Rev E, Jun-12-2015

## 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. |
| 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, 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 (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, 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.

**Rev E, Jun-12-2015**

## 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. |
| **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, 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)** | 0.000018 |
| **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, 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.

**Rev I - Jan-21-2013**

## 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 |
| $\upsilon_{min} = \upsilon_{ha}$ | 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 | 0.31" | 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 |

**Rev I - Jan-21-2013**

# 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, $\varepsilon_d$*$E_a$ | 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 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 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.

# 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 | Series 20FRE, 20FRE-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 | 1.1 | 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.

**Rev: Oct-15-2012**

## Table 20FRE.E3.6A
## (20FR-E, 20FR-EC)
## 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 | 0.50 | 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 | | 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 |

**Rev: Jan-21-2013**

## 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 |

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

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

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