

**Table 110FW.E3.1A
(Series 110FW)
Mechanical Specifications**

Temp (F)	Pipe Strengths (psi)					Pipe Moduli (psi)				
	Axial Tensile	Hoop Tensile	Axial Flex.	Hoop Flex.	Axial Comp.	Axial Tensile	Hoop Tensile	Axial Flex.	Hoop Flex.	Axial Comp.
Ambient	8,400	26,400	16,800	N/A	18,000	1,400,000	2,200,000	1,400,000	2,200,000	1,500,000
150	8,400	26,400	16,800	N/A	18,000	1,400,000	2,200,000	1,400,000	2,200,000	1,500,000
175	8,190	25,740	16,380	N/A	17,550	1,365,000	2,145,000	1,365,000	2,145,000	1,462,500
200	7,980	25,080	15,960	N/A	17,100	1,330,000	2,090,000	1,330,000	2,090,000	1,425,000
225	7,770	24,420	15,540	N/A	16,650	1,295,000	2,035,000	1,295,000	2,035,000	1,387,500
250	7,560	23,760	15,120	N/A	16,200	1,260,000	1,980,000	1,260,000	1,980,000	1,350,000

ASTM D4024 / D5421 Flange Codes

2" - 6" Flanges, 150psi RTR-111C-334; CM-B4IF-66
 8" Flanges, 150psi RTR-111C-335; CM-B4IF-66
 10" - 12" Flanges, 150psi RTR-111C-336; CM-B4IF-66
 14" - 24" Flanges, 150psi RTR-111C-337; CM-B4IF-66

All materials are contact molded (closest definition to filament wound in D4024), epoxy vinyl ester resin, integrally molded flange.
 The grade epoxy is interpreted to include epoxy vinyl esters.

ASTM D2310 / D2996 Pipe Codes

2" - 3" Pipe RTRP-11FT1-1112
 4" Pipe RTRP-11FT1-1113
 6" Pipe RTRP-11FT1-1114
 8" and larger Pipe RTRP-11FT1-1116

All materials are filament wound, epoxy vinyl ester resin, reinforced liner, HDB of > 5,000psi for joints, > 10,000psi for pipe (axial loads included).
 Short term hoop strength > 10,000psi; long. tensile strength > 8,000psi;
 Long. tensile modulus > 1,000,000psi; stiffness factor varies with pipe size.
 The grade epoxy is interpreted to include epoxy vinyl esters.
 Replace 'T' with 'Q' for the HDB rating of joints.

ASTM F1173 / ISO15840 Codes

Type I, Resin 2, Class B, Rating Method 1

Other Properties

Density (lb/cu in.)	0.06
Shear Modulus (psi)	1,000,000
Thermal Expansion Coefficient (in./in./F)	0.00001
Thermal Conductivity (BTU-in./ft ² -hr-F)	1.3
Minor Poisson's Ratio, $\nu_{min} = \nu_{ha}$	0.55
Major Poisson's Ratio, $E_a/E_h * \nu_{ha} = \nu_{ah}$	0.35
Hazen Williams Coefficient	150
Specific Roughness (in.)	0.0002

ASTM D5685 Fittings Codes

2" - 24" Fittings, 150psi RTRF 54K4D
 Contact molded fittings, epoxy vinyl ester resin, reinforced liner,
 butt & strap joint, 150psig rating

Notes:

1. Axial flexural is also termed bending; hoop flexural is also termed circumferential.
2. Blank areas are Not Recommended.

**Table 110FW.E3M.1A (Metric)
(Series 110FW)
Mechanical Specifications**

Temp (C)	Pipe Strengths (MPa)					Pipe Moduli (GPa)				
	Axial Tensile	Hoop Tensile	Axial Flex.	Hoop Flex.	Axial Comp.	Axial Tensile	Hoop Tensile	Axial Flex.	Hoop Flex.	Axial Comp.
Ambient	57.9	182.0	115.8	N/A	124.1	9.7	15.2	9.7	15.2	10.3
65.6	57.9	182.0	115.8	N/A	124.1	9.7	15.2	9.7	15.2	10.3
79.4	56.5	177.5	112.9	N/A	121.0	9.4	14.8	9.4	14.8	10.1
93.3	55.0	172.9	110.0	N/A	117.9	9.2	14.4	9.2	14.4	9.8
107.2	53.6	168.4	107.1	N/A	114.8	8.9	14.0	8.9	14.0	9.6
121.1	52.1	163.8	104.3	N/A	111.7	8.7	13.7	8.7	13.7	9.3

ASTM D4024 / D5421 Flange Codes

2" - 6" Flanges, 150psi	RTR-111C-334; CM-B4IF-66
8" Flanges, 150psi	RTR-111C-335; CM-B4IF-66
10" - 12" Flanges, 150psi	RTR-111C-336; CM-B4IF-66
14" - 24" Flanges, 150psi	RTR-111C-337; CM-B4IF-66
All materials are contact molded (closest definition to filament wound in D4024), epoxy vinyl ester resin, integrally molded flange. The grade epoxy is interpreted to include epoxy vinyl esters.	

ASTM D2310 / D2996 Pipe Codes

2" - 3" Pipe	RTRP-11FT1-1112
4" Pipe	RTRP-11FT1-1113
6" Pipe	RTRP-11FT1-1114
8" and larger Pipe	RTRP-11FT1-1116
All materials are filament wound, epoxy vinyl ester resin, reinforced liner, HDB of > 5,000psi for joints, > 10,000psi for pipe (axial loads included). Short term hoop strength > 10,000psi; long. tensile strength > 8,000psi; Long. tensile modulus > 1,000,000psi; stiffness factor varies with pipe size. The grade epoxy is interpreted to include epoxy vinyl esters. Replace 'T' with 'Q' for the HDB rating of joints.	

ASTM F1173 / ISO15840 Codes

Type I, Resin 2, Class B, Rating Method 1

ASTM D5685 Fittings Codes

Other Properties

Density (g/cu cm)	1.7
Shear Modulus (GPa)	6.9
Thermal Expansion Coefficient (mm/mm/C)	0.000018
Thermal Conductivity (W-cm/cm^2-C)	0.0019
Minor Poisson's Ratio, ν_{ha}	0.55
Major Poisson's Ratio, $E_a/E_h \cdot \nu_{ha} = \nu_{ah}$	0.35
Hazen Williams Coefficient	150
Specific Roughness (cm)	0.0005

ASTM D5685 Fittings Codes

2" - 24" Fittings, 150psi	RTRF 54K4D
Contact molded fittings, epoxy vinyl ester resin, reinforced liner, butt & strap joint, 150psig rating	

Notes:

1. Axial flexural is also termed bending; hoop flexural is also termed circumferential.
2. Blank areas are Not Recommended.

**Table 110FW.E3.5A
(Series 110FW)
Stress Analysis Data (page 1 of 3)**

Material Properties

C_t	0.000010 in./in./F	0.000018 mm/mm/C
$E_a = E_x$	1,400,000 psi	9.7 GPa
$\nu_{min} = \nu_{ha}$	0.55	0.55
E_h	2,200,000 psi	15.2 GPa
rho	0.060 lb/in. ³	1.7 g/cm ³
$E_a/E_h * \nu_{ha} = \nu_{ah}$	0.35	0.35
Shear-Axial Modulus Ratio	0.71	0.71

Pipe Dimensions

Nominal Size		Pipe - tr		Bends - tnom		Pipe O.D.	
(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)
1	25	0.24"	6.1mm	0.25"	6.4mm	1.48"	37.6mm
1.5	40	0.24"	6.1mm	0.25"	6.4mm	1.98"	50.3mm
2	50	0.24"	6.1mm	0.25"	6.4mm	2.48"	63.0mm
3	80	0.24"	6.1mm	0.25"	6.4mm	3.48"	88.4mm
4	100	0.24"	6.1mm	0.31"	7.9mm	4.48"	113.8mm
6	150	0.30"	7.6mm	0.38"	9.7mm	6.60"	167.6mm
8	200	0.36"	9.1mm	0.44"	11.2mm	8.72"	221.5mm
10	250	0.42"	10.7mm	0.50"	12.7mm	10.84"	275.3mm
12	300	0.48"	12.2mm	0.56"	14.2mm	12.96"	329.2mm
14	350	0.53"	13.5mm	0.63"	16.0mm	15.31"	388.9mm
16	400	0.59"	15.0mm	0.69"	17.5mm	17.43"	442.7mm
18	450	0.65"	16.5mm	0.75"	19.1mm	19.55"	496.6mm
20	500	0.71"	18.0mm	0.88"	22.4mm	21.67"	550.4mm
24	600	0.83"	21.1mm	1.00"	25.4mm	25.91"	658.1mm

Nominal Size		Flange B.C.	
(in.)	(mm)	(in.)	(mm)
1	25	3.13"	79.4mm
1.5	40	3.88"	98.4mm
2	50	4.75"	120.7mm
3	80	6.00"	152.4mm
4	100	7.50"	190.5mm
6	150	9.50"	241.3mm
8	200	11.75"	298.5mm
10	250	14.25"	362.0mm
12	300	17.00"	431.8mm
14	350	18.75"	476.3mm
16	400	21.25"	539.8mm
18	450	22.75"	577.9mm
20	500	25.00"	635.0mm
24	600	29.50"	749.3mm

**Table 110FW.E3.5B
(Series 110FW)
Stress Analysis Data (page 2 of 3)**

UKOOA Data

SH, f_1 *LTHS	10,000 psi	69.0 MPa
R, Sa(0:1) / Sa(2:1)	0.64	0.64
f_2 - sustained	0.67	0.67
f_2 - thermal	0.83	0.83
f_2 - occasional	0.89	0.89
Elbows	Type 2 (CSM & Woven Roving)	
K	Mean temperature change multiplier, 0.85 for liquids, 0.8 for gases, 1.0 for amb. temp changes.	

BS7159 Data

SH, ϵ_d * E_a	2,520 psi	17.4 MPa
	(based on 0.0018 design strain)	
E_h/E_a	1.57	1.57
K	Mean temperature change multiplier, 0.85 for liquids, 0.8 for gases, 1.0 for amb. temp changes.	
Kn	Fatigue factor, 1.0 for static applications	

ISO14692:2002 Data

al(0:1)	3,196 psi	22.0 MPa
al(2:1)	5,022 psi	34.6 MPa
hl(2:1)	10,043 psi	69.2 MPa
Qs-bends*	9,570 psi	66.0 MPa
r-bends*	1.0	1.0
Eh/Ea-bends	1.0	1.0
Qs-joints	4,478 psi	30.9 MPa
r-joints	2.0	2.0
A_1	1.0 up to 185F	1.0 up to 85c
20yr design life	1.0	1.0
System design factor	0.67-sustained, 0.83-thermal, 0.89-occasional	
Thermal factor, k	Same as UKOOA	

* Values account for hoop SIFs applied in stress analysis.

B31.3 Data

SC	5,000 psi	34.5 MPa
SH (up to 185F, 85c)	5,000 psi	34.5 MPa
Fn (up to 7000 cycles)	1.00	1.00
Eff	1.00	1.00
Sy	5,000 psi	34.5 MPa

**Table 110FW.E3.5C
(Series 110FW)
Stress Analysis Data (page 3 of 3)**

Caution should be used when selecting ISO14692 as a design code in some software. The Qs values for tees, if defaulted to an r value of 1.0, will incorrectly calculate a low allowable longitudinal stress for bi-axially reinforced tees.

Caution should be used when selecting ASME B31.3 as a design code. While A302.3.2(c) specifies an HDBS per ASTM D2992, using the HDBS as an allowable stress (with a service factor of 0.5) will generally be too high (5,000 psi) for most applications. For sustained conditions, an allowable stress of 2,750 psi is recommended. For secondary stresses (e.g. thermal loads), an allowable stress of 3,000 psi is recommended. For hydrotest and other occasional loads, an allowable stress of 3,400 psi is recommended.

Note: the above recommendations are based on loading cases at or near the design pressure of the product. The "design envelope" of FRP is a trapezoidal shape (whereas alloys and other isotropic materials are rectangular in shape). This trapezoidal shape means that the allowable longitudinal stress will increase as the pressure (and consequently the hoop stress) is increased. As an example, the recommended allowable stress for occasional loads is 3,400 psi. This would be a suitable stress for the hydrotest loading case. However, if one were to evaluate an occasional load case without any internal pressure (e.g. an offshore platform being transported), the recommended allowable would drop to about 2,900 psi. Of course, while the allowable has dropped from 3,400 to 2,900 psi, there is no longitudinal stress due to internal pressure in the latter case.

Allowable stresses are based on a 20 year design life. For 25 years, multiply the allowables by 0.986. For 30 years, 0.974. For 50 years, 0.942.

**Table 110FW.E3.4A
(110FW)**

ISO 14692 Part 3 - Annex D Calculations

Stress Intensification Factors (SIFs), Flexibility Factors (Kappa), Pressure Stress Multipliers (PSMs)
(BS7159, Type 2 Laminate, 0.0015 design strain)

Size (in.)	Series 110FW, 110FW-C						
	Flexibility Factor	Elbows				Tees	
		Axial bending SIF		Hoop bending SIF		SIF	PSM
	In-plane	Out-of-plane	In-plane	Out-of-plane			
2	1.3	1.1	1.2	1.9	1.7	1.1	1.0
3	1.9	1.5	1.6	2.5	2.2	1.3	1.0
4	2.0	1.5	1.6	2.5	2.3	1.5	1.0
6	2.5	1.7	1.8	2.5	2.5	1.7	1.0
8	2.8	1.9	2.0	2.5	2.5	1.7	1.0
10	3.0	2.0	2.1	2.5	2.5	1.8	1.0
12	3.0	2.0	2.2	2.5	2.5	1.7	1.0
14	3.0	2.1	2.2	2.5	2.5	2.0	1.0
16	3.0	2.1	2.3	2.5	2.5	1.9	1.0
18	3.0	2.2	2.3	2.5	2.5	2.0	1.0
20	3.0	2.1	2.3	2.5	2.5	2.1	1.0
24	3.0	2.2	2.3	2.5	2.5	2.1	1.0
30	3.0	2.5	2.5	2.5	2.5	2.3	1.0
36	3.0	2.5	2.5	2.5	2.5	2.3	1.0
42	3.0	2.5	2.5	2.5	2.5	2.3	1.0
48	3.0	2.5	2.5	2.5	2.5	2.3	1.0

Note: Tees that are qualified according to ISO14692 have a PSM of 1.0. Tees that are not qualified will typically have PSMs ranging from 1.8 to 3.0. Reducing tees will have slightly different SIFs than tees; however, it is acceptable to use the same values as the same-size tees. e.g., a 6"x2" reducing tee or olet would have the same SIF as a 6" tee.

**Table 110FW.E3.6A
(110FW)
Flange Thickness and Weight**

Nominal Size	Flange			Flange Pair	
	thk	Weight		thk	Weight
		w/out bolts	w/ bolts		
	(in.)	(lbs)	(lbs)	(in.)	(lbs)
1	0.50	0.6	1.2	1.00	1.8
1.5	0.50	0.7	1.3	1.00	2.0
2	0.69	1.0	2.3	1.38	3.3
3	0.81	1.8	3.1	1.62	4.9
4	0.94	2.9	5.7	1.88	8.6
6	1.19	4.8	9.6	2.38	14.4
8	1.25	7.0	12.1	2.50	19.1
10	1.44	10.6	22.1	2.88	32.7
12	1.75	17.9	31.0	3.50	48.9
14	1.75	19.6	37.4	3.50	57.0
16	1.94	26.3	50.9	3.88	77.3
18	2.00	27.5	61.0	4.00	88.5
20	2.13	34.7	78.0	4.26	112.7
24	2.38	48.9	107.6	4.76	156.5

DN	Flange			Flange Pair	
	thk	Mass		thk	Mass
		w/out bolts	w/ bolts		
	(mm)	(kg)	(kg)	(mm)	(kg)
25	12.7	0.3	0.6	25.4	0.8
40	12.7	0.3	0.6	25.4	0.9
50	17.5	0.5	1.0	35.1	1.5
80	20.6	0.8	1.4	41.1	2.2
100	23.9	1.3	2.6	47.8	3.9
150	30.2	2.2	4.4	60.5	6.5
200	31.8	3.2	5.5	63.5	8.7
250	36.6	4.8	10.0	73.2	14.8
300	44.5	8.1	14.1	88.9	22.2
350	44.5	8.9	17.0	88.9	25.9
400	49.3	12.0	23.1	98.6	35.1
450	50.8	12.5	27.7	101.6	40.2
500	54.1	15.8	35.4	108.2	51.2
600	60.5	22.2	48.9	120.9	71.1

**Table 110FW.E3.7A
(110FW)
Recommended Allowables (in psi)**

Nominal Size	D / t	Sustained (f2 = 0.67)		Sustained (f2 = 0.67)		Sustained+Thermal (f2 = 0.83)		Occasional (f2 = 0.89)	
		P = 150 psig		P = 200 psig		P = 200 psig		P = 200 psig	
		Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)
1	4.17	388	1894	517	1918	517	2353	517	2517
1.5	6.25	544	1923	725	1956	725	2391	725	2554
2	8.33	700	1951	933	1993	933	2429	933	2592
3	12.50	1013	2008	1350	2069	1350	2505	1350	2668
4	16.67	1325	2065	1767	2145	1767	2581	1767	2744
6	20.00	1575	2110	2100	2206	2100	2641	2100	2804
8	22.22	1742	2140	2322	2246	2322	2682	2322	2845
10	23.81	1861	2162	2481	2275	2481	2710	2481	2874
12	25.00	1950	2178	2600	2297	2600	2732	2600	2895
14	26.89	2092	2204	2789	2331	2789	2766	2789	2930
16	27.54	2141	2213	2854	2343	2854	2778	2854	2942
18	28.08	2181	2220	2908	2353	2908	2788	2908	2951
20	28.52	2214	2226	2952	2361	2952	2796	2952	2959
24	29.22	2266	2236	3022	2373	3022	2809	3022	2972

$$\sigma_{a,sum} \leq f_2 * \sigma_{al(0:1)} + \frac{\sigma_{h,sum}}{\sigma_{qs}} * \left(\frac{\sigma_{qs}}{2} - \sigma_{al(0:1)} \right)$$

$$\sigma_{al(0:1)} = r * \frac{\sigma_{qs}}{2}$$

$$\sigma_{h,sum} = \frac{PD}{2t}$$