

CONTEMPORARY TRENDS IN THE STEEL TANK CONSTRUCTION

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1. Introduction

If we accept the year 1878 as a beginning of the steel tank construction, when Shuhov designed and constructed the first cylindrical steel tank in Russia [1], this kind of vessels are 130 years old. Five years later Shuhov invented and published a method for calculating of AST [8] and he revealed its rational constructive shape which is convenient for prefabrication and erection, with minimal metal consumption.

Since then the methods for calculations, constructions and erection have been improved without interruption. Accumulation of the knowledge and skills during the tank exploitation, damage and repair facilitates development of design methods. They impose decisions that increase the security of AST still in design phase.

2. Prolongation of the period of tank bottom exploitation

The tank bottom is the part which bears most strong corrosion impacts. During the exploitation its thickness decreases and the threat of hole appearance become bigger. Considering the experience obtained up to now which concerns the corrosion speed and the necessary period of 10 years between two complete internal inspections the following actions must be undertaken for the prolongation of tank bottom life:

- increase the thickness of bottom sheets on the design phase. According to [9] the minimal thickness is $t_b = 6$ mm;
- internal lining protection on the bottom which must be good for exploitation for the period bigger than the period between two complete inside inspections;
- the installation of cathodic protection on the bottom.

3. Installation of a double bottom of the tank

The installation of double bottom assures fast indication when the bottom is punctured and prevents the penetration of the product in the soil.

Generally the double bottoms can be classified by the following criteria:

a) according to the material used in the construction of the second supplementary bottom:

- made from steel;
- made from polymer material.

b) according to the system which is used for leaks findings:

- passive system – this is a system build from pipes which leads the product leaked between the two bottoms to come out in the place, which is easily accessible and purposely determined. The liquid is moved by its own weight. Because of it the hole of the bottom is found with some delay.

- incessantly switched on vacuum system – this system is watching incessantly for the increase of the pressure between the two bottoms. The bottom hole is detected immediately.

Fig. 1 shows different solutions for the second bottom of the tanks:

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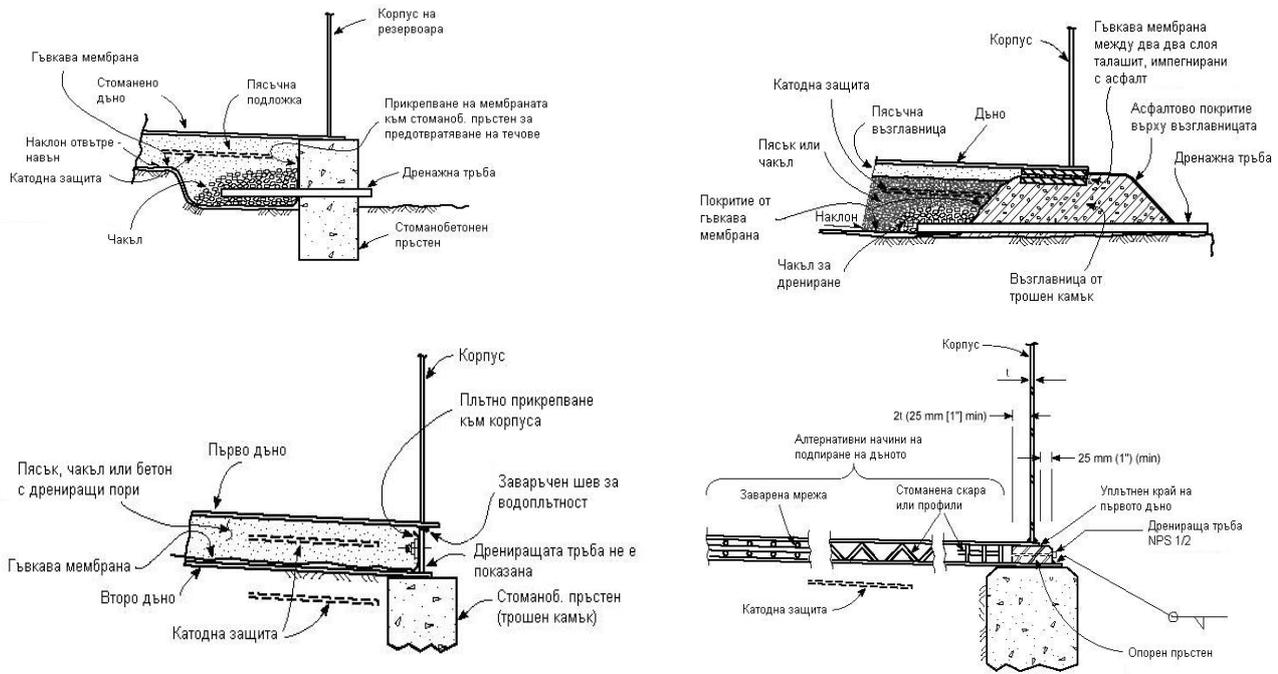


fig.1 Various types of double bottoms [9]

The contemporary trends are to put second steel bottom and active vacuum system (fig. 2). The pressure between two bottoms decreases by means of pump and its pressure has been incessantly watched. Every one increase of the pressure between the bottom means that bottoms integrity is broken. This scheme assures uninterrupted control for breaks on the whole bottom.

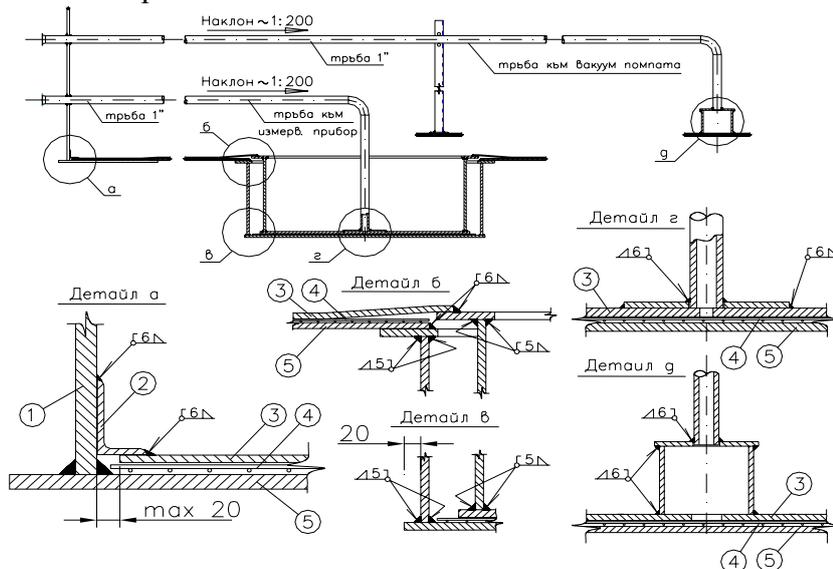


fig. 2 Double tank bottom with vacuum system

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|------------------|--------------------------|------------------------|
| 1. Tank shell | 3. Upper (second) bottom | 5. Lower (main) bottom |
| 2. Angle section | 4. Medial net | |

The sheets of the two bottoms are separated by steel net installed between them. This net is made by joint welded smooth steel bars with diameter $\text{Ø}3 \div \text{Ø}4$. The steel net does not allow the complete adherence of the sheets and appearance of the areas where the free movement of the liquids is impossible.

The research of the author for determination of the necessary net [3] density shows that the pressure is biggest at the points where the bars cross each other. In the fields and above the bars in the places of contact with the upper bottom the efforts are smaller several times which is due to the low bending stiffing of the steel bars.

The density of the net can be determined by fig. 3, depending by the internal pressure on the bottom and diameter of the smooth bars.

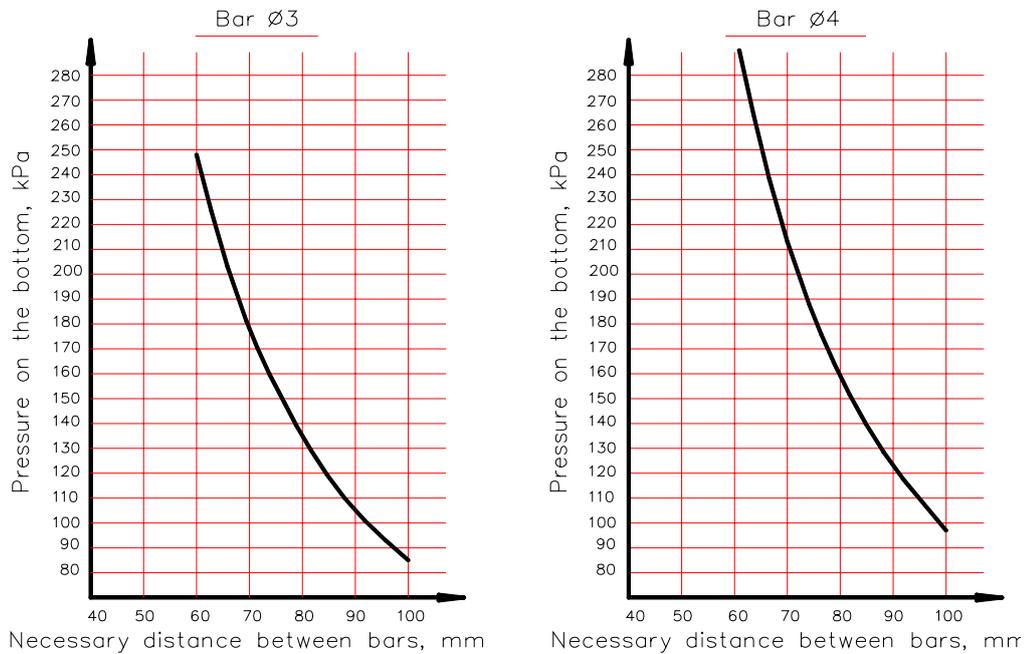


fig. 3 Distance between bars in the steel net

4. Improvement of the roll method and weld joints in shell made on site

In order to avoid some defects in rolls making and shell erection by roll method, executed following the classical method (fig. 4 - a), according to which method the length of all vertical joints is equal to the height of the shell, the vertical shop welded joints are made at the $\frac{1}{2}$ of the length of the shell sheet (fig. 4 - b). This solution is used to remove many uninterrupted vertical joints, but weld joint made on site, passing through all courses is still linear.

For tank security improvement it is necessary that all weld joints are not on vertical line but to it must follow the changes in the positions of the sheets in the rolls. In this case the distance between the vertical joints is 600 mm (fig. 4 - c), which is bigger than minimal required according to [5] and [7] distance 500 mm.

The temperature deformations caused by the welding operations influence the kind and the quality of the weld joints.

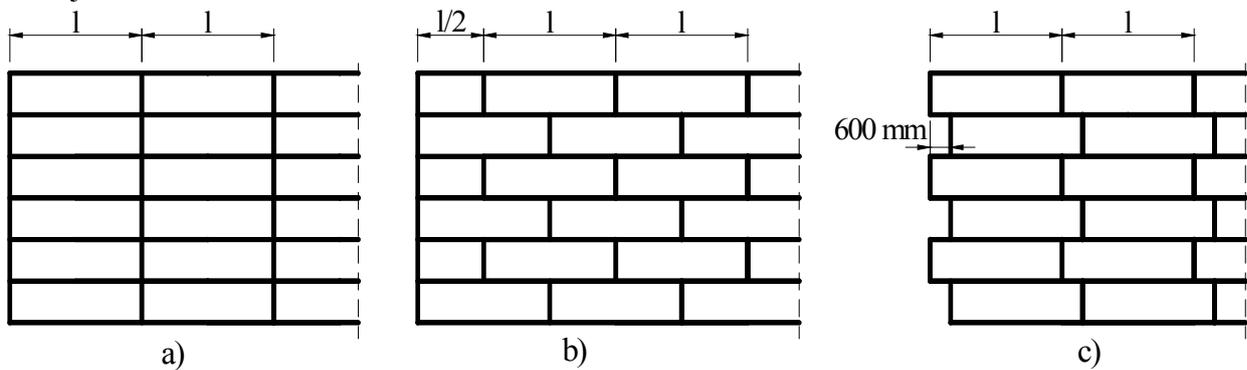


fig. 4 Trends in rolls making of the shell

- a) Typical rolls with uninterrupted vertical joints. ([4])
 b) Removing of the sheets at $\frac{1}{2}$ sheets, vertical weld joint having the shape of "T"
 c) The distance at 600 mm of "T" shaped cross and outline weld joints

5. Erection of tanks with supplementary second steel shell

This solution is usually applied when the ground is very expensive or when there are higher requirements for ecological security of the appliance. The tanks with double shell and double bottoms (fig. 5) are constructed in Germany, Check Republic, Hungary and Poland. This practice began to be used in Bulgaria too.



fig. 5 Tanks with double steel shell

As advantage of the tanks with double shells can be mentioned:

- the tank occupies smaller area;
- the area which is in fire and which must be extinguished during the fire is smaller;
- in case of shell break the product leak into the soil will be avoided.

The disadvantages are:

- the tank cost is higher;
- it is necessary to erect a supplementary foundation construction on which will step the steel catching basin;
- it is necessary to put devices which must compensate the crossing the shell pipes. The water leaks are more probable when anchors pass the bottom between the main and outside shell.

The tanks with double steel shell are relatively young group of facilities. In this moment they are still improved. In the beginning the requirements for their projecting are the following:

- the distance between the two shells must be approximately $1,8 \div 2,5$ m. It is necessary for free movements for the appropriate employees and the minimal distance is 1,5 m [6];
- the height of the second shell must be not smaller than 80 % from the height of the main shell;
- the capacity of outside shell must be enough big that the stored in it product must reach at maximum 1,0 m below the top edge of shell;
- the devices for compensation must be attached to all the passing pipes, which must neutralize the influence caused by shell moving under pressure;
- often the protective shell is protected as open on the top. In this case the space between the two shells remains uncovered for atmosphere influence. The medium bottom must has an incline toward the drain system.
- the shells of the main and the outside shell are put on their own annular bottom plates which dimensions are determined according to the normative documents. It is recommendable that the bottom will be executed as double one with functioning vacuum system.

The calculations for the steel catching basin must consider loads as follow:

a) pressure from product

The liquid impact upon the outside shell could be:

Hydrostatic – if there is a small break in the tank shell. The plates and welds are not destructed and the liquid slowly fill the gap between the two shells.

Hydrodynamic – there is a vertical tearing in the tank shell, which increases its dimension with big velocity (≈ 5000 m/s). The edges open and the liquid quickly and at once enter in the gap between the catching basin and the tank shell.

b) earthquake impact

The gap between the two bodies is filled in case of an accident and the pressure is contemporarily. The catching basin must be enough reliable for the earthquake impact when it is filled with liquid.

The calculation for the seismic influence must be done during two main cases:

- the tank is full with liquid at its maximum level and the gap between the two shells is empty. The methodology is the same as for the tank with one shell;

- there is a liquid in hydrostatic equilibrium in the tank and in the gap between the two shells.

The specific point during the calculations for the catching basin for earthquake resistance is the inside situated tank. It bears the impacts of all seismic waves [2], and therefore it will bear the hydrodynamic pressure.

When the distance between the two shells is small and the waves which press the catching basin are low there influence is not important.

в) wind pressure

Fig. 6 shows that the catching basin decreases the wind pressure upon the main tank.

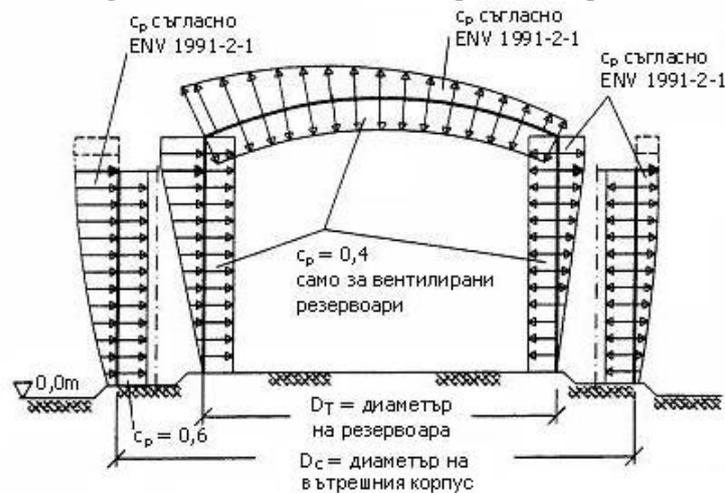


fig. 6 Wind pressure upon tank with steel catching basin [11]

6. Replacement of the traditional steel roofs with aluminum

Around the world the use of aluminum for the domes is increased (fig. 7), which is connected with higher requirements for environment protection and the lower price of aluminum. They are often applied on tanks in service with floating roofs. Another case when the aluminum domes are used is when supported cone roof is replaced by self-supporting aluminum dome with internal floating roof.



fig. 7 Aluminum dome roof

The advantages of the replacement of the steel roof with aluminum are as follow:

- the duration of the exploitation of the aluminum domes is up to 50 years ;
- decrease of the shell loading from dead loads and reduction of the risk of lose of stability in vertical direction;
- the less heavy roof is a better solution in case of earthquake;

- the periodical replacement of anticorrosion protection is not necessary;
- it can be used when the tank has big volume – 50 000 m³ and more.

It is necessary to mention that the possibility of snow pile accumulating on the roof must be considered in the project.

This uneven loading by snow plus wind pressure caused destruction of two domes in Baltimore, the USA and two domes in Northern Russia.

The diagram σ - ϵ of the aluminum does not have yield strength. It does not allow distribution of loads between the different elements when some of them are over loaded. The lack of additional bearing capacity of the aluminum as material is the main reason for very precise determination of loads upon the roof and the efforts of supporting elements which are result of roof loading.

7. Erection of internal floating roofs (pontoons)

The use of internal floating roofs is the easiest and cheapest way to reduce the loss of evaporation in the tank. They can decrease product evaporations with 98 %. According to the used material they can be:

- steel – they have construction similar to the external floating roofs;
- aluminum – most often used in the practice (fig. 8);
- from polymer material – they can cause some problems in the fire extinguishing under the product

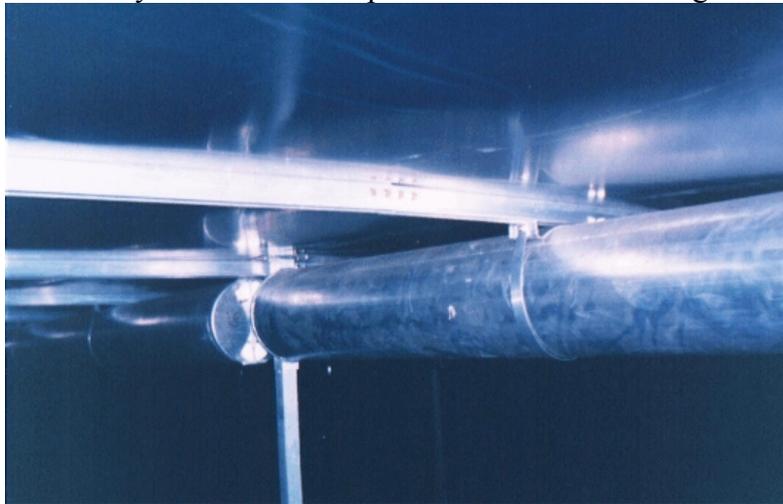


fig. 8 Internal floating roof

The supplementary advantages of the aluminum and synthetic pontoons are:

- the anticorrosion protection is not necessary ;
- high level of security when they are exploited;
- the erection of the pontoon is executed in the tank, needs not many workers and does not depend on external climate conditions;
- the elements of the pontoon are entered in the tank through the manhole or through the cleanout door, so it is not necessary to make a additional hole;
- all joints made on site are with bolts. There are not fire works into the tank.

The following disadvantages can be mentioned:

- the roof cover plates are put upon the floats and they are in permanent contact with the liquid. The vapors appear under the sheets which vapors pass through the rim seal in the atmosphere;
- the construction of this pontoons do not has enough stiffness and because of it the debit of tank filling is restricted when the roof is in the lower position;
- the low stiffness of the roof construction can cause the fatigue and weld joints destruction in joints between roof supports and floats.

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