Rev E, Jun-12-2015

Table 20FR16.E3.1A
(Series 20FR16, 20FR16-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, 232psi	RTR-111D-445; CM-B4I
8" Flanges, 232psi	RTR-111D-446; CM-B4I
10" - 12" Flanges, 232psi	RTR-111D-447; 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 (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, 232psi RTRF 54K4E
Contact molded fittings, epoxy vinyl ester resin, reinforced liner, butt & strap joint, 200psig rating (closest to 232psi)

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 20FR16.E3M.1A (Metric)
(Series 20FR16, 20FR16-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, 232psi	RTR-111D-445; CM-B4I
8" Flanges, 232psi	RTR-111D-446; CM-B4I
10" - 12" Flanges, 232psi	RTR-111D-447; 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, 232psi	RTRF 54K4E

Contact molded fittings, epoxy vinyl ester resin, reinforced liner, butt & strap joint, 200psig rating (closest to 232psi)

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

Rev I - Jan-21-2013

Table 20FR16.E3.5A
(Series 20FR16, 20FR16-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
$E_a/E_h * \nu_{ha} = \upsilon_{ah}$	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	0.28"	7.1mm
3	80	0.25"	6.4mm	0.25"	6.4mm
4	100	0.25"	6.4mm	0.25"	6.4mm
6	150	0.25"	6.4mm	0.27"	6.9mm
8	200	0.32"	8.1mm	0.35"	8.9mm
10	250	0.39"	9.9mm	0.43"	10.9mm
12	300	0.46"	11.7mm	0.51"	13.0mm
14	350	0.54"	13.7mm	0.60"	15.2mm
16	400	0.62"	15.7mm	0.68"	17.3mm
18	450	0.69"	17.5mm	0.76"	19.3mm
20	500	0.76"	19.3mm	0.84"	21.3mm
24	600	0.91"	23.1mm	1.00"	25.4mm

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

Rev I - Jan-21-2013

Table 20FR16.E3.5B
(Series 20FR16, 20FR16-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 20FR16.E3.5C
(Series 20FR16, 20FR16-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 20FR16.E3.4A
(20FR16, 20FR16-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 20FR16, 20FR16-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	1.8	1.0
6	3.0	2.0	2.2	2.5	2.5	1.8	1.0
8	3.0	2.1	2.2	2.5	2.5	1.8	1.0
10	3.0	2.1	2.2	2.5	2.5	1.8	1.0
12	3.0	2.1	2.2	2.5	2.5	1.8	1.0
14	3.0	2.1	2.2	2.5	2.5	1.8	1.0
16	3.0	2.1	2.2	2.5	2.5	1.8	1.0
18	3.0	2.1	2.3	2.5	2.5	1.8	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 20FR16.E3.6A
(Series 20FR16, 20FR16-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	0.52	0.7	1.4	1.04	2.1
2	0.64	1.0	2.2	1.28	3.2
3	0.77	1.7	3.0	1.54	4.8
4	1.01	3.1	6.1	2.02	9.2
6	1.19	4.8	9.6	2.38	14.4
8	1.36	7.6	12.7	2.72	20.3
10	1.69	12.4	25.0	3.38	37.4
12	1.95	19.9	33.5	3.90	53.5
14	2.03	22.8	41.9	4.06	64.7
16	2.34	31.8	59.1	4.68	90.9
18	2.32	31.9	67.7	4.64	99.6
20	2.57	41.9	89.5	5.14	131.4
24	2.88	59.2	125.0	5.76	184.2

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	13.2	0.3	0.6	26.4	0.9
50	16.3	0.4	1.0	32.5	1.4
80	19.6	0.8	1.4	39.1	2.2
100	25.7	1.4	2.8	51.3	4.2
150	30.2	2.2	4.4	60.3	6.5
200	34.5	3.4	5.8	69.1	9.2
250	42.9	5.6	11.3	85.9	17.0
300	49.5	9.1	15.2	99.1	24.3
350	51.6	10.3	19.0	103.1	29.4
400	59.4	14.4	26.8	118.9	41.3
450	58.9	14.5	30.7	117.9	45.2
500	65.3	19.0	40.6	130.6	59.7
600	73.2	26.9	56.8	146.3	83.6

Rev: Jan-21-2013

Table 20FR16.E3.7A
(20FR16, 20FR16-C)
Recommended Allowables (in psi)

Nominal Size	D / t	Sustained (f2 = 0.67) P = 232 psig		Sustained (f2 = 0.67) P = 0 psig		Sustained+Thermal (f2 = 0.83) P = 232 psig		Occasional (f2 = 0.89) P = 232 psig	
		Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)	Hoop (calc.)	Long. (allow.)
1	4.00	580	2247	0	2141	580	2758	580	2950
1.5	6.00	812	2289	0	2141	812	2800	812	2992
2	7.14	945	2313	0	2141	945	2824	945	3016
3	12.00	1508	2415	0	2141	1508	2927	1508	3119
4	16.00	1972	2500	0	2141	1972	3011	1972	3203
6	24.00	2900	2668	0	2141	2900	3180	2900	3372
8	25.00	3016	2690	0	2141	3016	3201	3016	3393
10	25.64	3090	2703	0	2141	3090	3214	3090	3406
12	26.09	3142	2712	0	2141	3142	3224	3142	3416
14	26.39	3177	2719	0	2141	3177	3230	3177	3422
16	26.21	3156	2715	0	2141	3156	3226	3156	3418
18	26.45	3184	2720	0	2141	3184	3231	3184	3423
20	26.64	3207	2724	0	2141	3207	3236	3207	3427
24	26.65	3207	2724	0	2141	3207	3236	3207	3427

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

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

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