FIBERGLASS REINFORCED PLASTIC (FRP) PIPING SYSTEMS

DESIGNING FOR VARIOUS LOADING CONDITIONS

A COMPARISON OF CURRENTLY AVAILABLE DESIGN PHILOSOPHIES

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Enclosed on the following pages is one in a series of papers written by the Engineering Department of EDO Specialty Plastics on fiberglass reinforced plastic (FRP) piping systems. This paper, on designing for various loading conditions, is one in a line of papers written on the basic principles involved in the selection, specification, and design of the components involved in fiberglass piping systems.

EDO Specialty Plastics, as a designer, manufacturer, and installer of fiberglass pipe systems with two decades experience in the advanced composites industry, provides this paper as a service to its customers involved in the design and selection of fiberglass reinforced plastic piping systems.

The intention of this paper is to present the various loading conditions encountered in above ground piping system design. These loading conditions could be applicable to both metallic and non-metallic piping materials. This paper, however, will tend to concentrate on the considerations that must be made because of the unique properties of fiberglass reinforced plastics.

The guidelines drawn in the report are based on the history and experience of EDO Specialty Plastics in the fiberglass composite piping industry. These guidelines, however, are intended to be just that - guidelines. Each application of an FRP piping system is unique and must be treated as such. Furthermore, because of certain intangibles involved with FRP piping systems, a "pre-engineered" system is not recommended. A detailed design of each pipe system is necessary to achieve the full potential of the FRP piping system. By doing so, the customer is ensured of a "custom-designed,""custom-manufactured," and "custom-installed" system to his specifications and needs.

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1 Introduction:

One of the obstacles that FRP (fiberglass reinforced plastic) sometimes has to overcome is proper design of the materials for its intended application. While design specifications such as B31.3 have existed for decades to provide guidance on the design of metallic materials, equivalent design specifications for non-metallics, such as FRP, have a much shorter history. There are, however, more and more sources of design guidance for FRP and other non-metallics. This paper provides a comparison of some of the standards currently available to the FRP piping designer. It provides, in detail, each standard's approach to calculating stresses due to various loading conditions.

2 An Introduction to the Codes and Standards

2.1 ASME B31.3 1996

The history of the B31 codes dates back to its first publication in 1935 as the first edition of the American Tentative Standard Code for Pressure Piping. From 1942 through 1955, the code was published as ASA (American Standards Association) B31.1. In 1955, the code was divided into separate documents for each industry section. ASA B31.3 was first published in 1959. In 1978, the B31 committee was reorganized as the ASME Code for Pressure Piping B31 committee. There are various sections of the B31 code, which include:

ASME B31.1	Power Piping
ASME B31.3	Process Piping
ASME B31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
ASME B31.5	Refrigeration Piping
ASME B31.8	Gas Transportation and Distribution Piping Systems
ASME B31.9	Building Services Piping
ASME B31.11	Slurry Transportation Piping Systems

The scope of the B31.3 code, per 300.1.1a, is to prescribe "...requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping." Per 300.1.1b, this code "...applies to piping for all fluids, including: 1) raw, intermediate, and finished chemicals, 2) petroleum products, 3) gas, steam, air, and water, 4) fluidized solids, 5) refrigerants, and 6) cryogenic fluids."

For metallic piping that is neither Category M nor high pressure fluid service, the code requirements can be found in Chapters I through VI.

For nonmetallic piping, the code requirements can found in Chapter VII. The base code (Chapters I through VI) only apply as stated in Chapter VII.

2.2 ASME RTP-1 1995

The ASME RTP-1, Reinforced Thermoset Plastic Corrosion Resistant Equipment, was first published in 1989. Editions followed in 1992 and 1995. The purpose of this standard is to "...establish rules of safety governing the design, fabrication, and inspection during construction of such equipment..."

The scope of RTP-1 1995, per 1-110a, includes "...stationary vessels used for the storage, accumulation, or processing of corrosive or other substances at pressures not exceeding 15 psig external and/or 15 psig internal above any hydrostatic head." There are certain applications that are excluded from this standard, including 1) vessels with internal operating pressures exceeding 15psig, 2) hoods, ducts, stacks, 3) fans and blowers, 4) pumps, 5) piping, and 6) fully buried vessels.

2.3 ASME 1995 Boiler and Pressure Vessel Code Section X

The history of the ASME Boiler and Pressure Vessel Code dates back to 1911 with the establishment of a committee to formulate standard rules for the construction of steam boilers and other pressure vessels. The Boiler and Pressure Vessel Code is divided into different sections. Section X is for Fiberglass Reinforced Plastic Pressure Vessels.

Section X, per RG-100a, "...establishes the minimum requirements for the fabrication of fiber-reinforced thermosetting plastic pressure vessels for general service, sets limitations on the permissible service conditions, and defines the types of vessels to which these rules are not applicable."

Design pressures are limited based on the class type, as defined by Section X, and on the type of construction. Class I contact molded vessels are limited to 150psi; Class I filament wound vessels are limited to 1500psi; Class I filament wound vessels with polar boss openings are limited to 3000psi (Class I vessels are qualified through destructive testing; Class II vessels are qualified by design rules and non-destructive testing).

Design temperatures are limited to a maximum of 250°F or 35°F below the maximum use temperature per RM-121. The minimum temperature shall be -65°F.

2.4 BS 7159:1989 British Standard Code of practice for Design and construction of glass reinforced plastics (GRP) piping systems for individual plants or sites

BS 7159, per its foreword, "...provides guidance for the design and construction of glass reinforced plastics (GRP) piping systems, within the boundaries of an individual site or adjacent sites." Per section 1.1, examples of these sites include "...chemical plants, process plants, refineries, steam-raising units, storage and distribution depots and tank farms." The 1989 edition is the first edition and has been written as a code of practice. The statements in this document are meant as recommendations not requirements.

Section 1.1 of the document identifies 1) pipe sizes 25mm to 1200mm, 2) temperatures from -30°C to 110°C, and 3) pressures up to 10 bar for sizes up to 600mm and up to 6 bar for larger sizes as being applicable.

2.5 ISO 14692 Working Draft

ISO WD 14692, currently a working draft, applies to GRP (glass reinforced plastic) "...piping installations associated with oil and gas industry processing and utility service applications. The document is primarily intended for offshore applications on both fixed and floating topsides facilities but it may also be used as guidance for the specification, manufacture, testing and installation of GRP piping systems in other similarly high criticality applications found offshore."

<u>3 A Comparison of the Loading Conditions</u>

3.1 Sustained Loads - Hoop Stress due to Internal Pressure

ASME B31.3 302.3.5(a) / 304.1.2

$$\boxed{\begin{gathered} t = \frac{P*D}{2*S*E} \\ or \\ t = \frac{P*D}{2*(S*E+P*Y)} \\ or \\ t = \frac{D}{2}*(1-\sqrt{\frac{S*E-P}{S*E+P}}) \\ or \\ t = \frac{P*(d+2*c)}{2*(S*E-P*(1-Y))} \end{gathered}}$$

t - pressure design thickness (reinforced only)
P - internal design gage pressure
D - outside diameter of pipe
S - stress value for material from Table A-1
E - quality factor from Table A-1A or A-1B (usually ranges from 0.8 - 1.0)
Y - coefficient from Table 304.1.1 (0.4 for most metallic materials below 482°C)

c - sum of the mechanical allowances plus corrosion and erosion allowances

ASME B31.3 A302.3.3(a) / A304.1.2 (Nonmetallic)

$$t = \frac{P * D}{2 * S + P}$$

$$t = \frac{P * D}{2 * S * F + P}$$

Variables are the same as above plus:

F - service (design) factor (usually < 1.0 when using cycle HDBS and < 0.5 when using static HDBS) (HDBS = LTHP from D2992)

ASME RTP-1 3A-210

$$t = \frac{P * D_i}{\frac{2 * S_h}{F}} \quad \text{; contact molded (laminated)}$$

$$t = \frac{P * D_i}{2 * (0.001 * E_h)} \quad \text{; filament wound}$$

t - total wall thickness
P - total internal pressure
D_i - inside diameter
S_h - ultimate hoop tensile strength (since this equation is for contact molded construction, this property is obtained from a flat plate test according to ASTM D638)
F - design factor = 10.0
E_h - hoop tensile modulus

ASME BPV Section X RD-1171.1

$$\boxed{t_2 = \frac{P * R}{0.001 * E_2 - 0.6 * P}}$$

t_2 - structural wall thickness for circumferential stress
P - internal pressure
R - inside radius
E_2 - tensile modulus in circumferential direction

BS 7159 Section 5.4

If you substitute equation 4.2 into equation 5.1, you can solve for t_d:

$$\boxed{t_d = \frac{D_i * P_d}{20 * E_{lam} * e_d - P_d}}$$

t_d - design thickness of the reference laminate excluding any corrosion barrier, mm
P_d - internal design gage pressure, bar
Di - internal diameter, mm
E_{lam} - modulus of elasticity of the laminate, Mpa
,$_d$ - design strain, typically 0.0009 - 0.0018

The equation above could also be derived from the equations in 7.3.4.1. While not explicitly stated, it is assumed that E_{lam} is the modulus of elasticity in the circumferential (hoop) direction.

$$t = \frac{P_{qs} * D}{2 * 10 * s_{qs}}$$

$$P_{qs} = A_1 * A_2 * A_3 * P_q$$

$$P_q = f_1 * LTHP$$

t - reinforced wall thickness, mm
P_{qs} - service qualified pressure, bar
D - mean diameter of reinforced wall, i.e. (2*R_i +t)
R_i - inside radius of reinforced wall, mm
F_{qs} - qualified service stress, MPa
A_1 - partial factor for temperature from 8.3.1
A_2 - partial factor for chemical resistance from 8.3.2
A_3 - partial factor for cyclic service from 8.3.3
P_q - qualified pressure, bar
f_1 - part factor equivalent to 97.5% confidence limit of the LTHP; default = 0.85
LTHP - Long term hoop pressure, bar

3.2 Sustained Loads - External Pressure

ASME B31.3 302.3.5(b) / 304.1.3

Calculations are performed according to the BPV Code, Section VIII, Division 1, UG-28 through UG-30.

ASME B31.3 A302.3.3(b) / A304.1.3 / A304.7.2 (Nonmetallic)

No equations are provided. The design is either based on previous experience or on a performance test.

$$P_a = \frac{K * \frac{E_r}{F} * \frac{D_o}{L} * (\frac{t}{D_o})^{2.5}}{1 - 0.45 * (\frac{t}{D_o})^{0.5}}$$

$$E_r = \sqrt{E_a * E_h}$$

$$K = 4.0 - 0.75 * \frac{E_r}{1{,}000{,}000}$$

P_a - allowable external pressure
E_a - axial tensile modulus
E_h - hoop tensile modulus
F - design factor = 5.0
D_o - outside diameter
L - design length of vessel section (if this were applied to piping, it would normally be the distance between stiffener rings, if used, or between hangers, with 360° contact, or between secondary overlays or other external stiffeners)
t - nominal wall thickness

ASME BPV Section X RD-1172.1

$$P_a = \frac{2 * \frac{E_r}{F} * (\frac{t}{D_o})^{3.0}}{1 - n_1 * n_2}; \quad \text{if } L_c \le L$$

$$P_a = \frac{K * \frac{E_r}{F} * \frac{D_o}{L} * (\frac{t}{D_o})^{2.5}}{1 - 0.45 * (\frac{t}{D_o})^{0.5}}; \quad \text{if } L_c > L$$

$$E_r = \sqrt{E_1 * E_2}$$

$$K = 3.6 - \frac{2 * E_r}{E_1 + E_2}$$

$$L_c = 1.14 * (1 - n_1 * n_2)^{0.25} * D_o * (\frac{D_o}{t})^{0.5}$$

P_a - allowable external pressure
E_1 - axial tensile modulus
E_2 - hoop tensile modulus
E_r - resultant modulus
F - design factor = 5.0
D_o - outside diameter
L - design length of vessel section (if this were applied to piping, it would normally be the distance between stiffener rings, if used, or between hangers, with 360° contact, or between secondary overlays or other external stiffeners)
t - shell structural thickness (0.25in. minimum)
L_c - critical length
$<_1$ - Poisson's ratio in the major direction
$<_2$ - Poisson's ratio in the minor direction

BS 7159 Section 6.1

As with internal pressure, if you substitute equation 4.2 into equation 6.1, you get:

$$\boxed{P_e = \frac{20 * E_{lam} * \left(\frac{t_d}{D_i + 2 * t_d}\right)^{3.0}}{F_s}}$$

P_e - allowable external pressure, bar
E_{lam} - modulus of elasticity of the laminate, MPa
t_d - design thickness of the reference laminate, mm
D_i - internal diameter, mm
F_s - factor of safety = 4.0

While not explicitly stated, it is assumed that E_{lam} is the modulus of elasticity in the circumferential (hoop) direction.

ISO 14692 AUGUST 1999 WORKING DRAFT
Part 3 8.4.2.3 and 9.3

$$P_c = 20 * E_h * \left(\frac{t}{D}\right)^3$$

$$P_{allowable} = \frac{P_c}{3}$$

P_c - buckling collapse pressure, bar
E_h - hoop modulus, MPa
t - wall thickness, mm
D - mean pipe diameter, mm
$P_{allowable}$ - allowable external pressure, bar

3.3 Sustained Loads - Longitudinal

ASME B31.3 302.3.5(c)

Longitudinal stresses due to pressure, weight, and other sustained loads must be less than S_h. S_h is the basic allowable stress at the maximum metal temperature.

ASME B31.3 A302.3.3(c) (Nonmetallic)

Only external loads are covered. When external loads occur, the design shall follow ASTM D3839 or AWWA C950.

ASME RTP-1 3A-210

$$\boxed{t = \frac{N_{ax}}{\frac{S_a}{F}}}$$

t - total wall thickness
N_{ax} - axial force per circumferential inch of shell, lb/in.
S_a - ultimate axial tensile strength
F - design factor = 10.0

ASME BPV Section X RD-1171.1

$$\boxed{t_1 = \frac{P * R}{2(0.001 * E_1 - 0.6 * P)}}$$

t_1 - structural wall thickness for longitudinal stress
P - internal pressure
R - inside radius
E_1 - tensile modulus in longitudinal direction

BS 7159 Section 7.3.4.2

For pipe, section 7.3.4.2 provides equations (7.23 - 7.25) to calculate the total longitudinal stress. 7.3.4.2 also provides an equation (7.26) for bends which includes stress intensification factors. This equation is not shown here.

$$s_x = s_{xp} + s_{xb}$$

$$s_{xp} = \frac{P*(D_i + t_d)}{40*t_d}$$

$$s_{xb} = \frac{M*(D_i + 2*t_d)}{2*I}$$

$$M = \sqrt{M_i^2 + M_o^2}$$

F_x - total longitudinal stress, MPa
F_{xp} - longitudinal pressure stress, MPa
F_{xb} - longitudinal bending stress, MPa
P - internal design gage pressure, bar
D_i - internal diameter, mm
t_d - design thickness of the reference laminate, mm
M - maximum bending moment, N-mm
M_i - maximum in-plane bending moment, N-mm
M_o - maximum out-of-plane bending moment, N-mm

While not explicitly stated, section 4.3.1 provides the design strain and design stress. Equation 4.3 can be modified slightly to provide a design longitudinal stress:

$$s_{x,d} = e_d * E_{x,lam}$$

$$s_x \le s_{x,d}$$

$F_{x,d}$ - design stress, longitudinal, Mpa
$,_d$ - design strain, see 4.3.2 Method A or or 4.3.3 Method B
$E_{x,lam}$ - modulus of elasticity of the laminate, longitudinal, MPa

ISO 14692 AUGUST 1999 WORKING DRAFT
Part 3 8.4.2.1

Longitudinal stresses are not differentiated from hoop stresses. Section 8.4.2.1 requires a partial factor of 0.67 (safety factor of 1.5) for sustained loads excluding temperature and 0.83 (s.f. = 1.2) for sustained loads including temperature. The allowable stress envelope from the applicable design option in 8.8 should be used. If we use the equation in 8.8.1 of Part 3 for F_{qs} at the 2:1 loading condition, we get:

$$s_{qs,hoop,allowable} = f_2 * \frac{P_{qs} * D}{2 * 10 * t}$$

$$s_{qs,axial,allowable,2:1} = f_2 * \frac{P_{qs} * r * D}{2 * 2 * 10 * t} \quad ;\ \text{for r} \ >= \ 1.0$$

$$s_{qs,axial,allowable,2:1} = f_2 * \frac{P_{qs} * D}{2 * 2 * 10 * t} \quad ;\ \text{for r} \ <= \ 1.0$$

$F_{qs,hoop,allowable}$ - allowable hoop stress, MPa
$F_{qs,axial,allowable,2:1}$ - allowable axial stress (at the 2:1 loading condition), MPa
f_2 - partial factor for sustained loading, default = 0.67 or 0.83
t - reinforced wall thickness, mm
D - mean diameter of reinforced wall, i.e. ($2*R_i$ +t)
R_i - inside radius of reinforced wall, mm
P_{qs} - service qualified pressure, bar
r - short term biaxial strength ratio, from Part 2 - 7.1.6 or Part 3 - 8.8.3 (typically varies from 0.4 to 2.0)

It should be noted that the allowable axial stress at the 0:1 loading condition may be different than at the 2:1 loading condition. If we use the assumptions in the document, the equation for the allowable axial stress at the 0:1 loading condition would be:

$$s_{qs,axial,allowable,0:1} = f_2 * s_{axial,ST} * \frac{s_{hoop,LT}}{s_{hoop,ST}}$$

$$\frac{s_{hoop,LT}}{s_{hoop,ST}} \approx \frac{f_1 * LTHP}{STHP}$$

or

$$s_{qs,axial,allowable,0:1} = f_2 * \frac{P_{qs} * r * D}{2*2*10*t}$$

$F_{qs,axial,allowable,0:1}$ - allowable axial stress (at the 0:1 loading condition), MPa
f_2 - partial factor for sustained loading, default = 0.67 or 0.83
$F_{axial,ST}$ - Short term axial strength, MPa
$F_{hoop,LT}$ - Long term hoop strength, MPa
$F_{hoop,ST}$ - Short term hoop strength, MPa
f_1 - part factor equivalent to 97.5% confidence limit of the LTHP; default = 0.85
LTHP - Long term hoop pressure, bar
STHP - Short term hoop pressure, bar
P_{qs} - service qualified pressure, bar
t - reinforced wall thickness, mm
D - mean diameter of reinforced wall, i.e. ($2*R_i$ +t)
R_i - inside radius of reinforced wall, mm
r - short term biaxial strength ratio, from Part 2 - 7.1.6 or Part 3 - 8.8.3 (typically varies from 0.4 to 2.0)

3.4 Sustained Loads - Expansion (Displacement)

ASME B31.3 302.3.5 / 319.4.4

$$S_E \leq S_A$$

$$S_A = f*(1.25*S_c + 0.25*S_h) \quad ;\text{ when } S_h \leq S_L$$

$$S_A = f*(1.25*(S_c + S_h) - S_L) \quad ;\text{ when } S_h > S_L$$

$$S_E = \sqrt{S_b^2 + 4*S_t^2}$$

S_E - computed displacement stress range
S_A - allowable displacement stress range
f - stress range reduction factor (=1.0 for static service, < 7000 cycles)
S_c - basic allowable stress at minimum metal temperature expected during the displacement cycle
S_h - basic allowable stress at maximum metal temperature expected during the displacement cycle
S_b - resultant bending stress
S_t - torsional stress

ASME B31.3 A319 (Nonmetallic)

No specific equations are provided. A319.1.1 states "Piping systems shall be designed to prevent thermal expansion or contraction, pressure expansion, or movement of piping supports and terminals from causing: a) failure of piping or supports from overstrain or fatigue; b) leakage at joints; or c) detrimental stresses or distortion in piping or in connected equipment (pumps, for example), resulting from excessive thrusts and moments in the piping."

ASME RTP-1 3A-210

These stresses are essentially covered in the minimum thickness equation for axial loading.

ASME BPV Section X

Under Design Rules - Method A, there are no specific equations for expansion. Method B describes thermal stresses in RD-1185 and specifies the requirements for an acceptable design in RD-1187.

BS 7159 Section 7.3.4.2

Expansion stresses due to sustained loadings are treated the same as longitudinal stresses due to sustained loadings. Therefore, the equations would be the same.

ISO 14692 AUGUST 1999 WORKING DRAFT
Part 3 8.4.2.1

Expansion stresses due to sustained loadings are treated the same as longitudinal stresses due to sustained loadings. The equations would be the same, however, as stated previously, the partial factor would increase to 0.83 (s.f. = 1.2).

3.5 Occasional Loads - Operating

ASME B31.3 302.3.6(a)

Longitudinal stresses due to pressure, weight, and other sustained loads plus occasional loads, such as wind or earthquake, may be as much as 1.33*S_h.

ASME B31.3 A302.3.4(a) (Nonmetallic)

No additional stresses are allowed.

ASME RTP-1 3A-400

Seismic, wind, and snow loads are addressed in this section. Safety factors on stresses from these loads (plus any working or "sustained" stresses) are 5.0 for contact molded (laminated) construction. A strain rate of 0.002in./in. is allowed for filament wound construction. This is essentially twice the value of the safety factors for "sustained" loads.

ASME BPV Section X

No specific equations are provided. RD-120 does specify that the following loads, which would normally be considered occasional, shall be included in the vessel design:

1) live loads due to personnel
2) snow and ice loads
3) wind loads and earthquake loads, where required

BS 7159 Section 9.6

There is no section dedicated to occasional loads. Section 9.6 does briefly mention wind loads.

ISO 14692 AUGUST 1999 WORKING DRAFT
Part 3 8.4.2.2

The allowable axial and hoop stress equations in the Sustained Loads - Longitudinal section would be the same for occasional loads, however, the partial factor, f_2, would change to 0.89 (s.f. = 1.12).

3.6 Occasional Loads - Test

ASME B31.3 345.2.1 / 345.4

The test pressure at ambient temperature shall be 1.5 times the design pressure, however, the it must be limited to a pressure that will not exceed the yield strength of the material.

For test pressure at design temperatures above the test temperature, 345.4.2(b) provides an equation for determining the test pressure. Again, yield strength must not be exceeded.

For piping designed for external pressure, the piping shall be hydrotested at a pressure of 1.5 times the external differential pressure (minimum test pressure of 15psig).

345.4.3(b) has a provision for piping connected to a vessel with a lower test pressure than the piping. If it is not possible to isolate the vessel, then the piping can be tested at the vessel test pressure provided the owner agrees and the vessel test pressure is not less than 77% of the piping test pressure.

ASME B31.3 A345.4.2 (Nonmetallic)

No limit is placed on the stress created by a hydrostatic test.

The test pressure shall not be less than 1.5 times the design pressure, however, it shall not exceed 1.5 times the design pressure of the lowest rated component.

The same provision for connection to vessels in 345.4.3(b) applies to nonmetallic piping.

ASME RTP-1 6-950

The scope of this document is limited to internal pressures of 15psig plus hydrostatic head. Therefore, the only hydrostatic testing requirement is a water filled hydrostatic test. The test pressure at the top of the vessel shall be 110% - 120% of the design pressure.

All vessels designed for external pressure, except those identified in 6-950(c), shall be evacuated to the design external pressure.

ASME BPV Section X RT-450 and RT-620

All Class I vessels, per RT-450, are to be pressure tested to 1.5 times the design pressure, whether internal or external, at ambient temperature for at least one minute.

All Class II vessels, per RT-620, are to be pressure tested to 1.1 times the internal design pressure and 1.0 times the external design pressure. The test temperature shall be within +/- 5°F of the design operating temperature unless the design operating temperature is 120°F or less. If so, the test temperature shall be 120°F or less. During the testing, acoustic emission sensors must be employed.

BS 7159
There is no section dedicated to testing.

ISO 14692 AUGUST 1999 WORKING DRAFT
Part 3 8.4.2.2

Testing loads are handled in the same section as occasional loads. The allowable axial and hoop stress equations in the Sustained Loads - Longitudinal section would be the same for testing loads, however, the partial factor, f_2, would change to 0.89.

4 Summary of Data

Summary of Loading Conditions (Table 1)

Loading Condition	ASME B31.3 Metallic	ASME B31.3 Nonmetallic	ISO 14692 August 1999 Working Draft
Sustained Loads - Hoop Stress due to Internal Pressure	302.3.5(a) / 304.1.2	A302.3.3(a) / A 304.1.2	Part 3 - 8.3 and Part 2 - 7.1
Sustained Loads - External Pressure	302.3.5(b) / 304.1.3	A302.3.3(b) / A304.1.3 / A304.7.2	Part 3 - 8.4.2.3 and 9.3
Sustained Loads - Longitudinal	302.3.5(c)	A302.3.3(c)	Part 3 - 8.4.2.1
Sustained Loads - Expansion	302.3.5 / 319.4.4	A319	Part 3 - 8.4.2.1
Occasional Loads - Operating	302.3.6(a)	A302.3.4(a)	Part 3 - 8.4.2.2
Occasional Loads - Testing	345.2.1 / 345.4	A345.4.2	Part 3 - 8.4.2.2

Summary of Loading Conditions (Table 2)

Loading Condition	ASME RTP-1	ASME BPV Sec X	BS 7159
Sustained Loads - Hoop Stress due to Internal Pressure	3A-210	RD-1171.1	5.4 or 7.3.4.1
Sustained Loads - External Pressure	3A-310	RD-1172.1	6.1
Sustained Loads - Longitudinal	3A-210	RD-1171.1	7.3.4.2
Sustained Loads - Expansion	3A-210	None	7.3.4.2
Occasional Loads - Operating	3A-400	None	None
Occasional Loads - Testing	6-950	RT-450 and RT-620	None