

**Table 20FRE.E3.1A  
(Series 20FRE, 20FRE-C)  
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.
<b>Ambient</b>	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
<b>150</b>	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
<b>175</b>	7,980	25,080	15,540	N/A	17,100	1,330,000	2,090,000	1,295,000	2,035,000	1,425,000
<b>200</b>	7,560	23,760	14,280	N/A	16,200	1,260,000	1,980,000	1,190,000	1,870,000	1,350,000
<b>225</b>										
<b>250</b>										

**ASTM D4024 / D5421 Flange Codes**

2" - 6" Flanges, 200psi	RTR-111D-445; CM-B4I
8" Flanges, 200psi	RTR-111D-446; CM-B4I
10" - 12" Flanges, 200psi	RTR-111D-447; CM-B4I
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 D5421 does not have ratings above 150psi.	

**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 and 4  
Fire Endurance: Fluid S, Fire Type IF, Integrity B, Duration 30

**ASTM D5685 Fittings Codes**

2" - 12" Fittings, 200psi	RTRF 54K4E
Contact molded fittings, epoxy vinyl ester resin, reinforced liner, butt & strap joint, 200psig rating	
14" - 24" Fittings, 150psi	RTRF 54K4D
butt & strap joint, 150psig rating	

**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 <sup>2</sup> -hr-F)	1.3
Minor Poisson's Ratio, $\nu_{min} = \nu_{ha}$	0.55
Major Poisson's Ratio, $E_a/E_h \cdot \nu_{ha} = \nu_{ah}$	0.35
Hazen Williams Coefficient	150
Specific Roughness (in.)	0.0002

Notes:

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

**Table 20FRE.E3M.1A (Metric)  
(Series 20FRE, 20FRE-C)  
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.
<b>Ambient</b>	57.9	182.0	115.8	N/A	124.1	9.7	15.2	9.7	15.2	10.3
<b>65.6</b>	57.9	182.0	115.8	N/A	124.1	9.7	15.2	9.7	15.2	10.3
<b>79.4</b>	55.0	172.9	107.1	N/A	117.9	9.2	14.4	8.9	14.0	9.8
<b>93.3</b>	52.1	163.8	98.5	N/A	111.7	8.7	13.7	8.2	12.9	9.3
<b>107.2</b>										
<b>121.1</b>										

**ASTM D4024 / D5421 Flange Codes**

2" - 6" Flanges, 200psi	RTR-111D-445; CM-B4I
8" Flanges, 200psi	RTR-111D-446; CM-B4I
10" - 12" Flanges, 200psi	RTR-111D-447; CM-B4I
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 D5421 does not have ratings above 150psi.

**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 and 4  
Fire Endurance: Fluid S, Fire Type IF, Integrity B, Duration 30

**Other Properties**

Density (g/cu cm)	1.7
Shear Modulus (GPa)	6.9
Thermal Expansion Coefficient (mm/mm/C)	0.00018
Thermal Conductivity (W-cm/cm^2-C)	0.0019
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 (cm)	0.0005

**ASTM D5685 Fittings Codes**

2" - 12" Fittings, 200psi	RTRF 54K4E
Contact molded fittings, epoxy vinyl ester resin, reinforced liner, butt & strap joint, 200psig rating	
14" - 24" Fittings, 150psi	RTRF 54K4D
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 20FR-E.E3.5A  
(Series 20FR-E, 20FR-EC)  
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. <sup>3</sup>	1.7 g/cm <sup>3</sup>
$E_a/E_h * \nu_{ha} = \nu_{ah}$	0.35	0.35
Shear-Axial Modulus Ratio	0.71	0.71

**Pipe Dimensions**

Nominal Size		Pipe - tr		Bends - tnom	
(in.)	(mm)	(in.)	(mm)	(in.)	(mm)
1	25	0.25"	6.4mm	0.25"	6.4mm
1.5	40	0.25"	6.4mm	0.25"	6.4mm
2	50	0.28"	7.1mm	0.31"	7.9mm
3	80	0.24"	6.0mm	0.25"	6.4mm
4	100	0.24"	6.0mm	0.25"	6.4mm
6	150	0.30"	7.5mm	0.31"	7.9mm
8	200	0.36"	9.0mm	0.44"	11.1mm
10	250	0.42"	10.6mm	0.50"	12.7mm
12	300	0.48"	12.1mm	0.63"	15.9mm
14	350	0.42"	10.6mm	0.56"	14.3mm
16	400	0.48"	12.1mm	0.63"	15.9mm
18	450	0.53"	13.6mm	0.69"	17.5mm
20	500	0.59"	15.1mm	0.75"	19.1mm
24	600	0.71"	18.1mm	0.88"	22.2mm

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 20FR-E.E3.5B  
(Series 20FR-E, 20FR-EC)  
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, $\epsilon_d$ * $E_a$	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 20FR-E.E3.5C**  
**(Series 20FR-E, 20FR-EC)**  
**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 20FRE.E3.4A  
(20FR-E, 20FRE-C)**

**ISO 14692 Part 3 - Annex D Calculations**

Stress Intensification Factors (SIFs), Flexibility Factors (Kappa), Pressure Stress Multipliers (PSMs)  
(BS7159, Type 2 Laminate, 0.0012 design strain)

Size (in.)	Series 20FRE, 20FRE-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	2.5	1.7	1.8	2.5	2.5	1.5	1.0
6	2.9	1.9	2.1	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	2.9	1.9	2.1	2.5	2.5	1.7	1.0
14	3.0	2.2	2.4	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	2.3	2.4	2.5	2.5	2.0	1.0
20	3.0	2.3	2.4	2.5	2.5	2.1	1.0
24	3.0	2.3	2.5	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 20FRE.E3.6A  
(20FR-E, 20FR-EC)  
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	1.00	3.1	6.1	2.00	9.2
6	1.19	4.8	9.6	2.38	14.4
8	1.38	7.7	13.1	2.76	20.8
10	1.63	12.0	24.5	3.26	36.5
12	1.88	19.2	32.8	3.76	52.1
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	25.4	1.4	2.8	50.8	4.2
150	30.2	2.2	4.4	60.5	6.5
200	35.1	3.5	5.9	70.1	9.4
250	41.4	5.4	11.1	82.8	16.6
300	47.8	8.7	14.9	95.5	23.6
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 20FRE.E3.7A  
(20FR-E, 20FR-EC)  
Recommended Allowables (in psi)**

Nominal Size	D / t	Sustained (f2 = 0.67) P = 150 psig		Sustained (f2 = 0.67) P = 200 psig		Sustained+Thermal (f2 = 0.83) P = 200 psig		Occasional (f2 = 0.89) P = 200 psig	
		Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)
1	4.00	375	2209	500	2232	500	2744	500	2935
1.5	6.00	525	2237	700	2269	700	2780	700	2972
2	7.14	611	2252	814	2289	814	2801	814	2992
3	12.63	1022	2327	1363	2389	1363	2900	1363	3092
4	16.84	1338	2385	1784	2466	1784	2977	1784	3169
6	20.21	1591	2430	2121	2527	2121	3038	2121	3230
8	22.46	1759	2461	2346	2568	2346	3079	2346	3271
10	24.06	1880	2483	2506	2597	2506	3108	2506	3300
12	25.26	1970	2499	2626	2619	2626	3130	2626	3322
14	34.29	2646	2622	3529	2783	3529	3294	3529	3486
16	34.21	2641	2621	3521	2781	3521	3293	3521	3484
18	34.15	2636	2621	3515	2780	3515	3292	3515	3483
20	34.11	2633	2620	3511	2779	3511	3291	3511	3483
24	34.04	2628	2619	3504	2778	3504	3290	3504	3481

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

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

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