**NATURAL RESOURCES CONSERVATION SERVICE**

**CONSERVATION PRACTICE STANDARD**

# IRRIGATION PIPELINE

**(Ft.)**

**CODE 430**

## I. DEFINITION

A pipeline and appurtenances installed to convey water for storage or application, as part of an irrigation water system.

## II. PURPOSE

Conveyance of water from a source of supply to an irrigation system or storage reservoir.

## III. CONDITIONS WHERE PRACTICE APPLIES

This standard applies to water conveyance and distribution pipelines installed above or below ground.

This standard does not apply to multiple outlet irrigation system components (e.g., surface gated pipes, sprinkler lines, or micro irrigation tubing).

## IV. CRITERIA

The water supply, quality, and rate of irrigation delivery for the area served by the pipeline shall be sufficient to make irrigation practical and feasible, for the crops to be grown and the irrigation water application methods to be used.

Pipelines shall be placed only in soils and environmental conditions suitable for the material type being selected.

Pipelines shall be designed to meet all service requirements such that internal pressure, including hydraulic transients or static pressure at any point is less than the pressure rating of the pipe.

A. Capacity

Capacity shall be sufficient to convey the design delivery flow rate for the planned conservation practices.

Design capacity of the pipeline conveyance or distribution system for irrigation systems shall be sufficient to meet the requirements for efficient application based on one of the following:

- Adequate to meet the moisture demands of all crops to be irrigated in the design area.
- Sufficient to meet the requirements of selected irrigation events during critical crop growth periods when less than full irrigation is planned.
- For special-purpose irrigation systems, sufficient to apply a specified amount of water to the design area in a specified operating period.

In computing the above capacity requirements, allowance must be made for reasonable water losses during application or use.

B. Friction and Other Losses

For design purposes, head loss for hydraulic grade line computations shall be computed using one Manning's or Hazen-Williams equations.

**Except where joints, connections, or condition of the pipe indicate that a higher value is required, the following equations and roughness coefficient shall be used:**

| Material | Equation | Recommended Roughness Coefficient | Source |
|---|---|---|---|
| PVC | Hazen Williams "C" | 150 | 1 |
| | Manning's "n" | .009 (clean water) | |
| Aluminum | Manning's "n" | 0.010 | 2 |
| Concrete | Manning's "n" | 0.011 Gasket<br>0.012 Mortar<br>0.014 Cast in Place | 3 |
| Polyethylene | Hazen Williams "C" | 150 Smooth wall | 4 |
| | Manning's "n" | 0.009<br>0.012 Bell Ends | |
| Corrugated/ Profile Wall Plastic Pipe | Manning's "n" | See manufacturer's association recommended values | |
| Steel, Smooth | Manning's "n" | 0.010 Lined<br>0.012 Unlined | 5 |
| Steel, Corrugated | Manning's "n" | Varies w/diameter, Shape of Corrugation. See reference 6 or 7 | |

**Reference Sources:**
**1. Unibell. 2001. Handbook of PVC Pipe Design and Construction, 4th Ed.. Unibell PVC Pipe Assn. Dallas, TX.**
**2. SCS. 1972. Practice Standard 430-A Underground Irrigation Tubing.**
**3. ACPA. 2000. Concrete Pipe Design Manual. American Concrete Pipe Association. Irving, TX.**
**4. PPI. Handbook of Polyethylene Pipe. Plastic Pipe Institute. www.plasticpipe.org**
**5. SCS. 1972. Practice Standard 430-F Irrigation pipe, Steel. (AWWA M-11 recommends n = 0.011)**
**6. Brater, et al. 1996. Handbook of Hydraulics, 7th Ed. McGraw-Hill. New York, NY.**
**7. AISI, 1999, Handbook of Steel Drainage and Highway Construction Products, 4th ed.**

Equation selection shall be based on the given flow conditions and the pipe materials used. Other head losses (also called minor losses) from change in velocity and direction of flow due to inlet type, valves, bends, enlargements or contractions can be significant and shall be evaluated as appropriate. For closed, pressurized systems, the hydraulic grade line for all pipelines shall be maintained above the top of the pipeline at all locations for all flows unless specifically designed for negative internal pressures.

C. Flexible Conduit Design

Flexible conduits such as plastic pipe, steel pipe, aluminum pipe, corrugated metal pipe, or ductile iron pipe, shall be designed using NRCS National Engineering Handbook (NEH) Part 636, Chapter 52, Structural Design of Flexible Conduits, and the following criteria:

1. Smooth Wall Plastic Pipe **with a pressure rating equal to or greater than 50 psi**

   When operating at design capacity, the full-pipe flow velocity should not exceed 5 feet per second in pipelines with valves or some other flow control appurtenances placed within the pipeline or at the downstream end. As a safety factor against surge, the working pressure at **all locations and under all anticipated flow conditions** should not exceed 72 percent of the pressure rating of the pipe. If either of these limits is exceeded, special design consideration **shall** be given to the flow conditions, and measures must be taken to adequately protect the pipeline against transient pressures. **Design considerations for surge in PVC pipe are contained in the Handbook of PVC Pipe. Considerations for surge in Polyethylene (PE) and High Density Polyethylene (HDPE) pipe are outlined in the Handbook of PE Pipe.**

2. Corrugated or Profile Wall Plastic Pipe

   When operating at design capacity, the full-pipe flow velocity should not exceed 5 feet per second in pipelines with valves or some other flow control appurtenance placed within the pipeline or at the downstream end. As a safety factor against surge, the working pressure at any point should not exceed 72 percent of the pressure rating of the pipe. If the pipe is not pressure rated, the maximum allowable pressure shall be 25 feet of head, or the maximum pressure as specified by the manufacturer for the pipe and connecting joints used.

3. Smooth Wall Steel Pipe

   The specified maximum allowable pressure shall be determined using the hoop stress formula, limiting the allowable tensile stress to 50 percent of the yield-point stress for the material **where:**

$$\boldsymbol{P = \frac{2St}{d}}$$

**Where:**

**P = Maximum working pressure in lb/in²**
**S = Allowable stress in lb/in2 (50% of the yield strength of steel)**
**d = Inside diameter of pipe in inches**
**t = Pipe nominal wall thickness in inches**

Design stresses for commonly used steel and steel pipe are shown in the NEH Part 636, Chapter 52.

**The minimum wall thickness for steel pipe shall be as follows:**

| Nominal Diameter (inches) | Pipe Gauge |
|---|---|
| 4-12 | 14 |
| 14-18 | 12 |
| 20-24 | 10 |
| 26-36 | 3/16 |
| 38-48 | 1/4 |

4. Corrugated Metal Pipe

Maximum allowable pressure for the pipe shall be:

- 20 feet of head for annular and helical pipe with sealed seams and watertight coupling bands.
- 30 feet of head for helical pipe with welded seams, annular ends, and watertight couplings.

5. Smooth Wall Aluminum Pipe

The maximum allowable pressure of the pipe shall be determined using the hoop stress formula **where:**

$$P = \frac{2St}{d}$$

**Where:**

**P = Maximum working pressure in lb/in²**
**S = Allowable stress in lb/in2 (50% of the yield strength of steel)**
**d = Inside diameter of pipe in inches**
**t = Pipe nominal wall thickness in inches**

6. **Pipe Deflection**
**The design of flexible pipe includes analysis of allowable long-term deflection. The allowable deflections for buried plastic, steel, aluminum, corrugated metal, polyethylene, and corrugated plastic are limited to 5 percent. The Spangler Modified Iowa equation described in NEH, Part 636, Chapter 52, Structural Design of Flexible Conduits may be used to compute the percent deflection for each type of pipe. This equation is also described in the Unibell Handbook of PVC Pipe, and AWWA M11, Steel Pipe, A Guide for Design and Installation.**

D. Rigid Conduit Design

Rigid conduits such as concrete pipe or plastic mortar pipe shall be designed using the following criteria:

1. Non-reinforced Concrete Pipe with Motor Joints

The maximum allowable pressure for pipe with mortar joints shall not exceed one-fourth of the certified hydrostatic test pressure as determined by the test procedure described in ASTM C118. Nor shall they exceed the following:

| Diameter (inches) | Maximum Allowable Pressure (feet) |
|---|---|
| 6 through 8 | 40 |
| 10 and greater | 35 |

2. Non-reinforced concrete Pipe with Rubber Gasket Joints

The maximum allowable pressure for non-reinforced concrete pipe with rubber gasket joints shall not exceed one-third the certified hydrostatic test pressure as determined by the test procedure described in ASTM C505. Nor shall they exceed the following:

| Diameter (inches) | Maximum Allowable Pressure (feet) |
|---|---|
| 6 through 12 | 50 |
| 15 through 18 | 40 |
| 21 and greater | 30 |

3. Cast-in-Place Concrete Pipe

Maximum working pressure for cast-in-place concrete pipe shall be 15 feet above the centerline of pipe. Cast–in-place concrete pipe shall be used only in stable soils that are capable of being used as the outside form for approximately the bottom half of the conduit.

4. Reinforced Concrete Pipe with Gasket Joints

The maximum allowable pressure for reinforced concrete pipe with rubber gasket joints shall be not exceed the rated hydrostatic pressure for the specified pipe according to appropriate ASTM or AWWA standards.

5. Reinforced Plastic Mortar Pipe

The pipeline shall be designed to meet all service requirements without a static or working pressure at any point greater than the maximum allowable working pressure of the pipe used. The static or working pressure of pipelines open to the atmosphere shall include free board. The minimum acceptable pipe pressure rating shall be 50 psi.

E. Support of Pipe

Irrigation pipelines both below and above ground shall be supported, where needed, to provide stability against external and internal forces. Pipe support shall be designed using NEH Part 636, Chapter 52.

F. Joints and Connections

All connections shall be designed and constructed to withstand the pipeline **static and** working pressure without leakage and leave the inside of the pipeline free of any obstruction that would reduce capacity.

Permissible joint deflection shall be obtained from the manufacturer for the joint type and pipe material used.

For sloping steel pipe, expansion joints shall be placed adjacent to and downhill from anchors or thrust blocks.

For welded pipe joints, expansion joints shall be installed, as needed, to limit pipeline stresses to the allowable values.

For suspended pipelines, joints shall be designed for pipe loading including the water in the pipe, wind, ice, and the effects of thermal expansion and contraction.

Joints and connections for metal pipes should be of similar materials whenever possible. If dissimilar **metal is** used, the joints or connections shall be protected against galvanic corrosion.

G. Depth of Cover

Buried pipe shall be installed at sufficient depth below the ground surface to provide protection from hazards imposed by traffic loads, farming operations, freezing temperatures, or soil cracking, as applicable.

Pipelines shall have sufficient strength to withstand all external loads on the pipe for the given installation conditions. Appropriate live loads shall be used for the anticipated traffic conditions.

**Shallow bury or aboveground pipe installations require special consideration for protection from physical and environmental hazards.**

**Refer to Handbook of PE Pipe (Plastics Pipe Institute), Handbook of PVC Pipe, (UniBell), and NEH, Chapter 52, Structural Design of Flexible Conduits for guidance when the depth of cover is less than the minimums.**

**The minimum depth of cover for pipe susceptible to any of these hazards shall be:**

| **Diameter (inches)** | **Depth of Cover (inches)** |
|---|---|
| **½ through 2½** | **18** |
| **3 through 5** | **24** |
| **6 or more** | **30** |

**Additional cover may be required where groundwater reaches the pipe. A buoyancy check shall be done to assure a factor of safety of at least 1.5 exists against floatation.**

**In areas where pipe is not susceptible to freezing, vehicular axle loads in excess of 2 tons, or cultivation hazards, and the soils do not crack appreciably when dry, the minimum depth of cover may be reduced to:**

| Diameter (inches) | Depth of Cover (inches) |
|---|---|
| **½ through 1½** | **6** |
| **2 through 5** | **12** |
| **4 through 6** | **18** |
| **6 or more** | **24** |

**At low places on the ground surface, extra fill may be placed over the pipeline to provide the minimum depth of cover. The top width of the fill shall be no less than 10 feet and the side slopes no steeper than 3:1, or 6:1 for traffic crossings.**

Where it is not possible to achieve sufficient cover or sufficient strength, a carrier (encasement) pipe or other mechanical measures shall be used.

H. Pressure Reduction

Pressure reduction shall be incorporated in circumstances such as head gain exceeding pressure loss by a significant amount, excessive line **pressures** for the type of irrigation system **supplied**, or excessive static pressures.

I. Inlets

Inlets shall be of adequate size for the type of entrance condition to ensure design flow capacity without excessive head losses.

Provision shall be made to prevent the inflow of trash or other materials into the pipeline if these materials would be detrimental to the pipe capacity or performance of the irrigation application system.

For gravity flow inlets with square-edged or gated orifices, the nappe created by inflow at the orifice entrance shall be vented.

Water control structures are commonly used for gravity flow pipelines, but do not account for removal of entrained air. Therefore, pipelines using these inlets must also meet the requirements listed under Vents.

J. Check Valves and Backflow Prevention

A check valve shall be installed between the pump discharge and the pipeline if detrimental backflow may occur. Check valves can cause extreme internal pressures, due to water hammer; if they close too fast as flow reversal occurs. "Non slam" type check valves or solenoid operated valves may be required.

Approved backflow prevention devices (chemigation valves) shall be used on all pipelines in which fertilizer, liquid manure, waste water, pesticides, acids, or other chemicals are added to the water supply. **Approved backflow prevention devices outlined in the National Engineering Manual (NEM), Part 503 (North Dakota supplement) shall be used** where back flow may contaminate the source water supply or groundwater.

**K. Flow Measurement**

**Measurement and determination of flow rate is a critical component of irrigation water management. A method of flow measurement (i.e. a flow meter) shall be in place or installed to facilitate irrigation scheduling and ongoing evaluation of system performance. Multiple flow measurement locations may be necessary. The flow measuring equipment shall display flow rate (i.e. gpm, cfs) and total volume (gallons or acre-feet). Manufacturer's recommendations must be followed regarding proper location in the system to achieve required flow conditions for accurate readings.**

L. Valves and Other Appurtenances

Pressure ratings of valves and other appurtenances shall equal or exceed the pipeline working pressure. When lever operated valves are used, an analysis shall be performed to evaluate potential surge/water hammer assuming an instantaneous valve closure.

M. Stands Open to Atmosphere

Stands shall be used when water enters the pipeline to avoid entrapment of air; to prevent surge pressures and collapse because of vacuum failure; and to prevent pressure from exceeding the design working stress of the pipe. The stand shall be designed to:

- Allow a minimum of 1 foot of freeboard. The maximum height of the stand above the centerline of the mainline pipeline must not exceed the maximum working head of the pipe.
- Have the top of each stand at least 4 feet above the ground surface except for surface gravity inlets or where visibility is not a factor. Gravity inlets and stands shall be equipped with trash racks and covers.
- Have a downward water velocity in stands not in excess of 2 feet per second. The inside diameter of the stand shall not be less than the inside diameter of the pipeline.

The cross sectional area of stands may be reduced above a point 1 foot above the top of the upper inlet, but the reduced cross section shall not be such that it would produce an average velocity of more than 10 feet per second if the entire flow were discharging through it.

If the water velocity of an inlet pipe exceeds three times the velocity of the outlet, the centerline of the inlet shall have a minimum vertical offset from the centerline of the outlet at least equal to the sum of the diameters of the inlet and outlet pipes.

Stands shall be constructed of steel pipe or other approved material and be supported on a base adequate to support the stand and prevent movement or undue stress on the pipeline.

Sand traps, when combined with a stand, shall have a minimum inside dimension of 30 inches and shall be constructed so the bottom is at least 24 inches below the invert of the outlet pipeline. The downward velocity of flow of the water in a sand trap shall not exceed 0.25 feet per second. Suitable provisions shall be made for cleaning sand traps.

The dimensions of gate stands shall be adequate to accommodate the gate or gates required, and shall be large enough to make the gates accessible for repair.

The size of float valve stands shall be adequate to provide accessibility for maintenance.

Stands must be constructed in a manner to insure vibration from the pump discharge pipe is not carried to the stand.

Pressure-relief valves can be used as an alternative to stands open to the atmosphere. A pressure-relief valve shall serve the pressure-relief function of the open stand or vent for which it is an alternative.

N. Stands Closed to the Atmosphere

If pressure-relief valves and air-and-vacuum valves are used instead of open stands, all requirements detailed in "Stands Open to the Atmosphere" shall apply except as modified below.

The inside diameter of the closed stand shall be equal to or greater than that of the pipeline for at least 1 foot above the top of the uppermost inlet of outlet pipe. To facilitate attaching the pressure-relief valve and the air-and-vacuum valve, the stand may be capped at this point, or if additional height is required, the stand may be extended to the desired elevation by using the same inside diameter or a reduced cross section. If a reduced section is used, the cross-sectional area shall be such that it would produce an average velocity of no more than 10 feet per second if the entire flow were discharged though it. If no vertical offset is required between the pump discharge pipe and the outlet pipeline and the discharge pipe is "dog-legged" below ground, the stand shall extend at least 1 foot above the highest part of the pump discharge pipe.

An acceptable alternative design for stands requiring no vertical inlet offset (when inlet velocity is less than three times that of the outletting pipeline) shall be:

- Construct the dog-leg section of the pump discharge pipe with the same nominal pipe diameter as that of the pipeline.
- Install the pressure-relief valve and the air-and-vacuum valve on top of the upper horizontal section of the dog-leg.

Pressure-relief and air-and-vacuum valves shall be installed on stands with the nominal size pipe required to fit the valves' threaded inlets.

O. Surge Tanks and Air Chambers

If surge tanks and/or air chambers are required for control of hydraulic transients or water column separation, they shall have adequate size to ensure the water volume needs of the pipeline are met without the tank/chamber being emptied, and that the required flow into the pipeline for the calculated pressure drop is met.

P. Pressure Relief Valves

A pressure relief (PR) valve shall be installed between the pump discharge and the pipeline if excessive pressure can build up when all valves are closed. If needed to protect the pipeline against pressure reducing valve malfunction or failure, PR valves shall be installed downstream of pressure reducing valves.

**Pressure relief valves should be provided upstream from shutoff valves and at the downstream end of pipeline sections when surge pressure might exceed the pressure rating of the pipe.**

Manufacturers of PR valves marketed for use under this standard shall provide capacity tables that give the discharge capacities of the valves at the maximum permissible pressure and differential pressure settings. These tables shall be based on performance tests, and shall be the basis for acceptance of these valves and selection of the design pressure setting.

PR valves shall be set to open at a pressure as low as practical, but no greater than 5 psi above the pressure rating or maximum allowable pressure of the pipe. The valves shall have sufficient flow capacity to reduce the excessive pressures in the pipeline. **Pressure relief valves shall be sized to release the entire flow rate before the pressure reaches 1.5 times the pressure rating of the pipe.** In lieu, of a detailed surge/pressure analysis, the minimum size of PR valve shall be ¼ inch nominal valve size per inch of the nominal pipeline diameter.

The pressure at which the valves start to open shall be marked on each PR valve. Adjustable PR valves shall be sealed or otherwise altered to prevent changing the adjustment from that marked on the valve.

Q. Air Release Valves

Five types of air vents/valves commonly used on irrigation pipelines are continuous acting air release valves (CAV), vacuum-relief valves (VR), air release and vacuum relief valves (AVR), combination air valves (COMB), and open vents. Open vents are described in the "Vents" section of this standard.

If accumulation of air during operation may occur CAV shall be used to release air from the filled pipeline while under pressure. Normal orifice venting diameter is 1/16 to 3/8 inch.

VR valves shall be used for relief of vacuum pressures (i.e., negative pressures) due to sudden gate or valve closure, pump shutoff, or drainage of the pipeline.

AVR valves may be used for the same requirements described for VR valves. These valves shall also be used to release air from the pipeline on filling prior to the pipe being pressurized. They shall be used to alleviate flow restrictions, air locks, and water surging due to the presence of air within pipelines.

COMB valves have the combined function of all three valves (CAV, VR, and AVR) in one body. COMB valves may be used for any of the conditions in which a CAV, VR, or AVR is required.

If needed to provide positive means for air escape during filling and air entry while emptying, an AVR, VR, or COMB valve shall be installed at all summits, upstream and downstream of all in line valves as needed, at the entrance, and at the **downstream** end(s) of the pipelines. Such valves are needed at these locations if the pipeline is closed to the atmosphere. However, they may not be needed if other features of the pipe system, such as permanently located sprinkler nozzles or other unclosed service outlets, adequately vent the particular location during filling and emptying operations. The use of these system features must be analyzed for air flow rate and the proper use of such features described in the Operation and Maintenance plan. High points in the pipeline require a CAV unless an outlet is located at that point.

In addition to the locations described above, an AVR or COMB valve shall be located at changes of grade in downward direction of flow in excess of 10 degrees, to ensure adequate air release during filling. On long pipelines, additional AVR or COMB valves may be required to adequately vent the pipe during filling.

For air release, the AVR or COMB valve shall be sized to exhaust air from the pipeline at the rate needed to prevent operational problems with the pipeline, while maintaining the proper operation of the valve. For design purposes, the exhaust pressure differential shall be limited to 2 psi. **Long pipelines may require CAV valves spaced in the range of 1,200 to 3,000 feet. Without site-specific analysis, a spacing of ¼-mile is recommended.**

For vacuum relief, the AVR, VR, or COMB valves shall be sized for air entry into the pipeline, ensuring the pipeline does not collapse due to vacuum created during drainage of the pipeline. For design purposes, the vacuum pressure differential shall be limited to **the computed pipe collapse pressure or** 5 psi**, whichever is less**.

If the required vacuum relief orifice diameter is significantly larger than the required air release orifice diameter, separate valves may be required to help eliminate excessive water hammer caused when the air is released too fast from the pipeline.

CAV or COMB valves shall be used as needed to permit air to escape while the line is at working pressure. Small orifices of these valve types shall be sized according to the design working pressure and venting requirements recommended by the valve manufacturer.

The location of the CAV or COMB valves shall be sufficient distance downstream from the introduction of air into the system (under pressure conditions) to allow the air to be collected at the top of the pipe. Under some circumstances (e.g., pumped system with low pressure or velocity) consideration should be given to installing vent chambers for CAV or COMB valves. The vent chamber should be constructed according to the requirements under the second criteria in the “Vents” section of this standard.

In lieu of a detailed design, for the corresponding pipe material below, the following size air valves shall be used:

- For Plastic **pipe** ≤ 50 psi - 0.22 x pipe diameter **(in.)**
- For Plastic **pipe** > 50 psi - 0.10 x pipe diameter **(in.)**
- For Metal **pipe** - 0.125 x pipe diameter **(in.)**
- For Concrete **pipe** - 0.125 x pipe diameter **(in.)**
- **For Aluminum pipe**

  **≤ 6 in. Dia. Pipe - 2 inch dia.**
  **8” – 10” - 3 inch dia.**
  **12” - 4 inch dia.**

Manufacturers of air valves marketed for use under this standard shall provide dimensional data or a capacity table based on performance tests, which shall be the basis for selection and acceptance of these valves.

R. Vents

Venting must be designed into systems open to the atmosphere to provide for the removal and entry of air and protection from surge **and collapse pressures.** The following criteria shall apply:

- Vents **on a gravity pipeline that are open to the atmosphere** shall have a minimum freeboard of 1 foot above the **static** gradeline.
- A vent chamber shall be constructed to intercept and/or capture air within the pipeline. The chamber shall intercept the circumference arc of 75 degrees at the top of the pipe (i.e., a vent chamber diameter of 2/3 the diameter of the pipeline). The chamber shall extend vertically at least one pipeline diameter up from the centerline of the pipeline. Above this elevation, the vent chamber may be reduced to minimum diameter of 2 inches.
- **A study by the Washington State Institute of Technology found that irrigation pipelines with cascading flow at the inlet structure entrained air bubbles into the pipeline. The bubbles rise to the top of the pipe and are carried by flowing water until released by a vent. The distance for the bubbles to rise to the surface is a function of pipeline velocity and diameter. The following equation gives general guidance regarding the distance from a pipeline inlet to an air vent when air entrained inlet conditions exist:**

$$L = 1.76\,V\,D$$

**Where:**
**L = Distance from inlet to vent (ft)**
**V = Average velocity (ft/sec)**
**D = Inside diameter of pipe (ft)**

- When an AVR or COMB valve is used instead of a vent, the above requirements shall apply except that the reduced section shall be sized to meet the nominal pipe size required to fit the valve's threaded inlet.
- A vent shall be located at the downstream end of laterals, at summits in the line, and at points where the grade changes more than 10 degrees in a downward direction of flow.

S. Outlets

Appurtenances to deliver water from the pipe system to the field, ditch, reservoir, or surface pipe system, are known as outlets. Outlets shall have adequate capacity **and pressure rating** to deliver the required flow to:

- The hydraulic gradeline of a pipe or ditch,
- A point at least 6 inches above the field surface,
- The design surface elevation in a reservoir, or
- An individual sprinkler, lateral line, hydrant, or other device at the required operating pressure.

Outlets shall be designed to minimize erosion, physical damage, or deterioration due to exposure.

T. Filling

**The pipe system shall have a means of controlling the filling of the pipeline to prevent entrapped air and excessive transient pressures.**

Filling velocities greater than 1 foot per second in a closed to the atmosphere pipe system (i.e., all outlets closed) requires special evaluation and provisions to remove entrapped air and prevent transient pressures.

If filling at a low flow rate is not possible, the system shall be open to the atmosphere (outlets open) prior to pressurizing. The valves to **supplied** irrigation system components (gated pipe, wheel line, pivot, etc.) should be opened to release entrapped air and minimize transient pressures in the system. The system shall be designed for air removal and excessive transient pressures that may develop at higher filling rate.

U. Flushing

If the sediment load in the water is significant, the pipeline shall have adequate velocity to ensure that sediment is moved through and flushed out of the pipeline.

If provisions are needed for flushing sediment or other foreign material, a suitable valve **and drain** shall be installed at the **downstream** end**s** or low point**s** of the pipeline.

V. Draining

Provisions shall be made for the complete removal of water from the pipeline by gravity or other means when:

- Freezing temperatures are a hazard.
- Draining is required by the pipe manufacturer.
- Draining of the pipeline is otherwise specified.

**Gravity drainage is required for all irrigation pipelines 6 inches in diameter or larger. Pumpouts at designed low points are acceptable if outlined in Operation and Maintenance Plan.**

The water drained from pipelines shall not cause water quality, soil erosion, or safety problems upon release. **Minimum grade for drainage shall be 0.005 feet per foot.**

W. Safe Discharge of Water

Provisions shall be made for water being discharged from valves, especially air valves and pressure relief valves. Such valves shall be located such that flows are directed away from system operators, livestock, electrical equipment, and other control valves or hook-ups.

X. Thrust Control

Abrupt changes in pipeline grade, horizontal alignment, tees, or reduction in pipe size, normally require an anchor or thrust blocks to absorb pipeline axial thrust. Thrust control is typically needed at the end of the pipeline, at in-line control valves**, at reducers and wyes, tees, and elbows**.

Y. Longitudinal Bending

For plastic pipe, the allowable longitudinal bending for the pipeline shall be based on material type and the pressure rating, and shall be in accordance with industry standards, or as described in NEH Part 636 Chapter 52.

**Industry standards for PVC pipe generally recommend a maximum joint deflection of one degree. For a 20-feet piece of pipe, this is a 4-inch offset per joint. The minimum radius of curvature for 20-feet joints is 1,146 feet. The following equation can be used to determine joint deflection angles or curve radii for various lengths of pipe.**

$$\text{Joint Deflection Angle} = \left( \frac{180}{\frac{R\pi}{L}} \right)$$

**Where:**
***R*** **= Curve Radii in ft.**
**π = 3.1416**
***L*** **= Pipe Length in ft.**

Z. Thermal Effects

For plastic pipe, thermal effects must be properly factored into system design. Pressure ratings for pipes are normally based on a pipe temperature of 73.4ºF. When operating temperature is higher the effective pressure rating of the pipe shall be reduced accordingly.

Values and procedures for pressure rating reduction shall follow information described in the NEH Part 636, Chapter 52.

**The pipe pressure rating shall be reduced where pipe temperatures may exceed 73.4° F using the factors in the following table, or factors obtained from the manufacturer. Tests have shown that HDPE pipe exposed to the sun can reach temperatures of 130° F when ambient temperatures are 85° F.**

| **Strength Reduction Factors for High Temperatures** | | |
|---|---|---|
| **Temperature, ° F** | **PVC Pipe** | **PE Pipe** |
| **< 73.4** | **1.0** | **1.0** |
| **80** | **0.88** | **0.92** |
| **90** | **0.75** | **0.81** |
| **100** | **0.62** | **0.72** |
| **110** | **0.50** | **0.63** |
| **120** | **0.40** | **0.60** |
| **130** | **0.30** | **0.55** |
| **140** | **0.22** | **0.50** |

AA. Physical Protection

Steel pipe installed above ground shall be galvanized or shall be protected with a suitable protective paint coating, including a primer coat and a minimum of two final coats.

Plastic pipe installed above ground shall be resistant to ultraviolet light throughout the intended life of the pipe or measures taken to protect the pipe from damage due to ultraviolet light. **PVC and fittings shall be protected from ultraviolet oxidation by painting with a heavy pigmented, exterior water-based latex paint. White or similar light color is recommended as it helps reduce water temperature. The latex paint must be thickly applied on pipe and fittings that have been well cleaned and lightly sanded.**

All pipes shall be protected from hazards presented by traffic loads, farm operations, freezing temperatures, fire, thermal expansion and contraction. Reasonable measures shall be taken to protect the pipe from potential vandalism.

BB. Corrosion Protection

All metal to metal fittings, such as risers, bends, tees, and reducers, should be of similar metals. If dissimilar metals are used, the fittings shall be protected against galvanic corrosion (e.g., separate dissimilar metals with rubber or plastic insulator).

Bolts used to join galvanized steel shall be galvanized; plastic coated, stainless steel, or otherwise protected to prevent galvanic corrosion. Bolts used to join aluminum, other than aluminum alloy bolts, must be plastic coated or otherwise protected to prevent galvanic corrosion.

1. Interior Linings

Interior protective **linings** shall be provided when the pH of the water falls outside the ranges shown in the following table.

| Material | Water pH |
|---|---|
| Aluminized Steel | Less than 5 or greater than 9 |
| Galvanized Steel | Less than 6 or greater than 10 |
| Aluminum Alloy | Less than 4 or greater than 10 |

Unlined steel pipelines can experience corrosion from very pure water (e.g., snow melt). If the Langelier Saturation Index (LSI) is **less than -1.0, interior corrosion protection shall be provided. LSI values less than 0 indicate corrosive conditions. An LSI number equal to zero indicates a balanced condition. Calcium carbonate will tend to form with LSI numbers greater than 0.**

To calculate the LSI, it is necessary to know the alkalinity (mg/l as CaCO3), the calcium hardness (mg/l Ca+2 as CaCO3), the total dissolved solids (mg/l TDS), the actual pH, and the temperature of the water (°C). These values are used in the following equations:

$$LSI = pH - pH_s$$
$$pH_s = (9.3 + A + B) - (C + D)$$

Where:
$A = (\text{Log10}\ [TDS] - 1) / 10$
$B = -13.12 \times \text{Log10}\ (°C + 273) + 34.55$
$C = \text{Log10}\ [Ca^{+2} \text{ as } CaCO_3] - 0.4$
$D = \text{Log10}\ [\text{alkalinity as } CaCO_3]$

**Interior pipe coatings can be selected from one of the following methods if the applied coating meets the requirements of the applicable reference specification:**

| Accepted Interior Coating | Reference Specification |
|---|---|
| **Coal Tar Enamel Coating** | **AWWA C203** |
| **Cement Mortar Lining** | **AWWA C205** |
| **Liquid Epoxy** | **AWWA C210** |

2. Exterior Protective Coatings and Cathodic Protection

**All underground steel pipelines shall be fully protected against corrosion. To meet protection requirements, all pipe must be coated and provided with supplementary cathodic protection as specified below:**

**All buried steel pipelines shall have Class A or Class B Coatings as follows: 1. Class A coating shall be provided if the Resistivity Survey shows that either (a) 20 percent or more of the total surface area of the pipeline will be in soil having a resistivity of 1,500 ohm-cm or less or (b) 10 percent or more of the total surface area of the pipeline will be in soil having a resistivity of 750 ohm-cm or less; 2. All other pipelines shall have Class B coating.**

**Class A coating shall be selected based on consideration of the on-site physical, chemical and biological conditions that may contribute to exterior corrosion of the pipeline, using procedures described in one or more of the design references listed in the Reference Section of this standard.**

**Class A Coating can be selected from one of the following methods if the applied coating meets the requirements of the applicable reference specification:**

| Accepted Type A Coating | Reference Specification |
|---|---|
| **Coal Tar Enamel Coating (Including asbestos felt or inert outer wrap)** | **AWWA C203** |
| **Tape Coating System (80 mil min. thickness)** | **AWWA C214** |
| **Polyurethane Coating (25 mil min. thickness)** | **AWWA C222** |

**Class B Coating can be selected from one of the following methods if the applied coating meets the requirements of the applicable reference specification:**

| Accepted Type B Coating | Reference Specification |
|---|---|
| **Coal Tar Enamel Coating (Excluding asbestos felt or inert outer wrap)** | **AWWA C203** |
| **Epoxy Coating (16 mil min. thickness)** | **AWWA C210 or 213** |
| **Tape Coating System (50 mil min. thickness)** | **AWWA C214** |
| **Prefabricated Tape Coating, 20 mil min.** | **AWWA C209** |
| **Prefabricated Tape Coating, 20 mil min.** | **AWWA C209** |

**Note: Class A coatings are also acceptable for Class B.**

**Coatings on all fittings shall provide equal protection to the specified pipeline coating.**

**Coatings shall be supplemented with cathodic protection if the soil resistivity survey shows that any part of the pipeline will be in soil whose resistivity is less than 10,000 ohm-cm. Pipe to soil potential shall be not less than 0.85 V negative, referred to as a copper/copper sulfate reference electrode, with the cathodic protection installed. The initial anode installation shall be sufficient to provide protection for a minimum of 15 years.**

Galvanized steel pipe may be used when the soil resistivity is greater than 4000 ohm-cm. Hot-dipped asphalt or polymeric-coated, galvanized steel pipe shall be provided if the soil resistivity along any part of the pipeline is between 3000 and 4000 ohm-cm. In addition to the above coatings, cathodic protection shall be provided for galvanized steel pipe if the soil resistivity is less than 3000 ohm-cm.

Aluminized steel pipe may be used when the soil resistivity is greater than 1500 ohm-cm and the soil pH is between 5 and 9.

Aluminum alloy pipe may be used when the soil resistivity is greater than 500 ohm-cm and the soil pH is between 4 and 10.

When cathodic protection is required, joints and connecting bands shall be electrically bridged to ensure continuous flow of current. A dielectric connection shall be placed between the pump and the pipeline and between pipes with different coatings.

The total current required, kind and number of anodes needed, and life expectancy for the cathodic protection shall be designed in accordance with NRCS Design Note 12, Control of Underground Corrosion.

**All metal to metal fittings, such as risers, bends, tees, and reducers, should be of similar metals. If dissimilar metals are used, the fittings shall be protected against galvanic corrosion (e.g., separate dissimilar metals with rubber or plastic insulator).**

**Bolts used to join galvanized steel shall be galvanized, plastic coated, stainless steel, or otherwise protected to prevent galvanic corrosion. Bolts used to join aluminum, other than aluminum alloy bolts, must be plastic coated or otherwise protected to prevent galvanic corrosion.**

CC. Resistivity Measurement Requirements for Metal Pipe

If risk of corrosion is "high" based on the Cooperative Soil Survey's Soil Features Report, soil-resistivity measurements shall be conducted to determine corrosion protection requirements. .For this purpose, field resistivity measurements shall be made or samples for laboratory analysis shall be taken at least every 400 feet along the proposed pipeline and at points where a visible change in soil characteristics occurs. If adjacent readings differ markedly, additional measurements shall be taken to locate the point of change. Resistivity determinations shall be made at two or more depths in the soil profile at each sampling station; with the lowest depth at the stratum in which the pipe will be laid. The lowest value of soil resistivity found at each sampling station shall be used as the design value for that station.

After the pipe trench is excavated, a detailed soil resistivity survey shall be made as a verification of the final required cathodic protection. At this time, resistivity measurements shall be made in each exposed soil horizon at intervals not exceeding 200 feet. The lowest value of soil resistivity found at each sampling station shall be used as the design value for that station. If design values for adjacent stations differ significantly, additional intermediate measurements shall be made.

DD. Electric Fields

An electric field can develop where a metal pipeline is installed adjacent to an existing metal pipeline. This situation can adversely affect the new pipeline. The new pipeline shall be adequately protected from this condition.

EE. Environmental Constraints for Aluminum Pipe

Water quality shall be considered for aluminum pipeline installations. A copper content in excess of 0.02 ppm produces nodular pitting and rapid deterioration of the pipe if water is allowed to become stagnant. When the copper content exceeds this limit, the pipeline shall be designed to allow draining after each use.

Protection from corrosion shall be provided for aluminum pipe installed in contact with concrete.

FF. Environmental Constraints for Concrete Pipe

Concrete pipelines shall not be installed on sites where the sulfate-salt concentration in the soil or soil water exceeds 1.0 percent. On sites where the sulfate concentration is more than 0.1 percent but not more than 1.0 percent, concrete pipe may be used only if the pipe is made with Type V or Type II cement, with tricalcium aluminate content not exceeding 5.5 percent.

## V. CONSIDERATIONS

**General.**

**Careful consideration should be given to determining the "working pressure" of pipelines.**

- **For example, for pipelines with downstream controls or in-line valves, consider the working pressure to be the static head on the pipeline at that point, rather than the pressure in the pipe under flowing conditions.**
- **Consider, also, the possibility of in-line valves being installed in open-flow pipelines in the future.**
- **For gravity flow, static head is typically defined as the pressure in the pipeline based on the distance between the static water level and the pipe centerline.**
- **For pumped systems, the static head as determined by the distance between the centerline of the pipe and the hydraulic grade line created by the pump "shutoff head" should be considered.**

**Pump shutoff head data can be obtained from the pump manufacturer. If this data is not available, the shutoff head for centrifugal pumps can be estimated by using the formula:**

$$Ps = \left(\frac{dn}{1840}\right)^2$$

**Where:**
**Ps = shutoff head in feet of water**
**d = pump impeller diameter in inches**
**n = speed of impeller, rpm**

**Hydraulic transients (surge pressures) due to valve closures can be minimized by closing the valve slowly. Consider the following:**

- **Avoid the use of quick closing, quarter-turn valves such as lever-operated butterfly valves, if possible.**
- **Specify slow closing valves, geared valve operators, "anti-slam" air valves, non-slam check valves, or other similar devices.**

**During construction, consider separation of pipe at the joints due to thermal contraction of exposed pipe. This can occur if the pipe is assembled when temperatures are warm, and allowed to cool overnight without backfill.**

**Safety.** Pipelines may present a threat to the safety of people **and property**, during both installation and operation. Consider safety as follows:

- Address trench safety in design and during construction.
- Provide protection for people from inlets of pipelines and open stands.
- Provide protection for people from water blowing from pressure-relief, air-release, and other valves.
- Determine the existence or non-existence of underground utilities prior to construction.

**Protection of Pipeline and Appurtenances. Consider protection of the pipeline and all appurtenances from potential damage:**

- **Locate and/or protect the pipeline and aboveground appurtenances and control structures to minimize potential damage from equipment and tillage practices.**
- **Protect all aboveground appurtenances and control structures from possible damage by livestock and wildlife.**

**Economic.** Economics can be a major factor in pipeline design, as follows:

- Select pipe based on lifetime energy requirements, as well as initial costs of materials.
- Select pipe material based upon expected life of practice.

**Water Quality and Quantity.** The effects of an irrigation pipeline on water quality and quantity should be considered when designing an irrigation pipeline. Consider the effects:

- On the water budget, especially on infiltration and evaporation,
- On downstream flows or aquifers that would affect other water uses or users,
- On potential use for irrigation management,
- Of installing a pipeline in vegetation that may have been located next to the original conveyance,
- Of installing the pipeline (replacing other types of conveyance) on channel erosion or the movement of sediment and soluble and sediment-attached substances carried by water,
- On the movement of dissolved substances into the soil and on percolation below the root zone or to ground water recharge,
- Of controlled water delivery on the temperatures of water resources that could cause undesirable effects on aquatic and wildlife communities,
- On wetlands or water-related wildlife habitats, and
- On the visual quality of water resources.

**Environment.** Base pipe material selection on exposure considerations (such as soil resistivity, pH, sunlight, and traffic). Soil texture, resistivity, pH, moisture content, redox potential and depth are important soil properties to be aware of for pipelines and in reducing soil limitations related to corrosivity, or packing of soil material. Refer to soil survey information of the area and on-site soil investigations should be considered during planning **and design process**.

The Langelier Saturation Index and related indices may be a factor in determining type of material to use for a pipeline.

Pipelines installed below the ground surface should have a soil plan describing soil reconstruction of disturbed soil during and after pipeline installation so original soil productivity is restored after pipeline installation.

Appropriate vegetation should be established to stabilize disturbed areas that will not be cropped.

## VI. PLANS AND SPECIFICATIONS

Prepare plans and specifications for irrigation pipelines that describe the requirements for applying the practice according to this standard. As a minimum the plans and specifications shall include:

- A plan view of the layout of the pipeline.
- Profile of the irrigation pipeline.
- Pipe material and sizes.
- **Locations and details for all appurtenances and control structures.**
- **Locations and specifications for all thrust blocks.**
- Pipe joint requirements.
- Site specific construction specifications that describe in writing the installation of the irrigation pipeline. Include the specification for pressure testing of the irrigation pipeline.
- Depth of cover and backfill requirements.
- Disposal requirements for excess soil material.
- Vegetative establishment requirements.

## VII. OPERATION AND MAINTENANCE

An Operation and Maintenance (O&M) Plan shall be developed for each pipeline system installed. The plan should document needed actions to ensure that practices perform adequately throughout their expected life.

O&M requirements shall be included as an identifiable part of the design. Depending on the scope of the project, this may be accomplished by brief statements in the plans and specifications, the conservation plan narrative, or as a separate O&M Plan.

Other aspects of O&M, such as draining procedures **for the pipeline and all valves and appurtenances**, marking crossing locations, valve operation to prevent pipe or appurtenant damage, appurtenance or pipe maintenance, and recommended operating procedures, should be described as needed within the O&M Plan.

Monitoring of any cathodic protection systems shall be performed as specified in the O&M Plan.

A filling procedure shall be developed, which details allowable flow rates and appurtenance operation at the various phases of the filling process, required to assure safe filling of the pipeline. Flow measuring appurtenances such as flow meters or weirs, or other means (e.g., number of turns of a gate valve) should be used to determine the rate of flow into the pipeline system. This information shall be provided to the operator, and shall be incorporated into the Operation and Management Plan as appropriate.

## VIII. REFERENCES

**ANSI/ASAE Standard S376.2 Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipelines, American Society of Agricultural and Biological Engineers, St. Joseph, MI, 2004.** (http://www.asabe.org/ [**as of 2/22/2010])**

ASTM C118, Standard Specification for Irrigation Pipe for Irrigation or Drainage

ASTM C505, Standard Specification for Nonreinforced Concrete Irrigation Pipe with Rubber Gasket Joints

**Handbook of PE Pipe, Second Edition, Plastics Pipe Institute, Irving, TX 75062** (http://www.plasticpipe.org/publications/pe_handbook.html **[as of 2/22/2010])**

**Handbook of PVC Pipe: Design and Construction, Fourth Edition, Uni-Bell PVC Pipe Association, Dallas, TX 75234** (http://www.watermainbreakclock.com/handbook/ **[as of 2/22/2010])**

**Handbook of Steel Drainage and Highway Construction Products, AISI**

**Seipt, W.R. 1974. Waterhammer Considerations for PVC Pipeline in Irrigation Systems. Transactions of the ASAE 17(3): 417-423**

**Steel Pipe – A Guide for Design and Installation, AWWA M11**

NRCS, Engineering Design Note 12, Control of Underground Corrosion

NRCS, National Engineering Handbook, Part 636, Chapter 52, Structural Design of Flexible Conduits

**Technical Note, Engineering #16, Air Vents, Vacuum Relief Valves, And Pressure Relief Valves In**

**Pressurized Systems, NRCS, Washington, October 2009**