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Interpretation of RID/ADR/ADN

Response to INF.12/Rev.1

Application of standards for LPG tanks

Transmitted by AEGPL

Summary

Executive summary: In ADR 2015 the EN 12493:2013 standard "Welded steel pressure vessels for LPG road tankers - Design and manufacture" was added to the table under 6.8.2.6.1This is the correct standard for the design of dedicated LPG road tankers.

Action to be taken: No action is necessary

Introduction

INF 12 Rev.1 was submitted by Poland and contained calculations to show that if EN 12493:2013 + A1;2014 is used to design tanks for the transport of LPG that they would have thicker shells than if they were designed in accordance with EN 14025.

The calculation submitted in INF 12 Rev.1 for EN 14025 did not use the correct working pressure and were therefore incorrect. The calculations submitted for EN 12493:2013 + A1:2014 incorporated additional shell thickness that is required when a tanker is being used to pull a tank trailer.

Using the correct calculations (example below for one size of tanker) it can be shown that even with the increased thickness required by the tanker and tank trailer combination that the minimum shell thickness will be less than if designed to EN 14025:2013 (but will be greater than if the thickness is calculated using the formula in ADR).

There was also a question raised as to which standard should be used for the design of a tanker that is in LPG service - for tanks in dedicated LPG service the correct design standard is EN 12493:2013+A1:2014, this is indicated in the scope of EN 14025:2013.

Sample calculations
Below are comparative calculations for the shells of a number of different diameters of tanks for the transport of UN 1965 Mixture C, all in cases the tank is to be fitted with thermal insulation (a sun shield).
UN 1965 Mixture C is listed in ADR 4.3.3.2.5 (see extract below) and therefore the minimum test pressure is 2.5 MPa

UN No.	Name	Classification code	Minimum test pressure for tanks				Maximum permissible mass of contents per litre of capacity
			With thermal insulation		Without thermal insulation		
			MPa	bar	MPa	bar	kg
1965	Hydrocarbon gas mixture, liquefied, n.o.s.:	2 F					
	Mixture A	2 F	1	10	1	10	0.50
	Mixture A01	2 F	1.2	12	1.4	14	0.49
	Mixture A02	2 F	1.2	12	1.4	14	0.48
	Mixture A0	2 F	1.2	12	1.4	14	0.47
	Mixture A1	2 F	1.6	16	1.8	18	0.46
	Mixture B1	2 F	2	20	2.3	23	0.45
	Mixture B2	2 F	2	20	2.3	23	0.44
	Mixture B	2 F	2	20	2.3	23	0.43
	Mixture C	2 F	2.5	25	2.7	27	0.42
	Other mixtures	2 F	see 4.3.3.2.2 or 4.3.3.2.3				

The material is used will be Steel P460NL1 or P460NL2, which has a yield strength of 460 and a tensile strength of 570.

Minimum thickness of the shell if designed using EN 12493:2013 (assuming the tanker is not in combination with a tanker trailer) are calculated as follows –

The nominal design stress f shall be the lesser of ReH/1,6 and Rm/2,5, where:
f is nominal design stress
R_{eH} is the yield strength specified in the material standard or specification;
R_m is the tensile strength specified in the material standard or specification;
The following units shall be used in the equations in this annex:

- pressure and stress – N/mm^2,
- dimensions – mm.

$\frac{460}{1,6}$ = 287,5 and $\frac{570}{2,5}$ = 228 – therefore the nominal design stress (*f*) shall be 228.
The minimum thickness shall be the greater of:
$e_{min} = \frac{0,883pD}{2fz+0,833p}$ and $e_{min} = \frac{D}{600} + 1,5$
where
D is the outside diameter of the shell;
p is the design pressure;
z is the joint efficiency = 1,0;
f is the nominal stress.

Example calculations –

***D* = 2000** (inside diameter) as EN 12493 uses outside diameter a thickness of 9,0 mm has been assumed in the example.

$e_{min} = \frac{0,833*2,5*2018}{(2*228*1)+(0,833*2,5)}$ = **9,17 mm**

and

$e_{min} = \frac{D}{500} + 1,5 = \frac{2018}{500} + 1,5 = 5,54$ mm

***D* = 2150** (inside diameter).

$e_{min} = \frac{0,833*2,5*2150}{(2*228*1)+(0,833*2,5)}$ = **9,77 mm**

and

$e_{min} = \frac{D}{500} + 1,5 = \frac{2150}{500} + 1,5 = 5,8$ mm

Further calculations for different diameters give the following results:

***D* = 2200** (inside diameter) = **10,09 mm**

***D* = 2400** (outside diameter) = **10,91 mm**

***D* = 2450** (inside diameter) = **11,24 mm**

The minimum thickness of the shell if designed using EN 14025:2013 is calculated as follows – EN 14025 requires that the minimum thickness calculations are undertaken at the MWP (route C) and at the test pressure (route D), the largest value obtained shall be used.

Table 1 — Design criteria for chapter 6.8 tanks

	Operating conditions	Test conditions
p	*MWP* but not less than (p_{vap} – 1 bar) + p_{dyn} if applicable [a]	p_{test} [b]
f_d for ferritic steels and aluminium alloys	min { $R_{e,t}$ / 1,5; R_m / 2,4}	min { 0,75 R_e ; 0,5 R_m }
f_d for austenitic steels with 30 % ≤ A < 35 %	$R_{e,t}$ / 1,5	
f_d for austenitic steels with A ≥ 35 %	max { $R_{e,t}$ / 1,5; min ($R_{e,t}$ / 1,2 ; $R_{m,t}$ / 3)} [c]	
Design temperature	20 °C provided that the operating temperature of the tank is within the range -20 °C to +50 °C. When the operating temperature is outside this range then the design temperature shall be taken as the extreme value of the operating temperature.	Temperature at the pressure test (normally +20 °C).

[a] The dynamic forces shall be taken into account. This may be done by introducing an equivalent pressure p_{dyn} determined on the basis of the forces specified in RID/ADR 6.8.2.1 but not less than 35 kPa (0,35 bar) and add it to the vapour gauge pressure (p_{vap} – 1 bar) with p_{vap} not less than 1 bar. The largest compartment needs to be taken into account.

[b] To be taken from RID/ADR 6.8.2.4.1.

[c] It needs to be noted that the guaranteed minimum mechanical values differ with the temperature, and have to be chosen accordingly. If no standard values are available, applicable values have to be determined otherwise.

EN 14025 defines MWP as – *MWP* maximum working pressure, in MPa
ADR defines Maximum Working Pressure as –

"*Maximum working pressure (gauge pressure)*" means the highest of the following three pressures:

(a) The highest effective pressure allowed in the tank during filling (maximum filling pressure allowed);

(b) The highest effective pressure allowed in the tank during discharge (maximum discharge pressure allowed); and

(c) The effective gauge pressure to which the tank is subjected by its contents (including such extraneous gases as it may contain) at the maximum working temperature.

Unless the special requirements prescribed in Chapter 4.3 provide otherwise, the numerical value of this working pressure (gauge pressure) shall not be lower than the vapour pressure (absolute pressure) of the filling substance at 50 °C.

That means that 'c' applies and according to the last paragraph as LPG is listed in Chapter 4.3, the values listed in the table in clause 4.3.3.2.5 must be used.
Therefore both the MWP and test pressure will be the same and therefore the minimum thickness as calculated by route 'C' (MWP) will be considerably more than by route 'D' (test pressure) and the calculations below only follow rout 'C'

The nominal design stress *f* shall be the lesser of $R_e/1.5$ and $R_m/2.4$, where:
R_e is the yield strength specified in the material standard or specification;
R_m is the tensile strength specified in the material standard or specification;
$\frac{460}{1,5}$ = 306,7 and $\frac{570}{2,4}$ = 237,5 – therefore the nominal design stress shall be 237,5.

Minimum wall thickness

$$e = \frac{p \cdot D}{2f \cdot \lambda - p}$$

e minimum wall thickness
D inside diameter of tank
f nominal design stress = 237,5
p design pressure
λ welding coefficient = 1,0

Example calculations –

***D* = 2000** (inside diameter)

$$e = \frac{2,5 \cdot 2000}{(2 \cdot 237,5 \cdot 1) - 2,5} = \mathbf{10,58\ mm}$$

***D* = 2150** (outside diameter) as EN 14025 uses inside diameter a thickness of 11,0 mm has been assumed in the example.

$$e = \frac{2,5 \cdot 2128}{(2 \cdot 237,5 \cdot 1) - 2,5} = \mathbf{11,26\ mm}$$

Further calculations for different diameters give the following results:

***D* = 2200** (inside diameter) = **11,64 mm**

***D* = 2400** (outside diameter) = **12,57 mm**

***D* = 2450** (inside diameter) = **12,96 mm**

Using the calculations above the minimum thickness of the shell will be as set out in the following table:

Tank Diameter	**EN 14025:2013**	**EN 12493:2013**	**EN 12493:2013** (with increased thickness – see below)
2000 (inside)	**10,58 mm**	**9,17 mm**	**9,56 mm**
2150 (outside)	**11,26 mm**	**9,77 mm**	**10,22 mm**
2200 (inside)	**11,64 mm**	**10,09 mm**	**10,56 mm**
2400 (outside)	**12,57 mm**	**10,91 mm**	**11,41 mm**
2450 (inside)	**12,96 mm**	**11,24 mm**	**11,76 mm**

For tankers with tank trailer combination (a tanker pulling a tank trailer) EN 12493 requires that the minimum thickness is multiplied by the following factor (where T_r is the reference temperature, in this case with a sun shield 60^0C)

$$1+\frac{0,6(65-T_r)}{65} = 1+\frac{0,6*(65-60)}{65} = 1,0462$$

Conclusion

In all cases the design minimum thickness for the tanker shell using EN 12493:2013+A1:2014: will be greater than the minimum thickness required by the ADR ,but always less than design minimum thickness if EN 14025:2013 is used.