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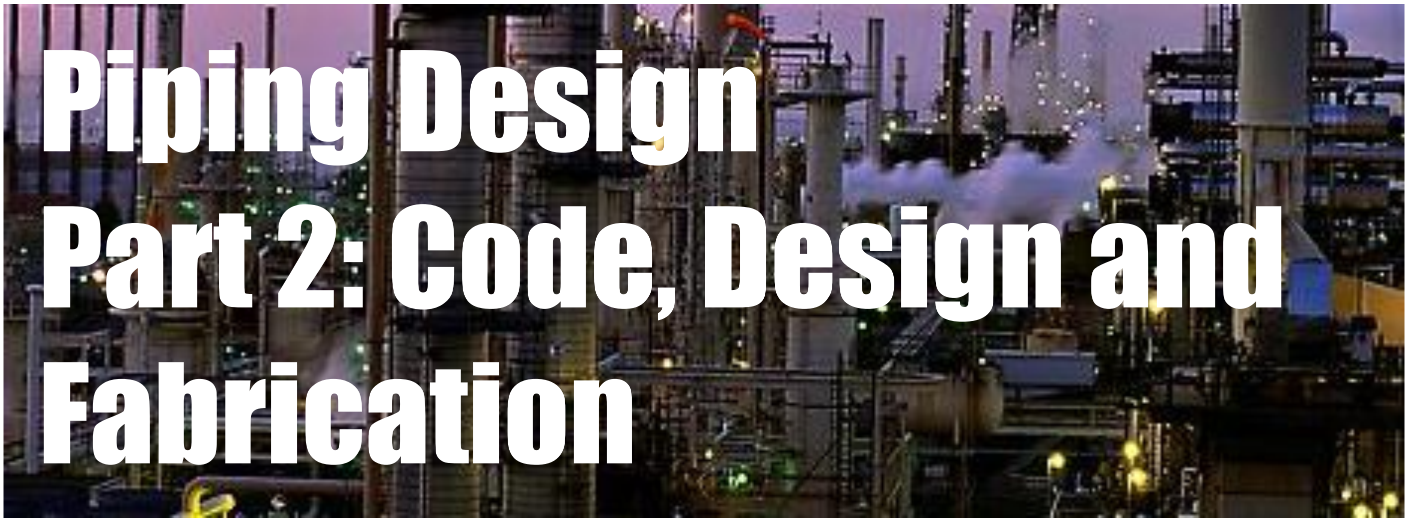

Piping Design Part 2: Code, Design and Fabrication

There is not a reason sufficiently good enough not to comply with appropriate industry Standards and Codes.

W. M. (Bill) Huitt
W. M. Huitt Co.

A request was put to me a few years back asking if I would respond in writing to the question, "Why do we, as a company, need to comply with a piping Code?" The question was in regard to the building of industrial facilities, and was in preparation for a meeting that was about to take place for which the main topic was going to be the issue of Code compliance.

If you considered the question while reading it you may have noticed that there is, although unintentional, a trick to it. Code, by definition is law with statutory force. Therefore the reason for complying with a Code is because you literally have to, or be penalized for non-compliance.

The question actually intended was, "why comply with or adopt a piping consensus standard?" When a question like the one above is phrased as it is it supports my contention that many people, referring to engineers and designers in our case, do not fully understand the difference between a Code and a Standard. And it doesn't help matters when some Standards are published as a Code, and some Codes are published as a Standard. This is certainly nothing to get excited about, but it is something worth pointing out.

My take on the reason for the misunderstanding of these two closely related terms, Standard and Code, is that they get bounced around so often in the same context that designers and engineers simply begin interchanging the two terms without much consideration for their different meanings. I'm going to explain the difference between a Standard and a Code, but before I do, here's the written response I gave to the above question:

Consensus Standards such as those published by ASME, ANSI, API, NFPA, ASTM, International Plumbing Code and others are not mandatory in and of themselves. However, federal, state, city and other local Codes are mandatory. In these municipal Codes you will find regulations that establish various requirements taken in whole, or in part from the Standards published by the above listed organizations, and others, as legally binding requirements. These Standards, as adopted, then become Code, which is enforceable by law.

When not addressed on a municipal level, but included in corporate specifications, the Standard becomes a legal Code on a contractual basis.

To comply with these Codes, irrespective of government regulations or corporate requirements, doesn't cost the builder any more than if they didn't comply. It does, however, cost more to fabricate and install piping systems that have a high degree of integrity as opposed to a system that doesn't.

By hiring non-certified welders and plumbers, by-passing inspections, examinations and testing, using material that may potentially not withstand service pressures and temperatures, and supporting this type of system with potentially inadequate supports is less costly but there's too much at risk. I don't think anyone in good conscience would *intentionally attempt to do something like that in order to save money, but then again the world is full of unscrupulous individuals and corporations.*

If anyone intending on fabricating and installing a piping system plans to:

1. Use listed material,
2. Specify material that meets the requirements for fluid service, pressure and temperature,
3. Inspect the material for MOC, size and rating,
4. Use certified welders and plumbers,
5. Inspect welds and brazing,
6. Adequately support the pipe,
7. Test the pipe for tightness;

Then they are essentially complying with Code. The Code simply explains how to do this in a formal, well thought-out manner.

There is not a reason sufficiently good enough not to comply with appropriate industry Standards and Codes. If there was a fee involved for compliance this might be a stimulus for debate. But there is no fee, and there is usually just too much at stake. Even with utility systems in an admin building or an institutional facility, the potential damage from a ruptured pipeline, or a slow leak at an untested joint could easily overshadow any savings gained in non-compliance. That's without considering the safety risk to personnel.

The first thing that someone should do, if they are considering to do otherwise, is check local and state Code. They may find regulations that require adherence to ASME, the International Plumbing Code or some of the other consensus Standards. If not already included, this should be a requirement within any company's specifications.

Just a bit of trivia:
ASME published the first edition of the Boiler and Pressure Vessel Code in 1914-15. Prior to creation of the Code, and what played a large part in instigating its creation, was that between 1870 and 1910 approximately 14,000 boilers had exploded. Some were devastating to both people and property. Those numbers fell off drastically as the Code was adopted.

Uniformity and regulation does have its place.

PIPING CODE

In a piping facility, defined here as an industrial facility requiring a significant amount (apply your own order of magnitude here) of pipe, the three key factors in its development are the governing Code, the design (includes specifications and engineering), and pipe fabrication (includes installation). These are the three topics we will discuss on a broad, but limited basis in this article.

Like the seatbelt law Code compliance is not just the law, it makes good sense. A professional Consensus Standard is, very simply put, a Code waiting to be adopted. Take the ASME Boiler and Pressure Vessel Code (BPVC), since its first publication in 1915 it has been adopted by 49 states, all the provinces of Canada, and accepted by regulatory authorities in over 80 countries.

On May 18, 2005 it was finally adopted by the 50th state, South Carolina. And this doesn't mean the BPVC is adopted in its entirety. A state, or corporation for that matter, can adopt a single section or multiple Sections of the BPVC, or they can adopt it in its entirety. Until South Carolina adopted the BPVC it was actually no more than a Standard in that state and only required compliance when stipulated in a specification. However, in all honesty you would not get a US boiler or pressure vessel manufacturer to by-pass Code compliance. That is, unless you wanted to pay their potential attorneys fees.

With regard to Code compliance, the question I get quite often is, "How do I determine which piping Code, or Standard, I should comply with for my particular project?"

Determining proper Code application is relatively straightforward while at the same time providing a certain degree of latitude to the Owner in making the final determination. In some cases that determination is made for the Engineer or Contractor at the state level, the local level or by an Owner company itself. Providing guidelines for Code adoption on a project basis is direction that should be included in any company's set of specifications, but quite often is not. This can cause a number of disconnects through design and construction.

In order to answer the question about Code assignment some history has to be told. In keeping this brief I will just touch on the high points. In 1942, ASA B31.1 – American Standard Code for Pressure Piping was published by the American Standards Association. This would later change to B31.1 - Power Piping. In the early 1950's the decision was made to create additional B31 Codes in order to better define the requirements for more specific needs. The first of those Standards was ASA B31.8 – Gas Transmission and Distribution Piping Systems, which was published in 1955. In 1959 the first ASA B31.3 – Petroleum Refinery Piping Standard was published.

After some reorganization and organizational name changes the ASA became ANSI, American National Standards Institute. Subsequent Code revisions were designated as ANSI Codes. In 1978, ASME was granted accreditation by ANSI to organize the B31 Committee as the ASME Code for Pressure Piping. This changed the Code designation to ANSI/ASME B31.

Since 1955 the B31 Committee has continued to categorize, create and better define Code requirements for specific segments of the industry. Through the years since then they have created, not necessarily in this order, B31.4 – Liquid Transportation Piping, B31.5 – Refrigeration Piping, B31.9 – Building Services Piping, and B31.11 – Slurry Transportation Piping. Each of these Standards is considered a stand-alone Section of the ASME Code for Pressure Piping, B31.

What the B31 committee has accomplished, and is continuing to improve upon, are Standards that are better focused on specific segments of industry. This alleviates the need for a designer or constructor building an institutional type facility from having to familiarize themselves with the more voluminous B31.3 or even a B31.1. They can work within the much less stringent and extensive requirements of B31.9, a Standard created for and much more suitable for that type of design and construction.

As mentioned above, ASME B31.1 – Power Piping, was first published in 1942. Its general scope reads: "*Rules for this Code Section have been developed considering the needs for applications which include piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems."*

The general scope of ASME B31.3 – Process Piping, reads: "*Rules for the Process Piping Code have been developed considering piping typically found in petroleum refineries, chemical, pharmaceutical, textile, paper, semiconductor and cryogenic plants; and related processing plants and terminals*."

ASME B31.5 – Refrigeration Piping, applies to refrigerant and secondary coolant piping systems.

Closely related to B31.1, but not having the size, pressure or temperature range, B31.9 was first published in 1982. It was created to fill the need for piping in limited service requirements. Its scope is narrowly focused on only those service conditions that may be required to service the utility needs of operating a commercial, institutional or residential building.

From its shear scope of responsibility, B31.3 encompasses virtually all piping, including those also covered by B31.1 (except for boiler external piping), B31.5 and B31.9. The difference, and distinction, as to which Code should apply to a particular project, lies with the definition and scope of the project itself.

If a project includes only the installation of perhaps a refrigeration system, B31.5 would apply. If a project's scope of work consists of an office, laboratory, research facility, institutional facility or any combination thereof, B31.1 or B31.9 and possibly B31.5 would apply. A laboratory or research facility could possibly require fluid services beyond the fluid service limits of B31.9. In that case, B31.3 would be adopted for those services.

In the case of a process manufacturing facility, B31.3 would be the governing Code. Since B31.3 covers all piping, B31.5 or B31.9 would not need to be included, not even necessarily with associated lab, office and research facilities. The only time B31.5 or B31.9 would become governing Codes, in association with a manufacturing facility, is if a refrigeration unit, or an office, lab and/or research facility were under a separate design/construct contract from the process manufacturing facility. Or they were a substantial part of the overall project.

As an example, project XYZ consists of a process manufacturing facility, related office building and lab facilities. If the utility service piping for the office and lab facilities is a small percentage of the overall project, and/or the design and construction contracts for those facilities are a part of the overall process manufacturing facility, all piping, with Code exclusions, could be governed by B31.3.

If, however, the office and lab facilities were a substantial part of the overall project, or they were to go to a separate constructor it may be more beneficial to determine battery limits for those facilities and designate anything inside those battery limits as B31.1 or B31.9 and/or B31.5. In such a case, separate pipe specifications may have to be issued for those portions of the project designated as being governed by B31.9. This is due to the range of fluid services and the corresponding pressure and temperature limits of B31.9 compared to those of B31.3. These differences in Code assignment and battery limits may be a driver for the project's contracting strategy.

Many piping service requirements such as steam, air, chilled water, etc. can come under the auspices of multiple Codes. These fluid services, which fall within the definition of B31.3 Category D fluid services, can just as easily fall within the requirements of B31.1 or B31.9 as well. In an effort at maintaining a high degree of continuity in the process of making the determination of which Code to apply to a project, company guidelines should be well defined.

The final determination as to what constitutes a governing Code, within the purview of the above mentioned Codes, is left to the Owner and/or to the local governing jurisdiction. Engineering specs should clarify and reflect the intent of the Owner and the respective Codes in an attempt to provide consistency and direction across all projects within a company.

PIPING DESIGN

Piping design is the job of configuring the physical aspects of pipe and components in an effort to conform with P&ID's, fluid service requirements, associated material specifications, equipment data sheets, and current Good Manufacturing Practice while meeting Owner expectations. All of this has to be done within a pre-determined three-dimensional assigned space while coordinating that activity with that of the architecture, structural steel, HVAC, electrical, video, data & security conduit and trays, and operational requirements.

Pulling together and coordinating the above mentioned discipline activities to achieve such a compilation of design requires a systematic methodology, planning, technical ability, coordination, foresight, and above all experience.

A note of omission here: CAD (Computer Aided Design) is such an integral part of piping design that it's difficult, if not impossible, to discuss design without including CAD in the discussion. It plays such a large part that, rather than enter into it here, I will dedicate an entire article to it at a later date. That article will discuss the integration of CAD into the industry including its merits, and how, in many respects, its method of implementation and integration has inversely diminished the quality of design with respect to industrial piping. The article will also discuss industry's reaction to this unexpected result, and the issues we are still dealing with today in the use of CAD.

PIPING SPECIFICATIONS

One of the first activities the piping engineer will be involved with is development of piping specifications, design guidelines and construction guidelines. 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. These documents also become contractual to the project and those contractors that work under them.

Design 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. That is, 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 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 what standard that component is manufactured to. Also included in the component description should be pressure rating, end connection type and surface finish where required.

There are a few rather consistent mistakes that companies make in developing or maintaining specs: 1. within the spec itself they are either not definitive enough or they are too definitive; 2. they are not updated in a timely manner; and/or 3. The specs are too broad in their content.

In defining the above issues we'll begin with:

Point #1: When defining pipe and components in a specification you should provide enough information to identify each component without hamstringing yourself or procurement in the process. What I mean by that is, do not get so specific or proprietary with the specification that only one manufacturer is qualified to provide the component, unless you intend to do just that. With standard pipe and fittings it's difficult to provide too much information. However, with valves and other inline equipment it can happen quite easily.

A common practice of spec writers 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 buy 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, in doing this, it would eliminate multiple bids for the valve based on the unintentional proprietary requirements in the spec. In actuality 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 actually the clarification, then goes back to the engineer and/or the Owner. The time necessary in 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. As an 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, etc. Each of these has specific formulations, which gives them different fluid service compatibility and pressure/ 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.

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 material 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.

In saying "almost" above what I meant by that is, 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. That would be a Viton GF. Or an FKM suitable for colder temperatures may be a better choice. That would be a Viton GFLT. Be specific for those that have to use the specs to design from and those that have to purchase the 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. Industry standards change, part numbers change, manufacturers are bought and sold; manufacturers improve their products, etc. All of these things constitute the need and necessity to review and revise specifications on a timely basis.

A company that houses their own set of specifications should review those specifications at least every two years. This timing works out for a couple reasons: 1. industry standards, on average, publish every two years, and 2. 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 being 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/Temperature limit of the spec
2. Limiting factor for Pressure/Temperature
3. Pipe material
4. Fitting type, rating and material
5. Flange type, rating and material
6. Gasket type, rating and material
7. Bolt & nut type and material
8. Manual valves grouped by type
9. Notes
10. Branch chart matrix with corrosion allowance

The ten line items above provide the primary component information and notations required for a typical piping system. Some specifications are written to include such components as steam traps, sight glasses, 3-way or 4-way valves, strainers, and other miscellaneous type items. Those miscellaneous items are better referred to as specialty items (or some other similar descriptive name) and are sized and specified for each particular application. This does not make them a good candidate 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 application the load requirements for each trap may vary.

As an example, a steam trap application at a drip leg will have a light steady load, whereas a steam trap application at a shell & tube heat exchanger may have a heavier modulating load. And that doesn't take into account the need for the different types of traps, e.g. F&T, inverted bucket, thermodynamic, etc.

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 that 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. Those 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. In attempting to include the specialty type items it will, at the very least, complicate and exacerbate the process.

DESIGN AND CONSTRUCTION GUIDELINES

Design and construction guidelines, working in conjunction with the piping specifications, 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 facilities 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 it helps facilitate the understanding and convey the magnitude of the, in most cases, reams of specifications and guidelines necessary to build an industrial facility of any appreciable size.

A narrative, in general, should explain in simple, straight-forward 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:

1. In scenario 1 the Owner, or Customer, has developed, throughout their existence, 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.
2. 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.
3. 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, making the assumption that both the engineer and constructor are qualified for the level of work required, they 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 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. It 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 it is the Owner expects of them in executing the design and construction of a facility. By actively and methodically developing a set of guidelines an Owner/Customer does not have to rely on an outside resource, such as an engineering firm or constructor, to hopefully provide them with the facility they require and hope to get.

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

Design Elements

In the first paragraph of this segment of the article, "Piping Design", I described the act of designing piping systems for a facility as bringing a number of technical components together to make the pipe 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 knowledge required is not taught through formal education, but is instead learned by being involved in the process of hands-on design over a period of time accompanied by ongoing learning.

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

Since we do not have enough space here to cover all of the design elements I would like to, I will key in on a few topics that generally find their way to me 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/MADP, design pressure/temperature, and charge accumulation.

Flanges

In the learning process, some designers (I include engineers as well) will gloss over some of the primary basics of design and go directly to the bottom line information they need. Case in point: In Part I, of this series of articles, we discussed ASME flanges and their Classifications. Most designers are familiar with ASME flange Classifications such as 150, 300, 400, etc. And even though verbally stating 150 pound flange (we discussed the origin of this term in Part I) rolls off the tongue much easier and is still an industry accepted term; Class 150 is the proper terminology and designation.

What you may not know is that the Class designation is a factor in the calculation for determining the rated working pressure of a flange. That calculation is:

$$P_T = P_r S_1 / 8750 \leq P_c \qquad \text{(eq. 1)}$$

Where:

P_c = ceiling pressure, psig, as specified in ASME B16.5, para. D3 at temperature T

P_T = Rated working pressure, psig,for the specified material at temperature T

P_r = Pressure rating class index, psi[1] (e.g., P_r = 300 psi for Class 300)

S_1 = Selected stress, psi, for the specified material at temperature T. See ASME B16.5, paras. D2.2, D2.3 and D2.4.

[1] This definition of P_r does not apply to Class 150. See ASME B16.5, paras. 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 semiconductor industries, but can also be an issue in the chemical industry.

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 industries.

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 as it relates to the industries mentioned above. Those issues are: 1. Cleanability/Drainability, 2. The ability to hinder the growth (we don't yet have the ability to control it) 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 this context. Meaning that, 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 hold-up, a contaminant, from both a bacterial standpoint and as a cross batch contaminant, it can also be costly due to the high cost of some drug products. Along those 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 (Fig. 1) is defined as a bacterial population composed of cells which are firmly attached as microcolonies to a solid surface.

A paper titled, "Microbial Biofilms – are they a problem in the Pharmaceutical Industry?", was delivered at an ASME-BPE symposium in Cork, Ireland, June 2004 by Frank Riedewald, a Senior Process Engineer with Lockwood-Greene IDC Ltd. In it he explains the results of testing that was performed to determine the relative association between the formation of biofilm, pipe wall surface finish and pipe wall surface cleanability.

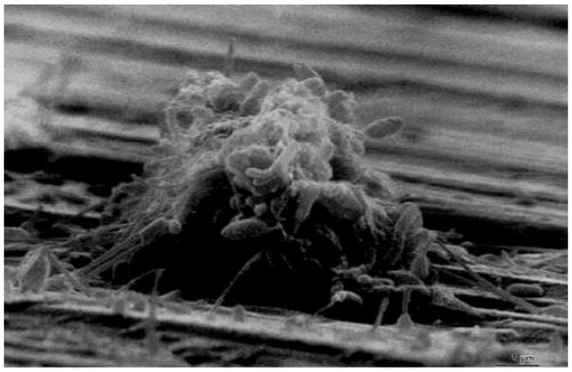

Fig. 1 – Biofilm magnified ≈2000X
(*Courtesy of Mr. Riedewald*)

One of the many interesting factors that came from the studies mentioned in this paper is the fact that the internal surface of the pipe wall can actually be too smooth. Referring to the graph in Fig. 2, results of the studies in the above mentioned paper indicate that the surface finish range best suited to reduce biofilm adherence to the internal pipe wall surface is from 0.4R_a μm to 1.R_a μm (15.7R_a μin to 58.8R_a 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 max surface finish in the pharmaceutical and bio-pharmaceutical industries is 25R_a μin (0.6 μm). In the semiconductor industry you might typically see surface finishes in the 7R_a μin to 15R_a 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.

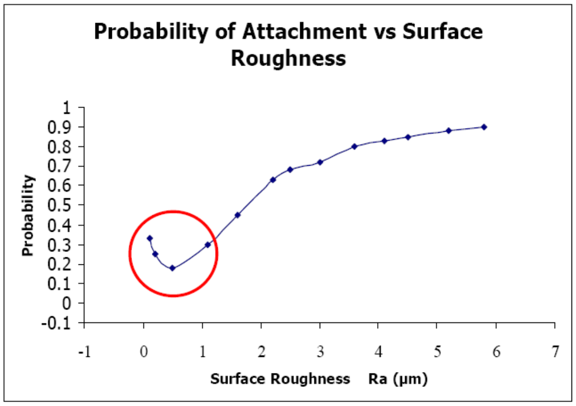

Fig. 2 – Biofilm Attachment vs Surface Roughness
(*Courtesy of Mr. Riedewald*)

Pipe Weld Seam Factor

Part I, 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 pipe wall thicknesses to calculate for. One is pressure design thickness (t) and the other is minimum required thickness (t_m).

There are two equations for finding pressure design thickness (t) for straight pipe under internal pressure. One is where $t < D/6$. This calculation (eq. 2) is based on internal pressure, 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].

The other calculation used is that in which $t \geq D/6$. This calculation (eq. 3) is based on the above listed criteria except for the OD and uses instead ID of the pipe, and the sum of all mechanical allowances.

The two equations look like this:

Where $t < D/6$:

$$t = \frac{PD}{2(SE + PY)} \qquad \text{(eq. 2)}$$

Where $t \geq D/6$:

$$t = \frac{P(d + 2c)}{2[SE - P(1 - Y)]} \qquad \text{(eq. 3)}$$

Where:

t	=	Pressure design thickness
t_m	=	Minimum required thickness, including mechanical, corrosion, and erosion allowances
c	=	Sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.02 in. (0.5 mm) in addition to the specified depth of the cut.
D	=	Actual pipe OD
d	=	Pipe ID
P	=	Internal design gage pressure
S	=	Stress value for material from ASME B31.3 Table A-1, at design temperature
E	=	Quality factor, or joint efficiency factor
Y	=	Coefficient from ASME B31.3 Table 304.1.1, valid for $t < D/6$.

The minimum required thickness (t_m) is simple enough:

$$t_m = t + c \qquad \text{(eq. 4)}$$

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, Para. 304.1.3.

Keep in mind that for seamless pipe E will be removed from equations eq. 2 & eq. 3.

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 vessel engineers will design to. The material, material thickness, welds, nozzles, flanges, etc. 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, etc. 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, etc. 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, which may exceed the design pressure; 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 Maximum Allowable Design Pressure (MADP).

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

The Barlow formula;

$$P_{BA} = \frac{2 \times T_F \times S_T}{D} \qquad \text{(eq. 5)}$$

The Boardman formula:

$$P_{BO} = \frac{2 \times T_F \times S_T}{D - (0.8 \times T)} \qquad \text{(eq. 6)}$$

The Lame` formula:

$$P_L = \frac{S_T \times (D^2 - d^2)}{(D^2 + d^2)} \qquad \text{(eq. 7)}$$

Where:

P_{BA}	=	Burst Pressure, psig (Barlow Formula)
P_{BO}	=	Burst Pressure, psig (Boardman Formula)
P_L	=	Burst Pressure, psig (Lame` Formula)
D	=	Actual pipe OD, inches
d	=	Pipe ID, inches
T_F	=	Wall thickness, inches, minus factory tolerance
S_T	=	Minimum tensile strength, psi, from

B31.3 Table A-1

S_f = Safety factor, a factor of 3 or 4 is applied to burst pressure to determine MADP

M = Maximum Allowable Design Pressure (MADP)

Using the results from any one of the above equations we can then solve for MADP as follows:

$$M = \frac{P_{**}}{S_f} \qquad \text{(eq. 8)}$$

** = *BA*, *BO*, or *L* subscript

Design Pressure and 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.*

It 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. What we did earlier in determining pipe wall thickness was based on design conditions, in which P = Internal Design Gage pressure and S = Stress value at design temperature. Design conditions are also used to determine component rating and as a basis for determining leak test pressure, which we will get into in the final article of this series.

There is no published standard, or real 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.

In understanding what constitutes design conditions we first of all need to define them. Following is some accepted terminology and their definitions:

System Operating Pressure: *The pressure at which a fluid service is expected to normally operate at.*

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 at.*

System Design Temperature: *Unless extenuating process conditions dictate otherwise, the design temperature, for operating temperatures between 32°F and 750°F, 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 straight forward for utility services such as steam, water, non-reactive chemicals, etc. 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, etc.

Charge Accumulation of Lined Pipe

Clarification

Internal and external charge accumulation, known as static electricity, or more technically known, as triboelectric charge accumulation, is the result of charge generation 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, 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).

External Charge Accumulation

ECA 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.

To explain the loss of spool-to-spool continuity: this lack of integral continuity is, as mentioned above, the result of the prime paint coat that is applied by the manufacture. When pipe spools, lined or un-lined, 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 generation resulting from an internal or an 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 in doing this (Electrostatic Discharge).

Internal Charge Accumulation

ICA, with regard to pipe, 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, used as a pipe liner, has a high ($>10^{16}$ Ohms/Square), resistivity factor. This is a relatively high resistance to conductivity. This means that any charge created internally to 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" of PTFE liner 450 volts of triboelectric charge will be required to penetrate the liner. For a 2" pipeline with a 0.130" thick liner this translates into 58500 volts of triboelectric charge to burn through the liner thickness.

When the liner is penetrated by an accumulated charge two additional problems (time bombs) are created: 1. Corrosive fluid (a major user 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 causing fluid to leak to the environment, and 2. The initial charge that burned through the liner is now charging the outer metal pipe, which, if continuity has not been achieved for the outer pipe, a spark of triboelectric charge is, at some point, going to jump to ground causing a spark.

Corrective Action

External Charge Generation

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 prime 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 Fig. 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.

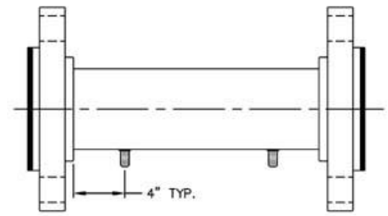

Figure 3 – Grounding Lug Location

Another method of creating continuity at flange joints, while being less obtrusive and more integral, is described as follows and represented in Fig. 4:

Referring to Fig. 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 will need to be centered between boltholes so that they line up after the flange bolts are installed. The tapped hole is 1/4" dia. x 1/2" deep.

After a flange set is installed and fully bolted the Continuity Plate (Fig. 4) can be installed using two 1/4" x1/2" long hex head screws and two lock washers. The Continuity Plate has two 0.312" 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.

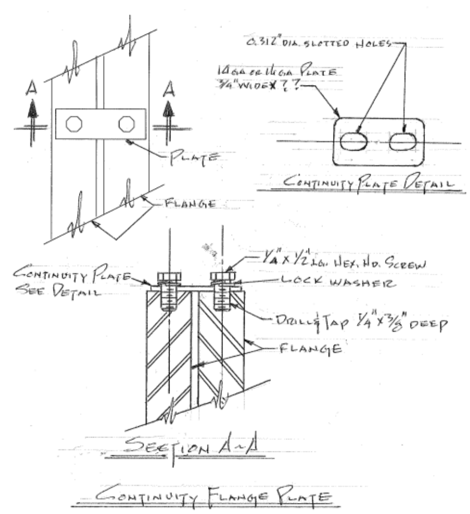

Figure 4 – Continuity Flange Plate

Internal Charge Generation

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 this 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 following as represented in Table 1 per BS 5958:

TABLE 1 - RECOMMENDED VELOCITIES

Liquid Conductivity	BS 5958 Recommended Flow Velocity
>1000 pS/m	No restriction
50 – 1000 pS/m	Less than 7 m/s
Less than 50 pS/m	Less than 1 m/s

pS/m (picosiemens/meter)

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 Internal Charge Generation might be called for.

One method for conducting charge accumulation from the interior of the pipe to ground is indicated in Figures 5 & 6. 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 it 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 providing 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.

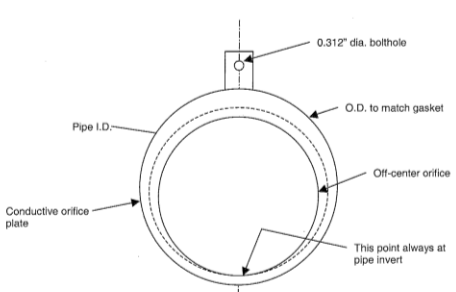

Figure 5 – Conductive Orifice Plate Assembly

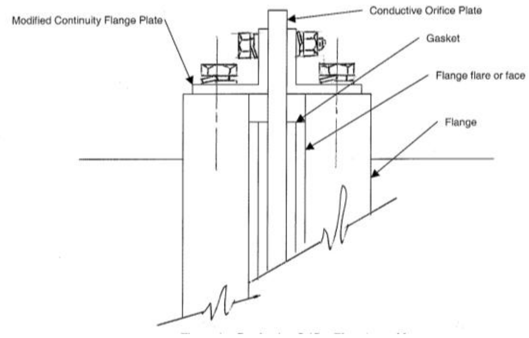

Figure 6 – Conductivity Orifice Plate Assembly Section

Conclusion and 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 to that 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 External Charge Accumulation, 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 un-primed pipe would be primed prior to installation with care given to primer touchup on flanges after installation by the installing contractor or their sub. 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 internal charge generation the orifice plate, as shown in Figures 5 & 6, is the only recommendation.

PIPE FABRICATION

Entering this part of the article on fabrication does not mean that we leave engineering behind. Indeed, the majority, if not all, fabricators (referring to the fabricators that are qualified for heavy industrial work) will have an engineering staff.

As a project moves from the design phase into the construction phase anyone with a modicum of project experience can acknowledge the fact that there will most certainly be conflicts, errors and omissions, no matter how diligent one thinks they are during design. This is inherent in the methodology of today's design/engineering process. There are methods and approaches to design in which this expected result can be minimized. It's actually a retrospective concept, but we will save that for a future article.

The preparation for such errors and omissions is always prudent. If, on the other hand, the assumption is made that the Issued for Construction design drawings will facilitate fabrication and installation with minimal problems, then you can expect to compound whatever problems do occur because you weren't prepared to handle them. The greatest asset a project manager can have is the ability to learn from past experience and the talent to put into practice what they have learned.

Fabrication

Pipe fabrication, in this context, is the construction of piping systems by forming and assembling pipe and components with the use of flanged, threaded, clamped, grooved, crimped and welded joints.

In Article I we discussed the flange joint, we will discuss the others here. There are various factors, or considerations, that prompt the decision as to which type of connection to use in the assembly of a piping system. To start with, any mechanical joint is considered a potential leak point and should be minimized. Also, the decision as to which type of joint should be specified comes down to accessibility requirements, installation requirements and joint integrity. Using that as our premise we can continue to discuss the various joining methods.

Threaded Joints

Pipe thread, designated as NPT (National Pipe Taper) under ASME B1.20.1, is the type of thread used in joining pipe. This is a tapered thread that, with sealant, allows the threads to form a leak-tight seal by jamming them together as the joint is tightened.

I described the threaded flange joint in Article I. Those same criteria apply also to threaded fittings, in which the benefits of the threaded joint is both in cost savings and in eliminating the need for welding. In this regard, to paraphrase Article I, threaded components are sometimes used in high-pressure service in which the operating temperature is ambient. They are not suitable where high temperatures, cyclic conditions or bending stresses can be potential concerns.

Hygienic Clamp Joint

The clamped joint, as mentioned in Article I, refers to the sanitary or hygienic clamp. As you can see in Fig. 7 there are issues with this type clamp.

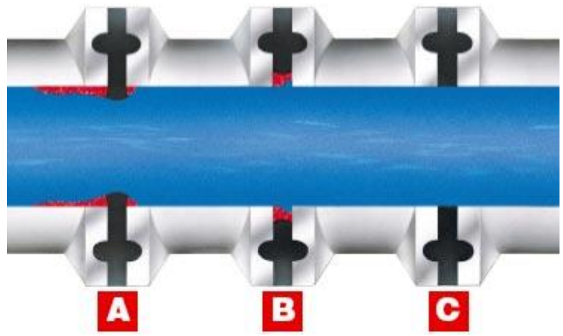

Figure 7 – Hygienic Clamp Joint
(*Courtesy Rubber Fab Technologies Group*)

Represented in Fig. 7 are three installed conditions of the hygienic joint, minus the clamp. Joint 'A' represents a clamp connection that has been over tightened causing the gasket to intrude into the ID of the tubing. This creates a damming effect, preventing the system from completely draining.

In joint 'B' the clamp wasn't tightened enough and left a recess at the gasket area. This creates a pocket where residue can accumulate and cleanability becomes an issue.

Joint 'C' represents a joint in which the proper torque was applied to the clamp leaving the ID of the gasket flush with the ID of the tubing.

The clamp 'C' representation is the result that we want to achieve with the hygienic clamp. The problem is that this is very difficult to control on a repeatable basis. Even when the gasket and ferrules are initially lined up with proper assembly and torque on the joint, some gasket materials have a tendency to creep (creep relaxation), or cold flow.

Creep relaxation is defined as: *A transient stress-strain condition in which strain increases concurrently with the decay of stress. More simply put, it is the loss of tightness in a gasket, measurable by torque loss.*

Cold Flow is defined as: *Permanent and continual deformation of a material that occurs as a result of prolonged compression or extension at or near room temperature.*

There have been a number of both gasket and fitting manufacturers that have been investing a great deal of research in attempting to resolve this issue with the clamp joint. Some of the solutions regarding fittings were addressed in Article I. Additionally, gasket manufacturers, and others have been working on acceptable gasket materials that have reduced creep relaxation factors, as well as compression controlled gasket designs.

When mentioning acceptable gasket material in the previous paragraph, what I am referring to is a gasket that is not only compatible with the hygienic fluid service, but also meets certain FDA requirements. Those requirements include Gasket material that complies with USP Biological Reactivity Test #87 & 88 Class VI for Plastics and FDA CFR Title 21 Part 177.

Grooved Joint

The grooved joint (Fig. 8), from simply a static internal pressure containment standpoint, is as good as or, in some cases superior to the ASME Class 150 flange joint. In the smaller sizes, 1” through 4” the working pressure limit will be equal to that of a Class 300, carbon steel, ASTM A105, ASME B16.5 flange.

Its main weakness is in its allowable bending and torsional stress at the coupling. This can be alleviated with proper support. Because of this design characteristic the manufacturers of grooved joint systems have focused their efforts and created a niche in the fire protection and utility fluid service requirements, with the exception of steam and steam condensate.

This type of joint is comparatively easy to install and enhances that fact in areas that would require a fire card for welding. Since no welding is required modifications can be made while operation continues. Some contractors choose to couple at every joint and fitting, while others choose to selectively locate couplings, much as you would selective locate a flange joint in a system. It’s a decision that should be made based on the particular requirements or preference of a project or facility.

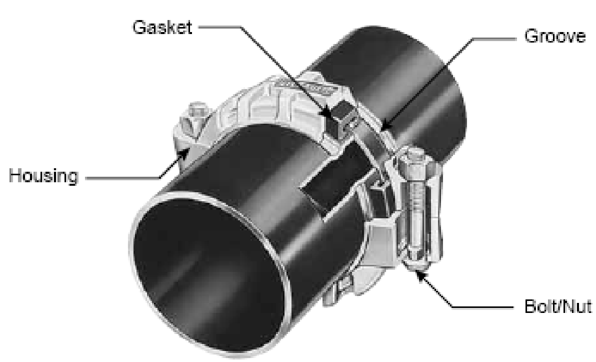

Figure 8 – Grooved Pipe & Coupling
(*Courtesy Victaulic*)

Pressed Joint

The pressed joint is actually a system that uses thin wall pipe, up through 2” NPT, to enable the joining of pipe and fittings with the use of a compression tool. Welding is not required and threading is only necessary when required for instrument or equipment connection.

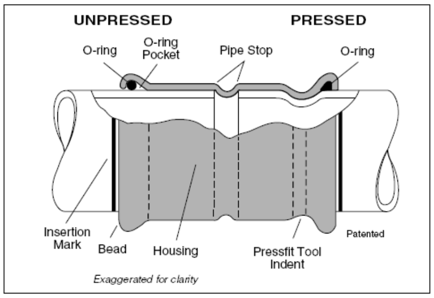

Figure 9 – Pressed Joint
(*Courtesy Victaulic*)

These types of systems are available from various manufacturers in carbon steel, 316 and 304 stainless steel and copper. Because of the thin wall pipe corrosion allowance becomes a big consideration with carbon steel.

While the static internal pressure rating of these systems is comparable to an ASME Class 150 flange joint there are additional fluid service and installation characteristics that need to be considered. With axial and torsional loading being the weak spot in these systems they are not practical where water hammer is a potential, such as in steam condensate. The axial load consideration carries over to supporting the pipe as well. Ensure that vertical runs of this pipe are supported properly from beneath. Do not allow joints in vertical runs to be under tension. They must be supported properly from the base of the vertical run.

Welded Joint

The welded joint is by far the most integrated and secure joint you can have. When done properly it is as strong as the pipe itself. The key to a weld’s integrity lies in the craftsmanship of the welder or welding operator, the performance qualification of the welder or welding operator, and the weld procedure specification.

Before I go further I want to explain the difference between the terms welder and welding operator. A welder is, as you might have guessed, someone who welds. To be more precise, it is someone who welds by hand, or manually. A welding operator is someone who operates an automatic welding machine. The ends of the pipe still have to be prepared and aligned, and the automatic welding machine has to be programmed.

The advantage of machine welding is apparent in doing production welds. This is shop welding in which there is a quantity of welds to be made on the same material type, wall thickness and nominal pipe size. Once the machine is set up for a run of typical pipe like this it is very efficient and consistent in its weld quality.

This is another topic that could easily stand alone as an article, but we won't do that here. Instead we will focus on some of the primary types of welding used with pipe. Those types include:

1. GMAW (Gas Metal Arc Welding) or MIG
2. GTAW (Gas Tungsten Arc Welding) or TIG
3. SMAW (Shielded Metal Arc Welding) or MMA or Stick Welding
4. FCAW (Flux Cored Automatic welding)

GMAW: Most often referred to as MIG, Metal Inert Gas welding, GMAW (Gas Metal Arc Welding) can be an automatic or semi-automatic welding process. It is a process by which a shielding gas and a continuous, consumable wire electrode is fed through the same gun (Fig. 10). The shielding gas is an inert or semi-inert gas such as argon or CO_2 that protects the weld area from atmospheric gases, which can detrimentally affect the weld area.

There are four commonly used methods of metal transfer used in GMAW. They are:

1. globular,
2. short-circuiting,
3. spray, and
4. pulsed-spray

With the use of a shielding gas the GMAW process is better used indoors or in an area protected from the wind. If the shielding gas is disturbed the weld area can be affected.

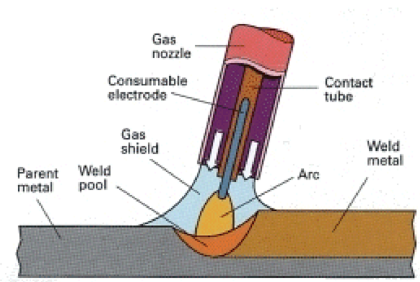

Figure 10 – GMAW (MIG) Welding
(*Courtesy The Welding Institute*)

GTAW: Most often referred to as TIG, Tungsten Inert Gas welding, GTAW (Gas Tungsten Arc Welding) can be automatic or manual. It uses a nonconsumable tungsten electrode to make the weld (Fig. 11), which can be done with filler metal or without filler metal (autogenous). The TIG process is more exacting, but is more complex and slower than MIG welding.

In Article 1 I mentioned the use of orbital welding for hygienic tube welding. Orbital welding uses the GTAW method. Once the orbital welder is programmed for the material it is welding it will provide excellent welds on a consistent basis. Provided, that is, that the chemistry of the base material is within allowable ranges.

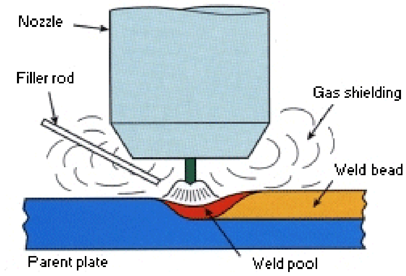

Figure 11 – GTAW (TIG) Welding
(*Courtesy The Welding Institute*)

A wide differential in sulfur content between the two components being joined can cause the weld to drift into the high sulfur side. This can cause welds to be rejected due to lack of full penetration.

SMAW: Also referred to as MMA, Manual Metal Arc welding, or just simply Stick welding, SMAW (Shielded Metal Arc Welding) is the most common form of welding used. It is a manual form of welding that uses a consumable electrode, which is coated with a flux (Fig. 12). As the weld is being made the flux breaks down to form a shielding gas that protects the weld from the atmosphere.

The SMAW welding process is versatile and simple, which allows it to be the most common weld done today.

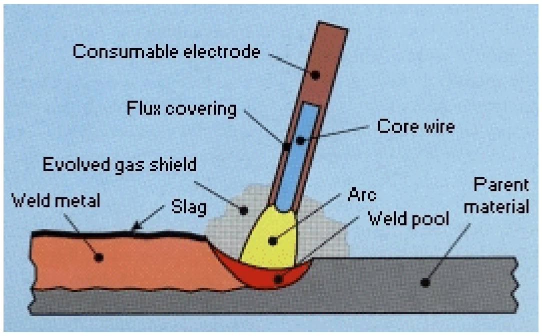

Figure 12 – SMAW (Stick) Welding
(*Courtesy The Welding Institute*)

FCAW: Flux Cored Arc Welding is a semiautomatic or automatic welding process. It is similar to MIG welding, but the continuously fed consumable wire has a flux core. The flux provides the shielding gas that protects the weld area from the atmosphere during welding.

Welding Pipe

The majority of welds you will see in pipe fabrication will be full penetration circumferential buttwelds, fillet welds or a combination of the two. The circumferential buttwelds are the welds used to weld two pipe ends together or other components with buttweld ends. Fillet welds are used at socketweld joints and at slip-on flanges. Welds in which a combination of the buttweld and fillet weld would be used would be at a stub-in joint or a joint similar to that.

A stub-in joint (not to be confused with a stub-end) is a connection in which the end of a pipe is welded to the longitudinal run of another pipe (Fig. 13). Depending on what the design conditions are this can be a reinforced connection or an unreinforced connection. The branch connection can be at 90º or less from the longitudinal pipe run.

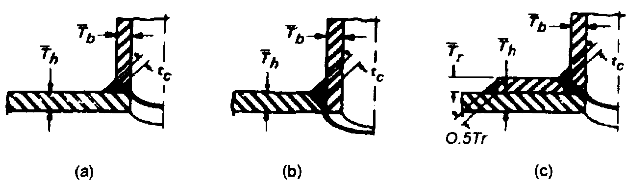

Figure 13 – Sample Stub-In Connections
(*Courtesy ASME B31.3*)

Hygienic Fabrication and Documentation

Hygienic and semiconductor pipe fabrication uses automatic autogenous welding in the form of orbital welding. This, as explained in Article I, is a weld without the use of filler metal. It uses the orbital welding TIG process. In some cases hand welding is required, but this is kept to a minimum, and will generally require pre-approval.

When fabricating pipe for hygienic services it will be necessary to comply with, not only a specific method of welding, but also an extensive amount of documentation. As mentioned in Article I, developing and maintaining the required documentation for hygienic pipe fabrication and installation can add an additional 30% to 40% to the piping cost of a project.

The documentation needed, from the fabrication effort for validation, may include, but is not limited to:

1. Incoming Material Examination Reports
2. Material Certification
    a. MTR's
    b. Certification of Compliance
3. Weld Gas Certification
4. Signature Logs
5. WPQ's (Welder & Welding Operator Performance Qualification)
6. Welder & Welding Operator Inspection Summary
7. Mechanical and electropolishing procedures
8. Examiner Qualification
9. Inspector Qualification
10. Welder Qualification Summary
11. Gage Calibration certifications
12. Weld Continuity Report
13. WPS's (Weld Procedure Specifications)
14. PQR's (Procedure qualification Record)
15. Weld Coupon log
16. Weld Maps
17. Slope Maps
18. Weld Logs
19. Leak Test Reports
20. Inspection reports
21. Passivation Records
22. Detail mechanical layouts
23. technical specifications for components
24. As-Built Isometrics
25. Original IFC isometrics
26. Documentation recording any changes from IFC to As-Build isometrics

The above listed documentation, which closely parallels the list in ASME-BPE, is that which is generally required to move an installed hygienic system through validation, commissioning and qualification (C & Q). And this isn't all that's required. There is additional supporting documentation such as P&ID's, procedural documents, etc. that are also required. Depending on the size and type of a project it can be a massive undertaking. If not properly set up and orchestrated it can become a logistical nightmare.

What you do not want to do is discover during C&Q that you are missing a portion of the required documentation. Resurrecting this information is labor intensive and can delay a project's turn-over significantly. I cannot stress it strongly enough just how imperative it is that all necessary documentation be identified up front. It needs to be procured throughout the process and assimilated in a turnover package in a manner that makes it relatively easy to locate needed information while also allowing the information to be cross indexed and traceable within the TO package.

The term validation is a broad, generalized, self-defining term that includes the act of commissioning and qualification. Commissioning and qualification, while they go hand in hand, are two activities that are essentially distinct within themselves.

For this article I will go no further with the topic of Validation, Commissioning and Qualification. This is a topic that I will touch on again in Article III.

Future Articles

The third and final article in this series, titled "Piping Design Part III – Installation, Cleaning, Testing and Verification", will wrap up the series by discussing the four title points.

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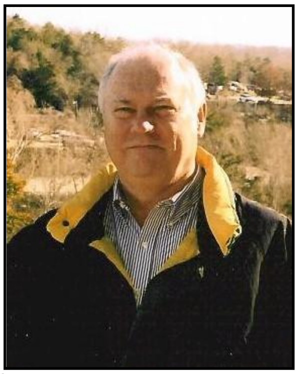

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