CONQUEST® Flangeless Lined Piping System

Available in 1" - 4" PTFE, PP and PVDF (1"-2" PFA)

Our flangeless systems are designed to reduce the maintenance and risk associated with flanged joints. These systems include Conquest® flangeless piping, Extra-Long Pipe (up to 40 ft long), and MultiAxis piping. These technologies can be used separately, but the best systems combine elements to balance reduced risk with installation and operational flexibility. Connections can be reduced by 90%.

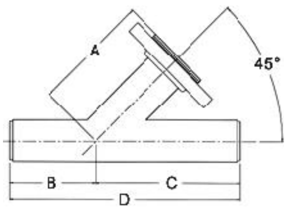
Final on-site assembly is done using Resistoflex butt-fusion weld tooling that can be rented or purchased.

Contact Resistoflex to inquire about CONQUEST™ Fabrication Certification Training that can be provided at your site or at our plant.

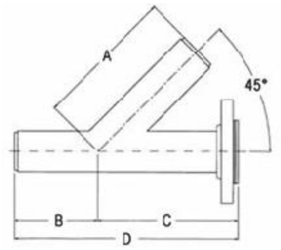
CONQUEST® Dimensional Data and Weights

Laterals - PTFE Only

Fitting Dia.	Option	Part Number	A	B	C	D
2"	Flange on Outlet	LN00M3WWZR200	6 5/8	4 13/16	8 3/16	1'-1"
2"	Flange on Run	LN00M3WZWR200	8 3/16	4 13/16	8 1/8	1'-015/16
3"	Flange on Run	LN00M3WZWR300	11 3/8	6 13/16	1'-1 9/16	1'-8 3/8



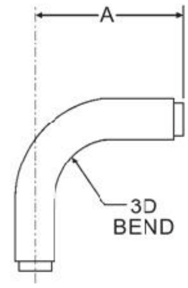
flange on outlet



flange on run

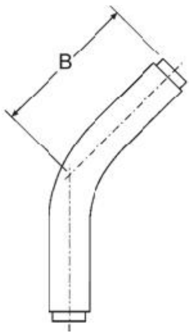
90° Elbows

Fitting Dia. in. (mm)	A in. (mm)	PTFE	PVDF	PP	Weight lbs. (kg)
1 (25)	11 (279)	E900M3WW00100	E900K3WW00100	E900P3WW00100	4 (1.8)
1.5 (40)	13 (330)	E900M3WW00B00	E900K3WW00B00	E900P3WW00B00	7 (3.2)
2 (50)	15 (381)	E900M3WW00200	E900K3WW00200	E900P3WW00200	10.4 (4.7)
3 (80)	21 (533)	E900M3WW00300	E900K3WW00300	E900P3WW00300	28.5 (13.2)
4 (100)	26 (660)	E900M3WW00400	E900K3WW00400	E900P3WW00400	50.1 (22.7)



45° Elbows

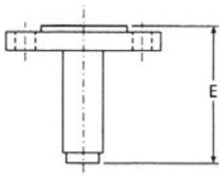
Fitting Dia. in. (mm)	B in. (mm)	PTFE	PVDF	PP	Weight lbs. (kg)
1 (25)	8 (203)	E500M3WW00100	E500K3WW00100	E500P3WW00100	3 (1.4)
1.5 (40)	9 (229)	E500M3WW00B00	E500K3WW00B00	E500P3WW00B00	5 (2.3)
2 (50)	10 (254)	E500M3WW00200	E500K3WW00200	E500P3WW00200	7.5 (3.4)
3 (80)	13 (330)	E500M3WW00300	E500K3WW00300	E500P3WW00300	19.1 (8.7)
4 (100)	17 (432)	E500M3WW00400	E500K3WW00400	E500P3WW00400	36 (16.3)



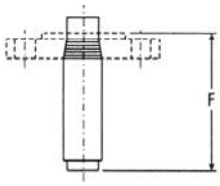
Adapters

Dia. in. (mm)	E in. (mm)	F in. (mm)
1 (25)	10 (254)	4 (102)
1.5 (40)	11 (279)	5 (127)
2 (50)	12 (305)	6 (152)
3 (80)	15 1/2 (394)	8 (203)
4 (100)	18 (457)	8 (203)

Adapter With Flange

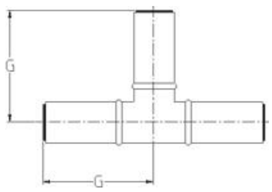


Adapter Without Flange

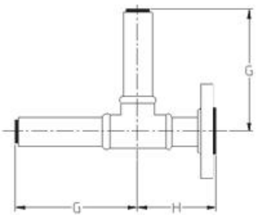


CONQUEST® Dimensional Data and Weights

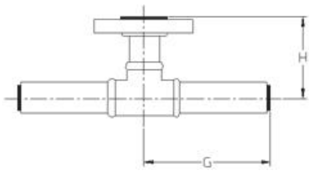
Standard Tees and Instrument Tees



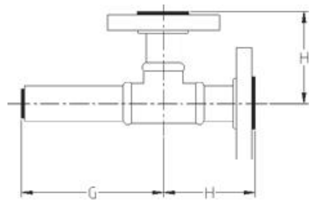
All Conquest



Flange on Run



Flange on Outlet or Instrument Tee



Flanged on Both Ends

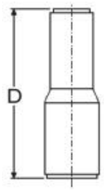
Size (NPS)	Dimensions (in.)		Option	PTFE	PVDF	PP
	G	H				
1	5 1/2	3 1/2	All CONQUEST®	TN00M3WWW0100	TN00K3WWW0100	TN00P3WWW0100
			Flange on Run	N/A	TN00K3WZWS100	TN00P3WZWS100
			Flange on Outlet	N/A	TN00K3WWZS100	TN00P3WWZS100
			Flange on Both	N/A	TN00K3WZZS100	TN00P3WZZS100
			Instrument	T400M3WWZS110	T400K3WWZS110	T400P3WWZS110
1.5	6	4	All CONQUEST®	TN00M3WWW0B00	TN00K3WWW0B00	TN00P3WWW0B00
			Flange on Run	N/A	TN00K3WZWSB00	TN00P3WZWSB00
			Flange on Outlet	TN00M3WWZNB00	TN00K3WWZSB00	TN00P3WWZSB00
			Flange on Both	N/A	TN00K3WZZSB00	TN00P3WZZSB00
			Instrument	T400M3WWZSB10	T400K3WWZSB10	T400P3WWZSB10
2	6 1/2	4 1/2	All CONQUEST®	TN00M3WWW0200	TN00K3WWW0200	TN00P3WWW0200
			Flange on Run	N/A	TN00K3WZWS200	TN00P3WZWS200
			Flange on Outlet	TN00M3WWZN200	TN00K3WWZS200	TN00P3WWZS200
			Flange on Both	N/A	TN00K3WZZS200	TN00P3WZZS200
			Instrument	T400M3WWZS210	T400K3WWZS210	T400P3WWZS210
3	7 1/2	5 1/2	All CONQUEST®	TN00M3WWW0300	TN00K3WWW0300	TN00P3WWW0300
			Flange on Run	N/A	TN00K3WZWS300	TN00P3WZWS300
			Flange on Outlet	N/A	TN00K3WWZS300	TN00P3WWZS300
			Flange on Both	N/A	TN00K3WZZS300	TN00P3WZZS300
			Instrument	T400M3WWZS310	T400K3WWZS310	T400P3WWZS310
4	9 1/2	6 1/2	All CONQUEST®	TN00M3WWW0400	TN00K3WWW0400	TN00P3WWW0400
			Flange on Run	N/A	TN00K3WZWS400	TN00P3WZWS400
			Flange on Outlet	N/A	TN00K3WWZS400	TN00P3WWZS400
			Flange on Both	N/A	TN00K3WZZS400	TN00P3WZZS400
				T400M3WWZS410	T400K3WWZS410	T400P3WWZS410

Instrument port outlet is 1" pipe size

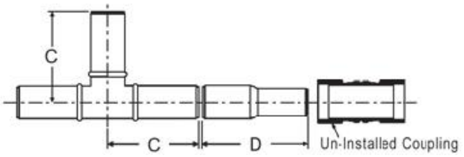
CONQUEST® Dimensional Data and Weights

Concentric Reducers

Fitting Dia. in. (mm)	D in. (mm)	PTFE	PVDF	PP	Weight lbs. (kg)
1.5 x 1 (40 x 25)	6.5 (165)	6000M3WW00B10	6000K3WW00B10	6000P3WW00B10	7 (3.2)
2 x 1 (50 x 25)	7.5 (191)	6000M3WW00210	6000K3WW00210	6000P3WW00210	7 (3.2)
2 x 1 1/2 (50 x 40)	7.5 (191)	6000M3WW002B0	6000K3WW002B0	6000P3WW002B0	7 (3.2)
3 x 2 (80 x 50)	10.5 (267)	6000M3WW00320	6000K3WW00320	6000P3WW00320	14 (6.4)
4 x 3 (100 x 80)	13 (330)	6000M3WW00430	6000K3WW00430	6000P3WW00430	30 (13.6)

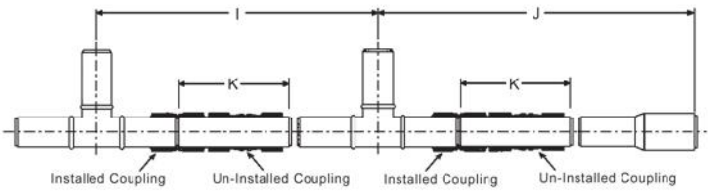


Standard Tee-to-Concentric Reducer



Tee-to-decreasing size concentric reducer, no filler pipe needed.

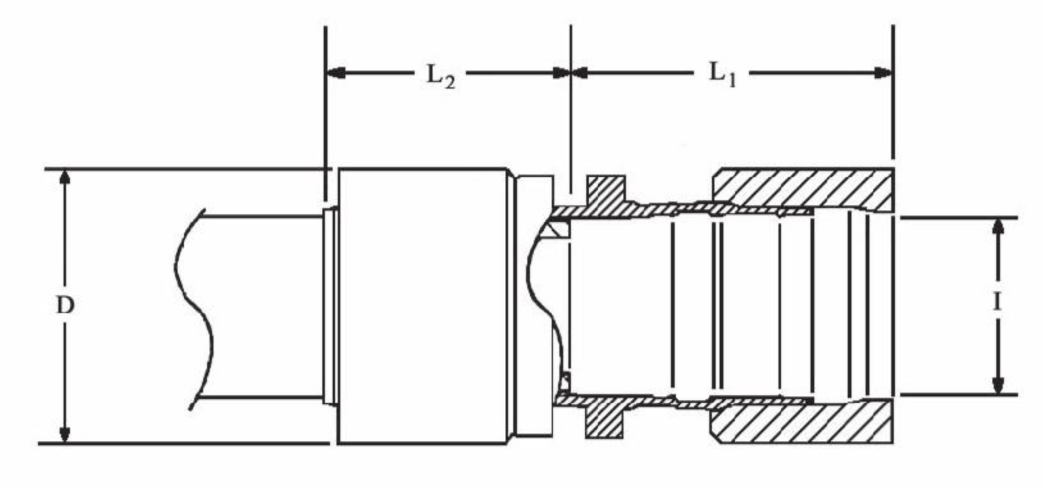
Standard Tee-to-Tee, or Tee-to-Concentric Reducer



Minimum tee-to-tee or tee-to-increasing size concentric reducer length.

Fitting Dia. in. (mm)	I in. (mm)	J in. (mm)	K in. (mm)
1 (25)	20 (508)	21 (533)	9 3/8 (238)
1.5 (40)	23 3/4 (603)	23 3/4 (603)	10 5/8 (270)
2 (50)	24 5/8 (625)	28 5/8 (727)	12 (305)
3 (80)	30 1/2 (775)	31 1/2 (800)	15 7/8 (403)
4 (100)	37 1/4 (946)	40 3/4 (1035)	18 1/4 (464)

CONQUEST® Coupler Dimensions



Fitting Size in. (mm)	($2xL_1$) Overall Length Max. Prior to Installation	($2xL_2$) Overall Length, Max. After Installation	D Outside Diameter, Max.	I Inside Diameter, Max.
1 (25)	4.55	3.42	1.97	1.338
1 1/2 (40)	5.44	4.10	2.64	1.923
2 (50)	6.54	5.03	3.28	2.415
3 (80)	9.55	6.80	4.45	3.536
4 (100)	11.03	7.77	5.60	4.551

1. Fittings are designed for use on Resistoflex plastic-lined steel pipe, schedule 40.
2. Standard coating for Swage Rings is black oxide per LMS-93-12. Contact factory for other platings.
3. Fittings available with and without 1/8” vent hole between tool flange.

Tapped Vent CONQUEST® Coupler

CONQUEST Plastic Lined Piping uses a mechanical coupler over a welded liner to provide a leak-free, flangeless joint. PTFE lined systems require a venting system to prevent permeants from collecting between the liner and steel shell. The tapped vent coupler provides more flexibility by allowing a variety of devices to be attached to the coupler:

- Vent Extenders

  For insulated pipe, vent paths should be provided between vent holes and the atmosphere. Failure to do so often results in accelerated corrosion of the steel shell and contamination of the insulation. (Learn more about Venting and Insulation). PTFE-lined CONQUEST is designed to vent at the coupling. The coupling has a 1/8" NPT tapped vent hole which allows extenders to be threaded in, and routed through the insulation.

- Leak Detection

  A breech in the liner or weld can result in fluid traveling between the liner OD and metal ID to the annular space between the butt weld and the coupling body. Attachment of sensors to the tapped vent may provide early warning of a liner failure.

- Collection Systems

  In some cases, venting of even minute quantities of permeants to the atmosphere is undesirable. This may be true with extremely hazardous or toxic chemicals, or in environmentally sensitive areas. The tapped vent allows attachment of collection systems to prevent permeant release to atmosphere.

High Integrity vent extender featuring Fire-Safe Design

A Hastelloy® porous disc vent fitting is shipped with the coupler as an optional addition to the completed installation. It's porous nature allows permeated gases to escape the system, but contains any entrained liquids which may result from a liner breech. The vent fitting is also designed according to the same principles as the Fire-Safe Factory Mutual approved HIF system.

Dimension Differences

The tapped vent coupler is different than the standard vented coupler. The tapped vent holes required a thicker cross section in the coupler body than is possible with the standard coupler. The groove that accommodates the jaw of the installation tool was previously located in the center of the coupler. The new center rib requires that the groove be located on both sides of the new rib. These changes add to the overall length of the coupler. There is adequate design tolerance in the CONQUEST® fittings to use the longer tapped vent coupler without concern for joint make-up clearance. The exact length of standard vented and the tapped vent couplers are as follows:

To accommodate the extra thickness, a center rib has been added to the coupling body.

Size	Part Number		Standard Couplings - w/ or w/o Vent		Part Number	Tapped Vent Couplings	
	Standard w/o Vent	Standard w/ Vent	As Shipped Length	Installed Length	Tapped Vent	As Shipped Length	Installed Length
1"	K00003W000100	KV0003W000100	4.50"	3.37"	KV0003W000101	5.64"	4.51"
1.5"	K00003W000B00	KV0003W000B00	5.44"	4.06"	KV0003W000B01	6.55"	5.21"
2"	K00003W000200	KV0003W000200	6.50"	5.00"	KV0003W000201	7.68"	6.15"
3"	K00003W000300	KV0003W000300	9.50"	6.81"	KV0003W000301	10.76"	8.16"
4"	K00003W000400	KV0003W000400	11.25"	7.75"	KV0003W000401	12.02"	9.00"

CONQUEST® Flangeless Piping

Design Considerations

Thermal Expansion Considerations

Like other piping materials, CONQUEST flangeless piping from Crane Resistoflex requires the designer or specifier to consider system movement caused by thermal expansion and contraction of piping components. This movement can typically be compensated for by using expansion loops and direction changes, along with the proper placement of piping supports and anchors.

You may find it necessary to conduct a computer-generated stress analysis of your piping system because of its size and complexity. Although most stress analysis programs simulate the movement of a single piping materials and plastic-lined piping is a composite of plastic and steel, use the coefficient of thermal expansion for steel in your stress analysis. That's because Crane Resistoflex Plastic-Lined Piping Products uses a swaging fabrication process for CONQUEST piping that locks the liner inside the steel shell and restricts its movement relative to the steel. The locking process distributes the liner's thermal expansion and contraction stress evenly throughout the entire steel pipe.

Table 1: Coefficients of Thermal Expansion for Plastic Liners and Steel		
Material	α (in/in/°F)	α (mm/mm/°C)
Polypropylene (PP)	4.8×10^{-5}	8.64×10^{-5}
Polyvinylidene Fluoride (PVDF Homopolymer)	$6.6\text{-}8.0 \times 10^{-5}$	$11.9\text{-}14.4 \times 10^{-5}$
PVDF/Hexafluoropropylene (PVDF/HFP Copolymer)	7.8×10^{-5}	14×10^{-5}
Polytetrafluoroethylene (PTFE)	5.5×10^{-5}	9.9×10^{-5}
Perfluoroalkoxy (PFA)	7.8×10^{-5}	14×10^{-5}
Steel	5.9×10^{-6}	10.6×10^{-6}

How to Calculate Expansion Loop

Size and Dimensional Change - The expansion and contraction (ΔL) of a piping system is a function of the coefficient of thermal expansion for the piping material (α), the length of the pipe, and the upper and lower temperature limits of the system. These limits are the highest and lowest temperatures the system will experience at start-up, shut-down, and during operation.

Use Equation 1 to calculate the growth of shrinkage of pipe after a thermal cycle, where:

ΔL = Dimensional change due to thermal expansion or contraction (inches).

α = Expansion coefficient (in./in/°F or mm/mm/°C), refer to Table 1 for steel.

$(T_1 - T_2)$ = Change in temperature (°F or °C).

L = Length (in inches or mm) of straight pipe being considered.

Equation 1: $\Delta L = \alpha \times (T_1 - T_2) \times L$

The minimum offset and loop size can be determined from the calculated dimensional change using Equation 1 & 2.

The loop size is a function of the pipe diameter and the length the pipe moves during a thermal cycle. See Equation 2. The expansion loop depicted in Figure 1 can be fabricated by using a combination of straight pipe, elbows, and/or MULTI-AXIS® precision-bent pipe.

To calculate loop size, use Equation 2 where:

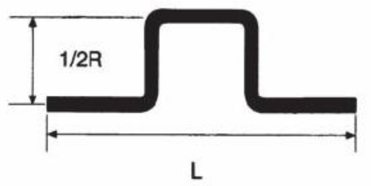
R = Minimum expansion loop length (in feet or mm)

D = Actual outside diameter of the pipe (in inches or mm)

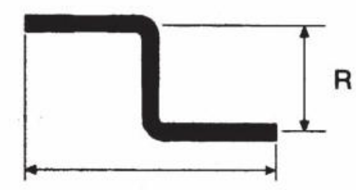
ΔL = Change in length (in inches or mm) due to expansion or contraction

Equation 2: $R = 6.35 \times (D \times \Delta L)^{1/2}$

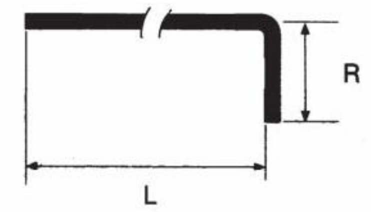
(Metric) $R = 76.4 \times (D \times \Delta L)^{1/2}$



Loop



Offset



Direction Change

Example: To determine how much expansion and contraction will occur in a 530-foot straight length of 2" PVDF-lined pipe and how long the expansion loop will have to be to compensate for this, you must first determine the highest and lowest temperatures the system will experience. Assume the pipe will be installed at 60°F, operated at 75°F, and experience temperatures of 0°F in winter and 120°F in summer.

With this information, use Equation 1 to determine the dimensional change of the straight pipe section.

$\Delta L = 5.9 \times 10\text{-}6 \times (120\text{-}0) \times 530 \times 12 = 4.5$ inches

The change in length of the straight pipe section due to expansion is 4.5 inches. Substituting 4.5 inches for ΔL in Equation 2, determines the loop size to compensate for this expansion.

$R = 6.35 \times (2.375 \times 4.50)^{1/2} = 20.8$ ft.

Therefore, the minimum expansion length offset or direction change is 20.8 feet.

Torque Considerations for the CONQUEST Coupling

Torsional loading is a consideration in the design of any piping system, but is particularly important with CONQUEST flangeless piping. Reason: The inner plastic liner of adjacent pipe sections are butt-welded together and, therefore, cannot act independently of each other. If torsional loading on the joint exceeds the mechanical coupling's ability to resist turning, the plastic liner may twist and break at the connection.

Torsional loading can occur in many situations, particularly where there are direction changes, during the transport of a flangeless assembly, or while lifting a flangeless assembly into a pipe truss.

Table 2 lists the torque values that are not to be exceeded for the CONQUEST Connection after the mechanical coupling is installed.

Table 2: Maximum Allowable Torque Values

Pipe Size inches (mm)	Allowable Torque ft-lb (N-m)
1 (25)	450 (610)
1 1/2 (40)	750 (1017)
2 (50)	1000 (1356)
3 (80)	2100 (2848)
4 (100)	3100 (4204)

MULTI-AXIS® Bent Piping

- Available in 1" - 4" CS lined with PTFE, PP, PVDF (1" - 2", only, in PFA)*
- Eliminates flange connections at elbows
- Up to 4 compound bends (3D) in a single piece of pipe
- Sections are bent at any angle up to 90° with a tolerance of ±1°
- Reduces pressure drop across the bend and reduces energy costs
- Longer bend radius (3 diameters vs. 1.5 diameters)
- Flanges are threaded rotatable

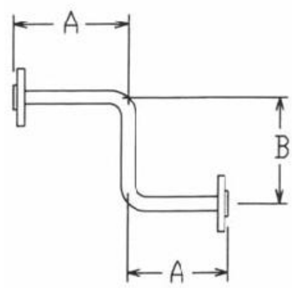
The Bending Process

Although the concept behind MULTI-AXIS pipe is simple, successfully bending swaged plastic-lined pipe is not. It is considerably more difficult than bending unlined pipe. As for loose-lined pipe, it is virtually impossible to bend without distorting the liner. The liner in Resistoflex Plastic-Lined Pipe is locked into position and resists distortion.

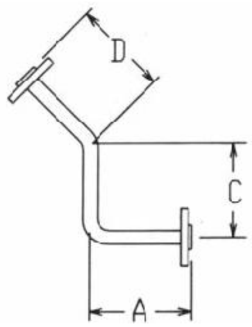
Resistoflex uses special bending equipment and proprietary manufacturing techniques to provide bends in any angle up to 90° and compound bends on a single section of pipe. MULTI-AXIS pipe is a high-quality product with dimensional tolerances of ± 0.125" (3.2mm), even on pieces with multiple bends. Due to the complexity of the bending operation, field bending of MULTI-AXIS pipe is not available. MULTI-AXIS pipe can be supplied with Class 150 steel rotatable flanges or with plain ends that can be joined in the field with other plastic-lined pipe sections using CONQUEST® flangeless connections.

When considering MULTI-AXIS pipe, it's important to carefully examine directional changes in a system to determine whether the centerline-to-face or centerline-to-centerline dimensional requirements of bent pipe can be met within the parameters of the initial design. If not, design adjustments may be required.

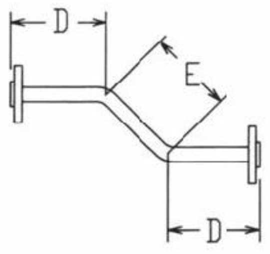
Minimum Lengths Required for MULTI-AXIS Plastic Lined Pipe



90° Bends



90° & 45° Bends



45° Bends

Pipe Size in. (mm)	A	B	C	D	E
1 (25)	6 1/8 (156)	11 3/8 (289)	8 1/2 (216)	4 1/4 (108)	6 3/4 (171)
1 1/2 (40)	9 3/16 (233)	15 3/16 (386)	12 1/2 (318)	6 7/16 (164)	9 3/4 (248)
2 (50)	11 1/4 (286)	18 1/4 (464)	14 5/8 (371)	8 (203)	10 3/4 (273)
3 (80)	15 (381)	26 11/16 (678)	22 (559)	10 (254)	15 3/4 (400)
4 (100)	19 3/4 (502)	36 1/2 (927)	29 1/2 (749)	12 7/8 (327)	22 1/4 (565)

Tolerances:

Center-center and center-face dimensions = +/- 1/8"
Bend angle = +/- 1°

1.5" and larger available as rotationally lined with Tefzel® ETFE. Consult factory for dimensional requirements.

Note: Angle can be within 1 degree of specified angle. If there is a long run of straight pipe after the bend, this can result in the center of the next bend or the face of the flare being offset an inch or more from what was intended. In most cases, this can be compensated for in the field installation. In the case of bolting Multi-Axis to flanged equipment that is in a permanent fixed location, the offset may present an installation problem.

CONQUEST® Flangeless Piping for PTFE

Testing and Verification Data for CONQUEST Flangeless Piping Systems 1" to 4" Polytetrafluoroethylene (PTFE) Lined Systems

To verify the integrity of the CONQUEST flangeless connection, Resistoflex conducted tests on three separate components o the connection:

- The mechanical coupling, which has been developed by LOKRING for use with RESISTOFLEX Plastic-Lined Piping
- The liner butt weld.
- The CONQUEST flangeless connection as a whole.

A summary of these tests and results are contained in this technical data sheet.

Testing of the RESISTOFLEX / LOKRING™ Mechanical Coupling

A. Coupling Bend Test

Test Procedure - Mechanical couplings were used to join two sections of plastic-lined pipe from RESISTOFLEX Plastic-Lined Piping Products. These newly created sections of joined pipe were then subjected to a full reverse bend test.

These tests were performed by the Lokring Corporation at their facility in Foster City, California. The load applied to the bend was the equivalent to subjecting the pipe to a minimum stress of 30 psi (2.07 bar). The minimum number of cycles required to pass the test was set at 7,000 cycles. The test was carried out until either 7,000 cycles were completed or coupling failure was observed.

Results - All four pipe sizes tested passes the minimum requirement of 7,000 cycles. The test on the 1" (25 mm) size was allowed to continue in order to determine approximately how many full reversing cycles the pipe could actually withstand. The test terminated after 71,089 cycles and still no failure was observed.

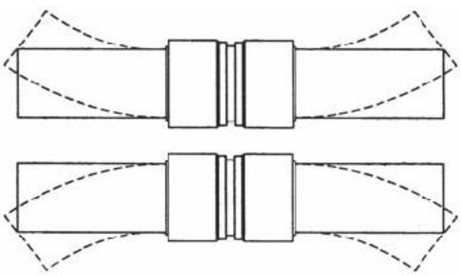


Table 1 - Bend Test Results		
Pipe Size in. (mm)	Number of Cycles	Result
1 (25)	71,089	Pass
1 1/2 (40)	7,399	Pass
2 (50)	7,251	Pass
3 (80)	7,500	Pass

B. Coupling Burst Test

Test Procedure - Test samples were produced by connectir two sections of plastic-lined pipe from RESISTOFLEX Plas Lined Piping Products with a mechanical coupling. Each e was then capped. The cap at one end was equipped with a connection that permitted internal hydraulic pressure to be applied. The requirement to pass the test was set at having the pipe fail before the coupling. Internal pressure was ther applied and steadily increased. These tests were performe by the Lokring Corporation at their facility in Foster City, California.

Results - The internal pressure was increased until the coupling failed or the pipe burst. Testing was completed fo three different sizes of plastic-lined pipe and is summarize Table 2. Note that in each case the pipe burst, which demo strates that the coupling is actually stronger than the steel pipe.

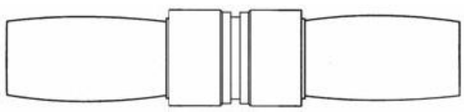


Table 2 - Coupling Burst Test Results		
Pipe Size in. (mm)	Burst Pressure psi (Bar)	Result
2 (50)	7,500 (517)	Pipe Rupture
3 (80)	10,000 (690)	Pipe Rupture
4 (100)	5,200 (359)	Pipe Rupture

C. Coupling Torsion Test

Test Procedure - Pipe samples were produced by connecting two sections of plastic-lined pipe from RESISTOFLEX Plastic-Lined Piping Products with mechanical couplings. Three samples of each size were produced and testing was performed by Lokring Corporation in Foster City, California. The minimum torques required to pass the test were set at 450 ft-lbs (610 N-m), 750 ft-lbs (1017 N-m) and 1,000 ft-lbs (1356 N-m) for each pipe size, respectively. Lokring Corporation conducted initial torque testing up to 600 ft-lbs (813 N-m), which is the maximum torque Capability of their apparatus. Torque was then applied until either the maximum torque capability of 600 ft-lbs (813 N-m) was reached or movement of the pipe in the coupling was detected. The test samples were then shipped to E.J. Daiber Company, Inc. in Cleveland, Ohio in order to complete the testing at torques greater than 600 ft-lbs (813 N-m). Here, the samples were fixed between a torque transducer and pneumatic torque generator. Torque was increased until movement was detected. The average torque at which movement was detected for the three test specimens of each size was then recorded.

Results - All samples passed torque tests up to 600 ft-lbs (813 N-m) conducted by Lokring Corporation. In torque tests conducted by E.J. Daiber Company, Inc., all samples exceeded the minimum torque requirements before movement of the pipe in the coupling was detected. The average torque size is shown in Table 3. The 3" was also tested by Lokring Corporation and passed the 600 ft-lbs (813 N-m) requirement.

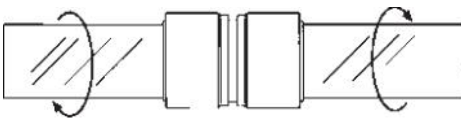


Table 3 - Torsion Test Results			
Pipe Size in. (mm)	Minimum Torque Requirement ft-lbs (N-m)	Average Torque Test Results ft-lbs (N-m)	Result
1 (25)	450 (610)	848 (1150)	Pass
1 1/2 (40)	750 (1017)	942 (1277)	Pass
2 (50)	1,000 (1356)	1,159 (1571)	Pass

Testing of the Liner Butt Weld

To test the integrity of the liner butt weld, it was subjected to tests in two separate categories: burst and pressure fatigue. Testing was performed on Resistoflex pipe in a test lab by RESISTOFLEX Plastic-Lined Piping Products at their Bay City, Michigan facility. These tests were conducted on 1", 2", and 4" diameter PTFE welded pipe.

All PTFE test samples were 36" (914 mm) long and were butt welded at their mid-point using the PFA Film method, wrapped with PTFE adhesive tape and vent coupling installed. The ends of each sample were flanged and blanked, and equipped with connections that permitted internal hydraulic pressure to be applied. The coupling prevents the butt weld from being subjected to tensile stress produced by the internal pressure on the flanged ends.

A. Liner Butt Weld Burst Test

Test Procedure - Liner butt welds were fabricated using standard fabrication techniques described in Resistoflex's PTFE Technical Data Sheet "Joint Fabrication Procedures for CONQUEST Flangeless Piping Systems with PTFE Liners". Two samples of each size and liner type were produced. Samples were filled with water and connected to a hand pump with a 10,000 psi (690 bar) capability. A 5,000 psi (345 bar) pressure gauge was attached to the pump outlet. The requirement to pass the test was set at a minimum of 1,100 psi (76 bar). Samples were pressurized to 500 psi (34.5 bar) and held there for three minutes, then increased in 1000 psi (69 bar) increments to a maximum test pressure of 4500 psi (310 bar). The unit was held at each increment for a minimum of three minutes. Either the burst pressure in which failure occurred for the two test specimens of each size, or the maximum pressure attained, was recorded.

Results - All samples exceeded the minimum burst pressure requirement of 1,100 psi (76 bar). Pressure was ultimately released when the gaskets failed on the flared ends. The samples were sectioned for visual inspection after each test. The inspection revealed that all welds were 100% intact and were not compromised in any way by the burst testing.

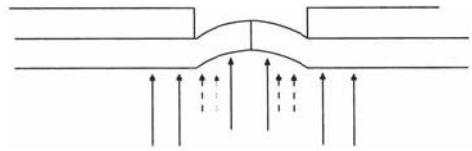


Table 4 - Burst Test Results			
Pipe Size in. (mm)	Liner Type	Minimum Burst Pressure Requirement psi (Bar)	Max. Burst Test Pressure psi (Bar)
1 (25)	PTFE	1,100 (76)	4,500 (310)[†]
2 (50)	PTFE	1,100 (76)	4,500 (310)[†]
4 (100)	PTFE	1,100 (76)	4,500 (310)[†]

[†]Gaskets on flared ends failed without compromising the weld integrity.

B. Liner Butt Weld Pressure Fatigue Test

Test Procedure - Test samples were 36" (914 mm) long and were butt-welded together at their mid-point. The samples were connected to a high-pressure piston pump capable of producing 1,400 psi (97 bar). Description of pressure fatigue test cycle: increase internal pressure to 550 psi (38 bar), hold for 10 seconds, reduce pressure to 50 psi (3.4 bar), hold for 5 seconds, then increase to 550 psi (38 bar) to repeat the cycle. The minimum requirement to pass the test was set at 7,000 cycles.

Results - All samples withstood the minimum 7,000 cycles without displaying any evidence of failure. All tests were allowed to continue in order to determine approximately how many pressure fatigue cycles the butt weld could actually withstand. The test was terminated after 100,000 cycles and still no failure was observed. The samples were sectioned for a visual inspection after each test. The inspection revealed that all welds were 100% intact and were not compromised in any way by the fatigue testing.

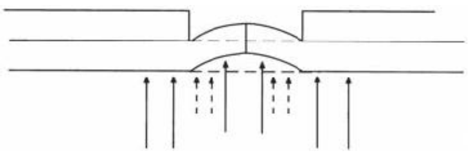


Table 5 - Pressure Fatigue Test Results			
Pipe Size in. (mm)	Liner Type	Minimum Number of Cycles Required	Actual Number of Cycles Achieved
1 (25)	PTFE	7,000	100,000
2 (50)	PTFE	7,000	100,000
4 (100)	PTFE	7,000	100,000

Testing of CONQUEST connection

To test the integrity of the CONQUEST connection, it was subjected to tests in two separate categories: ASTM Steam/ Cold Water and Cold Temperature.

A. ASTM Steam/Cold Water

Test Procedure - Testing was performed on RESISTOFLEX Plastic-Lined Pipe in a test lab by RESISTOFLEX Plastic-Lined Piping Products at their Bay City, Michigan facility. Tests were conducted on two sets of 1", 1-1/2", 2", 3", and 4" welded diameter PTFE-lined pipe spools. Plastic-lined pipe spools were subjected to the appropriate ASTM Steam/Cold Water test for lined pipe. Each spool was 20 feet (12.2 m) long, consisting of two 10-foot (6.1 m) lengths joined by CON-QUEST flangeless connection at the mid-point. The test spools contained the standard flanged connection at each end. The test involved subjecting the spool to 100 alternating cycles of heating with steam, then cooling with water.

Results - All spools passed the requirements of the ASTM Steam/Cold Water test. These samples were sectioned for a visual inspection after each test. The inspection revealed that all welds were 100% intact and were not compromised in any way by the Steam/Cold Water testing.

B. Cold Temperature Test

Test Procedure - Testing was performed on RESISTOFLEX Plastic-Lined Pipe in a test lab by RESISTOFLEX Plastic-Lined Piping Products at their Bay City, Michigan facility. Spools were fabricated by joining two 10-foot (3 m) sections with a CON-QUEST flangeless connection at the mid-point. Testing included 1", 1-1/2", 2", 3", and 4" diameter welded PTFE-lined pipe spools. The test involved inserting a sample into a freezer with a -40°F (-40°C) capability and cooling it until either the liner failed or the maximum low temperature was reached. Description of test procedure: Insert sample into freezer with temperature set at 20°F (-7°C) and hold for a minimum of 8 hours. Visually inspect each sample and, if no liner failure has occurred, reduce the temperature in 10°F (6°C) increments and hold at each increment for a minimum of 8 hours. Visually inspect each sample after each 8-hour interval.

Results - All spools withstood a low freezer temperature of -20°F (-29°C). The samples were sectioned for a visual inspection after each test. The inspection revealed that all welds were 100% intact and were not compromised in any way by the freeze testing.

CONQUEST® Flangeless Piping for PP / PVDF / PFA

Testing and Verification Data for CONQUEST Flangeless Piping Systems with 1" to 4" PP, 1" to 4" PVDF/HFP, and 1" & 2" PFA Liners

To verify the integrity of the CONQUEST flangeless connection, Resistoflex conducted tests on three separate components of the connection:

- The mechanical coupling, which has been developed by LOKRING for use with RESISTOFLEX Plastic-Lined Piping.
- The liner butt weld.
- The CONQUEST flangeless connection as a whole.

A summary of these tests and results are contained in this technical data sheet.

Testing of the RESISTOFLEX / LOKRING™ Mechanical Coupling

A. Coupling Bend Test

Test Procedure - Mechanical couplings were used to join two sections of plastic-lined pipe from RESISTOFLEX Plastic-Lined Piping Products. These newly created sections of joined pipe were then subjected to a full reverse bend test.

These tests were performed by the Lokring Corporation at their facility in Foster City, California. The load applied to the bend was the equivalent to subjecting the pipe to a minimum stress of 30 psi (2.07 bar). The minimum number of cycles required to pass the test was set at 7,000 cycles. The test was carried out until either 7,000 cycles were completed or coupling failure was observed.

Results - All four pipe sizes tested passes the minimum requirement of 7,000 cycles. The test on the 1" (25 mm) size was allowed to continue in order to determine approximately how many full reversing cycles the pipe could actually withstand. The test terminated after 71,089 cycles and still no failure was observed.

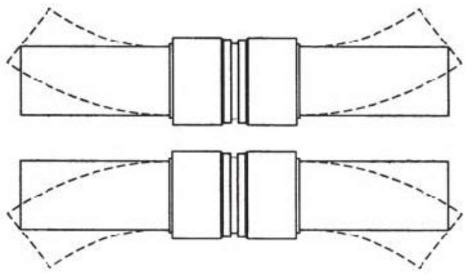


Table 1 - Bend Test Results		
Pipe Size in. (mm)	Number of Cycles	Result
1 (25)	71,089	Pass
1 1/2 (40)	7,399	Pass
2 (50)	7,251	Pass
3 (80)	7,500	Pass

B. Coupling Burst Test

Test Procedure - Test samples were produced by connectin two sections of plastic-lined pipe from RESISTOFLEX Plast Lined Piping Products with a mechanical coupling. Each en was then capped. The cap at one end was equipped with a connection that permitted internal hydraulic pressure to be applied. The requirement to pass the test was set at having the pipe fail before the coupling. Internal pressure was then applied and steadily increased. These tests were performe by the Lokring Corporation at their facility in Foster City, California.

Results - The internal pressure was increased until the coupling failed or the pipe burst. Testing was completed for three different sizes of plastic-lined pipe and is summarized Table 2. Note that in each case the pipe burst, which demor strates that the coupling is actually stronger than the steel pipe.

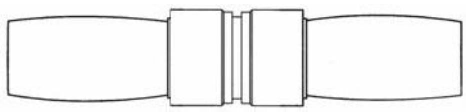


Table 2 - Coupling Burst Test Results		
Pipe Size in. (mm)	Burst Pressure psi (Bar)	Result
2 (50)	7,500 (517)	Pipe Rupture
3 (80)	10,000 (690)	Pipe Rupture
4 (100)	5,200 (359)	Pipe Rupture

C. Coupling Torsion Test

Test Procedure - Pipe samples were produced by connecting two sections of plastic-lined pipe from RESISTOFLEX Plastic-Lined Piping Products with mechanical couplings. Three samples of each size were produced and testing was performed by Lokring Corporation in Foster City, California. The minimum torques required to pass the test were set at 450 ft-lbs (610 N-m), 750 ft-lbs (1017 N-m) and 1,000 ft-lbs (1356 N-m) for each pipe size, respectively. Lokring Corporation conducted initial torque testing up to 600 ft-lbs (813 N-m), which is the maximum torque Capability of their apparatus. Torque was then applied until either the maximum torque capability of 600 ft-lbs (813 N-m) was reached or movement of the pipe in the coupling was detected. The test samples were then shipped to E.J. Daiber Company, Inc. in Cleveland, Ohio in order to complete the testing at torques greater than 600 ft-lbs (813 N-m). Here, the samples were fixed between a torque transducer and pneumatic torque generator. Torque was increased until movement was detected. The average torque at which movement was detected for the three test specimens of each size was then recorded.

Res□ - All samples passed torque tests up to 600 ft-lbs (813 N-m) conducted by Lokring Corporation. In torque tests conducted by E.J. Daiber Company, Inc., all samples exceeded the minimum torque requirements before movement of the pipe in the coupling was detected. The average torque size is shown in Table 3. The 3" was also tested by Lokring Corporation and passed the 600 ft-lbs (813 N-m) requirement.

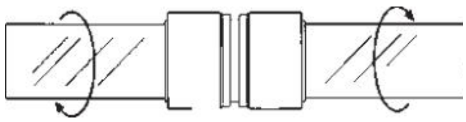


Table 3 - Torsion Test Results

Pipe Size in. (mm)	Minimum Torque Requirement ft-lbs (N-m)	Average Torque Test Results ft-lbs (N-m)	Result
1 (25)	450 (610)	848 (1150)	Pass
1 1/2 (40)	750 (1017)	942 (1277)	Pass
2 (50)	1,000 (1356)	1,159 (1571)	Pass

For 3” the coupling withstood in excess of 2,000 ft-lbs of torque.

Testing of the Liner Butt Weld

To test the integrity of the liner butt weld, it was subjected to tests in two separate categories: burst and pressure fatigue. Testing was performed on Resistoflex pipe in a test lab by RESISTOFLEX Plastic-Lined Piping Products at their Bay City, Michigan facility. These tests were conducted three sets of plastic-lined pipe. The first set was lined in polypropylene (PP), the second in polyvinylidene (PVDF), and lastly in perfluoroalkoxy (PFA).

All test samples were 24" (610 mm) long and were butt welded at their mid-point. The ends of each sample were flanged and blanked, and equipped with connections that permitted internal hydraulic pressure to be applied. Three steel bars were then welded to the steel shell spanning the exposed liner in the area that contained the butt weld. This prevented the butt weld from being subjected to tensile stress produced by the internal pressure on the flanged ends. The liners and butt-welds were visually monitored throughout the testing.

A. Liner Butt Weld Burst Test

Test Procedure - Liner butt welds were fabricated using standard fabrication techniques described in Resistoflex’s Technical Data Sheet “Joint Fabrication Procedures for CONQUEST Flangeless Piping
Systems with PP, PVDF/HFP, and PFA-Liners”. Three samples of each size and liner type were produced. Samples were filled with water and connected to a hand pump witha 10,000 psi (690 bar) capability. A 5,000 psi (345 bar) pressure gauge was attached to the pump outlet. The requirement to pass the test was set at a minimum of 1,100 psi (76 bar). Samples were pressurized to 500 psi (34.5 bar) and held there for three minutes, then increased in 1,000 psi (69 bar) increments and held at each increment for a minimum of three minutes. The burst pressure range in which failure occurred for the three test specimens of eaP□m□S□s□b□v

Results - All samples exceeded the minimum burst pressure requirement of 1,100 psi (76 bar). Failures ultimately occurred in the burst pressure range given in Table 4. However, it should be noted that all failures occurred in the exposed portion of the liner and not at the butt weld faces.

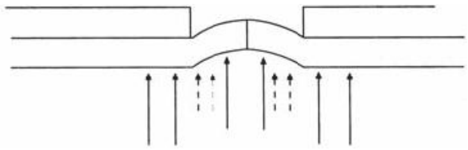


Table 4 - Burst Test Results			
Pipe Size in. (mm)	Liner Type	Minimum Burst Pressure Requirement psi (Bar)	Burst Pressure Range psi (Bar)
1 (25), 1 1/2 (40), 2 (50), 3 (80), 4 (100)	PP	1,100 (76)	3,500 - 4,400 (241-303)
1 (25), 1 1/2 (40), 2 (50), 3 (80), 4 (100)	PVDF	1,100 (76)	4,500 - 5,000 (311-345)†
1 (25), 1 1/2 (40), 2 (50)	PFA	1,100 (76)	2,000 - 3,000 (139-208)

†The test was discontinued after the pressure exceeded 5,000 PSI (345 Bar), the maximum pressure gauge reading.

B. Liner Butt Weld Pressure Fatigue Test

Test Procedure - Test samples were 2" (50 mm) spools of pipe lined with PP and PVDF, each 24" (610 mm) long and containing a butt weld at their mid-point. The samples were connected to a high-pressure piston pump capable of producing 1,400 psi (97 bar). Description of pressure fatigue test cycle: increase internal pressure to 1,000 psi (69 bar), hold for 10 seconds, reduce pressure to 50 psi (3.4 bar), hold for 10 seconds, then increase to 1,000 psi (69 bar) to repeat the cycle. The minimum requirement to pass the test was set at 7,000 cycles.

Results - All samples withstood the minimum 7,000 cycles without displaying any evidence of failure. All tests were allowed to continue in order to determine approximately how many pressure fatigue cycles the butt weld could actually withstand. The test was terminated after 50,115 cycles and still no failure was observed.

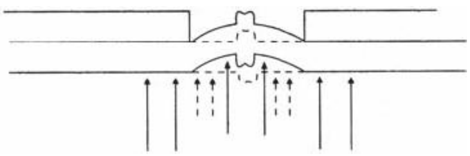


Table 5 - Pressure Fatigue Test Results			
Pipe Size in. (mm)	Liner Type	Minimum Number of Cycles Required	Actual Number of Cycles Achieved
2 (50)	PP	7,000	50,115
2 (50)	PVDF	7,000	50,115

Testing of CONQUEST connection

To test the integrity of the CONQUEST connection, it was subjected to tests in two separate categories: ASTM Steam/Cold Water and Cold Temperature.

A. ASTM Steam/Cold Water

Test Procedure - Testing was performed on RESISTOFLE Plastic-Lined Pipe in a test lab by RESISTOFLEX Plastic Lined Piping Products at their Bay City, Michigan facility. Tests were conducted on one set of 1"(25 mm) 1-1/2" (40 mm) 2" (50 mm) pipe lined with polyvinylidene fluoride (PVDF) and two 2" (50mm) sections of pipe, one lined wi polypropylene (PP) and the other with perfluoroalkoxy (PFA). Plastic-lined pipe spools were subjected to the appropriate ASTM Steam/Cold Water test for lined pipe. Each spool was 40 feet (12.2 m) long, consisting of two 20-foot (6.1 m) lengths joined by a CONQUEST flangeles connection at the mid-point. The test spools contained th standard flanged connection at each end. The test involve subjecting the spool to 100 alternating cycles of heating with steam, then cooling with water

Results - All spools passed the requirements of the ASTN Steam/Cold Water test.

B. Cold Temperature Test

Test Procedure - Testing was performed on RESISTOFLE Plastic-Lined Pipe in a test lab by RESISTOFLEX Plastic Lined Piping Products at their Bay City, Michigan facility. The 2" (50 mm) spools were fabricated by joining two 10-foot (3 m) sections with a CONQUEST flangeless connec tion at the mid-point. One pipe section was lined with polyvinylidene (PVDF), the other with polypropylene (PP). The test involved inserting a sample into a freezer with a -40°F (-40°C) capability and cooling it until either the liner failed or the maximum low temperature was reached. Description of test procedure: Insert sample into freezer with temperature set at 20°F (-7°C) and hold for a minimu of 8 hours. Visually inspect each sample and, if no liner failure has occurred, reduce the temperature in 10°F (6°C increments and hold at each increment for a minimum of hours. Visually inspect each sample after each 8-hour interval.

Results - All spools withstood a low freezer temperature c -40°F (-40°C).

Joint Reduction Technologies - Life Cycle Cost Estimating

Many specifiers of piping systems limit their economic analysis to piping material costs only, because they are relatively simple to estimate. Yet this approach creates some pitfalls when selecting either an installation of conventional flanged plastic-lined piping (PLP) or an installation that fully incorporates Resistoflex's Joint Reduction Technologies (JRT), consisting of CONQUEST® flangeless connections and MULTI-AXIS® precision bent piping. An evaluation that considers only the cost of pipe, fittings, flanges and connectors may result in specification of a system with the higher life cycle cost.

Life Cycle Cost Considers All Cost Factors

Life cycle cost (LCC) analysis includes all costs of system ownership and permits selection of the less expensive system. Costs can be divided into the following categories:

- Initial acquisition costs
- Initial acquisition labor
- Operating and maintenance costs
- Costs associated with flange leaks

When deciding to utilize JRT, it's often helpful to perform the evaluation based on the LCC of current practice (i.e., the use of flanged PLP) and then consider which costs would change if the system were designed and installed using the various Joint Reduction Technologies. Different alternatives can be evaluated with the judicious use of JRT and elimination of many, but not all, flanged connections resulting in the most economical PLP installation.

Cost Elements to Consider When Evaluating JRT vs. Conventional PLP

- ***Initial Acquisition Costs***

- Pipe, fittings, flanges, venting & locking collars and CONQUEST® connectors. These are the items that are purchased from the supplier of PLP. Pipe can be supplied already flanged, or spooled, ready for installation. If the pipe will be fabricated on-site, then a sufficient number of flanges and/or CONQUEST® connectors should be purchased. Don't overlook venting collars for PTFE (polytetrafluoroethylene) or PFA (perfluoroalkoxy) lined pipe if flanged pipe ends will be fabricated onsite. These collars are not needed if the pipe is joined with a CONQUEST® flangeless connection.

- Nuts, bolts or studs needed to join flanged connections.

- Flange protectors or spray shields. Many corporate or government regulations require that flanged connections be covered or protected so that if a leak occurs, it is either contained or flows in a controlled, predictable pattern instead of spraying at the flanged connection.

- Registration of flanged connections in a corporate database. Often the location of a flanged connection must be noted in records so that its location, maintenance and inspection can be reported. One common technique is to attach a bar code label to the flanged connection, input location and chemical service information into a database. Registration is essential if the service is covered by the 1990 Clean Air Act Amendments (CAAA) or other similar laws governing chemical processes. Many companies register all flanged connections in critical or hazardous services, even if the service isn't currently included in regulations. This is often done either for safety reasons or in anticipation of changes in regulations. Registration usually occurs at the time of installation and is in additional to the recurrent costs of periodic inspection.

- Items that are less costly when flanged connections are eliminated because the piping system is lighter in weight and has a more streamlined profile. These could includes:

- number and type of hangers
- support structure
- diameter or configuration of insulation
- complexity of heat tracing around connections

- Diameter of the piping system and size of pumps. Don't overlook the improved flow characteristics of JRT, especially of MULTI-AXIS® precision bent piping. The 3-D bends of MULTI-AXIS® create less pressure drop than the standard 1.5-D bends of conventional PLP. It may be possible to specify a smaller diameter piping system and/or smaller pumps if JRT is specified instead of conventional PLP.

Initial Acquisition Labor

- Design and design review. Usually PLP systems are designed with all piping spool lengths calculated and shown on detailed isometric drawings. This level of detail is often not needed if CONQUEST® flangeless connections are used in piping runs since the pipe can be field routed.

- Material acquisition cost. The cost of specifying, ordering and receiving materials can be reduced if the piping is bought as bulk quantities of unflanged, standard length pipe instead of numerous flanged spools with different custom lengths. Also the material acquisition costs for some items (like nuts, bolts, studs, flange protectors and spray shields) are reduced in direct portion to the number of flanged connections eliminated by the use of JRT.

Joint Reduction Technologies - Life Cycle Cost Estimating

- *Field fabrication of custom length pipe.* The process of PLP custom spool fabrication includes cutting and threading the pipe, installing and aligning the flange, installing the venting or locking collar, heating the plastic stub, flaring the plastic face, cooling and removing the flaring die and installing a protective wooden cover over the flared face. This process can be time-consuming and quality difficult to control if performed on-site by personnel who fabricate PLP on an infrequent basis. Often custom spools are fabricated at the factory or by nearby stocking distributors who have fully equipped shops and certified personnel that fabricate PLP routinely. If conventional PLP is fabricated at the factory or by a distributor, then the cost will be part of the purchase price quoted by the supplier of the fabricated pipe. Understandably, flanged and fabricated spools are more expensive than plain-end PLP.

- *Cost of installation.* This includes the cost of installing the piping system and the associated nuts, bolts, studs, flange protectors and spray shields with conventional PLP or the cost of fabricating a CONQUEST® connection when the method is used to create a joint.

- *Miscellaneous labor cost savings.* Be sure to include labor cost savings if the use of lighter weigth, streamlined JRT piping permits a reduction in the number of hangers and supports and if the elimination of flanged connections speeds up the installation of insulation and heat tracing. Also, the time required for painting can be reduced when flanged connections are eliminated. If installation time is reduced, then it's often possible to reduce the time required for rental or recharge of equipment like man-lifts.

- *Start-up costs.* This includes the time to hydrotest the piping system and perform the recommended retorqing of bolts after 24 hours of operation. When flanged connections are eliminated, the start-up time can be substantially reduced. This means that the system is operational sooner and the process is out of commission for a shorter period of time.

Operating and maintenance costs

- *Monitoring and associated paperwork.* Government or corporate regulations may require the periodic monitoring of flanged connection for leaks and records of that monitoring activity. If a service is listed in the 1990 CAAA, then the connection must be "sniffed" for fugitive emissions and detailed records maintained for submittal to the government. The monitoring frequency ranges from every six months to biannually, depending upon the service and history of the site. Even if regulations don't require monitoring, it's still good chemical plant operations practice to visually inspect flanged connections periodically for signs of leaks or emissions.

- *Periodic retorquing of flange bolts.* It's common for flange bolt torques to be checked and bolts tightened, if needed, on a periodic basis. Often this is done semi-annually or annually depending upon the thermal cycling history of the piping. This retorquing isn't needed when flanged connections are eliminated through installation of JRT.

- *Cleaning costs.* Consider the cost difference in batch-to-batch cleaning of conventional PLP vs. JRT. In some batch processes this can be a savings, particularly when directional changes in the piping are created with MULTI-AXIS® piping instead of with conventional flanged elbows, which have a discontinuity or crevice at the flanged connection.

Costs associated with flanged leaks

- *Unused capacity.* Consider the likelihood of plant outages due to flange leaks and the cost of production that is lost when the plant isn't operating.

- *Out-of-spec product.* Flange leaks can create a sudden and unexpected plant outage resulting in the production of out-of-spec product.

- *Safety issues.* The "cost" is difficult to estimate but can be a tangible concern for some chemical services and/or some piping system locations. This could include direct injury to workers and passers-by and indirect issues such as evacuation of the process site and adjacent areas.

- *Reporting requirements.* Government or corporate regulations can require lengthy and time-consuming reports and investigations in the event of flange leaks. The direct and indirect costs of these reports shouldn't be overlooked.

Example of Life Cycle Cost Estimating Analysis

Consider a piping system that was recently installed with extensive use of JRT. The system consists of 2-in diameter (50 mm N.B.) PVDF-lined piping that was installed in an existing, overhead pipe rack to replace a conventional PLP system that had reached the end of its useful life of several decades. The conventional system consists of 670 ft (204 m) of piping, ten directional changes for routing the thermal expansion purposes and two tees installed as "stand-pipes" to reduce the effect of water hammer. By specifying JRT, all the flange connections, except for the first and last connections. In JRT, the system consists of 620 ft of straight-run piping, three pieces of MULTI-AXIS® precision-bent piping, two CONQUEST® flangeless tees and thirty-seven CONQUEST® connections. The system is depicted in the isometric drawing. Costs are estimated using 1995 data for the upper mid-west and listed is U.S. dollars.

Initial Acquisition Labor Savings

- Design, design review and material acquisition costs. Since this system represents an initial JRT installation at this location, the specifiers decided that the design, review and acquisition of the system would be no different with either design. After the installation, they report that the project went very "smoothly" and they can anticipate savings in design, review and acquisition of future JRT installations.

- Elimination of field fabrication of flanged custom length pipe. It takes about 1.15 hr to completely cut, thread, flange, flare and block the two ends of a 2" PVDF-lined spool. There are thirty-seven spools in the conventional flanged system design, representing a total fabrication time of 42.55 hours. It takes about 0.6 hours to cut, align, trim, butt-fusion weld and install a CONQUEST® connection. There are thirty-seven CONQUEST® connections in the system, with a total installation time of 22.2 hours.

- Cost of installation. It takes about 0.4 hr to install the nuts, bolts and flange shield of a 2" diameter connection. There are forty-nine flanged connections in the conventional design, for a total installation labor of 9.80 hours. The CONQUEST® connections are installed during the fabrication process outlined above, so there is no additional installation time since there are no nuts, bolts or spray shields used.

- Start-up costs. It's assumed that the cost to hydrotest the system would be identical for conventional piping and for a JRT system. However, the costs for hydrotesting of the conventional system would be higher if leaks occurred at the flanged connections and had to be corrected during the hydrotest. A leak occurring in a CONQUEST® connection during hydrotest would not be likely. These costs could be included based on previous experience at the site. However, the cost of the 24-hr retorqing of the flanged connections is tangible, at 0.2 hr per connection. With forty-nine flanged connections, there's an additional 9.8 hrs needed to start up the conventional system. The conventional PLP system takes nearly fifty hours more to fabricate, install and start-up than the same system that fully incorporates JRT to eliminate flanged connections. At $50.00 per hour, the seemingly "less expensive" system is nearly $2500 more expensive to install and commission.

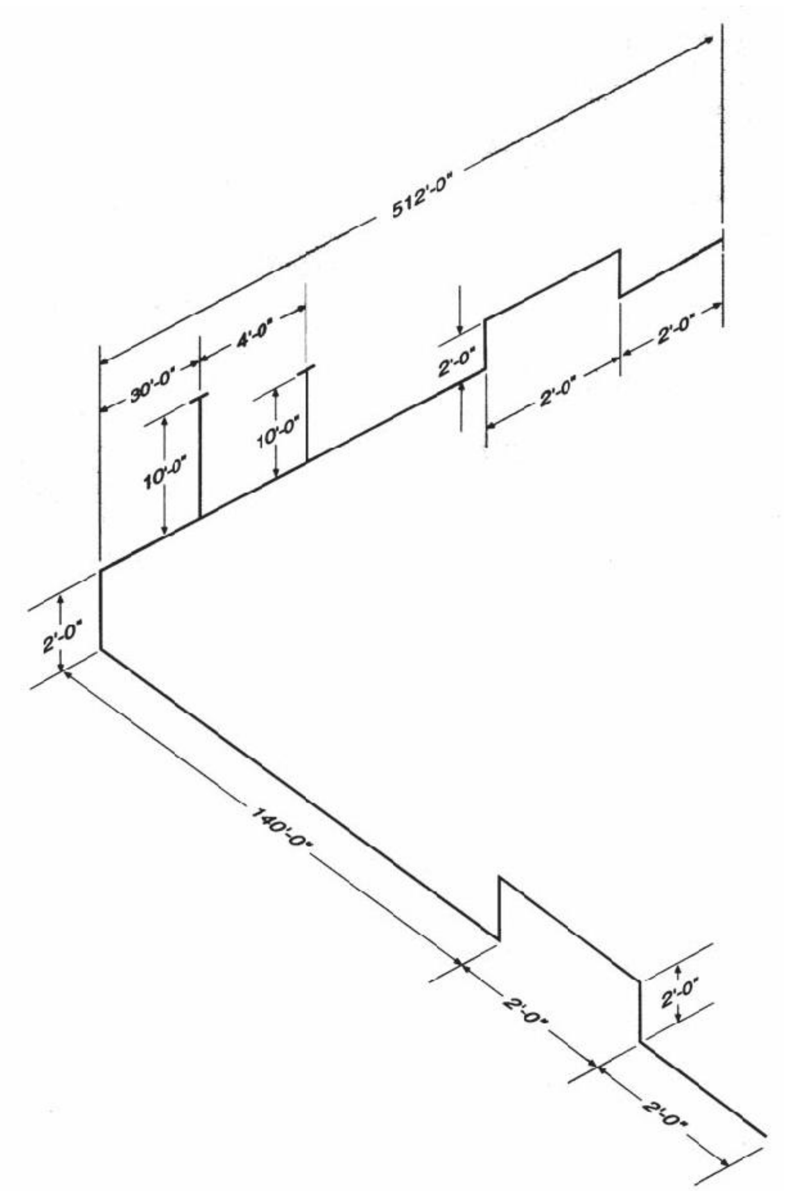
So, if both the initial acquisition costs and the initial acquisition labor is considered, the total installed cost of the system that incorporates CONQUEST® flangeless joints and MULTI-AXIS® precision-bent piping is $3,800 less than the same system installed with conventional flanged plastic-lined piping. This savings increases if the operating and maintenance costs are also considered.

Operating and maintenance costs

- Annual monitoring and record keeping. It costs about $75.00 annually to monitor and record the testing of each flanged connection in a conventional PLP system. With forty-nine flanged connections, the system will cost an additional $3,675 per year to maintain.

- Annual retorquing. The cost to retorque each connection is about $10.00 per year, creating an additional $490 in annual operating costs not required to maintain a JRT system. In certain critical services, retorquing is required semi-annually or quarterly.

- Other costs. Leaks and shut-downs can be very expensive, yet each location will have to evaluate their annual cost potential based upon system configuration, location, process conditions and history. These costs should not be overlooked, but are beyond the scope of this study.



Initial Acquisition Costs

- Pipe, fittings, flanges, locking collars and CONQUEST ® connections. The conventional flanged system consists of: ten 90° elbows; two standard tees; thirty-three plain end pieces of pipe, 20 ft (6.1 m) long; one plain-end piece of pipe, 10 ft (3 m) long; seventy-four threaded flanges; and, seventy-four locking collars. The net price is $17,032. If the system is designed with JRT, then it consists of: two MULTI-AXIS® four-bend pieces, 20 ft (6.1 m) long, plain one end, flanged the other; one MULTI-AXIS® two-bend piece, 20 ft (6.1 m) long, plain both ends; two CONQUEST® tees; thirty-one plain-end pieces of pipe, 20 ft (6.1 m) long; and, thirty-seven CONQUEST® connectors. It has a net price of $20,073. Thus the system that utilized JRT has a piping material cost premium of $3,041 (the difference between $20,073 and $17,073). If the economic study ended at this point, then the conventional, flanged PLP system would be specified. However, complete life cycle cost analysis reveals that it is the most expensive of the two alternatives.

For the other initial costs (nuts, bolts, flange protectors, and registration of connections) consider the relative cost differences between the two systems.

- Nuts and bolts. A set of four bolts or studs and nuts cost about $3.00 to $5.00 for a 2", four bolt flanged connection. The specification of fluorocarbon-coated studs or bolts can increase the cost of the hardware to $10.00 to $12.00 for the connection.
In this example, uncoated bolts and nuts, with a cost of $4.00 per set, are used on the forty-nine flanged connections. Total nut and bolt cost is $196.

- Flange protectors or spray shields. Simple polyethylene spray shields cost about $5.00 each, and shields of PVDF (the same material at the pipe liner) cost about $10.00 each. Sometimes, fluorocarbon drain guards are specified for especially critical areas to permit collection of any leaks or drips. These deluxe guards can cost up to $25.00 per connection. In this system, PVDF spray shields, at $10.00 each are used on each of the forty-nine flanged connections with a total shield cost of $490.

- Registration of connectors. Each flanged connection is labeled with a bar code and its location and chemical service is recorded on a corporate database system at a unit cost of $75.00 per connection. The total cost for the forty-nine flanged connections is $3,675. Many connections are totally eliminated through the use of MULTI-AXIS® in the JRT alternative and the remaining CONQUEST® connections are considered to be permanent connections and thus are not subject to periodic monitoring and record-keeping.

- Other possible savings. In this example, an existing pipe rack is used and the piping system isn't insulated or heat traced. However, in other installations where this isn't the case, these savings should be considered. For example the cost to insulate a 2" (50 mm) flange set is $75-90 if common calcium silicate insulation is used.

	Conventional Flanged PLPP			Joint Reduction Technologies			JRT vs. Flanged	
	Qty.	**Unit Price $**	**Ext. Price $**	**Qty.**	**Unit Price $**	**Ext. Price $**		
Initial Acquisition Costs								
Pipe, fittings, flanges, collars and connectors			17,031.60			20,072.55	3,040.95	
Nut & bolts for connection	49	4.00	196.00				-196.00	credit
Flange protectors	49	10.00	490.00				-490.00	credit
Registration of connection	49	75.00	3,675.00				-3,675.00	credit
	Qty.	**Unit Hours**	**Ext. Hours**	**Qty.**	**Unit Hours**	**Ext. Hours**		
Initial Acquisition Labor, hours								
Field fabrication 1.15 hr for flanged pipe spool	37	1.15	42.55					
Field fabrication 0.6 hr for CONQUEST connection				37	0.60	22.2		
Install nuts, bolts, shields 0.4 hr per connection	49	0.40	19.60					
24 hr retorque, 0.2 hr per connection	49	0.20	9.80					
Total Hours			71.95			22.2		
Extra Hours for Conventional PLP			45.75					
	Conventional Flanged PLPP			**Joint Reduction Technologies**			**JRT vs. Flanged**	
	Qty.	**Unit Price $**	**Ext. Price $**	**Qty.**	**Unit Price $**	**Ext. Price $**		
Initial Acquisition Labor Extra hours @ $50/hr	49.75	50.00	2,487.50				-2,487.50	credit
Difference in Cost of Initial Acquisition Materials and Labor							**-3,807.55**	credit
Annual Operating and Maintenance Costs								
Monitor & record connection	49	75.00	3,675.00				-3,675.00	credit
Retorque connection	49	10.00	490.00				-490.00	credit
Annual Operating Cost Difference							**-4,165.00**	credit

Discussion of results

A simplistic comparison of the cost of an un-installed CONQUEST® connector with the cost of two threaded flanges would have clearly supported the continued use a flanged plastic-lined pipe. That approach would have shown it "cost" about $60 per connection to have a flangeless joint. This approach ignores the total elimination of any type of connection due to the use of MULTI-AXIS® piping and the total cost of the hardware and labor needed to install a piping system. It obviously doesn't consider the long-term maintenance cost of the connections, either.

A slightly more sophisticated approach would have been to consider the total cost of the pipe, fittings, flanges, collars and connectors for each system. But, this evaluation would also have resulted in an incorrect specification. This is because the piping materials for a conventional system are about $3,040 less expensive than for a JRT system with the same configuration.

It isn't until the installation hardware (nuts, bolts, spray shields) and labor is considered that the truly "less expensive" alternative is revealed. A JRT system costs about $3,800 less to purchase, install and commission than does the same system in conventional flanged PLP.

The recurring annual cost savings realized by elimination of monitoring, retorquing and record-keeping make the JRT system $4,165 less expensive to operate each year. This can create a cost savings of tens of thousands of dollars over the life of the system, more than paying for the initial investment.

Obviously, each piping system is different and operating conditions are sometimes difficult to predict. As this study shows, there's no quick answer to the question, "How much more will it cost me to use JRT?" The answer is "it depends" and it's usually less expensive to use JRT instead of conventional PLP when all costs associated with installation and maintenance are considered.

We've based our study on costs in the upper mid-west and are interested in the experience in your facility. Please contact us to share your comments and insight.