RESISTOFLEX®

Corrosion Control in Oil & Gas Production: A New Product Solution

Plastic Lined Steel Piping

CRANE®

Crane ChemPharma & Energy

www.cranecpe.com

CRANE® Co. And Resistoflex®

ABOUT CRANE CO.

Crane Co. is a diversified manufacturer of highly engineered industrial products with a substantial presence in a number of focused niche markets. With approximately 12,000 employees working together in five business segments across 25 countries, Crane generated 2017 net sales of $2.8 billion.

Financial Strength

Crane has a strong financial position, giving it the capacity to continue strategic acquisitions.

Global Reach

Worldwide operations in over 120 locations grow Economic Value Added (EVA) with top people and products, customer focus, and a common Crane Business System throughout the Company.

Leadership

Our businesses have leading market shares in focused niche markets and seek to produce high returns and excess cash flow.

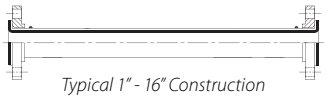
ABOUT RESISTOFLEX

Resistoflex® is the largest plastic-lined piping products supplier in the world, with manufacturing and sales locations in North America, Europe, the Middle East, China, South-East Asia and Australia.

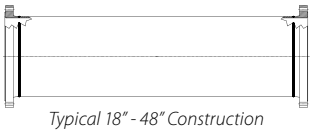
Resistoflex® invented the PTFE lined hose technology in 1953 for the aerospace and chemical industries, and in 1956 introduced the world's first pipe and fittings lined with PTFE. We also offer a full line of pipe and fittings lined with Polypropylene, PVDF, ETFE and now HDPE.

Resistoflex® corrosion-resistant plastic lined pipe, fittings, hoses and expansion joints are used in corrosive fluid services as an economical alternative to expensive alloys.

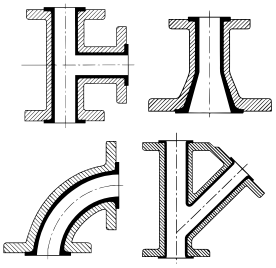
Product Overview 1”–48”

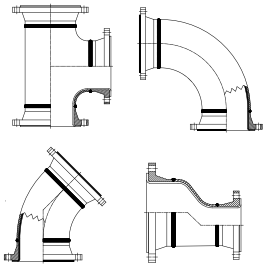


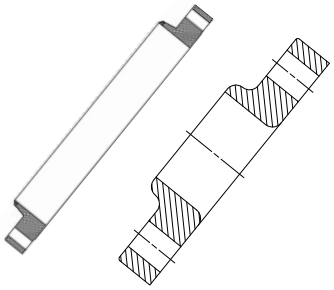
Typical 1” - 16” Construction



Typical 18” - 48” Construction







1” – 48” Pipe Spools:

- ASTM A53B ERW (Standard)
- ASTM A106 Gr. B
- API 5L
- ASTM A312, 304L or 316L
- Other alloys
- 20 foot maximum length

1” – 12” Fittings:

- 45 & 90 Degree Elbows
- Equal Tees
- Reducing Tees
- Concentric & Eccentric reducers
- A216 WCB cast steel or A395 ductile iron
- Standard dimensions are ASME B16.5 Class 150
- Other dimensions available
- Complex shapes available

14” – 48” Fittings:

- 45 & 90 Degree Elbows
- Equal Tees
- Reducing Tees
- Concentric & Eccentric reducers
- Standard dimensions are achieved with standard B16.9 forgings welded to B16.5 or B16.47 series A flanges
- Other dimensions available
- Complex shapes available

1” – 48” Flanges:

- 1”-16” standard pipe flange is class 150 lap joint
- Slip-on & weld neck available
- 18” – 48” standard pipe flange is ASME B16.5 or B16.47
- Slip-on & lap joint available
- Blinds & plate flanges available in all sizes
- ASME, DIN, JIS & other standards

Paint:

- Polyamide epoxy is standard
- Optional paints:
  - Inorganic zinc silicate
  - Organic zinc epoxy
  - Epoxy mastic
  - Epoxy phenolic
  - Novolac epoxy
  - Polyurethane
  - Siloxane
  - Electrically conductive epoxy
  - Customer Specific Paint System

Industry Standards:

- ISO 9001
- ASTM F1545-15
- Design Standard: ASME B31.1 and B31.3
- Welding ASME BPVC Section IX
- 1” – 24” flanges: ASME B16.5
- 26” – 48” flanges: ASME B16.47 Series A
- 14” – 48” pipe: ASME 36.10 Sch. STD
- 14” – 48” weld fittings: ASME B16.9 Sch. STD

Plastic Liner Data

ETFE Flange

Polypropylene Flange

HDPE Flange

As the world's largest supplier of plastic-lined piping products, Resistoflex® offers a 14"-48" product line that includes not only pipe, but a full complement of fittings, flanges, spacers, and specialty items. Liner materials include polypropylene, ETFE, and high-density polyethylene (HDPE). Contact the Resistoflex® Applications Specialist to select the right liner material for your application.

ETFE

Ethylene tetrafluoroethylene is a partially fluorinated thermoplastic with several characteristics that make it ideal for rotational lining. Typical applications are hydrochloric acid, hydrofluoric acid, sulfuric acid, caustics, bleaches, all at temperatures up to 300°F. ETFE has the highest temperature and chemical resistance of any plastic except PTFE.

PP

Polypropylene is a thermoplastic that offers good chemical resistance at a price point lower than ETFE. It is widely used in hydrochloric acid to 200°F, and also sees applications in sulfuric acid up to 80% concentration, and HF up to 60%. Where polypropylene has replaced Fusion Bonded Epoxy (FBE) lined piping in cooling water intake from brackish sources, pipe replacement has gone from every two years to ten years and longer.

HDPE

High density polyethylene provides an economical liner choice that is widely known for its abrasion resistance and general chemical resistance to 180°F. HDPE finds extensive use in oilfield and natural gas production sites in wastewater and multiphase fluid pipelines. HDPE-lined pipe and fittings differ from field-installed HDPE liners by the bonding of the plastic to the metal substrate and the absence of plastic weld seams at the flare faces.

Liner Data

Property	Polypropylene	ETFE	HDPE
Service Temperature Range, oF	0°F - 225°F	-20°F - 300°F	-20°F - 180°F
Liner Color	Orange	Natural	Black
Color of Identification Band	Orange with Black Lettering	Gray with Black Lettering	Red with White Lettering
Coefficient of Thermal Expansion of Liner. (in/in/ oF)	4.8 x 10-5	7.4 x 10-5	6.7 x 10-5
Thermal Conductivity, (BTU-in)/hr-sq ft-oF)	0.8	1.65	Consult Factory
Tensile Strength of Liner at Yield, (psi, min)	4000	6500	1760
Elongation of Liner at Yield, (%)	10	275	400
Compressive Strength of Liner	5500	2500	2000
Specific Gravity	0.9	1.7	0.94
Durometer Hardness, (Shore "D")	72	72	70

Features and Benefits

In high volume process flow applications, requiring 14" - 48" piping, designers have limited options for corrosion resistance. Compared to others, the Resistoflex® 14" - 48" range of plastic-lined pipe and fittings is an economical choice in corrosive applications. Resistoflex' thick, chemical resistant liners offer superior performance and durability.

Properly specified, plastic-lined pipe and fittings have a "zero corrosion rate" at temperatures up to 300˚F, depending on the plastic resin and the chemical service.

1. Choice of **THREE CHEMICAL RESISTANT LINERS** from our most economical **HDPE** to performance/price balanced **PP**, to **ETFE**, which offers outstanding chemical resistance at a lower price point than most alloys.
2. 100% of lining is performed in our North Carolina facility starting with raw plastic resin. Our liners are **VERY THICK TO ALLOW THERMAL STABILITY, AND TO PROVIDE RESISTANCE AGAINST VACUUM.**
3. Resistoflex® lining processes provide a liner that is **MECHANICALLY LOCKED INTO THE HOUSING**. The result is that metal pipe and plastic liner (with dissimilar rates of thermal contraction and expansion) act as **ONE MONOLITHIC UNIT** even during frequent thermocycling. This is proven by successful steam-cold water thermal cycling testing required by **ASTM F1545-15A** Standard Specification for Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges.
4. **SMOOTH LINERS PREVENT BUILDUP OF SCALE AND BIOLOGICS**, and the seamless construction prevents failures known to occur with fusion-welded, bonded lap and other joining methods.
5. **LENGTHS UP TO 20 FT** minimize flange connections, installation time, weight, and potential leak points.
6. Resistoflex® plastic-lined pipe and fittings are **FLANGED AND READY TO INSTALL** upon arrival at the job site. All standard dimensions are based on weld neck flanges welded directly to buttweld fittings. Non-standard or special dimension components are readily available as well.
7. Class 150 flanged pipe and fittings follow the pressure tables in **ASME B16.5 AND ASME B16.47**. Class 300 flanged pipe and fittings maximum pressure is lower than true Class 300 ratings due to the plastic-to-plastic seal between flanges. **THE USE OF RETAINER RINGS ENABLES FULL CLASS 300 AND HIGHER-PRESSURE RATINGS**.
8. Resistoflex® can provide plastic-lined complex shapes, such as manifolds, elbows with process branches, ASME code and non-code pressure vessels and other custom construction, in a wide range of diameters **UP TO 161"**. Maximum diameter depends on the configuration.

Key Applications

Key Applications

- Seawater for Cooling
- Waste Water Collection and Treatment
- Brackish Water
- Condenser Water Recirculation
- River or Well Water
- Demineralized Water
- Oily Water / Drain Lines
- Acids (Sulfuric, Hydrochloric)
- Lube Oil Vessels

Applications & Case Study

High flow cooling water piping is an integral part of the process piping in most refineries as well as both upstream and downstream petrochemical operations. Without cooling water, many of the required reactions and other processes are impossible. During a shutdown, cooling water piping is typically the last to be taken offline, and the first that is started up, making it one of the most critical sub-systems, despite the fact that the media is typically nontoxic, non-flammable and non-hazardous: water. Any downtime in the cooling water piping can lead immediately to a wider area shutdown and significant cost due to lost production and maintenance. Therefore, ensuring the reliability of the cooling water piping systems is a critical factor in overall plant productivity.

Cooling water sources include seawater, river water, brackish canals and well-water among others. This can vary depending on the site of the facility and the available options. Each water source will have a differing degree of corrosivity, depending on salinity and other chemistry which may be present. Acidic and alkaline treatment and buffering chemicals can also have an effect on the corrosive nature of the cooling water. It is incumbent upon the piping designer to ensure the cooling water piping is resistant to all the potential corrosive media fluid components that may be present in the cooling water in order to maximize uptime

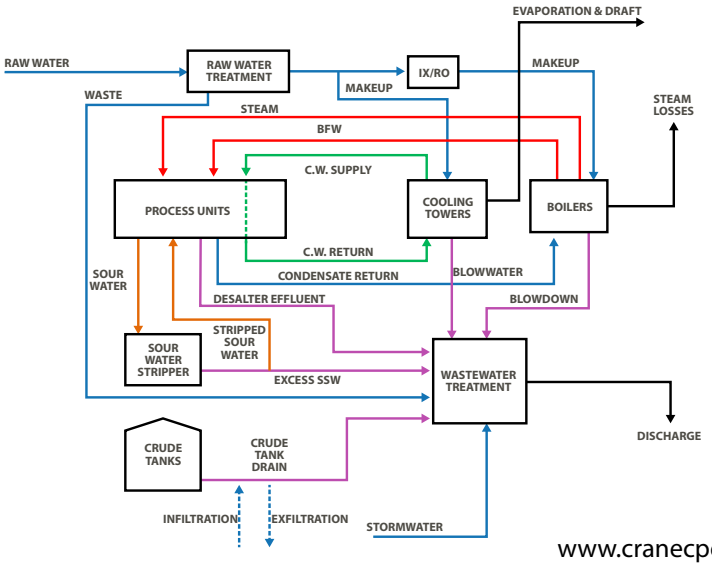
Refinery Cooling Water

Resistoflex® was approached by a major refinery in North America for an economical piping solution for their seawater cooling system. They were unhappy with the service life of the incumbent piping systems—a mix of epoxy lined steel and cement mortar lined pipe. Epoxy lined steel or fusion bonded epoxy piping has a thin coating which is susceptible to damage. Very minor imperfections such as holidays and scratches had led to cell corrosion and disbonding of the liner. Cement mortar lined piping is often used to handle seawater due to a lack of alternatives. However, that product is prone to failure by either cracking or spalling due to shock or water hammer in the system. Some believe that the concrete mortar has self-healing properties if it becomes cracked or otherwise superficially damaged, but this is not true. Concrete linings do not self-heal or regenerate and cracks do not repair themselves.

In addition to a solution that provided superior corrosion resistance and a rigid housing; the customer was also looking for a product that could meet their 220°F temperature requirement.

Resistoflex® offered and supplied polypropylene lined pipes and fittings. Polypropylene lined products were the natural choice as the product has the strength of the steel housing and the corrosion resistance of the plastic liner. The thick and seamless liner delivers nearly a *zero corrosion rate* at temperatures up to 225°F. In over 15 years of service at this refinery, no Resistoflex® polypropylene lined piping has failed.

While Resistoflex® has been supplying small diameter (1"–12") polypropylene lined pipes and fittings to this customer for many years now, it was difficult to compete for the large diameter (>14") due to a product limitation. Larger diameter lined pipes and fittings were only available with PTFE lining prior to 2019 largely because PTFE has two disadvantages in these sizes. The cost of the resin is considerably more expensive than polypropylene and the overall pipe length is shorter. With the investment in machinery and the development of large diameter PP lined pipes and fittings in up to 20ft long pipes, Resistoflex® finally has an economical solution for these applications.

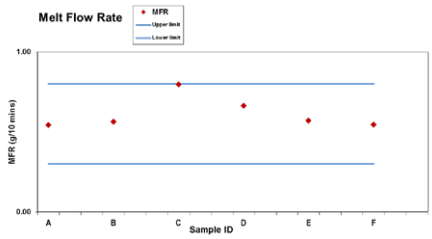


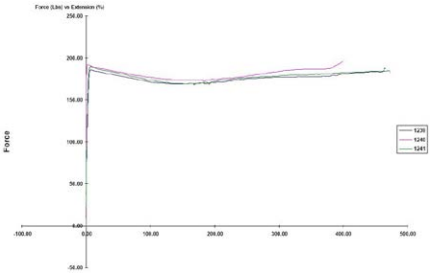
Key Applications

3-Phase Salt Water, Crude Oil and Salt Water / Crude Oil Mix Experiment

Resistoflex® and a leading Middle Eastern Oil and Gas corporation have executed a 3-Phase trial to document the suitability of polypropylene lined pipes and fittings being exposed to Salt Water, Crude Oil and a Salt Water / Crude Oil Mix at various temperatures.

The 1st Phase of the experiment was executed in Resistoflex® state-of-the-art test laboratory in Marion, NC. The test consisted of (18) polypropylene copolymer tensile specimens, which had been machined from the molded liner. Three specimens each were weighed and placed in a separate vessel containing the prescribed media for the required time of 60 days with varying temperatures up to 199°F. Following the completion of the exposure, the specimens were removed from the solutions, rinsed and dried. The next step was to carry out a weight change evaluation as well as tensile & elongation testing as per AST D638 as well as a melt flow rate determination per ASTM D1238. After careful review of the results, it was determined that weight change from exposure was insignificant to mechanical properties of exposed Polypropylene were unaffected. It was thus determined that Polypropylene is suitable for service in mixed crude oil and chloride salt water applications.





For the 2nd Phase of the experiment Resistoflex® manufactured some lined pipes and fittings for the installation in a service at a plant in the Middle East. The field survey was scheduled for several months of exposure at one of their salt water injection pump trains. The installation was monitored frequently for the duration of the test period. After the completion of the test period, removal of some parts and no obvious visual anomalies, the samples were shipped back to Resistoflex® for the last phase of the experiment.

The 3rd Phase was to determine any effects from the applied service. The predetermined evaluation included a visual inspection, hydrostatic proof test, specific gravity and a melt flow rate (MFR) determination. The visual inspection revealed no defects or anomalies. The hydrostatic test confirmed the integrity of the component. The specific gravity revealed no notable difference between the returned material and new material. The MFR results indicated that the liner had experienced no degradation from the service conditions and was acceptable per Resistoflex® standards.

ID	Pre weight (gm)	Post weight (gm)	Delta (%)	Tensile Strength at Yield (PSI)	Tensile Strength at Yield Avg (PSI)	Elongation at Yield (%)	Elongation at Yield Avg (%)	Ultimate Tensile Strength (PSI)	Ultimate Tensile Strength Avg (PSI)	Ultimate Tensile Strength Avg (PSI)	Elongation at Break Avg (%)	MFR (gm/10 min)
A1	7.06	7.07	0.1%	3680	3715	6.90	7.06	3742	3736	479	483	0.54
A2	7.08	7.07	-0.1%	3739		6.88		3741		460		
A3	7.08	7.10	0.3%	3725		7.40		3725		510		
B1	7.05	7.03	-0.3%	3750	3755	7.09	5.27	3781	3797	465	445	0.56
B2	7.08	7.11	0.4%	3739		2.11		3834		399		
B3	7.09	7.10	0.1%	3776		6.61		3776		472		
C1	7.10	7.31	3.0%	3238	3280	23.39	22.42	4820	4868	638	614	0.80
C2	7.06	7.29	3.3%	3271		22.44		4788		584		
C3	7.07	7.27	2.8%	3330		21.43		4995		621		
D1	7.09	7.26	2.4%	3331	3332	21.34	21.69	4430	4780	456	568	0.66
D2	7.08	7.26	2.5%	3329		22.08		4979		623		
D3	7.12	7.30	2.5%	3335		21.65		4932		624		
E1	7.06	7.01	-0.7%	3850	3854	9.27	6.61	3851	3854	603	538	0.57
E2	7.08	7.09	0.1%	3853		5.02		3853		561		
E3	7.04	6.99	-0.7%	3858		5.53		3859		449		
F1	7.08	7.07	-0.1%	3815	3833	9.53	9.02	3815	3840	359	447	0.55
F2	7.05	7.03	-0.3%	3845		8.79		3846		513		
F3	7.05	7.06	0.1%	3839		8.73		3858		469		

Key Applications

Microbiological Induced Corrosion (MIC)

Resistoflex® was approached by a major US power plant operator. They were experiencing Microbiological Induced Corrosion, (MIC) in cooling water lines throughout their facilities. Carbon steel piping exhibited rapid buildup of microbial colonies in these lines, which, untreated, led to compromise of the metal wall. This kind of MIC is a widespread problem in industry where unheated lines offer an environment which allows both aerobic and anaerobic bacteria to reproduce. The respiratory and metabolic excretions of these bacteria can contain aggressive corrosive chemical species, such as sulfuric acid, sulfurous acid, nitric acid and many others. Other contributing factors include the creation of microscopic zones of altered pH and electro-chemical potential. This well documented phenomenon has been recorded in both stagnant and high velocity water flows and across the salinity spectrum from high purity to near saturated saltwater. The annual cost to US industry is estimated at thirty billion dollars.

In this specific case, preferential attack was noted along both longitudinal and circumferential weld seams. The appearance of the bacteria colonies was multi-colored gelatinous masses, which congregated along the weld seams. They were present to a lesser degree in other seamless areas as well. Pigging had proven ineffective due to the inability of the pig brushes to sweep into the small crevices and pits found in the welds. A more effective treatment proved to be mechanical descaling by flushing heavy slurries of water loaded with metallic shot through the lines, then flushing with fresh water. This had very undesirable after effects, because it was impossible to completely remove all the shot. The small fraction of residual shot inevitably passed downstream and was later implicated in fouling of pumps and valves. The plant operator was desperate for a simpler, more robust solution.

Resistoflex® offered PP lined steel piping as a drop-in replacement for the carbon steel piping they had been using. The price for this solution was actually less than stainless steel piping, which has also been shown to exhibit MIC.

The rate of buildup of MIC was immediately reduced, due to the non-stick properties and smooth surface of the PP lined piping. Another factor in the reduction is the inherent structural complexity of the polymer, which confounds the ability of the bacteria to adapt to the material. Structural complexity refers to the random side chain comonomers, intermittent crystalline constructs, and varying molecular weight. Collectively, these nano-scale material features provide a constantly changing terrain that the bacteria cannot adhere to on a macro-scale. When small buildup did occur, it was easy to remove with a chlorinated biocide. This was not feasible with carbon steel piping, as the biocide itself was highly corrosive to the carbon steel piping. PP lined steel piping is inert to most chlorinated fluids, although free chlorine itself should be avoided.

add credit

Competitive Solutions

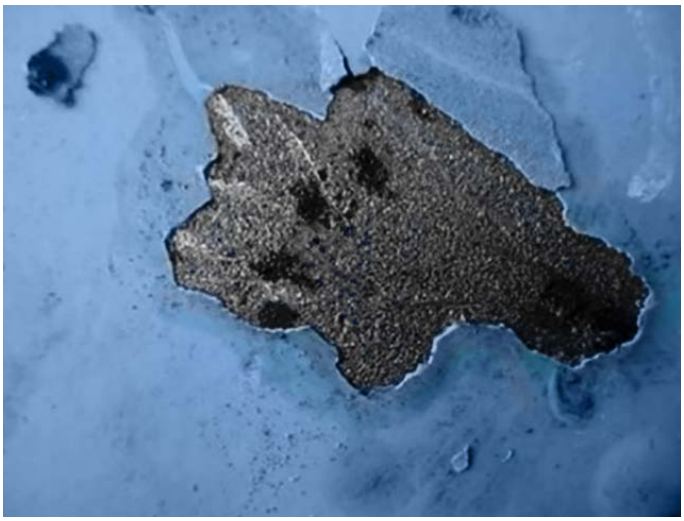
Fusion Bonded Epoxy

FBE is an epoxy-based thermosetting powder coating widely applied to steel pipe, steel reinforcing bars for concrete, tanks, and a wide variety of piping connections (valves and fittings). The "fusion-bonded" designation comes from the chemical cross-linking that occurs during the application process, which differs from the application of standard paints and coatings. FBE is applied by preheating the substrate, typically over 401°F and spraying the coating powder onto the surface. Small parts and fittings can be dipped into FBE powder that has been fluidized by air. Only a small number of types of FBE are suitable for long-term service in water.

Disbondment of the coating is the primary failure mode reported by users of piping with an interior FBE coating. A primary cause of disbondment is cell corrosion starting at minor holidays and scratches, which exist in virtually all systems. Other factors can also cause disbondment, including poor surface preparation, moisture absorption and permeation. The coating is typically about 0.020" (0.5mm) thick. This makes is susceptible to impact and abrasion damage.

CONS

- All coatings have minor imperfections (holidays and scratches) leading to the potential for cell corrosion and disbonding
- Thin coating leading to reduced corrosion and abrasion protection
- Thin coating susceptible to damage
- High moisture absorption and permeation
- Requiring internal access



Plastic & FRP Piping

Thermoplastic and FRP piping systems are widely used in normal fluid service and category D piping due to its relatively high corrosion resistance. The profile extrusion and winding processes used to produce the piping provides an economical solution where the process permits these materials.

Thermoplastics cannot nearly match the physical strength nor the ruggedness of metallic piping. In addition, special pipe supports are often required, and safety considerations may limit not only allowable temperatures and pressures, but system locations as well. Many chemical, physical and age-related effects can alter the pressure rating of this piping as the polymer structure weakens due to leaching, swelling, UV or other environmental stresses.

FRP systems typically increase the range of allowable temperatures and pressures compared to thermoplastics but still require special supporting procedures, protection from external loading and allowances for expansion and contraction. FRP is very resistant to seawater, but it is subject to joint cracking and leaks after extended service in some operating conditions. Field joining is typically a fusion bonding process, which is a relatively highly skilled trade. Environmental conditions such as wind, rain and dust can create very difficult conditions for the bonder.

CONS

- External impact can induce star cracking of the barrier layer, with no apparent damage to the surface of the pipe
- Low resistance to external mechanical damage caused by poor handling and installation practice
- Field joints difficult to make in hot, cold, windy or dirty environments
- Flexible wall makes FRP sensitive to buckling due to vacuum
- Extra supporting, restraint, or expansion allowances

Competitive Solutions

Cement Mortar Linings

Cement-mortar-lined pipes are centrifugally lined at the factory. This creates a uniform thickness of mortar throughout the entire length of the pipe. Cement linings are also smooth, which results in high flow coefficients. The protective properties of cement linings are due to two properties of cement. The first is the chemical alkaline reaction of the cement and the second is the gradual reduction in the amount of water in contact with the iron.

There is a need for extra care in handling and fitting. If pieces of the lining break off, the area of bare steel exposed is anodic to the steel embedded in the cement. The corrosion rate in such a cell will be determined by the flow of oxygen through the cement and, as the area relationship ratio of embedded to exposed steel is high, the corrosion rate can also be high. Joints at valves and fittings must also be covered with cement to prevent cell corrosion.

Either corrosion or physical damage can cause the lining to spall off and pieces of lining can partially block heat exchanger tubing.

Cement linings are most effective in long, straight runs of large (>1m) diameter. The ability to maintain lining integrity decreases rapidly with diameter, number of fittings, and valves

CONS

- Failure of the cement lining by either cracking or spalling due to shock or water hammer in the system
- Bolting induced stresses crack the lining and initiate corrosion
- Difficulties of lining coverage for welded joints (in e.g. nozzles)
- Due to the fragility of the cement lined coating, it is recommended that the pipe is handled as delicately as possible
- Requiring internal access

Nickel-Copper Alloys

There are many common nickel alloys used in piping. Nickel-copper alloys and nickel-chrome-molybdenum alloys are the ones commonly used in seawater service. Monel 400 also called alloy 400 has been around for over 100 years being originally developed in 1905. It contains about 30% copper and a minimum of 63% nickel. Manganese, iron and silicon are present in smaller amounts. The alloy has high strength and good corrosion resistance in many aqueous environments. The addition of copper to nickel makes it more inert compared to either pure nickel or copper so that this type of alloy has a lower corrosion rate in reducing conditions than nickel and a lower rate of corrosion than copper under oxidizing conditions. Generally, nickel-alloys are very resistant to SCC (stress corrosion cracking) but can be stress cracked in the presence of chlorides or caustic solutions. SCC resistance is increased by increasing nickel content in alloys, which also increases cost. There are various factors promoting SCC of nickel alloys in aqueous chloride solutions such as elevated temperatures, chloride content, low pH, presence of H_2S, presence of other oxidizing agents and/or high stress. In laboratory and field experiments alloy 400 was highly susceptible to SRB (sulfate-reducing bacteria) in both chlorinated and unchlorinated seawater where oxygen was available. Alloy 400 tubes failed in 3 to 8 months in a refinery heat exchanger using Arabian Gulf seawater as coolant. There have been several other industrial cases of MIC in various nickel alloys reported, too.

CONS

- Cost of material and installation especially for large diameter piping, (and wide swings in cost as market conditions dictate).
- Susceptible to microbiologically influenced corrosion
- Stress corrosion cracking

Vessels, Columns & Complex Shapes

The resin of choice for Resistoflex® rotationally lined vessels, columns and complex shapes is ETFE, due to its many outstanding features. ETFE is a rugged thermoplastic with an excellent balance of chemical and mechanical properties. ETFE bonds to the metal substrate, with the ability to adhere to virtually any type of metal weldment, casting or forging.

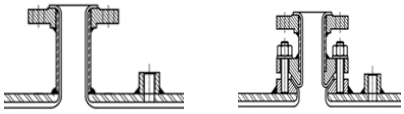
It offers outstanding resistance to attack by a wide range of chemicals and solvents. Additionally, its broad thermal capability (-150°F to 300°F) allows for a multitude of uses. Some of the most common chemical compounds are HCl, HF, H_2SO_4 and HBr.

ETFE roto-lined products come with the security of full vacuum resistance throughout the temperature range. Columns made with paste extruded liners or welded sheet liners either have limited vacuum rating or require additional measures such as vacuum plugs or graphite sleeves.

Wall thickness for ETFE vessel and column linings is variable based on customer specification. However, it is desirable to minimize the thickness as the cost of the ETFE resin is a significant part of the total cost of the lined vessel or column. In traditional lined process piping, permeation is a great concern, and hence, many manufacturers differentiate and promote their products based on a "thicker is better" mindset. In vessels and columns, vapor pressure, a primary driving force for permeation, is typically carefully modulated. This fact, coupled with the very low permeability of ETFE, (5-25% of that of standard PTFE) makes permeation less concerning, and thinner liners become a feasible option.

Nozzles can be fitted at almost any location of the column. Multiple nozzles with different sizes per column section are well within the capabilities of roto-lining. Advantages of this method over housings lined with paste extruded liners are:

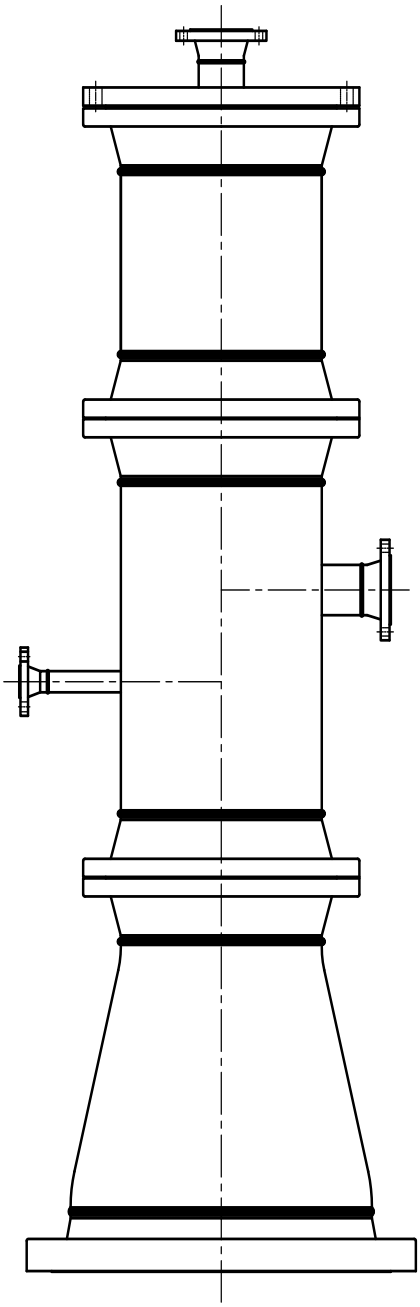
Nozzles are welded on the housing as a single piece vs. multi piece block flange connection



Uniform liner thickness vs. varying thickness because of the blow molding process

Venting is required for each PTFE lined pipe and fitting per ASTM F1545-15a to release any pressure between the liner and the housing. These vent holes are prone to corrode the housing because of permeation. Vent couplings and PTFE vent plugs have been adopted by end users as a solution but do not eliminate the problem completely. ETFE, as a low permeability lining bonded to the metal housing, does not require venting. Hence the risk of a liner collapse due to vent hole blockage is not existing.

Vessel and Column Design



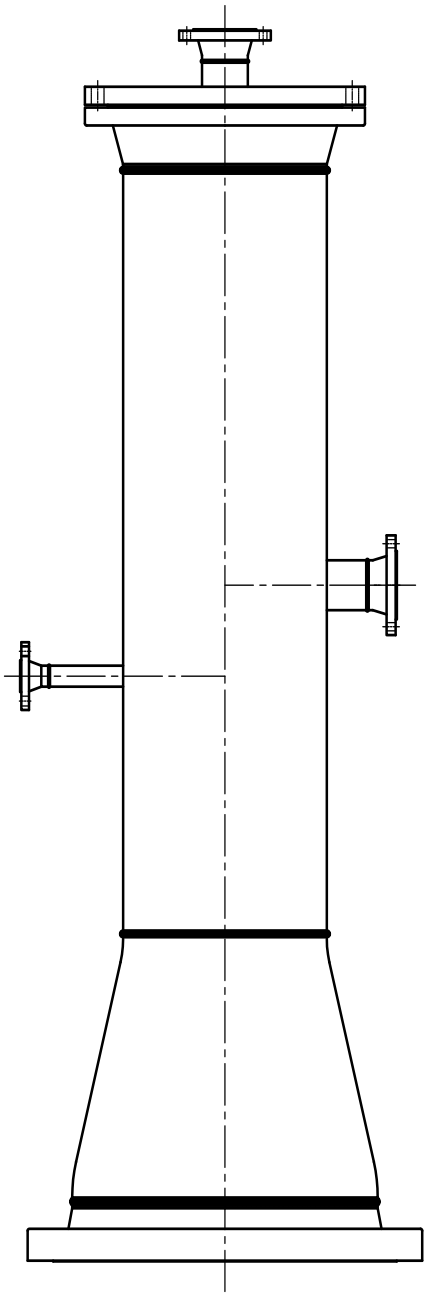
Design Standards	• ASME B31.1 and B31.3 • Available ASME Section VIII Div. 1 "U" stamp • 161" maximum diameter
Welding Standards	• ASME Pressure Vessel and Boiler Code Section IX
Liner Availability	• Ethylene tetrafluorethylene (ETFE) • Polypropylene (PP) • High Density Polyethylene (HDPE)

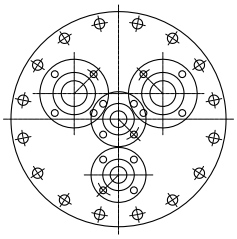
Body Material	• Carbon Steel
	  • ASTM A53 Gr. B
	  • ASTM A106 Gr. B
	  • API 5L
	  • ASTM A234 WPB
	• Stainless Steel (304L, 316L, other grades)
	  • ASTM A312
	  • ASTM A403

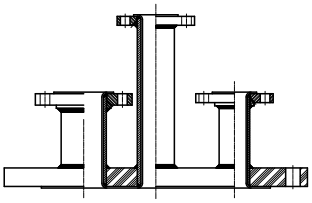
Flange Material	• ASTM A105 and A105N • ASTM A182

Paint	• Polyamide epoxy is standard
	• Optional paints:
	  • Inorganic zinc silicate
	  • Organic zinc epoxy
	  • Epoxy mastic
	  • Epoxy phenolic
	  • Novolac epoxy
	  • Polyurethane
	  • Siloxane
	  • Electrically conductive epoxy

Optional Internals	• Trays • Liquid distributors • Liquid collectors • Support grids • Support Plates • Bed limiters • Saddles, rings, and or structured packing



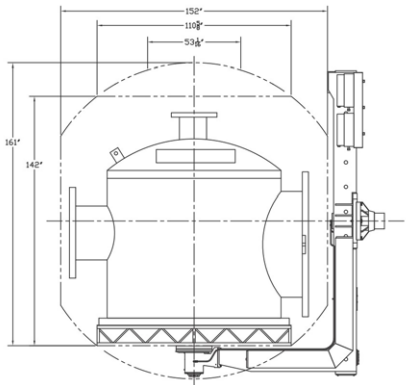




Rotational Lining Well-Suited to Large Diameter Pipes & Fittings and Custom Configurations

Melt processable resins such as ETFE (ethylene tetrafluoroethylene), PP (polypropylene), and HDPE (high-density polyethylene), in conjunction with rotational lining, have allowed Resistoflex® a new freedom in producing lined steel piping products with custom or complex dimensions—with the same excellent Resistoflex® quality the industry has come to expect, at a price lower than expensive metal alloys and features superior to other lining and coating solutions.

We can supply your corrosion resistant lining requirements for large diameters (up to 161") and custom-dimension fittings, valve bodies, pump casings, flowmeters, and vessels. In fact, our capabilities are limited only by your imagination.



Rotational lining is an ideal method to line the interior surfaces of complex metal fabrications:

1. A pre-weighed amount of granular resin is placed inside the part.
2. With the flanges sealed, the part is heated in a forced-air oven while being rotated on two axes simultaneously.
3. The bi-axial rotation transfers the heat evenly to the fitting, until the resin's melt temperature is reached. As the resin melts, it uniformly coats the interior, regardless of the geometry of the fitting.
4. The heat is turned off, and the part continues to rotate as it cools, allowing the resin to set. The result is a seamless, heavy-duty plastic lining with available thicknesses up to .450" depending on the application.
5. Prior to shipping, all parts must pass an electrostatic test or hydrostatic test as required by ASTM F1545-15a, specification for plastic lined ferrous metal pipe and fittings.

Why is Rotational Lining Superior to Other Lining Methods for Complex Shapes and Large Diameter Pipe and Fittings?

vs Sheet Lining

- Rotational lining provides a seamless liner, no matter the complexity of the part.
- No internal access to the part needed with rotational lining.
- Mechanically bonded liner eliminates the need for adhesives.

vs Fiberglass Reinforced Plastic (FRP) / Dual Laminate

- FRP is inherently mechanically weak, with a limited pressure rating compared to plastic-lined steel.
- What FRP gains in weight savings, it gives back in support complexity.
- Plastic-lined composite cannot pass the ASTM F1545 qualification tests required for plastic-lined steel.

vs Exotic Alloys

- Plastic-lined steel provides a "zero corrosion rate" at an economical price.
- Alloy pricing fluctuates wildly. Rotationally-lined steel is predictable and stable.
- Many alloys require cost-prohibitive welding processes and non-destructive testing

vs Fusion Bonded Epoxy (FBE) Coating

- Thick plastic liner is more durable and reduces permeation better than typically thin (< 0.040") powder coating.
- No internal access to the part needed with rotational lining.
- Thin liner is easily damaged.

vs Powder Coating

- Thick plastic liner is more durable and reduces permeation better than typically thin (< 0.040") powder coating.
- No internal access to the part needed with rotational lining.
- Thin liner is easily damaged.

vs Glass Lining

- Plastic-lined steel has excellent impact resistance compared to naturally brittle glass.
- Glass lining is extremely expensive compared to plastic lined steel.
- ETFE and polypropylene are fully resistant to hydrofluoric acid and sodium hydroxide, both of which attack glass.

Flange Reduction by Design

Resistoflex® processing technology and your freedom of design can help reduce emissions as required by the 1990 *Clean Air Act* amendments. Flanged pipe connections are among the most numerous potential emissions points in any chemical process facility. The use of corrosion-resistant plastic-lined complex fittings dramatically reduces the number of flange connections needed in a manifold or short run of piping. In the example below, a customer designed a line using standard pipe and fittings for a total of 11 flange connections. Through weld fabrication and rotational lining, the number of flange connections was reduced to two.

Professional Support for Every Stage of the Project

Whether you're working on a new project or a retrofit job, you probably have your hands full. Unfortunately, many pipe manufacturers treat lined pipe as a commodity product and offer little technical support.

Resistoflex®, on the other hand, realizes that plastic-lined pipe is used where safety and environmental issues are a major concern. We recognize the need for personal technical support. Resistoflex® backs up its products with the most comprehensive package of service capabilities available. Resistoflex' support services are designed to take some of the burden off you and your people.

Our piping specialists can help you meet tight deadlines and take care of much of the time-consuming paperwork involved in the typical project. We offer the kind of on-site personal attention that's becoming rare in the industry today.

Bill of Material Take-Off

Submit your isometric drawings to us as CAD or PDF files, and we provide you a bill of materials, by drawing, for each item, including part number, description, tag number, and price. We can add the tag numbers to your drawings as an aid during installation.

Isometric Drawing Service

We can convert your orthographic drawings into isometric drawings showing all dimensions and tag numbers. Additionally, we can convert a welded metallic-system into isometric drawings of a plastic-lined flanged system.

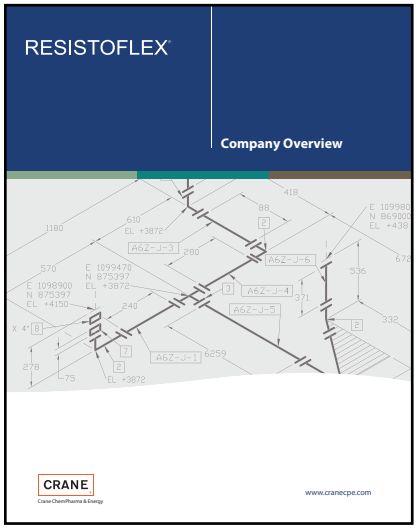
On-Site Training

We can send our technician to your site for training on installation and maintenance or field fabrication certification. We will train your operators in the Resistoflex® procedures, and you can be sure that each trainee will have a thorough understanding of the training materials and procedures.

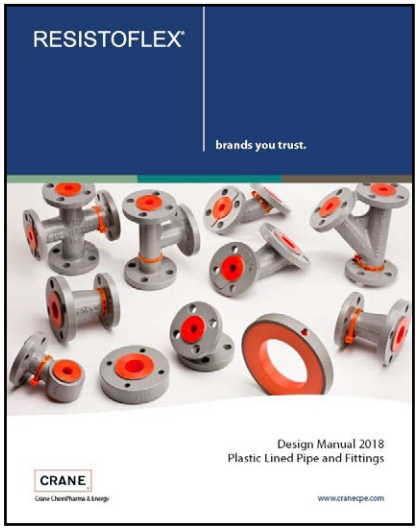
Factory and Field Support After Installation

Resistoflex® support doesn't stop after the pipe is installed. Our field technical representatives and trained distributors are always available to help you find piping solutions. Your distributor for Resistoflex® plastic lined piping products maintains a large inventory of piping items for fast delivery when you have field changes or need closure spools. Whenever you need our products or the service that goes with them, you can count of Resistoflex®.

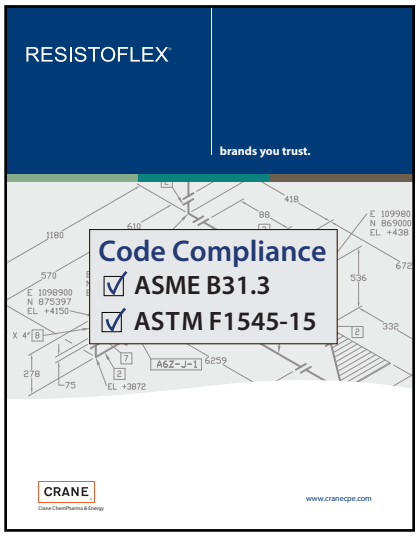
Resistoflex® Literature



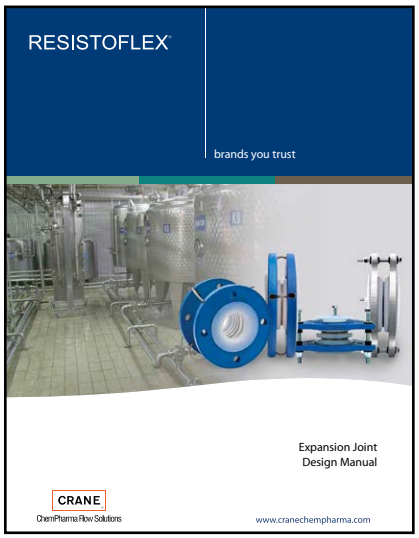
Company Overview



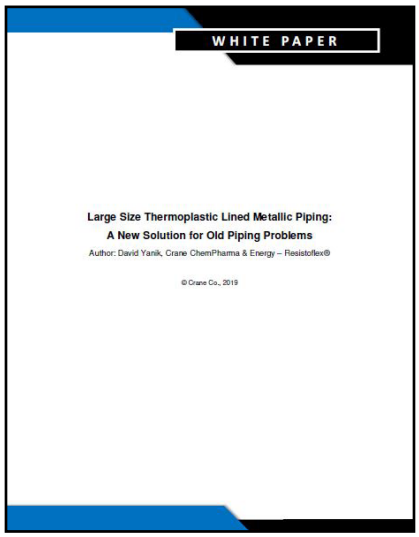
Pipe and Fittings Design Manual



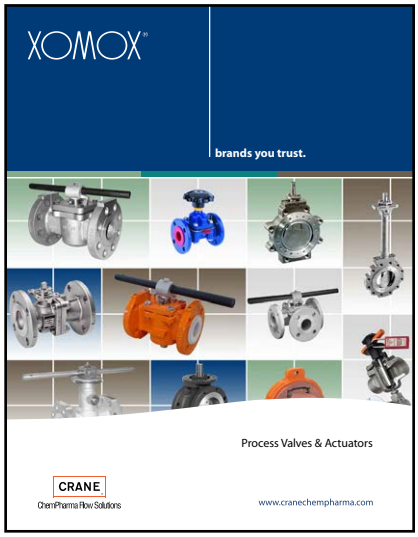
Code Compliance



Expansion Joint Design Manual



Resistoflex® Large Diameter Pipe White Paper



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Per the Pressure Equipment Directive 97/23/EC Essential Safety Requirements Annex I Checklist, the following Essential Requirements are within the customer scope for all products: Wind, Earthquake, Reaction forces and Moments, Fire, Safety devices, permeation, temperature and pressure spikes. For all products, it is recommended that customer remove representative sample for examination of internal corrosion every 2 years.

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ELRO® DUO-CHEK® FLOWSEAL® SINCE 1864 JENKINS® FK® KROMBACH ARMATUREN
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