PUBLIC WORKS TECHNICAL BULLETIN 420-49-6
31 MAY 1996

THE USE OF PLASTIC PLUMBING MATERIALS: LESSONS LEARNED

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DEPARTMENT OF THE ARMY
U.S. Army Center for Public Works
7701 Telegraph Road
Alexandria, VA 22315-3862

Public Works Technical Bulletin No. 420-49-6

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FACILITIES ENGINEERING
Maintenance and Repair

THE USE OF PLASTIC PLUMBING MATERIALS: LESSONS LEARNED

1. Purpose. This Public Works Technical Bulletin (PWTB) provides information on problems identified and remedies used with plastic plumbing materials both within and outside the Army.

2. Applicability. This information applies to all Army installations responsible for installation, operation, and maintenance of plastic pipe and plumbing systems as well as fiber-reinforced plastic underground storage tanks.

3. References.

a. Army Regulation (AR) 420-49, Heating, Energy Selection and Fuel Storage, Distribution and Dispensing Systems, 22 June 1990.

b. AR 420-46, Water Supply and Wastewater, 1 May 1992.

c. AR 420-70, Buildings and Structures, 29 May 1992.

d. AR 420-54, Air Conditioning and Refrigeration, 5 November 1990.

4. Background.

a. Plastic materials have been used for plumbing applications since the mid-1940s. Once introduced, their use has increased steadily, primarily due to economics. (Plastic pipe of 6-in. diameter or less on a first-cost basis is less to purchase, transport, and install than metallic pipe of the same size and service. For larger diameters, the relatively low cost per pound of metals used for pipe manufacture offsets those cost advantages for plastics.) Plastic pipes are lightweight and typically require much less labor and equipment to handle and install than metallic pipe. The pipes are not susceptible to corrosion, so the requirement for the cathodic protection needed for metallic pipe is eliminated. In some applications, plastics are used where reactivity or compatibility problems occur with copper, iron, or steel pipe. These advantages, together with research and development efforts aimed at improvements in materials and installation techniques, have provided stimulus for the growth in the use of plastic pipe.

b. All materials have their own set of problems unique to the material and application. Plastic plumbing materials are no exception. While plastics solve some of the drawbacks of metal plumbing materials (i.e., corrosion, weight, scaling, etc.), they create a unique set of plumbing deficiencies. For many plumbing applications (i.e., high temperature water or steam lines and high pressure steam or gas lines), plastics will not work at all or they perform far inferior to metallic materials. For other applications, plastic materials will work as well or better than metals, if properly installed.

c. Army guidance restricts the use of plastic plumbing materials in some situations. For example, use of plastic plumbing is restricted to the first three floors of a building and cannot be used for firewall penetrations. Many builders, however, want to use plastic everywhere because of its ease of installation and cost, and they cite U.S. Army Corps of Engineers guide specifications for justification. As a result, installations sometimes have a problem acquiring the plumbing systems they specify. Corps of Engineers guide specifications are intended to be a guide for the installations and contractors. The guide specifications, therefore, allow a variety of materials to be used. Contractors often choose from the options given in the specifications only because they are standard practice at certain locations and provide opportunities for greater profit through reduced transportation, equipment and labor costs. Because plastic pipe installation is typically much less labor intensive and uses new and often simpler installation procedures than metallic pipe, if given the choice, contractors often substitute plastics. Since plastic plumbing is simpler to install than metallic plumbing, plumbers with little or no training in installing plastic plumbing are employed. The plumbers sometimes make small mistakes, which can lead to widespread or severe problems. Therefore, installations sometimes do not get the construction quality they need or for which they pay.

5. Summary of Lessons Learned. The following lessons are discussed in detail in the attached publication, *Lessons Learned: The Use of Plastic Plumbing Materials.*

a. Carefully consider material properties when making the choice of materials for plumbing systems; standard practice is not a satisfactory single criterion.

b. Use plastic pipe designed for the application; do not substitute.

c. Design for thermal expansion and contraction of the plastic pipe.

d. Design for thermal environment.

e. Ensure that plumbers and pipefitters have the training and experience necessary for joining plastic pipe.

f. Record accurate, reliable information on the exact location of buried plastic pipes and ensure any changes are reflected in as-built drawings.

g. Design underground distribution trenches and manholes to reduce the danger of damaging plastic plumbing when maintaining adjacent utility systems.

h. Institute safeguards to prevent damage to plastic distribution and plumbing systems by nonplumbers.

i. When installing fiber-reinforced plastic underground storage tanks (FRP-USTs) in areas with a high water table, install the fabric filter hole liner specified by the tank manufacturer to allow the flow of water around the tank, but prevent the migration and mixing of native soil and backfill material. Do not allow the tanks to remain in the ground in an empty or near empty condition.

j. Carefully monitor an FRP-UST for roundness when it is emptied and refilled.

6. Points of Contact. Questions and/or comments regarding this subject, which cannot be resolved at the installation or MACOM level, should be directed to the U.S. Army Center for Public Works, CECPW-ES, 7701 Telegraph Road, Alexandria, VA 22315-3862,

at (703) 806-5196 or DSN 656-5196. Questions may also be directed to USACERL, CECER-FL-M, P.O. Box 9005, Champaign, IL 61826-9005, (800) USA-CERL.

FOR THE DIRECTOR:

FRANK J. SCHMID, P.E.
Director of Engineering

APPENDIX A

LESSONS LEARNED

I. Carefully consider material properties when making the choice of materials for plumbing systems; standard practice is not a satisfactory single criterion.

1. A major part of the successful use of any building component begins with selecting the right material for the job by understanding the material's properties and limitations. Standard practice is not always the best criterion by which to judge. Manufacturers' recommendations and material specifications also must be considered.

2. In the 1970s, polybutylene pipe with acetal fittings became popular as a carrier for potable water. It was used by cities and home builders across the country. By the early 1980s, these plumbing systems were failing miserably, resulting in thousands of leaks, mostly at the fittings. It was known and published in manufacturers' literature that acetal was susceptible to chemical attack by hypochlorites, the chlorine constituent in chlorinated water.

3. One military installation constructed 200 prefabricated housing units that contained polybutylene plumbing for both hot and cold potable water (an acceptable material for this service). Within two years, maintenance personnel were getting five to ten calls per day from that particular housing area for leaking or broken water pipes, mostly in the hot water lines. The pipes all had acetal plastic fittings. The hot water temperature in some of the housing units was measured in excess of 160 °F (71 °C). Because heat accelerates chemical reactions, the hypochlorite attack progressed much quicker on fittings in the hot water lines. Stress on the fittings induced by thermal expansion of the polybutylene pipes contributed to the brittle fractures in the fittings. Polybutylene pipe manufacturers recommend that in chlorinated water systems either copper or chlorinated polyvinyl chloride (CPVC) fittings should be used rather than acetal. The installation determined that it was more cost effective to abandon the polybutylene plumbing in-place than to replace each acetal fitting in the housing area with copper or CPVC fittings. They also chose to install PVC pipe for the cold water lines and copper for the hot water lines.

4. Polyvinyl chloride (PVC) also was installed at several Army installations for natural gas distribution systems. Excessive failures in the PVC gas pipelines resulted in most of the lines being replaced with polyethylene pipe. Some of the problems noted with the PVC gas distribution systems included leaking joints (glued), inferior materials, and brittleness of the PVC material. The brittleness was caused by aging and exposure to sunlight, especially at the risers. One installation had several instances of children bumping the risers with their toys and causing cracks and breaks. The PVC risers at that installation were replaced with steel. PVC gas lines are being replaced with polyethylene pipe at installations where they are still in use. Polyethylene pipe can be used for above ground applications but must be in a metallic casing. U.S. Army Corps of Engineers guide specifications do not allow PVC as an option for gas line pipe material.

5. Several installations found that PVC is preferred for mess hall drains because cast iron drains corrode. Kool Aid® and other soft drinks have a severely corrosive effect on cast iron, but not on plastic.

6. An emerging problem with metal valves is maintaining them in the ground. Work force reductions at many installations severely limit the resources to maintain these valves. One installation is attempting to reduce the maintenance requirement for lubrication and corrosion prevention by replacing metal gas line valves in the ground with plastic valves. Plastic gas line valves are available for pipelines up through 8-in.*, and the plastic replacements require no maintenance.

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*1 in. = 25.4 mm; 1 ft = 0.305 m; 1 mi = 1.61 km.

II. Use plastic pipe designed for the application; do not substitute.

1. Plastic pipe manufacturers produce their pipe within particular design specifications. They also specify the sort of applications the pipe is designed for. That specification is based on material properties and production specifications. When a pipe is used for an application other than what it is designed for, the likelihood of failure greatly increases.

2. One installation used fiber-reinforced plastic (FRP or fiberglass) pipelines as part of their airfield fuel distribution system. The internal pipe pressure was a nominal 110 psi with surges up to 150 psi. The contractor installed a pipeline designed for a condensate return system and not for high pressure fuel system. Clearly this was an error in obtaining and using the correct pipe material. The pipe soon split and shot fuel into the air, contaminating the soil around it. Maintenance crews thought it was a broken water main until they smelled the JP-4 fuel. The line was replaced with coated stainless steel pipe and cathodic protection. Good on-site quality control is the only means of preventing this type of incident.

3. Another installation installed a hot water heat pump system in a headquarters-type building. The contractor who installed the heat pump used a PVC pipe rated for cold water rather than the CPVC pipe required for hot water. When the system was turned on, the pipe sagged and soon broke (Figure 1). The contractor replaced the PVC pipe with CPVC pipe.

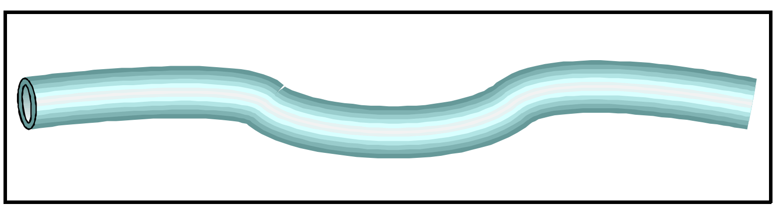

Figure 1 Cold water PVC pipe sags when used to carry hot water.

III. Design for thermal expansion and contraction of the plastic pipe.

1. An important design consideration when plastic pipe materials are used is thermal expansion or the change in unit length or volume with a change in temperature. Depending on the plastic material, the differences can be significant. For example, a temperature change of 20 degrees can alter the length of a 10-ft pipe by:

- 0.016 in. if steel
- 0.022 in. if copper
- 0.036 in. if PVC
- 0.067 in. if polyethylene
- 0.192 in. if polybutylene.

Thus, designs must take into account such length changes, especially since the temperature of a hot water pipe may have a range of 50 to 80 °F (10 to 26 °C) variation.

2. Polybutylene plumbing was used in a motor pool tactical equipment maintenance facility to prevent pipes from bursting. A positive attribute of polybutylene piping is its ability to withstand the forces caused by water freezing inside it. However, to accommodate the thermal expansion and contraction, the pipe was installed so it sagged between pipe hangers. The weight of the water in the pipes combined with thermal expansion during hot weather caused the pipes to sag to the point that, over time, they began pulling out of the compression fittings (Figure 2).

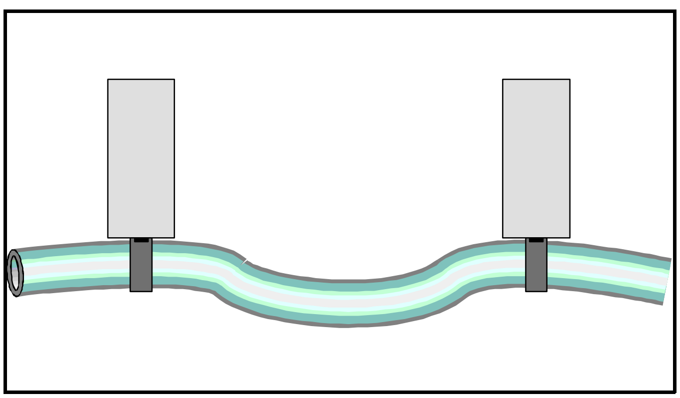

Figure 2 Water weight and thermal expansion may cause polybutylene piping to pull out of compression fittings.

3. Another installation built some barracks with all PVC plumbing in the winter of 1987. After the pipe was placed, the builders cemented it tightly against the barracks floor. The cement did not allow thermal expansion or contraction in the pipe, so the pipe burst and flooded the barracks soon after it was placed in use (Figure 3). Installation personnel took out the cemented plumbing and replaced it using brackets to hold the PVC pipe in place. A barracks built three or four years ago, however, has not had the same problem even though the plumbing was cemented in place. The area was heated when the pipe was laid and cemented in place.

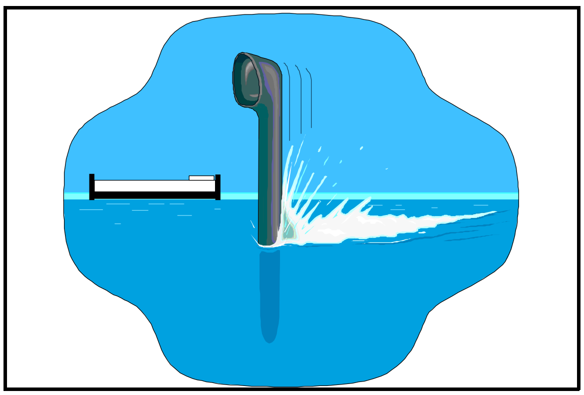

Figure 3 Not allowing for thermal expansion or contraction may cause pipes to burst.

4. An accident occurred in Nebraska in January 1976 when natural gas leaked into a six-story hotel and was ignited. The hotel exploded and burned killing 20 people and injuring 39 others. The investigation disclosed that about 18 months before the accident a new plastic main had been installed by inserting the plastic pipe into the existing steel pipe. The nearly 350-ft-long pipe had been installed in hot weather. With the onset of colder temperatures, the 2-in. polyethylene plastic main contracted longitudinally and pulled out of a compression coupling. Polyethylene gas pipe should only be joined using the manufacturer’s approved procedures.

5. In December 1977, another 2-in. plastic pipe main pulled out of a compression coupling in Kansas creating a gas leak and explosion. Two people were killed, three were injured, and a building was destroyed. The National Transportation Safety Board (NTSB) determined that the probable cause of the accident was the failure of the gas company to properly design, install, test, inspect, and anchor the 394-ft-long polyethylene main that had been inserted in a steel casing. They had only connected it to a steel gas main by a compression coupling. The 2-1/2-year-old, unrestrained plastic gas main contracted 3-l/2 in. longitudinally during cold temperatures and pulled out of the compression coupling (Figure 4). Tests conducted during the investigation indicated that a plastic pipe's resistance to pullout from a standard compression coupling decreases with time due to stress relaxation at the clamp. U.S. Army Corps of Engineers guide specifications describe compression coupling material requirements. The 49 CFR 192 requires that the joint be designed to withstand longitudinal pullout forces using procedures proven by test or experience to produce strong, gas-tight joints.

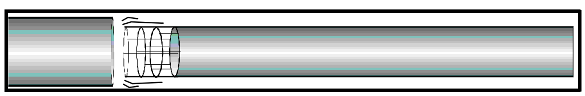

Figure 4 Compression coupling fails.

IV. Design for thermal environment.

1. Excessive heat adversely affects plastic plumbing materials. Thermoplastic materials melt at moderately high temperatures. The melting points vary depending on the plastic material. Thermoset materials typically can withstand higher temperatures because they do not get soft at these temperatures. They do, however, decompose and fail without warning at elevated temperatures. When designing a plumbing system, real and potential heat sources must be considered in selecting a plastic pipe material.

2. Several installations have tried using FRP condensate return lines with little success. The major problem with FRP lines is that if a steam trap should fail and allow steam into the pipeline, the pipes do not hold up (Figure 5). Steam destroys the polymer matrix of the pipe resin, leaving just the reinforcement in place. Army Corps of Engineers guidance requires the installation of a relief tank at each steam trap for FRP condensate return lines. Where the relief tank has been installed, no failures have been reported. Draft guidance (AR 420-consolidated)

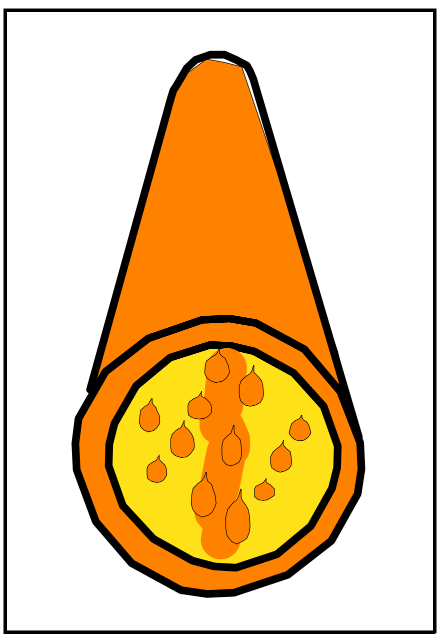

Figure 5FRP condensate return lines do not hold up if a steam trap fails and allows steam in the pipeline.

states that for class A sites, those with a high water table or poor drainage characteristics, above ground installation of heat distribution systems is preferred. However, if it is necessary to bury the system, a shallow trench installation is recommended. If direct burial is the alternative of choice, non-FRP pipe must be used. For direct burial applications, FRP pipe can only be used at class B or lower sites.

3. The Army Corps of Engineers recently built five 1,100-man barracks at a major installation in the United States. They installed a chilled water distribution system using 12-in. PVC pipe between the buildings and a steel heating pipeline beside the chilled water line in a shallow trench. No problems occurred during warm weather; however, when the weather turned cold, the chilled water was turned off for the winter. The 300 °F heat pipe destroyed the adjacent PVC chilled water pipe because the heat pipe was placed where temperatures could reach or exceed the chilled water pipe materials’ softening point. The installation replaced the PVC chilled water line with a steel one.

V. Ensure that plumbers and pipefitters have the training and experience necessary for joining plastic pipe.

1. It is important to hire qualified *and* experienced plumbers to install the pipe. Just being qualified is not enough, field experience is necessary. Many problems associated with the use of plastic plumbing materials are the result of carelessness or poor workmanship by the plumbers installing the systems. One advantage to using plastic pipe is that it is easier to install than metallic pipes. Often the idea of being easier to install is interpreted to mean that it is something anyone can do with minimal training or experience. This is not necessarily true. Because of the character of plastic pipe and pipe fittings, training and experience specific to plastic pipe is necessary.

2. An 8-mi-long gas pipeline was constructed at one installation using 8 in. polyethylene pipe. When the work began, the temperature was below freezing and ice was on the ground. The workers compensated for the cold by turning up the temperature on the butt-fusion irons rather than using a longer heating time when making the butt-fusion welds. During the initial integrity tests, the pipeline failed twice due to poor butt welds. Those welds were repaired and the line put into service. Following 17 more failures, 3.5 mi of the line was shut off and the old line put back in service until a new pipeline could be installed. The remaining 4.5 mi of the pipeline, installed using proper methods, has had no problems. On the first 3.5 mi, the plumbers experienced failures and subsequently learned the proper methods for assembling the pipe. Warmer weather during the last portion of the pipeline construction undoubtedly helped as well.

3. The National Transportation and Safety Board investigated another accident involving improper installation that occurred in Texas in October 1971. A woman who resided in a small frame house lit a gas stove. The explosion that followed blew the roof off the house and blew out the four walls. The woman was burned severely. The Safety Board's investigation revealed that the explosion and fire resulted from the ignition of natural gas that had accumulated in the house after migrating, under pressure, from a failed saddle-tapping nipple connection on a plastic pipe. A 1/8-in.-wide crack extended across the top half of the pipe nipple's circumference. About 9 months before the accident, an independent contractor had installed a 4-in. polyethylene high-pressure gas distribution system in the area. The 3/4-in.-diameter plastic service line, which connected the

main to the houses, was heat-fused to the main by means of a polyethylene saddle. After burial of the main and service line, heavy rainfall caused the earth to shift. At the same time, heavy construction equipment traversed over the pipe line, which stressed the service line connection to the point of failure. Investigators determined that the saddle joint was not properly installed resulting in the joint's failure when subjected to the heavy equipment loading.

4. Polybutylene pipe was installed for hot and cold water plumbing in a family housing area at one installation. During construction, metal pipe hangers that held the pipes in position were fastened so tightly that they partially crushed the polybutylene pipes. Hairline cracks eventually developed at these points, especially in the hot water lines. In a few instances, the pipes burst. Without exception, there was evidence of the pipe being crushed by hangers or being crimped where the leaks occurred. The crushing or crimping weakened the pipe hoop to the point that the thermal expansion and contraction cycling of the pipes initiated a split.

5. Because of the isomorphic properties* of polybutylene, special care in heating the pipe and fitting surfaces are required as well as providing sufficient time (5 to 10 days) for the crystalline transition to occur before loading a fusion welded system. One Army installation had polybutylene plumbing installed using fusion welded pipes for both hot water and cold water. The plumbing was not given sufficient time for the crystalline transition to occur before it was pressure tested. Once the pipes were in use, the welded joints began failing.

6. Problems with PVC drains in some three-story housing renovations occurred at another installation. Once the housing units were in use, leaks began occurring in the walls. When the maintenance crews investigated, they found that poor workmanship in the second and third floor lavatories caused problems with the

*Polybutylene is unique in that it is one of the few commercially available polymers that exhibits a significant degree of isomorphism, or simultaneous coexistence of two different crystalline forms. When polybutylene crystallizes from the melt, it forms an unstable crystalline structure referred to as Form II. At room temperature, the Form II tetragonal crystals slowly convert to Form I hexagonal crystals, the final stable structure accompanied by a change in density. This transformation normally requires 5 to 10 days to complete. During that transition time both structures coexist within the polymer matrix. The time requirement for the transition can be reduced by subjecting the material to high pressure (10 min. at 30,000 psi). To avoid potential problems associated with fusion welds, polybutylene plumbing is installed using metal or plastic compression fittings.

rear-discharge commodes installed during the renovations. The PVC drain lines sagged and pulled out from the commode flanges (Figure 6). Examples of poor workmanship identified in the renovations include no primer used during assembly, some pipe fittings not pushed on the pipes to their bottom, some joints dry with no cement in them, and insufficient pipe hangers used to secure the PVC drains in the walls. The installation replaced the PVC drains with cast iron pipe to avoid further problems in the upper stories. The contractor either had no knowledge of the basics of joining PVC pipe or was negligent in performing the work. Had the joints been properly assembled, they would not have failed, and the problem would never have occurred.

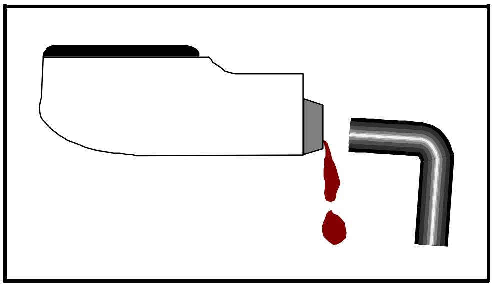

Figure 6 Improperly joined PVC drain pipes pull away from wall flanges.

8. It seems like a simple step to take, but solvent-welded joints for PVC pipe require cement when joining them. To obtain their rated strength in a system, the cemented fittings and the pipe to which they attach must be properly prepared for the cement and then mated correctly. The quality of the cemented joint depends on the expertise and thoroughness of the installers. When joining PVC pipe, qualified plumbers should know that:

a. All raised ridges caused by cutting pipe ends must be chamfered and removed to prevent cement in the fitting socket from being scraped from the socket surface when joining. Omitting the chamfering step can result in a dry joint with a high probability of failure.

b. Surfaces to be joined must be cleaned and free of dirt, moisture, oil, and other foreign material.

c. A primer must be applied to both joining surfaces to clean, soften, and dissolve the joining surfaces to prepare them for solvent cementing. If sufficient primer penetration is not achieved, it is unlikely that a suitable joint will result. Often the manufacturer of the solvent cement does not mention the need for the primer, but that need always exists.

d. PVC solvent cement is fast drying, so the cement should be applied as quickly as possible, consistent with good workmanship.

e. The surface temperature of the mating surfaces should not exceed 110 °F (45 °C) at the time of assembly.

f. The pipe or fitting should be rotated 1/4 turn during assembly (but not after the pipe is bottomed) to distribute the cement evenly.

g. Until the cement is set in the joint, the pipe may tend to back out of the fitting socket if not held in place after assembly. In addition, fresh joints can be destroyed by rough handling.

h. PVC piping is sensitive to ultraviolet light. When exposed to sunlight for a long time it becomes noticeably more brittle.

i. Extremes of hot or cold also weaken PVC pipe.

j. Vibration and surging effects are deleterious to PVC piping. Repeated pressure surges below the rated burst strength of the pipe can lead to failures.

9. An installation installed a schedule 40 PVC water line under a dining facility. It soon began leaking at the fittings. They replaced it with schedule 80 pipe and have had no more problems. The same thing occurred on their golf course and, again, the schedule 80 pipe replacement worked. All of the leaks occurred at the fittings. Because no breaks occurred in the schedule 40 pipes, installing schedule 80 pipe served no purpose beyond replacing all the poorly assembled pipe fittings with properly joined ones.

10. Another installation had a plumbing problem when a building contractor connected cold water PVC to the hot water lines. The PVC pipes quickly sagged and broke when the water was turned on.

The installation inspector noted that even if the contractor had installed the proper pipe, it probably would have had similar results because he installed the hangers too far apart. The cause of this problem was carelessness, inexperience or both on the part of the plumbing contractor. The hanger bracket spacing design was also part of the problem. PVC- and CPVC-pipe manufacturers have literature that specifies the maximum hanger spacing for the different grades, schedules, and diameters of PVC and CPVC pipe. Their specifications should be followed.

11. One installation had some FRP-wrapped steel condensate return lines fail shortly after they were installed. When the system was turned on, condensate began leaking and deteriorating the FRP wrap. An investigation into the cause of the failure concluded that the contractor who installed the lines did not exercise quality control on the steel welds when the pipeline was assembled. The bad pipeline runs were replaced with the same system by a different contractor. No problems have occurred with the new system.

VI. Record accurate, reliable information on the exact location of buried plastic pipes and ensure any changes are reflected in as-built drawings.

1. A general problem with plastic pipe is that it can be damaged easily if it is dug up for any reason. Damage by excavation equipment or tools such as backhoes, front-end loaders, ditchers, graders, augers, iron stakes, and hand shovels are the major cause of leaks in buried plastic pipes. Maintenance workers often comment that it seems like all a person has to do is touch a buried pipe with a backhoe and it springs a leak. This is also true for some metal pipes. For that reason, dependable information on the location of buried plastic pipe is vital.

2. Accurate and up-to-date as-built drawings are always hard to come by, but they are particularly important when performing maintenance and repair operations on or near plastic pipe. This is especially a problem when the maintenance crew is digging near a gas pipeline. An installation had an instance where the as-built drawings showed a 4 to 5 ft separation between a water main and a gas line. They were digging a ditch between the lines and hit the gas pipe, breaking it. In reality, the separation between the lines varied and, at times, came within a couple of feet of each other.

3. Several installations have had problems identifying the location of buried plastic pipelines. Attaching reflective metallic or magnetic tape has been tried, but the tape cannot be detected at the depths most of the pipes are buried. Some installations have had success putting tracer wires in the ditch with the pipe when it is installed and having it come out of the ground at gas risers. When maintenance crews are working in the area, they put a signal on the wire at the risers that they can easily detect at the ground's surface. The 49 CFR 192.707(a) precludes wrapping the plastic gas pipe with the tracer wire. If lightning strikes, the wire could burn a hole in the pipe. Also, those installations that follow the DOT guidelines strictly and install the tracer wire above the pipe rather than getting a variance to place the wire in the ditch with the pipe have a problem with tracer wires being broken by people digging or driving stakes or posts into the ground. Knowing where the pipe is protects it better than any other method. Tracer wires and tapes are not reliable for locating buried plastic pipelines, so it is important that installations ensure as-built drawings reflect all changes accurately.

VII. Design underground distribution trenches and manholes to reduce the danger of damaging plastic plumbing when maintaining adjacent utility systems.

1. A common complaint about engineers by maintenance workers is that engineers do not design things so that they can be easily maintained. At one installation, several locations have the gas, water, electrical, and sewer lines all stacked on top of one another. If maintenance is required for one, the other pipelines are in danger of being damaged by the maintenance crew (Figure 7).

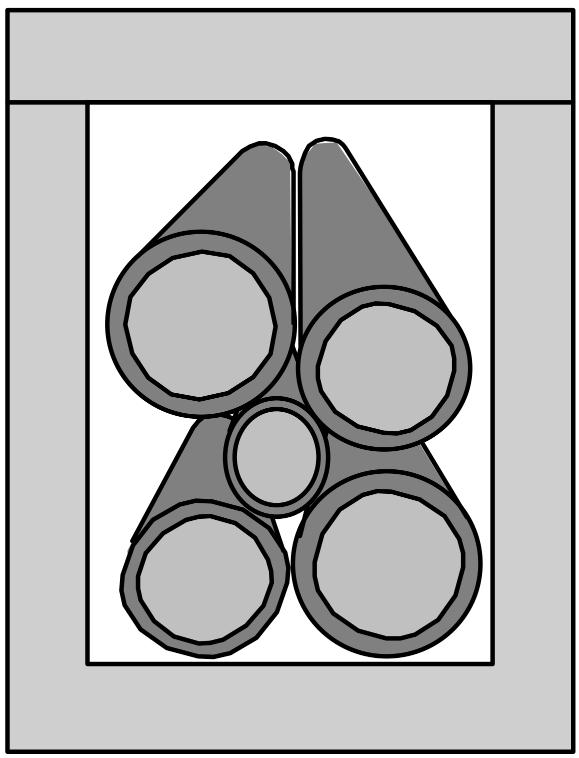

Figure 7 Pipes stacked around each other are difficult to maintain without risk to other pipes.

VIII. Institute safeguards to prevent damage to plastic distribution and plumbing systems by nonplumbers.

1. The majority of buried pipeline leaks are due to damage from excavation, and 95 percent of those leaks are caused by people other than maintenance crews. Gas company data for gas lines show that over 60 percent of the leaks caused by nonmaintenance crew excavation were caused by people who had not contacted their gas company or system operator regarding the location of buried gas lines or their intent to excavate.

2. A common problem at installations involves troops driving grounding rods, stakes, and steel fenceposts into the ground and accidentally puncturing gas lines. Generally, the problem is not discovered until the unit moves and the stakes and rods are pulled up. In many places, the only soil soft enough to drive a rod easily is over a buried utility line. The only way to avoid such occurrences is to clearly mark where the underground utility lines run and keep informing the units to watch for the markers.

3. At one installation a soldier was planting a garden and drove stakes into the ground to support the plants. One of the stakes was driven through a polyethylene gas pipeline causing a gas leak. Since buried gas pipelines can be as close to the surface as 12 in. in residental areas, tenants need to be advised concerning the location of buried plastic gas pipelines that cross their property lines. They should also be warned to contact the gas company if they plan to do any excavation or digging.

4. People other than plumbing maintenance crews also cause leaks in plumbing systems. Both tenants and construction workers sometimes accidentally drive nails into plastic pipes installed in walls. On several occasions at one installation, family housing tenants drove nails into PVC vent pipes and broke them. At another site, polybutylene pipes were punctured by nails when the carpenters installed the drywall in the housing units. The cold water pipes were little problem because the thermal contraction induced by the cold water kept a tight seal around the nails. The hot water pipes, however, expanded at the nail holes and leaked, thus ruining the dry wall. Tenants and construction workers need to be made aware of the location of plastic pipe in housing units to reduce the likelihood of these accidents occurring.

IX. When installing fiber-reinforced plastic underground storage tanks (FRP-USTs) in areas with a high water table, install the fabric filter hole liner specified by the tank manufacturer to allow the flow of water around the tank but prevent the migration and mixing of native soil and backfill material. Do not allow the tanks to remain in the ground in an empty or near empty condition.

1. Three FRP-USTs failed recently at a major Army installation. Two 30,000 gallon, 10-ft diameter double-wall storage tanks with brine interstitial solutions failed within three months of their installation in 1991. They were repaired by the manufacturer onsite and put back in service. No cause for the failure was determined at the time. However, similar problems occurred at other Army facilities. During the course of a site visit to the installation by engineers from USACERL, an inner wall failure was discovered in another tank, bringing the count to three failures. It was also noted that the bedding had shifted on some of the tanks. The bedding shift was evident because of a angle shift in the above-ground vent pipe. The engineers determined that the failures were caused by critical stresses induced in the inner liner near the bottom of the tanks because of stresses induced by differential settling of the soil under the tanks. If a tank is nearly empty, the wall deflections need to be monitored to ensure they do not exceed the manufacturer's allowable deflection specifications for the major vertical diameter of the FRP-UST.

2. Tanks were installed in an area with a high water table, at times only a few inches below grade. At installation, several of the tanks were left nearly empty for approximately three weeks while tightness testing was performed on other tanks. The stresses that created the cracks were due to a combination of buoyant forces developed by high groundwater, near-empty tanks, and water-induced shifting of bedding materials. The engineers recommended that steps be taken to avoid water-induced stresses by avoiding excessive emptying of underground tanks, and that for any new tank installations in similar high water conditions, manufacturer-specified fabric filters be used. Filter fabrics allow the flow of water but prevent migration and mixing of native soil and backfill material. Continuous polyethylene sheeting is not an acceptable substitute for filter fabric. Mixing of sand or native soil with the bedding gravel can result in a tank failure. For tidal or other areas subject to frequent changing groundwater levels, unstable soils and water conditions

with silty soil, filter fabrics should be used to stabilize the tank bedding.

X. Carefully monitor an FRP-UST for roundness if it is emptied and refilled.

1. A deflection measurement program should be performed as the minimum ongoing test regimen for FRP-USTs. Private consulting engineers recommend that, as a construction test, it is especially important to measure tank roundness. If, after they are put in the ground, the tanks are emptied for any reason and refilled, the bedding and backfill may shift due to reduced internal tank pressure against them. Any detected trend away from a circular cross-section is an accepted indicator of a decrease in mechanical properties of the FRP laminate. Using a dipstick to measure the depth of the tank and comparing the results with measurements taken when it was installed or other previous measurements is the optimum method to use. If the measurement is greater than the following allowed maximum deflections, the tank should be considered at or near failure due to stresses induced by shape distortion or out-of-roundness and action to remedy the situation should be taken. Maximum allowed deflections are:

- 4-ft tank: 0.50-in. deflection
- 6-ft tank: 0.625-in. deflection
- 8-ft tank: 1.25-in. deflection
- 10-ft tank: 1.50-in. deflection
- 12-ft tank: 1.50-in. deflection.

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Synopsis of PWTB 420-49-6

PWTB 420-49-6, The Use of Plastic Plumbing Materials: Lessons Learned, discusses the problems and advantages of plastic plumbing materials. The attachment details factual scenarios of plumbing failures, their causes, and their solutions.