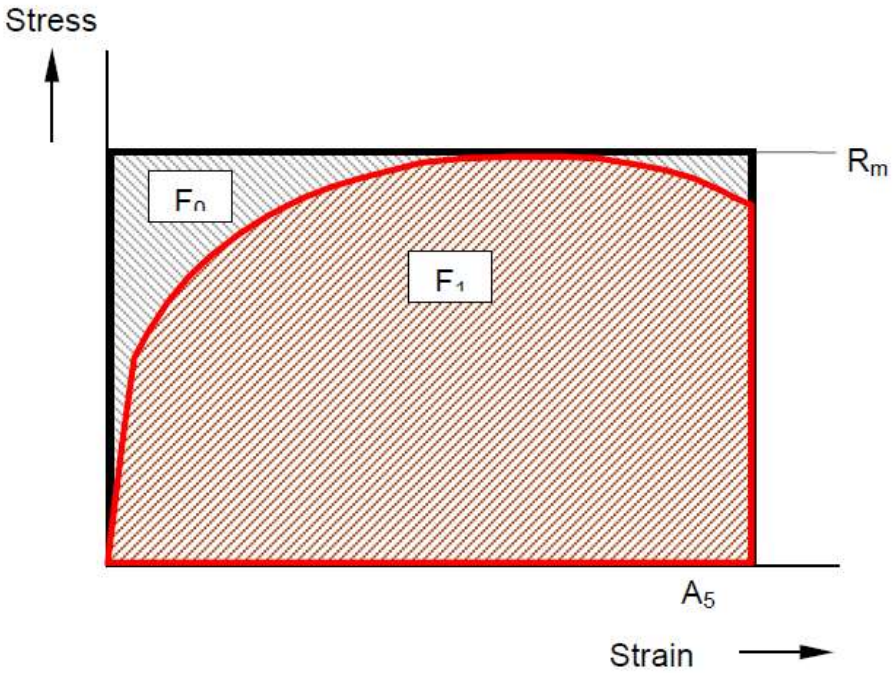
A Comparison between UN Model Regulations Ch 6.7 for metallic materials and Ch 6.9 for FRP materials used in the manufacture of UN Portable Tank shells

A comparison of shell design requirements which specify minimum tank wall thickness

Shell minimum thickness design considerations

Design Condition	Ch 6.7 Metallic Shells	Ch 6.9 FRP Shells
Test Pressure	Yes	Yes
MAWP + Pdyn	Yes	Yes
Resilience	Yes	No

What is the Resilience Energy of a material?



Area F_0: Strain energy (Ideal elastic-plastic behaviour)
Area F_1: Strain energy (Real stress-strain-curve)

Figure 2: ideal and real stress-strain-curves

How Does Ch 6.7 use Resilience to calculate minimum thicknesses?

BAM Research Report 203 by Germany in 1994

Demonstration that energy absorbed (or Work Done "W") in the penetration of a tank wall is proportional to a multiplication of:

- Thickness "e"
- Ultimate Tensile Stress "R_e"
- Elongation to Failure "A"

$$W \propto e \times R_e \times A$$

Government of Germany Paper to RID/ADR in 2001 (TRANS/WP.15/AC.1/2001/3)

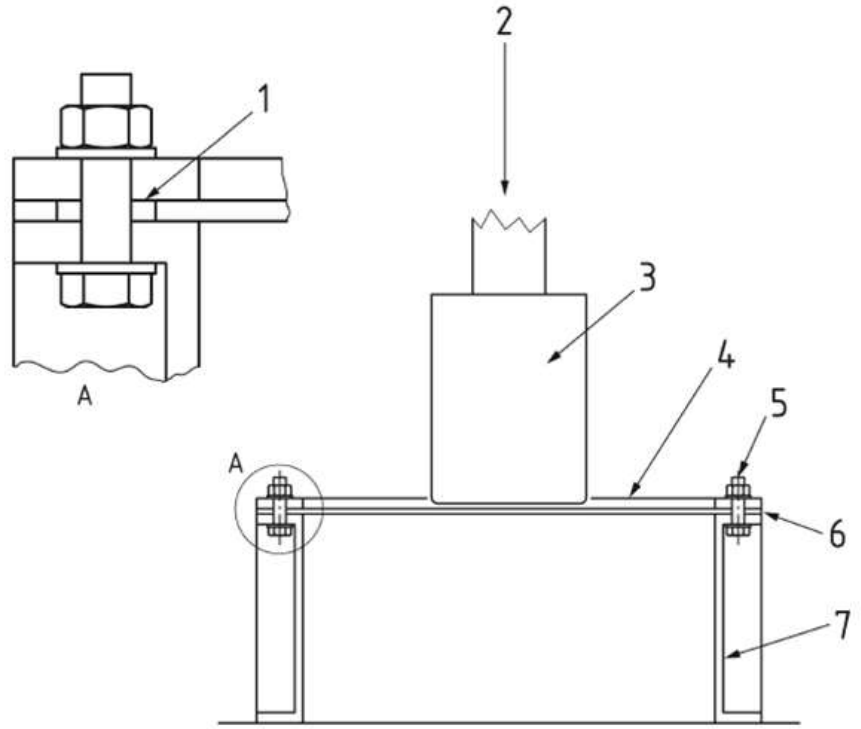
Introduced a formula to compare the minimum thickness required of proposed material of construction against a "Reference Steel" of 6mm/8mm/10mm

$$\frac{e_1}{e_0} = \frac{\sqrt[3]{(R_{m0} \times A_0)^2}}{\sqrt[3]{(R_{m1} \times A_1)^2}}$$

What laboratory testing did BAM (Germany) perform to demonstrate the resilience of materials of construction?

BAM Research Report 203 by Germany in 1994

EN 13094 2020 - Annex B



Key

1 for non-metallic test plates only – use clamp bolt sleeve (see Figure B.5)
2 test force F
3 test bar (Figure B.3)
4 clamping ring (Figure B.2)
5 20 bolts and nuts M 12 × 1,75 grade 8.8
6 test plate (Figure B.4)
7 body (Figure B.1)

What laboratory results did BAM publish?

BAM Research Report 203 by Germany in 1994

EN 13094 2020 - Annex B

Metal	e [mm]	W [kJ]	N.f.St. normalized specific resilience based on 6 mm MS = 1
Al Mg 4,5 Mn	4.0	4	0.18
	5.2	7	0.32
	7.8	12	0.55
Mild Steel	3.0	10	0.45
	5.0	17	0.77
	6.0	22	1.00
Austenitic Steel	3.0	28	1.27
	3.5	32	1.45

What provisions can we propose for Ch 6.9 so that FRP materials of construction are treated equally to metallic materials ?

6.9.2.4.1 Minimum thickness of the FRP shell shall be confirmed by check calculations of the strength of the shell considering strength requirements given in 6.9.2.3.4.

6.9.2.4.2 Minimum thickness of the FRP shell structural layers shall be determined in accordance with 6.9.2.3.4. However, this minimum thickness shall not be less than:

(a) that required to obtain a minimum "specific resilience" energy absorbed according to EN 13094:2020 annex B of:

(i) 22 kJ (or equivalent to 6 mm of reference steel) for portable tank instruction T1 to T19,

(ii) 30 kJ (or equivalent to 8mm of reference steel) for portable tank instruction T20,

(iii) 37 kJ (or equivalent to 10 mm of reference steel) for portable tank instruction T21-T22, and

(b) in any case the minimum thickness of the structural layers shall be at least 3 mm

What is the justification for making these proposals?

- Objective
  - to provide an "equivalent level of safety" between metallic and FRP UN Portable Tanks regarding shell resilience in accidents.
- Increase in FRP scope of use as UN Portable Tanks
  - New usage in Sea Mode in container ships (and therefore subject to intermodal handling by cranes worldwide)
  - New usage with Addition of Class 1 Explosives
  - New usage with an Increased products list from T11 (equivalent L4) to T15 to T22
- ITCO Reputation
  - Need to preserve the good reputation of safety and performance of all UN Portable Tanks
  - Tankwell and OmniTank are highly experienced and capable engineering businesses. It is important that regulations preserve public safety and also support such high quality businesses in the face of worldwide competition for manufacture of FRP Portable Tanks.

In Conclusion

- Thank you for listening
- I will be pleased to answer any questions either during or after the webinar