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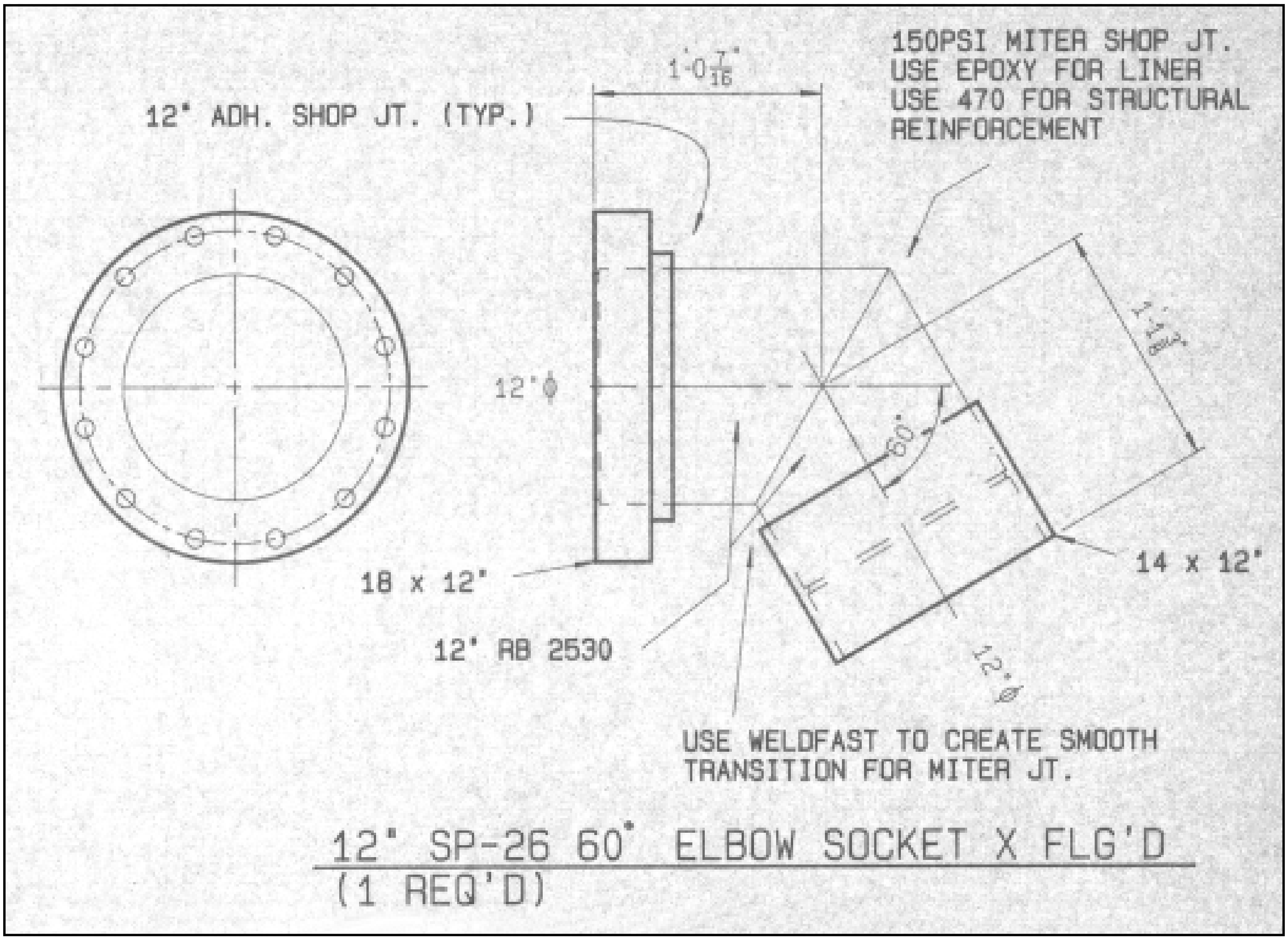
SMITH Fibercast™
A Varco Company

PIPING DESIGN MANUAL



FIBERCAST piping products are recognized worldwide for providing outstanding corrosion resistance, temperature capabilities and mechanical strength. Industry recognition of these properties has led to the successful use of FIBERCAST pipe in a wide range of applications.

Trained Field Technicians

As with any piping material, good design, fabrication and installation practices will add materially to the service life and reliability of your FIBERCAST piping system. Trained field personnel or factory trained field technicians are available to advise you on proper fabrication and installation techniques. It is recommended that they be consulted for assistance, particularly if the installation crew is inexperienced.

Consulting Engineering Services

In addition, consulting engineering services are available for assistance in designing new FRP systems or for reviewing existing FRP installations. FIBERCAST Engineers will analyze FRP pipe installations by any manufacturer. The intent of this new and updated brochure is to bring to your attention specific properties of FIBERCAST piping so that you, the Piping Designer or Project Engineer, may give full consideration to the most common design problems. This brochure is not intended to be the last word as a comprehensive piping design manual for FIBERCAST products, since this is the realm of professional design engineers. We attempt to improve our products continually and reserve the right to make changes in specifications, descriptions and illustrative material in this guide as conditions warrant.

The recommendations in this manual in no way, either expressly or implied, affect our standard warranty and Terms and Conditions of Sale.

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Guides

The utilization of expansion joints and loops requires that consideration be given to guides, as to both type and spacing. Guides are rigidly fixed to the supporting structure and allow the pipe to move in the axial direction only. Proper guide placement and spacing are important to ensure proper movement of the expansion joint or loop and to prevent buckling of the line.

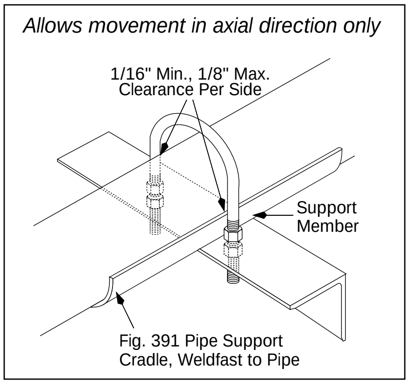


Figure 1 – Guide

The guiding mechanism should be loose so it will allow free axial movement of the pipe. “U” bolts, double-nutted so they cannot be pulled down tight, are often utilized for guides.

Primary and secondary guides, i.e., those immediately adjacent to expansion joints, are spaced more closely than intermediate guides (See Table I.)

TABLE I

Distance From Expansion Joints To Primary And Secondary Guides

Nominal Pipe Size (Inches)	Primary Guide (Inches)	Secondary Guide (Inches)
1	5	18
1 1/2	8	30
2	10	36
3	12	42
4	16	56
6	24	84
8	32	112
10	40	140
12	48	168
14	56	196

Anchors

Pipe anchors divide a pipeline into individual expanding sections. In most applications, major pieces of connected equipment, such as pumps and tanks, function as anchors. Additional anchors are usually located at valves, near changes in direction of the piping, at blind ends of pipe, and at major branch connections. Provisions for expansion should be designed into each of the individual pipe sections.

Caution

Do not install more than one expansion joint between the same two anchors in any straight pipe section.

Do not anchor FIBERCAST® pipe by applying external pressure as point loads, such as a "U"-bolt, directly to the bare pipe.

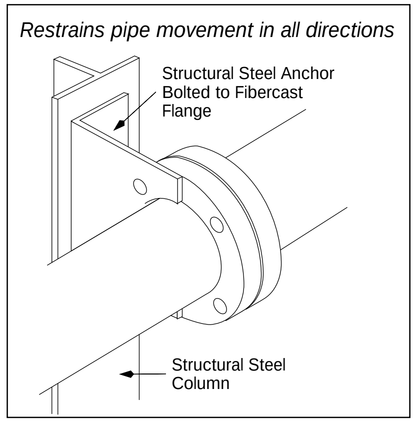


Figure 2 – Anchor

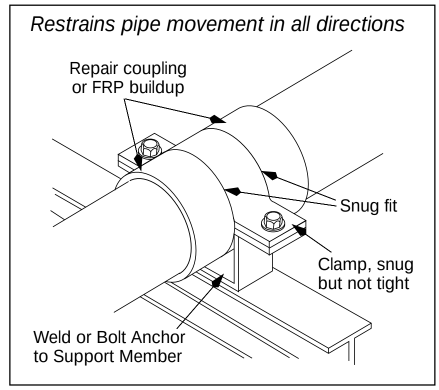


Figure 3 – Anchor

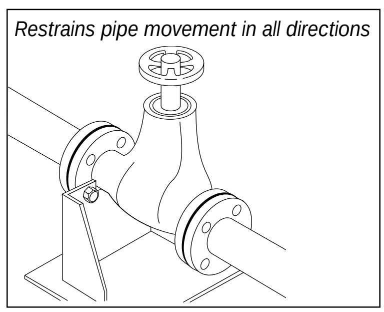


Figure 4 – Pipe Anchor

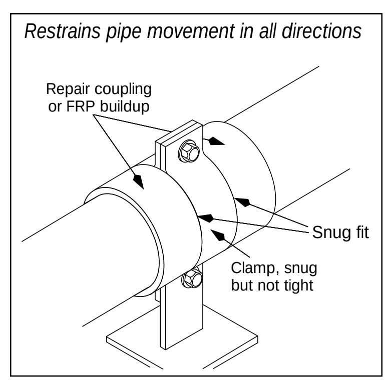


Figure 5 – Anchor

Supports

Piping supports for FIBERCAST pipe should be spaced at intervals as shown in the product bulletins.

Note: Properly spaced supports do not alleviate the need for guides as recommended in the preceding section.

Supports that provide point contact or that provide narrow supporting areas should be avoided. Sleeves made from half of a FIBERCAST coupling are suitable; however, some means of increasing the supporting area should be used.

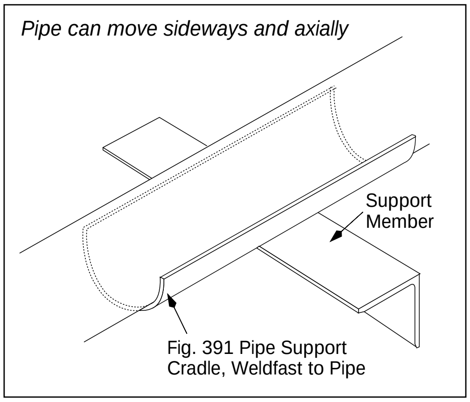


Figure 6 – Support

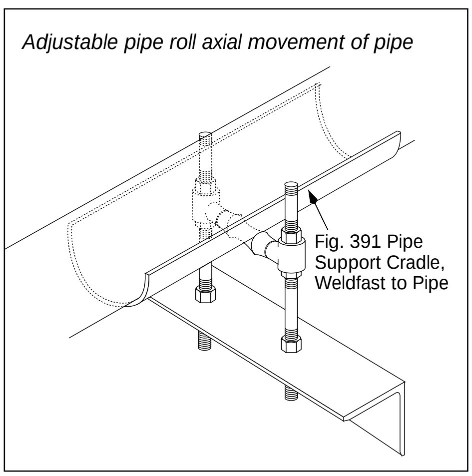


Figure 7 – Support

Valves and other heavy equipment should be supported independently of the pipe; however, in smaller sizes (2", 3" and 4" diameters), this rule may be ignored provided the weight of the valve is small and does not create excessive stresses or deflections in the adjacent pipe. In vertical runs, valves do not need to be independently supported if the pipe has adequate support above and below the valve. Before connecting valves to pipe, all adhesive joints must be properly cured. In the above exceptions, good engineering judgment must be used to determine whether or not valve supports are required.

Pipe Hangers

Pipe hangers, such as those shown, are often used to support FIBERCAST® pipe in buildings and pipe racks. The use of too many hangers in succession, however, can result in an unstable line when control valves operate and during pump start-up and shutdown. To avoid this condition, the designer should incorporate guides periodically in the line to add lateral and axial stability. In most cases, the placement of lateral auxiliary guides (see fig. 8) at intervals of every second or third support location will provide adequate stability in long pipe runs. Caution should be exercised in placing guides next to elbows since this can impede flexibility. Refer to figure 12, loop leg sizing diagram on Page 7. Where expansion joint, offset or loop legs are used to compensate for thermal expansion, it is recommended that lateral guides be installed at every other support. Axial guides are used to ensure that the movement of the pipe is directed into the offset, loop leg or expansion joint. Do not install guides nearer to the elbows than to the offset or loop leg lengths suggested in Table IV of the product bulletins.

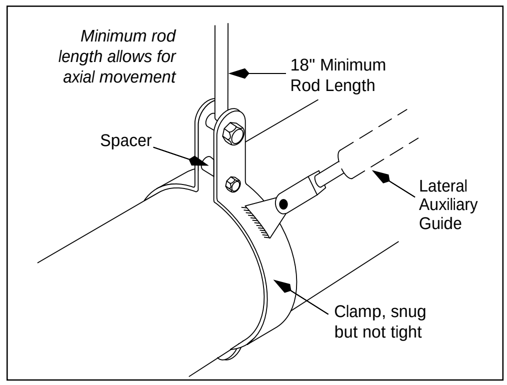


Figure 8 – Pipe Hanger Double Bolt Pipe Clamp

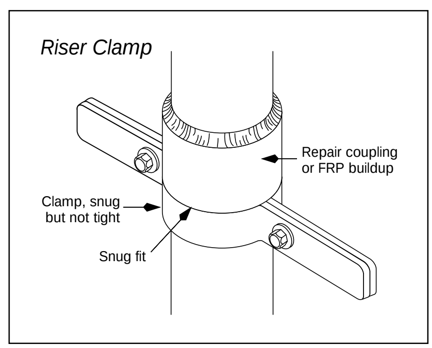


Figure 9 – Pipe Hanger

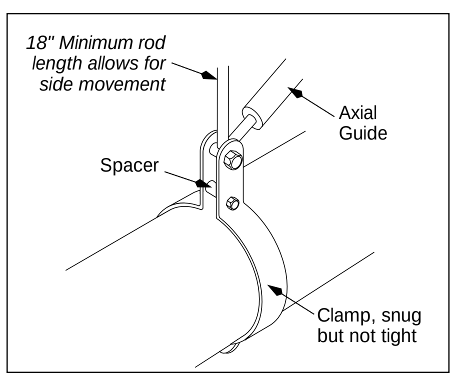


Figure 10 Pipe Hanger With Axial Guide

Thermal Expansion & Contraction

CENTRICAST® pipe has a coefficient of thermal expansion ranging from 8.4-11.4 x 10^{-6} in. / in. / ° F. The total expansion per 100 feet for RB-2530 and CL-2030 are shown in Table II in 25° F., Delta T increments.

FIBERCAST® pipe is a good thermal insulator and conducts heat very slowly. Metal pipe expands and contracts more rapidly. Consideration should be given to this fact to prevent undue stress when FIBERCAST pipe is connected to metal piping systems.

In many FIBERCAST pipe installations, directional changes in the piping may provide sufficient flexibility to compensate for expansion and contraction due to temperature changes. However, when this is not the case, expansion joints or expansion loops should be designed into the system to prevent overstressing.

For explanation and example purposes, see Tables II through Table V for CENTRICAST RB-2530 piping. Thermal expansion data for other pipe grades are shown in the product bulletins.

TABLE II
Thermal Expansion-Uninsulated Pipe

Change In Temperature ° F.	RB-2530 Change In Length (Inches/100 Ft.)	CL-2030 Change In Length (Inches/100 Ft.)
25	.34	.27
50	.68	.53
75	1.03	.80
100	1.37	1.07
125	1.71	1.34
150	2.05	1.60
175	2.39	1.84
200	2.74	2.14
225	3.08	2.40
250	3.42	—
275	3.76	—

The coefficient of thermal expansion for uninsulated RB-2530 pipe is 11.4 x 10^{-6} in./in./° F. Expected expansion and contraction in pipe runs from changes in temperature can be determined by simple interpolation from the previous data.

Expansion Joints

Teflon bellows-type expansion joints have been used successfully with FIBERCAST pipe. These are preferred over the wire-reinforced rubber expansion joints which require much higher forces to compress and elongate, and therefore, should be considered with caution. Metal expansion joints are NOT recommended.

Example:

Assume that 100' of 3" RB-2530 FIBERCAST pipe will be operated between +45° F. and 215° F. The outside installation temperature is to be 80° F. Assume that the expansion joint has a total travel of 3.0 inches. The total change in temperature, or Delta T is 170° F. (+135°F., -35°F.)

Reading from Table II, and interpolating between 125° F. and 150° F., the pipe will expand 2.33" (expand 1.85", contract .48") per 100 feet. The amount of pre-compression equals:

$$\frac{\begin{matrix}\text{Expansion Joint}\\ \text{Rated Movement}\end{matrix} \times \left(\begin{matrix}\text{Installation}\\ \text{Temperature}\end{matrix} - \begin{matrix}\text{Minimum}\\ \text{Temperature}\end{matrix}\right)}{(\text{Maximum Temperature} - \text{Minimum Temperature})}$$

Substituting values from the above example, we have:

$$\frac{3.0'' \times (80° - 45°)}{(215° - 45°)} = 0.62'' \text{ of Pre-compression}$$

Only 2.38" remains for compression from the installed position. Thus, the use of an expansion joint rated for 3.0" axial travel, installed pre-compressed 0.62" will provide a means for absorbing the contraction of the pipe from the installation temperature, as well as the expansion of the pipe from the installation temperature to the maximum temperature.

When no means for expansion is provided and the pipe is restrained, the pipe will be subjected to thermal end loads as shown in Table III.

TABLE III
Pipe Compressive End Loads Due To Restrained Thermal Expansion–Uninsulated Pipe

Nominal Pipe Size (Inches)	(Lbs. / ° F.)
1	11.87
1 1/2	20.80
2	28.01
3	42.12
4	65.91
6	98.25
8	143.49
10	207.41
12	246.81
14	271.43

The above data is based on Modulus of Elasticity values at Ambient Temperature.

Assuming no provisions for expansion have been designed into the example given for pre-compression of expansion joints, the 3" RB-2530 pipe would then have been required to absorb the anticipated expansion by means of compressive stress.

From Table III, 42.12 lbs. of thermal end load is created for each degree F. increase in temperature when the pipe is restrained.

(215° F. - 80° F.) x 42.12 lbs./ ° F. = 5,682 lbs.

Again, from Table III, 42.12 lbs. of thermal end load is created for each degree F. decrease in temperature when the pipe is restrained.

(80° F. - 45° F.) x 42.12 lbs. / ° F. = 1,474 lbs.

Therefore, the anchors utilized in this example must be capable of withstanding 5,682 lbs. for the compressive load and 1,474 lbs. for the tensile load.

Like centrifugally cast pipe, the compressive and tensile thermal loads will be approximately the same for filament wound pipe. Filament wound pipe is wound with continuous fiberglass strands at a helical angle which results in similar compressive and tensile modulus of elasticity values.

CENTRICAST® pipe is made with circumferential and longitudinal fiberglass fabrics.

When the pipe is subjected to thermal loads from restrained expansion as described previously, it is necessary to guide the pipe. Guiding is necessary at specific maximum intervals to keep the pipe straight. This directs the thermal load in an axial direction and prevents buckling which could otherwise occur. Calculations, using Euler's column buckling formula, are shown as the maximum guide spacing requirements in Table V, page 6. A safety factor has been used in the calculations. Maximum guide spacing allowed for 3" RB-2530 for a temperature increase of 135° F. is 7.3 feet.

Offset or Loop Leg Method–Offset or loop legs that are formed with 90° elbows are often used to compensate for thermal expansion. See Table IV for minimum leg lengths for various amounts of expected expansion in 1" increments up to 10". It is usually necessary to install intermediate guides at every other support to control the direction of this movement when expansion joints or offset legs are used.

TABLE IV
Offset or Loop Leg Sizing Chart For RB-2530 Pipe

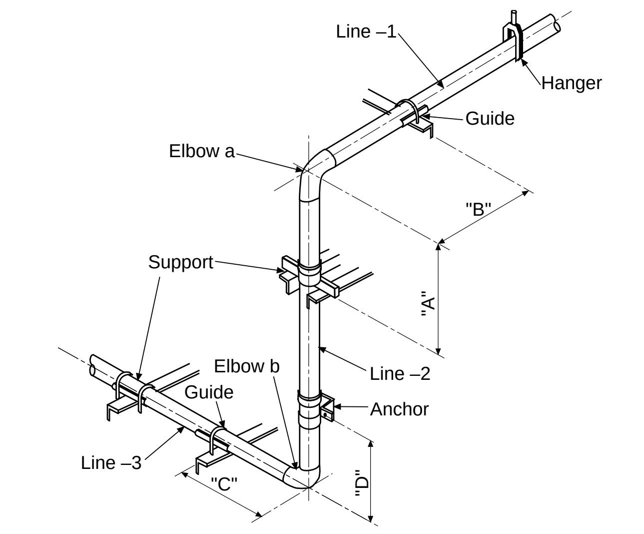
Pipe Size OD (Inches)	Thermal Expansion (Inches) vs. Minimum Leg Length (Feet) 1"	2"	3"	4"	5"	6"	7"	8"	9"	10"
1	4	5	6	7	8	9	9	10	11	11
1 1/2	6	8	10	11	12	13	14	15	16	17
2	7	9	11	13	15	16	17	18	19	20
3	8	12	15	17	19	21	22	24	25	26
4	12	16	20	23	26	28	30	32	34	36
6	13	19	23	26	29	32	35	37	39	41
8	16	22	27	31	35	38	41	44	47	50
10	19	26	32	37	41	45	48	52	55	58
12	20	28	34	39	44	48	52	56	59	62
14	19	26	32	37	41	45	49	52	55	58

Anchors With Intermediate Guides–Due to the relatively low compressive modulus of elasticity of CENTRICAST® pipe, it is often possible to anchor the ends of pipe runs to retain expansion. When this method is used, the pipe anchors or thrust blocks should be sized to prevent axial movement of the pipe. It is usually necessary to install guides periodically to prevent the pipe from bowing excessively from the restrained end loads. Data for determining anchor loads from restrained thermal expansion is shown in Table III. Maximum guide spacing for our CENTRICAST RB-2530 pipe where ends are restrained is shown in Table V for various delta T's in 25° increments.

TABLE V
For Pipe Runs Where Pipe Ends Are Restrained
Maximum Guide Spacing RB-2530 (Feet)

Nominal Pipe Size (Inches)	Temperature Change in ° F. (Δ T) 25° F.	50° F.	75° F.	100° F.	125° F.	150° F.	175° F.	200° F.
1	6.1	4.3	3.5	3.0	2.7	2.5	2.3	2.1
1 1/2	8.9	6.3	5.2	4.5	4.0	3.6	3.4	3.2
2	11.2	8.0	6.5	5.6	5.0	4.6	4.3	4.0
3	16.9	11.9	9.7	8.4	7.6	6.9	6.4	6.0
4	21.8	15.4	12.6	10.9	9.7	8.9	8.2	7.7
6	32.4	22.9	18.7	16.2	14.5	13.2	12.3	11.5
8	42.4	30.0	24.5	21.2	19.0	17.3	16.0	15.0
10	52.9	37.4	30.5	26.5	23.7	21.6	20.0	18.7
12	63.0	44.5	36.3	31.5	28.2	25.7	23.8	22.3
14	69.2	49.0	40.0	34.6	31.0	28.3	26.2	24.5

Figure 11 – Offset Leg Sizing Diagram



Legend

A = Minimum leg required for thermal expansion of Line l. The amount of thermal expansion is first found in Table I of the product bulletins. This value is then used in Table IV of the product bulletin to find the minimum leg length.

B = Minimum leg required for thermal expansion in portion of Line 2 from anchor point to elbow a. (Use same procedure as in Leg A.)

C = Minimum leg required for thermal expansion in portion of Line 2 from anchor point to elbow b. (Use same procedure as in Leg A.)

D = Minimum leg required for thermal expansion in Line 3. (Use same procedure as Leg A.)

Notes

1. Maximum Guide Spacing for pipe runs where pipe ends are restrained is found in Table V.
2. Typical Anchors, Guides, and Supports are shown on pages 3 and 4.

Procedure For Sizing Expansion Loops

1. Lay out line so that loop is located between two pipe anchors as shown in Figure 12.
2. Determine the maximum change in temperature (Δ Tmax) between the maximum operating temperature (Tinstal) and between the minimum temperature (Tmin) and installation temperature (Tinstal).

$$\Delta \text{ Tmax} = \left(\begin{matrix} \text{Tmax} - \text{Tinstal} \\ \text{Tinstal} - \text{Tmin} \end{matrix} \right) \text{ whichever is greater.}$$

3. Use the longest pipe run between either anchor and loop to size the loop. Knowing the maximum Δ T and longest run length, determine thermal expansion Δ L using Table I in the product bulletins.
4. From Table IV of the product bulletins, determine the minimum leg length “A” when considering the correct pipe diameter/grade and thermal expansion (Δ L) from item 3 above.
5. Leg length “B” should be a minimum of 1/2 leg “A”.
6. Place primary and secondary guides on either side of the loop, per recommendations shown in Table III of the product bulletins. Additional supports may be required in the pipe runs due to span support considerations. Do not provide guides within the loop which constrain pipe movement in the plane of the loop.

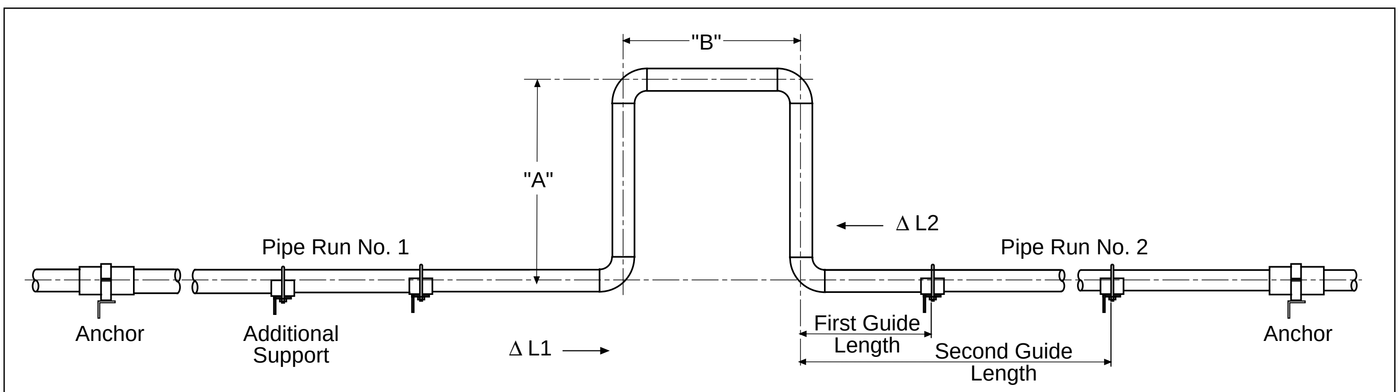


Figure 12 – Loop Leg Sizing Diagram

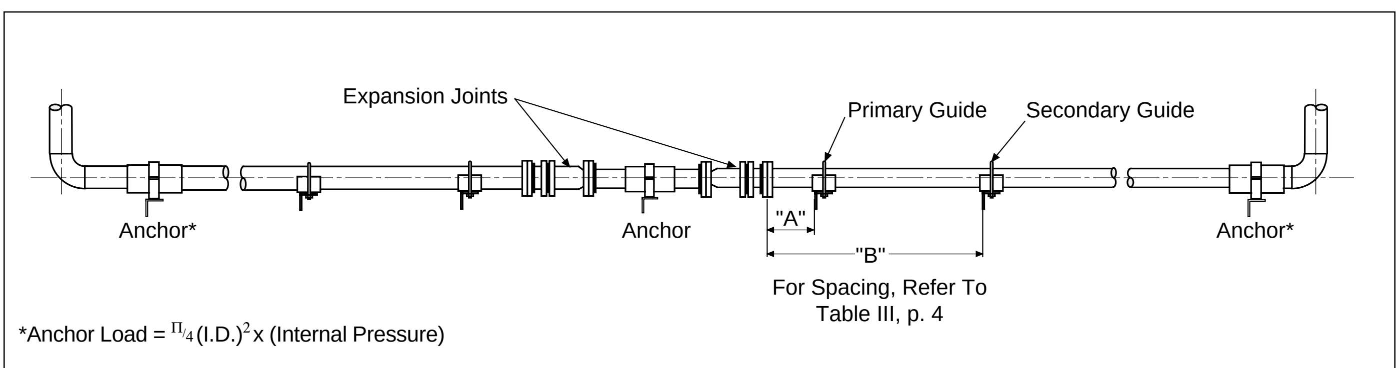


Figure 13 – Typical Expansion Joint Installation

Flanged

FIBERCAST® pipe connections to other pieces of equipment are normally made with our Figure 18 flanges. Use a full-face gasket of 50–70 durometer hardness. Tighten the flange bolts to a maximum of 50 foot-pounds torque (maximum of 20 foot-pounds if bolting to a raised flange configuration). Some care must be exercised to produce equal torque on all bolts. The use of a torque wrench is strongly recommended. Reduce maximum torque to 35 foot-pounds when thread lubricant is used. Torque should be limited to 10 foot-pounds on one-inch flanges.

It is often necessary to mate our Figure 18 flanges with raised faced flanges, butterfly or check valves having partial liner facings, Van Stone flange hubs, and other components which do not have a full flat flange face. The addition of a hard ring spacer placed between the raised face and the outer edge of the flange to form a full flat face on the mating flange is recommended. The purpose of the spacer is to fill the gap outside the raised face to prevent bolt loads from bending and breaking the FIBERCAST flange.

We have found, however, from field experience that it is not always possible to use the spacers to make flat faces. In addition, we have found that proper gasket sealing can usually be obtained without the spacer ring. The procedure is simple. Bolt the flanges and components together the same as you would any flange makeup. Use either a full face gasket or a ring gasket of 50-70 durometer. Tighten the flange bolts to only 15 to 20 foot-pounds torque instead of the 50 foot-pounds used with normal installation. This 15 to 20 foot-pound torque will produce the proper gasket seal in most instances since only a small ring of the gasket is being compressed. Apply proper fluid pressure to the line and, if any leaks are found, retighten the bolts slightly until the leak stops.

Flexible Connector

FIBERCAST pipe connections to pumps or other equipment that involve vibration, shock loads or other mechanical movements should include flexible connectors. These flexible connectors allow for the absorption of vibration and eliminate the placing of undue strain on the pipe and fittings. A bellows-type expansion joint is recommended, although rubber hose has also been used with success.

Threaded Joints

1. Before making any threaded joints, be sure all bonded joints are fully cured.
2. Apply thread lubrication to both male and female threads. A material which remains soft for the life of the joint is preferred. Be sure the thread lube is suitable for the fluid service.

NOTES:
1. *The use of WELDFAST® adhesive to bond a steel or metal pipe into a FIBERCAST flange is not recommended.*
2. *If mating a FIBERCAST system to steel or other FRP system, the preferred method is with flanges. Terminate the old system in their flange and bolt to the FIBERCAST flange on the new system.*
3. *Be sure to check the anchors, guides, and supports of an existing system to avoid transfer of any stresses or thermal expansion loads into the FIBERCAST system.*
4. *Do not try to thread pipe or fittings. This is very difficult and risky. Purchase the required factory part.*

TIPS: If no thread lube is available, the use of WELDFAST Part "A" will usually be acceptable. Two wraps of Teflon tape may also be used in lieu of thread lubricant.

TABLE VI
Bolts, Nuts, Washers and Gasket Requirements For Standard Figure 18 FIBERCAST Flanges

Flange Size	Quantity	Description
1"	4	$^1/_2$ -13 x 3 Bolts, nuts & washers
$1^1/_2$"	4	$^1/_2$ -13 x $3^1/_2$ Bolts, nuts & washers
2"	4	$^5/_8$ -11 x $3^3/_4$ Bolts, nuts & washers
3"	4	$^5/_8$ -11 x $3^3/_4$ Bolts, nuts & washers
4"	8	$^5/_8$ -11 x $4^1/_4$ Bolts, nuts & washers
6"	8	$^3/_4$ -10 x $4^1/_2$ Bolts, nuts & washers
8"	8	$^3/_4$ -10 x $5^1/_2$ Bolts, nuts & washers
10"	12	$^7/_8$ - 9 x 8 Bolts, nuts & washers
12"	12	$^7/_8$ - 9 x 8 Bolts, nuts & washers
14"	12	1 - 8 x 11 Bolts, nuts & washers

- *Use 3/16 " thick full face gaskets with a hardness of 50-70 durometer on the Shore A scale with FIBERCAST standard 14" and smaller flanges.*
- *Use SAE standard washers under all nuts and bolt heads.*
- *Maximum torque on dry bolt threads - 50 ft. lbs.*
- *Maximum torque on lubricated bolt threads - 35 ft. lbs.*
- *Do not exceed 10 foot-pounds torque on 1" flanges.*

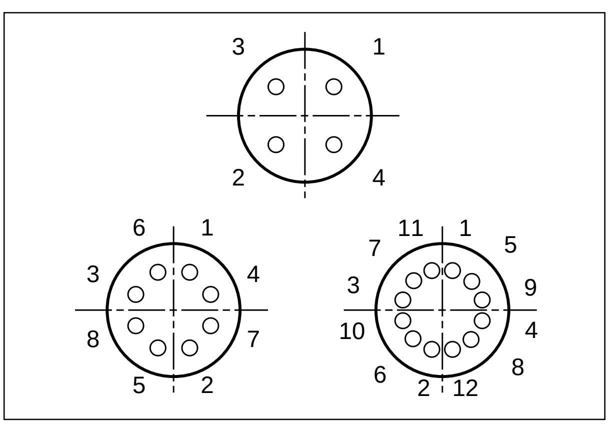


Figure 14 – Recommended Bolt Torquing Sequence For FIBERCAST Flanges

Engineering & Technical Services

In most instances, the information necessary to design FIBERCAST piping systems can readily be found in our product bulletins, or by asking our representatives responsible for customer technical support. Engineering services are also available. These include: Consulting Engineering; Computer Aided Engineering Analysis; and Engineering Service Contracts. Quotations for these services are based on the complexity of the piping and size of the installation.

When extensive analysis is required, FIBERCAST utilizes computer programming to design piping and other mechanical systems for maximum reliability and cost effectiveness. Programs include:

- Fluid Transient Analysis: A computer program that calculates the effects water hammer may have on your system.
- CAE Pipe: Calculates pipe movements, stresses and moments at each restraint with simultaneous calculations of thermal, dynamic, dead/wind/ice loads, as well as seismic considerations. These calculations are based on expected properties of new or existing FRP pipelines.

Extended warranties on our products are available under full Engineering Service Contracts. However, our customers may select individual engineering services or field technician assistance based on the requirements of their specific project.

Field Technician Services

Fibercast field technicians are available to train pipe fitters and/or supervise fabrication of our piping systems at the job site.

Qualified technicians travel to jobs world-wide to train fabrication and assembly crews; conduct and supervise fabrication work; or inspect work in progress. They provide owners, specifiers and installers the on-site assurance required for quality piping assembly.

Consulting Engineering

FIBERCAST is a registered engineering firm with over 50 years of corporate experience in designing and manufacturing nonmetallic piping systems and composite structures. Engineering services have been provided to leading consultants and mechanical contractors, as well as to many firms from the ENR top twenty.

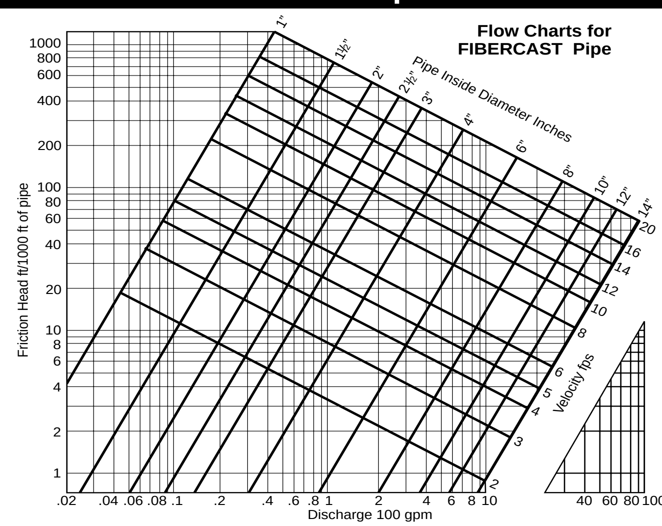
FIBERCAST has a staff of professional mechanical engineers, chemical engineers and technicians to design piping systems, perform specific engineering tasks, or troubleshoot systems. Their services are augmented by state-of-the-art testing equipment, CAD capabilities and modern production facilities. Consulting Engineering services offered by FIBERCAST® include:

- Reviewing applications and operating parameters, including making recommendations for suitable pipe grades, gasketing, fabrication and installation procedures.
- Performing a thermal dead weight analysis of the FRP piping system, based on hand calculations from published recommended operating data.
- Evaluating the potential for water hammer.
- Evaluating components through a visual examination of an existing FRP piping system.
- Determining the need for computer-aided engineering analysis.
- Reviewing physical and chemical resistance properties of fiberglass versus other materials.
- Reviewing burial concepts and importance of proper installation.
- Furnishing design concepts and procedures for determining anchors, guides, supports, legs, expansion joints/loops/ forces, and contraction forces.
- Discussing effects of wind, ice and snow loading, underwater installations, seismic considerations and vacuum for above and below ground piping systems.

Flow Loss Through FIBERCAST Pipe

In producing the flow chart for FIBERCAST pipe, a variety of standard hydraulic equations were used. In conjunction with these equations, a comprehensive study was made at Oklahoma State University in Stillwater, OK., to determine the surface roughness in FIBERCAST pipe. The equations involved in that study were by Hazen-Williams, Darcy-Weisbach and Colebrook. More accurate results can be obtained by calculating flow velocity and head loss or by using FIBERCAST Piping Pro software. The investigation revealed that the inside diameter of FIBERCAST pipe is considerably smoother than steel pipe. This results in more flow through FIBERCAST pipe than steel pipe, given the same diameter and pump horsepower.

The chart shown is for water under turbulent flow conditions. If head loss is needed for laminar flow or fluids with other viscosities, contact FIBERCAST for recommendations. The surface roughness parameter for Fibercast pipe is 1.7×10^{-5} ft.



NOTE: The flow chart represents an average of all grades of FIBERCAST pipe and is based on a Hazen Williams Flow Factor of C-150. More accurate results can be obtained by calculating flow velocity and head loss, or by using Fibercast Piping Pro software.

Figure 15 – Flow Charts For FIBERCAST Pipe

Installation Considerations

Storage and Handling

When storing FIBERCAST pipe directly on the ground, select a flat area free of rocks and other debris that could damage the pipe. Also, when preparing the ends for joining (butt wrap or tapered bell and spigot joints), do not roll the pipe over rocks, debris, or uneven ground that does not fully support the pipe.

Before installation, inspect the pipe's inner surface (if possible) and outer surface for any damage. Do not use damaged pipe unless inspected and approved by a FIBERCAST® Company Representative.

Lift pipe sections only with wide fabric straps or belts. Do not use chains or cable to lift the pipe.

Heat Tracing

FIBERCAST piping has excellent insulating properties. The coefficient of thermal conductivity for CENTRICAST® pipe is:

.8712 (BTU-inch) per (Ft.^{2} - hr.- ° F.)

Consideration of this property can often eliminate the need for tracing and/or reduce the thickness of insulation required to maintain a given temperature.

Heat tracing of FIBERCAST piping is common practice where it is necessary to maintain a certain temperature in process fluids, or to prevent freezing in outside lines.

In any case, tracing temperatures should not exceed the recommended operating temperature of the pipe, and such tracing should spiral the pipe to equalize distribution of heat. A hot tracer applied along only one side of the pipe may cause heat shock, and excessive "bowing" may occur.

FIBERCAST piping's low conductivity rate is also an important factor to consider in the system design when using heat tracing.

Electrical heating devices have been used successfully; however, they are susceptible to burnout, and should be designed into the system with care. Special attention should be given to their flexibility so that normal movement of the line will not overstress the electrical tracing media, which could result in a burnout.

When heat tracing, the temperature and insulation loads should be considered in arriving at the span support distances.

Water Hammer

The internal shock or pressure surge known as "water hammer" is produced by the abrupt change of fluid velocity within the pipe. Under certain conditions these shock forces can reach magnitudes sufficient to rupture any piping system.

Rapid valve closure can result in the build up of shock waves due to the kinetic energy in the moving fluid which must be absorbed. These pressure waves will travel throughout the piping system and can cause damage far away from the source.

The magnitude of water hammer is a function of the fluid and pipe material properties, fluid velocity, line length, and the speed in which the momentum of the fluid is changed. Many fluid mechanic and hydraulic handbooks provide procedures for calculating pressure surges as a result of single valve closures in simple piping systems. Sophisticated fluid transient computer programs are available to analyze water hammer in complex multi-branch piping systems under a variety of operating conditions.

In addition to instantaneous valve closing, water hammer can also be created by rapid valve opening as well as pump start-up and shutdown. Water hammer pressure surges cannot readily be observed on conventional Bourdon pressure gauges because of the instrument's slow response. The net effect of water hammer is excessive and sometimes results in violent vibration or movement which can cause failure in pipe and fittings.

In some cases, this problem can be corrected by thoroughly anchoring the piping system, but in other cases, mechanical valve operators, accumulators, or feedback loops around pumps may be required to remove the source of water hammer from the system.

Good design practices can generally prevent water hammer occurrence in most systems. Installation of valves which cannot be opened or closed instantaneously is the simplest precaution. In addition, pumps should never be started into empty discharge lines unless slow-opening, mechanically operated valves are used to gradually increase flow to the system. Check valves on pumps should close as quickly as possible to minimize the velocity of liquid flowing back through the check valve.

Compressible Gases

Special precautions should be rigidly observed when compressed gas or air is introduced into a fiberglass piping system.* The stored energy in the compressed gas or air presents an undue hazard should a piping failure occur. Fiberglass piping is particularly hazardous due to the possibility of brittle failure of the piping material or catastrophic joint failure. Gas line pressure must never exceed those shown in Table VIII**

Table VIII

Pipe Size	1"-6"	8"	10"	12"	14"	16"	18"-30"	36"-54"	60"-72"
Maximum Allowable Pressure (psi)	25	14	9	6	5	4	3	2	1

The line must be hydrostatically tested to four times the maximum operating pressure prior to introducing compressed gas or air into the system. The line must have a functioning relief valve set at no more than 1.25 times the maximum operating pressure.

If Fibercast piping is used for compressed gas or air, Fibercast will not be responsible for any resulting injury to personnel or damage to property, including the piping system. The use of Fibercast piping for compressed gas or air is done entirely at the discretion and risk of the customer.

** Reference ASME B 31.3–1990 Sections 345.1, 345.5 and FA 323.4.*
***Reference Fiberglass Pipe Handbook, second edition, SPI Composites Institute.*

Hydrostatic Testing

Wherever possible, FIBERCAST piping systems should be hydrostatically tested prior to being put into service. Care should be taken when testing, as in actual installation, to avoid water hammer.

All anchors, guides and supports must be in place prior to testing the line. To hydrostatically test the line, observe the following:

Water is usually introduced into the system through a one-inch diameter or smaller pipe. Provision for bleeding air from the system should be made. Water should be introduced at the lowest point in the system and the air bled off through a partially open valve or loose flange at the highest point. Slowly close the valve, and bring the system gradually up to the desired pressure.

Test pressure should not be more than $1^1/_2$ times the working pressure of the piping system, and never exceed $1^1/_2$ times the rated operating pressure of the lowest rated component in the system.

Air Testing

Hydrostatic test should be used instead of air or compressed gas pressure test if possible. When air or compressed gas is used for testing, tremendous amounts of energy can be stored in the system. If a failure occurs, the energy may be released catastrophically, which can result in property damage and personal injury. In cases where system contamination or fluid weight prevents the use of hydrostatic test, air test may be used with extreme caution. To reduce the risk of air testing, pressurize the system to no more than 15 psig. When pressurizing the system with air or compressed gas, the area surrounding the piping must be cleared of personnel to prevent injury. Hold air pressure for one hour, then reduce the pressure to one half the original. Personnel can then enter the area to perform soap test of all joints. Again, extreme caution must be exercised during air testing to prevent property damage or personnel injury. *If air or compressed gas testing is used, Fibercast will not be responsible for any resulting injury to personnel or damage to property, including the piping system. Air or compressed gas testing is done entirely at the discretion and risk of management at the job site.*

System Start-Up

On any pressurized piping system, the initial start-up should be gradual to prevent excessive loads and pressure surges which may damage or weaken the piping.

One method is to slowly fill the system while bleeding off all air before starting any pumps or opening valves into pressurized piping. An alternate method is to start the centrifugal pump against a closed, adjacent valve; then slowly open the valve to gradually build up system pressure. The air should be bled off while the line is filling as in the first method.

For positive displacement pumps, consult FIBERCAST® Engineering for recommendations.

Verification Testing

FIBERCAST provides our clients with wide-ranging verifications including material physical properties; chemical resistance; and nondestructive laminate testing.

We offer a full array of QA / QC and verification testing procedures ranging from completely installed piping systems to individual fittings from any fiberglass manufacturer. Tests include:

- Standard ANSI / ASTM
- Acoustic Emission
- Cyclic Loading
- Chemical Immersion
- Stress/Strain Analysis
- Material Evaluation
- Corrosion Resistance
- Physical Properties Analysis

All Engineering Services are quoted upon request and tailored to match specific client needs.

Fabrication

Adhesive Storage

FIBERCAST® epoxy and vinyl ester adhesives and polyester weld kits can be damaged by storage in warm places. FIBERCAST recommends that epoxy adhesives be stored in a dry area where temperatures do not exceed 90° F. The normal maximum storage life for epoxy adhesive is one year.

WELDFAST® CL-200 vinyl ester adhesive and vinyl ester and polyester field weld kits are even more sensitive to damage from heat and prolonged storage durations. It is recommended that these adhesive systems not be shipped to the job site until just prior to use. **Maximum storage life for vinyl ester adhesives is three months at 90° F. and five months at 80° F.** Storing adhesives at temperatures below 40° F. until just prior to use is recommended. If refrigerated, the adhesive should be allowed to slowly rise to room temperature for several hours prior to usage.

Cutting FIBERCAST Pipe

A cutting tool should be selected that will generate a reasonable amount of heat minimizing damage to the pipe ends adjacent to the pipe cut. The order of preference for cutting tools is as follows:

1. Aluminum oxide abrasive wheel, used on a power saw.
2. Band saw, 16-22 teeth/inch at speeds of 200 feet to 600 feet per minute.
3. Hand hacksaw (22-28 teeth/inch).

In order to minimize crazing or chipping of the pure resin liners of FIBERCAST CENTRICAST grades RB-2530 and CENTRICAST RB-1520, it is necessary that the temperature of the pipe be in excess of 55° F. when cut. Heating is not required for CL-2030, CL-1520 or F-CHEM pipe. Cuts should be made square with the axis of the pipe in order to fit satisfactorily into the adjoining fitting socket. Larger pipe sizes are occasionally marked with masking tape prior to making the cut as an aid to the pipe fabricator in squarely cutting the pipe.

Joint Preparation

As shipped from the factory, FIBERCAST pipe requires thorough sanding of the surface area to be bonded. No special tapering or expensive tools are required in this process. The pipe OD is manufactured with a glossy finish, and is covered with a film of silicone mold release (CENTRICAST pipe) or air inhibited surface (filament wound pipe) which must be removed to ensure proper adhesion. The necessary, but simple removal of the surface finish to a dull, flat appearance can be accomplished by several methods.

For 14" and smaller CENTRlCAST pipe and the smaller filament wound pipe sizes, 36–60 grit emery tape may be used to sand the pipe ends. Use 60 grit when power sanding equipment is used. (Emery tape greater than 60 grit removes material at a prohibitively slow rate, and yields a smoother than desired surface. Emery tape with less than 36 grit may possibly remove more than the required amount of material.)

Where several connections must be made, or filament wound pipe in sizes 6" and larger is required, power sanding equipment should be arranged. If power sanding equipment is used to prepare the pipe surface, special care should be taken to avoid removing an excess amount of material which might degrade the strength of the pipe.

Where substantial amounts of material must be removed to fabricate the larger filament wound pipe grades, FIBERCAST recommends a disc sander using a 36 grit aluminum oxide open coat abrasive sanding disc. The disc sander should have a rubber backing for the sanding disc rather than metal.

Since the presence of grease, water, dirt or other foreign substances will necessitate additional sanding, do not perform the initial sanding operation more than two hours in advance of the actual fabrication time. FIBERCAST socket fittings are shipped with machined and sanded sockets ready for fabrication, but they should be sanded to eliminate any contamination from grease, oil, or other foreign substances just prior to assembly. All sockets should be cleaned with a dry cloth after sanding. Particular care should be taken to prevent contamination of the prepared fitting sockets from oily, dirty or greasy gloves or fingerprints. A properly prepared bonding surface is a primary requirement for achieving a satisfactory connection. Do not wipe prepared surfaces with solvents.

Fabrication of FIBERCAST pipe and fittings should be performed on a bench, rack or in a position to allow the fabricator full view of the pipe ends and socket interiors during application of adhesive.

Adhesives

After a final check of the preparation of the joint surfaces, the proper WELDFAST adhesive should be mixed in accordance with the instructions included. It is necessary that Parts “A” and “B” be thoroughly mixed together prior to use. The components of WELDFAST 440 are black and buff and the components of WELDFAST CL-200 are light purple and clear. Parts “A” and “B” components should be mixed until no streaks are visible.

Using an application tool with a straight edge and smooth surface (putty knife, wooden tongue depressor or other), the WELDFAST should first be applied to the socket surface of the joint. The entire surface of the socket should be thoroughly coated with a thin, even layer of adhesive. A 1/16" layer of adhesive in the socket is recommended. (Excessive adhesive in the socket could cause a squeeze-out in the flow area of the system.)

The sanded end surface of the pipe should then be coated with a heavy layer of WELDFAST. With this procedure, the excess adhesive applied to the pipe end will be forced to the outside of the pipe joint during insertion of the pipe into the socket. The cut end of the pipe should also be protected with a light coat of adhesive when applying the WELDFAST to the pipe end.

After applying the adhesive, insert the pipe end into the socket in a straight, forward direction; slowly and without twisting the pipe. Final alignment of the fitting should be made before removing the excess adhesive. Handle the fabricated assembly carefully to prevent movement in the adhesive joint before the adhesive has gelled. (Excessive movement of the joint could cause air pockets in the adhesive area.)

When removing the excess adhesive, a fillet should be formed on the body of the pipe on the outer edge of the socket opening. The fabricated joint should then be allowed to cure in the recommended method before moving.

The following points are paramount in the fabrication of a FIBERCAST® socket type connection:

- Thoroughly mix WELDFAST® adhesive in accordance with instructions.
- Uniformly coat both the fitting socket surface and exterior of the pipe with WELDFAST, after following the steps listed for surface preparation.
- Avoid movement of the joint until the adhesive has hardened.

A suitable temperature must be maintained in order for the adhesive to properly cure within the joint. Minimum curing temperature for WELDFAST CL-200 is 60° F., and 70° F. for WELDFAST 440. Cure time for these minimum temperatures is 24 hours. A constant temperature of 100° F. will allow the adhesive to cure satisfactorily in approximately four hours.

Complete cure of the resin system can be obtained in about two hours by maintaining a temperature of approximately 200° F. If a faster cure is required for the CL-2030 and CENTRICAST CL-1520 vinyl ester grades of pipe, WELDFAST CL-200 QS may be used. Refer to the Fittings and Accessories section of the FIBERCAST General Catalog.

The age of the adhesive, humidity conditions and variables resulting from mixing different amounts of curing agent with the Part “A” adhesive in the field can vary the cure time considerably. It is recommended that WELDFAST CL-200 or CL-200 QS not be cured at temperatures in excess of 200° F. and WELDFAST 440 not be cured at temperatures in excess of 250° F.

Adhesive Cure Time and Temperatures

Minimum recommended cure temperature for WELDFAST CL-100 and CL-200 is 60° F., and 70° F. for WELDFAST 440. Cure temperatures up to 200° F. will accelerate cure time and increase joint strength. For applications above 150°F., the adhesive joints must be heat cured at approximately 250°F. for epoxy and 200°F. for vinyl ester to achieve maximum corrosion resistance and strength.

Note: *Inadequate joint strength may result if adhesive is cured at temperatures less than these minimum recommended curing temperatures.*

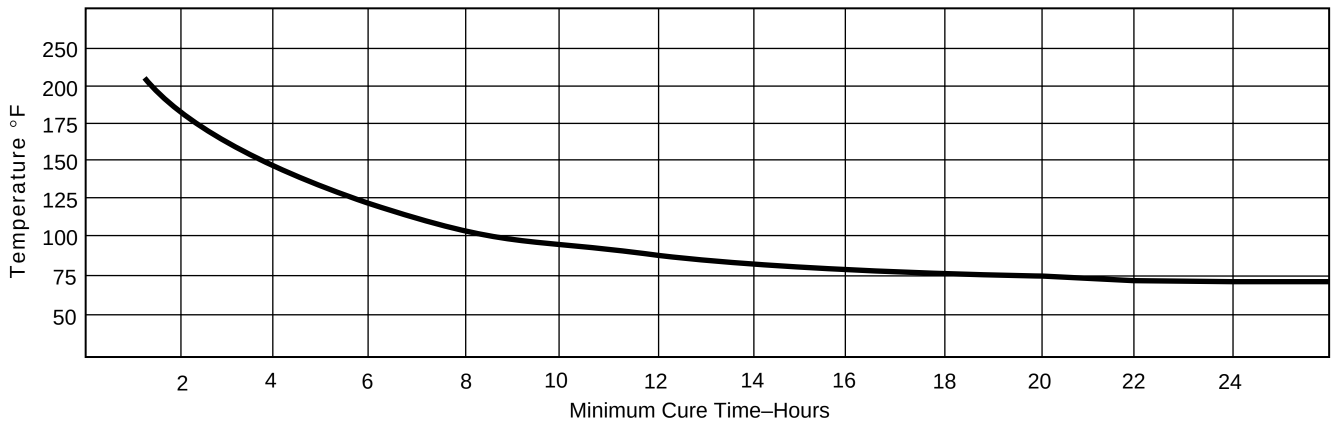


Figure 16 – Adhesive Cure Time and Temperature Charts for WELDFAST CL-100 and CL-200 Vinyl Ester Adhesives

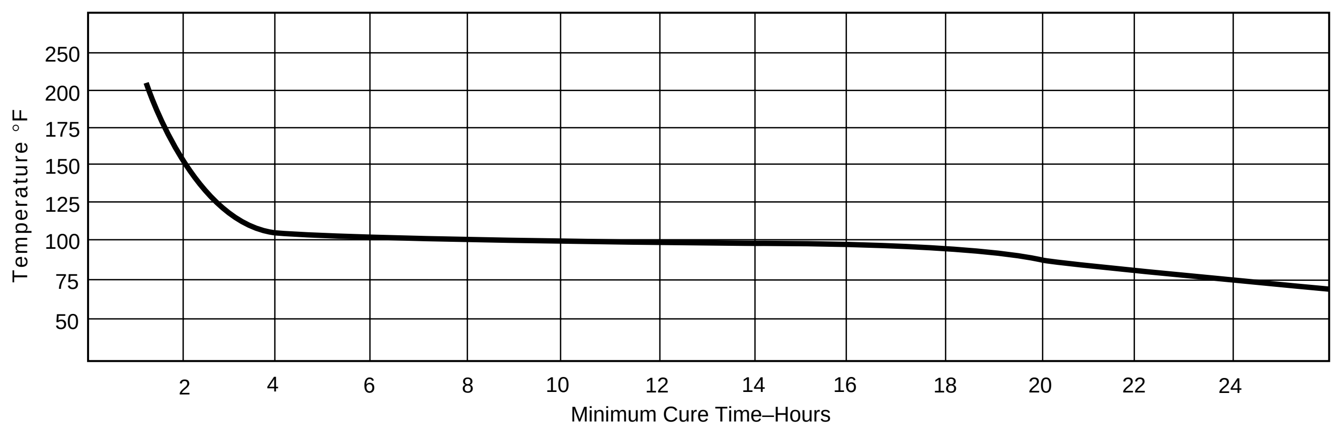


Figure 17 – Adhesive Cure Time and Temperature Charts for WELDFAST 440 and 220 Epoxy Adhesives

Fabrication In Extreme Weather Conditions

Cold Weather Installation Tips

The curing time for field welds is directly related to the temperature. Colder temperatures result in longer curing times. The following steps should be used when applying a field weld in colder temperatures:

1. Field weldkits should be placed in a warm room for six to twelve hours before application in order to reach temperatures of 70°F to 80°F. This will make mixing much easier and speed cure times. <u>The resin, hardener and catalyst should not be applied at temperatures in excess of 100°F.</u>
2. When possible, piping should be field-welded indoors into subassemblies. The warmer conditions of these areas will allow faster curing times and, in most cases, save installation time and labor.
3. It is often helpful to warm the pipe ends and fittings before joint makeup. Because Fibercast pipe and fittings conduct heat slowly, the warm parts will contribute to faster curing times.
4. A heat gun or blanket may be used to obtain a faster cure time. Hold the nozzle of the gun 8" to 12" away from the joint and slowly rotate the heat over the joint until a tack-free surface is obtained.
5. Refer to the field fabrication instructions supplied in the weldkit for the proper amount of catalyst for vinyl ester kits.

Hot Weather Installation Tips

1. Avoid direct sunlight on the joining surfaces, resin, catalyst, and fiberglass.
2. Cool resin and catalyst in an ice chest with ice.
3. Plan and organize job to reduce working time.
4. Refer to the field fabrication instructions supplied in the weldkit for the proper amount of catalyst in vinyl ester kits.
5. Butt weld laminates must be "staged" by applying no more than three layers of fabmat at a time. Staging prevents excess exothermic heat. Sand the bonding surface after each stage has gelled and cooled to less than 120°F.

Instructions for Using FIBERCAST® Heat Blanket
***Caution:* Read Operating Instructions Before Using**

- **Use only with 120 volt power outlet**
- **Blanket should not be used in wet conditions**
- **Tears, cuts or punctures in the blanket can create a potential safety hazard**
- **The thermostat must be wrapped in the blanket to prevent overheating**

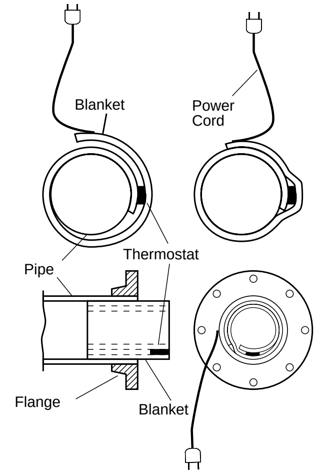
1. Use only the proper size heat blanket for the pipe being joined.

Model	Pipe Size	Volts	Watts
B	1"– 3"	120	160
C	4"– 8"	120	400
D	10"– 14"	120	850
E	16"– 20"	120	1,850

2. Wrap blanket around the joint by first placing the thermostat end of the blanket against the joint with the thermostat facing out. Wrap the remainder of the blanket tightly around the pipe or fitting surface so that any overlap of the blanket will cover the thermostat. Use VELCRO® seal to secure the blanket, or tie the wrap with glass tape or other suitable material to hold it in place during the heating process.
3. Flanged joints require heating from the inside. First, lay the blanket flat with thermostat down. Next, roll up the blanket starting at the thermostat end. Insert the blanket into the pipe or fitting to the depth of the adhesive joint. Leave the cord and remaining part of the blanket exposed. The blanket may be held in position against the ID of the joint being heated by inserting a short section of smaller size FRP pipe inside the rolled blanket.
4. Avoid excess flexing of the blanket while the heating wires are hot. Abnormal flexing of the hot wires can cause breakage and shorten the service life of the blanket.
5. DO NOT crease the heat blanket.
6. DO NOT use cleaning solvents. Solvents penetrate the rubber and damage the heating wires.

Approximate Cure Time Versus Pipe Size Using Heat Blankets

After gelation begins, apply heat blanket, heat box, or other approved heat source that will provide uniform heat to the joint. Temperatures up to 300°F will accelerate cure time and maximize joint strength and corrosion resistance.



Nominal Pipe Size	Heat Blanket Model	Bell & Spigot and Flanges	Couplings and Other Fittings
2"	B	1 hr.	1-1/2 hrs.
3"	B	1 hr.	1-1/2 hrs.
4"	C	1 hr.	1-1/2 hrs.
6"	C	1-1/2 hrs.	2 hrs.
8"	C	1-1/2 hrs.	3 hrs.
10"	D	1-1/2 hrs.	3 hrs.
12"	D	1-1/2 hrs.	3 hrs.
14"	D	1-1/2 hrs.	3 hrs.

**Heat blanket cure time refers to that time when the heat source can be removed and the pipe installed and tested as recommended pressures. Heat blanket hours pertain to 70°–100°F fabrication environment. Cure times will be longer for colder temperatures. For temperatures below 70°F, see "Conditions on Extreme Cold" on page 13 or consult Fibercast Technical Services staff at 1-800-331-4406. If no heat source is available, WELDFAST® adhesives will cure at ambient temperatures of 70°–100°F in 24 hours.*

7. DO NOT carry or move the blanket by lifting it with the cord alone. Support the weight of the blanket separately from the cord to avoid abusing the cord-to-blanket connection.

Improper sizing or use of the heat blankets can cause excess heating which can damage both the piping and heat blankets. The heating wires expand when heated and can be damaged by flexing while hot.

Painting FIBERCAST Piping

All FIBERCAST piping OD surfaces should be sanded or sandblasted prior to painting. FIBERCAST CENTRICAST® pipe and molded fittings have a silicone mold release film on the OD when manufactured. This film is necessary for preventing the plastic from bonding to the metal mold tubes and dies during the manufacturing process. The film can inhibit the paint bond and must be removed prior to painting. Filament wound pipe and hand laid-up fittings have either air inhibited films or wax coatings on the OD since they are not cured against closed molds. These surfaces also are not suited for painting and should be sanded to a dull, rough surface prior to painting. Coatings should not be applied over any glossy, smooth surfaces. The sanded or sandblasted surface should be clean and dry prior to painting.

Since FIBERCAST® products are generally used in corrosive environments, or areas where corrosive materials are present, a coating capable of resisting the specific environment should be used. Such coatings are two-component epoxies, two-component urethanes, alkyd enamels and others. Per the coating manufacturer’s recommendation, a primer or intermediate coating may be required.

Custom Fabrication

Over the years, FIBERCAST has become increasingly recognized for our custom fabrication capabilities. Stringent client and customer demands have placed FIBERCAST squarely in the business of manufacturing prefabricated FRP assemblies because:

- Job site cost can be reduced
- Construction time can be reduced
- Quality workmanship is performed by highly skilled and experienced fabricators
- Compliance with strict specifications and close dimensional tolerances is accomplished with less difficulty

Experienced Fabricators

Work is conducted in a controlled shop environment with experienced, skilled fabricators and supervisors–in either open or closed shop conditions. FIBERCAST's QA / QC systems and plant security meet government requirements for custom fabricated FRP products.

FIBERCAST has been nationally recognized as one of the leading manufacturers of reinforced plastic products for many years. This experience, combined with an aggressive research and development program, has enabled us to acquire the technology and equipment to manufacture many types of custom fabricated FRP products.

Special Design Capabilities

In addition to our piping, FIBERCAST can provide high strength, light weight, maintenance free FRP components with excellent chemical resistance and dielectric properties. When designing with reinforced plastic composites, strength may be added with numerous combinations of plastic resins and reinforcing fibers such as glass, carbon, kevlar and boron in specific areas required. Also, special abrasion resistance, fire retardancy, temperature resistance, or other capabilities may be designed into the product.

These capabilities have enabled us to provide our customers with:

- High strength components for corrosion resistant FRP pumps and valves
- Tanks and other custom fabricated vessels
- Complicated piping manifold assemblies prefabricated to close tolerances
- Electrical housings
- High strength adhesives for bonding plastics and other materials to metal
- Structural rods and shapes for sucker rods, railings and stanchions
- Large, free standing FRP support structures for antennas and sophisticated electronic equipment

Stringent Quality Control

FIBERCAST offers an outstanding QA / QC program for custom fabricated products. Stringent quality control procedures are conducted on raw materials, goods in process and finished products. Our QC procedures also require inspection of all special materials, equipment, tooling and work provided by our subcontractors. Our testing facilities include the latest equipment for determining hydrostatic, tensile, bending and flexural strengths and testing under long-term elevated temperature and cyclic loading conditions. We also utilize acoustic emission, strain testing equipment and conduct long-term corrosion resistant testing. Our R&D and Quality Control programs are second to none in the industry.

Ask your FIBERCAST Representative for more details.

Pipe Burial

Introduction

These specifications pertain to buried flexible piping where the pipe, trench walls and bedding material work together to form a complete pipe support system.

The elements of this system can best be defined by considering a section of buried flexible pipe and the loads acting on it. These loads, the dead load (backfill) and the live loads (vehicle traffic), act downward on the pipe tending to deflect it into an oval shape. If the bedding material at the sides of the pipe is compacted sufficiently, it will resist the pipe movement and minimize the deflection and ovalization to an acceptable amount. For this reason, the construction of the trench and selection of bedding materials must be closely controlled.

These specifications cover the burial techniques required for the installation of FIBERCAST pipe under most conditions. For recommendations on installation under unusual or special conditions, contact FIBERCAST's Engineering Department.

Trench Excavation and Preparation

The nominal trench widths are listed by pipe size in Table IX. Minimum burial depths (measured from top of pipe) are listed in Tables X-A, X-B, and X-C. The actual depth of the trench is determined by the final grade, plus the depth required for the initial (bottom) layer of bedding material.

This additional depth will be determined by the soil conditions and bedding material being used.

TABLE IX
Nominal Trench Widths*

Nominal Pipe Size (Inches)	Minimum Width Earth Excavation (Inches)	Maximum Width (Inches)
2	18	26
3	18	27
4	18	28
6	20	30
8	23	32
10	25	34
12	28	36
14	31	38
16	33	40
18	36	42
20	39	44
24	44	48
30	52	56
36	60	64
42	66	70
48	72	80
54	78	86
60	84	96
72	96	108

** Trench widths may be wider depending on soil conditions.*

Trench construction in solid rock conditions: If solid rock conditions are encountered during trench constructions, the depth and width of the trench must be sufficient to allow the minimum required bedding between the rock and pipe surface when the pipe is at the design grade. When additional bedding and backfill materials are brought in, they must meet the specified criteria listed in Table XI Page 19.

Granular or loose soils: These types of soils are characterized by relatively high displacement under load, and soft to very soft consistencies. The walls of trenches in this type of soil usually have to be sheeted or shored, or the trench made wide enough to place a substantial amount of bedding material in order to prevent excessive deformation in the pipe sides (see Figs. 18, 19 and 20). In some cases, additional depth of supplementary trench foundation material may be required.

Bell and spigot pipe/butt wrap joint: For bell & spigot pipe, slight over-excavation is allowed at each joint. For butt wrap joints, considerable over-excavation is required at each joint to allow for the wrapping operation. After the joint has cured, fill this over-excavation with bedding material.

Allowable burial depths: Standard FIBERCAST pipe grade burial depths are shown in Tables X-A, X-B, and X-C.

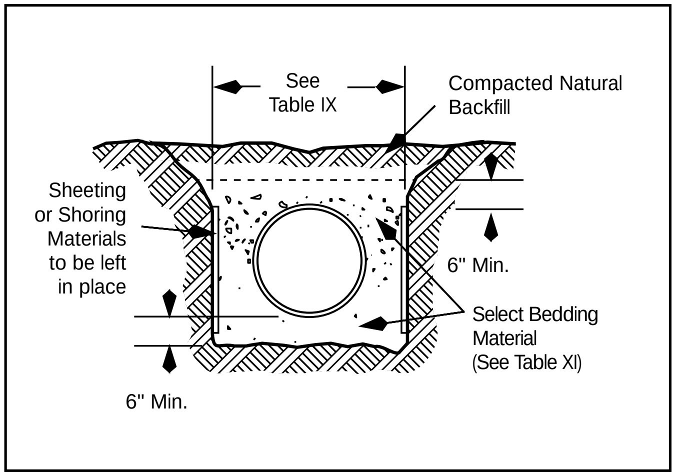


Figure 18 – Trench shape and bedding for soft and medium consistency soil w/ sheeting or shoring

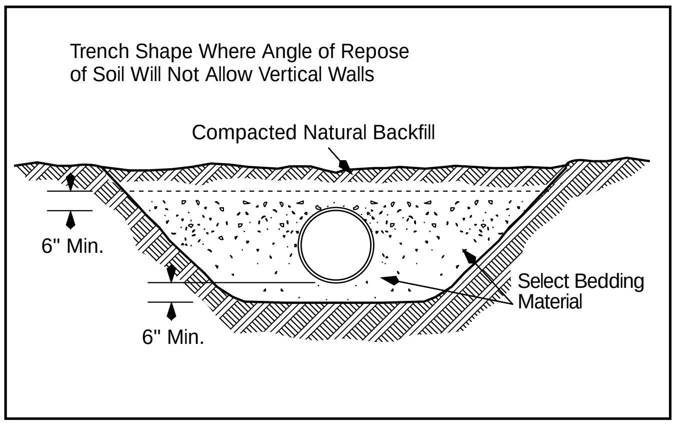


Figure 19 – Granular Type Soils (sand, etc.)

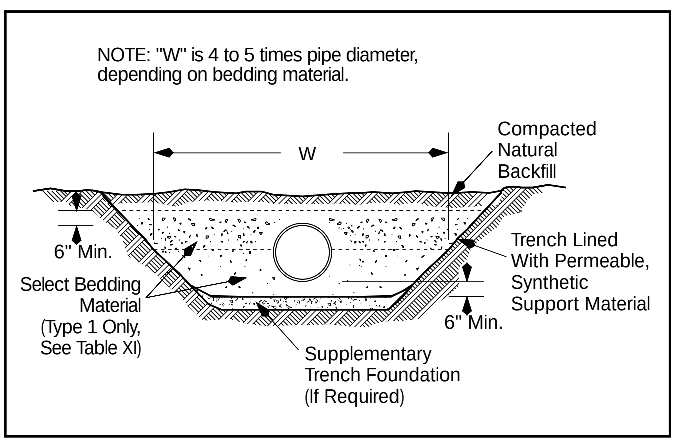


Figure 20 – Wide Trench
For Very Soft Consistency Soils

TABLE X-A
Pipe Burial Ranges For Off Highway Vehicle Loading For CENTRICAST® Piping

Nominal Pipe Size (inches)	CENTRICAST CL-1520		CENTRICAST RB-1520		CL-2030		RB-2530-IR	
	Min. (feet)	Max. (feet)	Min. (feet)	Max. (feet)	Min. (feet)	Max. (feet)	Min. (feet)	Max. (feet)
1	2	20	2	20	2	20	2	20
1 1/2	2	20	2	20	2	20	2	20
2	2	20	2	20	2	20	2	20
3	2	20	2	20	2	20	2	20
4	2	20	2	20	2	20	2	20
6	2	20	2	20	2	20	2	20
8	2	20	2	20	2	20	2	20
10	2	20	2	20	2	20	2	20
12	2	20	2	20	2	20	2	20
14	—	—	—	—	2	20	2	20

Recommendations based on design assumptions shown below.

1. Design Assumptions (per AWWA Specification C-950):
   A. Modulus of soil reaction = 1,000 lb./in.^{2}
   B. Earth density = 120 lb./ft.^{3}
   C. Circumferential modulus of elasticity = 2 x 10^6 lb./in.^{2}
   D. Factor of safety in buckling = 2.5
   E. Maximum deflection = 5%
   F. Ambient temperature
   G. Maximum combined strain = 0.0045 in./in.
   H. Does not include vacuum service
2. Consult FIBERCAST® Engineering for vacuum conditions and burial depths outside the above ranges.
3. Consult factory for other pipe burial recommendations.
4. Live load coefficients per ASTM D 3839, Table A3. Standard ASHTO-H20-S16 truck loading, 32,000 lbs. per axle.

TABLE X-B
20 Mil Lined, 14" Diameter & Larger F-CHEM®-V Pipe Burial Ranges For Off-Highway Vehicle Loading

Nominal Pipe Size (inches)	75 psi		100 psi		125 psi		150 psi	
	Wall Thickness (inches)	Burial Range (feet)	Wall Thickness (inches)	Burial Range (feet)	Wall Thickness (inches)	Burial Range (feet)	Wall Thickness (inches)	Burial Range (feet)
14	—	—	.15 / .02	4.0-13.0	—	—	.19 / .02	3.0-20.0
16	—	—	.15 / .02	4.0-12.0	.19 / .02	3.0-20.0	.23 / .02	3.0-20.0
18	—	—	.19 / .02	4.0-13.0	—	—	.23 / .02	3.0-20.0
20	—	—	.19 / .02	4.0-14.0	—	—	—	—
24	—	—	.23 / .02	4.0-14.0	—	—	—	—
30	.23 / .02	4.0-13.0	.27 / .02	3.0-20.0	—	—	—	—
36	.23 / .02	4.0-12.0	.31 / .02	3.0-20.0	—	—	—	—
42	.27 / .02	4.0-13.0	—	—	—	—	—	—
48	.31 / .02	4.0-12.0	—	—	—	—	—	—
54	.36 / .02	4.5-13.0	—	—	—	—	—	—
60	.40 / .02	5.0-12.0	—	—	—	—	—	—
72	—	—	—	—	—	—	—	—

Recommendations based on design assumptions are shown above.

TABLE X-C
100 Mil Lined, 14" Diameter & Larger F-CHEM Pipe Burial Ranges For Off-Highway Vehicle Loading

Nominal Pipe Size (inches)	75 psi		100 psi		125 psi		150 psi	
	Wall Thickness (inches)	Burial Range (feet)	Wall Thickness (inches)	Burial Range (feet)	Wall Thickness (inches)	Burial Range (feet)	Wall Thickness (inches)	Burial Range (feet)
14	—	—	.23 / .10	4.0-12.0	—	—	.27 / .10	3.0-20.0
16	—	—	.23 / .10	4.0-14.0	.27 / .10	3.0-20.0	.31 / .10	3.0-20.0
18	—	—	.27 / .10	4.0-13.0	—	—	.31 / .10	3.0-20.0
20	—	—	.27 / .10	4.0-14.0	—	—	—	—
24	—	—	.31 / .10	4.0-14.0	—	—	—	—
30	.31 / .10	4.0-13.0	.35 / .10	3.0-20.0	—	—	—	—
36	.31 / .10	4.0-12.0	.39 / .10	3.0-20.0	—	—	—	—
42	.35 / .10	4.0-13.0	—	—	—	—	—	—
48	.39 / .10	4.0-12.0	—	—	—	—	—	—
54	.44 / .10	4.5-13.0	—	—	—	—	—	—
60	.48 / .10	5.0-12.0	—	—	—	—	—	—
72	—	—	—	—	—	—	—	—

Recommendations based on design assumptions are shown above.

Bedding and Backfilling

Trench bottom: The trench bottom is the first element of the pipe support system. This surface shall either be shaped by hand to conform to the bottom 1/4 pipe diameter, or, if flat, the bedding material carefully placed and tamped by hand to ensure complete pipe support (see Figs. 21 A and B).

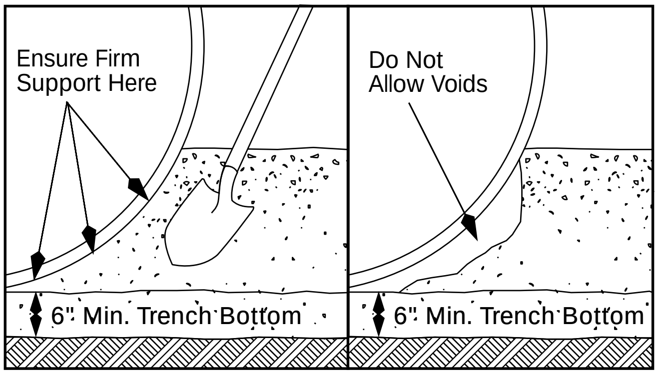


Figure 21A –Flat Trench Bottom– Figure 21B

Bedding materials: Bedding material at the sides of the pipe is to be added in lifts, not to exceed 6" at a time, mechanically compacted to the required density, and continued to 6" above the top of the pipe. This degree of compaction is dependent upon the type of bedding material being used. Water flooding for compaction is not recommended, nor is compacting the bedding material while it is highly saturated.

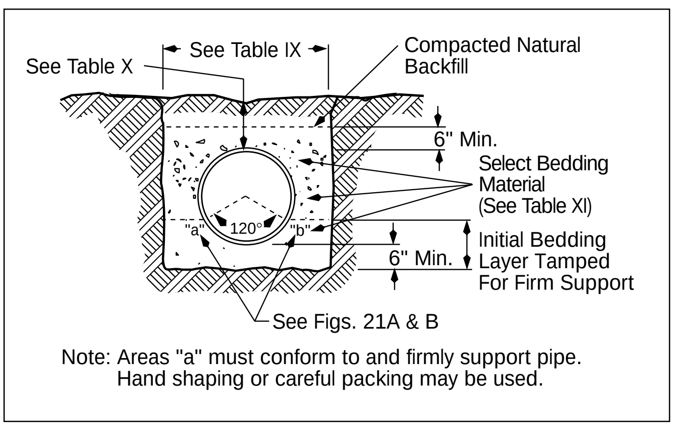


Figure 22 – Standard Conditions Firm or Hard Soils Typical Class "B" Bedding

The primary factor for bedding and backfilling is the correct compaction of the proper selected bedding materials. Sand, pea gravel, or crushed rock are the recommended bedding materials for FIBERCAST pipe, compacted per Table XI.

If excavated material meets the requirements listed in Table XI, it may be used for bedding, provided there is no organic matter, frozen lumps or particles larger than 1/2 inch. If there is any question as to the classification of the native soil, a soils testing laboratory should be consulted.

In poor soil conditions, however (i.e., very soft soils), only pea gravel or crushed rock compacted to the proper density is acceptable. In addition, a permeable, synthetic support fabric should be utilized as a trench liner to prevent migration of the gravel into native soil.

Layers: The next two layers, (12" cover over pipe), in lifts of 6", may be the excavated material, provided there is no organic matter, frozen lumps or particles larger than 1/2 inch. Each layer is to be compacted to the required density.

The remainder of the backfill may be completed with machines, such as front end loaders, provided there are no pieces larger than 12" and the lifts do not exceed 12". Again, each layer is to be compacted to the required density.

Do not allow heavy machinery to cross before final shaping unless there is adequate planking to distribute the load.

Note: Under most soil conditions, FIBERCAST pipe requires a minimum of a First Class or 'Class B' bedding. This is defined as a shaped trench bottom of select material and carefully compacted select sidefill material as previously defined. (See Fig. 22).

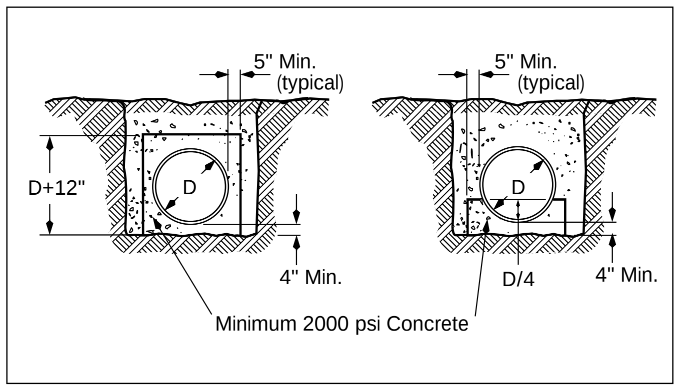


Figure 23 – Typical Class "A" Bedding

High water table: Areas with permanent high water tables are usually coincident with very poor soil conditions. In most of these areas, it will be necessary to use crushed rock or pea gravel as the bedding and backfilling material. In addition, a permeable, synthetic support fabric should be utilized as a trench liner to prevent migration of the gravel into the native soil. In extreme cases such as soft clay and other plastic soils, it will be necessary to use "Class A" Bedding. (See Figure 23). Also, if the depth of the pipe and the depth of cover is less than one pipe diameter, tiedowns or concrete encasement will be recommended in sufficient quantity to prevent flotation.

Artificial water table: In some areas with a normally low water table (i.e., below the installed depth of the pipe and bedding material), it is possible to have a false or artificial water table created due to flooding, poorly draining soil, and/or inadequate drains in the surrounding area. These areas can usually be determined by the local test laboratories. If this situation exists, refer to above High Water Table information.

TABLE XI
Bedding Material For Burial of FIBERCAST® Pipe

Type	Typical Names	Description*	Unified Soils Classification System†	Degree of Compaction Required**
1	Crushed rock or pea gravel	3/4" max. size with less than 50% passing No. 4 sieve	GW, GP	80-85%
2	Sand	Coarse or medium sand, moist	SW, SP	90-95%
3	Gravel, sand, clay and gravel, sand silt mixtures	Coarse grained soils 5% and 12% fines	GW-GM, GW-GC, SW-SM, GP-GM, SP-SM, GP-GC, SW-SC, SP-SC	85-90%
4	Silty gravels, clayey gravels, silty sands, clayey sands	Coarse grained soils more than 12% fines–low compressibility	GM, GC, SM, SC	90-95%

* All types have a maximum particle size of 3/4 inch.
** Compaction required: Standard Proctor Density per ASTM D 698
† See page 51 for soil classifications

Thrust blocks: All buried "O" Ring bell and spigot type pipe must have concrete thrust blocks at elbows, tees, etc. The size of the thrust blocks is determined by the pipe size, pressure and the load-bearing capabilities of the native soil.
When butt and wrap, adhesive socket, or tapered bell and spigot joints are utilized, thrust blocks are generally recommended when soft soils, high temperatures, or high pressures are encountered in the system. Consult factory for specific recommendations.

The concrete used in thrust blocks shall have a minimum compressive strength of 2000 psi with the load-bearing sides poured directly against undisturbed soil. Non-load-bearing sides may be poured against forms. (See Fig. 24 and Table XII). In very soft soils, supplementary foundations beneath and behind the thrust block may be required.

Dewatering systems: In all cases of pipeline burial, it is an absolute necessity that the trench be kept free of water to allow dry compaction of the bedding material.

If in a high water table area, a dewatering system must be used continuously. In other areas where rain or leakage creates water in the trench, it may be pumped as required.

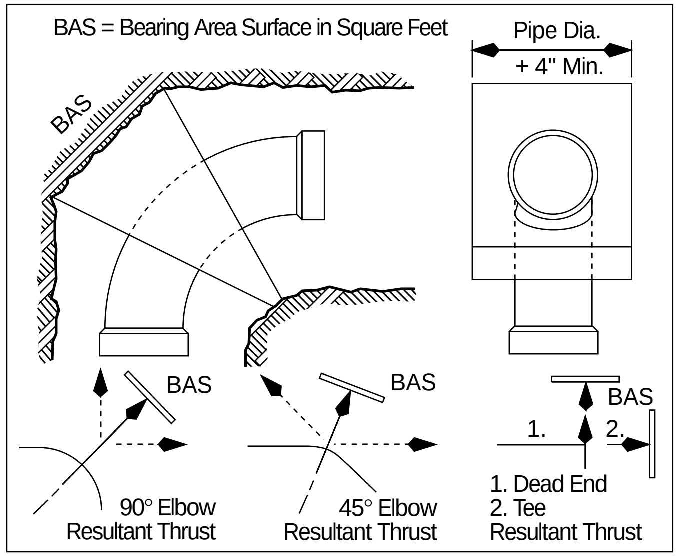


Figure 24 – Suggested Thrust Block Design For Elbows, Tees, and Dead Ends

TABLE XII
Thrust Block Minimum Bearing Area In Square Feet

Nominal Pipe Size (Inches)	Tees and Dead Ends	90° Elbows	45° Elbows	$22^1/_2$° Elbows	$11^1/_4$° Elbows
14	4	5.5	3	1.5	1
16	5	7.5	4	2	1
18	6.5	9	5	2.5	1.5
20	8	11.5	6	3.5	1.5
24	11.5	16	9	4.5	2.5
30	18	25	13.5	7	3.5
36	26	36	19.5	10	5
42	35	49	27	14	7
48	46	64	35	18	9
54	58	81	44	22	11.5
60	71	100	54.5	28	14
72	102	144	78	40	20

Bearing Area Designed for 50 psi Working Pressure					
If design working pressure is:	75	100	125	150	200
Multiply bearing area by:	1.5	2	2.5	3	4

Notes:
- *Values based on a test pressure of 1.5 x design working pressure and soil bearing load of 3,000 lb. / ft.^{2}. For other allowable soil bearing loads, multiply final minimum required bearing area by 3,000 and divide by actual allowable soil bearing load.*
- *Values do not include provisions for loads due to thermal expansion.*

TABLE XIII

Load Bearing Capabilities of Various Soils

Soil Type	Load Bearing Range	
	Minimum Load	**Maximum Load**
Rock	20,000 lb. / ft. ^{2}	30,000 lb. / ft.^{2}
Shale	12,000 lb. / ft. ^{2}	20,000 lb. / ft.^{2}
Sand and Gravel with Clay	8,000 lb. / ft. ^{2}	12,000 lb. / ft.^{2}
Sand and Gravel	6,000 lb. / ft. ^{2}	8,000 lb. / ft.^{2}
Sand	4,000 lb. / ft. ^{2}	6,000 lb. / ft.^{2}
Soft Clay	2,000 lb. / ft. ^{2}	4,000 lb. / ft.^{2}
Alluvial Soil	1,000 lb. / ft. ^{2}	2,000 lb. / ft.^{2}

Note:

No responsibility can be assumed for the accuracy of the data in this table due to the wide variation of bearing load capabilities of each soil type. Actual safe allowable soil bearing values can be obtained through the services of a soils laboratory.

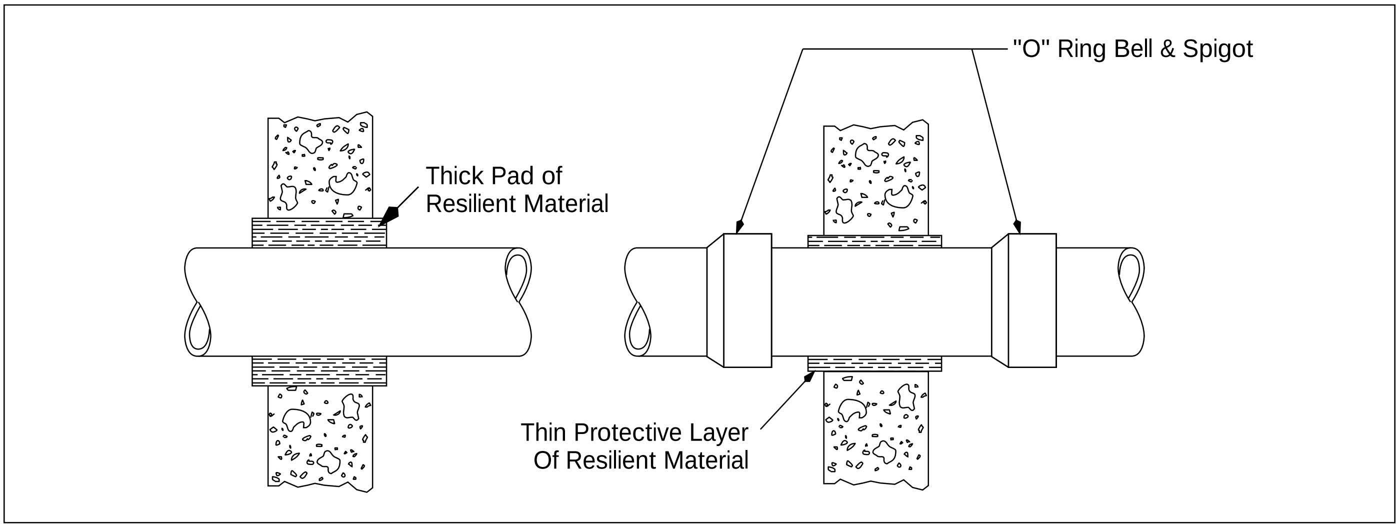


Figure 25 – Pipe Penetrating Concrete

Concrete Structure

Where the pipe goes through or passes under a concrete structure, precautions must be taken to prevent excessive strain on the pipe due to the differential settling between the structure and pipe (see Fig. 25).

Several methods are available to compensate for this settling without straining the pipe. A flexible joint, such as an "O" ring bell and spigot, may be used at the interface of the structure. Also, a sufficient thickness of a resilient material, such as rubber, wrapped around the pipe before pouring the concrete, will prevent localized or point loading for small amounts of differential settling.

The correct trench configuration adjacent to the structure is shown in Fig. 26. To allow for the possibility of unequal settling of the concrete and pipe, it is necessary to have extra bedding to prevent overstressing the pipe.

Where the pipe is buried under a non-paved roadway, it is recommended that a concrete or steel conduit be used as a sleeve, especially for shallow burial depths. A sleeve must be used if the depth below a paved roadway (i.e., H-20 Loading, is less than the minimum listed in Tables X-A, X-B and X-C).

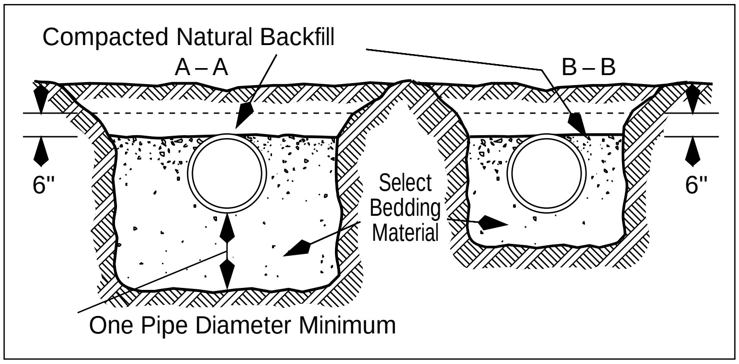


Figure 26 – Pipe Going Through (or under) Concrete Structure

Information Sheet

Appendix A

Fibercast Company
Buried Pipe Information Sheet

Name ______________________________ Company Name ______________________________

Date ______________________________ Mailing Address ______________________________

Phone ______________________________ ______________________________

City State Zip

I. Pipe Configuration (For multiple diameters, attach a second sheet.) Line No.

A. 12" Diameter & Under (Adhesive Socket Joint)

1. Diameter ____________________ Laying Length ____________________

(circle one of the following)

2. CENTRICAST PLUS RB-2530

3. CENTRICAST PLUS CL-2030

4. NOVACAST®VE-150

5. CENTRICAST®RB-1520

6. CENTRICAST CL-1520

B. 14" Diameter & Larger F-CHEM®

1. Diameter ____________________ Laying Length ____________________

2. Type of Joint *(circle one of the following)*

- Butt wrap Joint
- Matched Tapered Bell & Spigot Adhesive Joint
- "O" Ring Bell & Spigot Joint

3. Type of Liner *(circle one of the following)*

- .02 Thick (Veil)
- .10 Thick (SPI)
- Other (specify)

4. Liner Resin *(circle one of the following)*

- Vinyl Ester
- Epoxy (only with epoxy liner)
- Polyester (Specify type) ______________________________
- Other ______________________________

5. Reinforcement Shell Resin *(circle one of the following)*

- Vinyl Ester
- Epoxy (only with epoxy liner)
- Polyester (Specify type) ______________________________
- Other ______________________________

II. Burial Information

A. Maximum burial depth (cover depth to top of pipe) ______________________ Ft.

B. Minimum burial depth (cover depth to top of pipe) ______________________ Ft.

C. Depth of water table ____________________ Ft.

D. Type of native soil

E. Backfill soil type

F. Modulus of soil reaction of backfill material (if known) ____________________ psi

G. Density of soil ___________________ Lb./Ft.^{3}

III. Operation Conditions *(circle one of the following)*

A. • Gravity Flow

• Forced Flow

• Pump (type) ____

B. Nominal operating pressure _____________________ psi

C. Design pressure _______________________________ psi

D. Test pressure _________________________________ psi

E. Internal vacuum (from ambient pressure) __________ psi

F. Max/min operating temperature __________________ ° F.

G. Minimum ambient temperature ___________________ ° F.

H. Installation temperature ________________________ ° F.

IV. Live Loads *(circle one of the following)*

A. • H-20 Highway loading

• E-72 Railroad loading

B. Off- road vehicle traffic _________________ Lbs./Axle

C. Other loads___________________________________

V. Other Design Information

____

____

____

____

Submit this form with all available engineering specifications and drawings to:

Quotations Department
Fibercast Company
P.O. Box 968 • 25 S. Main
Sand Springs, OK 74063
Fax: 800-365-7473 or 918-245-0508
Fax: (International) 918-241-1143

Requested Reply Date: __________________________________

Instructions For Filling Out Buried Pipe Information Sheet

The purpose of the Buried Pipe Information Sheet is to obtain the information required to specify and/or design the optimum piping system for the required service.

1. Complete customer section for company and person to contact for additional information.
2. Section I – Fill in blanks and check appropriate blocks for the type and size of pipe required.
3. Section II – Fill in actual information, if known. Where estimates are used, please indicate.
4. Section III – Fill in and check as required.
5. Section IV – Fill in and check as required. If dead loads only (i.e., overburden), indicate in "C": Other loads.
6. Section V – Add any pertinent information such as widely varying temperatures and/or pressure cycles under normal operation; fluid specific gravity extremes; flood prone areas, etc. Attach separate sheet if necessary.

Definition of Terms

- *E or Modulus of Soil Reaction*: This term reflects the stiffness of the soil surrounding the pipe; i.e., the bedding material. Its value is dependent on the soil type and density. Granular type soils have a higher modulus than cohesive soils, and this modulus is further increased by compaction.

- *Dead Loads:* This is the weight of the overburden acting on the pipe. The value is determined by multiplying the density of the soil (lb./in.^{3}) by the depth of cover (inches).

- *H-20 Loading:* This is a standardized live load of 32,000 lbs./axle per the American Association of State Highway Transportation Officials (AASHTO) considered to be applied through a pavement one foot thick.

- *Off Road Vehicle Traffic Load:* As used in burial calculations is defined as 32,000 lbs./axle with 50% impact allowance. This load is considered to act at the surface without the benefit of pavement.

- *Supplementary Foundations:* Usually crushed rock or pea gravel dumped and properly compacted in over-excavated trenches because of very poor soil conditions. In some cases, concrete supplementary foundations are required.

- *Angle of Repose:* The maximum angle soil can be piled without additional support.

Unified Soil Classification System Soils Designations

G – Gravel [No. 4 Sieve (3/16") to 3" Size]
S – Sand [No. 200 Sieve (1/64") to No. 4 Sieve]
P – Poorly Graded (predominately one size)
W– Well Graded (even size distribution)
M– Low Plasticity (i.e., GM or SM)
C – Plastic or Clay-like Soils (i.e., GC or SC)
L – Low Compressibility (i.e., ML or CL)
H – High Compressibility (i.e., CH or MH)
O – Includes Organic Matter (i.e., OL or OH)

Combinations of these designations are used to define particular types of soil. GW-GM soil would be well graded with a small amount of low plasticity fines.

Information Sheet

Appendix B

Fibercast Piping
Recommendation Request

TO: Fibercast Application Engineering
Fax 800-365-7473 or 918-245-0508

Name ________________________ Company Name ________________________

Date ________________________ Mailing Address ________________________

Phone ________________________ ________________________

City State Zip

Fax ________________________

Customer Contact ________________________ Phone ________________________

Application Data:

Nominal Pipe Sizes ________________ Above Ground ____________ Buried __________

(If buried, complete "Buried Pipe Information Sheet", pages 43 & 44, Piping Design Manual)

Is this a: Vent Line _____ Gravity Drain _____ Pressure System _____ Required Pressure Rating ______psig

Operating Temperature: Normal____ degrees F. Max. Upset ____degrees F. Time at Max _____ Min.____degrees F.

Chemical Composition of the fluid stream:

(Include all chemicals including trace amounts)

Chemical (Do not use trade names)	Concentration (Should add to 100%)	Continuous/Intermittent Exposure (If intermittent, give time of exposure)

Other Information ________________________

Commercial Data:

Preferred Fibercast Products ________________________

Other products being considered ________________________

If an existing line, what product is being used ________________________

How long has this existing line performed ________________________

FIBERCAST RECOMMENDATION ________________________

____

FIBERCAST CONTACT ________________________

Information Sheet

Appendix C

Fibercast Inquiry
Information Checklist

The following information should be supplied to FIBERCAST whenever an inquiry is placed. Supplying this information will help ensure an accurate and timely quotation.

TO: Fibercast Application Engineering
Fax 800-365-7473 or 918-245-0508

All Inquiries:

Customer Contact ________________________________ Company Name ________________________________

Date ________________________________ Mailing Address ________________________________

Phone ________________________________ ________________________________

City State Zip

Fax ________________________________

Distributor Rep Name ________________________________ Phone ________________________

Quotation Due Date ____

Any available competitive product information:

Manufacturer/Grade ____

Operating Pressure, Internal ________________ External ______________

Temperature Operating: Max ____________ Min ____________ Installation ____________

QUOTE _______ Loose _______ Prefabricated

Complete legible drawings (list lines to be quoted) ________________________________

Inquiries Based On Customer-Supplied Specifications

Inquiries based on customer-supplied specifications should include all sections which affect the piping to be supplied. This may include the following sections of the specification:

1. Piping Specification
2. Factory & Field Test Requirements
3. Shipping Requirements
4. Submittal Information

Inquiries Based On Application Data

Fluid stream chemical composition ____ Fluid ____ Vapor ____ Slurry

% concentration and name ____

Preferred joining method

____ Socket Joint ____Tapered B&S ____ Butt Wrap ____ Flanged ____ O-Ring B&S

For buried applications, provide the information per Appendix A of the Piping Design Manual, pages 21 & 22

Special requirements

____ Fire Retardancy ____ UV Protection ____ Painting ____ UL Listing ____ FM ____ Other

Conversions

TABLE XIV
Centigrade Fahrenheit

Centigrade	Farenheit	Centigrade	Farenheit	Centigrade	Farenheit	Centigrade	Farenheit
-200	-328.0	24	75.2	59	138.2	94	201.2
-100	-148.0	25	77.0	60	140.0	95	203.0
-90	-130.0	26	78.8	61	141.8	96	204.8
-80	-112.0	27	80.6	62	143.6	97	206.6
-70	-94.0	28	82.4	63	145.4	98	208.4
-60	-76.0	29	84.2	64	147.2	99	210.2
-50	-58.0	30	86.0	65	149.0	100	212.0
-40	-40.0	31	87.8	66	150.8	110	230
-30	-22.0	32	89.6	67	152.6	120	248
-20	-4.0	33	91.4	68	154.4	130	266
-10	14.0	34	93.2	69	156.2	140	284
0	32.0	35	95.0	70	158.0	150	302
1	33.8	36	96.8	71	159.8	160	320
2	35.6	37	98.6	72	161.6	170	338
3	37.4	38	100.4	73	163.4	180	356
4	39.2	39	102.2	74	165.2	190	374
5	41.0	40	104.0	75	167.0	200	392
6	42.8	41	105.8	76	168.8	210	410
7	44.6	42	107.6	77	170.6	212	414
8	46.4	43	109.4	78	172.4	220	428
9	48.2	44	111.2	79	174.2	230	446
10	50.0	45	113.0	80	176.0	240	464
11	51.8	46	114.8	81	177.8	250	482
12	53.6	47	116.6	82	179.6	260	500
13	55.4	48	118.4	83	181.4	270	518
14	57.2	49	120.2	84	183.2	280	536
15	59.0	50	122.0	85	185.0	290	554
16	60.8	51	123.8	86	186.8	300	572
17	62.6	52	125.6	87	188.6	310	590
18	64.4	53	127.4	88	190.4	320	608
19	66.2	54	129.2	89	192.2	330	626
20	68.0	55	131.0	90	194.0	340	644
21	69.8	56	132.8	91	195.8	350	662
22	71.6	57	134.6	92	197.6		
23	73.4	58	136.4	93	199.4		

TABLE XV
Metric – U.S.

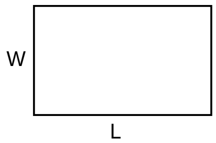
	Metric Units	U.S. Equivalents
Lengths	1 millimeter	0.03937 inch
	1 centimeter	0.3937 inch
	1 meter	39.37 inches or 1.0936 yards
	1 kilometer	1093.61 yards or 0.6214 mile
Areas	1 square millimeter	0.00155 square inch
	1 square centimeter	0.155 square inch
	1 square meter	10.764 square feet or 1.196 square yards
	1 square kilometer	0.3861 square mile
Volumes	1 cubic millimeter	0.000061 cubic inch
	1 cubic centimeter	0.061 cubic inch
	1 liter	61.025 cubic inches
	1 cubic meter	35.314 cubic feet or 1.3079 cubic yards
Capacities	1 millileter (0.001 liter)	0.0338 U.S. fluid ounce
	1 liter	2.1134 U.S. liquid pints
	1 liter	1.0567 U.S. liquid quarts
	1 liter	0.2642 U.S. gallon
Weights	1 gram	0.03527 avoir. ounce or 15.4324 grains
	1 kilogram(1000 grams)	2.2046 avoir. pounds

	U.S. System Units	Metric Equivalents
Lengths	1 inch	25.4 millimeters or 2.54 centimeters
	1 foot	0.3048 meter
	1 yard	0.9144 meter
	1 mile	1.6093 kilometers
Areas	1 square inch	645.16 square millimeters or 6.452 square centimeters
	1 square foot	0.0929 square meter
	1 square yard	0.8361 square meter
	1 square mile	2.59 square kilometers
Volumes	1 cubic inch	16,387.2 cubic millimeters or 16.3872 cubic centimeters
	1 cubic foot	0.02832 cubic meter
	1 cubic yard	0.7646 cubic meter
Capacities	1 U.S. fluid ounce	29.573 milliliters
	1 U.S. liquid pint	0.47317 liter
	1 U.S. liquid quart	0.94633 liter
	1 U.S. gallon	3.78533 liters
Weights	1 grain	0.0648 gram
	1 avoir. ounce	28.35 grams
	1 avoir. pound	0.4536 kilogram
	1 Troy ounce	31.1035 grams

Note: *The cubic millimeter, cubic centimeter and cubic meter are units of volume derived from basic units of length. The liter, however, is defined as the volume occupied by a kilogram of water at 4 ° C, and at standard atmospheric pressure. Consequently, the cubic centimeter (c.c.) and the milliliter (ml.) are not exactly similar. (1 ml. = 1.000027 c.c.) The milliliter, by common consent, is now recognized as the preferable unit for the measurement of volume in chemical laboratory practice.*

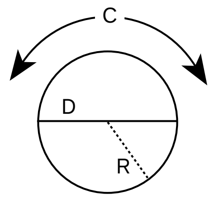
Useful Formulas

Where: A = Area; A1 = Surface area of solids; V = Volume; C = Circumference



Rectangle

$A = W \times L$



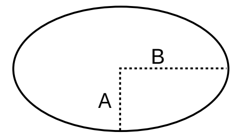
Circle

$A = 3.142 \times R \times R$

$C = 3.142 \times D$

$R = D / 2$

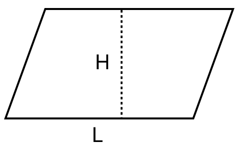
$D = 2 \times R$



Ellipse

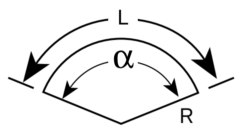
$A = 3.142 \times A \times B$

$$C = 6.283 \times \sqrt{\frac{A^2 + B^2}{2}}$$



Parallelogram

$A = H \times L$



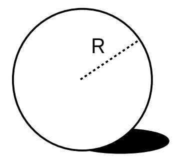
Sector of Circle

$$A = \frac{3.142 \times R \times R \times \alpha}{360}$$

$L = .01745 \times R \times \alpha$

$$\alpha = \frac{L}{.01745 \times R}$$

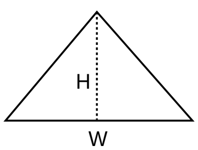
$$R = \frac{L}{.01745 \times \alpha}$$



Sphere

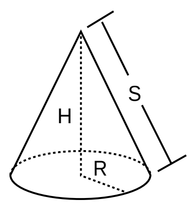
$A = 12.56 \times R \times R$

$V = 4.188 \times R \times R \times R$



Triangle

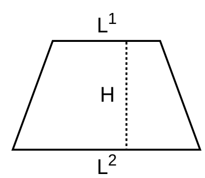
$$A = \frac{W \times H}{2}$$



Cone

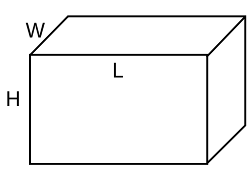
$A = 3.142 \times R \times S + 3.142 \times R \times R$

$V = 1.047 \times R \times R \times H$



Trapezoid

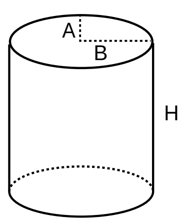
$$A = H \times \frac{L^1 + L^2}{2}$$



Rectanglular Solid

$A = 2 [W \times L + L \times H + H \times W]$

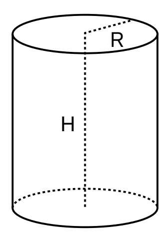
$V = W \times L \times H$



B
Elliptical Tanks

$$A_1 = 6.283 \times \sqrt{\frac{A^2 + B^2}{2}} \times H + 6.283 \times A \times B$$

$V = 3.142 \times A \times B \times H$



A
Cylinder

$A_1 = 6.283 \times R \times H + 6.283 \times R \times R$

$V = 3.142 \times R \times R \times H$

For Above Containers:

Capacity in gallons $= \frac{V}{231}$ when V is in cubic inches   Capacity in gallons = 7.48 x V when V is in cubic feet

TABLE XVI
Water Pressure To Feet Head

Pounds Per Square Inch	Feet Head	Pounds Per Square Inch	Feet Head
1	2.31	100	230.90
2	4.62	110	253.98
3	6.93	120	277.07
4	9.24	130	300.16
5	11.54	140	323.25
6	13.85	150	346.34
7	16.16	160	369.43
8	18.47	170	392.52
9	20.78	180	415.61
10	23.09	200	461.78
15	34.63	250	577.24
20	46.18	300	692.69
25	57.72	350	808.13
30	69.27	400	922.58
40	92.36	500	1154.48
50	115.45	600	1385.39
60	138.54	700	1616.30
70	161.63	800	1847.20
80	184.72	900	2078.10
90	207.81	1000	2309.00

Note: *One pound of pressure per square inch of water equals 2.309 feet of water at 62° Fahrenheit. Therefore, to find the feet head of water for any pressure not given in the table above, multiply the pressure pounds per square inch by 2.309.*

TABLE XVII
Feet Head of Water To psi

Feet Head	Pounds Per Square Inch	Feet Head	Pounds Per Square Inch
1	.43	100	43.31
2	.87	110	47.64
3	1.30	120	51.97
4	1.73	130	56.30
5	2.17	140	60.63
6	2.60	150	64.96
7	3.03	160	69.29
8	3.46	170	73.63
9	3.90	180	77.96
10	4.33	200	86.62
15	6.50	250	108.27
20	8.66	300	129.93
25	10.83	350	151.58
30	12.99	400	173.24
40	17.32	500	216.55
50	21.65	600	259.85
60	25.99	700	303.16
70	30.32	800	346.47
80	34.65	900	389.78
90	38.98	1000	433.00

Note: *One foot of water at 62° Fahrenheit equals .433 pound pressure per square inch. To find the pressure per square inch for any feet head not given in the table above, multiply the feet head by .433.*

TABLE XVIII
Dry Saturated Steam Pressure

ABS. Press., Lbs./Sq. In.	Temp. ° F.	ABS. Press., Lbs./Sq. In.	Temp. ° F.
0.491	79.03	30	250.33
0.736	91.72	35	259.28
0.982	101.14	40	267.25
1.227	108.71	45	274.44
1.473	115.06	50	281.01
1.964	125.43	55	287.07
2.455	133.76	60	292.71
5	162.24	65	297.97
10	193.21	70	302.92
14.696	212.00	75	307.60
15	213.03	80	312.03
16	216.32	85	316.25
18	222.41	90	320.27
20	227.96	100	327.81
25	240.07	110	334.77

TABLE XIX
Specific Gravity of Gases
(At 60° F. and 29.92" Hg)

Dry Air (1cu. ft. at 60° F. and 29.92" Hg. weighs .07638 pound)		1.000
Acetylene	C_2H_2	0.91
Ethane	C_2H_6	1.05
Methane	CH_4	0.554
Ammonia	NH_3	0.596
Carbon-dioxide	CO_2	1.53
Carbon-monoxide	CO	0.967
Butane	C_4H_{10}	2.067
Butene	C_4H_8	1.93
Chlorine	Cl_2	2.486
Helium	He	0.138
Hydrogen	H_2	0.0696
Nitrogen	N_2	0.9718
Oxygen	O_2	1.1053

TABLE XX
Specific Gravity of Liquids

Liquid	Temp ° F.	Specific Gravity
Water (1cu. ft. weighs 62.41 lb.)	50	1.00
Brine (Sodium Chloride 25%)	32	1.20
Pennsylvania Crude Oil	80	0.85
Fuel Oil No. 1 and 2	85	0.95
Gasoline	80	0.74
Kerosene	85	0.82
Lubricating Oil SAE 10-20-30	115	0.94

TABLE XXI
Weight of Water

1 cu. ft. at 50° F .... weighs 62.41 lb.
1 gal. at 50° F .... weighs 8.34 lb.
1 cu. ft. of ice .... weighs 57.2 lb.
1 cu. ft. at 39.2° F .... weighs 62.43 lb.
Water is at its greatest density at 39.2° F.

TABLE XXII
Conversion Factors

Pressure

1 in. of mercury	= 345.34 kilograms per sq. meter
	= 0.0345 kilograms per sq. centimeter
	= 0.0334 bar
	= 0.491 lb. per sq. in.
1 lb. per sq. in.	= 2.036 in. head of mercury
	= 2.309 ft. head of water
	= 0.0703 kilogram per sq. centimeter
	= 0.0690 bar
	= 6894.76 pascals
1 pascal	= 1.0 newton per sq. meter
	= 9.8692×10^{-6} atmospheres
	= 1.4504×10^{-4} lbs. per sq. in.
	= 4.0148×10^{-3} in. head of water
	= 7.5001×10^{-4} cm. head of mercury
	= 1.0200×10^{-5} kilogram per sq. meter
	= 1.0×10^{-5} bar
1 atmosphere	= 101,325 pascals
	= 1,013 milibars
	= 14.696 lbs. per sq. in.

Temperature

° C.	= (° F.-32) x 5/9

Weight of Liquid

1 gal. (U.S.)	= 8.34 lb. x sp. gr.
1 cu. ft.	= 62.4 lb. x sp. gr.
1 lb.	= 0.12 U.S. gal. ÷ sp. gr.
	= 0.016 cu. ft. ÷ sp. gr.

Flow

1 gpm	= 0.134 cu. ft. per min.
	= 500 lb. per hr. x sp. gr.
500 lb. per hr.	= 1 gpm ÷ sp. gr.
1 cu. ft. per min.(cfm)	= 448.8 gal. per hr. (gph)

Work

1 Btu (mean)	= 778 ft. lb.
	= 0.293 watt hr.
	= 1/180 of heat required to change temp of 1 lb. water from 32° F. to 212° F.
1 hp-hr	= 2545 Btu (mean)
	= 0.746 kwhr
1 kwhr	= 3413 Btu (mean)
	= 1.34 hp-hr.

Power

1 Btu per hr.	= 0.293 watt
	= 12.96 ft. lb. per min.
	= 0.00039 hp
1 ton refrigeration (U.S.)	= 288,000 Btu per 24 hr.
	= 12,000 Btu per hr.
	= 200 Btu per min.
	= 83.33 lb. ice melted per hr. from and at 32° F.
	= 2000 lb. ice melted per 24 hr. from and at 32° F.
1 hp	= 550 ft. lb. per sec.
	= 746 watt
	= 2545 Btu per hr.
1 boiler hp	= 33,480 Btu per hr.
	= 34.5 lb. water evap. per hr. from and at 212° F.
	= 9.8 kw.
1 kw.	= 3413 Btu per hr.

Mass

1 lb. (avoir.)	= 16 oz. (avoir.)
	= 7000 grain
1 ton (short)	= 2000 lb.
1 ton (long)	= 2240 lb.

Volume

1 gal. (U.S.)	= 128 fl. oz. (U.S.)
	= 231 cu. in.
	= 0.833 gal. (Brit.)
1 cu. ft.	= 7.48 gal. (U.S.)

Torque Strengths

The following may be used to calculate allowable torque and deflection when subjected to torsion:

S_s = 2,500psi, allowable shear stress
T = Torque, pounds–inches
R = Outside radius of pipe
r = Inside radius of pipe
θ = Angle of twist in radians
L = Shaft length, inches
G = 2.3×10^6

$$S_s = \frac{2TR}{\pi(R4-r4)} \quad \text{and} \quad \theta = \frac{2TL}{\pi(R4-r4)G}$$

Glossary

The following brief definitions are given as they are typically applied to fiberglass piping systems. The definitions may not be complete or may not be accurate for other applications.

Catalyst:The chemical added to vinyl ester resins which cause them to harden. Usually Methyl Ethyl Ketone Peroxide (MEKP).

Centrifugal Casting: A process for making pipe in which resin and fiberglass are placed into the interior of a spinning rotary mold, forming the pipe through centrifugal force.

Chopped Fiber: Continuous glass fibers cut into short (0.125 to 2.0 inch) lengths.

Chopped Strand Mat: Coarse fabric sheets made from chopped strands randomly placed and held together by resin binders.

Cure: The hardening of a thermoset resin system by the action of heat or chemical action.

Cure Time: The time it takes for a resin system to reach full strength.

Curing Agent: Any of a number of chemicals added to epoxy resin to cause it to harden. Aromatic amine curing agents are commonly used for high temperature corrosion service. Anhydride cured epoxy resins are typically used for less stringent applications.

Down Hole Casing: The outer fiberglass pipe used in chemical disposal and other wells.

Down Hole Tubing: The inner fiberglass pipe used in chemical disposal and other wells.

Epoxy Resin: A thermosetting resin used in caustic, solvent, salt and some acid solutions.

Fabmat: A combination of woven roving and chopped strand mat held together with resin binders. Usually used for making contact molded fittings and butt weld joints.

Filament: A single fiber of glass, e.g. a monofilament.

Gel Time: The time it takes for a resin system to harden so flow will not occur.

Hardener: Any of a number of chemicals added to resin which cause hardening to occur.

Line Pipe: Fiberglass pressure pipe used to transport fluid over relatively long distances.

Liner: The resin rich interior surface of the pipe or fitting. The liner provides the corrosion resistance for chemical service.

Nexus: Porous surfacing mat of synthetic used to provide a resin rich layer or liner.

Novolac Resin: A premium epoxy vinyl ester resin used in a broad range of corrosive applications.

Process Pipe: Fiberglass pipe and fittings usually used to transport fluids within the confines of a process area.

Reinforcement: Typically fibers of glass used to provide strength and stiffness to a composite material.

Resin: The polymer or plastic material used to bind the glass fibers together in fiberglass pipe and fittings.

Roving: A collection of one, or more, strands of glass filaments. The typical form of glass fiber used in the manufacture of filament wound pipe.

Thermoset Resin: A resin cured by heat or chemical additives. Once cured a thermoset resin cannot be remelted.

Veil: Surfacing mat of porous fabric made from filaments. Used to provide a resin rich layer or liner.

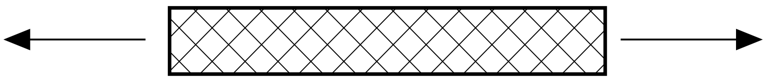
Vinyl Ester Resin: A thermosetting resin used in strong acids, chlorine, and oxidizing agents.

Woven Roving: Coarse cloth like material made by weaving fiberglass roving.

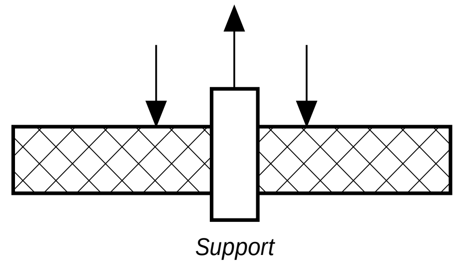
Simplified Terms and Properties

Following are simplified explanations of engineering terms and properties used in the Fibercast catalog.

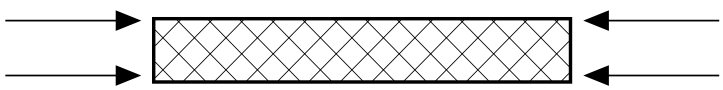
Stress – The amount of force on the laminate (psi) with respect to the dimensions of the laminate and direction of the force.



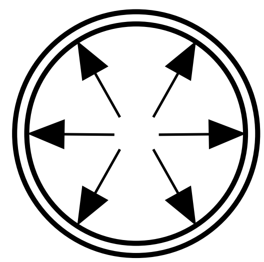
Axial Tensile Stress



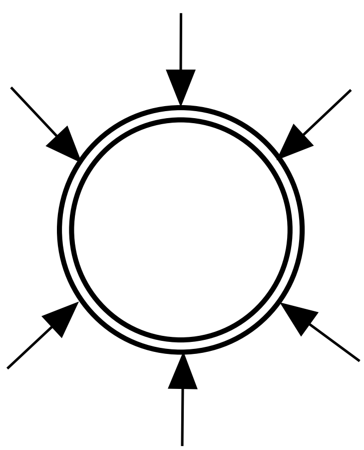
Shear Stress



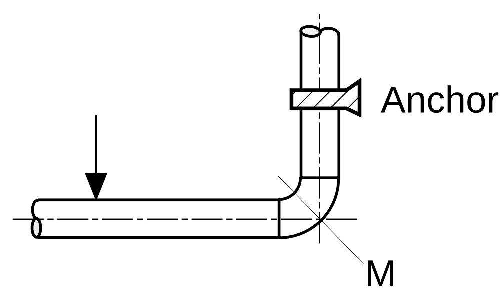
Axial Compressive Stress



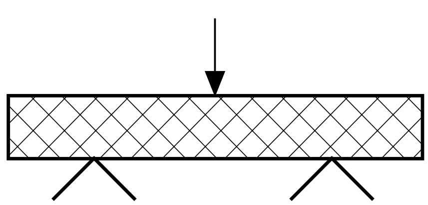
Hoop Tensile Stress From Internal Pressure



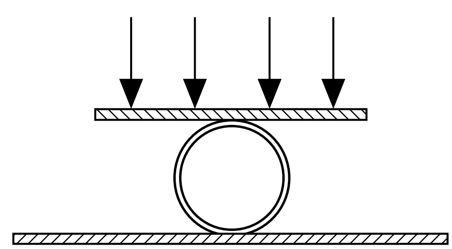
Circumferential Stress From External Pressure or Burial Loads



Elbow Bending Moment



Beam Bending Stress



Pipe Stiffness = PS = $\frac{F}{\Delta Y}$

SMITH Fibercast™

A Varco Company

2700 West 65th Street
Little Rock, AR 72209
(501)568-4010
Fax:(501) 568-4465
http://www.smithfiberglass.com

P.O. Box 968 • 25 South Main
Sand Springs, OK 74063
(800) 331-4406 or (918) 245-6651
Fax: (Local/International) 918-241-1143
Fax: 800-365-7473
http: //www.fibercast.com