Neutrino project – compliance with EC3

jcbl

edms: 1509563

EN 1993-4-2 : Tanks

1.1 Scope

(1) Part 4.2 of Eurocode 3 provides principles and application rules for the structural design of vertical cylindrical [AC1⟩ and rectangular ⟨AC1] above ground steel tanks for the storage of liquid products with the following characteristics

a) characteristic internal pressures above the liquid level not less than –100mbar and not more than 500mbar [1];

b) design metal temperature in the range of –50ºC to +300ºC. For tanks constructed using austenitic stainless steels, the design metal temperature may be in the range of –165ºC to +300ºC. For fatigue loaded tanks, the temperature should be limited to T < 150ºC;

c) maximum design liquid level not higher than the top of the [AC1⟩ cylindrical and rectangular tank ⟨AC1].

(2) This Part 4.2 is concerned only with the requirements for resistance and stability of steel tanks. Other design requirements are covered by EN 14015 for ambient temperature tanks and by EN 14620 for cryogenic tanks, and by EN 1090 for fabrication and erection considerations. These other requirements include foundations and settlement, fabrication, erection and testing, functional performance, and details like man-holes, flanges, and filling devices.

Partial safety factors for actions

Sd=1.35 *hydrostatic load + 1.4 * overpressure

design situation	liquid type	recommended values for γ_F in case of variable actions from liquids	recommended values for γ_F in case of permanent actions
liquid induced loads during operation	toxic, explosive or dangerous liquids	1,40	1,35
	flammable liquids	1,30	1,35
	other liquids	1,20	1,35
liquid induced loads during test	all liquids	1,00	1,35
accidental actions	all liquids	1,00	

Partial factors for resistance

Beam stability : 1.0

Shell: 1.1

Bolts/welds :1.25

Resistance to failure mode	Relevant γ
Resistance of welded or bolted shell wall to plastic limit state, cross-sectional resistance	γ_{M0}
Resistance of shell wall to stability	γ_{M1}
Resistance of welded or bolted shell wall to rupture	γ_{M2}
Resistance of shell wall to cyclic plasticity	γ_{M4}
Resistance of welded or bolted connections or joints	γ_{M5}
Resistance of shell wall to fatigue	γ_{M6}

$\gamma_{M0} = 1,00$	$\gamma_{M1} = 1,10$	$\gamma_{M2} = 1,25$
$\gamma_{M4} = 1,00$	$\gamma_{M5} = 1,25$	$\gamma_{M6} = 1,10$

Resistance and stability requirements

- Ultimate limit states (cross-sections, buckling, joints…checks)
  - Refers to other parts of EC3
  - Shell of rectangular tanks
    - **either** by compliance: EN 1993-1-7: Strength & stability of planar plated structures subject to out of plane loading.
    - **Or**, shell modelling with all stiffeners, openings… (Possibility to treat each panel as an individual segment)
    - geometric imperfections.
- Serviceability limit states (usually conditioning – pinned/less rigid joints may not work out)
  - Shell: (but EN 1993-1-1 limits displacement for beams ~ l/300)

(3) Specific limiting values, appropriate to the intended use, should be agreed between the designer, the client and the relevant authority, taking account of the intended use and the nature of the liquids to be stored.

Other standards – EN 14620

All EN 14620 parts apply to cylindrical tanks…
Similar scope to EN 1993-4-2 + rectangular tanks

BS EN 14620-1 is a European Standard that provides the specification for vertical, cylindrical tanks, built on site, above ground and of which the primary liquid container is made of steel. The secondary container, if applicable, may be of steel or of concrete or a combination of both. An inner tank made only of pre-stressed concrete is excluded from the scope this standard.

The standard specifies principles and application rules for the structural design of the "containment" during construction, testing, commissioning, operation (accidental included), and decommissioning. It does not address the requirements for ancillary equipment such as pumps, pumpwells, valves, piping, instrumentation, staircases etc. unless they can affect the structural design of the tank.

It is applicable to storage tanks designed to store products, having an atmospheric boiling point below ambient temperature, in a dual phase, i.e. liquid and vapour. The equilibrium between liquid and vapour phases being maintained by cooling down the product to a temperature equal to, or just below, its atmospheric boiling point in combination with a slight overpressure in the storage tank.

The maximum design pressure of the tanks covered by this European Standard is limited to 500 mbar. For higher pressures, reference can be made to BS EN 13445, Parts 1 to 5.

The operating range of the gasses to be stored is between 0 °C and −165 °C. The tanks for the storage of liquefied oxygen, nitrogen and argon are excluded.

More standards – ANSI-AISI 360-10

Specification for Structural Steel Buildings

June 22, 2010

"American EC3"

Supersedes the
Specification for Structural Steel Buildings
dated March 9, 2005
and all previous versions of this specification

Approved by the AISC Committee on Specifications

SCOPE

The *Specification for Structural Steel Buildings* (ANSI/AISC 360), hereafter referred to as the Specification, shall apply to the design of the *structural steel* system or systems with structural steel acting compositely with reinforced concrete, where the steel elements are defined in the AISC *Code of Standard Practice for Steel Buildings and Bridges*, Section 2.1, hereafter referred to as the *Code of Standard Practice*.

Limit States

"ULS" "SLS"

Design shall be based on the principle that no applicable strength or *serviceability limit state* shall be exceeded when the structure is subjected to all appropriate *load* combinations.

Design shall be performed in accordance with Equation B3-1:

$$R_u \leq \phi R_n$$

"partial safety factors"

where

R_u = required strength using LRFD load combinations
R_n = *nominal strength*, specified in Chapters B through K
ϕ = *resistance factor*, specified in Chapters B through K
ϕR_n = design strength

Moment Connections

Two types of moment connections, fully restrained and partially restrained, are permitted, as specified below.

Serviceability is a state in which the function of a building, its appearance, maintainability, durability and comfort of its occupants are preserved under normal usage. Limiting values of structural behavior for serviceability (such as maximum deflections and accelerations) shall be chosen with due regard to the intended function of the structure. Serviceability shall be evaluated using appropriate *load combinations* for the *serviceability limit states* identified.

"SLS"

More standards – ANSI-AISI 360-10

B4. MEMBER PROPERTIES

“section classification”

1. Classification of Sections for Local Buckling

General Analysis Requirements

“Imperfections”

The analysis of the structure shall conform to the following requirements:

(1) The analysis shall consider flexural, shear and axial member deformations, and all other component and *connection* deformations that contribute to displacements of the structure. The analysis shall incorporate reductions in all *stiffnesses* that are considered to contribute to the *stability* of the structure, as specified in Section C2.3.

(2) The analysis shall be a *second-order analysis* that considers both *P*-Δ and *P*-δ *effects*, except that it is permissible to neglect the effect of *P*-δ on the response of the structure when the following conditions are satisfied: (a) The structure supports *gravity loads* primarily through nominally-vertical *columns*, walls or

TENSILE STRENGTH

“Capacity design”

The *design tensile strength*, $\phi_t P_n$, and the *allowable tensile strength*, P_n/Ω_t, of tension members shall be the lower value obtained according to the *limit states* of *tensile yielding* in the gross section and *tensile rupture* in the net section.

(a) For tensile yielding in the gross section:

$$P_n = F_y A_g \quad \text{(D2-1)}$$

$\phi_t = 0.90$ (LRFD) $\quad \Omega_t = 1.67$ (ASD)

$$F_{cr} = 0.877 F_e \quad \text{(E3-3)}$$

“Capacity with reduced elastic buckling loads”

where

F_e = elastic *buckling* stress determined according to Equation E3-4, as specified

The *design strength*, ϕR_n and the *allowable strength*, R_n/Ω, of welded joints shall be the lower value of the base material strength determined according to the *limit states* of *tensile rupture* and *shear rupture* and the *weld metal* strength determined according to the limit state of *rupture* as follows:

For the base metal

“fvwd”

$$R_n = F_{nBM} A_{BM} \quad \text{(J2-2)}$$

Flange Local Bending

“connections: component capacity method”

This section applies to tensile *single-concentrated forces* and the tensile component of *double-concentrated forces*.

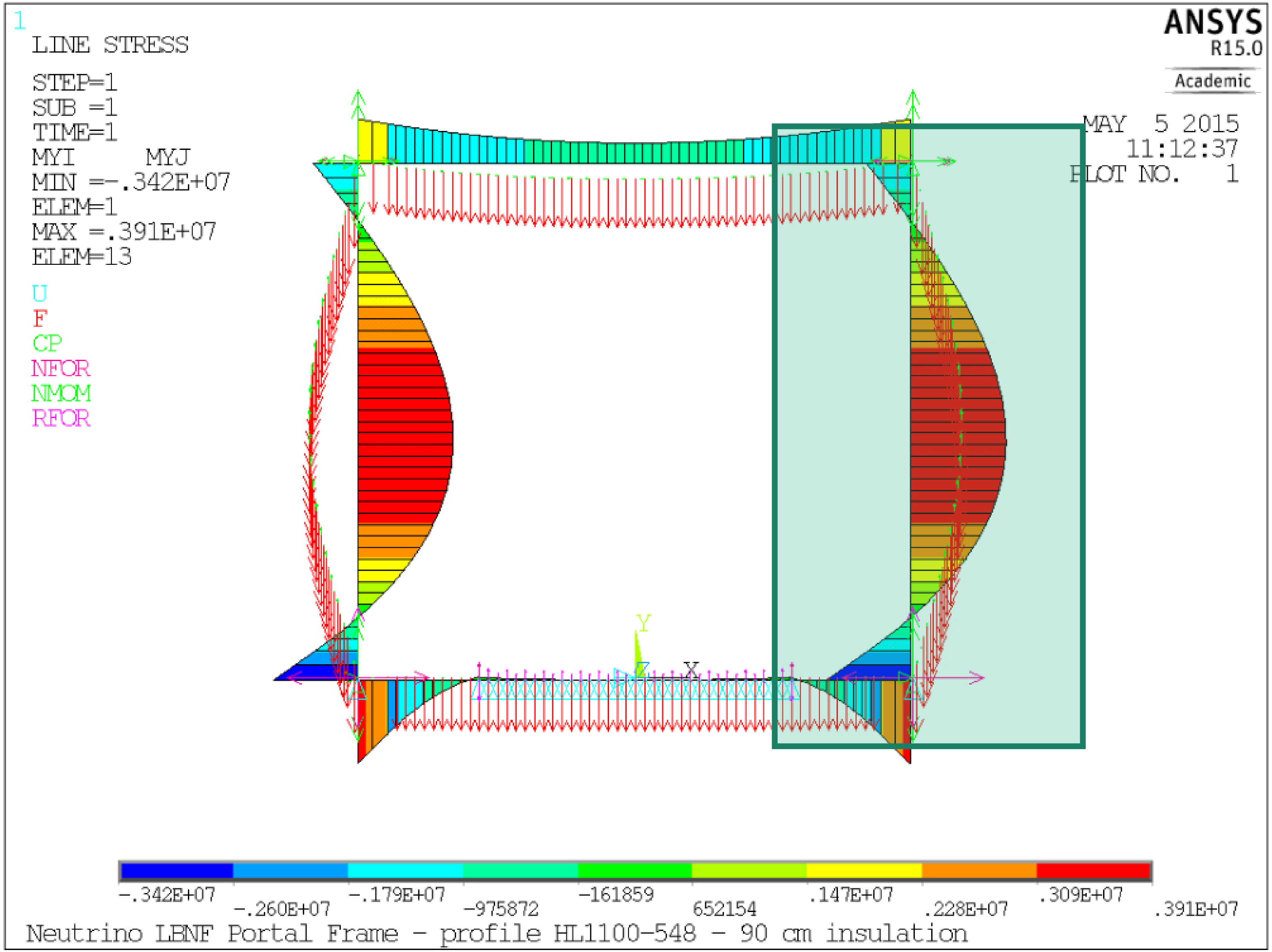
The *design strength*, ϕR_n, and the *allowable strength*, R_n/Ω, for the *limit state* of flange *local bending* shall be determined as follows:

$$R_n = 6.25 F_{yf} t_f^2 \quad \text{(J10-1)}$$

$\phi = 0.90$ (LRFD) $\quad \Omega = 1.67$ (ASD)

Compliance with EC3

Main vertical beam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SUB =1
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MYI MYJ
MIN =-.342E+07
ELEM=1
MAX =.391E+07
ELEM=13
U
F
CP
NFOR
NMOM
RFOR
ANSYS
R15.0
Academic
MAY 5 2015
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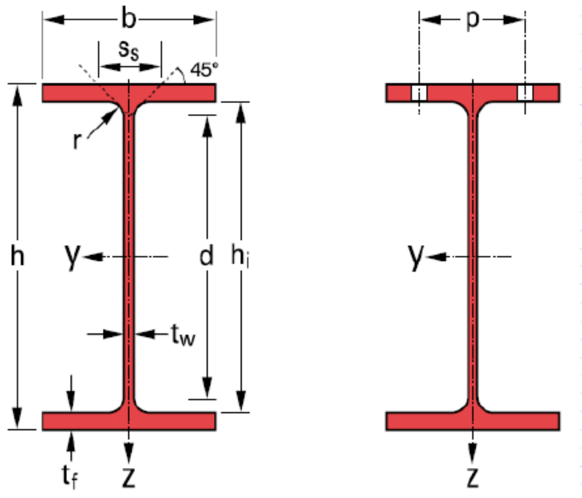
Y
X
-.342E+07
-.260E+07
-.179E+07
-975872
-161859
652154
.147E+07
.228E+07
.309E+07
.391E+07
Neutrino LBNF Portal Frame - profile HL1100-548 - 90 cm insulation

Cross-section checks



$h := 1128\ mm$

$b := 407\ mm$

$t_w := 28\ mm$

$t_f := 50\ mm$

$r := 20\ mm$

Applied load:	$N_{Ed} = 200\ kN$
Tension resistance:	$N_{t.Rd} = 24788.714\ kN$
Compression resistance:	$N_{c.Rd} = 24788.714\ kN$
Resistance to normal forces:	$N_{Rd} := min(N_{t.Rd}, N_{c.Rd}) = 24788.714\ kN$

y - direction

Applied shear force (y axis)	$V_{y.Ed} = 1\ kN$
Shear resistance (y axis)	$V_{y.Rd} := V_{pl.y.Rd} = 8412.221\ kN$

z - direction

Applied shear force (z axis)	$V_{z.Ed} = 2726.831\ kN$
Shear resistance (z axis)	$V_{z.Rd} := V_{pl.z.Rd} = 6666.787\ kN$

y - direction

Applied bending moment	$M_{y.Ed} = (3.9 \cdot 10^3)\ kN \cdot m$
Bending moment resistance	$M_{c.y.Rd} = (1.048 \cdot 10^4)\ kN \cdot m$
Bending and shear	$M_{V.y.Rd} = (1.048 \cdot 10^4)\ kN \cdot m$
Bending and axial forces	$M_{N.y.Rd} = (1.048 \cdot 10^4)\ kN \cdot m$
Bending, shear and axial forces	$M_{VN.y.Rd} = (1.048 \cdot 10^4)\ kN \cdot m$

Design resistance to bending moments:

z - direction

Applied bending moment	$M_{z.Ed} = 15.8\ kN \cdot m$
Bending moment resistance	$M_{c.z.Rd} = (1.544 \cdot 10^3)\ kN \cdot m$
Bending and shear	$M_{V.z.Rd} = (1.544 \cdot 10^3)\ kN \cdot m$
Bending and axial forces	$M_{N.z.Rd} = (1.544 \cdot 10^3)\ kN \cdot m$
Bending, shear and axial forces	$M_{VN.z.Rd} = (1.544 \cdot 10^3)\ kN \cdot m$

Design resistance to bending moments:

Buckling checks

y - direction

Applied load: $N_{Ed} = 200\ kN$

Flexural elastic critic buckling (Euler) $N_{cr.y.F} = 120025.685\ kN$

Elastic torsional buckling $N_{cr.y.T} = 22132.331\ kN$

Elastic torsional-flexural buckling $N_{cr.y.TF} = 22132.331\ kN$

Design buckling resistance $N_{b.y.Rd} = 13894.621\ kN$

Elastic torsional-flexural buckling $N_{cr.z.TF} = 4680.431\ kN$

Design buckling resistance $N_{b.z.Rd} = 3806.216\ kN$

Applied bending moment: $M_{y.Ed} = 3.9\ MN \cdot m$

Elastic critic moment $M_{cr} = 5.738\ MN \cdot m$

Bracing is critical!

Design buckling resistance $M_{b.Rd} = 4.222\ MN \cdot m$

$$Check_1 := \text{if } \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y.Ed}}{\chi_{LT} \cdot \frac{M_{y.Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z.Ed}}{\frac{M_{z.Rk}}{\gamma_{M1}}} \le 1 \ \text{"OK"} \ \text{else "Failure"} = \text{"OK"}$$

0.76

$$Check_2 := \text{if } \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y.Ed}}{\chi_{LT} \cdot \frac{M_{y.Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z.Ed}}{\frac{M_{z.Rk}}{\gamma_{M1}}} \le 1 \ \text{"OK"} \ \text{else "Failure"} = \text{"OK"}$$

0.974

Minimum bracing = 2.5%*member compression load

Same exercise with safety factor of 1.35?

And SLS? Dmax~15000/300=50 mm?

Safety factor of 1.35

$$Check_1 := \begin{cases} \text{if } \dfrac{N_{Ed}}{\dfrac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \dfrac{M_{y.Ed}}{\chi_{LT} \cdot \dfrac{M_{y.Rk}}{\gamma_{M1}}} + k_{yz} \cdot \dfrac{M_{z.Ed}}{\dfrac{M_{z.Rk}}{\gamma_{M1}}} \le 1 \\ \quad \text{“OK”} \\ \text{else} \\ \quad \text{“Failure”} \end{cases} = \text{“Failure”}$$

1.024

Usually Check 2 governs for most the cases. the worst case scneario is to consider kzy=1 and kzz=1.5

$$Check_2 := \begin{cases} \text{if } \dfrac{N_{Ed}}{\dfrac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \dfrac{M_{y.Ed}}{\chi_{LT} \cdot \dfrac{M_{y.Rk}}{\gamma_{M1}}} + k_{zz} \cdot \dfrac{M_{z.Ed}}{\dfrac{M_{z.Rk}}{\gamma_{M1}}} \le 1 \\ \quad \text{“OK”} \\ \text{else} \\ \quad \text{“Failure”} \end{cases} = \text{“Failure”}$$

1.294