SPECIFICATION: **FRP Pipe and Pipe Fittings**

CUSTOMER / PROJECT: _____

REQUIREMENTS

1.0 GENERAL

The pipe in these specifications is to be manufactured by hand lay up, filament winding or a combination of the two to meet the design conditions specified for the system. Pipe and fittings are to be designed for an internal pressure of (25-150) PSIG. The pipe is to include a corrosion liner of (0.100"). The corrosion liner is to be (included/excluded) in the pipe structural calculations.

Contact molded components are to conform to the requirements of PS-15-69. Filament wound pipe shall conform to ASTM D-2996.

Pipe and fittings are to be manufactured by Composites USA.

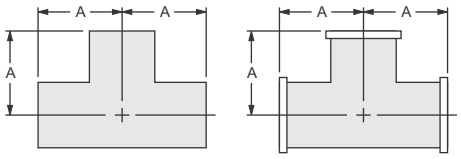
2.0 MATERIALS

2.1 **RESIN** - The resin used will be a thermoset resin considered suitable for the application based upon its demonstrated prior success in similar applications or other test data. The type of resin to be used will be specified on the customer purchase order or job specification. Catalysts and promoters shall be those recommended by the resin manufacturer.

2.1.1 Unless otherwise specified, the resin used shall be a premium grade corrosion resistant vinyl ester such as Reichhold Chemicals Dion 9100, Dow Chemical Derakane 411, Ashland Chemicals Hetron 922 or equal. The same resin shall be used throughout.

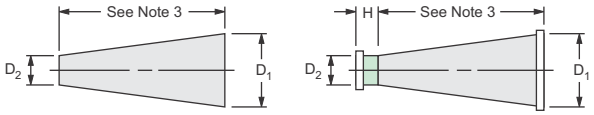
TABLE 1: Standard Duct and Pipe Fitting Dimensions (all dimensions in inches)

TEE



Plain Flanged

CONCENTRIC REDUCER



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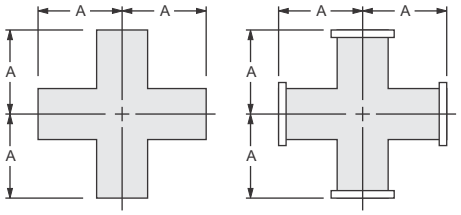
CROSS



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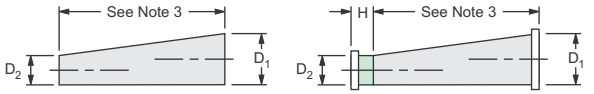
ECCENTRIC REDUCER



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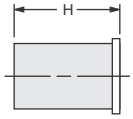
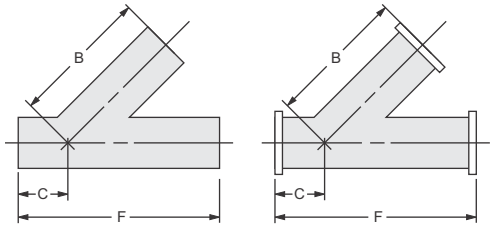
STUB FLANGE

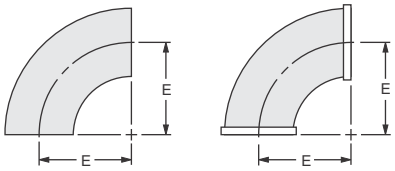


45 DEGREE LATERAL



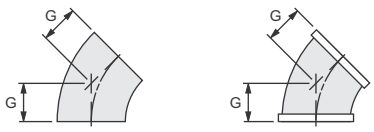
Plain Flanged

90 DEGREE ELBOW



Plain Flanged

45 DEGREE ELBOW



Plain Flanged

Dia.	A	B	C	E	F	G	H
1-1/2	6	10	6	3	16	1-1/4	6
2	6	10	6	4	16	1-5/8	6
3	7	12	6	4-1/2	18	1-7/8	6
4	8	14	6	6	20	2-1/2	6
6	10	16	8	9	24	3-3/4	8
8	12	20	10	12	30	5	8
10	14	24	10	15	34	6-1/4	10
12	16	26	12	18	38	7-1/2	10
14	18	30	12	21	42	8-3/4	12
16	20	32	14	24	46	10	12
18	21	36	14	27	50	11-1/4	12
20	22	38	16	30	54	12-1/2	12
24	24	42	18	36	60	15	12
30	30	52	20	45	72	18-5/8	15
36	33	62	22	54	84	22-3/8	15
42	36	72	24	63	96	26	15
48	42	82	30	72	108	29-7/8	18
54	48	92	36	81	120	33-1/2	18
60	54	102	42	90	132	37-1/4	18
72	66	122	54	108	144	44-3/4	18

Note:
1. Standard elbow radius is 1.5:1, face to centerline (long radius). Short radius (1:1) is also available.
2. Due to dimensional interferences, flanged elbows below 6" diameter require stub flanges joined to plain end elbows.
3. Standard reducer length is 2.5 x the diameter difference for pipe (5 x difference for duct).
4. Custom dimensions and assembly for all fitting styles available.

2.2 **FILLERS AND PIGMENTS** - The resins used shall not contain fillers except as required for viscosity control, fire or smoke retardance. Up to 5 percent by weight of thixotropic agent which will not interfere with visual inspection may be added to the resin for viscosity control. Resins may contain pigments and dyes by agreement between Composites USA, Inc., and purchaser, recognizing that such additions may interfere with visual inspection of laminate equality. Antimony compounds or other fire retardant agents may be added as required for improved fire resistance.

2.3 **REINFORCING MATERIAL** - The reinforcing material shall be a commercial grade of E-glass fiber having a coupling agent that will provide a suitable bond between the glass reinforcement and the resin.

2.4 **SURFACING MATERIALS** - Unless otherwise agreed upon between Composites USA, Inc. and purchaser, material used as reinforcing on the surface exposed to chemical attack shall be a commercial grade chemical-resistant glass (C-glass) having a coupling agent. Alternative surfacing materials available for use include polyester (Nexus), Halar ECTFE, and graphite.

2.5 **LAMINATE** - The laminate shall consist of an inner surface, an interior layer, and an exterior layer or laminate body. The compositions specified for the inner surface and interior layer are intended to achieve optimum chemical resistance and are designated as the corrosion liner.

2.6 **INNER SURFACE** - The inner surface shall be free of cracks and crazing. The surface shall have a smooth finish and with an average of not over 2 pits per square foot, providing the pits are less than 1/8 inch in diameter and not over 1/32 inch deep and are covered with sufficient resin to avoid exposure of inner surface fabric. Some waviness is permissible as long as the surface is smooth and free of pits. Between 0.010 and 0.020 inches of reinforced resin-rich surface shall be provided, depending upon the surfacing material used. This surface may be reinforced with glass surfacing veil, carbon or synthetic veil, or other material as usage requires.

2.7 **INTERIOR LAYER** - A minimum of 0.090 inch of the laminate next to the inner surface shall be reinforced with not less than 20 percent nor more than 30 percent by weight of non-continuous glass strands (having fiber lengths from 0.5 to 2.0 inches).

2.8 **EXTERIOR LAYER** - The exterior layer or body of the laminate shall be of chemically resistant construction suitable for the service and providing the additional strength necessary to meet the tensile and flexural requirements.

2.8.1 Contact Molded: Where separate layers such as mat, cloth, or woven roving are used, all layers shall be lapped a minimum of 1 inch. Laps shall be staggered as much as possible. If woven roving or cloth is used, a layer of chopped-strand glass shall be placed as alternative layers to minimize bridging and air gaps.

2.8.2 Filament Wound: Prior to filament winding of the structural wall, the interior layer shall be allowed to sufficiently gel to prevent squeeze out of the corrosion resistant liner. Winding is to be at a controlled uniform tension at a wind angle of 54.7° +/-2° with respect to the pipe axis, unless engineering calculations demonstrate a different angle is better suited for the specific project. All strands shall be completely wet out and shall lay flat and parallel with no bunching or gap between strands.

2.8.3 The exterior surface shall be relatively smooth with no exposed fibers or sharp projections. Hand work finish is acceptable, but enough resin shall be present to prevent fiber show. When the outer surface is subject to a corrosive environment, the exterior surface shall consist of a chopped-strand glass over which shall be applied a resin-rich coating as described in INNER SURFACE. Other methods of surface protection may be used as agreed upon between Composites USA, Inc., and Customer.

2.9 **CUT EDGES** - All cut edges shall be coated with resin so that no glass fibers are exposed and all voids filled. Structural elements having edges exposed to the chemical environment shall be made with chopped-strand glass reinforcement only.

2.10 **JOINTS** - Finished joints shall be built up in successive layers and be as strong as the pieces being joined and as crevice free as is commercially practicable. The width of the first layer shall be 2 inches minimum. Successive layers shall increase uniformly to provide the specified minimum total width of overlay which shall be centered on the joint. Crevices between jointed pieces shall be filled with resin or thixotropic resin paste, leaving a smooth inner surface. (See INNER SURFACE) The interior of joints may also be sealed where accessible, by covering with not less than 0.100 inch of reinforced resin-rich surface as described in INNER SURFACE and INTERIOR LAYER.

2.11 **WALL THICKNESS** - The minimum wall thickness shall be as specified in Table 3. Isolated small spots may be as thin as minimum specified hardness for the cured resin. This applies to both interior and exterior surfaces.

2.12 **SURFACE HARDNESS** - The laminate shall have a Barcol hardness of at least 90 percent of the resin manufacturer's minimum specified hardness for the cured resin. This applies to both interior and exterior surfaces.

2.13 **APPEARANCE** - The finished laminate shall be as free as commercially practicable from visual defects such as foreign inclusions, dry spots, air bubbles, pinholes, pimples, and delamination.

TABLE 2: Requirements for properties of reinforced vinyl ester laminates.

Property at 73.4°F (23°C)	Laminate Hand Lay Up Thickness (inches)			
Minimum Values (PSI):	All Thickness Type I	0.22 inch Type II	0.29 inch Type II	0.37 inch Type II
Ultimate tensile strength - Flexural strength - Flexural modulus (tangent) -	9,000 16,000 700,000	12,000 19,000 800,000	13,500 20,000 900,000	15,000 22,000 1,000,000
	Filament Wound Properties for 54.7° +/- 2° Wind Angle			
Hoop Tensile Strength Hoop Tensile Modulus Axial Tensile Strength Axial Tensile Modulus	24,000 2,000,000 12,000 1,650,000			

3.0 PIPE SIZES AND TOLERANCES

3.1 **SIZE** - The standard pipe size shall be the inside diameter in inches. Standard sizes are 3/4, 1, 1-1/2, 2, 3, 4, 5, 6, 8, 9, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 42, 48, 54, 60, 72 inches. The tolerance including out-of-roundness shall be +1/16 inch for pipe up to and including 6 inch inside diameter, and +1/8 inch or +1 percent, whichever is greater, for pipe exceeding 6 inches inside diameter. This measurement shall be made at the point of manufacture with the pipe in an unstrained vertical position.

3.2 **LENGTH** - Pipe is available in nominal random lengths or cut to order. Random lengths are nominally 20 ft on pipe greater than 2" diameter, 10 ft on 1-1/2" or 2" diameter, and 5 ft on sizes less than 1-1/2". The length of each fabricated piece of pipe cut to order shall not vary more than +1/8 inch from the ordered length.

3.3 **WALL THICKNESS** - The minimum wall thickness of the pipe shall be in accordance with Table 3.

3.4 **SQUARENESS OF ENDS** - All non-flanged pipe shall be cut square with the axis of the pipe within +1/8 inch up to and including 24 inch diameter and to within +3/16 inch for all diameters above 24 inches.

3.5 **FITTINGS** - All fittings such as elbows, laterals, tee's, and reducers shall be equal or superior in strength to the adjacent pipe section and shall have the same internal diameter as the adjacent pipe. The dimensions of fittings shall be as shown in the Data Sheet. Tolerance on angles of fittings shall be 1° through 24 inches in diameter and 1/2° for 30 inch diameter and above. Where necessary, minimum overlay widths may be less than those specified in Table 4, but the joint strength shall be at least equal to the strength of the adjacent pipe.

3.6 **ELBOW** - Standard elbows shall have a centerline radius of one and one half times the internal diameter. Standard elbows up to and including 48 inches shall be sweep elbows, molded of one piece construction. Elbows of 54 inch diameter and larger may be of mitered construction using pipe for the mitered sections. The width of the overlay on the mitered joint may have to be less than the minimum supecified in Table 4 to avoid interference on the inner radius, but the joint strength must be at least equal to the strength of the adjacent pipe. Mitered elbows 45° or less will be one-miter, two gore. Elbows above 45° and through 90° shall have a minimum of two miters. Incorporation of straight pipe extensions on elbows is permissible.

3.7 **REDUCERS** - Reducers of either concentric or eccentric style will have a length as determined by the diameter differences of the reducer as indicated in Table 1 (2.5x the differences in diameter unless otherwise specified).

3.8 **BUTT JOINTS** - This type of joint shall be considered the standard means of joining pipe sections and pipe to fittings. The finished joint thickness is the same as the hand lay up structural wall thickness shown in Table 3.

3.8.1 The procedure used in making the butt joint is as follows: The finished joints shall be built up in successive layers and be as strong as the pieces being joined and as crevice free as in commercially practicable. The width of the first layer shall be 2 inches minimum. Successive layers shall increase uniformly to provide the specified minimum total width of the overlay, which shall be centered on the joint. Crevices between jointed pieces shall be filled with resin or thixotropic resin paste leaving a smooth inner surface.

3.8.2 All pipe 20 inches in diameter and larger shall be overlaid both inside (when accessible) and outside. Pipe less than 20 inches in diameter shall be outside overlaid. The minimum width of the overlay shall relate to wall thickness and shall be of the dimensions indicated in Table 4. Inside overlays may be made to seal the joint if necessary, but shall not be considered in meeting the strength requirement specified.

3.9 **FLANGES** - The use of flanges shall normally be kept to a minimum with the butt joint being used as the standard means of joining pipe sections. All flanges shall be of the minimum thickness given in Table 5. The construction of flanges is the same as that for laminates, using all mat construction, ie., no woven roving, for the flange faces.

TABLE 3A: Reinforced-vinyl ester pipe wall thickness - Hand Lay Up

Diameter (Internal)	25 psi	50 psi	75 psi	100 psi	125 psi	150 psi
	inches	inches	inches	inches	inches	inches
2	.14	.14	.14	.14	.14	.19
3	.14	.14	.14	.19	.22	.22
4	.14	.14	.19	.22	.22	.26
6	.14	.19	.22	.26	.29	.34
8	.14	.22	.26	.29	.37	.41
10	.14	.22	.29	.37	.42	.50
12	.19	.26	.34	.41	.50	.60
14	.22	.29	.37	.49	.58	.70
16	.22	.29	.41	.53	.67	.80
18	.22	.34	.46	.60	.75	.90
20	.22	.37	.50	.67	.83	1.00
24	.26	.41	.60	.80	1.00	1.20
30	.29	.46	.75	1.00	1.25	1.50
36	.34	.61	.90	1.20	1.50	1.80
42	.37	.70	1.05	1.40	1.75	2.10
48	.41	.80	1.20	1.60	2.00	2.40
60	.49	1.0	1.50	2.00	2.50	3.00

[1]The specified hand lay-up wall thicknesses are based upon a 10 to 1 safety factor for the strengths listed in Table 2. These ratings are suitable for use up to 180°F (82.2°C); for ratings at higher temperatures, consult the manufacturer. All lay-ups include a 0.100° hand laid corrosion liner.

3.10 **FLANGE ATTACHMENT** - The minimum flange sheet surface shall be four times the flange thickness indicated in Table 5. The thickness of the flange hub reinforcement measured at the top of the fillet radius shall be at least one-half the flange thickness and shall be tapered uniformly the length of the hub reinforcement. The fillet radius, where the back of the flange meets the hub, shall be 3/8 inch minimum.

3.11 **FLANGE FACE** - The flange face shall be perpendicular to the axis of the pipe with 1/2 and shall be flat to +1/32 inch up to and including 18 inch diameter and +1/16 inch for larger diameters. The face of the flange shall have a chemical resistant surface as described in SURFACING MATERIALS and INNER SURFACE.

TABLE 3B: Reinforced-vinyl ester pipe wall thickness - Filament Wound

Diameter (Internal)	25 psi	50 psi	75 psi	100 psi	125 psi	150 psi
	inches	inches	inches	inches	inches	inches
2	.15	.15	.15	.15	.15	.15
3	.15	.15	.15	.15	.15	.15
4	.15	.15	.15	.15	.15	.15
6	.15	.15	.15	.15	.20	.25
8	.15	.15	.15	.20	.25	.30
10	.15	.15	.20	.25	.35	.40
12	.15	.15	.25	.30	.40	.45
14	.15	.20	.30	.35	.45	.55
16	.15	.20	.30	.40	.50	.60
18	.15	.25	.35	.45	.60	.70
20	.15	.25	.40	.50	.65	.75
24	.15	.30	.45	.60	.75	.90
30	.20	.40	.60	.75	.95	1.15
36	.25	.45	.70	.90	1.15	1.35
42	.30	.55	.80	1.05	1.35	1.60
48	.30	.60	.90	1.20	1.50	1.80
60	.35	.75	1.15	1.50	1.90	2.25

[2]The specified filament would wall thicknesses are based upon a 0.1% hoop strain from Table 2. These ratings are suitable for use up to 180°F (82.2°C); for ratings at higher temperatures, consult the manufacturer. All lay-ups include a 0.100° hand laid corrosion liner.

TABLE 4: Minimum total widths of overlays for reinforced-vinyl ester butt joints.

Minimum total width of overlay	Equivalent Hand lay-up Pipe wall thickness, inches									
	.187	.250	.313	.375	.437	.500	.563	.625	.688	.750
	3	4	5	6	7	8	9	10	11	12

4.0 RECOMMENDED INSTALLATION PRACTICE

4.1 **BRANCH CONNECTIONS** - All branch connections are to be shop fabricated.

4.2 **PIPE HANGERS AND SPACING** - Hangers shall be band type hangers or saddle supports contacting a minimum of 180 degrees of the pipe surface. The maximum pipe hanger spacing shall be in accordance with Table 6.

4.3 **UNDERGROUND INSTALLATION** - Special consideration must be given to installing pipe underground. It is recommended that Composites USA, Inc. be consulted for pipe design and installation procedures.

4.4 **EXPANSIONS** - Since the thermal expansion rate of vinyl ester is several times that of steel, proper consideration should be given to any pipe installation to accommodate the overall linear expansion. Consult Composites USA when in doubt.

4.5 **MECHANICAL PROPERTIES OF PIPE** - The minimum mechanical properties of pipe shall be in accordance with Table 2 for filament would or hand lay up as appropriate. For combination or Type X laminates, manufacturer is to provide evidence of physical properties, either through destructive laminate physical property tests, or rigorous laminate analysis simulations.

4.6 **VACUUM SERVICES** - Pipe through 18 inch in diameter is generally suitable for full vacuum service. Flanges have a rating of 25 psi are suitable for full vacuum service. Special engineering consideration is required for larger pipe sizes and for operation at temperatures above 180°F/82°C.

TABLE 5: Minimum flange thickness[1] for reinforced-vinyl ester.

Diameter & Thickness	25 psi	50 psi	75 psi	100 psi	125 psi	150 psi
	inches	inches	inches	inches	inches	inches
2	.500	.500	.500	.563	.625	.688
3	.500	.500	.625	.688	.750	.813
4	.500	.563	.688	.813	.875	.938
6	.500	.625	.750	.875	1.000	1.063
8	.563	.750	.875	1.000	1.125	1.250
10	.688	.875	1.063	1.188	1.313	1.438
12	.750	1.000	1.250	1.438	1.625	1.750
14	.813	1.063	1.313	1.500	1.750	1.875
16	.875	1.188	1.438	1.625	1.875	2.000
18	.938	1.250	1.500	1.750	2.000	2.500
20	1.000	1.313	1.625	1.875	2.250	2.750
24	1.125	1.500	1.875	2.250	2.750	3.250
30	1.375	1.875	2.000	2.750	3.250	3.500
36	1.750	2.000	2.250	3.250	3.500	4.000
42	2.000	2.250	2.750	3.500	4.000	4.500
48	2.250	2.563	3.125	4.000	4.563	5.125
60	2.813	3.188	3.875	5.000	5.688	6.375

[1]Based on Type 1 liminate, flat-faced flanges with full-face Shore A60 hardness gaskets. Flange dimensions (except thickness) and bolting correspond to the following standards:
- 2 inch through 24 inch sizes: USA Std. B16.5 for 150 lb steel flanges.
- 30 inch through 42 inch sizes: USA Std. B16.1 for 125 lb C.I. flanges.

This table is based on a safety factor of 8 to 1 and a flexural strength of 16,000 psi.

TABLE 6A: Maximum spacing of pipe hangers for Hand laid reinforced-vinyl ester pressure pipe.

Pipe Diameter	Maximum pipe hanger spacing at pressure ratings: Hand Lay-up					
	25 psi	50 psi	75 psi	100 psi	125 psi	150 psi
	Ft	Ft	Ft	Ft	Ft	Ft
2	6.0	6.0	6.0	6.0	6.0	6.0
3	6.5	6.5	6.5	6.5	8.0	8.0
4	7.0	7.0	7.0	8.5	8.5	8.5
6	8.0	8.0	9.0	9.0	10.0	10.5
8	8.5	10.0	10.0	10.5	11.0	11.5
10	9.5	10.5	11.5	12.0	12.5	13.0
12	10.0	11.5	12.5	13.0	13.5	14.0
14	11.5	12.5	13.0	14.0	15.0	15.5
16	12.0	13.0	14.0	15.5	16.5	17.0
18	12.5	14.5	15.0	16.0	16.5	17.5
20	12.5	15.0	15.0	17.0	18.0	18.5
24	8.5	15.0	17.5	18.5	19.0	19.0
30	9.5	17.5	19.5	21.0	21.0	21.0
36	10.5	19.5	21.0	21.0	21.0	21.0
42	8.0	21.0	22.5	22.5	22.5	22.5

Note: The above table is based on uninsulated pipe containing liquids having a specific gravity of 1.3 and at a maximum temperature of 180°F (82.2°C), consult the manufacturer relative to hanger spacing.

TABLE 6B: Maximum spacing of pipe hangers for Filament Wound reinforced-vinyl ester pressure pipe.

Pipe Diameter	Maximum pipe hanger spacing at pressure ratings: Filament Wound					
	25 psi	50 psi	75 psi	100 psi	125 psi	150 psi
	Ft	Ft	Ft	Ft	Ft	Ft
2	9.6	9.6	9.6	9.6	9.6	9.6
3	10.8	10.8	10.8	10.8	10.8	10.8
4	11.6	11.6	11.6	11.6	11.2	10.0
6	12.9	12.9	12.0	10.2	12.2	13.8
8	13.9	12.7	10.4	11.8	13.1	14.2
10	14.4	11.7	12.5	13.2	16.6	17.0
12	13.9	10.5	14.3	14.5	17.2	17.3
14	13.5	13.2	15.9	15.6	17.9	19.8
16	13.0	12.1	14.6	16.7	18.5	20.0
18	12.4	14.5	16.2	17.7	21.1	22.2
20	11.9	13.5	17.7	18.7	21.6	22.4
24	10.6	14.8	17.9	20.5	22.6	24.5
30	12.8	17.9	21.6	22.9	25.7	28.1
36	14.7	18.2	22.9	25.1	28.4	30.0
42	16.4	20.7	24.2	27.1	31.0	33.0

Note: The above table is based on uninsulated pipe containing liquids having a specific gravity of 1.3 and at a maximum temperature of 180°F (82.2°C), yielding a maximum deflection of 1/2" between supports or a maximum axial stress of 1650 psi (including stress due to rated pressure plus stress due to bending).

4.7 **BOLTS, NUTS, AND WASHERS** - Bolts, nuts, and washers shall be furnished by the customer, unless otherwise agreed in the purchase order acceptance. Metal washers shall be used under all nut and bolt heads. All nuts, bolts, and washers shall be of materials suitable for use in the exterior environment.

4.8 **GASKETS** - Gaskets shall be furnished by the customer, unless otherwise agreed in the purchase order acceptance. Recommended gasketing materials shall be a minimum of 1/8 inch in thickness with a suitable chemical resistance to the service environment. Gaskets should have a Shore A or Shore A2 Hardness of 40 to 70.

5.0 SPECIAL REQUIREMENTS: