Quick Guide into the ISO 14692 (revision 2016)

Jan Steen GRP Consultant - NL
Richard Lee GRP Consultant - UK
www.grpcenter.com

Editorial.

This document can be downloaded from the website: www.grpcenter.com.
It is a living document and the intention is to regularly update it with upgrades from readers' comments and will be posted at the GRP Center website.

- All comments are appreciated,
- Please report mistakes or provide comments and suggestions,
- Requests for clarifications for all parts of the upcoming 2016 version of ISO 14692 will be considered seriously.

For all communications please e-mail: jan50steen@gmail.com .

60km buried section in Oman
Courtesy: Gulf Petrochemical Services & Trading LLC (Oman)

Jan Steen MSc.
Consultant

www.grpcenter.com

+31 623376194 jan50steen@gmail.com
Ruisvoorn 43, 4007NE Tiel, The Netherlands

Richard Lee
Technical Consultant – GRP/GRE

+44 1235 200259

RichardJ.Lee@ntlworld.com
Abingdon, Oxfordshire, UK

Content

1. Introduction

This document is an overview of the main differences between the previous ISO 14692 (published in 2002) and the current revision of the ISO 14692 standard for glass reinforced plastic piping (expected to be published later in 2016). The international standard is in four parts:

- Part 1 Vocabulary, symbols, applications and materials
- Part 2 Qualification and manufacture
- Part 3 System design
- Part 4 Fabrication, installation, inspection and maintenance

Main users of the ISO 14692 document are expected to be system designers, end users, engineering companies, inspection companies, manufacturers and installers. The scope of the original 2002 standard was specific to offshore oil and gas applications but the newer standard has now been extended to a wider range of industry applications found onshore. Other GRP standards may be more appropriate for municipal and industrial uses where pipelines are usually buried and axial tensile forces are minimal. The standard is not intended to be applied to sewerage and drainage applications although it may provide some useful guidance in specific areas not addressed in alternative standards. It covers all the main components that form part of a GRP pipeline and piping system (plain pipe, bends, reducers, tees, supports, flanges, etc.) with the exception of valves and instrumentation. The general design approach is to consider the eight steps defined in Part 1, the required end use application and use ISO 14692 to provide the necessary guidance and recommended practice for the purchase, qualification, manufacturing, design, handling, storage, installation, commissioning and operation of GRP piping systems.

The main basic steps defined in Part 1 are given below and illustrated in Figure 1:

- Step 1: The Bid Process.
- Step 2: Manufacturer's Data.
- Step 3: Qualification Process.
- Step 4: Quality Programme.
- Step 5: Generate Envelopes.
- Step 6: Stress Analysis.
- Step 7: Bonder Qualification.
- Step 8: Installation, Field Hydrotest.

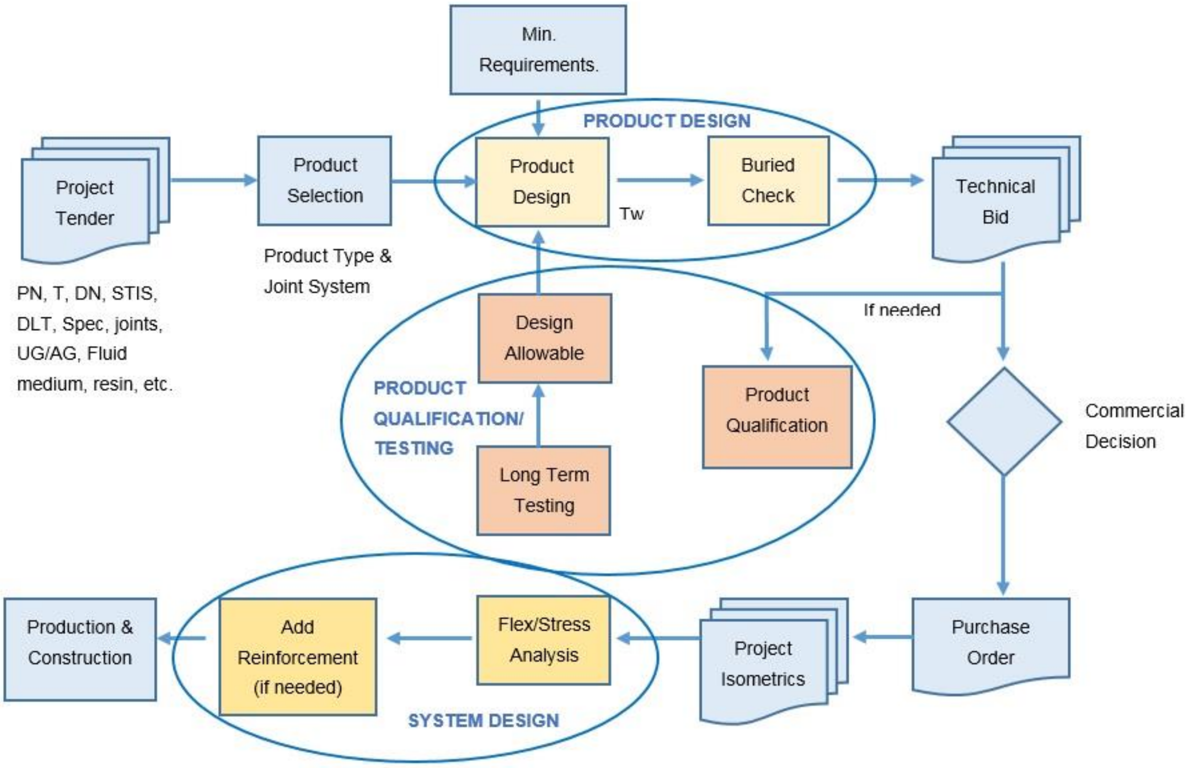


Figure 1: Typical Manufacturer's Design Process.

The key to trouble free GRP/GRE piping systems is to use qualified products from reputable manufacturers, performing a fully engineered system design and installation according to the manufacturer's guidelines using trained/certified installers and independent QA/QC checks. The design method defines the required design parameters:

- Calculation of pipe wall reinforcement thickness *t*,
- 1000 h pressure test and number of samples required,
- Provides definitions of pressure terminology including P_{des} (design pressure), MPR_{xx} (maximum pressure rating at sustained conditions for a 20-year design life at the required temperature) respectively, and the relation with long term hydrostatic stress (LTHS) and long term hydrostatic pressure (LTHP).
- Long term axial/hoop stress envelope and how is it generated.
- Hydraulic design (pressure losses, transient surges, erosion/cavitation, reduction of noise, etc.)
- Structural design (sustained and occasional loads, thermal stresses, buried pipes, etc.)
- Fire performance (fire endurance, reaction and protective coatings).
- Static electricity (conductive coatings for hazardous areas).

The process may appear complicated at first sight but is relatively straightforward provided the guidelines are followed and documented.

For both the current and revised ISO's some of these issues can be elaborated so that the main differences can be found. The main changes are in the pressure terminology definitions and the mathematical approach but fundamentally the two approaches are quite similar.

Some additional requirements of interest for the end-users are described in order to be better informed and to get a more reproducible product.

This document also provides a view about independent applicator and supervisor training and the DNV GL certification of competency is added for completeness. Fire testing is briefly introduced and an example of the IMO L3 fire test is given.

The book is not a substitute for obtaining the new ISO standard. It should be noted that once the system has been carefully designed and installed the in-service performance of GRP pipelines can generally be regarded as successful and is well established worldwide.

Figure 2: Field installation of buried GRP/ GRE piping in Oman (Courtesy Jishnu Narayanan Kutty).

2. Brief description of pressure tests

Qualification is covered in Part 2 of the standard and includes long term regression testing on a single pipe size and pressure class. A manufacturer uses the long term regression data to declare a gradient (slope of graph) for a particular operating temperature (65°C or higher for GRE and 21°C for GRP/GRVE).

2.1. Short term test ASTM D 1599

The short term test according to ASTM D 1599 is to increase the pressure of a pipe, fitting, spool until failure. The samples are unrestrained, closed end pressure vessel. The failure should occur between 60 and 70 seconds, this is sometimes difficult to achieve due to various practical reasons: size specimen, pump and uncertainties at what pressure the specimen will ultimately fail. Mostly this requirement has been replaced by failure shall occur at greater than 60 seconds.

The failure for pipes with ±55-degree angle of winding and without an elastic liner is mostly by weeping. The reason is that the strain to failure of the glass is higher than of the matrix material EP, VE etc. A liner in the pipe will increase the short term pressure.

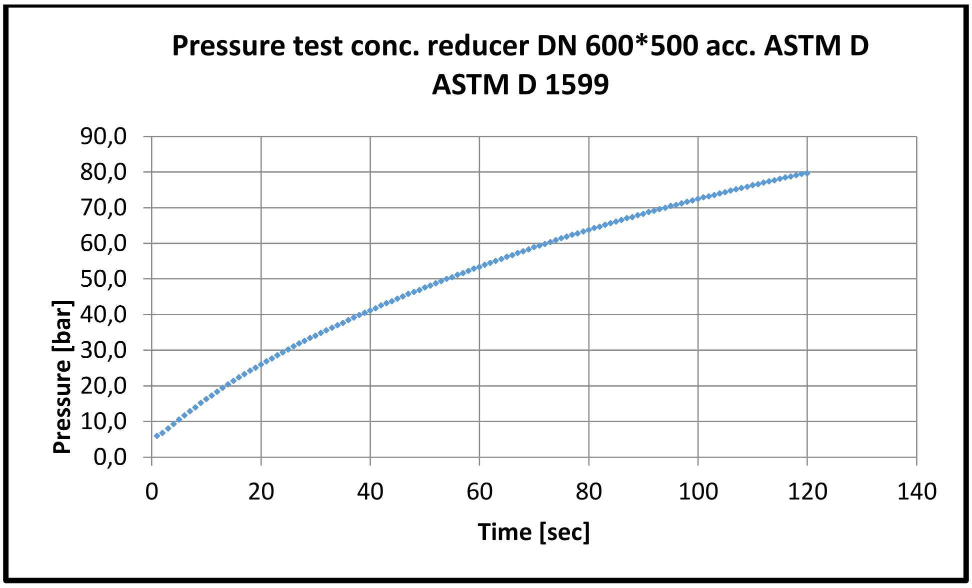


*Figure 3: Hydro test: Concentric Reducer 600*500 mm according to ASTM D 1599,*

Source: Report Fiberdur November 2010 nr. 2 (witnessed by DNV GL).

2.2. Medium term test ASTM D 1598

An extensive testing qualification program is required to determine the performance of the GRP/GRE components with respect to pressure, temperature, chemical resistance, fire performance, electrostatic performance, impact, etc. The medium term test according to ASTM D 1598 is to pressurize a pipe spool relatively slowly, until the required pressure is obtained, then maintain a constant pressure in the spool. The test is executed at a constant temperature e.g. 65^{o}C or 82^{o}C or as specified. The requirement for a 1000 h survival test is that the pressure is maintained for at least 1000 h. The pipe test samples have floating (unrestrained) closed ends.

It is important that the test temperature is stabilized first, this can take several days, unless tested in a heated water bath. The pressure is then increased in small incremental steps until the required test pressure is reached. This can take quite some time as well e.g. a few bar per 5 minutes. Pressure is maintained within ± 2% of test value and test temperature within ± 2 ^{o}C.

2.3. Regression line ASTM D 2992

For each product family (component type), a full regression line according ASTM D-2992 must be determined (usually witnessed by a third party inspector). The test consists of at least 18 samples. The test pieces are plain ended and the test setup is a closed end pressure vessel. Samples are subject to different pressures and held at constant pressure until failure (weeping). The pipe pieces are unrestrained, so there is a biaxial (2:1 hoop: axial) stress in the pipe wall. After the pipes are pressurized the time taken until failure is recorded. In this way a table with data is generated, hours vs pressure or hours vs stress in the pipe wall. The stress in the pipe wall can be calculated by using the closed end pressure formula's, when pressure, structural wall thickness and diameter are known.

$$\sigma_h = P \times \frac{D}{2t_r}$$

Each product family (pipe, elbow, reducer, tee, flange, etc.) is divided into product sectors. Two representative samples, usually the largest diameter and highest pressure class, from each product sector are taken and fully tested according to ASTM 1598 (1000 h at 65°C). The pressure test medium is usually water. The representative samples are called the product sector representatives. For calculation of the test pressure, the regression line of the pipe or the fitting is used. In the absence of a regression line, a default value can be obtained from a look-up table. For details on these calculations, see the ISO document. In general, the 1000 h test is performed at approximately 2.5 to 3 times the design pressure. A 20 bar system is tested around 50 to 60 bar. A product sector contains all the items within its diameter and pressure range, the so called component variants. Component variants are qualified by either two 1000 h tests or through the scaling method. For quality control, short-term tests could be performed, if required and agreed with the principle. These are done to establish a baseline value for quality control. Other aspects to be considered are: the glass transition temperature (T_g), the glass resin ratio and component dimensions. These have to be determined from the replicate samples and used by quality control during production as base line values.

The pipe pressure test data is usually plotted in a log stress – log time graph and the linear regression line is then calculated. It is required that there are sufficient data point in several decades. This means failures in the range from 1 to 10 hours, 10 to 100 hours, 100 to 1000 hours, and 1000 to 10000 hours. The regression equation (slope and intercept) can be calculated from the data.

For example, the following graph, Figure 4, represents such a regression line and the 95% lower confidence level (LCL), the data used here are representative and not real values chosen at random.

The formula for the regression line is calculated by a least squares fit.

Log Stress = 2,4876 - 0,0791 x Log Time

"This equation means that the *degradation* of the material between 1 hour and 10 hours is the same as between 10 and 1000 h or 10 years and 100 years!"

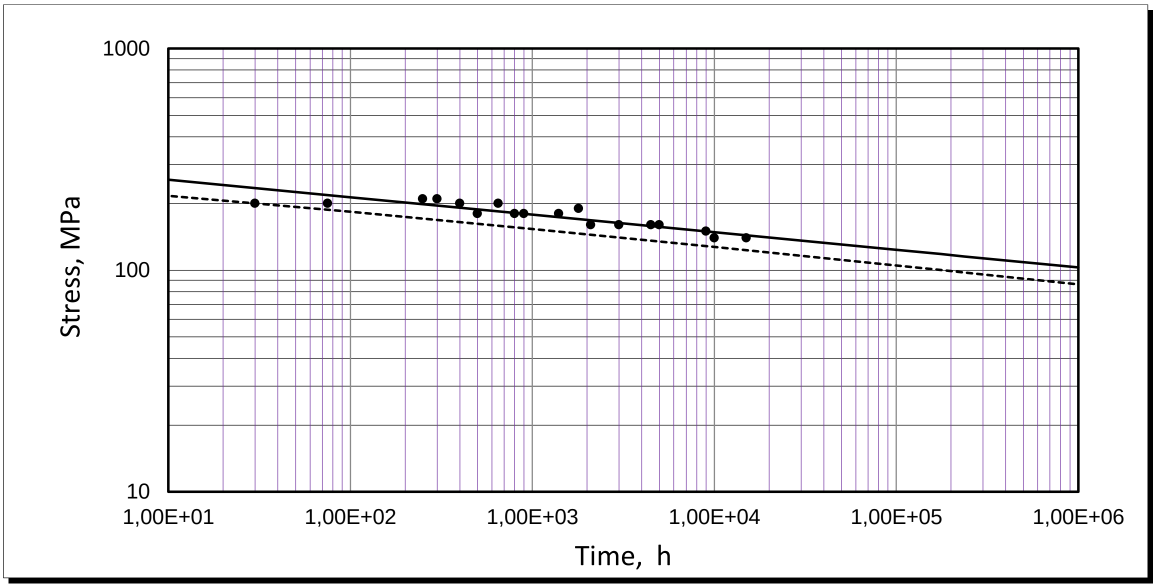


Figure 4: Typical Linear Regression line (Gradient G_{xx}) where xx is temperature.

The dotted line in Figure 4 is based on the lower confidence limit of 95 %. This line is calculated with student t statistics (according to ASTM D 2992) and gives an idea of the data scatter. The safety factor f1 is related to this scatter, in this example it is 0,85, but can be much higher or can be lower depending on the magnitude of the scatter.

The regression technique may be applied only if all the samples fail in a similar way and if the relationship between logarithm of stress and the logarithm of time is reproducible and linear. This allows the relationship to be extrapolated with some reliability beyond the end of the test period.

Remarks:

- Log Log graphs are very tricky, **generated random** numbers can look as a nice curve in such a graph.
- This test is not very realistic as the higher stressed pipes (early failures) are usually above the pipe wall elastic strain limit. If the pipe wall strain is within the elastic strain limit, then no failure usually occurs!

3. Product Family/ Sector representatives etc.

3.1. Family representative

The Family representative is mostly a plain pipe, with a specific diameter and wall thickness, of which such a full regression line according to ASTM D 2992 can be determined. This is the family representative of the pipes (the pipe family). However, for a fitting such as an elbow, tee or flange etc. a regression line can also be determined. Family representatives for all fittings - elbows (elbow family), tees (tee family), and flanges (flange family). Although some manufacturers have generated these regression lines, they are seldom used in practice. The main reason is that the regression line of a 4" elbow have no relationship with a 40" elbow, regarding manufacturing method, reinforcement, build up, curing, etc. The manufacturer declares the flexibility factors and stress intensity factors (SIFs) for bends and tees. They also declare the general production process (e.g. filament wound, contact moulded or resin transfer moulded) and jointing instructions sufficient to verify that scaling rules have been met without disclosing proprietary processes involved. The qualification test is a one-time test and a manufacturer has the option of using test data from previous projects provided that the method of manufacture and materials used are unchanged. The qualification programme is based on a standard design life of 20 years and the test fluid is potable water using unrestrained (floating) ends.

3.2. Product sector representative

What are the sectors?

"Sectors": diameter ranges from d to D in mm						
25 to 250	250 to 400	400 to 600	600 to 800	800 to 1200	1200 to 2400	>2400-

Table1: Overview sectors.

What are the sector representatives? These are the largest diameters in a range

"Sectors representative" diameter D in mm						
250	400	600	800	1200	2400	>2400-

Table 2: Sector representatives.

What are product sector representatives? **Product sector representatives** are the largest diameter in the ranges per family.

Families are: Family joints, family Elbows, family Tees, Family etc.

"Product sectors representative"						
Joint 250	Joint 400	Joint 600	Joint 800	Joints 1200	Joints 2400	Joints >2400
Elbows 250	Elbows 400	Elbows 600	Elbows 800	Elbows 1200	Elbows 2400	Elbows >2400
Tee 250	Tee 400	Tee 600	Tee 800	Tee 1200	Tee 2400	Tee >2400
Reducing Tee 250	Reducing Tee 400	Reducing Tee 600	Reducing Tee 800	Reducing Tee 1200	Reducing Tee 2400	Reducing Tee >2400
Reducers	Reducers	Reducers	Reducers	Reducers	Reducers	Reducers

250	400	600	800	1200	2400	>2400
Flange 250	Flange 400	Flange 600	Flange 800	Flange 1200	Flange 2400	Flange >2400
etc 250	etc 400	etc 600	etc 800	etc 1200	etc 2400	etc >2400

Table 3: Product sector representatives.

3.3. Component variants

What are component variants? **Component variants** are: all products minus Product sector representatives.

4. Wall thickness according to ISO 14692 (2002)

The structural wall requirements of pipes are given in Part 2 of the ISO 14692 (2002). The calculation mentioned in section6.2.3.1. in part 2 are only valid for thickness-to-diameter ratios that are in accordance with the next equation.

With t_r <= 0,1 D

Where:

t_r is the average reinforced thickness of the pipe wall, in millimetres, i.e. excluding liner and added thickness for fire protection.

D is the mean diameter, in millimetres, of the structural portion of the wall.

D_i is the internal diameter of the reinforced wall of the component, in millimetres.

In order to provide sufficient robustness during handling and installation, the minimum total wall thickness, t_{min}, of all components shall be defined as:

Minimum wall thickness:

$$For\ D_i \geq 100\ mm:\ \ t_{min} \geq 3mm$$

$$For\ D_i < 100\ mm:\ \ \left[\frac{t_{min}}{D_i}\right]\ \geq 0{,}025mm$$

For more onerous applications, for example offshore, consideration should be given to increasing the minimum wall thickness to 5mm.

Accurate wall thickness measurements for GRP pipes require destructive testing and cannot be measured on every pipe. Filament winding and other methods have inherent variations in pipe wall thickness. This variation in pipe wall thickness can be found along a single length of pipe, between pipe from the same lot, from the same products produced from different lots, and also from a single cross section.

The minimum wall thickness of the pipe at the joint, i.e. at the location of the O-ring or locking-strip groove, shall be at least the minimum thickness used for the qualified pipe body. Depending on location, the system design pressure and other design factors can significantly increase the required wall thickness.

5. Amount of tests, 1000hrs, ISO 14692 (2002)

An approach for describing the amount of test needed according to ISO 14692 (2002).

Formula for amount of tests = {250, 400, 600, 800, etc.} * {pipe, joints, elbow, tee, reducer, (blind) flanges, etc.} *{GRE, GRVE,..}*{major changes}* 2

Figure :5 Test spool elbow and joint (Courtesy Fiberdur Germany).

Also short term tests are required, but very rarely seen that this is required by any customer, lately not at all. It is recommended to test the adhesives as well, meaning if you have as a GRP manufacturer 3 types of adhesive, use all 3 adhesives for the different diameters. To be redone when a major change is involved like changing glass supplier or resin supplier, so the numbers of testing can be onerous. In such a case a common sense approach is required, to redo a selection of tests. Some end users are asking to redo or do the required 1000 h tests again for their project(s). Previous tests are discarded then.

Include laminated joint in 1000 h testing

In case a project contains only adhesive bonded joints, it is recommended to include a 1000 h pressure test always with the laminated joints as well. To have a qualified lamination procedure can be useful when a repair is needed further on in the project.

6. 1000 h test pressure ISO 14692 (2002)

All pipe wall thickness shall be qualified by 1000 h survival tests using the published default gradients. Default gradients as a function of temperature and resin system are provided in Annex A of Part 2 of the 2016 version.

6.1. 1000 h test pressure pipe

There are two ways in the ISO 14692 (2002) for calculating the 1000 h pressure rating, one is based on the regression line only and the other is based on the P_{npr}.

a. Based on the regression line

Regression line, straight line, is:

$$Log\ (P) = Constant + G \times Log(T)$$

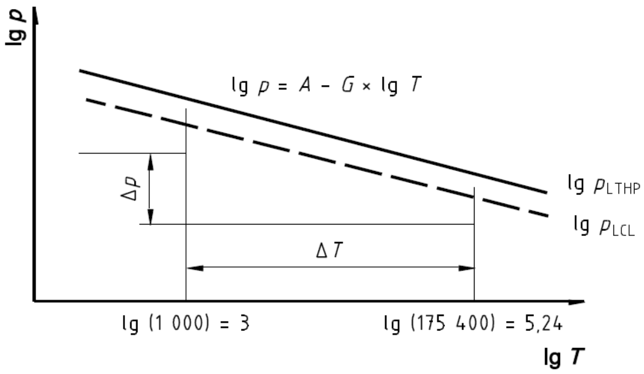


Figure 6: Regression line.

T = when design life is 20 years=20*365*24=175 400 h, In case of 33 years replace 175400 by 33*365*24 h.

$$Log(P_{LTHP}) = Constant + G \times Log\ (175400)$$

$$P_{LTHP} = 10^{Constant} \times 10^{G \times 5.24}$$
$$P_{LCL} = P_q = f_1 \times P_{LTHP}$$

Alternatively,

b. Based on the P_{NPR}

$$P_{NPR} = f_2 \times f_{3,man} \times P_q$$

$$P_{LCL} = P_q = \frac{P_{NPR}}{f_2 \times f_{3.man}}$$

So two ways to calculate the P_{LCL}. The next steps are independent of the definitions above.
In case the pipe is buried f_3=1 (or sometimes smaller) and default f_3=0,85. A good choice would be an f_3<0,9 as buried usually means in practice quite rough handling and preparation of trench and backfilling, creating additional stresses in the pipe wall.

Regression line (dotted line):

- $Log(P_{LCL}) = Constant + G \times Log\ (175400)$ (formula belonging to the dotted line)

$a: \quad Log(P_{T1000hrs}) = Constant - G \times Log(1000) = Constant - G \times 3$
$b: \quad Log(P_{LCL}) = Constant - G \times Log(175400) = Constant - G \times 5.24$

$a - b = Log(T_{P1000hrs}) - Log(P_{LCL}) = -G \times 3 + G \times 5.25 = G \times 2.24$

$$10^{[Log(T_{P1000hrs}) - Log(P_{LCL})]} = 10^{[G\times2.24]}$$
$$10^{[Log(T_{P1000hrs})]} \times 10^{[-Log(P_{LCL})]} = 10^{[G\times2.24]}$$
$$\frac{10^{[Log(P_{T1000})]}}{10^{[Log(P_{LCL})]}} = 10^{[G\times2.24]}$$
$$\frac{P_{T1000}}{P_{LCL}} = 10^{[G\times2.24]}$$
$$\leftrightarrow P_{T1000} = P_{LCL} \times 10^{[G\times2.24]}\ is\ the\ 1000\ hrs\ test\ pressure$$

6.2. 1000 h test pressure fitting

The 1000 h test pressure calculation for a fitting can be done as follows:

A choice of method can be:

Method A:

$$P_{NPR} = f_2 \times f_3 \times P_q$$
$$P_{LCL} = P_q = \frac{P_{NPR}}{f_2 \times f_3}$$

And use default gradients in the following equation:

$$\mathrm{P_{T1000}} = \mathrm{P_{LCL}} \times 10^{[\mathrm{G}\times2.24]}$$

Figure 7 Bonded GRP spool (Courtesy Fiberdur Germany).

Alternatively,

Method B. (using the Shell Design & Engineering Practice DEP):
In the absence of suitable regression data and any physical relationship between pipe and fittings, simply use a factor 2,5 times design pressure (approximate value used to estimate for a 30-year design life). This is based on extensive experience, and is not any better or worse argument to the above methods, but generates a clear communication between the client and end user. The test pressure (2,5 times PN) gives quite some certainty about the quality of the fittings and connections.

Default gradients in the ISO 14692 (2002)

Default Gradients		
$G_{default}$ Plain pipe having regression line with a slope < 0,06	$G_{default}$ Plain pipe having regression line with a slope > 0,06 but < 0,075	$G_{default}$ Plain pipe having regression line with a slope > 0,075
0,075	0,100	0,125
NOTE The unit of gradient is pressure per time. Since the scale is logarithmic, whether the units of measurement are in bar or MPa does not affect the value.		

Table4: Default gradients.

T_{P1000}/P_{LCL}		
$G_{default}$ = **0,075** MPa (bar)/h	$G_{default}$ = **0,1** MPa (bar)/h	$G_{default}$ = **0,125** MPa (bar)/h
0,147 (1,47)	0,167 (1,67)	0,191 (1,91)

Table 5: Ratio of TP_{1000} hour test to P_{LCL}..

7. Approach using Shell DEP method for 1000 h testing

Rules for 1000 h testing of fittings, joints and pipe

To conform to the ISO 14692 Standard, it is necessary to perform 1000 h tests according to ASTM D 1598 with the following additional “rules”:

Test all components with a diameter greater or equal to 1200 mm to qualify the manufacturer’s design and production procedures and methods, **in duplicate.** For larger diameters, greater than 1200 mm, only one test per component shall be executed.

- Components are: fittings, joint, pipe and laminates.
- For large diameters >= 1200 mm only one test per component shall be executed.
- The spools tested are unrestrained (closed end pressure vessel) and under constant hydrostatic internal pressure and at a constant internal and external temperature.
- The objective of the 1000 h test is to qualify the representative components, pipes, joints, laminates and fittings, according ISO 14692 “Petroleum and natural gas industries -Glass-reinforced plastics (GRP) piping". This means: in case the spool passes the 1000 h test the components in the spool are qualified.
- Test pressure shall be X or Y times design pressure, depending on design temperature. The test temperature shall be the maximum operating temperature or otherwise agreed between PRINCIPAL and SUPPLIER. The multiplication factor X or Y depends on the required design life. In the next table an overview is given for the multiplication factors as function of design life and design temperature.

Multiplication factors static			
Design Temperature	**<=65 C**	**>65 C**	**Default LCL**
Required design life	X	Y	Z
20 years	2.4	2.6	**Default LCL**
20+n*10 years	$(1.03)^n$*2.4	$(1.03)^n$*2.6	**Default LCL/{**$(1.03)^n$}
60 years	**$(1.03)^4$*2.4 = 2.70**	**$(1.03)^4$*2.6 =2.93**	

Table 6: Multiplication factors.

These Multiplication factors are based on the Shell DEP 31.40.10.19-Gen (January 2010) "Glass-Fiber reinforced plastic pipeline and piping systems" and are a simplification of the calculations in the ISO 14692, by some seen as more conservative, however one can defend that it is a realistic approach.

Example

Minimum test required to qualify a complete system for 20 bar design and max operating temperature 65°C and a design life of 20 Years, is given in Table 7.

Diameter <= 1200 mm All type of components in project#				
Diameter mm	Design pressure	Test temperature	Test pressure	*Qualified range& pressure rating*
250	20 bar	65°C	48.0 bar	[25-250] & 20 bar
600	20 bar	65°C	48.0 bar	[250-600] & 20 bar
1000	20 bar	65°C	48.0 bar	[600-1000] &20 bar
800	20 bar	65°C	48.0 bar	[600-800] & 20 bar

Table 7: Overview tests required.

unless otherwise agreed and specified between principal and supplier

OR

Figure 8: Applying fit laminate (Courtesy FPI).

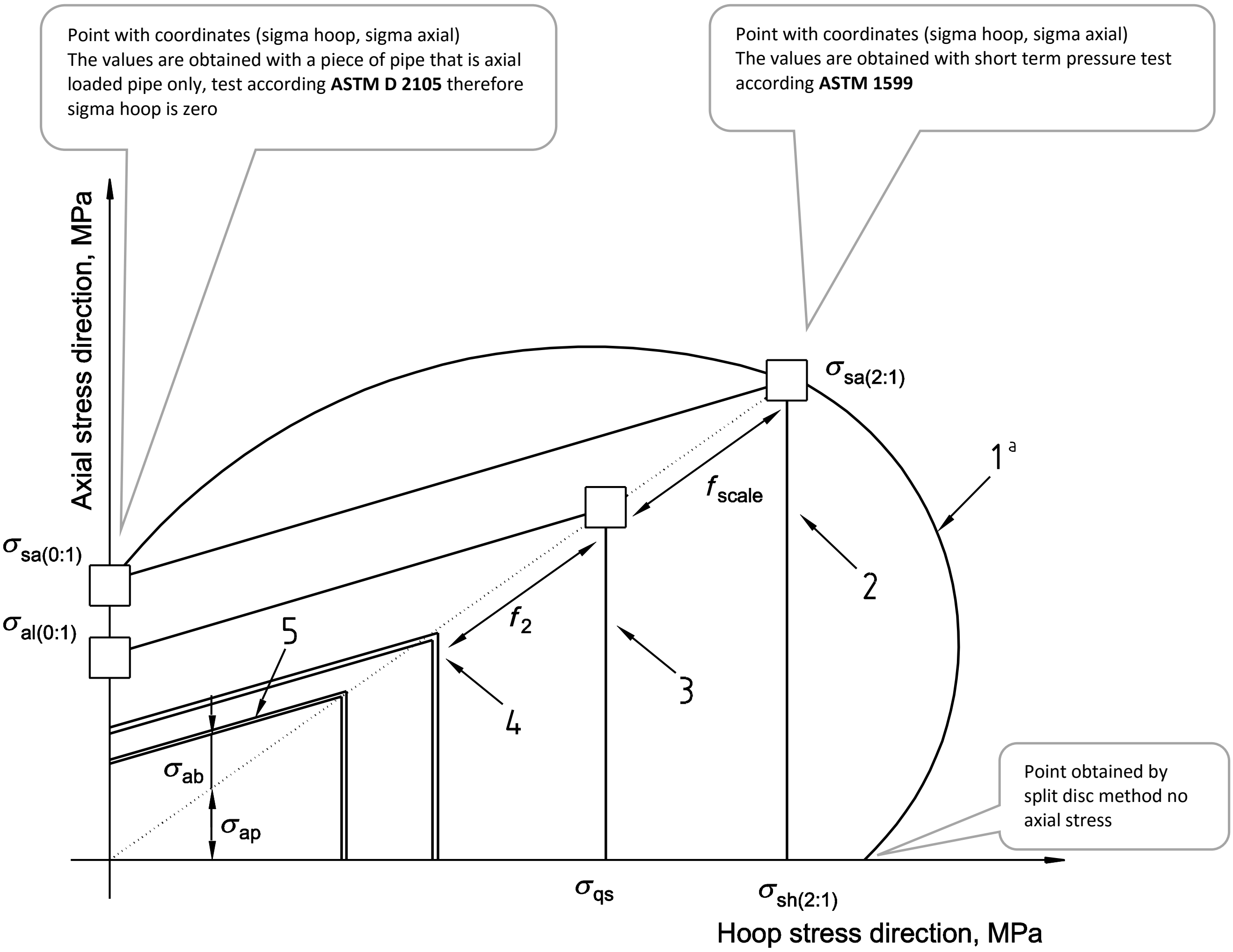
Diameter <= 1200 mm All type of components in project#				
Diameter mm	Design pressure	Test temperature	*Test pressure*	*Qualified range & pressure rating*
300##	*10 bar*	65°C	*24.0*	*[250-300] & 10bar*
450	*18 bar*	65°C	*43.2*	*[250-450] & 18 bar*
700	*20 bar*	65°C	*48.0*	*[600-700] & 20 bar*

Table 8: Overview minimum test required when there are only the diameters 300, 450 and 700 involved.

unless otherwise agreed and specified between principal and supplier
is also qualified by 450mm diameter

8. Explanation design envelope ISO 14692 (2002)

How is a design envelope devised in current ISO 14692 plus explanation about formula f3 in the ISO?



Graph 1: Design envelope (source ISO 14692(2002)).

ASTM D1599, Standard test method for resistance to short-time hydraulic failure pressure of plastic pipe, tubing, and fittings.
ASTM D2105, Standard test method for longitudinal tensile properties of “fiberglass” (glass-fiber-reinforced thermosetting-resin) pipe and tube.

Remark: The short term failure envelope is determined by 2 points, namely:

1. (σ_{hoop}, σ_{axial}) based on ASTM D 1599: e.g. (300, 150) OR (250, 125).
2. (σ_{hoop}, σ_{axial}) based on ASTM D 2105, typical values: (0, 55) to (0, 80) MPa.

The value for the axial stress is lower than the value for the axial stress of the short term burst test (bi-axial test). The reason is that the failure modes are different.

Explanation of stress terms:

σ_{qs} is the qualified stress, in MPa.
$\sigma_{al(0:1)}$ is the long-term axial (longitudinal) strength at 0:1 stress ratio, in MPa; is pulling of the pipe in axial direction only.
$\sigma_{sa(0:1)}$ is the short-term axial strength at 0:1 stress ratio, in MPa; obtained with split disc method in hoop direction only.
$\sigma_{sh(2:1)}$ is the short-term hoop strength at 2:1 stress ratio, in MPa; is obtained with short term test.

(2:1) means: 2 times axial stress = Hoop stress
(1:1) means: axial stress = hoop stress
(0:1) means: only axial stress
(1:0) means: only hoop stress

How to obtain σ_{qs}

σ_{qs} is the qualified stress in MPa.

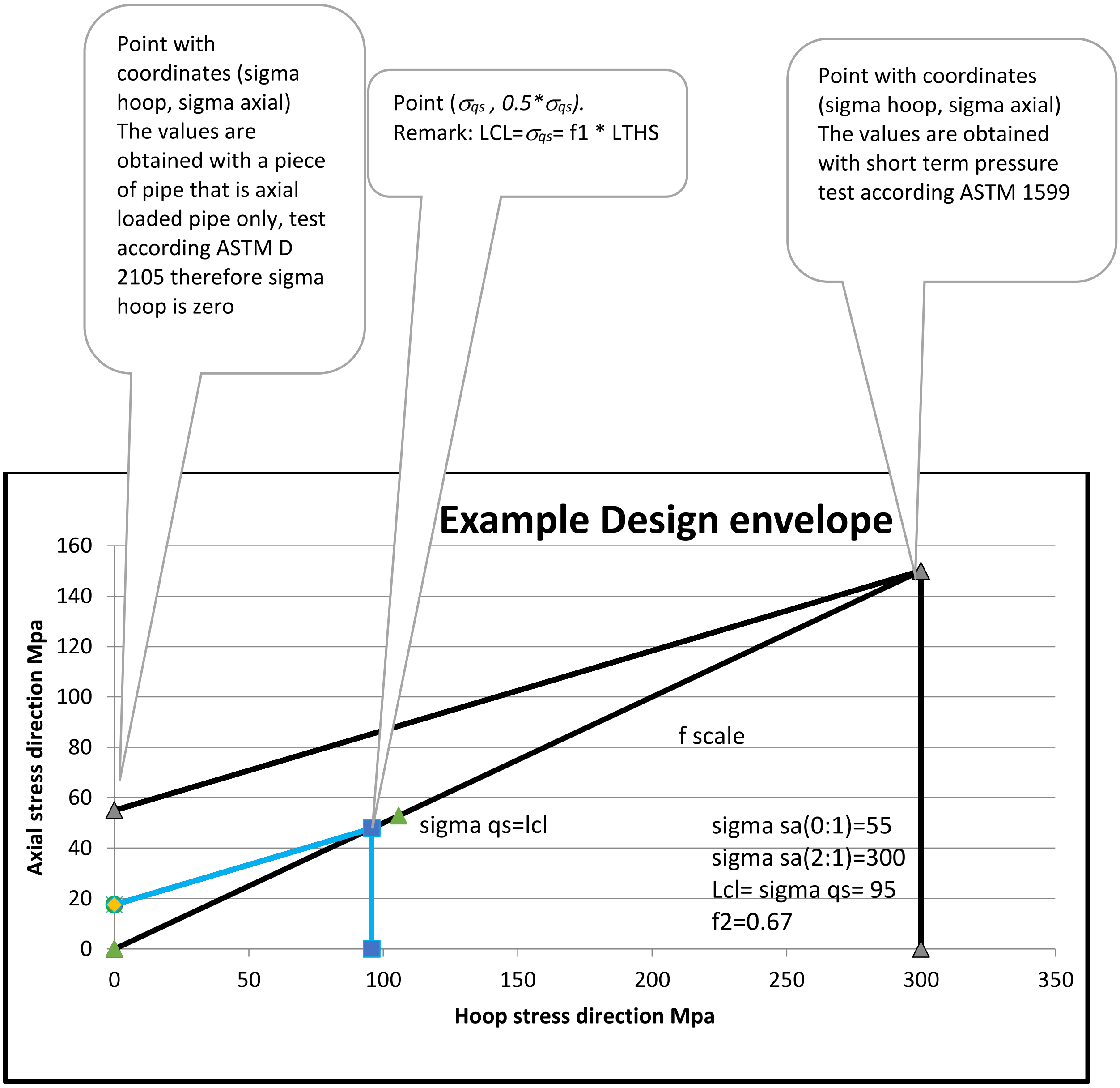
Log Stress = 4.8424 -0.1416 x Log Time
Log Time = 34.204 -7.063 x Log Stress

Insert for time e.g.: 27 years = 27*365*24 Hours.

Calculate the stress at 27 years. We call this the LTHS (Long Term Hydrostatic Stress). Multiply this stress by f1. f1 is obtained by using the student-t test statistical method mentioned in the ASTM D 2992 or using the improved statistics in the ISO 14692. Alternatively, take the default value from the ISO14692 namely 0,85.

So LCL=σ_{qs}= f1 * LTHS.

The f_{scale} is the multiplication factor used to scale the short term stress envelope to a stress envelope at in this case 27 years. Because the short term envelope is known and the point LCL=σ_{qs}= f1 * LTHS is known from the regression line the value (σ_{qs} , 0.5*σ_{qs}) can be put in the graph.

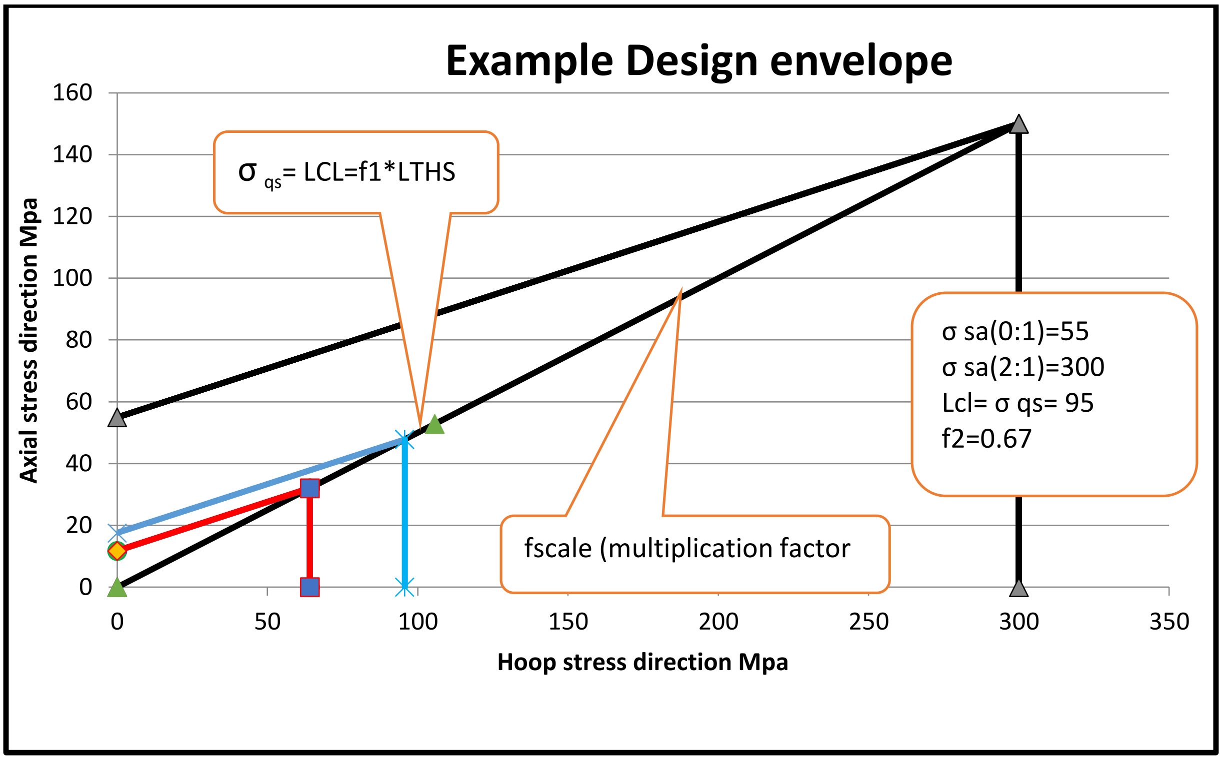


Graph 2: example design envelope.

Example:
f_{scale} is now:

$$f_{SCALE} = \frac{\text{LCL}=\sigma_{qs}=\text{f1}*\text{LTHS}=95}{\text{sigma sa(2:1)}=300} = \frac{95}{300}$$

Now multiply from the origin (0,0) the short term design envelope with the f_{scale} factor and you will obtain the blue line.

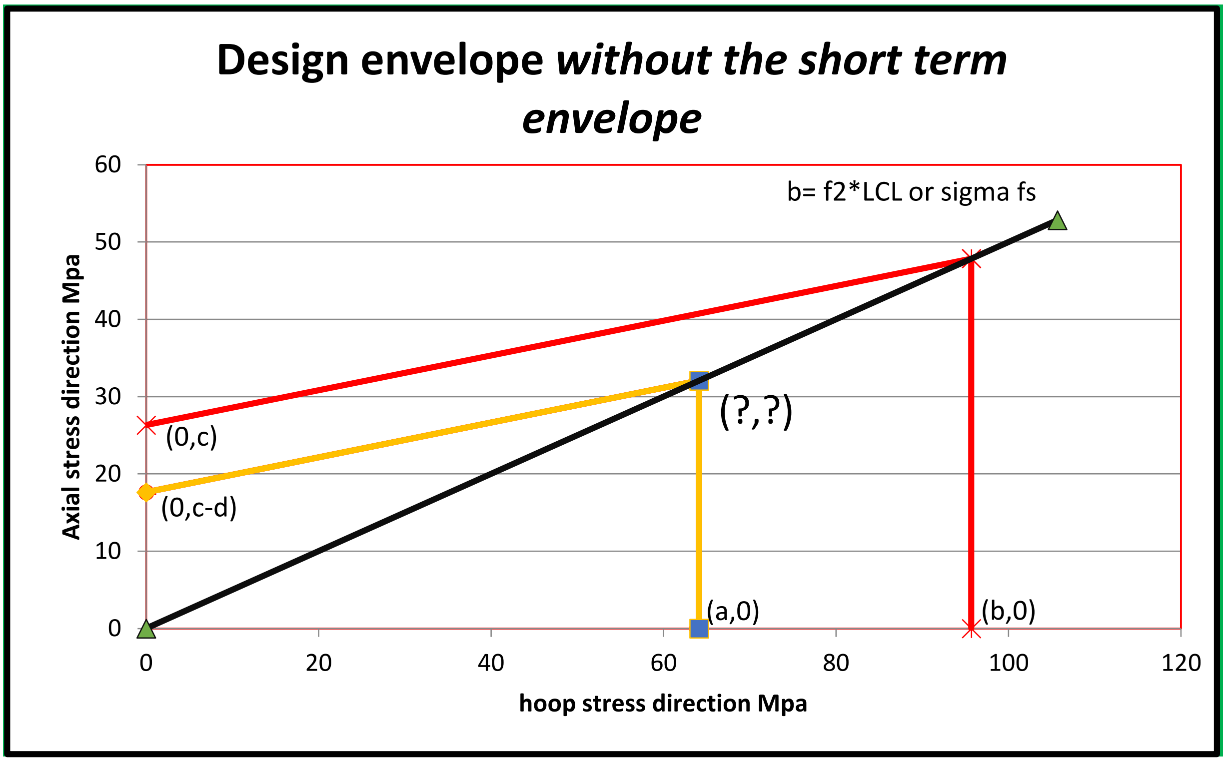


Graph 3: example design envelope.

Multiply the blue line (the scale envelope) from the origin (0,0) with f2 you will get the red lines and when required multiply with other reduction factors A_i

Very important, this is the basis for stress analysis: All stresses calculated with a pipe analysis program (e.g. Caesar 2) you have to stay within this red envelope. Stress here is meant to be both hoop and axial stress. All these stress pairs must be within this red envelope.

Finally, the red-envelope can be multiplied by f3. This is only for explanation but not necessary for evaluating a stress analysis of a piping system. f3 can be calculated with the formulas given in the ISO 14692 when assumed e.g. an extra axial stress of say 10 MPa. In the next page this is called parameter d.



Graph 4: example design envelope.

c= f2*fscale*sigma (0,1)
b=f2*fscale*STHS
a= f3*b
d= the allowed extra axial stress on top of the axial stress as a result of the internal pressure only.

f3 is also a multiplication factor from the origin (0,0)
(x-axis approach): f3=a/b or
(y-axis approach): f3= (c-d)/c)

Explanation:
What is the multiplication factor from the origin to achieve point (0, c-d) from point (0, c)?

c * c-d/c = c-d
so multiplication factor is c-d/c
therefore, a= (c-d/c) *b
so the coordinate {?,?} = { ((c-d)/c) *b, (0,5*(c-d)/c)*b }

9. Allowable Stress vs Qualified Stress for Elbows and Tees.

Either manual or computer methods can be used for structural analysis of piping systems. The degree of analysis depends on the following factors:

- Pipework flexibility.
- Layout complexity.
- Pipe supports.
- Pipework diameter.
- Magnitude of temperature change.
- System criticality rating.

Allowable deflections and modelling of fittings is given in Section 7 of Part 3 of the revised standard. The terms and expressions appear for both above ground and buried systems.

Quote ISO 14692 (2002) Part 3

The qualified stress for fittings shall be calculated according to the following equation.

$$\left(\frac{\sigma_{qs}}{P_q}\right)_{fitting} = \left(\frac{\sigma_{qs}}{P_q}\right)_{pipe}$$

This can be expressed as:

$$\left(\frac{\sigma_{qs,fitting} \times t_{fitting}}{P_q}\right)_{fitting} = \left(\frac{\sigma_{qs,pipe} \times t_{pipe}}{P_q}\right)_{pipe}$$

However one has to take into account that the diameter D = ID+ t_r + 2 * liner and has a higher value for D of fittings because of lower σ_{qs}.

In the following example it is assume that the Pq = P_{LCL} of a fitting has the same magnitude as of a pipe.

Note: "*At the intersection point of tee sections, stresses and their direction become complex and cannot easily be related to applied pressure and tensile loads.*". Nevertheless following example with simple "approximation" formula's.

Example: Elbow and Tee:

It is given that the allowable stress of a pipe is 73,7 MPa, an elbow is 40 MPa and a tee is 32 MPa.

In the case where $P_{q,pipe}$= $P_{q,fitting}$ the following "approximation" formulas can be used for $t_{r,\,fitting}$.

For pipes the following formula is valid:

- $\sigma_{qs\ PIPE} = p_q \times \dfrac{D}{2t_r}$, or $\quad t_{r\ PIPE} = \dfrac{ID+2\times liner}{\frac{2\times\sigma_{q\ PIPE}}{Pq,PIPE}-1}$

Where:

$P_{q,\ pipe}$ is the qualified pressure, in MPa.

D is the average diameter of the pipe, in mm. (=ID + $t_{r\ PIPE}$ + 2 * liner).

$t_{r\ PIPE}$ is the average reinforced wall thickness of the pipe, in mm.

Elbow: f2 * $\sigma_{qs\ ELBOW}$ = allowable stress$_{ELBOW}$ = 40 therefore $\sigma_{qs\ ELBOW}$ = 40/f2= 40/0,67 ≈ 60 MPa Same for Tee, $\sigma_{qs\ TEE}$ = 32/0,67 ≈48.

- Wall thickness Elbow: $t_{ELBOW} = \frac{ID+2\times liner}{\frac{2\times\sigma_{qs\,ELBOW}}{Pq,ELBOW}-1}$
- Wall thickness Tee: $t_{TEE} = \frac{ID+2\times liner}{\frac{2\times\sigma_{qs\,TEE}}{Pq,TEE}-1}$

Component	Allowable stress MPa, f2=0,67	σ_{qs} MPa	Wallthickness Incl. liner, mm
Pipe	73,7=f2 * $\sigma_{qs\ PIPE}$	110	2,3
Elbow	40,0 = f2 * $\sigma_{qs\ ELBOW}$	60	4,3
Tee	32,0 = f2 * $\sigma_{qs\ TEE}$	48	5,4

Table 9: Example DN 200 and PN 16 (valid for 16 bar only).

The allowable stress of a fitting is smaller than of a pipe, it is compensated by the wall thickness of the fitting.

10. MPR versus P_q comparison between ISO 14692 (2002) vs ISO 14692 (2016) revision

In the next table a comparison is made between parameters used in the old version of 2002 and the "renamed" versions with small alterations. Table comparison formula's used in the ISO 14692 (2002) and ISO14692 (2016) revision;

Assumption all A_i equal to 1.

ISO 14692 (2002)	ISO 14692 (2016) revision	relation
$\sigma_{qs} = P_q \times \frac{D}{2 \times t_r}$	$\sigma_{h,thr,2:1} = MPR_{Temp} \times \frac{D_{r,min}}{2 \times 0{,}67 \times t_{r,min}}$	$\sigma_{qs} = \sigma_{h,thr,2:1}$
$P_q = \frac{2 \times t_{r,min} \times \sigma_{qs}}{D_{r,min}}$	$MPR_{Temp} = \frac{0{,}67 \times 2 \times t_{r,min} \times \sigma_{h,thr,2:1}}{D_{r,min}}$	$MPR_{Temp} = f_2 \times P_q = 0{,}67 \times P_q$

Table 10: comparison formula's ISO 14692 (2002) and ISO14692 (2016) revision.

$t_r = t_{r,min}$, minimum reinforced pipe wall thickness, expressed in millimetres

$\sigma_q = \sigma_{h,thr,2:1}$ threshold envelope hoop stress for an unrestrained, hydraulic (2:1) condition, expressed in MPa

$D = D_{r,min}$ mean diameter of the minimum reinforced pipe wall, expressed in millimetres.

ISO 14692 (2002)	ISO 14692 (2016) revision
	Partial factor A_0 for design life A_0 shall be used to scale the threshold envelope to the design envelopes at design lives other than 20 years.
A_1 partial factor for temperature	Does not exist
A_2 partial factor for chemical resistance	Partial factor A_2 for chemical resistance A_2 shall be used to scale the threshold envelope to the design envelopes to account for the effect of chemical degradation.
A_3 partial factor for cyclic service	Partial factor A_3 for cyclic loading A_3 shall be used to scale the threshold envelope to the design envelopes to account for the effects of cyclic loading.

Table 11: comparison A_i factors ISO 14692 (2002) and ISO14692 (2016) revision.

11. Wall thickness according to ISO 14692 (2016) revision

An estimate for the wall thickness can be made by using for the f3 factors following default values. The ~~correct~~ wall thickness can be verified with a stress analysis requiring that for all stresses (both axial and hoop) and the different load cases they are within the defined stress-envelopes. The wall thickness is derived from the pipe stress analysis.

A calculation for determining the wall thickness is not given. The determination of the wall thickness is as described above.

$$\sigma_{h,thr,2:1} = MPR_{Temp} \times \frac{D_{r,min}}{2 \times f_3 \times 0{,}67 \times t_{r,min}}$$

Assumption all A_i equal to 1.

Application	f_3	Notes
Process piping, Aboveground, Offshore & marine, max. 1,5 × P_{des} hydrotest	0,70	Occasional loads from wind and/or ship motions typically require a low f_3. Special design conditions such as wave loads may require a much lower f_3.
Process piping, Aboveground, Industrial, max. 1,5 × P_{des} hydrotest	0,85	Bending stress from dead weight will require some reduction via f_3, thus the recommendation of 0,85. Higher temperature applications (e.g., above 65 °C) may require a lower f_3 due to axial and bending stress from thermal loads. Applications in some seismic zones may require a lower f_3.
Process piping, Aboveground, Oil field, max. 1,5 × P_{des} hydrotest	0,85	Same as aboveground industrial process piping.
Pipelines, Aboveground, Oil field, max. 1,25 × P_{des} hydrotest	0,80	
Process Piping, Underground, max. 1,5 × P_{des} hydrotest	0,90	Hoop (circumferential) loads typically dominate the design. One exception may be relatively higher pressure (between 10 and 30 bar) underground pipelines that do not employ anchor blocks where the longitudinal bending loads are significant due to the axial thrust generated from the internal pressure. These systems may warrant an f_3 between 0,65 and 0,8.
Pipelines, Underground, max. 1,25 × P_{des} hydrotest	0,95	See note above
NOTE In buried pipelines the inclusion of elbows and tees can be accompanied by significant axial and bending loads and may require pipe and fittings of much thicker wall material for up to a pipe length each side of the fitting.		

Table 12: f3 factors.

12. 1000 h test pressure according to ISO 14692 (2016) revision

Item	ISO 14692 (2016) revision	Remarks
rd	$$P_{T\ 1000,temp} = rd_{1000,temp} \times \frac{MPR_{temp}}{0{,}67} \times \frac{t_{r,act} \times D_{r,min}}{t_{r,min} \times D_{r,act}}$$ Temp = 21 or 65°C	$\frac{t_{r,act} \times D_{r,min}}{t_{r,min} \times D_{r,act}}$ This factor takes care that the test pressure value is determined directly related the measured wallthickness This means a test pressure performed at a magnitude based on the actual wall thickness. The pressure test is calculated for a 20 years design life, correction for a requirement of a design life larger than 20 years are made with the A_0 factor.
A_0	$$A_0 = \frac{1}{10^{(\log(t)-\log(175200))\times G_{xx}}}$$	The pressure test is calculated for a 20 years' design life, correction for a requirement of a design life larger than 20 years are made with the A_0 factor Part 3 paragraph 5, in the threshold envelope. **This means everything is tested for 20 years ONLY and correction to longer than 20 years you see back in the threshold envelope by means of the factor A_0.** A_0 shall be used to scale the threshold envelope to the design envelopes at design lives other than 20 years. A_0 shall be defined by the following equation. where t time expressed in hours G_{xx} gradient of regression line at xx °C A_0 shall not be greater than 1,0.
	A_1 factor does not exist.	
	A_2	A_2 shall be used to scale the threshold envelope to the design envelopes to account for the effect of chemical degradation. Be aware that this can be a function of time as well, see A_0
	A_3	See ISO 14692 (2002), 7000 cycles is seen as static duty.
	f_2	• 0,67 for sustained loading conditions, • 0,83 for sustained loading plus self-limiting displacement conditions and • 0,89 for occasional loading conditions.

Table 13: Explaining A_i factors.

Resin System	Temperature						
	–35 °C	21 °C	50 °C	65 °C	80 °C	93 °C	121 °C
Anhydride	1,26	1,26		1,40	1,72		
Aliphatic Amine	1,26	1,26		1,40		1,68	
Cyclo-aliphatic Amine (IPD)	1,26	1,26		1,40		1,59	
Aromatic Amine (MDA)	1,26	1,26		1,40		1,59	1,81
Polyester	1,33	1,33	1,44				
Vinyl Ester	1,33	1,33	1,40	1,47			

Table 14: Default regression gradients acc. ISO 14692 (2016) revision.

Gradient G	Rd 1000 h 20 years	Rd 1000 h 25years	Rd 1000 h 30 years	Rd 1000 h 40 years	Rd 1000 h 50 years
0,045	1,26	1,27	1,28	1,30	1,31
0,050	1,29	1,31	1,32	1,34	1,36
0,055	1,33	1,35	1,36	1,38	1,40
0,060	1,36	1,38	1,40	1,42	1,44
0,065	1,40	1,42	1,44	1,47	1,48
0,070	1,44	1,46	1,48	1,51	1,53
0,075	1,47	1,50	1,52	1,55	1,58
0,080	1,51	1,54	1,56	1,60	1,63
0,085	1,55	1,58	1,61	1,65	1,68
0,090	1,59	1,62	1,65	1,70	1,73
0,095	1,63	1,67	1,70	1,75	1,78
0,100	1,68	1,71	1,75	1,80	1,84
0,105	1,72	1,76	1,79	1,85	1,89
0,110	1,77	1,81	1,85	1,91	1,95
0,115	1,81	1,86	1,90	1,96	2,01

Table 15: Default 1 000 h test ratios acc. ISO 14692 (2016) revision.

G_{xx}	20 Years	25 Years	30 Years	40 Years	50 Years
0,045	1	0,990	0,982	0,969	0,960
0,050	1	0,989	0,980	0,966	0,955
0,055	1	0,988	0,978	0,963	0,951
0,060	1	0,987	0,976	0,959	0,947
0,065	1	0,986	0,974	0,956	0,942
0,070	1	0,985	0,972	0,953	0,938
0,075	1	0,983	0,970	0,949	0,934
0,080	1	0,982	0,968	0,946	0,929
0,085	1	0,981	0,966	0,943	0,925
0,090	1	0,980	0,964	0,940	0,921
0,095	1	0,979	0,962	0,936	0,917
0,100	1	0,978	0,960	0,933	0,912
0,105	1	0,977	0,958	0,930	0,908
0,110	1	0,976	0,956	0,927	0,904
0,115	1	0,975	0,954	0,923	0,900

Table 16: A_0 as function of amount of Years and gradient G.

13. What to test

1. Tests are required at the max design temperature for the project.
2. Test must be performed for all fittings, joints, and flange types.
3. Test results at 65°C are not valid for 80°C and derating factor A1 is not allowed.
4. Test results can be used with formulae given in the table below to qualify other diameters. In the first case higher pressure in the last case lower.
   It is the opinion of the main author that item 4 (above) leads to a non-conservative approach and strongly recommends the approach of dividing testing into sectors as defined in ISO 14692 (2002). During testing the last 20 yrs a number of failures have been experienced particularly (at or around 400 mm).
5. The table below can be used for existing test data to cover the required testing and minimize testing in absence of test results.

	Product that has been tested	Products that are considered represented by DN_1 and MPR_1
1	$DN_1 > 300$ $MPR_1 > 25$	$0{,}5 \times DN_1 \leq DN_2 \leq 1{,}6 \times DN_1$ *and* $0{,}5 \times MPR_1 \leq MPR_2 \leq 1{,}6 \times MPR_1$ *and* $DN_2 \times MPR_2 \leq DN_1 \times MPR_1$
2	$DN_1 \leq 300$	Same as above point 1 except no limit on minimum DN
3	$MPR_1 \leq 25$	Same as above point 1 except no limit on minimum MPR

Table 17: Overview qualified test ranges as function of product tested.

The preference of the main author is to test according the Shell DEP, or as close as possible. Include the 400 mm diameter and qualify for every project at an independent test institute. Fittings should be carefully considered, weighted upfront of testing to set a benchmark and it is necessary to be clear about procedures used to make fittings and pipes joints (neck area of bell). **Demand a high reproducibility of products**.
The relations described in the new ISO 14692 (2016) are not universally agreed and require further testing.
Additionally: It should be noted that for many GRP manufacturers the step from a 10 bar GRP system knowledge level to a 16 bar/25 bar system is a huge step.
It is therefore recommended to/that end users work as close as possible to the Shell DEP with adding the diameter 400 mm.

Diameter <= 1200 mm All type of components in project[#]				
Diameter mm	Design pressure	Test temperature	Test pressure	*Qualified range& pressure rating*
250	20 bar	65°C	48.0 bar	[25-250] & 20 bar
400	20 bar	65°C	48.0 bar	[250-400] & 20 bar
600	20 bar	65°C	48.0 bar	[400-600] &20 bar
800	20 bar	65°C	48.0 bar	[600-800] & 20 bar
1200	20 bar	65°C	48.0 bar	[800-1200] & 20 bar

Table 18: Example recommended tests required acc. author and diameter ranges.

[#] unless otherwise agreed and specified between principal and supplier

14. Stress envelope according to ISO 14692 (2016) revision

For the construction of the stress envelope the following essential information must be known after that it is relatively straightforward.

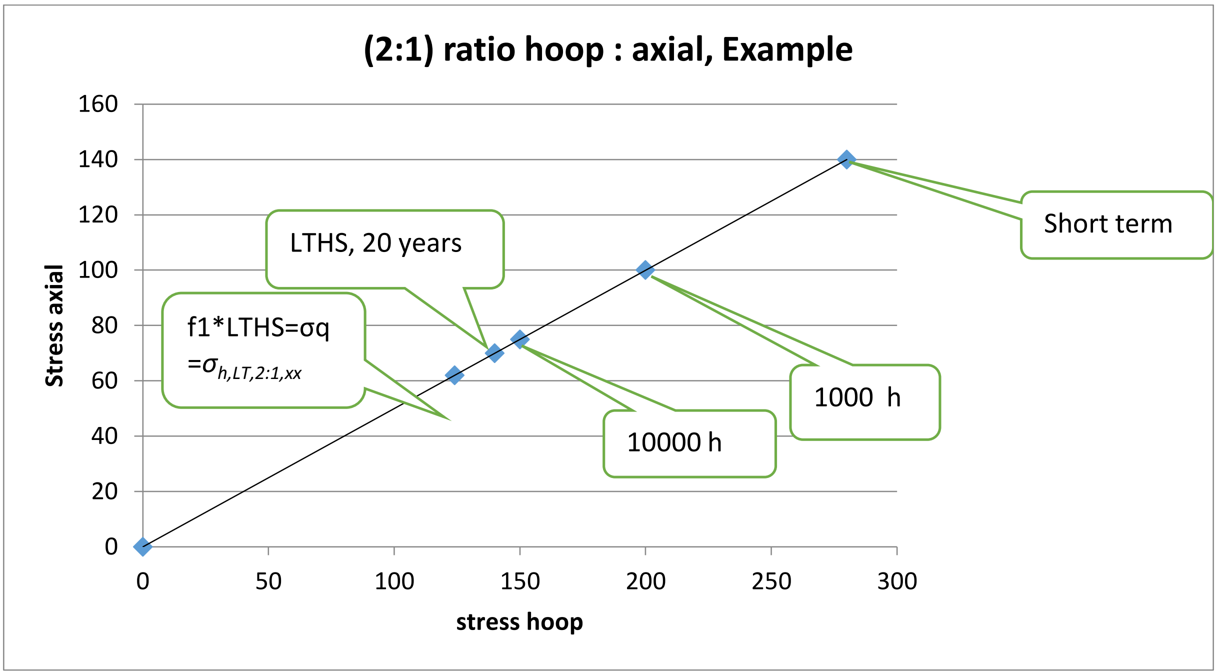
In the graph at the line (2:1) several data points can be drawn known as short term and long term values

- $(\sigma_{qs}, 0{,}5\ \sigma_{qs})_{20\ years}$ but also $(\sigma_{hoop}, 0{,}5\ \sigma_{hoop})_{1 years}$
- $(\sigma_{hoop}, 0{,}5\ \sigma_{hoop})_{6\ years}$ $(\sigma_{hoop}, 0{,}5\ \sigma_{hoop})_{1\ hour}$
- $(\sigma_{hoop}, 0{,}5\ \sigma_{hoop})_{10000\ h}$ or. $(\sigma_{hoop}, 0{,}5\ \sigma_{hoop})_{1000\ h}$

In the ISO 14692 (2002) a scaling factor was used to generate from a short term test an envelope that contains the point $(\sigma_{qs}, 0{,}5\ \sigma_{qs})_{20\ years}$.

However, you can also use a scaling factor from a point at 10000 h or 3 years, etc. In this revision 1000 h is chosen (instead of the short term value).

Remark: f1*LTHS=σq=$\sigma_{h,LT,2:1,xx}$ for explanation see chapter 15: f1 factor.



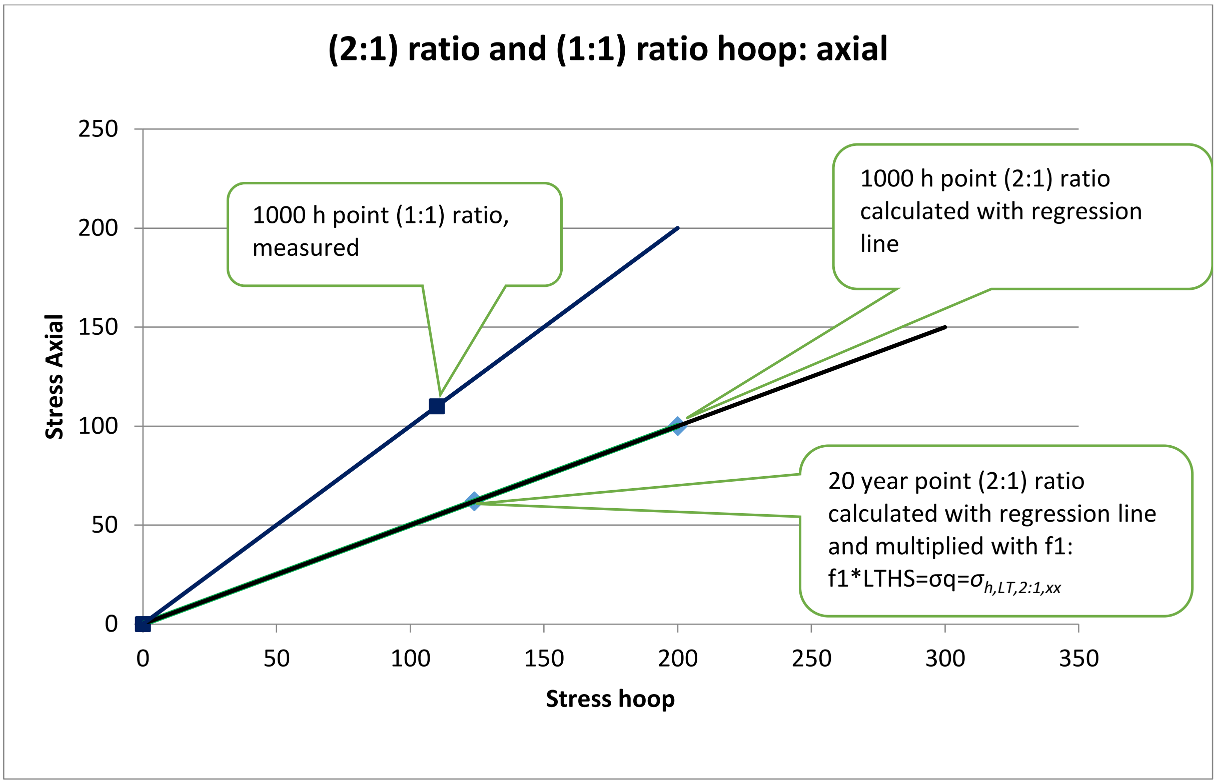
Graph 5: Stress envelope set up acc. ISO 14692 (2016) revision.

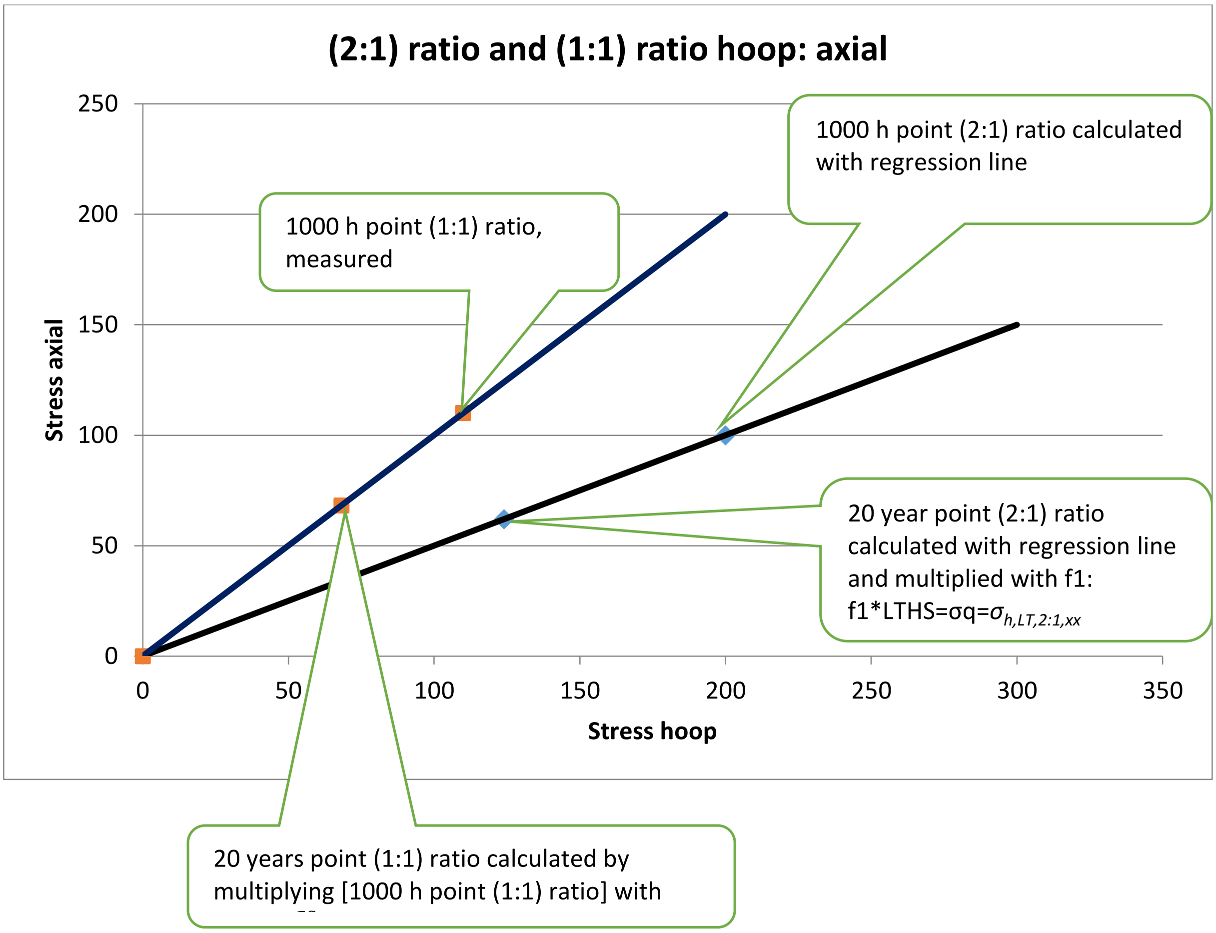
In the ISO 14692 (2002) a f_{scale} was calculated as follows: $\frac{\sigma q}{Short\ term\ hoop\ stress}$

But one can take other points as well like the 1000 h: $\frac{\sigma q}{1000hrs\ hoop\ stress}$

It is obvious one can do this for 10000 h as well. This is just added for understanding about the points that lying on this line. The points LTHS 20 years, 10000 h and 1000 h can be found with the regression line. Only the LTHS and 1000 h is needed.

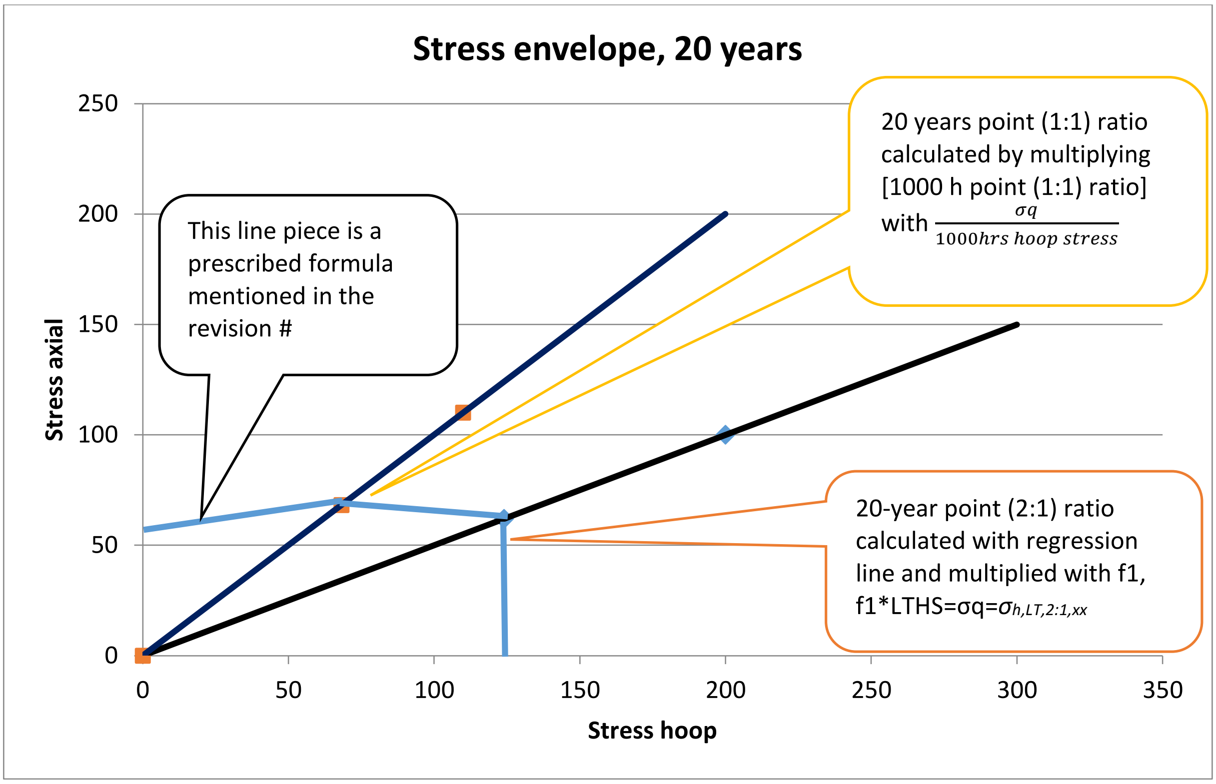
That the product, pipe, fulfils the requirement of 1000 h is proven with the 1000 h test (qualification).





Graph 6, 7: Stress envelope set up acc. ISO 14692 (2016) revision, continuing.

The 1000 h point (1:1) ratio is determined by testing, not by calculation.



see Annex D part 2.

Graph 8: Stress envelope acc. ISO 14692 (2016) revision.

15. f1 factor

The f1 factor is mentioned in the ISO 14692 (2002) and is **not** mentioned in the ISO 14692 (2016) , however the value f1 is per definition part of the ASTM D 2992, when evaluating the regressionline data points with student t statistics.

Where is then this f1 factor used in the ISO 14692(2992)?

ISO 14692 (2002) + ASTM D 2992: f1 * LTHS = LCL

ISO 14692 (2016) + ASTM D 2992: $\boldsymbol{\sigma_{h,LT,2:1,x}}$ **= f1*LTHS** (ASTM D 2992) (per definition: private communication with chairman ISO14692 committee)

$\sigma_{h,LT,2:1,xx}$ long term envelope hoop stress for an unrestrained, hydraulic (2:1) condition at xx °C, expressed in MPa (part 3 ISO 14692 (2016).

16. Additional Recommendations

16.1. Glass: Resin ratio

As the determination of the glass content of a fitting is destructive, it is important for cost reasons to limit the amount of testing. It is obvious that the amount of costs can be substantial in case of large diameter fittings.
In the ISO 14692 is stated that 1% of continuous production should be tested. It is for end-users of GRP fittings not clear which amount have to be tested in case of e.g. 6 large diameter tees.

As a guideline for the amount of tests: the number of glass content tests of fittings to be executed for one specific project can be determined as follows:

Amount of fittings used in 1 specific project #	Number of tests
amount fittings < 100	0
100 ≤ amount fittings < 200	1
200 ≤ amount fittings < 300	2
300 ≤ amount fittings < 400	3
n * 100 ≤ amount fittings < (n+1)* 100 and n ϵ N	n
Or use a smaller discrete step e.g. 50 n * 50 ≤ amount fittings < (n+1)* 50 and n ϵ N, etc.	n

Table 18: Suggestion for amount of tests glass resin ratio.

- # = combining of projects is excluded for the amount of fittings to be tested. (One project determines a fixed set of fittings, and therefore immediately the end of discussion about what amount has to be tested.)
- Definition amount of fittings = number of same type of fitting with the same diameter and pressure class.
- Type of fitting is e.g. Tee, Elbow, Lateral, Flange, etc.
- In case of pipes: Number of glass content tests = round {amount of pipes= number of pipes/100}.

16.2. Qualification reducing tee's

For qualification of reducing tees, the following applies:

a. For each "type" of tee, a qualification (1000 h) test is required, i.e.:

- saddle connection (filament wound branch pipe - filament wound main pipe);
- laminate connection - local (filament wound branch pipe - filament wound main pipe);
- laminate connection - fully wrapped around the main pipe (filament wound branch pipe - filament wound main pipe);
- fully hand lay-up tee;
- fully filament wound tee;

b. Qualification requirement: For "each" type of tee (see a), the tee with the "smallest" D/d ratio shall be 1000 h tested. Tees within the same type (see a), however, with "higher" D/d ratio's, may be accepted based on calculation method, e.g. BS 7159 (and allowable stresses based on qualified tee).

A D2 * d2 reducing Tee qualifies a D1 * d1 reducing Tee when following conditions are fulfilled:

- D, D1, D2 is diameter main
- D, d1, d2 is diameter branch
- D2 >= D1
- D2/d2 <=D1/d1
- D2 * d2 is qualified by 1000 h test
- The D2 * d2 reducing Tee is fabricated in the same way as the D1 * d1 reducing Tee
- D1 and D2 belongs to same product sector.

17. Summary Recommendations to the 1000 h test.

The rather straightforward Shell Dep multiplication factors for the 1000hrs test pressure of pipes and fittings can clearly be communicated with engineering bureaus and end users. The multiplication factors are realistic, not conservative and do have a proven track record over the last 30 years.

- It is recommended to end users to be as close as possible to the Shell DEP multiplication factors with adding the diameter 400 mm for the testing.
- Test at independent institute.
- Weight samples upfront the 1000 h test, this weight is the minimum weight for supply.
- Determine at strategic places the wall build-up and wall thickness e.g. Neck area bell of a pipe etc.
- Supplier shall demonstrate reproducibility of their products.

Remark: sometimes it is stated that 90% of the weight of the fitting is also OK. If that is true then test the fitting with the 90% weight and if this one is OK test the one with 90*90 % weight and so on. Somewhere you will find that the 90% of the weight will not function. This means the tested weight is the minimum weight.

Diameter <= 1200 mm All type of components in project#				
Diameter mm	Design pressure	Test temperature	Test pressure	*Qualified range& pressure rating*
250	20 bar	65°C	48.0 bar	[25-250] & 20 bar
400	20 bar	65°C	48.0 bar	[250-400] & 20 bar
600	20 bar	65°C	48.0 bar	[400-600] &20 bar
800	20 bar	65°C	48.0 bar	[600-800] & 20 bar
1200	20 bar	65°C	48.0 bar	[800-1200] & 20 bar

Table 19: Example recommended tests required acc. author and diameter ranges, required life time20 years acc. Shell DEP multiplication factor = 2,4.

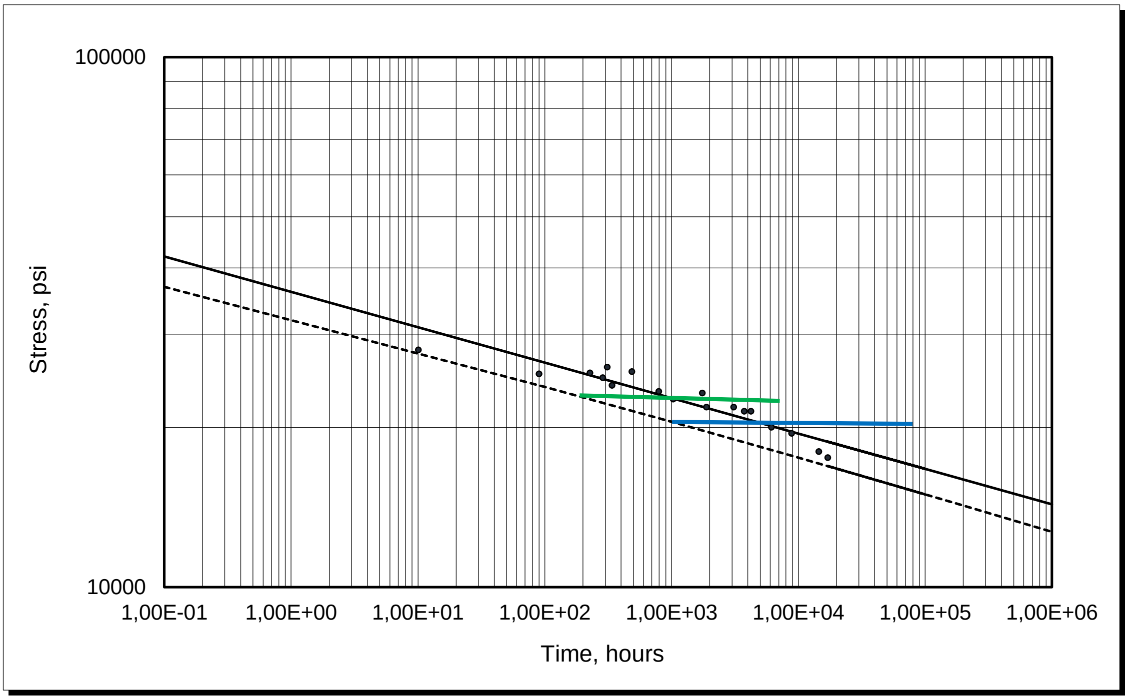
unless otherwise agreed and specified between principal and supplier

Multiplication factors static			
Design Temperature	**<=65 C**	**>65 C**	**Default LCL**
Required design life	X	Y	Z
20 years	2.4	2.6	**Default LCL**
20+n*10 years	$(1.03)^n*2.4$	$(1.03)^n*2.6$	**Default LCL/{**$(1.03)^n$}
60 years	**$(1.03)^4*2.4$ = 2.70**	**$(1.03)^4*2.6$ =2.93**	

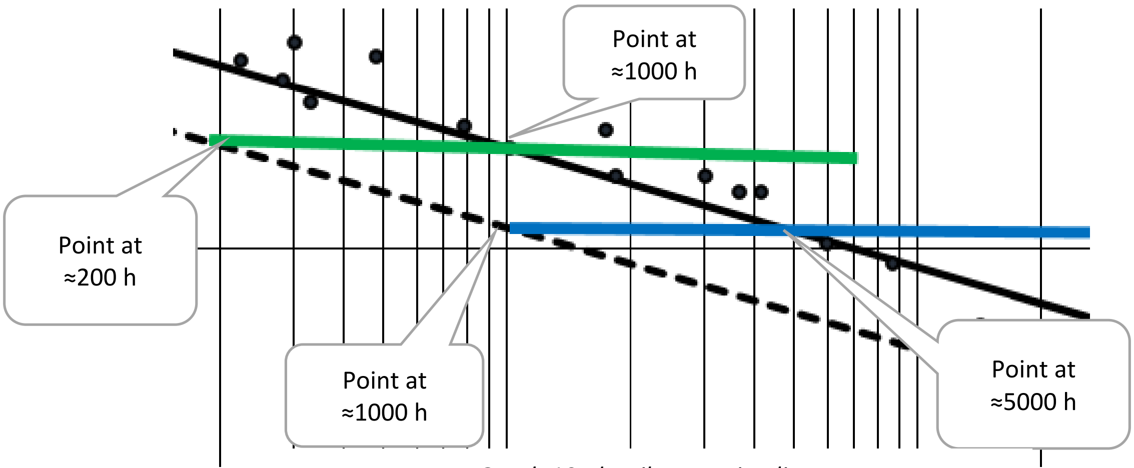
Table 20: multiplication factors.

18. What is the influence of the f1 factor ?

The f1 term was the partial factor that provided a measure of the degree of scatter in the long-term pressure tests but has not been adopted in the revised version. If a 1000 h test was done with an internal pressure corresponding to the blue line then it intersects at 1000 h the LCL (dotted line) and at 5000 h the regression line. This is just an example to demonstrate the impact of the f1 factor and accepting that when the 1000 h test passed the dotted line it is OK. Vice versa for the green line if the intersection point lies on the regression line the corresponding time is about 200 h.
f1 does not appear but is still in it because f1 is in the ASTM D2992.



Graph 9: regression line



Graph 10: detail regression line

19. IMO L3 Test

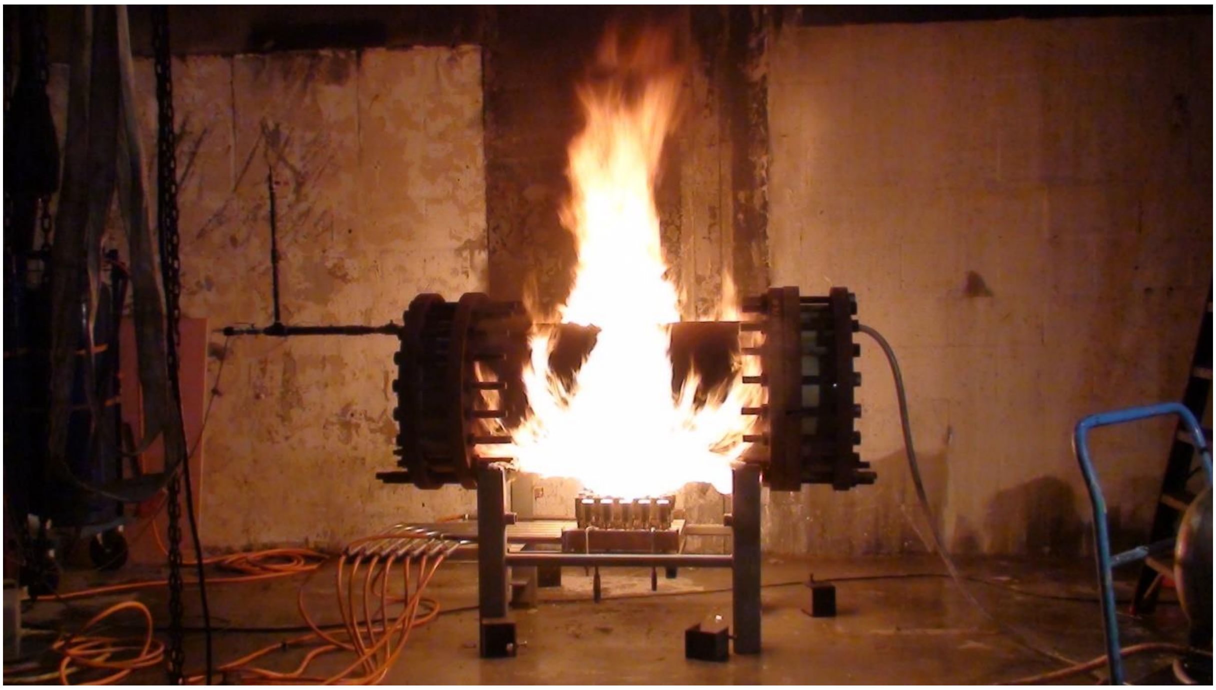
Amendments to the International Convention for the Safety of Life at Sea (SOLAS) to make mandatory the International Code for the Application of Fire Test Procedures (2010 FTP Code) were adopted by the IMO's Maritime Safety Committee (MSC) in December 2010. The 2010 FTP Code, along with relevant SOLAS amendments to make it mandatory, was adopted, and entered into force in July 2012.

The 2010 FTP Code provides the international requirements for laboratory testing, type-approval and fire test procedures for products referenced under SOLAS chapter II-2. It comprehensively revises and updates the current Code, adopted by the MSC in 1996. The 2010 FTP Code includes the following fire tests:

- Combustibility;
- Smoke and toxicity;
- Fire test for “A”, “B” and “F” class divisions;
- Fire door control systems;
- Surface flammability (surface materials and primary deck coverings);
- Vertically supported textiles and films;
- Upholstered furniture;
- Bedding components;
- Fire-restricting materials for high-speed craft;
- Fire-resisting divisions of high-speed craft.

It also includes annexes on Products which may be installed without testing and/or approval and on Fire protection materials and required approval test methods.

To give an impression about the IMO L3, use following link:
https://www.youtube.com/watch?v=aZkcLM07XH8, or go to www.grpcenter.com



20. Competency Certification

What is the set-up of a certification scheme?

Demonstration of competency is very important to produce acceptable products. A driving licence for a car is an equivalent to the DNV GL certification. In fact, the rules valid for the DNV GL certification are similar to those for a driving licence, see Table 21 for a comparison.

The certification scheme is now well established regarding the GRP bonders, - spool builders - pipe fitters, supervisors and inspectors must be operated by an independent and accredited certification body, working in full compliance with the ISO 17024. The certification body shall be acceptable to the principal and authority having jurisdiction in the country of intended application.

The independent and accredited certification body shall be independent of the organizations that carry out the training. The training courses shall be conducted by suitably competent organizations.

The certification scheme must be accepted, developed and maintained through structured input and commitment of both end users and manufacturers.

An independent examination committee shall validate the exams and examination methods, the examination committee shall consist of, but not be limited to: experts in the field of installing GRP piping systems, examination experts, GRP project leaders. This committee must be active and ongoing.

The certification body shall have the authority to issue, suspend and revoke the certificates and shall maintain a public register of all certificates and their status.

The final certificate shall clearly state the certified pressure ratings, diameters, resin type, joint types and manufacturer(s) of the GRP piping systems.

DNV

DET NORSKE VERITAS

CERTIFICATE OF COMPETENCE

CERT-GRPIN-20140528-10001

Det Norske Veritas Certification B.V. certifies that:

Name of the certificate holder : J. Steen
Date of birth : 6 December 1957
Place of birth : Den Ham, The Netherlands

Has fulfilled the conditions to be certified as:

RTR / FRP / GRP Inspector
Glass reinforced Plastics (GRP/RTR) pipe installations,
Competence profiles section, Attachment D2-2

Date of examination : 28 May 2014
Place of examination : Barendrecht
Country of examination : The Netherlands
Examination organisation : DNV supervision

This Certificate of Competence is valid only after the certificate holder has signed, as per examination date until 28 May 2016. The validity conditions of this Certificate of Competence are specified in the relevant standard, endorsed by the DNV Certification Committee of GRP pipes Attachment D1 and relates to ISO 14692. See reverse side for the information statement by employer and prolongation by Det Norske Veritas Certification B.V. Additional information can also be stated in the column "supplementary remarks".

Thus agreed and signed,
The certificate holder:
Signature

Barendrecht, 2 June 2014
For Det Norske Veritas Certification B.V.
Signature

A.A. den Boer
Stamp

This certificate is property of Det Norske Veritas Certification B.V. By misuse of this Certificate of Competence, this certificate will be declared null and devoid. Det Norske Veritas Certification B.V. is registered at the Dutch College Bescherming Persoonsgegevens ("protection of personal data") by number m1012137. Det Norske Veritas Certification B.V. P.O. Box 9599, 3007 AN Rotterdam. Tel. int.:+31 10 2922810. Fax:+31 10 4979622. Email: [illegible]

The principal, contractor, engineering company, end user or GRP manufacturer shall take care that only qualified and certified GRP bonders, - spool builders - pipe fitters, supervisors and inspectors are assembling GRP pipes and fittings (assembling=jointing, laminating, etc). Even people who are doing, e.g. “only mixing of adhesive”, or “only grinding” or similar shall also be certified. When not certified one is not permitted to assemble a GRP piping system. It is not permitted to start installation before the GRP bonders, - spool builders - pipe fitters, supervisors and inspectors are trained and certified.

The DNV GL certification scheme fulfils all the above mentioned conditions and has demonstrated compliance with the ISO standard for GRP piping system builders.

Item	Driving licence	DNV GL certificate
1. Defined competence profile	Yes	Yes by the market
2. Defined examination requirements	Yes	Yes by experts in the field of GRP
3. Adjustments of examination requirements in time	Yes	Yes
4. Training	Yes/ driving schools	Yes/trainers (independent or manufacturers)
5. Theoretical and practical part	Yes	Yes
6. More than 1 competence profile	Yes (car, truck, heavy goods vehicles)	Yes (GRP bonder/jointer, spoolbuilder, pipefitter, supervisor, inspector)
7. Validity	Yes (5-10 years)	Yes (2 years)
8. Renewal	Yes	Yes (when proving: worked with GRP)
9. Central public database	Yes	Yes
10. The licence can be revoked e.g. due to misconduct	Yes	Yes
11. Appeal	Yes	Yes
12. Written and practical part examination independent	Yes/government	Yes/ ISO 17024
13. Trainer is NOT examiner	Yes	Yes
14. Re-exam	Yes, n-times	Yes, n-times

Table 21. Comparison Driving licence and DNV GL certificate.

21. Independent Training (the next level)

The preparation of a craftsman for the exam and consequently certification must start with a training which meets the requirements set out in the examination documents. In the next table an overview is given about the differences between a trainer from a manufacturer and an independent trainer. In the opinion of the Author the next level in the preparation of a candidate must be an independent. This would make the GRP world again more mature and aspiring to the present level of welding certification. Which steel manufacturer provides training in welding…? This part was already handled for several decades by professionals and is well established in the steel industry. There are not any questions left unanswered by the market.

The ISO 14692 has made the initial step some years back but the standard is still governed far too much by the pipe manufacturers, which for no sound reason stick to their primitive, photo shopped certification programmes which are so negative for GRP market growth! True Independence one cannot find and examination goes along as part of the training at the same time which means the training is the examination and the trainer is the examiner! When you compare that approach to your driving licence…… what would then be your opinion...? More accidents!

End users are lacking the time and are missing the knowledge to influence this part 4 of the ISO 14692 towards their required direction. It should in fact be the opposite as there is an easy cost saving expense to find for their companies in eliminating accidents and mistakes in installation.
Bottom line: A wise economical approach is to go for an independent trained and DNV GL certified craftsman from bonder/jointer up to inspector.

	Trainer manufacturer	Independent trainer
1. Competence trainers	Yes, mostly	Yes, mostly
2. Education material	Glossy product brochure, not mentioning failures in the field	More additional facts
3. Procedures	Limited	Missing items, adding explanation to them
4. Speak about mishaps of product, assembly, installation and hydrotests	Limited	Yes, adding “many” mishaps, focus on learning from mistakes
5. Weakness of product e.g. type of joint	Limited	Yes
6. Free to speak about quality product manufacturer	Limited	Yes, given in an independent, unbiased manner
7. Comparison with other manufacturers and differences	Not done	Yes, given in an independent and unbiased manner
8. Ensuring open communication and responses on questions/ problems from the field installation	Some of the time, providing there is nothing to hide	Providing frank and unbiased assessments to provide the best solution for all parties

Table 22. Comparison Trainer manufacturer and Independent trainer.

22. Disclaimer

This literature is intended for use by personnel having specialised training in accordance with currently accepted industry practice and engineering. We recommend that users verify the suitability of this document for their intended application. Since we have no control over the conditions of service, we expressly disclaim responsibility for the results obtained or for any consequential or incidental damages of any kind incurred.