Rev E, Jun-12-2015

Table 20FR20.E3.1A
(Series 20FR20, 20FR20-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.
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	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
200	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
225										
250										

ASTM D4024 / D5421 Flange Codes

2" - 6" Flanges, 290psi	RTR-111F-665; CM-B4I
8" Flanges, 290psi	RTR-111F-666; CM-B4I
10" - 12" Flanges, 290psi	RTR-111F-667; CM-B4I

All materials are bi-axially laminated (closest definition to filament wound in D4024), epoxy vinyl ester resin, integrally molded flange.
The D4024 codes are the closest codes to the 290psi ratings.
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 (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, υmin = υha	0.55
Major Poisson's Ratio, Ea/Eh*υha = υah	0.35
Hazen Williams Coefficient	150
Specific Roughness (in.)	0.0002

ASTM D5685 Fittings Codes

2" - 12" Fittings, 290psi RTRF 54K4G
Contact molded fittings, epoxy vinyl ester resin, reinforced liner, butt & strap joint, 300psig rating (closest to 290psi)

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

Rev E, Jun-12-2015

Table 20FR20.E3M.1A (Metric)
(Series 20FR20, 20FR20-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.
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	55.0	172.9	107.1	N/A	117.9	9.2	14.4	8.9	14.0	9.8
93.3	52.1	163.8	98.5	N/A	111.7	8.7	13.7	8.2	12.9	9.3
107.2										
121.1										

ASTM D4024 / D5421 Flange Codes

2" - 6" Flanges, 290psi	RTR-111F-665; CM-B4I
8" Flanges, 290psi	RTR-111F-666; CM-B4I
10" - 12" Flanges, 290psi	RTR-111F-667; CM-B4I

All materials are bi-axially laminated (closest definition to filament wound in D4024), epoxy vinyl ester resin, integrally molded flange.
The D4024 codes are the closest codes to the 232psi ratings.
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)	0.000018
Thermal Conductivity (W-cm/cm^2-C)	0.0019
Minor Poisson's Ratio, υmin = υha	0.55
Major Poisson's Ratio, Ea/Eh*υha = υah	0.35
Hazen Williams Coefficient	150
Specific Roughness (cm)	0.0005

ASTM D5685 Fittings Codes

2" - 12" Fittings, 290psi RTRF 54K4G
Contact molded fittings, epoxy vinyl ester resin, reinforced liner, butt & strap joint, 300psig rating (closest to 290psi)

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

Rev H - Jan-21-2013

Table 20FR20.E3.5A
(Series 20FR20, 20FR20-C)
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
$\upsilon_{min} = \upsilon_{ha}$	0.55		0.55	
E_h	2,200,000	psi	15.2	GPa
rho	0.060	$lb/in.^3$	1.7	g/cm^3
$E_a/E_h * v_{ha} = \upsilon_{ah}$	0.35		0.35	
Shear-Axial Modulus Ratio	0.71		0.71	

Pipe Dimensions

Nominal Size (in.)	Nominal Size (mm)	Pipe - tr (in.)	Pipe - tr (mm)	Bends - tnom (in.)	Bends - tnom (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	0.28"	7.1mm
3	80	0.25"	6.4mm	0.25"	6.4mm
4	100	0.25"	6.4mm	0.25"	6.4mm
6	150	0.30"	7.6mm	0.33"	8.4mm
8	200	0.39"	9.9mm	0.43"	10.9mm
10	250	0.48"	12.2mm	0.53"	13.5mm
12	300	0.58"	14.7mm	0.63"	16.0mm
14	350	0.61"	15.5mm	0.67"	17.0mm
16	400	0.69"	17.5mm	0.76"	19.3mm
18	450	0.78"	19.8mm	0.85"	21.6mm
20	500				
24	600				

Nominal Size (in.)	Nominal Size (mm)	Flange B.C. (in.)	Flange B.C. (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		
24	600		

Table 20FR20.E3.5B
(Series 20FR20, 20FR20-C)
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 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	5,037 psi	34.7 MPa
r-bends	1.9	1.9
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	

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 20FR20.E3.5C
(Series 20FR20, 20FR20-C)
Stress Analysis Data (page 3 of 3)

Caution should be used when selecting ISO14692 as a design code in some software. The inability to adjust the biaxial stress ratio for tees and the inability to select Type 2 laminate construction for elbows may have an effect on the results. UKOOA as a design code is a better selection even though this code does not offer the ability to adjust f_2 for the various loading cases.

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.

Rev 3.0C, Apr-24-2008

Table 20FR20.E3.4A
(20FR20, 20FR20-C)
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	Series 20FR20, 20FR20-C						
	Elbows					Tees	
	Flexibility	Axial bending SIF		Hoop bending SIF			
(in.)	Factor	In-plane	Out-of-plane	In-plane	Out-of-plane	SIF	PSM
2	1.3	1.1	1.2	1.9	1.7	1.3	1.0
3	1.9	1.4	1.5	2.5	2.2	1.6	1.0
4	2.5	1.7	1.8	2.5	2.5	1.6	1.0
6	2.7	1.8	2.0	2.5	2.5	1.6	1.0
8	2.8	1.8	2.0	2.5	2.5	1.6	1.0
10	2.8	1.9	2.0	2.5	2.5	1.6	1.0
12	2.9	1.9	2.0	2.5	2.5	1.6	1.0
14	3.0	2.0	2.1	2.5	2.5	1.7	1.0
16	3.0	2.0	2.1	2.5	2.5	1.7	1.0
18	3.0	2.0	2.1	2.5	2.5	1.7	1.0
20	3.0	2.1	2.3	2.5	2.5	1.8	1.0
24	3.0	2.1	2.3	2.5	2.5	1.8	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.

Rev: Oct-15-2012

Table 20FR20.E3.6A
(Series 20FR20, 20FR20-C)
Flange Thickness and Weight

Nominal	Flange			Flange Pair	
Size	thk	Weight		thk	Weight
		w/out bolts	w/ bolts		w/ bolts
	(in.)	(lbs)	(lbs)	(in.)	(lbs)
1	0.50	0.6	1.2	1.00	1.8
1.5	0.58	0.8	1.4	1.16	2.2
2	0.71	1.1	2.3	1.42	3.4
3	0.86	1.9	3.2	1.72	5.2
4	1.13	3.5	6.7	2.26	10.1
6	1.32	5.3	10.4	2.64	15.7
8	1.50	8.4	14.0	3.00	22.4
10	1.87	13.7	26.8	3.74	40.6
12	2.16	22.1	36.7	4.32	58.8
14	2.13	23.9	43.7	4.26	67.6
16	2.46	33.4	61.7	4.92	95.1
18	2.44	33.6	70.5	4.88	104.0
20					
24					

DN	Flange			Flange Pair	
	thk	Mass		thk	Mass
		w/out bolts	w/ bolts		w/ bolts
	(mm)	(kg)	(kg)	(mm)	(kg)
25	12.7	0.3	0.6	25.4	0.8
40	14.7	0.3	0.7	29.5	1.0
50	18.0	0.5	1.1	36.1	1.5
80	21.8	0.9	1.5	43.7	2.3
100	28.7	1.6	3.0	57.4	4.6
150	33.5	2.4	4.7	67.1	7.1
200	38.1	3.8	6.4	76.2	10.1
250	47.5	6.2	12.2	95.0	18.4
300	54.9	10.0	16.7	109.7	26.7
350	54.1	10.8	19.8	108.2	30.7
400	62.5	15.2	28.0	125.0	43.2
450	62.0	15.2	32.0	124.0	47.2
500					
600					

Rev: Jan-21-2013

Table 20FR20.E3.7A
(Series 20FR20, 20FR20-C)
Recommended Allowables (in psi)

Nominal Size	D / t	Sustained (f2 = 0.67) P = 290 psig		Sustained (f2 = 0.67) P = 261 psig		Sustained+Thermal (f2 = 0.83) P = 290 psig		Occasional (f2 = 0.89) P = 290 psig	
		Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)
1	4.00	725	2273	653	2260	725	2784	725	2976
1.5	6.00	1015	2326	914	2307	1015	2837	1015	3029
2	7.14	1181	2356	1063	2334	1181	2867	1181	3059
3	12.00	1885	2484	1697	2450	1885	2995	1885	3187
4	16.00	2465	2589	2219	2545	2465	3101	2465	3292
6	20.00	3045	2695	2741	2639	3045	3206	3045	3398
8	20.51	3119	2708	2807	2652	3119	3220	3119	3411
10	20.83	3166	2717	2849	2659	3166	3228	3166	3420
12	20.69	3145	2713	2831	2656	3145	3224	3145	3416
14	23.36	3532	2783	3179	2719	3532	3295	3532	3486
16	23.55	3560	2788	3204	2724	3560	3300	3560	3492
18	23.40	3538	2784	3184	2720	3538	3296	3538	3487
20									
24									

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

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

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