Piping design is the job of configuring the physical aspects of pipe and components in an effort to conform with piping and instrumentation diagrams (P&IDs), fluid-service requirements, associated material specifications, equipment-data sheets, and current good manufacturing practices (GMP) while meeting owner expectations. All of this must be accomplished within a pre-determined, three-dimensional assigned space, while coordinating the activity with that of the architecture, structural steel, HVAC (heating, ventilation air conditioning), electrical, video, data-and-security conduit and trays, and operational requirements.

Pulling together and coordinating these activities to achieve such a compilation of design requires a systematic methodology, planning, technical ability, interdisciplinary coordination, foresight, and above all, experience. This third part in a series on piping design* discusses a number of key elements, including how to prepare specifications and guidelines, and some insights on flanges, surface finish and charge accumulation. Although computer-aided design (CAD) has become an integral part of piping design, it will not be discussed in this article.

**SPECS AND GUIDELINES**

One of the first activities the piping engineer will be involved with is development of piping specifications (specs) and guidelines on design and construction. Piping specifications, as an overview, should provide essential material detail for design, procurement and fabrication. Guidelines, both design and construction, should provide sufficient definition in a well organized manner to allow the designer and constructor the insight and direction they need in order to provide a facility that will meet the expectation of the owner with minimal in-process direction from the owner or construction manager.

**Piping specifications**

A piping specification is the document that will describe the physical characteristics and specific material attributes of pipe, fittings and manual valves necessary to the needs of both design and procurement personnel. These documents also become contractual to the project and the contractors that work under them. Designers will require a sufficient degree of information in a specification that will allow for determining the service limitations of the specification and what fluid services the specification’s material is compatible with. For example, a project may have, among other fluid services, sulfuric acid and chilled water. The economic and technical feasibility of the material selection for chilled water service would not be technically feasible for sulfuric acid. Inversely, the economic and technical material selection for sulfuric acid service would not be economically feasible for chilled water service.

Procurement personnel, too, will need detailed specifications to limit the assumptions they will have to make or the questions they will have to ask in preparing purchase orders. The piping specification should make clear exactly what the material of construction is for each component, and to what standard that component is manufactured. Also included in the component description should be pressure rating, end-connection type and surface finish where required.

There are a few rather common mistakes that companies make in developing or maintaining specifications:

1. The specification itself is either not definitive enough or too definitive;
2. The specifications are not updated in a timely manner; and
3. The specifications are too broad in their content.

Let’s consider each of these points in more detail.

**Point 1.** When defining pipe and components in a specification, you should provide enough information to identify each component without “hamstringing” yourself or procurement personnel in the process. In other words, do not get so specific or proprietary with the specification that only one manufacturer is qualified to provide the component (unless that is the actual intent). With standard pipe and fittings, it’s difficult to provide too much information. However, with valves and other inline equipment, overspecification can happen quite easily.

A common practice is to write a
specification for a generic type valve, one that can be bid on by multiple potential suppliers, by using the description of one particular valve as a template. What happens is that proprietary manufacturer trade names, such as some of the trim materials, are carried over to the generic valve spec. When the procurement person for the mechanical contractor, or whoever is buying the valves for the project, gets ready to purchase this valve, the only manufacturer that can supply it with the specified proprietary trim is the one from which the spec was copied.

You would think that doing this would eliminate multiple bids for the valve based on the unintentional proprietary requirements in the spec. Instead, it creates confusion and propagates questions. The valve bidders, other than the one the spec was based on, will bid the valve with an exception to the proprietary material, or they will contact the purchasing agent for clarification. Since the purchasing agent won’t have the answer, the question or clarification goes back to the engineer and/or the owner. The time necessary for responding to these types of issues is better spent on more pressing matters.

When developing a spec, be specific, but try not to include proprietary data unless you intend to. For example, when specifying Viton you are specifying a generic DuPont product — generic in that there are several different types of Viton, such as Viton A, Viton B, Viton GF, Viton GFLT and so on. Each of these has a specific formulation, which gives it different fluid-service compatibility and pressure and temperature ranges.

Viton is a type of fluorocarbon. Fluorocarbons are designated FKM under ASTM D-1418, so when specifying “Viton” you are identifying a specific product from a specific manufacturer — almost. By almost, what is meant is that, if you write the spec as Viton you would most likely get the original formulation, which is Viton A. The fluid service may be more suited for an FKM with polytetrafluoroethylene in it (Viton GF) or an FKM suitable for colder temperatures may be a better choice (Viton GFLT). Be specific for those who have to use the specs for design and purchase of the material.

If, in developing a specification, you wish to establish minimum requirements for a component or a material, it is certainly acceptable to identify a specific proprietary item as a benchmark. In doing this — and we’ll stay with the fluorocarbon gasket or seal example — you could identify Viton GF or equal, which would indicate that a comparable material from one of the other fluorocarbon manufacturers would be acceptable so long as the fluid service compatibility and pressure/temperature ranges were equal to or greater than the Viton GF material.

Point 2. All too often after a specification is developed it will reside in the company’s database without being periodically reviewed and updated. However, industry standards change, part numbers change, manufacturers improve their products, and so on. All of these things constitute the need and necessity to review and revise specifications on a timely basis.

A company that houses its own set of specifications should review them at least every two years. This timing works out for a couple reasons. Firstly, industry standards, on average, publish every two years, and secondly, capital projects, from design through close-out, will arguably have an average duration of two years. Lessons learned from projects can then be considered for adoption into company specs, prompting a new revision.

Point 3. Specs that are too broad in their content refers to an attempt at making the specs all-inclusive. A piping specification should contain only those components and information that would typically be used from job to job. That would include the following (as an example):

1. Pressure and temperature limits of the specification
2. Limiting factor for pressure and temperature
3. Pipe material
4. Fitting type, rating and material
5. Flange type, rating and material
6. Gasket type, rating and material
7. Bolt and nut type and material
8. Manual valves, grouped by type
9. Notes
10. Branch chart matrix with corrosion allowance

These ten line items provide the primary component information and notations required for a typical piping system. Some specifications are written to include components, such as steam traps, sight glasses, three- or four-way valves, strainers, and other miscellaneous items. These miscellaneous items are better referred to as specialty items (or some other similarly descriptive name) and are sized and specified for each particular application. This does not make them good candidates for inclusion into a basic pipe specification.

To explain the above we can use, as an example, a carbon-steel piping system that is specified to be used in a 150-psig steam service. The pipe, flanges, fittings, bolts, gaskets and valves can all be used at any point in the system as specified. The specification for a steam trap, however, will vary depending on its intended application. And depending on its applica-
tion, the load requirements for each trap may vary. For example, a steam-trap application at a drip leg will have a light steady load, whereas a steam-trap application at a shell-and-tube heat exchanger may have a heavier modulating load. And that doesn't take into account the need for the different types of traps, including F&T (float-and-thermostatic), inverted bucket, and thermodynamic.

You could, depending on the size of the project, have multiple variations of the four basic types of steam traps with anywhere from 30 to 300 or more traps in multiple sizes and various load requirements. I think you can see why this type of requirement needs to be its own specification and not a part of the piping specification.

A piping specification should be concise, definitive and repeatable. Adding specialty type items to the specification makes it convoluted and difficult to control and interpret. Users of these specifications are designers, bidders, procurement personnel, fabricators, receipt verification clerks, validation and maintenance personnel.

With this in mind, you can better understand, or at least value the fact, that these documents have to be interpreted and used by a wide range of personnel. These personnel are looking for particular information, written in a concise manner that will allow them to design and order or verify components within that specification. Inclusion of the specialty type items will, at the very least, complicate and exacerbate the process.

**Design/construction guidelines**

In conjunction with the piping specifications, the design and construction guidelines should convey to the designer and constructor point-by-point requirements as to how a facility is to be designed and constructed. The guidelines should not be a rhetorical essay, but instead should follow an industry standard format, preferably a CSI (Construction Specifications Institute) format.

Look at it this way: the material specifications tell the designer and constructor what material to use; the guidelines should tell them how to assimilate and use the material specifications in applying them to good design practice. Without these guidelines as part of any bid package or request-for-proposal package, the owner is essentially leaving it up to the engineer and/or constructor to bring their own set of guidelines to the table. And this may or may not be a good thing. Leaving the full facility's delivery to the engineer and constructor depends a great deal on the qualifications of the engineer and the constructor, and whether or not consistency from plant to plant and project to project is an issue.

If the owner approaches a project with expectations as to how they would like their plant or facility designed and built, then some preparation, on the owner's part, is in order. Preparation should include, not only material specifications as described earlier, but also the guidelines and narratives (yes, narratives) necessary to define the design and construction requirements.

I mention the use of narratives here because a narrative helps facilitate the understanding and conveys the magnitude of the, in most cases, reams of specifications and guidelines necessary to build an industrial facility of any appreciable size.

In general, a narrative should explain in simple, straightforward language, for each discipline: the numbering scheme used for the specifications and guidelines; association between the material specifications and the guidelines; an explanation as to why the project is governed by a particular code or codes; and a brief description of expectation.

The narrative allows you to be more explanatory and descriptive than a formal point-by-point specification. It gives the bidder/engineer a "Readers Digest" version of the stacks of specifications and guidelines they are expected to read through and assimilate within a matter of a few weeks.

How piping specifications are delivered to a project can have a significant impact on the project itself. There are, generally speaking, three scenarios in which project specifications and guidelines are delivered to a project. In Scenario 1, the owner, or customer, has developed a complete arsenal of specifications and guidelines. In the older, more established petroleum-refining and chemical companies you will see entire departments whose mission is to create, maintain and refine all of the specifications and guidelines necessary to execute a project. When a project is approved to go out for bid to an engineer, the necessary specifications and guidelines along with the requisite drawings are assembled, packaged and provided to the engineer as bid documents, and beyond that as working documents in the design, engineering and construction efforts.

In Scenario 2, the owner, or customer, has some specifications and guidelines that have possibly not been updated for several years. These are provided to the engineer with the understanding and stipulation that any errors or omissions in the documents should be addressed and corrected by the engineer. These, too, would be used in the bid process as well as on the project itself.

In Scenario 3, the owner, or customer, brings no specifications or guidelines to the project table. Specification development becomes part of the overall project engineering effort.

Scenarios 1 and 3 are at opposite ends of the spectrum, but afford the best situation for both the owner and engineer/constructor. By providing the engineer and constructor, as in Scenario 1, with a full set of current specifications and well-articulated guidelines, the assumption is made that both the engineer and constructor are qualified for the level of work required, and can very effectively execute the design, engineering and construction for the project.

Scenario 3 allows the engineer and constructor to bring their own game plan to the project. This too is effective, due only to the fact that the learning curve is minimal. Most engineering firms will be prepared to execute a project with their own set of specifications and guidelines. This applies
to qualified constructors as well. The down side of this is in the project-to-project inconsistency in specifications and methodology when using different engineers and constructors.

Scenario 2 is a worse case situation. Ineffective and outdated owner specifications create confusion and inefficient iterations in both the bid process and the execution of a project. Scenario 2 additionally creates the greatest opportunity for conflicts between owner documents and the engineer’s documents. For project management, this translates into change orders at some point in a project.

A guideline should explain to the engineering firm or constructor, in a concise, definitive manner, just what the owner expects in executing the design and construction of a facility. By actively and methodically developing a set of guidelines, an owner or customer does not have to rely on an outside resource, such as an engineering firm or constructor, to provide the facility required and hoped for.

Developing guidelines to convey your company’s requirements and expectations can be accomplished using one or both of the following two basic methods:

1. A formal point-by-point format that covers all necessary criteria that you, as the owner, require on a proprietary basis, plus a listing and description of the necessary code and GMP requirements.

2. A narrative for each discipline that allows the writer to expand and define, in a much more descriptive manner, the points that aren’t made clear enough, or readily apparent in the more formal format.

The guideline can be structured on one of the CSI formats. The format examples provided by CSI give a company sufficient flexibility in editing guidelines, or specifications for that matter, to allow the document to conform to its own particular brand of requirements and nuances. The format also lends a degree of intra-industry conformity to the guidelines and specifications, providing a degree of familiarity to the engineers and constructors who will have to adhere to them.

**DESIGN ELEMENTS**

In the first paragraph of this article, I described the act of designing piping systems for a facility as bringing a number of technical components together to make the piping conform to a specific set of requirements, within a prescribed area.

That’s pretty simplistic, and does not really convey the magnitude of the experience, technical background or the imagination required to execute such a task. Experience is the essential component here. And that is simply because, aside from whatever innate ability a good designer might possess, the required knowledge is not taught through formal education, but is instead learned by experience.

Ongoing learning can be in the form of organized classes, a mentor or any other means available to help learn and understand the physical requirements and restraints of various systems and industries.

Since we do not have enough space here to cover all of the design elements, I will key in on a few topics for clarification. (And this doesn’t even scratch the surface.) We will discuss flanges, pipe internal-surface finish, weld seam factor, pipe wall thickness, MAWP and MADP, design pressure and temperature, and charge accumulation.

**Flanges**

In Parts 1 and 2 of this series of articles (see footnote on first page), we discussed ASME flanges and their classifications. Most designers are familiar with ASME flange classifications such as 150, 300, 400, and so on. And even though verbally stating 150 pound flange (the origin of this term is discussed in Part 2) rolls off the tongue much easier and is still an industry accepted term, Class 150 is the proper terminology and designation.

What may be less familiar is that the class designation is a factor in the calculation for determining the rated working pressure of a flange. That calculation is:

\[ P_{w} = P_{c} S_{I} / 8,750 \leq P_{c} \]  

where

\[ P_{c} = \text{Ceiling pressure, psig, as specified in ASME B16.5, paragraph D3, at temperature } T \]

\[ P_{T} = \text{Rated working pressure, psig, for the specified material at temperature } T \]

\[ P_{r} = \text{Pressure rating class index, psi (for instance, } P_{r} = 300 \text{ psi for Class 300). Note: This definition of } P_{r} \text{ does not apply to Class 150. See ASME B16.5, paragraphs D2.2, D2.3 and D2.4} \]

\[ S_{I} = \text{Selected stress, psi, for the specified material at temperature } T \]

See ASME B16.5, paragraphs D2.2, D2.3 and D2.4.

**Pipe internal-surface finish**

Internal surface roughness is a topic that is specific to the pharmaceutical, bio-pharmaceutical and semiconduc-
tor sectors, but can also be an issue throughout the CPI. Quantifying and specifying a maximum surface roughness for internal pipe wall for use in what is referred to as direct impact fluid services, is a necessity in the above-mentioned sectors. Direct impact piping systems are those systems that carry product or carry a fluid service that ultimately comes in contact with product.

The need for a relatively smooth internal pipe wall is predicated on three primary issues: 1. Cleanability and drainability; 2. The ability to hinder the growth of biofilm and to enhance the ability to remove it once it does appear; and 3. To reduce, to a microscopic level, crevices in which microscopic particles can reside and at some point dislodge and get carried along in the fluid stream to damage product.

Regarding the first point, cleanability and drainability are associative; in order for a system to be fully cleanable it has to be designed and laid out in a manner that will eliminate any pockets and provide enough slope to eliminate any residual liquid (drainable). Not only is this residual liquid (or holdup) a contaminant — from both a bacterial standpoint and as a cross batch contaminant — but it can also be expensive due to the high cost of some drug products. Along these lines, the ASME-BPE Standard provides criteria for minimum slope, maximum deadleg, gasket intrusion, gasket concavity, and many other criteria for design of cleanable and drainable hygienic piping systems.

Regarding the second point, biofilm is defined as a bacterial population composed of cells that are firmly attached as microcolonies to a solid surface (see Figure 1). At a recent ASME-BPE symposium [7], Frank Riedewald, a senior process engineer with Lockwood-Greene IDC Ltd., explained the results of testing that was performed to determine the relationship between the formation of biofilm, pipe wall-surface finish and pipe wall-surface cleanability.

One of the many interesting factors that came from these studies is the fact that the internal surface of the pipe wall can actually be too smooth. Referring to the graph in Figure 2, results indicate that the surface finish range best suited to reduce biofilm adherence to the internal pipe wall surface is from 0.4Ra µm to 1.0Ra µm (15.7Ra µin. to 58.8Ra µin.). What this implies is that, while we currently do not have the means to prevent the onset of biofilm on the internal walls of hygienic or semiconductor piping systems, we can facilitate its removal in the cleaning process by specifying the proper surface finish of the internal pipe walls.

The accepted maximum surface finish in the pharmaceutical and biopharmaceutical industries is 25Ra µin. (0.6 µm). In the semiconductor industry you might typically see surface finishes in the range of 7Ra µin. to 15Ra µin., particularly in gas delivery systems. While the pharmaceutical industry is concerned with bacterial growth and cross contamination, the semiconductor industry is concerned more with particulate damage to product on the microscopic level. This pertains to point three above.

**Pipe weld seam factor**

Part 2 of this series of articles mentioned the fact that the weld seam in longitudinally welded pipe is a factor in the pipe-wall-pressure-design thickness calculation.

In ASME B31.3, there are two pipewall thicknesses for calculations. One is pressure design thickness (t) and the other is minimum required thickness (t<sub>m</sub>).

There are two equations for finding pressure-design thickness for straight pipe under internal pressure. Equation 2 is where t < D/6, where D is the actual pipe outer diameter (OD); this calculation is based on internal pressure, the actual (not nominal) OD of the pipe, stress value of the material at design temperature, joint efficiency factor, and the coefficient Y [a factor used to adjust internal pressure (P) for a nominal material at temperature]. Equation 3 is used when t ≥ D/6; this calculation is based on the above-listed criteria except that ID is used instead of OD, and the sum of all mechanical allowances is included.

\[
t = \frac{PD}{2(SE + PY)}
\]

for when \( t < D/6 \)

\[
t = \frac{P(d + 2c)}{2(SE - P(1 - Y))}
\]

for when \( t \geq D/6 \)

\[t_m = t + c\]

where

\[ t = \text{Minimum required thickness, including mechanical, corrosion and erosion allowances}\]

\[ c = \text{Sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances}\]

\[ P = \text{Internal design gage pressure}\]

\[ S = \text{Stress value for material from ASME B31.3 Table A-1, at design temperature}\]

\[ E = \text{Quality factor, or joint efficiency factor}\]

\[ Y = \text{Coefficient from ASME B31.3 Table 304.1.1}\]

To determine wall thickness for pipe under external pressure conditions, refer to the Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 1, UG-28 through UG-30 and ASME B31.3, paragraph 304.1.3.

Keep in mind that for seamless pipe, \( E \) will be removed from Equations 2 and 3.

**Determining MAWP**

Taking a page from the BPVC, we will go through a few brief steps to determine maximum-allowable working pressure (MAWP) for straight pipe. But let me begin by saying that MAWP is not a B31.3 expression, it comes from the BPVC. We will instead transpose this term to MADP (maximum-allowable design pressure), which is also not a B31.3 term, but more closely relates to piping.

When a vessel goes into design it is assigned a coincidental design pressure and temperature. These are the
maximum conditions the vessel is expected to experience while in service, and what the engineers will design the vessel to handle. The material, its thickness, welds, nozzles, flanges, and so on are all designed predicated on this predetermined design criteria.

Throughout design, the vessel's intended maximum pressure is referred to as its design pressure. All calculations are based on specified material and component tolerances along with fabrication specifics, meaning types and sizes of welds, reinforcement and so on. Not until after the vessel is fabricated can the engineer know what the actual material thickness is, the type and size of each weld, thickness of each nozzle neck, and so on. Only when all of the factual data of construction is accumulated and entered into vessel engineering programs can the MAWP be determined. This value, once determined, then replaces the design pressure, and is calculated based on the installed configuration of the vessel (that is, mounted vertically or horizontally; mounted on legs; or mounted on lugs).

The difference between the design pressure and the MAWP is that the engineer will design to the design pressure, but the final MAWP is the limiting pressure of the vessel. The MAWP may exceed the design pressure, but it can never be less than the design pressure.

In applying this to piping we will first calculate the burst pressure of the pipe and then determine the MAWP, or, as was mentioned earlier, a term more closely related to piping, the MADP.

There are three equations generally used in calculating burst pressure for pipe. They are:

- The Barlow formula:
  \[ P_{BA} = \frac{2 \times T_F \times S_T}{D} \]  
- The Boardman formula:
  \[ P_{BO} = \frac{2 \times T_F \times S_T}{D - (0.8 \times T)} \]  
- The Lamè formula:
  \[ P_L = \frac{S_T \times (D^2 - d^2)}{(D + d)^2} \]  

where:
  \[ P_{BA} = \text{Burst pressure, psig (Barlow)} \]
  \[ P_{BO} = \text{Burst pressure, psig (Boardman)} \]
  \[ P_L = \text{Burst pressure, psig (Lamè)} \]
  \[ D = \text{Actual pipe OD, in.} \]
  \[ d = \text{Pipe ID, in.} \]
  \[ T_F = \text{Wall thickness (minus factory tolerance), in.} \]
  \[ S_T = \text{Minimum tensile strength, psi, from B31.3 Table A-1} \]
  \[ S_f = \text{Safety factor, a factor of 3 or 4 is applied to burst pressure to determine MADP} \]

Using any of the three results from any one of the above equations we can then determine MADP \( M \) as follows:

\[ M = \frac{P_i}{S_f} \]  

where the subscript \( i \) is \( BA \), \( BO \), or \( L \), depending on which formula is used.

**Design pressure & temperature**

The ASME B31.3 definition for design pressure and design temperature is stated as two separate definitions. I will integrate them into one by stating: The design pressure and temperature of each component in a piping system shall be not less than the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service.

B31.3 goes on to state: The most severe condition is that which results in the greatest required component thickness and the highest component rating.

How do you determine these values and where do you apply them? We'll cover the where first. The discussion on determining pipe wall thickness was based on design conditions, in which \( P \) is the internal design gage pressure and \( S \) is the stress value at the design temperature. Design conditions are also used to determine component ratings and as a basis for determining leak test pressure.

There is no published standard, or genuine industry consensus, on how to determine design conditions. It basically comes down to an owner's or engineer's experience. What I will provide here is a resultant philosophy developed from many sources along with my own experiences.

To understand what constitutes design conditions, we first need to define them. The following are some accepted terms and their definitions:

- **System operating pressure**: The pressure at which a fluid service is expected to normally operate.
- **System design pressure**: Unless extenuating process conditions dictate otherwise, the design pressure is the pressure at the most severe coincident of internal or external pressure and temperature (minimum or maximum) expected during service, plus the greater of 30 psi or 10%.
- **System operating temperature**: The temperature at which a fluid service is expected to normally operate.
- **System design temperature**: Unless extenuating process conditions dictate otherwise, the design temperature, for operating temperatures between 32°F and 750°F, this value shall be equal to the maximum anticipated operating temperature, plus 25°F rounded off to the next higher 5°.

Applying a sort of philosophy created by the above definitions is somewhat straightforward for utility services, such as steam, water, and...
non-reactive chemicals. However, that part of the above definitions for design conditions that provide the caveat, “...extenuating process conditions...” implies a slightly different set of rules for process systems.

Extenuating process conditions can mean increased pressure and temperature, beyond that defined above, due to chemical reaction, loss of temperature control in heat transfer, and so on.

**Charge buildup in lined pipe**

Internal and external charge accumulation, known as static electricity, or more technically known as triboelectric charge accumulation, is the result of charge that is unable to dissipate. If a charge generated in a flowing fluid is allowed to dissipate to ground, as it does in grounded metallic pipe, then there is no problem. However, if a charge cannot dissipate and is allowed to accumulate, as it may in non-conductive pipe liners, it now becomes a problem by potentially becoming strong enough to create an electrostatic discharge (ESD). With regard to thermoplastic lined pipe there are two forms of this to be considered: external charge accumulation (ECA) and internal charge accumulation (ICA).

**ECA.** This is a concern with lined pipe due to the possibility of not achieving spool-to-spool continuity during installation due, in large part, to improved paint primer on flanges. When pipe spools (lined or unlined) are joined by flanges using non-metallic gaskets, the only thing that completes the spool-to-spool continuity is the bolting. The improved paint primer on lined pipe flanges makes this more difficult to achieve because normal bolt tightening doesn’t guarantee metal-to-metal contact between the nut and the flange.

Pipe generally does not come with a prime coat of paint; however, lined pipe does. Since flange bolts are used to complete continuity from spool to spool, the installer has to make certain, when installing lined pipe, that the bolts, at least one of the bolts, has penetrated the primer and made contact with bare metal. This was achieved in the past by using star washers on at least one flange bolt while assuming possible bare metal contact with the other bolts, allowing the washers, as they were tightened, to scrape away the prime coat so that contact was made with the bare metal of the flange. With improved prime coat material this is no longer a guarantee.

If continuity from spool to spool is not achieved, any charge generated resulting from an internal or external source cannot readily dissipate to ground. The voltage in triboelectric charge generation will build until it is strong enough to jump to the closest grounded object creating an undesired spark of electricity (ESD).

**ICA.** With regard to pipe, ICA is unique to thermoplastic lined pipe and solid thermoplastic pipe. Without being impregnated with a conductive material, thermoplastics are not good conductors of electricity. PTFE (polytetrafluoroethylene), as an example, has a high (>10^16 Ohms/unit area), resistivity factor. This is a relatively high resistance to conductivity, which means that any charge created inside the pipe cannot readily be conducted away to ground by way of the PTFE liner. Instead, the charge will be allowed to build until it exceeds its total dielectric strength and burns a pinhole in the liner to the internal metal wall of the casement pipe. It isn’t charge generation itself that is the problem, it’s the charge accumulation. When the rate of charge generation is greater than the rate of charge relaxation (the ability of material to conduct away the generated charge), charge accumulation occurs.

The dielectric strength of PTFE is 450 to 500 volts/mil. This indicates that for every 0.001 in. of PTFE liner 450 V of triboelectric charge will be required to penetrate the liner. For a 2-in. pipeline with a 0.130-in. thick liner, this translates into 58,500 V of triboelectric charge to burn through the liner thickness.

When the liner is penetrated by an accumulated charge, two additional problems are created: 1. Corrosive fluid (a major use of lined pipe) is now in contact with and corroding the metal pipe wall and at some point, depending on rate of corrosion, will fail locally and cause fluid to leak to the environment, and 2. The initial charge that burned through the liner is now charging the outer metal pipe. If continuity has not been achieved for the outer pipe, a spark of triboelectric charge is, at some point, going to jump to ground and cause a spark.

**Corrective action**

**ECG.** The simplest method to ensure continuity is to sand away any primer on the back side of each flange to ensure good metal-to-metal contact between nut and flange. Aside from that or the use of a conductive priming paint, the current ready-made solution to the external continuity problem is the addition of stud bolts located in close proximity to flanges on both pipe spools and fittings (see Figure 3). These studs can be applied at the factory or in the field. At each flange joint a grounding strap (jumper) is then affixed to a stud on one spool with a nut, extended over the flange joint and attached to a stud on the connecting spool completing continuity throughout the chain of connecting spools and fittings.

Another method of creating continuity at flange joints, while being less obtrusive and more integral, is described as follows.

Referring to Figure 4, flanges would be purchased pre-drilled and tapped in the center of the outer edge of the flange between the backside of the flange and the face side of the flange. The drilled and tapped hole in each flange would need to be centered between bolt holes so that they line up after the flange bolts are installed. The tapped hole is 1/4-in. dia. x 1/2-in. deep.

AFTER a flange is fully bolted, the continuity plate (Figure 4) can be installed using two 1/4-in. x 1/2-in. long hex-head screws and two lock washers. The Continuity Plate has two 0.312-in. slotted
boltholes allowing for misalignment and movement.

The entire continuity plate assembly is relatively simple to install, unobtrusive and establishes integral contact with the pipeline.

ICG. One of the first options in preventing internal charge accumulation is by minimizing charge generation. This can be done by adjusting the flow velocity relative to the liquid’s conductivity. To minimize design impact, cost and even schedule impact on a project, ICG needs to be evaluated early in the project due to the possibility of a change in line size.

To retard charge generation by reducing flow velocities, British Standard (BS) suggests the values presented Table 1 (per BS 5958).

If velocity reduction is not an option, or if further safeguards against charge accumulation are warranted, then a mechanical solution to provide a path to ground for ICG might be necessary.

One method for conducting charge accumulation from the interior of the pipe to ground is indicated in Figure 5. What is shown is an orifice plate made of conductive (static dissipative) material that is compatible with the fluid service. The orifice itself is off center to the OD of the plate and the pipeline itself. With the shallow portion of the ID at the invert of the pipe, the orifice allows the piping to drain in horizontal runs.

The tab portion of the plate extends beyond the flange OD. On the tab is a bolthole for attaching the modified continuity flange plate. The plate is designed to come in contact with the interior surface of the liner wall as well as protrude into the flowing fluid to provide a conduit for internally generated charge. Continuity is achieved by attaching the plate to the flange OD that is in contact with the piping, which is, in turn, grounded through equipment.

Recommendations

It is difficult to pre-determine what fluid services and systems will be candidates for charge accumulation prevention and electrostatic discharge protection. The simplest and most conservative answer is to assume that all fluid services in lined pipe systems are susceptible. In saying that, we then have to declare that a company’s pipe specifications need to reflect a global resolution that will affect all installations.

With regard to ECA, the recommendation for future installations with the least impact would be to specify pipe with no prime coat or at least no primer on the flanges, or a prime coat using a conductive paint. The unprimed pipe would be primed prior to installation with care given to primer touchup on flanges after installation. This would better ensure spool-to-spool external continuity.

For existing installations, either the studs or the continuity plate installation would work. It can also be suggested that the continuity plates can be tacked on to one flange rather than drilling and tapping both flanges.

For dissipating ICG, the orifice plate, as shown in Figure 5, is the only recommendation.

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References


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