Piping Design Part 5: Installation and Cleaning

These practical guidelines for deciding which installation procedure to follow, and for cleaning a new pipeline system can prevent problems from happening during startup.

W. M. Huitt
W. M. Huitt Co.

This fifth in a series of articles [1-4] on piping design discusses the practical issues of installation and cleaning.

PIPE INSTALLATION
The installation of pipe follows its fabrication and is very frequently a part of it. The installation of pipe can be accomplished in the following four primary ways, or combinations thereof:
1. Field fabricate and install
2. Shop fabricate and field erected
3. Skid fabrication, assembly and installation
4. Modular construction

Field fabricate and install
In the first method, the pipe is fabricated onsite, either in place or in segments, at an onsite field-fabrication area and then erected. A number of factors will dictate whether or not it is feasible to field fabricate, including the following: the size and type of the project; pipe size and material; the facility itself; weather conditions; availability of qualified personnel; existing building operations; cleanliness requirements; and time available to do the work.

Efficiency, quality and safety are the imperatives that are factored in when considering field fabrication. And cost is the fallout of those factors. Logistically speaking, if all pipe could be fabricated onsite in a safe and efficient manner — maintaining quality while doing so — it would make sense to do it in that manner. However, before making that final decision, let’s look at some of the pros and cons of field fabrication:

Pros:
- Only raw material (pipe, fittings, valves and so on) need to be shipped to the site location. Such materials are much easier to handle and store than multi-plane configurations of pre-fabricated pipe
- No time-consuming need to carefully crib, tie-down and chock pre-fabricated spool pieces for transport to the job site
- Reduced risk of damage to spool pieces
- More efficient opportunity to fabricate around unexpected obstacles (structural steel, duct, cable tray, and so on)
- Fabricate-as-you-install reduces the rework risk assumed when pre-fabricating spools, or the cost related to field verification prior to shop fabrication
- The field-routing installation of pipe through an array of insufficiently documented locations of existing pipe and equipment, on a retrofit project, is frequently more effective than attempting to pre-fabricate pipe based on dimensional assumptions

Cons:
- Weather is arguably the biggest deterrent. If the facility under construction is not enclosed, then protection from the elements will have to be provided
- When welding has to be done in conditions that are not environmentally controlled, then pre-heating will be required if the ambient temperature (not the metal surface temperature) is 0°F or below
- In a new facility, as opposed to having to route piping through an array of poorly located existing pipe and equipment, field fabrication of buttwelded pipe is not as efficient and cost effective as shop fabrication
- There may be concerns about safety and efficiency when working in a facility while it is in operation in advance of a turnaround or to begin advance work on a plant expansion

Generally speaking, threaded, socket-weld, grooved, and other proprietary-type joints that do not require butt welding are field fabricated and installed. Buttwelding of small, 1 1/2-in. NPS and less, are very often field fabricated and installed because
of the added risk of damage during transport, in pre-fabricated form, from the shop to the site.

**Shop fabricate and install**

Shop fabrication refers to, generally speaking, any pipe, fittings and components that are assembled by welding into spool assemblies at the fabricator's facility. The spools are then labeled with an identifier and transported to the job site for installation.

Each spool piece needs its own identifier marked on the piece itself in some fashion that will make it easy to know where its destination is in the facility and where it belongs in a multi-spool system of pipe. This will allow the installer to efficiently stage the piece and ready it for installation.

As part of the process of developing spool sections, field-welded joints need to be designated. These are welded joints that connect the pre-fabricated spools. In doing this the designer or fabricator will identify two different types of field-welded joints: field weld (FW) and field closure weld (FCW).

FW indicates a joint in which the end of a pipe segment is prepared for the installer to set in place and weld to its connecting joint without additional modification in the field. This means that the length of pipe that is joined to another in the field is cut precisely to length and the end prepared in the shop for welding.

FCW provides the installer with an additional length of pipe, usually 4 to 6 in. longer than what is indicated on the design drawings, to allow for field adjustment.

What has to be considered, and what prompts the need for a FCW, is the actual, as-installed, location of both the fixed equipment that the pipe assemblies may connect to and the actual installed location of the pipe assembly itself. Odds are that all equipment and piping will not be installed exactly where indicated on design drawings.

The dimensional location of the equipment items given on design drawings is not a finite location, it is merely an intended location, as are dimensional locations on drawings for building steel, pipe supports and others. What factors into the installation of shop-fabricated pipe is the actual location of the equipment nozzle it will be connecting to in relation to the pipe's installed location.

In connecting to equipment there is a build-up, or stack-up, of tolerances that will effectively place the actual, or final, location of the nozzle at some point in three-dimensional space, other than where the design drawing indicates. The tolerance stack-up results from the following circumstances:

- Manufacturing tolerances in material forming, nozzle location, and vessel support location
- The actual set-in-place location of the vessel
- Load cell installation (when applicable)
- The actual set-in-place pipe run-up location

In order to allow for these inevitable deviations between the drawing dimensions used to fabricate the vessel, set the vessel and install the pipe assembly and the actual installed location of the connecting points, a field-closure piece, or two, will be required for that final adjustment.

The field-closure piece is a designated section of the pipe assembly in which a field-closure weld has been indicated.

**Skid (super skid) fabrication**

A skid is a pre-packaged assembly that may contain all or some of the following: vessels, rotating equipment, piping, automation components, HVAC, instrumentation, electrical wiring and connectors, framework, walls, architectural components, lighting, supports, inline piping components, and insulation. A single process or utility system may fit onto one skid or, depending on size restraints, may comprise multiple skids.

After fabrication of a skid is complete, it will typically go through factory-acceptance testing (FAT) at the fabricator’s facility. The skid is then shipped to the job site where it is installed in its final location. After installation it would typically go through a follow-up site-acceptance test (SAT), including additional hydrotesting. This is basically a system shake-down to determine that everything is intact, and that those things that did not remain intact during transport are discovered and repaired.

Logistics and the necessary skill set required for the installation, connection and startup of a particular skid package will dictate to what extent the skid fabricator will be involved after it is shipped to the job site.

**Modular construction**

The term module or modular construction is quite often, in this context, interchanged with the term skid fabrication. A module can refer to pre-fabricated units that actually form the structure of a facility as each is installed. Or, the units may be smaller sub-assemblies that, when combined, make up a complete process or utility system.

Modules also consist of all or some of the following: vessels, rotating equipment, piping, automation components, HVAC, instrumentation, electrical wiring and connectors, framework, walls, architectural components, lighting, supports, inline piping components, and insulation. This, as an example, allows a complete locker-room module to be placed and connected to a complete process or utility system.

The smaller sub-assembly modules, in many cases, are interchanged with the term skid. Misconception can be avoided when a company defines these terms, both for internal discussion and for the purpose of making it clear to outside contractors, as to what is meant when using the term module.

**Installation approach**

Now that we have a general idea of the four primary approaches to piping installations how do we decide which is the best method, or combination of methods, to use for a particular project? Each project is unique with its own particular set of decision drivers with regard to a selected execution approach. There are no hard and fast
rules for determining a best approach. It requires experienced personnel to assign values to the various aspects of project execution, overlay a timeline, and then assess logistics. It sounds simple, but in actuality can be a very complex process.

Therefore, the following is a guideline and not a hard and fast set of rules. There are simply too many project variables and complexities otherwise.

When considering an approach, keep in mind that the method of installation needs to be weighed against a contractor's preferred methodology. This does not imply that the contractor's preferred methodology should drive your decision on how to execute a job. On the contrary, once you determine how the job needs to be executed, then look to only those contractors whose preferred methodology agrees with your project execution plans.

Some contractors prefer to do most, if not all, fabrication in the shop, others prefer to set up at the job site, while others are flexible enough to utilize the best of both methods.

The three main criteria discussed above—efficiency, quality and safety—would apply here as well. Using these three elements as a basis for making a determination, let us look at some common variables.

Environment: The environment is only a factor when work has to be done in an open-air structure or other outdoor installation (such as tank farm, pipeline, pipe rack or yard piping). Working in an open-air structure will require protection from the elements (such as rain, snow, wind and cold). In addition, there may also be a requirement to work in elevated areas with the use of scaffolding. All of this can have a potential impact on safety and efficiency.

Pipe-rack installation consists mainly of straight runs of pipe, and will not necessarily have a requirement or need for pre-fabrication. That is, unless it is pre-fabricated as modular-skid units. Depending on the project, it could be cost effective on an overall strategic basis to modularize the pipe rack, steel and all.

The big advantage to shop fabrication is the controlled environment in which it’s done. This includes the quality control aspect, better equipment (generally speaking), a routine methodology of how a piece of work progresses through the shop, and better control, through a developed routine of required documentation.

Industry: The various sectors of the chemical process industries (CPI) can be grouped into two categories: clean/indoor build and non-clean/outdoor build. Realizing that there will be exceptions to this generalization, we can include in the clean/indoor built category: pharmaceutical, biopharmaceutical, semiconductor and food and dairy. Under non-clean/outdoor build we can include: petroleum refining; bulk chemicals; pulp and paper; oil and gas; and power generation.

The clean-build philosophy comes from the need to construct certain facilities with a more stringent control on construction debris. Those industries included in this category often require a facility—at least a portion of a facility—to be microbial and particulate free, as stipulated by the design.

There can be no debris, organic or inorganic, remaining after construction in accessible or inaccessible spaces of the facility. Of particular concern with pharmaceutical, biopharmaceutical, semiconductor and food and dairy facilities are food waste and hidden moisture. Food waste can entice and support rodents and insects, and hidden moisture can propagate mold, which can eventually become airborne. If these intruders are not discovered until the facility is in operation, the impact, upon discovery, can potentially be devastating to production.

Such contamination can be found in one of two ways. Discovery at the source, possibly behind a wall or some other out-of-the-way place, means that not only does current production have to cease, but product will have to be analyzed for possible contamination. Once found, it then has to be remediated.

The other method of discovery comes from the continuous testing and validation of the product stream. If a contaminant is discovered in the product, the production line is stopped, and the problem becomes an investigation into finding the source of the contamination.

The clean-build philosophy, therefore, dictates more stringent and strict requirements for controlling and inspecting for debris on an ongoing basis throughout construction and startup.

It will be necessary, on a clean-build site, to adhere to the following rather simple rules:
• Smoking or smokeless tobacco products of any kind are not allowed on the site property
• Provide for offsite break and lunch areas; no food or drink, other than water, are allowed on the site premises
• Do not begin installing pipe, duct or equipment until, at the very least, a roof is installed
• After roof and walls are installed, ensure that there is no standing water remaining in the facility
• Prior to and during the construction of hollow walls, such as those framed and dry-walled, ensure on a daily basis that there is no moisture or debris in the wall cavity
• Dust work delivered to the job site shall have the ends covered with a plastic sheet material, which shall remain on the ends until connected in place
• Fabricated pipe delivered to the job site shall have the ends covered in a suitable fashion with suitable material, and the cover shall remain on the ends until pipe is ready to be connected in place
• During and after flushing and testing of pipelines, all water spills shall be controlled to the extent possible and shall be cleaned after each flushing and testing or at the end of the workday

Type of project
While the type of project is not the main influence in determining how you approach the execution of a project, it does play a key role. It will help drive the decision as to how the piping should be fabricated and installed.

For example, if the project is a retrofit, it will require much of the pipe, regardless of size and joint connection, to be field fabricated and installed. This is due simply to the fact that the effort and cost necessary to verify the location of all existing pipe, equipment, walls, columns, duct and
so on, in a somewhat precise manner, would not be very practical. You would be better served by field verifying the approximate location of the above items with existing drawings, for planning and logistic purposes, then shop or field fabricate, verify and install as you go.

A fast track project, one that has a compressed schedule, will require parallel activities where possible. Shop and skid fabrication would be utilized as much as possible simply to expedite more man-hours over a shorter time period while attempting to maintain efficiency, even though there may be added cost to this approach. This approach is time driven and not budgetary driven.

A new grassroots facility still requires routing verification as you go, but certainly not the much-more involved need to locate previously installed obstructions that is necessary when working with an existing facility.

If the project is a clean-build project inside an environmentally controlled area, it will be more practical to shop fabricate or utilize skid or modular fabrication for most, if not all of the piping. This will reduce the number of personnel and the amount of fabrication debris in the facility, and provide better control for keeping it out of the pipe itself. With personnel, you could have food wrappers, drink cans and bottles, food waste, and clothing items. Fabrication debris could include metal filings, cutting oil, pieces of pipe, weld-rod and weld-wire remnants, and so on.

If the project is not a clean-build, but is still inside an environmentally controlled facility, the same logic does not necessarily apply. The decision to shop fabricate and install or to field fabricate and install becomes one based on efficiency rather than how best to maintain a clean area. But that's not to say that if it doesn't qualify as a clean-build project then the construction debris can just be allowed to pile up.

There is still safety and efficiency to consider on any project, and a clean job site is a major part of that. Maintaining a clean job site is an integral component of good project execution.

Keeping personnel and equipment to a minimum at the job site is not an absolute, but is one of the key considerations to the efficiency of pipe installation. Following that logic, most of the butt welded pipe should be shop fabricated. A couple of things to consider, when determining which butt welded pipe to shop fabricate, are size and material.

### Pipe material and size range

Shop fabricated spools need to be transported to the job site, which requires handling. Handling and transporting small diameter pipe and thin-wall tubbing spools create the potential for damage to those spools.

If you are shop fabricating everything and the distance from shop to site is across town, the risk to damaging small diameter pipe spools is a great deal less than if they have to be shipped halfway across the U.S., Europe or Asia, or even across an ocean.

In transporting spools over long distances, unless there is a great deal of thought and care given to cribbing the load of spools, it may not be beneficial to transport butt welded pipe spools NPS 1 1/2 in. and less. It may be more practical to fabricate these sizes on site, unless you are fabricating hygienic or semiconductor piping; these types of systems require a great deal more control and a cleaner fabrication, meaning that pipe fabrication will require a clean shop area on site, or the pipe will need to be fabricated at an offsite, better controlled shop facility.

A practical rule of thumb in determining what to fabricate in the shop or in the field is provided in Table 1. Dictates of the project and a contractors’ standard operating procedures will determine how best to define what is shop fabricated and what is field fabricated.

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### TABLE 1. SHOP VERSUS FIELD FABRICATION

<table>
<thead>
<tr>
<th>Size (in.)</th>
<th>Material</th>
<th>Joint Type</th>
<th>Shop or Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1 ½</td>
<td>Pipe</td>
<td>1, 2, 3, 6</td>
<td>Field</td>
</tr>
<tr>
<td>≤ 1 ½</td>
<td>Pipe</td>
<td>4 &amp; 5</td>
<td>Shop</td>
</tr>
<tr>
<td>≥ 2</td>
<td>Pipe</td>
<td>3 &amp; 6</td>
<td>Field</td>
</tr>
<tr>
<td>≥ 2</td>
<td>Pipe</td>
<td>4 &amp; 5</td>
<td>Shop</td>
</tr>
<tr>
<td>≤ 1</td>
<td>Tubing</td>
<td>5</td>
<td>Field</td>
</tr>
<tr>
<td>≤ 1</td>
<td>Tubing</td>
<td>5</td>
<td>Shop (a, b)</td>
</tr>
<tr>
<td>≥ 1 ½</td>
<td>Tubing</td>
<td>5</td>
<td>Shop</td>
</tr>
</tbody>
</table>

- **Joint Type:**
  1 = Socket weld
  2 = Threaded
  3 = Grooved - Fully (Grooved fittings and pipe ends)
  4 = Grooved - Partially (Shop welded spools with grooved ends)
  5 = Butt weld
  6 = Flanged - Lined or unlined Pipe

Notes:
- a. Hygienic tubing
- b. Special cribbing and support for transport

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### Bioengineering

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Bioengineering, Inc.
Waltham, MA 02451, USA
Bioengineering AG
8636 Wald, Switzerland
info@bioengineering.ch
www.bioengineering.ch

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Engineering Practice

Petroleum-refining and bulk-chemical projects are generally open-air projects in which field fabrication and installation of pipe are exposed to the elements. While a clean build is not a requirement on these types of projects efficiency and, above all, safety are. Because of this, it would make sense to utilize shop fabrication as much as possible.

Fabricating pipe spools under better-controlled shop conditions will provide improved efficiency and safer-per-hour working conditions over what you will generally find in the field. This translates into fewer accidents.

Referring back to Table 1, with respect to the potential for damage during transport, pipe sizes NPS 2–3 in. and larger ship much better than smaller pipe sizes, particularly when working with thin-wall tubing.

Location

Job site location is one of the key markers in determining shop or field fabrication. In many cases, building a facility in a remote location will be a driver for utilizing a disproportionate amount of skid or module fabrication — disproportionate in the sense that project management may look at modularizing the entire job, rather than mobilize the staffing and facilities needed to fabricate and install on or near the job site. This would constitute a larger amount of modularization over what might normally be expected for the same type project in a more metropolitan region, or an area with reasonable access to needed resources.

To expand on that thought; it was pointed out to me by Earl Lamson, senior project manager with Eli Lilly and Co., that project resources, even in metropolitan areas, are quite frequently siloed around a specific industry segment. In certain regions of the U.S., for example, you may discover that there is an abundance of craftsmen available when building a refinery, but that same region may have difficulty, from a trained and experienced personnel perspective, in supporting the construction of a semiconductor facility.

Consequently when building a pharmaceutical facility in another region you may find a sufficient population of trained and experienced craftsman for that industry, but may not find resources adequate when building a chemical plant.

Building a project in a remote location requires the project team to rethink the job-as-usual methodology. From a logistics standpoint, mobilization of personnel and material become a major factor in determining the overall execution of such a project. Project planning is a big component in project execution, but is more so when attempting to build in remote areas. And this doesn’t even touch on the security aspect.

Nowadays, when constructing in any number of remote areas, security is a real concern that requires real consideration and real resolution. Reduced onsite staffing is a good countermeasure in reducing risk to personnel when building in remote or even non-remote third-world areas.

PIPE SYSTEM CLEANING

While there are requirements in ASME for leak testing, cleaning requirements do not exist. ASTM A 380 and 967 has standards on cleaning, descaling and passivation, but there is nothing in ASTM on simply flushing and general cleaning. Defining the requirements for the internal cleaning of piping systems falls within the responsibilities of the owner.

The term “cleaning”, in this context, is a catch-all term that also includes flushing, chemical cleaning, and passivation. So before we go further, let me provide some definition for these terms as they apply in this context, because these terms are somewhat flexible in their meaning, depending on source and context, and could be used to describe activities other than what is intended here.

Definitions

Cleaning: This is a process by which water, solvents, acids or proprietary cleaning solutions are flushed through a piping system to remove contaminants such as cutting oils, metal filings, weld spatter, dirt and other unwanted debris.

TABLE 2. GENERAL CLEANING SCENARIOS

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>Flush only (water, air or inert gas)</td>
</tr>
<tr>
<td>C-2</td>
<td>Flush, clean with cleaning solution, flush</td>
</tr>
<tr>
<td>C-3</td>
<td>Clean with cleaning solution, flush</td>
</tr>
<tr>
<td>C-4</td>
<td>Flush, clean, passivate, flush</td>
</tr>
</tbody>
</table>

Flushing: This is a process by which water, air or an inert gas is forced through a piping system either in preparation for chemical cleaning or as the only cleaning process. Flushing can be accomplished by using dynamic pressure head or released static pressure head, as in a fill-and-dump procedure. Blow-down can be considered as flushing with a gas.

Passivation: In this process, a chemical solution, usually with a base of nitric, phosphoric, citric acid or other mild oxidant, is used to promote or accelerate the formation of a thin (25–50 Å), protective oxide layer (a passive layer) on the internal surfaces of pipe, fittings and equipment. In stainless steels — the most commonly used alloy at present — passivation removes any free iron from the pipe surface to form a chromium-rich oxide layer to protect the metal surface from aggressive liquids such as high-purity waters.

Note that the terms cleaning and flushing can be interchanged when the process only requires water, air or an inert gas to meet the required level of cleanliness. When the term “cleaning” is used in this context it may infer what is defined as flushing.

Cleaning and testing

With regard to cleaning and leak testing, and which to do first, there are drivers for both and different schools of thought on the overall process. Each contractor will have its preference. It is in the owner’s best interest to determine its preference or be at risk in just leaving it to the contractor. In either case you should have a line of thought on the process, if for no other reason than to be able to understand what the contractor is proposing to do.

At the very least, in advance of leak testing, perform either a basic flush of a test circuit, or perform an internal visual examination as the pipe is in-
installed. A walk-down of the test circuit should be done just prior to filling the system with any liquid. The last thing you want to happen is to discover too late that a joint wasn't fully connected or an inline component was taken out of the pipeline. In a facility that is not a clean-build, it can simply be a mess that has to be cleaned. In a clean-build facility, an incident such as this can potentially be costly and time consuming to remediate.

Tables 2 and 3 list general cleaning and testing procedures along with easy-to-use indicators.

Since this article is concerned with new pipe installations, we will not include steam-out cleaning or pipeline pigging in our discussion. These are cleaning procedures that are used on in-service piping to clean the fluid service residue buildup from interior pipe walls after a period of use.

Before subjecting the system to an internal test pressure, you should perform a walk-down of the piping to make certain, as mentioned earlier, that there are no missing or loose components. The system is then flushed with water or air to make sure that there are no obstacles in the piping. Over the years, we have discovered everything from soda cans to shop towels, work gloves, nuts and bolts, weld rod, Styrofoam cups, candy wrappers, and other miscellaneous debris, including dirt and rocks in installed piping systems.

After an initial flush, which could also be the only flush and cleaning required, the system is ready for chemical cleaning or leak testing. In large systems, it may be beneficial to leak test smaller test circuits and then perform a final cleaning once the entire system is installed and tested. This would include a final completed system leak test that would test all of the joints that connect the test circuits. That is, unless these joints were tested as the assembly progressed.

On large systems, if it is decided to leak test smaller segments, or test circuits as they are installed (prior to flushing the entire system), the piping needs to be examined internally as it is installed. This is to prevent any large-debris items from remaining in the piping during the test.

Now that we have touched on generalities, let's take a look at each of the cleaning categories listed in Table 2 and see how to apply them.

**Cleaning Category C-1:** This is simply a flush with water, air or inert gas. The one non-manual assist that water requires in order for it to clean the inside of a piping system is velocity. But what velocity is necessary?

The main concept behind flushing a pipeline is to dislodge and remove suspected debris. In order to dislodge, suspend and remove this unwanted material in the piping system, it is necessary that water or air be forced through the piping system at a velocity sufficient to suspend the heaviest suspected particles and move them along the pipeline.

The velocity required to suspend the particles and move them along the pipeline for removal is dependent upon their size and weight, and the flush medium. Metal filings, arguably the heaviest particles normally found in newly fabricated pipe, will have a terminal mid-range settling velocity, in water, of approximately 10 ft/s. Therefore, a flushing velocity of approximately 10 ft/s should be achieved during the flush. (This does not apply to acid cleaning.) Table 4 indicates the rate of flow required to achieve approximately 10 ft/s of velocity through various sizes and schedules of pipe.

Purging a piping system clear of debris with air requires a velocity of approximately 25 ft/s. Table 5 indicates the air flowrate required to achieve approximately 25 ft/s of velocity through various sizes and schedules of pipe.

One thing you might notice is that the size range only extends to 4-in. NPS for both the liquid flush and for the air or gas blow-down. The reason for that is the volume of liquid or gas required to achieve the necessary velocity through the larger pipe sizes is quite significant.

For example, a 6-in. NPS pipeline would require approximately 900 to 1,000 gal/min, depending on wall thickness of the pipe, to achieve a velocity of 10 ft/s. This gets a little cumbersome and costly unless you have pumps or compressors in place that can achieve the necessary flowrate.

The alternative for liquid flushing the larger pipe sizes other than using source line pressure or a pump is to perform a fill-and-dump. In this process, the pipe system is completely filled with liquid and then drained through a full-line-size, quick-opening valve. In doing this, there has to be enough static head to generate sufficient force and velocity to achieve essentially the same result as the pumped or line pressure liquid.

**Cleaning Category C-2:** This is a three-step process by which the piping system is initially flushed out with a liquid to remove most of the loose debris. This is followed by the circulation of a cleaning solution, which is then followed by a final flush of water.

Cleaning solutions are, in many cases, proprietary detergent or acid-based solutions each blended for specific uses. Detergent-based solutions are generally used for removing dirt, cutting oils and grease. Acid-based solutions are used to remove the same contaminants as the detergent-base plus weld discoloration and residue. The acid-based solution also passivates the pipe wall.

As defined earlier, passivation provides a protective oxide barrier against corrosion. The acids used in some cleaning solutions for ferrous and copper materials leave behind a passivated interior pipe surface as a result of the cleaning process. In utility water services, such as tower and chilled water, this barrier against corrosion is maintained with corrosion inhibitors that are injected into the fluid stream on an ongoing basis.

Keep in mind that the formation of passivated surfaces is a natural occurrence with metals in an oxygen envi-
ronment; the acid merely initiates and speeds up the process.

When using stainless alloys — usually 316L, in hygienic-water services such as water for injection (WFI), purified water, deionized (DI) water and in some cases soft water — passivation is a final step in the preparation for service of these pipelines.

Passivation is also a periodic ongoing preventative-maintenance procedure. High-purity water is very corrosive and attacks any free iron found on the surface of stainless-steel pipe. Free iron has a tendency to come out of solution when material is cold worked, as in bending or forming pipe without the benefit of heat. It also occurs with the threading of alloy bolts, which are solution annealed (heat treated) after threading. Passivation removes this free iron while also accelerating, in the presence of O₂, the oxidation rate of the stainless steel, providing a chromium-rich, oxide corrosion barrier as defined above.

Over time (and this is one hypothetical thought on the subject), this very thin corrosion barrier tends to get depleted or worn off, particularly at high impingement areas of the piping system, such as elbows, tees and pump casings. Once the passive layer wears through, any free iron exposed to the high purity water will oxidize, or rust. This will show up as surface rouge.

Rouging is an unwanted surface discoloration that is periodically removed by means of a derouging process. This is an operational, as-needed chemical-cleaning process that will remove all or most of the rouge and also re-passivate the internal pipe surface.

Discussions and research on the topic of rouging continue. This is a subject that has more questions than answers at the present time. Currently, the ASME-BPE is looking into this issue. One of the questions to be answered is whether or not rouge is actually detrimental to product streams.

Cleaning Category C-3: This is a two-step cleaning process that uses a detergent- or acid-based solution to clean the pipe interior of any unwanted residue or debris. This is then followed by a final flush of water.

Cleaning Category C-4: This is a three- or four-step process generally
used in hygienic service piping. In most cases, simply due to the clean fabrication approach used in hygienic pipe fabrication, only a water flush with deionized-(DI) quality water, or better, would be necessary for cleaning, followed by passivation of the piping system, then a final flush of water.

There are variations to each of these primary cleaning functions and it would be in an owner's best interest to define these requirements, by fluid service, in advance of the work to be done.

Cleaning procedures

This section describes some fundamental cleaning procedures as they might appear in a specification or guideline and includes the leak-test procedures that will follow in Part 6. This will give you some idea as to what you might consider developing for your own set of specifications. Assuming that if your company repeatedly executes projects you will have cleaning and testing guidelines, in some form, prepared for your contractor. If not, you may not get what you expect. It's better to give some forethought to these activities rather than be surprised at the results.

Once a menu of these cleaning and testing procedures are developed, using pre-assigned symbols, similar to those given in the following, they can then be specified in the line list with the respective fluid services as you require. In this manner, there is no second guessing during construction. Each piping circuit is assigned a specific clean and test protocol in advance.

Many pre-developed procedures I have seen over the years, those developed by owners in particular, have been very simplistic, and typically out of date. This is an indicator to most contractors that the owner's representative will most likely not attempt to enforce them. The contractor, in making that assumption, may simply ignore them and perform their own procedures.

Your procedural guidelines should be explicit and current to ensure that the contractors know that someone has given some thought to how he or she wants that work accomplished, making it far more likely that the contractors will execute your procedure instead of their own.

It is certainly acceptable to accommodate suggestions to a procedure from a contractor when they don't compromise the intent of the owner's requirements and are likely to improve the efficiency of the contractor. If a submitted alternate procedure does not compromise the intent of the owner, it is recommended that it be accepted. This will allow the owner to see if that efficiency is really there. With that in mind, let's create a couple of general cleaning procedures.

A general practice in the flushing and cleaning process (also indicated in leak testing), is the evacuation of air when using liquids. Always provide high-point vents for evacuating air during the fill cycle, and low point drains for clearing out all of the liquid when the process is complete.

Using the same terminology in Table 2 these cleaning procedures will be categorized as follows:

**Category C-1:** Flush or blowdown only (water, air or inert gas)

**C-1.1** — These systems shall be flushed with the fluid that the system is intended for. There shall be no hydrostatic or pneumatic leak test. An initial-service leak test will be performed.

a. Connect system to its permanent supply line. Include a permanent block valve at the supply line connection. All outlets shall have temporary hoses run to drain. Do not flush through coils, plates, strainers or filter elements.

b. Using supply line pressure, flush system through all outlets until water is clear and free of any debris. After which the process will start over with Step 2.

c. Use a once through procedure (not a re-circulation), and the rate of flow in Table 4, perform an initial flush through the system with a quantity of potable water not less than three times that contained in the system. Use Table 6 to estimate volume of liquid in the system. Discharge to sewer, or as directed by owner representative.

d. After the initial flush, insert a conical strainer into a spool piece located between the discharge of the piping system and the outlet hose. Perform a second flush with a volume of potable water not less than that contained in the system.

e. After the second flush pull the strainer and check for debris; if debris is found repeat Step c. If no debris is found, the system is ready for leak testing.

**Category C-2:** Flush then clean with neutralization rinse. Because of the thoroughness of the flush, clean and rinse process there should be no need to

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**TABLE 5. RATE OF AIR FLOW (FT³/S) TO MAINTAIN A VELOCITY OF APPROXIMATELY 25 FT/S**

<table>
<thead>
<tr>
<th>Pipe Sch.</th>
<th>Pipe Sizes (in.)</th>
<th>½</th>
<th>⅜</th>
<th>⅝</th>
<th>1</th>
<th>1 ½</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press. 15 psig</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>0.14</td>
<td>0.23</td>
<td>0.39</td>
<td>0.86</td>
<td>1.39</td>
<td>3.06</td>
<td>5.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.11</td>
<td>0.19</td>
<td>0.30</td>
<td>0.71</td>
<td>1.18</td>
<td>2.59</td>
<td>4.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>0.08</td>
<td>0.15</td>
<td>0.25</td>
<td>0.62</td>
<td>1.04</td>
<td>2.32</td>
<td>4.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Press. 60 psig</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>0.30</td>
<td>0.51</td>
<td>0.84</td>
<td>1.88</td>
<td>3.02</td>
<td>6.67</td>
<td>11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.23</td>
<td>0.41</td>
<td>0.66</td>
<td>1.56</td>
<td>2.56</td>
<td>5.65</td>
<td>9.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>0.18</td>
<td>0.33</td>
<td>0.55</td>
<td>1.35</td>
<td>2.26</td>
<td>5.05</td>
<td>8.79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

During the flushing procedure, and as the system is placed into service, all joints shall be checked for leaks. Any leaks discovered during the flushing process, or during the process of placing the system into service, will require the system to be drained and repaired. After which the process will start over with Step 2.
check for transient debris, only for neutralization. However, if circumstances dictate otherwise, then a final check for debris may be warranted. C-2.1 — These systems shall be preflushed with potable water, cleaned with (indicate cleaning agent) then a rinse/neutralization followed by leak testing with potable water. If it is determined that the system will be installed and tested progressively in segments, the sequence of cleaning and testing can be altered to follow the segmented installation, thereby leak testing segments of a piping system as they are installed without cleaning. The entire system would then be cleaned once installed and tested.

- a. Hook up flush/test manifold at a designated temporary inlet to the system between the circulating pump discharge and the system inlet. Install a temporary hose or pipe on the designated outlet(s) of the system.
- b. Route temporary hose or pipe from potable water supply, approved by owner, and connect to flush/test manifold. Route outlet hose or pipe to sewer, or as directed by owner’s representative.
- c. Close valve between the circulating pump (if no valve is included in the system design, insert a line-blind or install a blind flange with a drain valve) discharge and flush/test rig.
- d. Open valve between flush/test manifold and piping system.
- e. Discharge to sewer, or as directed by owner’s representative.
- f. After completing the initial flush, drain remaining water in the system. Or, retain water if cleaning chemicals will be added to the circulating water.
- g. Configure valves and hoses to circulate through pump. Connect head tank, or other source containing cleaning agent, to connection provided on circulation loop.
- h. Fill the system with the pre-measured (indicate preferred cleaning agent and mixing ratio or percentage by volume) and circulate through the system for 48 h. To minimize corrosion, if anticipated, circulate cleaning agent at a low-velocity rate prescribed by the cleaning-agent manufacturer.
- i. Drain cleaning agent to sewer or containment, as directed by owner.
- j. Reconnect, as in Step a, for the once-through flush/neutralization, and flush system with potable water using a quantity not less than three times that of the system volume. Since the (name cleaning agent) solution has a neutral pH, the rinse water will have to be visually examined for clarity. Rinse until clear. The rinse must be started as quickly after the cleaning cycle as possible. If cleaning residue is allowed to dry on the interior pipe wall, it will be more difficult to remove by simply flushing. The final rinse and neutralization must be accomplished before any possible residue has time to dry.
- k. Test pH for neutralization. Once neutralization is achieved proceed to Step 1.
- l. Remove pump and temporary circulation loop, then configure the system for leak testing. This may include removal of some components, insertion of line-blinds, installation of temporary spools pieces and so on.

These three examples should provide an idea as to the kind of dialog that needs to be created in providing guidance and direction to the contractor responsible for the work. And, as stated earlier, these procedures, for the most part, are flexible enough to accommodate suggested modifications from the contractor.

Acknowledgement

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References


Author

W. M. (Bill) Huitt has been involved in industrial piping design, engineering and construction since 1965. Positions have included design engineer, piping design instructor, project engineer, project supervisor, engineering manager and president of W. M. Huitt Co. (PO. Box 31154, St. Louis, MO 63131-0154). His experience covers both the engineering and construction fields and crosses industrial lines to include petroleum refining, chemical, petrochemical, pharmaceutical, pulp & paper, nuclear power, and coal gasification. He has written numerous specifications including engineering and construction guidelines to ensure that design and construction comply with code requirements, owner expectations and good design practices. Bill is a member of ISPE (International Society of Pharmaceutical Engineers), CSI (Construction Specifications Institute) and ASME (American Society of Mechanical Engineers). He is a contributor to ASME-BPE and sits on two corporate specification review boards.