CONQUEST® Flangeless Lined Piping System

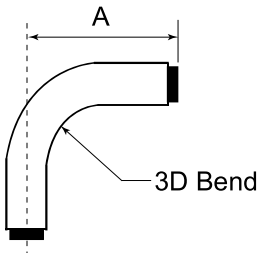
Available in 1" - 4" PTFE, PP and PVDF

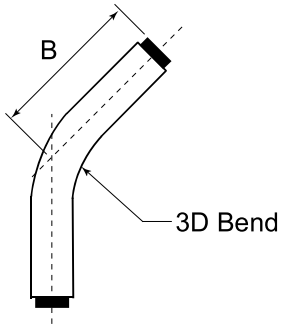
Our flangeless systems are designed to reduce the maintenance and risk associated with flanged joints. These systems include Conquest® flangeless piping, Extra-Long Pipe (up to 40 ft long), and MultiAxis piping. These technologies can be used separately, but the best systems combine elements to balance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

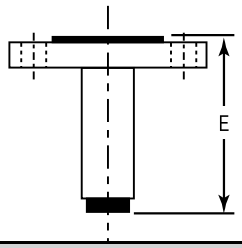
Final on-site assembly is done using Resistoflex butt-fusion weld tooling that can be rented or purchased.

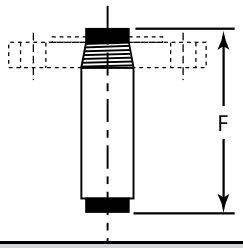
Contact Resistoflex to inquire about CONQUEST™ Fabrication Certification Training that can be provided at your site or at our plant.

CONQUEST® Elbows and Laterals

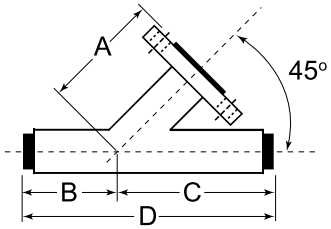




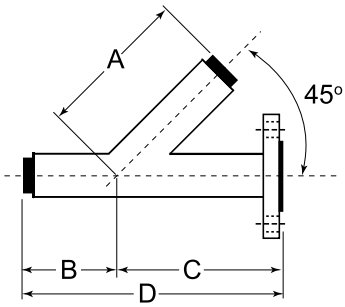




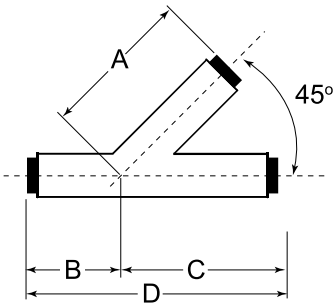
Carbon Steel Construction. Available Liners are PTFE, PP, and PVDF						
90 Degree Elbows		**45 Degree Elbows**		**Adapters**		
Size NPS (DN)	A inch (mm)	Size NPS (DN)	B inch (mm)	Size NPS (DN)	E (Adapter with Flange) inch (mm)	F (Adapter without Flange) inch (mm)
1 (25)	11 (279)	1 (25)	8 (203)	1 (25)	10 (254)	4 (102)
1 1/2 (40)	13 (330)	1 1/2 (40)	9 (229)	1 1/2 (40)	11 (279)	5 (127)
2 (50)	15 (381)	2 (50)	10 (254)	2 (50)	12 (305)	6 (152)
3 (80)	21 (533)	3 (80)	13 (330)	3 (80)	15 1/2 (394)	8 (203)
4 (100)	26 (660)	4 (100)	17 (432)	4 (100)	18 (457)	8 (203)



Flange on Outlet



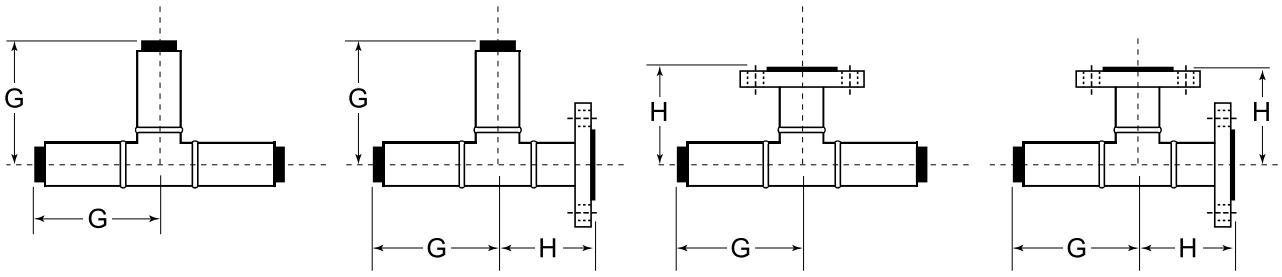
Flange on Run



All CONQUEST®

Carbon Steel Laterals, PTFE-Lined, Only									
Size NPS (DN)	Option	A		B		C		D	
		in.	mm	in.	mm	in.	mm	in.	mm
2 (50)	Flange on Outlet	6 5/8	168	4 13/16	122	8 3/16	208	13	330
2 (50)	Flange on Run	8 3/16	208	4 13/16	122	8 1/8	206	12 15/16	329
3 (80)	Flange on Outlet	10	254	8	203	14	356	22	559
3 (80)	Flange on Run	14	356	8	203	10	254	18	457
3 (80)	All Conquest	14	356	8	203	14	356	22	559
3 (80) X 2 (50)	All Conquest	9	229	8	203	13 1/2	343	21 1/2	546
4 (100)	Flange on Outlet	12	305	8 1/2	216	15	381	23 1/2	597
4 (100)	Flange on Run	15	381	8 1/2	216	12	305	20 1/2	521
4 (100)	All Conquest	15	381	8 1/2	216	15	381	23 1/2	597
4 (100) X 3 (80)	All Conquest	14	356	8 1/2	216	15	381	23 1/2	597

CONQUEST® Tees and Reducing Tees

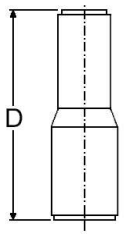


All CONQUEST® | Flange on Run | Flange on Outlet | Flange on Run and Outlet

Carbon Steel Tees								
Size NPS (DN)	Option	Available Liner			G		H	
		PTFE	PP	PVDF	in.	mm	in.	mm
1 (25)	All Conquest	•	•	•	5 1/2	140	3 1/2	89
	Flange on Stack	•	•	•				
	Flange on Run	•	•	•				
	Flange on Run and Outlet	•	•	•				
1 1/2 (40)	All Conquest	•	•	•	6	152	4	102
	Flange on Stack	•	•	•				
	Flange on Run	•	•	•				
	Flange on Run and Outlet	•	•	•				
2 (50)	All Conquest	•	•	•	6 1/2	165	4 1/2	114
	Flange on Stack	•	•	•				
	Flange on Run	•	•	•				
	Flange on Run and Outlet	•	•	•				
3 (80)	All Conquest	•	•	•	7 1/2	191	5 1/2	140
	Flange on Stack	•	•	•				
	Flange on Run	•	•	•				
	Flange on Run and Outlet	•	•	•				
3 (80) x 2 (50)	All Conquest	•			7 1/2	191	5 1/2	140
	Flange on Stack	•						
4 (100)	All Conquest	•	•	•	9 1/2	241	6 1/2	165
	Flange on Stack	•	•	•				
	Flange on Run	•	•	•				
	Flange on Run and Outlet	•	•	•				
4 (100) x 3 (80)	All Conquest	•			9 1/2	241	6 1/2	165
	Flange on Stack	•						

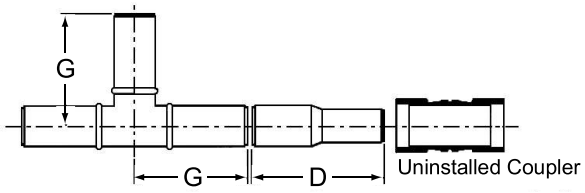
CONQUEST® Concentric Reducers and Minimum Dimensions

Carbon Steel Concentric Reducers				
Size NPS (DN)	D inch (mm)	Available Liner		
		PTFE	PP	PVDF
1 1/2 (40) x 1 (25)	6 1/2 (165)	•	•	•
2 (50) x 1 (25)	7 1/2 (191)	•	•	•
2 (50) x 1 1/2 (40)	7 1/2 (191)	•	•	•
3 (80) x 2 (50)	10 1/2 (267)	•	•	•
4 (100) x 3 (80)	13 (330)	•	•	•



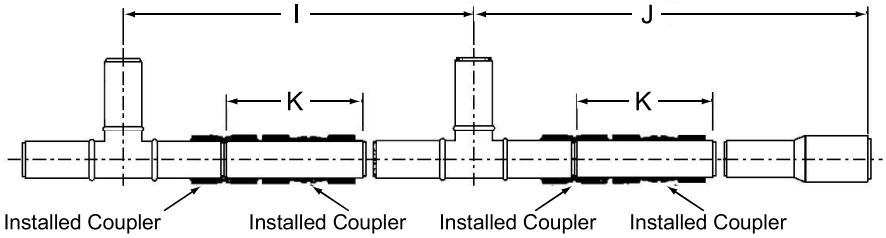
Minimum Connection Dimensions					
Size NPS (DN)	D inch (mm)	G inch (mm)	I inch (mm)	J inch (mm)	K inch (mm)
1 (25)	- -	5 1/2 (140)	20 (508)	21 (533)	9 3/8 (238)
1 1/2 (40)	6 1/2 (165)	6 (152)	23 3/4 (603)	23 3/4 (603)	10 5/8 (270)
2 (50)	7 1/2 (191)	6 1/2 (165)	24 5/8 ((625)	28 5/8 (727)	12 (305)
3 (80)	10 1/2 (267)	7 1/2 (191)	30 1/2 (775)	31 1/2 (800)	15 7/8 (403)
4 (100)	13 (330)	9 1/2 (241)	37 1/4 (945)	40 3/4 (1035)	18 1/4 (464)

Standard Tee-to-Concentric Reducer



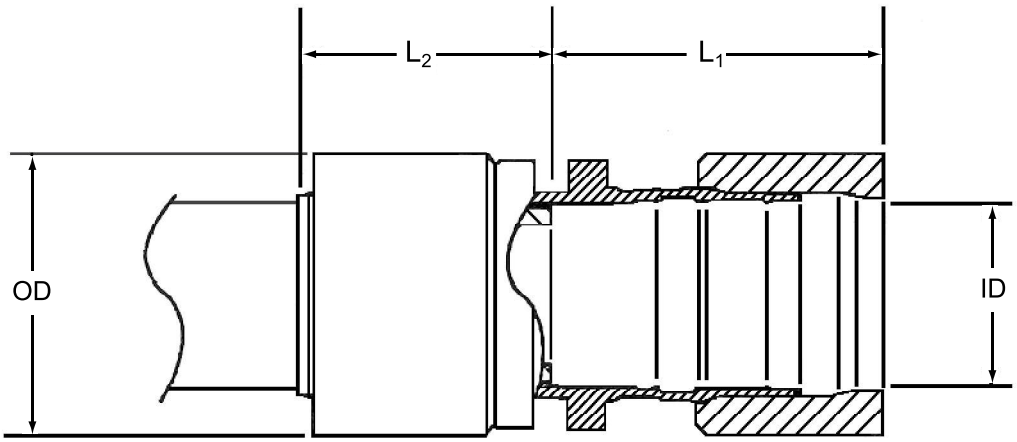
Tee-to-decreasing size concentric reducer, no filler pipe needed.

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



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

CONQUEST® Coupler Dimensions



Coupler Dimensions				
Size NPS (DN)	Overall Length Max Prior to Installation ($2 \times L_1$) in. (mm)	Overall Length Max After Installation ($2 \times L_2$) in. (mm)	OD Outside Diameter Max. in. (mm)	ID Inside Diameter Max. in. (mm)
1 (25)	4.55 (115.6)	3.42 (86.9)	1.97 (50)	1.338 (34)
1 1/2 (40)	5.44 (138.2)	4.10 (104.1)	2.64 (67.1)	1.923 (48.8)
2 (50)	6.54 (166.1)	5.03 (127.8)	3.28 (83.3)	2.415 (61.3)
3 (80)	9.55 (242.6)	6.80 (172.7)	4.45 (113)	3.536 (89.8)
4 (100)	11.03 (280.2)	7.77 (197.4)	5.60 (142.2)	4.441 (112.8)

Couplers are designed for use on Resistoflex Sch. 40 plastic-lined pipe.
Couplers are made from AISI 15V24 micro alloyed steel
Standard coating for swage rings is black oxide. Contact factory for other coatings.
Couplers available with vent holes for PTFE-lined systems

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**

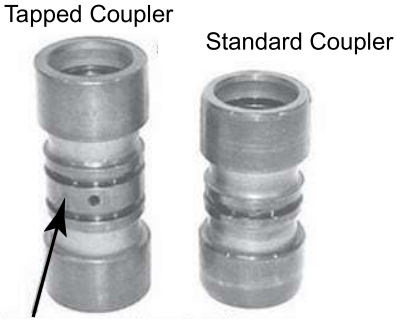
  In some cases, venting of even minute quantities of permeants to the atmosphere is undesirable. This may be true with extremely hazardous or toxic chemicals, or in environmentally sensitive areas. The tapped vent allows attachment of collection systems to prevent permeant release to atmosphere.

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 accomodate the extra thickness, a center rib has been added to the coupler body

Coupler Dimensions				
Size NPS (DN)	Standard Coupler w/ or w/o vent holes		Tapped Vent Coupler	
	As-Shipped Length in. (mm)	Installed Length in. (mm)	As-Shipped Length in. (mm)	Installed Length in. (mm)
1 (25)	4.55 (115.6)	3.37 (85.6)	5.64 (143.3)	4.51 (114.6)
1 1/2 (40)	5.44 (138.2)	4.06 (103.1)	6.55 (166.4)	5.21 (132.3)
2 (50)	6.54 (166.1)	5 (127)	7.68 (195.1)	6.15 (156.2)
3 (80)	9.55 (242.6)	6.81 (173)	10.76 (273.3)	8.16 (207.3)
4 (100)	11.03 (280.2)	7.75 (196.9)	12.02 (305.3)	9 (228.6)

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}
VDF/Hexafluoropropylene (PVDF/HFP Copolymer)	7.8×1^{-5}	14×10^{-5}
Polytetrafluoroethylene (PTFE)	5.5×10^{-5}	9.9×10^{-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.

CONQUEST® Flangeless Piping

To calculate loop size, use Equation 2 where:

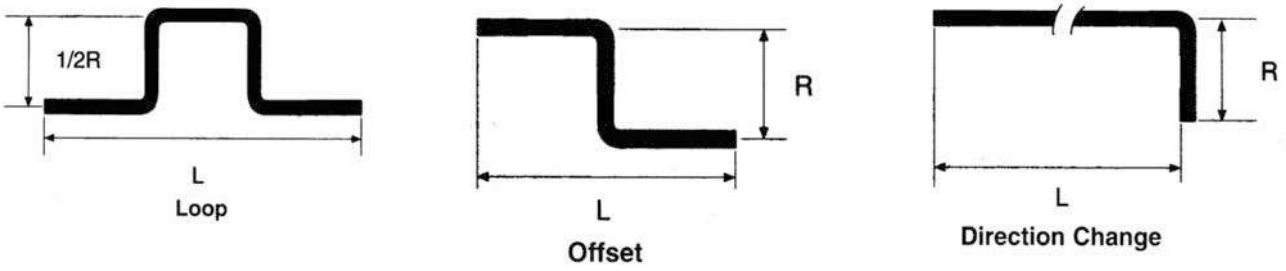
R = Minimum expansion loop length (in feet or mm)

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



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)

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 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.

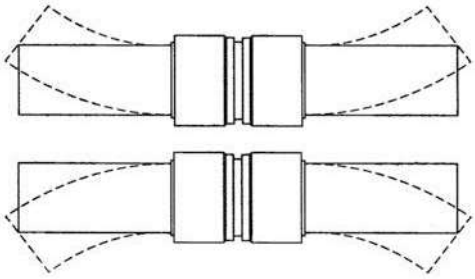


Table 1 - Bend Test Results

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 connecting two sections of plastic-lined pipe from RESISTOFLEX Plastic-Lined Piping Products with a mechanical coupling. Each end 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 performed 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 in Table 2. Note that in each case the pipe burst, which demonstrates that the coupling is actually stronger than the steel pipe.

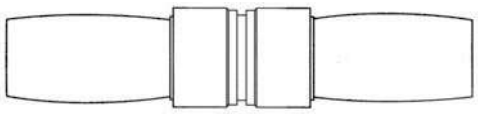


Table 2 - Coupling Burst Test Results

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

CONQUEST® Flangeless Piping for PTFE

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.

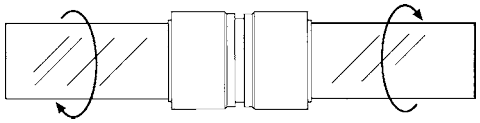


Table 3 - Torsion Test Results

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 45 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.

CONQUEST® Flangeless Piping for PTFE

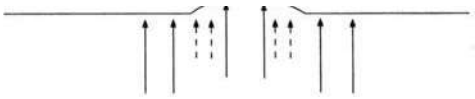


Table 4 - Burst Test Results

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.

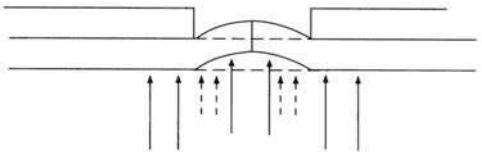


Table 5 - Pressure Fatigue Test Results

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

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 CONQUEST 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 CONQUEST 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 and PVDF

Testing and Verification Data for CONQUEST Flangeless Piping Systems with 1" to 4" PP and 1" to 4" PVDF

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.

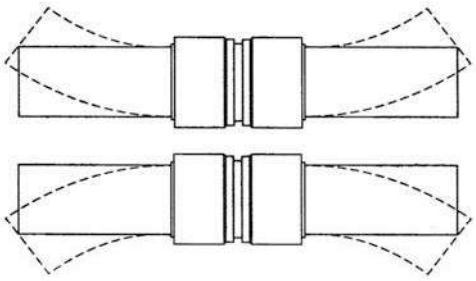


Table 1 - Bend Test Results

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 connecting two sections of plastic-lined pipe from RESISTOFLEX Plastic-Lined Piping Products with a mechanical coupling. Each end 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 performed 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 in Table 2. Note that in each case the pipe burst, which demonstrates that the coupling is actually stronger than the steel pipe.

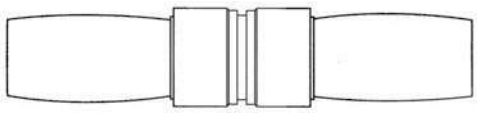


Table 2 - Coupling Burst Test Results

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

CONQUEST® Flangeless Piping for PP and PVDF

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.

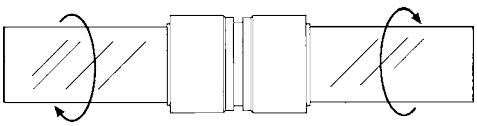


Table 3 - Torsion Test Results

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

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 each size was recorded.

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.

CONQUEST® Flangeless Piping for PP and PVDF

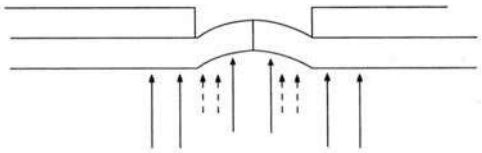


Table 4 - Burst Test Results			
Pipe Size in. (mm)	Liner Type	Minimum Burst Pressure Requirement psi (Bar)	Burst Pressure Range psi (Bar)
1 (25), 1 1/2 (40), 2 (50), 3 (80), 4 (100)	PP	1,100 (76)	3,500 - 4,400 (241-303)
1 (25), 1 1/2 (40), 2 (50), 3 (80), 4 (100)	PVDF	1,100 (76)	4,500 - 5,000 (311-345)†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

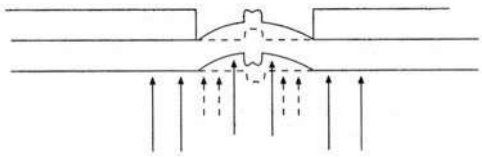


Table 5 - Pressure Fatigue Test Results			
Pipe Size in. (mm)	Liner Type	Minimum Number of Cycles Required	Actual Number of Cycles Achieved
2 (50)	PP	7,000	50,115
2 (50)	PVDF	7,000	50,115

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 RESISTOFLEX 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 with 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 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.

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. The 2" (50 mm) spools were fabricated by joining two 10-foot (3 m) sections with a CONQUEST flangeless connection 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 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 -40°F (-40°C).