated on the profile drawings. Vents and drains are similar to those used for the concrete shallow trench system, Figure 5-17.

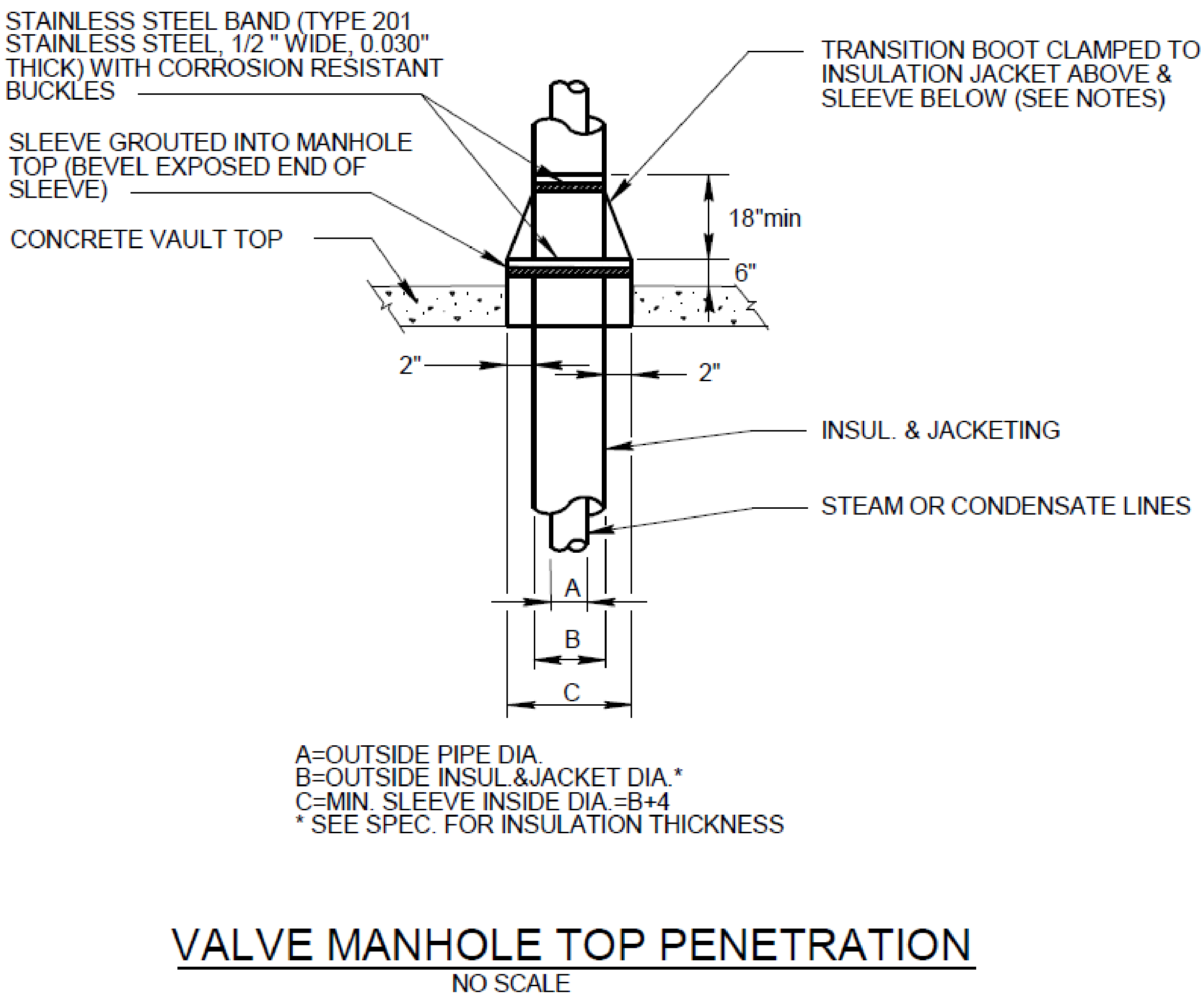
8-2.7 Transition to Buried Systems.

When a buried system transitions to an aboveground system a valve manhole will be provided at that point. A manhole top penetration will be provided to allow expansion of the distribution piping in the man-hole top yet keep rain and ground water out of the manhole. Figure 8-1 shows such a transition in a valve manhole with a concrete cover. The valve manhole used for this transition must be large enough to be accessible and will be designed in accordance with Chapter 3.

8-2.7.1 Buried Piping.

Where the aboveground distribution piping must be transitioned below grade, the below grade section of metal piping requires a cathodic protection system. This system must be a sacrifical anode type cathodic protection system.

Figure 8-1 Valve Manhole Top Penetration Detail



Notes:

1. Transition boot (liner) must be:
   - 25 MIL (0.635 mm) THICKNESS MINIMUM
   - E.P.D.M. TYPE MEMBRANE
   - Compatible at high 220°F (104.4°C) and low -40°F (-40°C) temperatures
   - Resistant to ultraviolet light degradation
2. Liner seam must provide 2" (51 mm) minimum of overlap. Use solvent cement as approved by liner manufacturer.
3. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

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CHAPTER 9 STEAM SYSTEM SPECIAL CONSIDERATIONS

9-1 STEAM SYSTEMS.

Although it is impractical to cover all special considerations, which arise in steam distribution designs, this chapter presents typical design problems and solutions associated with steam systems.

9-1.1 Trap Selection.

Steam traps are used to separate the condensate and non-condensable gases from the steam. Many types of traps are used on drip legs for steam distribution systems. Those trap types include float and thermostatic, inverted bucket, thermostatic and thermodynamic (disc). However, for buried heat distribution drip leg applications, inverted bucket or thermostatic (bimetallic type) must be the trap types selected. For drip leg applications where freezing is a consideration, thermodynamic type (installed vertically) or bimetallic thermostatic type must be selected. Additionally, refer to Naval Civil Engineering Laboratory [NCEL] UG-0005, Steam Trap Users Guide.

9-1.2 Trap Sizing and Location.

Trap sizing is important for obtaining an efficient steam distribution system. Condensation in the steam line is caused by heat loss from the steam line. Trap life will be shortened, function affected, and excessive energy will be wasted if traps are oversized to handle the higher initial startup condensate flows. Therefore, the traps must be sized for the condensate load seen during the distribution system normal operation. Because the traps are not sized for startup loadings, the bypass must be opened at startup to allow condensate to pass until the steam line has reached normal operating temperatures (see Figure 9-1). The designer will calculate heat loss and condensate flow for that particular design using the methods presented in Appendix A for determining condensate loads during normal operation. It is critical that the designer calculate trap capacity using the Appendix A method for each trap station in the design to ensure proper steam system operation. In addition to trap capacity, steam trap type, differential pressures, and inlet pressure must always be provided on the contract documents. Do not locate steam drip legs, with associated traps, more than 500 feet apart.

9-1.3 Drip Leg Sizing.

Drip legs, installed vertically down from the steam pipe, are used to collect condensate. Design all steam lines to slope at 2-1/2 inches (64 mm) per 100 feet (30.5 m) minimum toward these drip legs. It is preferable to slope the steam lines in the direction of steam flow whenever possible. The steam trap line and bypass line are connected to the drip leg as indicated in Figure 9-1. The drip leg will be the same nominal pipe size as the main line (up to a 12-inch [300 mm] line) and will provide a storage capacity equal to 50% of the startup condensate load (no safety factor, one-half of an hour duration) for line sizes 4 inches (100 mm) in diameter and larger and 25% of the startup condensate load (no safety factor, one-half of an hour duration) for line sizes less than 4 inches (100 mm). In no case will the drip leg be less than 18 inches (457 mm) in length or larger than 12 inches (300 mm) in diameter for all steam line sizes. The designer will calculate startup loads for drip leg sizing using the methods presented in Appendix A.

9-1.4 Trap Station Layout.

All trap stations will be piped as indicated in Figure 9-1, as a minimum. Valve and strainer sizes will match the line sizes on which they are installed. Pipe lines to and from the steam trap will be sized based on calculated trap capacity but will be no less than 3/4-inch (20 mm) nominal size (line size "A" on Figure 9-1). If reducing fittings are needed at the trap inlet and outlet, eccentric reducers must be used. The bypass line will be sized to accommodate warm-up condensate loads. For steam systems with an operating pressure of 150 psig (1.03 MPa) or less and pipe sizes 12 inches (300 mm) or less, provide a 3/4-inch (20 mm) bypass line. If the condensate return main is a low pressure or gravity flow type, the trap discharge line will be routed through an accumulator, as indicated in Figure 9-2. The accumulator will lower the trap discharge temperature and minimize flashing when the condensate is introduced into sloped condensate lines which are routed to receiver/pump sets located in valve manholes. The pumps push the condensate back to the central plant in a separate pressurized condensate line. See Figure 9-3 for a duplex condensate pump set connection detail. This type of condensate return system is referred to as a "three pipe" or a "pumped return" system. If the steam pressure is sufficiently high, it may be used to force the condensate through the condensate return system to the central plant as shown in Figure 9-1. No accumulator is required for this type system, which is referred to as a "two pipe" system. Sizing of the lines for both of these systems is presented in Table A-7 in Appendix A.

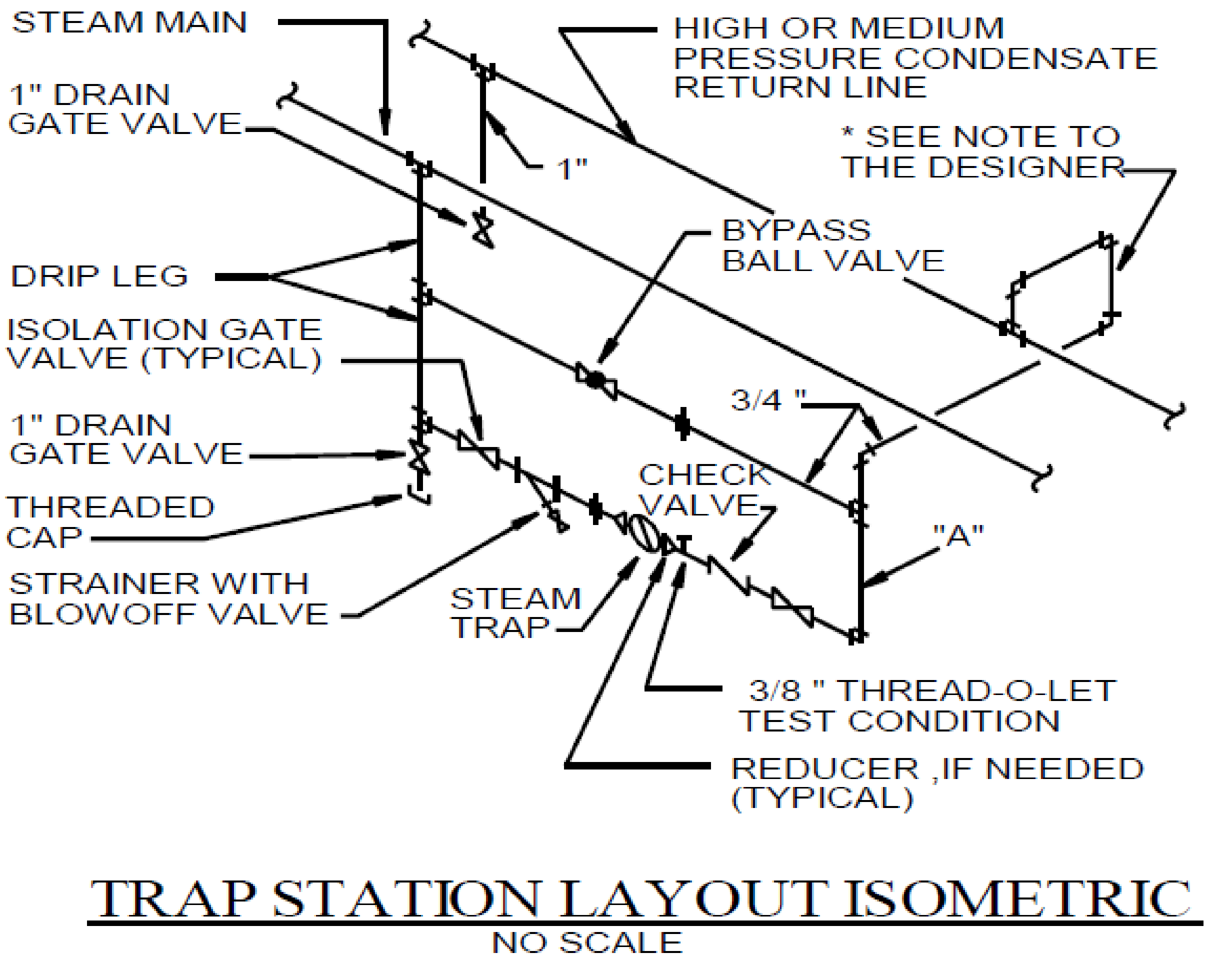
9-1.5 Non-Metallic Pipe Anchors in Valve Manholes.

If anchoring of a non-metallic piping system is required at the valve manhole wall to comply with the distribution system stress analysis, a typical method is as detailed in Figure 9-4. If the system is to be anchored at both of the valve manhole wall penetrations, provide adequate piping bends in the manhole to accommodate the expansion between the two anchors. Steel straps and bolts will be sized to accommodate the axial force of that particular piping layout. These sizes will be entered on the detail. Also, valve manhole sizes must be large enough to accommodate the anchors and still allow for maintenance access.

9-1.6 Field Joints.

Radiographic examination of all carrier pipe field joints is required.

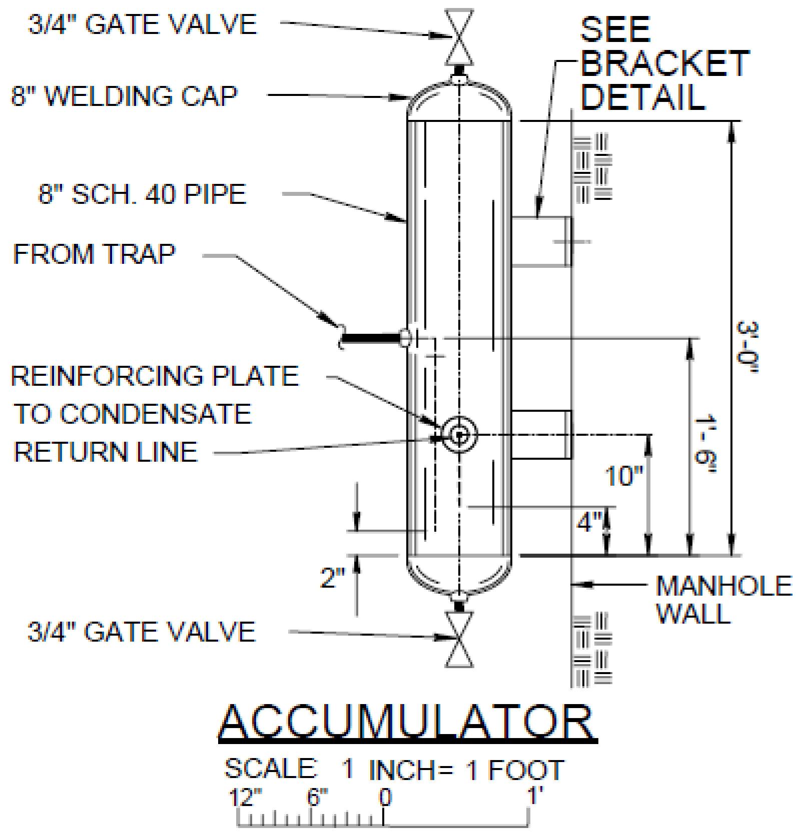
Figure 9-1 Trap Station Layout Isometric

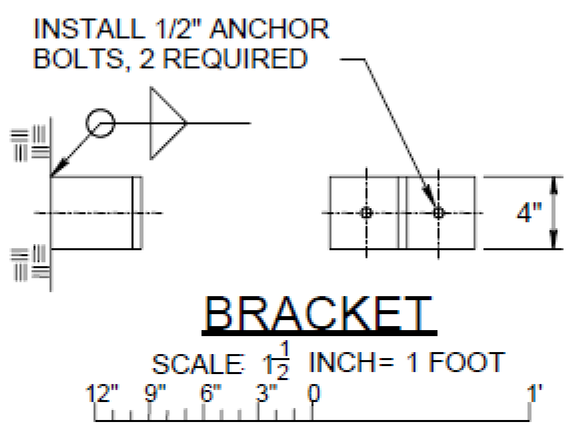


Notes:

1. Note to the Designer: * High pressure condensate discharge from the trap will not be directly routed to a gravity or low pressure condensate system. In this instance, a 3/4" line will be routed to an accumulator before being routed to a condensate pump (see Figure 9-2).
2. Pipe sizes imperial to metric conversion: 3/8" = 10 mm, 3/4" = 20 mm, and 1” = 25 mm.

Figure 9-2 Accumulator Detail

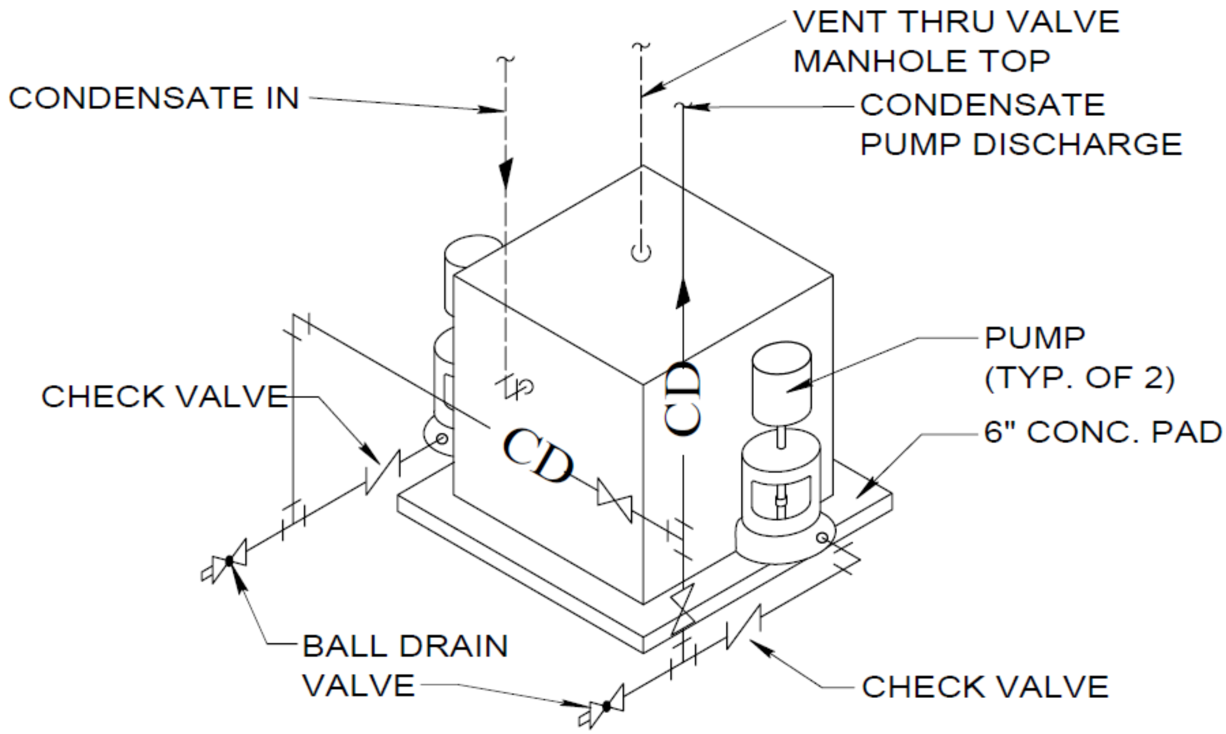




Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
3. Pipe sizes imperial to metric conversion: 3/4" = 20 mm and 8” = 200 mm.

Figure 9-3 Duplex Condensate Pump Set Connection Detail



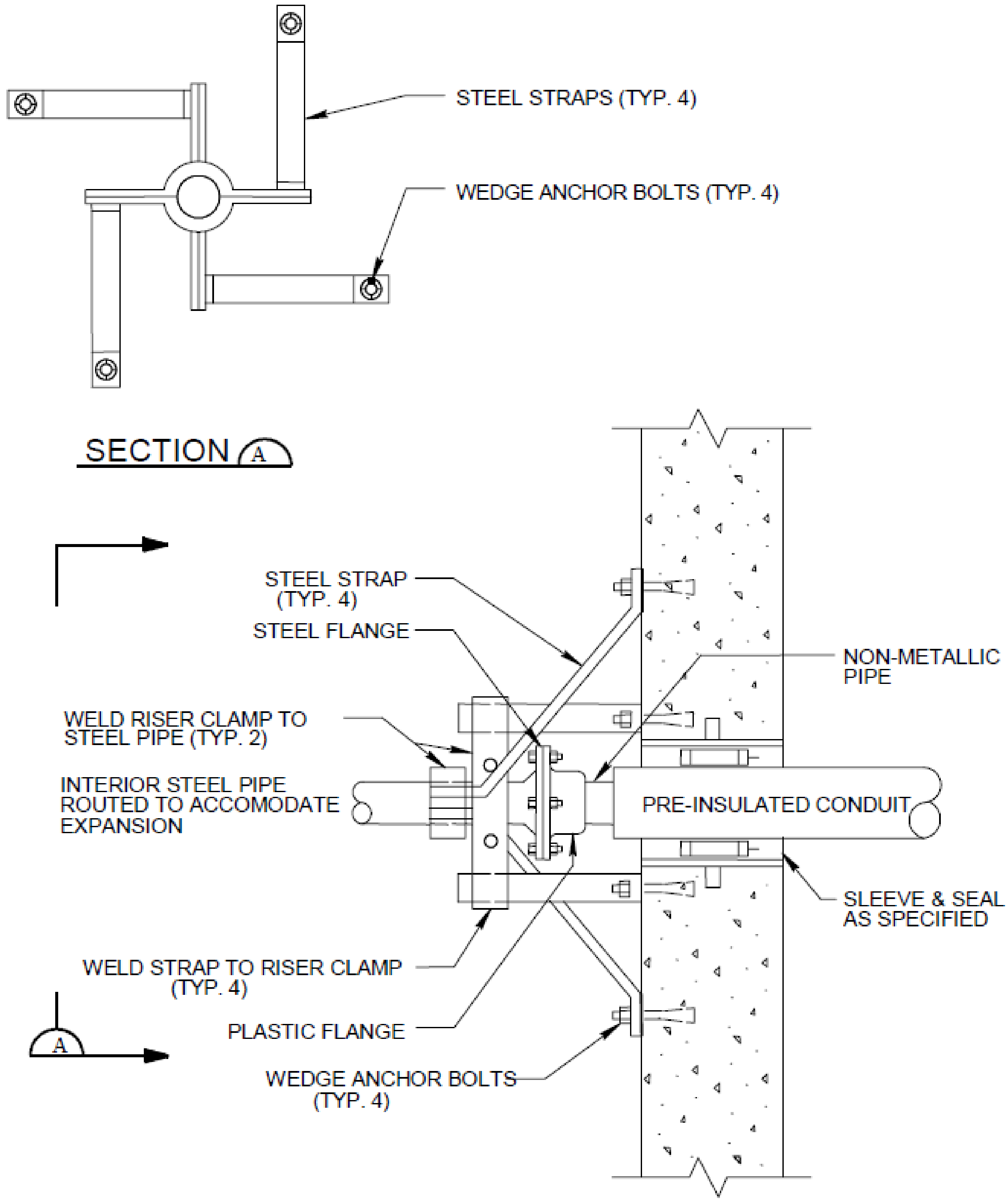
DUPLEX CONDENSATE PUMP
SET CONNECTION DETAIL

NO SCALE

Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

Figure 9-4 Non-metallic Piping Systems Anchor Detail



NON-METALLIC PIPING SYSTEM ANCHOR DETAIL
NO SCALE

APPENDIX A BEST PRACTICES

A-1 HEAT LOSS CALCULATION DATA.

A-1.1 Earth Thermal Conductivity Data.

The earth thermal conductivity factors (Ke) in Btu-in/(hr) (sq-ft) (degrees °F) to be used in the heat loss calculations are as follows:

Table A-1 Moisture Content in Varying Types of Soil

Moisture Content of Soil	Type of Soil		
	Sand	Silt	Clay
Low (less than 4% by weight)	2	1	1
Medium (from than 4% to 20% by weight)	13	9	7
High (greater than 20% by weight)	15	15	15

Notes:
1. Dry soil is exceedingly rare in most parts of the United States, and a low moisture content can be assumed only if the assumption can be proven valid.
2. Earth thermal conductivity factor conversion to metric is 1 Btu-in/(hr) (sq-ft) (degrees °F) = 1.73 Watt/(m K).

A-1.2 Earth Temperatures.

The earth temperatures (Te) to be used in the heat loss calculations are listed below. The list presents the average earth temperature from 0 to 10 feet (0 to 3.05 M) below the surface for the four seasons of the year and for the whole year for the indicated locale. The temperatures were computed on the basis of the method described in the 1965 ASHRAE technical paper entitled "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States" by T. Kusuda and P. R. Achenback (in ASHRAE Transactions, Volume 71, Part 1, p. 61, 1965) using the monthly average air temperatures published by the U.S. Weather Bureau for the listed localities in the United States. Earth temperatures are expressed in Fahrenheit degrees. AP refers to airport data, CO to city office data, COOP to cooperative weather station data, and OBS to observation station data. When data is not available for exact project location, use nearest location shown in following table. To convert the earth temperature from ℃F to ℃C utilize the following equation:

Equation A-1 Temperature Conversion Factor

$$Te°C = (Te°F - 32°F) \times 5/9$$

Where:
Te°F = Earth temperature in °F
Te°C = Earth temperature in °C

Table A-2 Earth Temperatures by Location / Season

Location	Winter	Spring	Summer	Autumn	Annual
Alabama					
Anniston AP	55	58	70	67	63
Birmingham AP	54	58	71	68	63
Mobile AP	61	63	74	71	67
Mobile CO	61	64	75	72	68
Montgomery AP	58	61	73	70	65
Montgomery CO	59	62	74	71	66
Arizona					
Bisbee COOP	55	58	70	67	62
Flagstaff AP	35	39	54	50	45
Ft Huachuca (proving ground)	55	58	71	68	63
Phoenix AP	60	64	79	75	69
Phoenix CO	61	65	80	76	70
Prescott AP	46	49	65	61	55
Tucson AP	59	62	76	73	68
Winslow AP	45	49	65	61	55
Yuma AP	65	69	84	80	75
Arkansas					
Fort Smith AP	52	46	72	68	62
Little Rock AP	53	57	72	68	62
Texarkana AP	56	60	74	71	65
California					
Bakersfield AP	56	60	74	70	65
Beaumont CO	53	56	67	64	60
Bishop AP	47	51	65	61	56
Blue Canyon AP	43	46	58	55	50
Burbank AP	58	60	68	66	63
Eureka CO	50	51	54	54	52
Fresno AP	54	58	72	68	63
Los Angeles AP	58	59	64	63	61
Los Angeles CO	60	61	68	66	64
Mount Shasta CO	41	44	57	54	49
Oakland AP	53	54	60	59	56
Red Bluff AP	54	58	72	69	63
Sacramento AP	53	56	67	64	60
Sacramento CO	54	57	68	65	61
Sandberg CO	47	50	63	60	55
San Diego AP	59	60	66	65	62
San Francisco AP	53	54	59	57	56
San Francisco CO	55	55	59	58	57
San Jose COOP	55	57	64	62	59
Santa Catalina AP	57	58	64	62	60
Santa Maria AP	54	55	60	59	57

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Colorado					
Alamosa AP	30	35	52	48	41
Colorado Springs AP	39	43	59	55	49
Denver AP	39	43	60	56	50
Denver CO	41	45	61	58	51
Grand Junction AP	39	44	65	60	52
Pueblo AP	41	45	62	58	51
Connecticut					
Bridgeport AP	40	44	61	57	50
Hartford AP	39	43	61	57	50
Hartford AP (Brainer)	39	43	60	56	50
New Haven AP	40	44	60	56	50
Delaware					
Wilmington AP	44	48	64	60	54
Washington D.C.					
Washington AP	47	51	66	63	56
Washington CO	47	51	66	63	57
Silver Hill OBS	46	50	65	61	55
Florida					
Apalachicola CO	63	65	75	73	69
Daytona Beach AP	65	67	75	74	70
Fort Myers AP	70	71	78	76	74
Jacksonville AP	63	66	75	73	69
Jacksonville CO	64	66	76	73	70
Key West AP	74	75	80	79	77
Key West CO	75	76	81	79	78
Lakeland CO	68	69	77	75	72
Melbourne AP	68	70	77	75	72
Miami AP	72	74	79	78	76
Miami CO	72	73	78	77	75
Miami Beach COOP	74	75	80	78	77
Orlando AP	68	70	77	75	72
Pensacola CO	62	64	74	72	68
Tallahassee AP	61	64	74	72	68
Tampa AP	68	69	77	75	72
West Palm Beach	71	73	79	77	75

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Georgia					
Albany AP	60	63	75	72	67
Athens AP	54	58	71	68	63
Atlanta AP	54	57	70	67	62
Atlanta CO	54	57	70	67	62
Augusta AP	56	59	72	69	64
Columbus AP	56	59	72	69	64
Macon AP	58	61	74	71	66
Rome AP	53	56	70	67	61
Savannah AP	60	63	74	71	67
Thomasville CO	62	64	74	72	68
Valdosta AP	61	64	74	72	68
Idaho					
Boise AP	40	44	62	58	51
Idaho Falls 46 W	30	35	55	50	42
Idaho Falls 42 N W	28	33	54	49	41
Lewiston AP	42	46	63	59	52
Pocatello AP	35	40	59	55	44
Salmon CO	32	37	56	52	44
Illinois					
Cairo CO	49	53	70	66	60
Chicago AP	38	43	62	57	50
Joliet AP	37	42	61	56	49
Moline AP	38	43	62	58	50
Peoria AP	39	44	63	58	51
Springfield AP	41	45	64	60	52
Springfield CO	43	47	66	62	54
Indiana					
Evansville AP	47	51	67	63	57
Fort Wayne AP	39	43	61	57	50
Indianapolis AP	41	46	64	59	52
Indianapolis CO	43	48	65	61	54
South Bend AP	38	42	61	56	49
Terre Haute AP	42	47	65	60	53
Iowa					
Burlington AP	39	44	64	59	51
Charles City CO	33	38	60	55	46
Davenport CO	39	44	64	59	51
Des Moines AP	37	42	63	58	50
Des Moines CO	38	43	64	59	51
Dubuque AP	34	39	60	55	47
Sioux City	35	40	62	57	49
Waterloo AP	35	40	61	56	48

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Kansas					
Concordia CO	42	47	67	62	54
Dodge City AP	43	48	67	62	55
Goodland AP	38	43	62	57	50
Topeka AP	43	47	66	62	55
Topeka CO	44	49	68	63	56
Wichita AP	45	50	68	64	57
Kentucky					
Bowling Green AP	47	51	67	63	57
Lexington AP	44	48	65	61	54
Louisville AP	46	50	67	63	56
Louisville CO	47	51	67	64	57
Louisiana					
Baton Rouge AP	61	63	74	72	67
Burrwood CO	65	67	77	74	71
Lake Charles AP	61	64	75	73	68
New Orleans AP	63	65	75	73	69
New Orleans CO	64	66	77	74	70
Shreveport AP	58	61	75	72	66
Maine					
Caribou AP	24	29	50	45	37
Eastport CO	33	37	51	48	42
Portland AP	33	38	56	51	44
Maryland					
Baltimore AP	45	49	65	61	55
Baltimore CO	47	51	67	63	57
Frederick AP	44	48	65	61	55
Massachusetts					
Boston AP	41	44	61	57	51
Nantucket AP	41	44	57	54	49
Pittsfield AP	34	28	55	51	44
Worcester AP	36	40	58	54	47

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Michigan					
Alpena CO	33	37	54	50	43
Detroit Willow Run AP	38	42	60	56	49
Detroit City AP	38	43	60	56	49
Escanaba CO	30	35	53	49	42
Flint AP	36	40	58	54	47
Grand Rapids AP	36	40	58	54	47
Grand Rapids CO	38	42	60	56	49
East Lansing CO	36	40	58	54	47
Marquette CO	31	35	53	49	42
Muskecon AP	36	40	57	53	47
Sault Ste Marie AP	28	32	51	47	39
Minnesota					
Crookston COOP	25	31	55	49	40
Duluth AP	25	30	52	47	38
Duluth CO	26	31	52	47	39
International Falls	22	27	51	45	36
Minneapolis AP	32	37	60	54	46
Rochester AP	31	36	58	53	44
Saint Cloud AP	28	33	56	51	42
Saint Paul AP	32	37	60	54	46
Mississippi					
Jackson AP	57	61	73	70	65
Meridian AP	57	60	72	69	64
Vicksburg CO	58	61	74	71	66
Missouri					
Columbia AP	43	48	66	62	55
Kansas City AP	55	49	68	64	56
Saint Joseph AP	42	47	67	72	54
Saint Louis AP	45	49	67	63	56
Saint Louis CO	46	50	68	64	57
Springfield AP	45	49	66	62	56
Montana					
Billings AP	35	40	59	55	47
Butte AP	27	31	50	45	38
Glasgow AP	27	33	56	51	42
Glasgow CO	28	34	57	52	43
Great Falls AP	34	38	56	52	45
Harve CO	31	36	57	52	44
Helena AP	31	36	55	50	43
Helena CO	32	36	55	50	43
Kalispell AP	32	37	54	50	43
Miles City AP	32	37	59	54	45
Missoula AP	33	37	56	51	44

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Nebraska					
Grand Island AP	38	43	64	59	51
Lincoln AP	39	44	64	60	52
Lincoln University CO	40	45	65	61	53
Norfolk AP	35	40	62	57	48
North Platte AP	37	42	62	57	49
Omaha AP	39	44	65	60	52
Scottsbluff AP	36	41	60	56	48
Valentine CO	35	40	61	56	48
Nevada					
Elko AP	34	39	57	53	46
Ely AP	35	39	56	52	45
Las Vegas AP	56	60	78	74	67
Reno AP	40	44	58	55	49
Tonopah	41	56	61	57	51
Winnemucca AP	38	42	60	56	49
New Hampshire					
Concord AP	33	38	56	52	45
Mt Washington COOP	17	21	37	33	27
New Jersey					
Atlantic City CO	45	49	63	60	54
Newark AP	43	47	63	59	53
Trenton CO	43	47	64	60	53
New Mexico					
Albuquerque AP	46	50	67	63	57
Clayton AP	43	47	63	59	53
Raton AP	38	42	58	54	48
Roswell AP	51	54	69	66	60
New York					
Albany AP	36	40	59	54	47
Albany CO	38	43	61	56	49
Bear Mountain CO	38	42	59	55	48
Binghampton AP	34	38	56	52	45
Binghampton CO	38	42	59	55	48
Buffalo AP	37	41	58	54	47
New York AP (La Guardia)	44	48	64	60	54
New York CO	44	47	63	59	53
New York Central Park	44	48	64	60	54
Oswego CO	36	40	58	54	47
Rochester AP	37	41	58	54	47
Schenectady COOP	35	40	59	55	47

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Syracuse AP	38	42	60	56	49
North Carolina					
Asheville CO	48	51	64	61	56
Charlotte AP	52	55	69	66	60
Greensboro AP	49	53	67	64	58
Hatteras CO	56	59	70	68	63
Raleigh AP	51	55	69	65	60
Raleigh CO	52	56	70	66	61
Wilmington AP	56	59	71	69	64
Winston Salem AP	50	53	67	64	58
North Dakota					
Bismarck AP	27	33	56	51	42
Devils Lake CO	24	29	54	48	39
Fargo AP	26	32	56	50	41
Minot AP	25	31	54	49	39
Williston CO	27	33	56	50	41
Ohio					
Akron-Canton AP	39	43	60	56	50
Cincinnati AP	43	47	64	60	54
Cincinnati CO	46	50	66	63	56
Cincinnati ABBE OBS	45	49	65	61	55
Cleveland AP	40	44	61	57	51
Cleveland CO	41	45	62	58	51
Columbus AP	41	46	62	59	52
Columbus CO	43	47	64	60	53
Dayton AP	42	46	63	59	52
Sandusky CC	41	45	62	58	51
Toledo AP	38	43	60	56	49
Youngstown AP	39	43	60	56	50
Oklahoma					
Oklahoma City AP	50	54	71	67	60
Oklahoma City CO	50	55	71	68	61
Tulsa AP	50	54	71	67	61
Oregon					
Astoria AP	47	48	56	54	51
Baker CO	36	40	56	52	46
Burns CO	36	40	58	54	47
Eugene AP	46	48	59	57	52
Meacham AP	34	38	52	49	43
Medford AP	46	49	62	59	54
Pendelton AP	42	46	63	59	53

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Portland AP	46	49	60	57	53
Portland CO	48	50	61	59	55
Roseburg AP	47	49	60	57	53
Roseburg CO	48	51	61	59	55
Salem AP	46	49	60	57	53
Sexton Summit	42	44	55	52	48
Troutdale AP	45	48	59	57	52
Pennsylvania					
Allentown AP	40	44	62	58	51
Erie AP	38	42	58	55	48
Erie CO	40	44	60	56	50
Harrisburg AP	43	47	63	59	53
Park Place CO	36	40	57	53	46
Philadelphia AP	44	48	64	61	54
Philadelphia CO	46	50	66	62	56
Pittsburgh Allegheny	42	46	62	58	52
Pittsburgh GRTR PITT	40	44	61	57	51
Pittsburgh CO	44	48	64	60	54
Reading CO	43	47	64	60	54
Scranton CO	40	44	61	57	50
Wilkes Barre-Scranton	39	43	60	56	49
Williamsport AP	40	44	61	57	51
Rhode Island					
Block Island AP	41	45	59	55	50
Providence AP	39	43	59	56	49
Providence CO	41	45	62	58	51
South Carolina					
Charleston AP	58	61	72	70	65
Charleston CO	60	62	74	71	67
Columbia AP	56	59	72	69	64
Columbia CO	57	60	72	69	64
Florence AP	55	59	72	69	64
Greenville AP	53	56	69	66	61
Spartanburg AP	53	56	70	66	61
South Dakota					
Huron AP	31	37	60	55	46
Rapid City AP	34	39	58	54	46
Sioux Falls AP	32	37	60	55	46

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Tennessee					
Bristol AP	48	51	65	62	56
Chattanooga AP	51	55	69	65	60
Knoxville AP	50	54	68	65	59
Memphis AP	52	56	71	68	62
Memphis CO	53	57	72	68	62
Nashville AP	51	54	69	66	60
Oak Ridge CO	49	52	67	64	58
Oak Ridge 8 S	49	52	67	64	58
Texas					
Abilene AP	55	58	73	70	64
Amarillo AP	47	50	67	63	57
Austin AP	60	63	76	73	68
Big Springs AP	56	59	74	70	65
Brownsville AP	68	70	79	77	74
Corpus Cristi AP	65	68	78	76	72
Dallas AP	57	61	76	72	66
Del Rio AP	62	65	77	75	70
El Paso AP	54	58	72	69	63
Fort Worth AP (Amon Carter)	57	60	75	72	66
Galveston AP	63	66	77	74	70
Galveston CO	63	66	77	74	70
Houston AP	62	65	76	73	69
Houston CO	63	66	77	74	70
Laredo AP	67	70	81	79	74
Lubbock AP	50	54	69	65	59
Midland AP	55	59	73	70	64
Palestine CO	58	62	74	71	66
Port Arthur AP	61	64	75	72	68
Port Arthur CO	63	65	76	74	69
San Angelo AP	58	61	74	71	66
San Antonio AP	61	64	77	74	69
Victoria AP	64	67	78	76	71
Waco AP	58	62	76	73	67
Wichita Falls AP	53	57	73	69	63
Utah					
Blanding CO	39	43	60	56	50
Milford AP	37	42	61	56	49
Salt Lake City AP	40	44	63	59	51
Salt Lake City CO	41	46	65	60	53
Vermont					
Burlington AP	32	37	57	52	44

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Virginia					
Cape Henry CO	51	55	68	65	60
Lynchburg AP	48	51	66	62	57
Norfolk AP	51	54	68	64	59
Norfolk CO	52	56	69	66	61
Richmond AP	48	52	67	63	58
Richmond CO	50	53	68	64	59
Roanoke AP	48	51	66	62	57
Washington					
Ellensburg AP	37	41	59	55	48
Kelso AP	45	47	57	54	51
North Head L H RESVN	47	49	54	53	51
Olympia AP	44	46	56	54	50
Omak 2 mi N W	36	40	59	55	47
Port Angeles AP	45	46	53	52	49
Seattle AP (Boeing Field)	46	48	58	56	52
Seattle CO	47	50	59	57	53
Seattle-Tacoma AP	44	47	57	55	51
Spokane AP	37	41	58	54	47
Stampede Pass	32	35	48	45	40
Tacoma CO	46	48	58	55	52
Tattosh Island CO	46	47	52	51	49
Walla Walla CO	44	48	65	61	54
Yakima AP	40	44	61	57	50
West Virginia					
Charleston AP	47	50	65	61	56
Elkins AP	41	45	59	56	50
Huntington CO	48	52	67	63	57
Parkersburg CO	45	49	65	61	55
Petersburg CO	44	48	63	60	54
Wisconsin					
Green Bay AP	31	36	56	51	44
La Crosse AP	32	38	60	55	46
Madison AP	34	39	59	54	47
Madison CO	34	39	60	55	47
Milwaukee AP	35	40	58	54	47
Milwaukee CO	36	41	59	55	48
Wyoming					
Casper AP	34	38	57	52	45
Cheyenne AP	35	39	55	51	45
Lander AP	31	35	56	51	43
Rock Springs AP	31	35	54	50	42
Sheridan AP	33	37	56	52	44

Earth Temperatures by Location / Season (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Hawaii					
Hilo AP	72	72	74	74	73
Honolulu AP	74	75	77	77	76
Honolulu CO	74	74	77	76	75
Lihue AP	72	73	76	75	74
Alaska					
Anchorage PA	25	29	46	42	35
Annette AP	40	42	51	49	46
Barrow AP	4	7	16	14	10
Bethel AP	18	23	41	37	30
Cold Bay AP	33	35	43	41	38
Cordova AP	32	35	45	43	39
Fairbanks AP	14	19	38	34	26
Galena AP	13	18	37	33	25
Gambell AP	15	19	34	30	24
Juneau AP	34	36	47	45	41
Juneau CO	36	39	49	46	42
King Salmon AP	25	28	44	40	34
Kotzebue AP	10	14	31	27	21
McGrath AP	14	18	37	33	25
Nome AP	16	20	37	33	26
Northway AP	12	16	32	29	22
Saint Paul Island AP	31	32	40	38	35
Yakutat AP	33	36	45	43	39
West Indies					
Ponce Santa Isabel AP	75	76	78	78	77
San Juan AP	77	77	79	79	78
San Juan CO	77	77	79	79	78
Swan Island	80	80	82	81	81
Virgin Islands					
St. Croix, V.I. AP	78	78	81	80	79
Pacific Islands					
Canton Island AP	83	84	84	84	84
Koror	81	81	81	81	81
Ponape Island AP	81	81	81	81	81
Truk Moen Island	81	81	81	81	81
Wake Island AP	79	79	81	81	80
Yap	81	81	82	82	82

A-2 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 A-3.

Table A-3 Representative Equivalent Length in Pipe/Diameter Ratio (L/D) for Various Valves and Fittings

Item	Description of Product		Equivalent Length in Pipe Length/ Diameter
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,		Fully open	13
disc, plug or gate		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 globe
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%	Flow straight through	44
	of pipe area (fully open)	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.

A-3 STEAM AND CONDENSATE SIZING GUIDELINES AND EQUATIONS.

A-3.1 Steam Flow Charts.

For pressures of 30 psig (207 kPa), 50 psig (345 kPa), 100 psig (689 kPa), and 150 psig (1034 kPa), see the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Fundamentals Handbook, Chapter "Pipe Design", for these steam sizing tables. 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. These charts are based on the Moody friction factor, which considers the Reynolds number and the roughness of the internal pipe surfaces. For higher pressures, refer to Piping Handbook, by Crocker and King.

A-3.2 Rational Flow Charts.

The simplified rational flow formula (Darcy) is used for compressible fluids for all pressures:

Equation A-2 Rational Flow Charts Formula

$$P_{100} = W^2 (0.000336f)\, v/d^5 = C_1 \times C_2 \times v$$

Where:
P_{100} = *Pressure drop per 100 feet of equivalent length of pipe (psi)*
C_1 = *Discharge Factor, use the* C_1 *value from Figure A-1 that corresponds to the rate of*
flow (W) or calculate as $C_1 = W^2 \times 10^{-9}$
C_2 = *Size Factor,* $336{,}000f/d^5$ *(For values, refer to Table A-4)*
W = Rate of flow, pounds per hour (pph)
f = friction factor
d = inside diameter of pipe (in)
v = specific volume of fluid (ft^3 *per lb) at average pressure*

Metric to imperial conversions:
1 pph = 0.454 kg/hr
1 in = 25.4 mm
1 ft^3 *per lb = 0.0624* m^3 *per kg*
100 feet = 30.5 m
1 psi = 6.8948 kPa

A-3.3 Velocities.

Refer to Table 4-1.

Equation A-3 Velocities Formula

$$V = 3.06W*v/d^2$$

Where:
V = Velocity of flow (fpm)
W = Rate of flow, pounds per hour (pph)
d = inside diameter of pipe (in)
v = specific volume of fluid (ft^3 per lb) at average pressure

Metric to imperial conversions:
1 pph = 0.454 kg/hr
1 in = 25.4 mm
1 ft^3 per lb = 0.0624 m^3 per kg
1 fpm = 0.3048 meters per minute

Figure A-1 Values of C_1, Flow Factor in Equation A-2

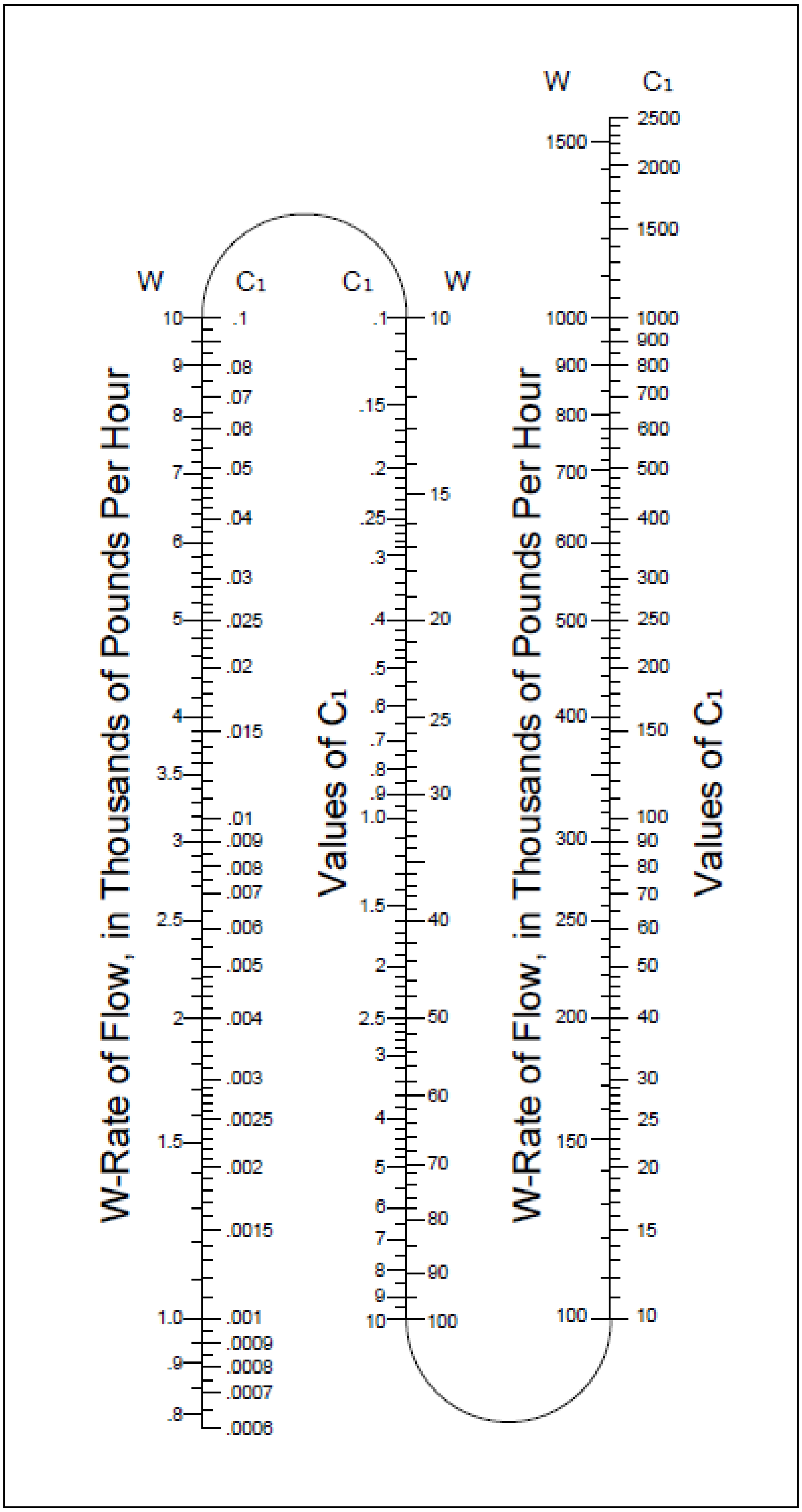


Table A-4 Values of C_2, Flow Factor in Equation A-2

Nominal Pipe Size	Schedule	Value of C_2	Nominal Pipe Size	Schedule	Value of C_2	Nominal Pipe Size	Schedule	Value of C_2
1/2	40 S	93500	6	40 S	0.610	16	10	0.00463
(15 mm)	80 X	186100	(150 mm)	80 X	0.798	(400 mm)	20	0.00483
	160	430000		120	1.015		30 S	0.00504
	XX	11180000		160	1.376		40 X	0.00549
				XX	1.861		60	0.00612
3/4	40 S	21200					80	0.00700
(20 mm)	80 X	36900	8	20	0.133		100	0.00804
	160	100100	(200 mm)	30	0.138		120	0.00926
	XX	627000		40 S	0.146		140	0.01099
				60	0.163		160	0.01244
1	40 S	5950		80 X	0.185			
(25 mm)	80 X	9640		100	0.211	18	10	0.00247
	160	22500		120	0.252	(450 mm)	20	0.00256
	XX	114100		140	0.289		S	0.00266
				XX	0.317		30	0.00276
1-1/4	40 S	1408		160	0.333		X	0.00287
(32 mm)	80 X	2110					40	0.00298
	160	3490	10	20	0.0397		60	0.00335
	XX	13640	(250 mm)	30	0.0421		80	0.00376
				40 S	0.0447		100	0.00435
1-1/2	40 S	627		60 X	0.0514		120	0.00504
(40 mm)	80 X	904		80	0.0569		140	0.00573
	160	1656		100	0.0652		160	0.00669
	XX	4630		120	0.0753			
				140	0.0905			
2	40 S	169		160	0.1052	20	10	0.00141
(50 mm)	80 X	236				(500 mm)	20 S	0.00150
	160	488	12	20	0.0157		30 X	0.00161
	XX	899	(300 mm)	30	0.0168		40	0.00169
				S	0.0175		60	0.00191
2-1/2	40 S	66.7		40	0.0180		80	0.00217
(65 mm)	80 X	91.8		X	0.0195		100	0.00251
	160	146.3		60	0.0206		120	0.00287
	XX	380.0		80	0.0231		140	0.00335
				100	0.0267		160	0.00385
3	40 S	21.4		120	0.0310			
(80 mm)	80 X	28.7		140	0.0350	24	10	0.000534
	160	48.3		160	0.0423	(600 mm)	20 S	0.000565
	XX	96.6					X	0.000597
			14	10	0.00949		30	0.000614
4	40 S	5.17	(350 mm)	20	0.00996		40	0.000651
(100 mm)	80 X	6.75		30 S	0.01046		60	0.000741
	120	8.94		40	0.01099		80	0.000835
	160	11.80		X	0.01155		100	0.000972
	XX	18.59		60	0.01244		120	0.001119
				80	0.01416		140	0.001274
5	40 S	1.59		100	0.01657			
(125 mm)	80 X	2.04		120	0.01898			
	120	2.69		140	0.0218			
	160	3.59		160	0.0252			
	XX	4.93						

Note: The letters S, X, and XX in the columns of Schedule indicate Standard, Extra Strong, and Double Extra Strong pipe respectively.

Table A-5 Return Pipe Capacities for 30 psig (207 kPa) Steam Systems (Capacity Expressed in lbs/hr)

Drop in Pressure (psi per 100 ft in Length)					
Pipe Size inch (mm)	**1/8**	**1/4**	**1/2**	**3/4**	**1**
3/4 (20 mm)	115	170	245	308	365
1 (25 mm)	230	340	490	615	730
1-1/4 (32 mm)	485	710	1,025	1,290	1,530
1-1/2 (40 mm)	790	1,160	1,670	2,100	2,500
2 (50 mm)	1,580	2,360	3,400	4,300	5,050
2-1/2 (65 mm)	2,650	3,900	5,600	7,100	8,400
3 (80 mm)	4,850	7,100	10,300	12,900	15,300
3-1/2 (90 mm)	7,200	10,600	15,300	19,200	22,800
4 (100 mm)	10,200	15,000	21,600	27,000	32,300
5 (125 mm)	19,000	27,800	40,600	55,500	60,000
6 (150 mm)	31,000	45,500	65,500	83,000	98,000

Notes:

1. Table Based on 0-4 psig maximum return pressure.
2. Imperial to metric conversion: 1 psi per 100 feet = 6.89 kPa per 30.48 m.
3. Imperial to metric conversion: 1 lbs/hr = 0.454 kg/hr.

Table A-6 Return Pipe Capacities for 150 psig (1034 kPa) Steam Systems (Capacity Expressed in lbs/hr)

Drop in Pressure (psi per 100 ft in Length)						
Pipe Size inch (mm)	1/8	1/4	1/2	3/4	1	2
3/4 (20 mm)	156	232	360	465	560	890
1 (25 mm)	313	462	690	910	1,120	1,780
1-1/4 (32 mm)	650	960	1,500	1,950	2,330	3,700
1-1/2 (40 mm)	1,070	1,580	2,460	3,160	3,800	6,100
2 (50 mm)	2,160	3,300	4,950	6,400	7,700	12,300
2-1/2 (65 mm)	3,600	5,350	8,200	10,700	12,800	20,400
3 (80 mm)	6,500	9,600	15,000	19,500	23,300	37,200
3-1/2 (90 mm)	9,600	14,400	22,300	28,700	34,500	55,000
4 (100 mm)	13,700	20,500	31,600	40,500	49,200	78,500
5 (125 mm)	25,600	38,100	58,500	76,000	91,500	146,000
6 (150 mm)	42,000	62,500	96,000	125,000	150,000	238,000

Notes:

1. Table Based on 1-20 psig maximum return pressure.
2. Imperial to metric conversion: 1 psi per 100 feet = 6.89 kPa per 30.48 m.
3. Imperial to metric conversion: 1 lbs/hr = 0.454 kg/hr.

Table A-7 Pipe Sizing Guidelines for Condensate Return Systems

Two-Pipe System Sizing Guidelines

1. DETERMINE CONDENSATE LINE PRESSURE (AS OBSERVED FROM ON-SITE PRESSURE GAGES).
2. DETERMINE CONDENSATE LOAD (lbm/hr) FROM CENTRAL PLANT LOGS AND OTHER INPUT.
3. ASSUME CONDENSATE AT TRAP DISCHARGE IS A COMBINATION OF CONDENSATE AND FLASH STEAM.
4. SIZE LINE TO ACCOMMODATE 5,000 ft/min (1524 m/min) STEAM AND CONDENSATE MIXTURE VELOCITY AND TO ENSURE MIXTURE PRESSURE IS HIGH ENOUGH TO OVERCOME LINE LOSSES.

Three-Pipe System Sizing Guidelines

GRAVITY LINE

1. SLOPE AT 1 inch/20 feet (25.4 mm/6.10 m) MINIMUM TOWARD RECEIVER
2. TOTAL PRESSURE DROP LESS THAN 0.25 psi (1.72 kPa).
3. LINE SIZE WILL BE TWO (2) INCHES (50 mm).

PUMPED LINE

1. SIZE PUMPS TO MOVE CONDENSATE TO THE CENTRAL PLANT AT THE REQUIRED HEAD AT 200°F (93°C).

A-3.4 Condensate Load Calculations (Startup).

Step #1 Determine the heat loss per foot of line.

The startup load can be calculated by determining the amount of heat that is required to heat the steam pipe from an ambient temperature to the saturation temperature of the steam the pipe is to carry. This is done by using the following equation:

Equation A-4 Heat loss Formula

Heat Loss Formula.

$$Q = (v_p * c_p * \rho * (T_{st} - T_{out}))/t; BTU/ft$$

where:

$$v_p = \pi (r_o^2 - r_o^2); in\ ft^3/ft$$

Step #2 Determine the pounds of condensate per foot from the heat loss calculated in step #1.

$$m = Q/(h_{st} - h_{con}); lbm/ft$$

Step #3 Multiply the condensate per foot, calculated in step #2, by the total number of feet of steam line that slopes toward the drip leg in question. Then convert the total pounds of condensate to gallons assuming 200°F condensate:

$$\text{Total Condensate Volume (gallons)} = (m*L/\rho_w)*7.49\ \text{gallons/ft}^3$$

where:

Q = heat loss per foot of pipe; BTU/hr-ft
T_{st} = *temperature of steam; °F*
T_{out} = *temperature of ambient conditions; °F*
r_o = *outside pipe radius, feet*
r_i = *inside pipe radius, feet*
m = *mass flow rate of condensate, lbm/hr-ft*
h_{st} = *enthalpy of saturated steam: Btu/lbm*
h_{con} = *enthalpy of condensate: Btu/lbm*
c_p = *specific heat of pipe (steel); (0.10 to 0.11) Btu/lbm/°F, (0.42 to 0.46 kJ/kg/°C)*
ρ = *density of pipe (steel); (489) lbm/*ft^3, (7832.8) kg/m^3
t = *length of time for startup; hrs (typically 0.5 hrs.)*
L = *total length of pipe draining to drop; ft*
v_p = *volume of pipe material per foot;* ft^3/ft
ρ_w = *density of water at 200°F; (60.1) lbm/*ft^3, (962.682) kg/m^3
π = *mathematical constant equal to 3.14159*

Metric to imperial conversions:

1 BTU/hr-ft = 0.962 W/m
°F = °C x 9/5 + 32
1 foot = 0.3048 m
1 lbm/hr-ft = 1.488 kg/m-hr
1 Btu/lbm = 2.326 kJ/kg
1 ft^3 per lbm = 0.0624 m^3 per kg
1 ft^3/ft = 0.0929 m^3/m

A-4 TABLES AND DETAILS FOR DISTRIBUTION PIPING.

Table A-8 Advantages and Disadvantages of Steam and Hot Water Distribution Systems

Steam Systems Advantages 1. Smaller return pipe sizes are required. 2. Pumping costs for maintaining circulation are lower. Motor size is a 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.	**Hot Water Systems 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.
Steam Systems 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 Handbook – HVAC Systems and Equipment ASHRAE Handbook -– HVAC Applications	**Hot Water Systems 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 Handbook – Fundamentals

Table A-9 Support Spacing Schedule

Maximum Horizontal Pipe Support Spacing for Steel Distribution Piping	
Pipe Size inches (mm)	**Spacing feet (meter)**
1 (25 mm)	7 (2.1 m)
1-1/4 (32 mm)	7 (2.1 m)
1-1/2 (40 mm)	9 (2.74 m)
2 (50 mm)	10 (3.05 m)
2-1/2 (65 mm)	11 (3.35 m)
3 (80 mm)	12 (3.66 m)
3-1/2 (90 mm)	13 (3.96 m)
4 (100 mm)	14 (4.27 m)
5 (125 mm)	16 (4.88 m)
6 (150 mm)	17 (5.18 m)
8 (200 mm)	19 (5.79 m)
10 (250 mm)	22 (6.71 m)
12 (300 mm)	23 (7.01 m)
14 (350 mm)	25 (7.62 m)
16 (400 mm)	27 (8.23 m)
18 (450 mm)	28 (8.53 m)
20 (500 mm)	30 (9.14 m)
24 (600 mm)	32 (9.75 m)
30 (750 mm)	33 (10.06 m)

Notes: To the Designer: These spacings are maximum for horizontal, straight runs. More closely spaced supports must be provided for bends and risers and at equipment.

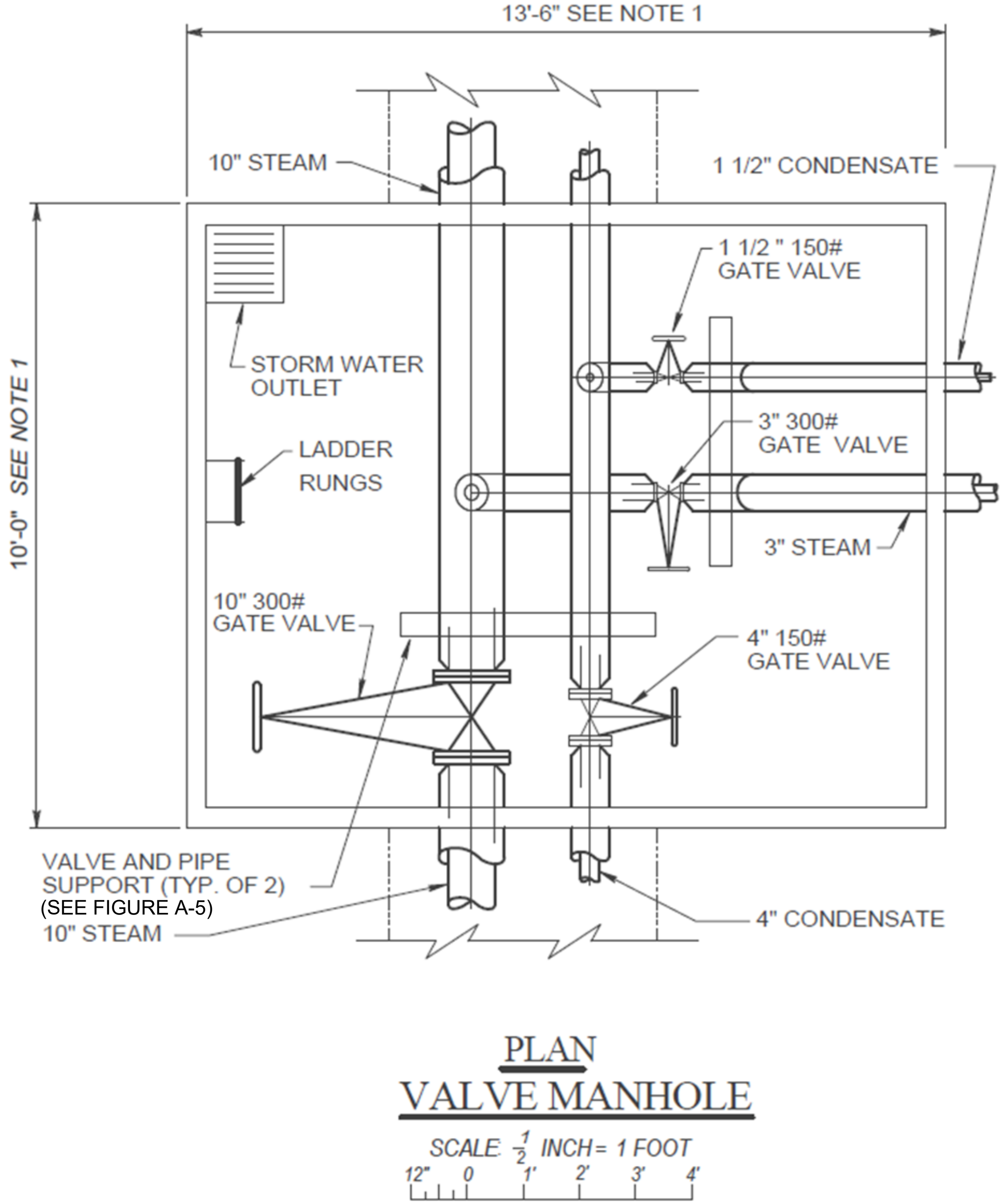
Table A-10 Pipe Expansion in Inches Per 100 Feet (30.5 m) of Length for Temperature Shown

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

Notes:

1. Imperial to metric conversion: Change in Temperature °F to in temperature °C conversion factor is ∆°F x 5/9 = ∆°C.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.

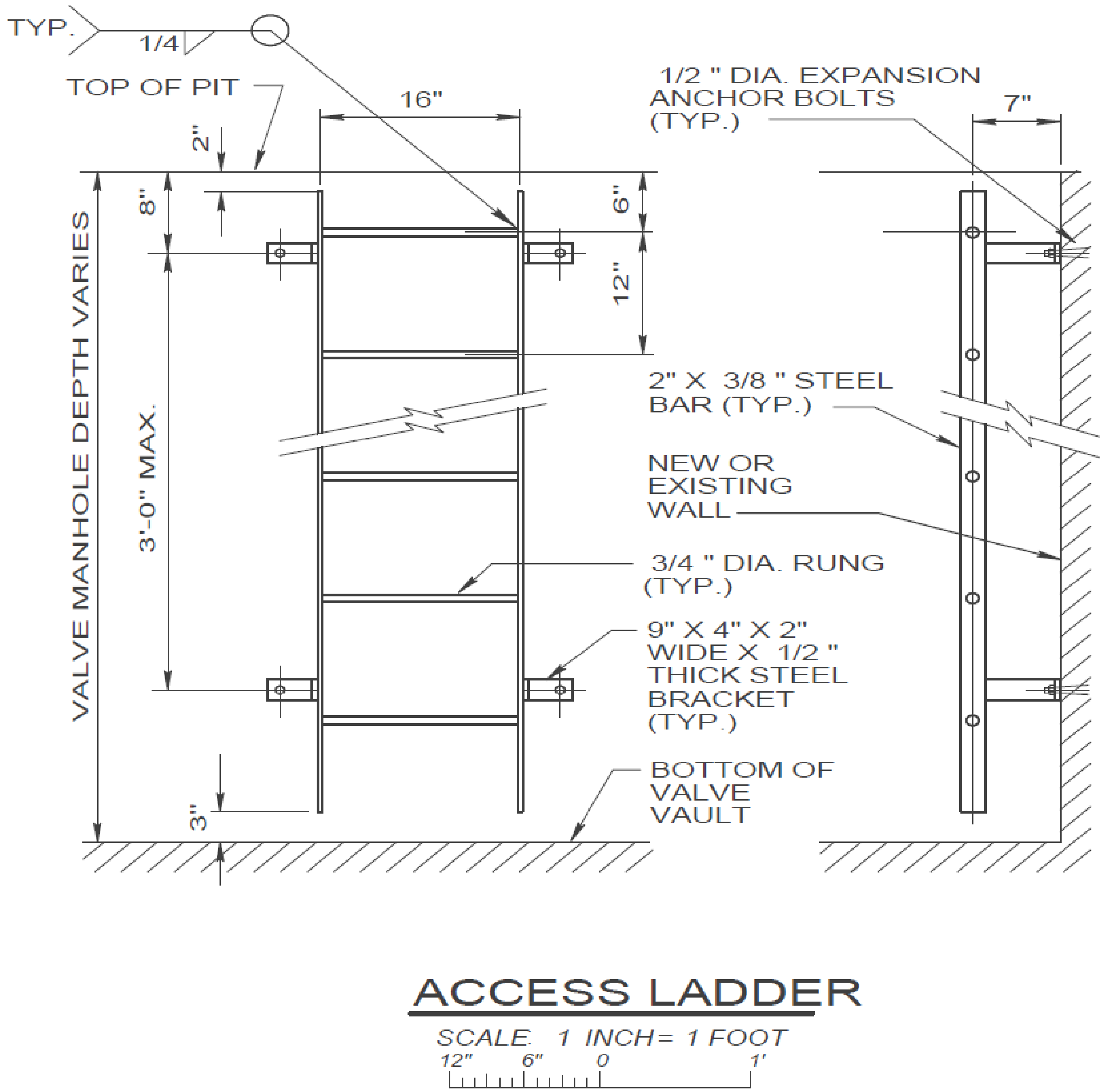
Figure A-2 Typical Valve Manhole Plan



Notes:

1. To the Designer: Dimensions of valve manholes determined on a case by case basis.
2. Drip leg trap station is not shown on the plan view.
3. Pipe sizes imperial to metric conversion: 1 1/2" = 40 mm, 3" = 80 mm, 4" = 100 mm, and 10" = 250 mm.
4. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.
5. Imperial to metric conversion: Feet to mm conversion factor is 1'-0" = 304.8 mm.

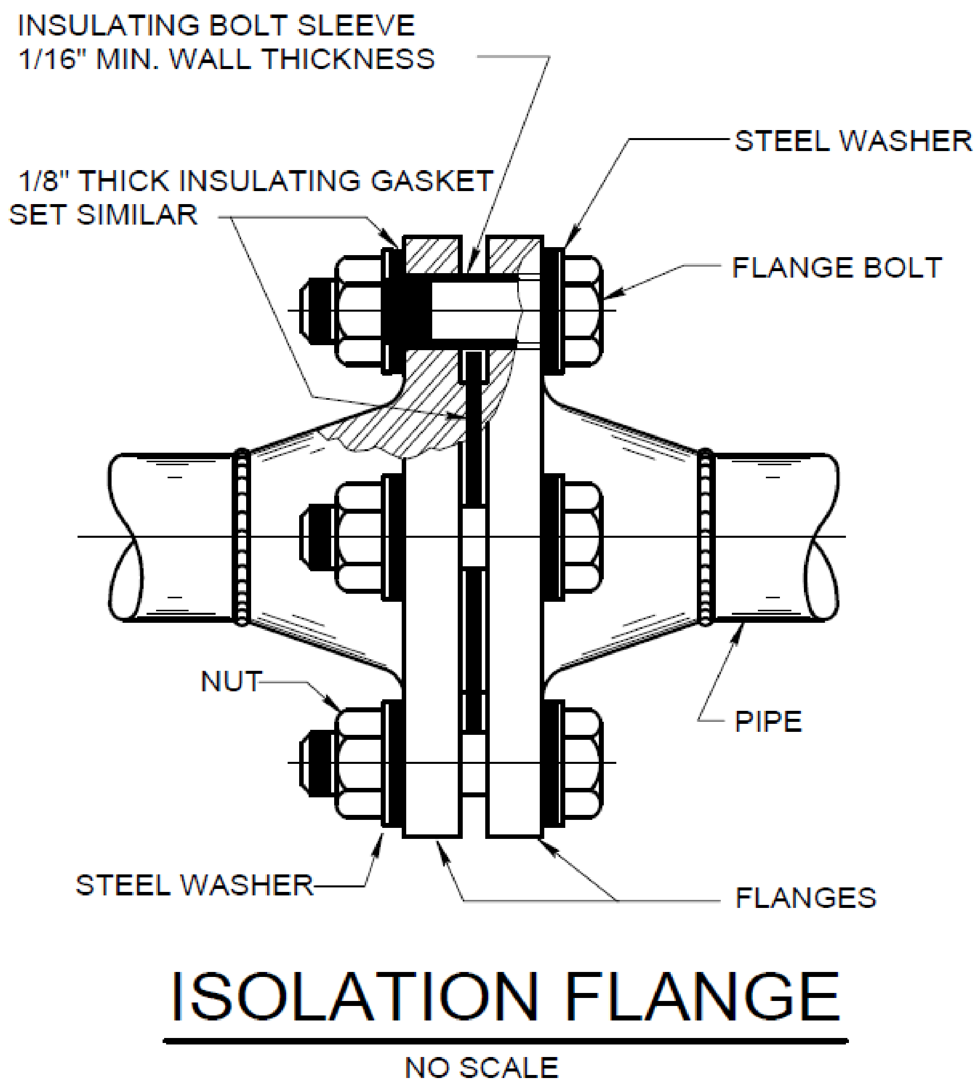
Figure A-3 Access Ladder Detail



Notes:

1. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
2. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.

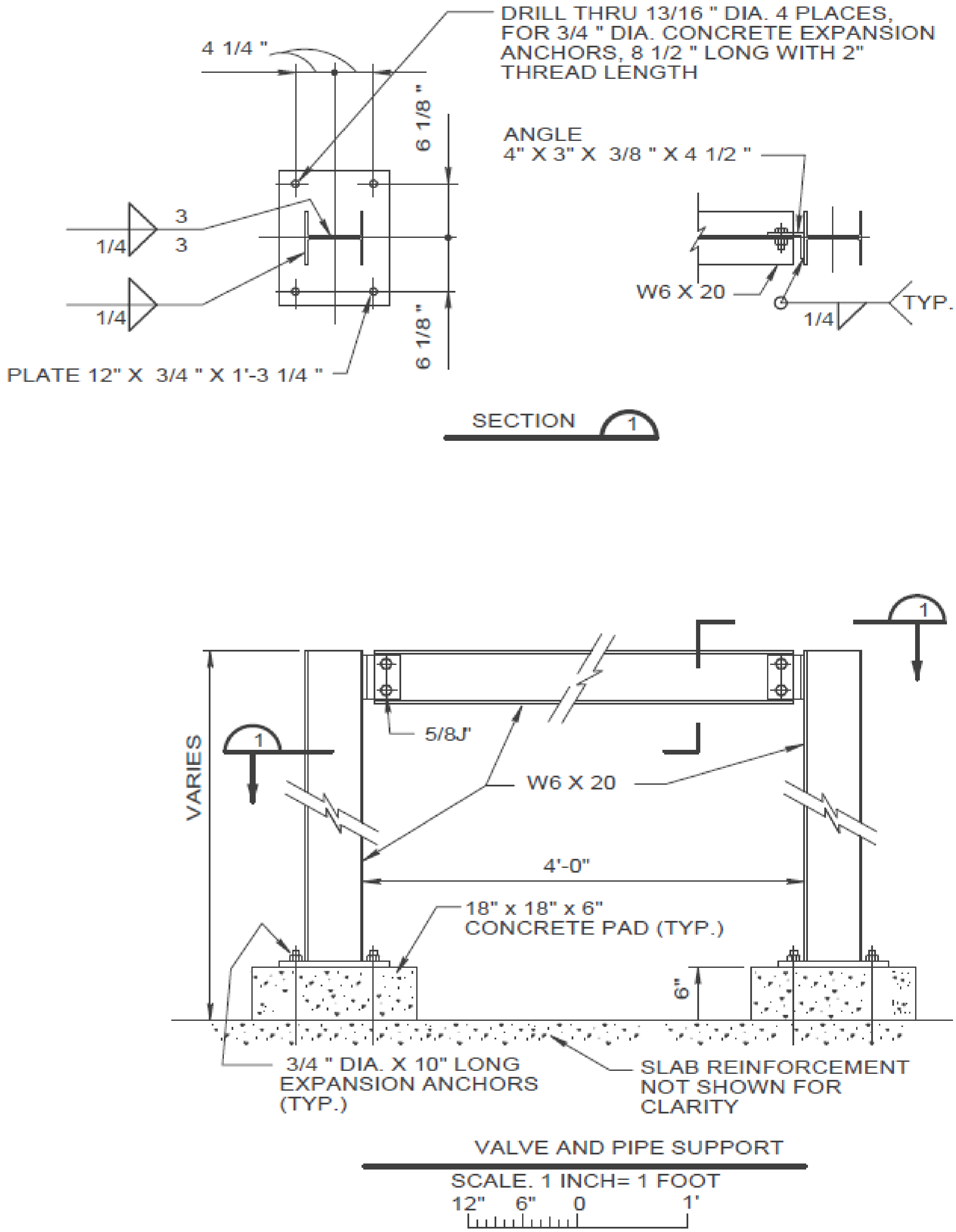
Figure A-4 Typical Isolation Flange Detail



Notes:

1. Contractor must comply with the isolation flange manufacturer's recommendations for bolt torques and bolting pattern. Contractor must also recheck bolt torques 72 hours after system startup.
2. Imperial to metric conversion: Inches to mm conversion factor is 1" = 25.4 mm.

Figure A-5 Typical Valve/Piping Support Detail



Notes:

1. Piping must rest on the pipe support. Pipe shoes must be centered on the top beam of this support in the cold condition.
2. Imperial to metric conversion: Inches to mm conversion factor is 1” = 25.4 mm.
3. Imperial to metric conversion: Feet to mm conversion factor is 1’-0” = 304.8 mm.
4. Imperial beam member W6x20 is equivalent to metric beam member W150x29.8.

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APPENDIX B GLOSSARY

B-1 ACRONYMS.

AFCEC	Air Force Civil Engineer Center
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
BIA	Bilateral Infrastructure Agreement
CHW	Chilled Water
CL-CH	Lean and Fat Clays
DDT	Drainable-Dryable-Testable
GS	Guide Support
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
HTW	High temperature hot water
LPG	Liquified Petroleum Gas
LTW	Low temperature hot water
MTW	Medium temperature hot water
NAVFAC	Naval Facilities Engineering Systems Command
NCEL	Naval Civil Engineering Laboratory
NIST	National Institute of Standards and Technology
NTIS	National Technical Information Service
OHM-CM	Ohms Per Cubic Centimeter
PVC	Polyvinyl Chloride
RTRP	Reinforced Thermosetting Resin Plastic
SOFA	Status of Forces Agreements
UFC	Unified Facilities Criteria

UFGS Unified Facilities Guide Specifications

WSL Water Spread Limiting

B-2 DEFINITION OF TERMS.

Designer: This term used throughout this UFC refers to the person or persons responsible for preparing contract drawings and specifications for a heating or cooling distribution design. The main engineering discipline areas of the "designer" are:

- Mechanical. Includes expansion compensation, stress analysis, piping system design (material selections, fittings, valves, insulation), equipment selection and sizing, and pipe sizing and routing.
- Structural. Includes reinforced concrete design, pipe supports, and valve manhole cover design.
- Electrical. Includes cathodic protection, electrical service and controls (for example, sump pumps).
- Civil. Includes earth work, road crossings (for buried systems), system plans and profiles, and area drainage designs.

APPENDIX C REFERENCES

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR CONDITIONING ENGINEERS (ASHRAE)

https://www.ashrae.org/

ASHRAE Handbook, *Fundamentals*

ASHRAE Handbook, *HVAC Applications*

ASHRAE Handbook, *HVAC Systems and Equipment*

ASHRAE 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

ASHRAE Transactions Volume 71, Part 1, p. 61, 1965, *Earth Temperature and Thermal Diffusivity at Selected Stations in the United States*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

https://www.asme.org/

ASME B31.1, *Power Piping*

ASME B31.9, *Building Services Piping*

MILITARY STANDARD

MIL-STD-3007G, *Standard Practice Unified Facilities Criteria, Facilities Criteria And Unified Facilities Guide Specifications*

NAVAL CIVIL ENGINEERING LABORATORY

NCEL UG-0005, *Steam Trap Users Guide*, available from Commanding Officer, Code L08B, Naval Civil Engineering Laboratory, Port Hueneme, CA 93043-5003.

NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY (NIST)

https://www.wbdg.org/nist/criteria/nist-handbook-135

NIST Handbook 135, *Life Cycle Costing Manual for the Federal Energy Management Program*

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/dod/ufc

UFC 1-200-01, *DoD Building Code*

UFC 3-130-05, *Arctic and Subarctic Utilities*

UFC 3-220-01, *Geotechnical Engineering*

UFC 3-301-01, *Structural Engineering*

UFC 3-401-01, *Mechanical Engineering*

UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

UFC 3-420-01, *Plumbing Systems*

UFC 3-420-02, *Compressed Air*

UFC 3-430-05, *Natural Gas and Liquified Petroleum Gas (LPG) Distribution Pipelines*

UFC 3-570-01, *Cathodic Protection*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems (FRCS)*

UFC 4-150-02, *Dockside Utilities for Ship Service*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

https://www.wbdg.org/dod/ufgs

UFGS 09 97 13.28, *Protection of Buried Steel Piping and Steel Bulkhead Tie Rods*

UFGS 22 14 29.00, *Sump Pumps*

UFGS 22 15 26.00 20, *High and Medium Pressure Compressed Air Piping*

UFGS 23 05 48.19, *Seismic Bracing for Mechanical Systems*

UFGS 23 07 00, *Thermal Insulation for Mechanical Systems*

UFGS 33 60 02, *Aboveground Heat Distribution System*

UFGS 33 61 13, *Pre-Engineered Underground Heat Distribution System*

UFGS 33 61 13.13, *Prefabricated Underground Hydronic Energy Distribution*

UFGS 33 61 13.19, *Valves, Piping, And Equipment in Valve Manholes*

UFGS 33 61 14, *Exterior Buried Preinsulated Water Piping*

UFGS 33 63 13, *Exterior Underground Steam Distribution System*

UFGS 33 63 13.19, *Concrete Trench Hydronic and Steam Energy Distribution*

UFGS 33 63 14, *Exterior Buried Pumped Condensate Return*

UFGS 33 63 16, *Exterior Shallow Trench Steam Distribution*

UFGS 33 63 23, *Exterior Aboveground Steam Distribution*

BOOKS

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

Hydraulic Institute, *Pipe Friction Manual,* Unless otherwise indicated, copies are available from Hydraulic Institute, 712 Lakewood Center North, 14600 Detroit Avenue, Cleveland, OH 44107.