DOUBLE WALLED PIPING SYSTEMS

The design and construction of a double wall pipe is more complex than a single wall pipe because of the additional pipe, associated welds and tie in procedures. There are numerous design, operating and monitoring difficulties associated with spacers and bulkheads or shear rings. There is no compelling reason to use them when the primary function of the outer pipe is secondary containment.

Double wall pipeline configurations offer moderate-to-significant operating and maintenance advantages relative to single wall pipelines because of the ability for secondary containment of hydrocarbon in the event of an inner pipe failure.

The main operating and maintenance disadvantages of a double wall pipeline relative to single wall pipelines are the limited capability to inspect and monitor the condition of the outer pipe.

Double wall and single wall pipeline configurations have similar operating and maintenance requirements on the product (inner) pipe for operational condition monitoring, leak detection, chemical inhibition application, pipe cleaning, defect monitoring and evaluation, and cathodic protection testing, monitoring and maintenance .

When evaluating single walled pipe vs. double walled pipe systems, one must consider two important types of failures: 'functional failure' and 'containment failure'. A functional failure is defined as pipeline system damage without loss of product containment integrity to the environment. A containment failure is defined as pipeline system damage with loss of product containment integrity, that is product loss to the external environment. Hence a breach of either the inner or outer wall of a double wall pipe is considered as a functional failure, provided the other pipe retains its integrity or containment. Loss of containment through only one of the two pipes comprising the double wall system is not considered to be a containment failure of the system. Any failure to a single walled pipe system would constitute a containment failure.

The most compelling reason for a double wall pipe, instead of a robust single wall pipeline, is the containment of a product leak. The annulus (headspace between the inner and outer pipes) can also be monitored for evidence of a leak (or even pipe degradation). In these respects it has advantages over a single wall pipe. However, a leak in a robust single wall pipe has a very low probability. The thicker wall than normally used provides greater strength to resist environmental loads and greater resistance to erosion and corrosion.

The major advantages of a single wall pipe are simpler construction, lower construction costs, lower life cycle costs and greater inspection reliability. The major disadvantage is that any size of leak will release product into the environment. The major advantage of the double wall pipe is that the probability of a failure or leak in both pipes at the same time is very low. It has a lower risk of product release to the environment than a single wall pipe. The disadvantages of the double wall pipe include its relative complexity and potential difficulties with integrity monitoring of the outer pipe.

Corrosion

The double wall pipe and single wall pipeline configurations have similar corrosion related design considerations.

The potential corrosion of the inside of the inner pipe of the double wall pipe is the same as the inside of the single pipe. The outside of the inner pipe and the inside of the outer pipe have low potential corrosion because of the nitrogen gas that will be used to fill the annulus. The outside of the outer pipe will have a slightly lower corrosion potential than the single wall pipe because of the somewhat lower skin temperature. It is assumed that the robust single wall pipe and the double wall pipe will have similar coating and cathodic protection.

Constructability

Construction of a double wall pipe is more complex than construction of a single wall pipe. The additional construction activities consist of inserting one pipe within the other, with the associated outer pipe tie-in welds, pressure testing the outer pipe and drying and charging the annulus following construction.

The amount of pipe and the number of girth welds is double for the double wall system.

Construction Quality

All welds of the double wall pipe can be inspected by radiography methods as for the single wall pipe with the exception of tie-in welds on the outer pipe. These tie-in welds can be adequately non-destructively examined by ultrasonic inspection.

Split sleeves may be required for final tie-in welds on the outer pipe of the double wall pipe. Manual ultrasonic inspection of the associated longitudinal welds should be adequate.

Operations and Maintenance

The double wall system has several maintenance disadvantages, relative to single wall pipelines. These include reduced outer pipe defect monitoring capability and more complicated commissioning requirements. Repair procedures would be more complicated and the increased complexity of the double wall system would increase the repair frequency.

Double wall pipe configurations have a potentially lower lifecycle cost for "containment failure", relative to single wall pipelines, due to the secondary containment capability offered by the outer pipe. Containment failure cost includes lost product, service interruption / lost production, cost of repair and recommissioning, environmental restoration and intangible costs.

Double wall configurations have a potentially higher lifecycle cost for functional failure, relative to single wall pipelines, due to the inability to readily inspect, evaluate, monitor and control outer pipe defects. Functional failure cost includes service interruption / lost production, and cost of repair and recommissioning.

Double wall and single wall pipeline configurations have similar operating and maintenance costs, for operations (operational monitoring, leak detection, application of corrosion and chemical inhibition) and for maintenance (corrosion control, inspection, defect evaluation and defect control).

Comparative Risk Assessment

The configuration of a double wall pipeline is more complex than a single wall pipeline; it has more material and more welds and it is more difficult to monitor. Hence it has a greater risk than a single wall pipeline for operational problems. However, a leak in a single wall pipe results in loss of product to the environment. It is unlikely that simultaneous failure of inner and outer pipe would occur with the double wall system. The risk of loss of product to the environment is lower for double wall system.

Pipe-in-pipe (PIP) configurations have been adopted for many different industrial applications. These applications include thermal insulation, leak containment and protection of flowlines. The PIP configurations may involve single or multiple inner pipes. For example, multiple flowlines and other service lines are often bundled together inside one outer pipe in a pipe bundle for ease of installation.

Thermal insulation is currently the most common application of single or multiple (pipe bundle) PIP systems. Hot water and chilled water, heat transfer fluids, hot oils, liquefied gases (cryogenic service) and molten sulfur are typical service types common to industrial and commercial construction.

Chemical Industry Application

Chemical process facilities handle a variety of chemical substances and compounds at various temperatures and pressures. The piping system for transporting the fluids must be compatible with the intended service conditions. The selection of piping materials of construction depends on the specific application. Petroleum refinery piping is generally characterized as large-diameter metallic piping, operated at elevated temperature and pressure. Chemical plant piping is typically characterized by relatively small diameter pipes (2 in or smaller), with lower operating pressure and temperature, and corrosive fluids. The use of exotic alloy materials, thermoplastics, and thermoset resin materials is common for the pipe construction. Many chemical plant pipes transport flammable and toxic substances.

Pipe-in-pipe (or more commonly jacketed pipe) systems are used in petrochemical industries mainly for containment and thermal insulation. Jacketed pipelines are commonly used to carry certain fluids in process facilities. Process fluids that require temperature control (i.e., molten sulfur) are good candidates for the applications of jacketed pipes. For molten materials (i.e., polymers) where high temperature is required, jacketed pipelines can also be used. Some advantages of jacketed pipelines are:

1) uniformity of heat input around circumference of process pipe;

2) tighter temperature control over entire pipeline length; and

3) elimination of cold spots that may cause degradation or localized freezing of process fluids.

Pipe bundles comprising several inner pipes in a single containment casing are also used for economic advantage.

In jacketed pipe systems, various heating media (liquid phase and vapor phase fluids) can be used for temperature control of process fluids. Jacketed piping systems where the annular space is evacuated are often used to convey cryogenic temperature process fluids. The vacuum minimizes heat gain from the atmosphere to the cryogenic fluids. The annulus of the system can also be used for passive thermal insulation by the addition of insulation materials.

The heat from the flowing fluids makes the outer pipes expand. Measures are available for reducing the thermal stresses in the jacketed pipes.

Regulatory Requirements

The US Environmental Protection Agency (EPA) regulations now require secondary containment for piping and storing hazardous fluids. The Health & Safety at Work Act has also imposed exacting standards for transporting dangerous chemicals through piping to prevent spillage or leak. A common solution is to use a jacketed pipe with the inner pipe within a containment casing equipped with leak detection. The inner pipe is normally within a size from 0.5 to 18 in. The outer pipe is approximately two nominal sizes larger than the inner pipe.

Double Walled Piping Design Considerations

The primary objective for considering a double wall pipe system is based on reducing the potential for accidentally releasing product from the pipeline into the environment.

Structural integrity issues are concerned with pipeline response and performance due to the imposed operational and environmental loads. General considerations for issues on pipeline structural response are summarized in the table below.

Structural Integrity Issues for Pipeline Design

Parameter		**Structural Integrity Issues**
Working Stress	MAOP	Maximum allowable internal operating pressure (MAOP)
	Temperature	Thermal stress load
	Stress	Membrane (i.e. in-plane) stress due to internal and external pressure
Strain Limit State	Rupture	Membrane tensile strain limit due to primary and secondary loads
	Combined Strain	Membrane strain due to combined differential displacements and/or rotations
Stress Limit State	Burst (Yield)	Maximum internal pressure limit
	Combined Stress	Membrane stress due to differential loads, pressure distributions or moment couples
Stability	Buckling	Loss of global or local structural stability due to bending moment, internal or external pressure, excess temperature differential
	Ovalization	Local sectional collapse due to effects such as overburden pressure, or interaction between carrier and outer pipe
Integrity	Weld CTOD	Interaction of weld defects with tensile strain and accumulated plastic strain

Acceptable stress or strain limits are established as a function of a number of parameters including operating pressure and temperature, pipeline diameter, wall thickness, material grade.

Double walled pipelines are generally expected to utilize a series of bulkheads or shear rings and/or spacers to transfer loads between the inner and outer pipes and centralize the inner pipe within the outer pipe.

Bulkheads are pressure containing, load transferring structural attachments between the inner and outer pipes. Shear rings are essentially bulkheads that contain ports that allow communication (fluid flow) between adjacent annular segments. Bulkheads and shear rings would be custom manufactured from low alloy steel very similar to the steel used in the line pipe. Spacers are generally non-metallic bands manufactured as half cylinders and fixed to the outside of the inner pipe. Each spacer has a series of longitudinal ribs that fit snugly inside the outer pipe. They serve to position the inside pipe within the outer pipe, allow more even annular space and allow less restricted movement of the inner pipe. Spacers are commercially available manufactured items. If specific dimensions are required, spacers can be customized. Typical spacer spacing is about thirteen feet. This amounts to three spacers per forty foot long joint of pipe.

Bulkheads isolate the annulus into a series of annular segments. Bulkheads have the potential advantage over shear rings of isolating a leak from the inside pipe from defective segments of outside pipe. There is no known inspection method for monitoring the overall condition of the outer pipe, however. Consequently, bulkheads are not considered to afford adequate advantage to compensate for the lost opportunity of utilizing the annulus to continuously monitor the pressure containing integrity of both the inner and outer pipes. As such, in principle, Venture Engineering favors spacers or shear rings over bulkheads.

For normal product pipeline operating temperatures when the only functional requirement of the outer pipe is containment, there does not appear to be any design imperative for the use of bulkheads, shear rings or spacers for double walled pipelines. This would reduce the fabrication and constructability issues of double walled pipelines significantly. The only caveat on this statement is that the overall condition of the outer pipe can only be monitored on a pass/fail basis with respect to its ability to contain a leak. This would be done by means of maintaining the annulus at a pressure above or below the ambient pressure and monitoring this pressure.

The double walled concept preferred by Venture Engineering is simply one pipe inserted within the next larger standard pipe size (simple double wall system). The inner and outer pipes would be suitably attached at each end by means of a bulkhead like device. Side outlets suitable for filling and purging the annulus and instrument connections would be installed on the outer pipe at each end to provide operating and maintenance access to the annulus.

The following design rationalizations were made with the decision to eliminate the bulkheads or shear rings and spacers for double walled pipe:

1. There seems to be no significant structural advantage to the use of a centered inner pipe.
2. There does not seem to be a requirement to avoid contact between the inner and outer pipes to control corrosion, as is the case with cased crossings where the annulus is vented to atmosphere.
3. To practically eliminate corrosion in the annulus, it is suggested that following construction, the pipeline be placed in service and allowed to warm up. The annular space can then be vacuum dried. Once dried, the annulus could be evacuated or filled with nitrogen. To provide an extra measure of insurance against corrosion in the annulus in case the drying is incomplete, a volatile amine vapor phase oilfield corrosion inhibitor could be injected into the annulus with the nitrogen to elevate the pH anywhere moisture is present.

Based on the following reasons, the simple double wall system should be at lower risk from corrosion than a single walled pipeline. Internal corrosion would be the same for both systems. There should be virtually no corrosion in the annulus. Pipe corrosion barrier coating and cathodic protection would be as effective in protecting the outside of a double walled pipeline as they are for a single walled pipeline. The outer pipe of a double walled pipeline operates at lower temperature than a comparable single walled pipeline by virtue of the heat transfer resistance provided by a vacuum or inert gas-filled annulus. It would therefore experience a lower rate of external corrosion in the event that external corrosion is not effectively mitigated. As a general rule, corrosion rate doubles for every 20F increase in system temperature. For example, the maximum temperature of the outer pipe is estimated to be 80F for a design product temperature of 110F. Such a temperature reduction would result in a reduction in the corrosion rate on the outer pipe compared to that of the single walled pipeline.

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