# CHAPTER B13

# DOUBLE CONTAINMENT PIPING SYSTEM DESIGN

**Christopher G. Ziu, P.E., C.I.P.E.**
*Author*
*Handbook of Double Containment Piping Systems*
*McGraw-Hill, Inc., Publishers*
*New York, New York*
*878 Pages, Copyright © 1995*
*ISBN 0-07-073012-1*

*Manager Piping Products*
*Orion Fittings, Inc.*
*Kansas City, KS*

## *INTRODUCTION*

### History of Double Containment Piping

Up until the 1970s, dual arrangements of piping systems utilizing a carrier pipe with a secondary piping providing containment for purposes of environmental protection or safety were limited to highly specialized applications. These involved rare applications in the nuclear, gas, or chemical processing industry, where highly toxic or lethal chemicals or fluids were transported. The use of an outer jacket to maintain a positive seal around a primary carrier piping system and protect the primary piping was rarely encountered.

In the 1970s, several large U.S. electronics manufacturers began placing their underground, and in some cases aboveground, hazardous chemical piping systems piping within an outer jacket for the sole purpose of preventing leakages from getting into the ground water supply. Part of the reason for doing so was due to inadequate performance on the part of ordinary single-walled piping components intended to handle these chemicals. Leakages from joints, failures of piping materials due to poor manufacture or installation practices, inappropriate material selection, and soil corrosion were some of the contributing factors. Thus began the modern day practice of placing underground piping systems within a secondary containment piping system for the sole purpose of protecting the local environment.

Unfortunately, many of these early systems met with complications that resulted in less-than-successful performance. The first attempts at dual arrangements met with frequent failure. This was primarily due to systems being designed with combinations of piping components whose geometries were not readily compatible. Also, there were technical issues that arose that had not been addressed in the design. This had to do with structural concerns (supporting and centering the inner system), differential thermal expansion issues, penetration sealing issues, and many others. Additionally, many of these systems were installed with poor fabrication techniques, resulting in installations that lacked inherent stability and were thus readily subject to premature failure. The lack of design consideration and installation deficiencies resulted in failures that manifested themselves in predictable ways. These included the separation of split outer pipe and split outer fittings, coupled with failed inner welds, thereby leading to a double failure. Other means of failure included premature failure of inner and outer pipes due to fatigue, excess strain, and many other reasons.

In certain individual states of the United States of America, such as California, there was a movement toward implementing secondary containment piping systems in gasoline and petroleum stations. The first known application of this was a service station in Torrance, Calif., in 1981, under the watchful eye of local fire officials and other environmental officials. Soon thereafter, other gasoline stations throughout California were implementing double containment piping systems with integral leak detection.

During this same time frame, the federal government of the United States was studying ways to protect against the failure of underground storage tanks and piping transportation systems. This resulted in revisions to the Resource Conservation and Recovery Act (RCRA) of 1976, which were enacted in 1984. Signed into law as the Hazardous and Solid Waste Amendments of 1984 (U.S. Public Law 98-616, signed Nov. 8, 1984), it extended and strengthened the Solid Waste Disposal Act, as originally amended by the Resource Conservation and Recovery Act of 1976. The amendments contained strict requirements and provisions for underground storage tank and piping systems.

For systems containing a hazardous waste [hazardous according to the EPA as defined in the Code of Federal Regulations (CFR), Title 40, part 241], hazardous substance [also according to §40CFR261], or petroleum-based substance with 10 percent or more of its volume underground (including piping), the regulations contained strict provisions. For hazardous waste the regulations [according to §40CFR264] required secondary containment and leak detection for all underground systems. They also required the same for aboveground systems unless they were visually inspected for leaks on a daily basis. For hazardous substance the regulations [according to §40CFR280] similarly required all undergound systems and aboveground systems not visually inspected on a daily basis to have secondary containment and leak detection as well.

For petroleum substances, the regulations [according to §40CFR280] gave the user a choice of providing secondary containment with leak detection or to use corrosion-resistant materials with frequent monitoring and tightness testing (petroleum-based products only). An alternative for petroleum piping applications involved the use of ordinary carbon steel (e.g., A-53 or A-106, Grade B) with some form of coating and cathodic protection added. In the case of the so-called hazardous chemicals, aboveground systems were regulated as well, unless the systems were to be inspected on a daily basis. The regulations applied to both new systems and existing systems. Existing systems were subjected to a retrofit requirement according to a time table, with the oldest systems being required to be replaced first. Thus, all existing systems in the United States installed prior to December 1988 were scheduled to be replaced within a 10-year time frame from the commencement of the regulations, by December 1998, if they were not already in compliance. It is important to note that there are many aspects to the U.S. regulations (e.g., minimum volume requirements, regulated substances, leak detection requirements and options, etc.), and that the requirements and degree of enforcement vary according to each individual state. Other countries beyond the United States are currently considering the development of similar regulations and are expected eventually to adopt them by the early twenty-first century.

The 1984 amendments passed in the United States provide a framework by which individual states, territories, and possessions of the United States are mandated to draft state legislation, with their laws being at least as stringent as the U.S. federal law. Enforcement is required at the individual state level, with the federal Environmental Protection Agency overseeing each state program. Prior to the federal laws being adopted in the United States, some of the individual states where ground water contamination has been a particularly bad problem have adopted similar laws, prior to the federal government requiring them to do so (e.g., California, New York, parts of Texas, and others). In certain parts of Europe and Canada, local, officials have in some cases required double containment piping for hazardous chemical systems on a limited basis.

## Overview of Double Containment Piping Systems

To provide secondary containment for piping systems, there are design considerations to be considered that are beyond those that apply to tanks. Whether the system is a pressure transfer pipe or a drain, waste, and vent system will have a significant impact on the design, layout, material selection, wall thicknesses, leak detection method chosen, and other aspects to be considered. Additionally, a system may be a relatively straight piping run, it may consist primarily of fittings, or it may have parts that are both straight in sections and fitting intensive in others. Further, whether a system is intended for burial or whether it is intended for aboveground use also have a significant impact on its design. Space limitations are an important consideration as well. A piping system that is intended for tight pipe-rack work, or is to be located near other buried structures, will have different installation requirements and different requirements for material selection, wall thicknesses, pressure ratings, et cetera, in comparison to a system that does not have space constraints.

In terms of material selections for the inner and outer pipes, there are a number of factors that have an effect on what should be selected. For primary piping components, the chief consideration in making its material selection has to do with the ability of the material to withstand the corrosive effects of the inner fluid. The same basic techniques and criteria used for selecting materials for single-walled piping systems must be used for primary piping in a double containment system. However, the interaction of the inner and outer systems, how they are tied together; the preferred joining method, and how joining affects system installation; the compatibility between the secondary system and its joining method, and how joining affects system installation; the compatibility between the secondary system and its joining methods all factor into the considerations for selecting the combination of materials to be used.

For secondary containment piping components, the considerations for choosing the material to be used must include risk analysis. The risk analysis used must take into account the anticipated frequency and duration that it is reasonably expected that the outer material may be in contact with the contained fluid. It also involves weighing the possibility of failure against the sensitivity of the external environment and the relative extent of damage that a *double failure* might cause. Since there may be only infrequent (or no) contact with the corrosive fluid in a properly designed system, and the time of contact once an event occurs may be short in duration, a less expensive material may be an appropriate choice for some applications. However, for many applications the risk created by even the remotest chance of a double failure might be too great even to take a chance on using a less corrosion-resistant material.

Leak detection in a double containment piping system usually consists of some means of monitoring the status of the annular space that exists in the system. Detection methods that are used typically measure the presence of a fluid or some change in physical state. Other methods can be used (i.e., flow measurement), but the most effective means is to monitor the status of the system's annular space to detect for a change from a status quo.

The proper design of any piping system must include all the forms of analysis that are normally applied to single walled systems (e.g. stress analysis, structural analysis, burial analysis, etc). However, the design of double containment piping systems adds several new twists to the already complex nature of piping design. This includes such novel items as the fluid dynamic requirements for draining or flushing the annulus, or the added mechanical complexities that result from the interaction of the separate, interacting inner and outer piping systems.

When one considers the interaction of an inner and outer pipe system, and the resulting stresses and reactions thereof, the analysis often becomes complex. In fact, most piping design stress computer codes are not capable of accurately modeling this situation. Structural analysis of double containment piping systems is also inherently complex, as one has to deal first with the structural supporting requirements of the inner system and then also deal with the support (or burial) of the complex assembly, which tends to be a more rigid assembly than a comparable single-walled pipe. In underground situations, for instance, the structural design for a combined system is governed by the burial situation, yet the structural design of the inner piping is according to aboveground single-wall pipe standards. In fact, the inner pipe can often be thought of as a single-walled pipe that is supported within a circular pipe rack.

The most important individual principle to consider when designing double containment piping systems is that the basic principles of piping design remain unchanged. The systems must first be designed according to the ordinary rules, codes, and considerations of single-pipe design. Then all the complexities of one pipe system interacting within another must be considered as well.

There are a vast number of material and system configurations to consider on any given project. However, this aspect of double containment piping may be viewed in a positive way. The vast number of choices presents a designer with an opportunity to provide a solution for every application. A suitable design can be achieved in every case. The final choice of material and system configuration usually is determined by price and code criteria, and to a certain extent, by personal preference.

A complete double containment piping system is one that is engineered, designed, installed, started up, and operated successfully. To engineer a double containment piping system fully typically involves much more than simply procuring preengineered components. The term *preengineered* is a widely used marketing term that usually refers to products that are sold as prefabricated components, which are in some cases available in standard sizes and materials. This term is often misused, as a surprising number of preengineered systems available from even the largest sources have been conceptualized and sold with little to no engineering having been performed on the system components. However, double containment piping systems by their nature usually have at least some unique requirements, necessitating a custom design to some extent. Thus designers must use good judgement when procuring preengineered components as part of their system.

Any two combinations of materials can be effectively combined for a given double containment piping application. However, there are many aspects involved to make this possible. Materials must be properly selected for the given application. System components must be procured; it must be known early on in a project whether they are commercially available in the sizes and pressure ratings required. They must also be available in the time frame required by the project. A system must always be engineered with sufficient detail, giving consideration to all applicable factors. All regulations governed by the local jurisdiction and appropriate design code rules must be satisfied. Ultimately, whoever is to take responsibility for the design and operation of the facility must be satisfied that the design is a safe and workable solution.

## Overview of Leak Detection Systems

While a double containment system can be designed without a leak detection or monitoring system, the effectiveness of a system is considerably lessened without it. There are many methods available to provide sensing of the annulus that exists between primary and secondary systems. These methods are divided into two basic categories: automatic sensing systems and nonautomatic sensing systems.

***Continuous Sensing Systems.*** Continuous sensing systems normally involve a sensing mechanism and an automatic alarm device. The most sophisticated form of sensing consists of continuous-line leak detection. Continuous-line leak detection is a technology designed to give relatively precise locating abilities for the determination of the location of leaks. For piping systems, this is a very important feature, although it also adds significantly to the initial cost of a system. There are two types of technologies; conductive (resistance)-based systems and those that are based on the measurement of impedance, commonly referred to as TDR-based systems (TDR is a common abbreviation for time-domain reflectometry). Both technologies are effective, although there are subtle differences between the two.

Other forms of continuous sensing are based on some form of point probes. These include liquid level sensing, pressure sensing, moisture sensing, pH sensing, conductivity (resistivity sensing), vapor detection, ultrasonic sensing, movement sensing, and many others. The various forms of sensing may also be combined for added effectiveness. The advantage of point probe systems is in the ability to customize the system, but an inherent disadvantage is the lack of ability to locate a leak with precision.

***Noncontinuous Sensing Systems.*** Noncontinuous leak-sensing systems consist of visual detection systems, manual detection, inventory monitoring (tanks), and soil and vapor monitoring. Soil and vapor monitoring may also be used on a continuous basis, although it is not very common to do so. Visual detection can be designed easily into aboveground systems, but for underground systems they must be placed in manholes or sumps. Two forms of underground visual monitoring are very inexpensive and can be facilitated readily by having the secondary system flow open at the end of the pipe system, or by designing low point sumps with risers to the ground surface. Manual detection is normally facilitated by installing drip legs with valves in aboveground systems and with either low point sumps with risers to the ground surface in underground systems, or by positioning drip legs with valves in manholes. Manual systems can be a very cost effective and efficient method of leak detection and usually are a good idea to have as a backup or redundant method when other methods are employed. Inventory monitoring is a practical method for tank systems, but for piping systems it becomes more costly and complex, as a material balance must be performed. Noncontinuous systems are for the most part nonspecific in terms of locating leaks, unless a system is designed with very frequent locations for visual or manual monitoring.

## Applicable Design Codes

Double containment piping systems must be designed, fabricated, inspected, and tested to applicable codes and regulations. Since by far, the majority of double containment piping systems are for drainage applications, plumbing codes play a particularly important role in double containment piping. Many nonpressure drainage piping systems are governed by local and/or national plumbing codes. Examples of these are the UPC (Uniform Plumbing Code), which is written by IAPMO (International Association of Plumbing and Mechanical Officials) and endorsed by the PHCC (Plumbing-Heating-Cooling Contractors), and additionally the IPC (International Plumbing Code), which is written by BOCA and ICBO. The most important requirement that these plumbing codes cover pertains to the carrier pipe fittings. Typically they should be approved by the respective code, such as the UPC or the IPC, according to the authorities having local jurisdiction.

Other nonpressure systems are often considered by local authorities having jurisdiction as *process* systems, and may thus be out of the jurisdiction of local plumbing codes. In many of these systems, there are no design standards that may govern the design. Thus it is up to the individual designer to use good judgment and to be sure that they at the very least meet or exceed applicable environmental standards.

In the United States and Canada, process piping systems are subject to the rules of the ANSI/ASME B31.3 Process Piping Code, including double containment piping systems. The ANSI/ASME B31.3 Code is a subset of the ANSI/ASME B31 Pressure Piping Code, which is described in more detail in Section 1.5.6, Piping Design Codes. The ANSI/ASME B31.3 Code references various applicable product manufacturing standards, performance standards, and material specifications that are to be used as a part of a double containment piping system. The Code covers all the rules necessary to complete a double containment piping system. However, the ultimate responsibility of interpreting and applying the ANSI/ASME B31.3 Code, in order to arrive at a completed double containment piping system that is safe and reliable, rests with each individual owner or owner-appointed representative.

In order for the ASME/ANSI B31.3 Code to apply to a double containment pipe system, most piping has to operate at a pressure of greater than 15 psi (1 bar), or contain a vacuum. However, the Code may still apply to a system having a positive internal pressure less than 15 psi (1 bar) if the fluid being conveyed meets certain requirements in terms of flammability or toxicity, which would apply to many chemicals commonly used in a double containment piping system. The ASME/ANSI B31.3 Code does provide all the information a designer needs to know to design a double containment piping system. However, it is up to the individual designer to interpret the Code as to how it instructs one to do so. There are no specific references to a double containment piping system or secondary containment piping component in the Code. There are specific references to the testing and inspection of outer jacketing, however.

In Europe, the European Parliament has adopted the Pressure Equipment Directive (PED) which will affect process piping and will go into effect on Nov. 29, 1999. The PED requires that piping systems comply with ''essential safety requirements'' as a function of the fluid service. One possible outcome presently being studied by the European Parliament and the ASME is to have piping systems meet these essential safety requirements by having piping systems comply with the ASME B31.3 Process Piping Code. Not enough is known at the time of this writing to determine the feasibility of whether the PED will ultimately reference the B31.3 Code.

## *DOUBLE CONTAINMENT PIPING COMPONENTS*

### Straight Piping Sections

Figure B13.1 illustrates required dimensional information needed for a typical layout for straight piping sections for both nonmetallic and metallic piping material–based

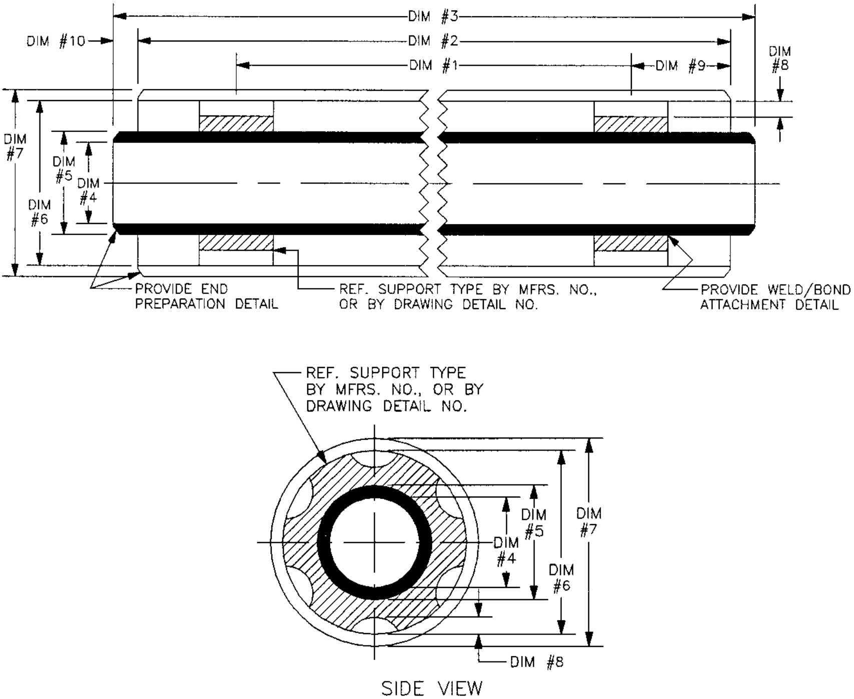
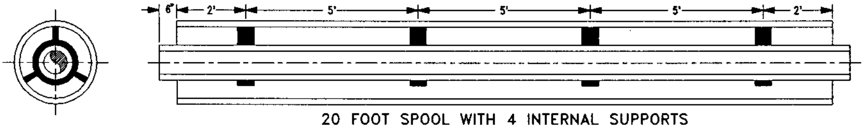
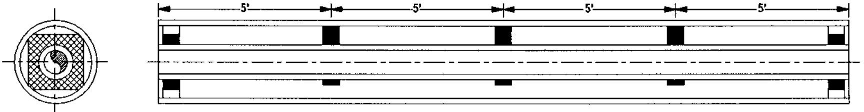


**FIGURE B13.1** Typical layout details for a straight pipe section of double containment piping. *(From* ''Handbook of Double Containment Piping Systems,'' *C. Ziu, McGraw-Hill, New York, 1995.)*



20 FOOT SPOOL WITH 4 INTERNAL SUPPORTS

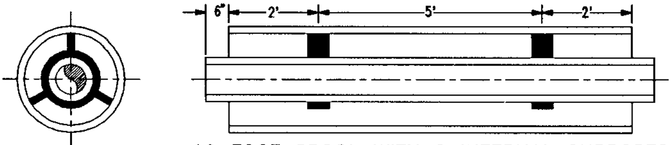


20 FOOT SPOOL WITH 2 END PLATES AND 3 INTERNAL SUPPORTS

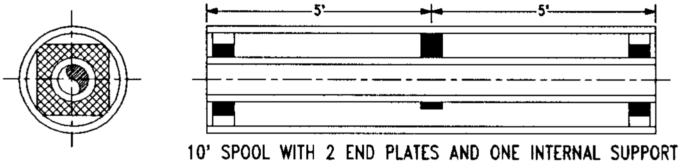
**FIGURE B13.2** Example of factory prefabricated 20-ft lengths of piping showing support spacing based on 5-ft spacing between supports for piping intended for staggered joining (top) and simultaneous joining (bottom). *(Orion Fittings, Inc., Kansas City, KS)*

systems, as may be used, for instance, in portions of double walled piping system on any project, each unique section of straight piping should have all details clearly indicated, except for highly fitting intensive projects where only short lengths of straight pipe exist.

Details that must be shown for a typical straight pipe section, or specified clearly, include: the materials of construction, with reference to the appropriate ASTM, DIN or AISI specifications; all inside and outside diameter sizes (including the annular space); wall thicknesses; applicable tolerances; location (spacing) and type of internal and external supports and leak detection cable (if applicable); and references to detail drawings of internal and external supports. A section of piping can be considered unique if any of these variables vary in any way. Both side and cross-sectional typical views should be shown. For intensive projects where separate spool drawings are to be prepared for each and every spool length of pipe, there is no need for typical straight pipe–section details on drawings. Figure B13.2, Fig. B13.3 and Fig. B13.4 show support-spacing options for various 20-ft, 10-ft and 5-ft sections of double containment piping.



10 FOOT SPOOL WITH 2 INTERNAL SUPPORTS



10' SPOOL WITH 2 END PLATES AND ONE INTERNAL SUPPORT

**FIGURE B13.3** Example of factory prefabricated 10-ft lengths of piping showing support spacing based on 5-ft spacing between supports for piping intended for staggered joining (top) and simultaneous joining (bottom). *(Orion Fittings, Inc., Kansas City, KS)*

## Termination and Initiation Component Design

There are several options for terminating a double containment zone, thereby making a transition from double containment piping to ordinary single-wall piping. The most simple option is to keep the annulus open ended where it is permissible. For most applications, end closures are required. Examples of some typical end closures are provided in Figs. B13.5 through B13.8.

***Closure Rings and Insert Rings.*** One of the more common termination arrangements for metallic systems that has been used extensively in jacketed pipe applications is the closure ring. Closure rings also find application as a termination device in double containment piping systems. Examples of closure rings are provided in Figs. B13.9 and B13.10. A closure ring is a concept similar to the internal anchor-baffle (see Fig. B13.12 and Fig. B13.13), except that an internal anchor-baffle is welded to the inner and outer pipes on both sides; a closure ring is welded only on one side to the secondary containment piping. A closure ring may be used on thermoplastic piping, as it is weldable, although the resulting secondary containment pressure rating (pressure capability of the annulus) may be substantially less than that of the primary piping. A variation of the closure ring is an insert ring (collar), which may be used in systems that use solvent cementing (PVC, CPVC, ABS) or adhesive bonding (all RTRP materials).

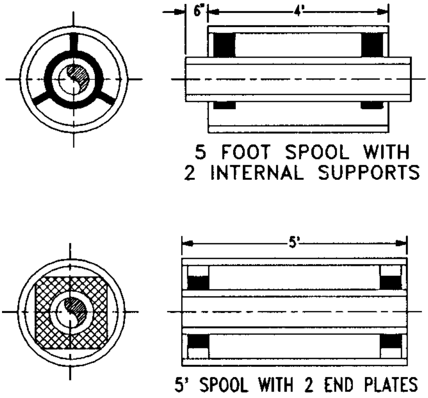


**FIGURE B13.4** Example of factory prefabricated 5-ft lengths of piping showing support spacing based on 5-ft spacing. *(Orion Fittings, Inc., Kansas City, KS)*

## Anchoring Components and Methods for Primary Pipe

It is occasionally necessary to restrain a piping system at a given point by securely anchoring it at that point. This may be for such reasons as controlling vibration; controlling, directing, and limiting the amount of thermal expansion in a pipe; and

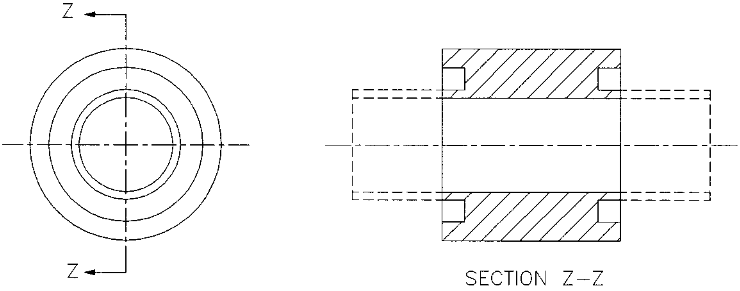


**FIGURE B13.5a** Illustration of a simple machined or molded block-style rigid termination fitting. *(U.S. Patent #4,930,544)*

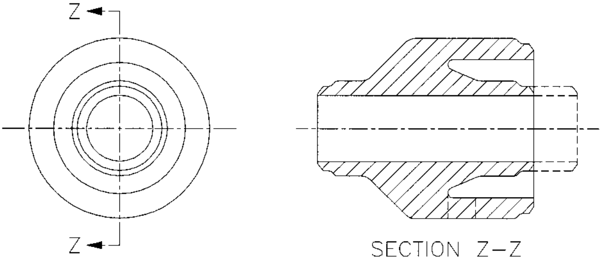


**FIGURE B13.5b** Illustration of a rigid termination fitting with contours, smooth radii, and external reinforcement to withstand concurrent axial loads due to thermal expansion, radial differential thermal expansion, vibration and dead weight testing. *(U.S. Patent #5,141,251, additional pages pending; Orion Fittings, Inc., from C. Ziu,* "Handbook of Double Containment Piping Systems," *McGraw-Hill, 1995.)*

other reasons. Since it is required in single-walled piping practice, anchoring is thus required for primary piping in double containment piping for the same reasons for its use in single-walled piping.

***External-Anchoring Components and Methods.*** A primary pipe in a double containment system may either be anchored externally (external to the annulus) or internally (internal to the annulus). An external arrangement involves interruption

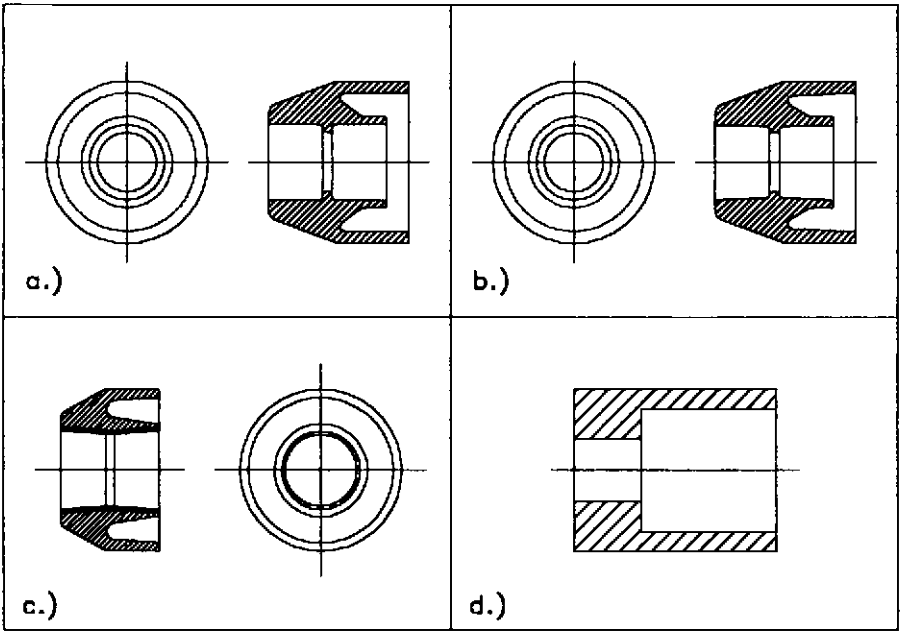


**FIGURE B13.6** Examples of solid RTRP termination fittings: (a) straight socket "V" fitting; (b) tapered socket "V" fitting; (c) tapered socket "V" fitting with reinforced corrosion liner; U.S. Patent 5,141,261 applies to a–c; (d) straight socket termination fitting (source for d: Fibercast Co.) *(From "Handbook of Double Containment Piping Systems," C. Ziu, McGraw-Hill, New York, 1995.)*

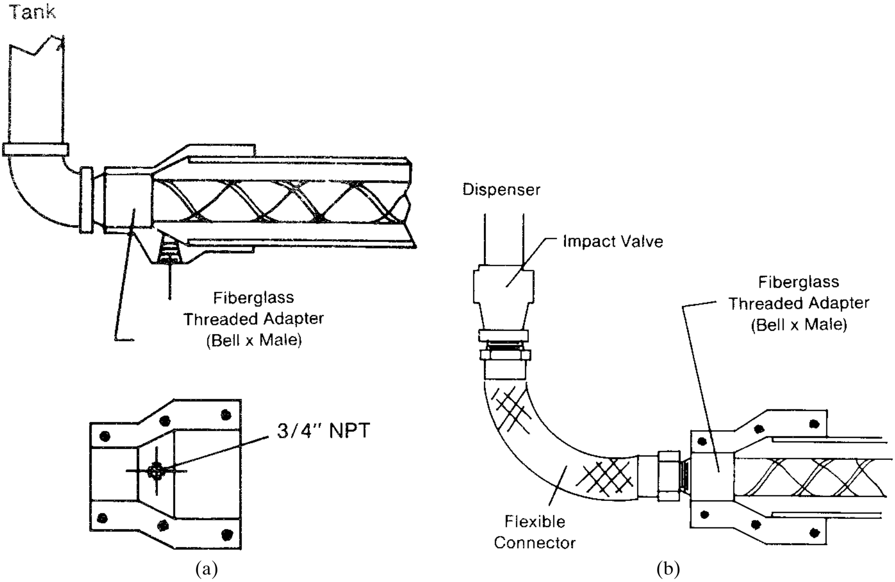


**FIGURE B13.7** Examples of clam-shell fiberglass termination fittings: (a) termination concentric reducer with integral drain; (b) termination concentric reducer. *(Source: Smith Fiberglass Products, Inc.)*

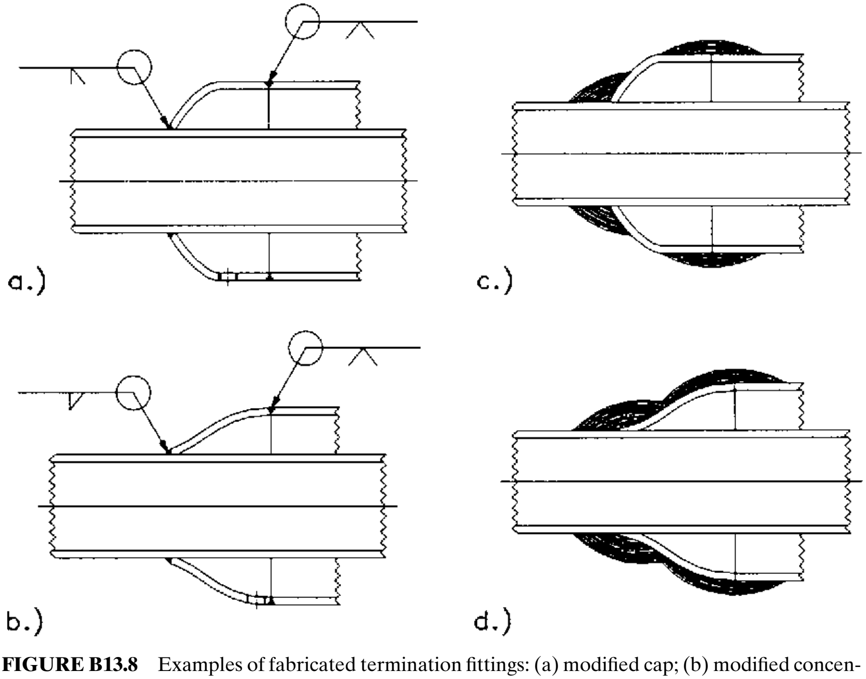


**FIGURE B13.8** Examples of fabricated termination fittings: (a) modified cap; (b) modified concentric reducer; (c) RTRP cap with overwrap; (d) modified RTRP concentric reducer with overwrap.

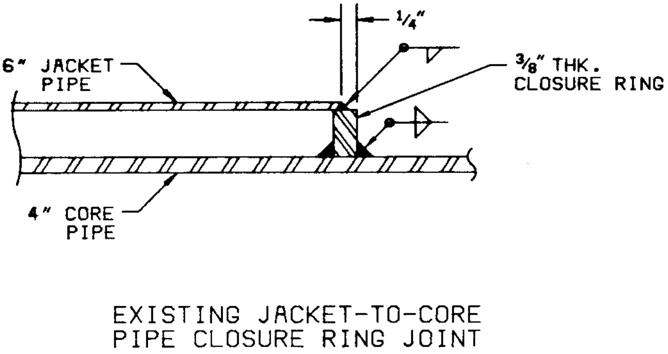


**FIGURE B13.9** Example of a termination closure ring for metallic systems. *(Source:* "Failure Assessment and Redesign of a Jacketed Piping System, a Practical Approach," *by W. E. Short II, Pressure Vessels and Piping Conference, 1988, ASME, PVP Vol. 139, #H00423.)*

of the secondary-containment feature, and is also referred to as a double termination arrangement. Since termination arrangements are a natural point of interconnection, the systems are restrained in place. Further, since they may be bolted together via a flange, the flanges may be secured to a building part, resulting in a completely rigid arrangement. The same effect can be achieved if an outer pipe is anchored at points away from the flange on both sides and sufficient intermediate guiding is provided.

The main drawback with this type of arrangement is that this area is no longer secondarily contained. Some other means of secondary containment must be added. If secondary containment is required to be provided, then possible solutions for aboveground systems include either a dike structure to be constructed around it, or a protective flange cover provided. An example of a protective flange cover for a double termination arrangement via flange is illustrated in Fig. B13.11. Another option in some aboveground applications is to leave the flange arrangement single contained and provide daily visual inspection at this point. In underground systems,

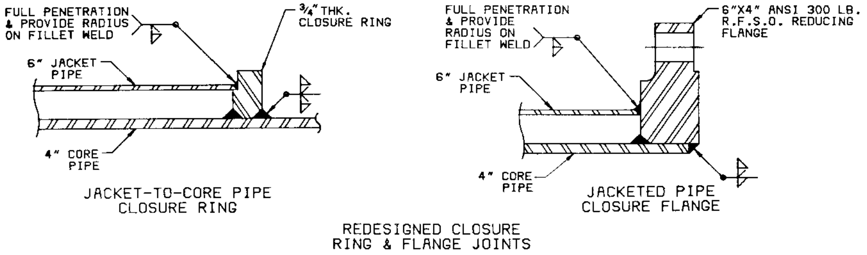


**FIGURE B13.10** Example of a termination closure ring for metallic systems that has an insert style secondary containment pipe attachment, and that extends beyond the secondary containment. Note the counter bevel weld details for the primary pipe attachment, and the thicker ring portion together adds strength and resistance to cyclic loads of a differential thermal expansion nature. *(Source:* "Failure Assessment and Redesign of a Jacketed Piping System, a Practical Approach," *by W. E. Short II, Pressure Vessels and Piping Conference, 1988, ASME, PVP Vol. 139, #H00423.)*

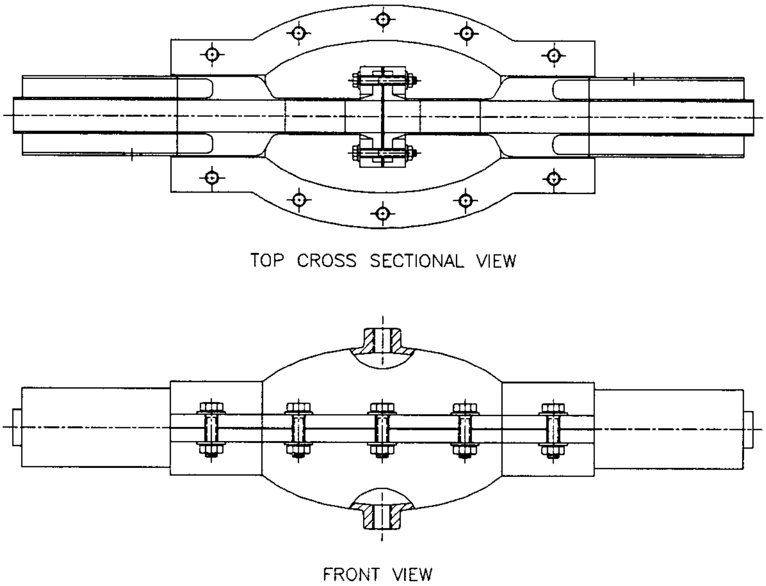


**FIGURE B13.11** Illustration of a protective flange cover. *(U.S. Patent #5,141,256)*

the arrangement will require either placement within a concrete sump or manhole, or the provision of a protective flange cover.

***Internal-Anchoring Components and Methods.*** There are options for anchoring the primary piping that eliminate the need to interrupt the containment casing. A variety of internal methods exist, some of which are fabricated, and others that involve specialized fittings.

A basic fabricated version, termed an *internal-baffle* arrangement, is illustrated in Fig. B13.12 and Fig. B13.13. This method is a variation of the termination closure

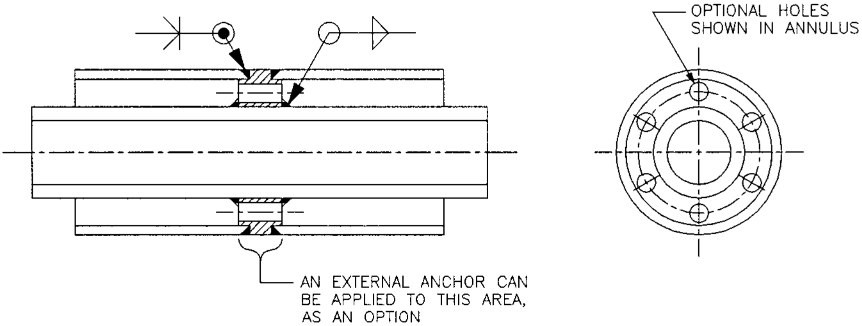


**FIGURE B13.12** A basic internal baffle–style internal anchor, which is a structural attachment to the primary pipe. This type of device is limited to metallic pipes due to the limitations of welding or bonding nonmetallic materials to achieve adequate shear strength.

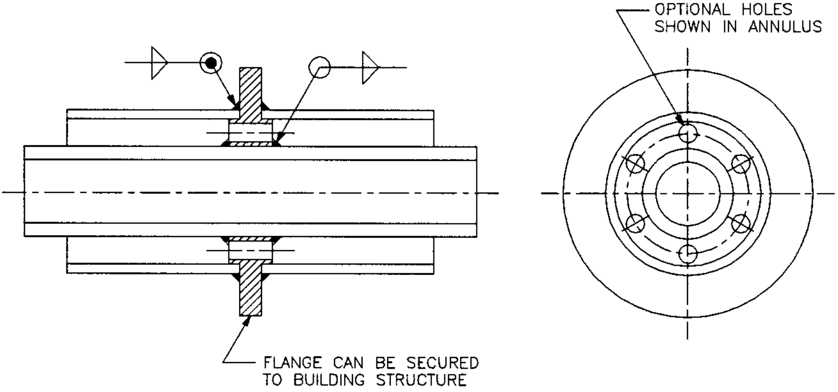


**FIGURE B13.13** A variation of the internal-baffle concept shown in Figure B13.12, in which the baffle extends radially beyond the secondary containment pipe for the purpose of being welded or bolted to an external structural member.

ring described earlier. It is suitable in metallic systems where the metal can be directly welded to the baffle.

A variation of the internal-baffle for use in systems that use a metallic primary piping and a nonmetallic outer system is illustrated in Fig. B13.14. This type, like the version shown in Figure B13.13, may have the baffle extend radially in order to allow it to be directly attached or secured to an external structure. These arrangements are suitable in aboveground applications; in underground applications the

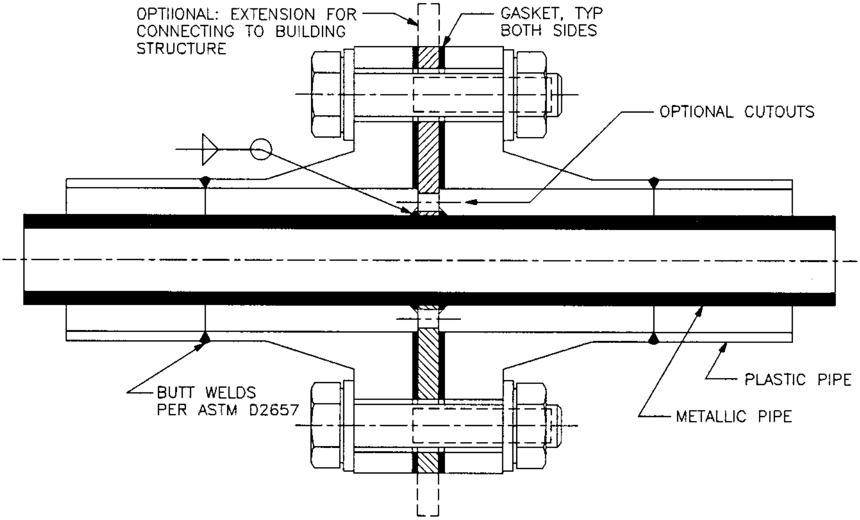


**FIGURE B13.14** Internal anchoring method for metallic primary, nonmetallic secondary containment piping arrangements.

flanges would have to be directly buried and may therefore require extra protection (i.e., coating and cathodic protection of the bolts, in addition to protective shrink-wrap covers, etc.).

A structural design of a homogeneous internal-anchor component (perhaps more appropriately termed an *internal termination anchoring fitting,* as it effectively terminates double containment at its point of use) is presented in Figs. B13.14 and B13.16. Figure B13.15 illustrates a solid annulus version, while Fig. B13.16 illustrates a version that is designed to allow annular flow (and maximize the flow through the component).

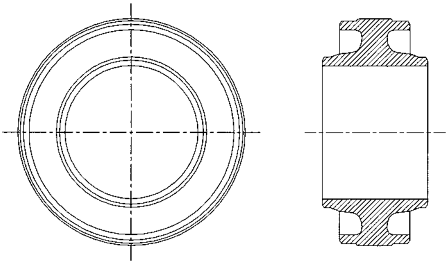


**FIGURE B13.15** An example of a homogeneous internal anchor coupling having a solid annulus for compartmentalization purposes. *(U.S. Patents #5,141,261 and 4,930,544)*

Any homogeneous-material internal-anchoring component is generally considered to possess single containment in its center portions. Therefore, these components may require additional secondary containment around their exterior (i.e., a concrete sump, dike, etc.) to satisfy secondary containment requirements.

Figure B13.17 illustrates another type of patented internal-anchor fitting, designed to enable the primary piping to be anchored while minimizing stresses on the component itself, lessening the chance of failure as compared to the homogeneous versions, yet maintaining 100 percent secondary containment and also allowing any combination of materials.

The fitting shown in Fig. B13.17 allows for drainage of leaks through the annulus.

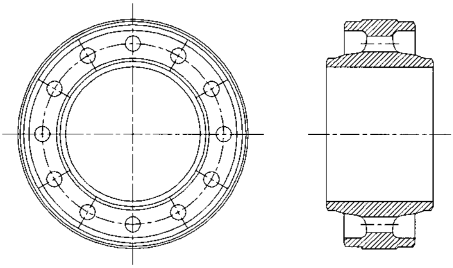


**FIGURE B13.16** An example of a homogeneous internal-anchor coupling having annular cutouts for flow or to allow for leak detection cable in the section. *(U.S. Patents #5,141,261 and 4,930,544)*

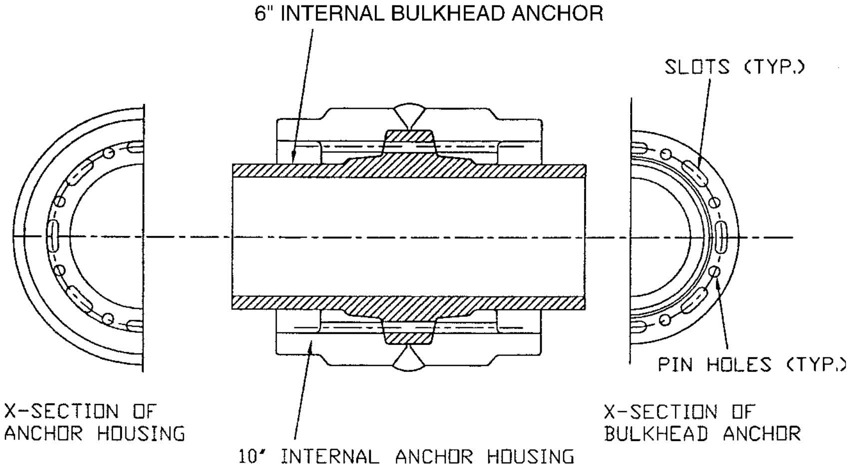


**FIGURE B13.17** Example of a patented proprietary internal-anchor coupling for thermoplastic or other material, primary piping with a separate secondary-containment housing that can be constructed of the same or a dissimilar plastic material. Shown is a copolymer polypropylene primary bulkhead housed inside an HDPE outer housing. *(U.S. Patents #5,085,471 and #5,141,261)*

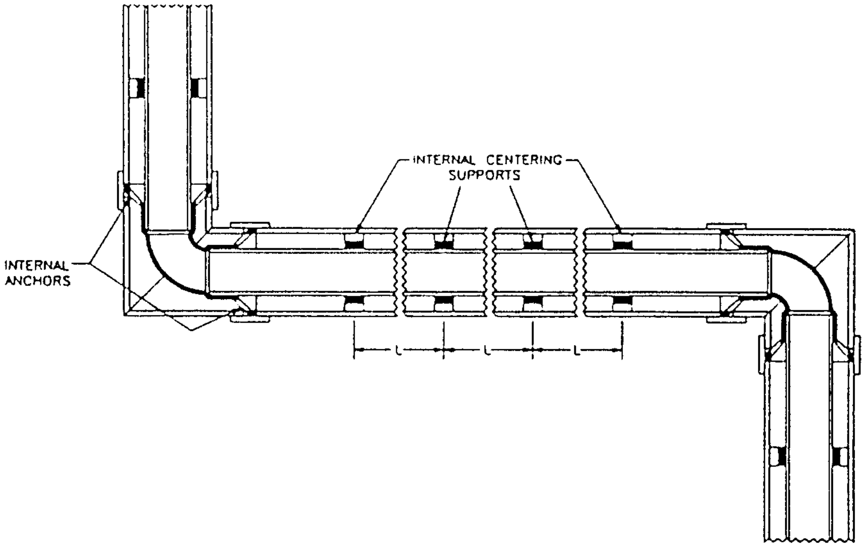


**FIGURE B13.18** Illustration of a totally restrained section of double containment metallic piping that is restrained by means of internal-baffle style anchors welded on each side of the 90° elbows.

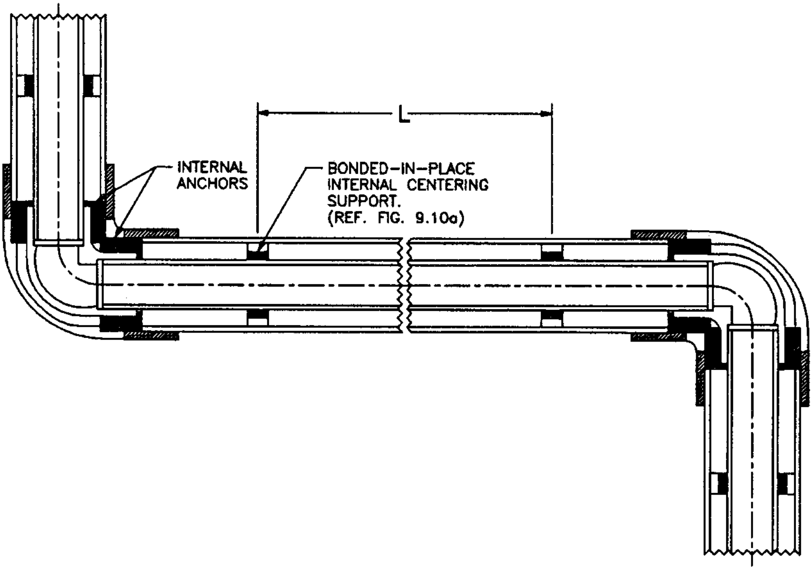


**FIGURE B13.19** Illustration of a totally restrained section of RTRP double containment pipe, which is restrained by means of bonded in place collar-style internal anchors on each side of the 90° elbows. *(Source: Fibercast Co., U.S. Patent #4,886,305.)*

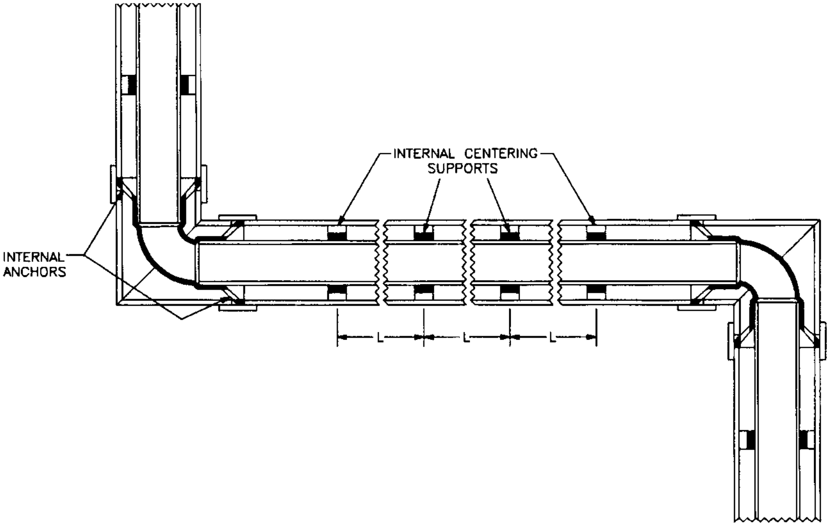


**FIGURE B13.20** Illustration of a totally restrained section of thermoplastic double containment pipe, which is restrained by means of Rionlock™ conical-shaped internal anchors on each side of the 90° elbows. *(Orion Fittings, Inc.; Patent Pending)*

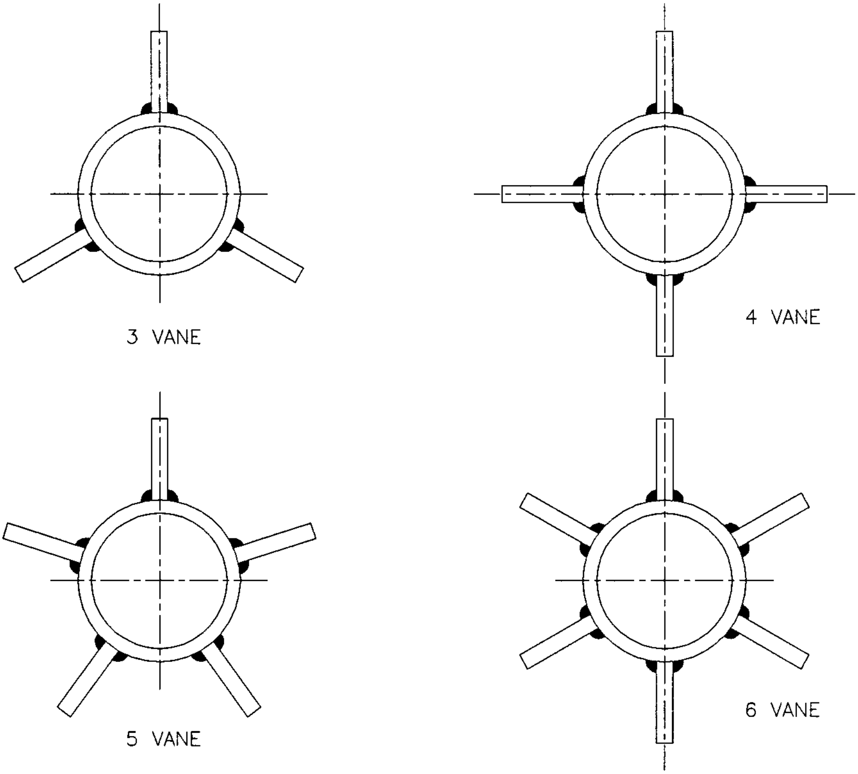


**FIGURE B13.21** Illustration of three-, four-, five-, and six-vane fabricated vane-type interstitial supports, where the vanes or fins are welded directly to the primary pipe.

Alternatively, it may be provided with specialized *annular plugs* or seals to prevent flow. One would desire to prevent annular flow when designing a system in a compartmentalized fashion or when using these fittings as termination fittings.

## Anchored Systems Using Anchored Fittings

One of the more common ways to anchor double containment piping systems is to anchor each and every fitting internally by the use of collar inserts or welded in place plate supports. This method has been used extensively for many years in jacketed process piping systems using metallic materials. However, the method has been popularized in recent years in double containment systems due to the highly successful commercial introduction of a patented system available from the Fibercast Co. (Sand Springs, Okla.) trademarked as the DualCast System. Examples of this type of system are shown for metallic systems and for the DualCast system in Figs. B13.18 and B13.19, respectively. An example of a patent pending system using conical internal anchors in thermoplastic socket-based drainage systems is shown in Fig. B13.20.

In this type of system it is important to anchor every outlet of every fitting. In other words, branch fittings require anchoring on all three sides and elbows on both sides. In doing so, the straight piping running between fittings are thereby anchored as well, although the straight pipes must still be adequately guided axially between consecutive fittings, except for very short runs.

### Interstitial Supports

Various types of interstitial supports (also referred to as centralizers, among other names) are shown in Figs. B13.21 through B13.26.

### Pressure Fittings

Examples of typical restrained and unrestrained pressure elbow and branch fittings are shown in Figs. B13.27 through B13.38.

### Nonpressure (Drainage) Fittings

Various types of restrained and unrestrained nonpressure drain, waste, and vent fittings are shown in Figs. B13.39 through B13.58.

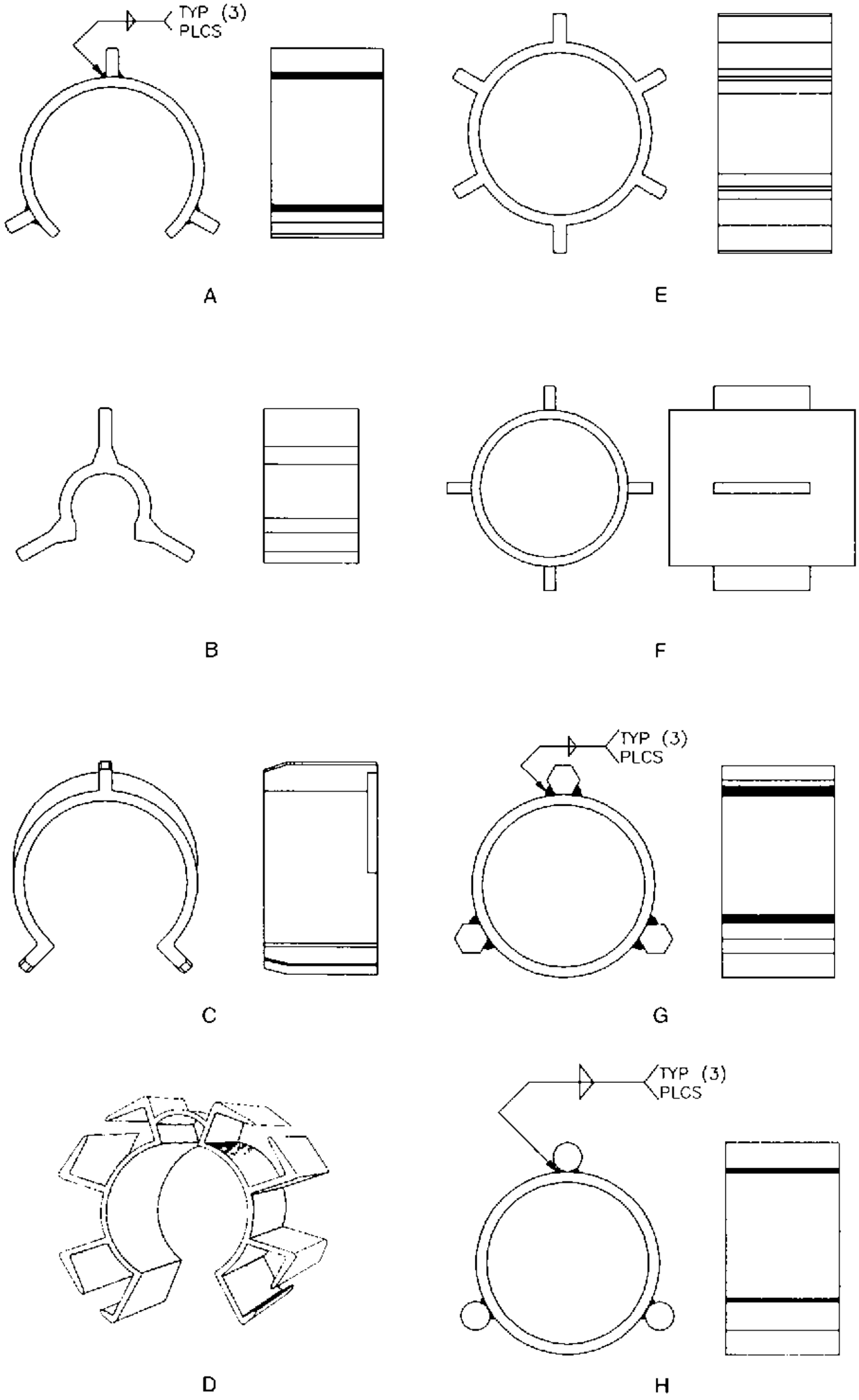


**FIGURE B13.22** (left) Examples of miscellaneous vane-type supports: (a) fabricated vane-type clip-on support; (b) molded or cast-vane support with integrally reinforced vanes (Guardian div. of Eslon); (c) molded vane support with lateral reinforcement of vanes (U.S. Patent 5,018,260) AGRU, Asahi/America; (d) complex molded vane support with external pads (G. Fisher/R&G Sloane); (e) collar-style with vanes; (f) vane-type coupling; (g) welded hex-rod with 3-vanes; (h) welded round bar stock with 3-vanes.

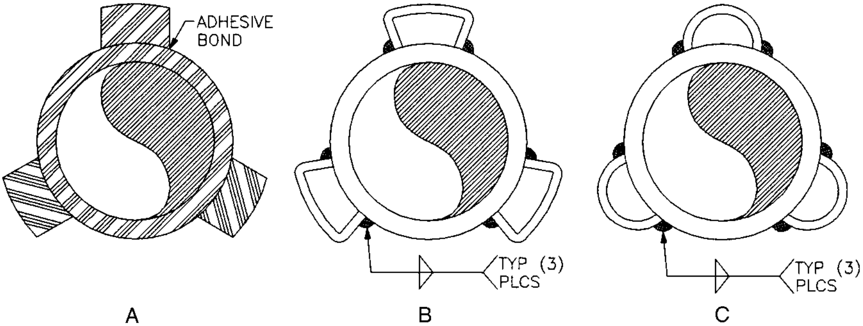


**FIGURE B13.23** Examples of support pad-type internal supports: (a) illustration of a typical bonded three-pad support arrangement for a fiberglass primary pipe; (b) illustration of a metallic primary pipe having three pipe saddles welded to its surface; (c) use of welded half-pipe saddles on a primary pipe.

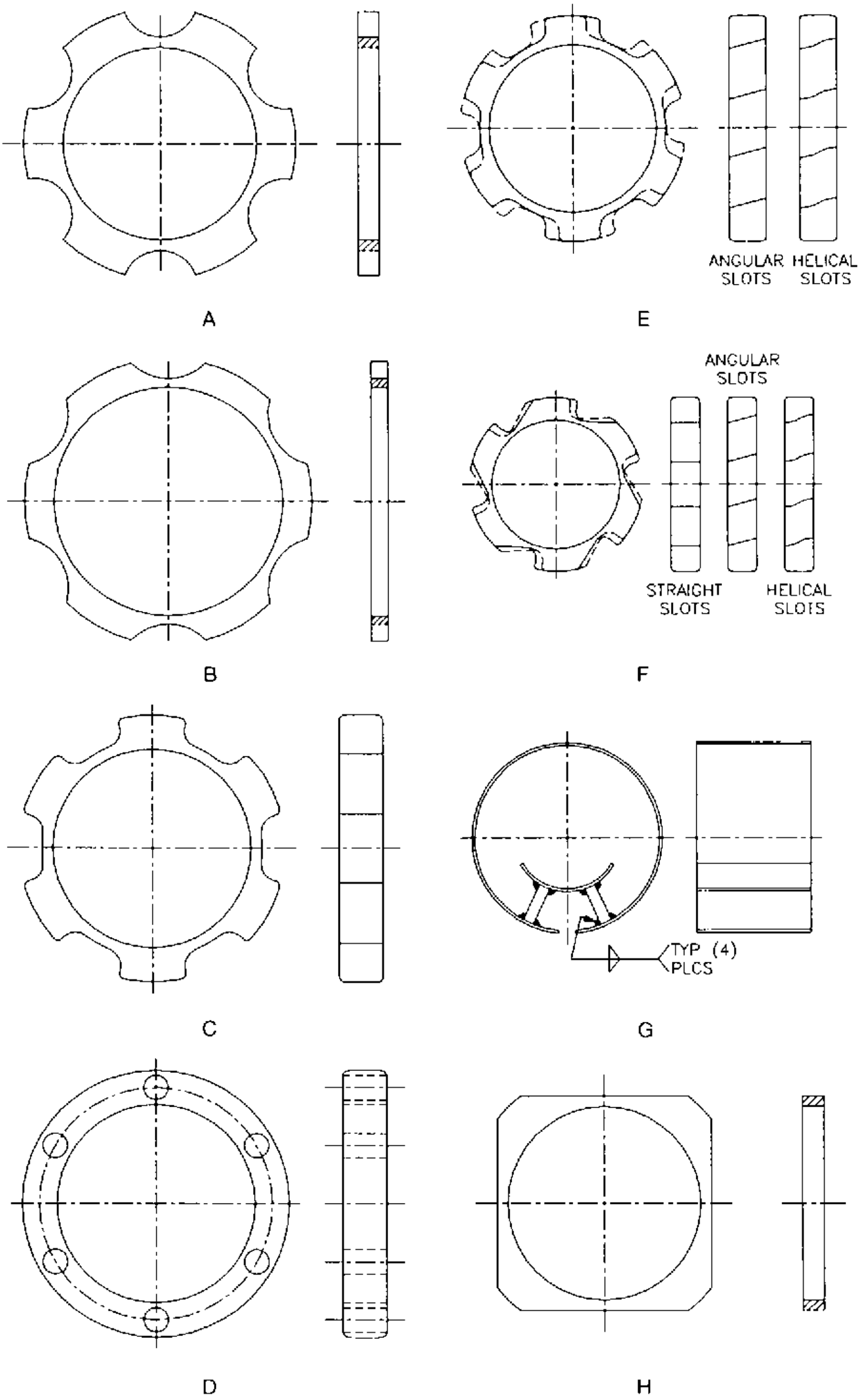


**FIGURE B13.24** (left) Various examples of collar-style interstitial supports: (a) basic support with half-moon cutouts; (b) with extended open area; (c) with annular slots; (d) with drilled holes; (e) with angular slots or curved helical vanes; (f) for improved annular flushing and drying *(U.S. Patent #5,400,828 applies to (e) and (f));* (g) fabricated saddle-type; (h) square shape for fabricated thermoplastic systems intended for simultaneous fusion.

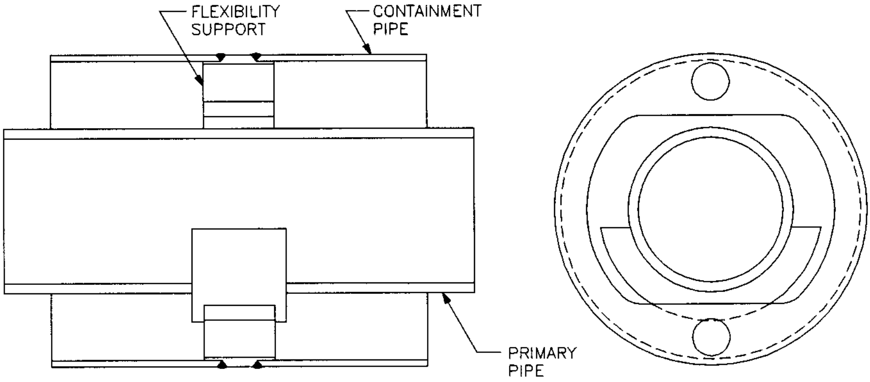


**FIGURE B13.25a** A basic flexibility support designed to be welded or bonded to the outer jacket. *(U.S. Patent Nos. 5,862,834 and 5,197,518; additional patents pending; Orion Fittings, Inc.)*

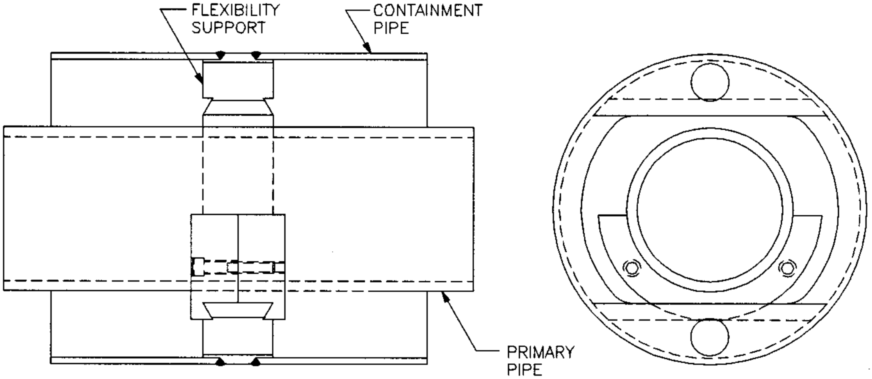


**FIGURE B13.25b** A flexibility support having a saddle that interlocks to the base via a dovetailed arrangement. *(U.S. Patent Nos. 5,862,834 and 5,197,518, additional patents pending; Orion Fittings, Inc.)*

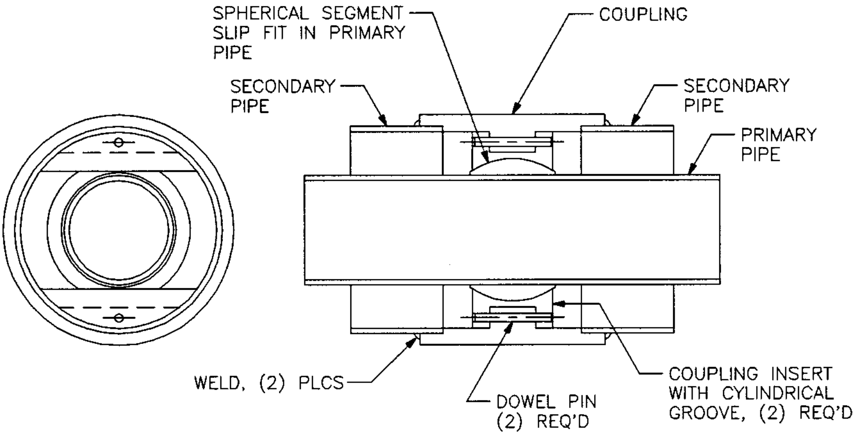


**FIGURE B13.26** Illustration of an internally guided ball-type flexibility support. The version shown is designed to use in an all-welded system. Variations are also available that are intended for use in systems with a mechanically joined outer jacket. *(U.S. Patent Nos. 5,901,753; 5,862,834 and 5,197,518; Orion Fittings, Inc.)*

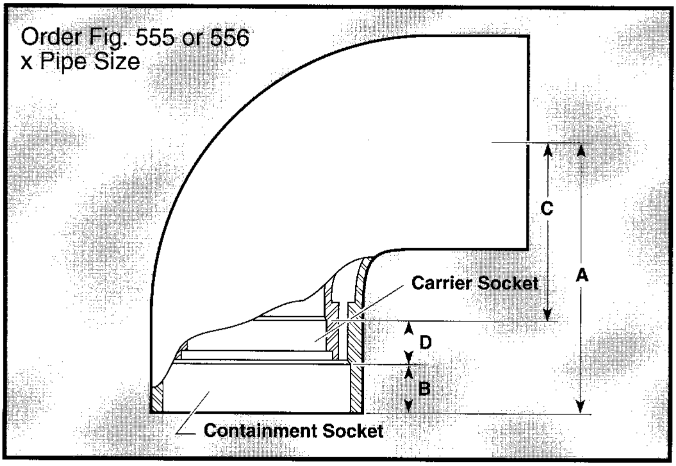


**FIGURE B13.27** Restrained fiberglass 90° elbow *(U.S. Patent 4,886,305; Fibercast Co.)*

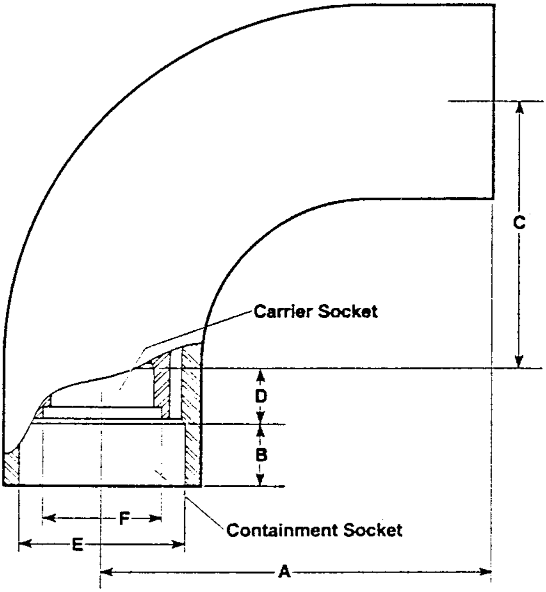


**FIGURE B13.28** Restrained fiberglass long radius 90° elbow *(U.S. Patent 4,886,305; Fibercast Co.)*

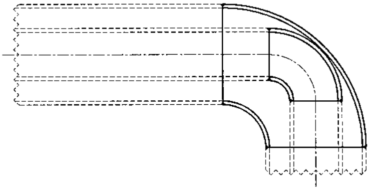


**FIGURE B13.29** Example of a double-containment elbow arrangement whereby the primary elbow has a shorter radius than that of the corresponding secondary containment elbow.

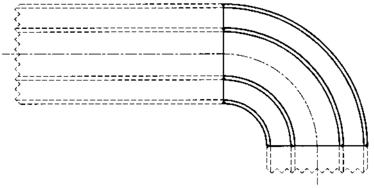


**FIGURE B13.30** Example of an elbow where the inner and outer radii are equal throughout their curved portion.

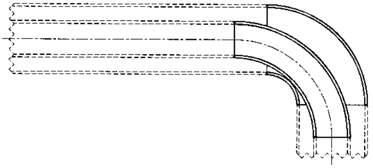


**FIGURE B13.31** Example of an elbow whereby the inner elbow has a radius which is longer than that of the corresponding secondary containment elbow. *(U.S. Patent 5,452,922; Orion Fittings, Inc.)*

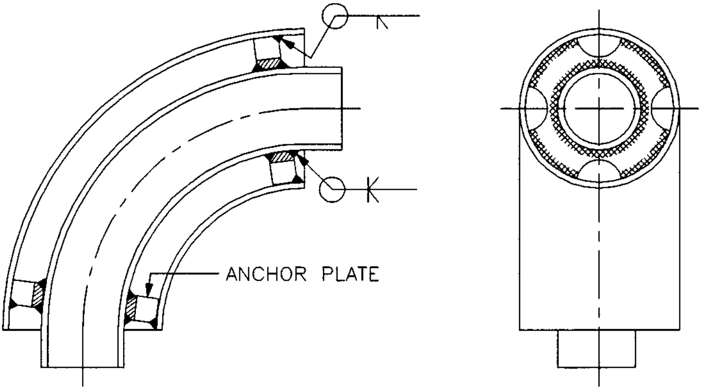


**FIGURE B13.32** Restrained metallic elbow.

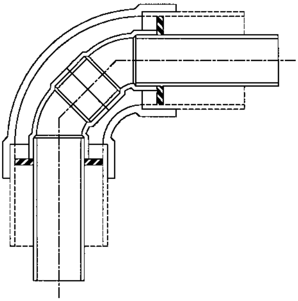


**FIGURE B13.33** Typical thermoplastic 90° elbow combination for parts using socket-type joining systems whereby the carrier elbow is made of two 45° elbows. *(Orion Fittings, Inc.)*

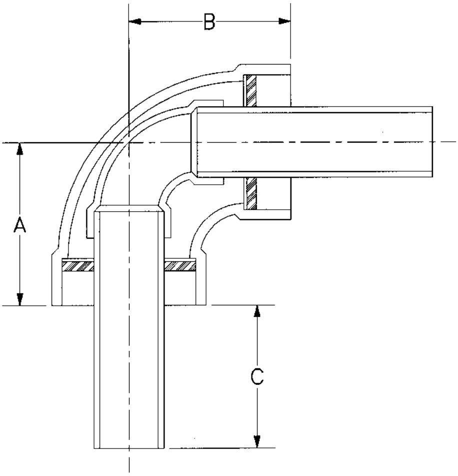


**FIGURE B13.34** Typical thermoplastic 90° elbow combination for parts using socket-type joining systems whereby the carrier elbow is a single 90° elbow. *(Orion Fittings, Inc.)*

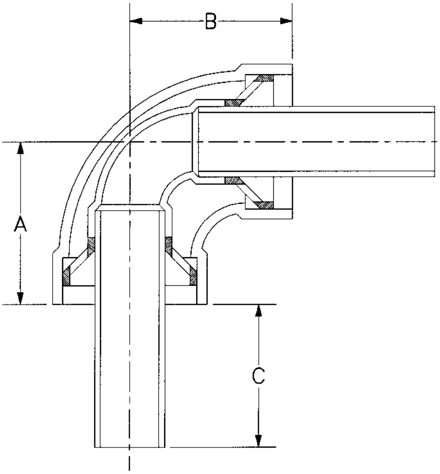


**FIGURE B13.35** Restrained thermoplastic 90° elbow combination for parts using socket-type joining systems whereby the carrier elbow is a single 90° elbow. *(Patent Pending; Orion Fittings, Inc.)*

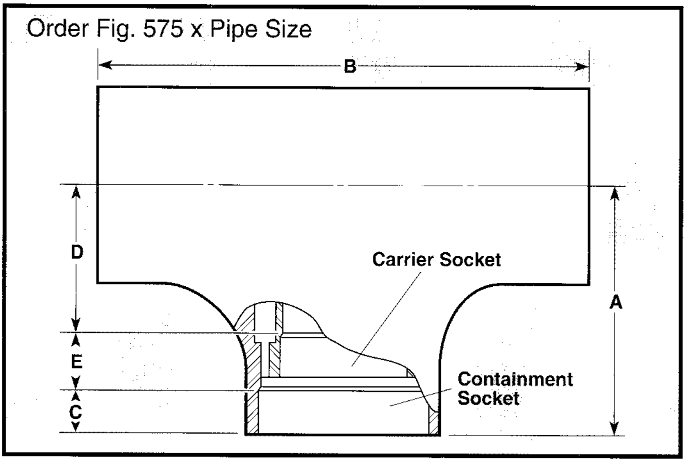


**FIGURE B13.36** Restrained fiberglass Tee *(U.S. Patent 4,886,305; Fibercast Co.)*

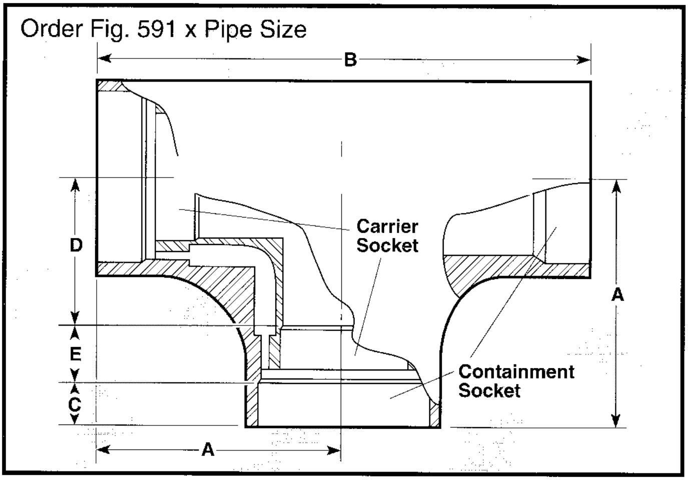


**FIGURE B13.37** Restrained fiberglass 90° carrier elbow contained in a Tee. *(U.S. Patent 4,886,305; Fibercast Co.)*

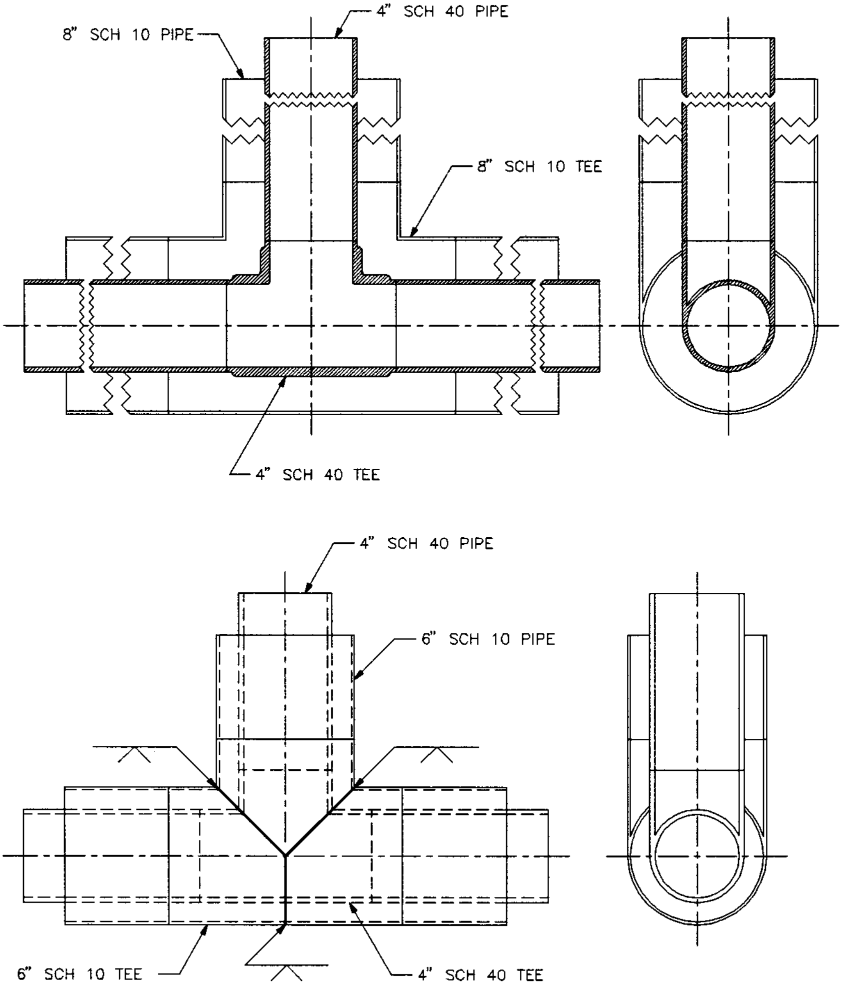


**FIGURE B13.38** (Above) Typical tee in a split-and-reassembled outer tee; (Below) Typical tee in a completely fabricated outer tee. *(From* "Handbook of Double Containment Piping Systems," *C. Ziu, McGraw-Hill, New York, 1995.)*

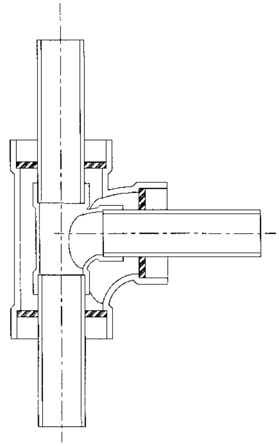


**FIGURE B13.39** Example of thermoplastic sanitary tee using molded code approved carrier fitting. *(Orion Fittings, Inc.)*

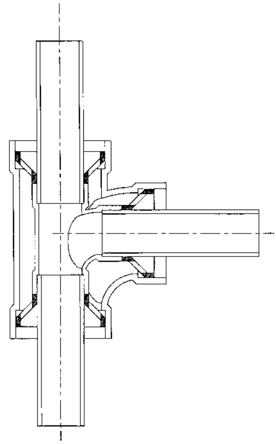


**FIGURE B13.40** Rionlock™ restrained thermoplastic sanitary tee using molded code approved carrier fitting. *(Patent Pending; Orion Fittings, Inc.)*

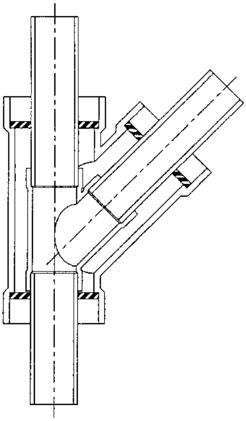


**FIGURE B13.41** Example of thermoplastic 45° lateral (wye) using molded code approved carrier fitting. *(Orion Fittings, Inc.)*

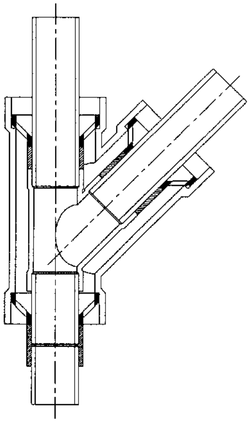


**FIGURE B13.42** Rionlock™ thermoplastic restrained 45° lateral (wye) using molded code approved carrier fitting. *(Patent Pending; Orion Fittings, Inc.)*

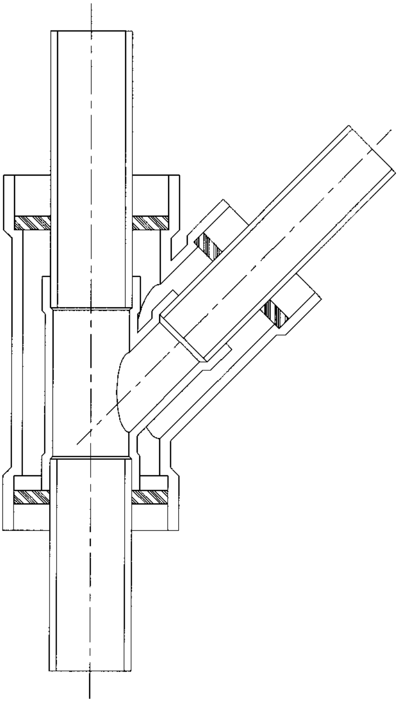


**FIGURE B13.43** Example of thermoplastic 45° reducing lateral (wye) using molded code approved carrier fitting. *(Orion Fittings, Inc.)*

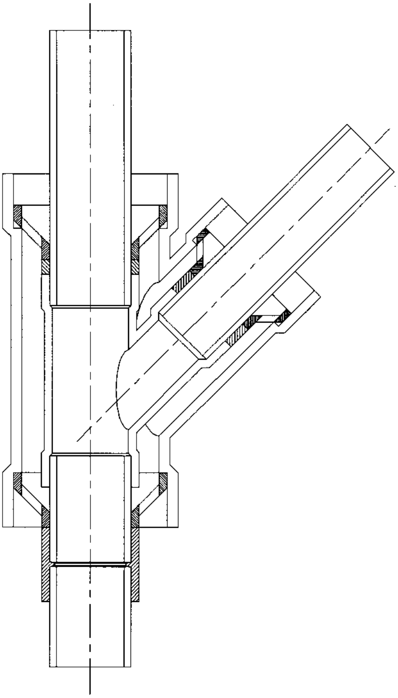


**FIGURE B13.44** Rionlock™ thermoplastic restrained reducing 45° lateral (wye) using molded code approved carrier fitting. *(Patent Pending; Orion Fittings, Inc.)*

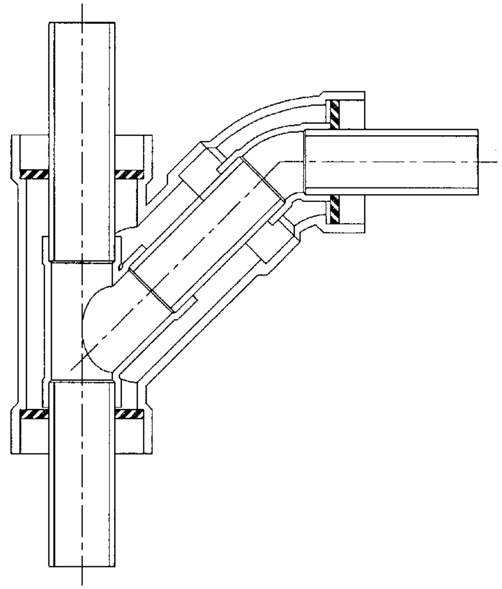


**FIGURE B13.45** Example of thermoplastic long-turn wye using molded code approved carrier fitting. *(Orion Fittings, Inc.)*

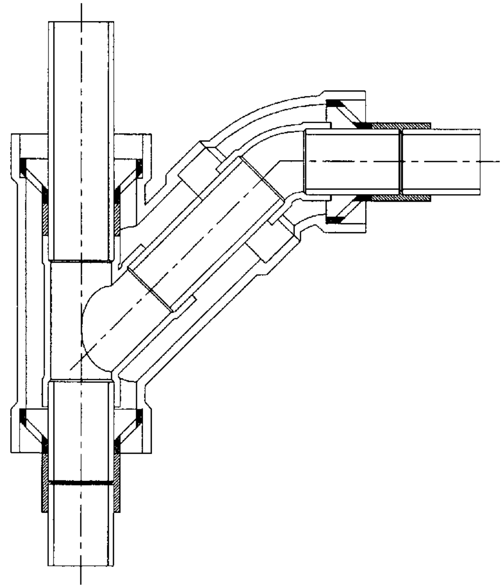


**FIGURE B13.46** Rionlock™ thermoplastic restrained long-turn wye using molded code approved carrier fitting. *(Patent Pending; Orion Fittings, Inc.)*

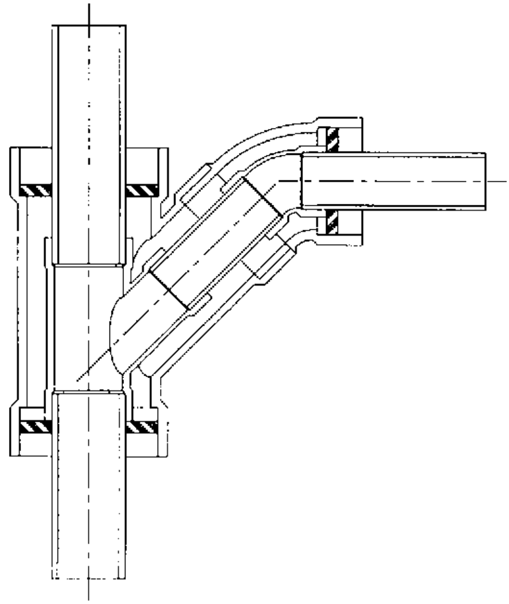


**FIGURE B13.47** Example of thermoplastic reducing long-turn wye using molded code approved carrier fitting. *(Orion Fittings, Inc.)*

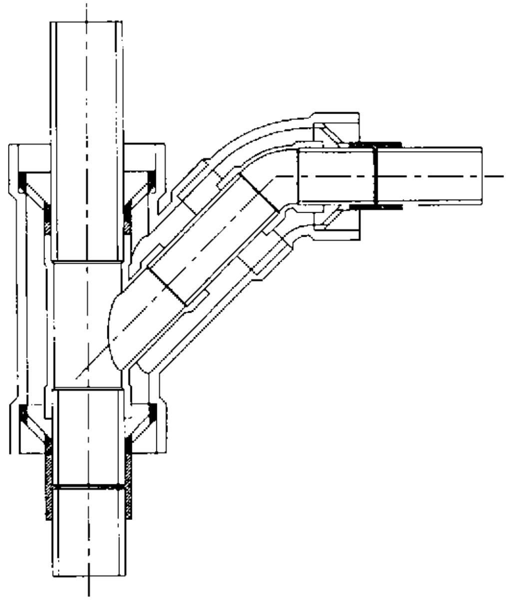


**FIGURE B13.48** Rionlock™ thermoplastic restrained long-turn wye using molded code approved carrier fitting. *(Patent Pending; Orion Fittings, Inc.)*

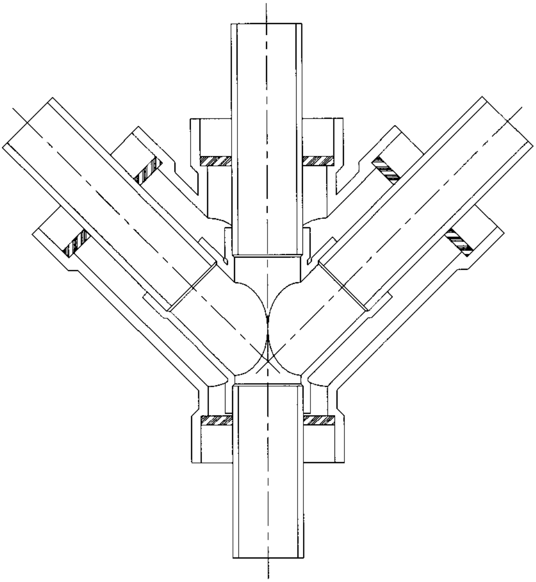


**FIGURE B13.49** Example of thermoplastic 45° double lateral (wye) using molded code approved carrier fitting. *(Orion Fittings, Inc.)*

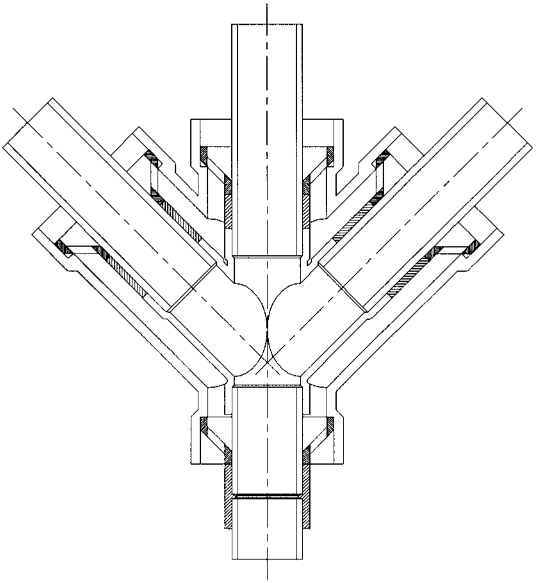


**FIGURE B13.50** Rionlock™ thermoplastic restrained 45° double lateral (wye) using molded code approved carrier fitting. *(Patent Pending; Orion Fittings, Inc.)*

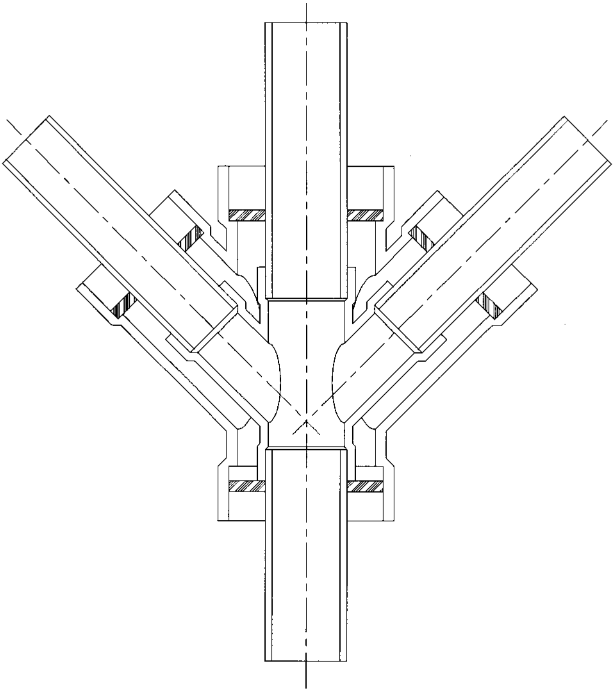


**FIGURE B13.51** Example of thermoplastic 45° double reducing lateral (wye) using molded code approved carrier fitting. *(Orion Fittings, Inc.)*

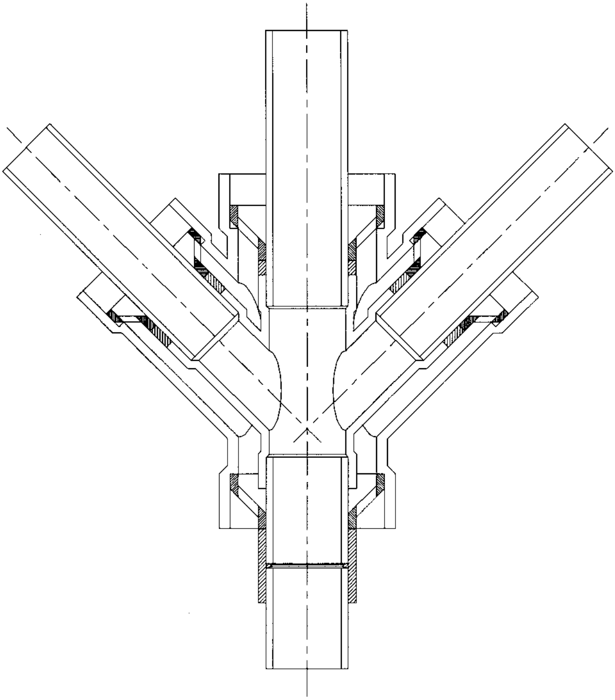


**FIGURE B13.52** Rionlock™ thermoplastic restrained 45° double reducing lateral (wye) using molded code approved carrier fitting. *(Patent Pending; Orion Fittings, Inc.)*

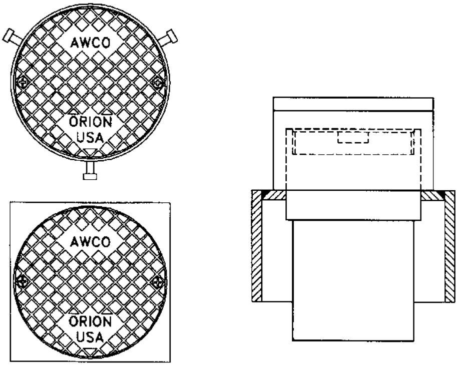


**FIGURE B13.53** Example of a thermoplastic double containment clean-out with nickel-bronze finished floor adjustable cover *(Orion Fittings, Inc.)*

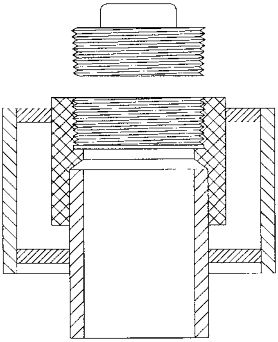


**FIGURE B13.54** Example of a thermoplastic double containment clean-out. *(Orion Fittings, Inc.)*

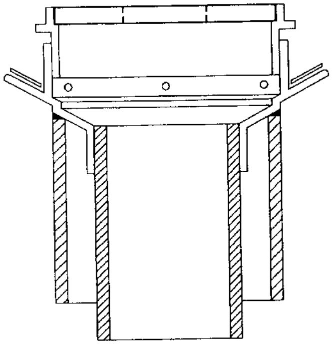


**FIGURE B13.55** Example of a thermoplastic double containment floor drain capable of withstanding a 10,000 pound load applied over its cover. *(Orion Fittings, Inc.)*

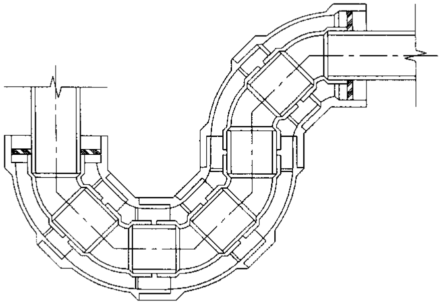


**FIGURE B13.56** Example of a thermoplastic double containment P-trap. *(Orion Fittings, Inc.)*

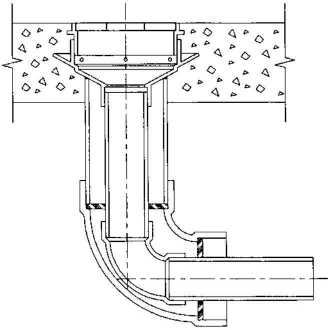


**FIGURE B13.57** Example of a thermoplastic double containment floor drain with factory preassembled 90° elbow outlet. *(Orion Fittings, Inc.)*

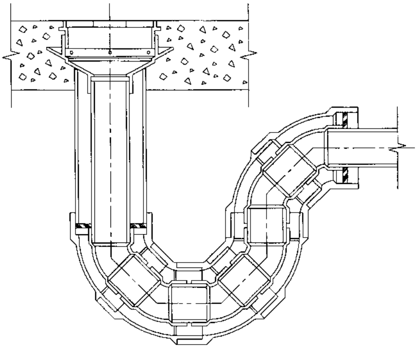


**FIGURE B13.58** Example of a thermoplastic double containment floor drain with factory preassembled P-trap outlet. *(Orion Fittings, Inc.)*

## *LAYOUT OF DOUBLE CONTAINMENT PIPING SYSTEMS*

A double containment piping system is only partially designed once its piping and components have been sized and their pressure ratings established. The layout of the system must then be determined, taking into account all the requirements of the application. These include: flexibility requirements, installation requirements, inspection, examination and testing requirements, leak detection–system requirements, and others. It also involves the detailed design of interconnecting parts, design and placement of centering devices (interstitial supports), and double containment fitting details. Space issues are of the utmost importance, as potential interferences may exist between inner and outer components. This includes interferences that may result from differential movements that occur when inner and outer systems are subjected to different amounts of thermal expansion, which may be undesirable. The allowable space can have a profound effect on the fabrication and installation of a system.

System layout is interrelated to all other aspects of system design by virtue of performance criteria. For instance, the final pressure rating of a primary pipe system will be directly affected by the layout and the resulting frictional losses that are calculated. Each layout choice will also result in unique stress levels developed in the system components, based on design temperatures and pressures. The distribution of these stresses will also change upon each change in layout detail. Layout choices will have an effect on other aspects of system design as well (i.e., structural, heat transfer, fluid dynamics, etc.). In each design, the layout process involves first selecting a layout and then determining its suitability for the given design conditions. Often this involves computing stresses or performing some other analysis to determine if the chosen layout will result in a safely working system over its design life; if it is determined that the system may fail under the layout that has been selected, aspects of the layout must be changed and a new analysis performed. By its very nature, the layout process involves trial and error on the part of the engineering design team.

There are two layout issues to which the first time designer and customer of a double containment piping system must pay special attention at the start of a project. The first concerns the overall size of double containment piping and its components. By its nature, the overall diameter sizes are much greater than their corresponding single-walled primary piping systems. While this aspect of double containment piping sounds obvious, it often is a source of surprise and frustration for facility owners and piping designers. This aspect of double-containment piping is a limiting factor, particularly when a system is being installed as a retrofit into an existing facility, or a specified slope has to be met.

A second major item of importance has to do with allowing sufficient clearance for primary fittings to be installed or fabricated within secondary containment fittings; in other words, providing adequate clearance between the two components or, stated differently, proving adequate internal clearance. This item is important for all systems, but it is highly important for those requiring an internally flexible design and layout.

It is difficult to present specific criteria for all layout details that may be encountered in a system design. There are an infinite set of conditions that may be encountered; no two piping systems are ever completely alike. However, considerations for many of the common aspects of double containment piping system layout can be described.

The layout selected will have an effect on the overall system performance. The overall layout of any system, consisting of each individual detail acting together to form a complete system, must always be analyzed as to its suitability by a competent professional to achieve a safe, working system.

## Pressure Piping Systems

Pressure piping systems include both aboveground and underground systems that operate at 15 psig (1.1 bar) or greater internal pressure, or operate at vacuum conditions (below 0 psig). Secondary containment portions of these systems may also be pressure rated to the same extent as the primary, but not in all cases. The choice is normally up to the designer, although code requirements may dictate whether it is required. Systems that operate under vacuum conditions (less than 0 psig, 14.7 psia, 1 bar absolute) are also classified as pressure piping systems even if they will never be subjected to a positive internal pressure.

The layout of a pressure piping system is far from an exact science and is not taught in schools. Most competent designers develop their techniques from experience and from working with other designers. The ASME B31 Pressure Piping Codes state many useful layout concepts based upon allowing adequate space and minimizing the stresses of pressure piping systems. To minimize stresses in a system layout, as described in the ASME Codes, one must provide a system whose stresses are well balanced during operation. A system whose stresses are evenly balanced will result in a system where detrimental stresses will not occur during operation. These criteria, which set a worldwide accepted basis for determining the layout of a pressure piping system, also provides the designer with guidance to determine if a system can have a restrained or flexible layout.

## Nonpressure Double Containment Piping Layout Considerations

Nonpressure systems include both aboveground and underground systems whose primary systems operate at a pressure between 0 and 15 psig (bar). The major type of nonpressure system is the gravity flow chemical drain waste and vent (DWV) system, which is designed to drain chemical waste by means of gravity to sewers, treatment or holding tanks, or a treatment facility. The secondary, containment portions of these systems are typically designed to the same performance specs as the primary system (i.e., to a pressure rating of 10 ft of head, or 0.3 bar). In some instances, the secondary containment jackets of these systems may be designed in an open-ended fashion, whereby the secondary containment jacket flows open ended over a tank or treatment pond. When a system is allowed to be designed in such a manner, the pressure rating of the secondary containment at most will accommodate any head buildup due to developed back pressures. The secondary, containment design normally is the choice of the designer, although Code or regulatory requirements may dictate what is required.

While many underground waste systems are of the gravity-fed, nonpressure type, some double containment waste-piping transfer lines can be pressurized due to the distance they must convey the fluids, or due to a lack of slope. Also, in some systems where a substantial change in elevation exists (> 33 ft, 10 m), the line may have to be reclassified as a pressure system, as some of its components will be subject to greater than 15 psi (1.1 bar). In many projects, the site does not allow for much change in elevation. Since elevation changes will be limited, the system may have both nonpressure and pressure characteristics. The usual design in such applications involves the nonpressure line (lines) draining into a sump, whereby the fluid is then moved within a force main by the use of a sump pump.

Underground piping may include pressure transfer lines that are routed underground at the choice of the owner. This may be due to reasons of surface aesthetics, unavailable surface space due to surface restrictions, the existence of underground tanks, or to control-piping temperatures-safety concerns. In the case of petroleum marketing outlets, piping is placed underground for all four reasons. Some aspects of underground layout apply to nonpressure lines and pressure lines. General layout considerations for underground pressure and nonpressure piping double containment systems are discussed here.

Many aspects of nonpressure waste piping and other non-ASME Code underground piping layout practices are defined in many localities by building or fire codes. There are also many well-defined layout practices that have been developed by various professional disciplines and their organizations (e.g., American Society of Civil Engineers, American Water Works Association, American Society of Plumbing Engineers, etc.). However, most competent designers involved in nonpressure piping and underground pressure piping applications gain their layout knowledge from working on actual projects and by following the practical methods of other accomplished designers.

Designers of nonpressure chemical DWV systems (e.g. from laboratories) should be aware of the differences between a plumbing code [e.g. IPC (BOCA/ICBO), UBC (IAPMO), CSA, etc.] and a design code (e.g. ANSI/ASME B31.3, 31.9). Design codes cover the mechanical design integrity of the components and system, whereas a plumbing code typically does not. Though a design code may not be required for certain systems by local jurisdiction, designers should consider applying such codes to verify the mechanical integrity of the system.

## Chemical Waste DWV Piping Systems, Acid Waste DWV Piping Systems, and Chemical Sewers

Chemical waste piping systems include those that serve as drain, waste, and vent piping for chemicals of all types. These types of systems are commonly referred to as *acid waste DWV systems* by plumbing engineers. Although the name implies that they are specific to the disposal of acids, they may be designed to convey acids, bases, organic chemicals, chlorinated solvents, or inorganic chemicals of all types. The name is designated as acid-waste piping because acids are among the most commonly encountered chemicals in laboratory and plating applications whereby such chemicals are commonly discharged into the waste piping after they have served their purpose. The plumbing and sanitary engineering profession has historically designated this piping with its specific label to distinguish it from other sanitary drain, waste, and vent lines in building services.

Chemical-waste materials should not be discharged into a regular sewer system without first being neutralized or treated in some fashion. Many chemical waste piping systems are designed to allow fluid to discharge into a neutralization basin or treatment pond, where the chemicals are treated. The neutralized or treated product is then allowed to be discharged into the sewer system or waterways once the effluent is within prescribed purity limits.

Layout considerations for these systems include such items as determination of diameter sizes (capacity of the piping), slope determination, determination of component style, and venting requirements. Other system selection factors (such as material selection) can, in certain locations, be based on fire-related considerations such as flame and smoke spread ratings of the materials, and adherence to U.L. (Underwriter Laboratories) and F.M. (Factory Mutual) standards. Whenever a layout is to be determined for nonpressure waste systems or other type of underground system, the authority having local jurisdiction must be contacted as to what codes, standards, and permits apply.

Whereas the design and layout of most sanitary drain, waste, and vent and other plumbing-related piping is governed by strict building codes, chemical, waste piping systems are not regulated in all areas. The reason that it may not be covered in certain local building codes is that in many municipalities it is classified as process piping. Process piping is ordinarily not covered by the general building codes. However, an aboveground system may be still subject to fire code regulations, depending on the locality where it is to be installed. Although there may not be strict coverage under building codes, the design and layout of such systems should still follow the well-defined engineering practices of ordinary DWV piping. This includes sizing practices, slope determination, provision of proper venting, and other principles of design and layout.

One aspect of chemical waste piping design that tends to be common among systems of this type is that most systems have at least part, if not all, of the system buried directly under a building slab or behind walls or between floors, which usually means very limited access to the piping system. If there is a leak detected, portions of the building usually have to be excavated to get at the pipes. It also means a disruption of ongoing activities within the building and could result in lost revenue in the event of a repair. Therefore, the selection of material for the secondary containment pipe becomes critical in this situation. The fluid will have a tendency to remain in the annulus for a fairly long period of time, at least until a repair operation can be scheduled. For these reasons, there is added incentive to use homogeneous inner and outer materials.

***Floor Drains and Other Fixture Outlets.*** The purpose of a chemical or acid waste drainage system is to collect waste from laboratory sinks, fume hoods, and floor drains. However, other applications exist for aboveground drain systems to allow drainage of fluids from process equipment, rinse-down areas, potential spill areas around tanks and vessels, and other areas in order to transport the waste to a remote treatment area. These lab sinks, fume hoods, and floor drains are the points of introduction of the waste fluids.

Typical diameters for outlet primary piping from fixtures range from NPS 1½ (DN 40) diameter to NPS 4 (DN 100) diameter. These outlet pipes must be equipped with secondary containment piping ranging in sizes from NPS 3 to 8 (DN 80 to 200) diameter sizes, respective of the aforementioned primary pipes. Outlets from floor drains are usually NPS 2 (DN 50) in diameter to a maximum of NPS 6 (DN 150).

Figure B13.59 details an ideal configuration for fixture outlets that must be equipped with secondary containment. In this example, the secondary containment jacket is shown as being directly welded (or bonded) to the underside of the sink, basin, or tank. This is possible only in systems involving homogeneous or highly compatible materials. It is something that is highly encouraged in the layout of such systems as it will lead to a transition involving high integrity. A reason why this is important is that it allows the transition from single containment to double containment to be made above the level of the first primary pipe joint. In contrast, Fig. B13.60 illustrates a transition from single containment to double containment where the transition is made below the level of the first joint. Either transition is acceptable if it occurs aboveground in an area considered to provide adequate

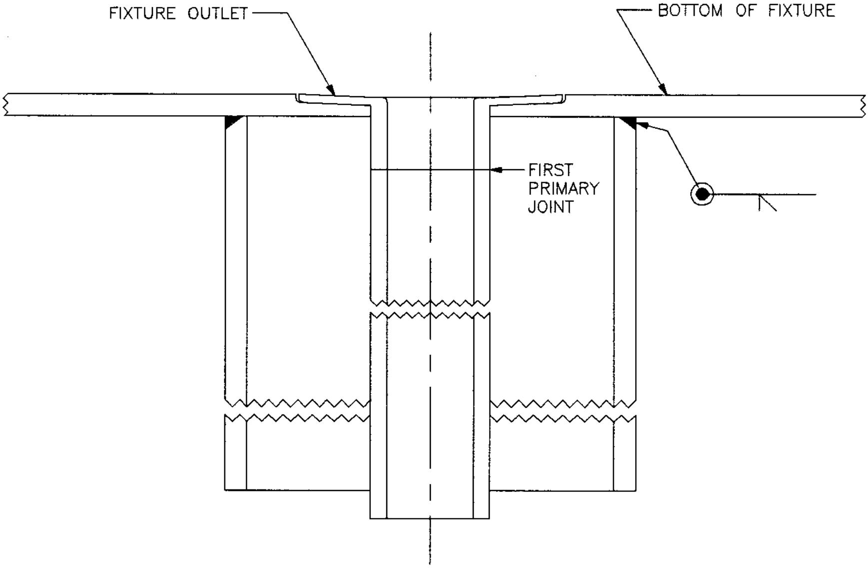


**FIGURE B13.59** Configuration for fixture outlets where the first carrier joint is below the level of the secondary containment jacketing.

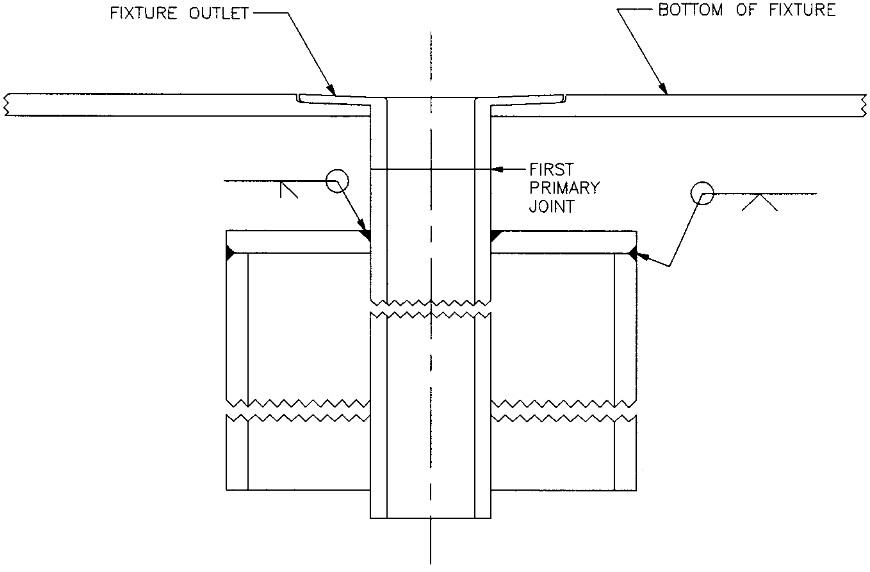


**FIGURE B13.60** Configuration for fixture outlets where the first carrier joint is above the level of the secondary containment jacketing. In this type of arrangement, a leak at this joint could escape around the secondary containment pipe.

secondary containment. If the transition occurs underground it is critical that it be made above the level of the first joint. Otherwise, a concrete sump equipped with a leak detection probe may have to be constructed around the area to prevent the possibility of leakage to the surrounding soil.

Floor drains also have many specific concerns that need to be addressed. The same transition concerns expressed in the previous paragraph apply. However, there are a number of additional concerns in comparison to fixture outlets. Figure B13.61 illustrates examples of typical double containment floor drains. These floor drains should be provided with a flashing in order to collect any leaks safely that occur where the brim is sealed into the floor, something that can be expected to occur eventually in many floor drains. There should be perforations provided in their basins that allow collected fluids that leak around the brim to drain into the primary portion of the drain, which will allow fluids to flow down their respective primary pipe outlets. It is important that fluid never be purposely introduced into the annulus of double containment piping because a leak would then be sensed and repair procedures may be initiated, though not needed. Thus, collected leaks around a brim are discharged into the primary portion of the drain.

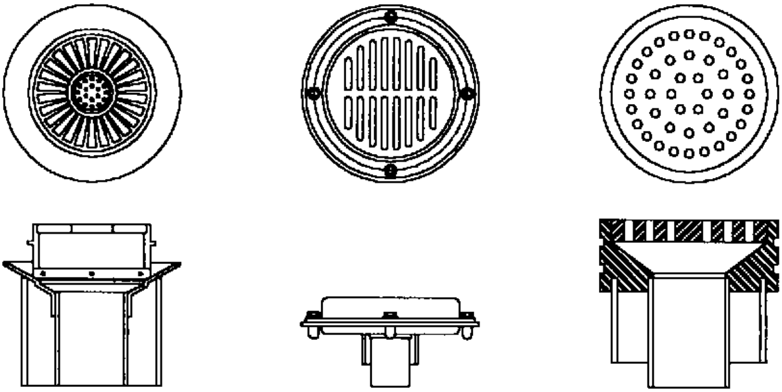


**FIGURE B13.61** Illustration of three types of double containment floor drains: (a) polypropylene *(Orion Fittings, Inc.);* (b) stainless steel *(J.R. Smith);* (c) epoxy or vinyl ester RTRP. *(Fibercast).*

In Fig. B13.61, the transition from single containment to double containment is made by attaching the secondary containment pipe directly to the underside of each drain's drip pan-flashing by using a weld or bond. This is often desirable for floor drains, as they typically are directly imbedded in concrete flooring. This is readily possible if the drain, the primary pipe, and the secondary containment pipe are constructed of homogeneous materials; if it is not possible (i.e., in hybrid material systems), then in most jurisdictions in the United States, a concrete sump has to be constructed around the area with some form of monitoring applied.

***Use of Traps.*** Floor drains and fixtures need to be provided with traps at their outlets in chemical systems where there is a possibility of backup of gases from the system through the fixtures or drains.

The most common type of trap in a chemical DWV system is the P-trap. A typical double-containment P-trap is illustrated in Fig. B13.62. A requirement of

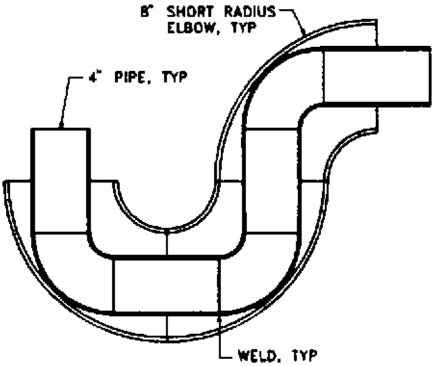


**FIGURE B13.62** Typical double containment P-trap where the system uses metallic or thermoplastic butt welding/fusion pattern pressure fittings as the basis to fabricate a non-plumbing-code approved drainage system.

P-trap design is that a minimum of a 2-in (50 mm) water seal be provided in the design. In a trap equipped with secondary containment, the annulus will always have the same theoretical seal dimension as the primary pipe, plus a small amount equal to the sum of the annulus available at the bottom of the bottom elbow and the wall thickness of the primary elbow. (One should note that the annulus is meant to remain normally empty, thus the seal dimension of the secondary pipe is described only in theoretical terms.) An alternative arrangement is illustrated in Fig. B13.63, where single-walled components are housed inside a secondary containment sump.

Another feature of traps that must be considered is whether or not the primary P-trap needs to be provided with a cleanout at its low point. Cleanouts are often provided at the bottom of traps in ordinary plumbing systems to allow the drain

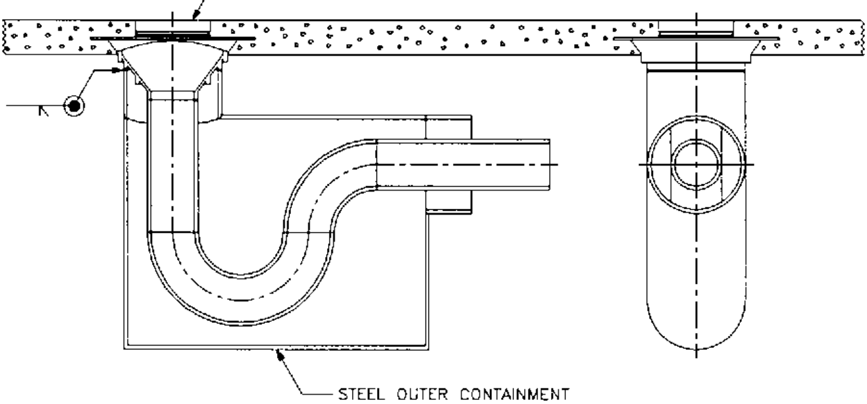


**FIGURE B13.63** Fabricated double containment P-trap incorporating a cleanout, where the system uses metallic or thermoplastic butt welding/fusion pattern pressure fittings as the basis to fabricate a non-plumbing-code approved drainage system.

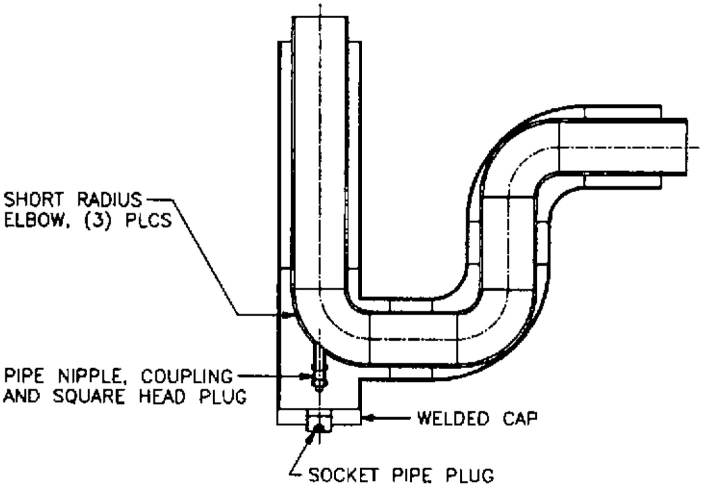


**FIGURE B13.64** Alternative arrangement for P-traps involving carrier components housed inside a specialized secondary containment tank-like structure.

to be unclogged of collected aggregates, hardened foam, etcetra. Therefore, if the trap requires a cleanout to be provided, then a specialized arrangement is required. Figure B13.64 illustrates an arrangement where the primary part of the trap has cleanout capability; the secondary containment portion is provided with a removable access cover that is further equipped with a digital liquid-sensing probe. An arrangement of this type would need to be placed inside a sump that can safely house such an arrangement and allow the safe collection of fluids when they spill. Care should be taken when opening a cleanout in this configuration, as the hazardous chemicals will likely be present in the bottom of the P-trap. The maintenance worker-contractor should be equipped with the proper safety clothing, masks, and protective eyewear.

***Underground Horizontal Headers.*** Most systems involve one or more vertical waste stacks that collect waste from horizontal branches and floor drains and discharge waste vertically into a common header installed under the building. Each stack normally connects to a header through either a 90°-long sweep elbow, or through a long-turn-tee-wye (45° lateral with a 1/8th bend). Floor drains that are used to collect emergency spills are typically connected to an underground P-trap that is in turn connected to the header at the exit of the trap. Underground headers usually connect outside the building to an underground main, are fed into a common sump or basin, or are drained into a neutralization tank.

A typical underground header system used at a laboratory-type facility is illustrated in Fig. B13.65 and shown in the accompanying photograph of the same system, Fig. B13.66. The layout of the system is typical of a two-story laboratory building that collects wastes from various fixtures, floor drains, and vertical waste stacks. Underground header systems should have orthographic plan view drawings prepared, similar to that shown. An overall plan view showing all headers should be prepared, as well as individual drawings for each header. The individual headers should include details of all connections, including fitting types, location, and method of attachment (type of weld or bond).

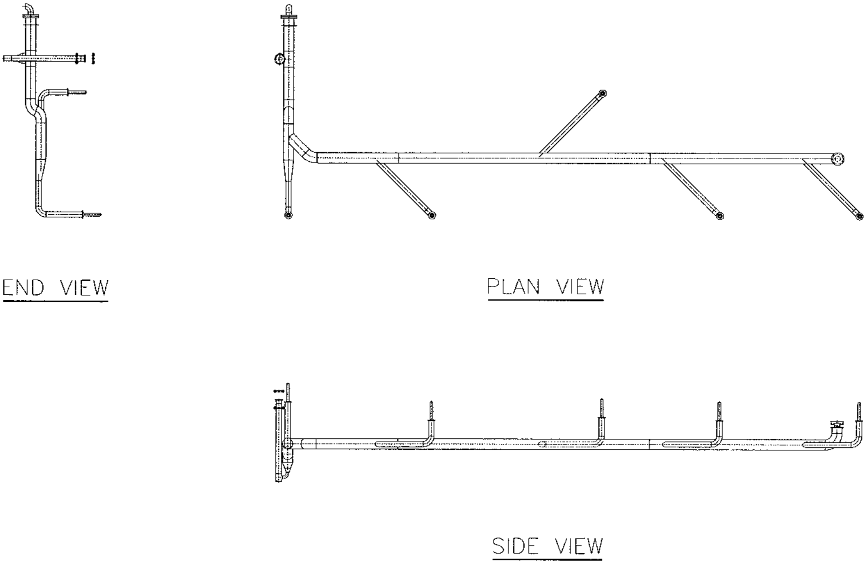


**FIGURE B13.65** A typical underground lab-waste header subassembly in a gravity-waste application.

An alternative design for underground headers that fall within a building's limits is to place a single-walled header within a lined or coated open trench. This can be done on all or a portion of an underground header that is within a building's limits. Fig. B13.67 is an example of single-walled underground headers contained within a coated, open trench. In this example, perpendicular double containment pipes are terminated upon entry to the common trench, whereby multiple pipes are secondarily contained by the associated common open trench. Shown in Fig.

**FIGURE B13.66** Photograph of the header illustrated in Fig. B13.65.

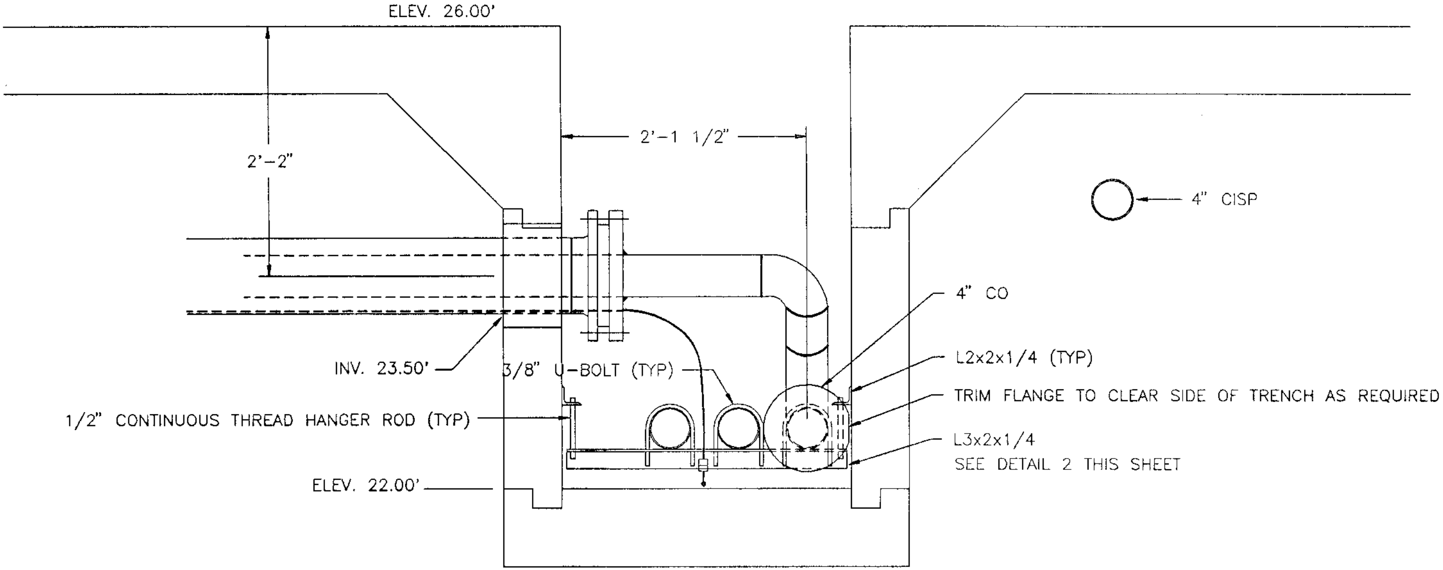


**FIGURE B13.67** An example of single-wall underground chemical waste headers housed inside of a coated secondary containment concrete trench in a chemical weapons testing and research facility for the U.S. Army Corps. of Engineers. *(Poole & Kent Co.)*. *(From* ''Handbook of Double Containment Piping Systems,'' *C. Ziu, McGraw-Hill, New York, 1995.)*

B13.68 is the structure designed to support the different pipes. While not indicated in the drawing, stainless steel or fiberglass pultruded grating is placed over the trench to prevent a worker's falling into the open trench.

In this example, there are also underground side headers feeding into the trench, each of which is individually double contained before it enters the common trench. When more than one header can run parallel to others it becomes economical to place them inside a common trench. Designers must consult with the authority having local jurisdiction to determine if a common means of secondary containment can be used for more than one primary pipe. Also, while open trenches are readily suitable inside a building, they lose some of their appeal outside a building. Outside building limits, rainwater will readily enter an open trench, which means that rainwater flow will have to be monitored and diverted to a waste treatment facility when contamination is detected. This can mean a very large increase in capacity for the waste treatment facility, making the use of open trenches less desirable outside a building's limits.

***Underground Horizontal Mains.*** When an underground header exits a building's limits, horizontal waste piping either continues as an underground main or ties in via branch connection to a main. Mains may collect wastes from one or more headers, possibly multiple headers from more than one building. An underground main typically carries waste to a remote site where it is processed, stored, or discharged into an industrial sewer. The main may either be a gravity-fed drain pipe, or it might operate as a pressure force main. The decision whether to move the chemical waste fluids by either gravity or pressure depends on the present and future capacity needs, the distance to be traveled, and available slope.

Several drawings are needed to depict the layout of the underground mains accurately. The overall schematic of the mains, including their relation to buildings and other surface structures, should be shown on a plan-view drawing, which should show all pipes, including branch connections and changes in direction of the piping. The location of fittings, manholes, and other major details should also be indicated. Any horizontal change in elevation should be shown by preparing a profile view drawing, indicating all changes in elevation of the pipe (or pipes) and the surface geography. The elevations should be indicated at various points along the drawing in order to determine burial depths, locations of manholes, and other details accurately. Whenever feasible, a combined drawing should be prepared so that it is easy to coordinate location and elevation. Both drawings should be drawn to scale in order to assist in preparing accurate takeoffs and estimates of project costs.

In addition to these drawings, detail drawings should be prepared for all unique aspects of underground mains. At least one typical detail drawing needs to be prepared for each unique section. A section is considered unique if there is any change in size, diameter (including annular space), wall thickness, materials of construction of the primary or secondary containment piping, type and spacing of interstitial supporting devices, or type of welds (bonds). If any of these variables changes, then a separate detail drawing needs to be prepared.

A typical drawing illustrating a combination plan view and profile view of an underground gravity-fed double containment main is shown in Fig. B13.69.

***Gradient of Internally Supported Headers to Prevent Pocketing.*** If primary pipes are intermittently supported by means of internal centering supports (centralizers), they must not contain sag pockets in order to drain freely. To eliminate pockets, each downstream internal centralizing support must be lower than its upstream neighbor by an amount that depends on the sag of the pipe between them. A

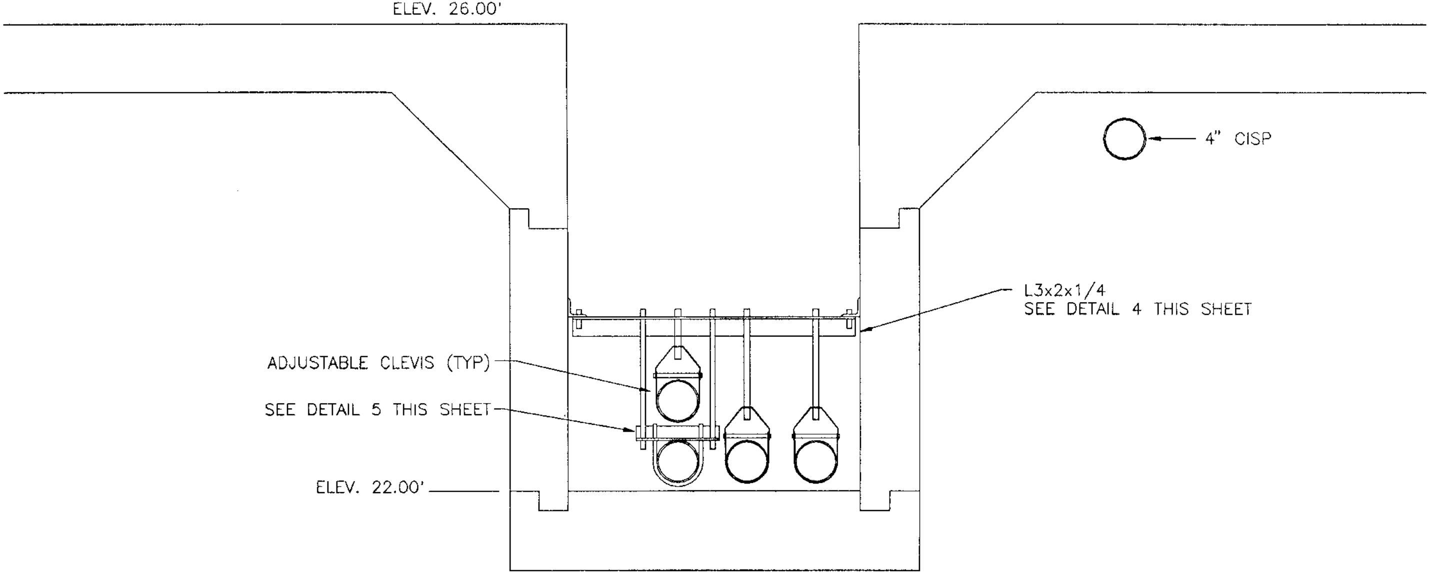


**FIGURE B13.68** A structural supporting system used to support the pipes shown in Fig. B13.67. *(Source: Poole and Kent Co.)*

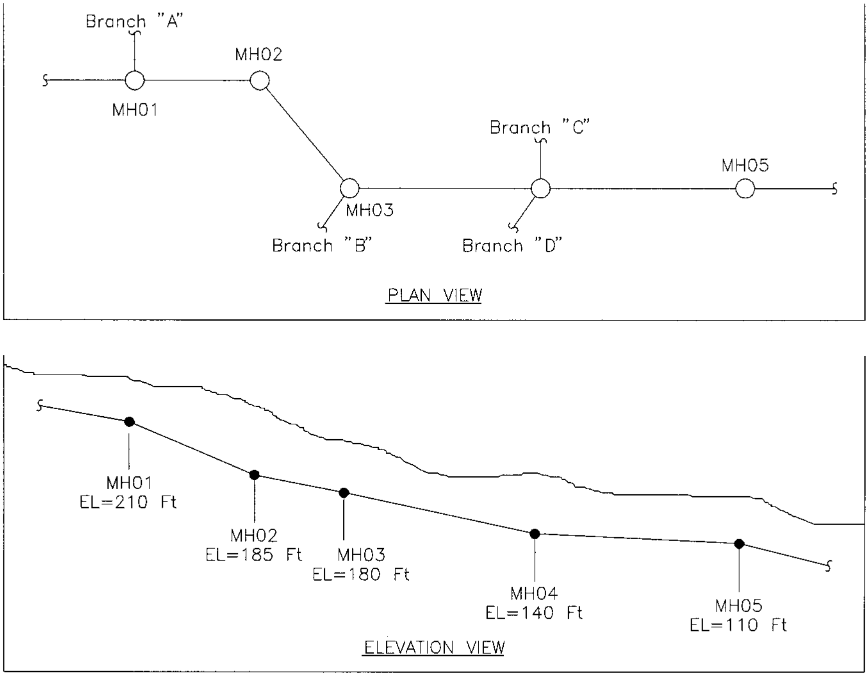


**FIGURE B13.69** A typical combined plan- and profile-view drawing for an underground gravity-flow chemical sewer.

practical average gradient of internal support elevations to meet this requirement may be found by using the following equation B13.1.

$$G = \frac{4y}{L} \tag{B13.1}$$

where $G$ = gradient, in/ft
$L$ = span, ft
$y$ = deflection, in

The difference in elevation between a downstream internal centering support and its upstream neighbor must be four times the theoretical deflection of the pipe between them to establish the grade. It has been suggested as a conservative measure to use twice the theoretical mid-span deflection when determining the slope of the double containment pipe. If so, the elevation difference between successive supports would be eight times the theoretical mid-span. The elevation of the internal supports is equal to the invert of the secondary containment pipe.

***Use of a Common Sump with Discharge into Pressure Force Mains.*** In the plan and profile view of Fig. B13.69, the elevation changes by more than 100 feet. What happens if a change in elevation is not available to allow the piping to experience

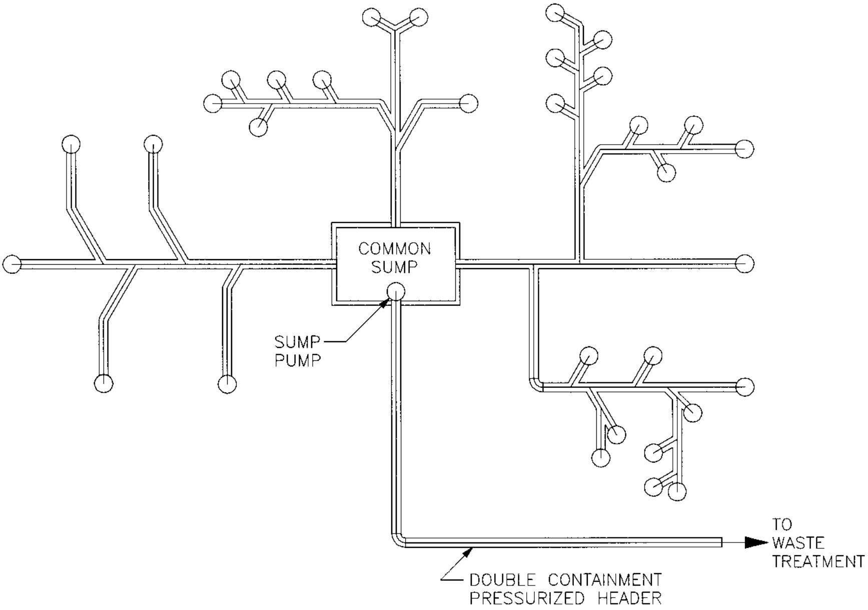


**FIGURE B13.70** A typical common sump system with a pressurized discharge header.

the minimum change in elevation required to sustain the minimum required slope? The normal procedure in this instance is to drain all horizontal underground headers into a common sump and then pump the fluids involved by use of a sump pump through a pressure-force main. When this method is used, the underground header should be designed as a pressure pipe, according to all the rules of design for pressure pipes described throughout this book.

An example of a system of this type is illustrated in the plan view shown in Fig. B13.70. When such a design is used, the sump may have to be provided with an integral liner and the interstitial space monitored for leaks, as it is in effect an underground storage tank. Local authorities having jurisdiction vary in their interpretation of this type of arrangement; thus, it is important to consult with them on any given project.

## Underground Fitting-in-Manhole Arrangements

In nonpressure and pressure systems that are installed underground, it is common to avoid direct burial of double-containment fittings. Most direct burial of double containment fittings is limited to bends and elbows. The direct burial of branch fittings is often avoided due to the difficulty in installing these fittings underground, leak detection concerns, and other reasons. Where there is a substantial amount of thermal expansion and contraction expected, the installation of double containment fittings underground of all types is usually avoided.

A common design approach for underground system (pressure and nonpressure) layout of fittings is to place single-walled fitting connections inside secondary con-

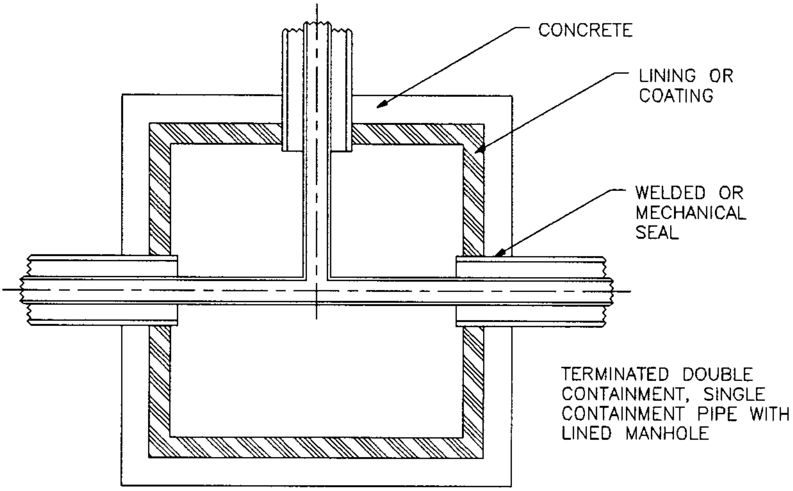


**FIGURE B13.71a** Plan details for manhole MH01 from Fig. B13.69.

tainment manholes. In most situations, it becomes more economical to terminate secondary-containment piping in the entry to a secondary containment manhole, thereby making use of single-walled fittings. Manholes, if constructed of lined or protected concrete, effectively serve as a means of secondary containment. Any secondary containment piping penetrations can be made watertight by the use of mechanical seals, by welding secondary containment piping to manholes (if a compatible lining material is used), or by using a waterstop with grouting applied

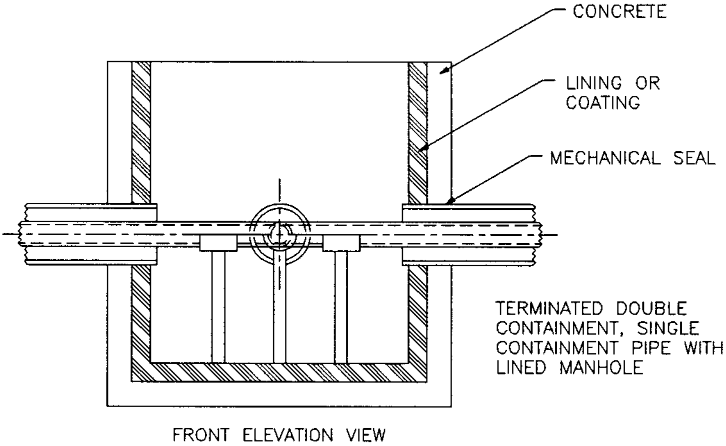


**FIGURE B13.71b** Front elevation details for MH01 from Fig. B13.69.

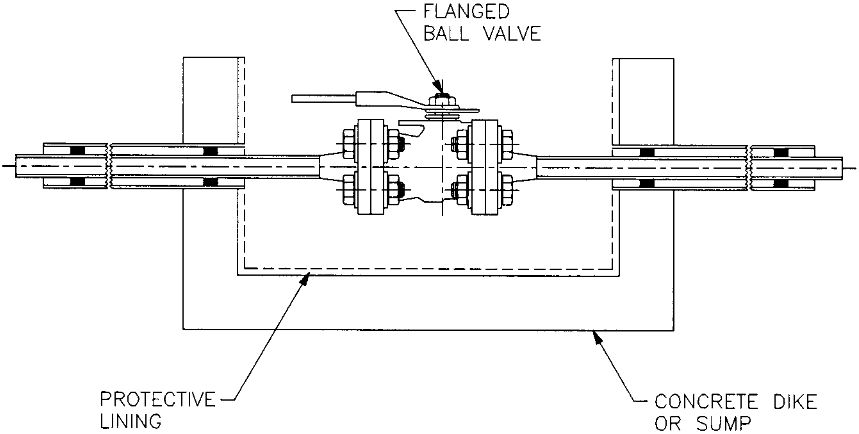


**FIGURE B13.72** An example of a valve contained inside a secondary containment open sump.

around the outer pipe circumference. Grouting can also be applied on the inside, outside, or both.

If manholes are designed to be readily accessible, primary piping fittings can be joined by using flanges. This greatly aids in the installation of such items, and makes maintenance easier. In addition, expansion joints can be incorporated in the layout, being positioned between the fittings and the pipe flanges. This can serve as a means of alleviating thermal expansion in the straight pipe sections (if the primary piping is designed in an unrestrained manner) and serves as a means of isolating fittings and complex fitting arrangements. As examples of possible designs, details of underground fitting manhole arrangements, for manhole MH01 that is referenced in Fig. B13.69, is shown in Fig. B13.71. An example of a valve in a secondary containment manhole is shown in Fig. B13.72.

When using a lined or coated concrete structure as a means of secondary containment, it is necessary to incorporate some means of leak detection in such structures. This is due to the fact that single-walled fittings in such structures, or their flange connections, may be a source of leaks. Furthermore, double containment pipes that have a non-open-ended annulus at the entry to such structures may also have some means of leak detection added to the straight pipe sections as well.

As an alternative design, the arrangement shown in Fig. B13.73 may be used. In the alternative arrangement, the fitting area that is positioned in the manhole is part of an uninterrupted double

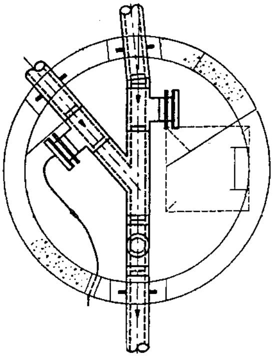


**FIGURE B13.73** A plan view of a manhole detail whereby the piping components housed within feature continuous double containment.

containment piping zone. The arrangement may be positioned as such to allow for easier installation of the fitting or fittings, incorporation of leak detection connections, future easy access, etcetra. When this type of arrangement is used, a manhole does not always have to be lined or coated, nor does it have to be provided with its own leak detection.

## Thermal Expansion Layout

***Using Internally Flexible Systems for Handling Differential Thermal Expansion.*** When adequate room to prevent contact due to differential expansion and contraction between primary and secondary containment elbows does not exist, the diameter of secondary containment elbows may be increased to allow primary elbows sufficient room to flex. In systems that have a significant amount of thermal expansion, expansion loops, offsets, or additional changes of direction might be required to achieve the desired level of flexibility. Alternatively, expansion joints may be added into the inner or outer pipe sections. Most nonmetallic materials have a linear coefficient of thermal expansion that is far greater than that of metals; additionally, they are subject to early failure due to creep-strain accumulation when they are designed in a restrained fashion. RTRP materials do not yield, and as such, they must be laid out with sufficient flexibility to avoid premature failure. However, due to the design of certain components and the high strength of machine-made RTRP components, it is usually best to lay out machine-made RTRP systems as restrained systems. This section discusses the different unrestrained possibilities for accommodating differential thermal expansion in these systems.

***Expansion Joints in Double Containment Systems.*** Expansion joints may be used in principle on both primary and secondary containment piping systems. They may be used in both primary, and secondary containment portions of nonrestrained systems. However, there are many limitations to their use. If expansion joints are to be used as part of a primary, piping system, ready access to the expansion joint must also be included in the design. This means provision of a tank or access device as a component of the secondary containment system. In underground systems, the use of expansion joints for compensation of primary pipes is limited to manholes or where a trench is used as a means of secondary containment. On the other hand, expansion joints may be readily applied to secondary containment pipes in aboveground, nonrestrained systems to compensate for differential thermal expansion. This is true regardless of which pipe is experiencing the larger temperature change.

***Use of Directional Changes (Elbows) to Accommodate Expansion of Double Containment Pipe Straight Sections.*** The natural changes of direction (elbows) that exist in any system can be used to accommodate thermal expansion and contraction. Additional changes of direction may also be added to the layout to increase the amount of flexibility inherent in a system. By doing so, stresses will be minimized and the distribution of stresses will be better balanced. Directional changes, like loops and offsets, can be positioned in a horizontal or vertical configuration. Like the two-elbow offset, they also can be rotated at any angle. An elbow used in this fashion is sometimes referred to as freely floating.

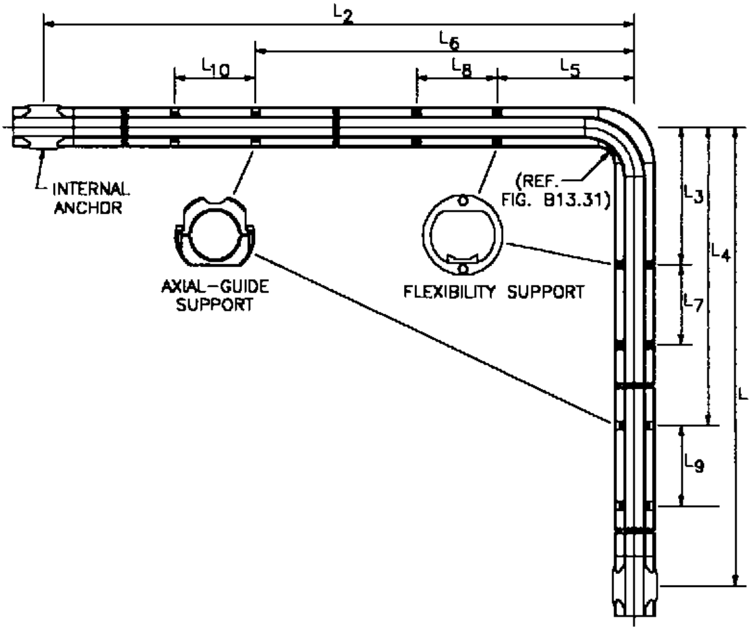


**FIGURE B13.74** A patented subassembly of a double containment system incorporating "internal-flexibility" by means of specialized elements that maximize flexibility of the carrier components and minimize stresses and the resulting strains on the subassembly components. The commercially licensed arrangement for thermoplastic systems is sold under the trade name Rionflex™. *(U.S. Patents: 5,482,088, 5,715,587, 5,690,148, 5,452,922, 5,901,753; 5,862,834, 5,197,518; others may apply; further patents pending; Orion Fittings, Inc.)*

Figure B13.74 illustrates the important aspects of a patented directional change assembly designed to accommodate large-magnitude differential expansion and contraction in a double containment piping system.

Two major design considerations are involved when using an elbow to accommodate thermal expansion and contraction. The first involves whether or not an inner elbow will come in contact with its associated outer elbow due to differential movements of the two systems. If they do contact each other, substantial stresses may develop in both primary and secondary containment components, which may lead to a premature double failure. To determine if this is possible, and thus if sufficient space exists, a dimensional analysis must be conducted.

A second major design issue involves the closest point of lateral restraint from the inner or outer elbow. Each elbow that requires movement must have its closest points of lateral restraint on each side far enough away so that adequate flexibility is provided to the elbow. The closest point that will provide lateral restraint to a primary-pipe elbow is where inner and outer components come in contact with each other whenever they are allowed to do so. If a system is designed such that inner and outer component contact is prevented through adequate annular space, the interstitial support that is closest to the elbow on each side will become the point of closest lateral restraint in most applications. There are interstitial supports that do not function as points of lateral restraint in horizontally positioned systems,

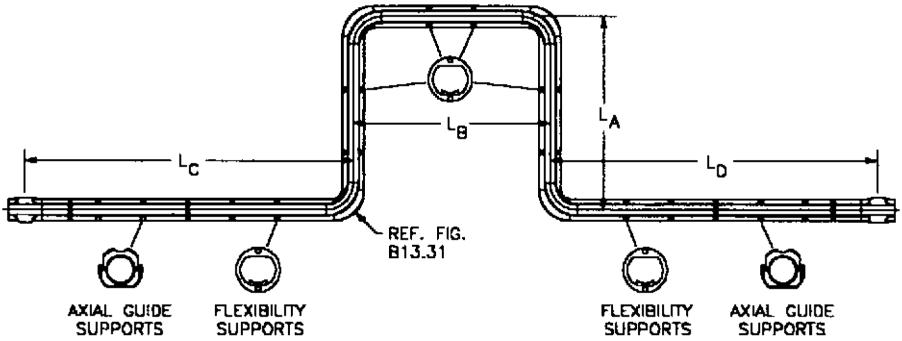


**FIGURE B13.75** A patented double containment expansion loop subassembly incorporating "internal-flexibility" by means of specialized elements that maximize flexibility of the carrier components and minimize stresses and the resulting strains on the subassembly components. The commercially licensed arrangement for thermoplastic systems is sold under the trade name Rionflex™. *(U.S. Patents: 5,482,088, 5,715,587, 5,690,148, 5,452,922, 5,901,753; 5,862,834, 5,197,518; others may apply; further patents pending; Orion Fittings, Inc.)*

which is referred to as a flexibility support. An example is illustrated in Fig. B13.25 and Fig. B13.26.

The analysis of aboveground secondary containment elbows may be treated similarly to the way that aboveground single-wall-piping elbows are. However, the added rigidity that interstitial supports provide, in terms of adding resistance to bending, must be included in any design. If a system is permanently and rigidly interconnected with frequency (i.e., a simultaneously fused system or a restrained-fitting RTRP system), there will be greatly added resistance to bending for the secondary containment elbows. Underground, direct-buried piping is substantially restrained from moving in most cases.

***Expansion Loop Design for Double Containment Pipes.*** Where other methods are not suitable, expansion loops offer an alternative method to compensate for thermal expansion and contraction. Loops may be positioned vertically or horizontally and may vary in configuration. They may be used in horizontal or vertical piping sections. One conventional approach for calculating the size of an expansion loop in a single-walled pipe is by using the guided-cantilever-beam theory. This approach assumes that piping demonstrates substantial elasticity and assumes limited piping rotation of the ends of each straight run. It also assumes that the loop consists of two cantilever beams, each with one end fixed and concentrated loads applied at their free ends. Figure B13.75 shows a standard four-elbow 90°-expansion loop in a double containment piping system. Figure B13.76 illustrates an expansion loop assembly involving four 45° elbows.

***Expansion Offset Design for Double Containment Piping.*** An expansion offset assembly is very similar to an expansion loop. The design requires the same general rules applied to expansion loop design sizing. Expansion offsets can also be positioned in either a horizontal or vertical configuration. The conventional method for calculating the size of expansion offsets in a single-walled pipe is by the use of the guided-cantilever-beam theory. This approach assumes that the piping demonstrates substantial elasticity and assumes the ends of the pipe are restrained against rotation. It also assumes that a pipe offset behaves as a cantilever beam, with one end fixed

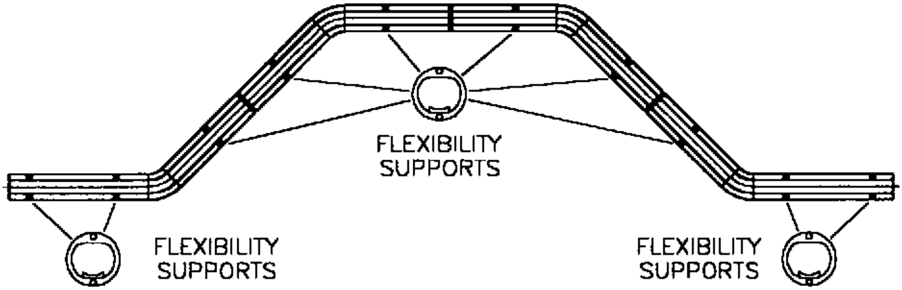


**FIGURE B13.76** Variation of the patented expansion loop subassembly shown in Figure B13.77 whereby 45° elbows are used in place of 90° elbows to minimize horizontal laying width. This type of arrangement is often preferred for gravity-drain systems. The commercially licensed arrangement for thermoplastic systems is sold under the trade name Rionflex™. *(U.S. Patents: 5,482,088, 5,715,587, 5,690,148, 5,452,922, 5,901,753; 5,862,834, 5,197,518; others may apply; further patents pending; Orion Fittings, Inc.)*

and a concentrated load applied at its free end. Figure B13.77 illustrates an example of an expansion offset in a double containment piping system.

## Installation-Related Layout Issues for Nonpressure and Pressure Piping Systems

***Types of Secondary Closures and Their Locations.*** Secondary closures consist of closures that are used to seal gaps remaining in a secondary containment piping system assembled using a staggered joining sequence in order to complete a contain-

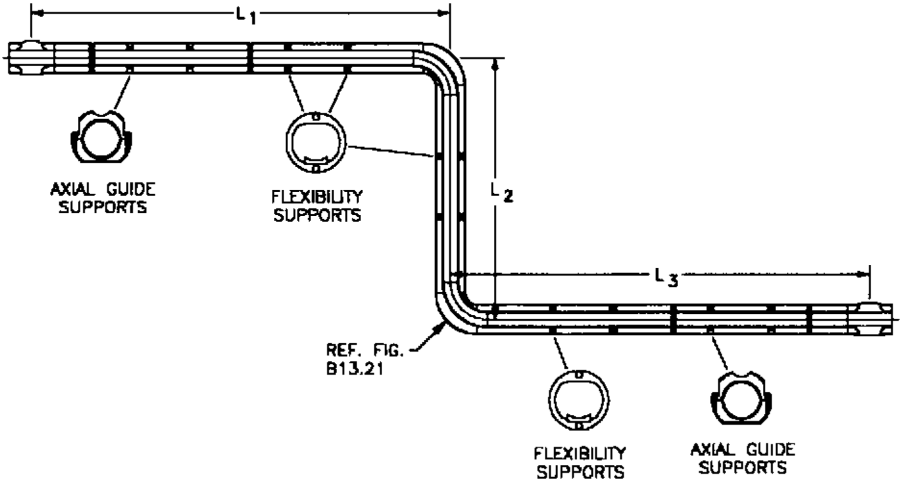


**FIGURE B13.77** An example of a Z-bend offset subassembly of a double containment system incorporating ‘‘internal-flexibility’’ by means of specialized elements that maximize flexibility of the carrier components and minimize stresses and the resulting strains on the subassembly components. The commercially licensed arrangement for thermoplastic systems is sold under the trade name Rionflex™. *(U.S. Patents: 5,482,088, 5,715,587, 5,690,148, 5,452,922, 5,901,753; 5,862,834, 5,197,518; others may apply; further patents pending; Orion Fittings, Inc.)*

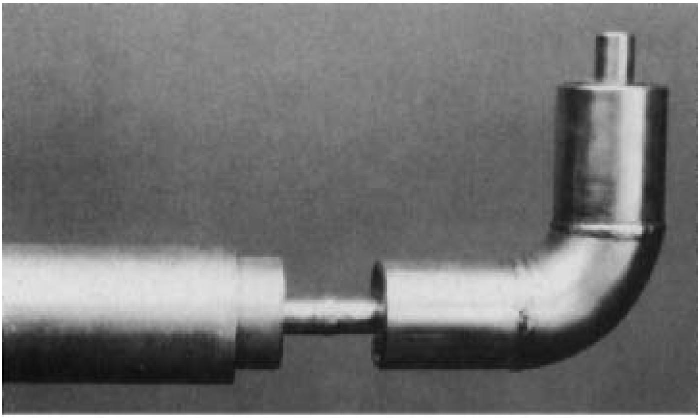


**FIGURE B13.78a** Illustration of a gap in a double-containment pipe. *(Source: Guardian division of Eslon Thermoplastics, Inc.)*

ment casing. Many secondary closure methods exist; however, they may be divided into two basic types: end-type closures (terminations) and midline closures.

End closures are described earlier in this chapter; midline-type secondary closures are discussed here. Midline closures are required whenever a gap exists either in a straight pipe section or in a secondary containment fitting. They are applicable mainly to systems where staggered welding is used as the sequence for joining and whenever sections are prefabricated. A gap in straight pipe section of a secondary containment pipe requiring a midline secondary closure is illustrated in Fig. B13.78. This type of gap exists for systems that use a staggered joining sequence.

There are a many options to complete containment casings where such a gap

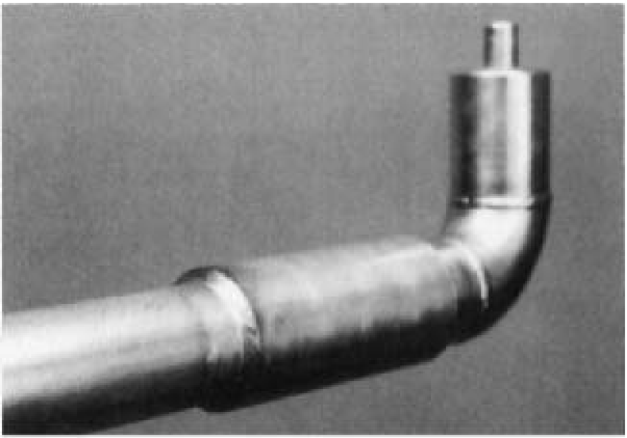


**FIGURE B13.78b** Shown here is the tubular slip-coupling after it is telescoped into position and welded on both ends to close the gap. *(Guardian Division of Eslon Thermoplastics, Inc.)*

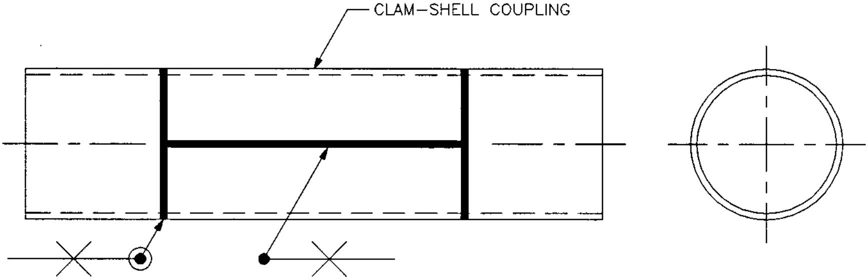


**FIGURE B13.79** Cross-sectional view of an assembled clam-shell coupling.

exists in straight pipe sections. Four basic welded (bonded) types include: (1) split-pipe sections or *clam-shell* couplings, (2) weld wraps, (3) sheet wraps, and (4) slip couplings. These four types are illustrated in their as-installed condition, designed to close a midline gap, in Figs. B13.79 through B13.82. Figure B13.83 is a photograph of a slip coupling being installed into an 8-in (200 mm) nominal-diameter secondary containment polyolefin pipe.

When secondary fittings are manufactured in two halves as clam-shell fittings, they can also serve as the point of closure in the jacket in lieu of, or in-addition to, having gaps in the straight pipe sections. Examples of fiberglass clam-shell fittings are shown in Fig. B13.84.

## Simultaneous Fusion

An alternative sequence of constructing a double containment piping assembly is termed *simultaneous fusion* and pertains only to systems composed of thermoplastic piping inner and outer components. Simultaneous fusion is most readily applied to heat-element-based butt-fusion-based thermoplastic systems due to the ability to

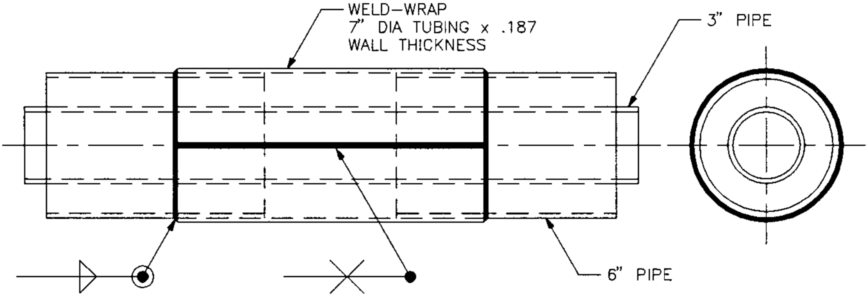


**FIGURE B13.80** Cross-sectional view of a weld-wrap assembly.

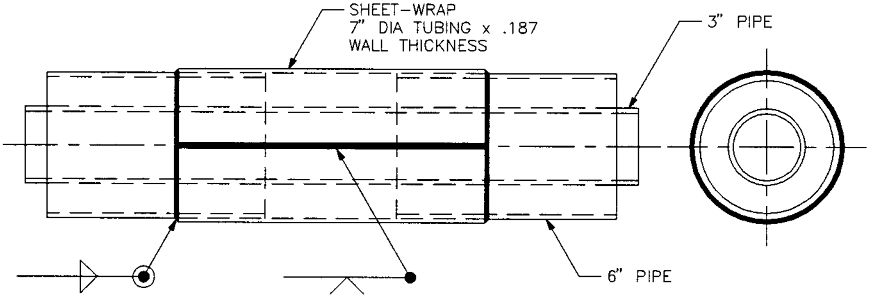


**FIGURE B13.81** Cross-sectional view of an assembled sheet wrap.

combine primary and secondary containment pipe sizes that are relatively close in diameter. The method can also be applied to small-diameter heat-element-based socket-fusion systems and solvent-cement-based socket systems. However, the necessary tools are not readily available, and if they were, it would be difficult to get them.

The object of any simultaneous fusion system is to prepare both primary and secondary containment components so that they are permanently fixed to each other and can thus be joined to a mating set of components. In some systems, simultaneous fusion can be used to join 100 percent of all components involved in the piping system. It can also be selectively used for situations where staggered welding is the primary method, in lieu of using secondary closures. Simultaneous fusion can substantially reduce overall labor involved on a project, unless primary piping joints leak upon initial pressure test. However, the inspection of primary welds is substantially limited, and the method is best suited for applications where a flexible (unrestrained) layout is not required. A simultaneously welded system will typically result in a structurally more rigid assembly.

Simultaneous fusion is more easily applied to systems that have identical primary and secondary containment materials. If a heat-element butt-fusion-based system is used, the materials should have a welding temperature range that overlaps and specific welding pressures that are nearly the same.

The procedure for simultaneous fusion is illustrated in Figs. B13.85a through

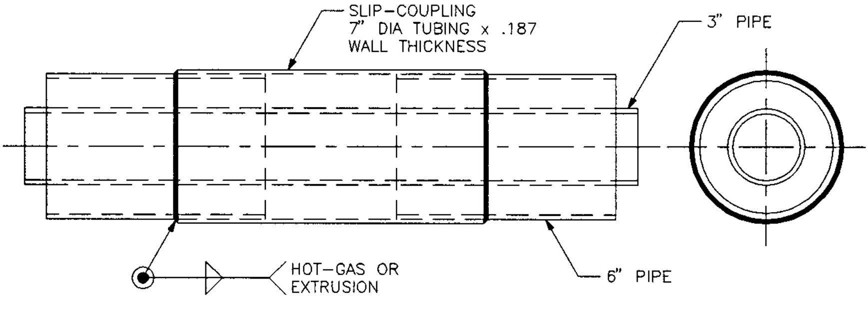


**FIGURE B13.82** Cross-sectional view of an assembled slip-coupling.

**FIGURE B13.83** A tubular slip-coupling is bonded to the secondary containment coupling using hot-air welding in a thermoplastic double containment piping system. *(Grewe Plastics)*

B13.85l. The single most important consideration in performing simultaneous fusion is that the components should be prefabricated so that they align on the same plane at their ends; the alignment must occur within very close tolerances ($< 5\%$ of diameter). The standards according to DIN, and accepted worldwide, requires that thermoplastic butt-fusion pipes be aligned to within 10 percent of their wall thicknesses in terms of their diametrical alignment. Therefore, the use of thick-walled pipes (SDR 17.6 or thicker) as the material of the primary pipes for primary pipes 8-in nominal diameter (approximately 200 mm ISO 161/1 outside diameter) and below is highly recommended.

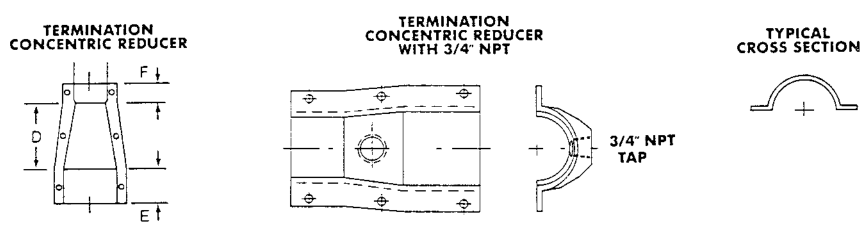


**FIGURE B13.84** Example of typical RTRP "clamshell" couplings and fittings. *(Smith Fiberglass Products Co.)*

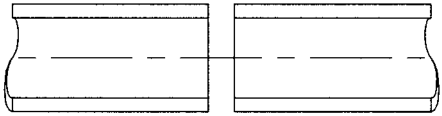


**FIGURE B13.85a** Position the primary pipes in place.

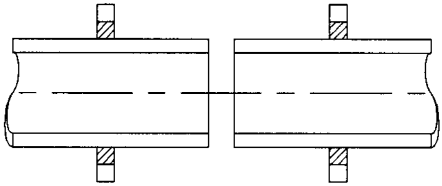


**FIGURE B13.85b** Position the interstitial centering supports in place approximately one inch from the end of the primary pipe.

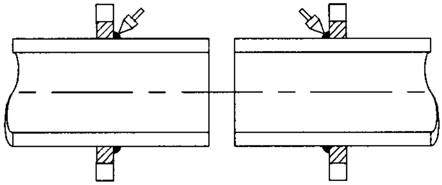


**FIGURE B13.85c** Weld the interstitial supports to the exterior of the primary pipe.

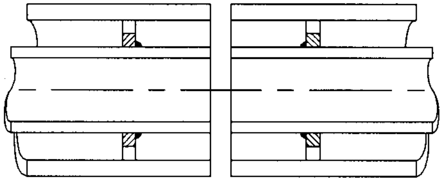


**FIGURE B13.85d** Slip the secondary pipe over the primary pipe interstitial supports.

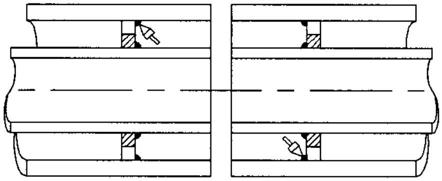


**FIGURE B13.85e** Weld the interstitial supports to the D of the secondary-containment pipe.

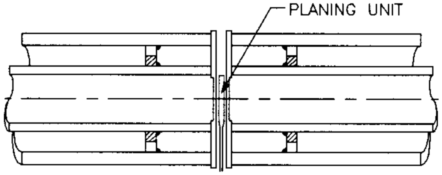


**FIGURE B13.85f** Plane the ends of the pipes to be sure that they are parallel and to expose a clean surface for welding.

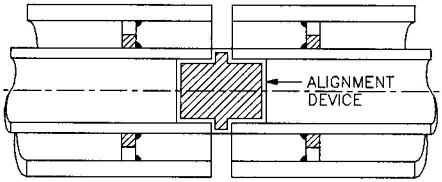


**FIGURE B13.85g** Check the alignment of the primary pipe after planing.

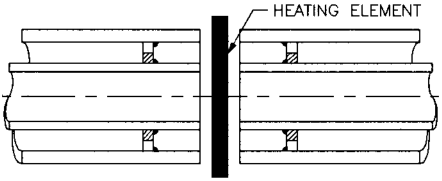


**FIGURE B13.85h** Position the heating element in place.

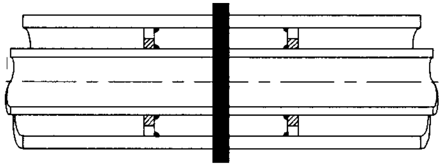


**FIGURE B13.85i** Bring the pipes up to the heating element under the specified initial weld pressure.

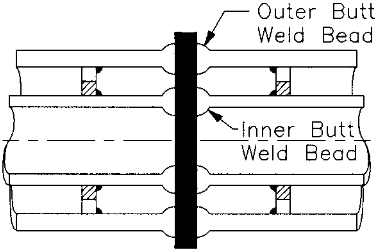


**FIGURE B13.85j** Allow the pipes to heat up for the required heating duration.

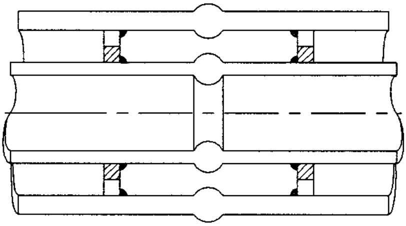


**FIGURE B13.85k** Remove the heater plate and bring the pipes together using the specified final weld pressure.

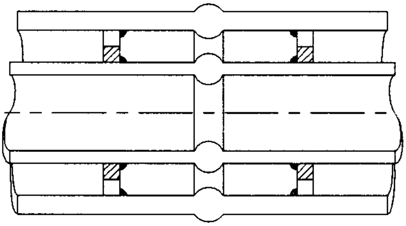


**FIGURE B13.85l** The illustration shows the final appearance of the joint section.

## Secondary Containment of Valves in Double Containment Piping Systems

Valves present unique layout concerns for double containment piping systems. By their nature, they are designed to be operating mechanical devices. Their operation can be either by manual or some automatic means (i.e., pneumatic or electrical operation). Either way, they require a considerable degree of access for either operation or maintenance purposes. Various valve types commonly encountered in chemical piping are discussed in this section, along with their associated layout alternatives.

Wherever possible, valve use should be maintained outside zones of pressurized secondary containment. By maintaining valves and other high-maintenance-operating mechanical items outside zones of secondary containment, added system complexity may be avoided. Whenever a valve must be added to a primary pipe system that is required to have pressurized secondary containment, there will be added expense. The added expense arises from the need to contain the valve in such a manner so as to enable ready access to its secondary containment housing, yet maintain its containment in a pressure-tight manner between times when access is required. Since valves are common sources of leaks and vapor emissions, additional and frequent maintenance of a double containment piping system will be required due to the increase in detected leaks. Thus it is much simpler and more cost effective to maintain a primary-pipe-system valve outside a zone of pressurized secondary containment.

Valves may still be secondarily contained; they just cannot be easily and inexpensively housed and still meet the necessary requirements. A common way to provide containment for such a valve is by the use of a lined or coated concrete dike, berm, or building floor in an aboveground application and by the use of a lined or coated concrete sump or accessible manhole in an underground application.

Valves may also be required as part of the secondary containment piping system (i.e., vent and drain valves, leak-detection and instrumentation isolation valves, etc.). These valves are usually small diameter ($<$ 2 in, 63 mm) and of the quarter-turn (on-off) variety. They are usually not required to be contained; however, as part of an underground system, they must be positioned inside a concrete housing (which does not normally have to be lined) in order to be accessed and operated and to prevent their being directly buried.

## Multiple Primary Pipe and Common Secondary Containment Pipe Systems

Multiple primary pipe systems (housed within a common secondary containment pipe) present additional layout complications beyond the ordinary complications discussed in this chapter for a single-walled pipe within a single secondary containment pipe. Many of the complications arise from the increased importance of the orientation of the primary pipes within the common secondary containment pipe. In such systems, the following factors have to be well thought out: (1) secondary containment sections must be initiated; (2) primary pipes have to follow bends; (3) in some systems they pick up branches along the way; and (4) secondary containment sections are eventually terminated. Throughout a system of this type, the pipes must maintain their relative positions within the cross-sectional plane.

Multiple pipe systems by their nature require additional detailed drawings to be prepared, as compared to single primary piping double containment systems. This is due to the fact that there are many more details to consider in order to create a successfully installed system. The details should include enough information to determine the method and spacing of supporting devices, termination and initiation arrangements and parts, welds (bonds) at each of these areas, and any other instructions the fabricator might need. The additional costs of fabrication, engineering, and capital costs of enlarged secondary containment pipes make multiple-pipe systems more expensive than running a series of individually contained primary pipes, in many situations. They also tend to be difficult to repair or modify. Therefore, secondary containment of multiple pipes should only be considered where space is limited. Common secondary containment of underground multiple pipes may be better accomplished with the use of lined tunnels (manways or walkways) or lined trenches. An example of a common secondary containment trench designed to house multiple primary pipes is shown in Fig. B13.67.

***Rotation in Multiple Primary Pipe and Common Secondary Containment Pipe Systems.*** An issue that arises in the design and layout of multiple primary pipe systems is called *rotation.* In rotation of multiple primary pipe systems, the pipes change their relative orientation in the cross section of the bundle after a change in direction. This will occur whenever a vertical pipe directional change occurs, followed by a perpendicular change in direction. This is illustrated in Fig. B13.86. If each of the four lines is followed, it can be noticed that they all change orientation.

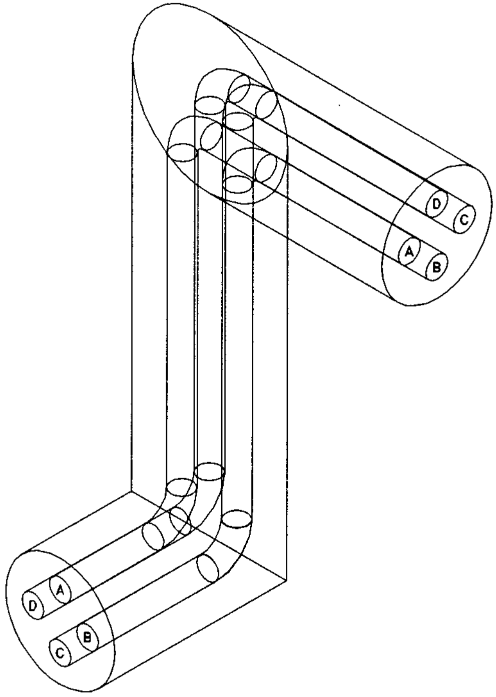


**FIGURE B13.86** Example of "rotation" in a multiple carrier pipe system. Note that the relative orientation of "a" through "d" change after undergoing two changes of directions. *(Reprinted with permission from* Chemical Engineering, *Sept. 1991, Copyright 1991, by McGraw-Hill, Inc. with all rights reserved).*

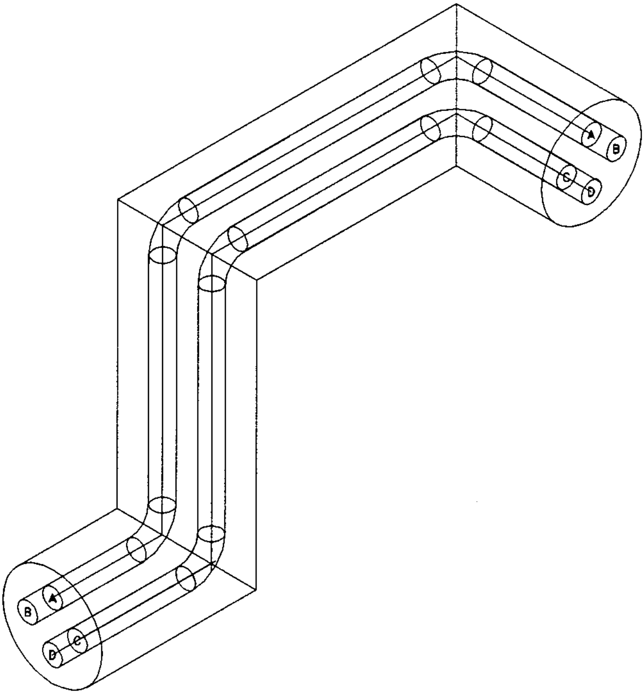


**FIGURE B13.87** Rotation in multiple pipe systems can be corrected by the addition of an additional elbow in some circumstances. Note how the overall orientation of (a) through (d) remain the same after the addition of the third elbow. *(Reprinted with permission from* Chemical Engineering, *Sept. 1991, Copyright 1991, by McGraw-Hill, Inc. with all rights reserved).*

Rotation in and of itself is not a bad situation. However, it can be an undesirable feature if the carrier pipes are to maintain their original positions, due to equipment connections, maintaining positions for branch connections, et cetera. To prevent rotation, a third elbow can be added into the system, as illustrated in Fig. B13.87.

## LEAK DETECTION METHODS AND REQUIREMENTS

### Overview of Leak Detection

Leak detection is one of the most important aspects of double containment piping and double-walled tank systems. Without an effective and reliable means to sense that a leak has occurred, the additional protection otherwise added by means of providing secondary containment may be compromised. Once a fluid leaks into an annulus of a pipe or the interstice of a tank, there is no longer any means to contain the leaked fluid secondarily; only a primary means of containment exists at that point, that is, unless tertiary containment has been incorporated into a system design (e.g., placing the double-walled pipe or tank into a tertiary concrete structure).

Left undetected, a fluid may have a chance to corrode through its secondary containment casing, or may find its way through defects in the containment to the surrounding environment. It is important that a leak be detected as early as possible so that any chance of fluid escaping to the surrounding environment is minimized. A system whose leaks are detected early can be repaired right away and quickly returned to its original safe working condition.

Both single-walled and double containment piping systems may be monitored for leaks by a wide variety of methods. There are likewise numerous methods to detect leaks that originate from single-walled or double-walled tanks and vessels. Both double containment piping and any associated tanks and vessels can be equipped with automatic sensing mechanisms to continuously monitor and activate an alarm as soon as system upset occurs. Alternatively, manual and visual leak detection methods may be incorporated by adding the necessary components into the design of a system. In addition to interstitial monitoring, there are both internal methods and external methods that exist to monitor for leaks, although most of these methods work best for tanks (as opposed to pipes). More than one method of leak detection may be used as a means of redundancy.

The successful implementation of any leak detection system is related to many different aspects of the design and installation of a piping and associated tank system. On any given project, it is essential that leak detection be considered from the conceptual phase of the project. By doing so, any needed design details or installation procedures may be taken into account from the start and carefully coordinated. When a project follows this practice, costly design changes and construction delays or problems can be avoided. The best overall result is achieved when leak-detection decisions are considered from the very start of a project.

## Leak Detection Cable Systems

Continuous line-leak–sensing and locating systems, commonly referred to as *leak detection cable,* have been installed in many double-containment piping systems. The appeal of leak detection cable is that approximate locations of leaks can be sensed early after a leak occurs. Several types exist, each based upon the continuous measurement of an energy source, thereby monitoring for changes in the energy source behavior. The two most common methods include: (1) conductance (resistance) -based cable systems, whereby the conductance (resistance) of an electrical signal is continuously measured; and (2) impedance-based systems, also referred to as TDR (time-domain-reflectometry) systems, whereby the impedance of an energy pulse wavelength is continuously monitored against a set pattern to detect changes. Each has subtle differences and capabilities; both are capable of performing their desired functions, namely, determining the approximate location of a leak and alarming a user as to its existence.

In one type of conductance-based cable, which is intended to sense conductive fluids, an electrical current is short circuited when a fluid bridges a gap between sensor and signal wires. Resistance monitoring is a straight-forward concept that applies Ohm's law to determine the location of a short. It is a method that can immediately sense small leaks, even over relatively long lengths of cable. Thus it has relatively sensitive reporting capabilities and is a well-proved technology. Unless condensation is eliminated or controlled, versions of conductivity-based cable which is designed to detect conductive fluids will report false leak signals due to its sensitivity.

Impedance-based (TDR) leak-detection cable technology is based on the measurement of the impedance of an energy pulse and is similar in concept to radar technology. It has the subtle advantage of locating multiple leaks if a prior leak is of small magnitude and confined to a local area. Impedance-based systems compare favorably with conductance-based systems, although impedance methods lack some of the precision inherent in resistance-based methods. This is particularly true if a leak occurs at the far end of a long length of cable.

Thus, both types of cable technologies have subtle differences that could prove useful for a given design condition. For instance, it was mentioned that conductance-based cables have the ability to detect very small leaks (some are capable of signaling a leak with $< 0.25$ in of cable length wetted, when fully immersed), thereby aiding in early detection of a leak. The ability to detect a leak early can help to limit the total quantity of a leak (release). Accordingly, the amount of work to repair a piping system could be kept to a smaller scope. If a leak were to remain undetected for a longer time, there is greater potential for more work to be involved in the repair of the system.

A unique feature of TDR-based technology is the ability to detect multiple leaks. This feature is interesting, but there are limited applications where it is of benefit. To continue to operate a double containment piping system once a leak has been detected is a somewhat self-defeating practice for the concept of double containment. Good operating practices suggest that a system be immediately repaired upon the detection of a leak. In fact, RCRA requirements in the United States would not allow a user to continue to operate a regulated system once an initial leak has been detected.

In order for a TDR-based cable to detect a second leak once the first has occurred, the system must map over the first leak. When this occurs, the cable sensing system is subject to a signal-attenuation effect, which will lead to a reduced sensitivity. Figure B13.88 graphically shows this effect, based upon a first leak at 150 ft down a TDR cable's length. The sensitivity of the TDR cable, as measured by an amount of wetted cable required to create an alarm condition, depends on the magnitude of the mapped-over leak, as shown in Fig. B13.88. However, it also depends on the distance of the first leak from the source of the signal. Sensitivity values will improve for TDR-based sensor cables exposed to fluids at less than the effective range; alternatively stated, this also means that sensitivity will lessen as cables are exposed to fluids at greater than the effective range.

Leaks that occur in a near-simultaneous manner could be detected using mapping-over techniques in a TDR-based system. However, it is very rare for multiple leaks to occur simultaneously once hydrostatic testing has been concluded. The time when multiple leaks may be reasonably expected to occur is during an initial primary-pipe hydrostatic test. Thus, having a cable of this type in place during initial pressure testing might be desirable. However, cable systems are not recommended to be installed prior to, or during, a hydrostatic-pressure test, according to manufacturers of both resistance-based and TDR-based sensing cables. Pull cable should always be installed first and left in place during pressure testing. Only upon completion of all testing should actual cable be installed. Thus, the ability to detect multiple leaks is of little real benefit.

Another difference between the two cable technologies involves their sensitivity in detecting a first leak, in relation to their overall length. For resistance-based systems, sensitivity is nearly constant over the full length of a cable, even for very long lengths ($> 1000$ ft). Sensitivities of TDR-based cables do vary according to

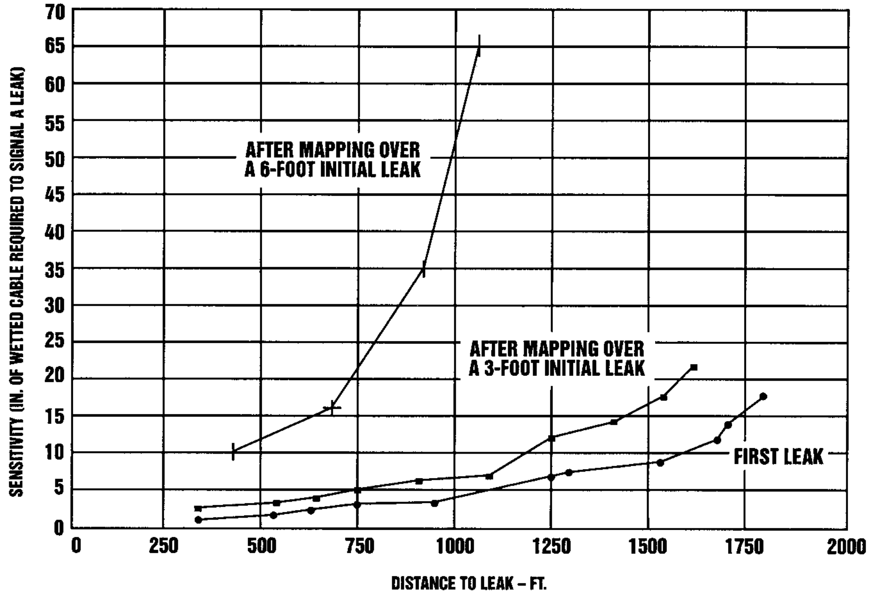


**FIGURE B13.88** Response of a typical TDR-based cable to a second leak, based upon a first leak that occurs 150 ft away. Data is shown for a leak that spreads 3 ft, and for one that spreads 6 ft. First leak data is shown for comparison. *(Source: Based on test data supplied by Raychem Corp.)*

length, however. The farther down the length of cable, the greater the wetted length of cable required to create an alarm condition, due to signal attenuation. For a long pipeline (>1000 ft), this effect can be significant, as illustrated by Fig. B13.89.

Both resistance-based and TDR-based cable sensing systems claim an accuracy in detecting leak location to within plus or minus 1 percent of the total cable length, or 5 ft, whichever is greater. Accuracy of leak location is functionally different from cable sensitivity. In assessing the performance capability of a leak detection cable system, one needs to consider both the claimed accuracy and the sensitivity of the cable to obtain a complete picture.

Installation of leak detection cable requires carefully planned coordination with other aspects of the piping system installation or associated tanks. It also requires that close inspection and control practices be followed during an installation. These functions can either be provided by outside inspectors or by the installers of the cable systems, provided they receive adequate training. Each detail must be carefully considered, both in the engineering design and during the installation process. Detailed requirements should be clearly described in project plans and specifications.

***Leak Detection Cable System Component Detail.*** There are many individual components that collectively make up a continuous sensing cable system. The exact design of components varies by manufacturer, and not all systems require the same type of components. For instance, some cable manufacturers do not use connectors to install straight lengths of cable. Instead, they use continuous cable spliced together

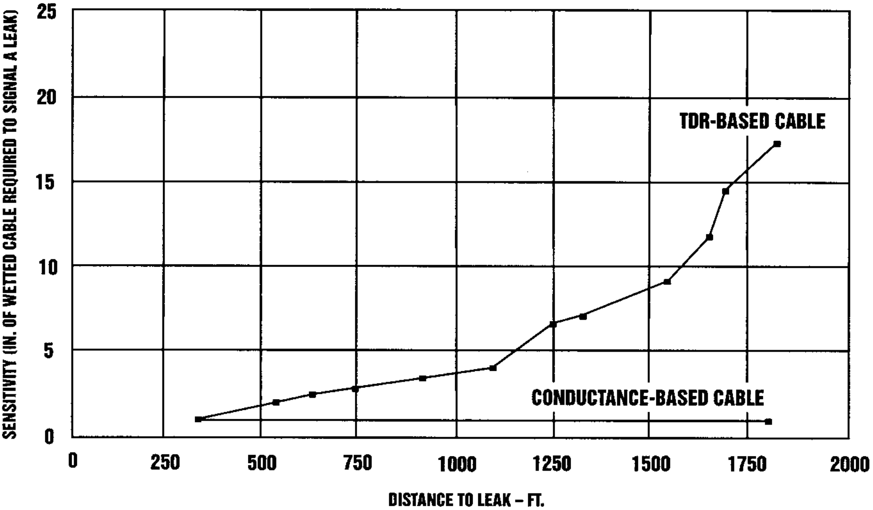


**FIGURE B13.89** Sensitivity of a typical TDR-based cable based on the length down the cable where a leak occurs. *(Source: Based on test data supplied by Raychem Corp.)*

at the ends. Examples of a variety of cable constructions are illustrated in Fig. B13.90 and Fig. B13.91.

The major components that may be encountered in any leak-detection cable system, aside from the alarm panel, consist of: (1) cable, (2) jumper cable, (3) jumper feedthrough fitting, (4) feedthrough assembly, (5) branch connector, and (6) termination device. All cable systems utilize cable, jumper cable, and some type of jumper feedthrough fitting. However, the actual design of the components varies considerably from manufacturer to manufacturer.

## Probe Monitoring Systems

Leak detection may be effectively provided by dividing a double containment piping system's annulus into separate, isolated leak detection compartments. Each compartment may then be monitored with some form of probe measuring device. The types of probes typically used include: (1) liquid level sensing, (2) moisture detection, (3) vapor detection, (4) conductivity and resistivity, (5) pH measurement, (6) pressure sensing, (7) flow measurement (primary piping), (8) density measurement, (9) wavelengths (light, radar, and sonar), (10) motion detection, and (11) others. While providing compartments in an annulus may be

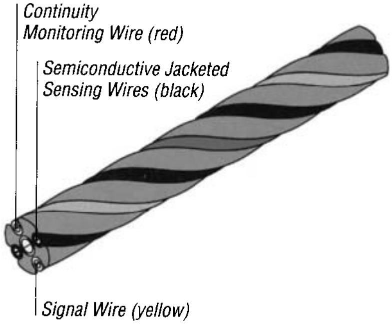
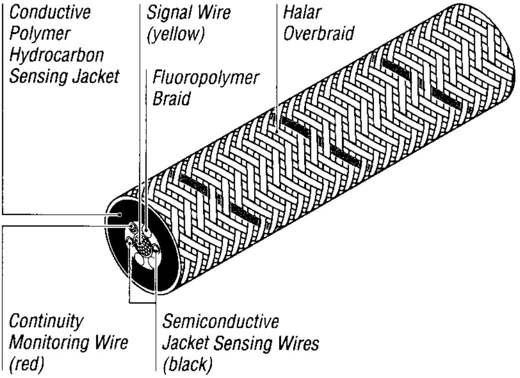


**FIGURE B13.90a** Example of the construction of a typical conductance-based leak-detection cable, which is specific to conductive fluids. *(Source: Raychem Corp.)*



*Sensing cables are specifically designed to detect either aqueous or hydrocarbon-based liquids. A unique branching connector lets locating systems follow complex, branching pipelines.*

**FIGURE B13.90b** Example of the construction of a typical conductance-based leak-detection cable that is specific to nonconductive fluids. *(Source: Raychem Corp.)*

the most efficient means of incorporating a point probe–based detection system, it is not the only approach. Point-probe systems may also be used in a system designed with a continuous annulus, although the ability to locate a leak reasonably is significantly less.

Normally, probes are housed within a branch outlet, or reducing-branch outlet, which is provided in the secondary containment pipe. Examples of possible arrangements are shown in Figs. B13.92 and B13.93. Such arrangements often function as a means to house a probe, in addition to functioning as a combination low-point drain (high-point vent) and manual detection point. Normally, probe systems are

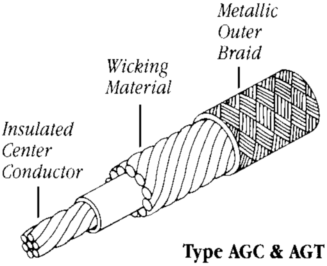


**FIGURE B13.91a** Example of the construction of a TDR-based cable designed to detect corrosive chemicals. *(Source: Midwesco)*

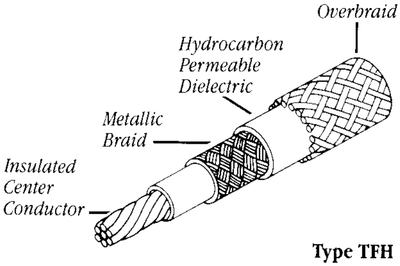
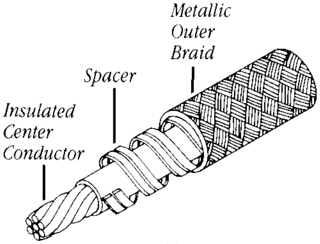


**FIGURE B13.91b** Example of the construction of a TDR-based cable designed to detect hydrocarbons. *(Source: Midwesco)* more readily applied to aboveground systems. In underground systems, probes can be attached at manhole locations using the branch arrangement illustrated in Fig. B13.93, immediately after piping-manhole penetration.



**Type AGW & FGH**

**FIGURE B13.91c** Example of the construction of a TDR-based cable designed to detect water and hydrocarbon fluids in addition to steam and hot water up to 400°F. *(Source: Midwesco)*

***Liquid Level Sensing.*** Detection of a fixed level of liquid is among the simplest probe systems to design and implement in a double containment piping system. A liquid level system will function in a very reliable manner to detect leaks. However, it will not distinguish between water (including groundwater or condensate) and service fluids. In this type of system it is important to have a pressure-tight annulus and to eliminate condensation by providing a moisture-free inert gas in the annulus (both items are important for most methods of sensing leaks). A liquid level detection system can be implemented by installing a liquid level measuring device in a vertically positioned dropleg branch, as shown in Figs. B13.92 and B13.93, or in low-point sumps such as those shown in Figs. B13.94 through B13.97.

A liquid level probe (or probes) may be connected to an alarm panel that signals an alarm when a specified level of liquid is detected. The system is good for establishing a leak in a certain zone of an annulus. It will not allow the source of a leak to be specifically identified within a leak zone, however. Also, it is not designed to detect small leaks quickly caused by a spraying but will rapidly respond to major leaks. A liquid level sensing system may be coupled with other types of probes to distinguish between types of fluids, resulting in a very effective overall approach to detecting leaks.

***Moisture Detection.*** Moisture probes are useful for detecting the presence of groundwater or service fluids that have a high water content. There is a wide variety of types of probes available; the sensitivities of available probes vary widely. The

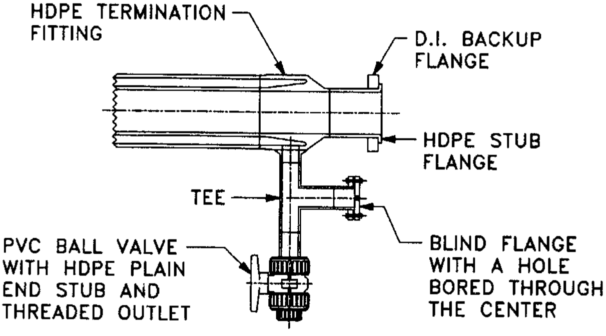


**FIGURE B13.92** Illustration of a downward-positioned probe attachment for a horizontally mounted liquid-level sensor future attachment.

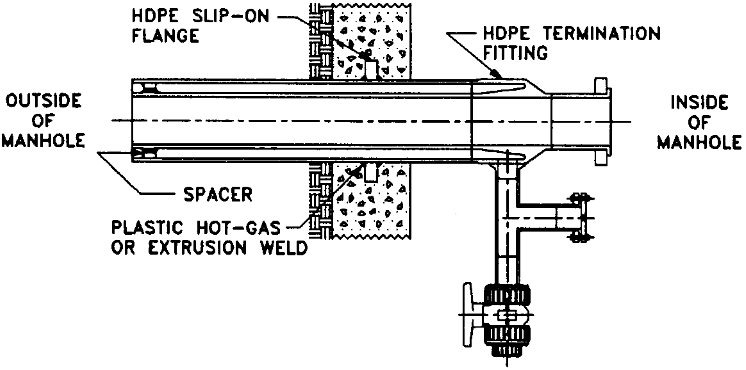


**FIGURE B13.93** Illustration of a probe attachment in a manhole location.

wide range of moisture probe styles available allows a system designer to select a customized system designed for a specific application.

A moisture probe system can be implemented by installing a moisture measuring device in a vertically positioned drop-leg branch. A branch for a probe of this type need not be at the 6 o'clock position of an annulus. Most sensitive probes can be positioned at the 12 o'clock position of an annulus, since they detect fine vapors.

A moisture probe (or probes) may be connected to an alarm panel that signals

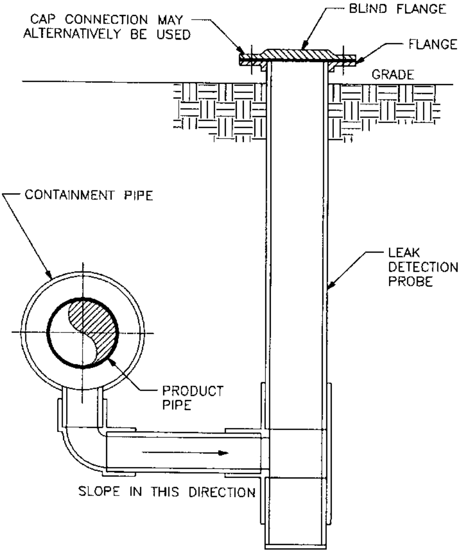


**FIGURE B13.94** Illustration of a typical underground vertical leak detection probe sump. *(Orion Fittings, Inc.)*

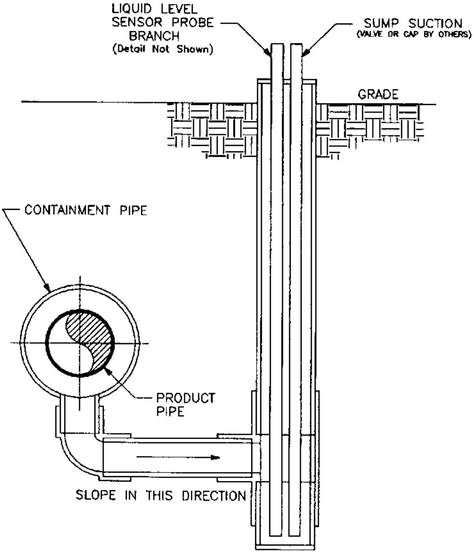


**FIGURE B13.95** Example of a low-point leak detection sump in a plastic gravity drain system. *(From* "Handbook of Double Containment Piping Systems," *C. Ziu, McGraw-Hill, New York, 1995.)*

**FIGURE B13.96** Example of a low-point leak-detection sump in a plastic gravity drain system.

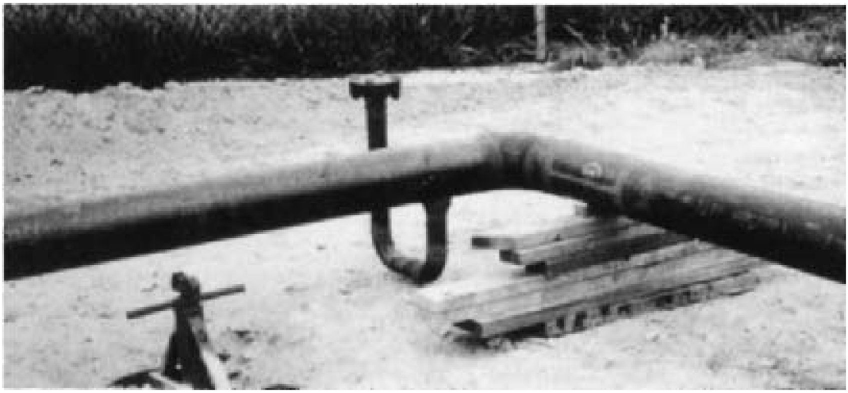


**FIGURE B13.97** Example of a low-point leak-detection sump in a metallic fuel oil system.

when a change in moisture content of the annular space is detected. Such a system is good for verifying that a leak of a primary service fluid has occurred in a certain zone of the annulus. It will not allow the position of a leak to be specifically located within a leak zone. However, it can be good for detecting small leaks if the probe used is highly sensitive.

***Vapor Detection.*** Vapor detection systems are very similar to moisture detection systems, except that vapor probes detect volatile chemicals other than water. This type of probe is normally designed to detect fluids that have high vapor pressures, including organic chemicals, halogens, and other chemicals that are relatively volatile. There are many types of vapor probes available with varying values of sensitivity. The type of organic chemical being carried in a primary piping system will determine the type of probe that should be selected for any given application. The sensitivity of the probe to be selected is based upon the type of leak to be detected (e.g., small leak versus major leak), although most vapor probes tend to be highly sensitive compared to other forms of leak detection. When an earlier response is desired, a probe that has a greater sensitivity is desirable.

***Conductivity (Resistivity) Measurement.*** The conductivity or resistivity of an annular space can be measured to detect whether a leak has occurred. This type of probe measurement system is most effectively used in conjunction with a liquid level or pressure sensing system as a means of classifying the type of fluid being sensed. In such an arrangement, liquid-level or pressure monitoring may be used as the primary system to detect the presence of fluids. The conductivity (resistivity) probe will then help to distinguish between water from groundwater or condensation and the service fluid (which must be of the conductive type), based on a change in conductivity. Conductive fluids include such fluids as acids, bases, salts, other organic chemicals, and a host of polar and semipolar organic solvents. Conductivity probes have also been used as the sole means of detection for double containment piping systems.

Conductivity probe systems can be incorporated into a double containment pipe annulus by installing a conductivity measuring device in a vertically positioned drop-leg branch or low point sump. The probe (or probes) may then be connected to a computer or recording device to record the conductivity continually, or may be directly connected to an audio alarm. Monitoring conductivity is good for identifying the fluid that has leaked but can also be used as the sole means to sense for leaks. Conductivity probes can detect small leaks in addition to major leaks. In a very general sense, leak detection cable is a form of conductivity (resistivity) probe. This is not the primary purpose of leak detection cable, but it has been used in this manner. Therefore, a short section of leak detection cable could theoretically be used as part of a point sensing approach.

***pH Probes.*** A pH measurement probe functions in much the same way as a conductivity (resistivity) measurement system. However, pH measurement is limited to detection of acids or bases as only this type of chemical can be measured in terms of pH. Since pH measuring devices are mostly designed to function in a wetted capacity, they normally are used as a secondary means of detection, in combination with some other type of probe. A pH probe system can be implemented by installing a pH measuring device in a vertically positioned drop-leg branch or low point sump. The probe (or probes) may be connected to an alarm panel that signals when a change in pH is detected. The system is good for classifying whether a leak of a primary service fluid has occurred in a certain annular zone by reporting its pH value. It will not allow a leak's location to be specifically identified within a given leak zone. It is best used in conjunction with some other leak detection method.

***Flow Measurement.*** A change in flow of primary piping may be related to the possibility that a leak has occurred. The means for accomplishing flow monitoring is to place a flow measuring device at the beginning and end of the piping system. If the flow of the primary pipe changes by more than a set amount, an alarm can be sounded. This method is good for detecting large leaks. However, it may not detect a fine spraying of fluid, such as would initially occur in a ductile material that is subject to stress cracking (e. g., polypropylene). Flow measurement can be very effective when used in conjunction with other methods.

***Pressure Sensing.*** The pressure of an annular space can be measured to determine changes in pressure. A pressure change can be used to determine whether primary or secondary containment has been breached, making it a very useful form of monitoring. The value and sign of the pressure change depend on the relative pressures of the annular space, the primary (core) pipe, and the pressure of the surrounding local atmosphere. For pressurized primary piping systems, a failure of the primary piping systems can be detected by a pressure rise in its annular space (assuming the annular space is maintained under a lower pressure than its primary pipe). In pressure piping systems where a positive pressure is maintained in its annular space, at an intermediate pressure between the primary pressure and the external environment, a drop in annular pressure will reflect a failure (breach) of the secondary containment system.

For drainage systems that maintain an annular space under a positive pressure, a pressure drop can signal a leak in the primary piping. However, a pressure drop in this type of system could also mean that the secondary containment has been breached. Therefore, a further investigation has to be made, unless a separate probe is added to provide additional information as to the origin of the leak.

Gas that is maintained under a low pressure tends to find its way out of threads, valve seals, et cetera over a period of time. Therefore, some loss of gas could occasionally be expected from secondary containment threaded joints, and resulting false (low-point) alarms triggered. This must be taken into account in operational training procedures so that false alarms do not lead to a leak detection system's being ignored.

The pressure of a primary piping system can also be monitored. A substantial drop in primary piping pressure will often mean that a leak has occurred somewhere over its length. This type of approach is useful for detecting large leaks.

The pressure of a double-walled tank's interstitial space can also be measured to determine if changes in pressure of a contained gas or liquid (e.g., brine) occur. The value and sign of the pressure change depend on the relative pressures of the interstitial space, the primary tank, and the pressure of the external atmosphere. Most double-walled tanks are for low-pressure service. Therefore, it may be difficult to distinguish between a breach of primary or a secondary containment of a double-walled tank in most applications.

## Manual/Visual Monitoring Methods

Noncontinuous sensing of double containment piping systems includes those methods that do not involve the incorporation of any type of continuous measuring device, or instrument, to the secondary containment piping system. The three main categories of noncontinuous sensing include manual detection, visual detection, and periodic annular pressure monitoring.

Manual detection typically is accomplished by adding valves to a secondary containment piping system at various low points in its annulus. The low-point valves can be occasionally opened to detect the presence of fluids. Such valves are normally positioned on drip legs, usually at each low point and other intermediate points of the double-containment piping system annulus.

Manual leak-detection methods are only effective when used as part of a regular inspection program where the system is routinely inspected. Manual systems serve as a very effective secondary means of leak detection, used in conjunction with any other method or methods. It is usually a built-in feature to most well-designed systems, where appropriate low-point drains are provided.

***Visual Detection Methods.*** Visual detection may be provided in a number of ways. It can be provided for the entire secondary containment piping system or any partial portion. Visual leak detection can be provided by using a transparent material (borosilicate glass, clear PVC, etc.) as the outside piping (and fittings where applicable). A more practical application involves flanging in a short section of clear piping, or providing clear piping or sight glass as part of a secondary containment drip-leg branch. Visual containment can also be provided where an open-ended secondary containment piping system is used, by observing the end of the pipe for fluid leakage. Visual detection is most effectively applied as part of a regular inspection program where the system is routinely inspected. Visual leak detection systems also serve as a very effective secondary means of leak detection, used in combination with any other method.

***Periodic Pressure Monitoring.*** The pressure of an annulus can be occasionally monitored to detect if a leak has occurred. To do so, a pressure gauge (instead of a transducer) must be provided in an annulus in at least one position. A typical connection for providing a pressure gauge in an annulus is illustrated in Fig. B13.98.

It may be desirable for some installations to maintain an inert gas under pressure and monitor the pressure of the gas. In applications involving pressure-rated primary

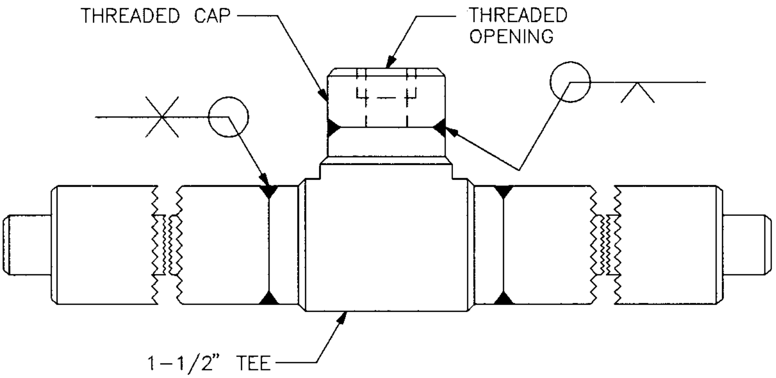


**FIGURE B13.98** Illustration of a pressure tap in a secondary-containment pipe for attachment of a pressure gauge.

piping, the annulus does not have to be maintained under a fixed pressure. A rise in pressure will signify that a breach of primary containment has occurred. However, it is not possible to detect a breach of secondary containment in such a system, unless a fixed pressure is maintained in the annulus.

## Condensation Effects in Annuli

If air that is warm and relatively humid is introduced into the annulus of a double containment piping system prior to final closure, moisture will condense when the system is subjected to a colder temperature. This often occurs when a system is constructed during the summer season and later subjected to cold winter operating temperatures.

Condensation is a common concern among designers and owners-to-be of double containment piping systems, and for very good reasons. The principal concern rests with the fact that a leak detection system may interpret this action as a false alarm. It does depend to some extent on the sensitivity of the leak detection system selected. However, no leak detection method is immune to this effect, including visual and manual means. Frequent false alarms may subsequently lead to ignoring actual alarms on the part of plant operations personnel, a very dangerous practice, and one that is self-defeating to the system. Also, metal materials could be subjected to various corrosion effects produced by the water (galvanic, pitting, microbiologically induced corrosion, etc.). Therefore, there are many reasons to avoid the possibility of condensation in an annulus.

The solution to the condensation dilemma is a simple and inexpensive one. Replace the original air with a dry or inert atmosphere. Alternatively, a vacuum may be pulled into the annular space, if inner and outer pipe components are mechanically strong enough to withstand vacuum conditions. It has been assumed by many that this is a very involved and expensive activity. However, if an annulus is designed in a leak-tight manner and has been provided with adequate high-point vents and drains, this task will actually be one of the least expensive aspects of the

**TABLE B13.1** Minimum Amount of $ft^3$ of $N_2$ that Must Be Added to Purge Various 1,000 ft Lengths of Double Containment Piping to Achieve a Dew Point of −20°F (−29°C)

| | Starting condition | | |
|---|---|---|---|
| Size | 90°F (32°C)/90% R.H. | 80°F (27°C)/80% R.H. | 70°F (21°C)/70% R.H. |
| 1" IPS/2"Sch. 10 | 1,380 | 890 | 550 |
| 1" IPS/3"Sch. 40 | 3,630 | 2,340 | 1,450 |
| 2" IPS/3"Sch. 10 | 2,360 | 1,520 | 950 |
| 2" IPS/4"Sch. 40 | 4,990 | 3,220 | 2,000 |
| 3" IPS/4"Sch. 10 | 5,790 | 3,730 | 2,320 |
| 3" IPS/6"Sch. 40 | 11,590 | 7,460 | 4,650 |
| 4" IPS/6"Sch. 10 | 9,530 | 6,130 | 3,820 |
| 4" IPS/8"Sch. 40 | 20,530 | 13,220 | 8,230 |
| 6" IPS/8"Sch. 10 | 12,040 | 7,750 | 4,830 |
| 6" IPS/10"Sch. 40 | 26,690 | 17,190 | 10,700 |
| 8" IPS/10"Sch. 10 | 16,160 | 10,400 | 6,480 |
| 8" IPS/12"Sch. 40 | 32,190 | 20,730 | 12,910 |
| 10" IPS/12"Sch. 10 | 17,930 | 11,540 | 7,190 |
| 10" IPS/14"Sch. 40 | 26,770 | 17,240 | 10,730 |
| 12" IPS/16"Sch. 40 | 29,500 | 18,990 | 11,830 |
| 12" IPS/18"Sch. 40 | 57,750 | 37,180 | 23,160 |

Notes:

1. Table assumes nitrogen to be completely dry at atmosphere pressure and 70°F, and assumes 100% mixing.
2. In many applications, a dew point of −20°F is lower than is necessary. A higher design dew point will require less nitrogen.
3. This table assumes 100% mixing, which yields results that are highly conservative. Actual practice should consume less nitrogen.

entire project. Table B13.1 shows that, for a majority of systems, it takes a relatively small amount of nitrogen to decrease the moisture content of a system to the equivalent of the saturation level (dew point) at −20°F, a level at which no condensation could be expected in most applications. Since bottled nitrogen currently (1994) costs approximately $0.14–0.15 (U.S.) per cubic ft when supplied in bottles that hold the gas at 2200 psi (150 bar), the cost for nitrogen will typically be less than $1000.00 (U.S.). The data assume 100 percent mixing in all cases, which is an extremely conservative assumption.

The discussion in the preceding paragraph is valid for systems where the annular space is closed in a leak-tight manner. However, in a system that terminates in an open end (including at a manhole entry), natural draft circulation will occur due to temperature differences between the gas in the annulus and the outside ambient air. This means that moist air eventually will return to the annular space through this process. The answer to this dilemma is that the atmosphere should be replaced initially, and then periodically recharged with the same dry gas to displace the moist air that periodically returns. The period of time for replacing the air will depend on the specifics of the climate, the season of the year, and the layout of the system. Another alternative is to install an air line at the beginning of the annulus from a source that continuously puts out relatively dry air at a pressure slightly higher than atmospheric, thereby continually displacing the volume of air in the system. This would most likely be an overly conservative and expensive approach for most systems, but an alternative none the less. In general, close-ended systems are preferable to open-ended systems so recharging can be minimized.