Proceedings of ETCE 2001
23rd ASME Energy Sources Technology Conference and Exposition
February 5 - 7, 2001, Houston, TX

ETCE2001-17040

# DEVELOPING A DESIGN ENVELOPE FOR GLASS REINFORCED PLASTIC (GRP) PIPING SYSTEMS ACCORDING TO ISO 14692

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## ABSTRACT

There are many methods available for designing GRP (glass reinforced plastic) piping systems for internal pressure. These include short term methods such as those found in ASME RTP-1 and long term methods such as ASTM D2996. Other standards, such as ASME B31.3, ASTM F1173, and ABS Rules for Steel Vessels and MODUs, provide options for both long term and short term methods. ASME RTP-1 goes one step further by allowing a design process based on design calculations only.

This paper will provide the details for designing GRP piping systems according to a new standard, ISO 14692. This method involves generating a design envelope to address all stresses from the design conditions of the system. This paper will also provide a comparison of this method's advantages and disadvantages to other standards currently in use.

Keywords: fiberglass, pipe, design, GRP, FRP, piping

**Required Testing**

Generation of the design envelope according to ISO 14692 begins with testing on the "family representative." The family representative is the component that is representative of the product family. As a minimum, the product families of any GRP piping system include: 1) pipe, 2) joints, 3) elbows and reducers, 4) tees, and 5) flanges. For most GRP products, testing is only required on either pipe or joints. The selection of which is determined by which component is weakest in the particular test. For example, in a long term and short term pressure test, it is the joint (or the joint in combination with the pipe), that is weaker than the pipe alone. Therefore, the joint is the product family that would be tested. For axial tensile tests, it is the opposite that may be true and, therefore, the pipe would be the product family that would be tested.

The minimum testing that is required includes

1) ASTM D2992 "B" (static) long term pressure test, 18 data points, testing time up to 10,000 hours
2) ASTM D638 short term axial tensile strength test, 5 data points
3) ASTM D1599 short term "burst" test, 5 data points

Testing would be performed on one product line in one pipe size. The component to be tested would either be a plain pipe or a pipe with a joint, whichever is weakest in the test.

**Data Obtained from Testing**

From the three types of tests performed, the following data would be obtained:

1) G, the gradient of the regression curve, = b from Annex A1 of ASTM D2992-96
2) LCL = Pq = f1 * LTHP from D2992
3) σ-sa, short term axial strength from D2105
4) σ-sh, short term hoop strength from D1599

**Calculations to be Performed**

The following calculations would then be performed:

Pqf = A1 * A2 * A3 * Pq

σ-qs = Pqf * D / (20 * t)

r = 2 * σ-sa / σ-sh

σ-a = σ-sa * σ-qs / σ-sh = r * σ-qs / 2

Below is a description of the above terms.

Pqf - Factored qualified pressure, bar
A1 - Partial factor for temperature, typically 1.0 for design temperatures below 65°C
A2 - Partial factor for chemical resistance, typically 1.0 for water and seawater below 65°C
A3 - Partial factor for cyclic service, 1.0 for static applications
σ-qs - Qualified stress, MPa
D - Component average diameter, mm
t - Component reinforced thickness, mm
r - Biaxial stress ratio
σ-a - Extrapolated long term axial strength, MPa

**Constructing a Long Term Design Envelope**

The first part of constructing a long term design envelope is to construct an "idealized" envelope. This envelope is plotted with three data points: σ-a, σ-qs, and σ-qs / 2. Hoop stresses are plotted along the x-axis (horizontal) and axial stresses are plotted along the y-axis (vertical).

From this idealized envelope, the"design" long term envelope is scaled down. The f2 factor is used to scale down this envelope. The f2 factor is a load factor whose value will depend upon the particular design case. For operational sustained loads, such as internal pressure, external pressure, pipe self weight, etc., the f2 factor is 0.67. For operational sustained loads and thermal induced loads, the f2 factor is 0.83. For occasional loads, such as those from water hammer, wind, earthquakes, transportation, etc., the f2 factor is 0.89.

An example of the "idealized" long term envelope and the design long term envelope are provided at the end of this paper.

**Expanding the Envelope to Other Components**

Once the design long term envelope is generated for plain pipe and/or joints, this information can then be used to generate similar envelopes for other components, such as elbows, tees, reducers, and flanges. For many GRP products, no further long term testing is required. Only a survival test, which is a 1000 hour 2:1 internal pressure test, is required on the product sector representatives. For a product line with sizes up to 300mm (12"), this would typically mean a 1000 hour test on 150mm (6") and 300mm (12") elbows, tees, and flanges. For a product line with sizes up to 600mm (24"), this would typically require an additional 1000 hour test on 600mm elbows, tees, and flanges (24").

Since this is a survival test, all of these components can be tested at once. As long as each component "survives" the test, i.e. does not show any signs of failure at the test pressure after 1000 hours, they meet the qualification requirements.

Once the survival tests are complete, standard biaxial stress ratios, 'r', can be used to complete the design long term envelope.

**Other Required Testing**

Additional design data may be required, depending upon the particular application. Below are some of the tests that may be required to be performed on the plain pipe family product representative (one pipe size only):

1) Longitudinal bending modulus per ASTM D2925
2) Hoop tensile modulus and minor Poisson's ratio per API 15HR
3) major Poisson's ratio per ASTM D2105
4) Thermal expansion coefficient per ASTM D696
5) Thermal conductivity (radial) per ASTM C177
6) Density

**A Comparison to Other Codes and Standards**

There are many other codes and standards that are in use today for designing GRP components. Some of these include:

ASME B31.3-1996 provides tables for hydrostatic design stresses (HDS) however, for GRP materials, it simply references other standards such as ASTM D2996 and AWWA C950. Section A302.3.2 of B31.3 does provide a method for determining the HDS and design stress (DS) for laminated GRP components and the HDS and hydrostatic design basis stress (HDBS) for filament wound GRP components. For filament wound components, the HDBS is equivalent to σ-qs except that it has not been factored by A1, A2, nor A3. HDS is then equivalent to f2 * σ-qs. Instead of using an f2 factor, ASME B31.3 specifies a "service factor" of no more than 0.5. This service factor can be interpreted to include the reduction in σ-qs by A1, A2, and A3.

ASME RTP-1 1995 provides a "Design by Rules" method where the entire design process is supported by calculations. Equations are provided to determine minimum thicknesses for the vessel shell and heads for internal pressure, external pressure, seismic loads, wind loads, and snow loads. A design method is also provided for nozzles (flanges).

ABS Rules for Steel Vessels and MODUs provides two methods for designing GRP components for internal pressure. One is a long term method where the hydrostatic test failure pressure at a design life of 100,000 hours or more is divided by a safety factor of 2.5. The second is a short term method similar to ASTM D1599 where the failure pressure is divided by a safety factor of 4.0. Other recommendations are provided for external pressure, axial strength, and temperature.

**Conclusions**

The design method in ISO 14692 is very comprehensive as it covers all of the major components of a piping system. The procedure is certainly lengthy: The main body of the qualification section is over 30 pages and has another 40+ pages of appendices. The design section has more than 30 pages plus another 30+ of appendices. In comparison, the majority of the information on plastic piping systems in the ABS Rules is only seven (7) pages. The entire ASTM F1173-95 document is 22 pages. Chapter 7 of ASME B31.3-1996, which covers non-metallic materials, is also 22 pages in its entirety.

This is certainly burdensome to the qualification and design process, however, one of the main reasons for this is the fact that it tackles the issue of designing systems rather than components. The ISO 14692 document also tackles many of the smaller issues in more detail than other codes and standards. For example, the qualification section of ISO 14692 provides two-and-a-half (2 1/2) pages on static electricity plus another nine (9) pages of appendices. ASTM F1173-95 provides six (6) sentences on the same subject.

Overall, the ISO 14692 document is not as user-friendly as other codes and standards currently in use. It does, however, provide much more guidance than these other documents. When used correctly, the design methods can certainly benefit all parties involved in the design, manufacture, fabrication, installation, and operation of a successful GRP piping system.

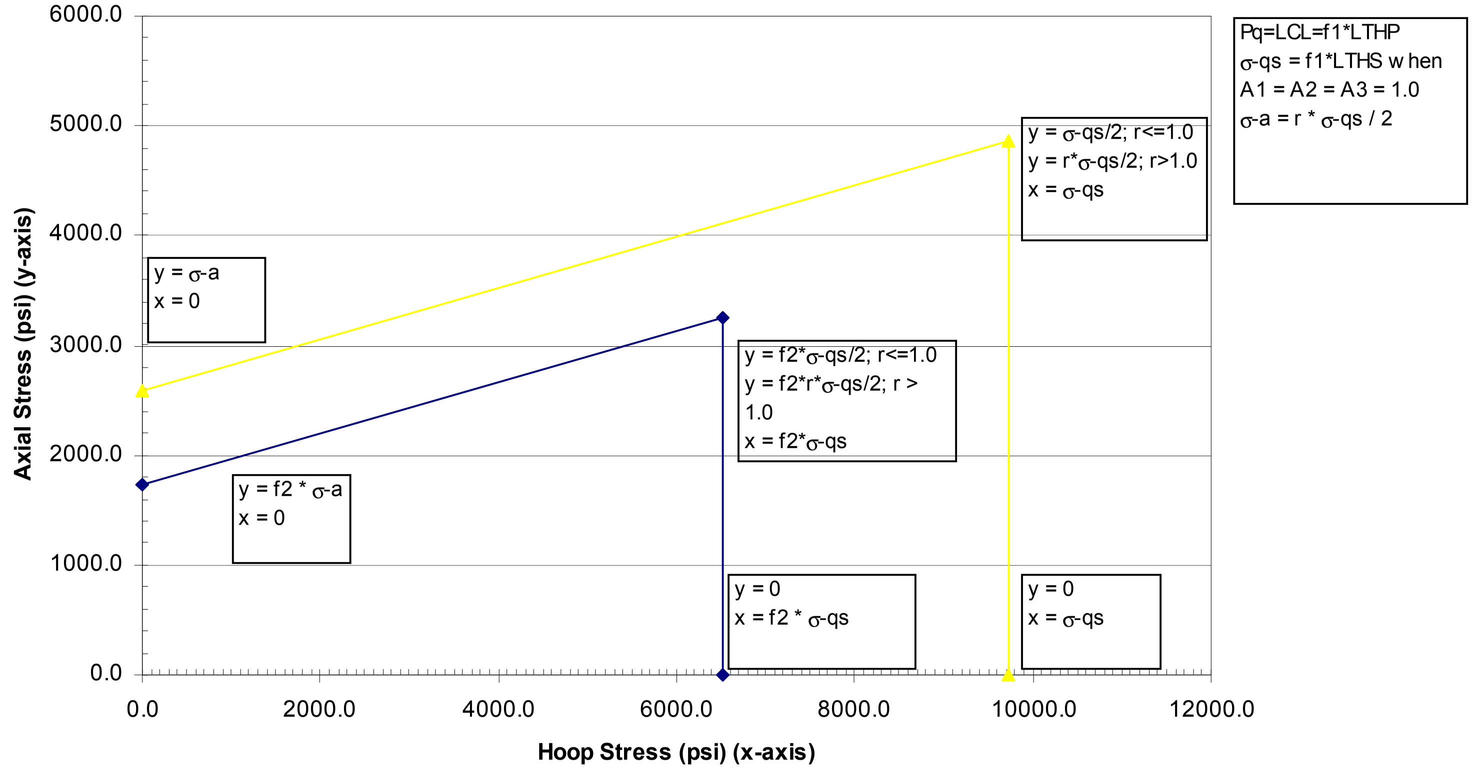
## REFERENCES

ASME B31.3-1996 Edition, Copyright 1996 by The American Society of Mechanical Engineers, New York, NY.

ASME RTP-1-1995 Edition, Copyright 1995 by The American Society of Mechanical Engineers, New York, NY.

ISO 14692 (DIS), Specification and recommended practice for the use of GRP piping in the petroleum and natural gas industries.

**Example ISO 14692 Design Envelope - Filament Wound Pipe**
**f1*LTHP=1789psi; f1*LTHS=9723psi; STHP=5520psi; STHS=30,000psi**
**σ-sa = Short Term Axial Strength = 8,000psi; σ-a = Estimated Long Term Axial Strength = 2,593psi; r=0.53**



**Testing Required to Generate a Design Long Term Envelope According to ISO 14692**

| **Size Range** | **Test Size** | **Component** | | | | |
|---|---|---|---|---|---|---|
| | | Pipe | Joint | Flange | Elbow | Tee |
| | | | | | | |
| 25-150mm | 150mm | D2992, 18 samples<br>D638, 5 samples<br>D1599, 5 samples | D2992, 18 samples<br>D638, 5 samples<br>D1599, 5 samples | 1000hr survival test, 2 samples of each component | | |
| 200 - 400mm | 400mm | 1000hr survival test, 2 samples of each component | | | | |
| 450 - 600mm | 600mm | 1000hr survival test, 2 samples of each component | | | | |