Besides flanges, there are also several different types of joints and welding processes to choose from. Additional decisions involve piping codes

PIPING CODE

Codes and standards

The query, “Why do we, as a company, need to comply with a piping code?” is actually a trick question. Code, by definition is law with statutory force. Therefore the reason for complying with a code is because you literally have to, or else be penalized for non-compliance.

A better question would be, “Why comply with or adopt a piping consensus standard?” When phrased this way, the question supports the author’s contention that many engineers and designers 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. The difference between a standard and a code will be explained shortly, but first let’s respond to the first question.

Why comply?

Consensus standards such as those published by ASME (American Soc. of Mechanical Engineering), ANSI (American National Standards Inst.), API (American Petroleum Inst.), NFPA (National Fire Protection Assn.), ASTM (American Soc. for Testing and Materials), 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.

Compliance with these codes, irrespective of government regulations or corporate requirements, doesn’t cost the builder any more than if it didn’t comply. It does, however, cost more to fabricate and install piping systems that have a high degree of integrity as opposed to systems that don’t.

Hiring non-certified welders and plumbers, bypassing 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 initially, 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.

If anyone intends on fabricating and installing a piping system plans to perform any of the following points, then they are essentially complying with code:

- Use listed material
- Specify material that meets the requirements for fluid service, pressure and temperature
- Inspect the material for MOC (material of construction), size and rating
- Use certified welders and plumbers
- Inspect welds and brazing
- Adequately support the pipe
- Test the pipe for tightness

The code simply explains how to do each of these activities in a formal, well thought-out manner.

There is not a reason sufficiently good enough to not 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 to ignore them. Even with utility systems in an administration 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 codes. 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.

Finally, it is worth taking a historical aside to make a point. ASME published the first edition of the Boiler and Pressure Vessel Code in 1914-1915. Prior to creation of the code, 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.

Which code to follow?
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 it can adopt the code 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 U.S. boiler or pressure vessel manufacturer to bypass code compliance. That is, unless you wanted to pay their potential attorneys' fees.

With regard to code compliance, the question often asked 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 and at the same time comes with 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

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Association (ASA). 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 these 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. 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 to 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 sheer 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 laboratory, office and research facilities. The only time B31.5 or B31.9 would become governing codes, in as-
I just as easily fall within the require-
vices and the corresponding pressure
which fall within the definition of
This is due to the
continuity in the process of
so on, can come under the auspices of
B31.3. These differ-
ences in code assignment and battery
limits as B31.1 or
B31.5. In such a case, separate pipe
specifications may have to be issued
and/or
B31.9 Category D fluid services, can
go to a separate constructor, it may
reflect the intent of the owner and the
respective codes in an attempt to pro-
vide consistency and direction across
all projects within a company.

**PIECE FABRICATION**

Entering this section on fabrication
does not mean that we leave engineer-
ing behind. Indeed, the majority, if not
all, fabricators (referring to the fabri-
cators that are qualified for heavy in-
dustrial work) will have an engineer-
ing staff.

As a project moves from the design
phase into the construction phase,
anyone with a modicum of project ex-
perience can acknowledge the fact that
there will most certainly be conflicts,
errors and omissions, no matter how
diligent one thinks he or she is during
design. This is inherent in the meth-
ology of today's design/engineering
process. Although there are methods
and approaches to design in which
this expected result can be minimized,
it is always prudent to be prepared for
such errors and omissions.

If, on the other hand, the assump-
tion is made that the Issued for Con-
sstruction design drawings will facil-
tate fabrication and installation with
minimal problems, then you can ex-
pect to compound whatever problems
do occur because you weren't prepared
to handle them. The greatest asset a
project manager can have is the abil-
ity to learn from past experience and
the talent to put into practice what he
or she has learned.

Pipe fabrication, in the context of
this article, is defined as the construc-
tion of piping systems by forming and
assembling pipe and components with
the use of flanged, threaded, clamped,
grooved, crimped and welded joints.

In Part 2 of this series, we dis-
cussed the flange joint; the others
will be discussed here. There are var-
iou factors, or considerations, that
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 jurisdic-
tion. Engineering specifi-
cations should clarify and
reflect the intent of the owner and the
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iou 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 pot-
tential leak point and should be mini-
mized. 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 vari-
ous joining methods.

**Threaded joint**

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.

The same criteria described (in Part
2) for the threaded flange joint 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,
threaded components are sometimes
used in high-pressure service in which
the operating temperature is ambient.
They are not suitable where high tem-
peratures, cyclic conditions or bending
stresses can be potential concerns.

**Hygienic clamp joint**

The clamped joint refers to the sanitary
or hygienic clamp (Figure 1). Three in-
stalled conditions of the hygienic joint,
minus the clamp are presented in Fig-
ure 1. Joint A represents a clamp con-
nection that has been over tightened
causing the gasket to intrude into the
inner diameter (ID) of the tubing. This
creates a damming effect, preventing
the system from completely draining.

In joint B, the clamp wasn't tight-
ened enough and left a recess at the
gasket area. This makes a pocket
where residue can accumulate, so
-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 gas-

---

**FIGURE 1. Problems can arise with a clamped joint if not properly installed.**

Over tightening the clamp can
cause the gasket to intrude into the tubing (A), whereas
under tightening results in pockets where residue can
accumulate (B). The ideal situation is joint C.
ket 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 Part 2 of this series. 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.

What is meant by acceptable gasket material is a gasket that is not only compatible with the hygienic fluid service, but also meets certain U.S. FDA (or comparable) 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 (Figure 2), from 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 to 4 in.), the working pressure limit will be equal to that of a Class 300, carbon-steel, ASTM A105, ASME B16.5 flange.

The main weakness of the grooved joint is the bending and torsional stress allowable at the coupling. This stress 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.

The grooved joint is comparatively easy to install, which is particularly important 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 selectively 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.

Pressed joint
The pressed joint (Figure 3) is actually a system that uses thin wall pipe, up through 2-in. 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.

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 spots in these systems, they are not practical where water hammer is a potential.
Welded joint

The welded joint is by far the most integrated and secure joint you can have. When done properly, a welded joint 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 going further, I want to explain the difference between the terms welder and welding operator. A welder 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 manually, 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 instead, here we will focus on some of the primary types of welding used with pipe. Those types include the following: GMAW (gas metal arc welding) or MIG (metal inert gas); GTAW (gas tungsten arc welding) or TIG (tungsten inert gas); SMAW (shielded metal arc welding) or MMA (manual metal arc) or stick welding; and FCAW (flux cored automatic welding).

**GMAW**: Often referred to as MIG welding, GMAW 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 (Figure 4a). The shielding gas is an inert or semi-inert gas such as argon or CO₂ 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:
- globular
- short-circuiting
- spray
- 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.

**GTAW**: Most often referred to as TIG welding, GTAW can be automatic or manual. It uses a nonconsumable tungsten electrode to make the weld (Figure 4b), which can be done with filler metal or without filler metal (autogenous). The TIG process is much more exacting, but also more complex and slower than MIG welding.

In Part 2 of this series, the use of orbital welding was mentioned 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.

A wide differential in sulfur content between the two components being welded joint is by far the most integrated and secure joint you can have. When done properly, a welded joint 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.

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A wide differential in sulfur content between the two components being
I Engineering Practice

FIGURE 4. Gas metal arc welding (GMAW; top) uses a shielding gas to protect the weld area from atmospheric gases. Gas tungsten arc welding (GTAW; center) is more exacting than GTAW, but also more complex and slower. Shielded metal arc welding (SMAW; bottom) is the most common form of welding. SMAW is performed manually, whereas GMAW and SMAW can be either performed manually or by an automated system.

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 welding, or just simply stick welding. SMAW 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 (Figure 4c). 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.

FCAW: Flux cored arc welding is a semi-automatic 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 butt welds, fillet welds or a combination of the two. The circumferential butt welds are the welds used to weld two pipe ends together or other components with butt weld ends. Fillet welds are used at socket weld joints and at slip-on flanges. Welds in which a combination of the butt weld and fillet weld would be used would be at a stub-in joint or a similar joint.

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 (Figure 5). Depending on what the design conditions are, this can be a reinforced connection or an unreinforced connection. The branch connection can be at 90 deg. or less from the longitudinal pipe run.

Hygienic fabrication
Hygienic and semiconductor pipe fabrication uses automatic autogenous welding in the form of orbital welding. This 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. 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. MTRs
   b. Certification of compliance
3. Weld-gas certification
4. Signature logs
5. WPQs (welder and welding operator performance qualification)
6. Welder and welding operator

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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. WPSs (weld procedure specifications)
14. PQs (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 IPC isometrics
26. Documentation recording any changes from IPC to as-built isometrics

The above listed documentation, which closely parallels the list in ASME-BPE, is what 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, and so on, which 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 turnover significantly. I cannot stress 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 (TO) 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.

Acknowledgement:
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