

SECTION 33 6300 – STEAM ENERGY DISTRIBUTION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies materials and procedures for construction of underground steam distribution and condensate return piping system, including manholes, outside the buildings. System shall be: **[walk through concrete tunnels / concrete shallow trenches / pre-engineered direct-buried drainable-dryable-testable (DDT) / pre-engineered direct-buried water-spread-limiting (WSL)]**.

1.2 RELATED WORK

- A. Excavation, Trench Widths, Pipe Bedding, Backfill, Shoring, Sheeting, Bracing: Section 31 20 00, EARTH MOVING.
- B. Concrete Work, Reinforcing, Placement and Finishing: Section 03 30 00, CAST-IN-PLACE CONCRETE.
- C. Submittals: Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA AND SAMPLES.
- D. Erosion and Sediment Controls: Section 31 10 00, SITE CLEARING.
- E. Tracer Wire: Section 22 0000 "Common Work Results for Plumbing"

1.3 DEFINITIONS

- A. System: The complete underground steam and condensate distribution system including all components such as carrier piping, pipe supports, insulation, protective enclosures, anchors, corrosion protection and accessories.
- B. Pre-Engineered Direct-Buried System: The factory-fabricated system.
- C. Drainable-Dryable-Testable (DDT) Pre-Engineered Direct-Buried System: A factory-fabricated system.
- D. Concrete Shallow Trench: A system with removable concrete covers located at grade.
- E. Walk-through Concrete Tunnels: A system located below grade with sufficient space for carrier pipes, other services, and space to walk upright along the entire length of the system.
- F. Carrier Pipe: Pipe carrying the steam or condensate.
- G. Encasement Pipe: Outer protective pipe on any main line pipe. Carrier pipe and insulation are within the casing.

- H. HP Systems: High-pressure piping operating at more than 15 psi (104 kPa) as required by ASME B31.1.
- I. LP Systems: Low-pressure piping operating at 15 psi (104 kPa) or less as required by ASME B31.9.

1.4 ABBREVIATIONS

- A. HDPE: high-density polyethylene
- B. RTRP: reinforced thermosetting resin plastic
- C. RTRF: reinforced thermosetting resin fittings
- D. WOG: water, oil and gas

1.5 DELIVERY, STORAGE AND HANDLING

- A. The Contractor is solely responsible for the protection of equipment and material against damage. Protect piping systems against the entry of water, mud or other foreign substances by installing watertight covers on open ends at all times. Protect direct-buried system coatings from ultraviolet light (sunlight). Existing equipment worked on by the Contractor or in the Contractor's working area shall be considered to be in the custody and responsibility of the Contractor.
- B. All insulated piping systems exposed to water must be replaced prior to installation.

1.6 COORDINATION

- A. Coordinate exterior steam lines and connections to building services up to the actual extent of building wall.

1.7 QUALITY ASSURANCE:

- A. Products Criteria:
 - 1. When two or more units of the same type or class of materials or equipment are required, these units shall be products of one manufacturer.
 - 2. A nameplate bearing manufacturer's name or trademark, including model number, shall be securely affixed in a conspicuous place on equipment. In addition, the model number shall be cast integrally with equipment, stamped, or otherwise permanently marked on each item of equipment.
- B. Contractor shall restore damaged items to as-new operating condition or replace damaged items as directed by Facilities Management Operations, at no additional cost to Northwestern University.
- C. Fiberglass Pipe and Fitting Installers: Installers of RTRF and RTRP shall be certified by manufacturer of pipes and fittings as having been trained and qualified to join fiberglass piping with manufacturer-recommended adhesive.
- D. Welding Qualifications: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with provisions in [ASME B31.9, Building Services Piping / ASME B31.1, Power Piping] .
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

E. ASME Compliance: Comply with [**ASME B31.9, Building Services Piping, / ASME B31.1, Power Piping**] for materials, products, and installation.

F. ASME Compliance: Safety valves and pressure vessels shall bear appropriate ASME labels.

1.8 SUBMITTALS

A. Manufacturers' Literature and Data shall be submitted, as one package, for pipes, fittings and appurtenances, including jointing materials, insulation, hangars and other miscellaneous items.

1.9 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of this specification to the extent referenced. The publications are referred in the text by basic designation only.

Federal Specifications (Fed. Spec.):

A-A-60005 NOT 1	Frames, Covers, Grating, Steps, Sump and Catch Basin, Manhole
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L-S-125	Screening, Insect, Nonmetallic
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Military Specifications (Mil. Spec.):

MIL-S-901	Shock Tests H.I. (High Impact) Shipboard Machinery, Equipment and Systems
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American Society for Testing and Materials (ASTM):

A36/A36M-08	Carbon Structural Steel
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A47/A47M-99(2009)	Ferritic Malleable Iron Castings
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A53/A53M-10	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
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A105/A105M-10a	Carbon Steel Forgings for Piping Applications
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A106/A106M-10	Seamless Carbon Steel Pipe for High-Temperature Service
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A126-04(2009)	Gray Iron Castings for Valves, Flanges, and Pipe Fittings
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A139/A139M-04(2010)	Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)
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A167-99(2009)	Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
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FOR: _____
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A193/A193M-10a	Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
A194/A194M-10a	Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A197/A197M-00(2006)	Cupola Malleable Iron
A234/A234M-10b	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
A240/A240M-10b	Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
A307-10	Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
A666-10	Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
A733-03(2009)	Welded and Seamless Carbon Steel and Austenitic Stainless Steel Pipe Nipples
B61-08	Steam or Valve Bronze Castings
C177-10	Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
C411-05	Hot-Surface Performance of High-Temperature Thermal Insulation
C449-07	Mineral Fiber Hydraulic-Setting Thermal Insulating and Finishing Cement
C450-08	Fabrication of Thermal Insulating Fitting Covers for NPS Piping, and Vessel Lagging
C533-09	Calcium Silicate Block and Pipe Thermal Insulation
C547-07	Mineral Fiber Pipe Insulation
C552-07	Cellular Glass Thermal Insulation
C585-10	Inner and Outer Diameters of Thermal Insulation for Nominal Sizes of Pipe and Tubing
C591-09	Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
C655-09	Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe
C920-10	Elastomeric Joint Sealants

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C1126-10a	Faced or Unfaced Rigid Cellular Phenolic Thermal Insulation
C1136-10	Flexible, Low Permeance Vapor Retarders for Thermal Insulation
D2996-01(2007)	Filament-Wound Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D4024-05	Machine Made Fiberglass (Glass-Fiber-Reinforced Thermosetting Resin) Flanges
E84-10b	Surface Burning Characteristics of Building Materials

American Society of Mechanical Engineers (ASME):

B1.20.1-2006	Pipe Threads, General Purpose (Inch)
B16.3-2006	Malleable Iron Threaded Fittings: Classes 150 and 300
B16.4-2006	Gray Iron Threaded Fittings: (Classes 125 and 250)
B16-5-2009	Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard
B16.9-2007	Factory-Made Wrought Buttwelding Fittings
B16.11-2009	Forged Fittings, Socket-Welding and Threaded
B16.21-2005	Nonmetallic Flat Gaskets for Pipe Flanges
B18.2.1-2010	Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)
B31.1-2010	Power Piping
B31.9-2008	Building Services Piping
B40.1000-2009	Pressure Gauges and Gauge Attachments

American Welding Society (AWS):

B2.1-B2.1M-BMG-2009	Base Metal Grouping for Welding Procedures and Performance Qualification
D10.12/D10.12M-2000	Guide for welding Mild Steel Pipe

American Association of State Highway and Transportation Officials (AASHTO):

M300-03	Inorganic Zinc-Rich Primer
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Manufacturer's Standardization Society (MSS):

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MSS SP 58

Pipe Hangers and Supports-Materials, Design, Manufacture,
Selection, Application and Installation

NACE International (NACE):

SP0169-2007

Control of External Corrosion on Underground or Submerged
Metallic Piping Systems

National Fire Protection Agency (NFPA):

255-2006 Ed.

Test Burning Characteristics of Building Materials

1.10 WARRANTY

- A. The Contractor shall remedy any defect due to faulty material or workmanship and pay for any damage to other work resulting there from within a period of **[one year / two years]** from final acceptance. Further, the Contractor will provide all manufacturer's and supplier's written guarantees and warranties covering materials and equipment furnished under this Contract.

PART 2 - PRODUCTS

2.1 STEEL PIPES AND FITTINGS

- A. Steel Pipe: ASTM A53, Type E, Grade A, wall thickness as indicated in "Piping Application" Article; black with plain ends.
- B. Cast-Iron, Threaded Fittings: ASME B16.4, **[Class 125 / and / Class 250]**, standard pattern.
- C. Malleable-Iron, Threaded Fittings shall be ASME B16.3, **[Class 150 / and / Class 300]**.
- D. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
1. Material Group: 1.1.
 2. End Connections: Butt welding.
 3. Facings: Raised face.
- E. Steel Welding Fittings: **[ASME B16.9 / and / ASTM A234]**, seamless or welded.
1. Welding Filler Metals shall comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- F. Nipples: ASTM A733, Standard Weight, seamless, carbon-steel pipe.
- G. Pipe-Flange Gasket Materials: ASME B16.21, suitable for chemical and thermal conditions of piping system contents, nonmetallic, flat, asbestos free, 1/8 inch (3.2 mm) maximum thickness unless thickness or specific material is indicated.
1. For flat-face, Class 125, cast-iron and cast-bronze flanges.
 2. For raised-face, Class 250, cast-iron and steel flanges.

- H. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

2.2 FIBERGLASS PIPE AND FITTINGS

- A. RTRP: ASTM D2996, filament-wound pipe with tapered bell and spigot ends for adhesive joints.
- B. RTRF: Compression or spray-up/contact molded of same material, pressure class, and joining method as pipe.
- C. Fiberglass Pipe Adhesive: Furnished or as recommended by the pipe manufacturer.
- D. Flanges: ASTM D4024, full-face gaskets suitable for the service, minimum 1/8 inch (3.2 mm) thick, 60-70 durometer. ASTM A307, Grade B, hex-head bolts with washers.

2.3 CONDUIT PIPING SYSTEM

- A. Conduit Piping System: Factory-fabricated and assembled, airtight and watertight, drainable, pressure-tested piping with conduit, inner pipe supports, and insulated carrier piping. Fabricate so insulation can be dried in place by forcing dry air through conduit.
- B. Carrier Pipe Insulation:
1. Mineral-Wool Pipe Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C547, [**Type I, 850 deg F (454 deg C)** / **Type II, 1200 deg F (649 deg C)**], Grade A.
 - a. Bands shall be ASTM A666, Type 304, stainless steel, 3/4 inch (19 mm) wide, 0.020 inch (0.5 mm) thick.
 2. Calcium Silicate Pipe Insulation: ASTM C533, Type 1, flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement.
 - a. Bands: ASTM A666, Type 304, stainless steel, 3/4 inch (19 mm) wide, 0.020 inch (0.5 mm) thick.
 3. Polyisocyanurate Foam Pipe Insulation: Unfaced, preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation.
 - a. Comply with ASTM C591, Type I or Type IV, except thermal conductivity (k-value) shall not exceed 0.19 Btu x in./h x sq. ft. x deg F (0.027 W/m x K) at 75 deg F (24 deg C) after 180 days of aging.
 - b. Flame-spread index: ASTM E84, 25 or less and smoke-developed index shall be 50 or less for thickness up to 1-1/2 inches (38 mm).
 - c. Fabricate shapes: ASTM C450 and ASTM C585.
 4. Polyurethane Foam Pipe Insulation: Un-faced, preformed, rigid cellular polyurethane material intended for use as thermal insulation.
 - a. Comply with ASTM C591, Type I or Type IV, except thermal conductivity (k-value) shall not exceed 0.19 Btu x in./h x sq. ft. x deg F (0.027 W/m x K) at 75 deg F (24 deg C) after 180 days of aging.

- b. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less for thickness up to 1-1/2 inches (38 mm) as tested by ASTM E84.
- c. Fabricated shapes: ASTM C450 and ASTM C585.

C. Minimum Clearance:

- 1. Between Carrier Pipe Insulation and Conduit: 1 inch (25 mm)
- 2. Between Insulation of Multiple Carrier Pipes: 3/16 inch (4.75 mm)
- 3. Between Bottom of Carrier Pipe Insulation and Conduit: 1 inch (25 mm)
- 4. Between Bottom of Bare, Carrier Pipe and Casing: 1-3/8 inches (35 mm)

D. Conduit shall be spiral wound, steel.

- 1. Finish: Two coats of fusion-bonded epoxy, minimum 20 mils (0.50 mm) thick.
- 2. Cover: Polyurethane foam insulation with an HDPE jacket; thickness indicated in "Piping Application" Article.
- 3. Piping Supports within Conduit: Corrugated galvanized steel with a maximum spacing of 10 feet (3 m).
- 4. Fittings: Factory-fabricated and insulated elbows and tees. Elbows may be bent pipe equal to carrier pipe. Tees shall be factory fabricated and insulated, and shall be compatible with the carrier pipe.
- 5. Expansion Offsets and Loops: Size casing to contain piping expansion.
- 6. Accessories include the following:
 - a. Water Shed: Terminal end protector for carrier pipes entering building through floor, 3 inches (75 mm) deep and 2 inches (50 mm) larger than casing; terminate casing 20 inches (500 mm) above the floor level.
 - b. Guides and Anchors: Steel plate welded to carrier pipes and to casing, complete with vent and drainage openings inside casing.
 - c. End Seals: Steel plate welded to carrier pipes and to casing, complete with drain and vent openings on vertical centerline.
 - d. Gland Seals: Packed stuffing box and gland follower mounted on steel plate, welded to end of casing, permitting axial movement of carrier piping, with drain and vent connections on vertical centerline.
 - e. Joint Kit: Half-shell, pourable or split insulation and shrink-wrap sleeve.

E. Manholes: Black steel with lifting eyes.

- 1. Finish: Spray-applied urethane, minimum 30 mils (0.75 mm) thick.
- 2. Access: 30 inches (750 mm) with waterproof cover, gasket, ladder, and two 6 inch (150 mm) vents, one high and one low, extending above grade with rain caps.
- 3. Conduit Stub-Outs and Seals: Welded steel with drain and vent openings.
- 4. Sump: 12 inches (300 mm) in diameter, 12 inches (300 mm) deep.
- 5. Floatation anchor: Oversized bottom keyed into concrete base.

F. Source Quality Control: Factory test the conduit to 15 psi (105 kPa) for a minimum of two minutes with no change in pressure. Factory test the carrier pipe to 150 percent of the operating pressure of system. Furnish test certificates.

2.4 LOOSE-FILL INSULATION

- A. Granular, loose-fill insulation: Inorganic, nontoxic, nonflammable, sodium potassium aluminum silicate with calcium carbonate filler. Include chemical treatment that renders insulation hydrophobic.
1. Thermal Conductivity (k-Value): 0.60 at 175 deg F (0.087 at 79 deg C) and 0.65 at 300 deg F (0.094 at 149 deg C).
 2. Application Temperature Range: 35 to 800 deg F (2 to 426 deg C).
 3. Dry Density: 40 to 42 lb/cu. ft. (640 to 672 kg/cu. m).
 4. Strength: 12,000 lb/sq. ft. (58,600 kg/sq. m).
- B. Powder, loose-fill insulation: Inert, nontoxic, nonflammable, calcium carbonate particles. Include chemical treatment that renders insulation hydrophobic.
1. Thermal Conductivity (k-Value): ASTM C177, 0.58 at 100 deg F (0.084 at 37 deg C) and 0.68 at 300 deg F (0.098 at 149 deg C).
 2. Application Temperature Range: Minus 273 to plus 480 deg F (Minus 169 to plus 250 deg C).
 3. Dry Density: Approximately 60 lb/cu. ft. (960 kg/cu.).
 4. Strength: 12,000 lb/sq. ft. (58,600 kg/sq. m).

2.5 PRE-ENGINEERED, FACTORY-FABRICATED, DIRECT-BURIED, DRAINABLE-DRYABLE-TESTABLE (DDT) SYSTEMS

- A. Complete steam and condensate piping system with carrier pipes, carrier pipe insulation with jackets and banding, air space, 0.25 inch (6.35 mm) thick steel casing, fusion-bonded epoxy casing coatings, cathodic protection, accessories. Do not locate condensate pipes in casings (conduits) that contain steam pipes.
- B. All components of system shall be suitable for carrier pipe pressures and temperatures as follows:
1. Steam System: 150 psi (1000 kPa); 366 deg F (185 deg C).
 2. Condensate System: 50 psi (345 kPa); 310 deg F (154 deg C).
- C. Steam Carrier Pipes and Condensate Carrier Pipes:
1. No piping joints are allowed in factory-fabricated straight sections of pre-engineered direct-buried systems.
 2. Factory-fabricated direct-buried piping sections that are a portion of an expansion loop or bend shall have all welded joints 100% radiograph inspected.
- D. Carrier Pipe Insulation shall:
1. Conform to minimum thickness and type of insulation listed in Tables 1 and 2 below as required for service temperature in carrier pipe as listed below.
 2. Section A: Steam temperature is [_____deg F (_____ deg C), steam pressure is _____psi (kPa)]. Pumped condensate temperature is 300 deg F (93 deg C). Drip return temperature is 212 deg F (100 deg C).
 3. Section B: Steam temperature is [_____deg F (_____ deg C), steam pressure is _____psi (kPa)]. Pumped condensate temperature is 200 deg F (93 deg C). Drip return temperature is 212 deg F (100 deg C).
 4. Allowable Carrier Pipe Insulation Type and Minimum Insulation Thickness:

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TABLE 1 Minimum Pipe Insulation Thickness mm (inches) For Steam 16 to 408 psi (110 to 2800 kPa) gage			
Nominal Pipe Diameter Inches (mm)	MPT-PC MPT-PF	Delta	Thermo-12 Super Caltemp
1 (25)	2 (50)	2-1/2 (65)	4 (100)
1-1/2 (40)	2 (50)	2-1/2 (65)	4 (100)
2 (50)	2-1/2 (65)	3-1/2 (85)	4-1/2 (110)
2-1/2 (65)	2-1/2 (65)	3-1/2 (85))	4-1/2 (110)
3 (80)	3 (75)	4 (100)	5 (125)
4 (100)	3 (75)	4 (100)	5 (125)
5 (125)	3 (75)	4 (100)	5 (125)
6 (150)	3-1/2 (85)	4-1/2 (110)	5-1/2 (135)
8 (200)	3-1/2 (85)	4-1/2 (110)	5-1/2 (135)
10 (250)	4 (100)	5 (125)	6 (150)
12 (300)	4 (100)	5 (125)	6 (150)
14 (350)	4 (100)	5 (125)	6 (150)
16 (400)	4 (100)	5 (125)	6 (150)
18 (450)	4 (100)	5 (125)	6 (150)

Notes:

- Insulation listed has passed the 96-hour boiling water test. Pipes smaller than 1 inch (25 mm) shall have same insulation thickness as 1 inch (25 mm) pipe.

TABLE 2 Minimum Pipe Insulation Thickness inches (mm) For Steam Less than 16 psi (110) gage, Condensate Return			
Nominal Pipe Diameter inches (mm)	Nominal Pipe Diameter inches (mm)	Nominal Pipe Diameter inches (mm)	Nominal Pipe Diameter inches (mm)
1 (25)	1-1/2 (40)	2 (50)	3 (75)
1-1/2 (40)	1-1/2 (40)	2 (50)	3 (75)
2 (50)	1-1/2 (40)	2 (50)	3 (75)
2-1/2 (65)	1-1/2 (40)	2 (50)	3 (75)
3 (80)	2 (50)	2-1/2 (65)	3-1/2 (85)
4 (100)	2 (50)	2-1/2 (65)	3-1/2 (85)
5 (125)	2 (50)	2-1/2 (65)	3-1/2 (85)
6 (150)	2-1/2 (65)	3 (80)	4-1/2 (110)
8 (200)	2-1/2 (65)	3 (80)	4-1/2 (110)
10 (250)	3 (80)	4 (100)	5 (125)
12 (300)	3 (80)	4 (100)	5 (125)
14 (350)	3 (80)	4 (100)	5 (125)
16 (400)	3 (80)	4 (100)	5 (125)
18 (450)	3 (80)	4 (100)	5 (125)

Notes:

- Insulation listed has passed the 96-hour boiling water test which indicates that satisfactory performance in underground service can be expected. Pipes smaller than 1 inch (25 mm) shall have the same insulation thickness as required for 1 inch (25 mm) pipe.

- E. Insulation Banding and Jacket: ASTM A167, stainless steel bands and clips, at least 0.5 inches (13 mm) wide, (304 stainless steel), maximum spacing 18 inches (460 mm). A minimum of two bands is required for each 4 foot (1300 mm) section of insulation.
- F. Vinyl-coated fiberglass scrim jacket: Fed. Spec. L-S-125, Type II, Class 2, with 18 x 16 mesh (number of filaments per inch) and made of 0.013 inches (0.335 mm) diameter vinyl-coated fibrous glass yarn. Install bands over the jacket to secure the insulation to the carrier pipe.
- G. Casing: ASTM A139, smooth-wall steel, electric resistance welded. Plastic casings are not permitted. Use eccentric connectors as necessary between casing sections to provide continuous gravity drainage in bottom of casing between manholes and between manholes and buildings.

Casing Diameter in. (mm)	Minimum Thickness in. (mm)
6 – 46 (150 - 1170)	0.250 (6.35)

- H. Casing End Seal Plates with Vents and Drains: ASTM A36, steel, minimum thickness 0.375 inches (9.5 mm) for casings up thru 12 inches (300 mm) diameter and 0.5 inches (13 mm) for casings over 12 inches (300 mm) diameter. Provide 1 inch (25 mm) drain at the bottom and vent at the top. Construct with threaded steel half couplings. Install threaded brass plugs in drains.
- I. Vent Riser Pipes: ASTM A53, Schedule 40, galvanized, extending through top of manhole and terminate 12 inches (300 mm) above grade with 180-degree bend.
- J. Gland Seals are not permitted because of the possibility of water entering the system thru the gland seal from a flooded manhole.
- K. Provide continuous 1 inch (25 mm) minimum air space between carrier pipe insulation and casing.
- L. Casing coating shall be dual layers of fusion-bonded epoxy, inner green-colored layer minimum thickness 0.020 inches (0.5 mm), outer black-colored layer minimum thickness 0.010 inches (0.25 mm). Rated by coating manufacturer for continuous service for at least 25 years at minimum temperature of 230 deg F (110 deg C) and having a coefficient of expansion similar to that of steel. Coating shall be applied in accordance to recommendations of coating manufacturer including surface preparation. Factory-inspect for holidays and make repairs as necessary.
- M. Coating of end plates and casing (conduit) sections extending in manholes shall be zinc-rich coating that conforms to AASHTO M300, Type IA except that volatile organic compounds shall not exceed 2.8 pounds per gallon (0.34 kg per liter). The zinc rich coating shall be applied in accordance with the recommendations of the coating manufacturer including surface preparation. No additional top coat shall be applied.
- N. Carrier pipe guides and supports shall be maximum spacing 10 feet (3000 mm) on centers, no more than 5 feet (1500 mm) from pipe ends, minimum of three guides per elbow section. Designed to permit thermal expansion without damage, provide proper pipe guiding and support, and to allow horizontal movement in two directions as necessary at expansion loops and bends. Design of guides and supports must permit continuous drainage of water in bottom of casing. Pipe insulation shall extend thru the pipe guides and supports and be protected by steel sleeves. Design of guides and supports shall be such that no metal-to-metal contact exists between the casing and the carrier pipe. Insulation or non-metallic material used to ensure no metal to metal contact shall be designed to not be compressed by the weight of the carrier pipe when full of water.

- O. Anchor plates shall be ASTM A36 steel, welded to carrier pipe and casing, 0.5 inches (13 mm) minimum thickness, passages for air flow and water drainage thru the annular air space in the system. Coated with same coating material as the casing. Locate 3 to 5 feet (900 to 1500 mm) from piping entrance to manhole or building wall. Walls of manholes and buildings cannot be utilized as anchor points.
- P. Field connection of casing sections shall be steel section conforming to casing specification, welded to casing sections, coated on all surfaces with system manufacturer's coating field repair compound, and covered with a 0.05 inch (1.3 mm) minimum thickness polyethylene shrink sleeve designed for a service temperature exceeding 176 deg F (80 deg C).
- Q. Manhole and building wall penetrations shall provide steel leak plates welded to wall sleeves or to casings. Where a wall sleeve is utilized, allow sufficient annular space between the sleeve and the casing and install a watertight seal, rated for 250 deg F (121 deg C) minimum. Manhole and building walls cannot be used as anchor points.
- R. Provide sacrificial anode type cathodic protection system with dielectric isolation devices and test stations for all systems. Design system for 25 years' service, assume two percent bare metal. System shall comply with NACE SP0169.
- S. Provide embossed brass or stainless steel tag hung by a brass or stainless steel chain at each end of each conduit or insulated piping in the manholes and buildings. The tag shall identify system manufacturer's name, date of installation, Northwestern University contract, and manufacturer's project number.
- T. All branch piping connections must be located in manholes.

2.6 MANHOLES

- A. Reinforced concrete manholes: Not less than 8 inches (200 mm) thick. Pour monolithically where possible. Place waterproof membrane between mud slab and bottom concrete slab, and continue up sides to top of sidewalls. Joints between manhole walls and conduit casings or concrete trench sections shall be watertight. Steel manholes or prefabricated concrete manholes are not permitted.
- B. Accessories for Manholes: Cast iron manhole frames and solid covers, not less than 28 inch (700 mm) clear openings. Unless otherwise shown on the drawings, frames and covers shall be as follows:
 - 1. For non traffic applications:
 - a. Fed Spec. A-A-60005 NOT1, Frame Type IV, Size 28
 - b. Fed Spec. A-A-60005 NOT1, Cover Type E, Size 28, cast identification "STEAM".
 - 2. For traffic applications:
 - a. Fed Spec. A-A-60005 NOT1, Frame Type I, Style A, Size 27A
 - b. Fed Spec. A-A-60005 NOT1, Cover Type A, Size 27A, cast identification "STEAM".
 - 3. Manhole steps shall be standard, cast iron.
- C. Manhole ventilation: As indicated on Drawings. Construct ventilation ducts of galvanized steel sheet metal and in accordance with ASHRAE Handbook recommendations for low pressure

ducts. Gravity ventilators shall be factory fabricated of aluminum or galvanized steel and arranged as indicated on drawings. Ventilating pipes shall be standard weight black steel and installed as shown on drawings.

- D. Drainage as shown on drawings. Provide a 24 inch (610 mm) square by 24 inch (610 mm) deep sump pit in each manhole where indicated on drawings. Provide larger sump pit if necessary to accommodate required electric sump pumps.
- E. Electric Sump Pumps with Automatic Controls and High Water Alarm:
 - 1. Type: High temperature submersible duplex pumps and automatic controls.
 - 2. Service: Continuous operation at required flows and pressures while completely submerged at 200 deg F (93 deg C). All pumps and pump controls shall have demonstrated 200,000 cycles of operation at 200 deg F (93 deg C) and 100% relative humidity while totally submerged in water.
 - 3. Capacity and pressure: Pumps shall be capable of passing 0.375 inch (10 mm) spheres. Pumps and motors shall be capable of operating continuously without damage when not submerged.
 - 4. Pumps: Epoxy-coated cast iron casing, cast iron impeller, stainless steel shaft, carbon/ceramic shaft seal, stainless steel hardware, permanently lubricated bearings, screened inlets. Schedule 80 discharge pipe protected from corrosion.
 - 5. Motors: Non-overloading at all points on the pump performance curve. Include overload protection.
 - 6. Controls: Automatic alternating lead-lag, with damp-proof electrical service.
 - 7. High water alarm switch: Set at level below lowest steam or condensate pipe in the manhole. Switch shall activate weatherproof red alarm light mounted above grade as shown. Provide contacts [**and connect to / for future connection**] to engineering control center.

2.7 TUNNELS (WALK THRU)

- A. Reinforced concrete tunnel: Place waterproof membrane between mud slab and bottom concrete slab and continue up sides and over top of tunnel roof slab.
- B. Precast concrete tunnel: ASTM C655. Construct precast concrete pipe tunnel with straight runs of tunnel. Provide cast-in-place concrete tunnel sections at each bend and at each change in grade of the tunnel. Mortar shall be as recommended by the precast concrete tunnel manufacturer.
- C. Ventilation ducts: Galvanized sheet steel constructed in accordance with ASHRAE Handbook recommendations. Gravity ventilators shall be factory fabricated of aluminum or galvanized steel.
- D. Provide drainage system at all low points of tunnel systems as shown on the drawings.
- E. Waterproof manholes and below grade ventilation ducts.

2.8 CONCRETE SHALLOW TRENCHES

- A. Reinforced Cast-in-Place Trench: Reinforced concrete with minimum thickness 8 inches (200 mm).

1. Trench covers: Precast reinforced concrete sections, set to existing grade, flat and true at all points of contact on trench wall; trench and cover to form a watertight envelope when assembled.
2. Waterproofing: Apply to all below grade portions of the trench.
3. Gaskets and sealants: ASTM C920, 1/4 inch (6 mm) thick neoprene pads with a minimum width of 2 inches (50 mm) between covers and tops of walls; elastomeric sealants that are available as a one or two component system. Asphaltic sealants are not permitted. Sealants must resist 50% total joint movement. Non-sagging sealant must be used for vertical joints. Self-leveling sealant must be used for trench top butt joints.

2.9 STEAM CARRIER PIPING

- A. Pipe: [ASTM A53, steel, seamless, Grade B / or / ASTM A106, Grade B, electric resistance welded / or / ASTM A53, Grade B, Schedule 40] . Standard weight permitted for pipe sizes 12 inches (300 mm) and above. Grade F, furnace butt-welded pipe, is not permitted.
- B. Joints:
 1. In trenches and direct-buried systems: Butt-weld; socket weld for pipe sizes 2 inches (DN 50) and below. Manufacturer's standard sliding gasketed joints are permitted between sections of WSL pre-engineered direct-buried systems. No joints are allowed in factory-fabricated straight sections of pre-engineered direct-buried systems. Factory-fabricated direct-buried piping sections that are a portion of an expansion loop or bend shall have all welded joints 100% radiograph inspected. All radiographs shall be reviewed and interpreted by an American Society for Non-Destructive Testing (ASNT) Certified Level III radiographer, employed by the testing firm, who shall sign the reading report. Dye penetrant testing may be utilized for pipe sizes 2 inches (50 mm) and below.
 2. In tunnels, manholes and open areas: Butt weld pipe sizes 2-1/2 inches (65 mm) and above; thread or socket weld pipe sized 2 inches (50 mm) and below.
- C. Fittings:
 1. Butt welded joints: ASTM A234 or ASME B16.9, steel, Grade B, same schedule as adjoining pipe. All elbows shall be long radius unless otherwise indicated. Tees shall be full size or reducing as required, having interior surfaces smoothly contoured.
 2. Threaded joints: ASTM A47 or ASTM A197 or ASME B16.3, malleable iron, 300 pound (2050 kPa) class.
 3. Socket welded joints: ASME B16.11, forged steel, 2000 psi (13,800 kPa) class.
- D. Flanges and bolts: [**ASME B16.5, weld neck, forged steel / or / ASTM A105, pressure class 150 psi (1025 kPa)] . Bolts shall be high strength ASTM A193, Class 2, Grade B8. Nuts shall be ASTM A194.**
- E. Unions: Pipe 2 inches (50 mm) and smaller shall be threaded, malleable iron or steel, 300 psi (2050 kPa) class.

2.10 STEAM CONDENSATE CARRIER PIPING

- A. Pipe: [ASTM A53, seamless, Grade B / or / ASTM A106, Grade B / or / ASTM A53 electric resistance welded, Grade B; Schedule 80] . Grade F, furnace butt-welded, pipe is not permitted.
- B. Joints:

1. In Trenches and direct-buried systems: Butt weld joints. Socket weld is required for pipe sizes 2 inches (50 mm) and below. Manufacturer's standard sliding, gasketed joints are permitted between factory-fabricated sections of direct buried WSL system. No joints are allowed in factory-fabricated straight sections of pre-engineered direct-buried systems. Factory-fabricated direct-buried piping systems that are a portion of expansion loops or bends shall have all welded joints 100% radiograph inspected. All radiographs shall be reviewed and interpreted by an ASNT Certified Level III radiographer, employed by the testing firm, who shall sign the reading report. Dye penetrant testing may be utilized for pipe sizes 2 inches (50 mm) and below.
2. In tunnels, manholes and open areas: Butt weld pipe sizes 2-1/2 inches (65 mm) and above; thread or socket weld pipe sizes 2 inches (50 mm) and below.

C. Fittings:

1. Welded joints: ASTM A234, steel, Grade B, or ASME B16.9, same schedule as adjoining pipe.
2. Threaded joints: ASTM A47 or A197, malleable iron, or ASME B16.3, 300 psi (2050 kPa) class.
3. Socket welded joints: ASME B16.11, forged steel, 2000 psi (13,800 kPa) class.

D. Unions (Except in Trenches) are allowed on piping 2 inches (50 mm) and under, 300 psi (2050 kPa) malleable iron or steel.

E. Flanges: Weld neck ASME B16.5 or ASTM A105, forged steel, 150 psi (1025 kPa).

2.11 EXPANSION LOOPS AND BENDS

A. Stresses: Less than the maximum allowable stress in the Power Piping Code (ASME B31.1). Submit shop drawings and stress and anchor force calculations for all loops and bends. Show locations of all anchors, guides and supports. Base calculations on 150 psi (1000 kPa) and 366 deg F (185 deg C) for steam line loops and bends and 50 psi (345 kPa) and 310 deg F (154 deg C) for condensate return line loops and bends. Base calculations on actual pressures and temperatures if they are higher than those listed above.

B. Low pressure steam systems 15 psi (100 kPa) and less: ASME B31.9, base calculations for steam and condensate on 15 psi (100 kPa) and 250 deg F (121 deg C).

2.12 EXPANSION JOINTS

A. Provide factory-built or field-fabricated guides located along the pipelines to restrain lateral pipe motion and direct the axial pipe movement into the expansion joints.

B. Minimum Service Requirements:

1. Pressure Containment:

- a. Steam Service 5-30 psi (35-200 kPa): Rated 50 psi (345 kPa) at 298 deg F (148 deg C)
- b. Steam Service 31-125 psi (214-850 kPa): Rated 150 psi (1025 kPa) at 366 deg F (186 deg C)
- c. Steam Service 126-150 psi (869-1025 kPa): Rated 200 psi (1375 kPa) at 382 deg F (194 deg C)
- d. Condensate Service: Rated 100 psi (690 kPa) at 310 deg F (154 deg C)

2. Number of Full Reverse Cycles without failure: Minimum 1000
3. Movement: Allowed as recommended safety factor of the manufacturer.

C. Internally pressurized bellows shall have:

1. ASTM A240, multiple corrugations, Type 304 or 321 stainless steel.
2. Internal stainless steel sleeve running the entire length of bellows.
3. External cast iron equalizing rings for services exceeding 50 psi (340 kPa).
4. Welded ends.
5. External tie rods: Design to withstand pressure thrust force upon anchor failure if one or both anchors for the joint are at change in direction of pipeline and integral external cover.

D. Externally pressurized bellows shall have:

1. ASTM A240, multiple corrugations, Type 304 stainless steel.
2. Internal and external guides integral with joint.
3. Design for external pressurization of bellows to eliminate squirm.
4. Welded ends.
5. Include threaded connection at bottom, 1 inch (25 mm) minimum, for drain or drip point and integral external cover and internal sleeve.

E. Slip Type Joints shall include:

1. Steel construction, except guides.
2. Base with integral anchor.
3. Internally and externally guided steel slip, chrome plated to reduce corrosion, ground to reduce friction.
4. Guides shall be non ferrous, non-corroding, low friction, designed to prevent scoring or binding of the slip.
5. Welded ends.
6. Limit stop to prevent slip disengagement if pipe anchor fails.
7. Semi plastic, self lubricating, injectable packing contained between sealing rings.
8. Injection devices to allow addition of packing under full line pressure. Provide one year supply of packing.
9. Threaded connection at bottom, 1 inch (25 mm) minimum, for drain or drip point.
10. 10. Bolted packing gland permitting replacement of all packing and all sealing rings without removing joint from the line.

F. Expansion Compensators are:

1. Permitted for condensate lines where pipe expansion is within limits of compensator.
2. Corrugated bellows, externally pressurized, stainless steel or bronze.
3. Internal guides and anti torque devices.
4. Threaded ends.
5. External shroud.

G. Stamped brass or stainless steel nameplate: Indicating on each expansion joint the manufacturer, the allowable movement, flow direction, design pressure and temperature, date of manufacture, and identifying the expansion joint by the identification number on the contract drawings.

H. Provide factory-built guides along the pipeline to permit axial movement only and to restrain lateral and angular movement. Guides must be designed to withstand a minimum of 15% of the axial force that will be imposed on the expansion joints and anchors. Field-built guides may be used if

detailed on the contract drawings. Guide locations must conform to recommendations of expansion joint manufacturer.

2.13 BALL JOINTS

- A. Factory built devices, inserted in pipe line offsets in groups of two or three as shown to absorb cyclical pipe movement which results from thermal expansion and contraction.
- B. Minimum service requirements shall be rated 250 psi (1725 kPa), 450 deg F (232 deg C), continuous on steam and condensate.
- C. Submit independent certification that similar units have passed the following tests with no leaks.
 - 1. Low Pressure Leakage Test: Minimum 6 psi (40 kPa) saturated steam for 60 days.
 - 2. Life Cycle Flex Test: Minimum 8000 flex cycles at 250 psi (1725 kPa) saturated steam.
 - 3. Thermal Cycling Test: Minimum 100 cycles from atmospheric pressure to operating pressure and back to atmospheric pressure with saturated steam.
 - 4. Environmental Shock Test: MIL S 901.
 - 5. Vibration Test: Test for 170 hours on each of three mutually perpendicular axes at 25 to 125 HZ; 0.05 to 0.10 inch (1 to 2 mm) double amplitude on a single ball joint and on a three ball joint offset.
- D. Joints: ASME B31.1:
 - 1. Cast or forged carbon steel with welded ends.
 - 2. Standard weight pipe wall thickness.
 - 3. Minimum angular movement capability: 15 degrees and 360 degrees rotational movement.
 - 4. Gaskets: Non asbestos.
 - 5. Packing injection devices, if provided: Allow injection under full line pressure. Provide one year supply of packing.

2.14 VALVES

- A. Gate Valves (ASTM A126):
 - 1. Type 101 shall have:
 - a. Cast steel body, rated 150 psi (1025 kPa) at 500 deg F (260 deg C), 11-1/2 to 13 percent chromium stainless steel flexible wedge and hard faced (stellite) or nickel copper alloy seats, 150 psi (1025 kPa) flanged ends, OS&Y, rising stem, bolted bonnet.
 - b. Factory installed globe valved bypass on all steam valves larger than 3 inches (80 mm).
 - c. Drill and tap bosses for connection of drains where shown.
 - 2. Type 102 is not used.
 - 3. Type 103 shall have:
 - a. Cast iron body, Class B, rated for 125 psi (850 kPa) saturated steam, 200 psi (1375 kPa) WOG, bronze or bronze faced wedge and seats, 125 psi (850 kPa) ASME flanged ends, OS&Y, rising stem, bolted bonnet, renewable seat rings.
 - 4. Type 104 shall have:

- a. Bronze body, rated for 200 psi (1375 kPa) saturated steam, 400 psi (2750 kPa) WOG, bronze wedges and Monel or stainless steel seats, threaded ends, rising stem, union bonnet.
5. Type 105 is not used.
 6. Type 106 shall have:
 - a. Forged steel body, rated for 300 psi (2050 kPa) at 420 deg F (216 deg C) minimum Class 600 psi (4130 kPa) or Class 800 psi (5500 kPa), hardened stainless steel or satellite wedge and seats, threaded ends, OS&Y, rising stem, bolted bonnet.
- B. Globe Valves (ASTM A126):
1. Type 201 shall have:
 - a. Cast steel body, rated 150 psi (1025 kPa) at 500 deg F (260 deg C), 11-1/2 to 13 percent chromium stainless steel or stellite disc and seat, 150 psi (1025 kPa) ASME flanged ends, OS&Y, rising stem, bolted bonnet, renewable seat rings. Drill and tap bosses for connection of drains.
 2. Type 202 is not used.
 3. Type 203:
 - a. Cast iron body, rated for 125 psi (850 kPa) saturated steam, 200 psi (1375 kPa) WOG, bronze or bronze-faced disc (Teflon or composition facing permitted) and seat, 125 psi (850 kPa) ASME flanged ends, OS&Y, rising stem, bolted bonnet, renewable seat rings.
 4. Type 204:
 - a. ASTM B61, bronze body, rated for 200 psi (1375 kPa) saturated steam, 400 psi (2750 kPa) WOG, hardened stainless steel disc and seat, threaded ends, rising stem, union bonnet, renewable seat rings.
- C. Check valves (ASTM A126):
1. Type 401 shall have:
 - a. Cast steel body, swing-type, rated for 150 psi (1025 kPa) at 500 deg F (260 deg C), stainless steel or stainless steel - faced disc and seat, 150 psi (1025 kPa) ASME flanged ends, bolted cover, renewable disc.
 2. Type 402 is not used.
 3. Type 403 shall have:
 - a. Cast iron body, Class B, swing-type, rated for 125 psi (850 kPa) saturated steam, 200 psi (1375 kPa) WOG, bronze or bronze-faced disc and seat, 125 psi (850 kPa) ASME flanged ends, bolted cover, renewable disc and seat.
 4. Type 404 shall have:
 - a. Bronze body, swing-type, rated for 200 psi (1375 kPa) saturated steam, 400 psi (2750 kPa) WOG, bronze disc, threaded ends, regrinding disc.

D. Ball valves (ASTM A126):

1. Type 501 is not used.
2. Type 502 shall have:
 - a. Bronze body, rated for 150 psi (1025 kPa) at 365 deg F (185 deg C), 250 psi (1725 kPa) at 250 deg F (121 deg C); reinforced TFE seat, stem seal and thrust washer; end entry, threaded ends, one-fourth turn to open.
3. Type 503 is not used.
4. Type 504 shall have:
 - a. Carbon steel or ductile iron body, saturated steam service, rated for 150 psi (1030 kPa), stainless steel ball and stem, Polyfil seat, live-loaded stem seal, 150 psi (1025 kPa) ASME flanged ends. Manufacturer: American, Worcester, or equal.

E. Butterfly valves (ASTM A126):

1. Type 601 shall have:
 - a. Ductile iron body, wafer style, rated for 125 psi (850 kPa), 212 deg F (100 deg C), bronze disc, stainless steel stem, EPDM liner, EPDM stem seal and body seal, neck extending beyond pipe insulation, geared handwheel operator for valves 4 inch (100 mm) pipe size and larger, ratchet handle operator for smaller pipe sizes.
2. Type 602:
 - a. Triple-offset, lug or flanged type, carbon steel body, steam service, rated for 150 psi (1025 kPa) at 500 deg F (260 deg C), stainless steel nitrided disc, stellite seat, stainless steel shaft, stainless steel/graphite-laminated seal ring, neck extending beyond pipe insulation, geared handwheel operator for valves 4 inch (100 mm) pipe size and larger, ratchet handle operator for smaller pipe size valves.

F. Valve Applications (Steam Lines):

1. Gate valves, 2 inches (50 mm) and under: Type 106.
2. Gate valves, 2-1/2 inches (65 mm) and above: Type 101.
3. Globe valves, 2 inches (50 mm) and under: Type 204.
4. Globe valves, 2-1/2 inches (65 mm) and above: Type 201.
5. Check valves, 2 inches (50 mm) and under: Type 404.
6. Check valves, 2-1/2 inches (65 mm) and above: Type 401.
7. Ball valves, 2 inches (50 mm) and under: Type 502
8. Ball valves, 2-1/2 inches (65 mm) and above: Type 504.
9. Butterfly valves, all sizes: Type 602.

G. Valve Applications (Condensate Lines):

1. Gate valves, 2 inches (50 mm) and under: Type 104.
2. Gate valves, 2-1/2 inches (65 mm) and above: Type 103.
3. Globe valves, 2 inches (50 mm) and under: Type 204.
4. Globe valves, 2-1/2 inches (65 mm) and above:
5. Type 203. Check valves, 2 inches (50 mm) and under: Type 404.
6. Check valves, 2-1/2 inches (65 mm) and above: Type 403.
7. Ball valves, 2 inches (50 mm) and under: Type 502.

8. Ball valves, 2-1/2 inches (65 mm) and above: Type 504.
9. Butterfly valves, all sizes: Type 601.

2.15 STEAM PRESSURE REDUCING VALVES

- A. Valves: Single seated, diaphragm operated, spring loaded, steam pilot controlled, normally closed, packless, adjustable set pressure. Pilot shall sense controlled pressure downstream of main valve.
- B. Controlled reduced pressure to steam piping systems: Design for saturated steam at pressures shown on drawings.
- C. Pressure control: Smooth, continuous. Maximum 10 percent deviation from set pressure over an 18/1 turndown. Refer to schedules on drawings for flow and pressure requirements. Maximum flow capability of each valve shall not exceed capacity of downstream safety valves.
- D. Construction:
 1. Main Valve – Pipe Sizes 2 inches (50 mm) and under: Cast iron body rated for 250 psi (1725 kPa), threaded ends. Valve plug and seat shall be replaceable, Type 316 stainless steel and include stainless steel stem.
 2. Main Valves – Pipe Sizes Above 2 Inches (50 mm): Cast steel body rated for 150 psi (1025 kPa) ASME flanged ends, or cast iron body 250 psi (1725 kPa) ASME flanged ends, valve plug and seat shall be replaceable, Type 316 stainless steel and include stainless steel stem.
 3. Pilot Valve: Valve plug and seat shall be replaceable, stainless steel.

2.16 STEAM TRAPS

- A. Apply at steam line drip points.
- B. Construct inverted bucket type with thermostatic vent in bucket, except closed-float-thermostatic on discharge side of pressure reducing stations. Each type furnished by a single manufacturer. Select the traps for pressures and capacities as shown or required. Fixed orifice or venturi type traps are not permitted.
- C. Traps: [**Cast iron / or / stainless steel**] bodies. Construction shall permit ease of removal and servicing working parts without disturbing connecting piping. Include stainless steel floats, hardened chrome steel valves, stainless steel mechanisms and bi-metallic air vent on inverted bucket traps.
- D. Provide electronic trap performance monitoring devices that are compatible with the existing monitoring system. Trap malfunctions shall be automatically transmitted to and properly interpreted by the existing monitoring system. Provide all necessary power sources, transmitting and retransmitting devices and batteries to achieve a properly operating system. The existing monitoring system is [_____].
- E. All traps shall include ports for future installation of monitoring devices. To facilitate future removal of plugs, remove plugs, install Teflon tape on the threads, and reinstall the plugs.
- F. Label each trap at the factory with an identification number keyed to the contract drawings. Label shall be a metal tag permanently attached to the trap.

2.17 STRAINERS, Y TYPE

- A. Provide as shown on steam and condensate piping systems.
- B. Include open end removable cylindrical screen and threaded blow off connection.
- C. For steam service up to 150 psi (1025 kPa) and at drip traps, strainer shall be rated for minimum 150 psi (1025 kPa) saturated steam; rated for 150 psi (1025 kPa), flanged ends, cast steel, for pipe sizes above 2 inches (50 mm). Use cast iron or bronze, rated for 250 psi (1725 kPa) saturated steam, threaded ends, for pipe sizes 2 inches (50 mm) and under.
- D. For condensate service, strainer shall be rated for 125 psi (850 kPa) saturated steam, 175 psi (1200 kPa) WOG. Provide 125 psi (850 kPa), flanged ends, cast iron, for pipe sizes above 2 inches (50 mm). Provide cast iron or bronze, threaded ends, for pipe sizes 2 inches (50 mm) and under.
- E. Strainer screen shall be stainless steel, with a free area not less than 2 1/2 times flow area of pipe. Diameter of openings shall be 0.05 inch (1.3 mm) or less on steam service and 0.06 inch (1.5 mm) or less on water service.
- F. Include gate type valve and quick couple hose connection on all blowoff connections.

2.18 SAFETY VALVES AND VENT CONNECTORS

- A. Safety valves: Conform to the requirements of ASME Boiler and Pressure Vessel Code (Section VIII, Unfired Pressure Vessels) and be approved by the National Board of Boiler and Pressure Vessel Inspectors.
- B. Relieving capacity: Not less than that shown on the drawings with a pressure rise above set pressure not to exceed 10 percent of set pressure.
- C. Provide, at the discharge of each safety valve, a special flexible connector attached to the vent pipe and the safety valve. Multi-ply stainless steel bellows, full internal pipe liner, protective exterior shroud, drip catching configuration with drain, designed to prevent blow back of steam into space, pressure tested at not less than 15 psi (100 kPa). Drip pan ells not allowed in tunnels or constricted spaces because of "blow-back" of steam from the drip pan ell openings.

2.19 PRESSURE GAGES

- A. Provide gages immediately downstream of each steam line isolation valve, before and after each steam pressure reducing station and where shown on the drawings.
- B. Gages: ASME B40.100
 - 1. Solid armored front between measuring element and dial, blowout back, bottom connection, phenol turret type.
 - 2. Non corrosive, 4-1/2 inch (110 mm) diameter face with black markings on white background.
 - 3. Bourdon tube measuring element designed for service. Provide bellows for pressure ranges under 15 psi (100 kPa).
 - 4. Stainless steel, rotary movement.
 - 5. Micrometer adjustable, black color pointer.
 - 6. Plastic window.

- 7. Provide liquid filled gages at outlet of all pumps.
- C. Accuracy: Grade 2A, 1/2 percent, on all gages; except Grade A, one percent permitted on diaphragm actuated gages, liquid filled gages, and compound gages.
- D. Include:
 - 1. Red set hands on gages located at automatic pressure regulator valve outlets.
 - 2. Needle valve or gage cock rated for the service.
 - 3. Syphon on all steam gages.
 - 4. Overload stop on all pressure gages.
- E. Except where otherwise shown on the drawings, pressure ranges shall be as follows:

SERVICE	RANGE
Steam to 15 psi (100 kPa)	0 to 30 psi (0 to 200 kPa)
Steam to 59 psi (407 kPa)	0 to 100 psi (0 to 700 kPa)
Steam above 59 psi (407 kPa)	0 to 200 psi (0 to 1500 kPa)
Condensate Pump Discharge	0 to 100 psi (0 to 700 kPa)
Vacuum Return	30 inches HG 0 - to 15 psi (100 kPa vacuum to 100 kPa)

2.20 THERMOMETERS, PIPE OR TANK MOUNTED

- A. Thermometer locations are shown on the drawings.
- B. Thermometers:
 - 1. Industrial type, separable well and socket, union connected.
 - 2. Red reading mercury combination Fahrenheit/Celsius scale, 9 inches (220 mm) long.
 - 3. Corrosion resistant case with glass or plastic front.
 - 4. Straight or back form except those located more than 7 feet (2100 mm) above floor shall be adjustable angle.
 - 5. Wells sized to suit pipe diameter without restricting flow, or provide oversized pipe at well location. Snug sliding fit between socket and well.
 - 6. Accuracy shall be one percent of scale range.
 - 7. 30 to 300 deg F (0 to 150 deg C).

2.21 PIPE HANGERS AND SUPPORTS

- A. Requirements: MSS SP 58 and ASME B31.1.
- B. Applies to all piping not in factory-fabricated direct-buried system. All systems shall be completely supported. Arrange supports so that all loads due to weight, thermal expansion, seismic shock (if applicable), and pressure are transferred from the support system to the structure. The design and location of supports shall at all times prevent excessive forces, moments, and stresses from being imposed on the equipment, structure, supported system, and supports. Heated systems generally require resilient or roller/slide supports.
- C. Manufacturer Certification: Factory built products of a manufacturer whose principle business is pipe supports for [5 / 10] years. All components must have published load ratings. For concrete trenches, non-factory built products that comply with details may be utilized.

D. Drawings:

1. Types, sizes, locations, and spacing of all hangers and supports.
2. Roller or slider supports for all horizontal steam and condensate piping.
3. Special supports including anchors, guides and braces.
4. If equipment and piping arrangement differs from that shown on the drawings, support locations and types shall be revised at no cost to Northwestern University.
5. Supports to permit removal of valves and strainers from pipelines without disturbing supports.
6. Spring hangers on all systems subject to vertical movement.
7. Roller hangers and sliding supports on all systems subject to horizontal movement.
8. If vertical angle of hanger rod exceeds four degrees, rollers or sliders are required.
9. Loads for all supports. On systems utilizing variable spring supports; show the loads at each support by calculating the forces and moments throughout the system. **[Seismic restraint calculations shall utilize the applicable shock spectra for the type of structure, type of supported system, and the locality.]**
10. Vertical deflection: Shall not exceed 0.1 inch (2.5 mm) between supports when system is filled with fluid normally carried. **[Deflections due to seismic shock shall be restrained as necessary to prevent overstressing the supported system or the connected equipment. Seismic restraints shall permit movement due to thermal expansion.]**
11. Individual drawing for each hanger assembly showing all components, sizes, calculated loadings. Provide identification tags, on each hanger part, keyed to the layout drawings.

E. Components:

1. Roller supports: MSS SP 58, Type **[41 / 43 / and / 46]** . Provide vertical adjustment for Type 41 with threaded studs and nuts adjacent to the roller.
2. Variable spring support assembly: MSS SP 58, **[Type 51 variable spring / Type 3 pipe clamp / or / Type 1 clevis / Type 53 variable spring trapeze]** . Locate Type 51 variable spring within 1 foot (300 mm) above pipe attachment. Attach rod to top of variable spring with Type 14 clevis.

F. Spring Cushion Support Assembly: MSS SP 58.

1. Double rod assembly: Type 41 and 49.
2. Single rod assembly: **[Type 48 spring cushion / Type 3 pipe clamp or / Type 1 clevis]** . Locate spring cushion within 1 foot (300 mm) above pipe attachment.

G. Clevis supports: MSS SP 58, Type 1.

H. Wall brackets: MSS SP 58, Type **[31 / 32 / or 33]** .

I. Pipe stands: MSS SP 58, Type 38.

J. Riser clamp: MSS SP 58, Type 42.

K. Alignment guides: Welded steel as shown to restrain movement perpendicular to the long axis of the piping. If not welded, provide steel spider clamped to pipe, enclosed within steel sleeve that is **[bolted / or / welded]** to structural support. Must provide lateral force equal to minimum of 15 percent of anchor loading.

L. Trapeze supports: MSS SP 58, may be used where pipes are close together and parallel, structural steel channels or angles. Bolt roller supports to steel to support piping subject to horizontal thermal expansion. Attach other piping with "U" bolts.

- M. Pipe covering protection saddles: MSS SP 58, Type 39. Provide at all support points on insulated pipe except where Type 3 pipe clamp is provided.
- N. Sliding supports: MSS SP 58, Type 35. Welded steel attachments to pipe and structure with Teflon or graphite sliding surfaces bonded to the attachments. Provide steel guides, except at expansion bends, to prevent lateral movement of the pipe.
- O. Pipe racks and miscellaneous supports: ASTM A36, structural steel shapes. Manufactured strut systems are acceptable if they have the required load carrying ability.
- P. Supports, including all structural steel, in trenches and manholes: Hot-dip galvanized.
- Q. Seismic Restraints:
1. Provide bracing as required. Refer to details on drawings.
 2. Shock Absorbers: MSS SP 58, Type 50. Mechanical or hydraulic type rated for shock loads. Pipe attachments shall be MSS SP 58, Type 3.
 3. Insulation Materials (In Manholes, Tunnels, Concrete Trenches, Open Areas)
- R. Calcium Silicate Insulation:
1. Preformed piping insulation: ASTM C533, Type I.
 2. Blocks: ASTM C533, Type I.
 3. Fitting Insulation: ASTM C533, with polyvinyl chloride, Type II Grade GU, and Type III, premolded fitted covering 0.020 inches (0.5 mm) thick.
- S. Fiberglass Insulation:
1. Preformed piping insulation: ASTM C547, 450 deg F (230 deg C).
 2. Fitting insulation: ASTM C547, 450 deg F (230 deg C), with polyvinyl chloride, Type II Grade GU, and Type III, premolded fitted covering 0.020 inches (0.5 mm) thick.
- T. Rigid closed cell phenolic foam: ASTM C1126, Type III, Grade 1, 250 deg F (121 deg C).
- U. Cellular glass insulation: ASTM C552.
- V. Insulating and finishing cements: ASTM C449, as recommended by the manufacturer for the type of insulation system and service conditions.
- W. Insulation bands: ASTM A167, minimum of 1/2 inch (12 mm) wide by 0.015 inch (0.4 mm) thick stainless steel.
- X. Aluminum jackets: Minimum of 0.016 inch (0.4 mm) thick aluminum, 3003 alloy, H-14 temper, with locking longitudinal joints. Jackets for elbows, tees and other fittings shall be factory fabricated to match material and construction of the straight run jackets. Factory fabricated stainless steel bands shall be furnished and installed on all circumferential joints. Bands shall be 0.75 inch (20 mm) wide on 18 inch (450 mm) centers. Bands shall be applied with manufacturers recommended sealant. Entire system shall be watertight.
- Y. Service jackets: ASTM C1136, white kraft bonded to 0.001 inch (0.025 mm) thick aluminum foil, fiberglass reinforced, pressure sensitive adhesive closure, beach puncture tested to 50 units, suitable for painting without sizing. Jackets shall have a minimum 1-1/2 inch (40 mm) lap on longitudinal joints and not less than 4 inch (100 mm) butt strips on end joints. Butt strip material

shall be same as the jacket. Lap and butt strips may be self-sealing type with factory-applied pressure sensitive adhesive.

- Z. Glass cloth jacket: A minimum 7.8 ounces per square yard (0.24 kg per square meter), 300 psi (2000 kPa) bursting strength, weathertight for outside service. Beach puncture test to 50 units.
- AA. Pipe covering protection saddles: MSS SP 58, Type 39 at all hanger points except where Type 3 pipe clamps are provided.
- BB. Fire and smoke ratings of assembled insulation systems: ASTM C411 and NFPA 255, flame spread (25) and smoke developed (50) ratings.

2.22 BURIED UTILITY WARNING TAPE

- A. Tape: 0.004 inch (0.1 mm) thick, 6 inches (150 mm) wide, yellow polyethylene with a ferrous metallic core, acid and alkali-resistant and shall have a minimum strength of 1750 psi (12,000 kPa) lengthwise and 1500 psi (10,300 kPa) crosswise with an elongation factor of 350 percent. Provide bold black letters on the tape identifying the type of system. Tape color and lettering shall be unaffected by moisture and other substances contained in the backfill material.

PART 3 - EXECUTION

3.1 GENERAL

- A. If the carrier pipe insulation has failed (disintegrated) in an existing buried piping system, but the system is otherwise sound, there is an alternative to total replacement of injecting foam insulation into the existing system from above grade.
- B. Connect new work to existing work in a neat and workmanlike manner. Where an existing structure must be cut or existing utilities interfere, such obstruction shall be bypassed, removed, replaced or relocated, patched and repaired. Piping connections shall be made only in manholes, tunnels or buildings.
- C. Coordinate the location of all items of equipment and work of all trades. Maintain operability and maintainability of the equipment and systems. The contractor at his cost shall perform any relocation of equipment or systems to comply with the requirement of operability and maintainability.
- D. Unless otherwise shown on drawings, steam lines shall be graded downward not less than 2 inches in 40 feet (50 mm in 12 meters) in direction of the flow. Provide eccentric reducing fittings on steam mains and branches, (except on vertical piping). Install said fittings to maintain continuity of grade in bottom of pipeline. Provide risers with drip pockets and steam traps on steam lines where space restrictions prevent continuous grading. All steam traps must be located in manholes or tunnels.

3.2 DEMOLITION

- A. Perform work in accordance with requirements for phasing and the Drawings.
- B. Completely remove all pipe, valves, fittings, insulation, and all hangers including the connection to the structure and any fastenings.

- C. Seal all openings in manhole or building walls after removal of piping.
- D. Unless stated otherwise by Facilities Operations Management all material and equipment removed shall become the property of the Contractor and shall be removed from Northwestern University property and shall not be stored in operating areas.
- E. All flame cutting shall be performed with adequate fire protection facilities available as required by safety codes and Contracting Officer's Representative.

3.3 PIPING APPLICATION

A. LP Steam Piping:

1. [**NPS 2 (DN 50) and Smaller**] : [**Schedule 40 / Schedule 80**] , Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.
2. [**NPS 2-1/2 through NPS 12 (DN 65 through DN 300)**] : [**Schedule 40 / Schedule 80**] , Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
3. [**NPS 14 through NPS 18 (DN 350 through DN 450)**] : Schedule 30, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
4. [**NPS 20 (DN 500) and Larger**] : Schedule 20, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
5. Conduit piping shall be [**Standard weight / Schedule 40 / Schedule 80**] steel carrier pipe, with [**mineral-wool / calcium silicate / polyisocyanurate**] carrier-pipe insulation and with [**coated / coated and insulated**] conduit.
 - a. Piping Insulation Thickness shall be [**1 inch (25 mm) / 2 inches (50 mm)**].
 - b. Conduit Insulation Thickness shall be [**1 inch (25 mm) / 2 inches (50 mm)**].
 - c. Insulation shall be [**Polyisocyanurate / Polyurethane**].
6. Piping with [**granular / powder**], loose-fill insulation.

B. HP Steam Piping:

1. NPS 2 (DN 50) and Smaller : [**Schedule 40 / Schedule 80**] , Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.
2. NPS 2-1/2 through NPS 12 (DN 65 through DN 300) : [**Schedule 40 / Schedule 80**] , Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
3. NPS 14 through NPS 18 (DN 350 through DN 450) : Schedule 30, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
4. NPS 20 (DN 500) and Larger : Schedule 20, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
5. Conduit Piping shall be [**Standard weight / Schedule 40 / Schedule 80**] steel carrier pipe, with [**mineral-wool / calcium silicate / polyisocyanurate** / carrier-pipe insulation and with [**coated / coated and insulated**] conduit.
 - a. Piping insulation thickness shall be [**1 inch (25 mm) / 2 inches (50 mm)**].
 - b. Conduit insulation thickness shall be [**1 inch (25 mm) / 2 inches (50 mm)**].
 - c. Insulation shall be [**Polyisocyanurate / Polyurethane**].

6. Piping with [**granular / powder**], loose-fill insulation.

C. Condensate Piping:

1. NPS 2 (DN 50) [**Insert pipe size**] and smaller shall be the following:

- a. Schedule 80, Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.
- b. RTRP and RTRF with adhesive or flanged joints.

2. NPS 2-1/2 (DN 65) and larger shall be either of the following:

- a. Schedule 80, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
- b. RTRP and RTRF with adhesive or flanged joints.

3. Conduit Piping: [Standard-weight, steel pipe and fittings / Schedule 40, steel pipe and fittings / Schedule 80, steel pipe and fittings] Fiberglass pipe and fittings [with / mineral-wool / calcium silicate / polyisocyanurate / polyurethane] carrier-pipe insulation and with [coated / coated and insulated] conduit.

- a. Piping insulation thickness shall be [**1 inch (25 mm) / 2 inches (50 mm)**].
- b. Conduit insulation thickness shall be [**1 inch (25 mm) / 2 inches (50 mm)**].

4. Piping with [**granular / powder**], loose-fill insulation.

3.4 PIPING INSTALLATION

A. Drawings indicate general location and arrangement of piping systems. Install piping insulation as indicated.

B. Standing water in the bottom of trench: Remove all water.

C. Pipe Bedding: Minimum 6 inch (150 mm) layer of sand.

D. Clearance: Minimum 6 inch (150 mm) clearance between the pipes.

E. Testing: Do not insulate piping or backfill piping trench until field quality-control testing has been completed and results approved.

F. Grade:

- 1. Install condensate piping at uniform grade of 0.4 percent downward in direction of flow.
- 2. Install piping at uniform grade of 0.2 percent downward in direction of flow or as indicated on the Drawings.

G. Drain Valves and Air Vents: In conduits, install at low points and air vents at high points.

H. Install components with pressure rating equal to or greater than system operating pressure.

I. Install piping free of sags and bends.

J. Install fittings for changes in direction and branch connections.

- K. Secure anchors with concrete thrust blocks.
- L. Connect to steam and condensate piping where it passes through the building wall.
- M. Loose-Fill Insulation Installation:
 - 1. Form insulation trench by excavation or by installing drywall side forms to establish the required height and width of the insulation.
 - 2. Support piping with proper pitch, separation, and clearance to backfill or side forms using temporary supporting devices that can be removed after back filling with insulation.
 - 3. Place insulation and backfill after field quality-control testing has been completed and results approved.
 - 4. Apply bitumastic coating to carbon-steel anchors and guides. Pour concrete thrust blocks and anchors.
 - 5. Wrap piping at expansion loops and offsets with mineral-wool insulation of thickness appropriate for calculated expansion amount.
 - 6. Pour loose-fill insulation to required dimension agitating insulation to eliminate voids around piping.
 - 7. Remove temporary hangers and supports.
 - 8. Cover loose-fill insulation with polyethylene sheet a minimum of 4 mils (0.10 mm) thick, and empty loose-fill insulation bags on top.
 - 9. Manually backfill with 6 inch (150 mm) lifts of clean backfill. If mechanical compaction is required, manually backfill with 12 inch (300 mm) lifts.
- N. Install Tracer Wire per 22 0000 "Common Work Results for Plumbing".

3.5 DRAIN VALVES AND VENT VALVES

- A. Provide 1-1/2 inch (40 mm) minimum pipe size drain valves on condensate return carrier pipes at all low points in manholes. Provide 1 inch (25 mm) minimum air vent valves in manholes at all high points in condensate return carrier piping.

3.6 PIPE SUPPORT INSTALLATION (IN TRENCHES, TUNNELS, MANHOLES)

- A. Coordinate support locations prior to erection of piping. Hanger parts must be marked at the factory with a numbering system keyed to hanger layout drawings. Layout drawings must be available at the site during construction.
- B. Upper Attachments to Structure:
 - 1. New reinforced concrete construction shall have concrete inserts.
 - 2. For existing reinforced concrete construction, upper attachment shall be welded or clamped to steel clip angles (or other construction shown on the drawings) that are expansion bolted to the concrete. Expansion bolting shall be located so that loads place bolts in shear.
 - 3. For steel deck and structural framing, upper attachments shall be welded or clamped to structural steel members.
- C. In existing concrete construction, expansion fasteners may be used for hanger loads up to one third the manufacturer's rated strength of the expansion fastener. Power set fasteners may be used for loads up to one fourth of rated load. When greater hanger loads are encountered, additional fasteners may be used and interconnected with steel members combining to support the hanger.

D. Special Supports:

1. Secure horizontal pipes where necessary to prevent vibration or excess sway.
2. Where hangers cannot be adequately secured as specified, make special provisions for hanging and supporting pipe as approved by the Contracting Officer's Representative.
3. Do not attach pipe supports, hangers, clamps or anchors to equipment unless specified for that equipment or unless the Contracting Officer's Representative gives written permission.

E. Locate spring hanger units within 1 foot (300 mm) of the pipe attachment, except in locations where spring assemblies interfere with pipe insulation.

F. Seismic Braces and Restraints: Do not insulate piping within 1 foot (300 mm) of device until device has been inspected by Contracting Officer's Representative. //

G. Minimum Clearances in Tunnels and Trenches:

1. Floor to bottom of pipe support beam: 2 inches (50 mm)
2. Floor to bottom of pipe insulation jacket: 6 inches (150 mm)
3. Wall to side of pipe insulation jacket: 3 inches (75 mm)
4. Ceiling to top of pipe insulation jacket: 1 inch (25 mm)

3.7 PAINTING EXPOSED STEEL SURFACES IN MANHOLES, TUNNELS AND CONCRETE SHALLOW TRENCHES

- A. For manholes and walk-through tunnels, provide surface cleaning and preparation and apply prime coat of rust resistant metal primer.
- B. For concrete shallow trenches, provide surface cleaning and preparation, apply primer and finish coat of zinc-rich paint.

3.8 DIRECT-BURIED SYSTEM INSTALLATION

- A. The Contractor shall oversee the deliver, store, install and test the system as per manufacturer's recommendations. All work shall be in strict accordance with the requirements specified by the manufacturer. Printed instructions must be available on site prior to delivery of system components. Any changes required to the design and layout of the system due to site conditions must be approved in writing by the Contracting Officer's Representative. All branch piping connections, valves and drip traps must be located within manholes.
- B. Excavation, Trenching, and Backfilling: Perform all excavation, trenching, and backfilling as required by the system manufacturer's design. Beach sand or any sand with large amounts of chlorides is not permitted. Place system on a 6 inch (150 mm) thick sand bed and backfill on all sides with 6 inch (150 mm) thick sand as measured from outside the carrier pipe/insulation. Foundation for system must be firm and stable. Foundation and backfill must be free from rocks. Concrete anchor and thrust blocks must be installed in undisturbed earth. Backfilling must not commence until elevations have been surveyed and accepted and system has been satisfactorily pressure tested including hydrostatic testing of carrier pipes and air testing of casings.
- C. Maintain constant slope of carrier pipes as shown or specified. Prior to backfilling over the top of the casing, but after removal of temporary supports, Contractor shall measure and record elevations of top of casing in the trench. Elevations shall be taken at every field joint, 1/3 points along each pipe section, and at tops of elbows. These measurements shall be checked against contract drawings and shall confirm that the conduit system has been installed to the elevations

shown on the contract drawings unless approved by the Contracting Officer's Representative. Slope shall be uniform within 0.1 percent. Measurements shall be recorded by the Contractor, included in the direct buried system manufacturer representative's daily report, and given to the Contracting Officer's Representative prior to covering the top of the casing with backfill.

- D. Provide cathodic protection for all steel casing systems and all buried exposed metal. Provide dielectric pipe flanges and unions and isolation devices at all points necessary. Provide test stations at grade on each section of the piping system. Isolation flanges and unions shall be rated for the carrier pipe service temperature and pressure.
- E. Remove all dirt, scale, and other foreign matter from inside the piping by use of a pipe swab or pipe "pig" before connecting pipe sections, valves, or fittings.
- F. Sections of system that have been fully or partially submerged in water must be replaced. Moisture content of insulation during installation shall not exceed five percent by weight.
- G. At each casing termination (end plate) in buildings and manholes, plug the casing drain openings with brass plugs and extend 1 inch pipe size galvanized vent pipes (ASTM A53) from the casing vents through the tops of the manholes or 1 foot (300 mm) above the conduit in buildings. Terminate the outside vents in 180-degree bends.
- H. Provide reports to the Contracting Officer's Representative that include:
 - 1. Daily written report: Prepared daily and signed by the Contractor. Submit the original report to the Contracting Officer's Representative on the same day it is prepared. Provide one set of field pictures of work daily.
 - 2. Report Contents: State whether or not the condition and quality of the materials used and the delivery, storage, installation and testing of the system are in accordance with the manufacturer's recommendations, changes to drawings and specifications, any corrective action that was taken of the system, identify any conditions that could result in an unsatisfactory installation.
 - 3. Report Certification: Daily reports are to be reviewed, signed and sealed by the Professional Engineer responsible for the system installation.
 - 4. Report Submittals and Stop Order: Daily reports shall be submitted with the payment requests. All work must stop if daily reports are not furnished and requests for payments shall be denied if the daily reports are not furnished.
 - 5. Certification of Compliance: Upon completion of the work and 30 days prior to final acceptance, deliver to Contracting Officer's Representative a notarized Certificate of Compliance signed by principal officers of Contractor, stating that the installation is satisfactory and in accordance with plans, specifications, and manufacturer's instructions.
 - 6. The Contractor shall retain copies of all the daily reports and the Certificate of Compliance for 5 years after final acceptance of the system by Northwestern University.
- I. Sections of system that have been fully or partially submerged in water must be replaced. Moisture content of insulation during installation shall not exceed five percent by weight.
- J. At each casing termination (end plate) in buildings and manholes, plug the casing drain openings with brass plugs and extend 1 inch pipe size ASTM A53 galvanized vent pipes from the casing vents through the tops of the manholes or 1 foot (300 mm) above the conduit in buildings. Terminate the outside vents in 180-degree bends.

3.9 JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Threaded joints: ASME B1.20.1, tapered pipe threads. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified. Joints made with oil and graphite pipe joint compound shall have compound applied to male threads only.
 - 2. Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
 - 3. Pipe threads shall be cut to give proper engagement in threaded fittings. Clean pipe and fittings before installation and ream pipe after cutting threads. Threaded pipe shall have clean-cut threads; dull or damaged pipe dies shall not be used.
- D. Construct welded joints: AWS D10.12, using qualified processes and welding operators according to "Quality Assurance" Article. Branch connections shall be made with either welding tees or welding outlet fittings. Welding outlet fittings shall be forged, integrally reinforced to provide 100 percent pipe strength, beveled for full penetration welding and funneled at inlet for full fluid flow.
- E. Flanged joints: Select gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads. Gaskets and bolting shall be applied in accordance with the recommendations of the gasket manufacturer and bolting standards of ASME B31.1. Strains shall be evenly applied without overstress of bolts. Gaskets shall cover entire area of mating faces of flanges.
- F. Location, spacing and cold set of ball joints: Conform to layout drawings approved by manufacturer of ball joints. Representative of manufacturer shall visit site and verify that installation is proper. Locate to allow access to all packing injection devices, when provided.
- G. Expansion Joints (Bellows And Slip Type):
 - 1. Type, quantity and spacing of anchors and guides as recommended by manufacturer of expansion joint and as shown. A professional engineer shall verify in writing that anchors and guides are properly designed for forces and moments that will be imposed.
 - 2. Cold setting of joint travel at installation as recommended by the manufacturer for the ambient temperature during the installation.
 - 3. Prepare for service by cleaning all sliding surfaces, add packing as necessary. Remove all apparatus provided to restrain joint during shipping or installation.
 - 4. Expansion joints must be located in readily accessible manhole or in walk-through tunnel. Locate joints to permit access without removing piping or other devices. Allow clear space to permit replacement of joints and to permit access to devices for inspection of all surfaces and for adding packing.
- H. Conduit piping joints shall be assembled in sections and finished with pourable or split insulation, exterior jacket sleeve, and apply shrink-wrap seals.
- I. All pipe intersections and changes in direction shall be made with factory-built-reinforced fittings. Field-fabricated fittings and miters are not permitted.

3.10 INSTALLATION - SAFETY VALVES

- A. Valves must be upright and oriented so that lifting levers are accessible from nearest walkway.
- B. Provide special flexible connector on each safety valve that is designed to avoid blow-back of steam into the tunnel or manhole. Slip joint to be arranged to prevent vent line from imposing any strain on safety valve and to prevent moisture accumulation in safety valve. Support vent line from above. Provide drain line to nearest floor drain from flexible connector. Provide separate vent line from each safety valve to atmosphere unless otherwise shown. Piping weight on safety valve outlet shall not exceed that allowed by valve manufacturer.
- C. Provide union or flanged connection at safety valve outlet to allow removal of safety valves without disassembling vents.

3.11 INSTALLATION - PRESSURE GAGES

- A. Locate at inlet and outlet of each pressure reducing station, on each pump discharge and after main stop valves (gate and butterfly valves) on steam distribution lines. Orient gages so that dials are upright and visible from nearest walkway and from operating point of main steam stop valves. Provide gage cock. Provide siphon on steam service. Provide liquid filled gages on pump discharge.

3.12 INSTALLATION – THERMOMETERS

- A. Orient thermometers so that scales are upright and visible from nearest walkway. Locate wells in flow stream.

3.13 INSTALLATION – VALVES

- A. Do not locate valve stems below the horizontal centerline of the pipe.
- B. Locate valves to permit access for operation, maintenance, and replacement.
- C. Provide 3/4 inch (19 mm) globe-valved warm-up bypasses at all steam gate and butterfly valves 3 inch (80 mm) pipe size and larger.
- D. Provide 3/4 inch (19 mm) gate or ball-valved drains at each side of steam gate and butterfly valves where condensate could collect, due to the slope of the pipeline, when the main valve is shut.

3.14 THERMAL INSULATION

- A. Steam, condensate and drip return piping, other than in pre-engineered direct buried systems, shall be insulated as follows:
 - 1. Piping in concrete trenches and manholes: Insulated with calcium silicate, fiberglass, or cellular glass pipe insulation, glass cloth or aluminum jacket.
 - 2. Exposed piping in walk through tunnels: Insulated with calcium silicate, fiberglass, or cellular glass pipe insulation, all service jacket. Condensate return piping may be insulated with rigid cellular phenolic, all service jacket.
 - 3. Piping in manholes: Insulated with calcium silicate or cellular glass pipe insulation, glass cloth or aluminum jacket.

4. Minimum Insulation Thickness: Insulation thicknesses given in Table 5 and 6 are minimum nominal thickness.

TABLE 5				
Minimum Pipe Insulation Thickness inches (mm) For Steam 16 to 250 psi (110 to 1724 kPa) gage				
Nominal Pipe Diameter inches (mm)	MPT-PC MPT-PF	Delta	Thermo-12 Super Caltemp	Foamglas
1 (25)	2 (50)	2-1/2 (63)	4 (100)	4-1/2 (110)
1-1/2 (40)	2 (50)	2-1/2 (63)	4 (100)	4-1/2 (110)
2 (50)	2-1/2 (63)	3-1/2 (85)	4-1/2 (110)	5 (125)
2-1/2 (65)	2-1/2 (63)	3-1/2 (85)	4-1/2 (110)	5 (125)
3 (80)	3 (75)	4 (100)	5 (125)	6 (150)
4 (100)	3 (75)	4 (100)	5 (125)	6 (150)
5 (125)	3 (75)	4 (100)	5 (125)	6 (150)
6 (150)	3-1/2 (85)	4-1/2 (110)	5-1/2 (135)	6 (150)
8 (200)	6 (150)	3-1/2 (85)	5-1/2 (135)	6 (150)
10 (250)	4 (100)	5 (125)	6 (150)	6-1/2 (165)
12 (300)	4 (100)	5 (125)	6 (150)	6-1/2 (165)
14 (350)	4 (100)	5 (125)	6 (150)	6-1/2 (165)
16 (400)	4 (100)	5 (125)	6 (150)	6-1/2 (165)
18 (450)	4 (100)	5 (125)	6 (150)	6-1/2 (165)

TABLE 6				
Minimum Pipe Insulation Thickness inches (mm) For Steam less than 16 psi (110 kPa) gage, Condensate Return				
Nominal Pipe Diameter inches (mm)	MPT-PC MPT-PF	Delta	Foamglas Thermo-12 Super Caltemp	Insul-phen
1 (25) and under	1-1/2 (35)	2 (50)	3 (75)	1 (25)
1-1/2 (40)	1-1/2 (35)	2 (50)	3 (75)	1 (25)
2 (50)	1-1/2 (35)	2 (50)	3 (75)	1 (25)
2-1/2 (65)	1-1/2 (35)	2 (50)	3 (75)	1 (25)
3 (80)	2 (50)	2-1/2 (63)	3-1/2 (85)	1 (25)
4 (100)	2 (50)	2-1/2 (63)	3-1/2 (85)	1-1/2 (38)
5 (125)	2 (50)	2-1/2 (63)	3-1/2 (85)	1-1/2 (38)
6 (150)	2-1/2 (63)	3 (76)	4-1/2 (110)	1-1/2 (38)
8 (200)	2-1/2 (63)	3 (76)	4-1/2 (110)	1-1/2 (38)

5. Parts not to be insulated are:
- a. Threaded valves
 - b. Steam traps
 - c. Check valves
 - d. Unions
 - e. Threaded strainers
 - f. Strainer basket removal cover and bolting
 - g. Dielectric flanges and unions
 - h. Expansion joints

- i. Flexible connectors
 - j. Ball joints except piping between joints
6. Installation of insulation:
- a. Pressure Tests: Complete all pressure tests before installing.
 - b. Insulation material: New, clean, dry and stored in a clean dry environment; jacketing materials to be clean and unmarred; store adhesives in original containers. Materials shall not have exceeded the predicted shelf life as set by manufacturer.
 - c. Identify all materials incorporated in the job on manufacturer's container by name, type and description.
 - d. Apply materials on clean, dry surfaces from which all dirt, loose scale, construction debris has been removed by wire brushing.
 - e. The installation shall be neat, thermally and structurally tight without sag, neatly finished at all hanger or other penetrations and shall provide a smooth finished surface primed as required to receive specified painting.
 - f. Do not use scrap insulation. Repair any work damaged by welding, burning, compressing due to concentrated construction loads.
 - g. Apply pipe covering protection saddles, MSS SP 58, Type 39, at all hanger points. Fill space between saddle and piping with high density insulation, thoroughly packed. Terminate jacket clear of saddle bearing area.
 - h. Insulation and jacket shall terminate hard and tight at all anchor points.
 - i. Insulation termination at piping facilities not to be insulated shall stop short, and be finished with 45 degree chamfered section of insulating and finishing cement, and covered with jacket.
 - j. Flanged fittings and valves shall be insulated with sections of pipe insulation cut, fitted and arranged neatly, and firmly wired in place. Insulating cement shall fill all cracks, voids and outer surface for covering with glass cloth. Insulation of valve bonnet shall terminate on valve side of bonnet flange to permit valve repair.
 - k. On calcium silicate, cellular glass and rigid cellular phenolic insulated piping systems, fittings shall be insulated with field or factory-shaped sections of insulation, finished with specified insulating and finishing cements and covered with jacket or PVC premolded cover. On sizes 2 inches (50 mm) and smaller it is permissible to apply insulating and finishing cements, and cover with jacket or PVC premolded cover.
 - l. Fiberglass insulated piping systems fittings over 2 inches (50 mm) shall be insulated with specified molded pipe fitting insulation or compressed blanket, finished with specified insulating and finishing cements and covered with specified PVC fitting jacket. On sizes 2 inches (50 mm) and under apply insulating and finishing cements and cover with PVC fitting jacket.
 - m. Apply glass cloth jacket using an approved adhesive. Glass cloth shall be smooth, tight and neatly finished at all edges; prime cloth to receive paint.

3.15 WELDING (ASME B31.1 AND AWA B2.1-B)

- A. The Contractor is entirely responsible for the quality of the welding and shall:
- 1. Conduct tests of the welding procedures used on the project, verify the suitability of the procedures used, verify that the welds made will meet the required tests, and also verify that the welding operators have the ability to make sound welds under standard conditions.
 - 2. Perform all welding operations required for construction and installation of the distribution system.

- B. Welder Qualifications: All welders shall be qualified as per ASME B31.1 and AWS B2.1-B2.1M-BMG.
- C. Field bevels and shop bevels: Done by mechanical means or by flame cutting. Where beveling is done by flame cutting, surfaces shall be thoroughly cleaned of scale and oxidation just prior to welding. Conform to specified standards.
- D. Utilize split welding rings or approved alternate method for field joints on all carrier pipes above 2 inches (50 mm) to assure proper alignment, complete weld penetration, and prevention of weld spatter reaching the interior of the pipe. Make field joints 2 inches (50 mm) and smaller with welding sockets.
- E. Piping shall not be split, bent, flattened, or otherwise damaged either before, during, or after installation. Where the pipe temperature falls to 32 deg F (0 deg C) or lower, the pipe shall be heated to approximately 100 deg F (38 deg C) for a distance of 1 foot (300 mm) on each side of the weld before welding, and the weld shall be finished before the pipe cools to 32 deg F (0 deg C).
- F. Replace and reinspect defective welds. Repairing defective welds by adding weld material over the defect or by peening will not be permitted. Welders responsible for defective welds must be requalified.
- G. Electrodes shall be stored in a dry heated area, and be kept free of moisture and dampness during fabrication operations. Discard electrodes that have lost part of their coating.
- H. An approved independent testing firm regularly engaged in radiographic testing shall perform radiographic examination of all field welds in the carrier piping of the systems, in manholes and in walk-through tunnels, in accordance with ASME B31.1. Furnish a set of films or pictures showing each weld inspected, a report evaluating the quality of each weld, and a location plan showing the physical location where each weld is to be found in the completed project, prior to installing conduit field joints, trench covers, backfilling and hydrostatic testing. All radiographs shall be reviewed and interpreted by an ASNT Certified Level III radiographer, employed by the testing firm, who shall sign the reading report. The Contracting Officer's Representative reserves the right to review all inspection records, and if any welds inspected are found unacceptable they shall be removed, rewelded, and radiographically reexamined at no cost to Northwestern University.

3.16 CLEANING OF PIPING:

- A. Clean pipe and fittings inside and outside before and after assembly. Remove all dirt, scale, and other foreign matter from inside the piping by use of a pipe swab or pipe "pig" before connecting pipe sections, valves, equipment or fittings.

3.17 IDENTIFICATION

- A. Install continuous plastic underground warning tapes during back filling of trenches for underground steam and condensate distribution piping. Locate tapes 12 inches (300 mm) below finished grade, directly over piping.

3.18 IDENTIFICATION SIGNS

- A. Valves: Provide laminated plastic signs, with engraved lettering not less than 3/16 inch (5 mm) high, on all isolating valves on steam and condensate return system, identifying building or area served. Attach to the valves with corrosion-resistant chains.
- B. Pipes: Label service of all pipes in manholes and walk-thru tunnels.

3.19 FIELD QUALITY CONTROL

- A. Demonstrate leak-tightness of all piping systems by performing hydrostatic and operational tests. All labor, material and test instruments must be furnished by the Contractor. All instruments must be approved by the Contracting Officer's Representative.
- B. Pressure test direct-buried systems in conformance with requirements stated in this specification and in printed instructions for the system supplied. Tests must include carrier piping and casing.
- C. Holiday testing of direct-buried system steel casings: Test entire surface of casings for faults in coating after installation in trench prior to backfilling. Use test method and voltage recommended by coating manufacturer. Repair any holidays found and retest. System shall not be backfilled until all holidays are eliminated.
- D. Before conducting steam system operating test, remove steam trap elements or use bypass connections around traps; then flush lines with high pressure water until discharge shows no foreign matter to the satisfaction of Contracting Officer's Representative.
- E. Steam and condensate carrier piping shall be tested hydrostatically before insulation is applied at field joints and shall be proved tight at a pressure 1 1/2 times distribution supply pressure for a period not less than 2 hours with no pressure decay.
 - 1. Test piping located in concrete trenches prior to installing trench covers. Test direct-buried systems prior to backfilling.
 - 2. Remove or isolate any elements of the system such as expansion joints, which are not designed for the test pressure.
 - 3. Prior to acceptance of installation, Contractor shall subject system to operating tests as may be required by Contracting Officer's Representative to demonstrate satisfactory functional and operating efficiency. These operating tests shall cover a period of not less than six hours for each portion of system tested. Conduct tests at times as the Contracting Officer's Representative may direct.
 - 4. Provide calibrated instruments, equipment, facilities and labor, at no additional cost to Northwestern University. Test gage shall read in increments not exceeding 0.1 psi (1 kPa).
 - 5. Repeat tests when failures occur.
 - 6. After completion of satisfactory test, replace all elements that have been removed prior to testing.
- F. Pneumatic Testing of DDT System Casings:
 - 1. Perform test on all sections of the system before field-coating the field joints and before back-filling.
 - 2. Test shall be with compressed air at 15 psi (100 kPa) for 24 hours with pressure source disconnected and with no decay in pressure. Corrections to the readings are permissible to compensate for significant ambient temperature changes during the test period.
 - 3. Pressure shall be measured with a gage with reading increments of 0.1 psi (1 kPa).

- 4. Each casing field joint shall be tested for leaks by means of soap solution or equivalent.
 - G. NACE-accredited corrosion specialist shall test cathodic protection systems and demonstrate proper operation and protection in accordance with the recommendations and criteria in NACE SP0169.
 - H. Deficiencies discovered shall be corrected at the Contractor's expense, to satisfaction of Contracting Officer's Representative. Major deficiencies or failure to correct deficiencies, to the satisfaction of the Contracting Officer's Representative, may be considered cause for rejecting the entire installation.
 - I. **[Owner will engage / Contractor will engage]** a qualified testing agency to perform tests and inspections.
 - J. Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations for the system.
 - K. Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
 - L. Tests and Inspections:
 - 1. Steam and condensate piping for testing: ASME B31.1 and ASME B31.9 and as follows:
 - a. Leave joints, including welds, uninsulated and exposed for examination during test.
 - b. Isolate equipment. Do not subject equipment to test pressure.
 - c. Install relief valve set at pressure no more than one-third higher than test pressure.
 - d. Fill system with temperature water. Where there is risk of freezing, air or a safe, compatible liquid may be used.
 - e. Use vents installed at high points to release trapped air while filling system. Use drip legs installed at low points for complete removal of liquid.
 - 2. Test steam and condensate piping as follows:
 - a. Subject steam and condensate piping to hydrostatic test pressure that is not less than 1.5 times the design pressure.
 - b. After hydrostatic test pressure has been applied for 10 minutes, examine joints for leakage. Remake leaking joints using new materials and repeat hydrostatic test until no leaks exist.
 - 3. Test conduit as follows:
 - a. Seal vents and drains and subject conduit to 15 psi (105 kPa) for four hours with no loss of pressure. Repair leaks and retest as required.
 - M. Prepare test and inspection reports.
- 3.20 APPENDIX I – ALLOWABLE SITE CHARACTERISTICS FOR CONCRETE SHALLOW TRENCH APPLICATION

APPENDIX I
ALLOWABLE SITE CHARACTERISTICS FOR CONCRETE SHALLOW TRENCH APPLICATION (SEE NOTE 1)

SITE CONDITION	GENERAL CONDITIONS OF GROUND WATER DURING THE WETTEST PERIOD OF THE YEAR	SURFACE WATER ACCUMULATION RAINFALL/ IRRIGATION	TRENCH CONSTRUCTION
A. Fine grained impervious or semipervious and coarse grained impervious	Water table generally 1 foot (300 mm) below lowest point of water entry (See Note 5) with not more than 25% of the length of the proposed concrete trench system showing water within 1 foot (300 mm) of the lowest point of water entry.	5 year - 7 day rainfall equal to or less than 10 inches (250 mm). (See Note 2)	Continuous wall and bottom.
B. Coarse grained semipervious and pervious (See Note 2)	Same as for A. above.	5 year - 7 day rainfall equal to or less than 10 inches (250 mm).	Same as for A. above
	Water table generally 2 feet (600 mm) or more below point of water entry with not more than 10% of the length of trench system showing water within 2 feet (600 mm) but not closer than 1 foot (300 mm) to lowest point of water entry.	5 year - 7 day rainfall equal to or less than 8 inches (200 mm). (See Note 2)	Continuous wall; openings may be provided in trench bottom to provide drainage.
C. Swelling soils (See Note 3)	Same as for A. above.	Same as for A. above.	Same as for A. above plus design of joint spacing and joint details to accommodate movement.

NOTES:

1. Shallow concrete trench system shall not be used if any conditions defined by these criteria are exceeded.
2. As shown in U. S. Weather Bureau (USWB) Technical Paper 40 and confirmed with local data and local weather patterns
3. Swelling soils are materials with high swell potential when subjected to an increase in moisture content.
4. Precipitation rates for a specific site should be used to design drainage systems and select sump pumps.
5. Lowest point of water entry is defined as the joint between trench wall and trench bottom.

3.21 APPENDIX II - CLASSIFICATIONS FOR DIRECT BURIED SYSTEMS

A. Groundwater conditions:

Site Classification	General Conditions for Such Classifications
A - Severe	1. The water table is expected to be frequently above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system, or
	2. 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.

B - Bad	1. 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
	2. 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.
C - Moderate	The water table is expected never to 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.
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.

1. System Temperature Classifications: High 261 to 450 deg F (127 to 232 deg C); Medium 201 to 260 deg F (94 to 126 deg C); Low 200 deg F (93 deg C) or lower.
2. Soil Conditions:

B. Soil Corrosiveness Classification:

1. The soil at the site should be classified as corrosive or noncorrosive on the basis of the following criteria:
2. Corrosive: The soil resistivity is less than 30,000 ohm-cm or stray direct currents can be detected underground.
3. Noncorrosive: The soil resistivity is 30,000 ohm-cm or greater and no stray direct currents can be detected underground.
4. The classification should be made by an experienced corrosion engineer based on a field survey of the site carried out in accordance with recognized guidelines for conducting such surveys.

C. Soil pH:

1. If there is any reason to suspect that the soil pH will be less than 5.0 anywhere along the proposed path of the system, pH measurements should be made at pipeline depth at close intervals along the proposed route, and all locations at which the pH is less than 5.0 should be indicated in the contract documents. An experienced soils engineer, preferably the same engineer responsible for other soil engineering work, should determine soil pH.
2. Type of Underground System Allowed:
 - a. Drainable-Dryable-Testable (DDT) shall be allowed for Site Classifications A, B, C, D.

END OF SECTION 33 6300