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GET TOPNOTCH PERFORMANCE FROM JACKETED PIPE

Careful attention to design and fabrication is a must to meet critical process requirements

Functioning as simple containment systems or basic shell-and-tube heat exchangers, jacketed pipes find many applications in the chemical process industries (CPI). But because these units are often treated as a "commodity" and expected to be furnished by a piping contractor, they sometimes fail to perform their intended function over the range of operating conditions typically encountered in a process.

A change in mind-set is in order. There are a number of situations where it is essential that jacketed pipes be designed and fabricated with as much engineering rigor as that afforded to such critical equipment as reactors, heat exchangers and distillation columns.

Hard-pressed to keep up with the deadlines for project completion, project teams often prefer to delegate the responsibility of the construction of jacketed pipes to an onsite piping contractor. By entrusting the associated design, engineering and purchasing tasks to the contractor, a project engineer can achieve appreciable manhour savings. Besides, field fabrication allows plant inspectors easier access to the work in progress. However, unless a piping contractor has a crew of fabricators with many years of experience in jacketed pipes, onsite fabrication usually results in products of less than acceptable quality. Such subquality jackets may result in unnecessary downtime for repair, and excessive emissions of hazardous materials from a jacketed containment system.

The best recourse is to begin with an assessment of the criticality of the jacketed pipe with regard to the proper functioning of the process in question. Then treat the jacketed pipe as either a critical piece of equipment or a commodity product to be handled along with the piping for the utility and noncritical segments of the process.

Keep in mind that the fabrication techniques for jacketed pipes are quite different from those for a single-wall pipe. For example, the fabricator of a single-wall pipe starts at one flanged end and adds piping segments in sequence. With jacketed pipes, however, the fabricator starts in the middle to accommodate tees and elbows, and works toward the flanged ends (Figure 1).

For those not familiar with the fine points of fabrication of jacketed pipes, it is important to recognize the conditions that warrant classifying this type of piping as critical equipment. In other words, shop fabrication of jacketed pipes is a must when:

- Cross contamination cannot be tolerated for the projected life of the piping system in question
- The surface finish of the core piping within the jacket must be substantially better than mill grade
- Jacket and process pressures exceed 300 and 1,000 psi, respectively
- Thermal gradients due to inaccurate fabrication of the piping can cause production of off-specification product
- Close tolerances and tight fits be-

FIGURE 1. The fabrication of jacketed pipes is often as complicated as that of such process equipment as reactors and distillation columns

tween numerous fixed points in the piping must be maintained

- Difficult-to-weld high alloys, such as Type AL6XN, duplex stainless steels, Inconel and Hastelloy, are to be used
- The process is considered a toxic service that must be contained and kept at stable temperatures
- Batch processing results in frequent thermal cycling (250°F or more) of the piping system
- Test probes into the core have narrow dimensional tolerances

Preventing cross contamination

Commingling of the process and heating fluids is caused by a failure in the core pipe, resulting from poor welding, faulty fabrication, inappropriate design, or a combination thereof. Often, it is extremely difficult to track down the exact cause of the failure and come up with a timely remedy. In many cases, complete piping systems have to be taken apart and replaced because of untraceable cross contamination, which occurs more frequently than is generally acknowledged.

When the process pressure is higher than the jacket pressure, the process fluid can flood the jacket annulus, often spreading to adjacent spools. In sulfur-handling systems, for example, a core pipe can develop a crack in the heat-affected zone of a butt weld, allowing sulfur to seep through the crack into the surrounding steam-carrying jacket (Figure 2). The result is cross contamination that generates sulfurous acid, overloading the ability of a boiler's automatic feedwater neutralizer to control the resulting pH shift of the returning condensate. Unless the problem is quickly corrected, acidic steam can gradually spread corrosion products throughout the entire piping network served by the boiler.

When the jacket pressure is greater than the core pressure, the heating medium can get into the process. This can cause production of off-specification products — for example, plastic films and chips laced with hot oil, watered-down chocolate, hydrated anhydrides and numerous other substances that cost more to dispose of than to make.

To avoid cross contamination, some designers opt to exclude welds concealed beneath a jacket from their piping systems. However, the thermal requirements of certain processes make it very difficult and expensive to do away with concealed welds by fabrication alone. For this reason, certain clamp-on heating devices have been developed to maintain uniform temperatures at the exposed weld areas. In any event, thorough engineering and knowledgeable inspection are the best defense against cross contamination.

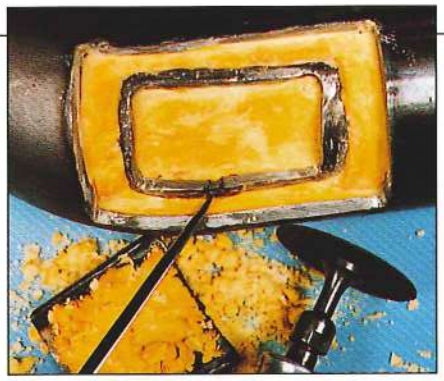

FIGURE 2. A crack in the heat-affected zone of a butt weld on a carbon steel elbow lets sulfur from the core piping seep through and flood the jacket annulus

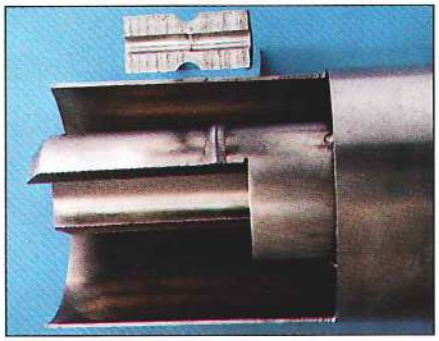

FIGURE 3. Mechanical polishing of butt welds (bottom) is often needed for heat-sensitive processes. However, carefully executed butt welds (top) may be the only recourse available when polishing isn't possible

FIGURE 4. An upsurge in the jacket pressure due to a sudden rise in the process temperature can squeeze, or even crush, the core piping

Providing the finishing touches

Products that must maintain specific properties, such as color, luster and taste, are very sensitive to the time duration of their thermal exposure. For example, the quality of molten products, such as certain polymers and foodstuffs, depends on their residence time in a process system.

But standard mill finishes and weld joints normally have voids and crevices where the molten products can stagnate and degrade. The degraded products continually break away from the pipe wall and mix with virgin product, resulting in an off-specification product. Needed: Polished surfaces to control residence time and eliminate product traps.

Some products require surface finishes approaching that of a mirror. Butt welds that are accessible during fabrication can be mechanically polished (Figure 3), while the inaccessible butt welds must be carefully executed to ensure zero concavity of the surface and minimum protrusion into the product stream. In some synthetic-fiber applications, residence time may be so critical that the core pipe must be machined and honed to the same precision as that of a gun barrel.

Methods of checking for smoothness include boroscopic and radiographic (X-ray) examination. Such inspections may increase the cost of jacketing a pipe, but there are often no alternatives when product quality is at stake.

Dealing with high pressures

When the process-fluid temperatures in hot-water- or steam-heated processes exceed the heating-medium temperatures, the core piping is prone to collapse under pressure. In one instance, a polymer producer started pumping an intermediate from a reactor through a jacketed piping system while the product temperature was around 450°F, substantially above its normal range of 320 to 330°F. Thus the process fluid

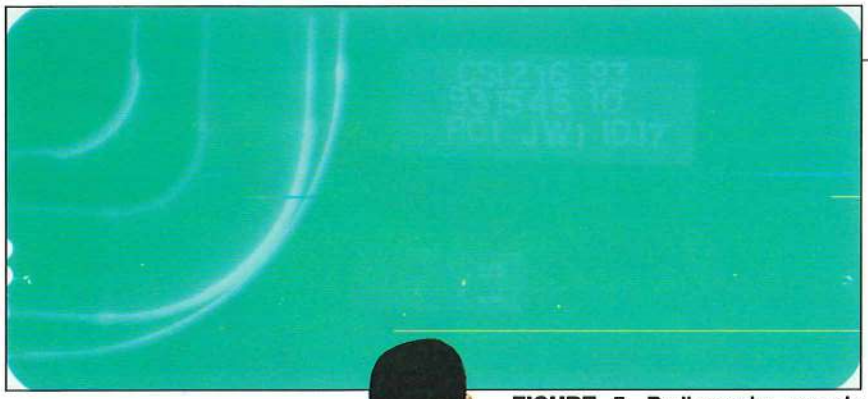

FIGURE 5. Radiography reveals how a core elbow jammed against a jacket elbow can block a heating or cooling medium, and produce severe stress due to variations in the thermal expansion of the core and the jacket

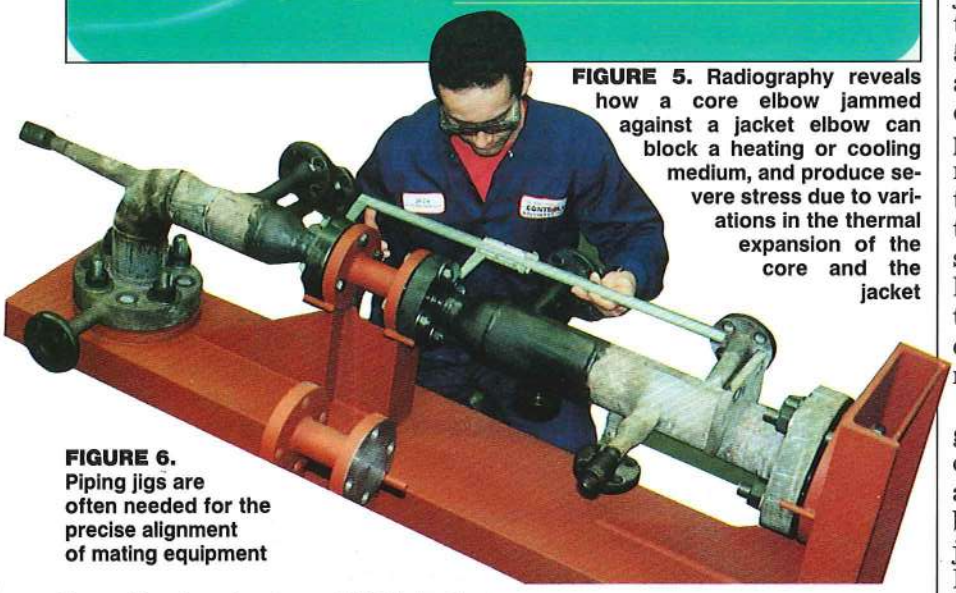

FIGURE 6. Piping jigs are often needed for the precise alignment of mating equipment

began heating the steam (350°F) in the jacket. Jacket pressures rose above 400 psi, collapsing the core pipe (Figure 4).

Core piping constructed from Schedule 10 stainless steel should always be checked for external pressure loads. Large pipe sizes (4 in. and up) of Schedule 10 are quite vulnerable to external pressure surges. Treating jacketed pipe as process equipment often avoids this kind of problem because the designs are likely to be analyzed for all reasonable process conditions.

When the core of a jacketed pipe operates above 1,000 psi, heavy-wall piping with flanges in the 1,500- and 2,500-psi class are normally required. Precision fabrication for heavy-wall jacketed pipe is critical for optimum installation. For pipes designed to withstand high pressures and temperatures, rigorous nondestructive testing of core welds must be performed via X-ray or ultrasonic waves whenever practical. Dye-penetrant and ultrasonic testing are appropriate for inspection of fillet welds, where full-penetration welding cannot be achieved.

Eliminating thermal gradients

Inspections of the dimensional integrity of a finished piece of jacketed pipe usually involve verifying that face-to-face tolerances are maintained, elbows are set at right angles with correct slopes and offsets. However, when thermal gradients (variations in process temperature over the length of a pipe) affect product quality, standard dimensional checks are not enough.

Thermal gradients occur when the core pipe comes in contact with the jacketed pipe or is so close to the jacket that the heating fluid is blocked (Figure 5). This blockage or stagnation creates a "chill spot" causing variation in the color or luster of some polymers and pigments. Serious stress problems can result if the jacket has a coefficient of thermal expansion that is lower than that of the core piping. Fabricating a spool of jacketed pipes of different lengths in two or three planes without the core pipe touching the jacket is a difficult and time-consuming task. It requires considerable expertise.

In cases where eliminating thermal gradients is a high priority, certain combinations of diameters for the core and jacket must be avoided. These combinations include: 1-in. core and 2-in. jacket; and 3-in. core and 4-in. jacket. Increasing the jacket diameters to 2.5 in. and 5 in., respectively, improves the chances of success.

Ensuring close tolerances

When a jacketed pipe is connected to precision machinery, the tolerances on the matching nozzles are critical to the proper functioning of the whole system. Knowing how to fabricate and hold these tolerances is essential for good fit-ups. Maintaining the design and fabrication requirements of the American National Standards Institute code ANSI B31.3 can be very difficult even with the help of jigs and optical alignment devices (Figure 6). Crucial to success is a thorough understanding of the relationship between pipe schedules, cut lengths and weld shrinkage.

Shrinkage due to welding affects the

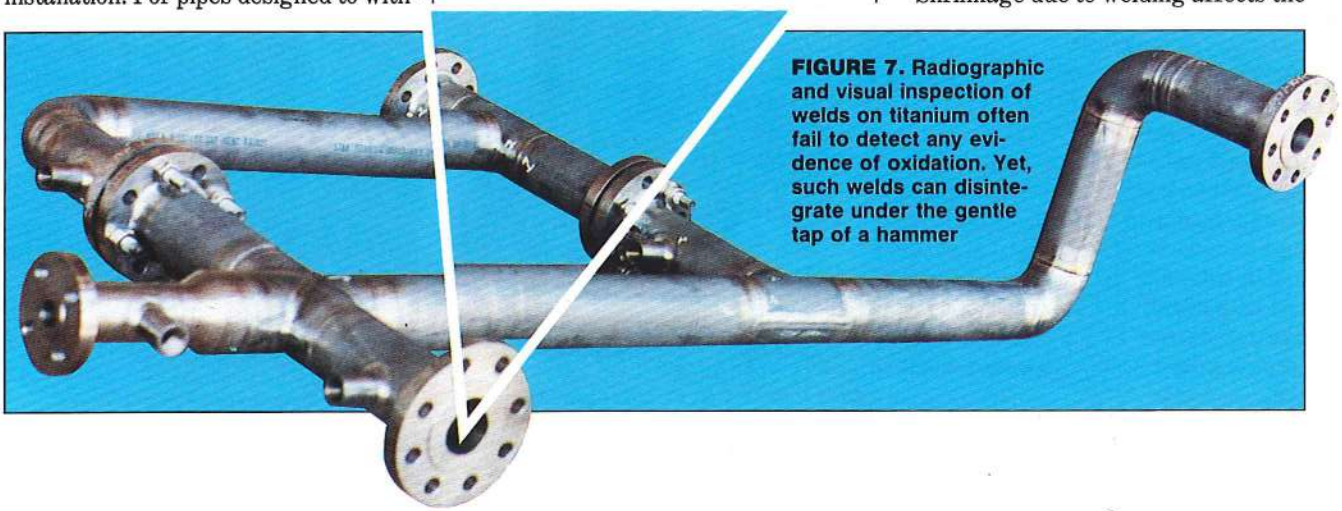

FIGURE 7. Radiographic and visual inspection of welds on titanium often fail to detect any evidence of oxidation. Yet, such welds can disintegrate under the gentle tap of a hammer

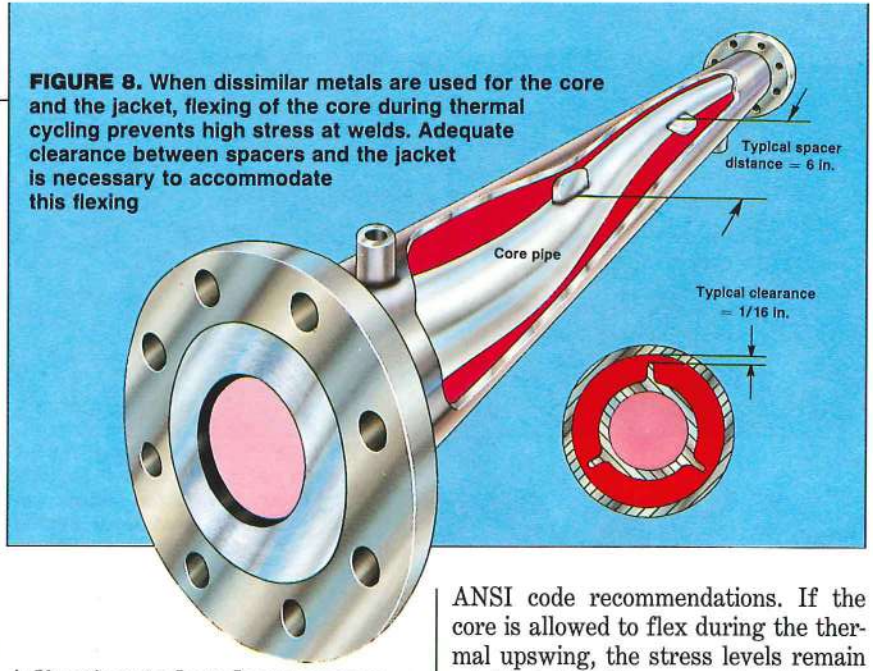

FIGURE 8. When dissimilar metals are used for the core and the jacket, flexing of the core during thermal cycling prevents high stress at welds. Adequate clearance between spacers and the jacket is necessary to accommodate this flexing

final, overall dimension of jacketed pipes with heavy-wall cores. Because of awkward configurations, it is difficult to machine most heavy-wall assemblies into the specified tolerances, especially after fabrication is completed. Tolerance-related misalignments can be avoided by ensuring correct cut lengths of the pipes, precise fit-ups, and excellent welding during fabrication.

Working with high alloys

Typical jacketed piping systems consist of carbon steel, stainless steel, or a combination of carbon and stainless steels for the core and the jacket. For aggressive process environments characterized by corrosive fluids at high temperatures and pressures, the optimum process piping may require special alloys, such as Hastelloy, Monel and Inconel. When these materials are specified, the jacketed pipe should be treated as critical equipment because the welding of such materials demands the skills of an experienced welder.

Since all of these materials are quite expensive, inspection and testing should be as thorough as possible. Even then, it is impossible to guarantee their structural integrity. Case in point: Welds on titanium can pass radiographic and visual examination, and yet shatter under a modest hammer tap because of undetected oxidation (Figure 7).

Handling toxic fluids

When the process chemicals are toxic, the quality of fabrication and welding is as important as the inspection and testing procedure. A number of tests via radiography, dye penetration, magnetic particle detection and positive material identification are often required to ensure the structural integrity of the jacketed pipes. When the jackets are for containment, temperature control, or both, design and construction of the piping call for the extensive knowledge and expertise of not only the best welders and fabricators, but also the most experienced engineers and inspectors available.

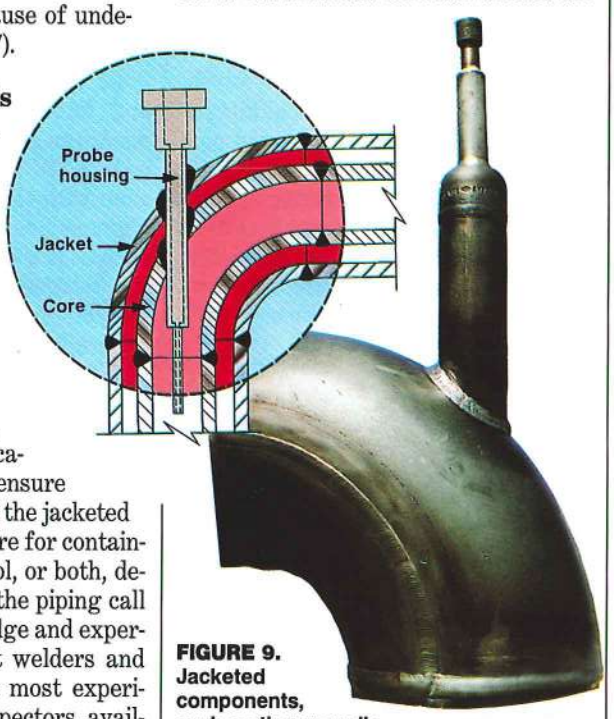

FIGURE 9. Jacketed components, such as thermowells, can be fabricated as subassemblies

Adjusting to batch processes

Many jacketed piping systems are used in batch processes where frequent heating and cooling are normal operating procedures. The frequent thermal cycling induces cyclic stress in the piping material. Forced-fitting of a jacketed pipe during installation coupled with cyclic heat loads can lead to premature cracking of flange welds, which are most susceptible to thermal cycling.

The higher the processing temperature, the more important it is to treat batch-process piping as critical equipment. When combinations of materials, such as a stainless-steel core and a carbon-steel jacket, are used, stress levels in the stainless core can exceed the ANSI code recommendations. If the core is allowed to flex during the thermal upswing, the stress levels remain relatively low. However, when the core is restrained by spacers, the stress levels may exceed the design limits (Figure 8). Poorly designed pipe spacers without sufficient clearance can actually puncture a jacket.

Short spools with a stainless core and carbon jackets fail more frequently than longer spools of the same construction. The core in a short spool has greater resistance to flexing than a core in a longer spool. This lack of flexibility induces higher levels of stress at the flange welds.

Peering into the core

Jacketed pipes are often equipped with temperature and pressure probes inserted through taps into the core. When prepared as a subassembly, like a short jacketed spool or an elbow, probe holes and sealing surfaces are machined after the core and jacket have been added (Figure 9).

The subassembly is then welded into the line like an additional piping section. This technique requires more welding and fabrication. But it is better than alternative methods that produce warped taps, which must be remachined to larger tolerances. Such tolerances can lead to premature leakage. ■

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