# GRP Pipe Systems
New Standardisation Developments

Thomas Simoner
Product Compliance and Quality Management

Amiblu®

Amiblu Europe - We are where you are

- Largest global GRP pipe technology centre in the World and the home of Hobas and Flowtite
- 6 GRP pipe factories strategically located within Europe
- 40 partners around the world
- 1500 employees in Europe
- References and installations all over the world with different installation methods like open cut, above ground, trenchless (jacking, relining),…

- Sewage systems
- Renovation systems
- Bridge drainage systems
- Drinking water supply
- Industrial applications
- Power plant pipelines
- Irrigation systems
- Storage Tanks

Sales office
Production plant

2

Production Process
Centrifugal Casting
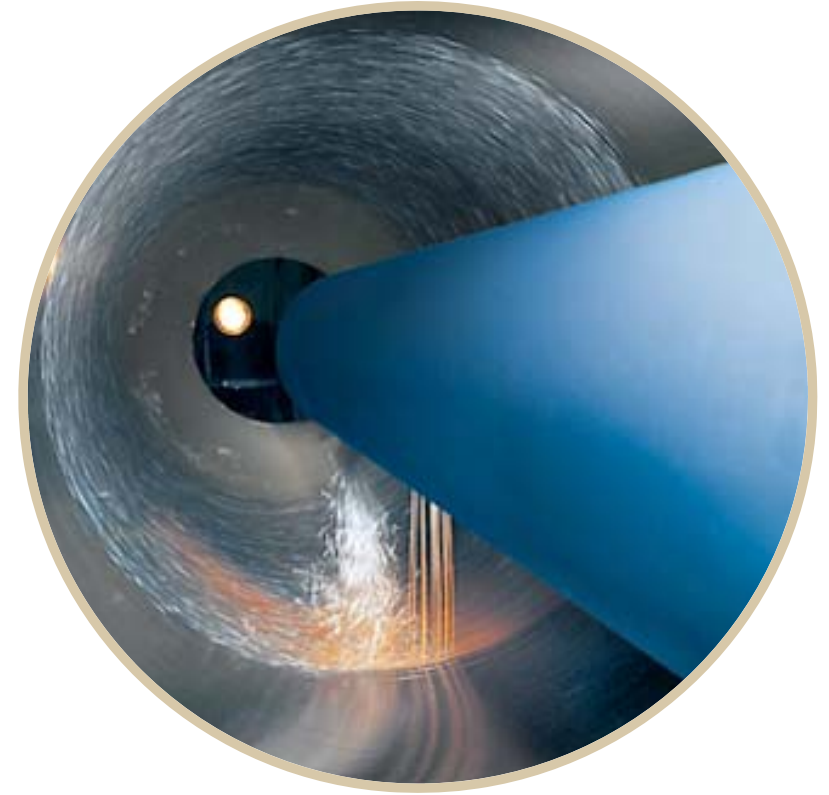
Amiblu CC-GRP (Centrifugally Cast Glass-fiber Reinforced Plastics) pipes are based on fiber reinforced composite materials made of unsaturated polyester or vinyl ester (VE) resins (UP), chopped glass fiber and minerals. These raw materials are progressively fed into a rotating mold, thus building up the wall structure from its exterior surface.

Amiblu

3

Production Process
Continuous Filament Winding

The fiberglass filaments are wound on in a continuous process involving continuous glass-fibers, chopped glass, specially selected fillers and resins. The strength of the pipes is determined by the mixing ratio for the various components.
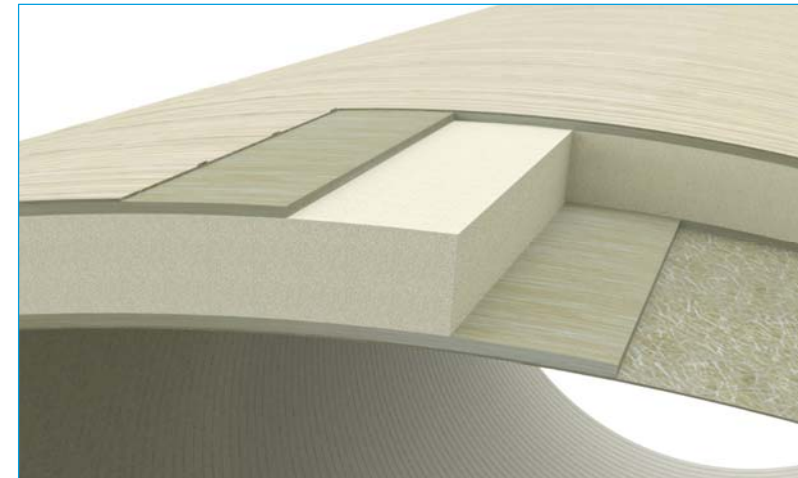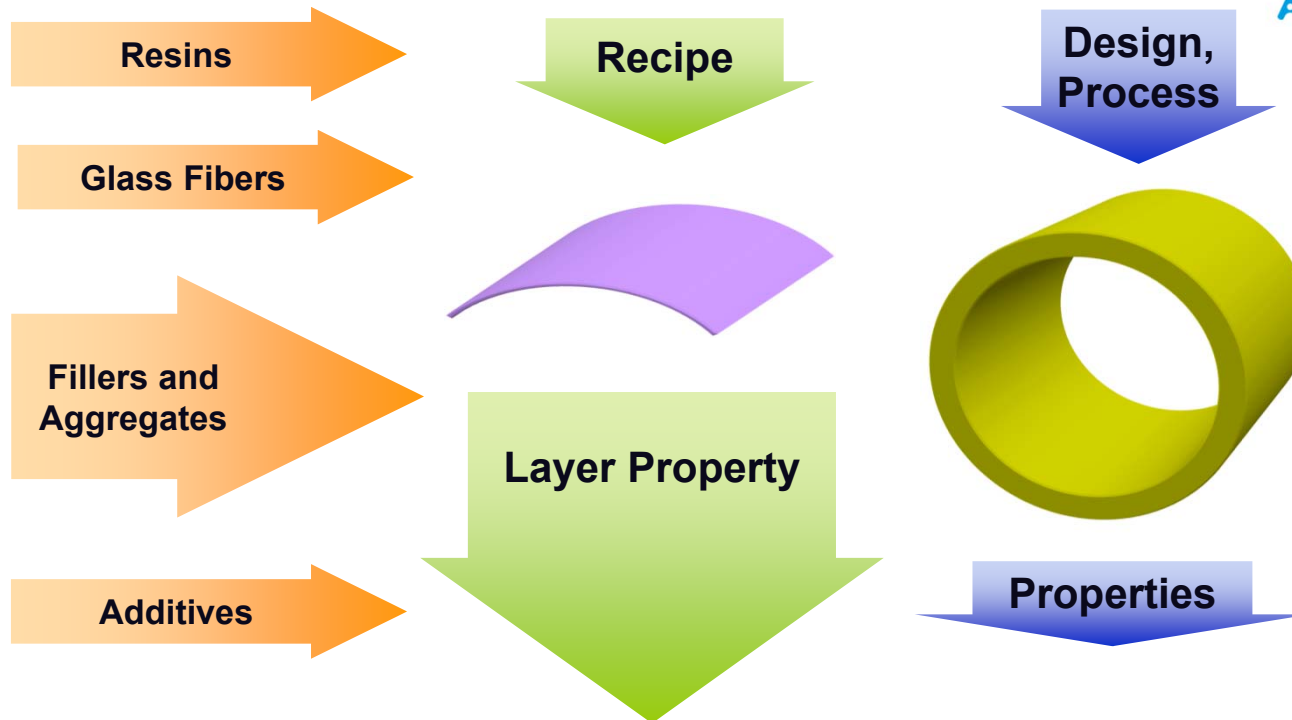
Amiblu

Composites
Fiber-Reinforced Composites
Tailor Made Product Design

Resins

Glass Fibers

Fillers and Aggregates

Additives

Recipe

Layer Property

Design, Process

Properties
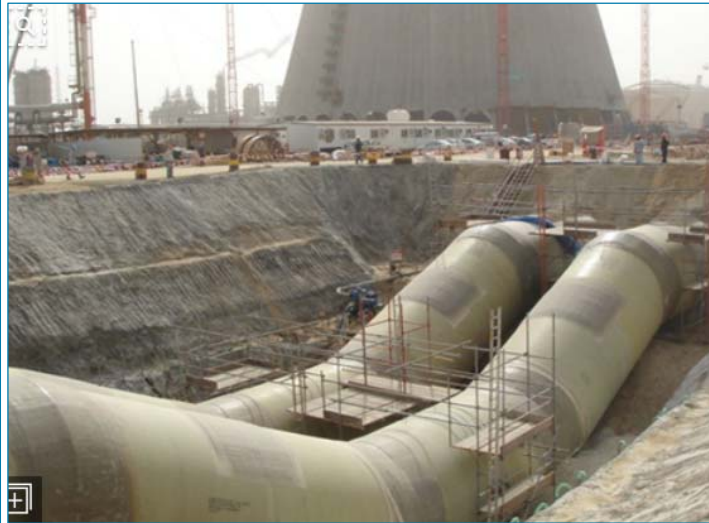
Glass Fiber Reinforced Plastics Pipes
Applications

New normative requirements for GRP pipes for water supply, drainage and sewerage

ISO/TC 138/SC 6 and CEN/TC 155/WG 14

Standardization Committees
ISO/TC 138/SC 6

- **ISO/TC 138** "Plastics pipes, fittings and valves for the transport of fluids"

- **ISO/TC 138/SC 6** "Reinforced plastics pipes and fittings for all applications"
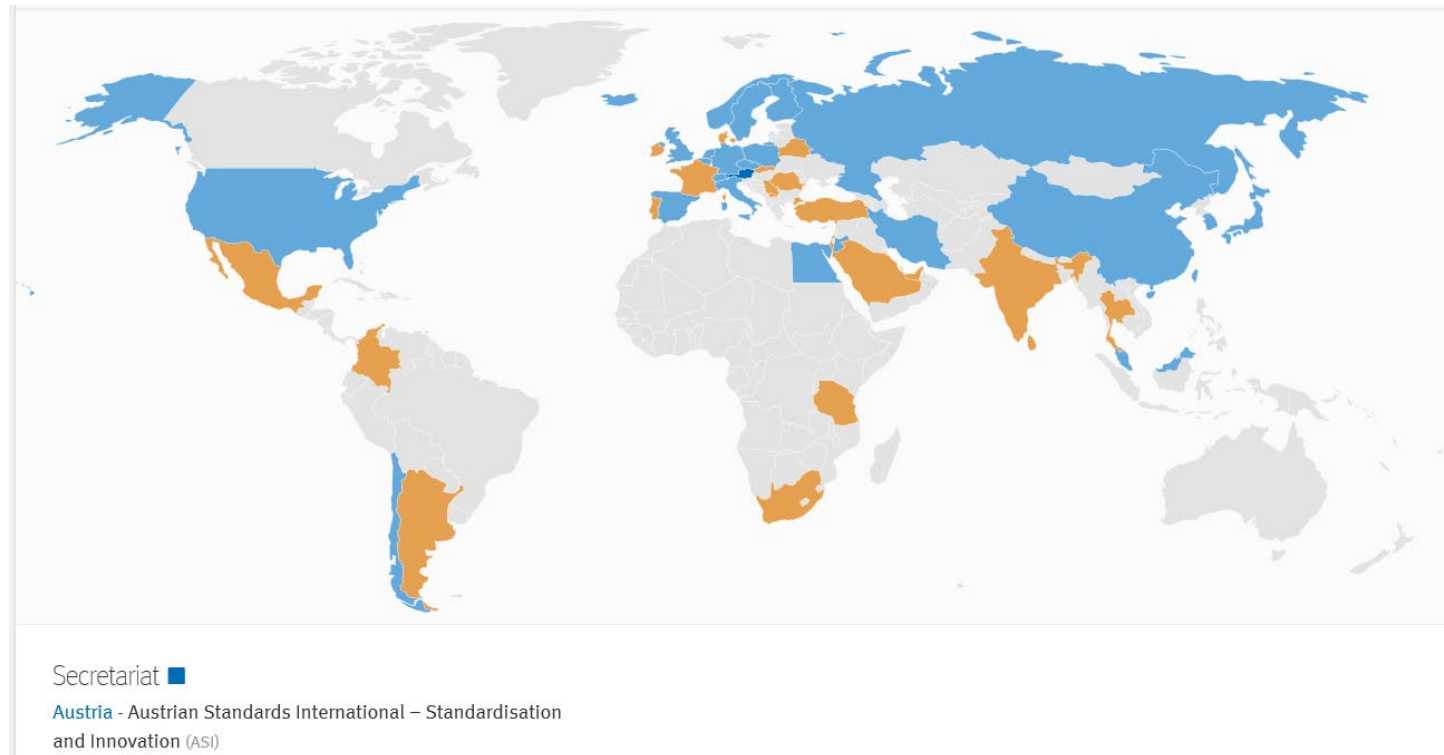
Established in **1983**

24 participating members

21 observing members

34 published standards

08 standards under development

Secretary by **Austrian Standards** (ASI, ÖNORM)

Secretariat ■

Austria - Austrian Standards International – Standardisation and Innovation (ASI)

Source: www.iso.org

Participating Members (24) ■   Observing Members (21) ■

8

Standardization Committees
ISO/TC 138/SC 6 and CEN/TC 155/WG 14

**Structure of Documents
The main activity is on the
ISO standardization level**

- **ISO/TC 138/SC 6/TG 1** "Design and test methods"

- **ISO/TC 138/SC 6/WG 1** "Methods of test"

- **ISO/TC 138/SC 6/WG 3** "Specifications for pipe systems"

- **ISO/TC 138/SC 6/WG 5** "Installation"

- **CEN/TC 155** "Plastics piping systems and ducting systems"

- **CEN/TC 155/WG 14** "Systems of glass-reinforced thermosetting plastics for all applications - Polyester, epoxy and polyester resin based concrete"

Amiblu®
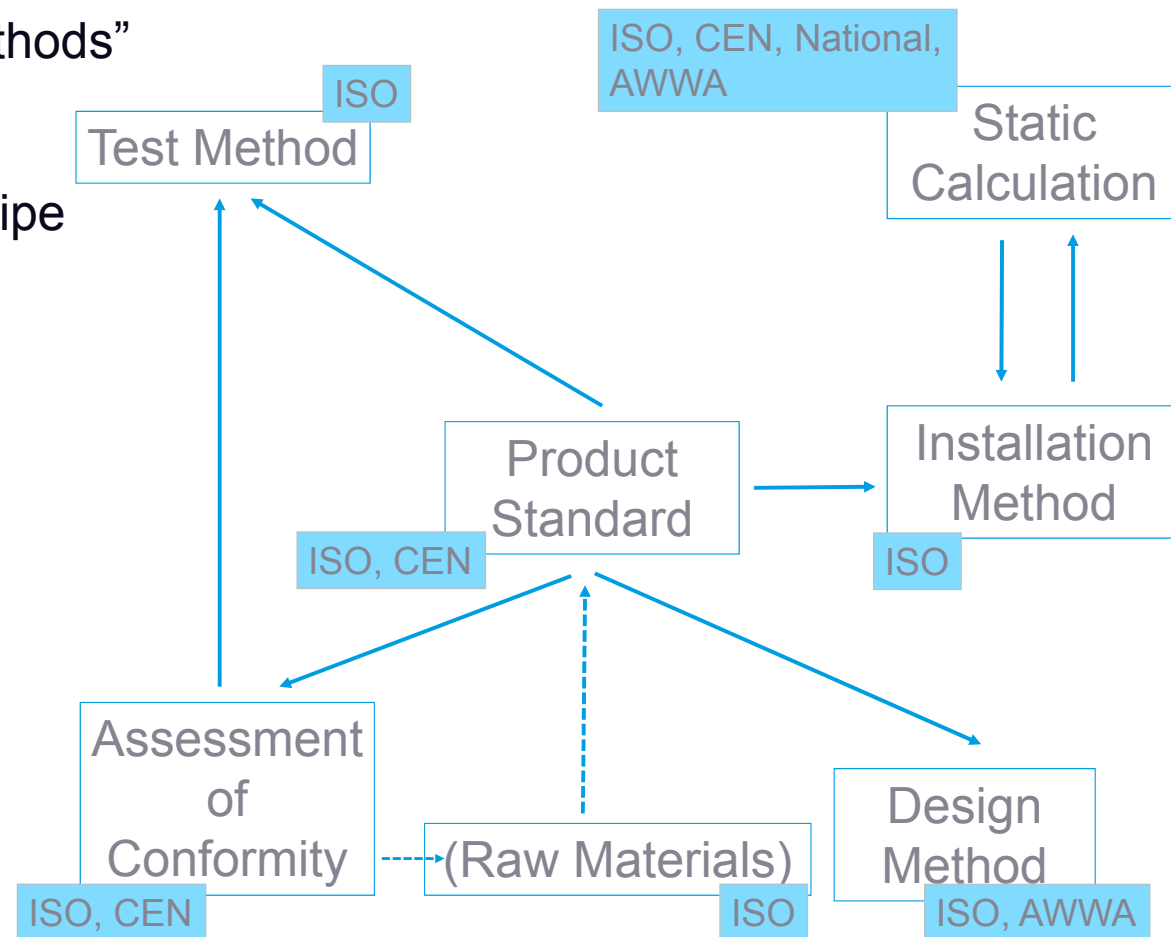
ISO/TC 138/SC 6 and CEN/TC 155/WG 14
Important GRP Pipe Standards

EN 1796
Plastics piping systems for water supply and for drainage and sewerage with or without pressure – Pipes, joints and fittings made of glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP)

EN 14364
Plastics piping systems for drainage and sewerage with or without pressure – Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP)

CEN/TS14632 Plastics piping systems for drainage, sewerage and water supply, pressure and non-pressure – Glass-reinforced, thermosetting plastics (GRP) based on polyester resin (UP) – assessment of conformity

EN 15383
Plastics piping systems for drainage and sewerage – Glass reinforced thermosetting plastics (GRP) based on polyester resin (UP) - Manholes and inspection chambers

ISO 10467
Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) Piping systems for pressure, and non-pressure, drainage and sewerage]

ISO 10639
Plastic piping systems for water supply, with or without pressure – Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin

ISO 16611
Plastics piping systems for drainage and sewerage without pressure - Non-circular pipes and joints made of glass-reinforced thermosetting plastics

ISO 25780
Plastics piping systems for pressure and non-pressure water supply, irrigation or drainage and sewerage. Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin. Components intended to be installed using trenchless construction techniques

New publications and improvements
ISO 16611 non-circular GRP pipes for renovation

ISO 16611:2017: "Non-circular pipes and joints made of glass-reinforced thermosetting plastics"

Document was based on an Austrian standard (**ÖNORM B 5163**) and a Belgian product specification (**BCCA PTV 652**) with specifications:

- for raw materials;
- dimensions and tolerances;
- short-term properties;
- long-term properties;

Mainly based on declared values that are used for static calculations
- Flexural strength (σ_b)
- Flexural modulus (E_b)
- Flexural strain at break (ε_b)

Amiblu®

New publications and improvements
ISO 16611 non-circular GRP pipes for renovation

**Difficulty how to perform reliable term tests on non circular products?**

Short-term properties: Samples are cut from sections with a **low curvature**.

Long-term properties: Type tests, that are carried on **circular products** that are made with the same materials, design and process as non-circular products.

→ Make usage of well established testing methods;

→ Elimination of geometry inaccuracies and static undefined loading conditions;

Strain Corrosion test method (ISO 10952) can also be used for determination of long-term bending strength
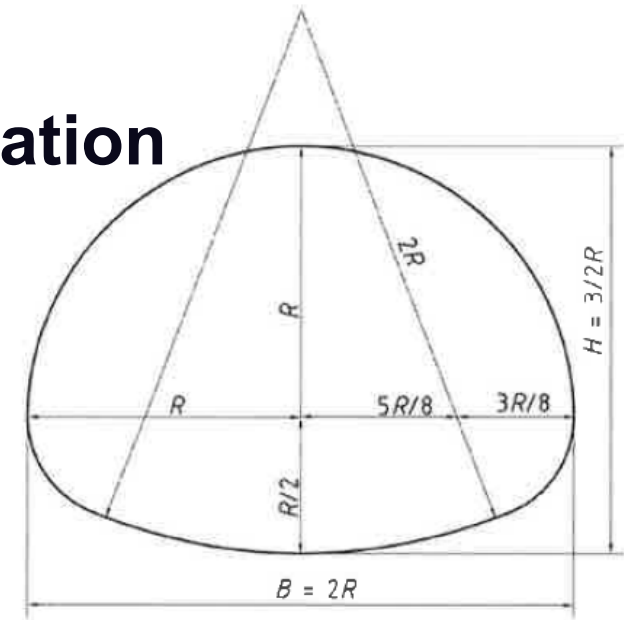
$$\sigma_{circ} = \frac{6 \cdot f\text{max} \cdot \frac{d_m}{2} \cdot \frac{1}{\pi}}{l \cdot e^2} \cdot \alpha_{ki} \qquad \alpha_{ki} = \frac{3 \cdot d_i + 5 \cdot e}{3 \cdot d_i + 3 \cdot e}$$

12

New publications and improvements
ISO 10639 and ISO 10467for GRP pipes for water supply, drainage and sewerage

ISO 10639:2017: "Plastics piping systems for pressure and non-pressure water supply - Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin"

ISO/FDIS 10467:2018: "Plastics piping systems for pressure and non-pressure drainage and sewerage -- Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin"

- Both standards were initially published in 2004;

- The only difference in the documents are requirements against chemical attack form the inside which is only mentioned in ISO 10467;

- A major revision on ISO 10639 was started in 2015;

- Based on ISO 10639, the drainage and sewer document ISO 10467 was adopted;

- The ISO documents will a model for the revision on the CEN standards;

Amiblu®

New publications and improvements
Major modification and improvements in the product standards
ISO 10639, ISO 10467

Following improvements have been taken into account during the revision of the product standards:

(1) Inclusion of a guidance for design practices which are based on a partial safety factor concept and risk management engineering, as well as inclusion of the probability of failure and possible consequences of failures → this included the development of a new standard **ISO/TS 20656-1**;

(2) References were made to the general principle for the **reliability of structures** detailed in ISO 2394 and EN 1990 (Eurocode);

(3) Clear reference for **assessment of conformity** → reference to **CEN/TS 14632**;

(4) Inclusion of **pressure tests requirements for fittings**;

(5) Inclusion of **mean-term pressure tests for joints** and inclusion of **bending test requirements for joints** based on CEN product standards → by modification of joint test methods

(6) Complete modification of Annex A for the establishment of the **design requirements**

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

- The previous pressure requirements were based on a so called sliding safety factor concept depending on the pressure classes. The safety factor is depending on the pressure class, variations of the material deviation are taken into consideration.

Pipe to which safety factor is to be applied	PN 32	PN 25	PN 16	PN 10	PN 6	PN 4	PN 2,5
Minimum safety factor, $\eta_{t, PN, 97,5\% LCL}$, to be applied to the long-term 97,5 % LCL	1,3	1,3	1,45	1,55	1,6	1,65	1,7
Minimum safety factor, $\eta_{t, PN, mean}$, to be applied to the long-term mean	1,6	1,6	1,8	1,9	2,0	2,05	2,1

Minimum and mean long-term pressure safety factors as given in EN 1796, EN 14364 (2013), ISO 10639 and ISO 10467 (2004)

- Partial safety factors for e.g. the effects of actions and the material resistance are not taken into consideration.

- There is no guidance for adjusting safety factors based on the risk in operation. There is no base for an adjusted design based on a risk management.

- There was a need identified to adjust the relevant product standards and start to align them also with the partial safety factor concepts described in the **Eurocodes EN 1990** or in **ISO 2394**.

Amiblu®

15

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

- The safety factor is based on **combined safety** factors based on the **effect of the action and the material resistance** (structural resistance). Basic model is shown in EN 1990 and ISO 2394. Default parameter are given in the product standard to calculate a base design

- **Uncertainties** in pressure (action) and material shall be taken into consideration.

- Pressure safety factor is independent from the pressure class (similar to the AWWA M45).

- The process consist of minimising the risks involved compared with the perceived costs. A **risk analysis for projects** shall be made to select appropriate safety classes and quality measures.

- Possibility of adding additional safety factors due to e.g. higher service temperature, chemical attack (see also the concept which is given in EN 13121-3)

- Clear definition of the quality criteria for the pressure test (requirements for the BRT -> batch release test)

Amiblu®

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

Table 2 — Consequence classes as defined in EN 1990:2002, Table B.1

Consequence class	Description	Examples of pipelines	Minimum value for β
CC3	High consequence for loss of human life, or economic, social or environmental consequences very great. Significant damage to the qualities of the environment contained at national scale but spreading significantly beyond the surroundings of the failure event and which can only be partly restored in a matter of months.	Major water supply and sewerage pipes within cities, transmission lines without back-up, oil and gas pipelines.	4,2
CC2	Medium consequence for loss of human life, economic, social or environmental consequences considerable. Damage to the qualities of the environment limited to the surroundings of the failure event and which can be restored in a matter of weeks.	Major water supply and sewerage pipes within cities, transmission lines with back-up, penstocks where flooding can wreak havoc.	3,7
CC1	Low consequence for loss of human life and economic, social or environmental consequences small or negligible. Damage to the environment of an order which can be restored completely in a matter of weeks.	Irrigation, small and remote penstocks.	3,1

β is based on a 50 year design life.

Amiblu®

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

Table 4 — Quality levels

| Quality level (QL)	Consequence class	Description	Control organism for specification of requirements and checking
QL3	CC3	Extensive quality level associated to extended measures for quality management, inspection, and control	Besides self-control and systematic control, independent party control shall also be executed: specification of requirements for quality management, assurance, and control, as well as the checking performed by an organisation different from that which has prepared the stage of the life cycle involved. Intensive supervision and inspection during construction of the structural main bearing system by well-qualified people with an expert knowledge (e.g. with respect to design and/or execution of structures).
QL2	CC2	Increased quality level	Specification of requirements for quality management, assurance, and control, as well as the systematic checking performed by self-control, as well as by different persons than those who prepared the stage of the life cycle involved and in accordance with the procedure of the organisation. Increased effort with respect to supervision and inspection during the construction of the structural key elements.
QL1	CC1	Basic quality level	Self-control: specification of requirements for quality management, assurance, and control, as well as the checking performed by the person who has prepared the stage of the life cycle involved.

Amiblu

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

Effects of action (internal pressure)

- Model uncertainty
- Uncertainty of pressure
- Uncertainty of long-term pressure
- Uncertainty of short-term pressure (surge)
- Uncertainty of thickness and Modulus
- Uncertainty of diameter
- Risk classification

Material resistance (internal pressure)

- Short- and long-term resistance
- Conversion factor short- to long-term resistance
- Coefficient of variation of material properties
- Availability of statistically verified material properties
- Process stability
- Lifetime, service time
- Etc.

Probability Density
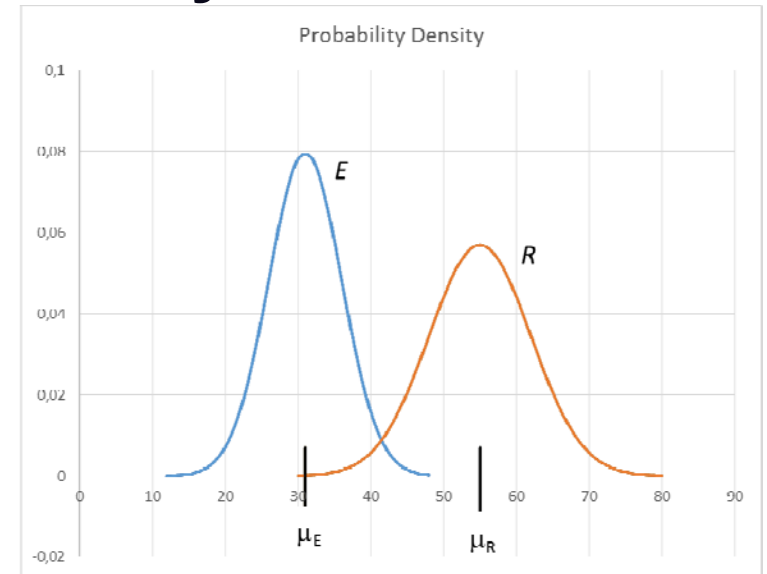
$$E_d = \mu \times (1 - \alpha \times \beta \times V)$$
$$R_d = \mu \times \eta \times (1 - \alpha \times \beta \times V)$$

μ mean value
α sensitivity factor, tabled value
β reliability index *(depending on possible failure consequences)*
V coefficient of variation
η conversion factor from short to long term property

Amiblu

19

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

Example of calculation of the combined uncertainty for strain as given in ISO/TS 20656-1

Pipe

$\varepsilon = 0,00233$
DN 600 (r=303 mm), t=10 mm, E=13000 N/mm²

$$u_\varepsilon^2 = \left(\frac{r}{t_R \times E_{ht}}\right)^2 \times u_p^2 + \left(\frac{p}{t_R \times E_{ht}}\right)^2 \times u_r^2 + \left(\frac{p \times r}{(t_R \times E_{ht})^2}\right)^2 \times u_{tE}^2$$

$$u_\varepsilon^2(y) = \left(\frac{303}{10 \times 13000}\right)^2 \times (1 \times 0,1)^2 + \left(\frac{1}{10 \times 13000}\right)^2 \times (0,004 \times 303)^2 + \left(\frac{303 \times 1}{(10 \times 13000)^2}\right)^2 \times$$

$$\times (0,05 \times 10 \times 13000)^2 = 54,3 \times 10^{-9} + 0,087 \times 10^{-9} + 13,6 \times 10^{-9} = 68,0 \times 10^{-9}$$

$\longrightarrow \quad u_\varepsilon = 0,00026$.

With a strain of 0,003 the variation becomes:

$v = 0,00026/0,00233 = 0,112$.

where
$u\varepsilon$ is the combined uncertainty;
up is the uncertainty of internal pressure;
ur is the uncertainty of pipe radius;
utE is the uncertainty of pipe wall thickness and modulus;
r is the mean pipe radius;
p is the internal pressure;
tR is the thickness of the load bearing layers (i.e. excluding liner and protective layers) of the laminate of the pipe in service;
Eht is the circumferential tensile modulus of the laminate.

Amiblu®

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

$$\gamma_p = (1 + 0.7 \times 3.7 \times 0.11) \times 1.01 \times 1.004$$

$$\rightarrow \quad \gamma_p = 1.3$$

- The partial safety factor can be calculated using the variation from the combined uncertainty in the strain.
- An error of the calculation model depending on using the inner or mean diameter for the pressure calculation (see ISO 20656-1 section 5.2) shall be taken into consideration.
- Correction factor for increased diameter under pressure.

Table 8 — Partial factor for long-term pressure with pressure as dominating action ($\alpha = -0.7$)

Consequence class	Probability of failure p_f	Reliability index β	Partial factor for pressure γ_p
CC3	10^{-5}	4,2	1,36
CC2	10^{-4}	3,7	1,3
CC1	10^{-3}	3,1	1,28

Amiblu®

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

For the reliability class RC2 and a coefficient of variation of the material not higher than 0,09 the partial material factor for pressure can be calculated as:

$$\gamma_{mp} = (1 - 1,64 \times 0,09) / (1 - 0,8 \times 3,72 \times 0,09) = 1,16$$

$\rightarrow \quad \gamma_{mp} = 1,16$

Table 13 — Partial factor for pressure resistance assuming a coefficient of variation of 0,09

Reliability class	Probability of failure p_f	Reliability index β	Resistance multiplier	Partial factor for ultimate limit state	Partial factor for use with lower confidence level γ_{mp}
RC3	10^{-5}	4,4	0,69	1,45	1,23
RC2	10^{-4}	3,8	0,73	1,37	1,16
RC1	10^{-3}	3,3	0,76	1,31	1,11

Amiblu

New publications and improvements
Guidance for design practices based on the partial safety factor concept and the principles of reliability of structures

The following table (Table A.1) shows default values for the minimum design safety factor Fsmin ($\gamma_p \times \gamma_{mp}$) and are recommended for products meeting ISO 10639, ISO 10467 and ISO 25780

Table A.1 — Default values for known design parameters

Partial factor for use with lower confidence level γ_p	Partial factor for pressure γ_{mp}	Minimum safety factor FS_{min}
1,3	1,16	1,5

As an example that the uncertainties are doubled (10% in pressure and 18% in material, instead of 10 and 9%) the designer shall consider the following min safety factor

Table A.2 — Default values for design parameters with high uncertainties

Partial factor for use with lower confidence level γ_p	Partial factor for pressure γ_{mp}	Minimum safety factor FS_{min}
1,56	1,52	2,4

New publications and improvements
Requirements for pressure tests for fittings

A test method has been developed for pressure tests on fittings (ISO 18851). The test and requirements are included in the product standards (ISO 10639 and ISO/FDIS 10467)

Property to be tested	Test to be performed	Test pressure	Duration
Initial leakage	initial pressure	1,5 times PN	15 min
Resistance to internal pressure	maintained pressure	2,5 times PN	100 h

New publications and improvements
Increased requirements for pressure tests for joints

The joint method have been revised to include a mean pressure tests for couplings.

A bending test for restrained joints as specified in the CEN standards (EN 1796, EN 14364) are included in the joint test methods.

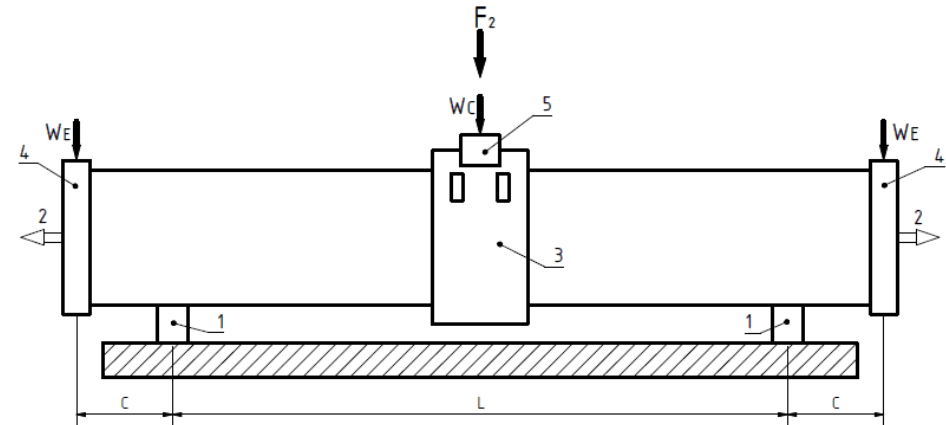The test and requirements are included in the product standards

Table 1 — Summary of test conditions for evaluating joints

Test	Pressure sequence	Minimum test pressure	Minimum duration
Draw	Negative pressure[a]	−0,8 bar (−0,08 MPa)	1 h
Angular deflection and draw	Initial pressure	1,5 × [PN]	15 min
	Positive static pressure	2 × [PN]	24 h
Deformation and draw	Initial pressure	1,5 × [PN]	15 min
	Positive static pressure	2 × [PN]	24 h
	Positive cyclic pressure[b]	Atmospheric to 1,5 × [PN] to atmospheric	10 cycles of 1,5 min to 3 min each
Draw	Positive static pressure	2,5 × [PN]	100 h

[a] Relative to atmospheric pressure, i.e. approximately 0,2 bar (0,02 MPa) absolute.

[b] Due to practical reasons (e.g. restriction of the test equipment such as pump capacities, etc.) the cycle time may be longer for larger DN and or higher PN.

New publications and improvements
Summary

(1) A new standard, **ISO 16611**, for non-circular products was developed and published in 2017

(2) The ISO product standards ISO 10639 and ISO 10467 (still as FDIS) were revised with major modifications and improvements.

- Pressure design based on partial safety factory concept and Eurocodes.

- Requirements for pressure tests on fittings to prove the structural design.

- Improved pressure requirements for joints and alignment of requirements of axially restrained joints with CEN requirements.

(3) A clear reference to the assessment of conformity document **CEN/TS 14632** has been made. Initial type tests should be done by accredited laboratories.

(4) The new product standards will be a model for the revision of the European product standards.

Amiblu®

Thank you.