ORDINE DEGLI INGEGNERI
PROVINCIA DI PERUGIA

Fondazione Promozione Acciaio
CRESCE L'ACCIAIO, CRESCE IL PAESE

PROGETTO DI STRUTTURE IN ACCIAIO

Corso di aggiornamento per ingegneri organizzato da APICE srl e prof. Aurelio Ghersi

col patrocinio di:

Ordine degli ingegneri della provincia di Perugia e Fondazione Promozione Acciaio

Problematiche costruttive, strutturali e funzionali di serbatoi e sili in acciaio

Parte 1: Tipologie di serbatoi

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Shell structures in transportation industry

Shell structures in industrial engineering

Shell structures in civil engineering

INTRODUCTION TO SHELL STRUCTURES

The shell structure is typically found in nature as well as in classical architecture. Its efficiency is based on its curvature (single or double), which allows a multiplicity of alternative stress paths and gives the optimum form for transmission of many different load types. Various different types of steel shell structures have been used for industrial purposes; singly curved shells, for example, can be found in oil storage tanks, the central part of some pressure vessels, in storage structures such as silos, in industrial chimneys and even in small structures like lighting columns (Figures 1a to 1e). The single curvature allows a very simple construction process and is very efficient in resisting certain types of loads. In some cases, it is better to take advantage of double curvature. Double curved shells are used to build spherical gas reservoirs, roofs, vehicles, water towers and even hanging roofs (Figures 1f to 1i). An important part of the design is the load transmission to the foundations. It must be remembered that shells are very efficient in resisting distributed loads but are prone to difficulties with concentrated loads. Thus, in general, a continuous support is preferred. If it is not possible to have a foundation bed, as shown in Figure 1a, an intermediate structure such as a continuous ring (Figure 1f) can be used to distribute the concentrated loads at the vertical supports. On occasions, architectural reasons or practical considerations impose the use of discrete supports.

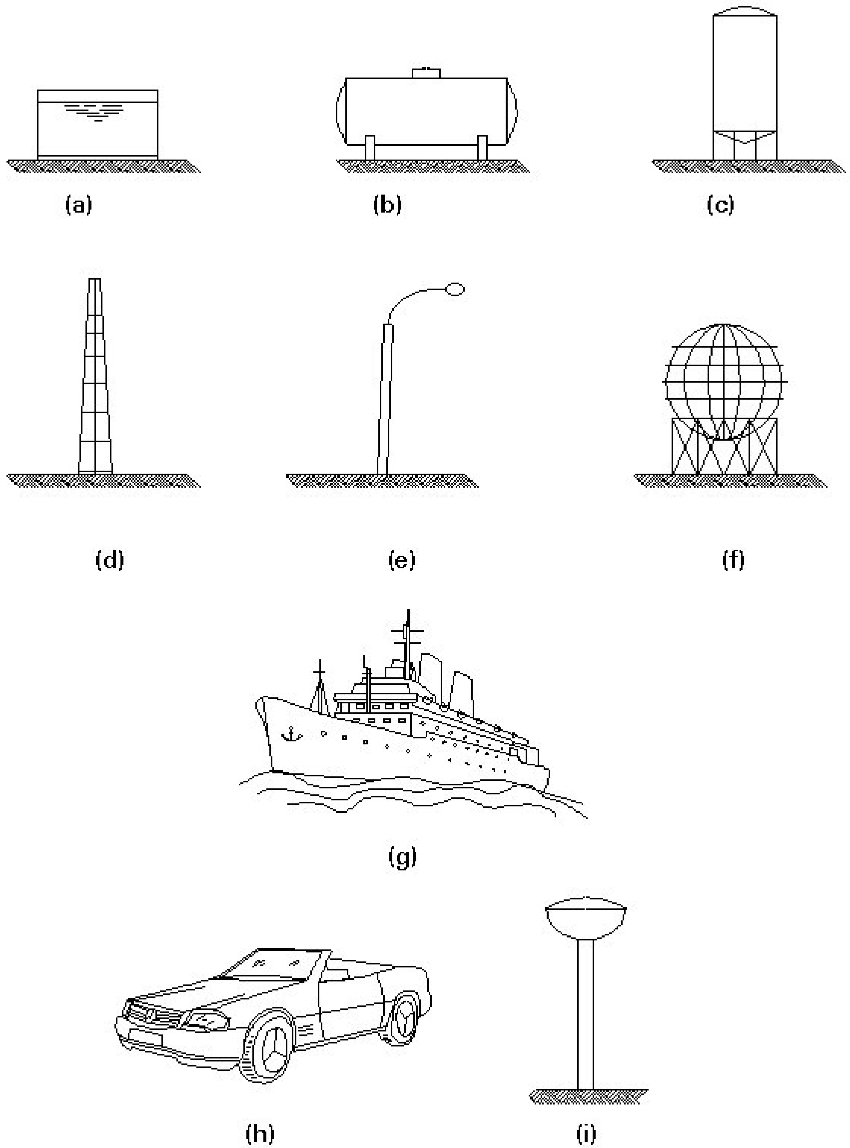


Figure 1 Different applications of shell structures

As mentioned above, distributed loads due to internal pressure in storage tanks, pressure vessels or silos (Figures 2a to 2c), or to external pressure from wind, marine currents and hydrostatic pressures (Figures 2d and 2e) are very well resisted by the in-plane behaviour of shells. On the other hand, concentrated loads introduce significant local bending stresses which have to be carefully considered in design. Such loads can be due to vessel supports or in some cases, due to abnormal impact loads (Figure 2f). In containment buildings of nuclear power plants, for example, codes of practice usually require the possibility of missile impact or even sometimes airplane crashes to be considered in the design. In these cases, the dynamic nature of the load increases the danger of concentrated effects. An everyday example of the difference between distributed and discrete loads is the manner in which a cooked egg is supported in the egg cup without problems and the way the shell is broken by the sudden impact of the spoon (Figure 2g). Needless to say, in a real problem both types of loads will have to be dealt with either in separate or combined states, with the conceptual differences in behaviour ever present in the designer's mind.

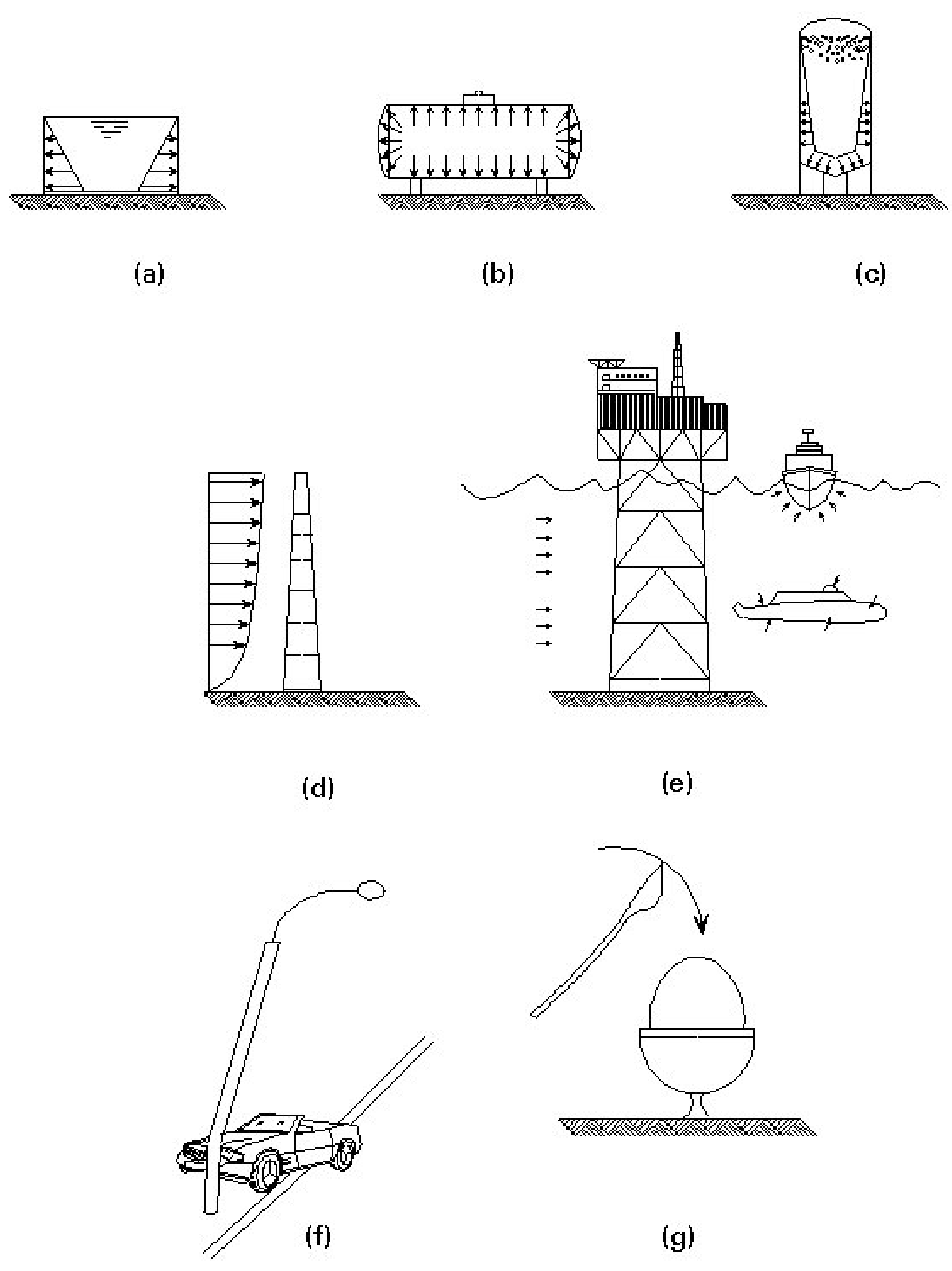


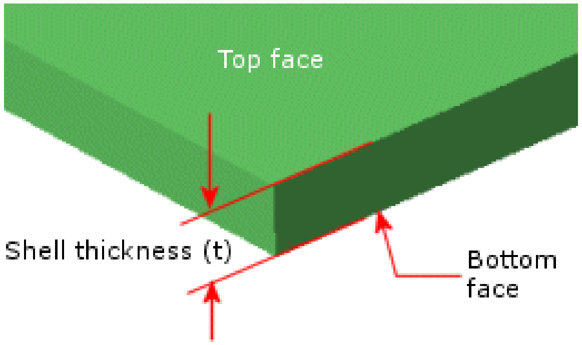
Figure 2 Load types

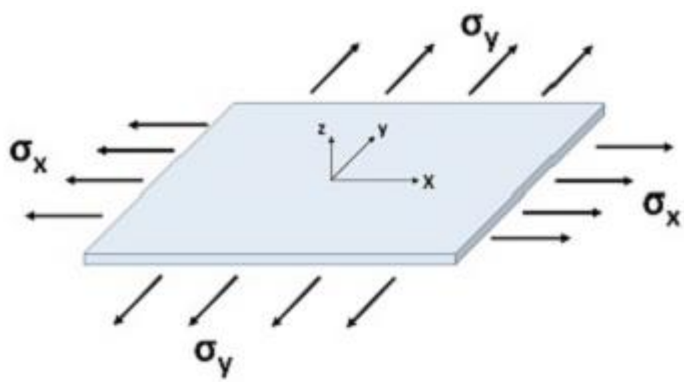
Main features of shell structures

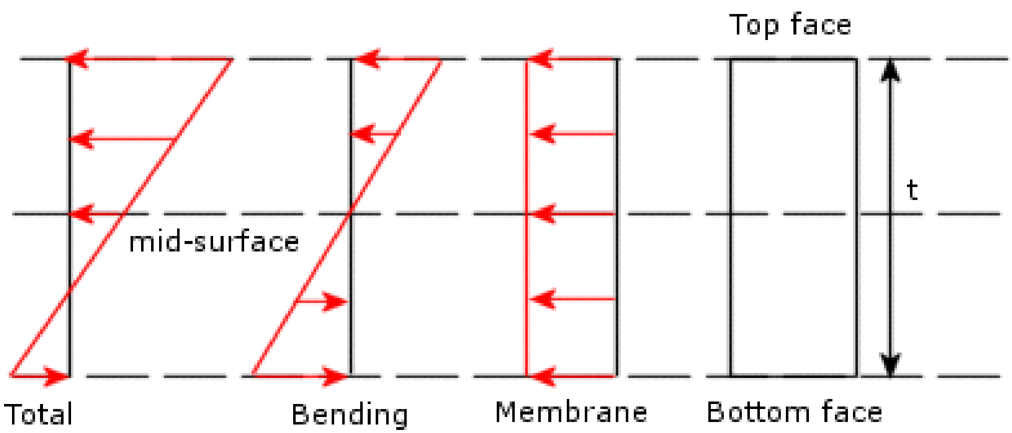
- PROS
  - High stiffness;
  - High strength to weight ratio;
  - Full exploitation of material properties;
  - High suitability to serve as holder, tank, bin, pipeline, etc.;
  - High capability to sustain structural damage when properly designed.

- CONS
  - Complex and hard to predict buckling behavior;
  - High sensitivity to structural imperfections and local effects;
  - Highly unstable postcritical behavior;
  - Remarkably brittle behavior after buckling;
  - Relatively great difficulty to model the actual behavior of the imperfect structure.

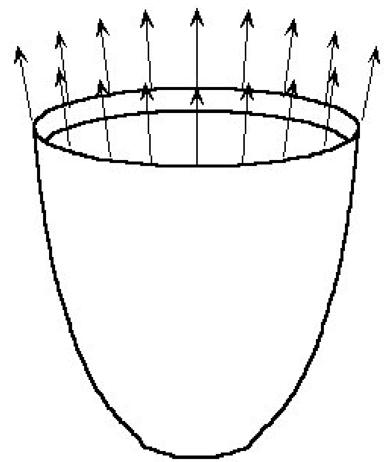
Membrane and bending state of stress

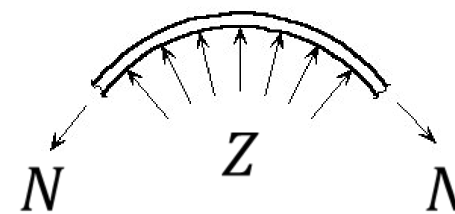




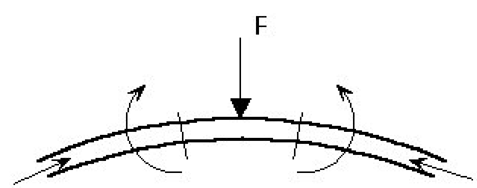


$$\frac{N_1}{R_1} + \frac{N_2}{R_2} = Z$$

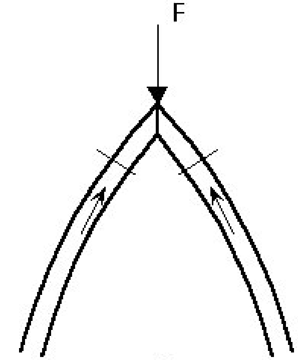




(a)



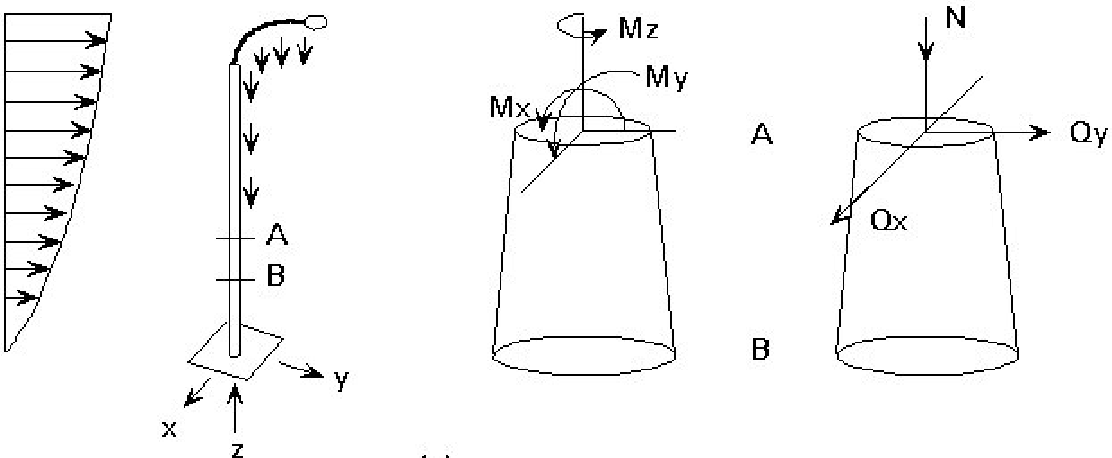
(b)



(c)

ESDEP

IMPORTANCE OF LOCAL EFFECTS



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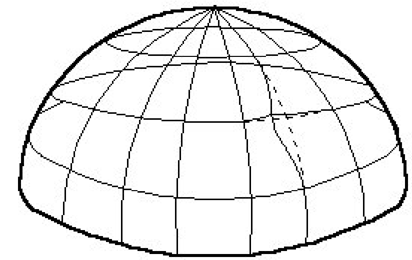
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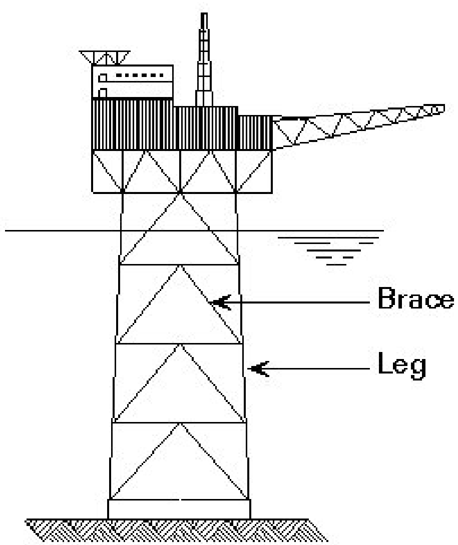

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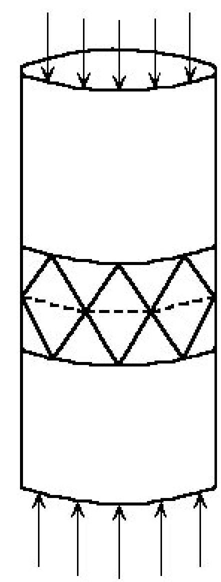
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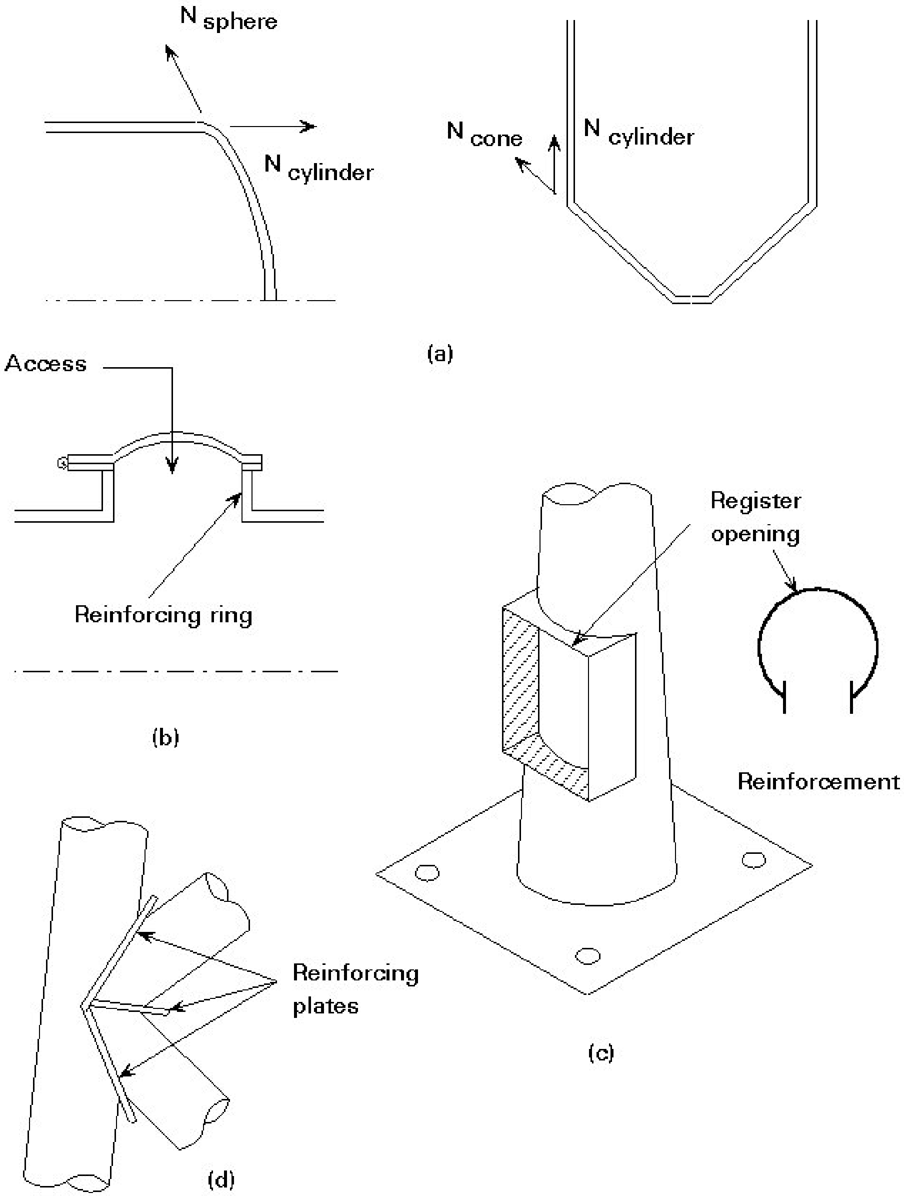
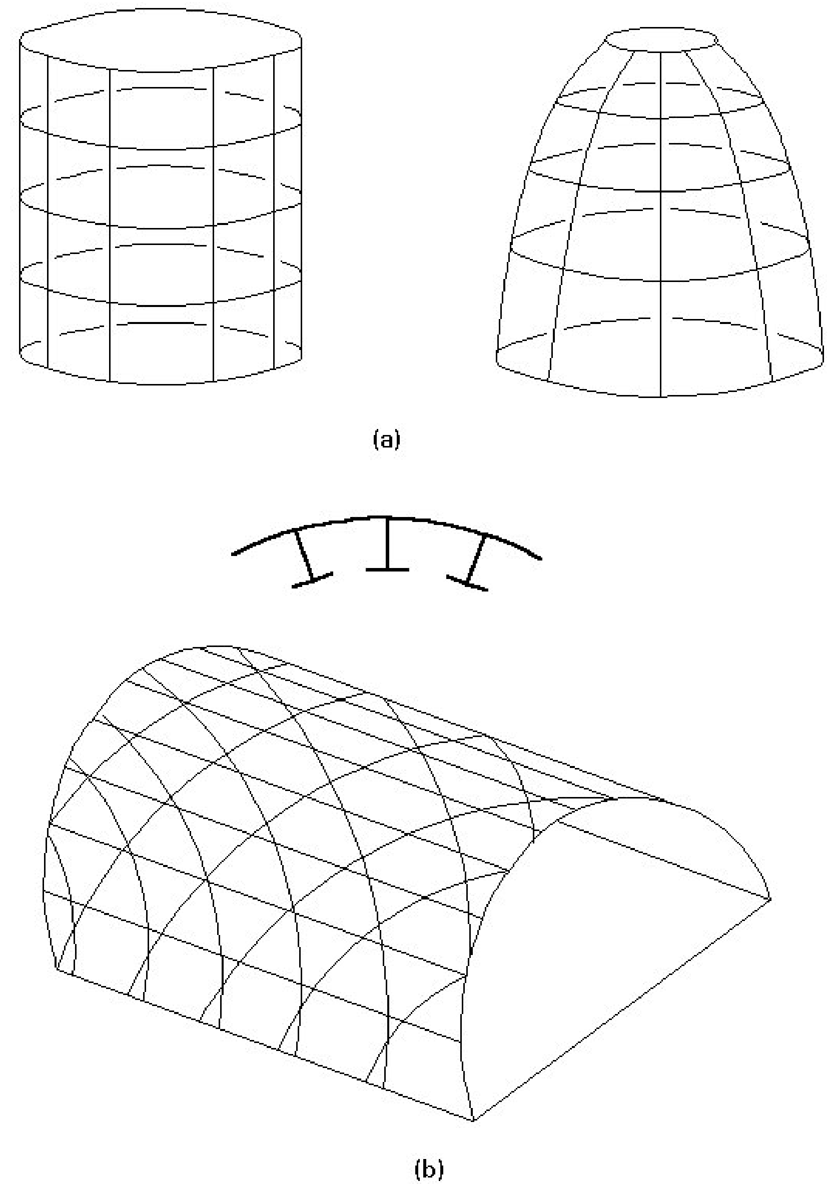
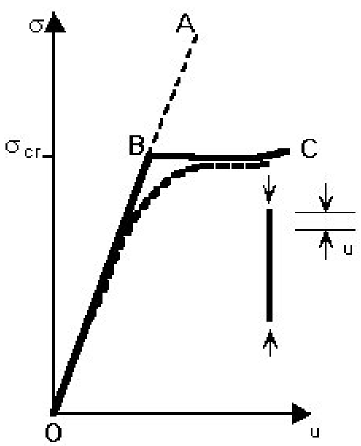
IMPORTANCE OF LOCAL EFFECTS

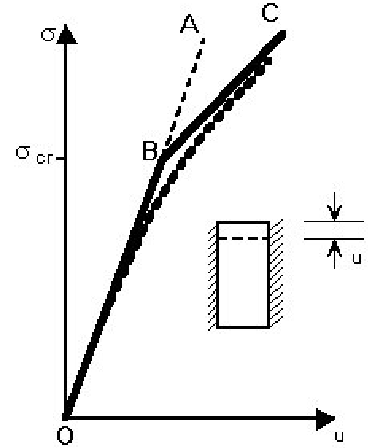




IMPORTANCE OF IMPERFECTIONS



(a)



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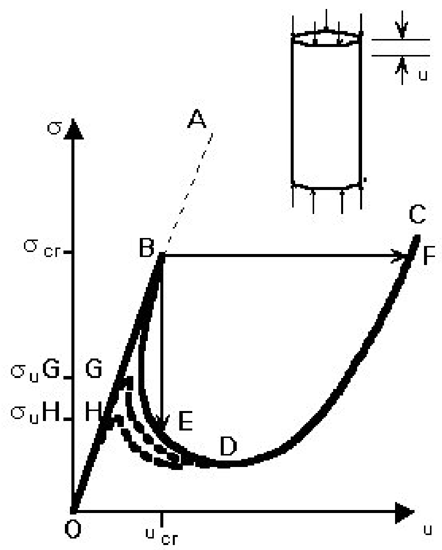


(c)

TRUSS

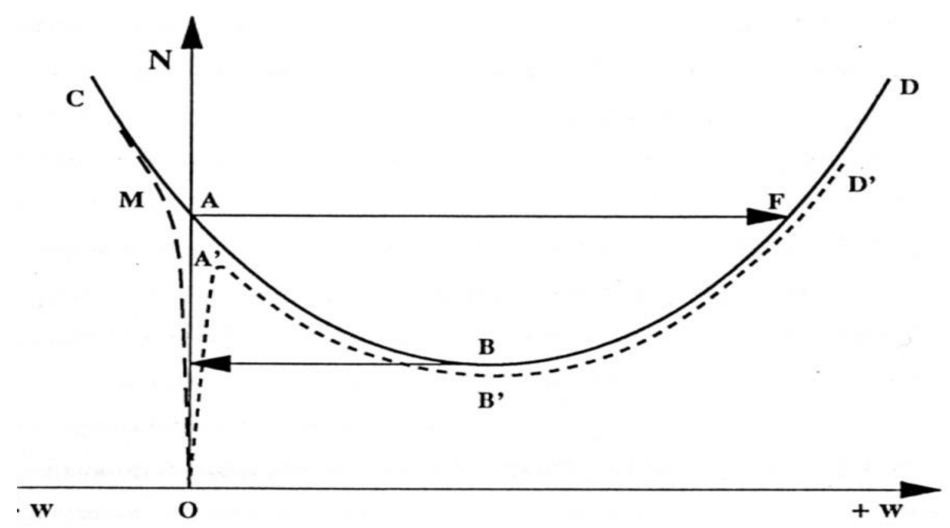
$$\sigma_{cr} = \frac{\pi^2 EI}{L^2}$$

PLATE

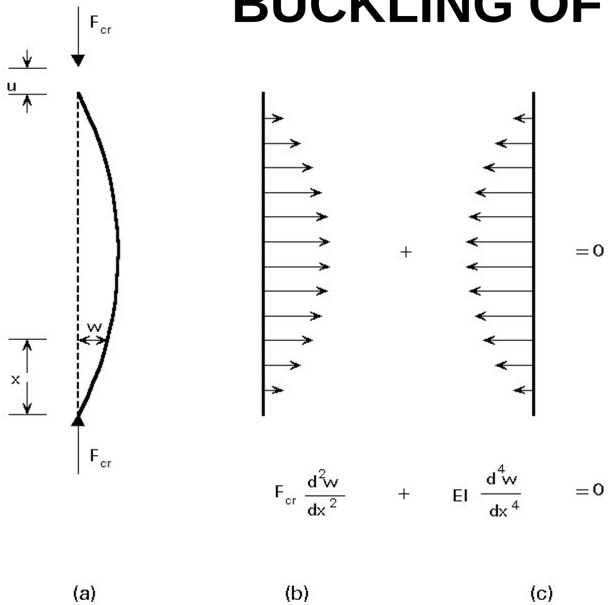
$$\sigma_{cr} = \frac{k\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{b}\right)^2$$

SHELL

$$\sigma_{cr} = \frac{E}{\sqrt{3\left(1-\nu^2\right)}}\frac{t}{R}$$



BUCKLING OF STRUTS, PLATES AND SHELLS



Strut buckling

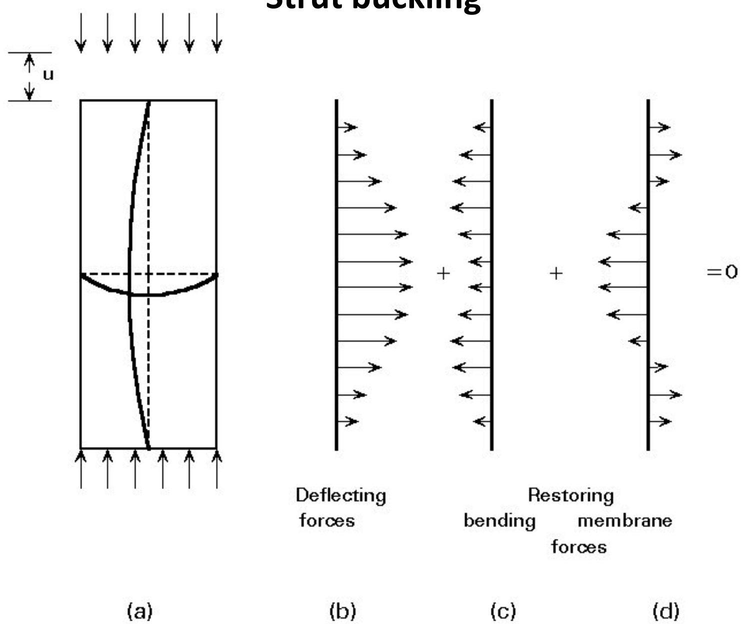
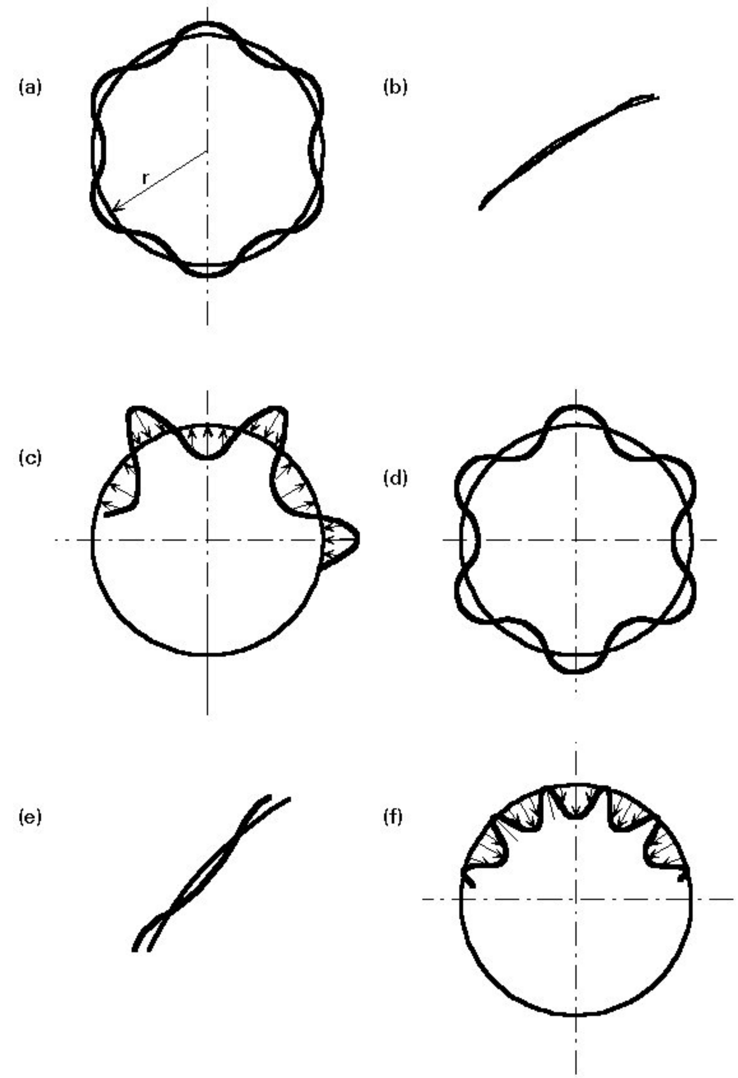


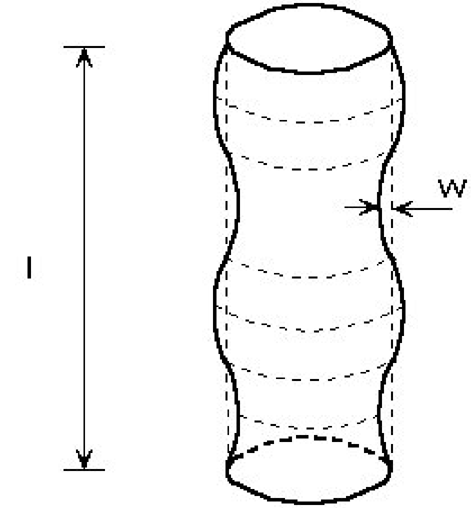
Plate buckling



Cylinder buckling

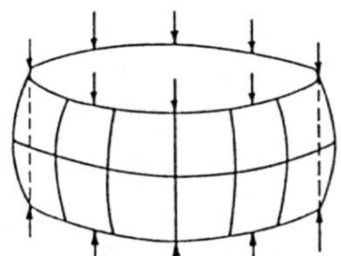
ESDEP

UNSTIFFENED CYLINDERS UNDER AXIAL COMPRESSION



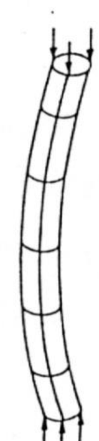
(a) Axisymmetric

$$L^2 / Rt < 3$$



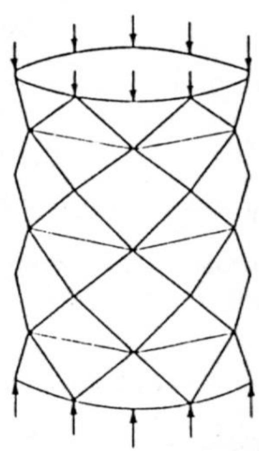
(a) Very short cylinders

$$L^2 / Rt > 8R^2 / t^2$$

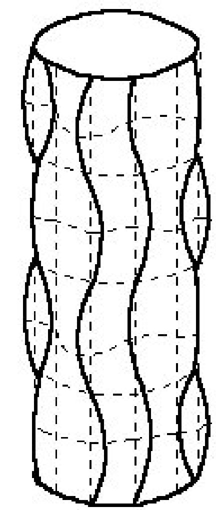


(b) Long cylinders

$$3 < L^2 / Rt < 8R^2 / t^2$$

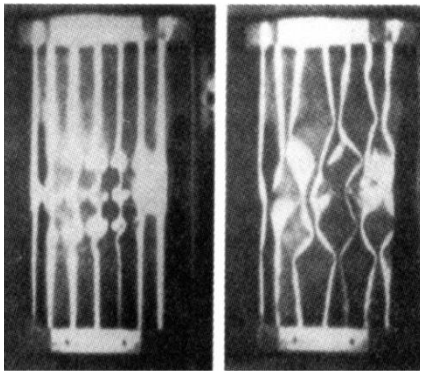


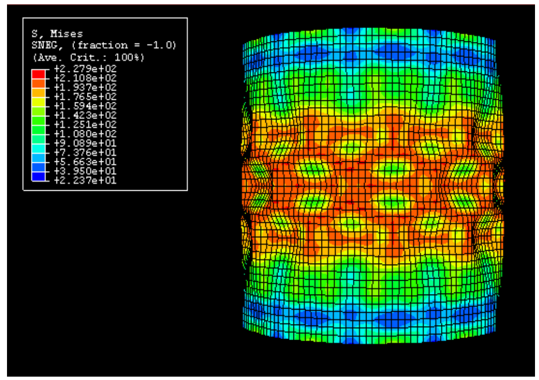
(c) Moderately long cylinders

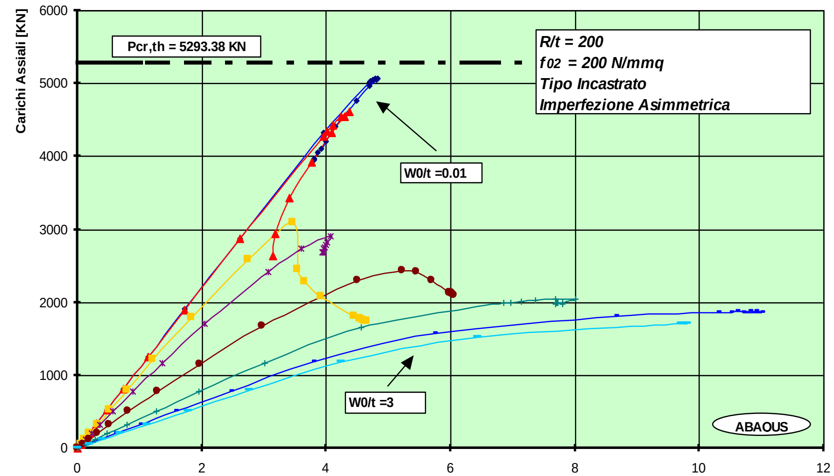


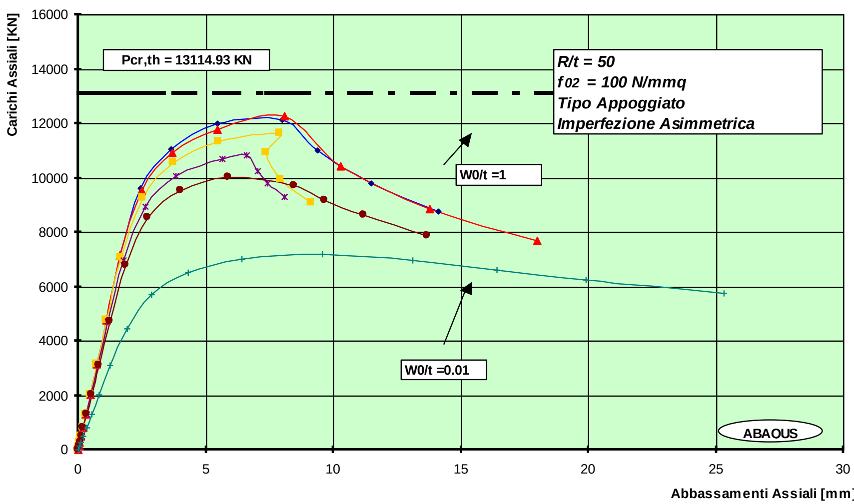
(b) Asymmetric

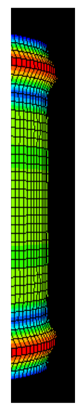
Buckling response of axially loaded cylinders

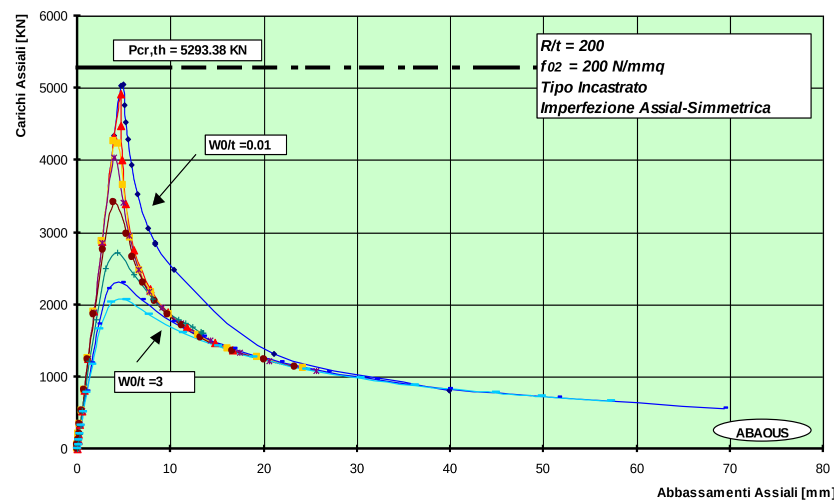




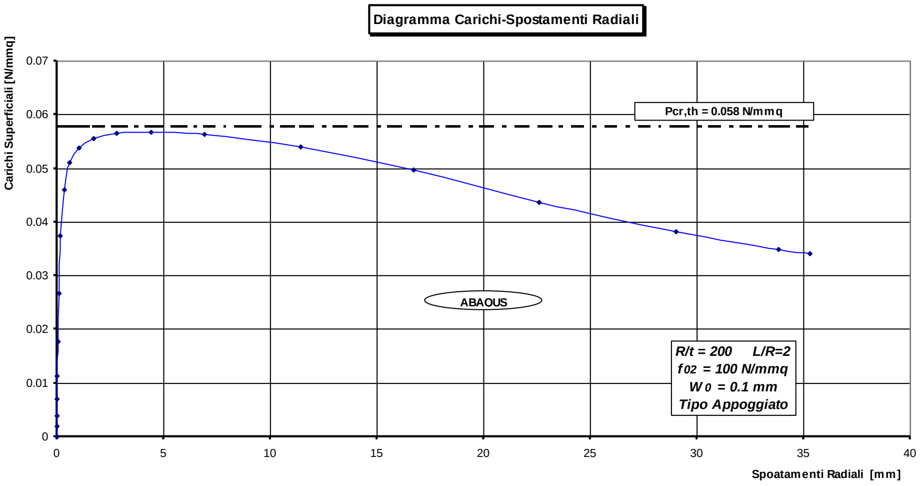


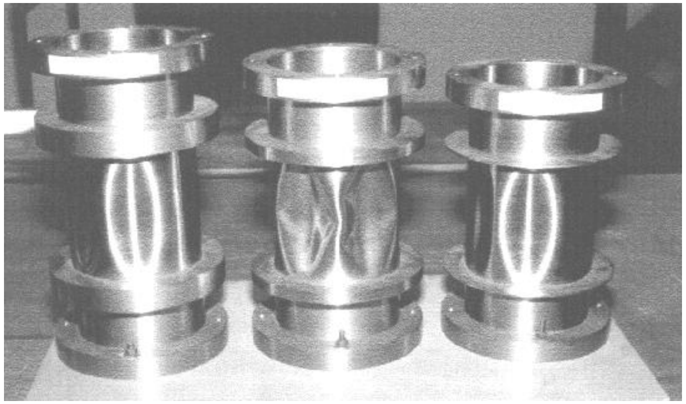


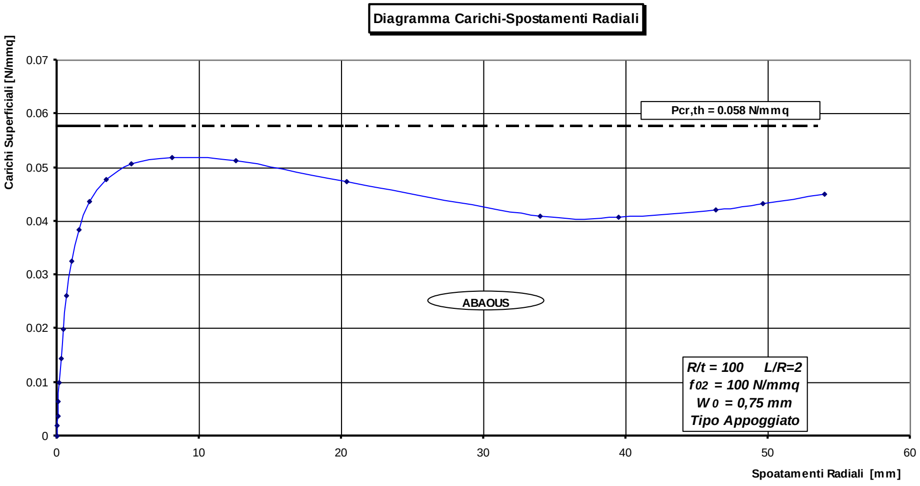


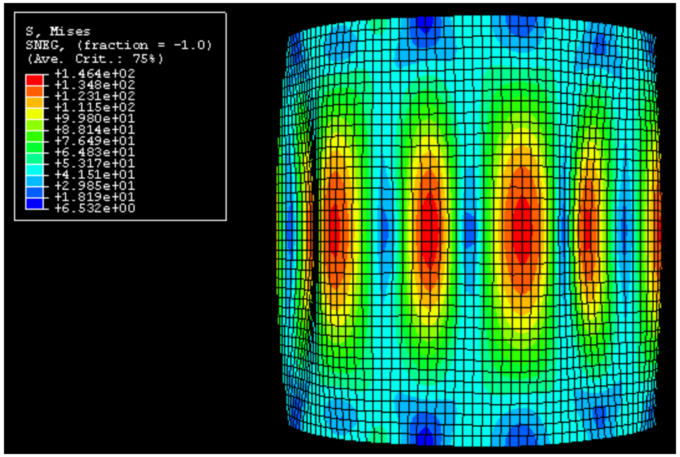


Deflected shapes at buckling (cylinders under uniform external pressure)



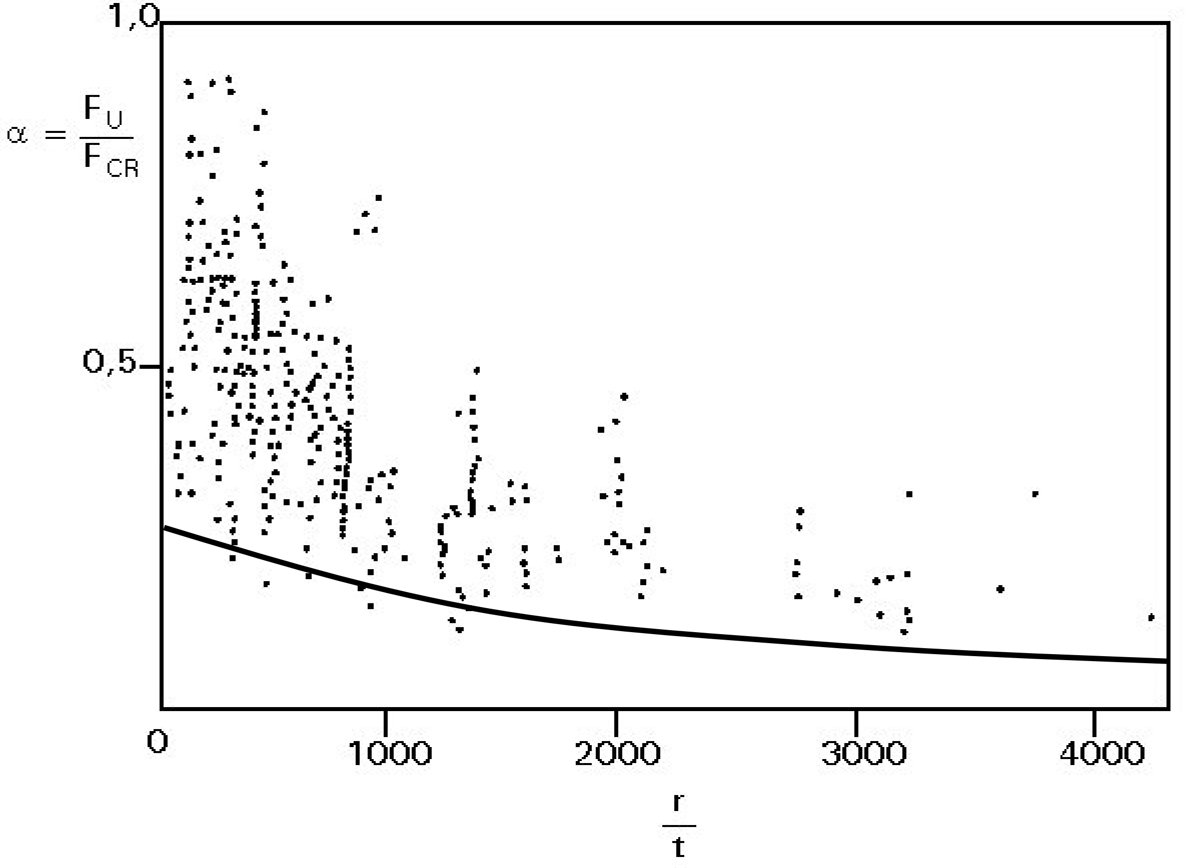




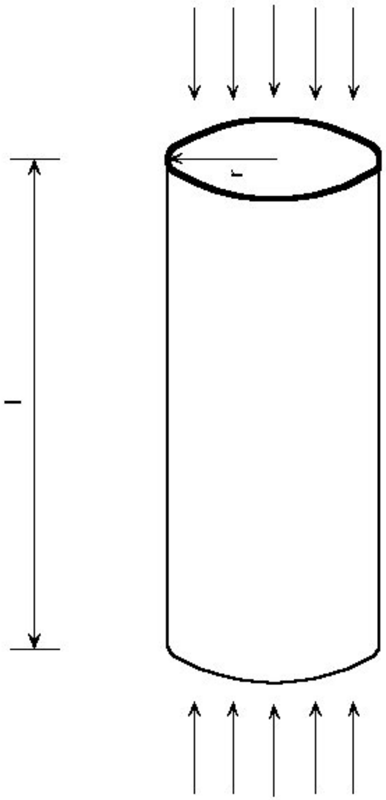


Lower Bound Design Philosophy

(axially loaded cylinders)



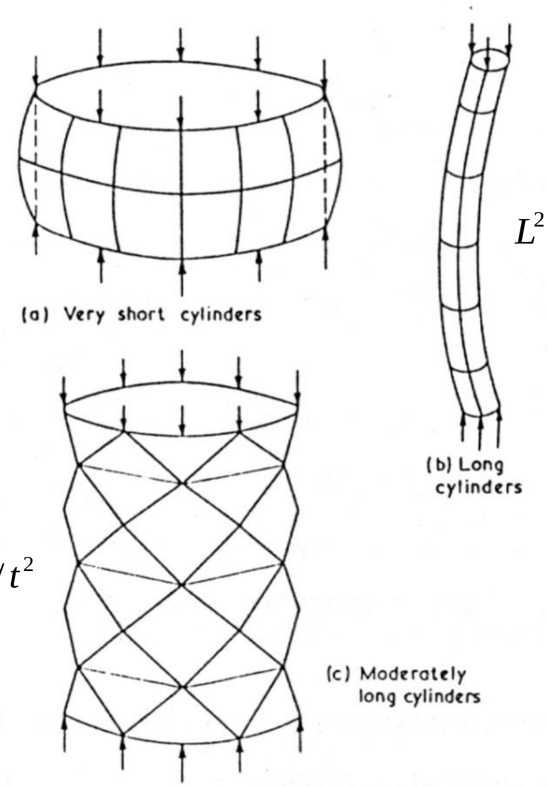
Unstiffened cylinders under axial compression

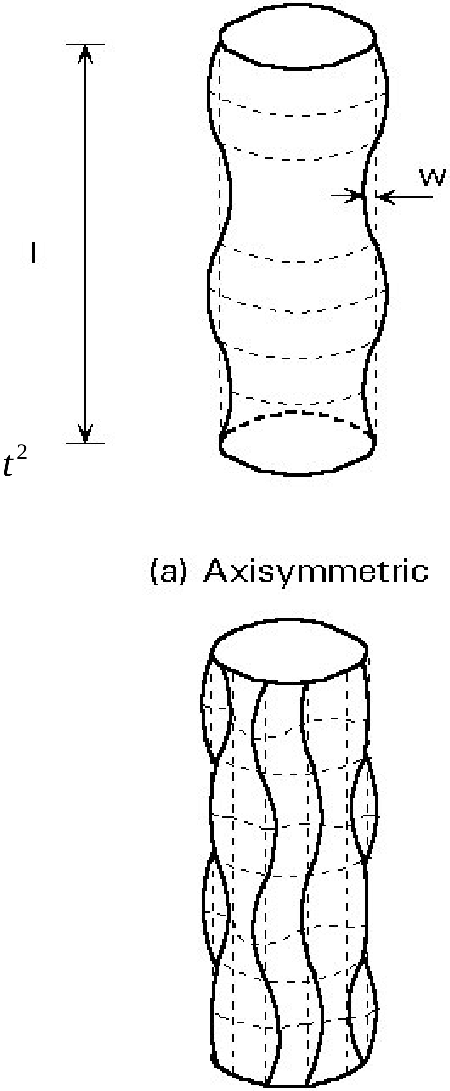


$L^2 / Rt < 3$

$L^2 / Rt > 8R^2 / t^2$

$3 < L^2 / Rt < 8R^2 / t^2$

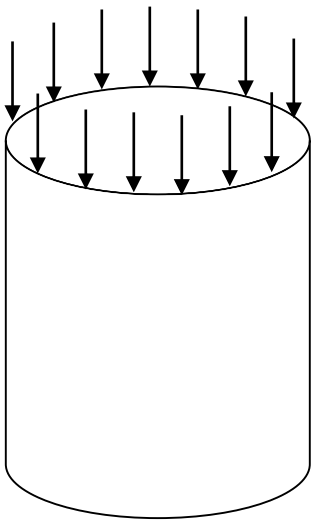


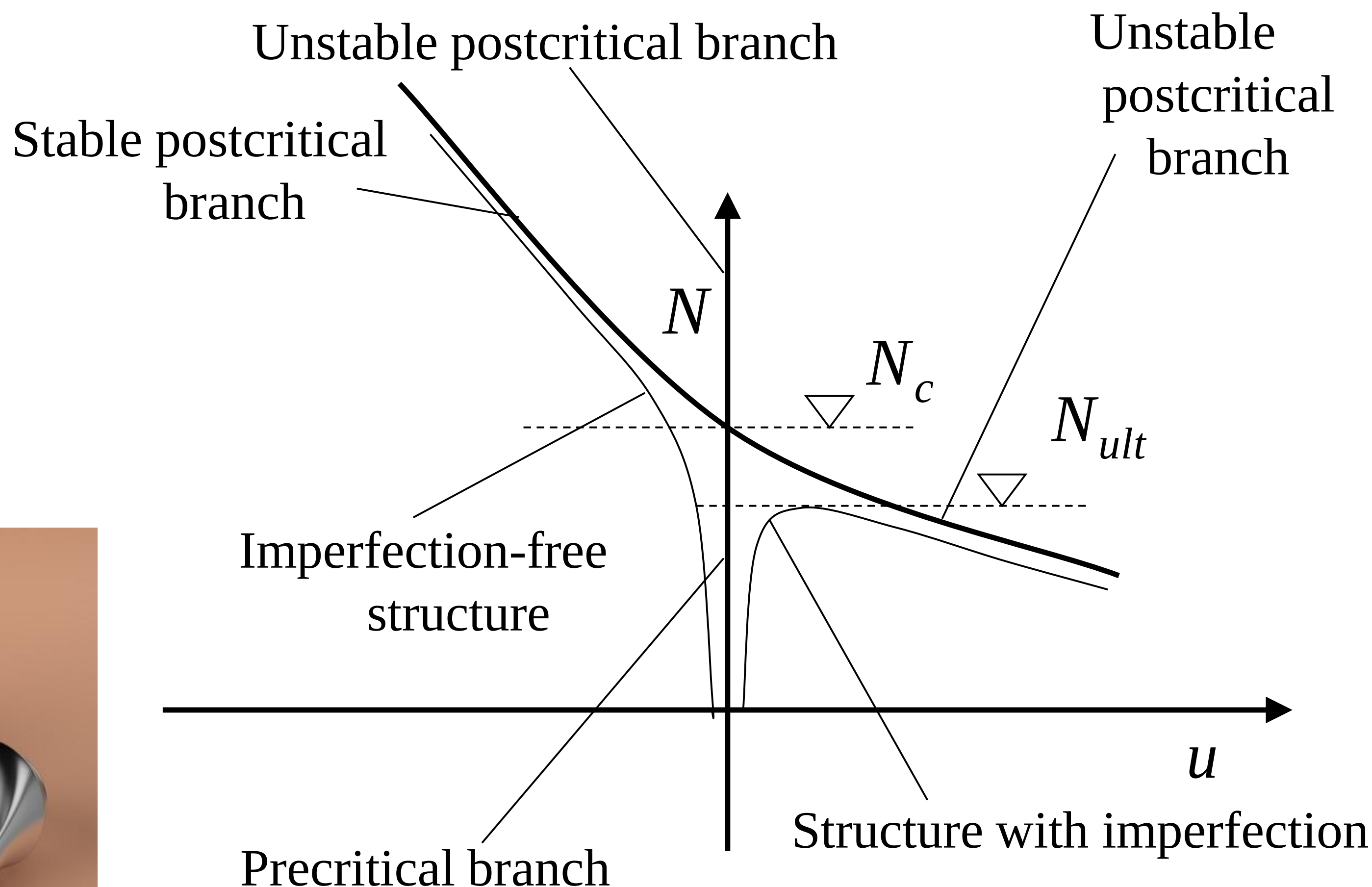


(a) Axisymmetric

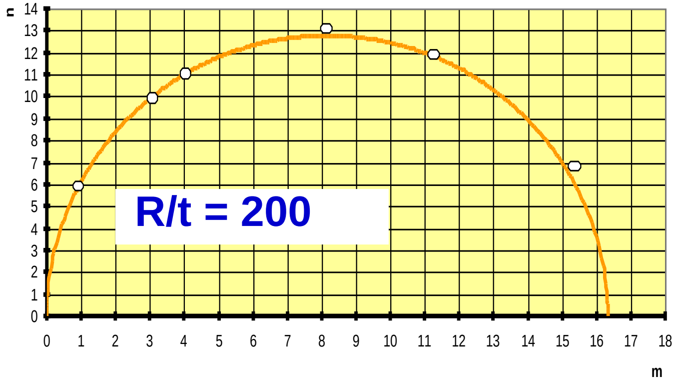
(b) Asymmetric

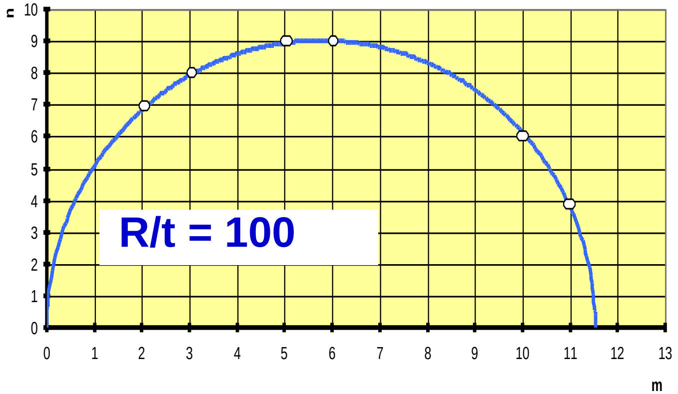
Cylinder under axial load

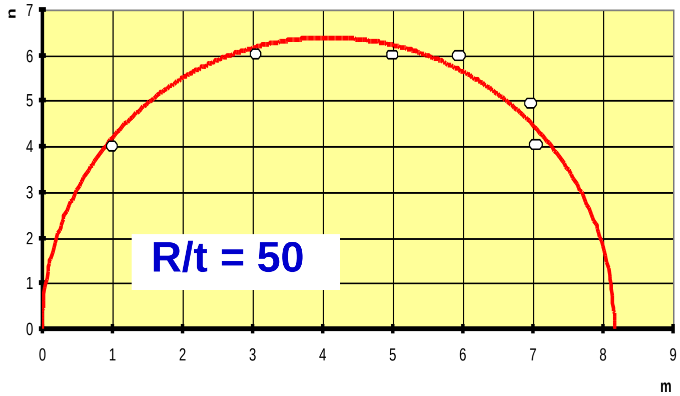


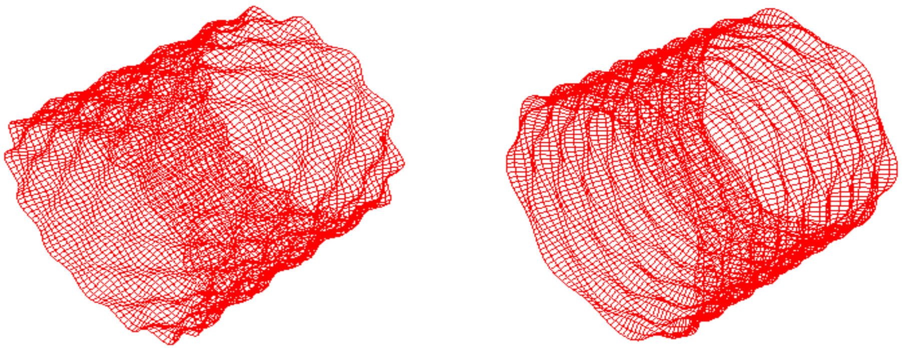


Elastic bifurcation load









$$\sigma_{cr} = \frac{E}{\sqrt{3\left(1-\nu^2\right)}}\frac{t}{R}$$

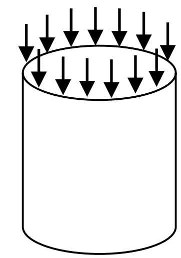
"Koiter" circle equation

$$\frac{(m^2+\beta^2)}{n^2} = \frac{2}{\pi}\sqrt{3}Z\left\{\begin{array}{l}\beta = nl\pi \\ Z = \dfrac{L^2}{Rt}\sqrt{1-v^2}\end{array}\right\}$$

Synopsis of buckling loads and critical modes for load cases under consideration in EC3 and EC9

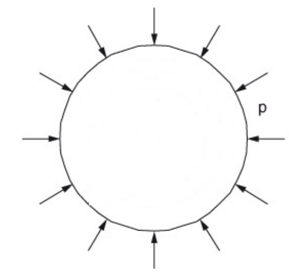
Cylinders under axial load

Elastic bifurcation load	Number of circumferential (n) and axial (m) waves at elastic buckling	Plasticity reduction factor	Number of axial (m) waves at plastic buckling
$\sigma_{cr,el} = \frac{E}{\sqrt{3(1-\nu^2)}}\frac{t}{R}$	$\frac{(m^2+(nL/\pi R)^2)^2}{m^2} = \frac{2}{\pi}\frac{L^2}{Rt}\sqrt{3(1-\nu^2)}$	$\eta = \frac{\sqrt{E_t E_s}}{E}$	$m = \frac{L}{\pi}\sqrt{\frac{12}{Rt\sqrt{6+9\frac{E_t}{E_s}+\frac{E_e}{E_t}}}}$



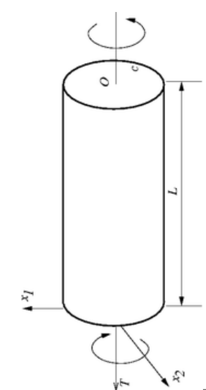
Cylinders under external pressure

Elastic bifurcation load	Number of circumferential (n) and axial (m) waves at elastic buckling	Plasticity reduction factor
$p_{cr,el} = \frac{Et/R}{n^2-1+\frac{1}{2}\left(\frac{\pi R}{L}\right)^2}\left[\frac{1}{\left(\left(\frac{nL}{\pi R}\right)^2+1\right)^2}+\frac{t^2}{12R^2(1-\nu^2)}\left(n^2-1+\left(\frac{\pi R}{L}\right)^2\right)^2\right]$	$n = 2.7\left(\frac{R}{L}\right)^{0.5}\left(\frac{R}{t}\right)^{0.25}$	$\eta = \frac{1}{4}\frac{E_s}{E}+\frac{3}{4}\frac{E_t}{E}$

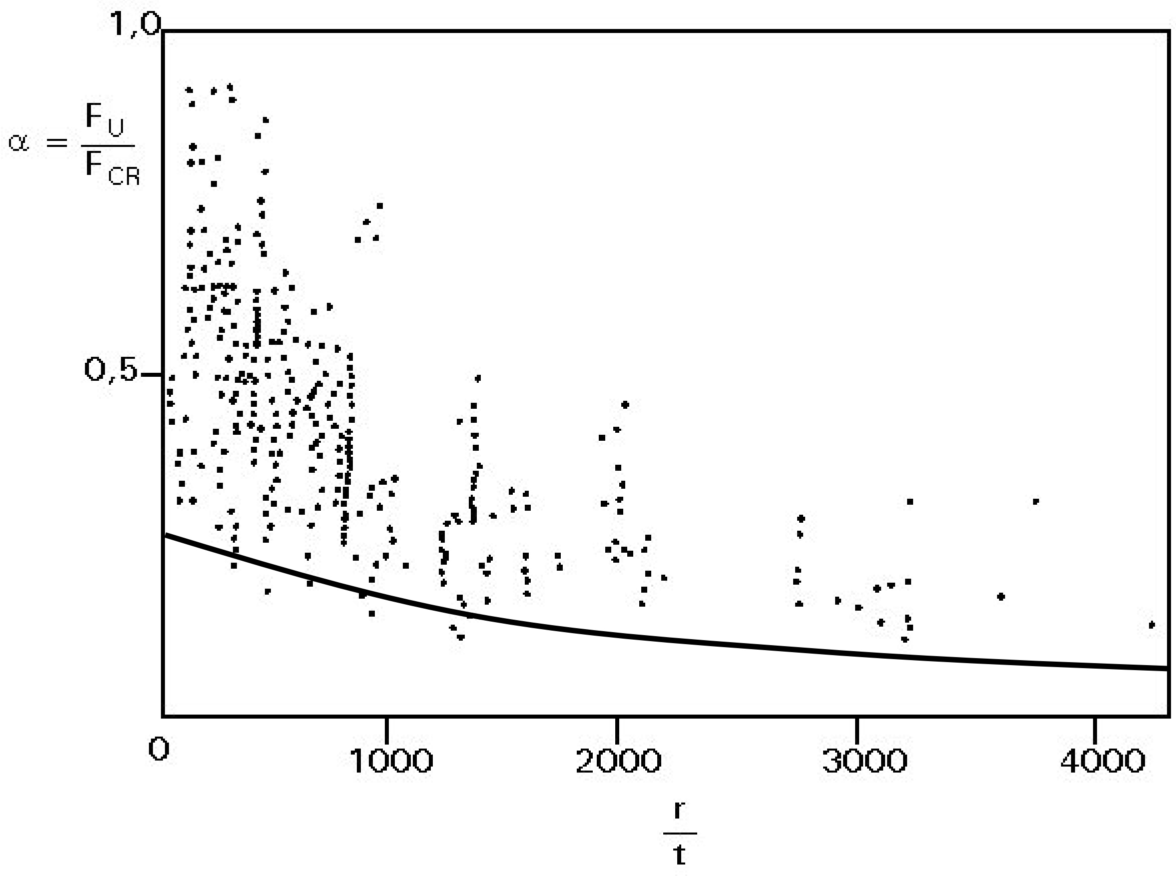


Cylinders under torsion

Elastic bifurcation load	Number of circumferential (n) and axial (m) waves at elastic buckling	Plasticity reduction factor
$\tau_{cr} = 0.75\,E\left(\frac{R}{L}\right)^{1/2}\left(\frac{t}{R}\right)^{5/4}$	$n = 4.2\,(0.75)^{1/8}\sqrt{\frac{R}{L}}\sqrt[4]{\frac{R}{t}}$	$\eta = \frac{E_s}{E}$



Lower Bound Design Philosophy



Imperfection sensitivity analysis

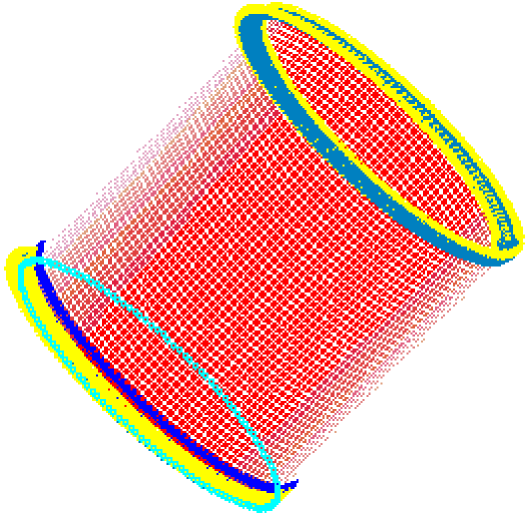
R/t	R [mm]	t [mm]	L [mm]	L/R
Cylinders under axial compression				
200	1000	5	2000	2
100	1000	10	2000	2
50	1000	20	2000	2
25	1000	40	2000	2
12.5	1000	80	2000	2
Cylinders under external pressure				
200	1000	5	4000	4
100	1000	10	4000	4
50	1000	20	4000	4
200	1000	5	2000	2
100	1000	10	2000	2
50	1000	20	2000	2
200	1000	5	1000	1
100	1000	10	1000	1
50	1000	20	1000	1
Cylinders under torsion				
200	1000	5	4000	4
100	1000	10	4000	4
50	1000	20	4000	4
200	1000	5	2000	2
100	1000	10	2000	2
50	1000	20	2000	2

Geometric data of analysed cylinders (R mean radius, t wall thickness, L overall length)

Parametric analysis: Shell geometrical data and material features

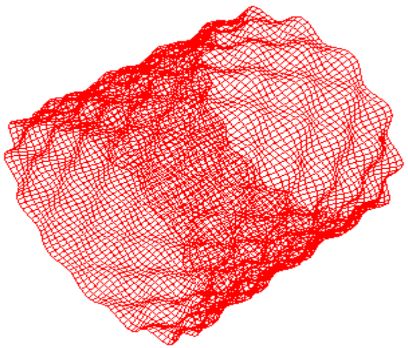
	$f_{0.2}$ [MPa]	$n_{R.O.}$
Strong hardening alloys	100	10
Weak hardening alloys (Heat-treated alloys)	200	20
	300	30

Mechanical features of alloys under consideration.

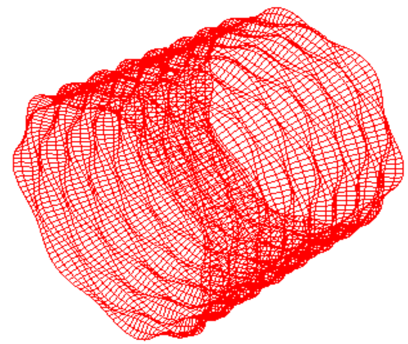


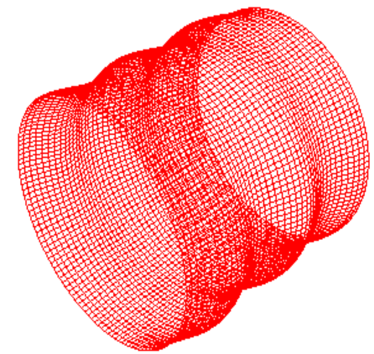
The ABAQUS model

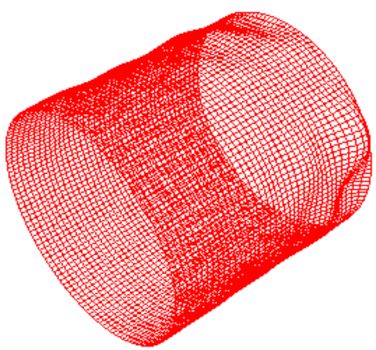
Imperfection sensitivity analysis

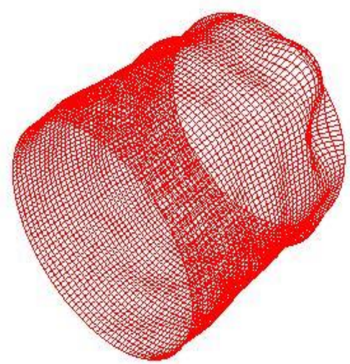


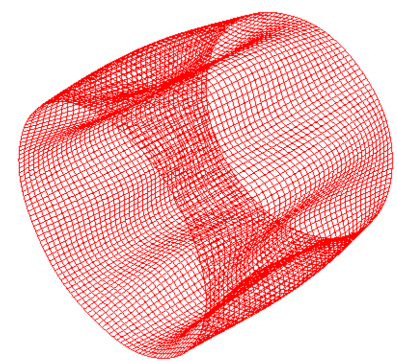
The imperfection model

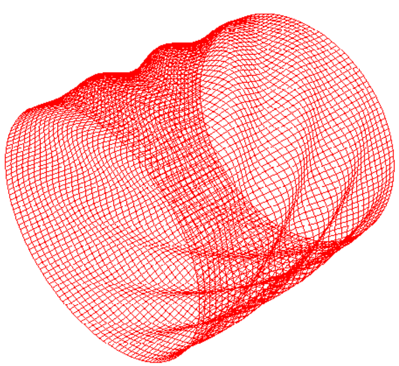








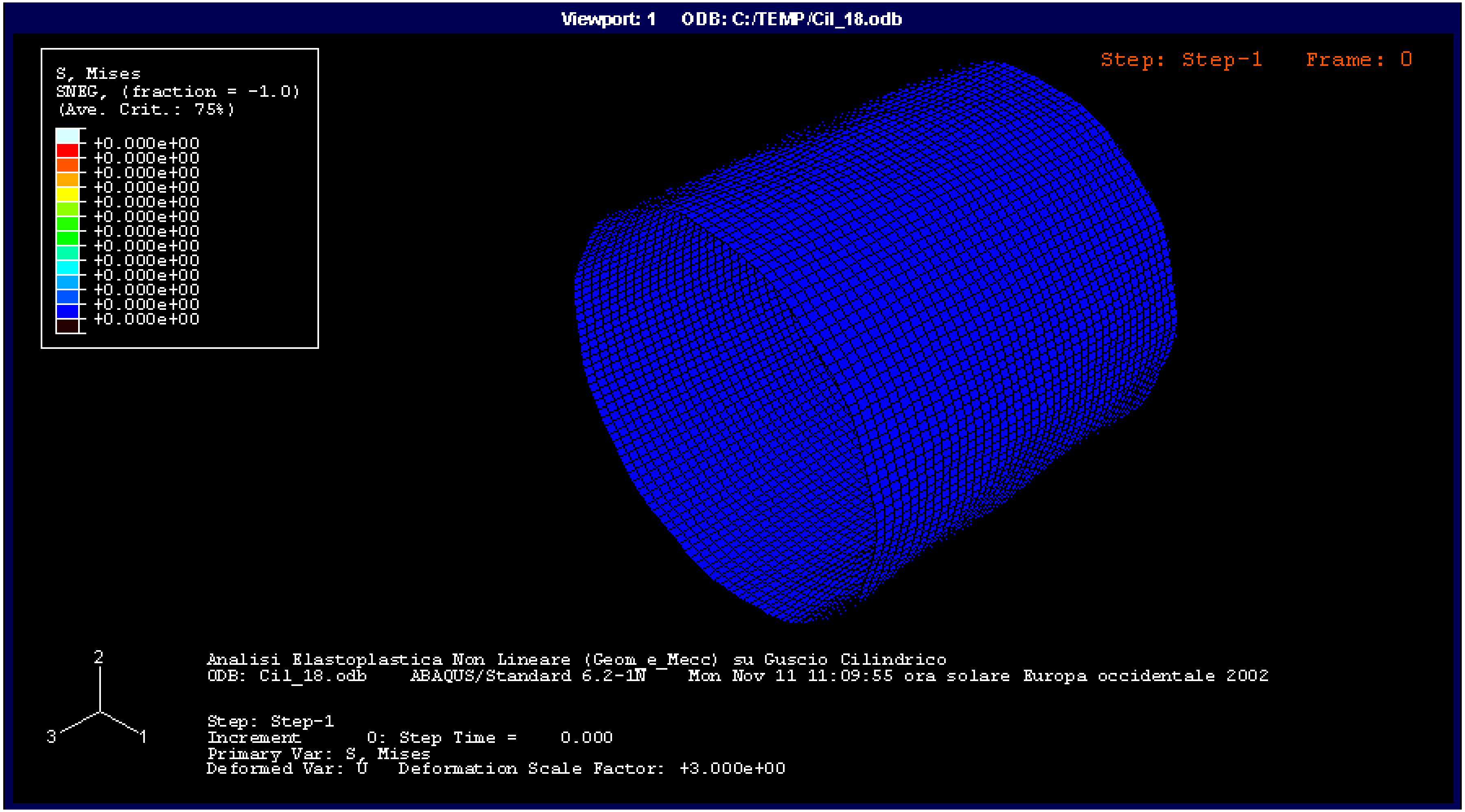




$$w = \sum w_0 e^{-k_{1x}(x-x_o)^2} \cos\left[k_{2x}\pi \frac{(x-x_o)}{L}\right] e^{-k_{1y}(y-y_o)^2} \cos\left[k_{2y}\pi \frac{(y-y_o)}{R}\right]$$

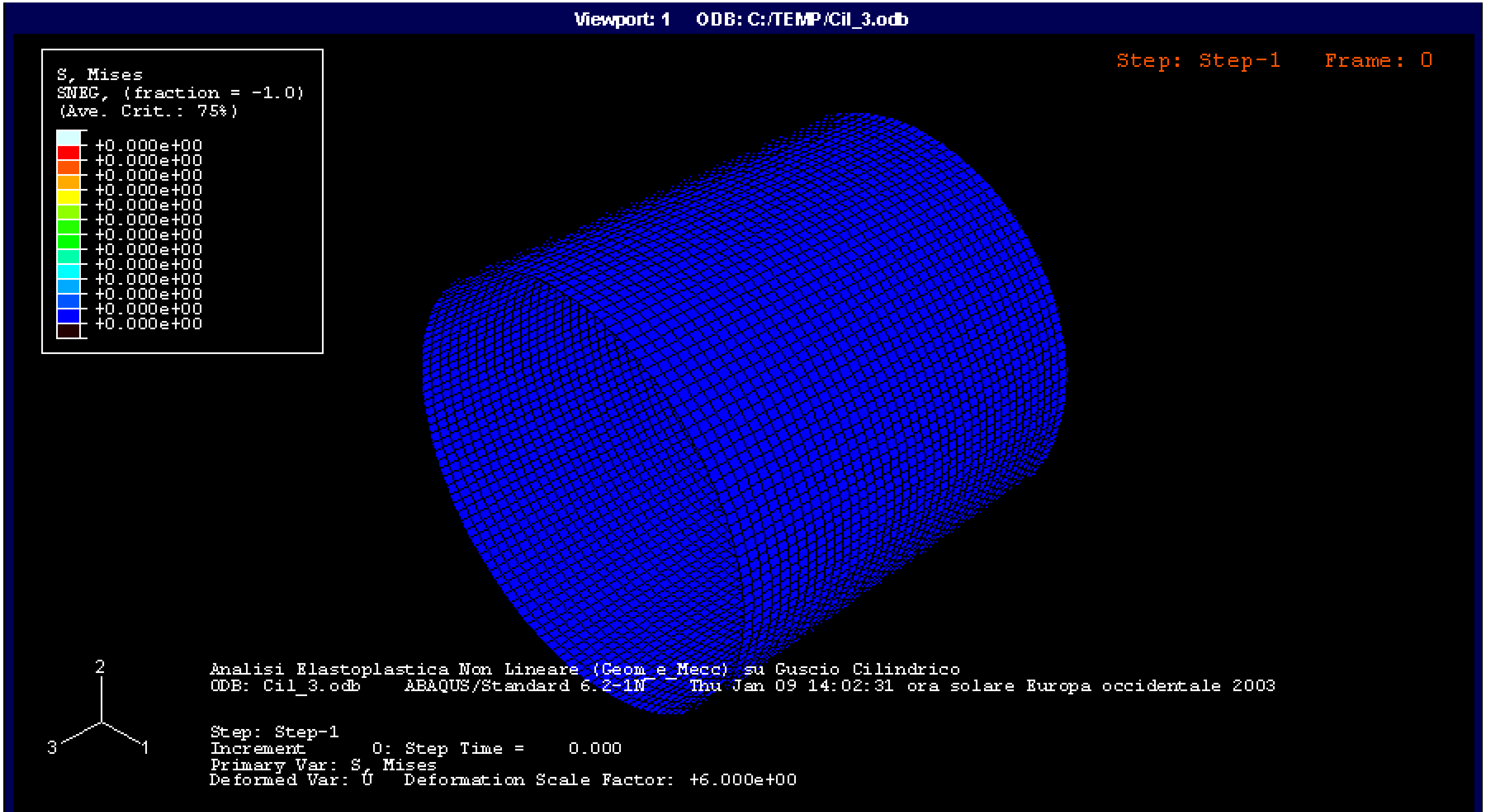
Imperfection sensitivity analysis

Deflected shapes at buckling
(cylinders under axial load – elastic buckling)



Imperfection sensitivity analysis

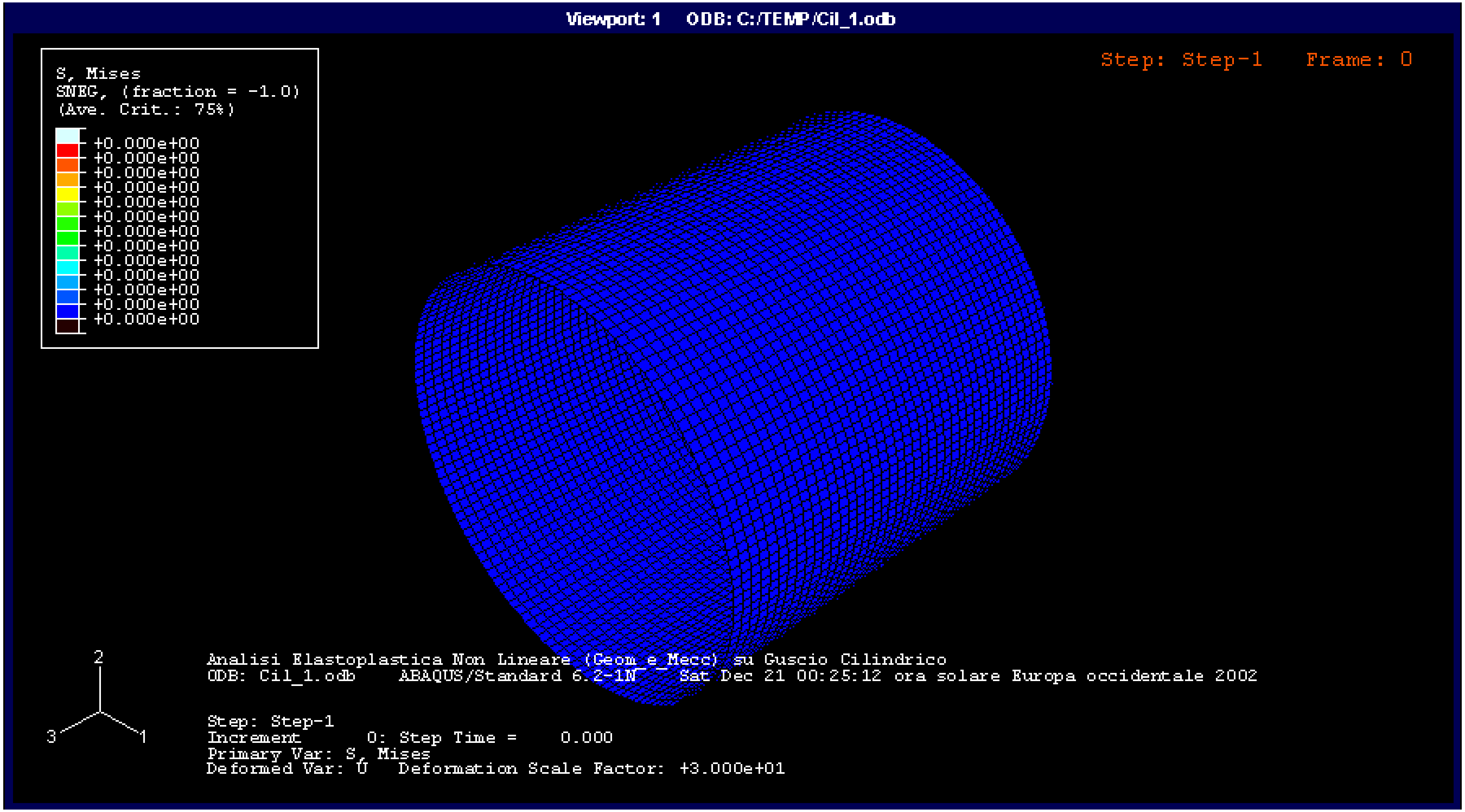
Deflected shapes at buckling
(cylinders under axial load – plastic buckling)



Imperfection sensitivity analysis

Deflected shapes at buckling

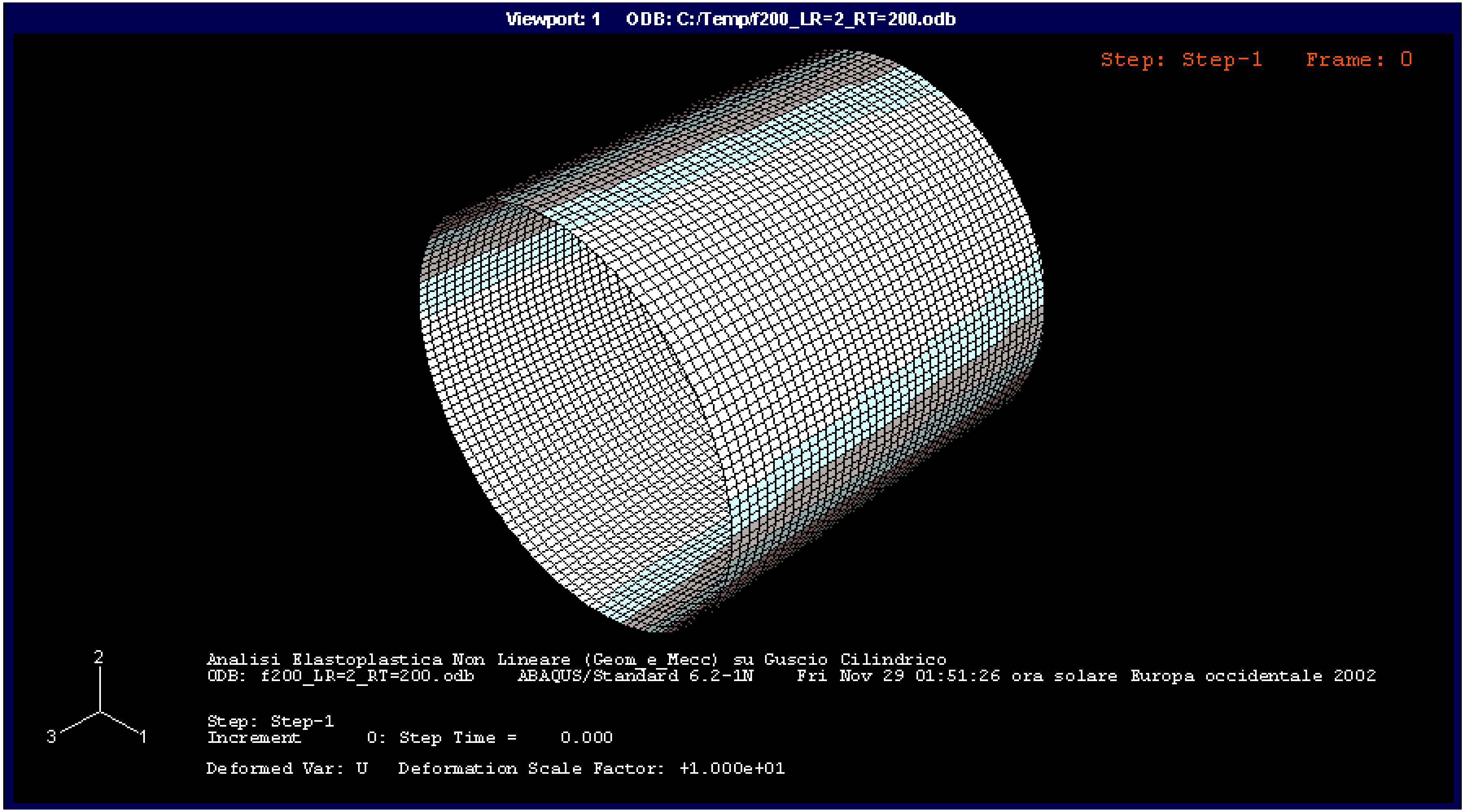
(cylinders under axial load – coupled buckling)



Imperfection sensitivity analysis

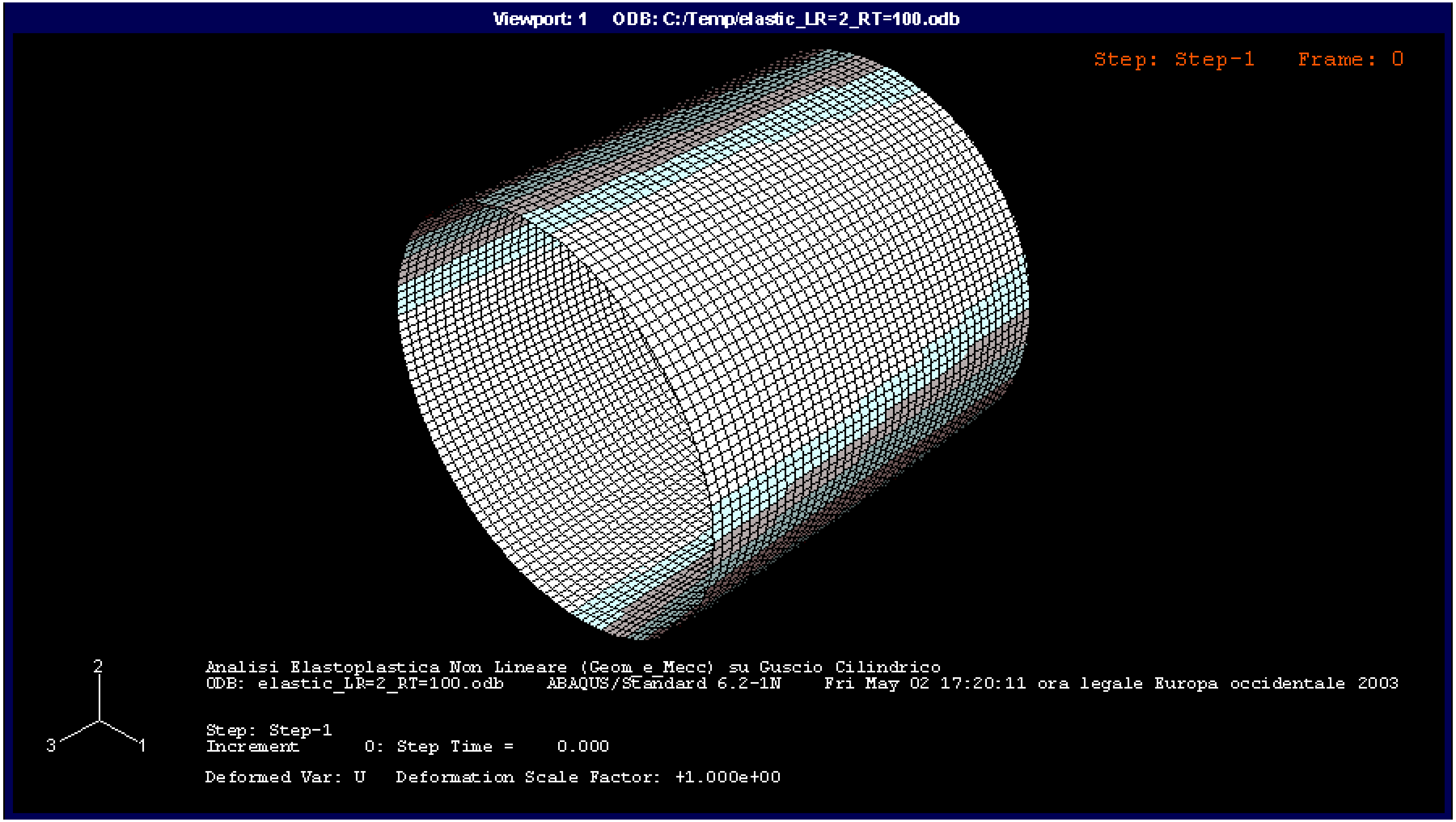
Deflected shapes at buckling

(cylinders under uniform external pressure)



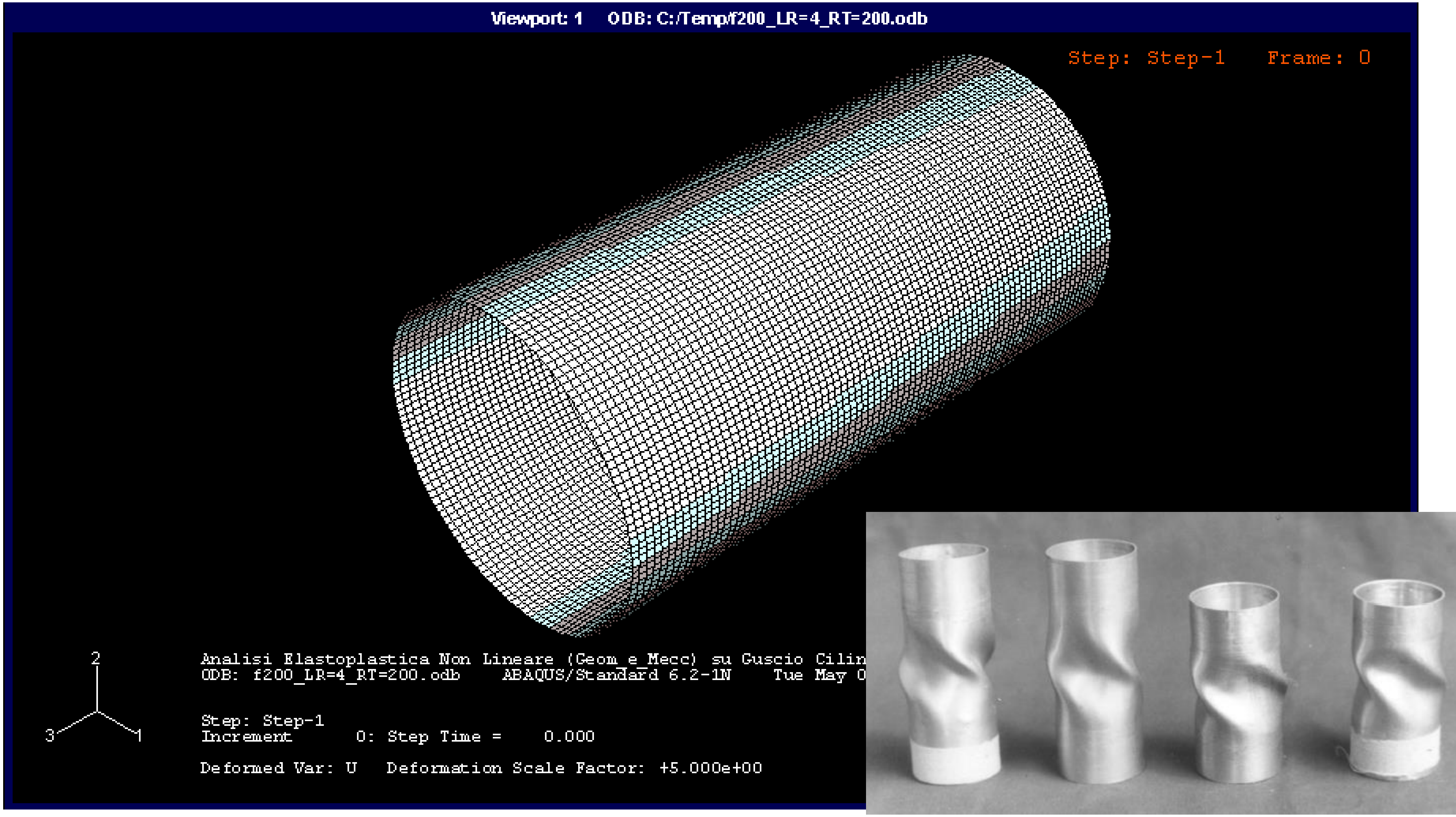
Imperfection sensitivity analysis

Deflected shapes at buckling (cylinders under torsion)



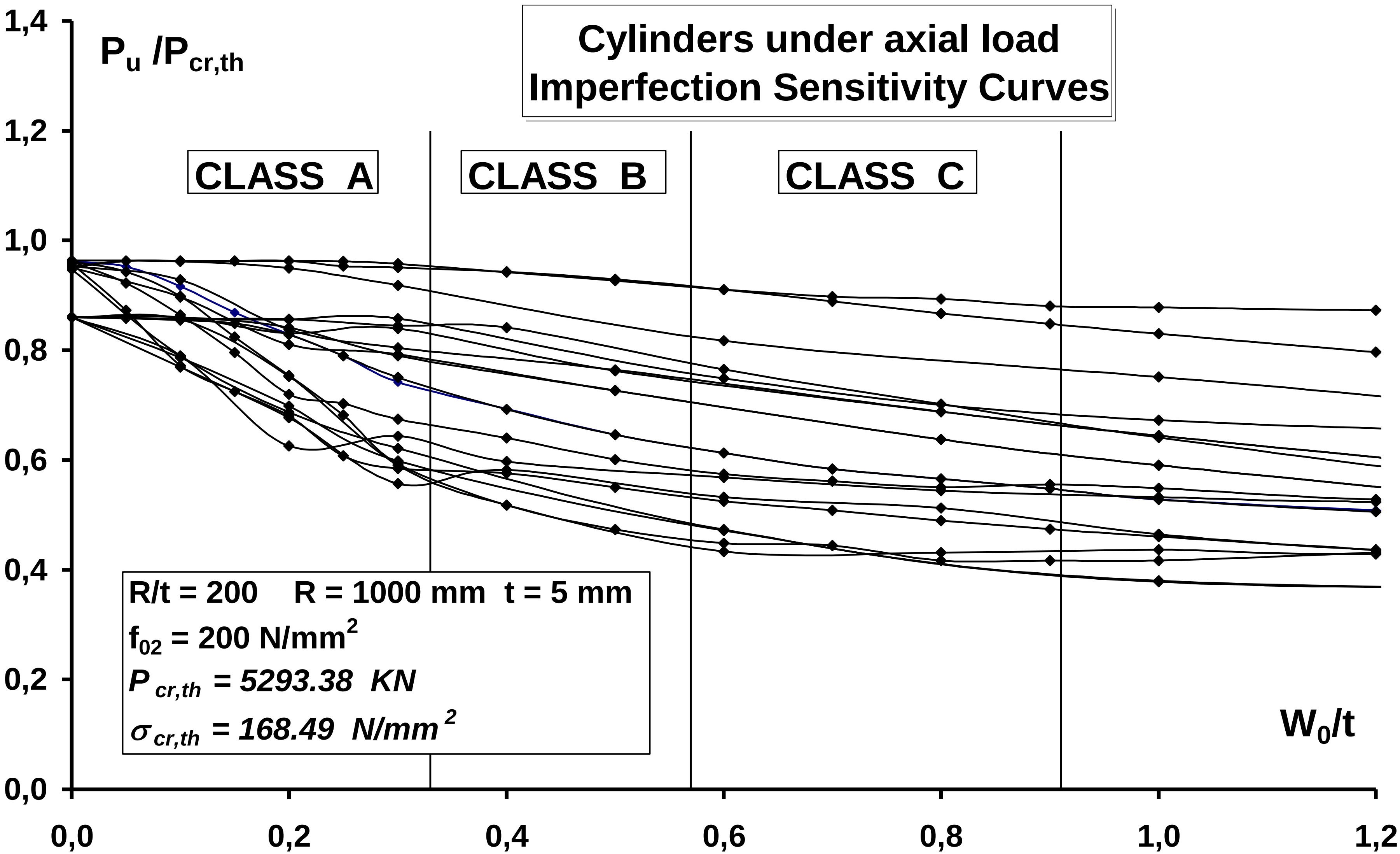
Imperfection sensitivity analysis

Deflected shapes at buckling (cylinders under torsion)



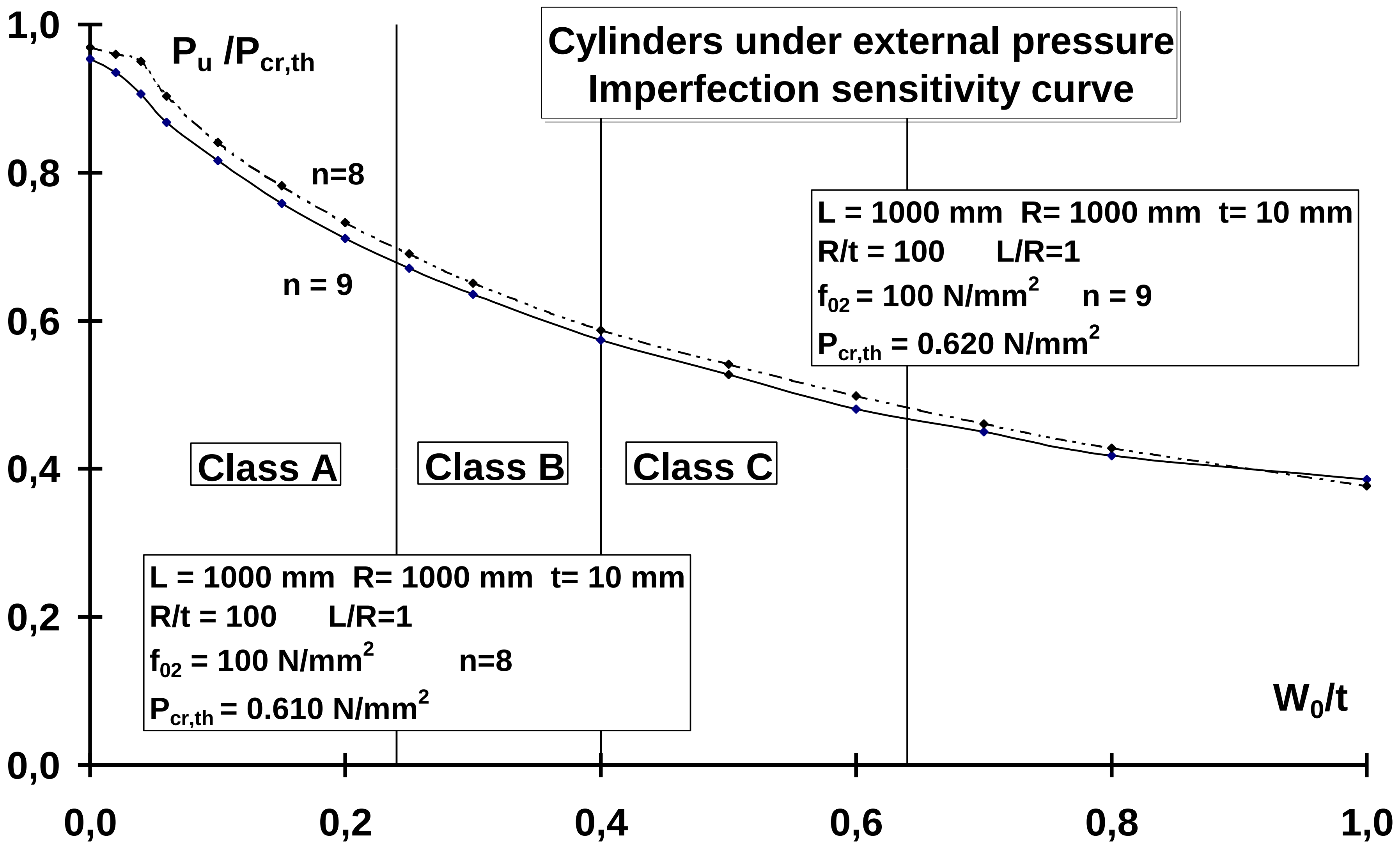
Imperfection sensitivity analysis

Imperfection sensitivity curves (axially loaded cylinders)



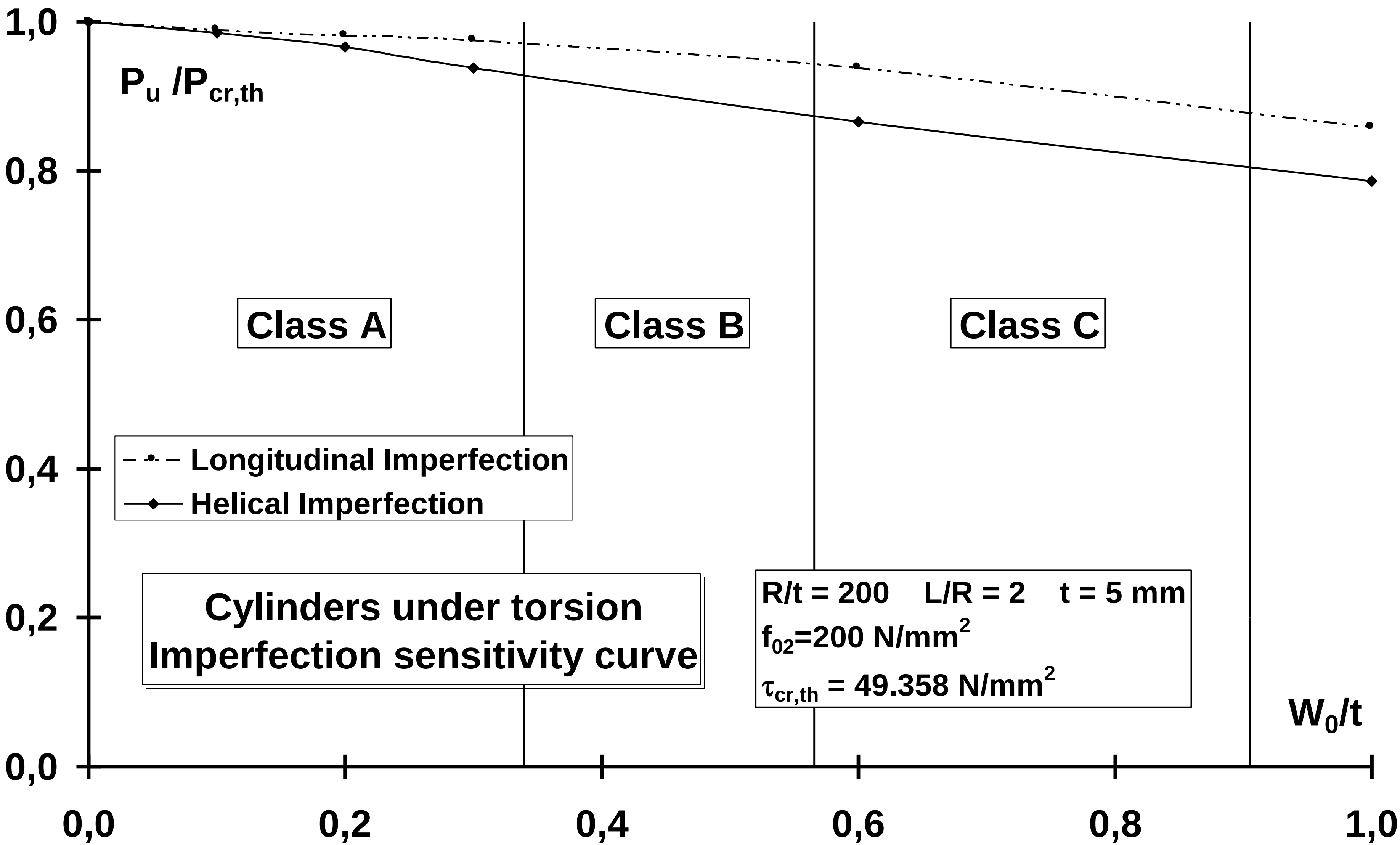
Imperfection sensitivity analysis

Imperfection sensitivity curves (cylinders under external pressure)

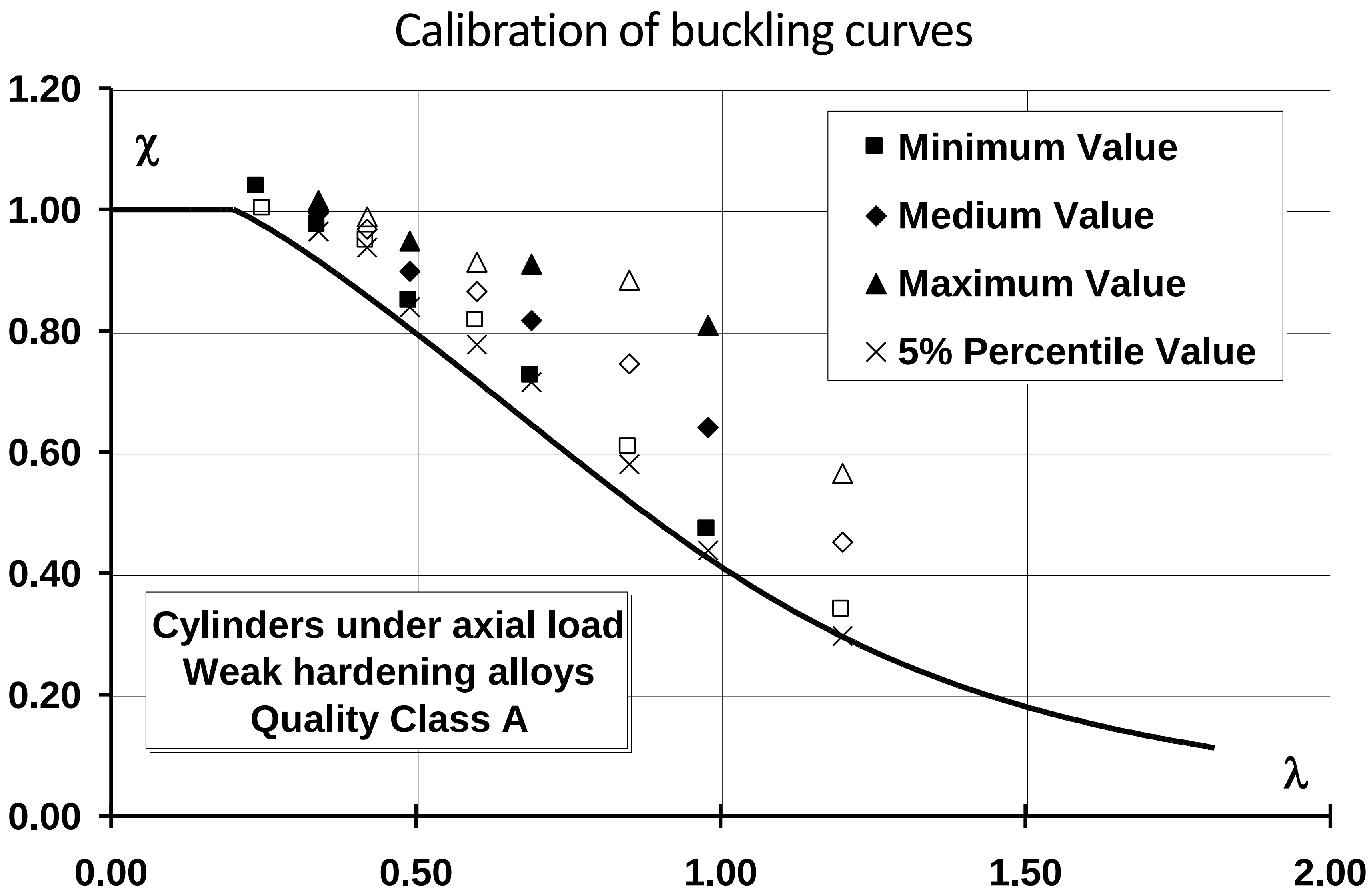


Imperfection sensitivity analysis

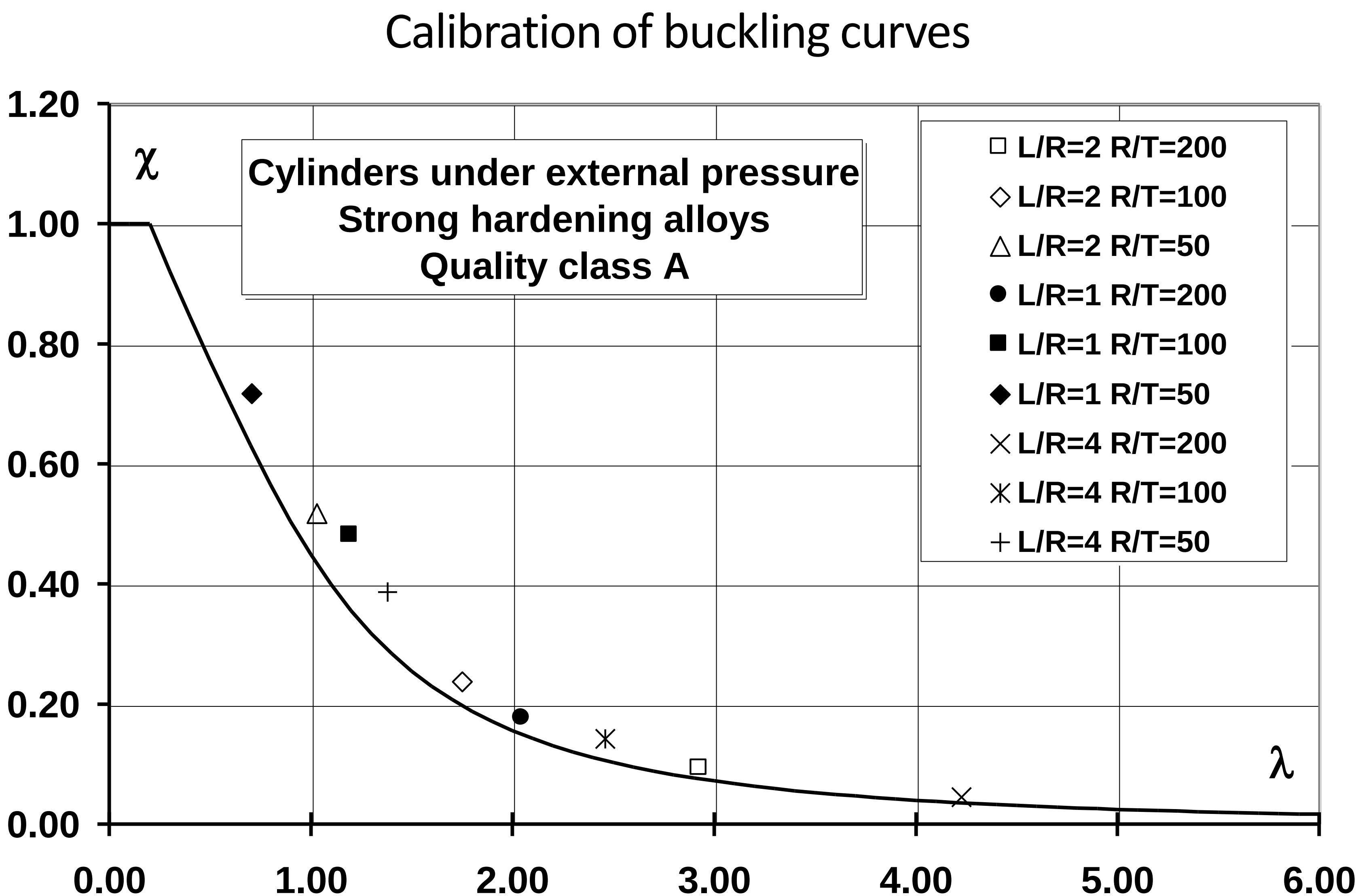
Imperfection sensitivity curves (cylinders under torsion)



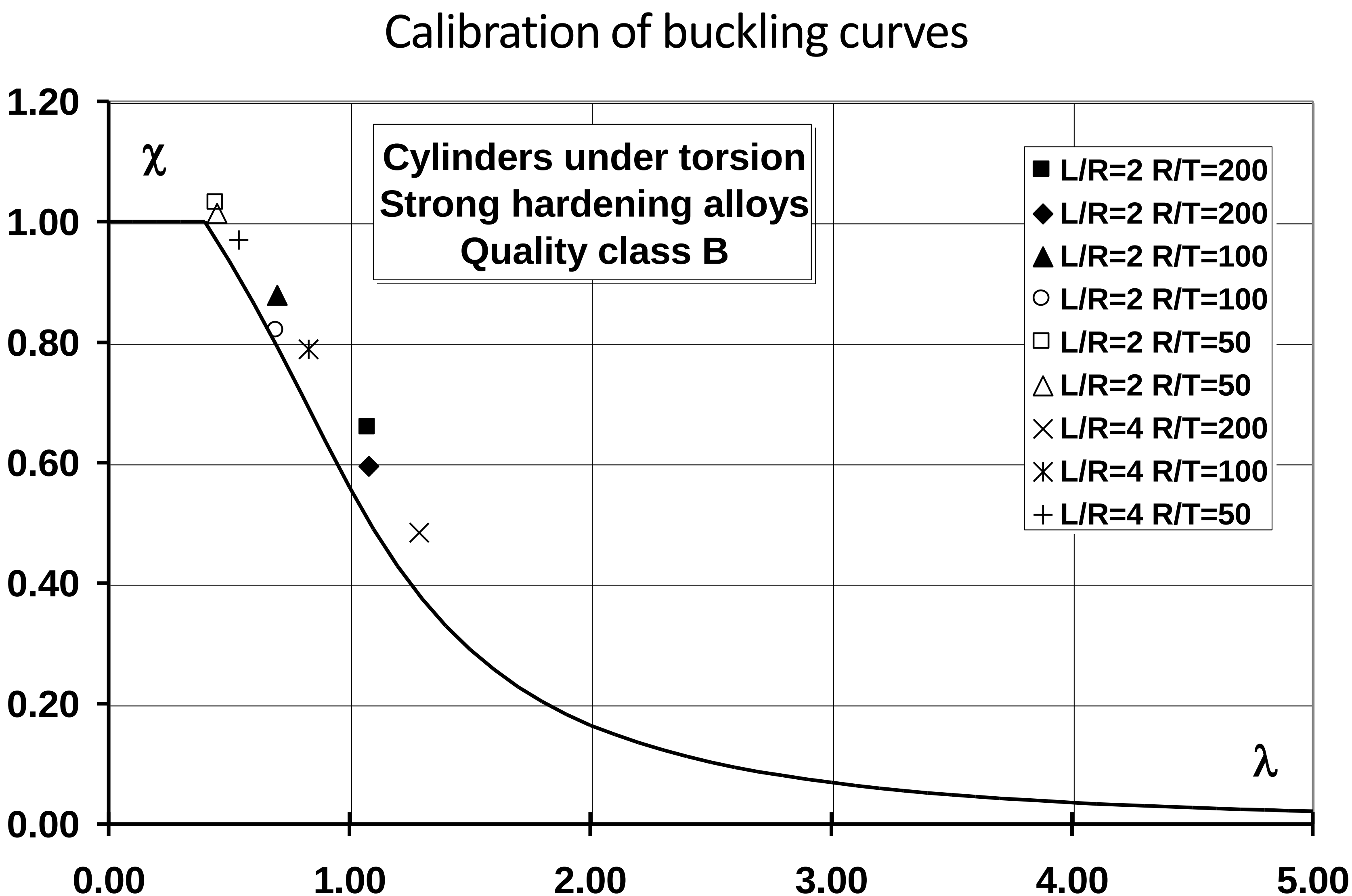
Set-up of buckling curves



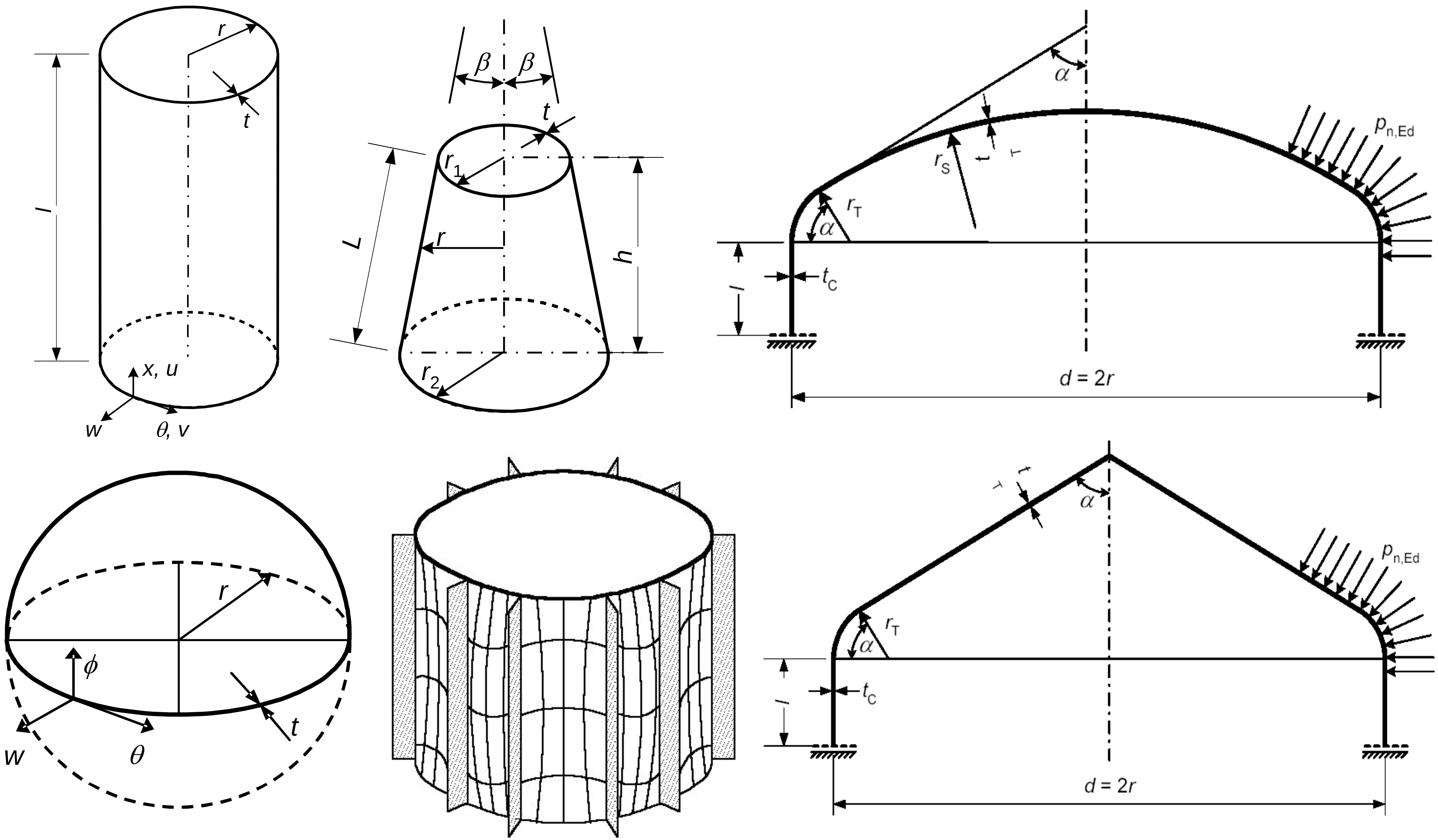
Set-up of buckling curves



Set-up of buckling curves



Shell configurations in EN1993-1-6 and EN1999-1-5



Types of shell analysis enabled in EN1993-1-6 and EN1999-1-5

Membrane theory analysis (MTA)	An analysis of a shell structure under distributed loads assuming a set of membrane forces that satisfy equilibrium with the external loads.
Linear elastic analysis (LA)	An analysis on the basis of the small deflection linear elastic shell bending theory assuming perfect geometry.
Linear elastic bifurcation (eigenvalue) analysis (LBA)	An analysis that calculates the linear elastic bifurcation eigenvalue on the basis of small deflections using the linear elastic shell bending theory, assuming perfect geometry. Note that eigenvalue in this context does not refer to vibration modes.
Geometrically non-linear analysis (GNA)	An analysis on the basis of the shell bending theory assuming perfect geometry, considering non-linear large deflection theory and linear elastic material properties.
Materially non-linear analysis (MNA)	An analysis equal to (LA), however, considering non-linear material properties. For welded structure the material in the heat-affected zone should be modelled.
Geometrically and materially non-linear analysis (GMNA)	An analysis applying the shell bending theory assuming perfect geometry, considering non-linear large deflection theory and non-linear material properties. For welded structure the material in the heat-affected zone should be modelled.
Geometrically non-linear elastic analysis with imperfections included (GNIA) [1)]	An analysis equal to (GNA), however, considering an imperfect geometry.
Geometrically and materially non-linear analysis with imperfections included (GMNIA)	An analysis equal to (GMNA), however, considering an imperfect geometry.
1) This type of analyses is not covered in this standard, however, listed here for the purpose of having a complete presentation of types of shell analysis.	

Shell buckling – EC3 formulation

$$\sigma_{x,Rk} = \chi_x f_{yk}, \quad \sigma_{\theta,Rk} = \chi_\theta f_{yk}, \quad \tau_{x\theta,Rk} = \chi_\tau f_{yk} / \sqrt{3}$$

$$\chi = 1 \Leftrightarrow \lambda \leq \lambda_0$$

$$\chi = 1 - \beta \left(\frac{\lambda - \lambda_0}{\lambda_p - \lambda_0} \right)^\eta \Leftrightarrow \lambda_0 < \lambda \leq \lambda_p$$

$$\chi = \frac{\alpha}{\lambda^2} \Leftrightarrow \lambda_p \leq \lambda$$

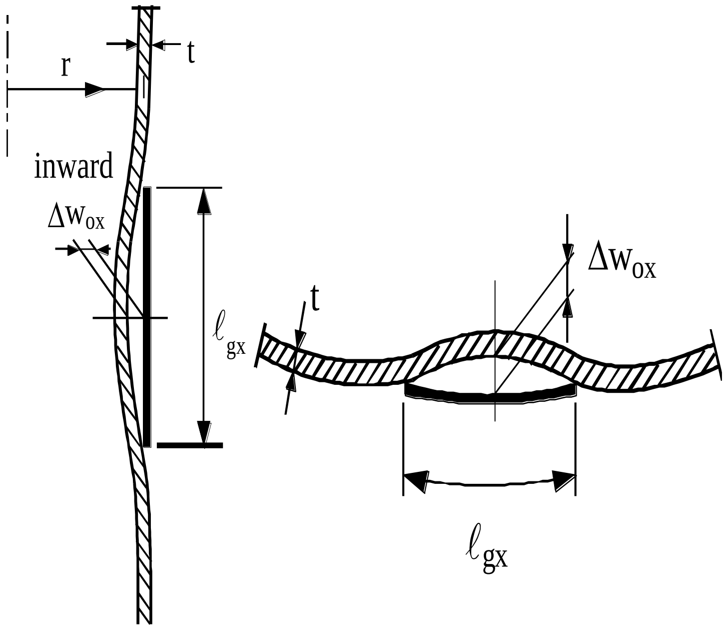
$$\lambda = \sqrt{\frac{f_{yk}}{\sigma_{xRc}}}$$

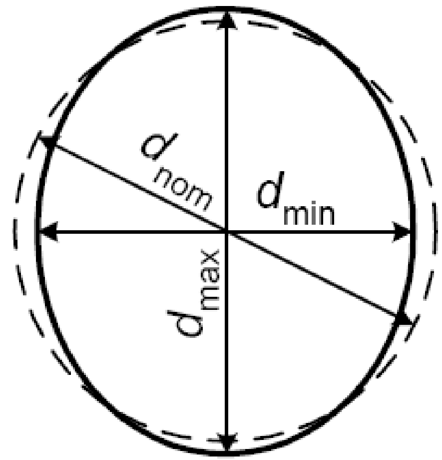
$$\lambda_p = \sqrt{\frac{\alpha}{1 - \beta}}$$

- $\sigma_{x,Rk}$, $\sigma_{\theta,Rk}$, $\tau_{x\theta,Rk}$, characteristic buckling stress;
- χ, buckling factor;
- λ, relative shell slenderness;
- λ_0, squash limit relative shell slenderness;
- λ_p, plastic limit relative shell slenderness;
- β, η, parameters of buckling curve;
- α, elastic imperfection reduction factor;
- f_{yk}, characteristic steel yield stress.

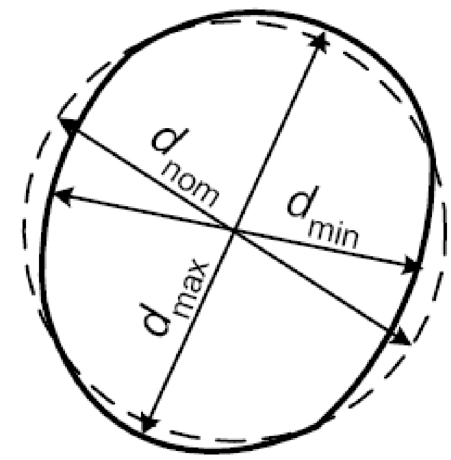
Set-up of buckling curves

Shell buckling – fabrication tolerance classes in EC3





a) flattening



b) unsymmetrical shape

Fabrication tolerance quality class	Description
Class A	**Excellent**
Class B	**High**
Class C	**Normal**

$$U_r = \frac{d_{max} - d_{min}}{d_{nom}}$$

$$\frac{w_0}{\ell_{gx}} \leq U_{0\,max} \Leftrightarrow \frac{w_o}{t} \leq \frac{U_{0\,max}\,\ell_{gx}}{t}$$

$U_{o\,max}$ Dimple tolerance parameter

$\ell_{gx} = 4\sqrt{Rt}$ Gauge length

Set-up of buckling curves

Expressions of buckling factors according to EC3

	Axial (meridional) load	External pressure and torsion (shear)
λ_0	0.20	0.40
β	0.60	0.60
η	1.00	1.00

Fabrication tolerance quality class	Description	Axial (meridional) load		External pressure (α_θ) and torsion (shear) (α_τ)
		Q	α_x	α_θ or α_τ
Class A	Excellent	40	$\alpha_x = \dfrac{0.62}{1+1.91\left(1/Q\sqrt{r/t}\right)^{1.44}}$	0,75
Class B	High	25		0,65
Class C	Normal	16		0,50

Set-up of buckling curves

Shell buckling – EC9 formulation

Load cases

- axial compression
- external pressure
- torsion

Unstiffened shells

$$\sigma_{x,\mathrm{Rd}} = \alpha_x \rho_{x,\mathrm{w}} \chi_{x,\mathrm{perf}} \frac{f_\mathrm{o}}{\gamma_{\mathrm{M1}}}$$

$$\sigma_{\theta,\mathrm{Rd}} = \alpha_\theta \rho_{\theta,\mathrm{w}} \chi_{\theta,\mathrm{perf}} \frac{f_\mathrm{o}}{\gamma_{\mathrm{M1}}}$$

$$\tau_{\mathrm{Rd}} = \alpha_\tau \rho_{\tau,\mathrm{w}} \chi_{\tau,\mathrm{perf}} \frac{f_\mathrm{o}}{\sqrt{3}\,\gamma_{\mathrm{M1}}}$$

Stiffened shells

$$n_{x,\mathrm{Rd}} = \alpha_{n,x} \chi_{x,\mathrm{perf}} \frac{n_{\mathrm{x,Rk}}}{\gamma_{\mathrm{M1}}}$$

$$p_{n,\mathrm{Rd}} = \alpha_{p,\theta} \chi_{\theta,\mathrm{perf}} \frac{p_{n,\mathrm{Rk}}}{\gamma_{\mathrm{M1}}}$$

Set-up of buckling curves

Shell buckling – EC9 formulation

$$\chi_{i,\mathrm{perf}} = \frac{1}{\phi_i + \sqrt{\phi_i^2 - \bar{\lambda}_i^2}} \quad \text{but} \quad \chi_{i,\mathrm{perf}} \le 1{,}00$$

$$\bar{\lambda}_x = \sqrt{\frac{f_o}{\sigma_{x,\mathrm{cr}}}}$$

$$\bar{\lambda}_\theta = \sqrt{\frac{f_o}{\sigma_{\theta,\mathrm{cr}}}}$$

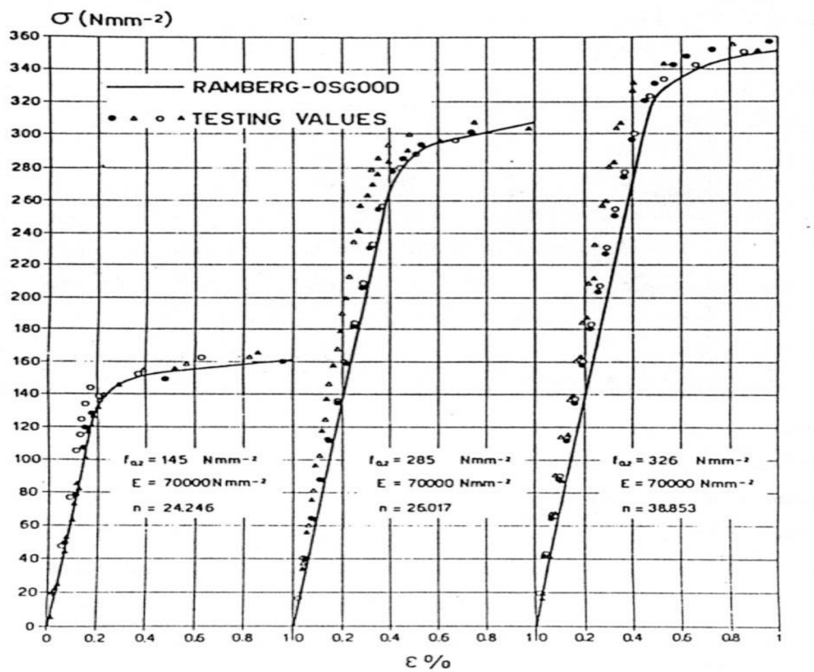
with:

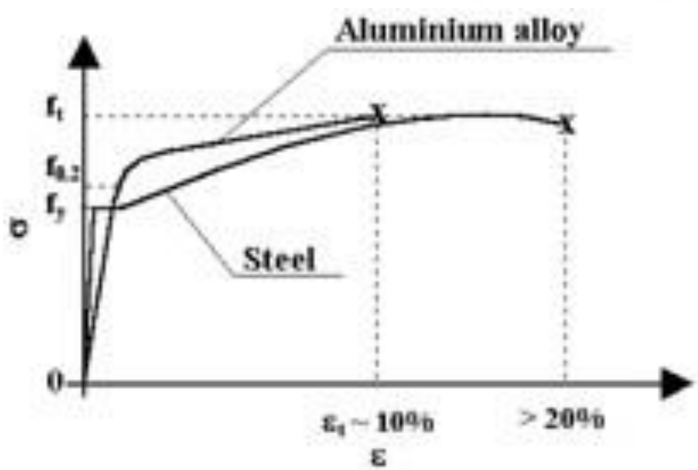
$$\phi_i = 0{,}5\left(1 + \mu_i(\bar{\lambda}_i - \bar{\lambda}_{i,0}) + \bar{\lambda}_i^2\right)$$

$$\bar{\lambda}_\tau = \sqrt{\frac{f_o}{\sqrt{3}\tau_{\mathrm{cr}}}}$$

Material buckling class	Axial (meridional) load		External pressure		Shear (torsion)	
	$\lambda_{x,0}$	μ_x	$\lambda_{\theta,0}$	μ_θ	$\lambda_{\tau,0}$	μ_τ
A (Weak hardening alloys)	0.2	0.35	0.3	0.55	0.5	0.3
B (Strong hardening alloys)	0.1	0.2	0.2	0.7	0.4	0.4

Elasto-plastic bifurcation load





$$\sigma_{cr,pl} = \eta \sigma_{cr,el}$$

$$\eta = \frac{\sqrt{E_t E_s}}{E}$$

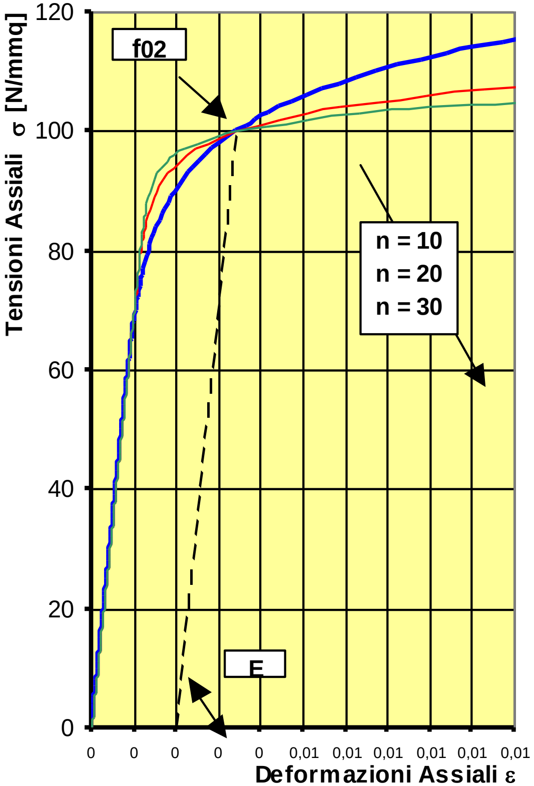
"Ramberg-Osgood" law:

$$\varepsilon = \frac{\sigma}{E} + 0.002\left(\frac{\sigma}{f_{02}}\right)^n$$

$$E_t = \frac{d\sigma}{d\varepsilon} = \frac{E}{1 + \frac{0.002nE}{f_{02}}\left(\frac{\sigma}{f_{02}}\right)^{n-1}}$$

$$E_s = \frac{\sigma}{\varepsilon} = \frac{E}{1 + \frac{0.002E}{f_{02}}\left(\frac{\sigma}{f_{02}}\right)^{n-1}}$$

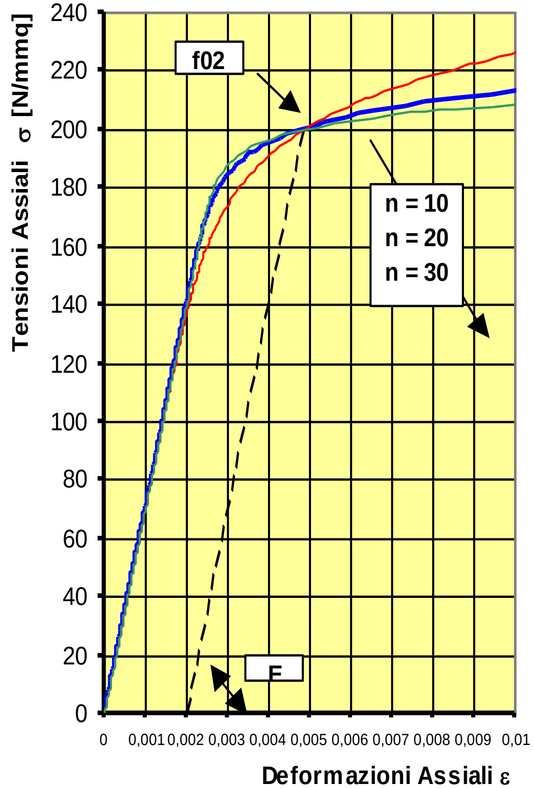
"Ramberg-Osgood" law



High hardening alloy

$f_{0.2}$ =100 N/mm^2

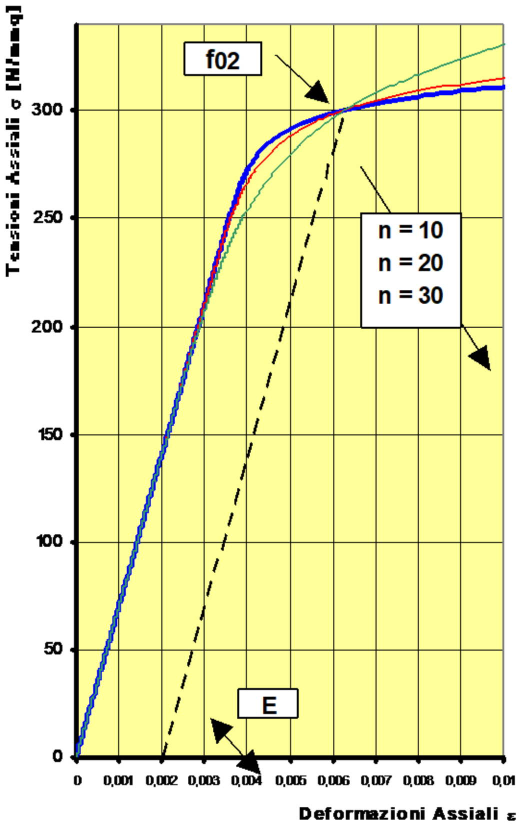
n = 10



Heat treatment alloy

$f_{0.2}$ =200 N/mm^2

n = 20



High strength alloy

$f_{0.2}$ =300 N/mm^2

n = 30

Set-up of buckling curves

Shell buckling – fabrication tolerance classes according to EC9

Fabrication tolerance quality class	Diameter range		
	$d \le 0{,}5$ m	$0{,}5$ m $< d < 1{,}25$ m	$1{,}25$ m $\ge d$
Class 4	0,010	$0{,}005 + 0{,}0067(1{,}25 - d)$	0,005
Class 3	0,014	$0{,}007 + 0{,}0090(1{,}25 - d)$	0,007
Class 2	0,020	$0{,}010 + 0{,}0133(1{,}25 - d)$	0,010
Class 1	0,030	$0{,}015 + 0{,}0200(1{,}25 - d)$	0,015

Fabrication tolerance quality class	**Axial (meridional) load**		**External pressure (α_θ) and torsion (α_τ)**	
	Q	α_x	α_{ref}	α_θ **or** α_τ
Class 1	**16**	$\alpha_x = \dfrac{0.62}{1+1.91\left(1/Q\sqrt{r/t}\right)^{1.44}}$	**0,50**	$\alpha_{\theta,\tau} = \dfrac{1}{1+0,2\left(1-\alpha_{ref}\right)\left(\bar{\lambda}-\bar{\lambda}_0\right)/\alpha_{ref}^2}$
Class 2	**25**		**0,65**	
Class 3	**40**		**0,75**	
Class 4	**50-60**		**-**	

Buckling curves - Comparison EC3 vs EC9

EN1993-1-6

$$\chi = 1 \Leftrightarrow \lambda \le \lambda_0$$

$$\chi = 1 - \beta\left(\frac{\lambda - \lambda_0}{\lambda_p - \lambda_0}\right)^{\eta} \Leftrightarrow \lambda_0 < \lambda \le \lambda_p$$

$$\chi = \frac{\alpha}{\lambda^2} \Leftrightarrow \lambda_p \le \lambda$$

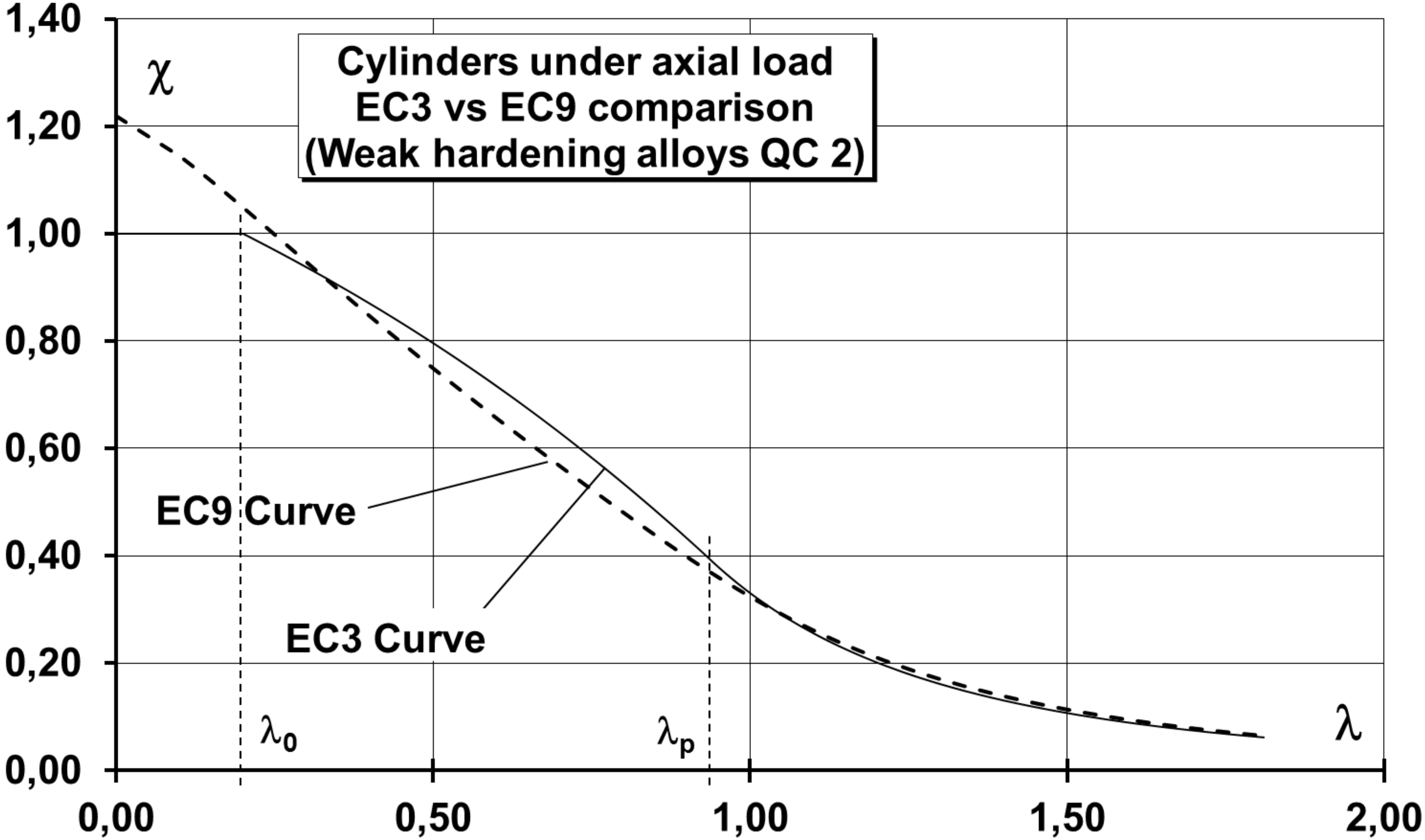
EN1999-1-5

$$\chi = \alpha \chi_{perf}$$

$$\chi_{perf} = \frac{1}{\phi + \sqrt{\phi^2 - \lambda^2}}$$

$$\phi = 0.5 \cdot \left[1 + \alpha_0\left(\lambda - \lambda_0\right) + \lambda^2\right]$$

Buckling curves - Comparison EC3 vs EC9



Calculation of critical stress according to Eurocodes

(4) For long cylinders as defined in Table A.1 that satisfy the additional conditions:

$$\frac{r}{t} \leq 150 \quad \text{and} \quad \frac{\omega t}{r} \leq 6 \quad \text{and} \quad 500 \leq \frac{E}{f_o} \leq 1000$$

the factor C_{xb} may alternatively be obtained by:

$$C_x = C_{x,N} \frac{\sigma_{x,N,Ed}}{\sigma_{x,Ed}} + \frac{\sigma_{x,M,Ed}}{\sigma_{x,Ed}}$$

where:

- $C_{x,N}$ is the parameter for long cylinder in axial compression according to Table A.1;
- $\sigma_{x,Ed}$ is the design value of the meridional stress ($\sigma_{x,Ed} = \sigma_{x,N,Ed} + \sigma_{x,M,Ed}$);
- $\sigma_{x,N,Ed}$ is the stress component from axial compression (circumferentially uniform component);
- $\sigma_{x,M,Ed}$ is the stress component from tubular global bending (peak value of the circumferentially varying component).

Cylinders under axial load

(4) For long cylinders that satisfy the special conditions of A.1.2.1(4), the meridional squash limit slenderness parameter may be obtained from:

$$\bar{\lambda}_{x,0,1} = \bar{\lambda}_{x,0} + 0{,}10 \frac{\sigma_{x,M,Ed}}{\sigma_{x,Ed}}$$

Definition of tank

EC3 - A tank is a vessel for storing liquid or gas products. In EC3 it is assumed to be prismatic with a vertical axis (with the exception of the tank bottom and roof parts).

Wikipedia - A storage tank is a container, usually for holding liquids, sometimes for gases (gas tank). The term can be used for both reservoirs (artificial lakes and ponds), and for manufactured containers. The usage of the word tank for reservoirs is common or universal in Indian English, and moderately common in British English. In other countries, the term tends to refer only to artificial containers.

Storage tanks operate under no (or very little) pressure, distinguishing them from pressure vessels. Storage tanks are often cylindrical in shape, perpendicular to the ground with flat bottoms, and a fixed or floating roof. There are usually many Environmental regulations applied to the design and operation of storage tanks, often depending on nature the fluid contained within. Aboveground storage tanks (AST) differ from underground (UST) varieties in the kinds of regulations that are applied.

Reservoirs can be covered, in which case they may be called covered or underground storage tanks or reservoirs. Covered water tanks are common in urban areas.

Container tanks can be many shapes, but large tanks tend to be cylindrical, or to have rounded corners, to easier withstand hydraulic pressure of contained liquid. Most container tanks for handling liquids during transportation are pressure vessels.

A large tank is sometimes mounted on a lorry or on an articulated lorry trailer, which is then called a tanker.

Classification of steel tanks according to application

Industrial tanks
- Fixed roof tanks
- Floating roof tanks
- Floating deck in fixed roof tank
- Low temperature tanks
- Cryogenic tanks
- Pressure vessels
- Marine tanks
- Modular tanks

These are “tanks”, too!...

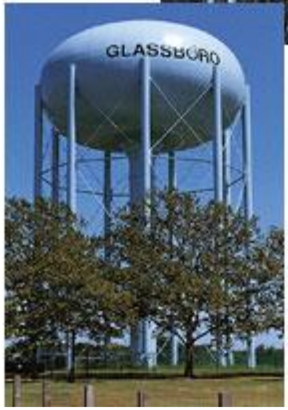
Water tanks
- Ground level tanks
- Elevated tanks
    - Flute column tanks
    - Single pedestal (pedeshpere) tanks
    - Multi column tanks
    - Composite tanks

Planar sided tanks
- Pressed Steel Sectional Water Tanks
- Profile Steel Welded Liquid Storage Tanks

WATER TANKS

Ground level

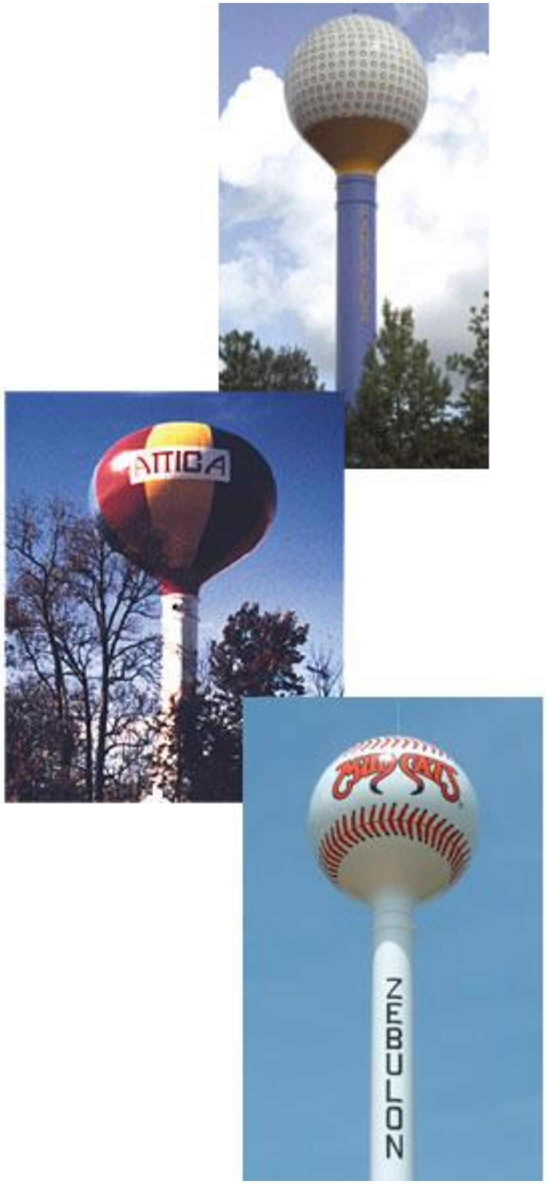
Multi column



Caldwell Tanks, Inc.

WATER TANKS

Pedesphere

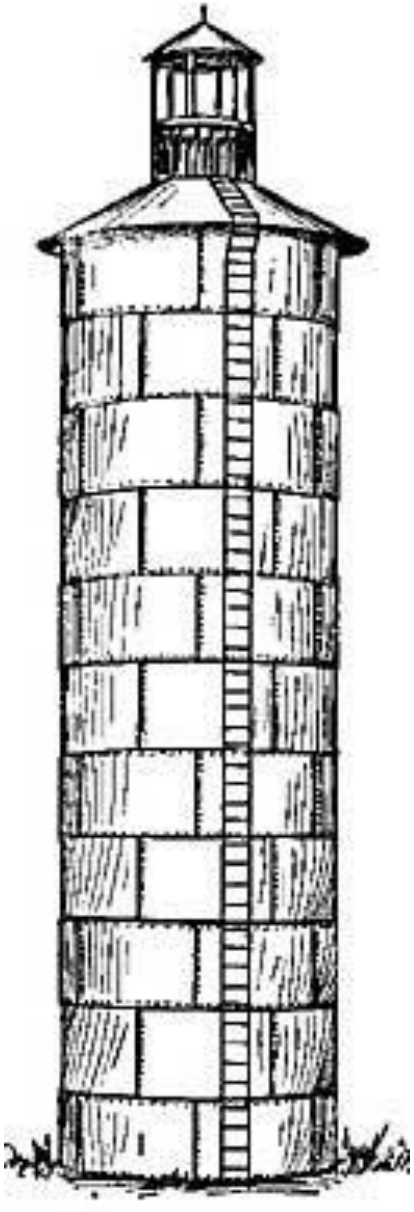


Fluted column

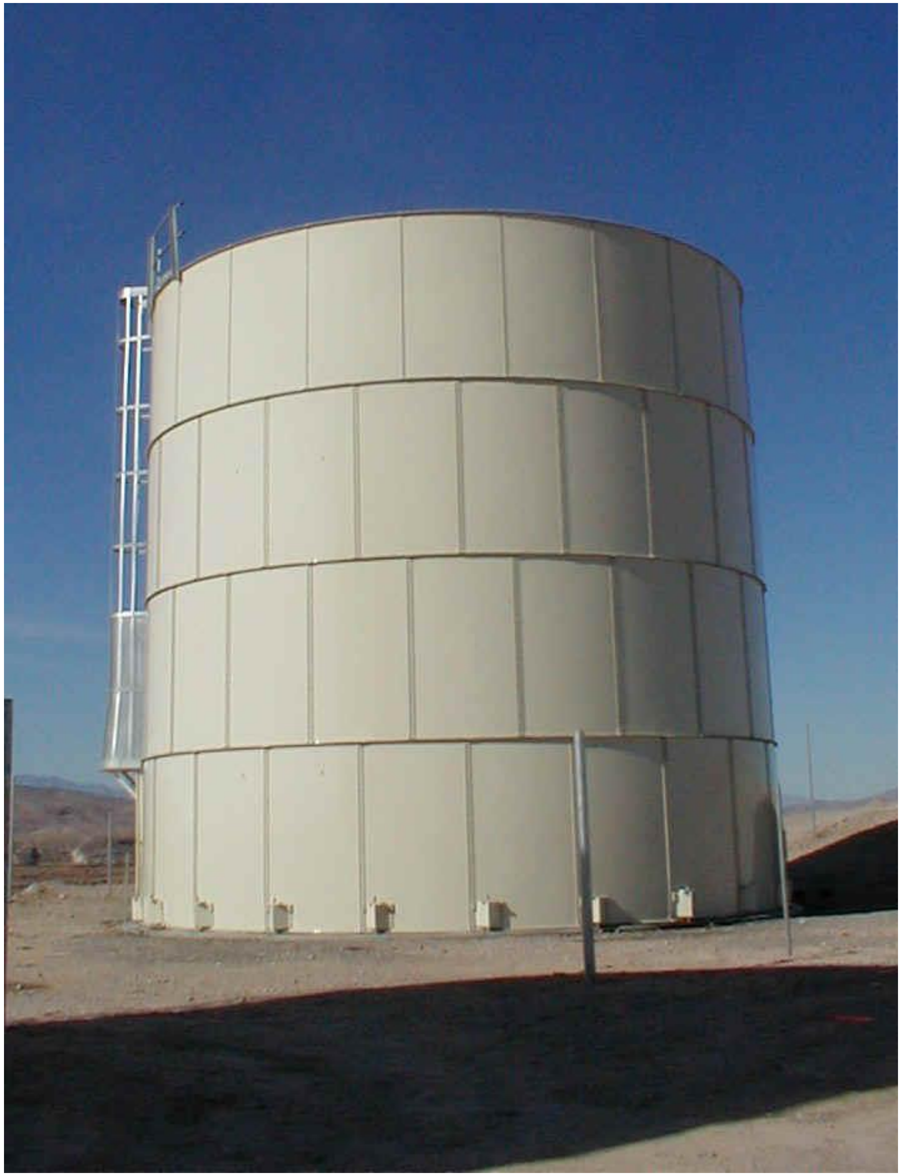
Composite

Caldwell Tanks, Inc.

“Standpipe” water tanks

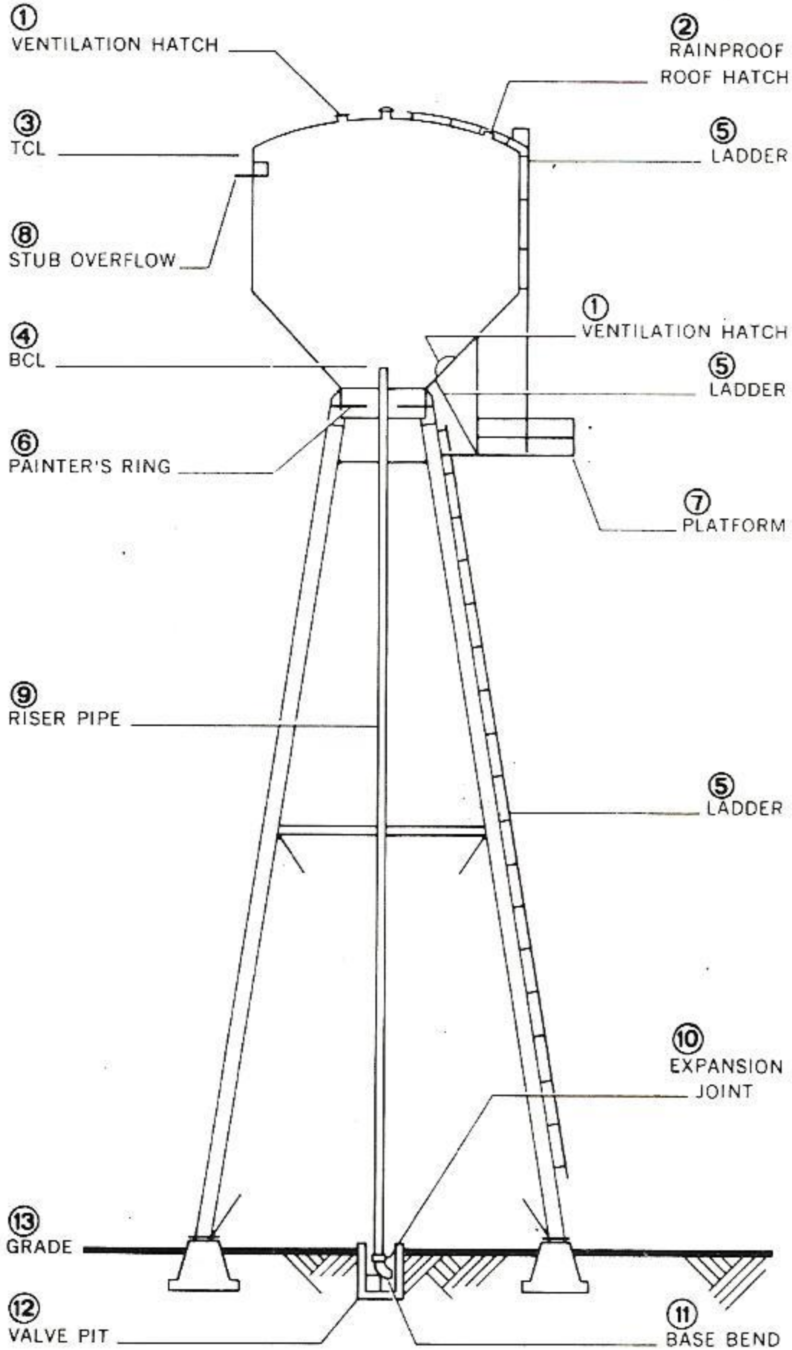


“Standpipe” water tanks

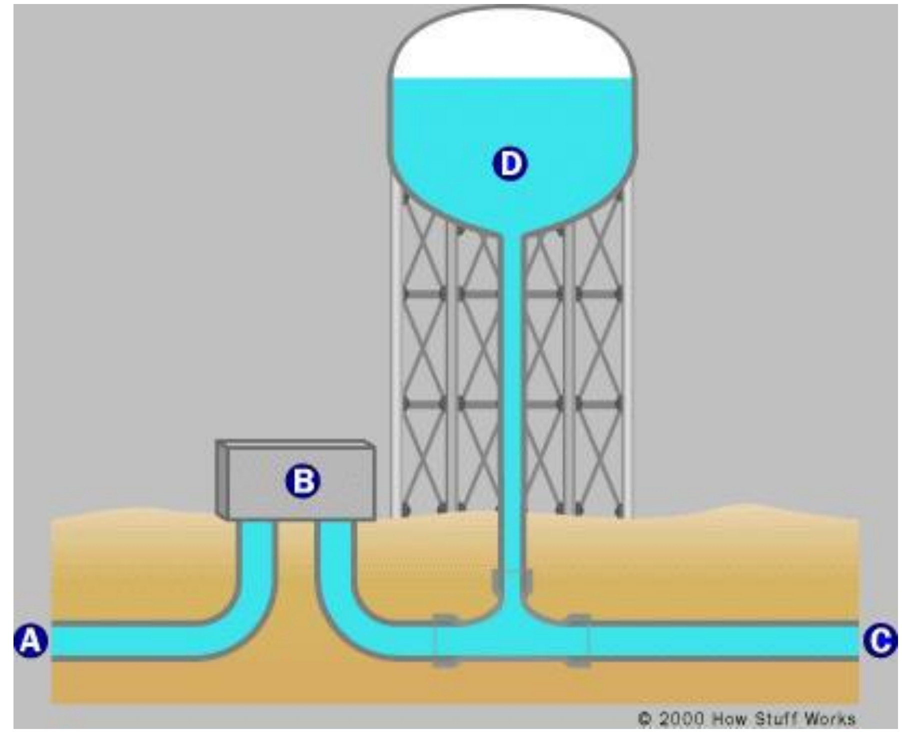


Fire tanks

Elevated water tanks

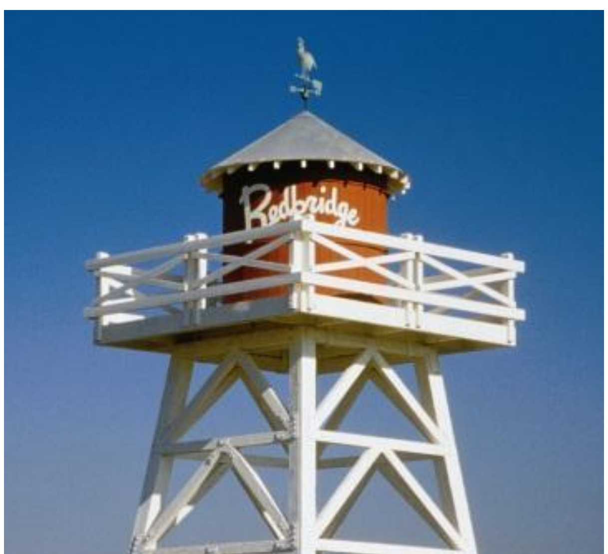


Tripod (< 700 m³)

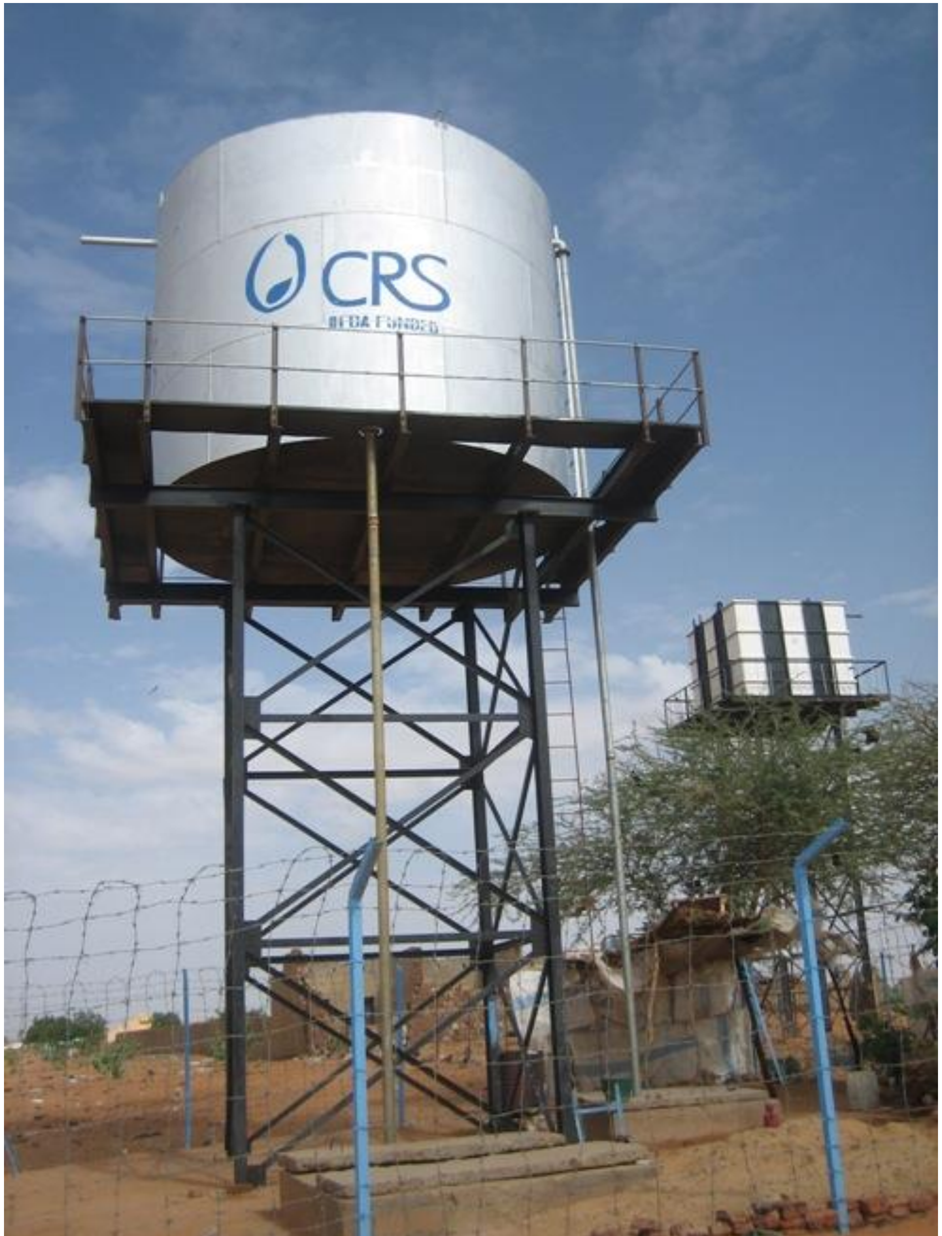


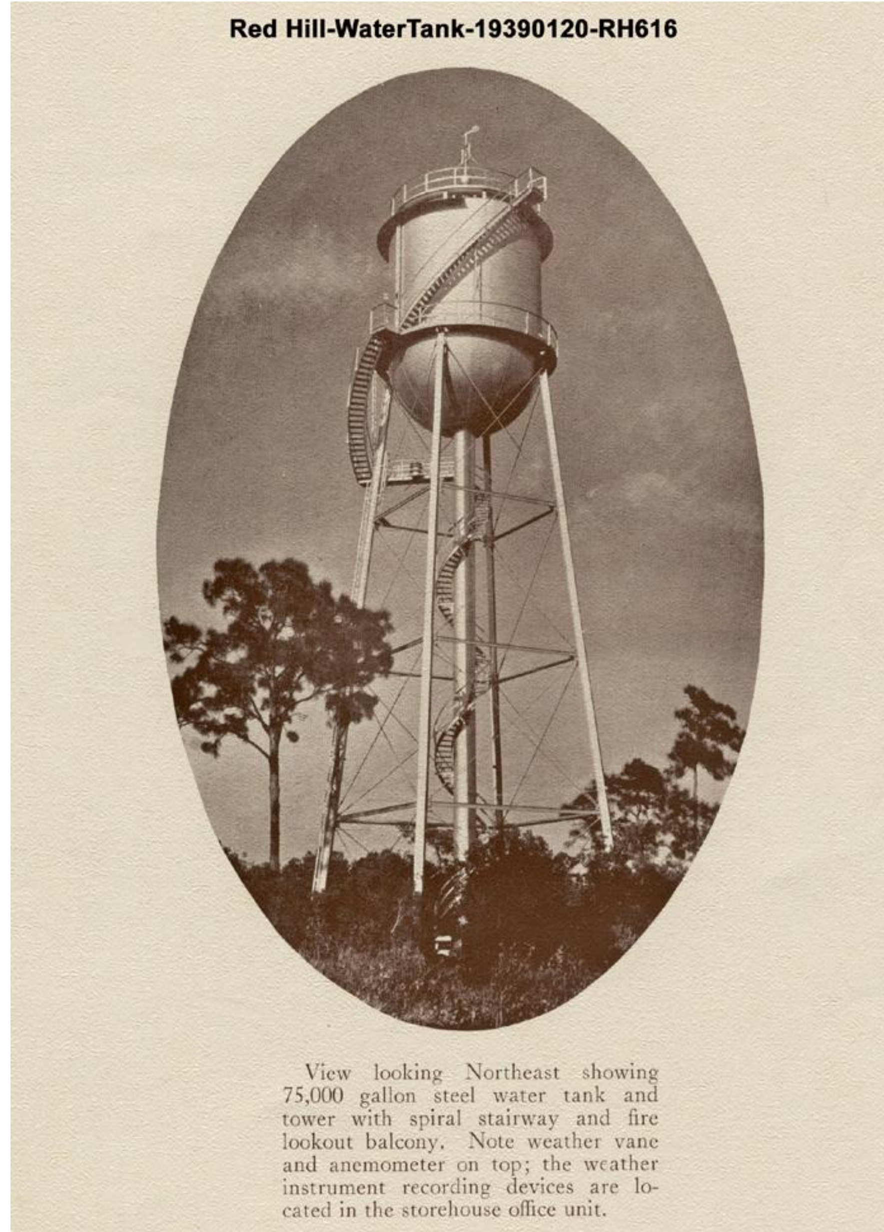
A From the treatment plant
B Pump
C To primary feeders and customers
D Water

Elevated water tanks



Elevated water tanks

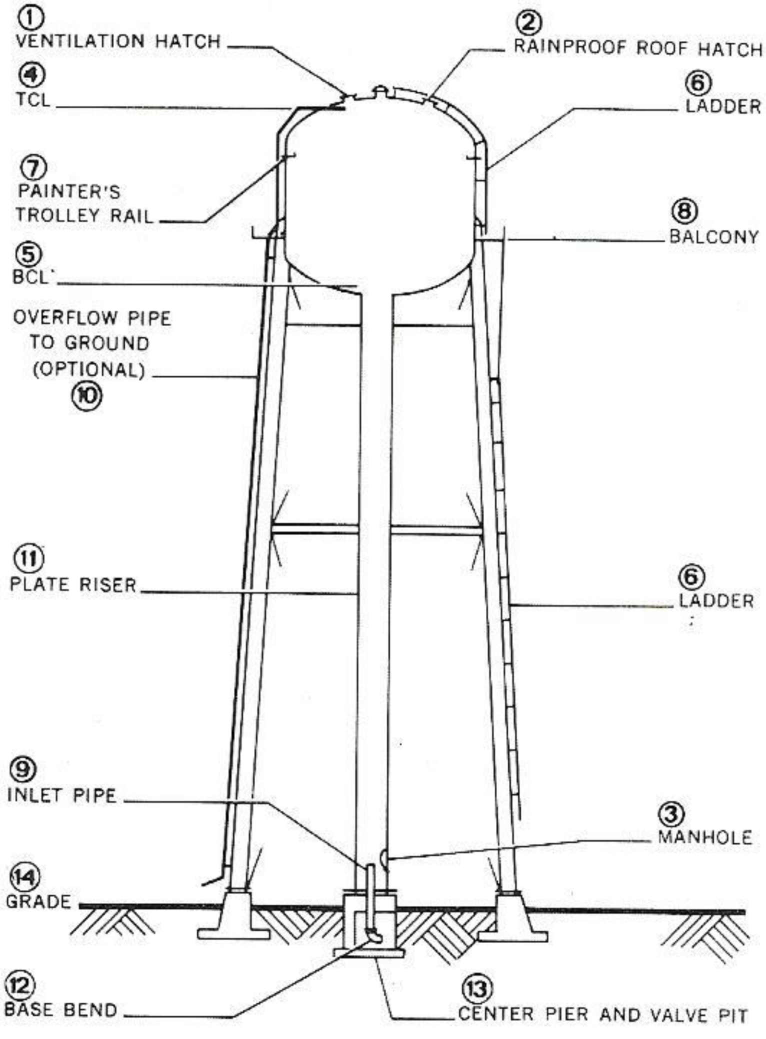




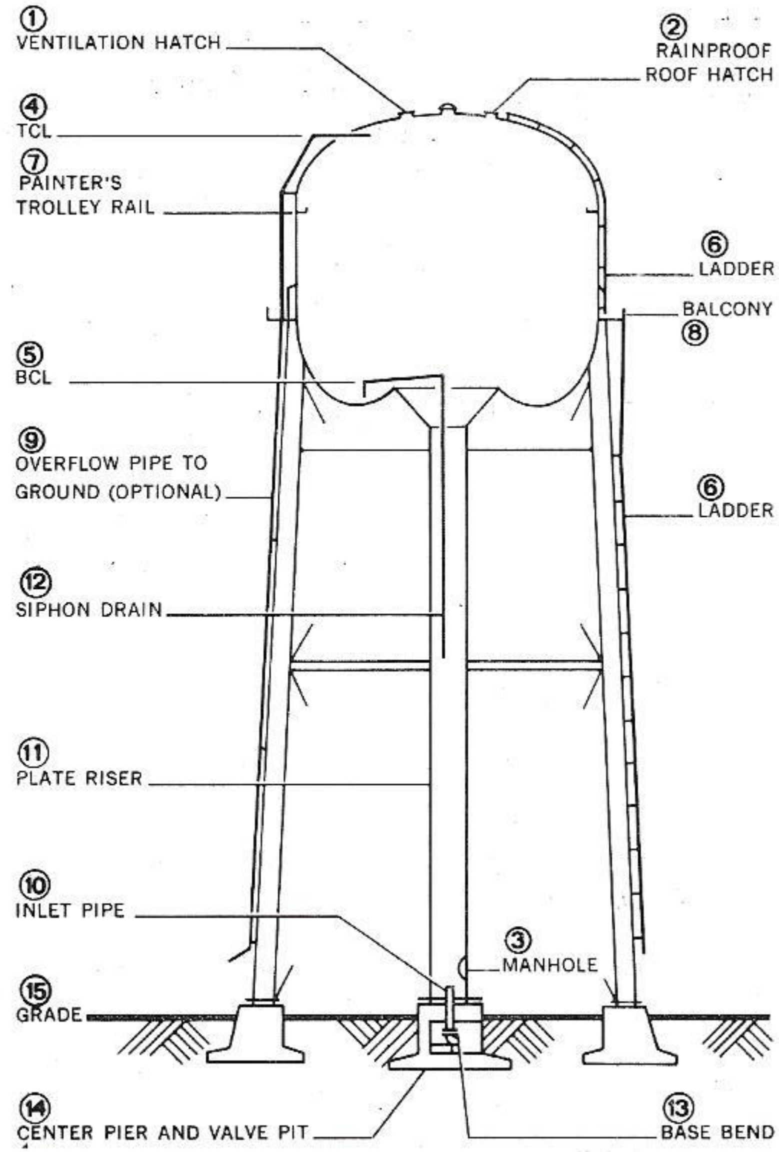
Elevated water tanks

Elevated water tanks

Water tanks
(Multi-column torispherical)



(< 700 m^3)

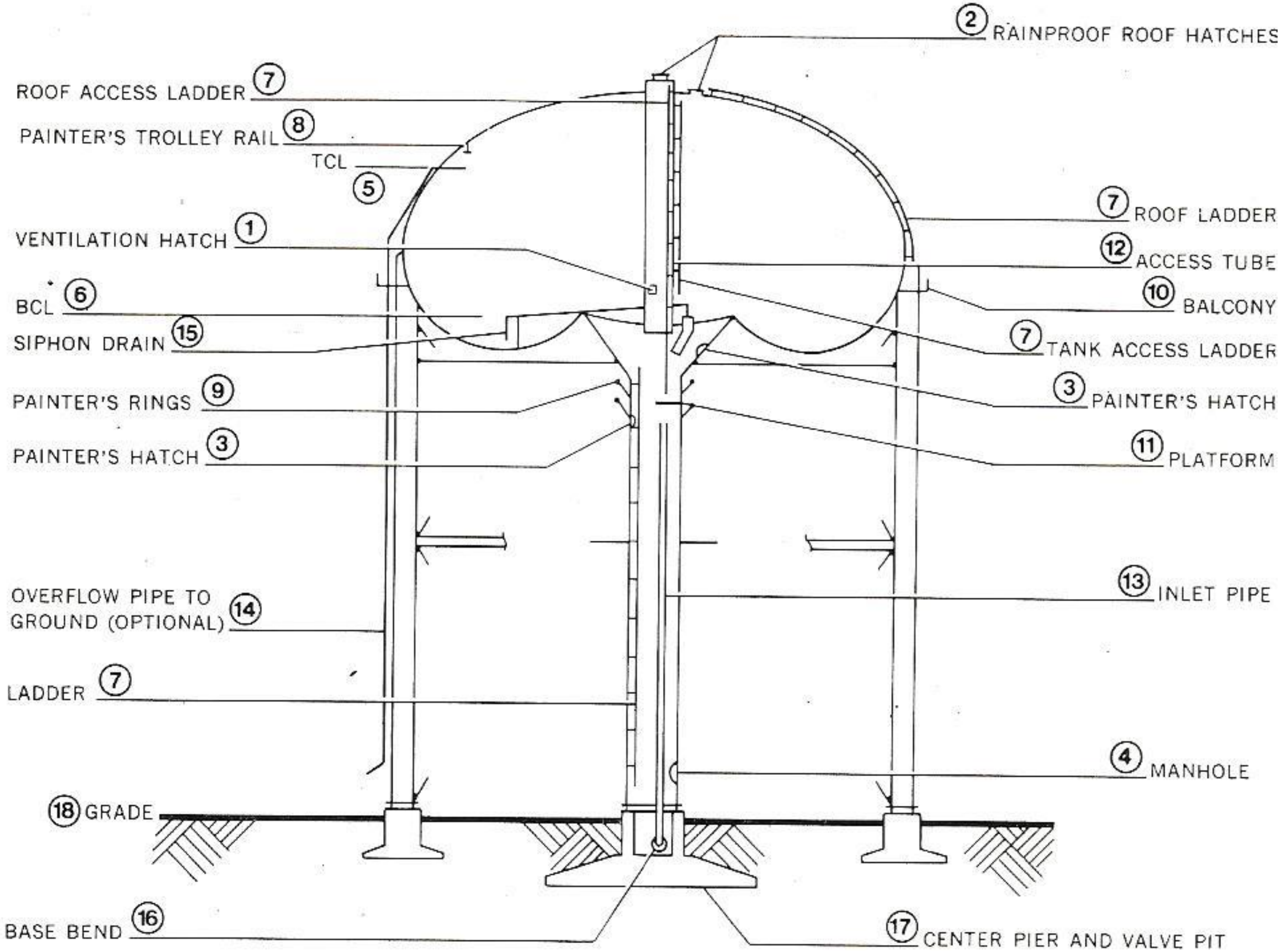


(> 700 m^3)

Water tanks
(Multi-column torispherical)

Water tanks
(Multi-column torispherical)

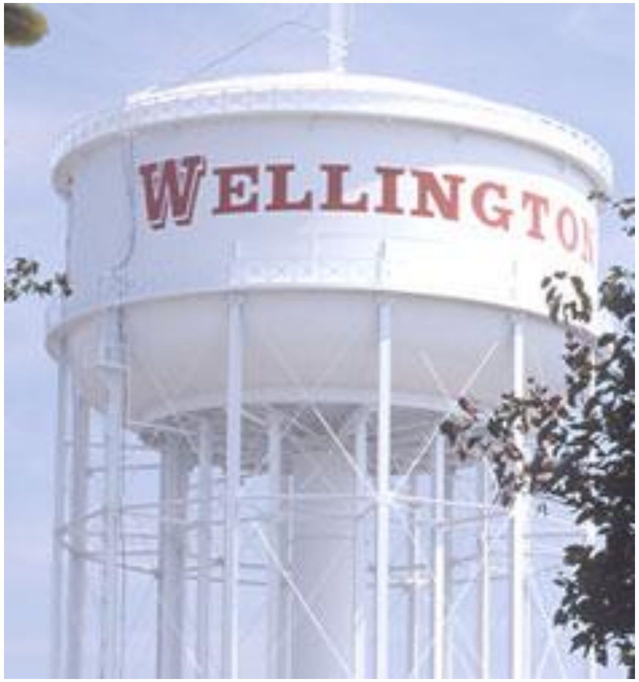
Water tanks



Multi column Spheroidal tank (> 700 m^3)

Multi-column Spheroidal tank

Multi-column spheroidal tanks

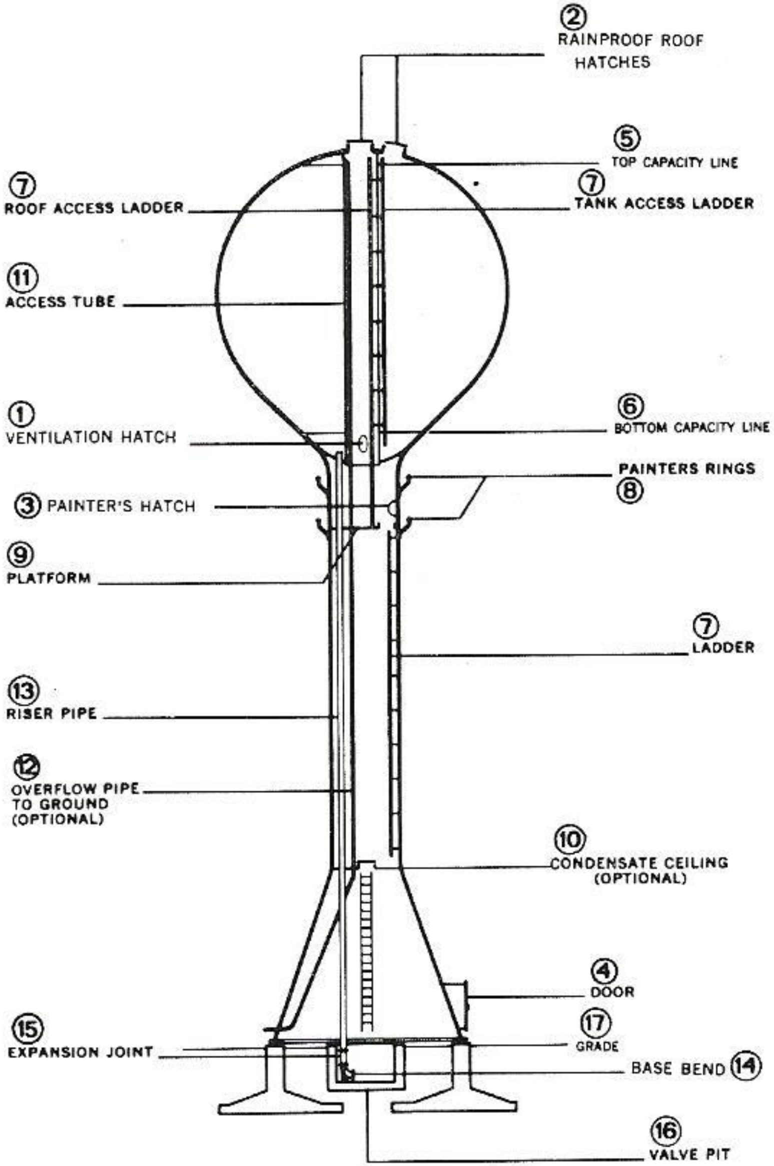


Multi-column spheroidal tanks

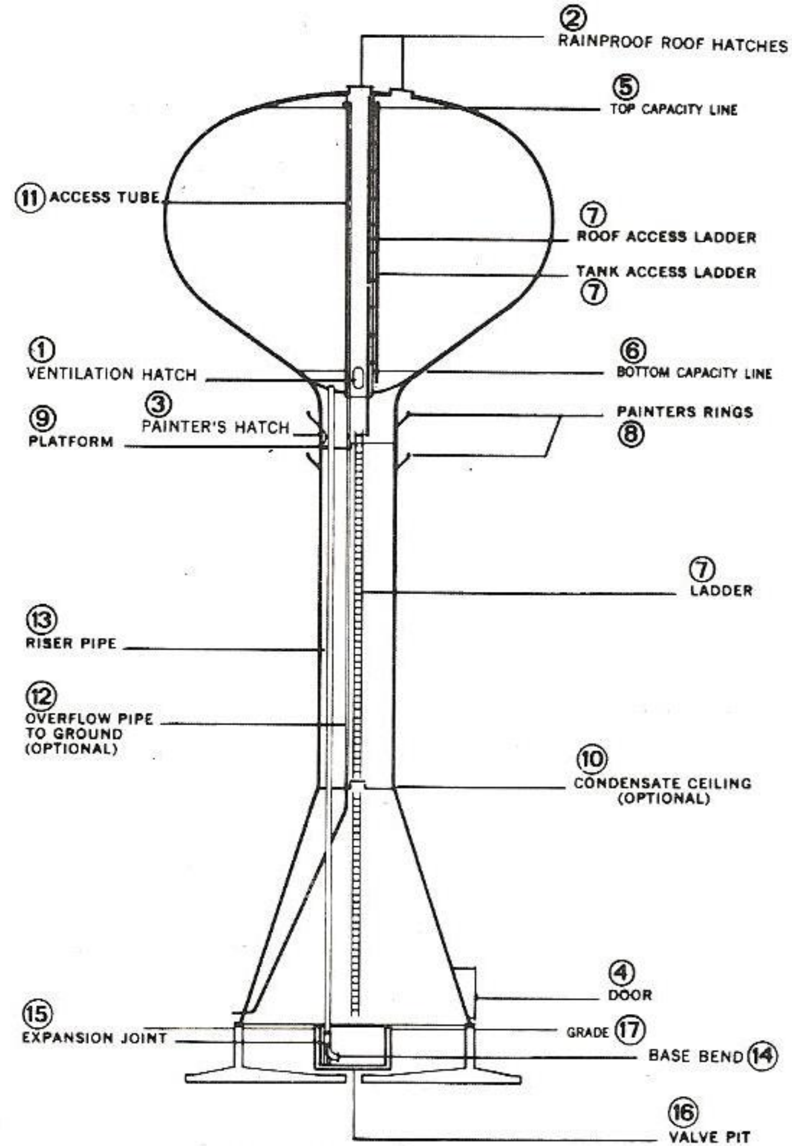
Multi-column Spheroidal tank

Multi-column Spheroidal tank

Water tanks
“pedesphere” type



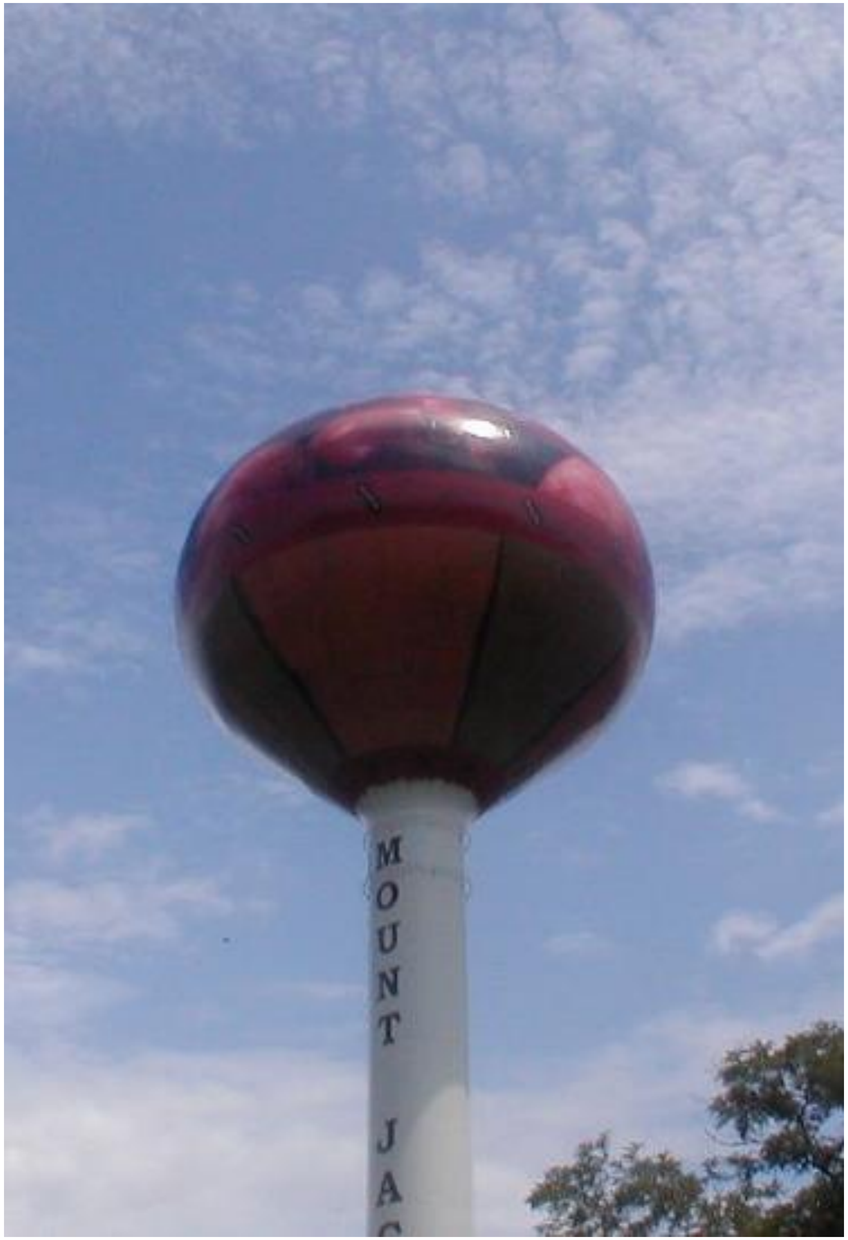
(spheroidal, < 700 m^3)



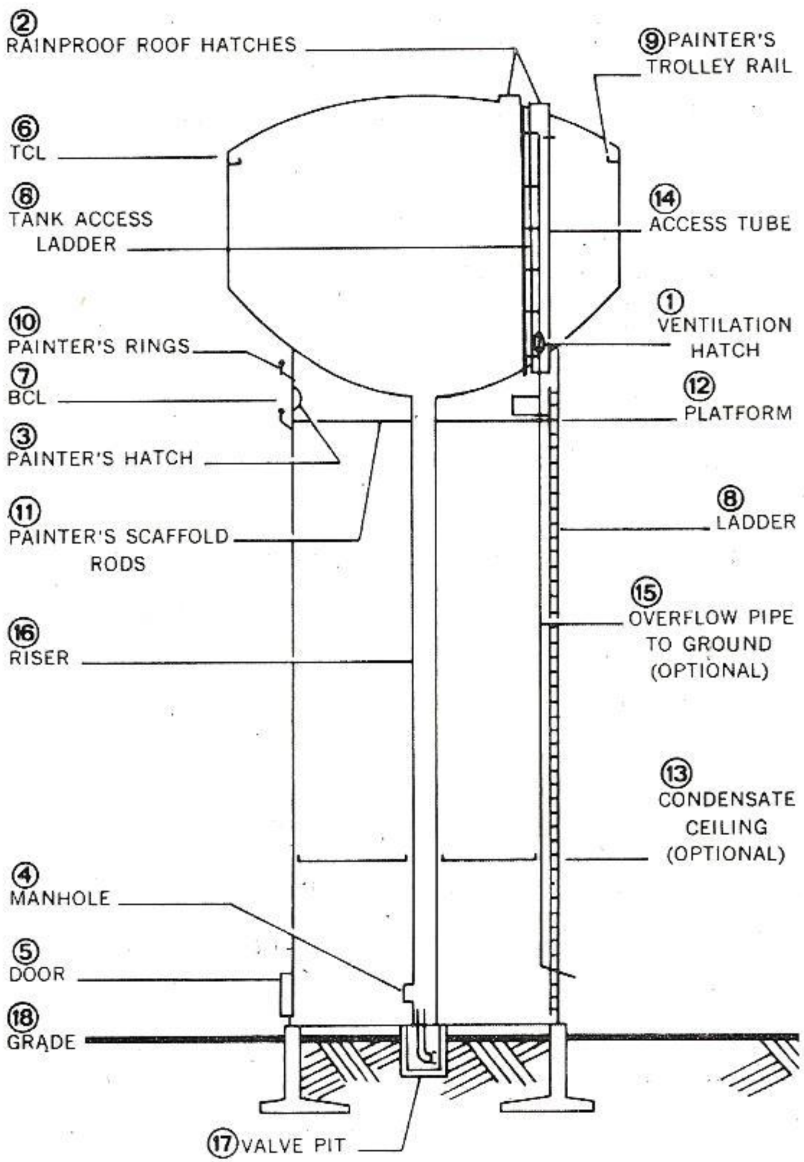
(ellipsoidical, > 700 m^3)

Water tanks
“pedesphere” type

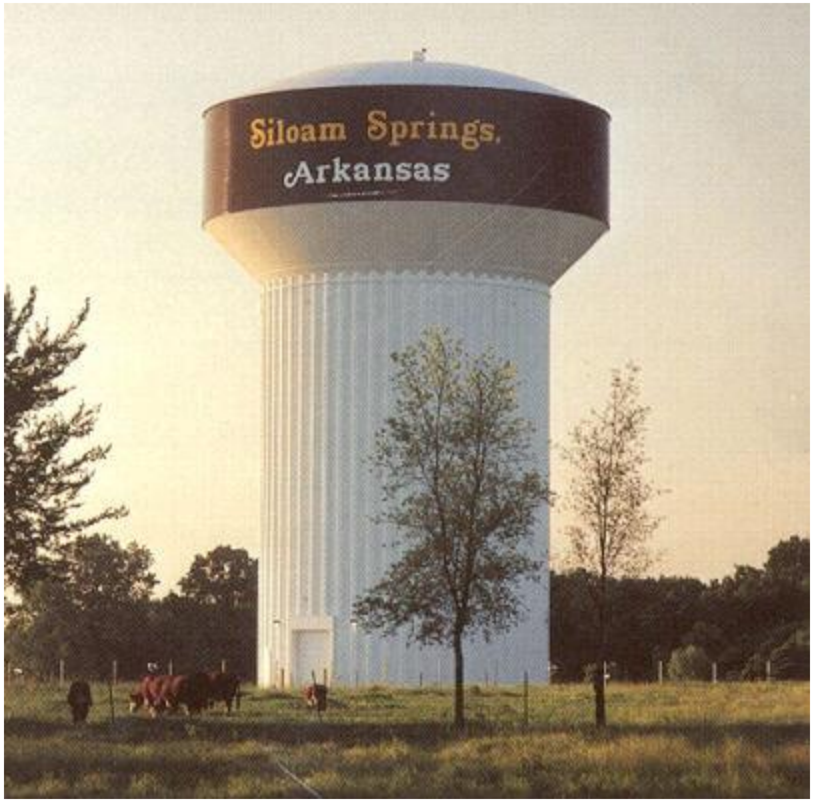
Water tanks
“pedesphere” type



Flute column tanks (> 700 m^3)



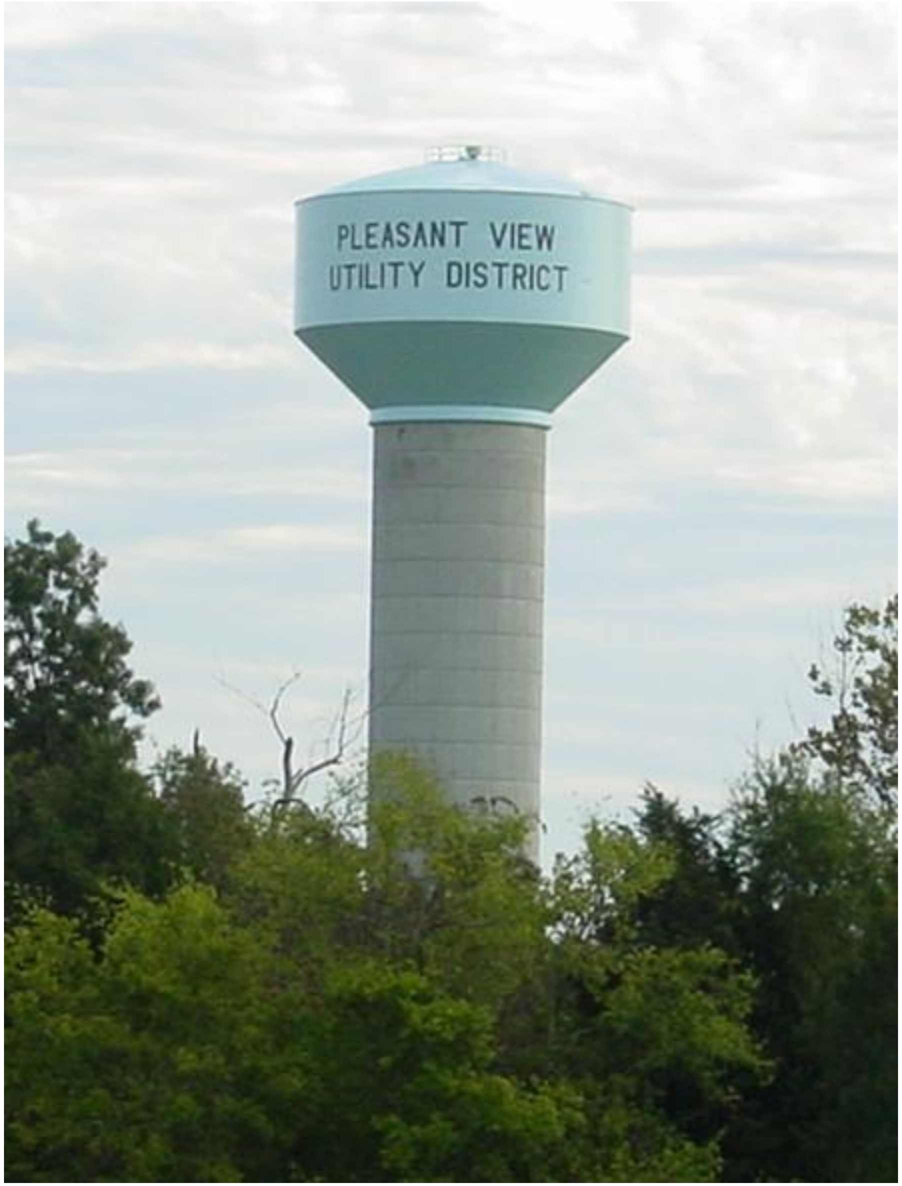
Flute column tanks



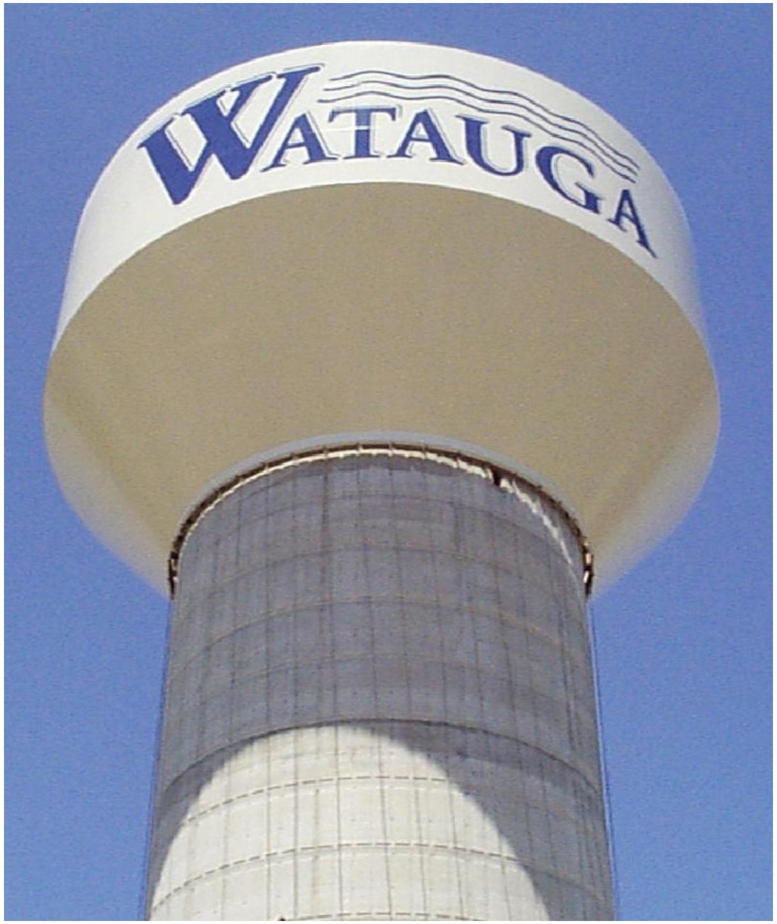
Composite tanks

Scania Water Tower Society
© Eber Ohlsson

Composite tanks



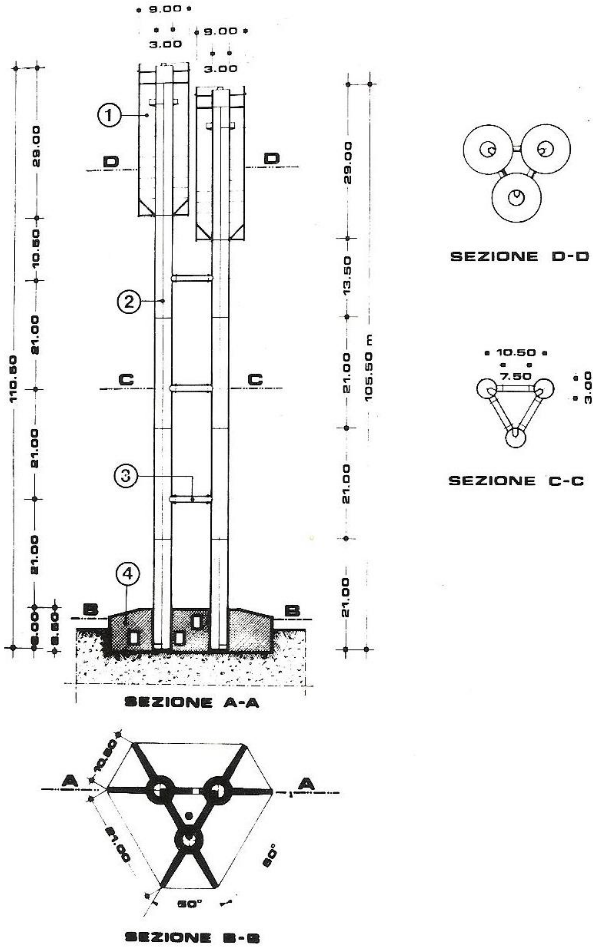
Composite tanks

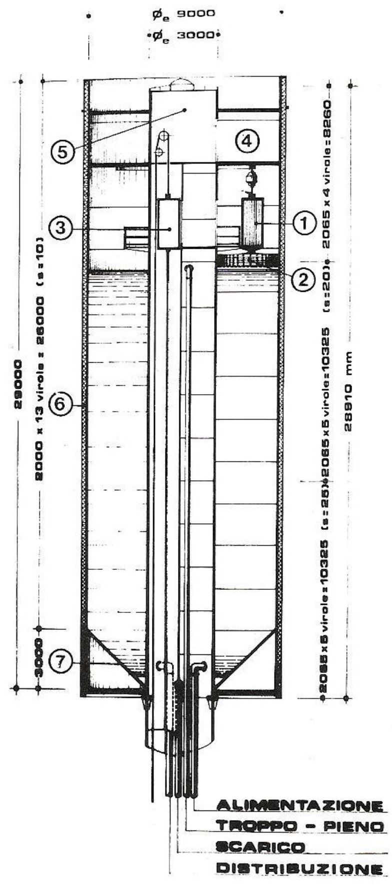


Tanks as architectural objects

Tanks as architectural objects

Tanks as architectural objects



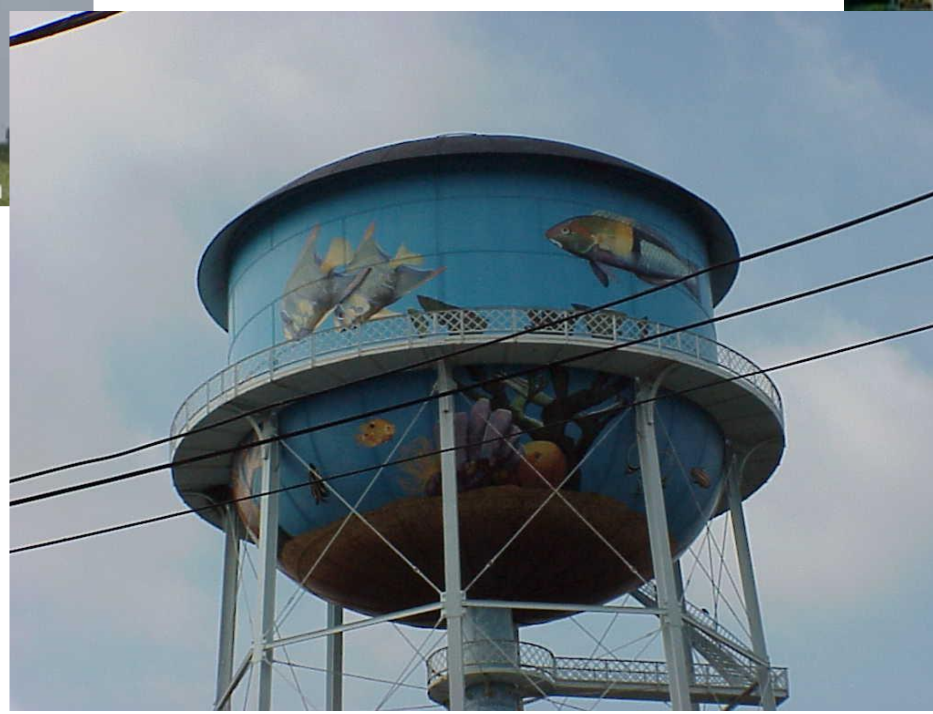


The “Babel” Tank

Christian de Portzamparcs
Marne-le-Vallèe, east of Paris.

Tanks as landmarks

Tanks as landmarks



Tanks as landmarks

Planar sided tanks
Braithwaite Pressed Steel Sectional Water Tanks
BS 1564: 1975 Type One

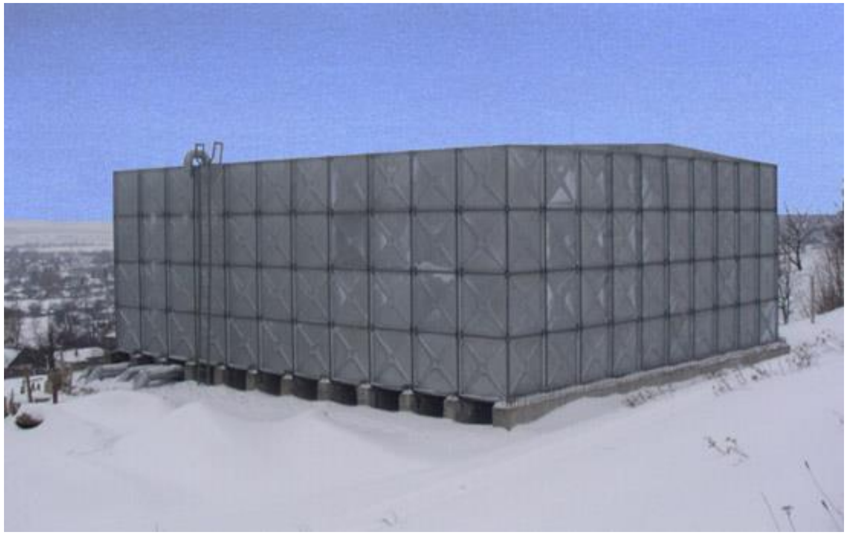
The modular concept and bolted construction allows for high speed assembly utilising semi skilled labour. This provides cost benefits when considered against traditional concrete tanks. Nominal capacities can be supplied in the range of 1m^3- 15000m^3, a notable advantage of modular construction.

Features of Braithwaite Steel Sectional Tanks:

- Infinite range of sizes and configurations
- Excellent flexibility to adapt as storage requirements change
- Ability to be installed in areas with restricted access
- Quick and easy assembly using hand tools
- Highly economical transportation
- Inherent strength and durability of the raw material
- Excellent substrate for a wide range of finishes
- Long term life expectancy
- Unlimited sizes and configuration
- Fully recyclable

With the appropriate combination from different panel designs, units of any capacity from 1 to 15.000m^3 or over may be constructed, in a configuration to respect any existing site restrictions (maximum height not exceeding 6.10m).

Braithwaite tanks



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Braithwaite tanks

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Braithwaite tanks

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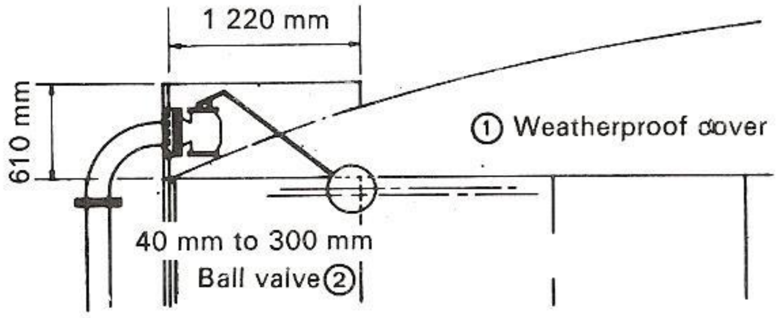
Braithwaite tanks



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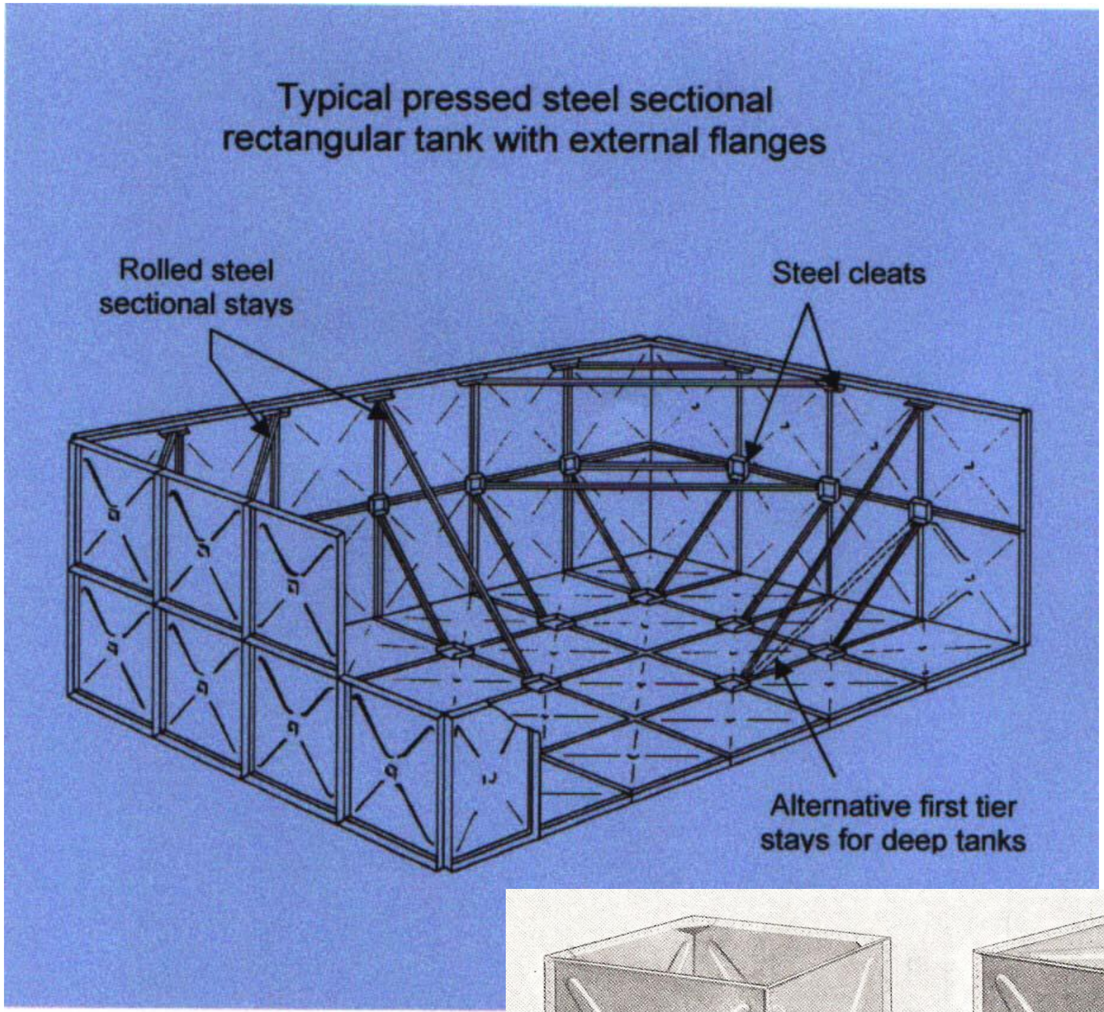
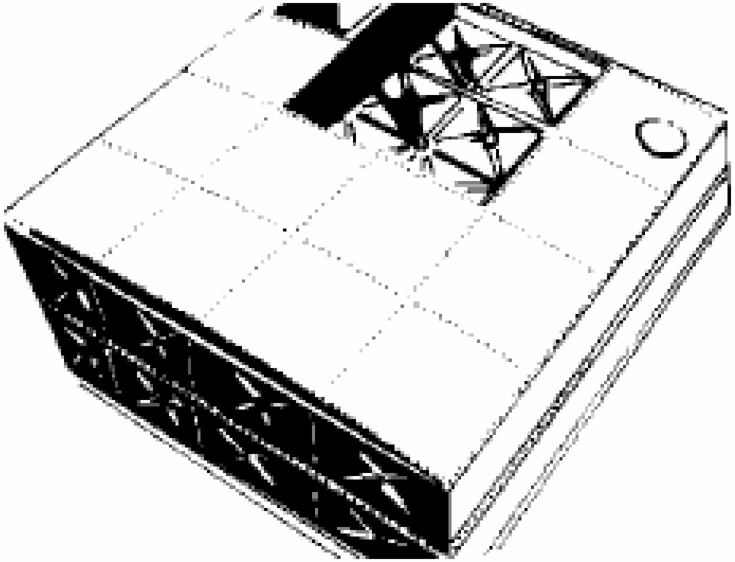
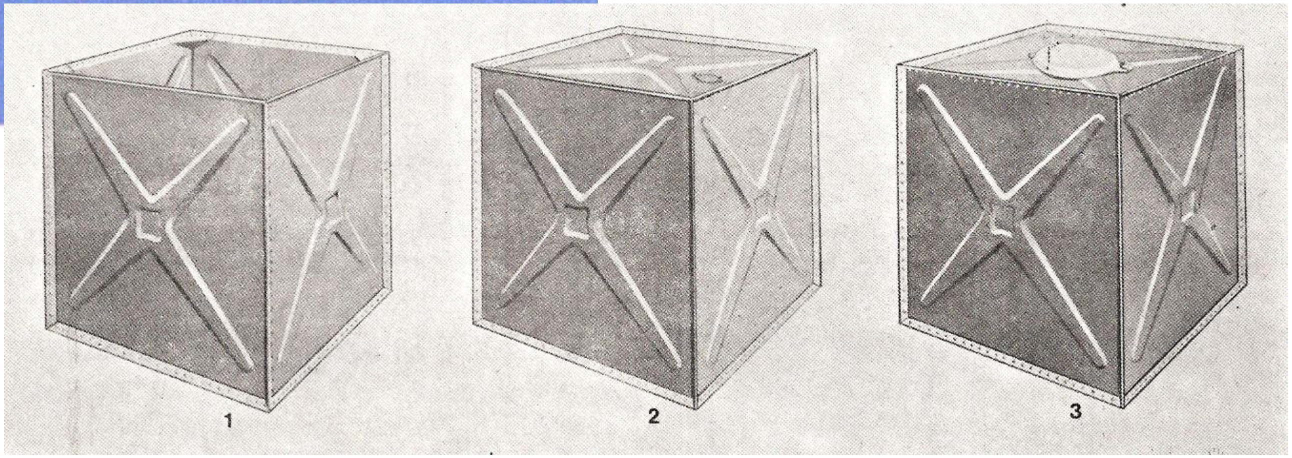
Pressed Steel Sectional Water Tanks







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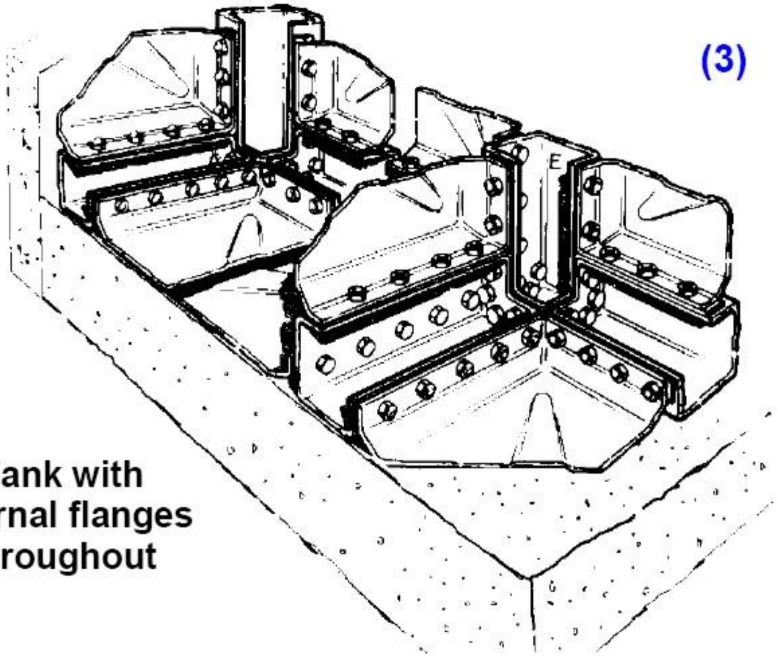
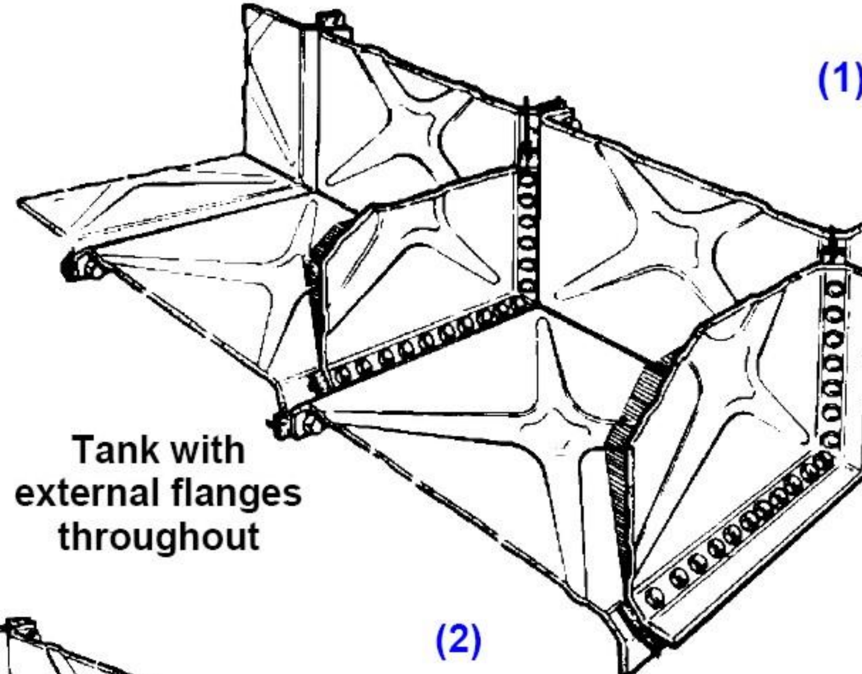
Pressed Steel Sectional Water Tanks



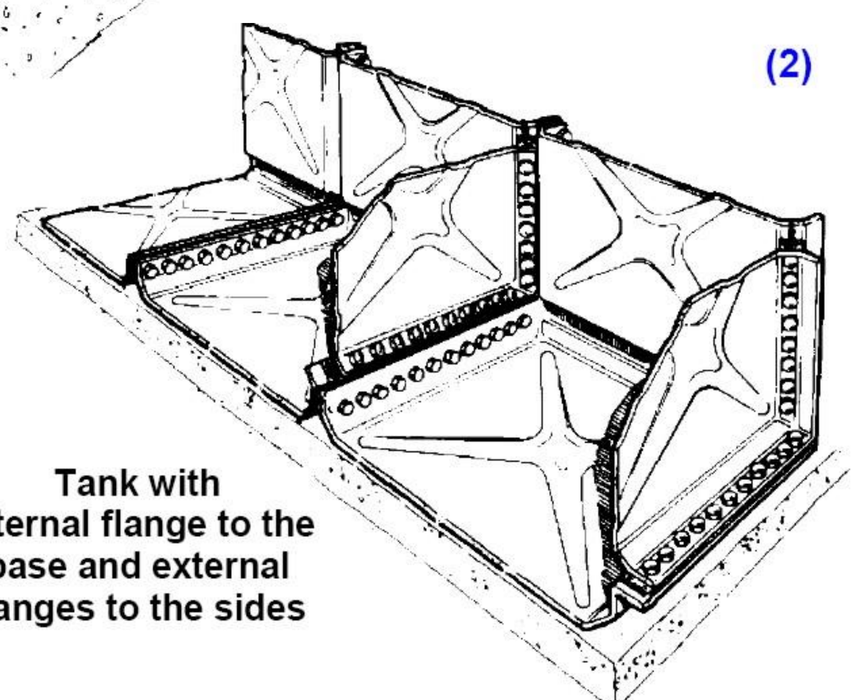
(3)

Tank with
Internal flanges
throughout



(1)

Tank with
external flanges
throughout



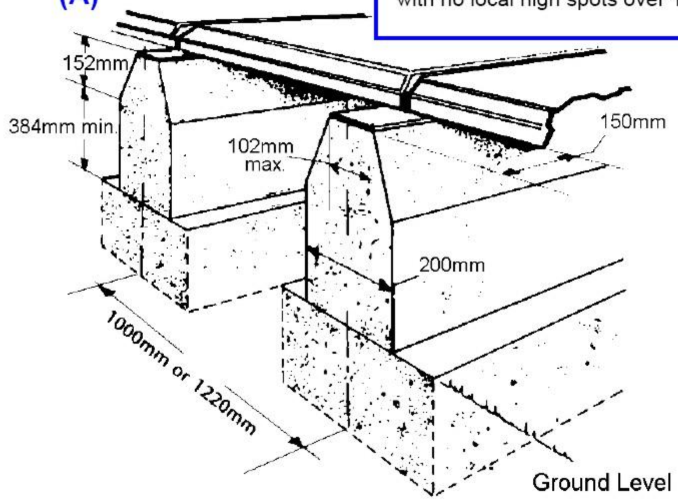
(2)

Tank with
internal flange to the
base and external
flanges to the sides

Pressed Steel Sectional Water Tanks

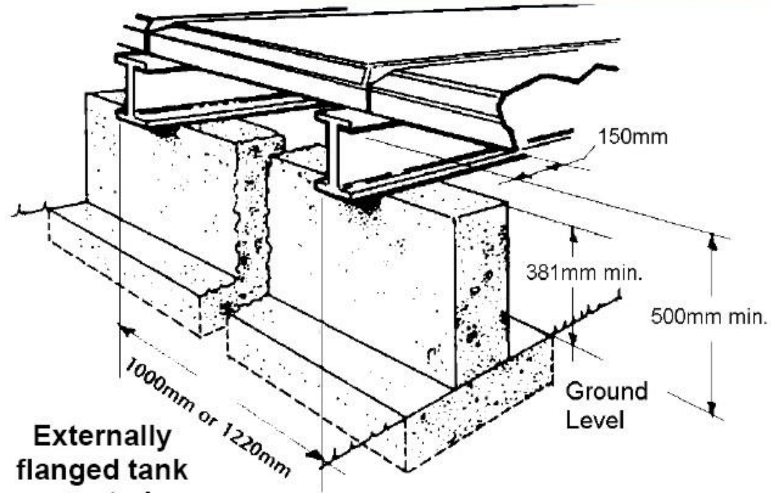
(A)

Walls are to be levelled to +/-3mm
with no local high spots over 1mm



(B)

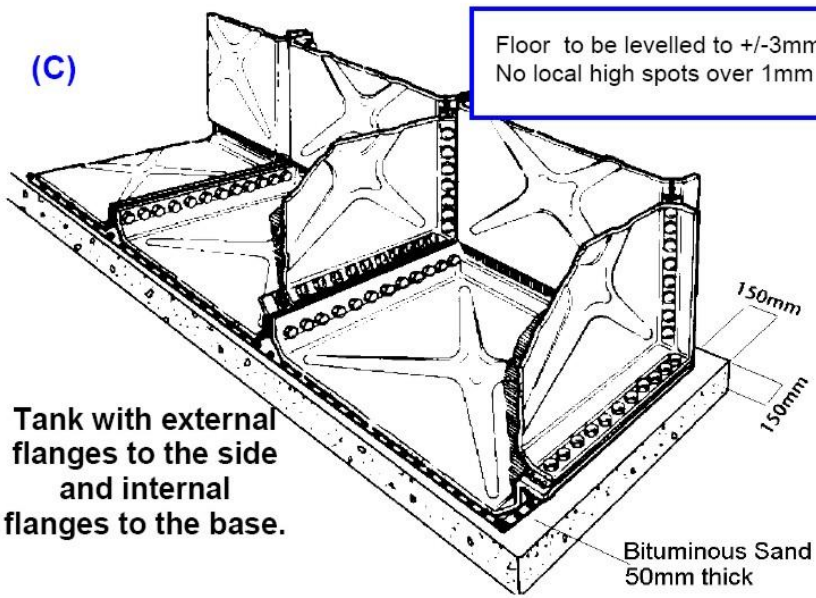
Steel beams are to be levelled to +/-3mm
Allowable deflection 1/500th of span



Externally flanged tank supported on steel grillage

(C)

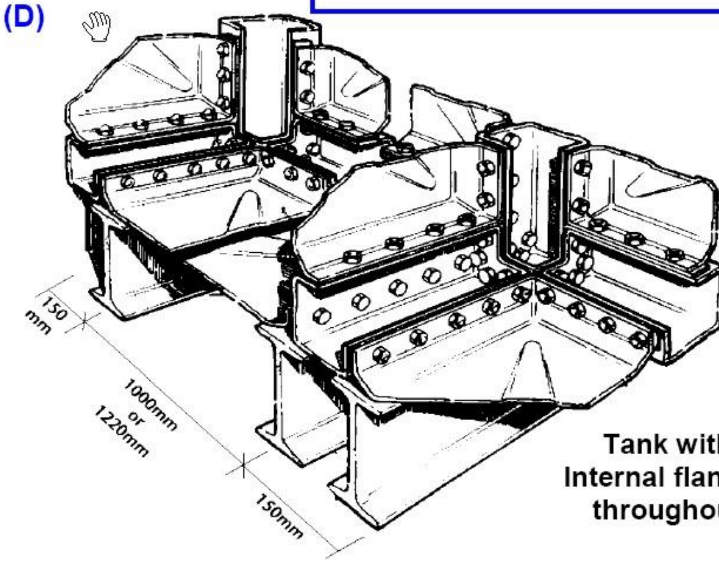
Floor to be levelled to +/-3mm
No local high spots over 1mm



Tank with external flanges to the side and internal flanges to the base.

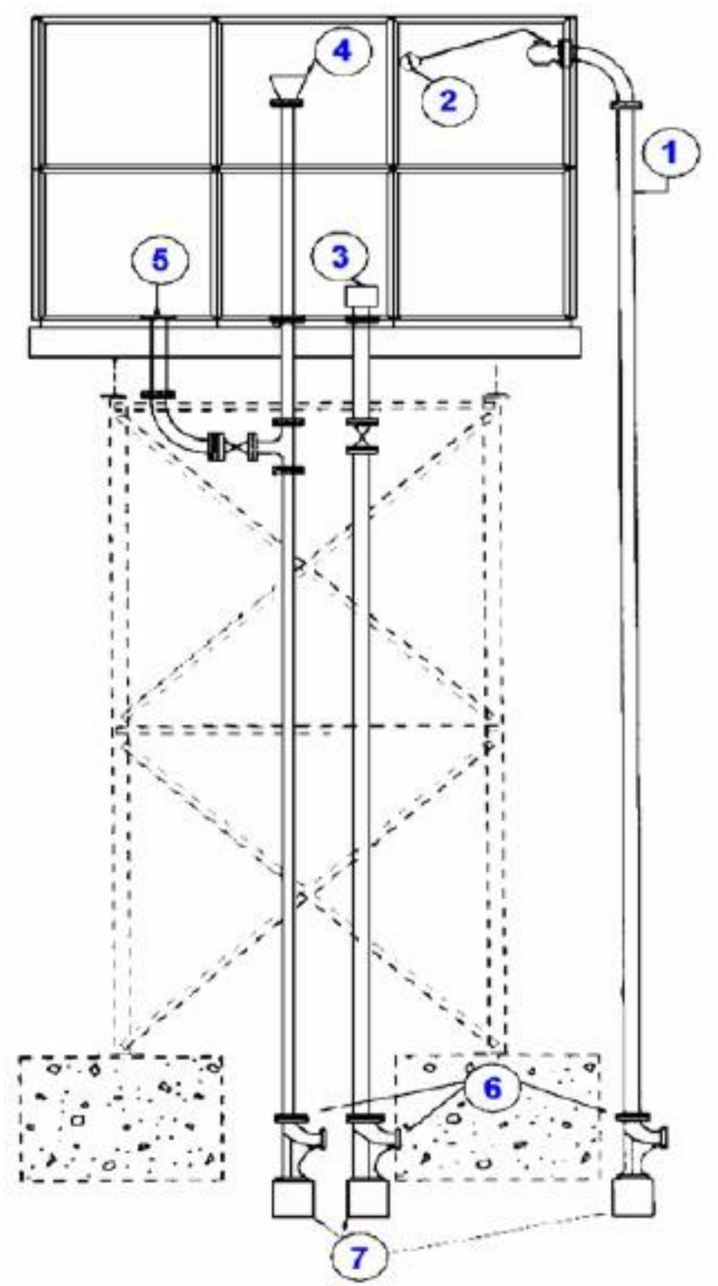
Steel beams are to be levelled to +/-3mm
Allowable deflection 1/500th of span

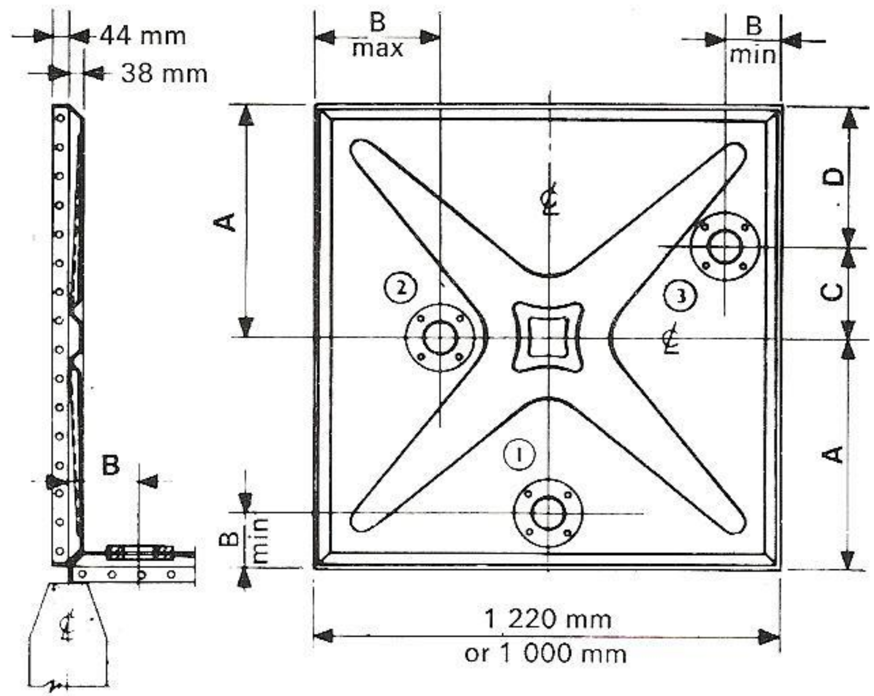
(D)

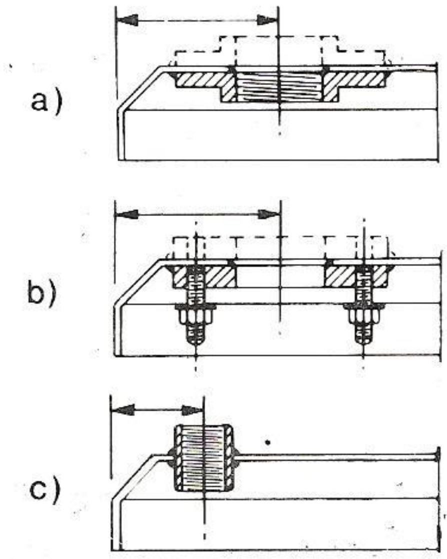


Tank with Internal flanges throughout

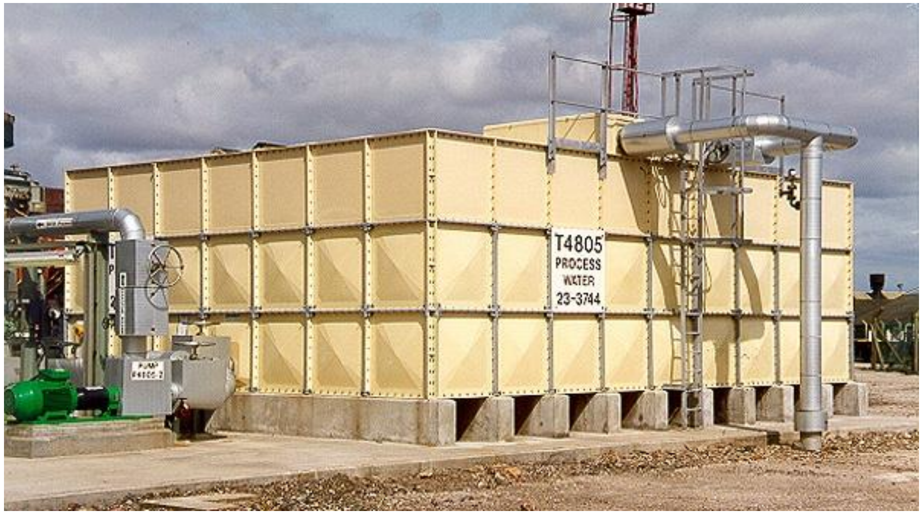
Pressed Steel Sectional Water Tanks
Hydraulic details







GRP Hot Pressed Moulded Sectional Water Tanks



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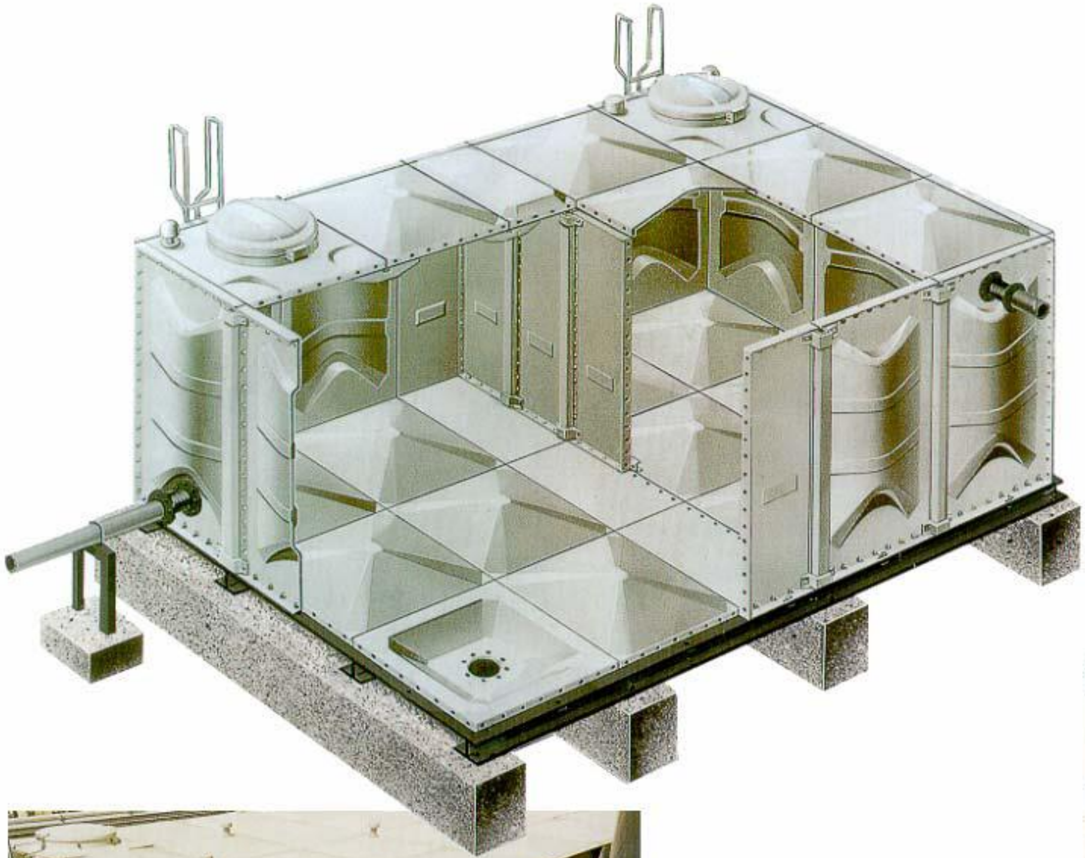
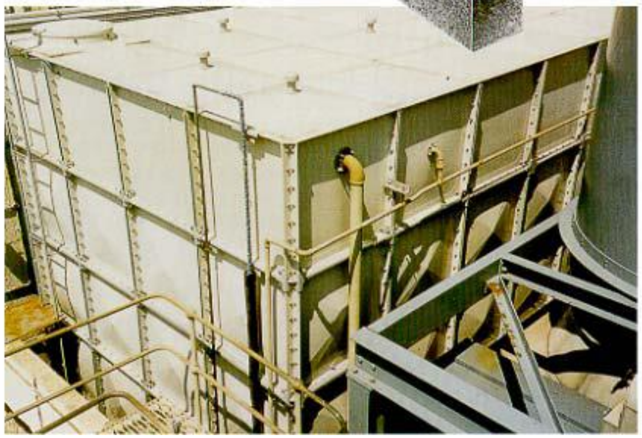
GRP Hot Pressed Moulded Sectional Water Tanks

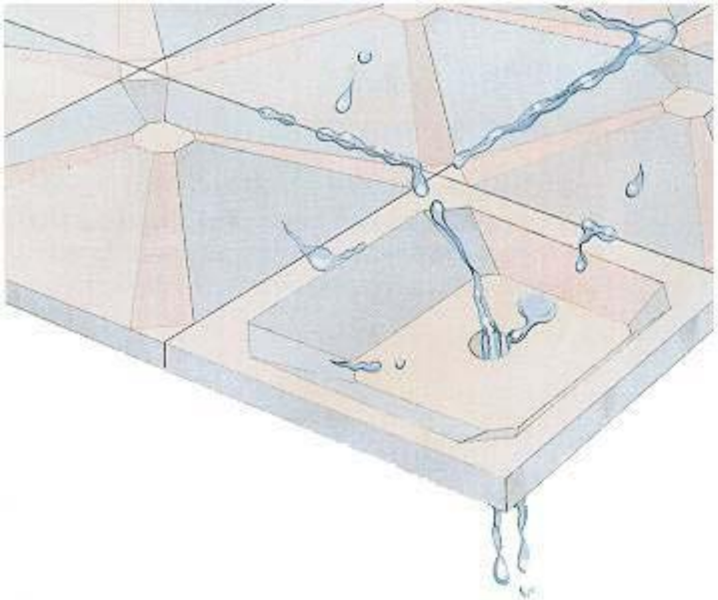
Benefits of GRP tanks

- Excellent corrosion resistance
- Uniformity of panel dimensions.
- Constant mechanical properties.
- Smooth surface finish on both sides of panel.
- Excellent resistance to ultra violet light.
- High strength to weight ratio.
- Trouble free installation and commissioning.
- Excellent quality of stored water.
- Low maintenance.
- Long service life.

GRP Hot Pressed Moulded Sectional Water Tanks







Planar sided tanks

Braithwaite Profile Steel Welded Liquid Storage Tanks

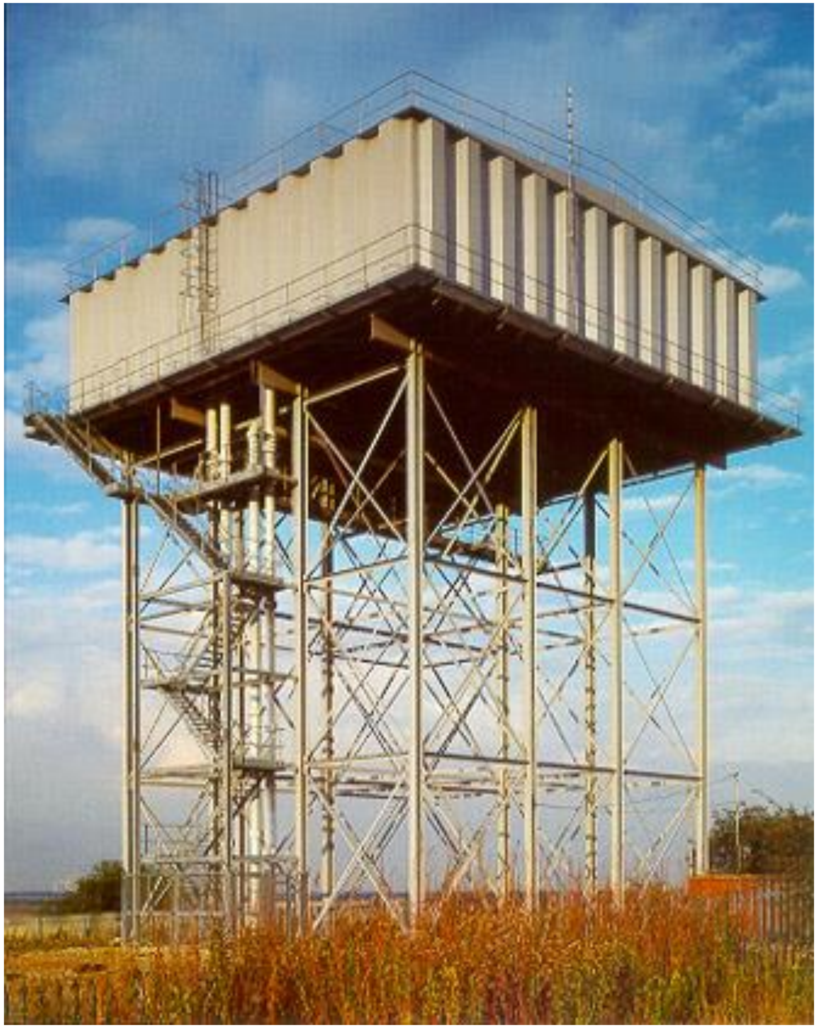
The Braithwaite profile steel welded tank is designed to store large quantities of liquids, particularly in rural areas. The tank system is approved for use with potable water. Delivered in sections for welding on site, profile steel welded tanks produce extremely strong and reliable storage vessels of unlimited capacity. Many Water Undertakers, Hospitals, Breweries and defence establishments now use this system instead of concrete to give a greater service life with minimal maintenance and at a low capital cost.

Features of Braithwaite Profile Steel Welded Tanks:

- Rectangular shape makes best use of available space
- Profiled sections offer great strength with pleasing appearance
- May be installed at or below ground level or on towers
- Tanks up to 5m high do not need internal support apart from roof posts
- Clear interior allows easy inspection, draining and cleaning
- Manways and pipe connections may be fitted on site
- External and Internal surfaces can be treated with numerous protective coatings to accommodate most environments
- Unlimited sizes and rectangular configuration
- Fully recyclable

With the appropriate design, units of any capacity from 1 to 15.000m^3 or over may be constructed, in a rectangular configuration to respect any existing site restrictions (maximum height not exceeding 6.10m) as standard.

Profile Steel Welded Liquid Storage Tanks



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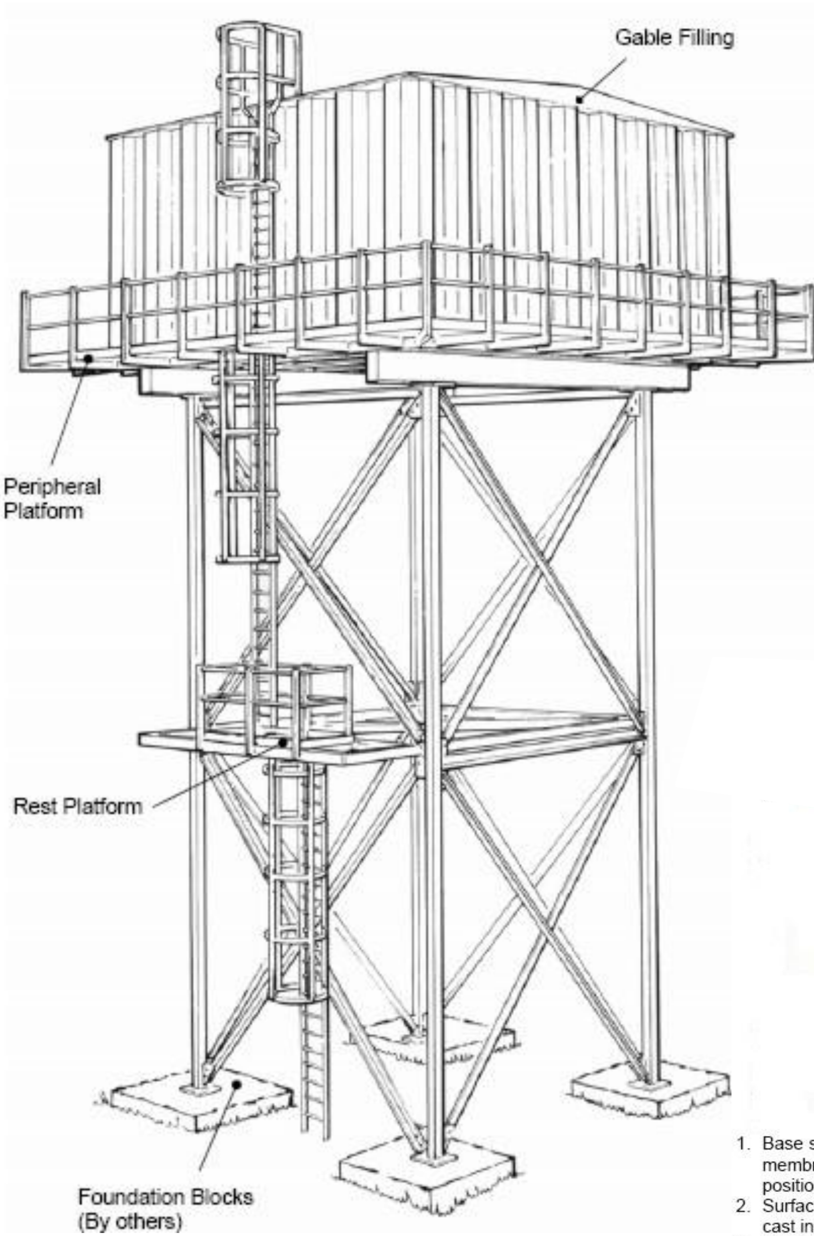
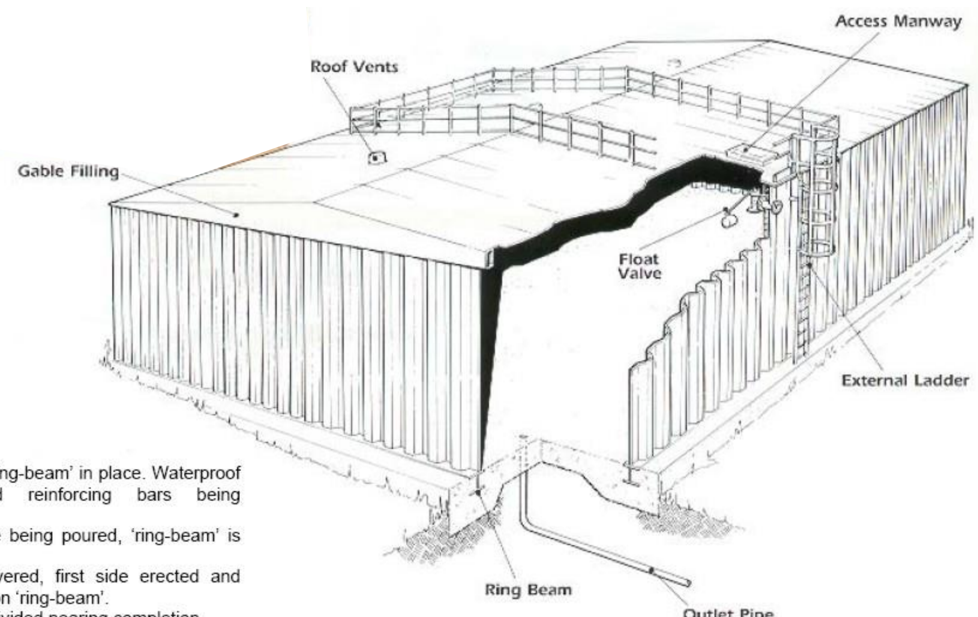
Profile Steel Welded Liquid Storage Tanks





1. Base slab with 'ring-beam' in place. Waterproof membrane and reinforcing bars being positioned.
2. Surface concrete being poured, 'ring-beam' is cast in.
3. Sheets are delivered, first side erected and welded in place on 'ring-beam'.
4. Tank walls and divided nearing completion.
5. First roof cover plate is positioned.
6. Tank completed, cleaned and primed.
7. Tank fully externally painted, inspection ladder and guard railing fitted, plant room completed.

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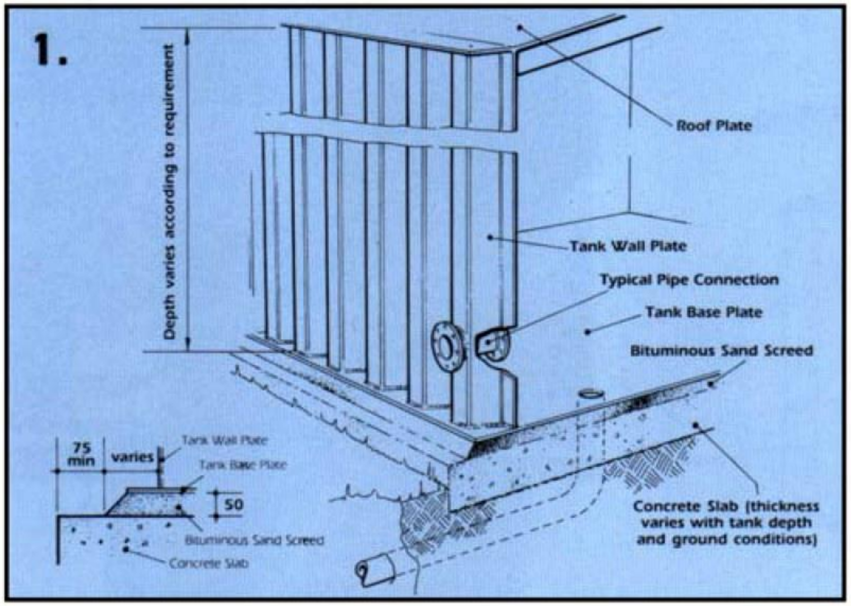
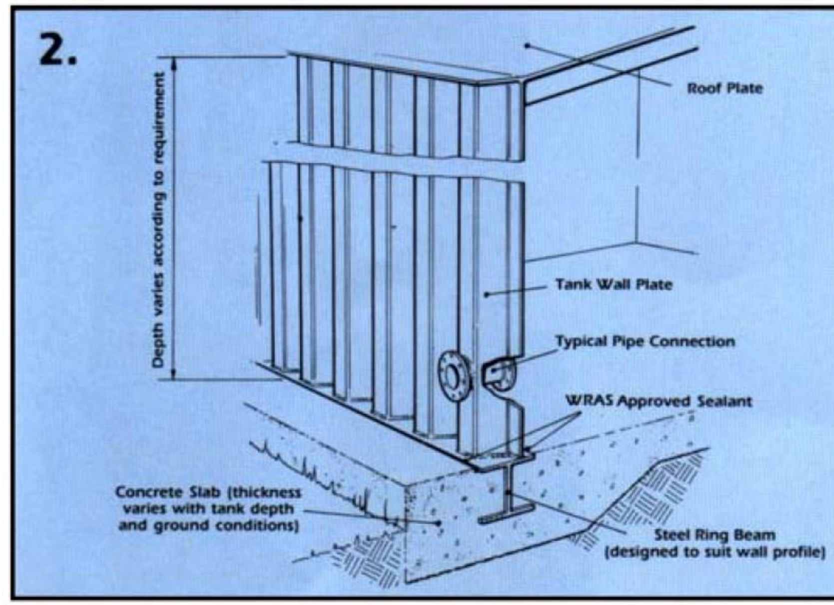
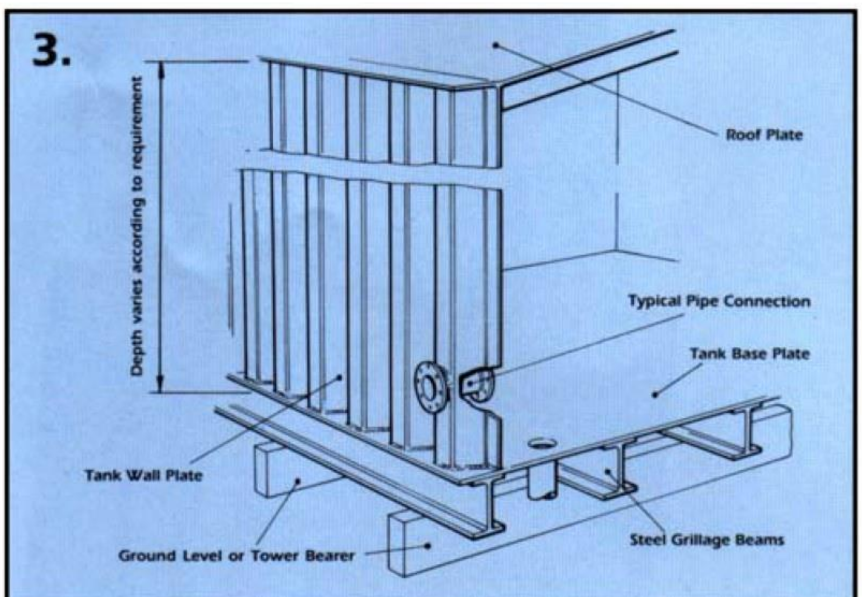
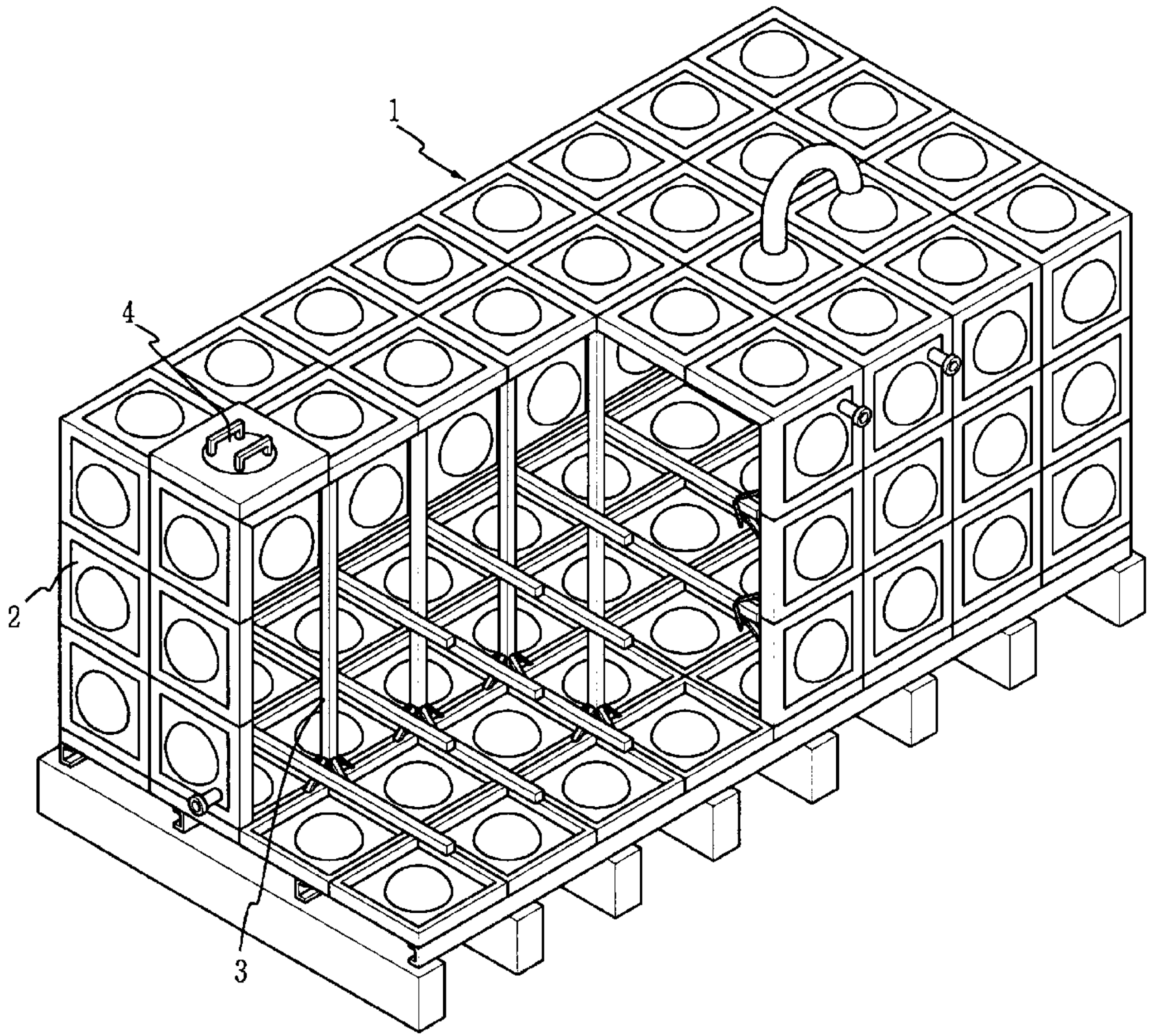
Profile Steel Welded Liquid Storage Tanks
Constructional and hydraulic details





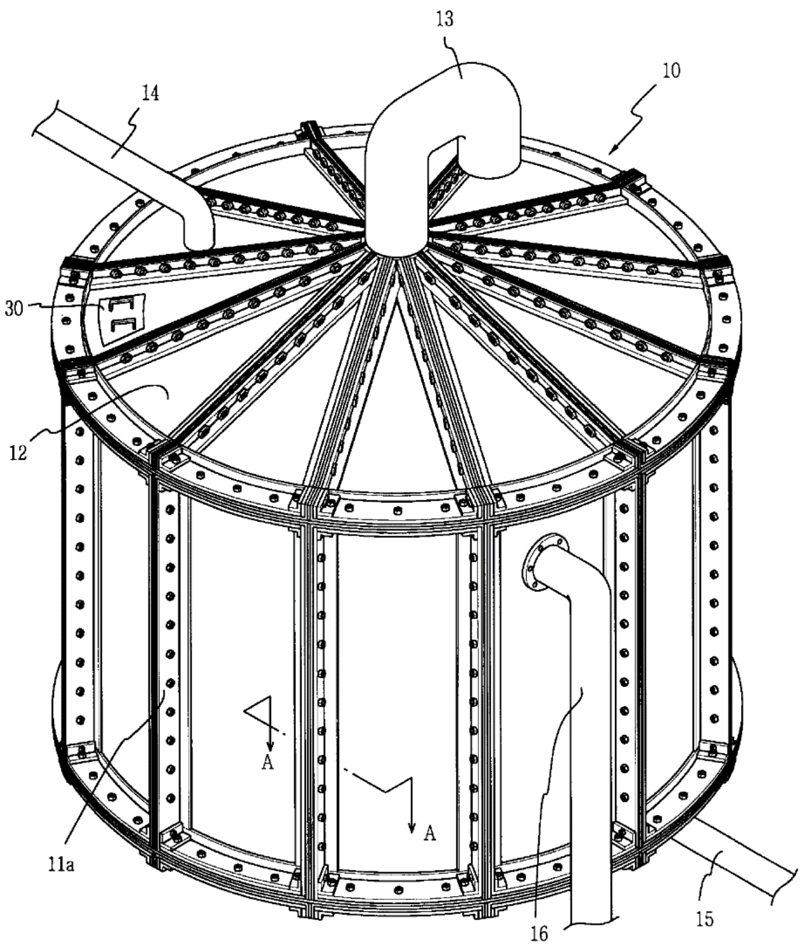


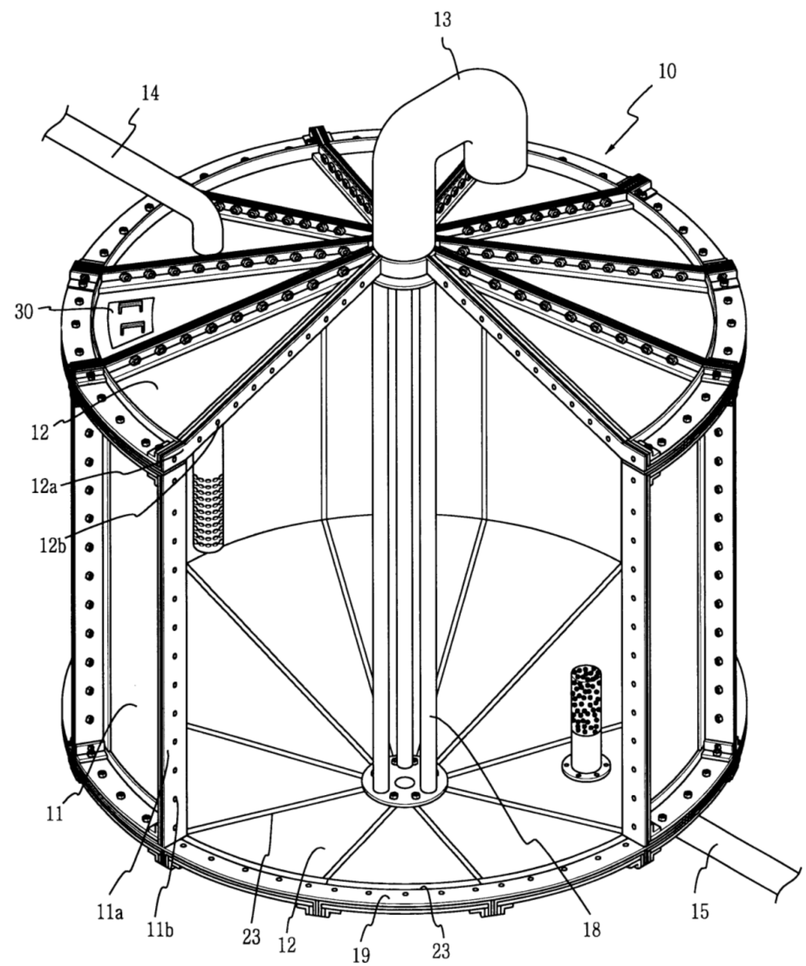
Alternatives to Braithwaite tanks



U.S. Patent 6739469

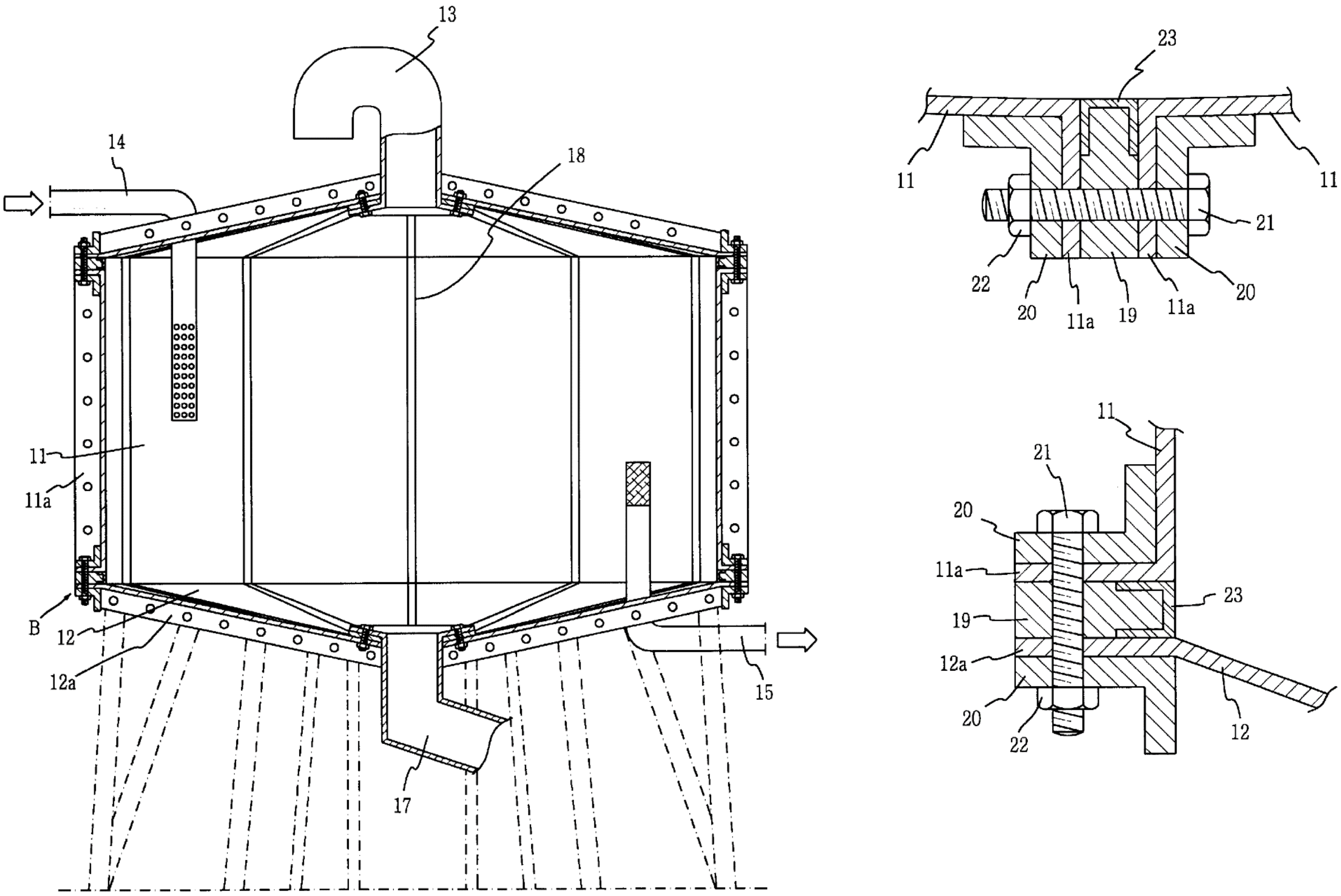
Alternatives to Braithwaite tanks





U.S. Patent 6739469

Alternatives to Braithwaite tanks



U.S. Patent 6739469

Not only for water…

WATER/WASTEWATER

Potable, Industrial, Domestic Waste Treatment, Food Waste Treatment, Metal Waste Treatment, Petroleum Waste Treatment, Sail Water, Detonized Water, Reverse Osmosis Water, Aerobic Digester, Anaerobic Digester, Backwash Holding, Clarifier with Launder, Landfill Leachate, Sludge, Fire Protection Water, Storm Water, Liquid Manure, Trickling Filter, Brackish Water, Irrigation Water, Treated Effluent Water, Water Emulsions, Waste Treatment Chemicals, Slurry, Lime, Slurry, Carbonate, Air Filtration, Demineralized Water, Pure Water

EDIBLE OILS

Soybean Oil, Olive Oil, Palm Oil, Sunflower Oil, Cottonseed Oil, Other Vegetable Oils

LIQUID CHEMICALS

Drilling Chemicals, Sodium Hydroxide, Liquid Fertilizer, Aluminum Sulfate, Ethylene Glycol, Industrial Acids

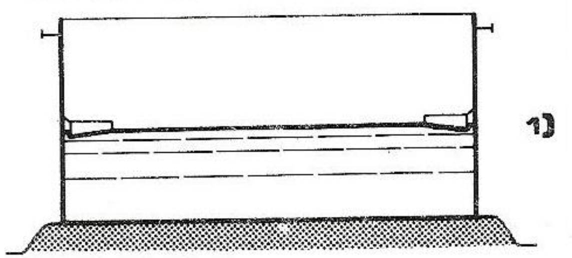
PETROLEUM & FUELS

Crude Oil, Synthetic Oil, Asphalt, Diesel Fuel, Aviation/Jet Fuel, Gasoline, Kerosene, Oilfield/Processed Water, Fuel Oil

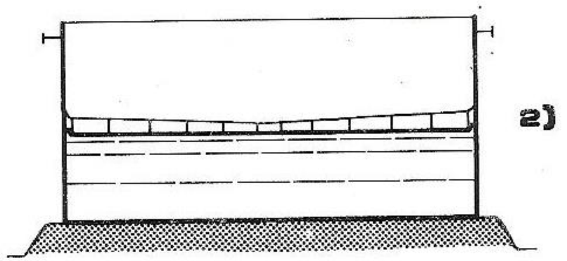
LIQUID PRODUCTS-OTHER

Alcohols, Molasses, Vinegar, Drilling Mud, Fats, TecLiners

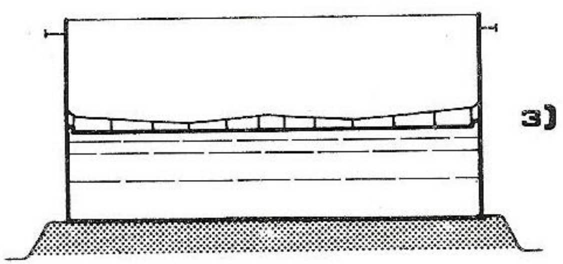
Floating roof tanks



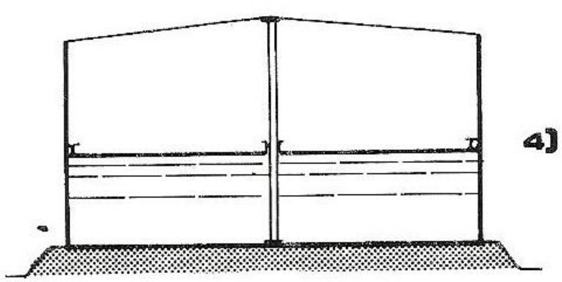
Single layer
floating roof tank



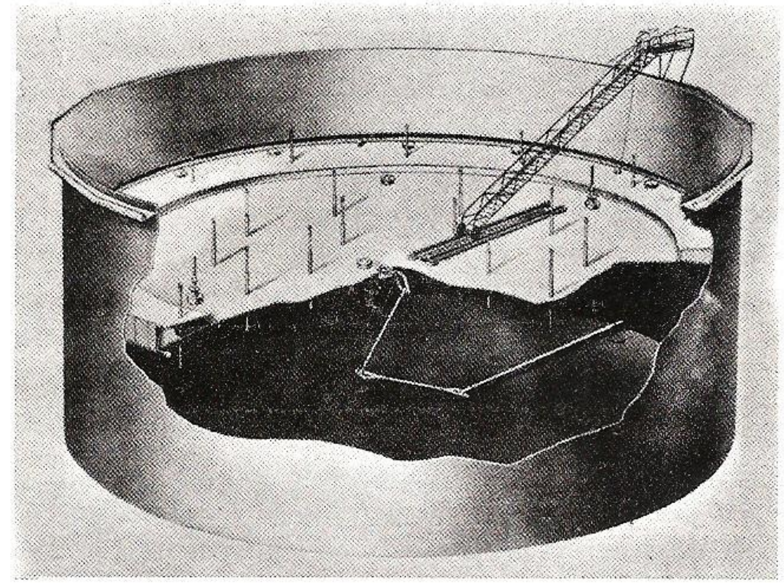
Double layer floating
roof tank with central
drainage

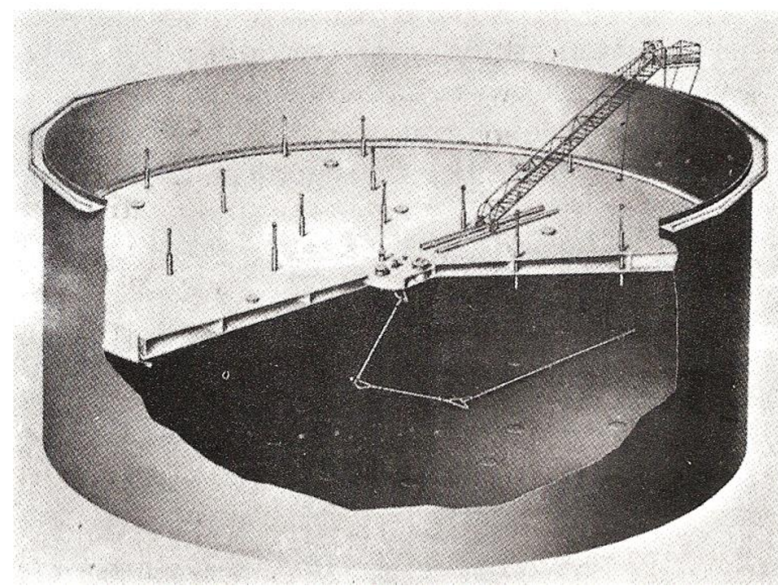


Double layer floating
roof tank with
intermediate drainage



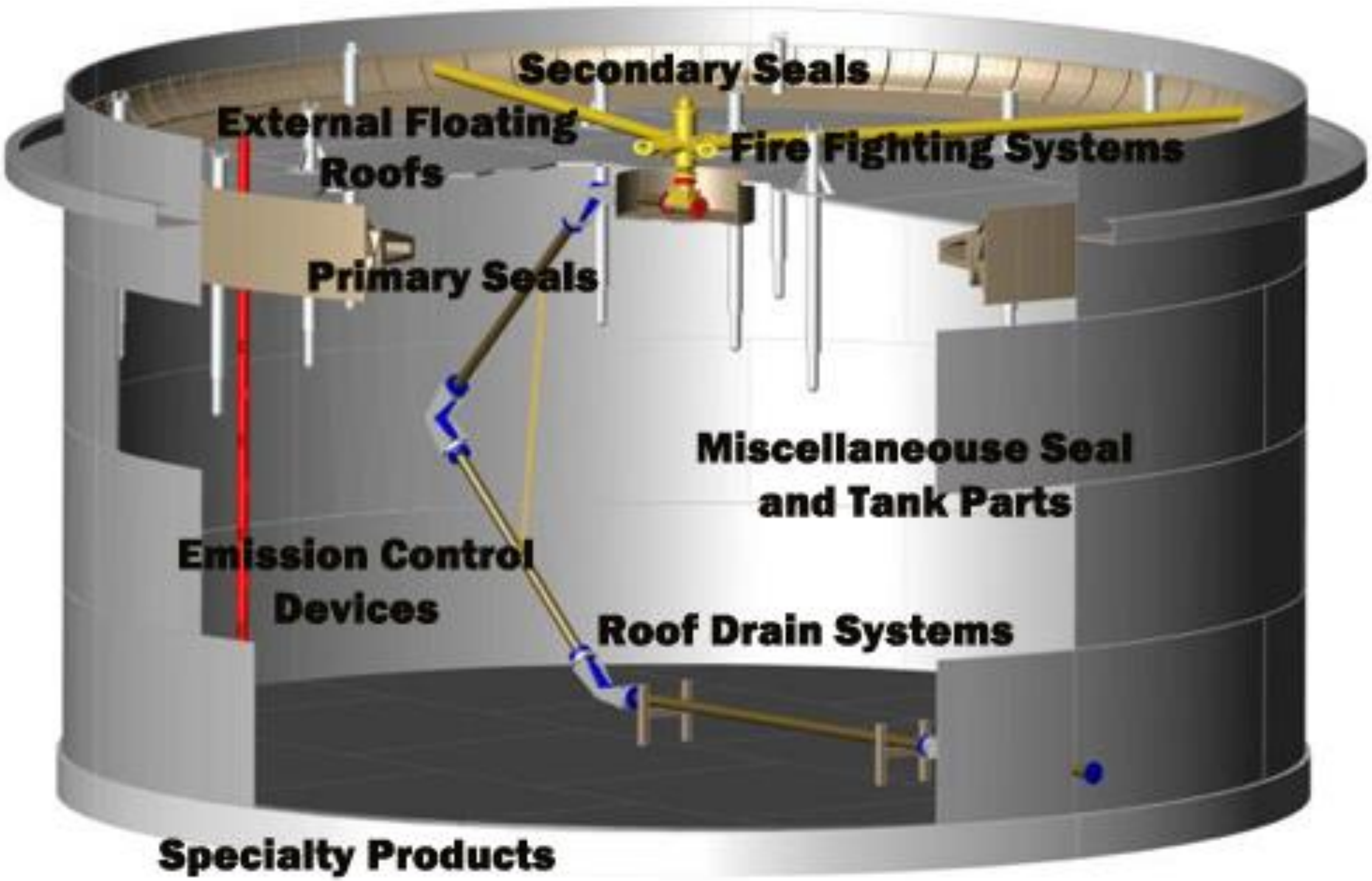
Floating deck in
fixed roof tank



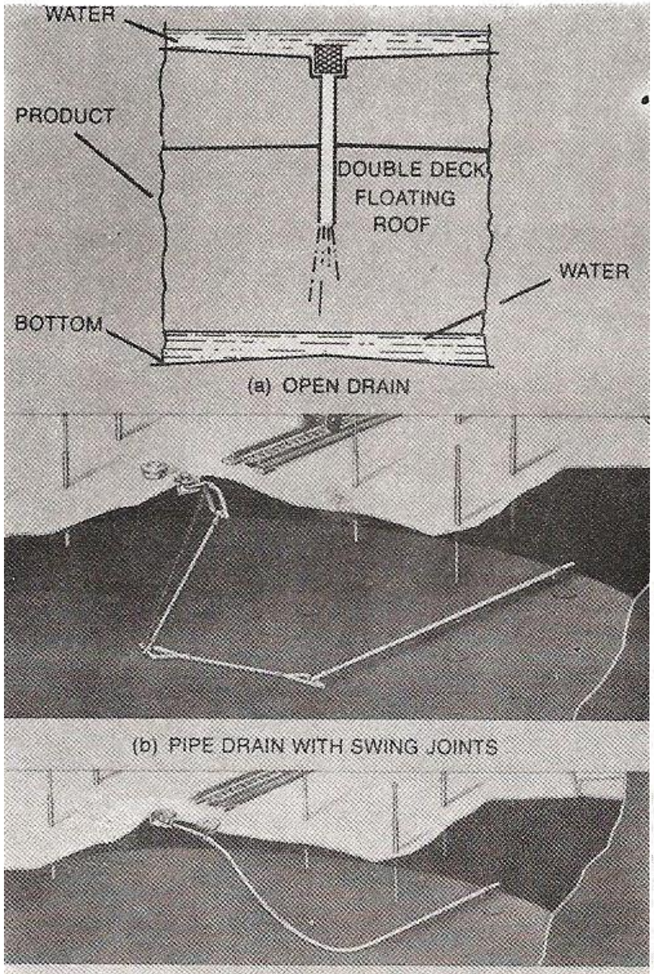


**Floating roof tanks
approved by API 650**

Floating roof tanks
Main parts



Floating roof tanks
Drain constructional details

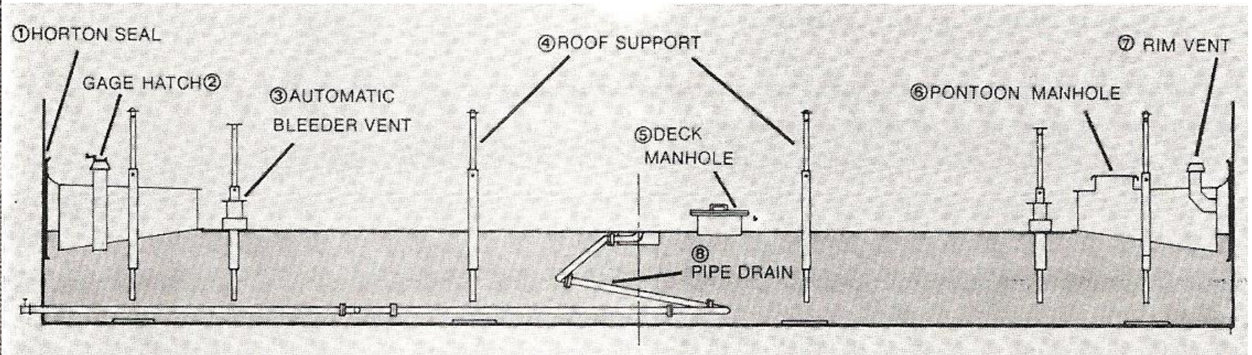


(a) OPEN DRAIN

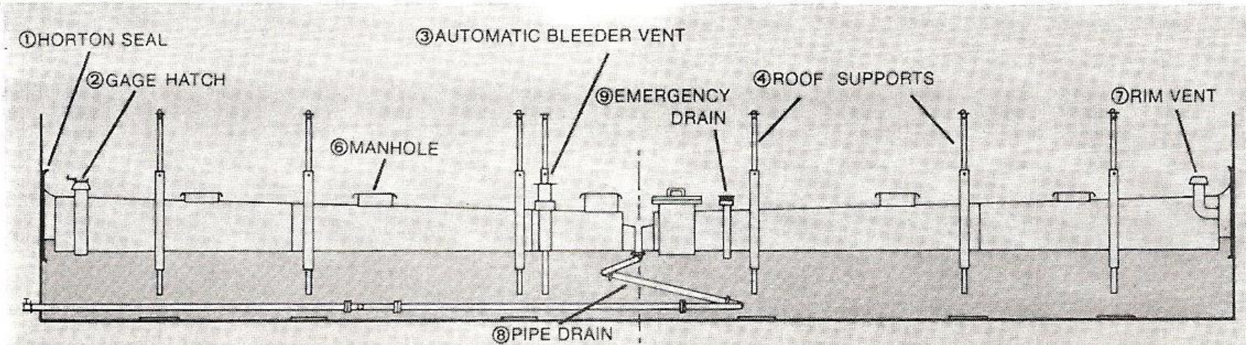
(b) PIPE DRAIN WITH SWING JOINTS

(c) FLEXIBLE HOSE DRAIN

Open and closed drain



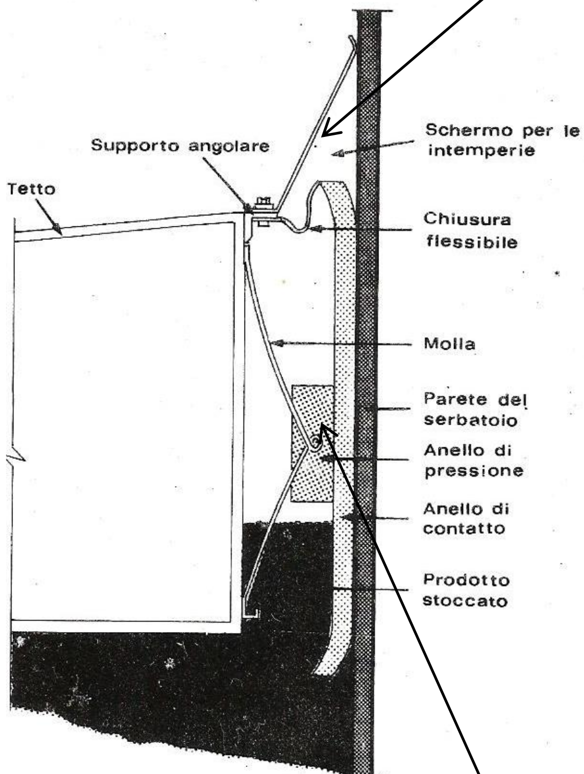
HORTON TYPE 5 FLOATING ROOF

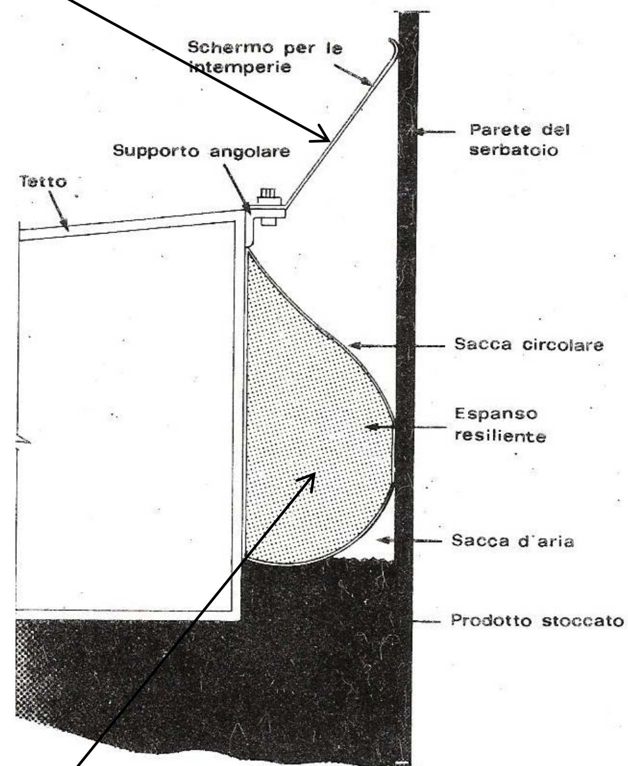


HORTON DOUBLE-DECK FLOATING ROOF

Floating roof tanks
Constructional details

Secondary seal





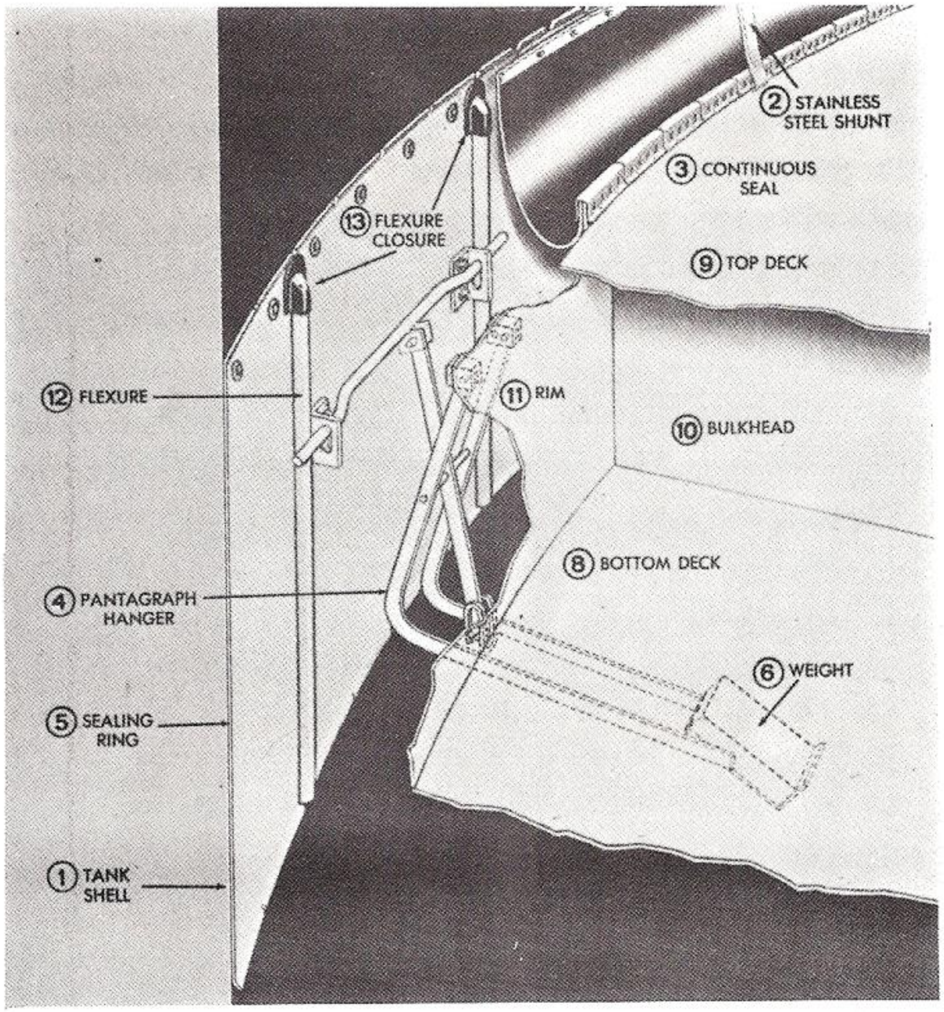
Metal joints

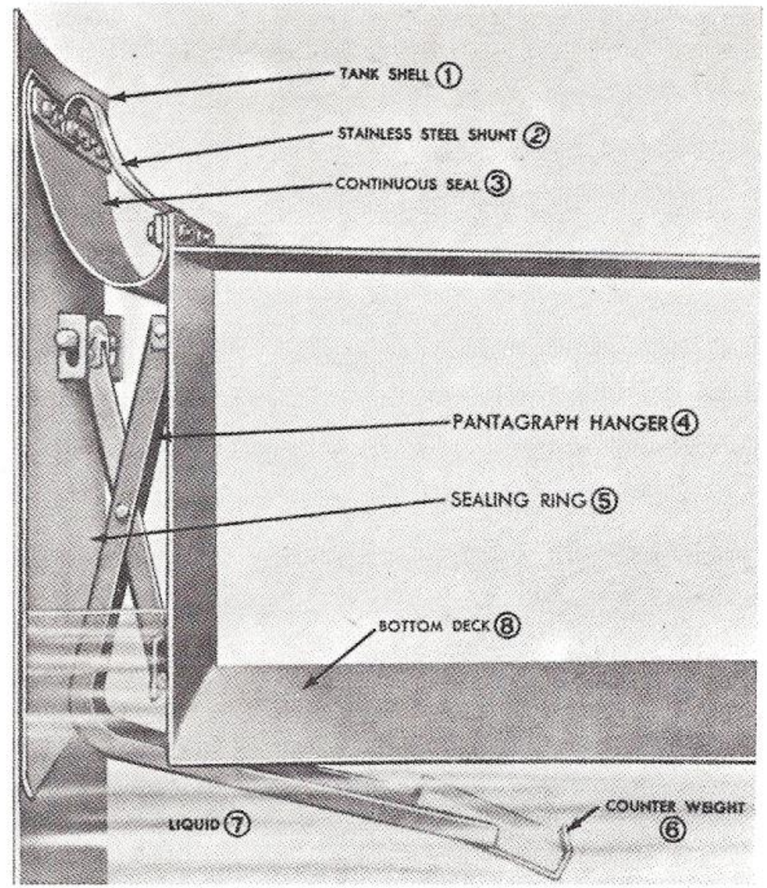
Non-metal joints

Primary seal

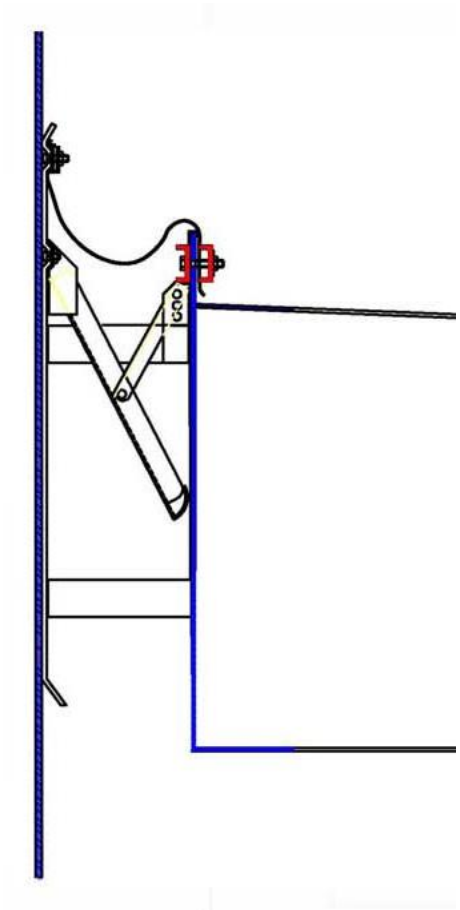
Seals can be liquid or vapour mounted

HORTON Metal joint





Scissor shoe plate seal



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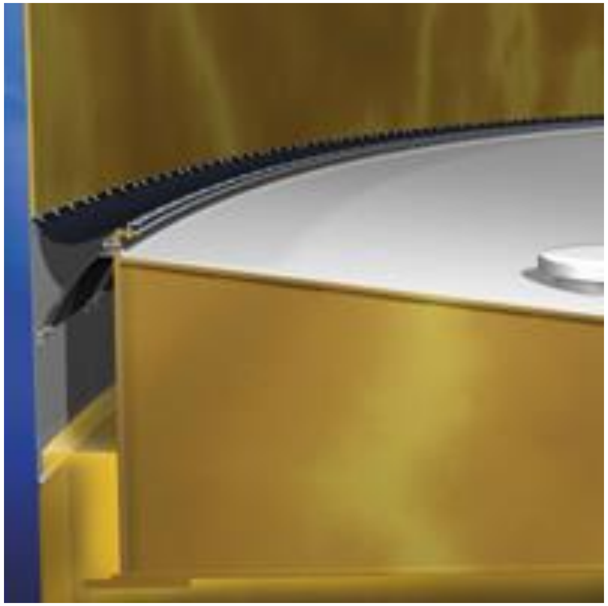
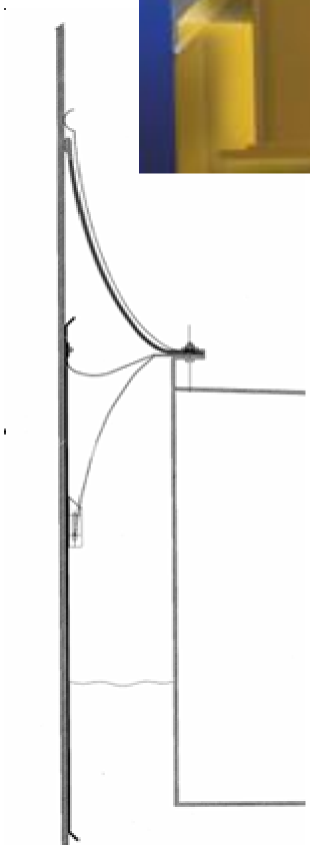
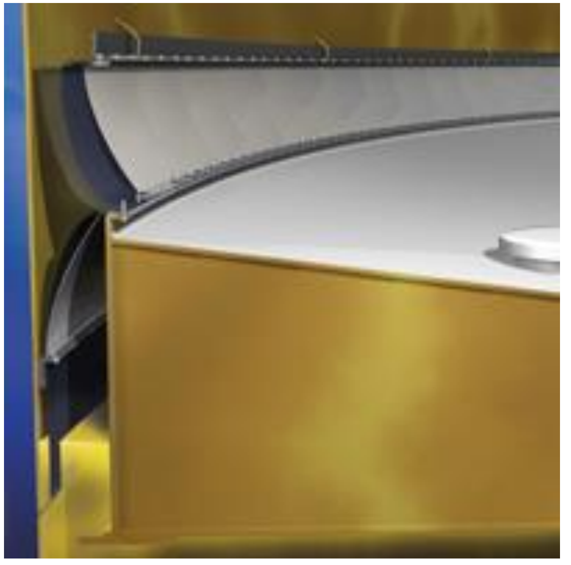
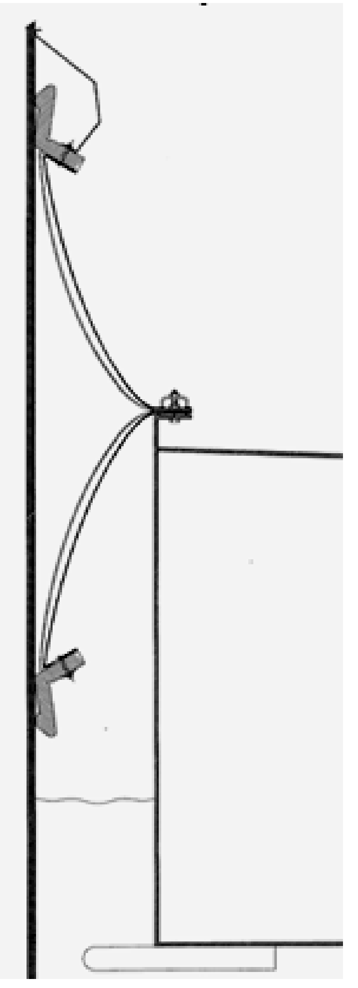
Mechanical shoe plate seal





Secondary compression plate seal



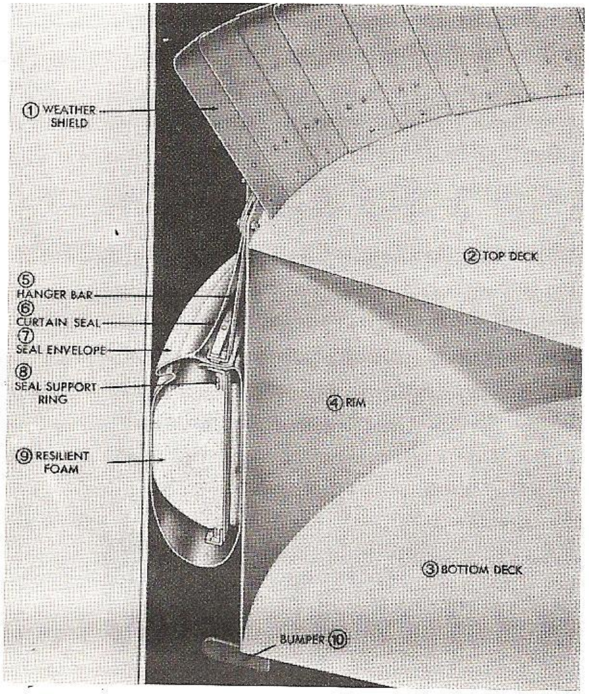


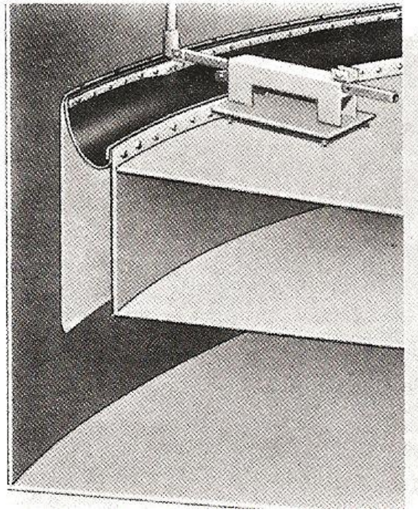
Rim mounted secondary seal that has developed itself as a leading design for secondary tank seals. Its design is based on compression plates pushing a rubber tip against the tank shell. As the seal design has no complex moving parts it will not encounter problems as a result of corrosion or any other hazards affecting seal performance through time. Each seal can be specifically engineered and manufactured to fit the tank involved, making sure the seal will be able to deal with both the product stored as well as with the particular dimensional and design aspects of this tank. Behind the compression plates is a continuous vapour barrier ensuring excellent vapour tightness and fully shielded from weather exposure by the covering compression plates.

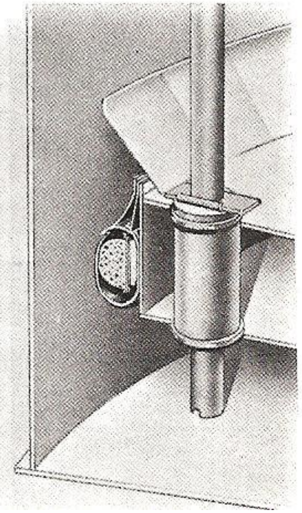
Compression primary plate seal

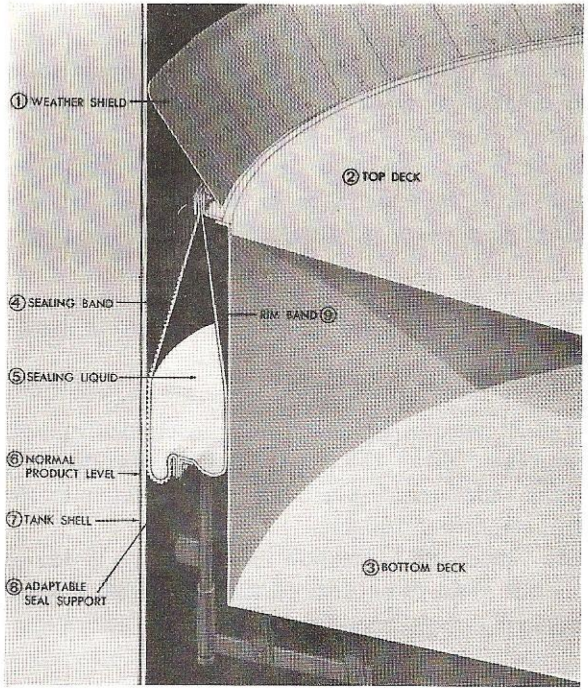
Liquid mounted primary seals are the most effective seals with respect to emission reduction for external floating roof tanks. Liquid mounted seals however will have to deal with liquid exposure for the seal materials in contact with the liquid phase of the product. These materials are prone from getting damaged by this liquid exposure where materials just being exposed to the product vapours are less likely to get damaged. The liquid contacting seal materials is known to result in compatibility problems especially when the product stored has a high content of aromatic hydrocarbons such as Benzene or Toluene.

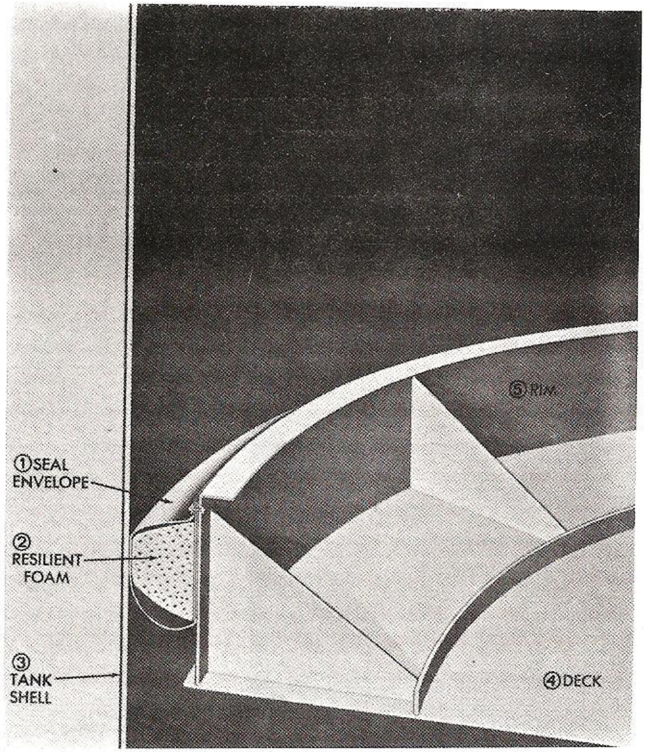
HORTON Non-Metal joint

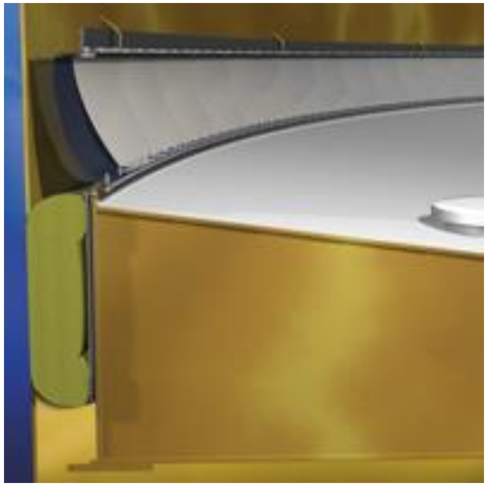




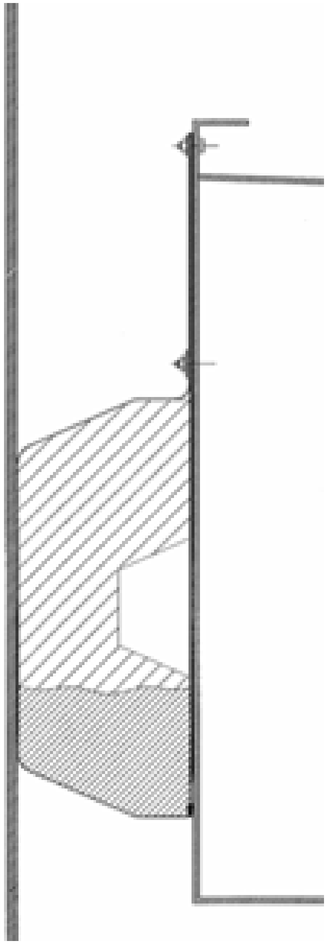








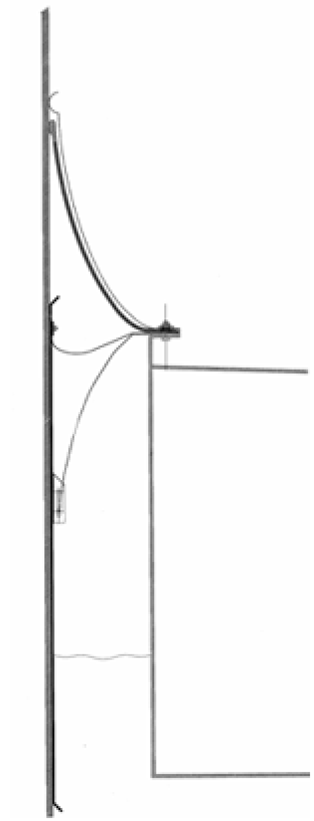
Primary foam seal



The primary foam seal is traditionally known as the most effective primary tank seal with respect to reducing emissions. Its design is based on using a polymer fabric reinforced cover around a resilient foam core being held down by hold down plates. As the seal is very flexible and contacting the tank shell in an extended area the vapour tightness is excellent. Each seal can be specifically engineered and manufactured to fit the tank involved, making sure the seal will be able to deal with both the product stored as well as with the particular dimensional and design aspects of this tank. Primary foam seals can either be vapour mounted or liquid mounted, and are available both for external floating roof as well as for internal floating roof tanks.

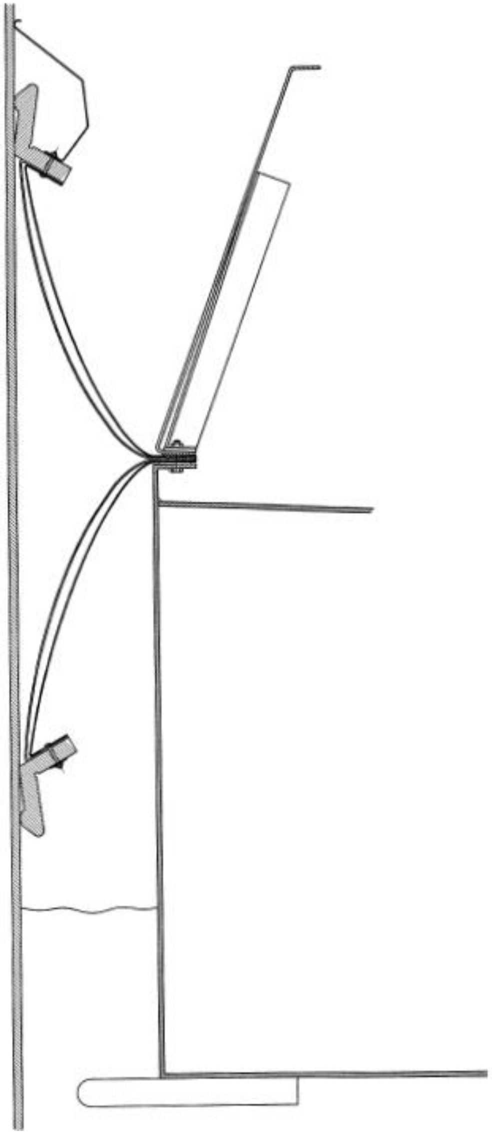
Secondary rubber seal

Rim mounted secondary seal based on individual rubber elements in direct contact with the tank shell. The rubber elements have integrated springs ensuring that the seal element is pushing with its tip against the tank shell. As the seal design has no complex moving parts it will not encounter problems as a result of corrosion or any other hazards affecting seal performance through time. Apart from that the modular design facilitates easy installation. The tongue and groove connection between the rubber elements ensures a tight fit, shielding the tank contents from rainwater penetrating the tank. As the elements are produced from an excellent rubber compound both vapour tightness, medium resistance as well as weather resistance are excellent.



Foam dam

Foam dams are installed on both external and internal floating roofs to concentrate fire fighting foam in the seal area .Fires typically occur at this seal area. The common design for a foam dam is a welded construction in the rim area of the roof. There are several disadvantages of a welded foam dam. An integral foam dam, fitted to the rim angle of the floating roof offers significant benefits. It is bolted directly to the rim angle and the base of the secondary seal. It is a well tested modular design and can be installed in little time. The integral foam dam can be supplied in both steel and stainless steel, engineered to match any secondary seal involved



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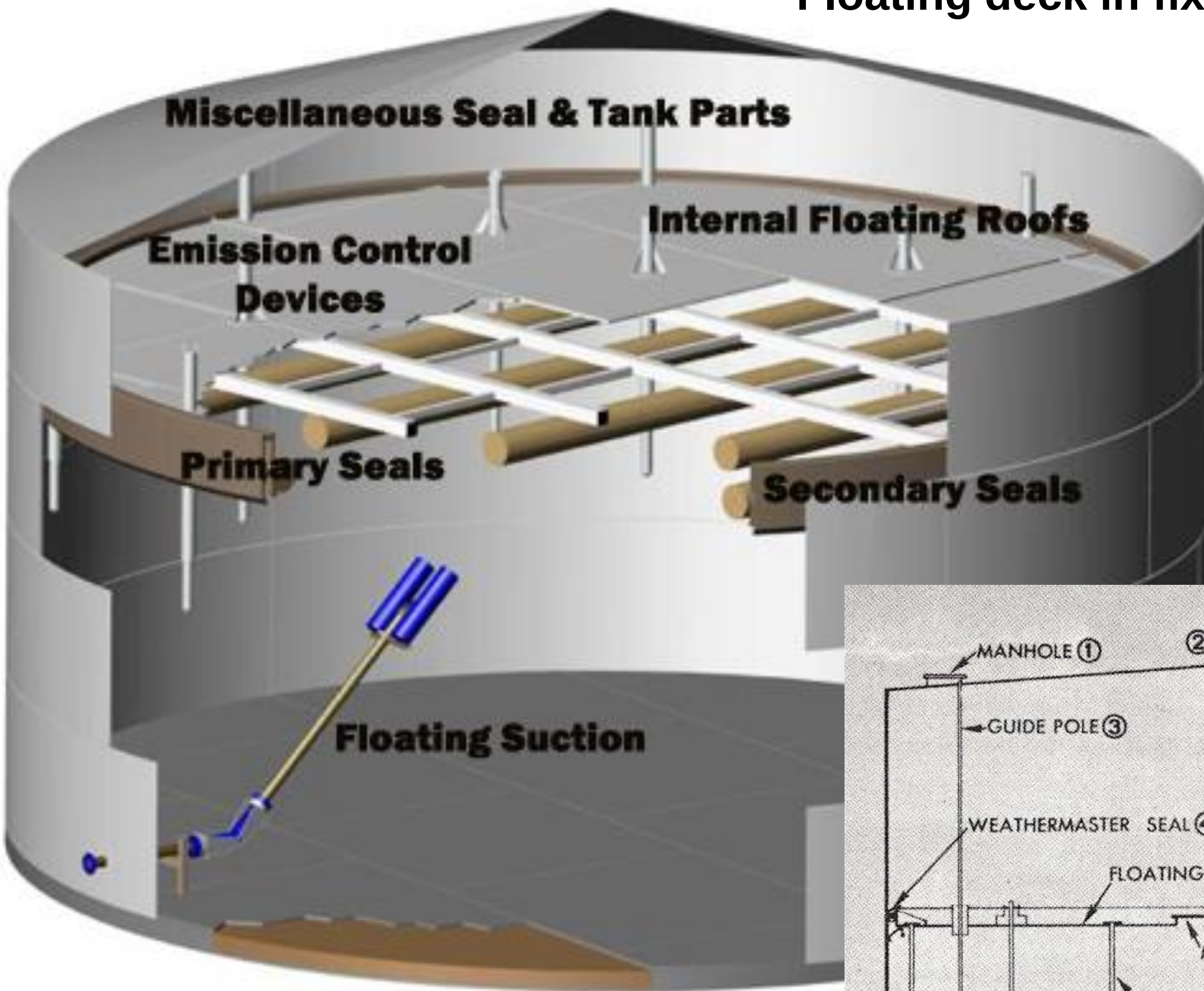
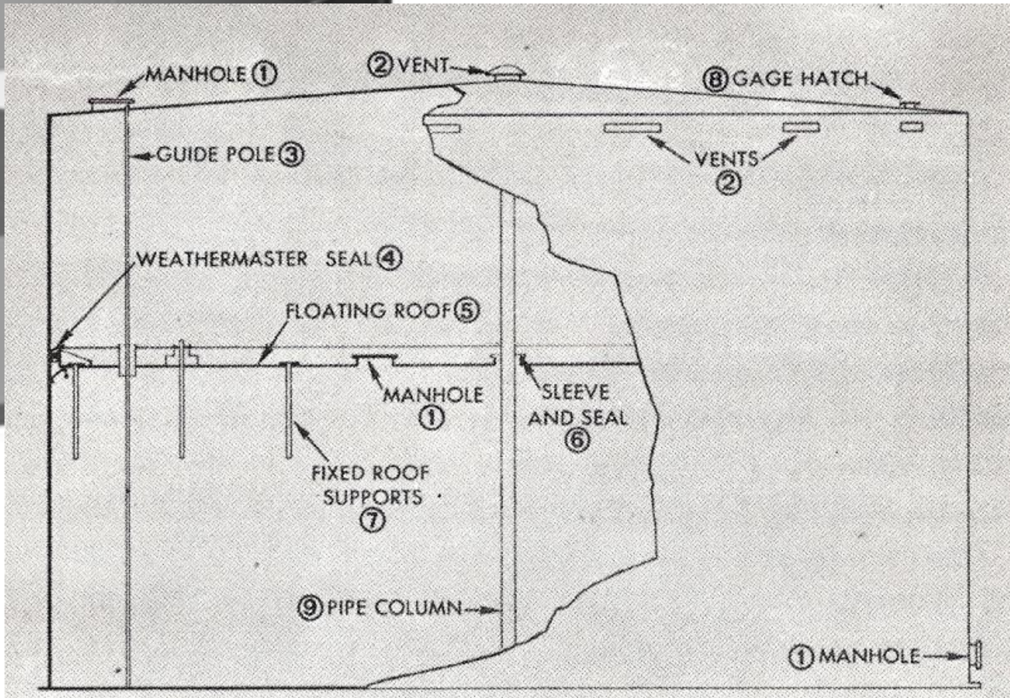
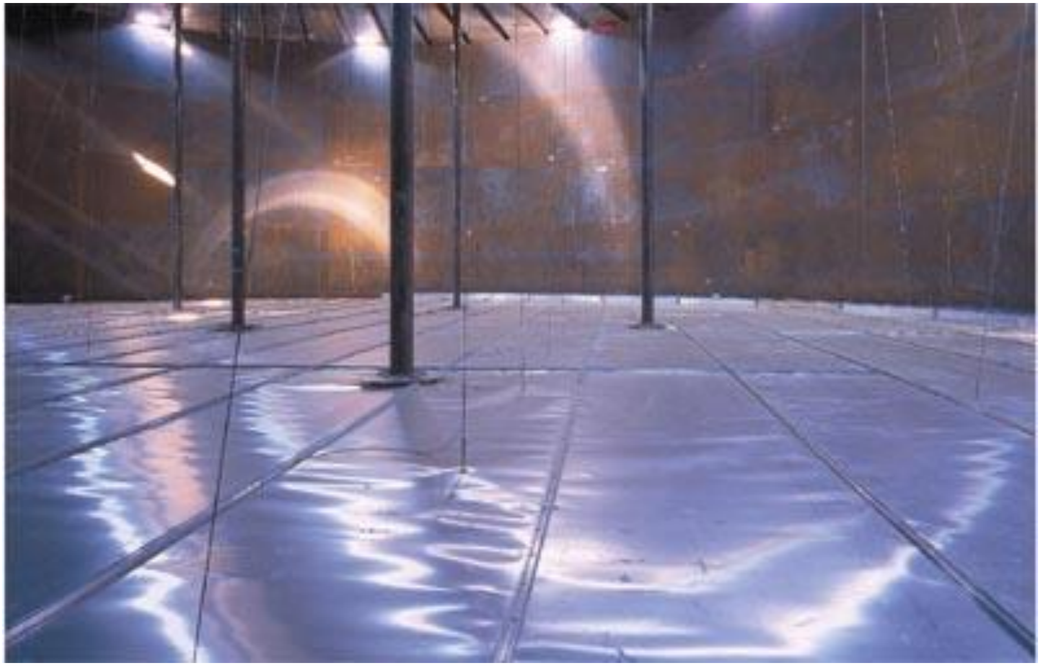
Floating deck in fixed roof tanks - Main parts





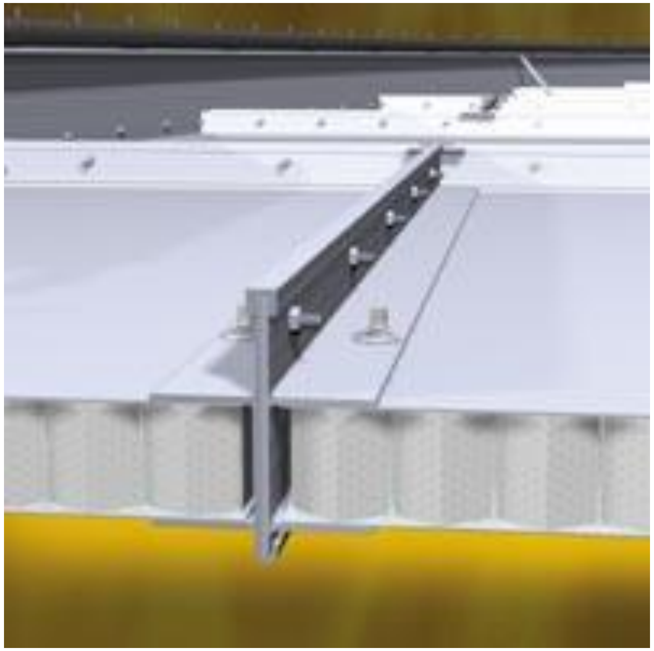
WEATHERMASTER FLOATING ROOF TANK

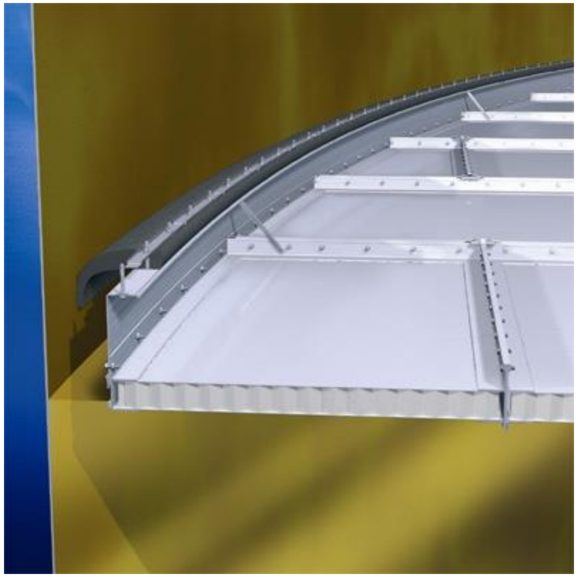


Pontoon type internal floating roofs

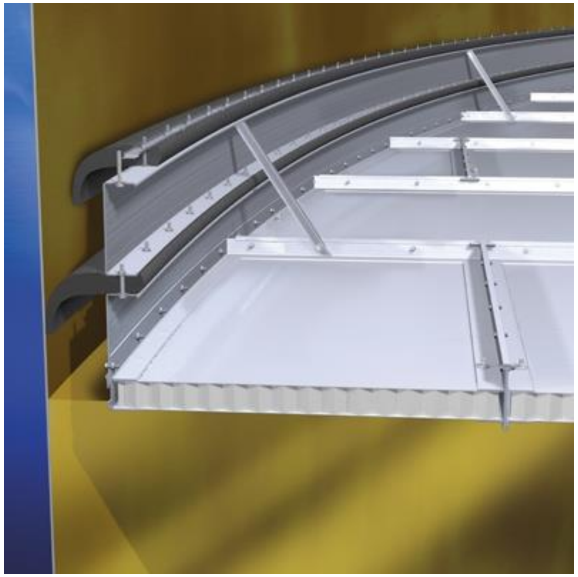
In recent decades internal floating roofs have developed into important systems to reduce emissions. When looking at internal floating roofs there are 2 basic designs available, being either a **full contact roof** or **non-contact internal floating roof**. The non-contact floating roofs are the most widely installed roofs world wide, for economic reasons. Typically they are based on aluminium pontoons, covered with a vapour tight deck skin to prevent product vapours to migrate in the space on top of the floating roof. The more recent development is the full contact aluminium roof. Where non contact roofs have a vapour area, Full contact roofs completely seal the space above the floating roof, preventing the evaporation at the most efficient point, the source.

Full contact internal floating roofs



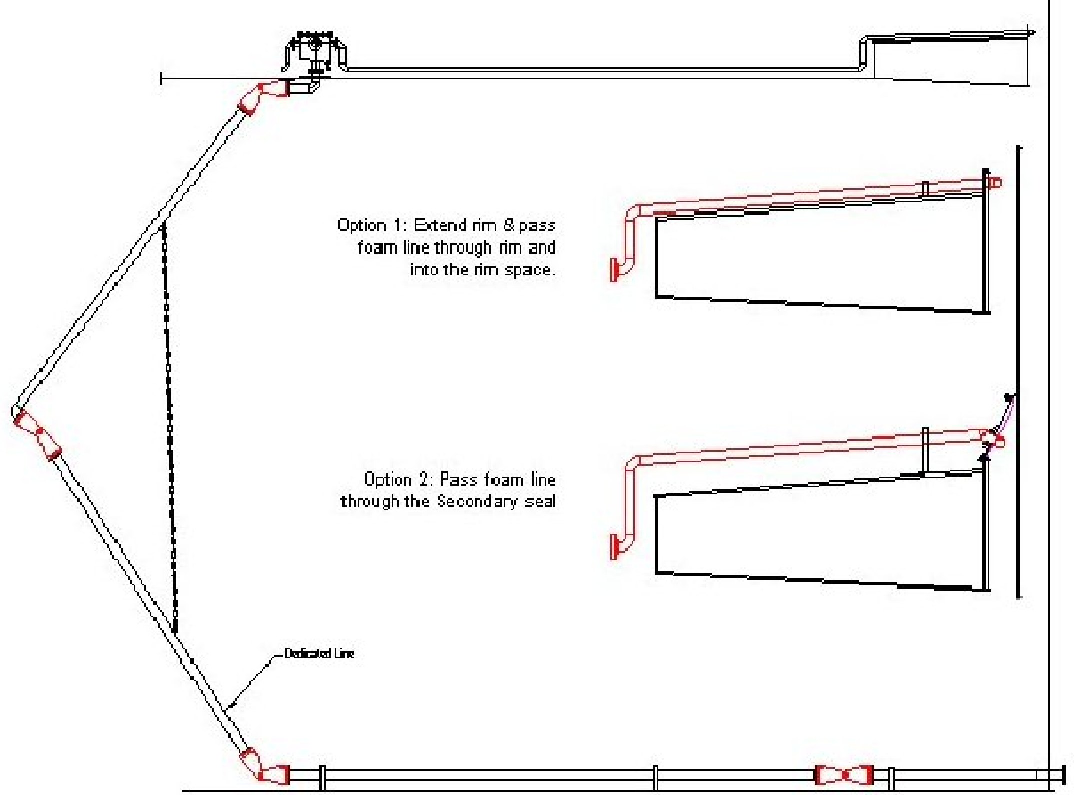


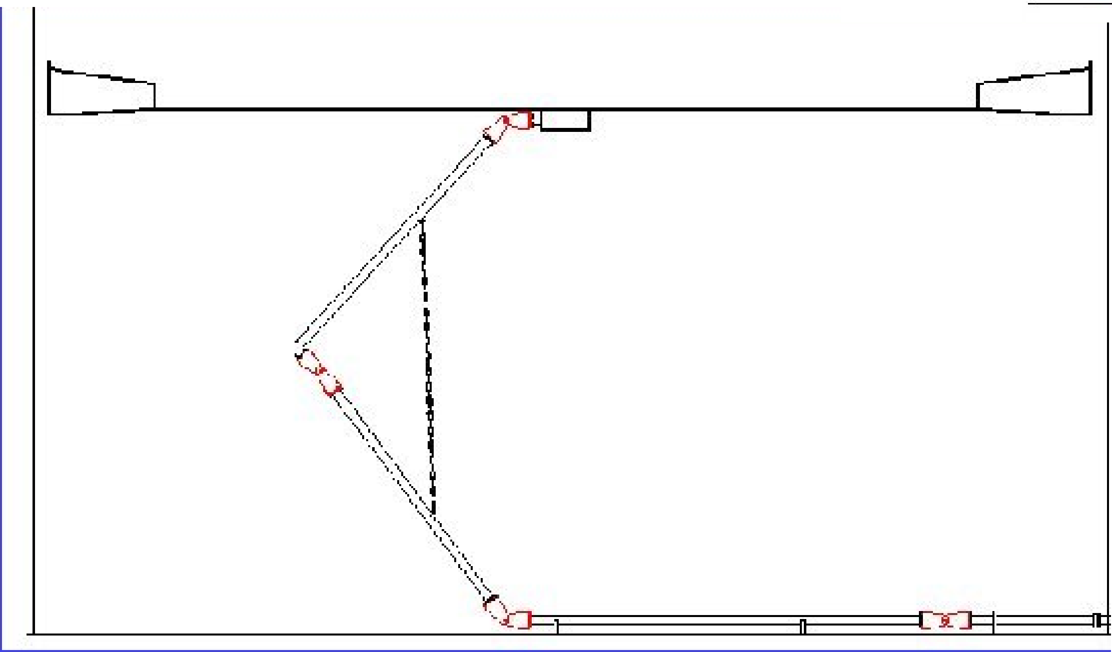
single wiper seal

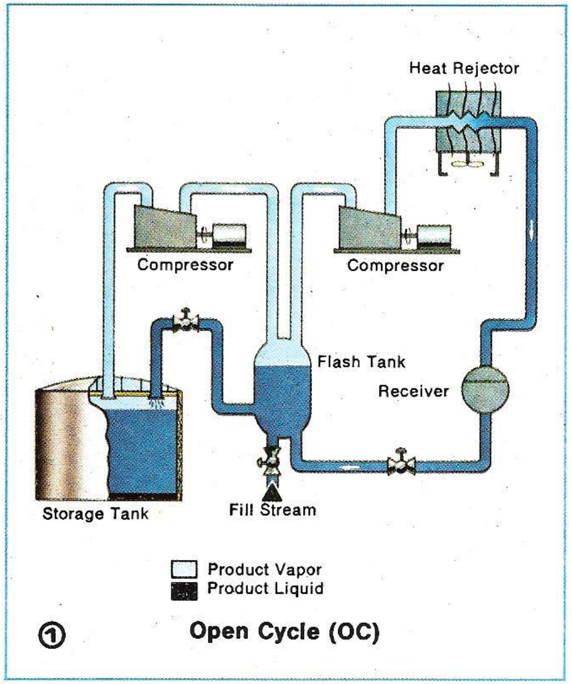


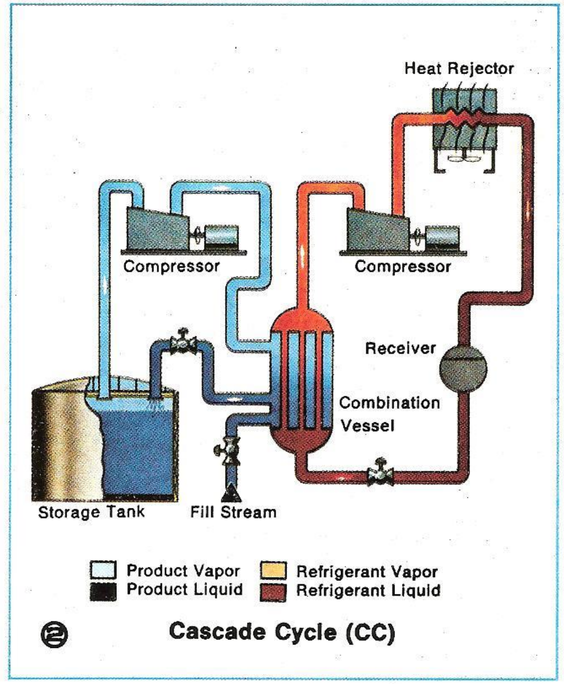
double wiper seal

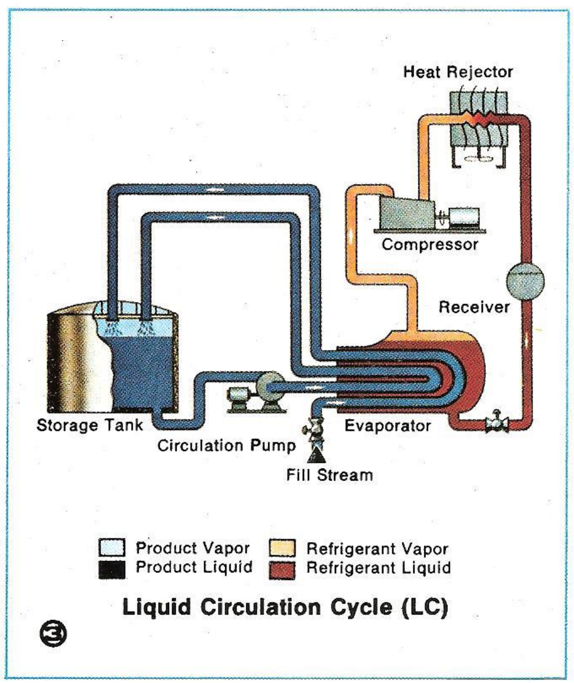
Floating roof drainage systems

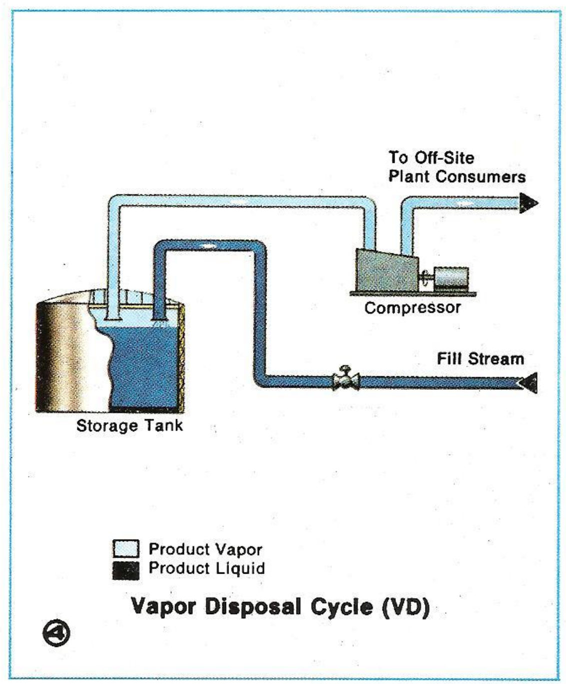








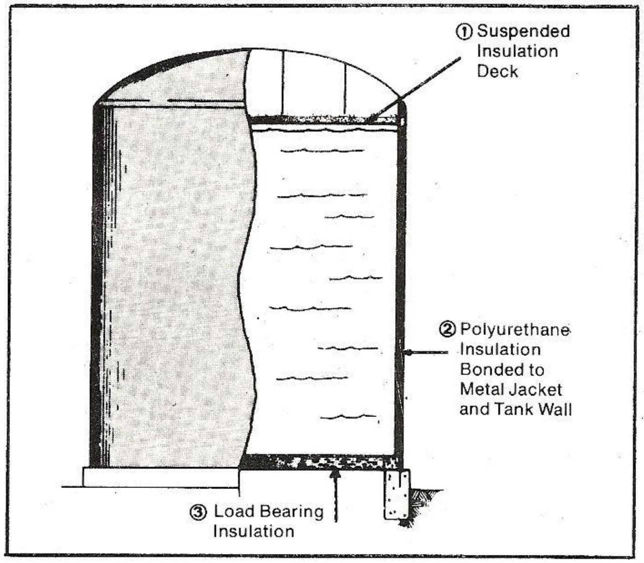


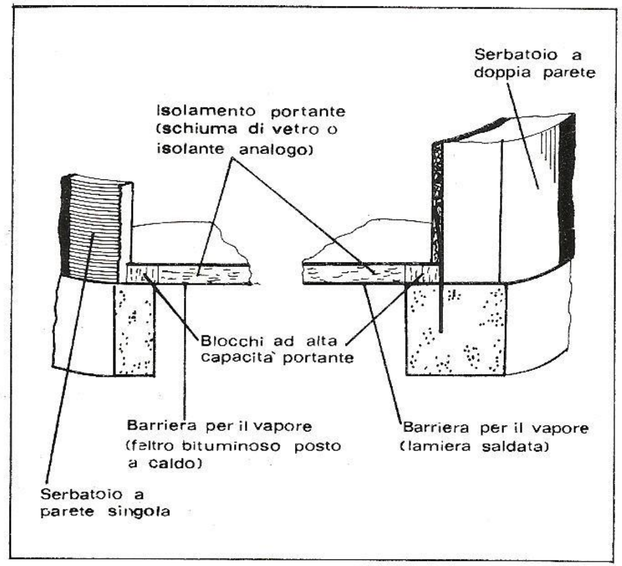


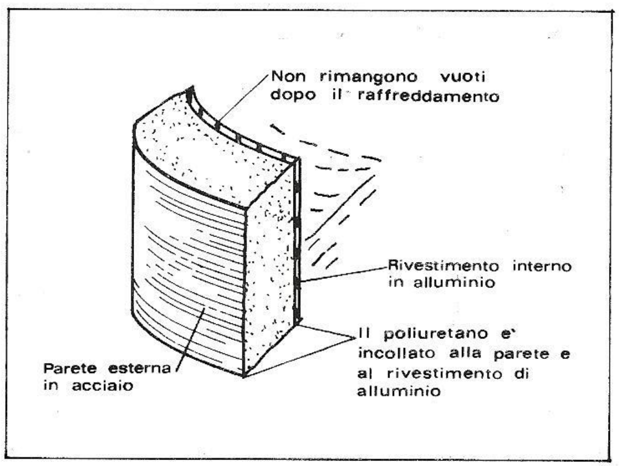
Low temperature tanks
-100 < T < 0°C

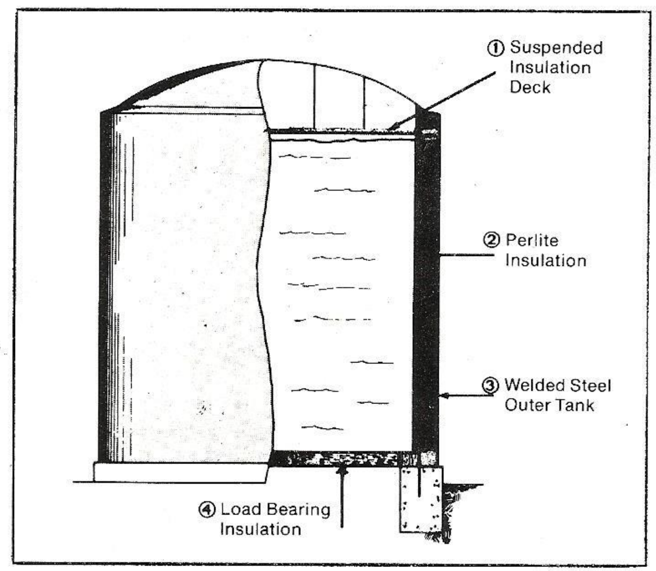
LG storage (butane, ethane, propane, propylene, ammoniac, etc.)

Flat bottom tanks

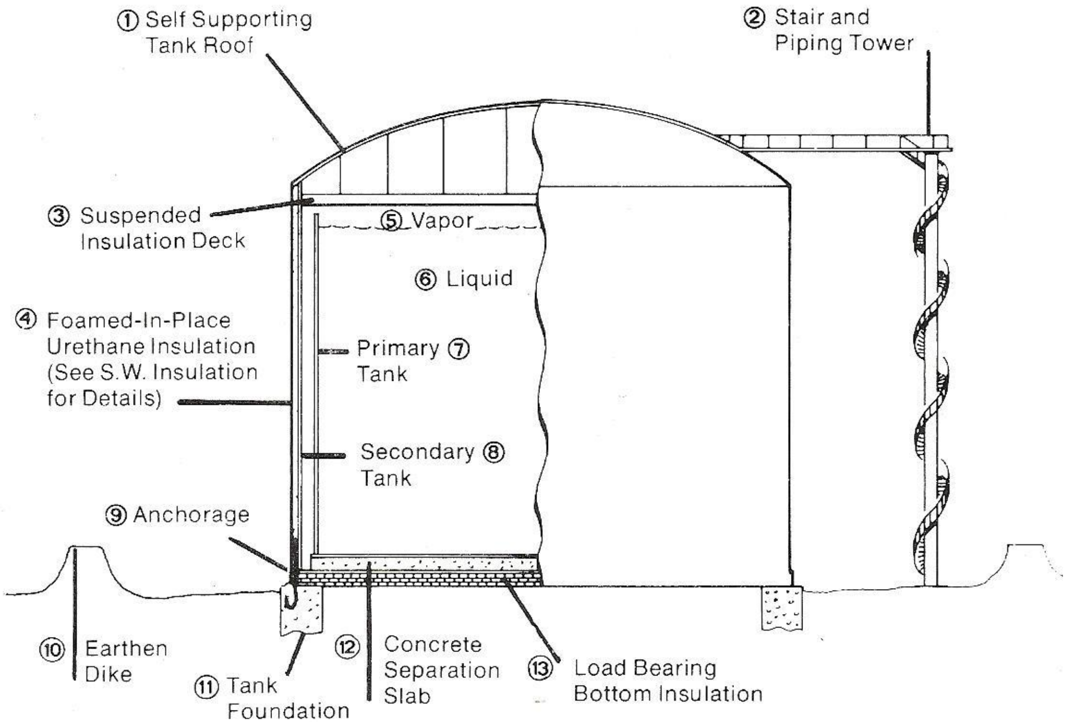


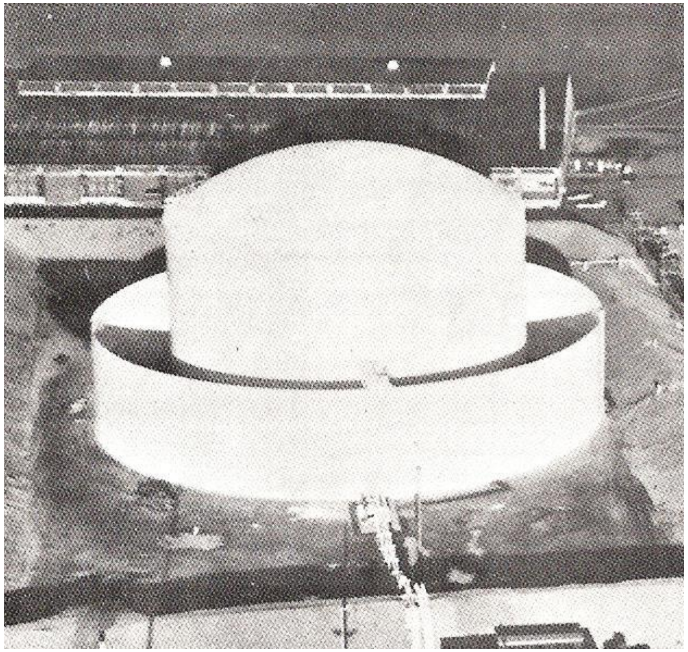




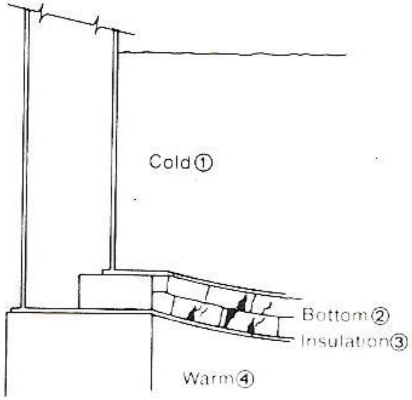


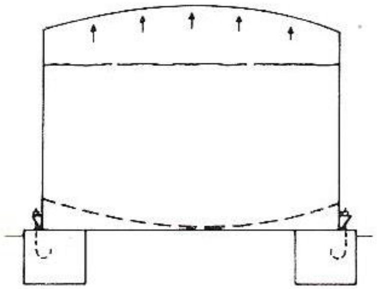
Problems of low temperature tanks





Dike wall

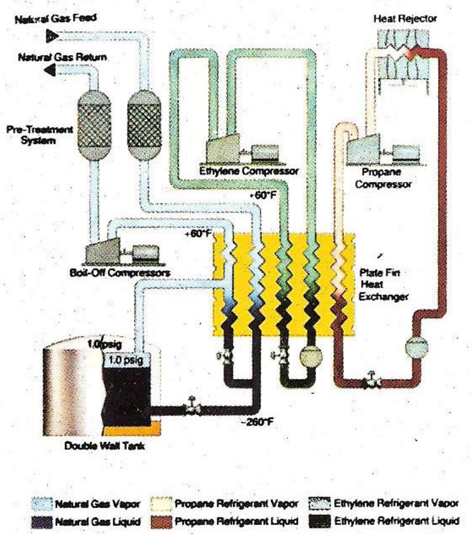




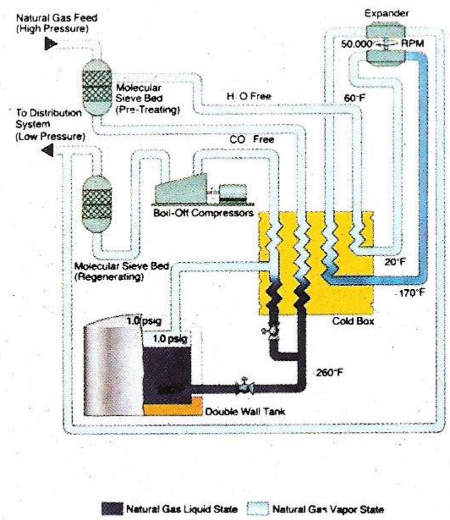
Differential settlements

Cryogenic tanks
T < - 100°C

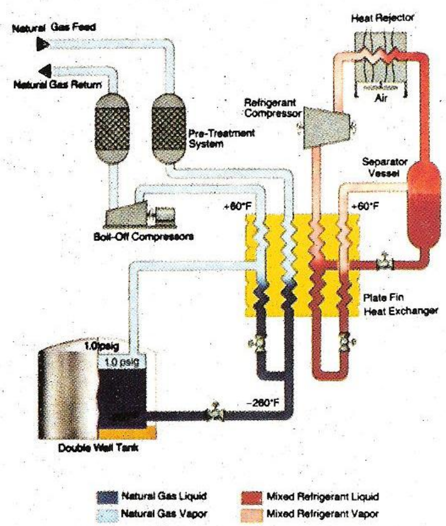
LNG storage (oxygen, nitrogen, argon, helium...)



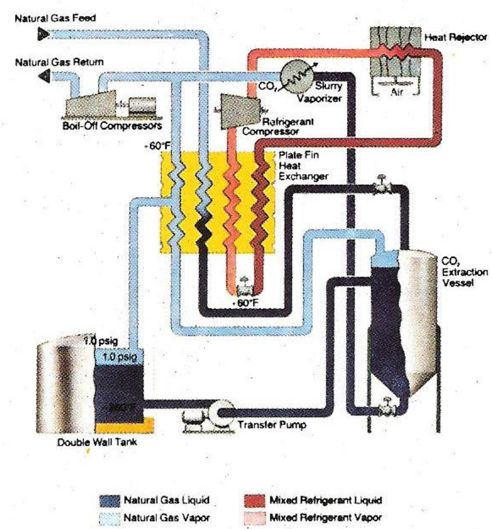
① Cascade Cycle



② Expander Cycle

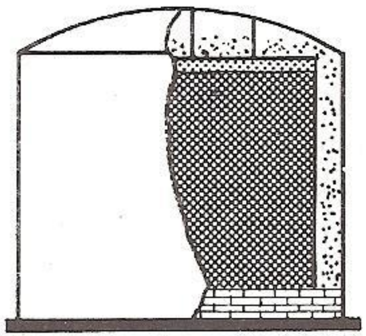


③ Mixed Refrigerant Cycle (Split MRL Cycle)

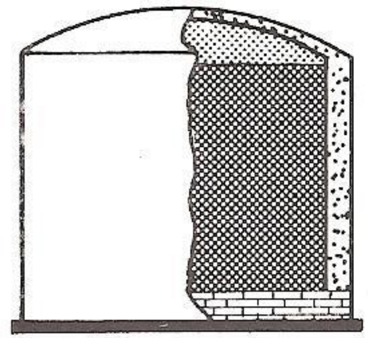


④ Integrated CRYEX/MRL Cycle (Straight MRL Cycle)

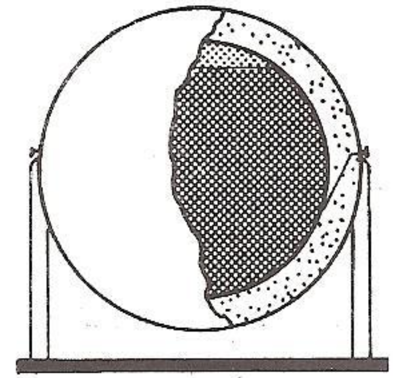
Types of cryogenic tanks



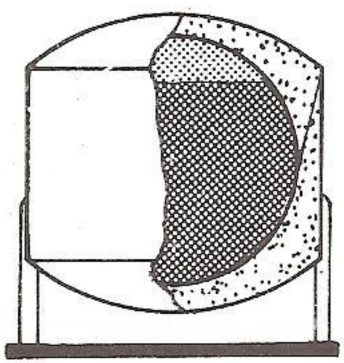
① Prodotti stoccati:
Etilene, LNG.



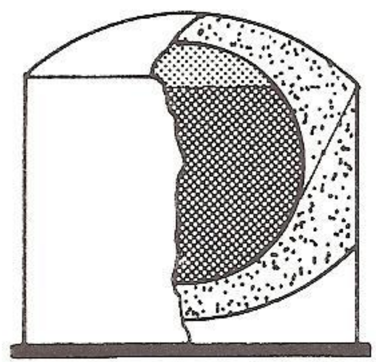
② Prodotti stoccati:
Ossigeno, LN_2, Etilene,
LNG.



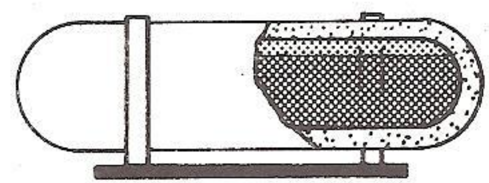
③ Prodotti stoccati:
Ossigeno, LN_2, LH_2,
Argon, Etilene e LNG.



④ Prodotti stoccati:
Ossigeno, LN_2,
Etilene.

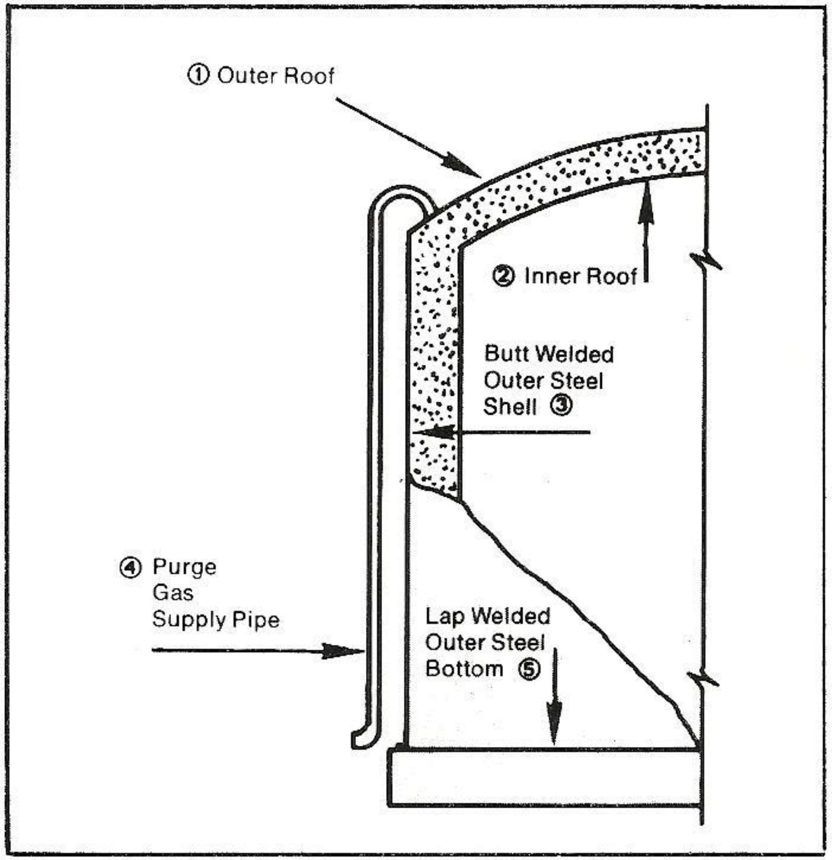


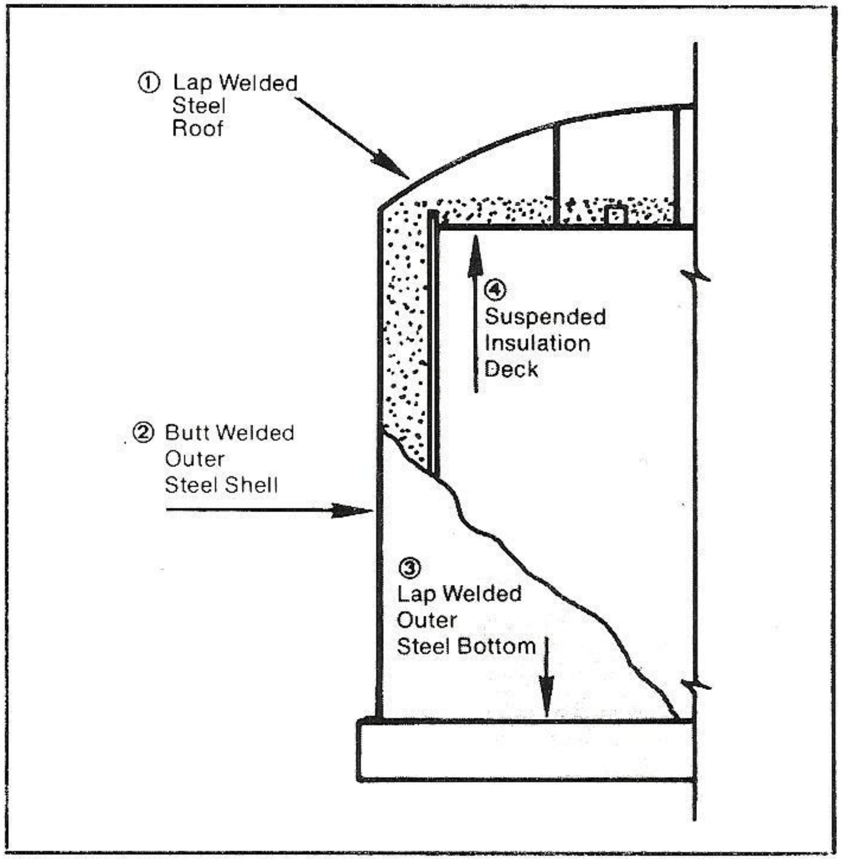
⑤ Prodotti stoccati:
Ossigeno, LN_2, LH_2.



⑥ Prodotti stoccati:
Ossigeno, LN_2, LH_2,
Argon, Etilene e LNG.

Thermal insulation of cryogenic tanks





Pressure vessels

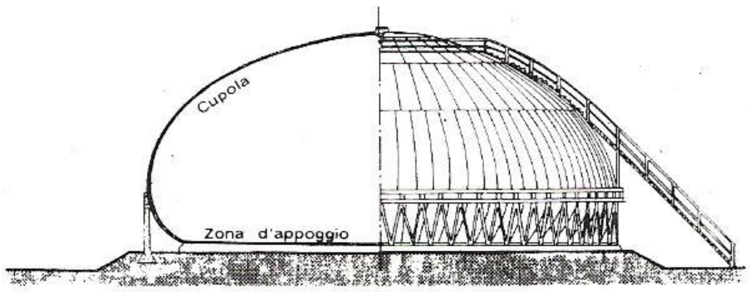
A pressure vessel is a closed container designed to hold gases or liquids at a pressure different from the ambient pressure. The legal definition of pressure vessel varies from country to country, but often involves the maximum safe pressure (may need to be above half a bar) that the vessel is designed for and the pressure-volume product, particularly of the gaseous part (in some cases an incompressible liquid portion can be excluded as it does not contribute to the potential energy stored in the vessel.)

Pressure vessels are used in a variety of applications. These include the industry and the private sector. They appear in these sectors respectively as industrial compressed air receivers and domestic hot water storage tanks, other examples of pressure vessels are: diving cylinder, recompression chamber, distillation towers, autoclaves and many other vessels in mining or oil refineries and petrochemical plants, nuclear reactor vessel, habitat of a space ship, habitat of a submarine, pneumatic reservoir, hydraulic reservoir under pressure, rail vehicle airbrake reservoir, road vehicle airbrake reservoir and storage vessels for liquefied gases such as ammonia, chlorine, propane, butane and LPG.

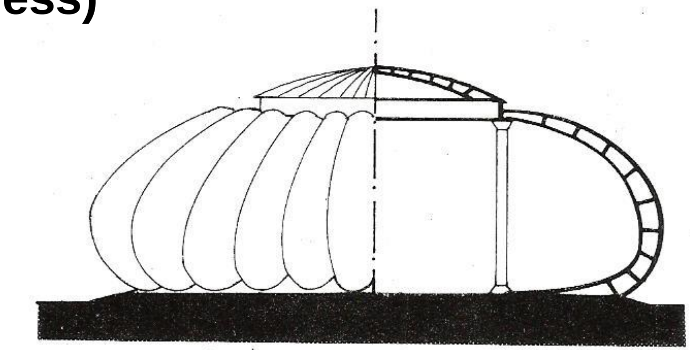
Main advantages
Storage economy, reliability, low fire risk, cheap maintenance, low corrosion, self-protection…

Pressure vessels

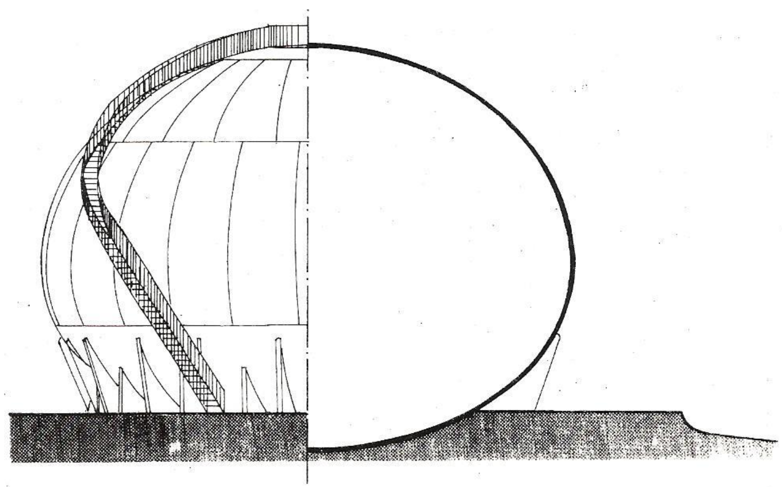
“Drop” tanks (uniform stress)



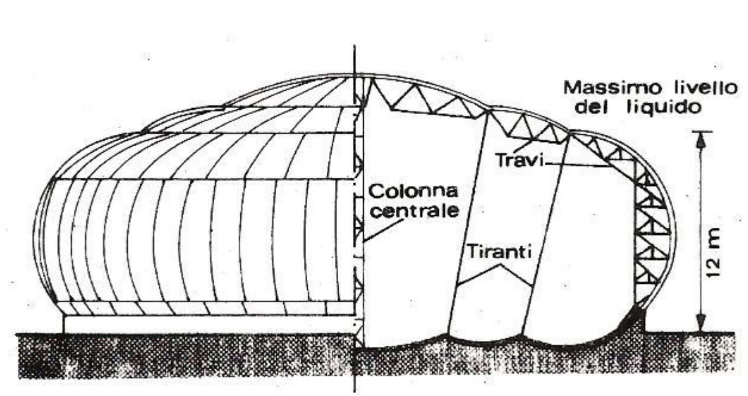
“Caquot” tank



“Zenhlé” tank



“Hortonspheroid” tank



“Hortonspheroid” noded tank

Submerged tanks

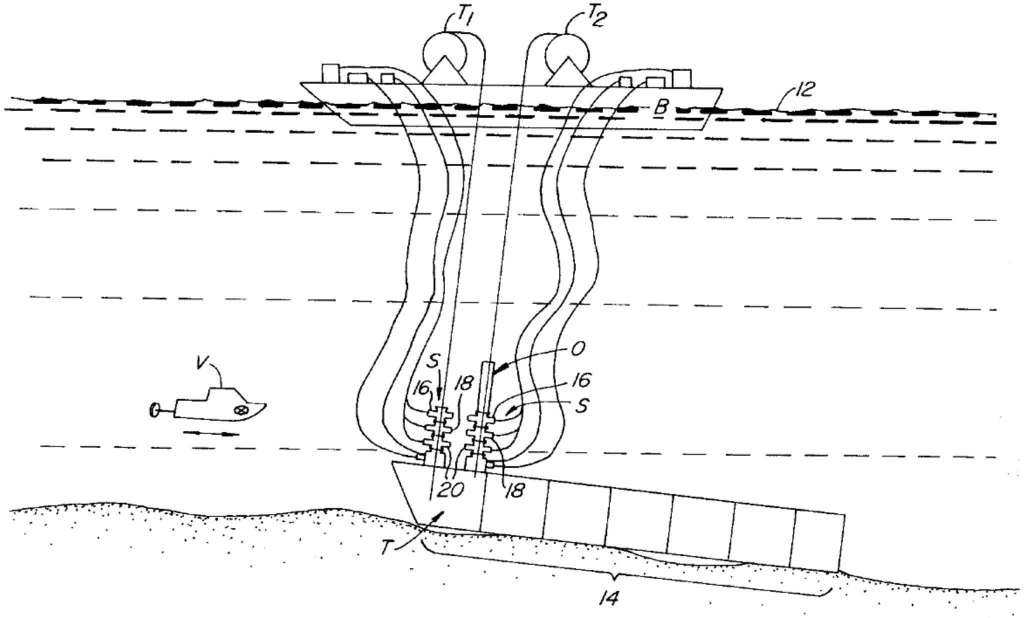
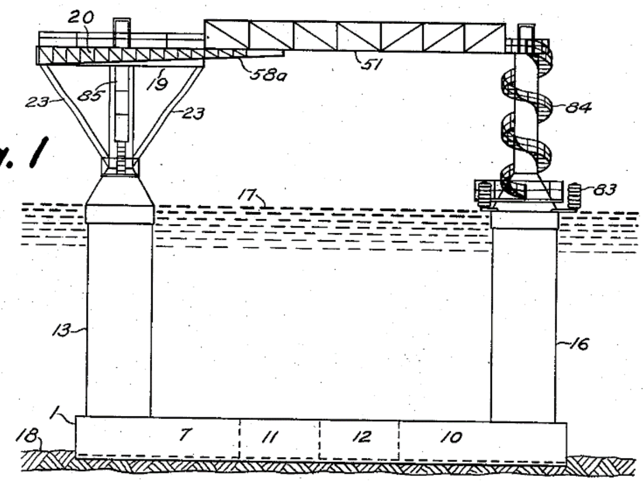
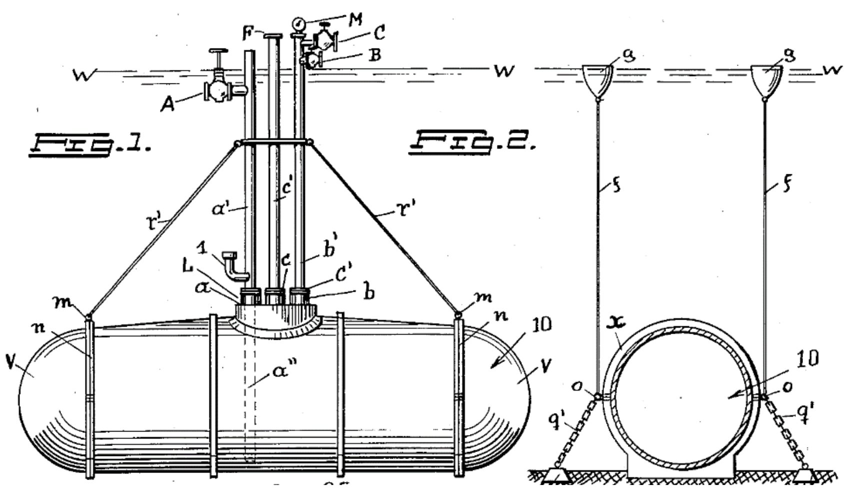
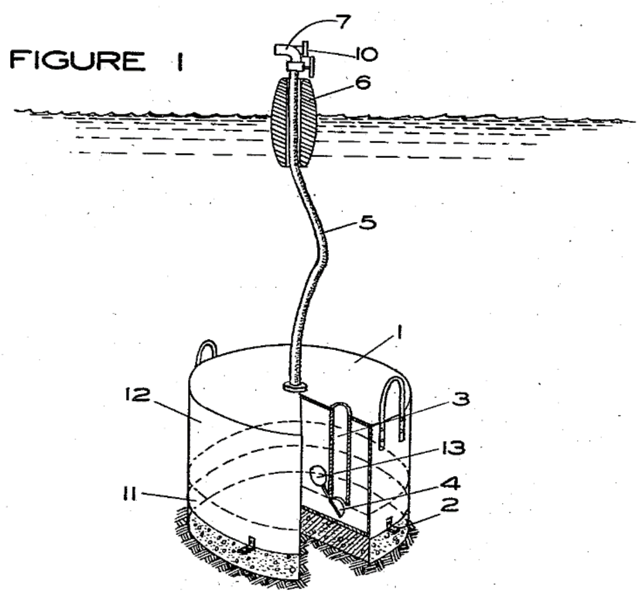


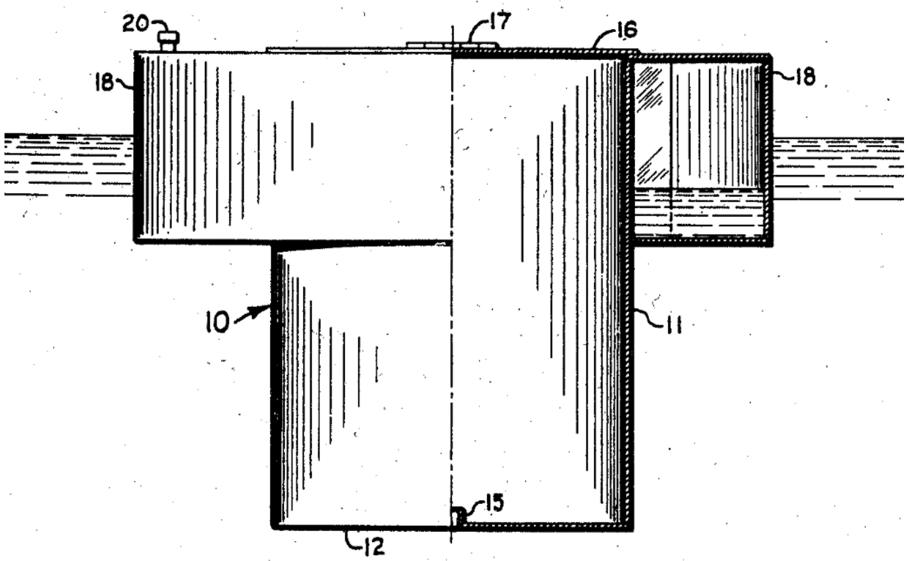
Fig. 1

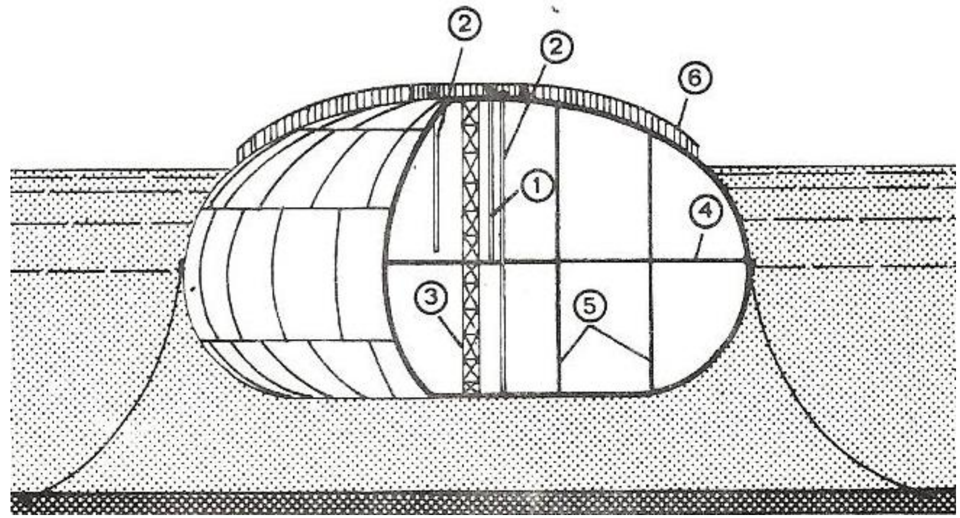


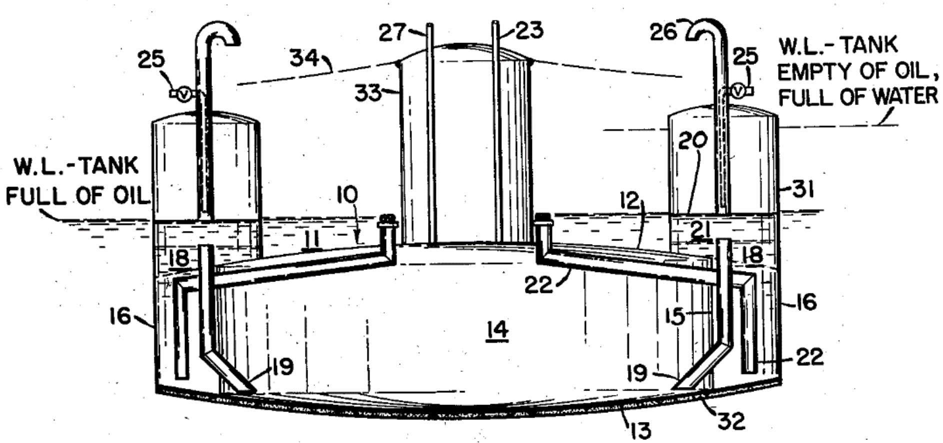


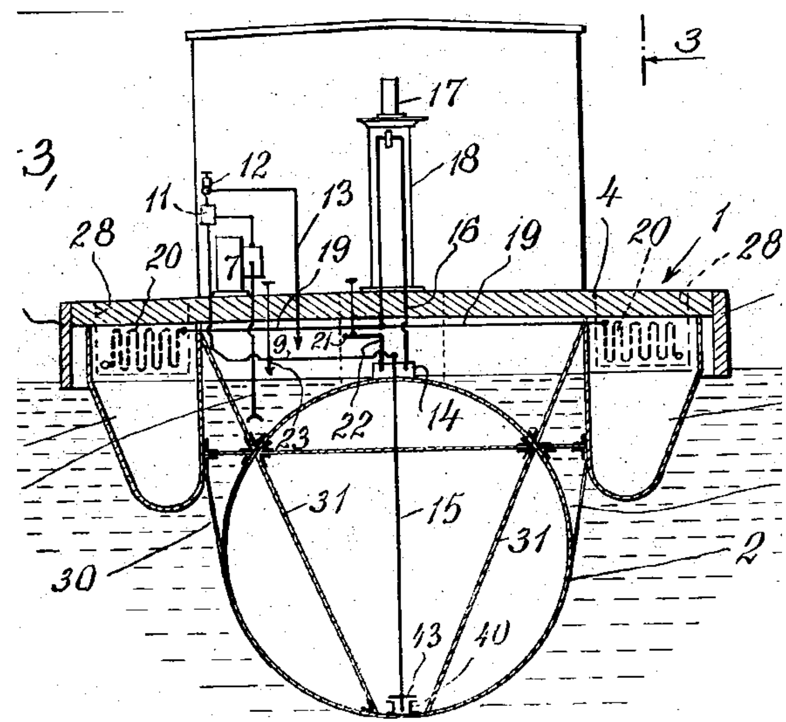


Submerged floating tanks







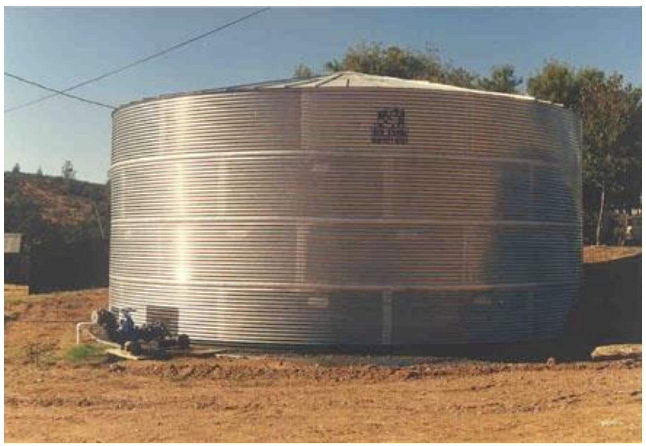


Classification of steel tanks according to constructional features

- Corrugated tanks

- Bolted or riveted tanks

- Welded tanks

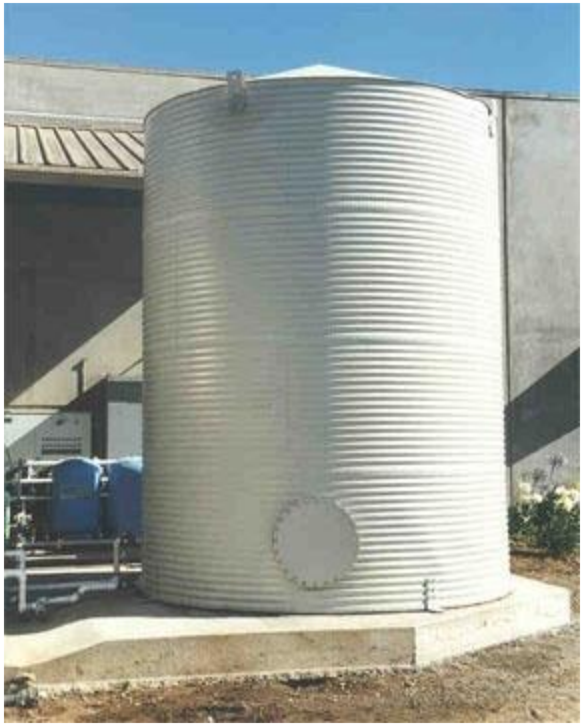


Corrugated tanks

- residential water supply
- fire protection reserve
- recycled water distribution
- irrigation water storage
- livestock water reserves
- difficult access situations
- redwood tank replacement
- poly tank replacement
- versatile storage solution

Corrugated tanks are the preferred choice to store groundwater for household uses, irrigation and fire protection. They are available in various sizes and capacities ranging from 20.000 to 2.500.000 liters.

Corrugated tanks



Corrugated tanks

bhtank.com

Bolted tanks

The primary advantages of bolted tanks are the cost savings associated with pre-engineered components, mass production methods and ultimately, the superiority of factory applied and baked-on coating systems. These features provide excellent long-term storage value and prompt turn-around times. 100 year life-cycle cost analysis for bolted tanks versus welded steel tanks in these capacity ranges have proven that "substantial savings can be realized" by using a bolted tank on new or tank replacement projects. **In fact, it is often more cost effective and quicker to replace a welded tank with a bolted tank than to re-coat it!**

The challenge of a successful bolted tank installation is in preserving the original factory coating and paying close attention to connection details.

Bolted Steel ground water storage tanks are utilized extensively in rural water districts, municipalities, and housing subdivisions. Industrial applications include process water and standby water for fire protection.

Erection time on average is typically 50% to 75% that of welded tanks.

A reduction of erection time leads to a reduction in costs.

A reason for the reduced erection time for bolted panel tanks is that for welded tanks the coatings can not be applied until the tanks are welded together. Once the tanks are welded there is a dependency on the quality of the local paint contractor assigned to the project. On the contrary, in bolted tanks all coatings are applied in the factory in a controlled environment, and this eliminates weather delays and other potential problems. If coatings are field applied, without acceptable outside environmental conditions such as the right temperature range and humidity, the coatings can not be properly applied. In addition, flash oxidation occurs in the field if coatings are not applied quickly.

Different types of bolted panel tanks

API 12B bolted tank

Archaic / outdated design originally adapted from crude oil storage.
Chime lap (bent flange) connection leaks and is difficult to seal in the field.
Light gauge material design up to 6mm plate.
Horizontal chime creates ledge for material hang-up.
Tank design has a history of continuous leak problems.
Tanks are built using the same erection process used 50 years ago. This includes elevating people in the air on scaffold brackets and using a gin pole and air tugger.

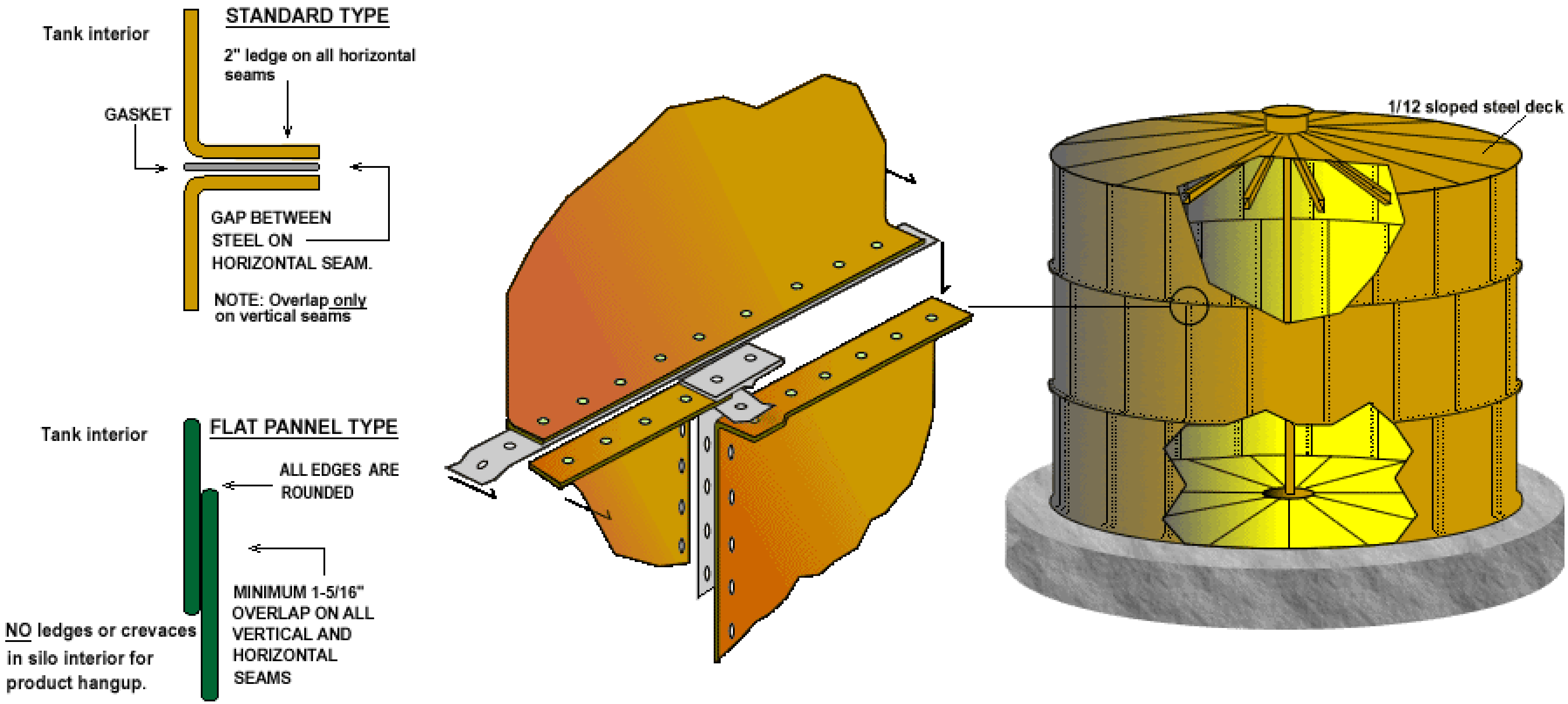
Vertical notched panel tank

Panels are vertical (ca. 2.5 x 1.5m wide) and conceived to remove the problematic (chime) flange connection on the API 12B tank.
When scaffold built, the tall & narrow panels tend to fold over in very low wind conditions. The panels have no arc rigidity, which enforces crews have to tie the scaffold boards and brackets together with “C” clamps, simulating a make-shift girder for stability. Sometimes this type of construction does not meet field safety requirements.

Smoothwall Bolted Design

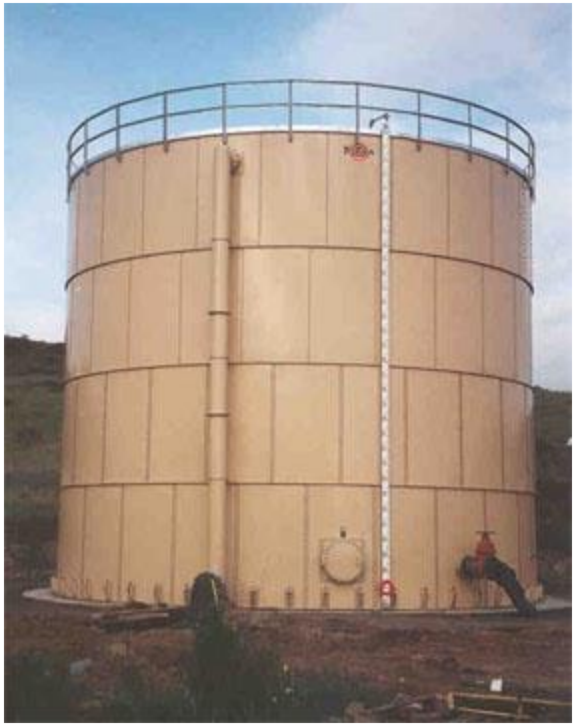
Designed for dry bulk & liquid storage applications.
Exact tolerance fabricated panels, which do not leak or develop future leaks
Heavy design up to 12mm plate.
No interior or exterior ledges for product hang-up.
Lap-joint connection allows pressure design use.
Storage tank design has a history of no leaks & the highest customer satisfaction level.
Silos are jacked from ground, which means safe tank construction.

API 12B flanged bolted tank



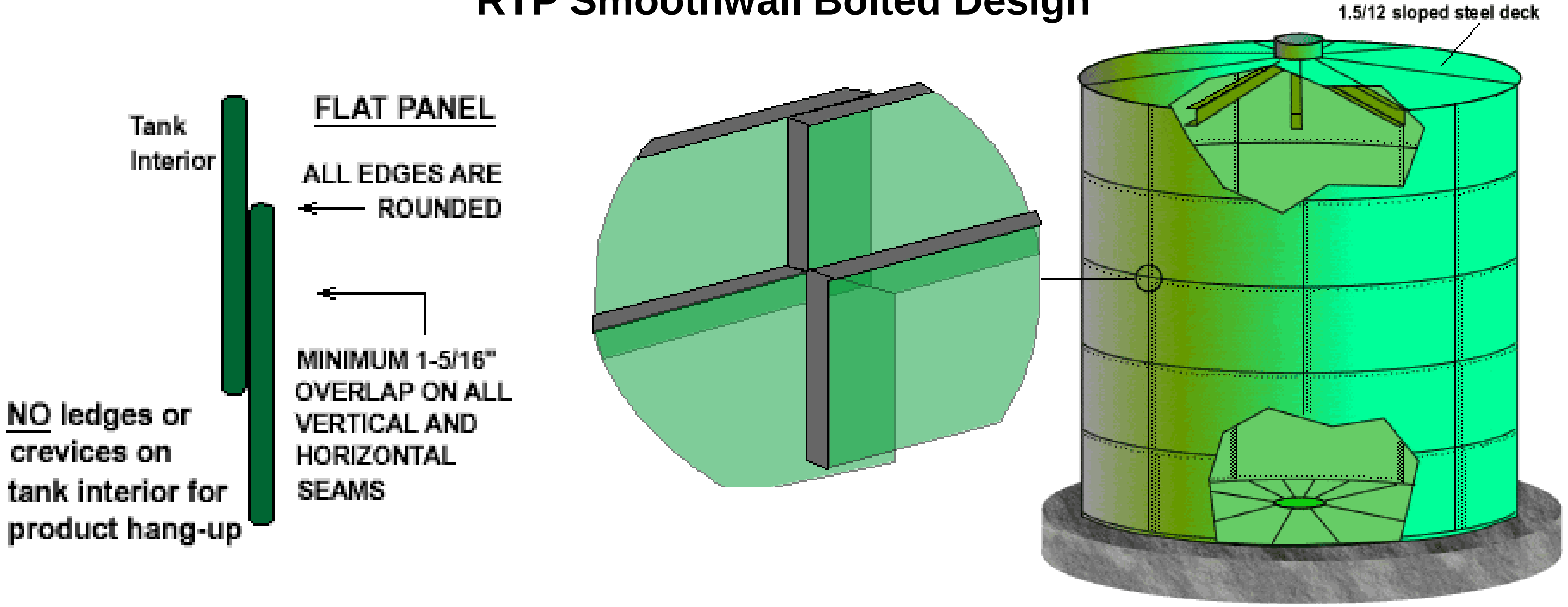
Panels are vertical (ca. 2.5 x 1.5m wide) and utilize an exterior horizontal flange connection called a chime. The API 12B flanged panel tank is a quite outdated bolted tank design that originated in the oil patch territories in the early 1900's. The big problem with this design is the exterior horizontal flange (chime) connection, which has a history of continuous leaks. Additionally, the exterior flange connection creates a ledge that holds material, moisture and debris, which removes the paint quickly. Typically, this product can be seen in the field with rusty horizontal connections from top to bottom of tank.

Bolted tanks (Vertical notched panel)



bhtank.com

RTP Smoothwall Bolted Design

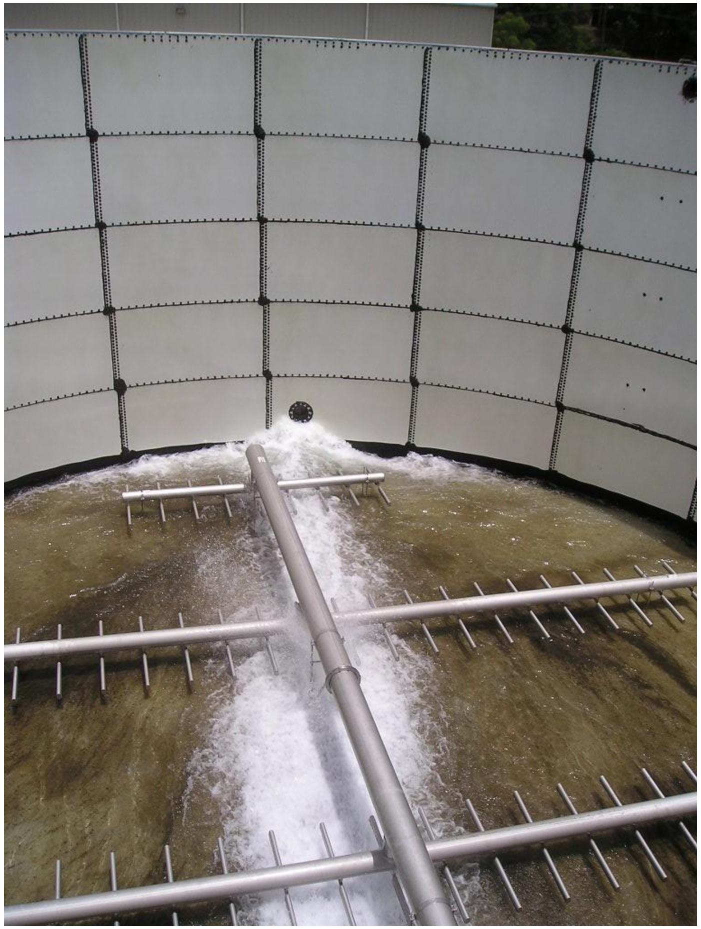


Because of design, flat panel tanks seal better. Flat Panel Tanks have only 2 exposed external edges vs. the 3 of the API 12B type bolted tank. The Flat Panel Tank has steel to steel overlap on both vertical and horizontal seams. There are no internal edges or crevices for product hangup, nor any external ledges for standing water. All parts of a flat panel tank are standardized which leads to consistency from one tank to another. Because of standardized parts on flat panel tanks, erection time can more easily be determined. With the time savings of eliminating skilled welders and eliminating field painting, the end user has realized cost savings on labor and materials because of lighter gauges on flat panel tanks. Because of standardized parts on a flat panel tank, the pricing of a flat panel tank is significantly more accurate. If tanks ever have to be expanded or relocated, it is a relatively simple proposition. Tanks can be dismantled, moved to another location and re-erected again easily and less expensively because all parts are standardized and interchangeable.

Bolted tanks (RTP Smoothwall Bolted Design)

bhtank.com

Bolted tanks (RTP Smoothwall Bolted Design)



Coca Cola Industrial Wastewater Treatment Plant
Florida Aquastore Utility & Construction, Inc.
(® glass-fused-to-steel tanks)

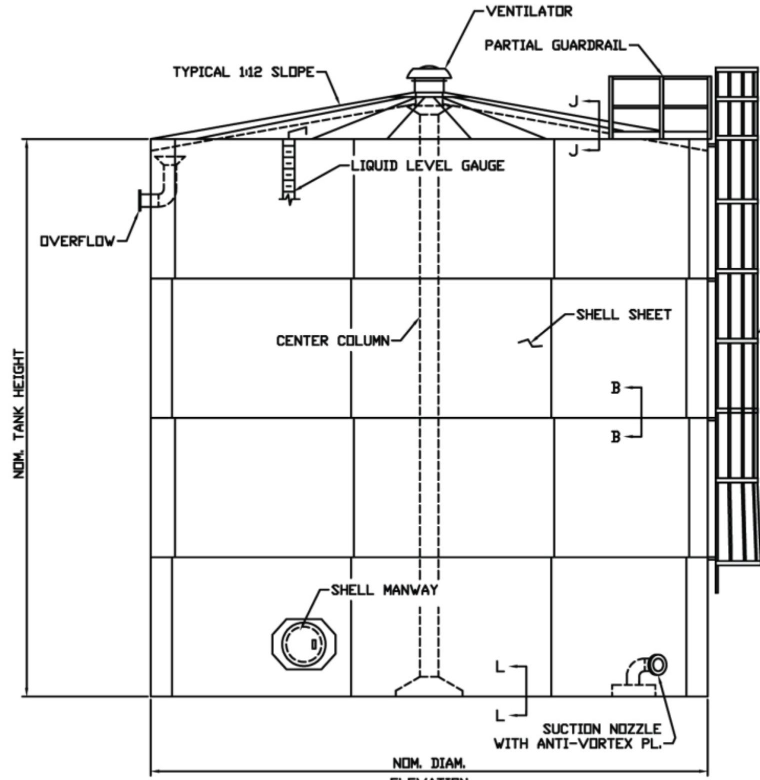
Potable Water
Arlington, Oregon
Aquastore NW

Bolted tanks

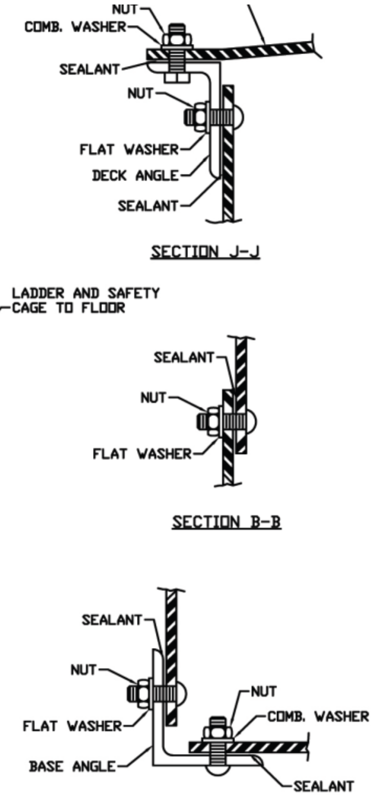
Potable Water
ETNA Corporate Park, OH
Gateway Tank, Inc.

Potable Water
Machias Water Company, Maine NEW ENGLAND TANK SYSTEMS, Inc

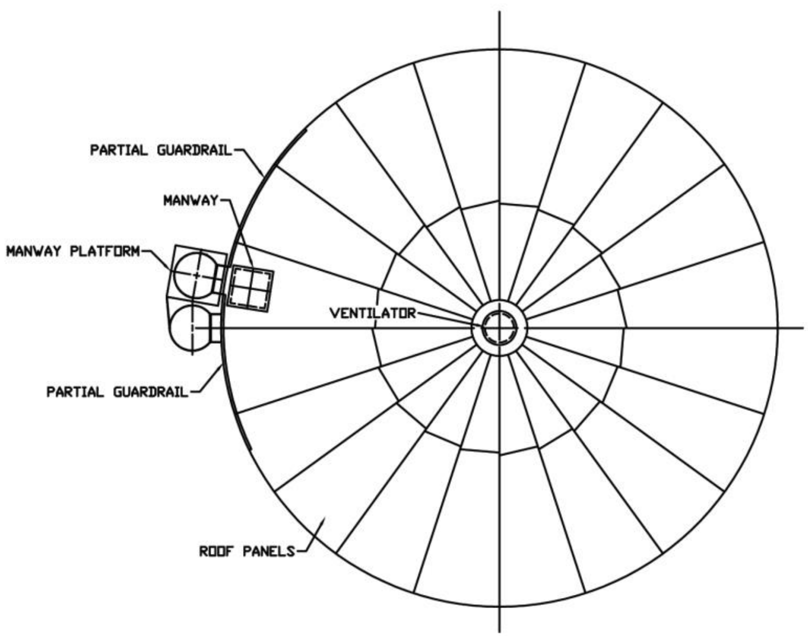
Fixed roof fire bolted "standpipe" tanks



ELEVATION

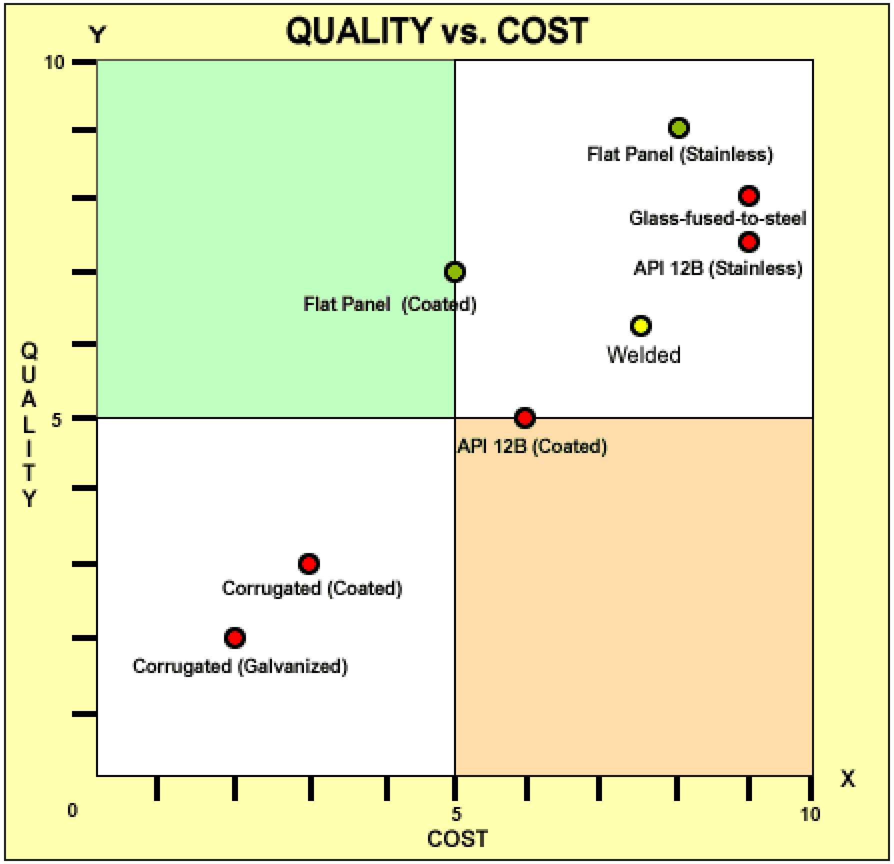


LAP-JOINTED BOLTED STEEL TANK.



PLAN

Liquidtanks.com



NOTE: THE VALUES DEFINING QUALITY ARE DESIGN, COATINGS OR FINISH, AND SERVICE . COSTS AND QUALITY ARE RELATIVE.

= International Tank

Welded tanks

Welded tanks are designed for rugged applications and are often preferred to polyethylene tanks due to their structural superiority, smooth monolithic design and inherent resistance to algae and bacterial growth. Welded steel tanks are more resistant to fire and vandalism, and are easier to clean and maintain than any other type of tank. Steel tanks require less maintenance than poly tanks and they have a proven track record of dependability.
Welded tanks are available in practically any size or configuration. The most economical configuration is a vertical, flat-bottom, conical cover cylinder, but horizontal cylinders and rectangular configurations are also available.

Welding Processes (MIG, TIG, MAG)

SMAW (Shielded Metal Arc Welding)
GMAW (Gas Metal Arc Welding)
FCAW (Flux Cored Arc Welding)
GTAW (Gas Tungsten Arc Welding)
SAW (Submerged Arc Welding)

Welded tanks

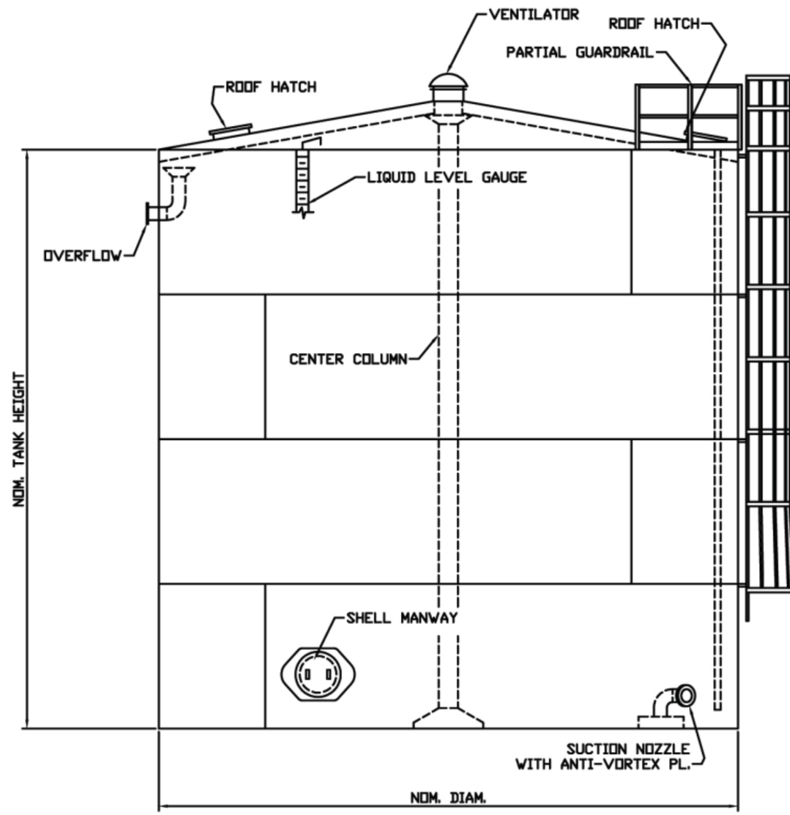
bhtank.com

Welded tanks

Tankconnection.com

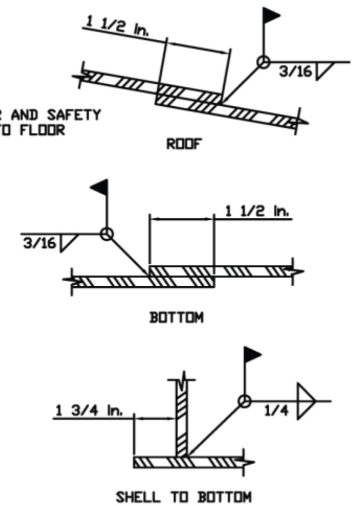
Welded tanks

Fixed roof fire welded "standpipe" tanks

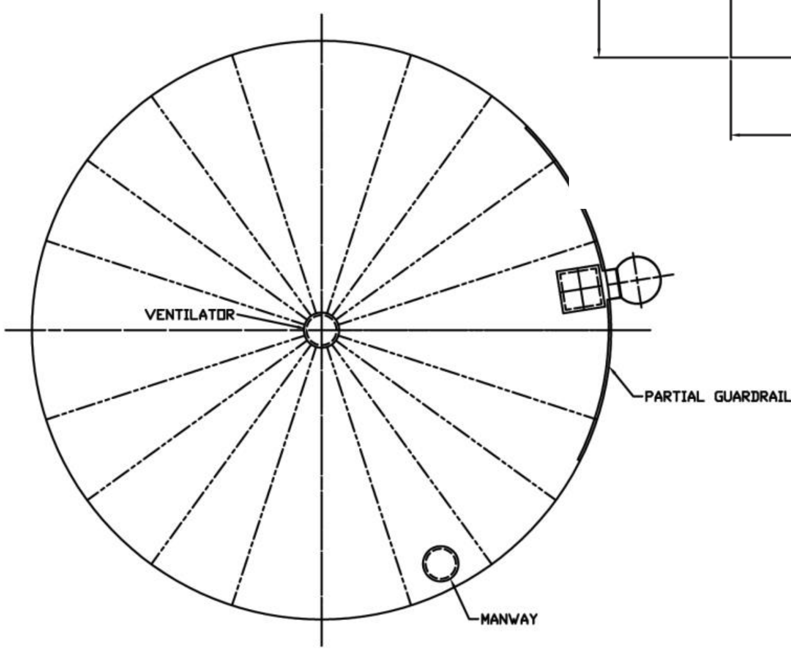


ELEVATION

WELDED-STEEL TANK.



WELDING DETAILS



PLAN

Liquidtanks.com

STAINLESS STEEL TANKS FOR FOODS
WINE – EN1993-1-4

STAINLESS STEEL TANKS FOR FOODS
CHEESE

STAINLESS STEEL TANKS FOR FOODS - CHEESE

STAINLESS STEEL TANKS FOR FOODS - DRINKS

STAINLESS STEEL TANKS FOR FOODS - DRINKS

STAINLESS STEEL TANKS FOR FOODS CHEMISTRY

STAINLESS STEEL TANKS FOR FOODS CHEMISTRY

STAINLESS STEEL TANKS FOR COSMETICS

STAINLESS STEEL TANKS FOR COSMETICS

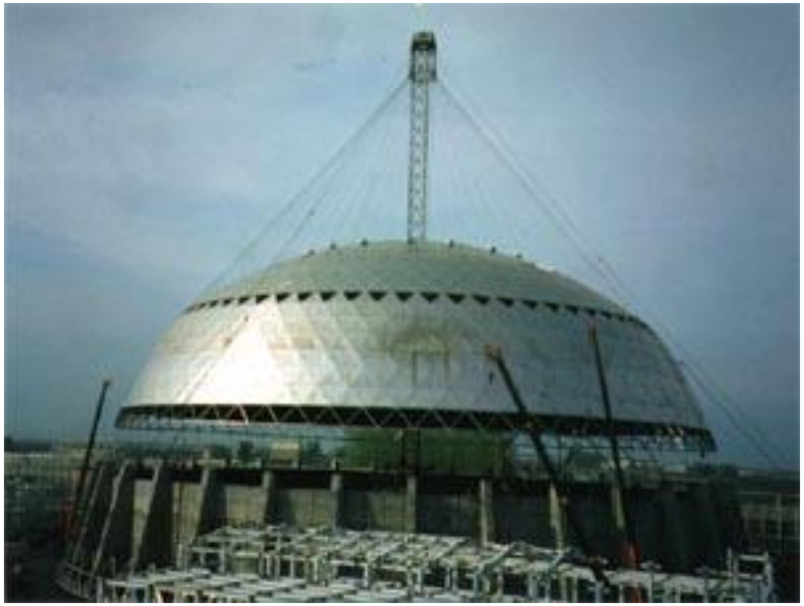
Aluminium dome roofs for storage tanks.

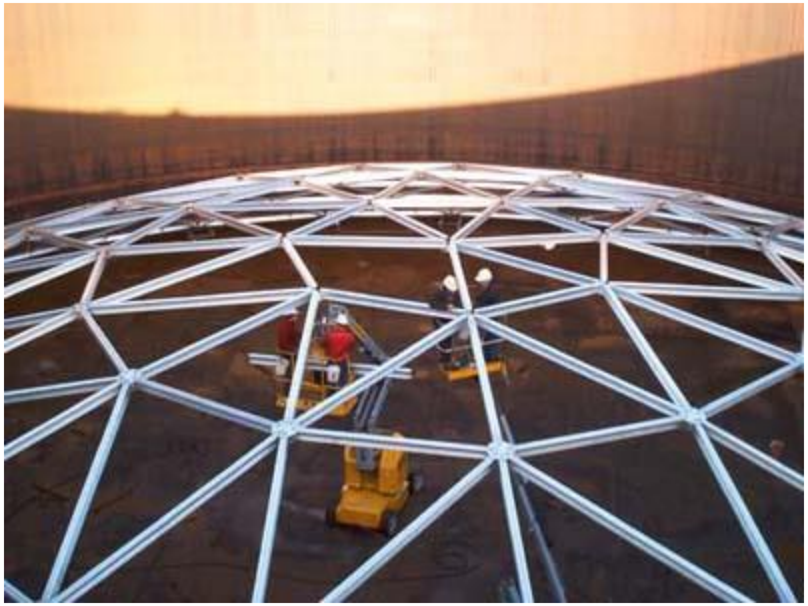
Aluminium dome roofs have developed into a frequently used roof system for covering storage tanks. They are used for covering external floating roofs as well as in replacing heavily corroded steel roofs. Aluminium dome roofs are light weight, esthetical all aluminium structures. They have significant benefits for tank owners. The API has also acknowledged the importance and relevance of this development by introducing a standard for aluminium dome roof structures (API 650 Appendix G). Any tank farm will benefit from these aluminium dome roofs by reducing vapour emissions, rainwater ingress and by eliminating future maintenance.

Aluminium dome Features:

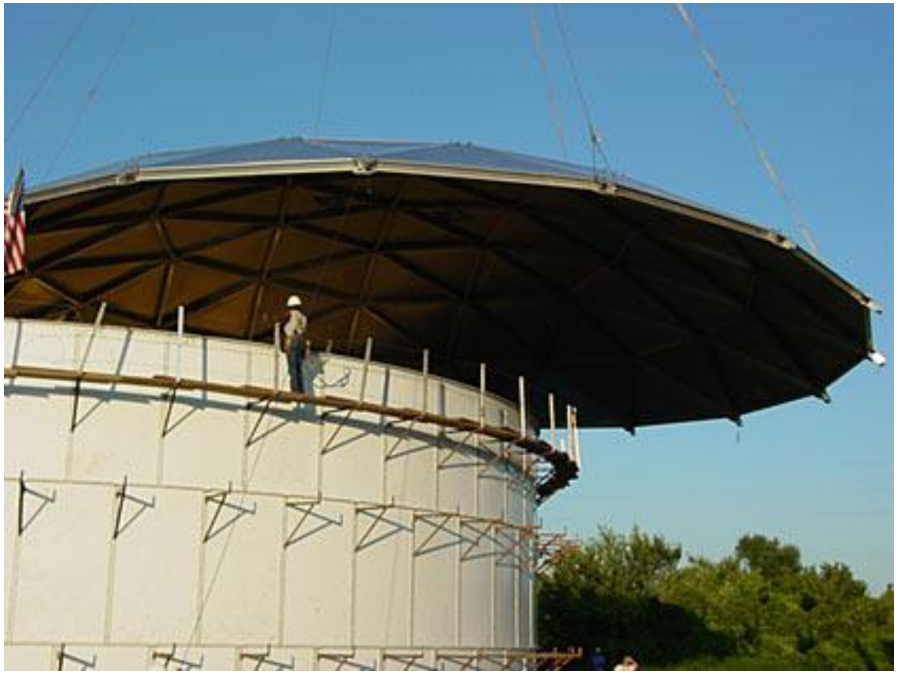
- maintenance free, no need for blasting and painting.
- excellent water tightness, resulting in eliminating rain water ingress to the stored product.
- reduces emissions by shielding the floating roof from heat and direct sun light.
- compatible with all stored products, including 100% aromatics.
- light weight and free-span structure manufactured from aluminium and stainless steel.
- can be fitted on tanks in service with a minimum of modifications.
- expected service life in excess of 40 years.
- custom designed for each specific tank.
- easy installation, full installation manuals and project support available.
- complies fully with API 650 standard.
- successfully used globally by many major oil and tank storage companies.
- realistic roof option for new storage tanks.
- can be designed for high wind- and snow loads.

Aluminium dome roofs

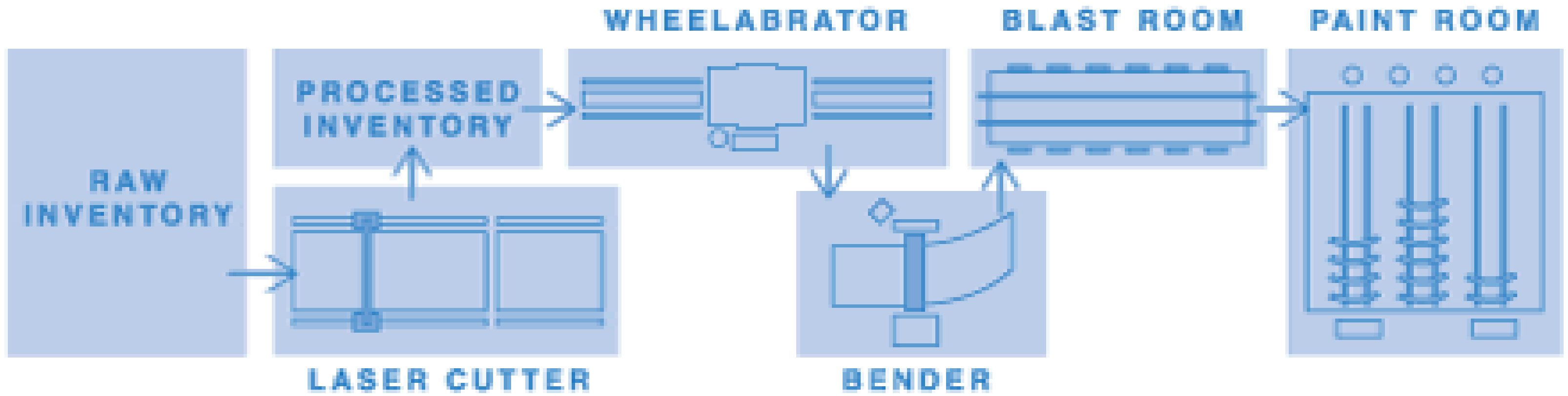




Aluminium dome roofs



Fabrication Sequence



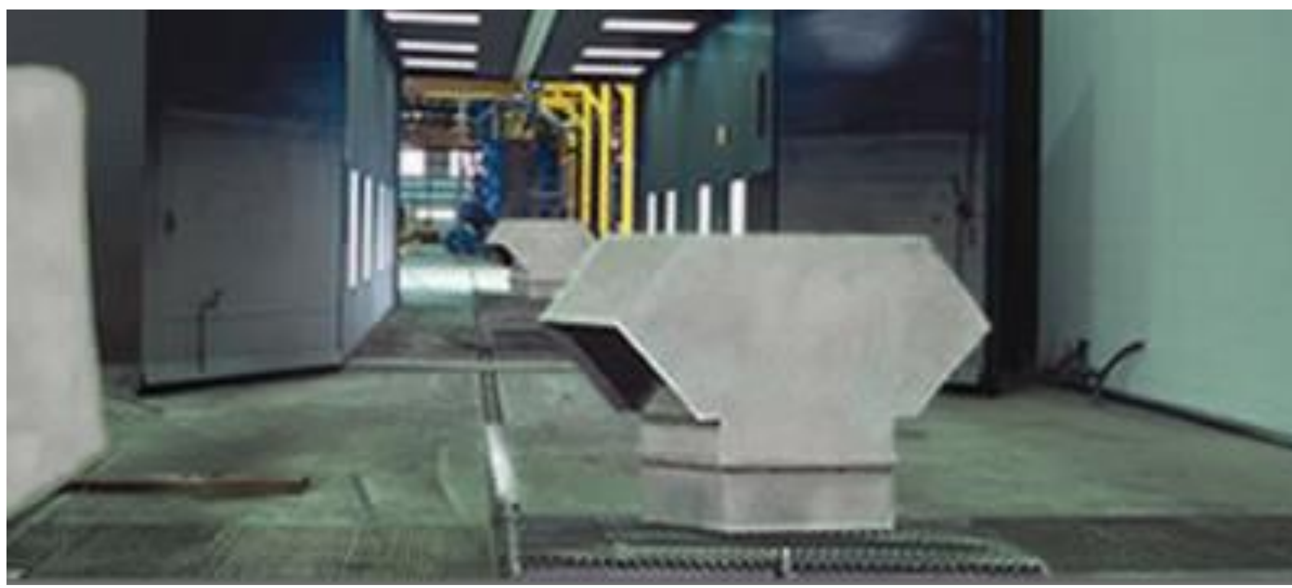
Wheelabrator

Bender

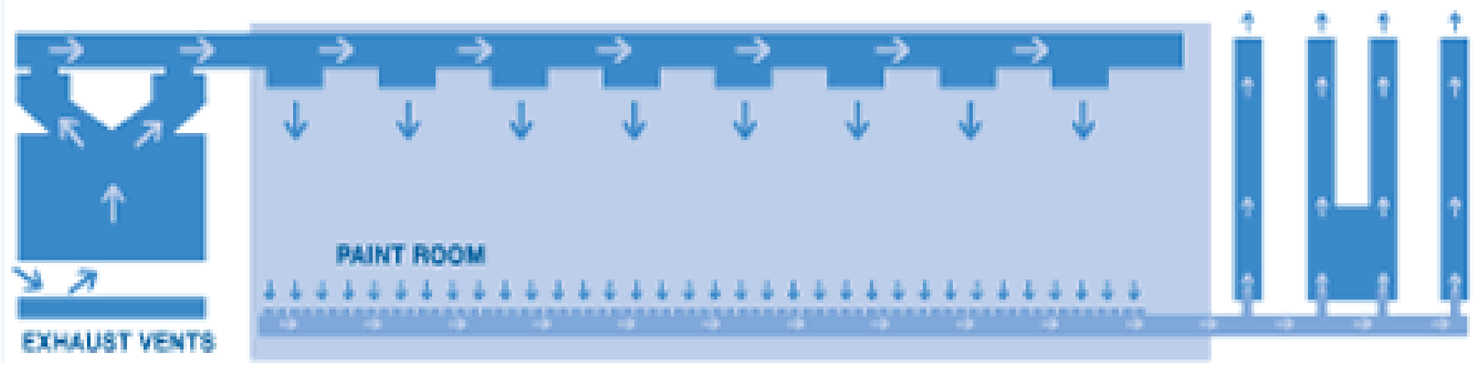
The wheelabrator performs surface preparation of steel plates prior to coating. The process achieves high cleanliness standards. Coatings manufacturers require these standards be achieved for surface profile and cleanliness prior to application of protective coatings.
The machine recycles metal blast abrasive in lieu of single-time usage and disposal. The steel abrasive minimizes surface contamination occurring with other forms of blast material, including sand. The closed chamber and automatic recycling reduces potential employee injury and exposure to blast media. All processed parts receive a consistent surface profile and cleanliness.

Blast room

The sealed blast room allows environmentally friendly surface preparations for fabricated sections too large for the wheelabrator. Preferably, the blast room is a full-recovery shot blast machine that requires no disposal of blast media and is equipped with dust collectors to reduce worker exposure to dust.



Temperature Controlled Paint Room



Wall coatings

Glass coating *has significantly lower coating maintenance costs compared to welded or painted bolted steel tanks. Glass formulation is inert and chemically bonds to the steel once the panels are fired at 850 °C. This gives the coating a great adherence (> 10 times the bond strength of field applied or baked on paint). The glass-fused-to-steel coating does not need to be re-applied vs. the periodic re-painting of other tanks. Also, it provides a water-resistant interior and a graffiti-resistant exterior.*

Epoxy coatings *are an excellent choice for hot and pure water applications as well other specialized storage needs. They have an interior liquid immersion coating system that combines good chemical resistance and physical properties and meets NSF Standard 61 requirements for potable water contact surfaces.*

Galvanized *tanks are hot dipped in compliance with relevant standards. Steel parts are pickled then dipped in molten zinc so both the interior and exterior is coated. These tanks are ideal in fire water, process water and wastewater applications.*

Stainless steel and aluminum alloy *tanks are offered in a variety of different grades. These tanks withstand the wider range of temperatures and PH factors encountered in industrial applications. Stainless steel and aluminum alloys tanks are virtually maintenance free and ideal for corrosive environments.*

Cathodic protection

Mounting procedures

Mounting procedures

Mounting procedures

Mounting procedures

Tankconnection.com


2007.06.06

Mounting procedures

Mounting procedures (bolted panel)

Mounting procedures (bolted panel)





9. 10. 2002


9. 10. 2002


9. 11. 2002


9. 11. 2002

Statewide Aquastore/New England Tank, Inc.

Statewide Aquastore/New England Tank, Inc.

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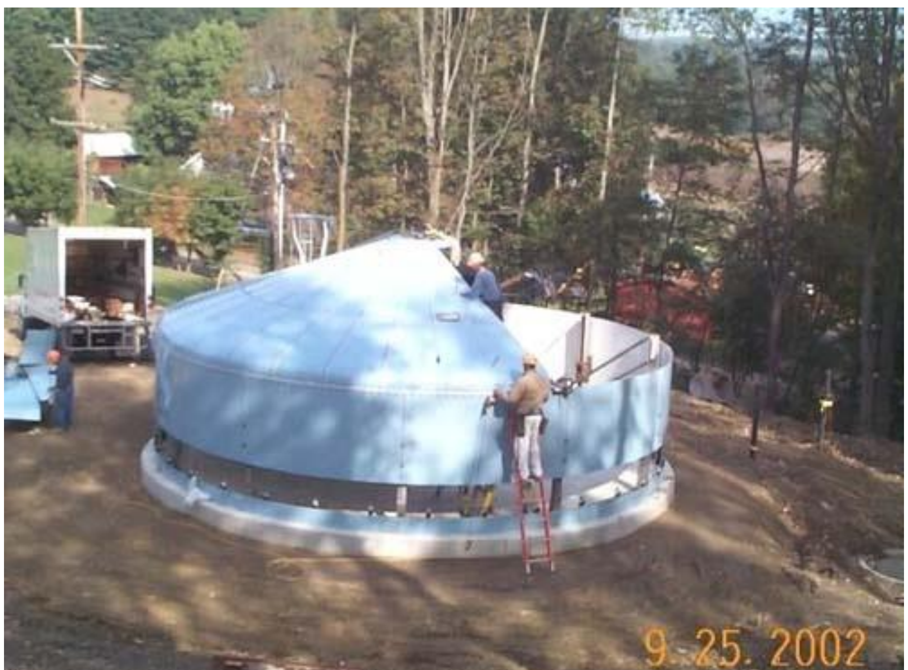
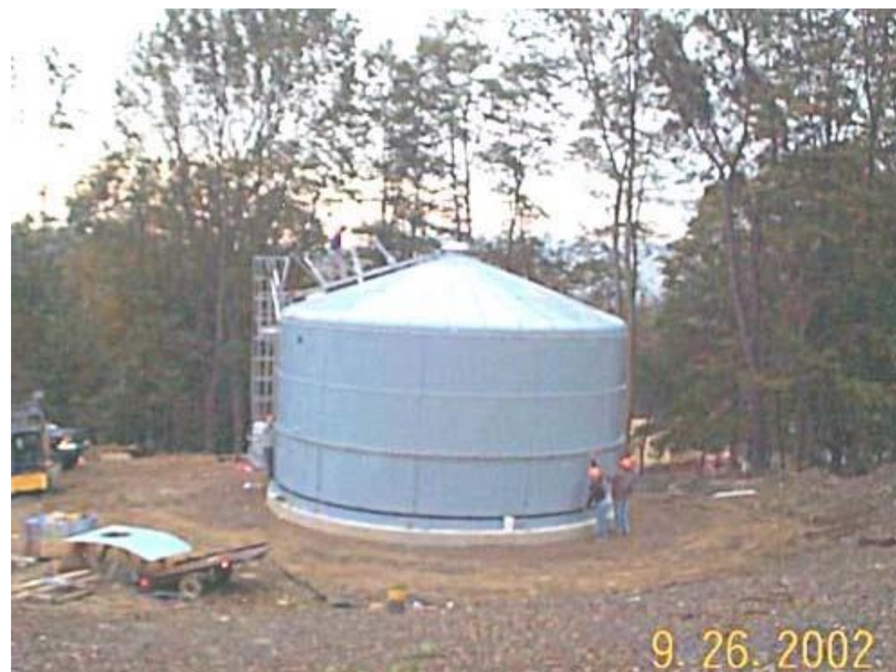


Statewide Aquastore/New England Tank, Inc.



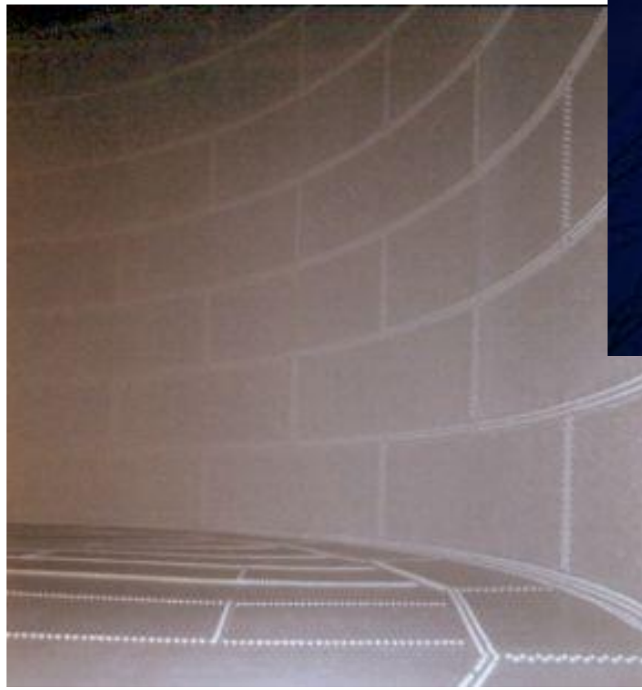
Statewide Aquastore/New England Tank, Inc.

Statewide Aquastore/New England Tank, Inc.

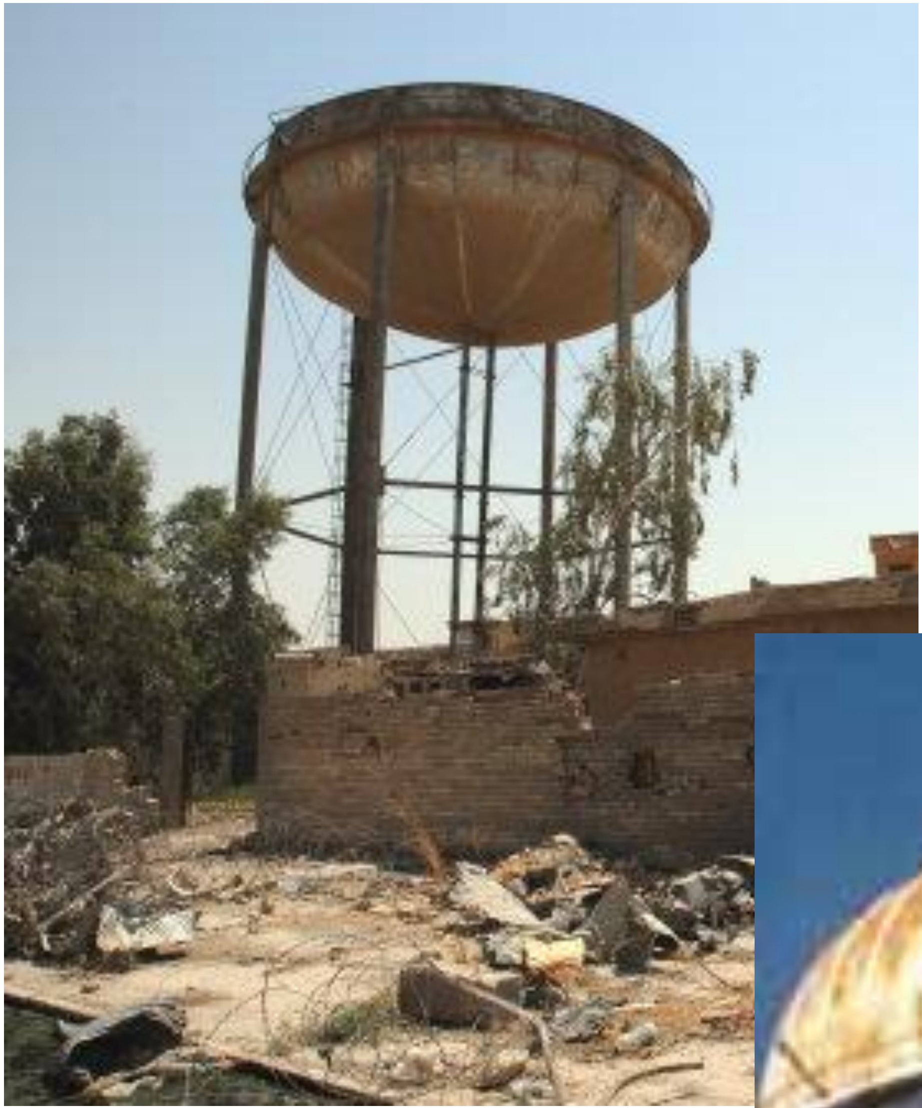
Statewide Aquastore/New England Tank, Inc.

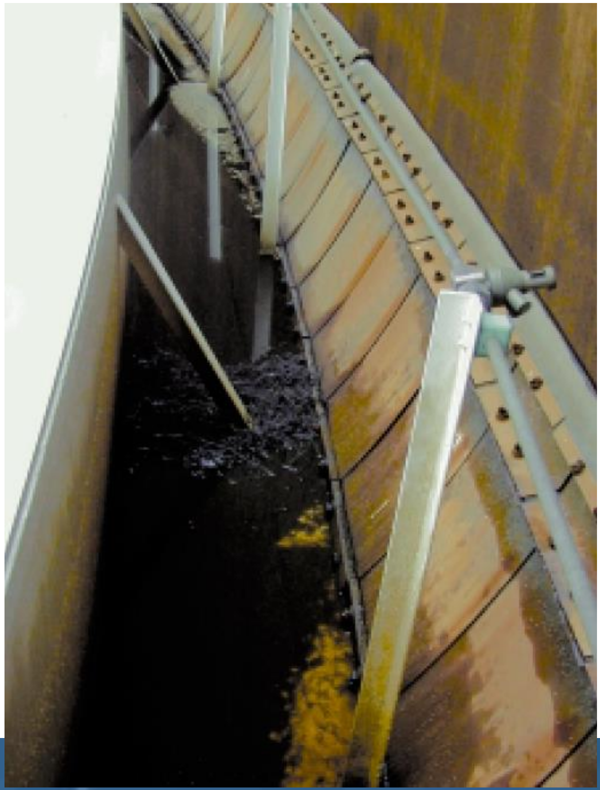
RTP smoothwall bolted tank mounting

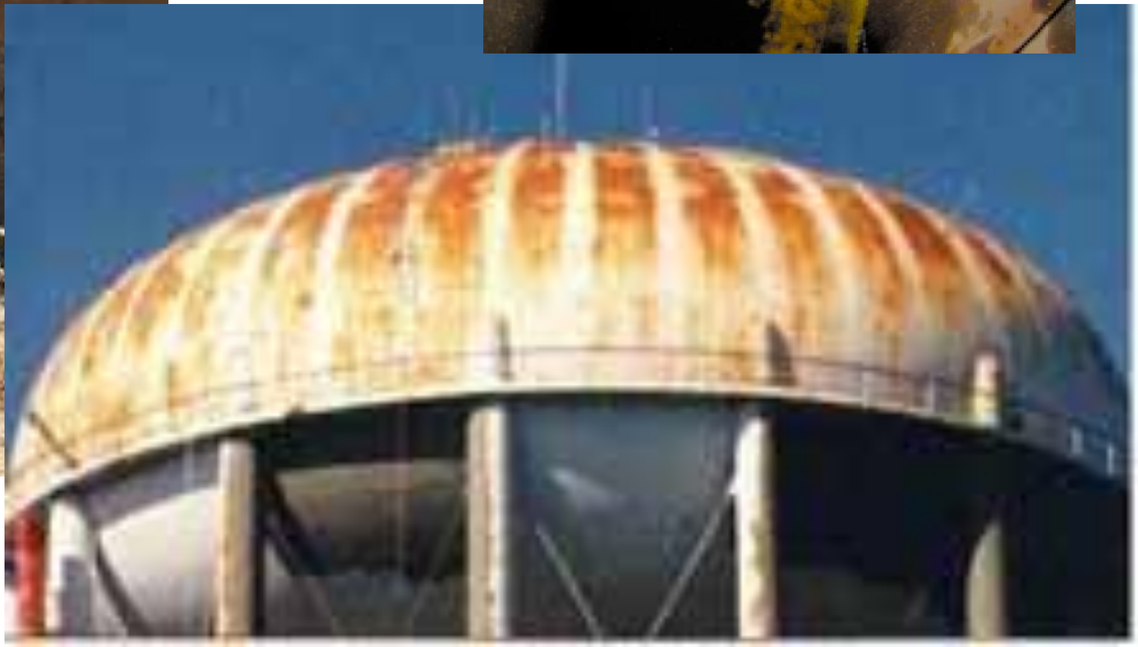
Thomas Hill Standpipe
Built 1897 – Maine, USA



Tank maintenance and refurbishment







Storage Tank Inspection

To extend the life of tanks and prevent service failures, regular professional tank inspections (dry or scuba) are essential to determine the tank's exact maintenance requirements. Inspections can detect inadequate conditions, non-compliance with current codes and possible latent defects.

To suit operational needs, inspections can be performed while the tanks are either in-service or out-of-service. After the inspections are completed, a written inspection report is to be furnished which includes a detailed component evaluation, photographs, recommendations for compliance and cost estimates.

Storage Tank Maintenance

The extent of maintenance resulting from the inspections could include:

- Shell, roof and bottom repairs or replacements
- Roof structural repairs or replacements
- Nozzle and manway repairs, relocations or replacements
- Repair of defective welds
- Bottom annular rings
- Double bottoms
- Secondary containments
- Leak detection systems
- Cathodic protection
- Cut-down, move and re-erect
- Foundation repairs and modifications
- Special equipment
- Cleaning and painting
- Testing

Storage Tank Repairing

- Secondary Containment Tank Bottoms & Systems
- Tank Bottom Replacements
- Floating Roof Drain Systems
- Cone Roof & Structure Repair & Replacements
- Sunken or Collapsed Floating Roof Repairs
- In-Service Tank Repairs
- Stairways, Handrails, & Platforms
- Out-of Round or Buckled Tank Shell Repairs
- Primary & Secondary Seals for Floating Roof Tanks
- Floating Roof Tank Conversions
- Fire Fighting Foam Systems
- Geodesic Dome Installations
- Internal & External Floating Roof Installations & Repairs
- Shell Nozzles, Manways & Appurtenances
- Tank Seal Inspection & Repairs
- Rolling Ladders and Stair Treads
- Tank Relocation
- Tank Jacking & Leveling
- Tank Foundations
- Cathodic Protection & Leak Detection

Tank appurtenances ("ancillaries")

- Handrails - Pipe and Angle
- Platforms
- Staircases - Spiral and Radial
- Vertical cage ladders
- Thickened inserts
- Rafters
- Roof sumps
- Carbon steel floating roofs and pontoon sections
- Rolling ladders
- Retrofit stair treads for rolling ladders
- Fire fighting foam chambers
- Fire fighting foam suppression systems
- Bleeder vents
- Gauge pole and gauge pole ladders
- Negotiator seals for gauge poles and columns
- Diffusers
- Leg sleeves
- Sample funnels
- Float wells
- Wind girders
- Floating suction lines
- Fabrication of underground pipe spools
- Suction troughs
- Weirs
- Gauge hatches
- Emergency drains
- Nozzles
- Goose neck vents
- Overfill vents
- Vent hoods
- Shafts, flanges
- Pipe caps and dished heads
- Galvanized stairs and platforms
- Application of protective coatings

TANK REFURBISHMENT

SURFACE PREPARATION:
Sandblasting
Power Tool Cleaning
Hand Tool Cleaning
Pressure Washing

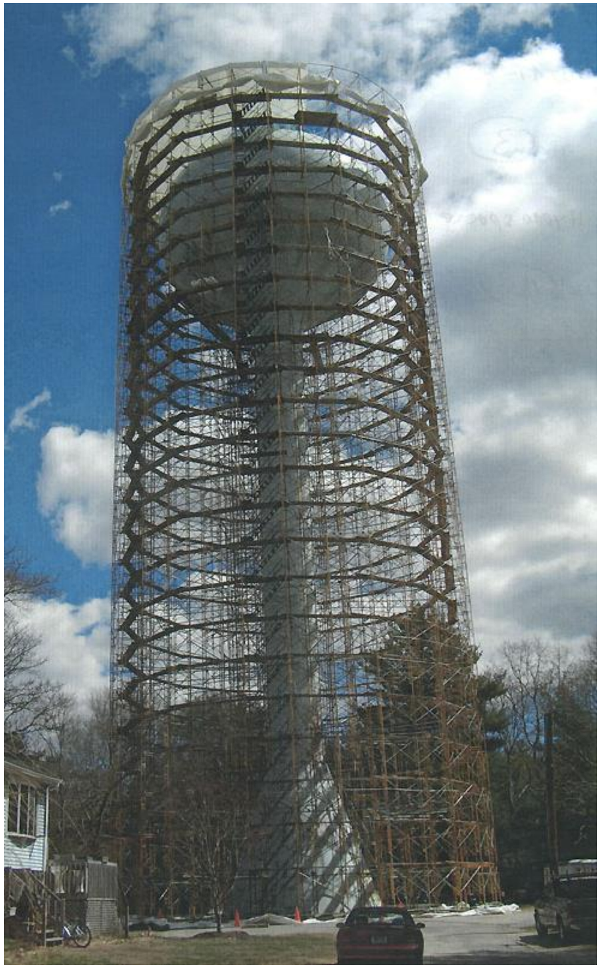
PAINTING:
Acrylics
Polyurethanes
Alkyds
Silicone Alkyds
Epoxies
Waxes

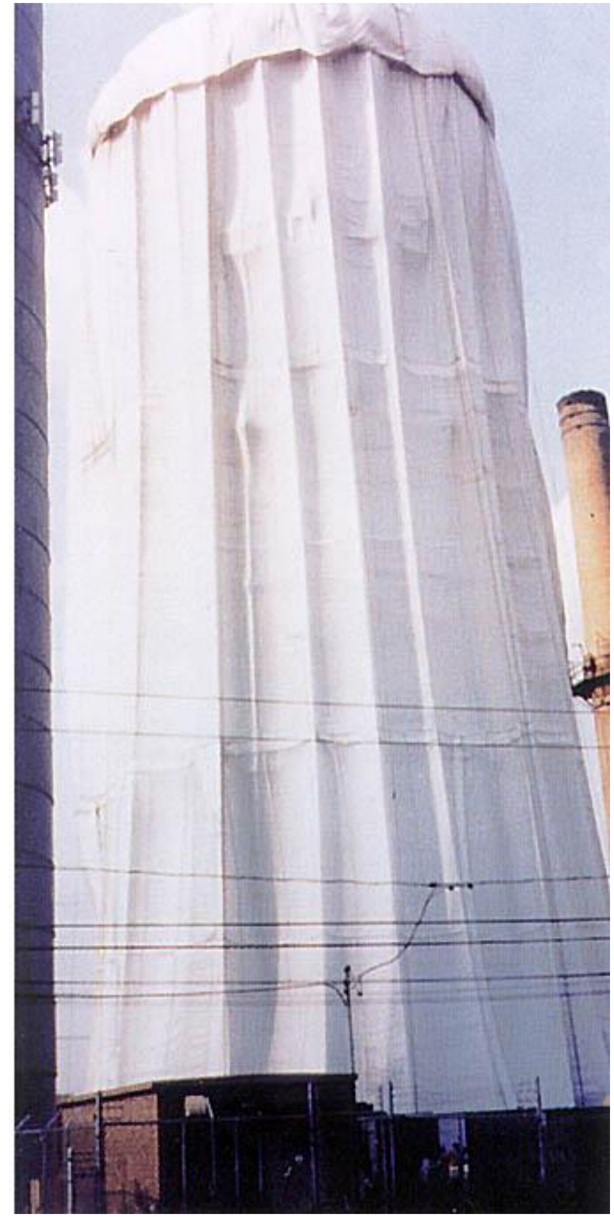
TANK REPAIRS:

Seam Repair
Rivet Repair
Pit Repair
Steel Replacement
Roofs
Riser Pipes
Frost Casings
Heating Systems
Overflow Pipes
Safety Climbing Devices

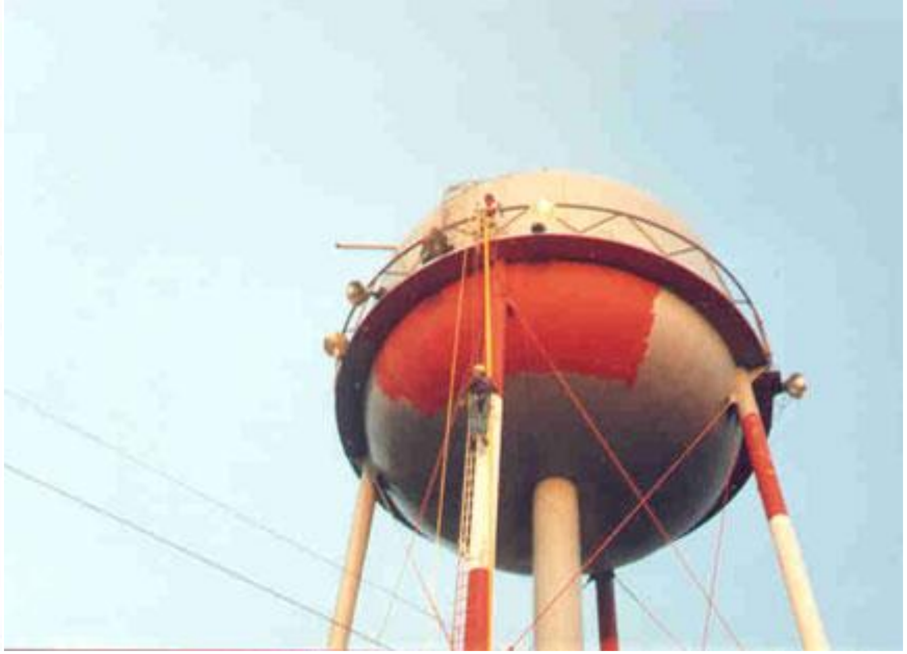
Tank maintenance and refurbishment

Tank maintenance and refurbishment



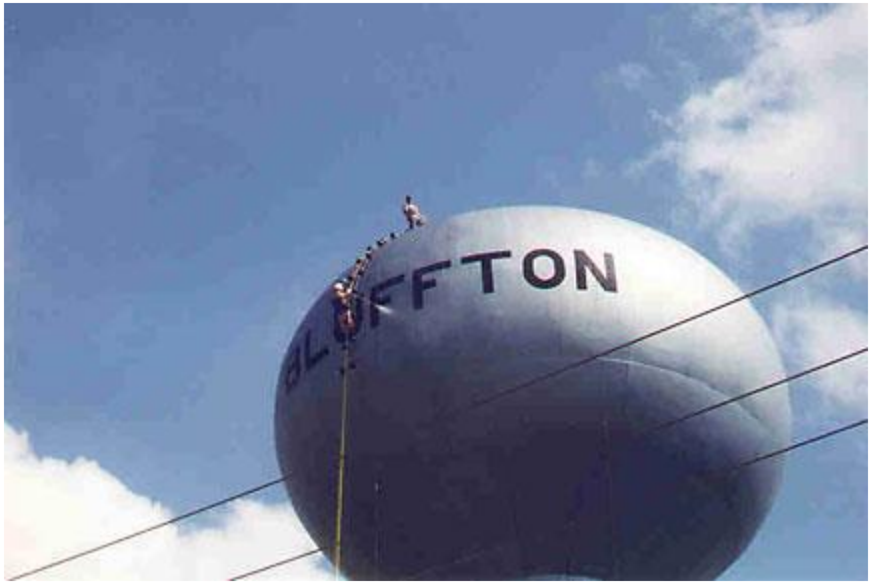


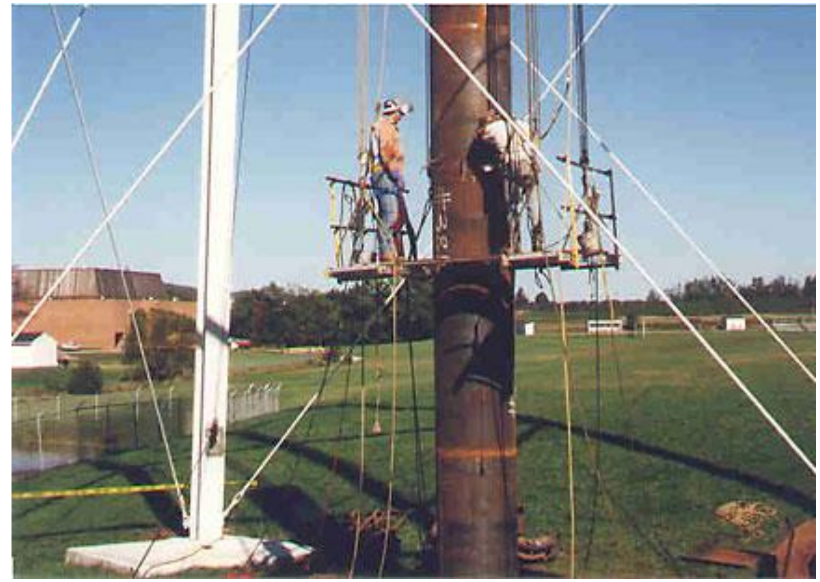
Tank maintenance and refurbishment



The Kessler Tank Co., Inc.

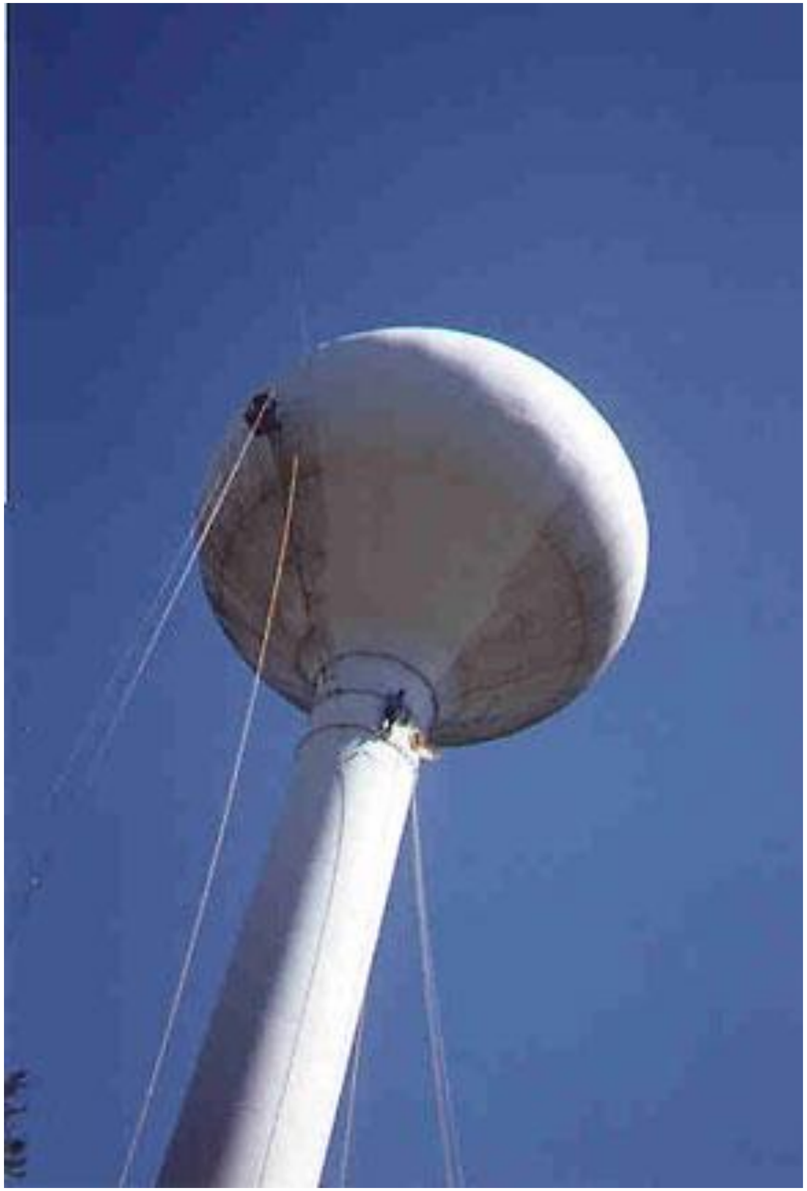
Tank maintenance and refurbishment





The Kessler Tank Co., Inc.

Tank maintenance and refurbishment



The Kessler Tank Co., Inc.

Tank maintenance and refurbishment

The Kessler Tank Co., Inc.

Tank collapse

Failures due to Design Errors

Bending of circular walls caused by eccentric load

Large and/or non-symmetric pressures caused by inserts

Special considerations with bolted tanks and r.c. construction

Special considerations concerning temperature and moisture

Failures due to Construction Errors

Incorrect material

Uneven foundation settlement

Design changes during construction

Failures Resulting from Tank Usage

Improper sequence of tank emptying

Lack of ventilation during emptying

Buckling of unsupported walls

Failures Due to Improper Maintenance

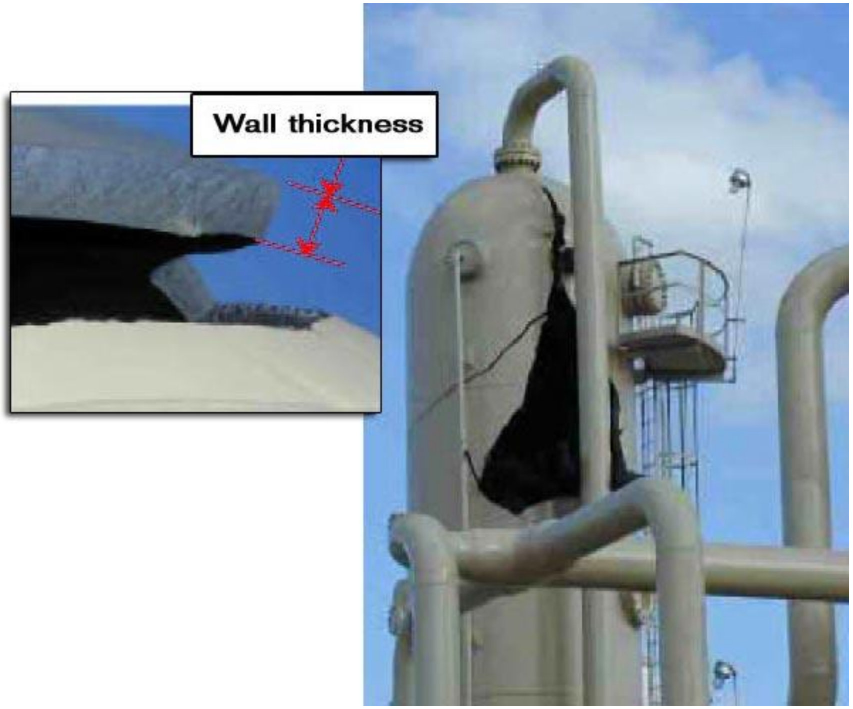
Corrosion and erosion

Lack of routine inspection

Improper reaction to signs of distress

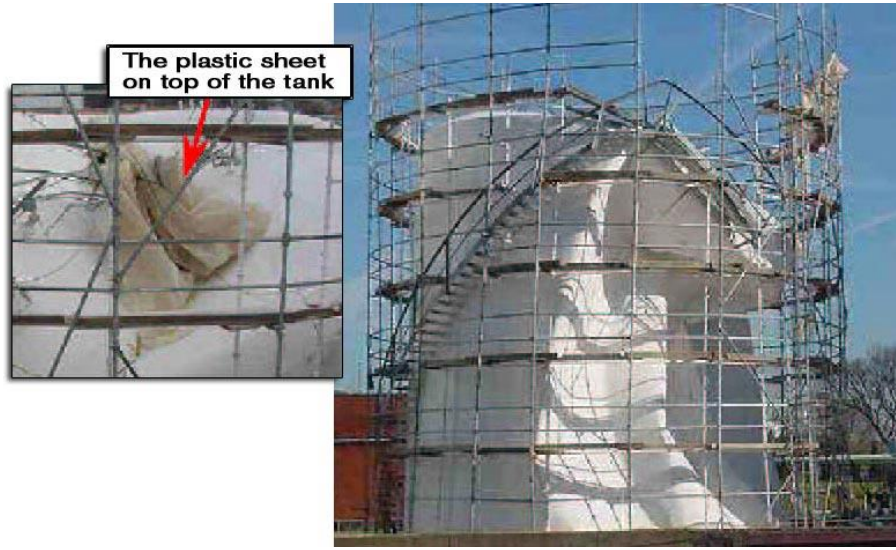
Tank collapse due to wind

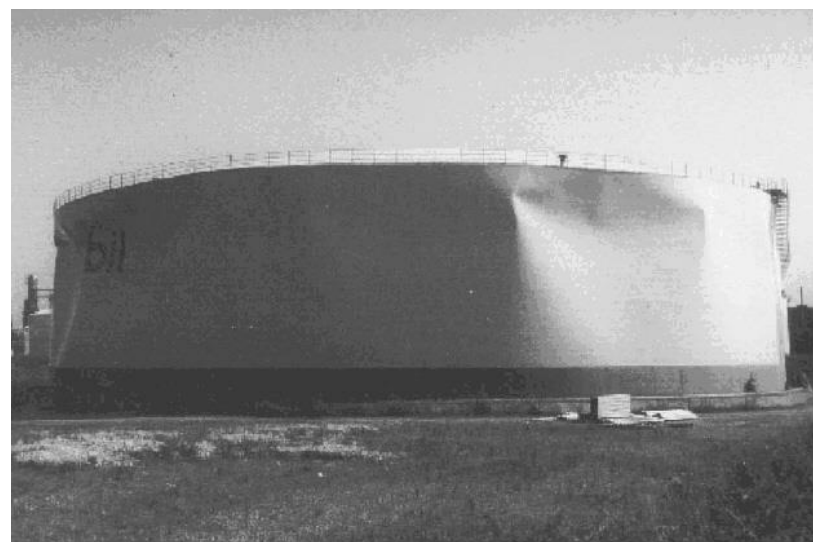
Tank collapse due to overpressure



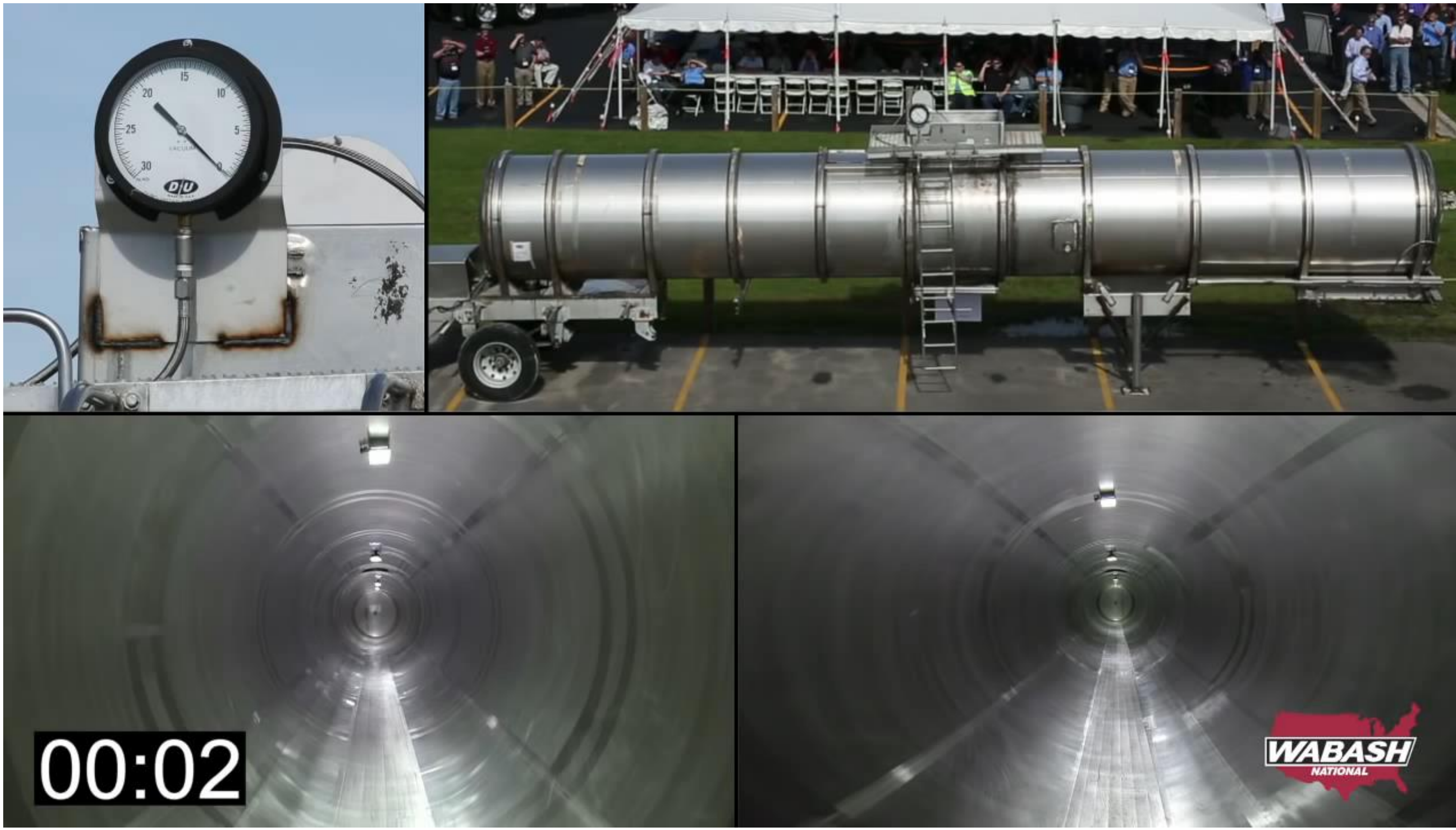
Tank collapse due to vacuum

Tank collapse due to vacuum






Eva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WABASH
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