UNDERGROUND PETROLEUM PIPING SYSTEMS

New York State Department of
Environmental Conservation
Bulk Storage Section
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I. Purpose
This bulletin is written for those who are seeking technical information on installing new underground petroleum pipelines. The bulletin addresses piping requirements covered by both the New York State Petroleum Bulk Storage Regulations and the Federal Underground Tank Regulations. It also discusses good engineering practices for preventing pipe leaks.

II. **State Requirements**

In December of 1985, the Department of Environmental Conservation established installation and equipment standards for all new underground storage facility pipelines. These standards apply to petroleum storage systems where the combined capacity exceeds 1,100 gallons, exempting on-premises heating oil tanks where the capacity is less than 1,100 gallons.

The standards, which are discussed in Section 614.14 of the Petroleum Bulk Storage Regulations, require that all new underground pipelines be as follows:

- pipes must be either constructed of;
  - a non-corrodible material such as fiberglass reinforced plastic, nylon or engineered thermo-plastic, or
  - metal such as steel with a cathodic protection system designed to protect it for 30 years.

- pipes may be in single or double-walled construction;

- access ports must be installed to permit tightness testing;

- installation must be in accordance with recognized engineering practices, and

- pipes and joints must be tightness tested before being covered and placed in use.

Other system requirements include impact valves at dispensers of motor fuel, overfill prevention equipment and a line leak detector for systems where the piping is operating under pressure. Suction systems must not be equipped with more than one check valve.

Each of these requirements is discussed in more detail below.

1. **Pipe Materials and Designs**

1.1 **Double Walled vs Single Walled Pipe** - Although the Department allows the use of single-walled underground pipe, double-walled pipe is encouraged. Double-walled pipe not only provides a higher level of environmental protection but because the space between the inner and outer wall can be readily checked for leaks, it provides the owner with the most efficient and cost
effective method of performing leak detection. With the advent of the flexible piping system, double-walled, piping with fewer joints has become easy and economical to install.

1.2  **Flexible Piping Systems** - Flexible pipe made of non-corrodible material complies with the Department’s underground piping regulations. The pipe which can be purchased in continuous rolls, typically several hundred feet in length, is installed in single long runs. There is no need for pipe fittings to extend the length of the line or change directions.

Most manufacturers offer pipe with nominal internal diameters between 1.5 and 2 inches. A few offer lines as small as 1 inch diameter (for heating oil applications) and as large as 3 inches.

Flexible piping has several advantages. Although the cost per foot for flexible pipe is higher than for rigid pipe, it has lower installation costs that may run as much as 70% below the costs for rigid piping. A typical system requires only one or two days to install. Total cost which include both the cost of pipe and installation is about the same as rigid piping. A second advantage is that because there are fewer joints and connections, fewer leaks occur over the life of the system. Double-walled flexible pipe has advantages over multi-jointed double-walled systems where making tight joints for both the inner and outer wall can be difficult to accomplish.

Although the installation of flexible pipe is generally simpler than that for rigid pipe, installers must be trained and the proper accessories must be used if environmental protection is to be maximized.

Mechanical leak detectors and continuous leak detectors seem to function adequately on pressurized flexible lines. Annual tightness tests can be readily performed, but the tester must be aware of the differences between the behavior of flexible pipelines and rigid pipelines. Suction systems may have some problems using flexible lines - check with manufacturer first.

Flexible pipe is constructed of polymeric compounds including nylon, polytetrafluoroethylene (PTFE or Teflon), high density polyethylene and proprietary composites. Pipes are generally strengthened with reinforcements of fiberglass, steel wire, or polyester braids. Most are layered with fuel resistant lining on the inside, a stronger intermediate layer and an outer abrasion resistant covering. Because these materials do not corrode, cathodic protection as for steel pipelines is not needed.

The elasticity of flexible pipe varies considerably from soft to somewhat rigid. Because of their inherent flexibility, they are sometimes pulled through a 4 inch flexible carrier pipe that serves as both a protective sleeve that enables future pipe replacement without excavation and as a secondary containment chamber that can be monitored for leakage.

All of the flexible pipe is available with secondary containment. These secondary containment systems are not intended to hold the working pressure of a pipeline, but can convey
leaks to a sump area where the product can be detected.

One safety concern involves the connection of flexible pipelines to the dispenser. In the event of a fire, the pipe could melt immediately below the emergency shut-off valve, increasing fire intensity. This problem can be mitigated by installing a fire rated flex connector or steel segment of pipe down to the flexible piping, or by covering the pipeline in the sump areas with gravel.

Compatibility and permeability are important characteristics of any containment systems, but the terms are often confused. Compatibility is the ability of a material to retain its physical properties when exposed to another substance. Permeability is a measure of the amount of a substance that migrates through a material over a given time period. For example, polyethylene is compatible with petroleum products. This means that it does not significantly dissolve, degrade, or fall apart when in contact with petroleum products. However, polyethylene is relatively permeable to petroleum products. This means that the liquid level in a tightly sealed polyethylene container filled with gasoline would slowly decrease over time as gasoline molecules migrate through the walls of the container.

To date, problems with flexible piping systems have been limited to fungal decay of first generation polyurethane coated piping. The fungal decay is mostly cosmetic and does not cause pipe failure, however, one manufacturer has changed the outer layer of pipe to polyethylene. Most manufacturers are now marketing third and fourth generation products. Problems with these systems have been infrequent, and manufacturers have stood by their products. From an environmental protection standpoint, the performance of this technology to date has been excellent.

There are several manufacturers of flexible pipeline systems. These are listed in Appendix 1. It is possible that other manufacturers exist or that new pipeline materials may enter the market in the future. Appendix 2 summarizes technical information on these systems.

1.3 Fiberglass Piping - Rigid Systems - Fiberglass reinforced plastic (FRP) may also be used to meet the Department’s standard for new underground piping. FRP is used in a variety applications. It is suitable for high pressure and low temperature service and is compatible with alcohols, petroleum and other chemicals when the resins used in the manufacture of FRP are matched with the chemical to be stored. FRP offers the advantage of corrosion resistance, low weight, low maintenance and economy of installation over a longer life expectancy.

Since FRP pipe has a lower structural strength, 3 times less than steel pipe, it requires extra caution in handling and installation. Cold weather installation is also a problem due to the very brittle nature of FRP and the difficulty of curing the pipe joints when temperatures drop below 50°F.

FRP piping involves the joining together of pre-sized lengths of pipe with joint adhesive. Typically these lengths are 15-30 feet long. Because an underground system can involve dozens of joints, it is essential that all joints be constructed in strict accord with manufacturers instructions. When connecting these sections, installers must maintain the joints at temperatures above 50°F for several hours to ensure proper curing and sealing of the adhesive. The pipe,
fittings and adhesive should all be compatible to ensure proper thermal welding of connections.

Because of the many joints and elbows inherent in rigid piping, constructing a double-walled FRP systems can be problematic, relying on mechanical connections and boots to ensure integrity of secondary containment.

**Don’t** confuse fiberglass reinforced plastic piping with ordinary plastic piping such as PVC and polyethylene which are not as strong or compatible with petroleum products as FRP.

The most common design standard for FRP pipes is the Underwriters’ Laboratories Standard UL971, “Non-metallic Underground Piping for Flammable Liquids.” Underwriters’ Laboratories also have a listing of FRP products which are approved for underground petroleum service. Any of these UL approved pipes are accepted by the DEC. Underwriters’ Laboratories can be contacted by calling (847) 272-8800.

For more information on rigid FRP systems, contact the Fiberglass Tank and Pipe Institute in Houston, Texas at (713) 952-2962.

1.4 **Metallic Piping Systems** - Since the passage of the Petroleum Bulk Storage Regulations in 1985, the Department has required that new underground metal pipelines be cathodically protected. Although for many years galvanized steel pipe was widely used at gasoline service stations, it is now recognized as unsuitable for underground use. The zinc coating designed to protect the piping against aboveground conditions was not adequate for corrosive conditions underground. Moreover, when the pipe was threaded, some of the coating and wall thickness was cut away, making these areas especially vulnerable to corrosion.

Today, galvanized steel piping is seldom used for underground petroleum service. If steel is used, the Department requires that it have a protective coating and either an impressed current or sacrificial anode system. A galvanized coating of pipe is *not* acceptable by itself. The pipe must be wrapped with dielectric tape or have a polyethylene, epoxy or urethane coating. Coatings must be dielectric; i.e., they must be resistant to the flow of electric current.

Impressed current or sacrificial anode systems must be designed and installed under the supervision of a qualified corrosion engineer. The standards to be followed by the corrosion engineer in designing the cathodic protection system is “NACE Standard RP 0169-96, Recommended Practice-Control of External Corrosion on Underground or Submerged Metal Piping Systems”. This is available from the National Association of Corrosion Engineers, Box 218340, Houston Texas 772180, Phone (281) 492-0535.

Both impressed current and sacrificial anode system require annual monitoring to ensure they are functioning properly. The methods for monitoring are discussed in Appendix 3. Impressed current systems rely on electrical current from the power company which must remain on at all times. If turned off, corrosion can actually be enhanced. Therefore, power should not be controlled by conventional switches. Switches should not be readily available to unauthorized personnel, and should also be protected against unauthorized disconnection. Maintenance of the system involves periodic checks of the ammeter to ensure that the system is
operating properly.

Appendix 3 contains further discussion of corrosion and cathodic protection systems.

Vent lines and fill pipes are exempt from the cathodic protection requirement, as they are not used for product transport and are therefore less likely to release product to the environment. They do, however, require some type of protection against corrosion. Galvanized steel alone, or steel/iron piping with any of the previously mentioned acceptable coatings are sufficient corrosion protection for these purpose.

Stainless steel and copper are sometimes considered for use as underground piping. While stainless steel is more corrosion resistant than carbon steel, it should not be assumed that it is suitable for use underground without cathodic protection. Because there are several different types of stainless steel, different type of connections (welded or screwed) and varying corrosive environments, a corrosion engineer should be consulted to ensure that the system truly has a 30 year life expectancy as required by the State regulations.

Copper piping is uncommon except when used for 1/2" feed lines to furnaces. Although copper is more corrosion resistance than steel, it is nevertheless subject to corrosion. Oxidizing agents rapidly corrode copper. Copper may also be susceptible to deterioration in acidic soils. Cathodic protection may therefore be required unless soil tests show that cathodic protection is unnecessary. One way to avoid cathodic protection is to enclose the copper pipe inside a plastic (FRP or PVC) pipe. By eliminating contact with water and corrosive environments, it is possible to reduce the risk of failure due to corrosion. Because of the inherent weakness of copper, only Type K or Type L copper should be used for piping.

1.5 **Piping in Non-Corrodi ble Encasement** - Any piping system that is isolated from a corrosive environment (soil) by use of a non-corrodible outer pipe or an encasement may also be exempt from the requirement for cathodic protection. For this type of system to be acceptable, the outer pipe or encasement must be made of a non-corrodible water-tight material such as PVC pipe. When an outer pipe is used, there must also be some type of monitoring system to ensure that the encasement contains no breaches in its surface. This can be easily accomplished by sloping the pipe toward a sump or some other collection system where the presence of water or product can be detected.

2. **Access Ports for Future Testings**

To eliminate the need for extensive excavation when performing a tightness test, Section 614.14(e) of the State Regulations requires that all new underground piping systems be designed, constructed and installed with access ports. There are two known methods of providing access for testing. Access may be provided simply by disconnecting the pipeline at the dispenser (usually at service stations). The pipe may then be pressurized against the check valve at the other end and monitored for leakage. Also, if double-walled pipe is used, then the sump to which the pipe runs, meets the requirement for an access port.

If it is not possible to obtain access at a dispenser, then a manway through which all
piping passes must be installed as required by the regulations.

3. **Installation of Piping System**

   The Section 614.14(f) of the PBS regulations requires that all underground piping systems be installed in accordance with recognized engineering practices. The industry standards for the installation of underground tanks including piping systems are PEI RP 100-97, *Recommended Practices for Installation of Underground Liquid Storage Systems*, and API 1615, *Recommended Practices for Installation of Underground Petroleum Storage Systems*.

   The major points in underground piping system installation are as follows.

   3.1 **Trenching and Bedding** - Whenever possible, product lines should be run in a single trench between the tank area and pump island area. Vent lines between the tank area and the building or other structure to which the aboveground vent lines are attached should also be installed in a single trench. (See Figure 1). Where more than one trench is needed, lines should not cross each other or cross over underground tanks.

   The trench should be large enough so that it provides a distance between any two adjacent pipes at least twice the nominal pipe diameter, and a distance between the piping and the trench excavation walls at least six (6) inches. Pipes should have at least six (6) inches of wall-compacted backfill and pavement for adequate protection from the loads of surface traffic. (See Figure 2). For an installation of three 2" diameter pipe, the trench would be 26" wide and a minimum of 26" deep.

   ![Figure 1 - Piping Layout](image)

   **Figure 1 - Piping Layout**

   Product and vent piping should have a uniform slope toward the tank of not less than ½ inch per foot. They should be evenly and adequately supported to prevent creation of traps or sumps. (See Figure 3)
Steel piping may be backfilled with clean, inert, well compacted sand, pea gravel, or crushed stone, while flexible piping and rigid FRP piping should only be backfilled with sand or pea gravel (not crushed stone). Before covering the pipe, any rocks, debris, chocks, ice, snow, organic materials, or bracing used during construction should be removed.

Before backfilling a non-metallic system, a metal tape or copper wire should be laid beside the piping system so that the piping system could be relocated in the future using a metal detector.

3.2 **Manufacturer’s Instructions** - In addition to the industry standards cited above, installers should follow manufacturer’s instructions. Each product will have somewhat different installation specifications.

Flexible piping systems require wide sweeping turns with an 18" to 36" minimum bend radius and may have some problems with suction system - check with the manufacturer first.

For FRP systems, good pipe joints are vital to a tight systems. Pipe joints must be straight and must be fully seated. The joint adhesive used must conform to the manufacturer’s recommendations for underground petroleum service and must not be used at temperatures below the recommended minimum.

For steel systems, cathodic protection system including coating, wrapping, and galvanic anodes or an impressed current system for metallic piping must be designed by a corrosion engineer or pursuant to standards set forth in PEI RP 100-97,

Installation of unions underground is not recommended. If unavoidable, the unions
should be at least schedule 80 or higher. Couplings furnished to protect metallic pipe threads are not generally suitable for use underground. Dispensers, submerged pumps, check valves, or other metallic components, not intended to be protected by the cathodic protection system provided for the piping, should be electrically isolated. This would be done by providing dielectric bushings at the tank top and dielectric unions under the dispenser. Dielectric unions should be 600 X.H. psi or heavier.

3.3 Flexible Connectors - Frost heaving and subsidence can damage underground pipes, especially when the pipe is connected to a fixed object such as a pump dispenser. Flexibility must be provided for FRP and steel piping at the tank, under the dispenser, and where the piping changes direction. This facilitates alignment of piping and equipment, also provides for differential movement and relieves stress. Flexible connectors should be used instead of swing joints or closed elbows for direction changes (See figure 4).

Figure 4 - Flexible Connector

4. Inspection and Testing of New Systems

4.1 System Inspection - Inspection is one of the most important steps to installing a trouble-free piping system. When the materials arrive on site, piping, including coatings, should be inspected for signs of damage. Inspection should continue during handling, installation, testing and backfilling to ensure that damage does not occur and that the system is installed pursuant to PEI RP 100-97.

4.2 Tightness Testing of Primary Piping - Before the piping system is backfilled, it should be isolated from the tanks and subjected to a pipe tightness test.

For metal and flexible piping systems, the piping is pressurized with air to 1.5 times the operating pressure of the system, but not less than 50 psig for 1 hour, soaping all joints and inspecting for bubbles. The importance of this test is to prove that the contractor has indeed installed a tight system, which can eliminate future liability on his part.

For FRP piping, air and soap tests are now discouraged by the manufacturers. Instead, they recommend hydrostatic testing at 110 percent of normal operating pressure, but not less than 50 psig, and inspection for visible leaks.

If the piping system has ever held product or has been backfilled, the piping system should be hydrostatic tested as noted above for FRP piping or a line tightness test should be used such as the Petro-Tite Line Tester.

4.3 Tightness Testing of Secondary Containment - If secondary containment piping is used, it should also be tested for tightness before it is backfilled. For non-flexible piping, test with air at 10 psig. For flexible secondary piping, test with air at 5 psig. Precise test pressure
and testing procedures for secondary piping are prescribed by each manufacturer and should be strictly followed.

Impervious barriers, if used, should be inspected to determine whether any damage has occurred before being covered. Liner manufacturers provide instructions for proper testing of their products as well as instructions for making any repairs. Replace the liner or repair any damage in accordance with the manufacturer’s instructions. This work should be performed only by a liner manufacturer-trained personnel.

4.4 Testing of Corrosion Protection System - For steel piping with a cathodic protection system (galvanic anodes or an impressed current), the cathodic protection system must be tested within three (3) to six (6) months after installation. The test for electrical continuity between the tank and associated piping must be performed. If dielectric bushings, flanges, or unions are installed, no continuity should exist between the tank and piping.

The owner/operator should keep a copy of all final test results and operating instruction.

5. Other System Requirements

5.1 Shear (Impact) Valves - Section 613.3(c)(1) requires that all dispensers of motor fuel under pressure from a remote pumping system be equipped with a shear (impact) valve which is located in the supply line at the inlet, below grade, of the dispenser. The valve must be designed to close automatically in the event that the dispenser is accidently dislodged from the inlet pipe.

The valve must be designed to close automatically in the event that the dispenser is accidently dislodged from the inlet pipe. Figure 5 is an example of this kind of valve.

5.2 Spill and Overfill Prevention Equipment - New underground storage tank fill systems must be equipped with spill and overfill prevention equipment pursuant to Section 614.14(g)(1). This should include: 1) a spill catchment basin which is installed around the fill port and is capable of containing any spillage which might occur during the filling process; and 2) an automatic shutoff device such as the fill pipe shutoff and venturi shutoff. As an alternative to the automatic shutoff device, an overfill alarm may be used.

A float vent valve (also called a ball valve) is not an acceptable means of providing overfill prevention pursuant to 614.14(g)(1), except for gravity drop systems employing a submersible pump and where the carrier is trained to recognize an imminent overfill. If a float
vent valve is used, a permanent label warning against pump filling must be affixed at the fill port.

For a further discussion of overfill prevention equipment, see SPOTS Memo #6, “Overfill/Spill Prevention Equipment For Petroleum Storage Tanks.”

5.3 **Pipe (Line) Leak Detectors** - Petroleum is transported in pipes in one of two ways; by pressure, using a remote pump in or near the tank or by suction using a suction pump under the dispenser. If a leak occurs, a pressurized pipe will result in a larger spill than a pipe operating under suction.

Section 614.14(g) of the State Petroleum Bulk Storage Regulations requires that all pressurized piping systems built after December 1986, be equipped with a line leak detector capable of detecting pressure or product loss on the discharge side of a delivering pump.

Line leak detectors are operated by using: 1) a pressure-sensing-and-reacting mechanism to signal if there is a leak, or 2) a sensor to determine if there is a detected product and/or water existing in the space being measured. The latter devices are mostly used in interstitial spaces as those in the double-wall tanks or double-wall pipes. Appendix 4 is an illustration of the pressure-sensing-and-reacting line leak detector.

Most importantly, an owner/operator should be prudent in choosing a system that has been evaluated and accepted by a nationally recognized testing organization.

These detectors should be tested for proper operation at least annually or in accordance with their manufacturer’s instructions.

Leak detectors are not required on suction systems because leaks are easily detected by the decrease in product flow they cause, and also because air is pulled in through a leak rather than product being forced out of pipe.

Section 614.14(g)(4) requires new underground piping systems employing a suction pump to be equipped with only one check valve. A check valve (also referred to as an unidirectional valve) is a valve which is opened by the fluid flow in one direction and which closes automatically to prevent flow in the reverse direction. Figure 6 shows a piston lift check valve in a globe shape.

III. **Federal Requirements**

In addition to the State requirements outlined above, the US Environmental Protection Agency enforces Federal Underground Storage Tank (UST) Regulations (40 CFR 280) which impose two added requirements; 1) pipes must be upgraded by December 22, 1998 and 2) pipes must be monitored for leakage.
1. **Upgrading**

Upgrading means that new pipes meeting DEC’s requirements must be installed, or existing pipes must be retrofitted with cathodic protection using an impressed current system designed and installed under the supervision of a qualified corrosion specialist. Sacrificial anodes are inadequate for existing uncoated piping systems. A discussion of impressed current systems can be found in the Appendix 1.

2. **Leak Monitoring**

Since December 1993, EPA has required leak detection for all federally regulated underground pipes. EPA requires that pressurized pipe meet the following:

- Pipes must have devices that automatically shut off or restrict flow, (such as the leak line leak detector discussed under State regulations) or pipes must have an alarm that indicates a leak with a sensibility as small as 3 gph at a line pressure of 10 psi.

- Pipes must be tightness tested annually, or one of the following monthly methods may be used: interstitial monitoring, vapor monitoring or groundwater monitoring or statistical inventory reconciliation.

If suction piping is used, leak detection may or may not be required, depending on the system. No leak detection is needed if the system is sloped so that the pipe contents will drain back into the storage tank if the suction is released, and the system has only one check valve. This check valve must be located directly below the suction pump.

Suction piping that does not exactly match the characteristics noted above must have leak detection which consist of either monthly monitoring (using one of the monthly methods noted above for use on pressurized piping) or tightness testing every 3 years.
## APPENDIX 1

List of Manufacturers of Flexible Pipeline Systems

<table>
<thead>
<tr>
<th>Name of Manufacturers</th>
<th>Contact / Address</th>
<th>Telephone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Polymer Technology, Inc.</td>
<td>Bob Versaw 28605 County Road 6 Elkhart, IN 46514</td>
<td>(616) 759-9112</td>
</tr>
<tr>
<td>Ameron Fiberglass Pipe Systems</td>
<td>Reid Van Cleave 5300 Holister St. Suite 111 Houston, TX 77040</td>
<td>(713) 690-7777</td>
</tr>
<tr>
<td>Buffalo Environmental Products Corp.</td>
<td>Dean Flessas 6720-F Ritchie Hwy #412 Glen Burnie, MD 21061</td>
<td>(410) 553-0170</td>
</tr>
<tr>
<td>Containment Technologies Corp.</td>
<td>Kurt Steinbergs 1650 West 82nd St. Minneapolis, MN 55431</td>
<td>(612) 881-0072</td>
</tr>
<tr>
<td>Environ Products, Inc.</td>
<td>Chris Ursillo 620 Pennsylvania Dr. Exton, PA 19341</td>
<td>(610) 321-0200</td>
</tr>
<tr>
<td>Total Containment, Inc.</td>
<td>Pierre Desjardins 422 Business Center A130 North Dr. Oaks, PA 19464</td>
<td>(610) 666-7777</td>
</tr>
<tr>
<td>Titeflex Industrial Americas</td>
<td>Bill Watkins 603 Hendee Street Springfield, MA 01139</td>
<td>(413) 739-5631</td>
</tr>
<tr>
<td>Western Fiberglass, Inc. (a.k.a. Western FG)</td>
<td>Richard Lewis 1555 Copperhill Parkway Santa Rosa, CA 95403</td>
<td>(707) 523-2050</td>
</tr>
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## APPENDIX 2. Summary of Information Obtained for Flexible Pipelines*

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Number of Installation**</th>
<th>Product Names(s)</th>
<th>Made From</th>
<th>Compatible Fuels</th>
<th>Available Sizes (ID)</th>
<th>UL Listed</th>
<th>Standard</th>
<th>Permeability Test</th>
<th>Pressure to Burst</th>
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<tr>
<td>Advanced Polymer Technology</td>
<td>100</td>
<td>Poly-Tech</td>
<td>Nylon 12; Nylon 6 yarn; Polyethylene piping</td>
<td>Fuel C; Ethanol; Methanol; Gasoline/ alcohol blends</td>
<td>1.75&quot;, 3&quot;</td>
<td>No</td>
<td>Being tested under UL 971</td>
<td>Yes</td>
<td>900 psi</td>
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<td>Ameron</td>
<td>4</td>
<td>Duraloy 3000/FL</td>
<td>Epoxy/fiberglass</td>
<td>Petroleum products; 100% alcohols; alcohol/ gasoline mixtures</td>
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<td>Yes</td>
<td>UL 971</td>
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<td>Buffalo</td>
<td>150</td>
<td>Bufflex</td>
<td>Bufflex II</td>
<td>Thermoplastic tube with high density polyethylene</td>
<td>Petroleum; alcohol and alcohol blends</td>
<td>1&quot;, 1.5&quot;, 2&quot;</td>
<td>No</td>
<td>ANSI B31.3 Yes (but not to UL standard procedure)</td>
<td>&gt;500 psi</td>
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<td>Containment Technologies</td>
<td>20</td>
<td>Flexpipe</td>
<td>Polymers polyethylene tube with fittings</td>
<td>Gasoline; alcohol</td>
<td>No</td>
<td>No</td>
<td>Swedish National Testing Institute</td>
<td>Yes</td>
<td>&gt;5 times operating pressure (not tested to destruction)</td>
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<tr>
<td>Environ Products</td>
<td>400</td>
<td>Geoflex</td>
<td>Fiber-reinforced thermoplastic composite</td>
<td>All petroleum products; alcohols; blends</td>
<td>1.5&quot;, 2&quot;</td>
<td>Currently under testing</td>
<td>UL 971</td>
<td>Yes</td>
<td>725 psi</td>
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<td>Total Containment</td>
<td>3000</td>
<td>Enviroflex Enviroflex II</td>
<td>Engineered thermoplastics</td>
<td>Petroleum products; MTBE; all blends</td>
<td>1.5&quot;, 2.5&quot;</td>
<td>Yes (Petroleum; in process for alc.)</td>
<td>UL 971</td>
<td>Yes</td>
<td>&gt;450 psi</td>
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*some information taken from “Piping Technology”, The Journal of Petroleum Marketing, April, 1993
**estimates obtained from each manufacturer
APPENDIX 3 - Corrosion and Cathodic Protection

A. Corrosion

Corrosion, according to the National Association of Corrosion Engineers, is the deterioration of a material, usually a metal, by reaction with its environment. The material does not have to be metal but is in most cases. The environment in general is the atmosphere, water, or the earth.

All materials in nature have an inherent tendency to revert to their more stable forms when exposed to the environment. This reversion process induces corrosion that occurs as a electrochemical reaction with the surrounding environment. Corrosion may be divided into two broad categories, wet corrosion and dry corrosion.

The wet corrosion occurs in the presence of moisture - water, condensed mixture, steam. Wet corrosion processes are likely to proceed when metals are exposed to the atmosphere, aqueous solutions, or to the soil. Dry corrosion is proceeded by direct attack when the metal is exposed to oxidizing gas at a temperature high enough to preclude the presence of moisture. In the process, it involves the exchange of electrons and the formation of anions (negative charges) and cations (positive charges), and creates anodic (+) and cathodic (-) sites on the metal surface. The whole corrosion reaction is carried out just like a battery cell.

There are four components for the corrosion reaction (an electrochemical reaction) to occur: an anode, a cathode, an electric conductor connecting the anode and cathode, and an electrolyte such as (moist) soils (See Figure A1). They are further explained as follows:

1. The anode (+): the base metal goes into solution (corrodes) by releasing electrons and forming positive metal ions.
2. The cathode (-): the cathode takes the electrons released at the anode and passes them to cations (+) to neutralize the positive charges and complete the chemical corrosion reaction. There is no metal loss at the cathode.
3. The electric conductor from a metal connecting the anode and cathode conducts electrons generated by the corrosion reaction at the anode to the cathode.
4. The electrolyte: the electrolyte can be moist air, water, or moist soil. Positive current flows through the electrolyte from the anode to the cathode to complete the electrical circuit.

Be noted that there are two different current flows indicated here, electron current and conventional current flow. Conventional current flow is a way of referring to current from positive to negative, while electron current flow is the movement of electrons from negative to positive.
Corrosion is usually not limited to a single point. Generally thousands of tiny micro-corrosion cells may occur randomly over the metal surface resulting in relatively uniform metal loss. The severity of corrosion depends upon the magnitude of the electrical potential differences, which are greatly influenced by the chemical, structural, and the characteristics of the metal surface and water or moisture content, chemical composition, conductivity, pH, and temperature of its environment.

There are four types of corrosion further explained below.

A1. Pitting - Pitting occurs in minute locations on metal surfaces where protective films or coatings have broken down. The breakdown is followed by the formation of electrolytic cells, the anodes being the minute areas of exposed metal and the cathodes, the larger surrounding areas of protected metal (Figure A1). The electrical potential difference induces a flow of current resulting in rapid corrosion of the anodes. Pitting processes are accelerated in the presence of chloride ions, especially when combined with such depolarizers as oxygen or oxidizing salts, e.g., ferrous chloride. Once an electrical potential has been established, the solution within the pit usually becomes increasingly acidic and corrosive, even though the surrounding material may be neutral or alkaline.

A2. Concentration Cells or Crevice Corrosion - A crevice is a narrow split or crack in the form of a cleft, rift, or fissure. Common forms of crevices include lap joints and areas of metals under dirt, debris, or moist insulation. Because of its shape, the crevice tends to hold the solution within its boundary, thus chemical reactions occur within the crevice. The chemical reaction depletes the oxygen contained in the crevice solution, it produces differences in oxygen.
Corroded End (Anodic, or Least Noble)

- Magnesium
- Zinc
- Galvanized steel or galvanized wrought iron
- Aluminum
- Cadmium
- Mild Steel
- Wrought iron
- Cast iron
- 13 % Chromium stainless
- 18-8 Stainless type 304
- Lead
- Tin
- Naval brass
- Nickel (active)
- Inconel (active)
- Yellow brass
- Aluminum Bronze
- Red brass
- Copper
- Silicon bronze
- Nickel (passive)
- 18-8-3 Stainless type 316
- Silver
- Graphite
- Gold
- Platinum

Protected end (Cathodic or Most Noble)

The difference in electrode potential between the two metals is the driving force for the reaction and is expressed in units of volts or millivolts. The corrosion damage is proportional to the amount of electrical current that flows as the result of the electrochemical reactions involved. Galvanic corrosion usually produces localized attack, which tends to be most intense at or near the point of dissimilar metal contact.

Table A1 shows the galvanic series of metals and alloys. In the galvanic series of various metals and alloys metals at the top of the list are more reactive (anodic) and have a greater tendency to corrode than those at the bottom of the list.
A4. Stray-Current Corrosion - Stray-current corrosion occurs in buried metallic objects when direct current travels through the soil (electrolyte), and enters and leaves the object, e.g., underground tanks and piping. Stray direct currents (DC) are the most common and potentially the most damaging. These currents are generated from grounded DC electric power operations including electric railroads, subways, welding machines and cathodic protection systems. Stray currents may enter a buried metal structure and travel through the low resistance path of the metal to an area on the structure closure to the current source. Current leaves the structure at this point to return to the source through the soil electrolyte. Corrosion occurs at the area where current leaves the structure (Figure A5).

B. Cathodic Protection

As indicated before, corrosion protection or control is a method to prevent the deterioration of a metal. They are done by three general ways: (1) change the environment, (2) change the material, or (3) place a barrier between the metal and its environment.

To change the environment it often chooses to install sacrificial anodes or impressed current in addition to have a proper bedding for the protected objects, e.g., UST or piping. Both sacrificial (or galvanic) anode and impressed current are referred to as cathodic protection. The principle of the cathodic protection is to make the entire surface of the metal to be protected into a cathode. Corrosion process is not eliminated. It is simply transferred from the metal surface to an external anode.

B1. Sacrificial Anode - The sacrificial or galvanic anode method utilizes a metal anode that is significantly more reactive (higher on the galvanic list) than the tank or pipe material being protected. For steel tanks or pipes, Magnesium or zinc anodes are commonly employed. The anodes are electrically connected to the UST or pipe; a galvanic corrosion cell develops; and the active anode sacrificially corrodes, while the UST or pipe becomes cathodic and is protected. The galvanic cell induces a current flow from the sacrificial or galvanic anode to the cathodic UST or pipe; the current then returns to the sacrificial anode through a metallic conductor (Figure A6). Once this galvanic corrosion cell has been established, it minimizes the potential for general or localized external corrosion processes to proceed by preventing the competing electrochemical reaction to occur.
(APPENDIX 3 continued)

The advantages of the sacrificial anode include:

- no external power supply is necessary
- installation is relatively easy
- cost is low for low current requirements
- maintenance costs are minimal after installation
- interference problems are rare
- current is uniformly distributed and efficient.

The disadvantages are:

- limited driving potential
- low current output, preventing protection of other structures
- possibility of a short life
- not applicable for protecting large bare steel structures
- ineffective protection in high resistivity environments.

Again any sacrificial anode system to be used to prevent corrosion of an underground storage system should be designed and installed by a qualified profession. A regular monitoring program is also necessary after installation to determine that corrosion protection is being maintained.

**B2. Impressed Current** - The impressed-current method utilizes an anode made of relatively inert electrically conductive materials that are subjected to a direct current from a rectifier powered by an alternate current (AC) power source. The system works on exactly the same principle as a sacrificial anode system, except for this external power source (Figure A6). Impressed-current cathodic protection is often the most economical way to control corrosion of existing buried steel petroleum storage tanks and distribution piping systems.

Materials commonly used include graphite, high-silicon cast iron, platinized niobium, tantalum, or titanium. Anodes can be located in remote ground beds, in deep wells, or distributed closely around the structure. Whenever possible, anodes should be installed in carbonaceous backfill, which provides good electrical contact and reduces the total circuit resistance by lowering anode-to-soil resistance.

A proper installation of the system is critical to the performance of the system. The negative lead of the rectifier must be attached to the UST or pipe. All connections and wire splices should be waterproofed and covered with electrical insulating material. Backfill should be free of sharp stones so as to prevent damage to wire insulation. A permanent soil-access manhole should be provided so that the cathodic protection system can be monitored and tested.
(APPENDIX 3 continued)

The advantages of the impressed-current method are:

- large driving potential
- high current output capable of protecting other underground steel structures with a low operating cost
- possibility of flexible current output
- applicability to almost any soil resistivity
- anode does not degrade.

The disadvantages are:

- may cause interference problems on foreign structures
- possible to switch off current and eliminate protection
- must be monitored and maintained on a regular schedule
- more expensive
- over-protection induced coating damage
- monthly power bills

Figure A6 - Sacrificial Anode/Impressed Current
1. **The Down position.** Under normal conditions, the lines are filled with product. When the system pressure is less than 1 psi, the piston and poppet are in the down position. At down position it allows approximately 1.5 to 3 gpm flow into the delivery line through a bypass opening in the PLD valve poppet when the pump starts. Since the system is full, pressure builds rapidly and the poppet moves to the leak sensing position assuming there is no leak. The pressure relief valve prevents any pressure build up under piston when in down position by allowing relief of trapped product.

2. **Leak Sensing Position.** As the pressure builds to about 20 to 22 psi, the piston has moved the poppet to such a position as to almost stop the flow into the piping through the poppet. In this position, all the flow must then travel around the metering pin which limits it to approx. 3 gph. If a simultaneous loss from the system equals or exceeds this amount, the line pressure will not build beyond this point and the valve will remain in the leak sensing position with the main flow blocked. If there is an attempt to dispense while the valve in this position, the line pressure will drop, the piston will respond, and the poppet will return to Position 1 where the 1.5 to 3 gpm will flow to the dispensers. Leaks smaller than 3 gph will be indicated by the PLD taking longer than 2 seconds to open completely. If there is no leakage in the system, the small flow around the metering pin increases the line pressure to 22 psi in about 2 seconds at which point the piston will snap the poppet to Position 3, allowing full flow. Any product relieved through pressure relief valve during down position will be vented through vent tube to tank. This allows piston to move freely with no back pressure to hamper its movement.

3. **Non-Leak Position.** This position allows full flow. The poppet will remain in this position as long as the system pressure remains above 1 psi. At less than 1 psi, the poppet will return to Position 1 and next time the pump is activated, the PLD will perform a line test.