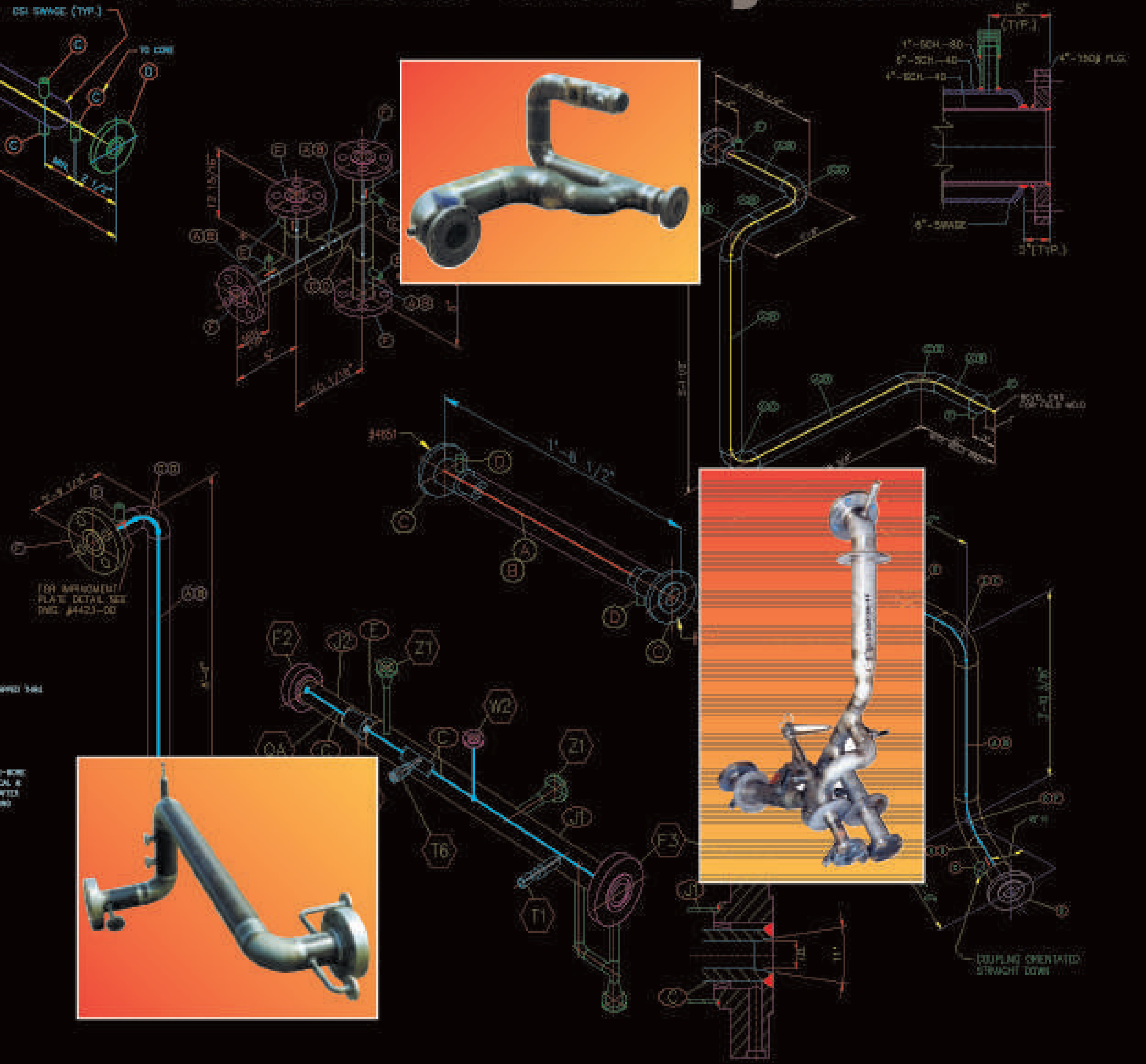
CSI Bulletin F-100

CSI Jacketed Piping Products and Systems



Engineering · Design · Fabrication · Installation

Controls Southeast, Inc.

Contents

Briefly (about CSI) .... Inside Front
Letter To CSI Customers & Friends 1
Choose A Specialist To Fabricate Your Jacketed Piping 2,3,4
Your Advantages When You Select CSI 5,6
Types and Sizes of Jacketed Pipe 7,8,9
Design Considerations 10,11
Typical Construction Details 12,13
Fabrication Examples 14,15
CSI Engineering Services 16,17,18,19,20
CSI Bolt-On Heating Technology 21

Briefly...

We began business in 1962 – repairing valves and meters, and producing flexible metal hose assemblies.

In 1970 we were fabricating valve jackets for several valve manufacturers, as well as the processing plants. In 1973 we began producing bolt-on cast aluminum jackets to complement our fabricated valve jackets.

Our first spools of jacketed pipe were produced in 1976, and in 1977 we became an ASME Code Shop.

By 1986 we had produced jacketed piping systems for most of the major chemical processors in the U.S. Our expanded engineering and design capabilities allowed us to solve process temperature problems with a variety of jacketing techniques.

In 1988 we began the service of installing the jacketed piping systems we produced. CSI field crews now have completed installation projects from Massachusetts to Puerto Rico, Texas to Illinois.

In 1998 we completed our first jacketed piping project in the U.K.

CONTROLS SOUTHEAST, INC.

To: CSI Customers and Friends

We appreciate your taking the time to review this brochure. It contains timely guidelines on the design and construction of jacketed piping systems, as well as plenty of details and examples.

From my perspective of more than 20 years in the jacketed piping business, the most significant information we're leaving with you are facts that pinpoint the critical nature of a jacketed piping system, and why you need to select a qualified fabricator to avoid problems too common in the majority of jacketed piping projects.

I'm talking about problems of heat transfer, of core/jacket stresses, and of cross contamination. It's important for process and project engineers to appreciate the effects and consequences of poor piping design, non-code fabrication, installation mismatches, and poor layout. As an old Shift Supervisor, I know that an emergency call at 2:00 in the morning because the plant's producing off-grade product with traces of hot oil probably isn't *operator error*. Most likely, it's *fabricator error*.

From experience, let me tell you that when you involve the jacketed piping specialist early in your project—even during preliminary discussions—your chances of on-time, on-budget success increase substantially.

In many instances, our customers are unaware of CSI's extensive capabilities. Again and again, I've listened to customers say, "We didn't know you guys did that!" Usually, it's in reference to one of our un-promoted services such as on-site layout, or a thermal analysis of jacket "A" design vs. jacket "B" design.

The fact is, we developed these special capabilities because we want to take care of our customers. CSI can assume full responsibility for your jacketed piping project—part of it, or all of it—from concept to installation.

May we serve your company?

Thanks,

Fred H. Stubblefield, Jr.
President

P. O. Box 7500, Charlotte, North Carolina 28241 / Telephone: (704) 588-3030 / Fax: (704) 588-3039 / e-mail: sales@csiheat.com / www.csiheat.com

Choose A Specialist To Fabricate Your Jacketed Piping

Jacketed piping, unlike single-wall (unjacketed) piping, is special. Navigating successfully through jacketed piping's maze of potential problems requires a specialist's skill and knowledge.

The potential problems start with the fundamental differences between the fabricating techniques of jacketed piping and those of single-wall piping. With single-wall piping, a fabricator begins at one flanged end, then adds piping components in sequence. With jacketed piping, the fabricator starts in the middle of the spool, adding tees, elbows and other segments, working outward to the flanges. This sequence is necessary to avoid excessive jacket welds and "clam-shell" construction.

It's important that design teams remember this fundamental difference. Often, to maintain project milestones, the design team assigns the fabrication of their jacketed piping to a general pipe shop or mechanical contractor along with the single-wall and utility piping.

By delegating the fabrication of the jacketed piping to the contractor, the team achieves man-hour savings by eliminating design and administrative time required to isolate and separate the jacketed piping from the total piping package. Since jacketed piping usually represents only a small segment to the total piping work, there seems to be little justification for the extra time and effort needed for the breakout.

Unfortunately, when the contractor's fabricators have minimal experience with jacketed piping, or the contractor's most recent jacketed piping work occurred several years ago, the results often are the tandem problems of poor quality and poor performance.

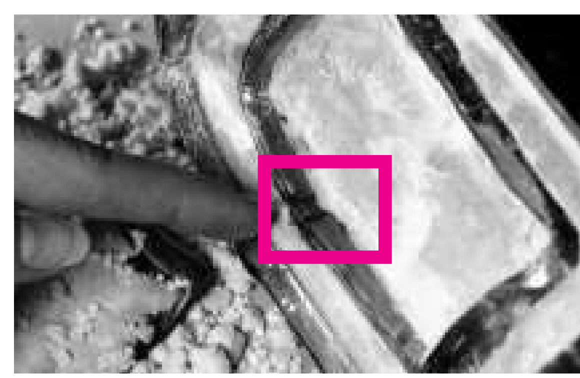
Other jacketed piping issues that contractors seldom are equipped to resolve expediently are code conflicts with design criteria, thermal stresses, heating medium circuitry, rigorous testing procedures, and complete documentation.

For the jacketed piping specialist these problems occur daily. They are solved daily. All welding, fabrication, testing, QC inspection, design and engineering converge on the production of a basic type of critical equipment. Fabricators with questions have ready access to experienced designers and engineers.

Here are some of the typical conditions of design, fabrication, and performance that establish the critical nature of jacketed piping. These conditions underscore the importance of selecting the specialist to fabricate your jacketed piping.

The risk of cross contamination must be avoided for the projected life of the piping system.

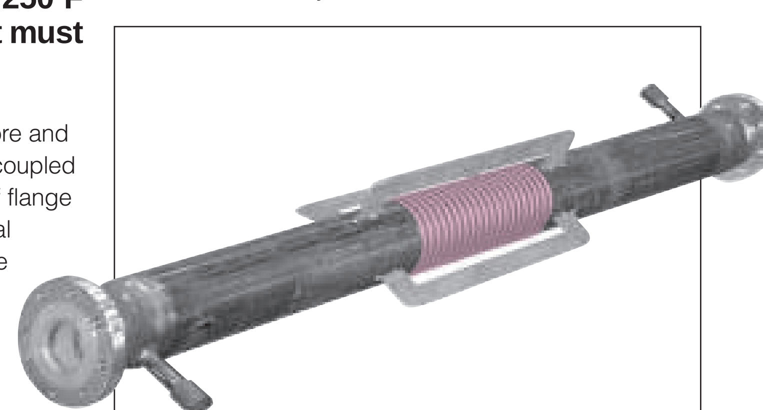
Cross contamination occurs most frequently at the heat affected zones of weldments. To avoid cross contamination, some designers opt to exclude concealed welds beneath the jacket, choosing swaged jacketing on straight sections and leaving fittings un-jacketed. Where narrow thermal profiles must be maintained, bolt-on heating jackets can provide heat coverage for the fittings and flanges (see Hybrid Jacketing, page 9). Regardless of the fabrication techniques specified, the designer's best defense against cross contamination is thorough engineering, knowledgeable inspection, and expert fabrication.



Heat affected zones adjacent to welds are "weak links" in jacketed piping systems. That's where stress fractures occur most frequently. The result is cross contamination, shown above in a sulfur transfer line. Sulfur breached the jacket annulus.

Batch-type processes that cycle to 250˚F or higher create stress problems that must be resolved before fabrication.

Frequent thermal cycling of jacketed piping used in batch-type service induces cyclic stresses in the core and jacket. Forced-fit installations of the jacketed pipe coupled with cyclic heat loads lead to premature cracking of flange welds--the welds usually most susceptible to thermal cycling. The higher the processing temperature, the more important it is to treat batch-process piping as critical equipment. When different material for the core and jacket are specified, such as a carbon jacket and a stainless core, stress in the core may exceed ASME Code recommendations. Stress analysis of the piping system, as well as design configurations of core and jacket, should be performed.

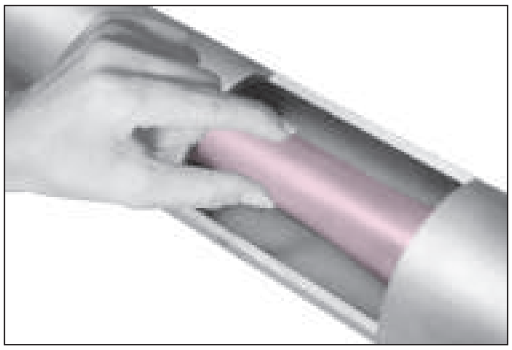


Swaged jacketed pipe spool with stainless core and carbon jacket. The jacket has an integral stainless expansion joint to relieve cyclic heat stress.

High jacket pressures can collapse core piping. High core pressures dictate rigorous testing.

Core piping should always be checked for external pressure loads created by the heating medium. If the core temperature rises higher than the temperature of the heating medium, pressure consequences for the core may be too severe.

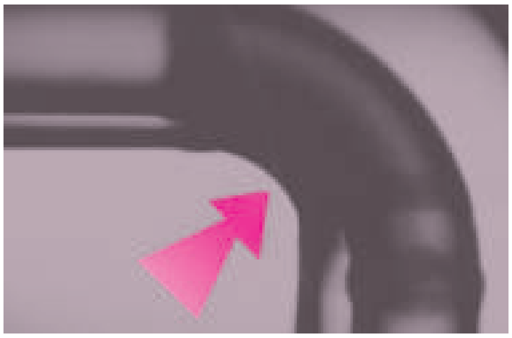
When the core piping operates above 1000 psi, heavy-wall piping with 1500 lb. and 2500 lb. class flanges, or high-pressure hubs are required. Precision fabrication of heavy-wall jacketed piping is critical for optimum installation. Rigorous nondestructive testing of core welds must be performed via radiographic (RT) or ultrasonic testing (UT) whenever practical. Fillet welds can be inspected by liquid penetrant testing (PT) or UT.



A sudden rise in process temperature caused the pressure of the steam in the jacket to increase dramatically, crushing the core.

Thermal gradients, caused by inaccurate fabrication, affect product quality.

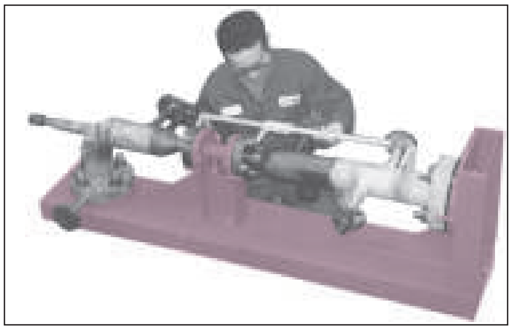
When quality of the product can be affected by variations in process temperatures over the length of a pipe, standard dimensional checks (verifying face to face dimensions, etc.) are not enough. Thermal gradients occur when the core pipe comes in contact with the jacket or is so close to the jacket that the flow of the heating fluid is blocked. This stagnation area creates a chill spot that can cause variations in color or luster of some polymers and pigments. Serious stress problems may result. Fabricating a spool of jacketed pipe in two or three planes without the core pipe touching the jacket is a difficult task. Expert fabrication is required. When thermal gradients must be avoided, using a jacket size larger than “standard” improves chances of success.



Radiography reveals a core elbow blocking the heating medium, which can create a chill spot in the process and induce severe stresses in the core pipe.

Maintaining close tolerances between numerous fixed points often calls for special fabrication jigs and test fixtures.

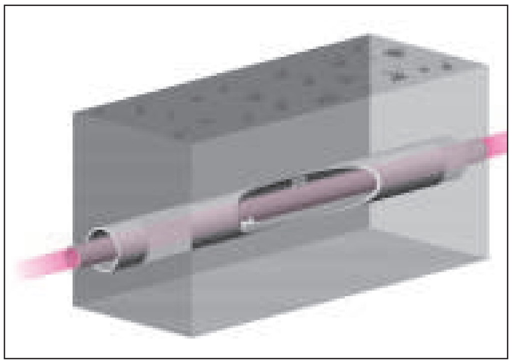
When jacketed pipe connects to precision machinery, the tolerances of matching nozzles is critical to the proper functioning of the entire system. Even with the help of jigs and optical alignment devices, maintaining the fabrication requirements of ASME B31.3 can be very difficult. Crucial to success is a thorough understanding of the relationships between pipe schedules, cut lengths and weld shrinkage. Awkward configurations often prevent post machining from correcting misalignments. Correct cut lengths, precise fit-ups, and excellent welding are the most effective tools to use in preventing tolerance-related misalignment.



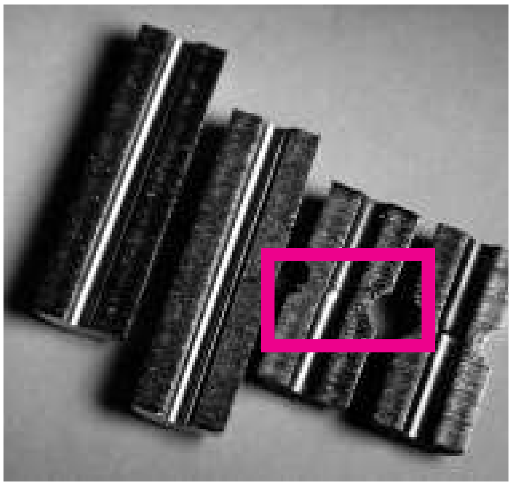
To ensure precise alignment of mating equipment, piping jigs may be required.

When the process is a hot, toxic fluid contained in a metallic jacket, stresses tend to be very severe, requiring special designs.

When the process chemicals are toxic, the quality of fabrication and welding is as important as inspection and testing. A number of different tests are needed to verify product integrity. These tests include RT, PT, UT, and positive material identification (PMI). When the jacket purpose is containment and temperature control, design and construction of the piping calls for the extensive knowledge of the best welders and fitters. It also calls for the most experienced engineers and inspectors available.



Buried containment piping for hot processes creates special stress problems due to wide temperature differences between the core and jacket.



Mechanically polishing of butt welds is often needed for heat sensitive products. Where polishing is not possible, expert welding is required.

The surface finish of the core piping may need to be substantially better than mill grade.

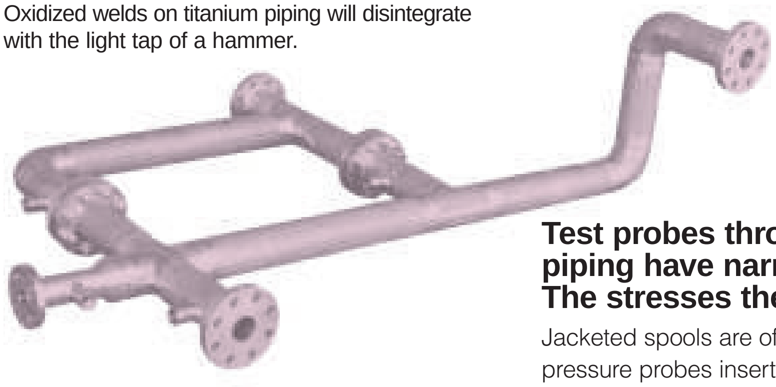
The quality of many polymers and foodstuffs depend on residence time in the hot process piping. Mill finishes and welded joints have voids and crevices where molten products stagnate, degrade, then break away, creating end products of poor quality.

Polished pipe surfaces help control residence time and eliminate product traps. Some processes require surface finishes approaching that of a mirror. Butt welds that are accessible during fabrication can be mechanically polished. Inaccessible butt welds must be carefully executed to ensure zero concavity of the surface and minimal protrusion of the weld into the product stream. Smoothness inspection methods include radiography and boroscopic examinations.

Mistakes with difficult-to-weld high alloys, such as AL6XN*, duplex stainless, Inconel*, Hastelloy*, or titanium are very expensive.

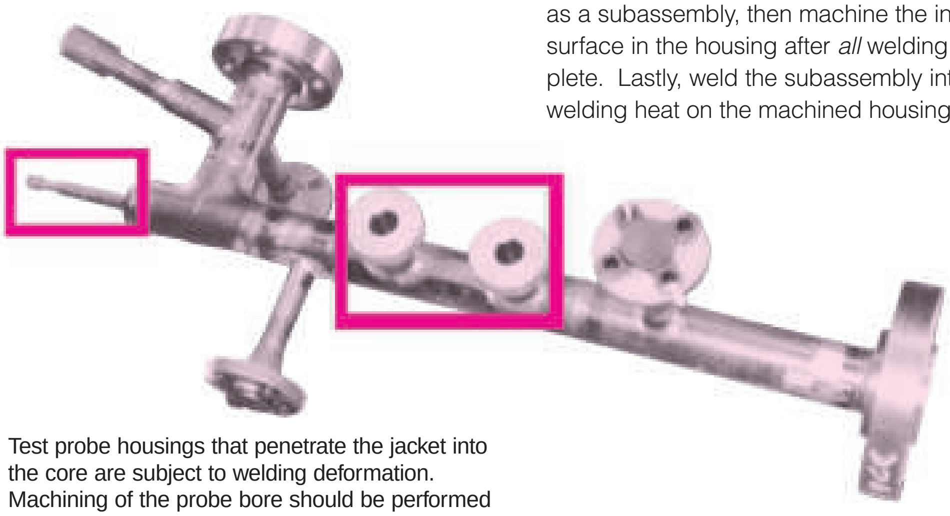
Corrosive, high-temperature process fluids may require special, high-alloy piping. These high-alloy piping materials demand the skills of experienced welders and fabricators working in controlled environments. Since all high-alloy materials are expensive, inspection and testing by the supplier as well as the customer must be thorough.

Radiographic and visual inspection of welds on titanium often fail to detect evidence of oxidation. Oxidized welds on titanium piping will disintegrate with the light tap of a hammer.



Test probes through the jacket into the core piping have narrow dimensional tolerances. The stresses they create can be significant.

Jacketed spools are often equipped with temperature and pressure probes inserted through the jacket into the core. Premachined probe housings often warp due to welding heat. Solution: Prepare an un-bored probe housing and adjacent piping as a subassembly, then machine the instrument hole and sealing surface in the housing after *all* welding around the housing is complete. Lastly, weld the subassembly into the spool, avoiding any welding heat on the machined housing.



Test probe housings that penetrate the jacket into the core are subject to welding deformation. Machining of the probe bore should be performed after the probe housing is installed in the piping.

*Trademark

What Are Your Advantages When You Select CSI?

Good People

Good people make good pipe. Many welders and fabricators at CSI have more than 10 years of service. Their safety record is a beacon in the industry.

The experienced welders and fabricators who produce jacketed piping spools in CSI shops also install those spools in our customers' plants. This system simplifies responsibility, promotes accountability, and maintains excellent team spirit.

Classroom and on-the-job training is the foundation of continuous improvement at CSI.

Visitors in the CSI shops usually see a variety of jacketed pipe under construction.

A recent expansion: A special facility for high precision fabrication such as polymer manifolds and piping.

Facilities

CSI facilities hold the following authorizations from the ASME National Board of Pressure Vessel Inspectors: "VR", "PP", "U" and "R".

The foremost engineering concerns have surveyed these facilities, commenting on the quality of welding and expert fabricating skills observed. We urge all of our customers to visit our facilities.

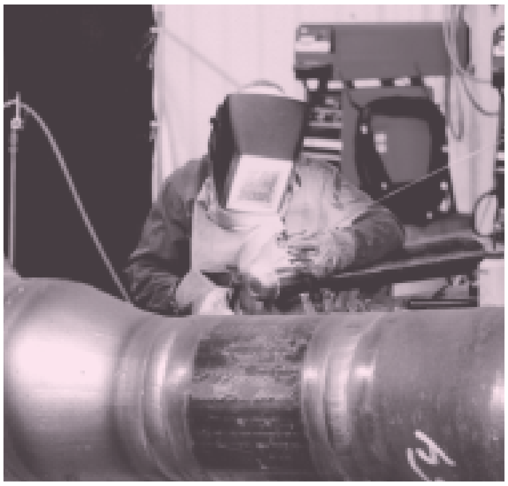
Know-How

Many customers depend on CSI's experience to design and fabricate jacketed piping. Some look to us for help in solving special heat transfer problems. Others count on our ability to assume full responsibility for their jacketed piping systems, starting with layout sketches through installation and start-up.

On any given day, piping projects progressing through our shops may be scheduled for sulfur service, polyester resin, sugar, Category M fluids, and several other processes.

This diversity of experience and know-how has a compelling benefit: We have the confidence, ability, and willingness to help you solve difficult process heating problems.

This CSI name tag on a spool of jacketed pipe is your assurance that it was produced by the most experienced team of fabricators in the business.



Testing and inspection are important tools used by CSI to assure quality fabrication; however, the welder's craftsmanship and execution is the primary ingredient for premium quality.

CSI has assumed responsibilities for projects in the U.S and overseas. From system layout to system sign-off, we are prepared to meet your challenges.

CSI has satisfied customers in every major chemical processing area of the U.S. We take special pride in taking care of our customers.

Quality

Radiographic examinations of CSI welders confirm acceptance rates above 99% for every inch of welding produced. This is a unique welding standard in the fabrication industry.

Many CSI craftsmen received comprehensive training in company-sponsored classes on welding, fabricating, math, blue-print reading, testing and safety. Our minimum quality standards are established by the ASME. We consistently exceed minimum standards.

CSI uses a variety of testing and inspection methods to verify quality: Radiography, magnetic particle testing, ultrasonic testing, dye penetrant testing, mass spectrometer testing, boroscopic examination, and visual examination.

Responsibility

CSI stands ready to assume full responsibility for your jacketed piping system – all of it or parts of it. If you want us to assume responsibility for heating your entire system, including all components, we will. We're prepared to accept responsibility for piping layouts, piping design, fit-ups and installations. We'll assume responsibility for the thermal performance of the overall system, including process heat-up. We'll assume responsibility for stress analysis. We'll assume responsibility for pressure drop analysis of the heating medium. From system layout to system sign-off, we make the assignment of responsibility easy, because whatever we make, we'll stand by it. And we'll stand by you.

Commitment

If our goal is to be the best at what we do, then our path is clear. Our customers must be satisfied with our products, our services, and our people. It is very important to us that our customers enjoy doing business with CSI. Our commitment: To take care of our customers to the very best of our abilities.

When you visit our facilities, we think you'll see this commitment in action throughout the organization. You'll see it reflected in the years of service, knowledge, and experience that our production people have achieved…in the level and diverse range of technical expertise offered by our engineering group…and in the product and process knowledge that our sales and customer service people willingly share with you.

Types And Sizes Of Jacketed Pipe

There are many different size combinations of jacketed pipe. Some of the more common types are charted in this section. Materials of construction vary widely, depending on the process, its temperature and pressure.

When the heating fluid is a vapor, the typical pipe size combinations are those shown in the left column. When the heating medium is a liquid, the typical size combinations are those shown in the right column.

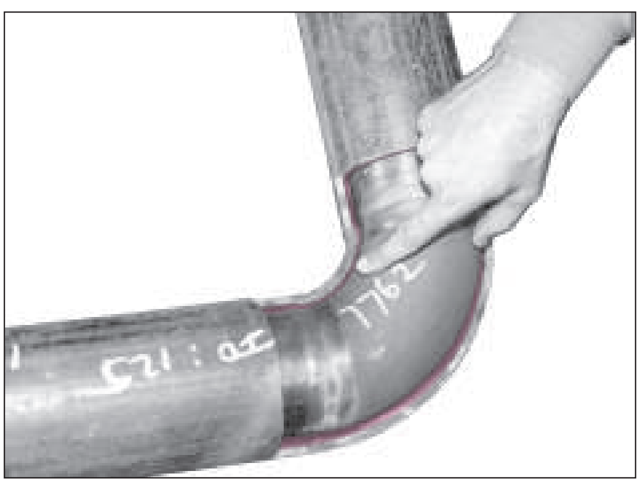
When different materials are used for the core pipe and the jacket pipe, the coefficients of expansion of the materials should be similar, or the process should have a relatively low operating temperature. All jacketed piping systems should be stress analyzed. All jacketed piping systems should be designed, constructed and tested in accordance with a recognized industry code, such as ASME B31.3.

Jacketed Pipe Sizes Vapor Heating Media (Core) x (Jacket)
1" x 2"
1-1/2" x 2-1/2"
2" x 3"
3" x 4"
4" x 6"
6" x 8"
8" x 10"
10" x 12"
12" x 14"

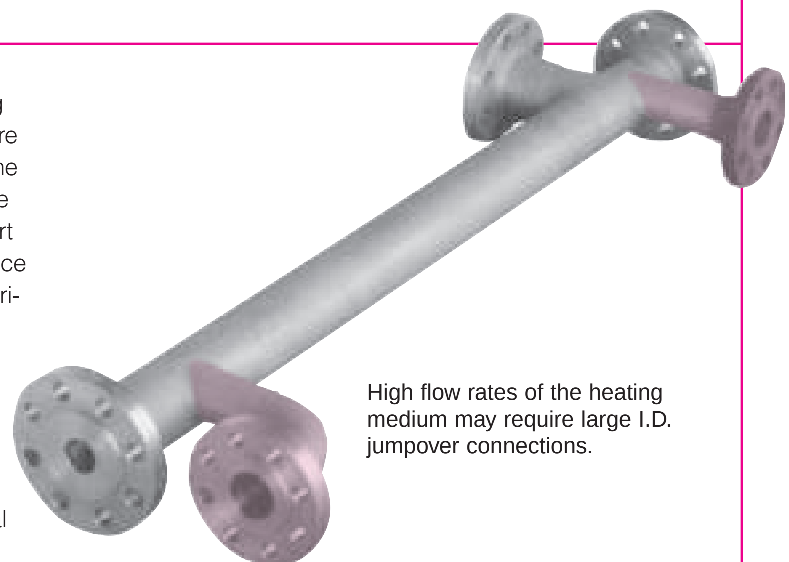
Jacketed Pipe Sizes Liquid Heating Media (Core) x (Jacket)
1" x 2-1/2"
1" x 3"
1-1/2" x 3"
2" x 4"
3" x 5"
4" x 6"
6" x 8"
8" x 10"
10" x 14"
12" x 16"

In applications that use a vapor for a heating medium (steam or hot oil) the jacket sizes shown above are relatively standard. These size combinations evolved in the processing industry because of the "closest" match for the centerline radii of long radius elbows for the core and short radius elbows for the jacket. Example: The annular distance between the exterior of a long radius 2" elbow and the interior wall of a 3" short radius elbow is constant because they both have a centerline radius of 3". For elbow sizes above 6" x 8", mismatch of the centerline radii requires modification to the either the core or the jacket elbow.

A couple of the smaller sizes (1" x 2" and 3" x 4") present fabrication challenges because of the mismatch in centerline radii. 3" x 4" piping, shown below, has a nominal annular clearance of 0.263" when the jacket is Sch. 40. In the throat of an elbow, however, the clearance drops to 0.2" producing high risks of fouling and stress failures. Eccentric reducers also present complex mismatches.



Mismatch of centerline radii between core and jacket elbows creates alignment problems during fabrication.



High flow rates of the heating medium may require large I.D. jumpover connections.

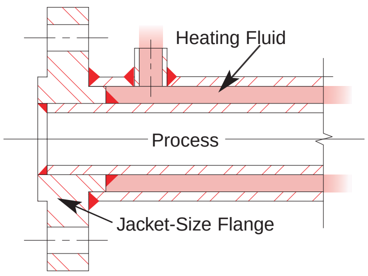
For systems using liquid heating media

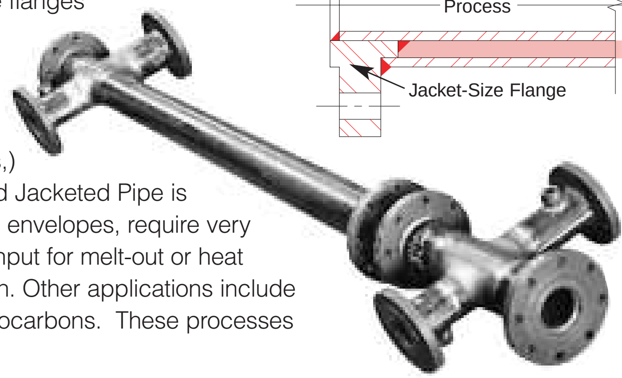
(water, water-glycol, hot oil, etc.), concentricity between the core and jacket may be very important for maintaining uniform process temperatures. When the temperature of the heating medium is only two or three degrees higher than the process, high flow rates of the heating medium are typical, requiring the turbulent-inducing flow that elbows promote. Therefore, it is important that designers look closely at system standards for concentricity, especially at fittings. High heating medium flow rates require thorough flow analysis of all jacket components. If pressure drop is a critical factor, jumpovers *must* be analyzed for flow-restricting properties. Pressure drops through jumpovers can be substantial.

When Sch.10 jacket piping is specified for the purpose of increasing annular space, it is important to specify "true" Sch.10 fittings, not fittings of a higher schedule with ends taper bored to the I.D. of Sch.10.

Standard Jacketed Pipe

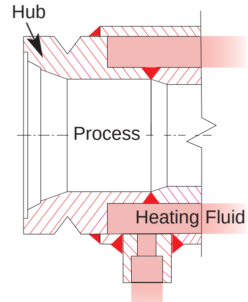
This type of piping generally is recognized as providing the most uniform application of heat to the process, as well as maintaining the most uniform processing temperatures. The jacket pipe is welded to the back of the flanges, which allows the heating fluid to heat the flanges as well as the process piping. This construction also requires the flanges be
“oversize” to allow sufficient room to tighten nuts on the backs of the flanges during pipe installation. To accommodate this space requirement, the flange size normally matches the size of the jacket pipe. Consequently, all equipment (valves, pumps, meters,) must utilize oversize flanges or special flange adapters. Standard Jacketed Pipe is used most frequently on processes that have narrow temperature envelopes, require very uniform temperature maintenance, or must have maximum heat input for melt-out or heat exchanger service. Batch-type processing is a typical application. Other applications include high-temperature, heat sensitive polymers, resins, and other hydrocarbons. These processes generally are in the low-to-medium pressure ranges.





High-Pressure Jacketed Pipe

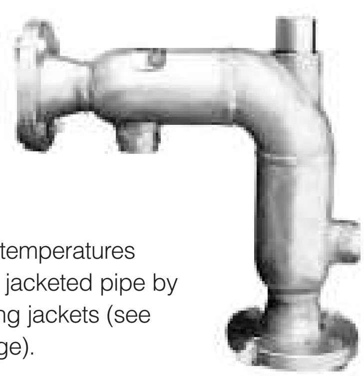
In many high-pressure applications, designers often opt to use hub-type (GrayLoc*) connectors with clamps for pipe-to-pipe connections in lieu of very heavy Class1500 or 2500 lb. slip-on flanges. Hub-type connectors are available in flow-through designs for transferring the heating medium directly from one pipe spool to another. In standard hub-type designs, as depicted right, the heating medium transfer for pipe-to-pipe connections must be accomplished with external jumpovers.



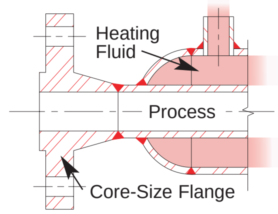
Swaged Jacketed Pipe

The jacket pipe terminates on the core pipe a short distance from the back of the flange by “swaging” or by the use of a bored, jacket-size welding cap. This construction allows the use of core-size flanges on both piping and mating equipment. Using equipment with standard, core-size flanges favorably impacts the cost of a piping system. Swaged Jacketed Piping is used on processes that have fairly broad temperature envelopes, require the fewest concealed welds to minimize the possibility of cross contamination, or need only normal heat-soak periods to achieve melt-out.

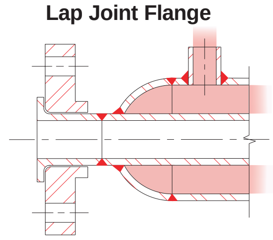
Note: Very narrow processing temperatures can be achieved with swaged jacketed pipe by the strategic use bolt-on heating jackets (see Hybrid jacketed pipe, next page).



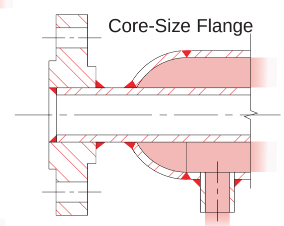
Welding Neck Flange



Stub End With Lap Joint Flange



Raised Face Slip-On Flange

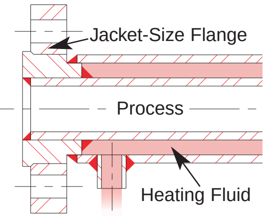


*Trademark

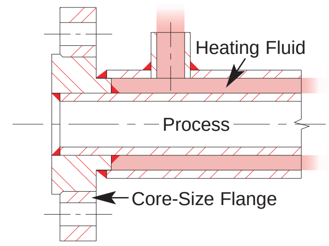
Insert Flanged Jacketed Pipe

There are two types of insert flanges, Reducing and Non-Reducing. The flanges consist of two separate parts: a hub – the insert – and a backing flange which is free to rotate (assuring bolt hole alignment during installation). In both types, the core pipe is welded to the front and back of the hub, as with any slip-on flange. The jacket, which heats the core pipe as well as the hub, is welded to a machined land on the back of the hub that matches the nominal size and schedule of the jacket pipe. Reducing Insert Flanged Jacketed Pipe has the same sizing requirements as Standard Jacketed Pipe. The backing flange size matches the nominal size of the jacket pipe. If equipment must mate with the Reducing Insert Flange, it requires oversize flanges. Non-Reducing Insert Flange Jacketed Pipe has the same sizing requirements as Swaged Jacketed Pipe – it allows the use of core-size equipment. Unlike Swaged Jacketed Pipe, it heats the back of the hub for more uniform temperature control. The Non-Reducing Insert Flange demands more dexterity of installation personnel than the Reducing Insert Flange. For this reason, many designers specify Reducing Flanges on pipe-to-pipe connections and Non-Reducing Insert Flanges on pipe-to-equipment connections.

Non-Reducing Insert Flange

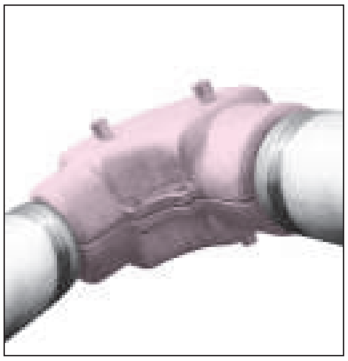


Reducing Insert Flange

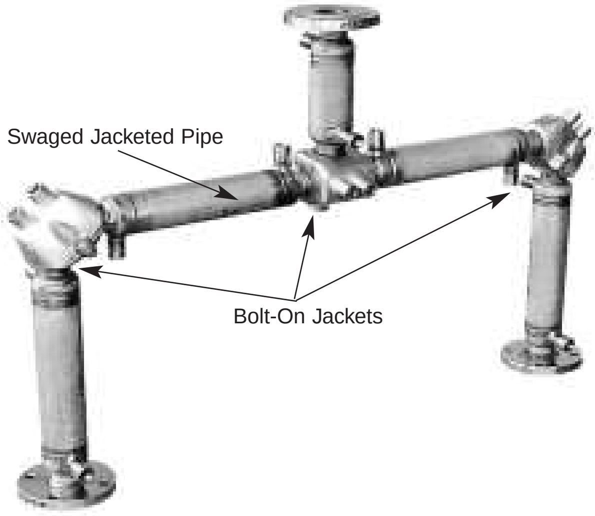


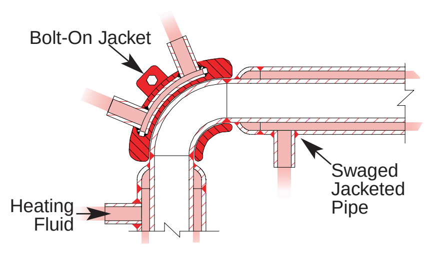
Hybrid Jacketed Pipe

This type of jacketed pipe, as the name implies, utilizes various products or fabrications to achieve specific processing or construction needs. For example, if the process requires very tight temperature control, yet project economies dictate the use of standard equipment, a typical solution is: Use Standard Jacketed Pipe for pipe-to-pipe connections and Swaged Jacketed Pipe or Non-Reducing Insert Flanged Jacketed Pipe for the pipe-to-equipment connections. Close temperature control of the core-size equipment can be maintained with bolt-on heating jackets (see CSI Bolt-On Heating Technology, page 21). Another example of the use of the Hybrid System is the elimination of concealed welds in the process piping where Swaged Jacketed Pipe is used for all straight runs and bolt-on jackets are used on all welded fittings – tees, elbows, reducers, and crosses (see examples below).



Large elbows in the Hybrid System use two-piece bolt-on jackets on fittings.



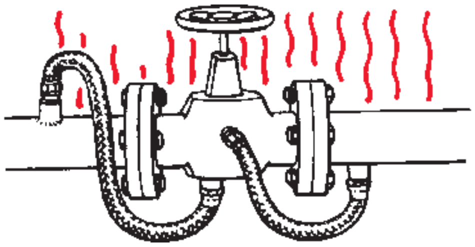


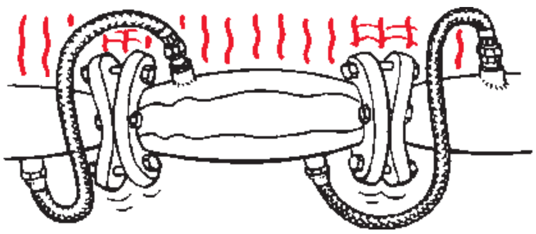
Design Considerations

Considerable analytical information is available to designers of piping systems. Very little of it, however, deals with jacketed systems. The following points are offered as general recommendations to be considered in overall system design. These suggestions are based on accepted practices within processing industries and our fabricating experience.

Design for a uniform temperature throughout the system.

Chill spots, even in moderate (250˚F- 350˚F) temperature systems, are the problems we most frequently encounter with jacketed systems. Temperature discontinuities at flanged connections, valves or fittings may cause product build-up and solidification at critical points.





Design for uniform heat stress.

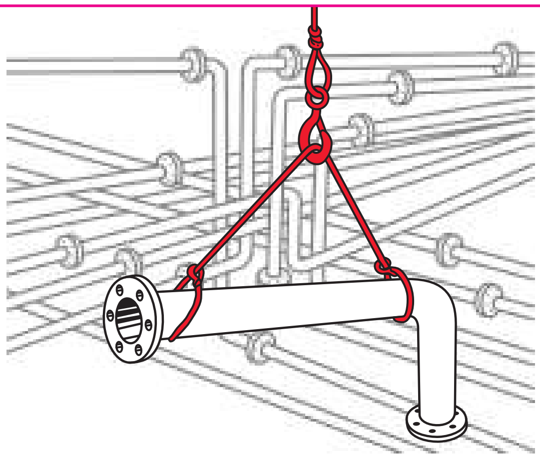
This is particularly important at temperatures over 250˚F and in batch-type service where the piping system is subject to frequent heat cycles. Under these conditions the core and jacket should be of the same material or have similar coefficients of expansion and thermal conductivities. For example, free-standing stainless steel pipe grows 2.6 inches per 100 linear feet when heated from 70˚F to 300˚F. Carbon steel pipe grows only 1.6 inches per 100 linear feet under the same conditions. Caveat: be very careful when mixing metals.

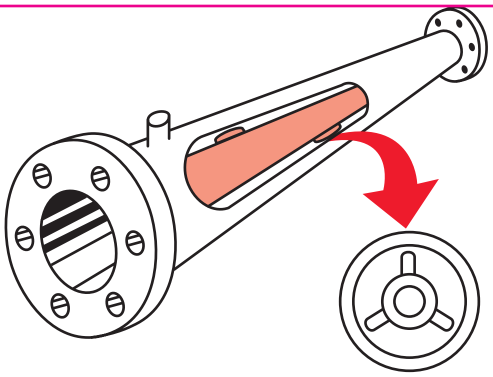
Consider the length of piping spools.

Lengths of jacketed pipe, which are to be shop fabricated and shipped to the site, are size limited by the carrier. Standard trucking carriers can accommodate spools approximately 40 feet in length, with adjacent legs in the same plane of no more than about eight feet in length. Usually, however, two other factors take precedence:

1) The piping density of the process area into which the spools are to be installed.

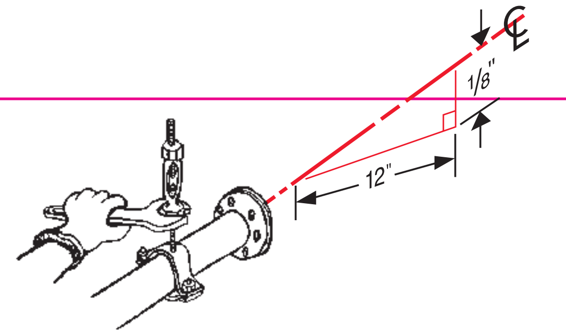
2) The material handling capability of installation crews. Where piping density or lifting capacities are primary considerations, maximum spool lengths of 20 feet are typical.





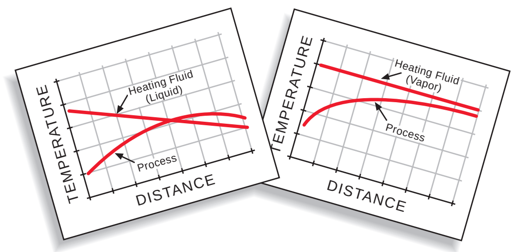
Keep an eye on spacer design and placement.

Spacers between the core and jacket, attached to the core, should have a nominal clearance of about 1/16" to maintain core concentricity within the jacket, and allow the jacket to slide over the core during fabrication. During operation, the clearance allows differential motion caused by heat stress. Incorrect placement of spacers can put extremely high specific stress at points of contact, sometimes resulting in catastrophic failure. See page 12 for additional design details on spacers.



Slopes and drains.

The slope of installed jacketed pipe should be gradual, about 1/8" per foot, to eliminate pockets and aid drainage of the heating fluid from the jacket. Slope is usually specified for all jacketed piping systems regardless of the heating fluid – vapor or liquid.

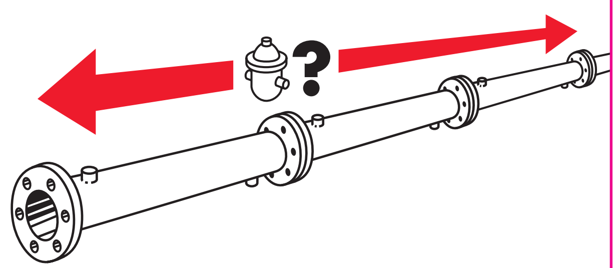


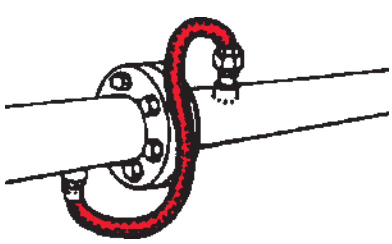
Heating fluid flow direction.

When the heating fluid is a liquid, flow direction depends on the thermal requirements of the process. If the jacketed piping is assigned heat exchanger duty, flow usually is countercurrent to the process – to put maximum energy into process, or remove it. When temperature maintenance is the primary consideration, concurrent flow is normally the preferred flow direction. With vapor heating media, slope will usually dictate the flow direction.

Energy in, energy out.

The length of jacketed runs or the number of spools per single supply of heating fluid should be carefully analyzed. There are no shortcuts or accurate rules of thumb. Practically every application has widely varying parameters: Type and thickness of insulation, degree days, type and quality of heating medium, heating requirements of the process, quantity of energy absorbed by the process, frequency of shutdowns and startups, and several other factors.





Jumpover sizes.

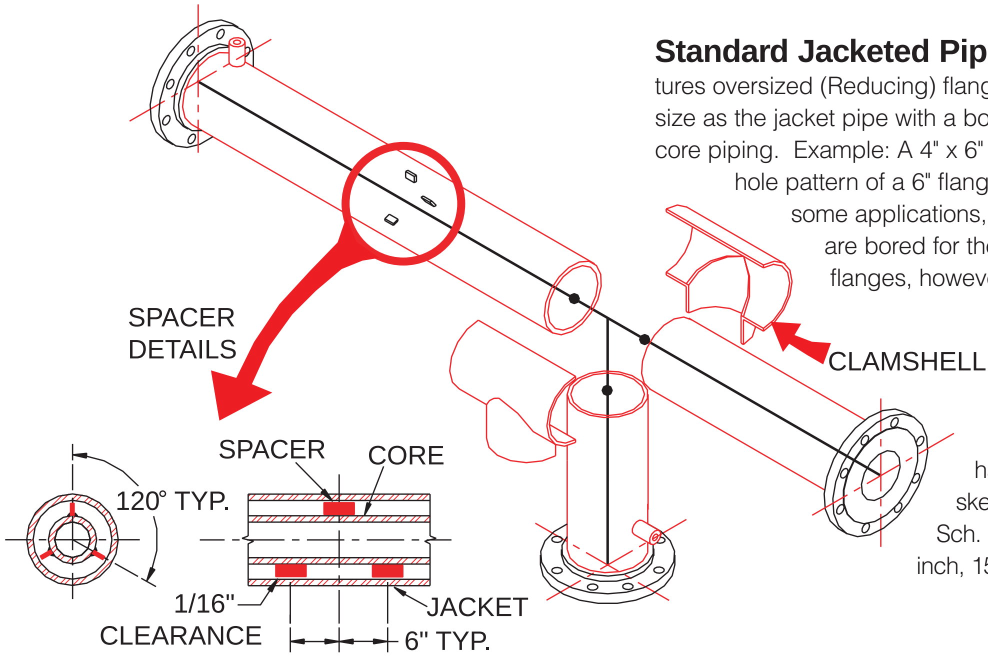
Jumpovers for steam service are usually 1/2", 3/4" and occasionally 1". Jumpovers for liquid heating media typically are 3/4" or 1". Where high flow rates of liquid media are used to maintain narrow, precise temperatures of the process, jumpovers as large as 3" are not uncommon. CSI offers standard flexible metal jumpover hoses in various sizes and pressure ratings. Many types of end connectors, including flanges, are available. CSI also provides rigid piping or tubing jumpovers. Pressure losses in jumpovers used with liquid media should be considered. Pressure drops in flexible metal hoses are higher than drops through rigid jumpovers. Note: Pressure drops through all types of jumpovers may be a significant portion of the system pressure drop.

Making jacketed pipe to the right standards.

As noted previously, design information on jacketed pipe is relatively scarce. ASME B31.3 and the ASME BPV Code cover specific welding details, inspection and testing, and design data on acceptable metals. Many large processing firms and engineering houses have developed specifications relative to certain services. CSI has developed a "generic" specification to help design teams pick and choose from a variety of constructions. The document contains more than 70 reproducible fabrication details. It also contains a draft specification that covers system description, design and fabrication, examination and testing, and documentation requirements. Customers who choose to involve CSI early in the design phase are furnished with complimentary copies.

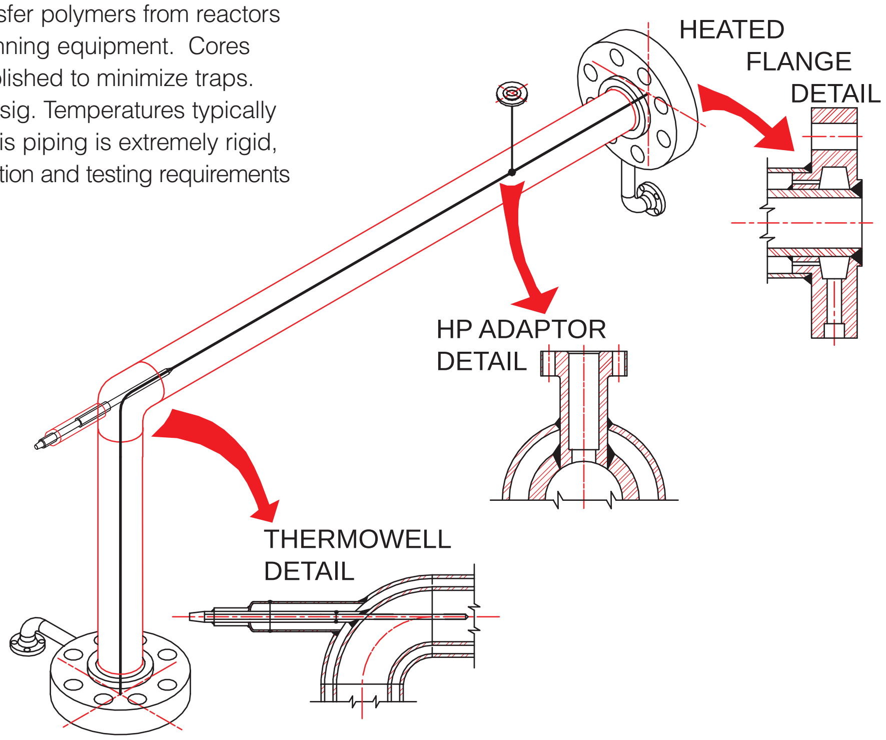
Typical Construction Details

Practically every jacketed piping system has construction details particular to the application. The details may range from unique flanges or fittings to special core taps and spacer designs. The topics discussed here are of a general nature. The construction details shown are typical of conventional designs. Note that most flange designs are shown on pages 8 and 9. The construction details shown are similar to detailed shop drawings developed by CSI designers for specific projects.



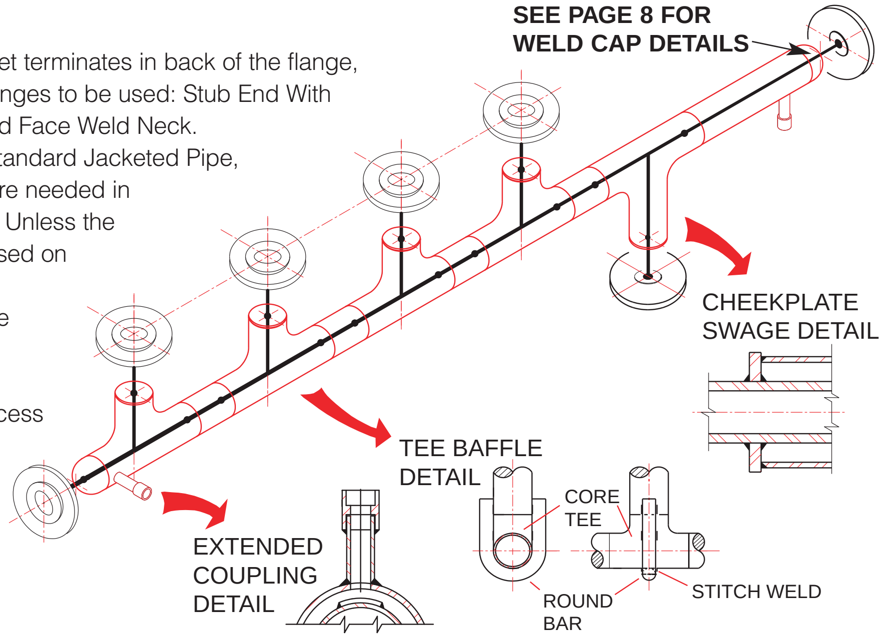
Standard Jacketed Pipe, or *fully* jacketed pipe, features oversized (Reducing) flanges which are the same nominal size as the jacket pipe with a bore the same nominal size as the core piping. Example: A 4" x 6" Reducing Flange has the bolt-hole pattern of a 6" flange and the bore of a 4" flange. In some applications, blind flanges of the jacket size are bored for the core size. Blind-and-bored flanges, however, do not have a raised hub on the back which make them unsuitable in many applications. Note: The oversized flanges require that mating components have oversized flanges. The spool sketched at left is a 4" x 6" assembly, Sch. 40 core and jacket, with three, 6-inch, 150 lb. reducing flanges.

Heavy-Wall Jacketed Pipe Construction is used throughout the polymer industry to transfer polymers from reactors to filters, extruders, pelletizers, and spinning equipment. Cores often are Sch.160 or XXS and highly polished to minimize traps. Process pressures may exceed 3000 psig. Temperatures typically range from 550˚F to 750˚F. Because this piping is extremely rigid, precise fabrication is mandatory. Inspection and testing requirements also must be very rigid.

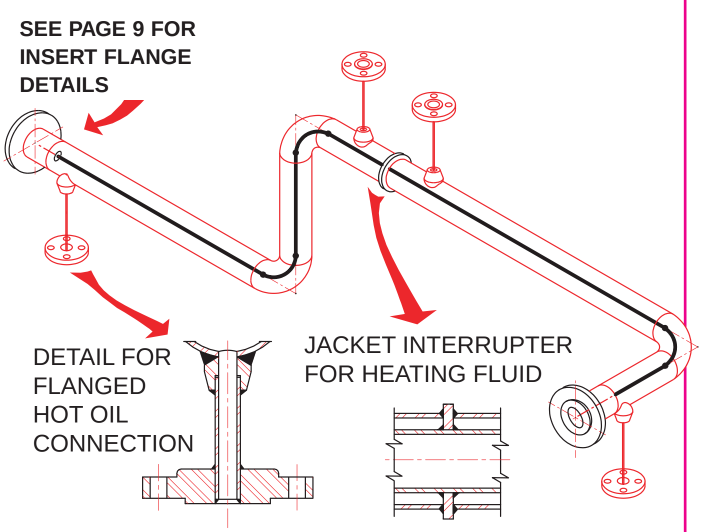


Swaged Jacketed Pipe. The jacket terminates in back of the flange, allowing a variety of line-size (core size) flanges to be used: Stub End With Lap Joint, Raised Face Slip-On, and Raised Face Weld Neck. Swaged Jacketed Pipe is not as rigid as Standard Jacketed Pipe, which may be an advantage when loops are needed in the system to absorb thermal expansions. Unless the selection of Swaged Jacketed Piping is based on historical process performance, thermal analysis of the unjacketed area in back of the flanges needs to be performed. CSI has analytical tools to help designers review the thermal requirements of the process in this type of jacketed system.

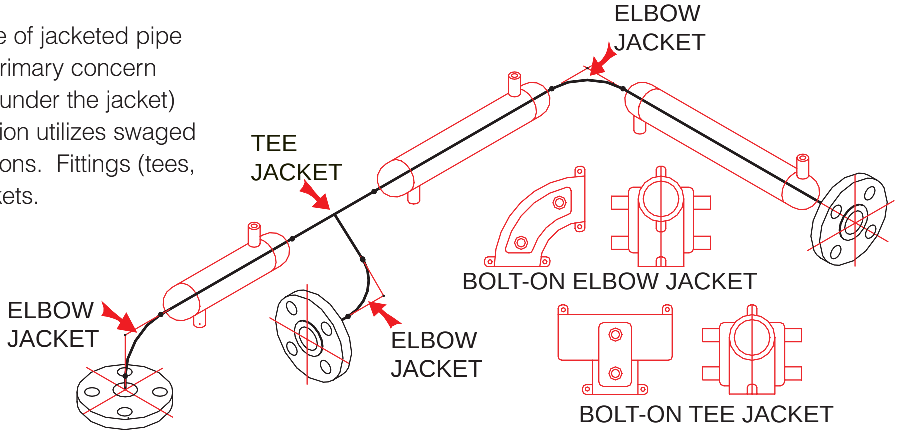
A distinct economic advantage of Swaged Jacketed Pipe is the use of line-size flanges which permits the use of off-the-shelf valves, pumps, instrumentation and other equipment.



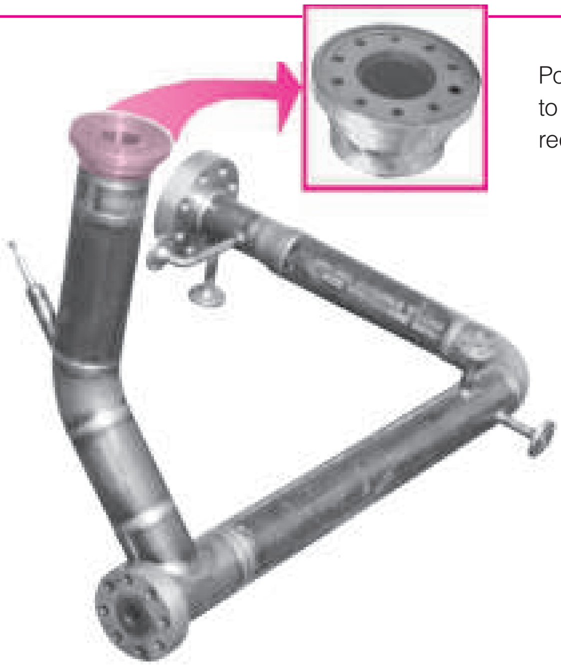
Insert Flanged Jacketed Pipe. Insert flanges utilize a rotatable flange on a hub similar to a stub end and lap joint flange. With insert flanges, however, the jacket can be extended to the back of the flange, thereby heating the flange. Two types of insert flanges used frequently in jacketed pipe applications are Reducing and Non-Reducing. Reducing Insert Flanges have bolt hole circles corresponding to the jacket size. Non-Reducing Insert Flanges have bolt hole circles corresponding to the core piping.



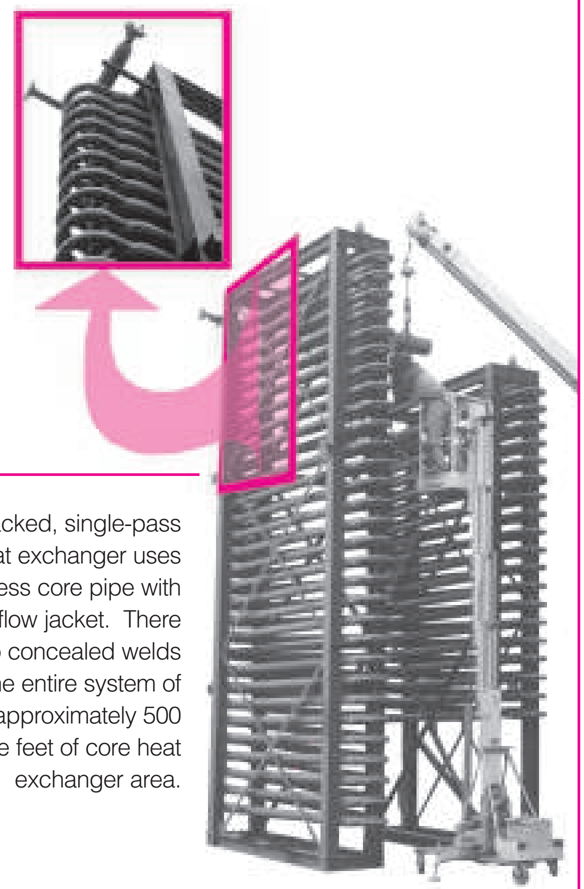
Hybrid Jacketed Pipe. This type of jacketed pipe is used where cross contamination is a primary concern and eliminating concealed welds (welds under the jacket) has a high design priority. The construction utilizes swaged jacketed construction on all straight sections. Fittings (tees, elbows, etc.) are heated with bolt-on jackets.



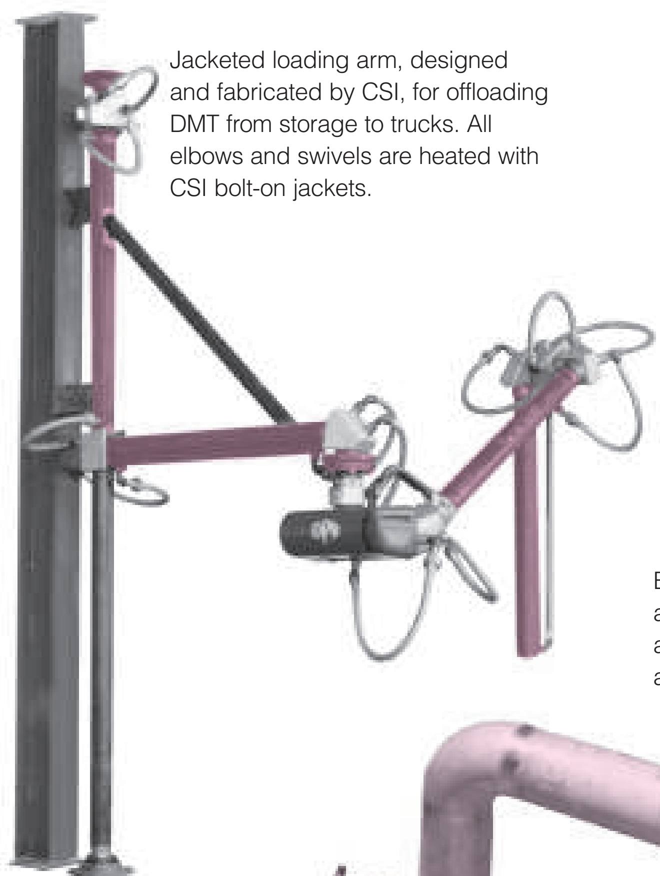
Fabrication Examples



Polymer piping, left, uses Class1500 lb. and 2500 lb. flanges to mate to system equipment. Flow-through, high-pressure hubs (no jumpover required) are used to mate with other polymer transport piping.

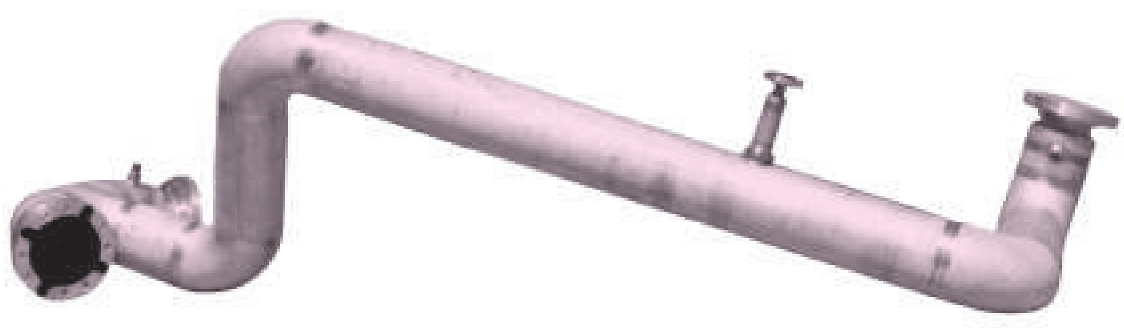


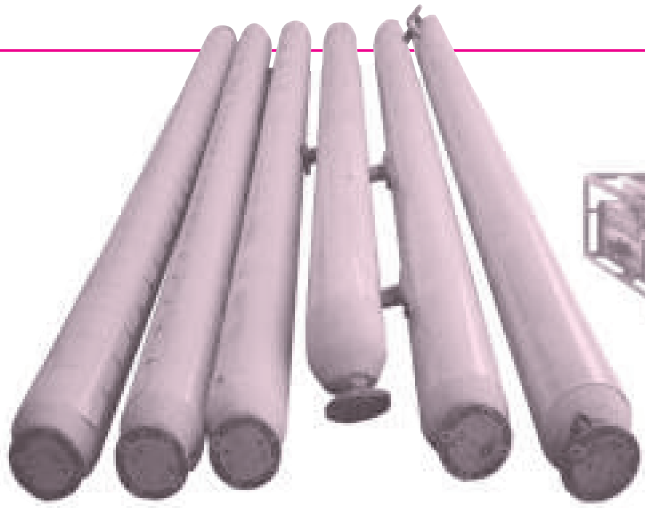
A stacked, single-pass heat exchanger uses seamless core pipe with a full-flow jacket. There are no concealed welds in the entire system of approximately 500 square feet of core heat exchanger area.



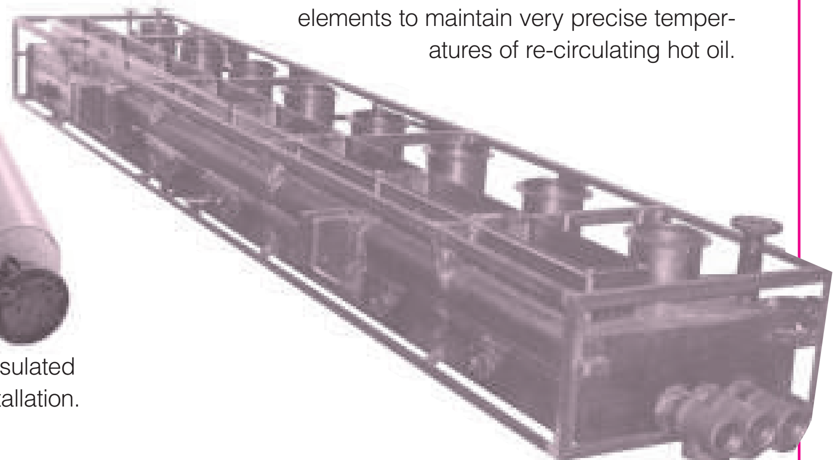
Jacketed loading arm, designed and fabricated by CSI, for offloading DMT from storage to trucks. All elbows and swivels are heated with CSI bolt-on jackets.

Building jacketed pipe in three dimensions (X, Y and Z planes) is a challenging test of the fabricator’s skills. Add “rolling offsets” and slope for drainage – while maintaining concentricity of core and jacket – demands experience that matches the skill.

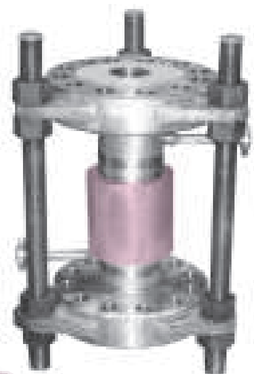




An eight-position polyester polymer manifold uses internal electric heating elements to maintain very precise temperatures of re-circulating hot oil.

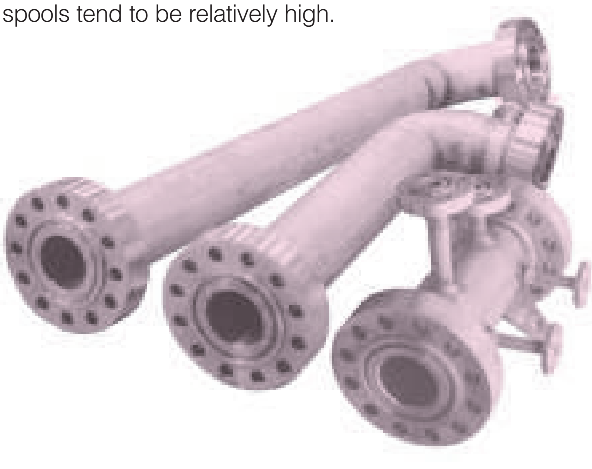


Jacketed pipe fabricated in CSI shops also can be insulated in our shops and shipped to the jobsite, ready for installation.

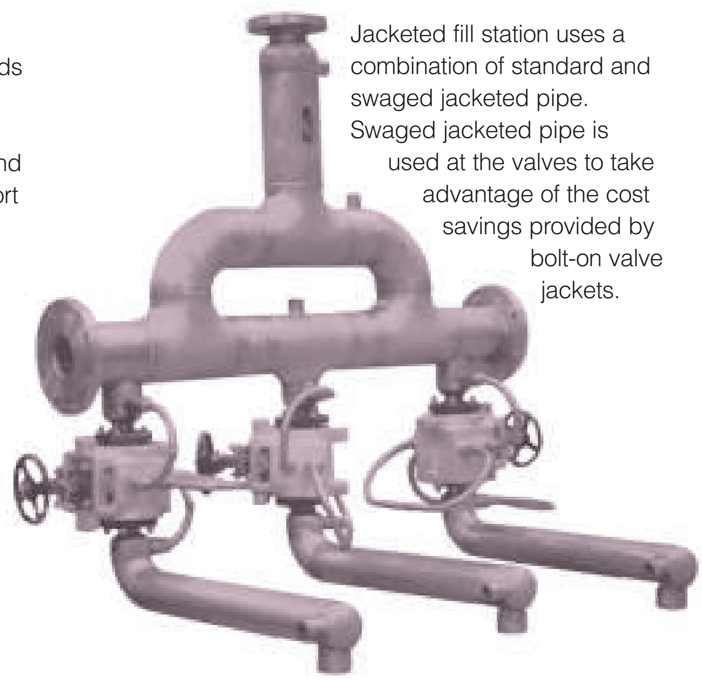


The 3" x 4" jacketed spool, left, has an integral expansion loop that safely compensates for about 0.5 inches of thermal growth. The jacketed expansion joint, left, compensates for 1.07 inches of axial movement with a design core pressure of 2500 psig.

High-pressure, heavy-wall jacketed pipe spools for polymer transfer near extruders, filters, screen changers and manifolds are often relatively short, as shown right. They are short because piping spools usually are the last pieces of equipment installed into "dense" equipment areas where safety and ease of handling are challenges. Heat stresses in these short spools tend to be relatively high.



Jacketed fill station uses a combination of standard and swaged jacketed pipe. Swaged jacketed pipe is used at the valves to take advantage of the cost savings provided by bolt-on valve jackets.



CSI Engineering Services

Jacketed pipe is very unforgiving. Mistakes are difficult and expensive to correct.

Several years ago, after learning this lesson the hard way, we promised ourselves to expand our engineering capabilities and our process heating knowledge. It was obvious that we needed to be on a higher technical plateau, to make sure our customers were getting their money's worth.

Today, we don't have all the answers, to be sure. We do have, however, confidence in our products, our craftsmen, and in our engineering abilities to help our customers optimize their jacketed piping systems. Our engineering staff stands ready to:

1. Make cost-saving suggestions on material selections and types of jacketing needed.
2. Help designers find the optimum piping configuration for the process.
3. Assist with pressure drop analysis of process heating fluids.
4. Perform macro and micro system thermal analysis, considering processes, heating fluids, and pipe construction details.
5. Perform stress analysis on piping systems and individual spool designs.
6. Provide on-site review of piping layouts and routing, and heating medium routing and tie-ins.
7. Organize and execute turnkey piping projects, from concept to customer sign-off.

We are prepared and committed to give jacketed piping the attention that *critical* equipment deserves.

Everything Starts With A Quotation.

Preparing quotations at CSI is similar to methods used by all fabricators. When the customer's bid package comes in, it is assigned to an engineer or designer who starts the review process of specifications and drawings. Depending on the complexity, several reviews by different CSI personnel may be used to make sure there are no surprises.

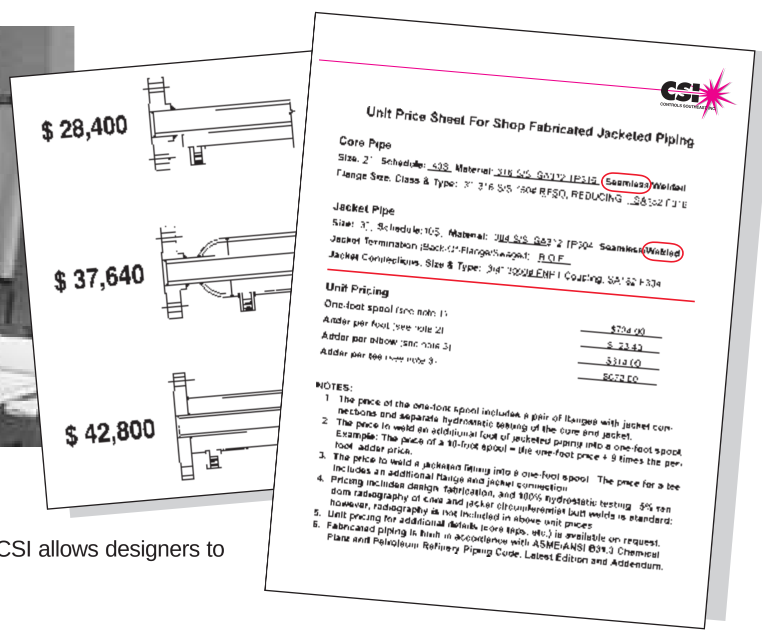
Material prices are obtained from takeoffs cycled through Purchasing. Manhours for fabrication and welding, engineering, inspection and testing, and painting, if required, are estimated.

A review team meets to go over the accumulated numbers. The team considers alternate material choices, fabrication methods, even alternative designs that may cut expenses out of the project. The customer's need date in light of CSI's production schedule is also reviewed. The quotation then goes to the customer. If the review team thinks that alternate suggestions have merit, these suggestions are included in the quotation with approximations of potential savings.

For fast-track projects proceeding without completed *isometric* or *plan & elevation* drawings, CSI has developed a simple, very accurate unit pricing schedule that allows the customer's design group to quickly and easily determine the final price of any jacketed spool that contains a variety of fittings, connectors, and instrument taps. The unit pricing information is based on the customer's design criteria of materials, schedules and operating conditions and any unique design details.

Depending on the customer's needs, CSI prepares quotations for a variety of engineering services, ranging from on-site piping layouts and routings to complete turnkey packages. When work scopes are not sufficiently defined to provide lump-sum quotations, unit or manhours pricing can be provided. Our preference, however, is to provide our customers with fixed, lump-sum proposals whenever practical.

(Above) A CSI review team considers alternate materials and fabrication methods that may save customers money.



(Right) A simple, easy-to-use pricing schedule developed by CSI allows designers to quickly determine the price of complex jacketed pipe spools.

Pay Attention To Stress.

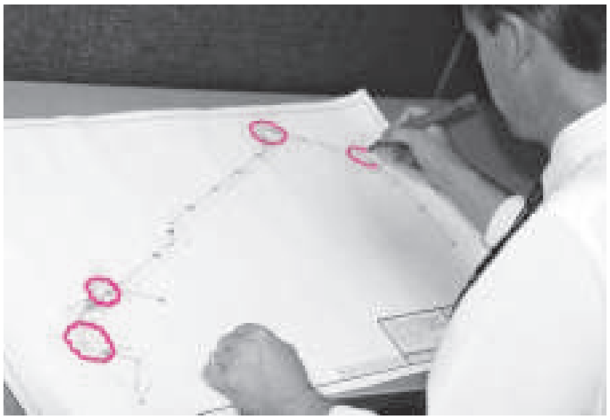
As a general rule, all jacketed piping systems should be stress analyzed. After CSI receives system drawings we review them, looking for potential trouble spots. We do not perform stress analysis unless specifically authorized by the customer. However, when we see conditions that we think deserve closer scrutiny, we notify the customer of our observations, suggesting that the customer double check the condition with the system designers, or authorize CSI to proceed with analysis. The following conditions are typical of the types of design conditions that "raise red flags" at CSI:

- Tight pipe routing with few changes in direction that may result in a very rigid piping system without enough flexibility.
- Piping construction that uses different materials for the core and jacket. The differential thermal expansions of the materials may cause unacceptable stress levels.
- Systems with wide temperature differences between the core and jacket. Example: Buried containment piping with the core at elevated temperature and the jacket at or near the temperature of the earth.
- Piping systems that operate in cyclic service (as in batch processes).
- Piping arrangements that appear to place lateral or axial loads on equipment nozzles that may not be capable of withstanding the loads. Examples: Pumps, reactors, vessels on load cells, heat exchangers, and filters.
- Unusual construction details that may have been dictated by equipment locations with unusual tie-ins. Example: Jacketed spools with little or no tangential runouts on elbows.

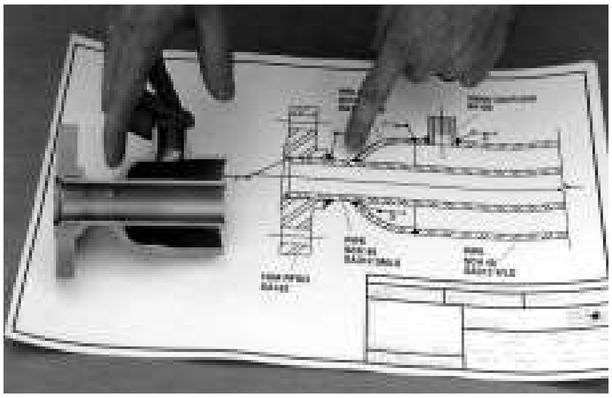
Depending on the service conditions, individual design details such as flange attachments, jacket terminations, core taps, spacer design and locations may need scrutiny. This need for scrutiny goes up with increasing service temperatures or widening temperature differential between the core and jacket.

The point to remember is that when jacketed pipe is considered to be critical equipment, it needs to be stress analyzed – whether the intended use is asphalt transfer or Category M service.

Good stress analysis is an important factor in designing jacketed piping systems. CSI engineers use traditional analysis software supported with two equally important elements: Knowledge and experience.



All system drawings released to CSI for production of individual spool drawings are reviewed by CSI project engineers for potential stress problems.



Individual weld joints of specific constructions need stress analysis (*micro analysis*) when the likely possibility of extreme operating conditions exists. Examples: Processing temperatures substantially exceeding heating medium temperatures, and traps of condensate causing wide temperature differential between core and jacket.

Where Does The Heat Go?

Process Fluid
Molecular Wt.
Specific Gravity
Specific Heat
Flow rate
Entrance temp.
Viscosity
Conductivity
Heating Medium
Type & Properties
Temperature
Pressure
Flow rate (liquid)
Ambient Temp.
Insulation
Type
Thickness
Piping Materials
Core & wall thk.
Jacket & wall thk.

Jacketed piping may be considered a system that maintains a process temperature, or it may be considered a system of single-tube heat exchangers.

If the process picks up or gives up heat, the system is performing the function of a heat exchanger.

Normally, jacketed piping systems are designed for temperature maintenance. That is, the process temperature should remain very uniform as it flows through the core piping. It needs to operate as a heat exchanger only during start-up or recovery from emergency shut-downs.

In reality, the dynamics of jacketed piping during normal operation are truly those of a heat exchanger, with the process accepting and giving up incremental energy based on the temperature differences between it and the heating fluid. The rate of heat transfer to and from the process, of course, depends on several factors such as film coefficients, velocities, and thermal conductivities of the several components.

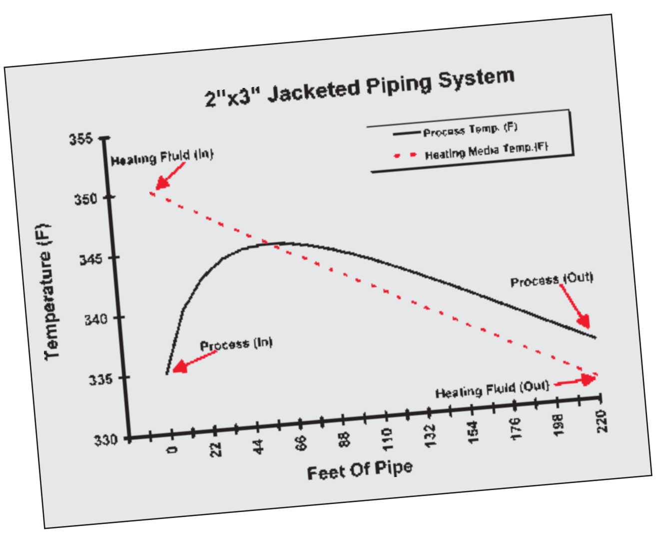
To illustrate, consider a 2" x 3" jacketed piping system approximately 220 feet long. The process is a hydrocarbon resin. System properties and operating data needed for analysis are listed in the accompanying table, center. Assume a water-glycol heating medium.

Using finite difference modeling techniques developed in-house and commercial analytical software, CSI engineers analyze heat transfer mechanisms that occur in systems like this, to help process designers establish specification and procedural parameters. The graph below depicts a system analyzed with the heating medium flowing concurrently with the process. Note that the process temperature increases and becomes hotter than the heating medium. Although the process temperature leaving the system equals the entrance temperature, a 3% process temperature swing occurred. If a material is heat sensitive and unable to tolerate temperatures above a certain value, the heating medium temperature must be reduced. In concurrent flow, this type of exchange mechanism occurs routinely. And the level of thermal analysis needed depends on the sensitivity of the process to temperature, or "time-at-temperature."

As a precaution, we also analyze no-flow conditions to see what happens when process flow stops.

The modeling tools used by CSI demonstrate the dynamic temperature profiles of systems under various operating conditions. Heating medium temperatures, flow patterns, and process flow rates can be tested. Similar modeling tools have been developed to study the thermal performance of specific piping details with certain processes and heating media.

These modeling services are available to CSI customers. We recommend that designers consider these services whenever process temperature envelopes are very narrow, equipment layouts dictate specific constructions that may create chill spots, and when newer processes must be incorporated into older systems with fixed heating medium parameters.



CSI has developed computerized heat transfer tools that can aid designers in establishing heating specifications and procedural parameters for piping systems.

The finite difference heat transfer modeling used by CSI incorporates the various fluid properties of the medium and process, as well as specific construction techniques.

Pressure Drops In Jacketed Piping.

Pressure drop analysis can be an arduous task in a jacketed piping system, especially when narrow temperature windows must be maintained. Often, the cumulative pressure drop through heating medium jumpovers is greater than the drop through the piping spools. This results mainly from the sharp angles the heating fluids must traverse as they enter and exit the jacketed spool.

To arrive at an optimal design, a thermal analysis of the system may be necessary, to determine not only how much heat is given up to the atmosphere, but also how much heat is absorbed by the process. Determining accurate heat loads is important for assessing accurate heating medium flow or capacity requirements.

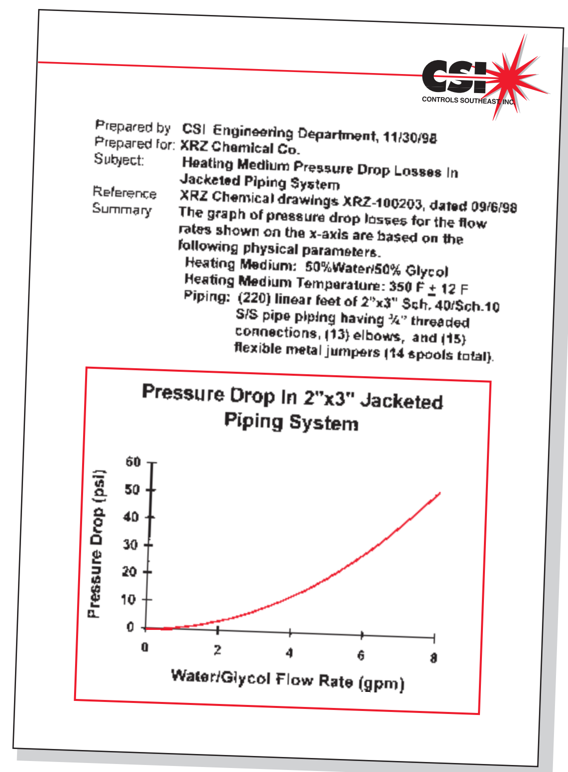
In liquid heating systems, designers have several pressure-reducing options to consider when pump heads and capacities are restricted:

1. Increase the nominal size of the jumpover.
2. Use tangential entrances to feed the heating fluid into the spool.
3. Increase the size of the jacket pipe, allowing lower flow rates (and lower pressure drops) through the core/jacket annulus.
4. Increase the number of circuits feeding the system from the main heating fluid header.

In systems using vapor as the heating medium, circuit lengths, trap size, start-up demand, as well as total heat loads during equilibrium operating conditions need to be considered.

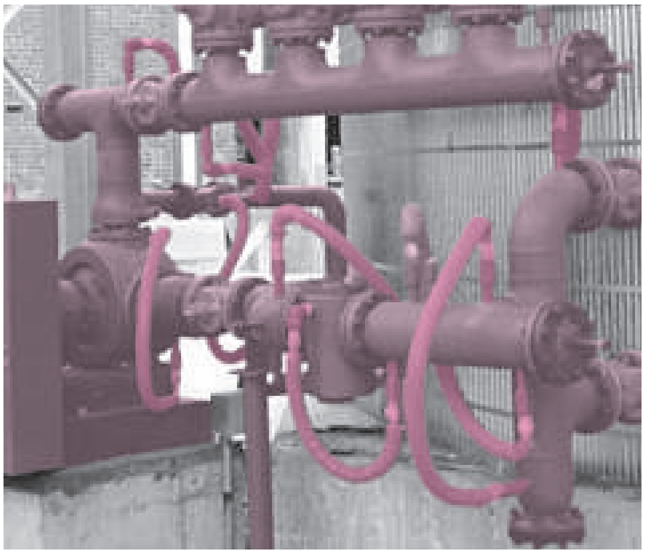
The CSI engineering staff conducts on-going tests to determine heating medium pressure drop losses through various components used in process temperature control.

Pressure drop analysis, pump and trap sizing, circuit layout, and jumpover design are services the CSI engineering staff routinely perform. The cost of these services is nominal, based on the complexity of the system and the degree of documentation required.

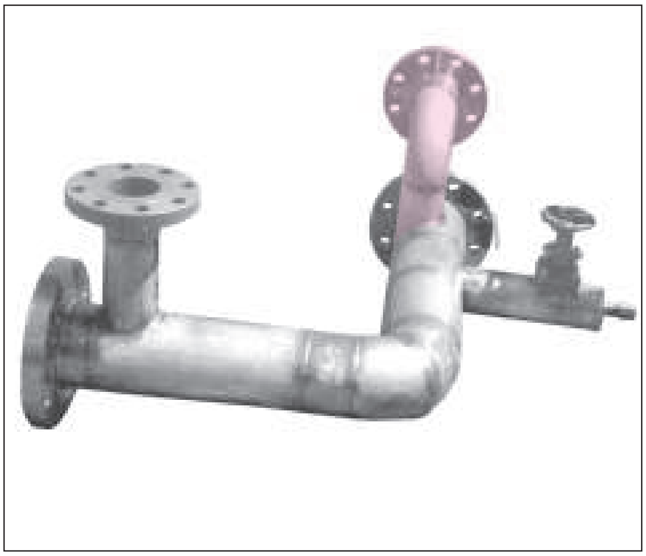

CSI
CONTROLS SOUTHEAST, INC.

Prepared by: CSI Engineering Department, 11/30/98
Prepared for: XRZ Chemical Co.
Subject: Heating Medium Pressure Drop Losses In Jacketed Piping System
Reference: XRZ Chemical drawings XRZ-100203, dated 09/6/98
Summary: The graph of pressure drop losses for the flow rates shown on the x-axis are based on the following physical parameters.
Heating Medium: 50%Water/50% Glycol
Heating Medium Temperature: 350 F ± 12 F
Piping: (220) linear feet of 2"x3" Sch. 40/Sch.10 S/S pipe piping having ¾" threaded connections, (13) elbows, and (15) flexible metal jumpers (14 spools total).

CSI has developed data and procedural techniques for approximating pressure drops in jacketed piping systems, based on component flow tests and conventional mathematical models.



The pressure drop through jumpover connections can be a significant component of the system's total head requirement.



This 3" x 5" jacketed spool uses a 2.5" tangential inlet jumpover to minimize head loss.

CSI Turn-Key Services

Rapidly changing business conditions have compelled many processing companies to focus their energies on reducing production costs... and engineering staffs. Similarly, many engineering houses, in efforts to speed up project response times and maintain maximum flexibility, are streamlining their project management teams, looking to outside sources for specialized talents.

In this fluid business climate, CSI stands ready with an array of highly specialized skills and capabilities that help customers keep jacketed piping projects on time, and on budget.

Our commitment to ourselves and to the processing industry is to design the right jacketed piping systems, then fabricate and install them. From start to finish, we willingly accept responsibility for your jacketed piping system. Our basic focus is simple: run a successful business by satisfying our customers.

CSI turn-key projects range in dollar value from $35,000 to $3.5 million. The projects cover many constructions, from heavy-wall polymer piping to light-wall tubing for dairy products. We have ambitions to assume responsibilities for larger projects.

We urge our customers and potential customers to visit our shops – to see first hand our commitment in action. To see and talk to...

- An engineering staff with the experience to anticipate a vast assortment of problems relating to jacketed pipe – a staff that works with heated processes every day; month by month; year by year.
- Skilled, capable fabricators and welders who build and install jacketed piping systems, and who individually have recorded thousands of safe manhours in developing the highest standards of craftsmanship.

Some customers tell us that it's CSI's demonstrated knowledge, experience and craftsmanship that give us an edge. In reality, any advantage we might enjoy, however small, comes from hard work toward one purpose: a satisfied customer.

CSI installation crews are the same team of engineers, fabricators, and supervisors who design and produce jacketed piping systems in our shops at Charlotte, NC, USA.

CSI has provided turn-key installations for a wide range of heated processes: Acrylic acid, bitumens, BPA, benzoic acid, caprolactam, DMT, EVA, phthalic anhydride, nylon and polyester polymers, viscose, sulfur, and several food items. All of these projects were performed under lump-sum contracts. The photo above and the photo left are typical examples of CSI turn-key projects.

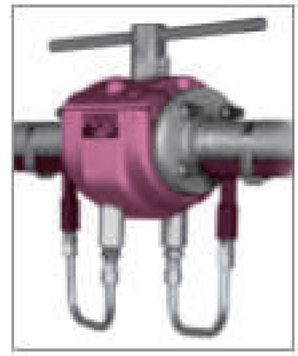
CSI Bolt-On Heating Technology

In addition to Jacketed Piping Systems and Products, CSI offers another process heating technology: The Bolt-On System.

There are two product groups that make up the CSI Bolt-On Heating System:

- **ControHeat Bolt-On Jackets** for valves, pumps, meters and other components.
- **ControTrace Heating Elements** for piping, tanks, and vessels.

All of the design and engineering services offered with CSI Jacketed Piping Systems are also available with CSI bolt-on technology.



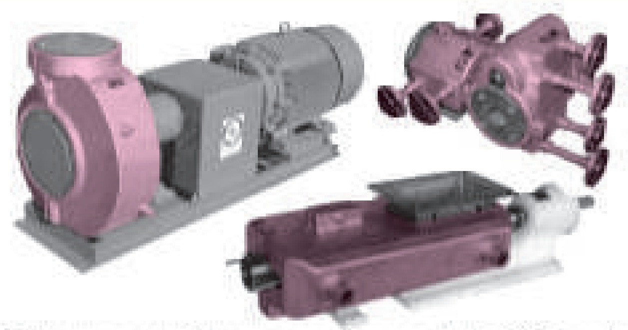
ControHeat Jackets are made of cast aluminum. Embedded in the aluminum is a steel pressure chamber that is designed and tested in accordance with the ASME Boiler and Pressure Vessel Code, Sec. VIII, Div 1.

ControTrace Elements are produced from SA178 Gr. A Boiler Tubing. These products also are designed and tested in accordance with Code requirements.

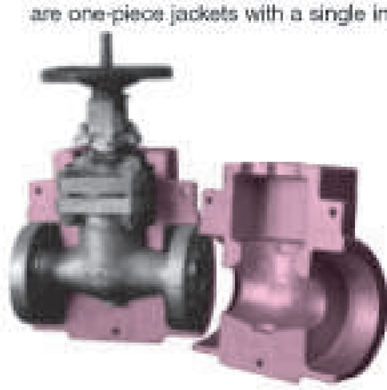
Illustrated below are typical applications for ControHeat Jackets and ControTrace Heating Elements.

ControHeat Jackets for Process Component

Bolt-On jackets keep valves heated flange to flange. Shown above are one-piece jackets with a single inlet/outlet for heating media.



Major pump manufacturers are well represented in CSI s inventory of jacket patterns.

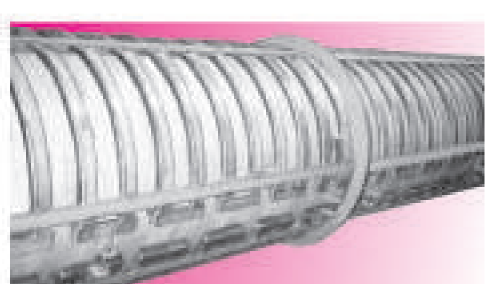


Depending on the size and configuration of the valve, the jacket may be a two-piece design with a pressure chamber in each jacket half, as illustrated here.

Meters and instruments are easily heated with bolt-on jackets.

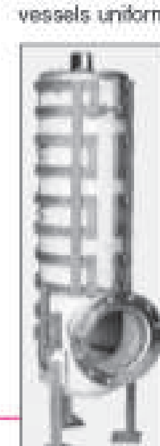
ControTrace Heating Elements for Piping and Vessels

The high thermal capacity of ControTrace Elements provides melt-out capability for many processes.

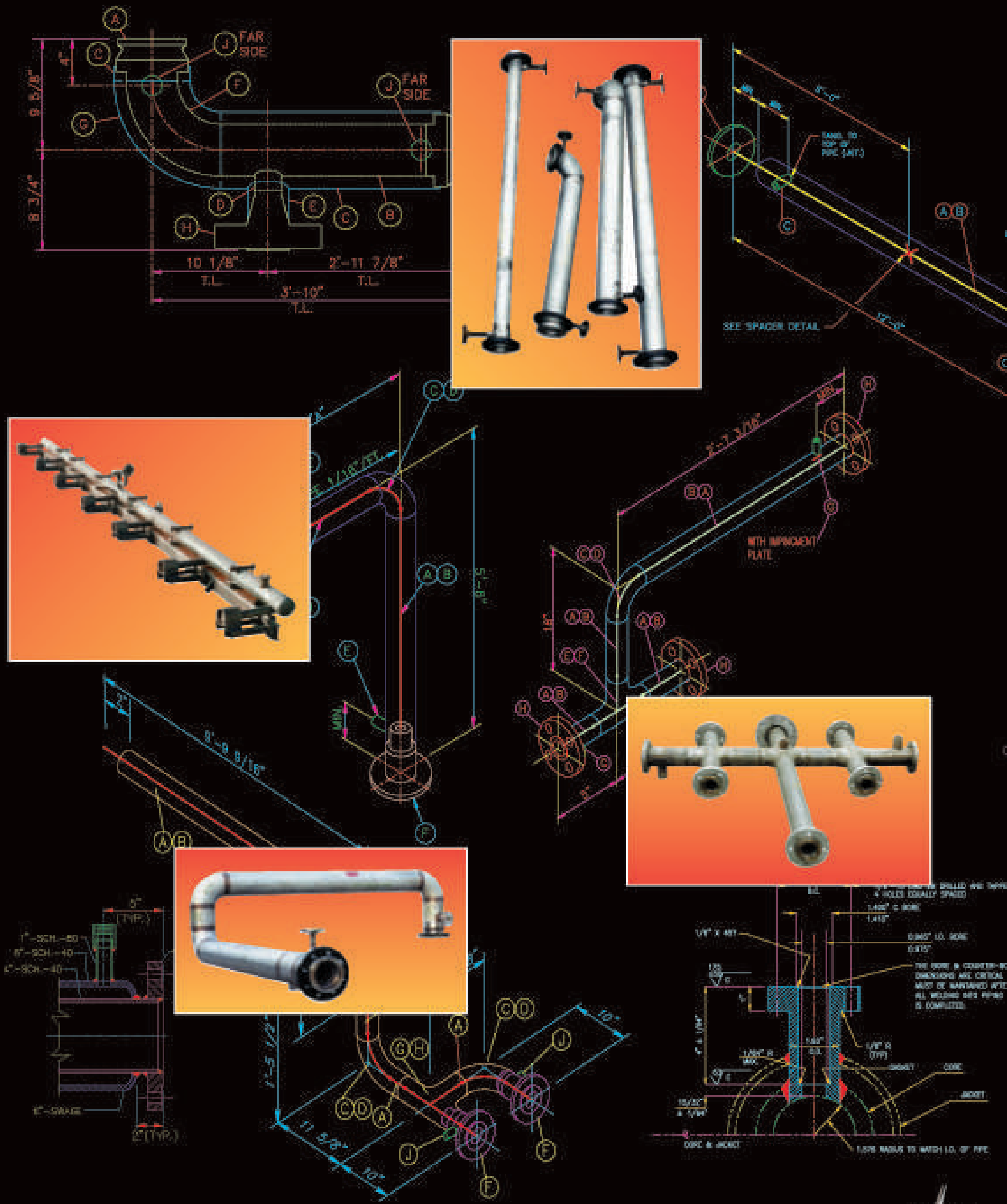


By using multi-channel ControTrace elements to heat large piping, in lieu of full jacketing, a CSI customer saved thousands of dollars.

ControTrace heating panels are designed to heat tanks and vessels uniformly.



Heat coverage can be designed for liquid or vapor heating media. This vessel uses a 3-zone, vapor-heated configuration that allows on/off control for each zone.



CSI
CONTROLS SOUTHEAST, INC.

P.O.Box 7500 / Charlotte, North Carolina 28241, USA / Telephone: 704-588-3030 / Fax: 704-588-3039
email: sales@csiheat.com **web:** www.csiheat.com

SM0196