

Design of FRP Piping Systems ©1993

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Background

In the late 1960's and early 1970's, FRP materials were being developed that would bring the market for FRP pipe to new heights. FRP was specified in many applications where only specialty alloys had been used and as the applications expanded, FRP was becoming the complete problem solver for corrosion service. Resin manufacturers were developing new polyesters and vinylesters that were tougher and more resilient. Manufacturers were developing fabrication methods that improved quality and reduced costs. In 1974 several business projections indicated that FRP was to be the growth industry of the future but about this same time some plant owners and engineers began to experience frequent piping failures. Many users were questioning the ability of this material to handle the operating stress of process piping.

One of the major producers of resins began a study in an attempt to understand the cause of these frequent failures. They discovered that 95% of all failures were tensile failures in the axial direction of the pipe and were the result of axial thrust or bending. Also of interest, 95% of these failures occurred at pipe joints. This study led engineers to believe that by restraining the pipe in the axial direction and by guiding the pipe to reduce bending, the failures could be eliminated. Support spans were reduced to compensate for pressure stress, which adds to the bending stresses. Almost all span calculations had been based on simple bending stress instead of total stress resulting in extremely long support spans. The most important finding from this study was that FRP piping could be successfully used when careful analysis of support, guide and anchor placement is considered.

The responsibility of the engineer is to insure that the piping system operates within allowable stresses when the system is subjected to the most severe operating condition. The allowable stress is usually 0.100 X ultimate strength for hoop stress and 0.050 X ultimate in the axial direction. The major difference between the design of a piping system and a tank is that the tank is one finite structure with easily defined boundaries – a piping system is a complex three-dimensional frame that has three degrees of freedom. An engineer usually performs the stress analysis, however the layout of the FRP piping system is best left to an experienced piping designer. This person learned the art of piping by years of painful experience with very little help from textbooks or handbooks.

If the designer does his job well, the layout will consider expansion, support locations, access to equipment and control stations, and will provide access and clearance for maintenance. The designer will find that FRP piping is somewhat more complex than metallic piping because of the lower strength, higher coefficient of expansion, installation differences and because FRP requires positive restraint to keep stresses within acceptable boundaries. A well planned routing will allow the engineer to analyze the system and with adequate support provisions, the system stresses can be controlled.

Before laying out the system the designer and engineer is referred to several technical papers that address important considerations for successful design. “Transition to FRP, Basic Guidelines for Piping Designers and Users” (4) “ Design Considerations for FRP Piping Systems”(5), and “Providing Proper Supports for Reinforced Thermoset and Non-Reinforced Thermoplastic Process Pipe” (6). Reference (5) and (6) provide a simplified method of analysis for FRP pipe that is presented in this paper. There are several formal stress programs that are designed for PC that have been used by experienced engineers but with a great deal of caution since the programs were not primarily designed to handle the unique properties of non-isotropic materials such as FRP.

Piping Design

The following steps concerning the design and installation of FRP pipe and supports are provided as a help to the designer or engineer. These design steps are intended to serve as a guide to the proper use of the supports, and while it is impossible to cover every piping condition, experience indicates that approximately 95% of the design requirements can be met through the use these procedures. If the designer is faced with special conditions where a special design might be required he should contact the engineer for assistance.

Review piping specifications.

- **Review piping drawings.**
- **Review structural drawings**
- **Review valve and fitting specifications.**
- **Locate possible hanger locations.**
- **Analyze thermal movement, stress and flexibility of the piping system.**
- **Calculate hanger loads.**
- **Select hanger types.**
- **Check piping and hanger clearance around existing piping structure and equipment.**

The principles of design and analysis for FRP pipe differ considerably from the principles of design for metallic pipe. The analysis of steel pipe normally begins with maximum flexibility and the final support-guide-anchor design ends when allowables are achieved. When dealing with FRP pipe, the analysis normally begins with a fully anchored system and the final support-guide-anchor configuration is established when the minimum stress condition is reached (based on the available structural steel).

The fully anchored FRP piping system is often referred to as an anchor-to-anchor system. This simply means that an anchor is placed at each end of a straight run of piping. The pipe is restrained from growing thermally by the anchors and is guided to prevent buckling. This arrangement is never considered with metallic pipe but the low compressive modulus of FRP allows anchoring. The anchor loads are normally less

than 1/60th that of steel but must be considered in the structural design of the support system, especially in large diameter pipe. In the design of a complex piping system that might include many changes in direction the final design might result in piping segments that are fully anchored (anchor- to- anchor) and segments that are semi-anchored where piping off sets are used to provide sufficient flexibility to absorb expansion and yet keep stresses within allowable. A fully flexible piping system that allows uncontrolled thermal expansion has been proven to be the major root cause of FRP piping failures and should be avoided.

Mechanical Properties

After the selection of a resin system, a determination as to the type of pipe must be made. There are three major categories of FRP pipe construction. They are: (1) contact molded, (2) filament wound, and (3) centrifugally cast. The mechanical properties of the pipe are closely linked to the method of fabrication and those properties vary considerably among the three types.

PIPE PHYSICAL PROPERTIES COMPARISON ⁽¹⁾					
	Filament Wound (2)	Centrifugally Cast (3)	Hand Lay-up (Contacted Molded)	Polyvinyl Chloride	Low Carbon Steel
Modulus of Elasticity in Tension Axial 77°F,psi	1.0 – 2.7 x 10 ⁶	1.3 – 1.5 x 10 ⁶	0.8 – 1.8 x 10 ⁶	3.5 – 4.0 x 10 ⁵	29 x 10 ⁶
Ultimate Axial Tensile Strength 77°F,psi	8,000 – 10,000	25,000	9,000 – 18,000	6,000 – 7,000	50,000 – 70,000
Ultimate Hoop Tensile Strength 77°F,psi	24,000 – 50,000	25,000	9,000 – 18,000	6,000 – 7,000	50,000 – 70,000
Modulus of Elasticity in Beam Flexure 77°F,psi	1 – 2 x 10 ⁶	1.3 – 1.5 x 10 ⁶	1.0 – 1.2 x 10 ⁶	3.5 x 10 ⁵	29 x 10 ⁶
Thermal Expansion in. / in. / °F	8.5 – 12.7 x 10 ⁻⁶	13 x 10 ⁻⁶	15 x 10 ⁻⁶	3.0 x 10 ⁻⁵	6.0 x 10 ⁻⁶
Heat Deflection Temperature 264 psi °F (4)	200 - 300	200 - 300	200 - 250	155 - 165	N/A
Thermal Conductivity BTU/hr./ft. ² /°F/in.	1.3 – 2.0	0.9	1.5	1.0 – 1.4	300 – 350
Specific Gravity	1.8 – 1.9	1.58	1.3 – 1.7	1.3 – 1.6	7.85
1. For exact values contact pipe manufacturer. 2. Values shown for Filament-Wound Pipe are based on pipe wound at an angle of approximately 54° 3. As published by a leading manufacturer of centrifugally cast pipe. 4. ASTM D 648					

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Despite conjecture as to the advantages and disadvantages of each type of pipe construction, it has been found that any of the three can be utilized if the pipe is of high

quality and if the system has been properly designed and supported. The specific mechanical properties of the pipe selected are incorporated into the design of the system. This includes the location and type of support. The mechanical properties inherent to the method of pipe fabrication are discussed in a later section.

The most important factor in the design of a piping system is the determination of the mechanical properties of the pipe over the operational temperature range of the system. The catalogs for many pipe manufacturers list the range of properties for various laminates, but very few provide performance data at elevated temperatures. The equation, which is used to determine the design aspects of any structural system, utilizes factors for the mechanical properties under the expected design conditions, including temperature. Without this information, the designer is severely handicapped.

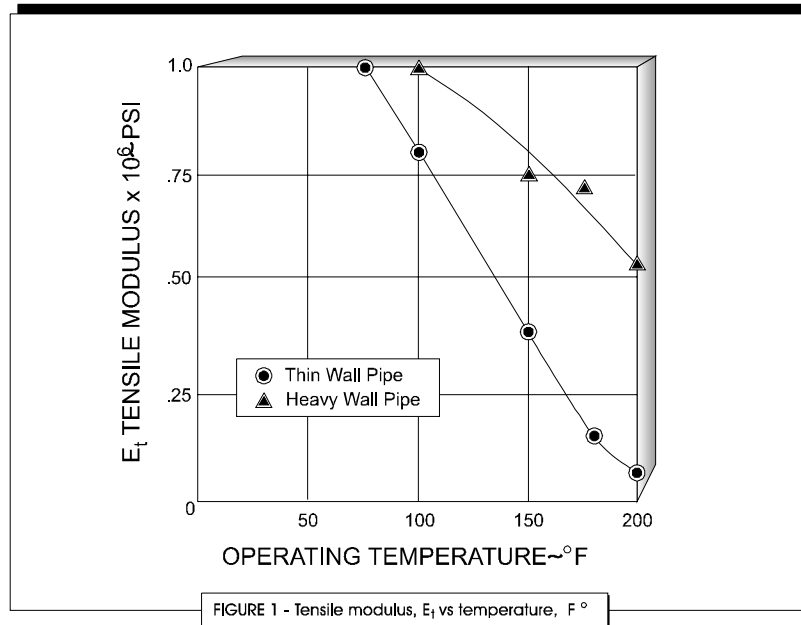
Many piping catalogs include tables that the designer can use to determine support, guide and hanger spacing. The spacings are usually based on a specific gravity of 1.2, a liquid temperature of 160 or 180 degrees F, and a limited deflection of 1/2". This information is useful for estimating but in most instances the spacings are not based on total pipe stress. Very seldom is pressure stress considered in the derivation of these tables. In FRP piping systems it is very important that the total stress be considered when selecting support spans. By using the equations presented in the Design Approach section, the designer can accurately define support and guide spacings and be assured that the pipe is designed to operate within the specified allowable stress.

The use of the procedures outlined in this section will greatly improve the reliability and service life of any FRP piping system. The same procedures will work equally well with duct systems. As these procedures were being developed it became evident that there were no commercially available standard supports for FRP piping. Many different designs were illustrated in many of the catalogs but a review of the designs indicated that additional work would be needed to make them acceptable for FRP piping and ducting. A family of special FRP pipe support designs is illustrated in "Support Design". This family of supports has been used in almost every environment and in almost every condition found in process industries. The applications need to be carefully checked to insure that loads are compatible but the basic design can be extended to include pipe diameters up to 120".

When specifying the supports the designer will become familiar with the unique features that are important to the design of an FRP system. The long support with a full bonded liner eliminates failures due to local stresses. The low profile of supports keeps the pipe close to the structural steel thus reducing the size and amount of auxiliary steel. Selecting standards greatly reduces design time and the standardization of supports reduces manufacturing costs. Interchangeability and standardization reduces or eliminates field rework thereby reducing construction costs. Each support should be clearly marked to identify type and location.

Duct systems can be supported using these same basic designs, however since duct systems very seldom have fluid loads, the supports can be much lighter.

Figure 1 shows the change in modulus at elevated temperatures for two filament wound polyester pipes. This type of data is required in system analysis if the design is to be sound.



Comparisons

The following compares and contrasts the design features and advantages of the three types of FRP pipe:

Contact Molded. The high resin to glass fiber ratio of this pipe makes it ideal for highly corrosive fluids. In order to meet the strength requirements in the hoop direction, it usually has a thicker wall than the other types of pipe. For this reason, it is heavier. Also, since it is virtually handmade, it is more expensive. Strength in the axial direction is higher than filament wound pipe. Because the pipe is handmade, it is subject to wider manufacturing tolerances than the other types of pipe. This is especially important to the support designer who is responsible for the designed fit of supports. Contact molded pipe is highly recommended for use where it might be subject to a severe exterior environment. Fittings are normally joined to the pipe using the butt and strap method.

Filament Wound. A high glass content and precise fiber orientation make this type of pipe ideal for pressure applications. Machines are used more in its fabrication so the tolerances are closer, the mechanical properties more consistent, and the production cost is lower than for contact molded pipe. Due to the low resin to glass fiber ratio, a

corrosion liner of a minimum 100 mils should be provided. Since the axial strength of filament wound pipe is less than that for contact molded pipe, at the same pressure rating, the filament wound pipe will require a much closer support spacing. This is due to the thinner wall common with filament wound pipe. The preferred method of joining fittings and pipe is the butt and strap method, although several manufacturers provide tapered bell and spigot ends for joining pipe and fittings. The bell and spigot joint is an adhesive joint that is dependent on the glue line between the bell and spigot.

Centrifugally Cast. This type of pipe is almost fully machine made and it provides the most consistent mechanical properties and the closest tolerances. It has a lower glass fiber content than filament wound pipe and features higher corrosion resistance. The smooth outside diameter also facilitates a more consistent support design. Cast pipe, due to fiber orientation and higher glass content, has a higher axial strength than either the filament wound or contact molded pipe. Cast pipe has an unreinforced corrosion liner, which is susceptible to damage by impact, but if the pipe is properly handled and supported, it should pose no problems. Fittings are normally of the socket weld type that can be over wrapped if added joint security is desired. However, with correct installation procedures and inspection, the over wrap is generally considered unnecessary.

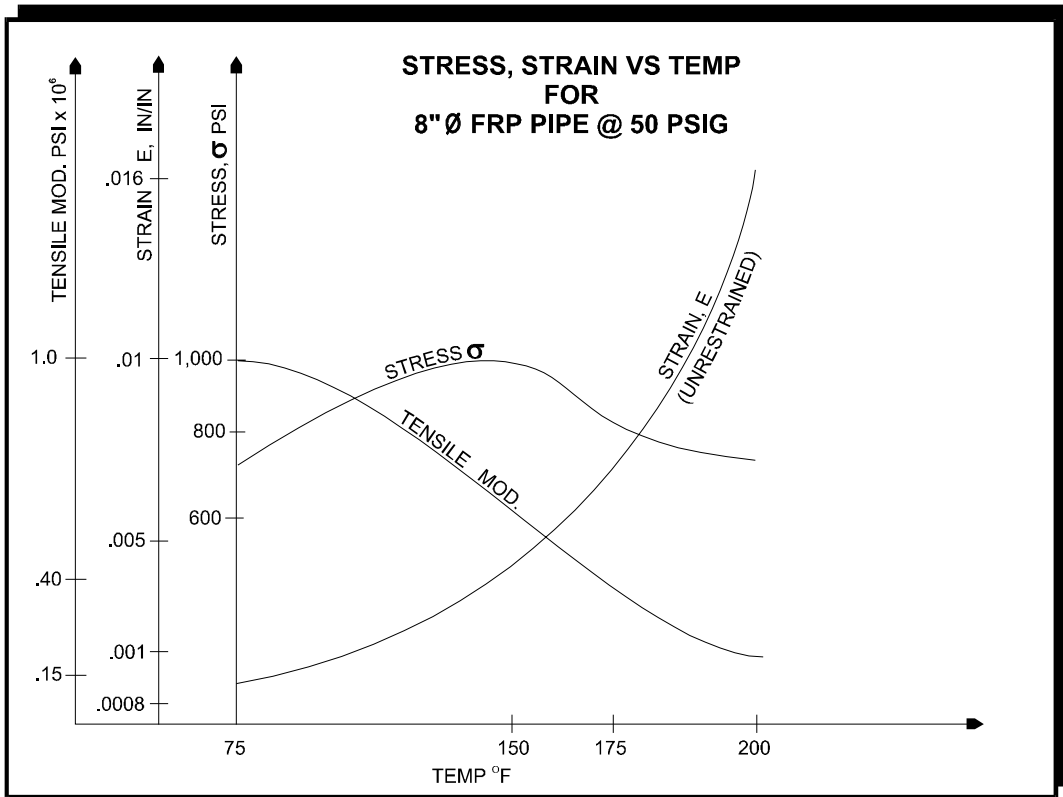
Design Approach

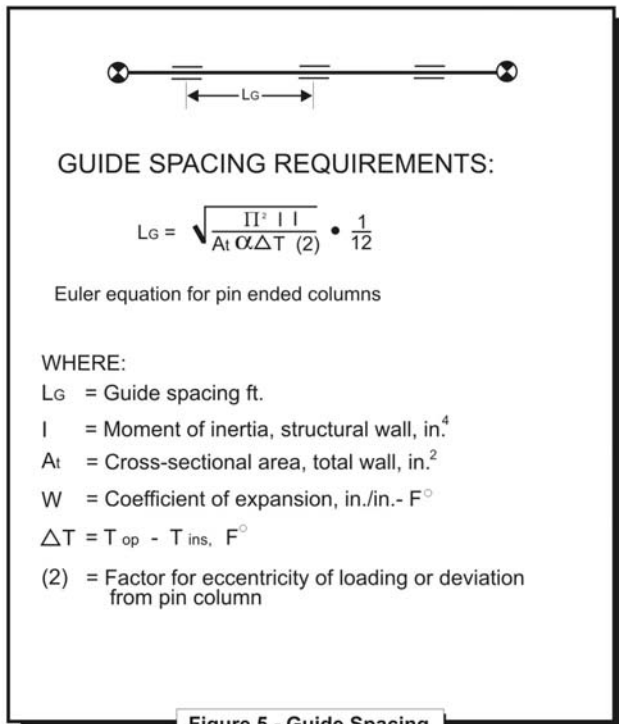
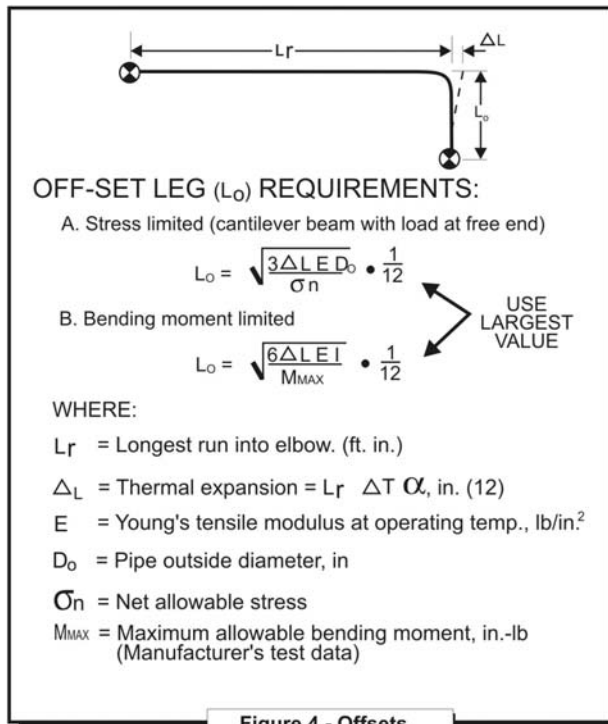
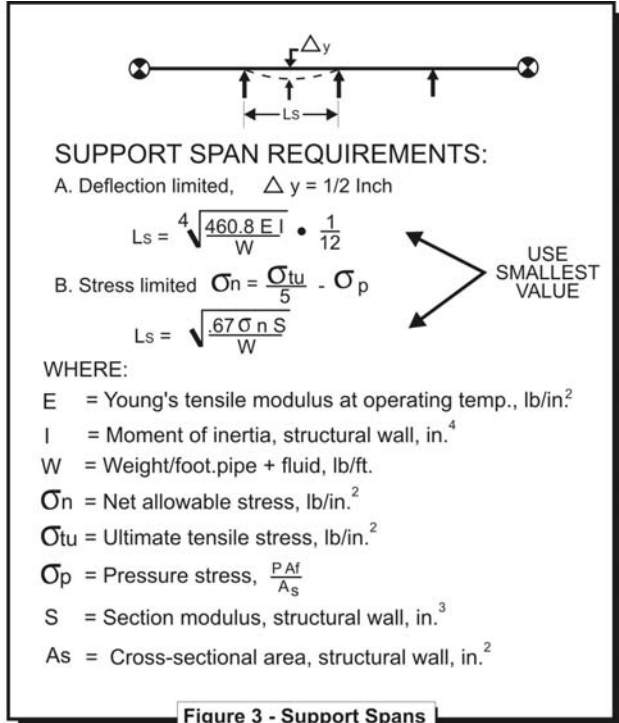
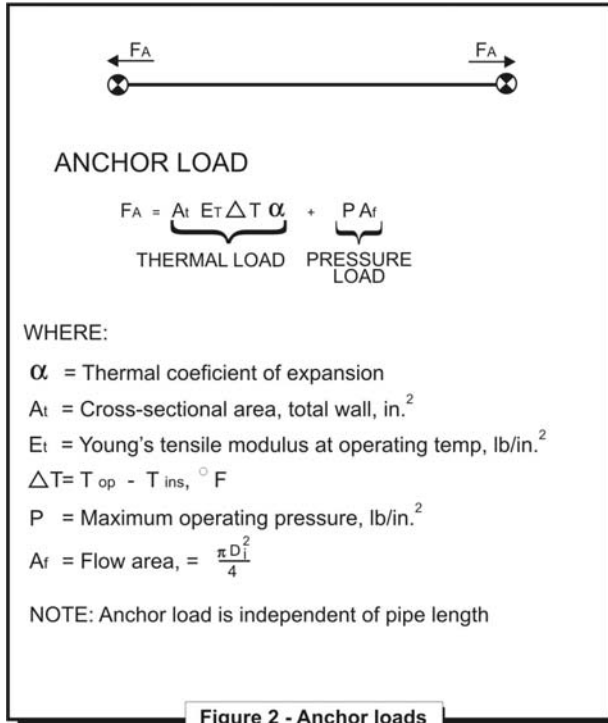
Contact molded FRP pipe, made according to PS 15-69, is normally rated by pressure in increments of 25 psi up to 150 psi. Standard machine made pipe does not follow this type of rating and the designers should refer to the ultimate pressure rating listed in the manufacturer's catalog. It is important to note that these ratings are based on the allowable pressure of a continuously supported pipe subject to pressure stress only. Since piping systems are almost never continuously supported, the stresses of bending must be considered when determining the allowable working pressure of an FRP pipe. The equations presented in the section on Support Design take these stresses into account.

Wall thickness is based on a 10:1 safety factor in the hoop direction and it is customary to use a 5:1 or 6:1 safety factor in the axial direction. By maintaining these safety factors in the design, stress risers in elbows and other fittings will be within the allowable stress limit.

The method of design layout preferred by many engineering firms is an anchor-to-anchor design. This design method can be economical and offers many advantages. The anchor-to-anchor system is more rigid and less susceptible to damage due to dynamic loading. This system also provides a means for controlling expansion (thermal and pressure), thereby reducing the length of offsets and eliminating the need for expansion joints. Anchors are placed on either side of every change in pipe direction and as near to the fitting as possible. The amount of structural steel required to absorb the loads imposed on the anchors can be minimized by keeping the pipe elevation close to the steel and by utilizing tension members between anchors. It is

important to recognize that the pipe must be guided between anchors to prevent buckling. In cases where there are long straight runs, anchors should be placed no more than 150 to 200 feet apart.





In many cases where the anchor-to-anchor design is not used, the pipe is often simply hung with rod hangers. This is an example of a highly flexible piping system. Expansion is uncontrolled and dynamic forces can cause very large movements of the pipe

system. This design will work where there operating temperature is near ambient temperature and fluid velocities are very low. However, even mild fluid dynamic forces can destroy a pumped system that is installed in this manner. Vibrations induced by the pump can damage sections of the system where frequencies are within the resonant range. Wind loads can also induce damaging stresses. To reduce vibration and wind load effects, the pipe should be laterally restrained at specified intervals along the pipe. These restraints should not be located near changes in direction where offset legs are required for flexibility.

Piping system failures that occur during hydrostatic testing, or even after years of service, have been attributed to poor workmanship but in reality, all failures are caused by overstress and this could be due to poor design. The task of the designer is to eliminate, as much as possible, the likelihood of failure. With sufficient effort spent on the design and in the instruction of installation personnel, failures can be effectively reduced.

The design techniques presented here have helped to standardize a conservative design approach. Beyond this, a great deal of work is necessary to standardize installation techniques, especially the methods for fabricating joints.

In an effort to reduce the possibility of failure, the designer should seriously consider the following:

- Keep the pipe run away from high traffic areas where damage from equipment impact is likely.
- Keep flange joints to a minimum. Flanges are expensive components and sources of leaks.
- Provide vents at each high point to allow air to be removed from the system prior to testing and system start up.
- Provide drains at each low point or pocket. Drains with blind flanges will allow the line to be drained if repairs are necessary.
- Ensure that all supports, anchors, and guides are installed prior to the hydro test. This cannot be over emphasized since the pipe system can be severely damaged without proper pipe support.
- All valves and valve operators, or components in the system must be independently supported.
- Valves that require high torque to open and close should be anchored so that the high torque does not damage the pipe.

- Riser supports for vertical runs should be guided or laterally restrained to reduce vibration and effects of wind load.

MAXIMUM ALLOWABLE BENDING MOMENT FOR ELBOWS

Nom. Size	I ref. (in.4)	Bending Moments (ft.-lbs.)		
		FRP	PVC	HDPE
2	.720	210	152	105
3	2.472	360	260	180
4	5.428	480	347	240
6	22.73	1,650	1,192	825
8	51.33	2,250	1,625	1,125
10	100.92	2,250	1,800	1,250
12	170.00	2,750	1,980	1,375
14	218.70	1,600	1,150	800
16	358.70	2,300	1,660	1,150
18	583.70	3,200	2,310	1,600
20	684.40	3,600	2,600	1,800
24	1405.80	6,100	4,400	3,050
30	3399.70	5,150	3,720	2,575
36	7004.90	8,500	6,140	4,250
42	12,918.50	13,000	9,390	6,500
48	21,813.30	20,700	14,950	10,350

Hydrostatic Testing

When filling the system for hydrostatic testing, open all high point vents to allow air to be vented. Fill the system at the lowest point and connect a small, positive displacement pump with a maximum flow rate of 3 to 5 gpm. The pump should be equipped with a pressure regulator and by-pass that will allow the system pressure to build slowly.

Hold pressure at 25, 50 75, 100 and 120% of the maximum operating pressure. The hold time at each level should allow sufficient time for checking for leaks. Any leaking flanges will require retorquing of bolts. Bleed off all pressure before retorquing. Increase torque to 110% of initial recommended value and retest the system. If the flanges continue to leak, bleed of pressure and increase torque to 120%. If the flanges continue to leak, drain the system and inspect the flange faces and examine the gasket for damage. **Never re-torque bolts when system is under pressure.**

Economic Considerations

With material prices and the cost of labor rising frequently, a cost comparison between an FRP system and any other corrosion resistant materials is difficult. FRP is normally selected because of its corrosion resistance, however one important point that should be made concerning any comparison is that the total installed cost be considered. Many studies do not include data on the support system required for FRP pipe. This is because most analysis procedures tend to regard all piping systems as being supported in the same manner and at the same relative cost. In addition, the cost of auxiliary steel, and the labor necessary to install that steel, should be evaluated.

The service life of each system is an important factor and should be included in the evaluation if sufficient historical data can be obtained. Many designers would probably elect to use materials other than FRP when the installed price of the two systems is relatively close, but the extended service life of FRP systems will usually be more favorable. Generally, experience has indicated that FRP systems are more economical than other systems in pipe sizes above 4 inches where special metallic materials are considered.

Applicable Codes and Standards

There are very few codes or standards applicable to the design of FRP piping systems. The designer should be familiar with the **American National Standard Code for Pressure Piping (ANSI) B31.3**, although it deals mainly with metallic pipe it has been expanded to cover non-metallics including thermoplastic and thermoset materials. The only other standard that could prove useful for design purposes is the **NBS Voluntary Product Standard PS 15-69**, which covers custom contact molded FRP equipment. This document is no longer published by NBS but copies can be obtained through some of the resin and glass manufacturers. The tables for pipe included in this Standard should be used with care.

The American Society for Testing and Materials (ASTM) has published standards for **Plastic Pipe and Building Products, Section 8, Volume 08.04, 1993**. This document is a compilation of test procedures and methods for establishing material and mechanical properties for plastics used in piping.

A number of codes and standards are being developed to promote standardization of the product but they are not available at this time. One excellent guide that is available is a book entitled **"Corrosion -- Resistant Plastic Composites in Chemical Plant Design"** by J. H. Mallinson, published by Marcel Dekker, New York, 1988. Another book that provides good overall coverage of the use of FRP is **"Fiberglass Reinforced Plastics Deskbook"** by N.P. and P.N. Cheremisinoff, Ann Arbor Science, Michigan, 1978.

The Composites Institute of the Society of Plastics Industry published a **"Fiberglass Pipe Handbook"** in 1989 that is a document that was written by the Fiberglass Pipe Institute, New York. The handbook is a compilation of technical sections covering above and below ground piping systems and while it is an excellent reference for piping design, the methods of analysis and design of supports presented in this book are not the same as recommended in this paper. Expansion joints and

expansion loops are very rarely used in practice and the supports recommended in the handbook should not be used except in very light duty service.

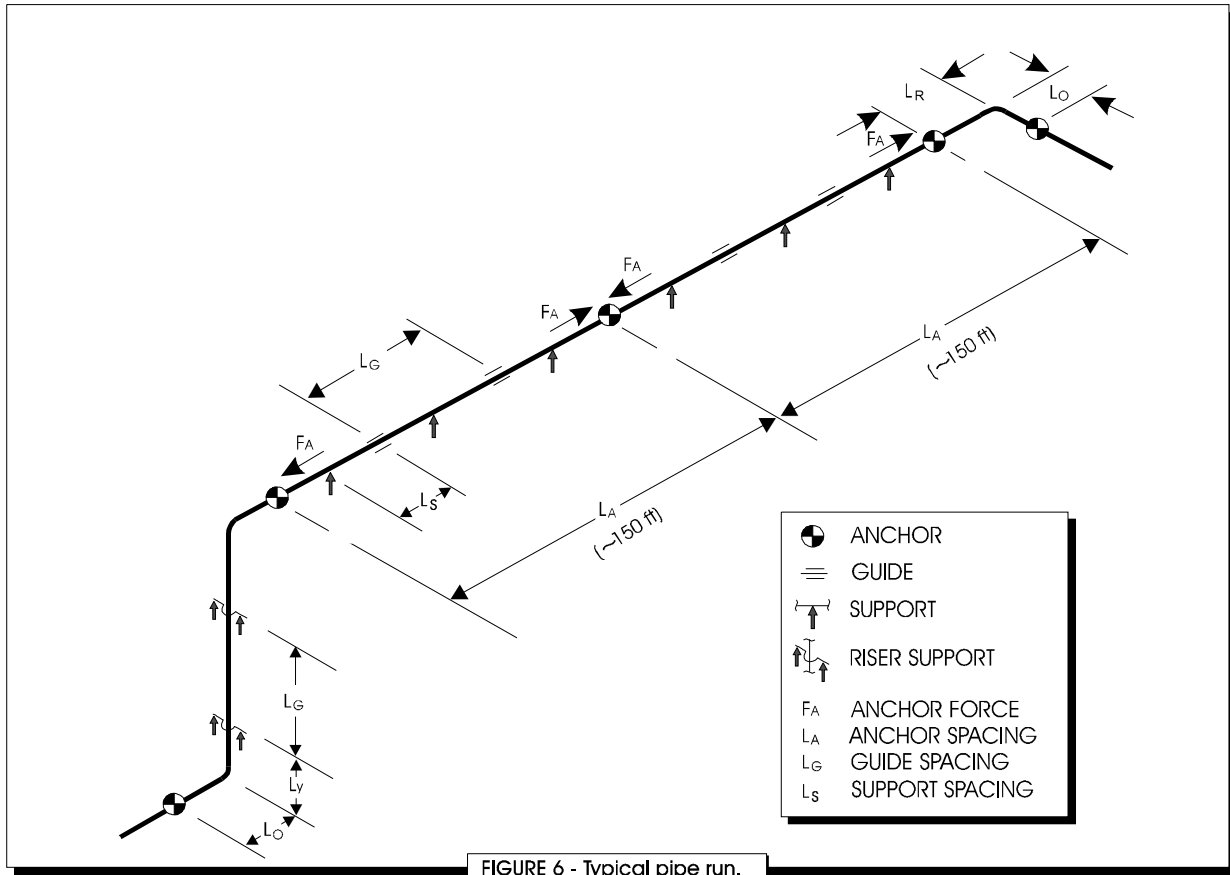
Layout and Design of Piping Systems

The preliminary piping layout for FRP piping is the same as for any other system (Figure 6). Once a general piping arrangement has been selected, an isometric of the system should be made and the following steps taken:

- Locate available support steel and establish the location of additional support steel as required. Existing bridges, pipe racks and building structural steel will establish the available support spacing.
- Locate anchors at each change in pipe direction and as close as possible to elbows.
- Locate riser supports and component supports. Riser supports can be tentatively located on 10-foot centers until calculations are made.
- Establish support design criteria and pipe wall thickness required using the equations in the section on Support Designs factoring the operating temperature and pressure of the system. An iterative process is employed to obtain wall thickness and to define acceptable support spans.
- Tabulate support design criteria shown in Table 2 and rearrange support spacing and anchor locations on the isometric to meet design criteria. Add guides at locations determined in the table.
- Check offset leg requirements between anchors at directional changes. Relocate anchors as required to meet offset requirements.
- Rearrange riser support locations. The distance between centers should not exceed the guide spacing. In areas where offset leg requirements cannot be met, consideration should be given to rerouting the pipe to provide more flexibility.

TABLE 3 - (Sample Only)

Nominal Pipe Size	Wall Thickness (Inches)	Support Span (Max.)	Offset Leg (Min.)	Guide Spacing (Min.)	Anchor Load (Max.)
4	.202	8.3	.47√L	11.5	3500
6	.202	9.6	.64√L	16.7	5200
10	.250	12.3	.82√L	28.0	9842
12	.265	13.1	.90√L	33.7	12250



Vibration

Pump or equipment vibrations are usually absorbed by the piping system; however, it is a good practice to use an expansion joint with tie rods at the pump discharge if the discharge pipe can be anchored. Care must be exercised to insure that the pump is capable of handling the thrust loads and/or thermal loads that are developed by the fittings.

Water Hammer

Water hammer is a serious enemy of FRP piping systems. An anchored system can handle all but the most severe conditions but the source and cause of the hammer should be determined and corrected. There are several successful methods for reducing the damaging effects of water hammer. Air chamber designs are available that will help reduce shock but the best method is to design the system so that slugging does not occur. By simply slowing the time to open, and close, for all flow control valves to a minimum of eight to ten seconds will usually achieve this.

Cavitation

This is caused by a restriction in the line, such as a control valve, that causes a drop in local pressure due to high flow velocities through the restriction. Cavitation will erode

the corrosion barrier and eventually damage the structural wall of the pipe. The effects of cavitation are usually limited to a short section of pipe just downstream of the restriction and can be detected by a noise that sounds like gravel being pumped through the line. Gate valves have much better flow characteristics than butterfly valves and should be used whenever possible. If the process will allow air to be bled into the system, a very popular and successful solution to cavitation can be achieved by continuously bleeding a small volume of air into the piping system just upstream of the valve or constriction.

SUPPORT DESIGN TIPS

The designer should review the following design considerations to insure that all supports are correctly used. If there are any deviations from these standard practices and designs the designer should contact the engineer.

1. **FITUP of SUPPORT** - The designer must specify the maximum OD of the FRP pipe to insure proper support fit. Pipe specifications normally require the pipe manufacturer to maintain a tolerance $+1/8" -0.0"$ on the OD and the manufacturer is required to state the maximum OD in his quotation. The support will be manufactured to fit within $1/16"$ of the maximum OD.
2. **Roundness-** Roundness or maximum allowable out of roundness should be defined in the specification. Limiting out of roundness to 30-40% of wall thickness will insure fit up of joints when joining pipe sections. Mismatch between sections can affect the strength of the joint. Forcing roundness by jacking the pipe is not recommended.
3. **LOCATION of SUPPORTS** - When supporting pipe inside of a building, the building steel will provide the easiest support points. If the support spacing is based on the spacing of the structural steel, and is found to exceed the calculated support spacing, use a slightly ($1/16"$) thicker pipe wall and re-run spacing calculations. Continue adding wall thickness until the required span is reached or until added wall thickness starts to decrease span capability. If the pipe will not meet the span then intermediate supports, requiring the addition of auxiliary steel, are required. Of course a comparison of the increased pipe cost vs. the cost of auxiliary steel will allow the designer to decide whether a heavier pipe will offer advantages.
3. **LOCATION of GUIDES** - Guides serve as supports and also provide lateral restraint to prevent buckling of the pipe due to forced generated by thermal expansion. Small diameter piping will require more frequent guiding and in some cases the use of guides may be required at every support point. Large piping may require every other support point to be a guide. Calculations should be made to determine exact requirements.

4. **LOCATION of ANCHORS** - Anchors can be located at each change of direction in many applications and allow the system to operate at the lowest possible stress. This increases service life and greatly reduces the susceptibility of failure due to dynamics. In some cases it may not be possible to fully anchor portions of the system due to structural limitations. When this occurs, the amount of offset must be determined through the use of the offset equation shown in the Technical Section.
5. **FIXING of ANCHORS** - FRP anchors are designed to lightly grip the pipe and are never to be allowed to clamp the pipe with any excessive force. The anchor is fixed to the pipe by applying shear collars, or FRP bands to the pipe on either side of the anchor. Except for very unusual cases, the collars are applied in the field after the anchor has been installed. The collars are built up of layer's of 1-1/2 oz. mat to a thickness that allows the anchor to bear against the collar. See Fig.130.
6. **RISER SUPPORTS** - Vertical runs of pipe inside of a building normally are supported on floor sleeves or off of curbs surrounding a pipe chase through the floor. Riser supports or riser guides when required, are fixed to the pipe using the same shear collars used with anchors, however the collar need only be applied to the top side of the support so that the weight of the riser can be carried by the riser support. The rule for riser guide spacing is the same as other guides unless the pipe is subjected to wind loads where more frequent guiding is required. It is important to note that loads for riser supports can be very high, especially in large diameter pipe. **Loads in excess of support ratings will require special designs and should be brought to the attention of the engineer.** Loads beyond the rated loads of the support may exceed allowable loads on the pipe and can cause local overstress and damage the pipe.
7. **SUPPORTS for INSULATED PIPE** - Special supports are used to accommodate up to 4" of insulation. In all except very special cases the supports, anchors, and guides are attached to the pipe and are not designed to clamp or support the outside of the insulation. When heat tracing is required the tracing passes outside of the support. *** **Important** *** If heat tracing is required, contact engineering for special details and designs.
8. **COMPONENT SUPPORTS** - It is very important that all valves and inline components be supported independently of the pipe. In some instances it is necessary to anchor the component where heavy actuators are cantilevered off of the valve or component or where external loads or dynamics might damage the pipe. Components in vertical and horizontal pipe runs require support although components in vertical runs may not require independent support of each component,
9. **EXPANSION** - The thermal expansion of FRP is two to three times that of steel and requires special attention especially where a fully anchored system is not

used. Expansion joints and expansion loops are sometimes specified but these add a weakness to the system. Expansion loops in addition to adding extra piping will add as many as four fittings and at least eight more joints. Each joint is an additional point of weakness. If lack of structural restraint presents a problem where anchor loads might preclude the use of the anchored system, there are several other design methods that can be employed, but in most cases the anchored system can be incorporated. The descriptions of the other design methods are beyond the scope of this manual because these are special cases.

- 10. COATINGS** - The standard coating for most support applications is either a high quality prime coat that is applied by spray coating, or hot dip galvanize. Paint systems must in compliance with EPA regulations regarding VOC and hazardous materials. It is very important that the designer select a corrosion resistant coating that will withstand the environmental conditions in the area where the pipe supports are to be installed. If special high performance coatings are required these should be specified in the purchase documents.

Conclusions

The design approach presented in this section has been successfully used for over twenty years and will provide the engineer and designer with analytical tools and procedures that will insure a successful piping system if reasonable care and control is exercised when the pipe is installed. The supports, guides, and anchors that are illustrated have been designed to match the analysis and support requirements for FRP pipe and will provide maximum service life for any FRP system. The designer is again cautioned to specify the finish and/or coating for the support to prevent or reduce corrosion of the supports. Standard finishes for most conditions are either epoxy primer or hot dip galvanize. Special coatings must be specified for extreme corrosion conditions and suppliers of these materials should be consulted for recommendations and specifications.

General Discussion

There is a wide selection of materials, methods of manufacture, pipe grades and ratings available to the engineer when specifying FRP pipe. Generally the hand lay-up pipe is specified for extreme conditions, especially where external corrosion might be expected. While this pipe has lower hoop strength, the higher axial strength provides better beam strength. The method fabrication allows this type of pipe to act more like an isotropic composite.

When the designer is considering the use of the more economical filament wound pipe he should consult the manufacturer's catalog data for mechanical properties. It is often assumed that the axial strength of the filament wound pipe is the same as the hoop strength; this is a dangerous assumption. The axial strength of this pipe varies between 9,000 and 11,000 psi. It is common practice to use 9,000 psi for all calculations.

The cast pipe offers some unique mechanical properties due to the nature of construction. Hoop and axial strengths are as high as 25,000 psi providing excellent mechanical properties for maintaining longer spans.

Selecting the method of joining pipe sections and fittings is an important consideration for the designer and while joint strength is a critical issue, the joint quality will always dictate the success of the piping system. There are three basic methods being used today, not counting the bolted flanged connection, which must be considered. The most widely accepted method is the butt and strap joint. In its simplest form, two pipe ends are butted together and overwrapped around the outer circumference of the pipe. This has been called the workhorse of all connections and is the easiest to fabricate and is easiest to inspect for quality. The outer wrap shrinks as it cures and provides a strong mechanical bond. Each step of the lay-up is performed in open view and any discrepancies are easily detected and corrected before the joint is complete.

Some filament wound or cast pipe, usually referred to as commodity type, is designed to be joined by means of a bell and spigot joint. The spigot end of the pipe is coated with an adhesive and inserted into a bell or coupling. Sometimes the bell and spigot is tapered rather than straight. Both of these joints are satisfactory when assembled by a skilled craftsman. Applying an even and smooth coating of adhesive is important as well as insuring that the spigot is inserted completely into the bell. Axial alignment is very important to insure the surfaces are parallel. Keeping the pipe rigid as the adhesive cures is also critical; any movement before the adhesive is fully cured can ruin the joint. The tapered joint adds a bit more difficulty and does not seem to offer any great structural advantage over the straight bell and spigot. After the joint has been completed there is no way to determine if the joint was properly made. The proof of the joint is not determined until the entire system is pressurized. Repairing discrepant joints at this point is very difficult and expensive.

In most critical process systems it is wise to select an engineered (custom) pipe and to use the Butt & Strap joint for most connections. Flanges should be kept to a minimum. Adhesive joints do not have the reliability of the simple Butt & Strap joint.

The most important factor in insuring a reasonable service life is the consideration of a well-designed support system. The designer can contribute to the success by routing the pipe through areas where access to structure is available for supporting the pipe. Many systems are compromised when the designer attempts to shorten the routing by using diagonal routes to save a few feet of pipe. The 45-degree fittings with diagonal runs are difficult to analyze and pose awkward support problems. The engineer and the designer need to work closely together during the preliminary pipe design in order to reduce support and structural costs.

Maintenance is a matter of paramount importance when designing the system. Keep clearances between pipes and between structures large enough to make joint repairs.

Make sure that FRP pipe is never allowed to rub or contact sharp edges during operation. Abrasion and impact damage can drastically shorten the life.

With all of the advantages that FRP can offer in handling corrosive fluids it is easy to see why the designer and engineer might prefer these materials, and when the principles of design are carefully followed there is no other cost effective competitor. But when the wrong resin or type of construction is selected, or when the designer neglects to properly design the needed supports, these materials can pose serious problems and cause the owner doubts whether there is a real advantage. The design principles in this section were developed for FRP pipe and have proven that failures can be virtually eliminated when put into practice.

The following illustrations from FRP Piping Manual (7), present a series of different support types that have been successfully used in conjunction with the design procedures and practices that have been presented in this section. These supports will cover almost any requirement needed in the design of a FRP piping system and can be adapted to duct systems by simply making a few design alterations to accommodate the lighter loads imposed by ducting.

Caution is again raised to insure the support hardware is protected by the proper coating or by galvanizing. A low Durometer rubber should be bonded to the support to protect the pipe surface. Roundness and concentricity are key elements of the support specification and the support diameter should closely match the unique diameter of the FRP pipe. Low clamping forces must be used so that local stress does not crush the pipe. Clamping forces should never be used to restrain the pipe. Forcing a pipe into a support that does not match the pipe diameter is never acceptable and a support that is too large to cradle the pipe must be rejected. Piping and dynamic forces must always be transferred to the anchor or riser support by means of a field applied shear collar. Shear collars are illustrated in Fig. 130 in ***Support Illustrations***.

SUPPORT ILLUSTRATIONS

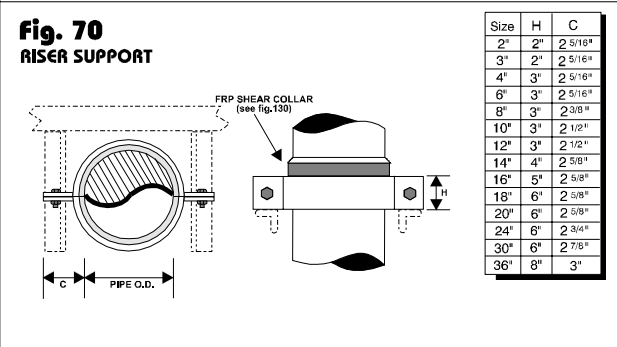
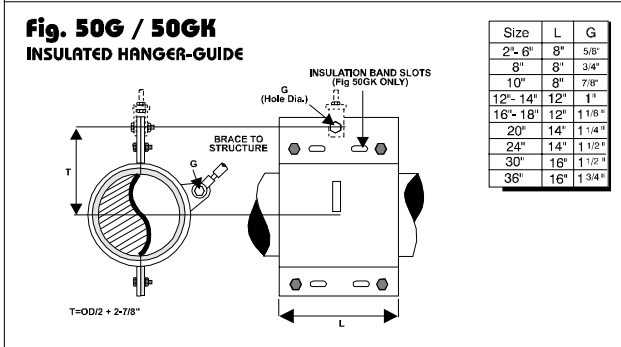
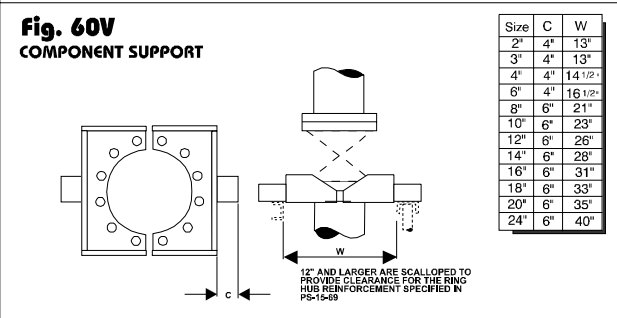
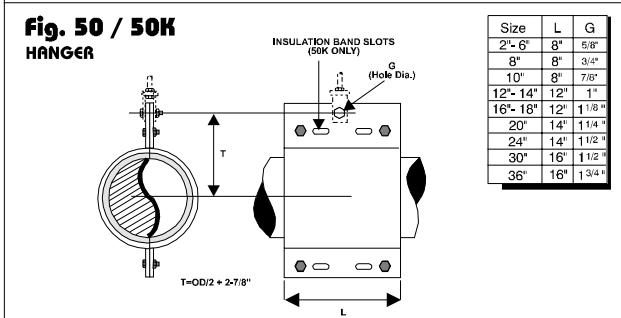
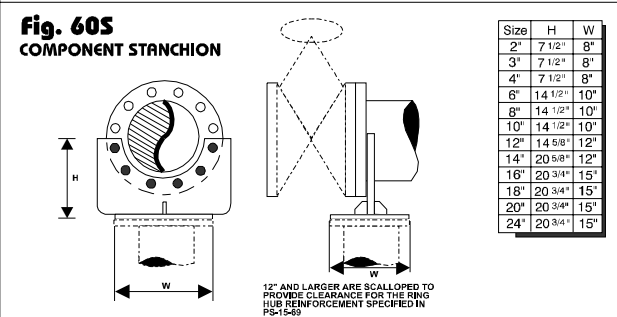
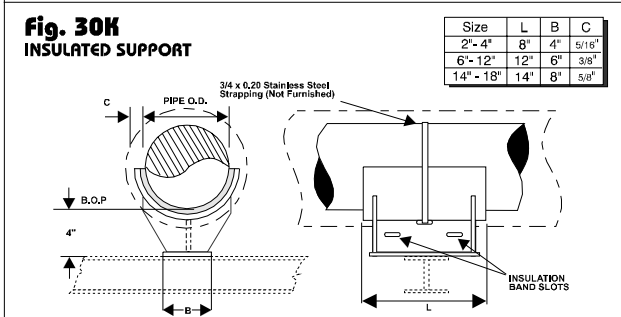
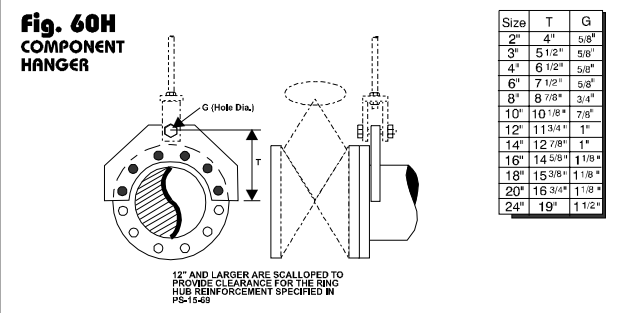
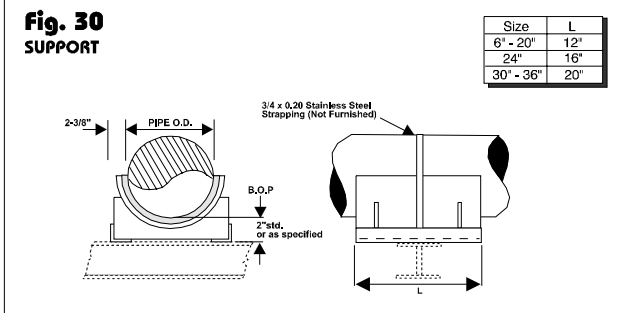
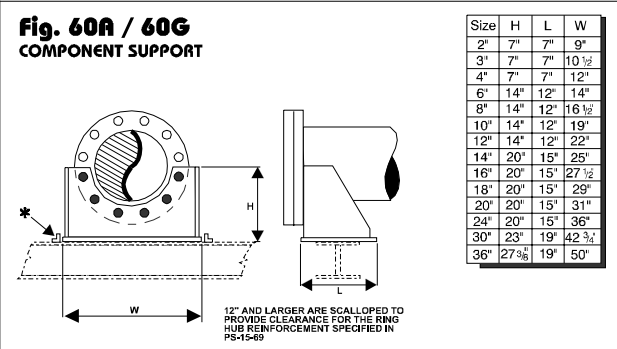
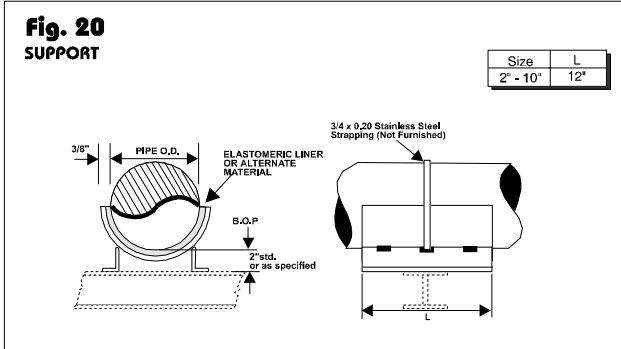
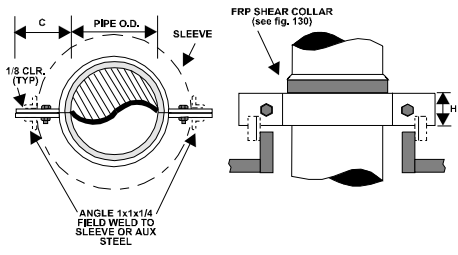
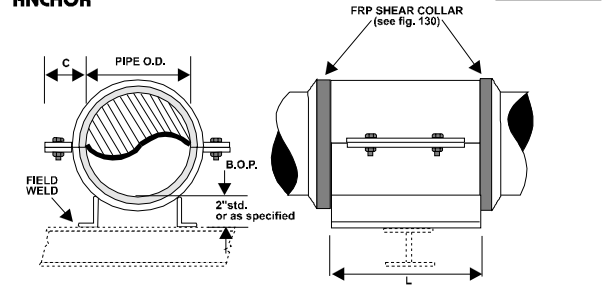


Fig. 70G
RISER GUIDE



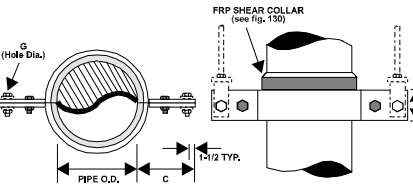
Size	H	C
2"	2"	6 5/16"
3"	2"	6 5/16"
4"	3"	6 5/16"
6"	3"	6 3/8"
8"	3"	6 3/8"
10"	3"	6 3/8"
12"	3"	6 3/8"
14"	3"	6 5/8"
16"	3"	6 5/8"
18"	4"	6 5/8"
20"	4"	6 5/8"
24"	4"	6 5/8"
30"	6"	6 5/8"
36"	6"	6 5/8"

Fig. 100
ANCHOR



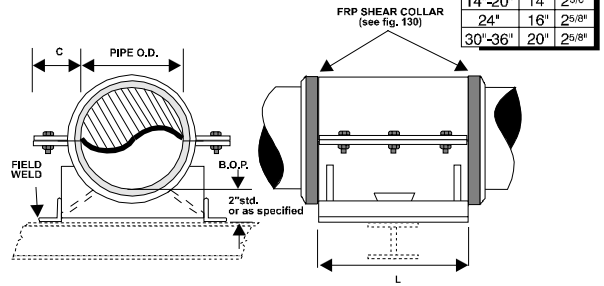
Size	L	C
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Fig. 70H
RISER HANGER



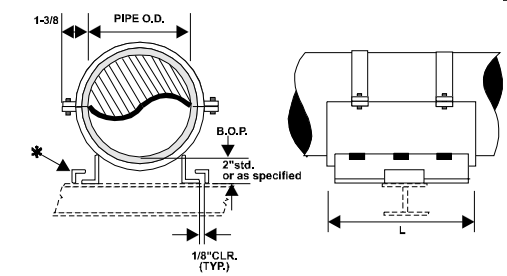
Size	H	C	G
2"	3"	6 5/16"	5/8"
3"	3"	6 5/16"	5/8"
4"	3"	6 5/16"	5/8"
6"	3"	6 3/8"	5/8"
8"	3"	6 1/2"	3/4"
10"	4"	6 1/2"	3/4"
12"	5"	6 1/2"	7/8"
14"	6"	6 5/8"	7/8"
16"	6"	6 3/4"	1"
18"	6"	6 3/4"	1"
20"	6"	6 3/4"	1"
24"	6"	7"	1 1/4"
30"	6"	7"	1 1/4"
36"	8"	7"	1 1/2"

Fig. 110
ANCHOR



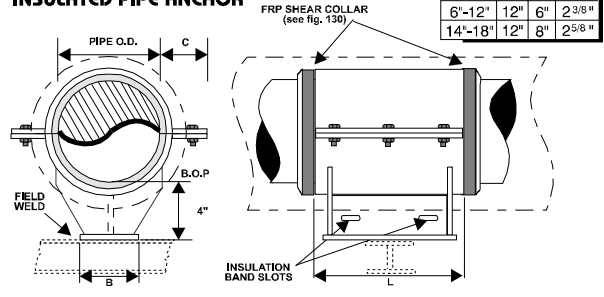
Size	L	C
6"-12"	12"	2 3/8"
14"-20"	14"	2 5/8"
24"	16"	2 5/8"
30"-36"	20"	2 5/8"

Fig. 80G
GUIDE



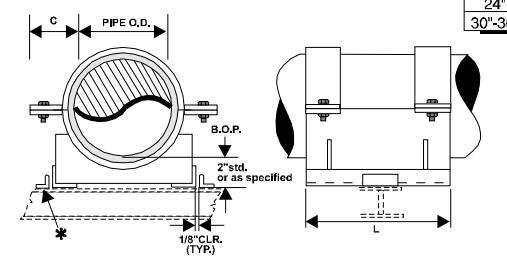
Size	L
2"-4"	12"

Fig. 110K
INSULATED PIPE ANCHOR



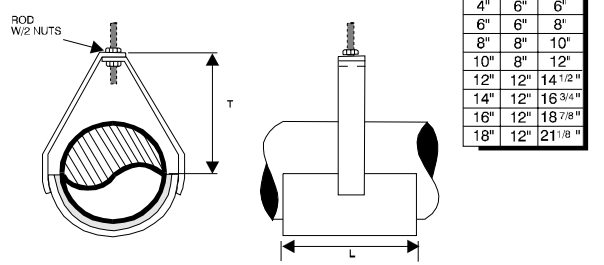
Size	L	B	C
2"-4"	8"	4"	2 5/16"
6"-12"	12"	6"	2 3/8"
14"-18"	12"	8"	2 5/8"

Fig. 90
GUIDE



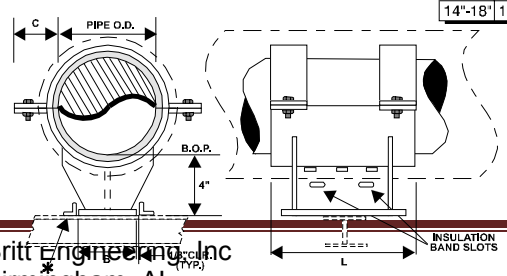
Size	L	C
6"-12"	12"	2 3/8"
14"-20"	14"	2 5/8"
24"	16"	2 5/8"
30"-36"	20"	2 5/8"

Fig. 120
HANGER



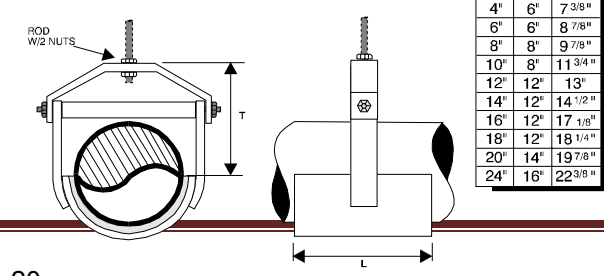
Size	L	T
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3"	6"	5"
4"	6"	6"
6"	6"	8"
8"	8"	10"
10"	8"	12"
12"	12"	14 1/2"
14"	12"	16 3/4"
16"	12"	18 7/8"
18"	12"	21 1/8"

Fig. 90K
INSULATED PIPE GUIDE



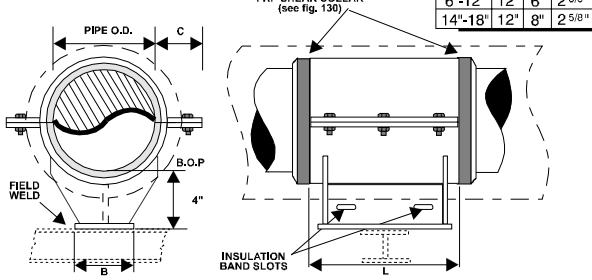
Size	L	B	C
2"-4"	12"	4"	2 5/16"
6"-12"	12"	6"	2 3/8"
14"-18"	12"	8"	2 5/8"

Fig. 120C
HANGER CLEVIS

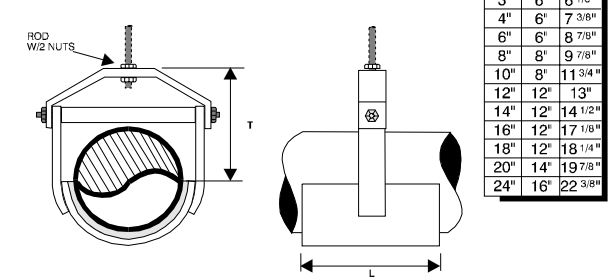


Size	L	T
2"	6"	5 5/8"
3"	6"	6 1/8"
4"	6"	7 3/8"
6"	6"	8 7/8"
8"	8"	9 7/8"
10"	8"	11 3/4"
12"	12"	13"
14"	12"	14 1/2"
16"	12"	17 1/8"
18"	12"	18 1/4"
20"	14"	19 7/8"
24"	16"	22 3/8"

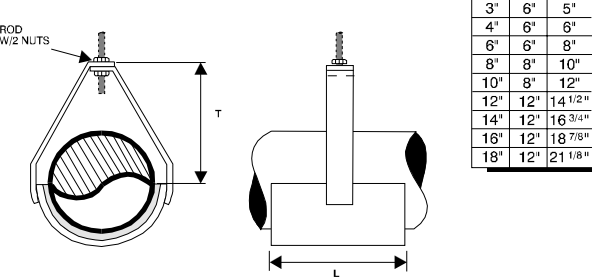
**Fig. 110K
INSULATED PIPE ANCHOR**



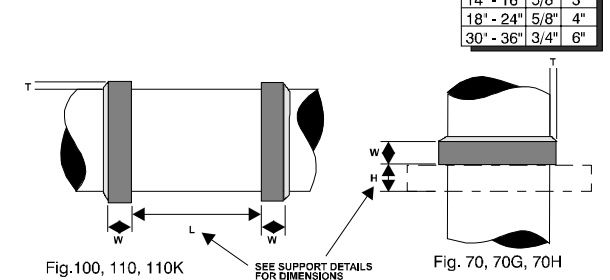
**Fig. 120C
HANGER CLEVIS**



**Fig. 120
HANGER**



**Fig. 130
FRP SHEAR COLLAR**



Pipe Support Load Ratings (Standard)

Fig.No.	Fig.30	Fig. 50 & 50G	Fig. 60A & 60G	Fig. 60H	Fig. 60S	Fig. 60V	Fig. 70	Fig. 70G	Fig. 70H	Fig. 90	Fig. 90K	Fig. 100	Fig. 110	Fig. 110K	Fig. 120 & 120C
Nom. Dia.	Vert Load	Vert Load	Vert Load	Axial Load	Vert Load	Vert Load	Vert Load	Vert Load	Vert Load	Vert Load	Vert Load	Axial Load	Vert Load	Axial Load	Vert Load
2"		610A*	115	3000	610A	400	115	400	400	400A	400	555		400	610A
3"		610A	200	3000	610A	400	200	400	400	400A	400	1130		400	610A
4"		610A	325	3000	610A	400	325	400	400	400A	400	1810		400	610A
6"	625	610A	510	11,000	610A	600	580	600	600	600A	640	600	640	3940	610A
8"	1430	1130B	1150	11,000	1130B	1400	1150	1400	600	1400B	1450	1450	1450	6690	1130B
10"	1635	1810C	1640	11,000	1810C	1600	1640	2800	600	1800B	1650	1650	1655	10160	1810C
12"	2040	2710D	2550	11,000	2710D	2000	2550	2600	600	2300C	2065	2065	2065	14650	2710D
14"	3075	2710D	3150	10,000	2710D	3000	3150	3200	1200	2600C	3120	3120	3125	19970	2710D
16"	3385	3770E	4020	10,000	3770E	3300	4020	3800	1200	4500D	3440	3440	3440	26100	3770E
18"	4000	3770E	5090	9,000	3770E	3900	4300	4300	1600	4500D	4055	4055	4060	33060	3770E
20"	4710	4960F	6360	9,000	4960F	4600	4300	4100	1500	4500D	4775	4775	4780	30370	4960F
24"	6750	6230G	8820	8,000	6230G	6600	4300	6500	1500	8600F	6835	6835	6345	42560	6230G
30"	8525	8000G	13240	15,000	8300G	8300		8700	2100	8000F	8645		8660	62460	8000G
36"	11550	11630H	19850	27,000	11630H	11630		14900	1900	10000G	11590		11600	87890	11630H

* REQUIRED ROD SIZES

A = 3/8" / 610	B = 1/2" / 1130	C = 5/8" / 1810	D = 3/4" / 2710	E = 7/8" / 3770	F = 1" / 4960	G = 1-1/4" / 8000	H = 1-1/2" / 11630
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End

The information presented in this technical paper is based on best available technology and many years of experience in the design and support of FRP piping systems. The author and the company take no responsibility for accuracy of this information and caution the user to employ good engineering judgment and use of applicable codes and specifications. Success of a design also mandates the application of specifications that insure mechanical properties of the pipe meet minimum standards and that the installation contractor employs trained FRP pipe technicians. The pipe support standards presented in the paper have been validated by over 30 years of successful applications.