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THE SELECTION OF THE OPTIMUM CONSTRUCTION SOLUTION FOR THE MULTI-CHAMBER TANK OF LARGE VOLUME

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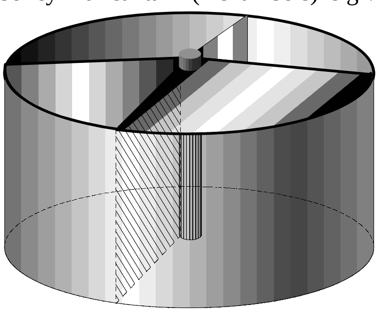
ABSTRACT
In the area of Bosnia and Herzegovina there exist a significant number of oil terminals as a legacy of Federal direction of commodity reserves of the former Yugoslavia, which today is at disposal and usage to company Terminals of the Federation BH. Within those storages there is also TTT S-105 Ribic in Bihac. The paper presents an outline of the procedure selection and calculation of the general model of the multi-chamber tank of large volume, higher than 5.000[m³], as a result of the reconstruction of the existing one-chamber tanks built 35 years ago, but destroyed due to war and not properly maintained in the post-war period.
Keywords: one-chamber tank, reconstruction, multi-chamber tank, optimum, general model.

1. INTRODUCTION
Vertical cylindrical tank of 5.000 [m^3] volume is built of steel S.0361, and is intended for storage of oil derivatives of specific weight – 10 [kN/m^3]. Internal diameter of the tank is Ø 24.384 [mm]. Height, measured from the bottom of the tank to the internal surface of the protruding arm of the boundary angle equals to 11.010 [mm]. These dimensions enable the tank to contain 5.000 [m^3] of useful volume. The layout of the vertical multi-chamber cylindrical tank (4 chambers) is given in Picture 1.



Picture 1. Multi-chamber cylindrical tank

The basic construction of the multi-chamber tank is one-chamber tank (vessel) of 5.000 [m^3] volume that can be sized according to the API standard. The general model of the multi-chamber vessel (4 chambers) is created by installing vertical partitions that need to be positioned in the basic model, without disturbing construction stability [1]. During the calculation of individual tank elements, the stress of tank dead weight and useful freight was used. Snow and wind were used as a total stress of 1,22 [kN/m^2]. The bottom of the tank has total useful surface of 466,5 [m^2]. It consists of sheets of 6 and 8 [mm] thickness. 8 [mm] thick sheets were placed in the peripheral area of the bottom. Plates in one strap, as well as all straps, are mutually lap welded with fillet weld.

Couplings between the bottom edge of the lowest mantle ring and boundary plate of the bottom should form continuous welds on both sides of the mantle plates. The size of each individual weld should be minimum 5 [mm]. Tank mantle has total height of 11.830 [mm] and consists of 7 horizontal bands of different sheet thickness. The ending edge of the mantle is bearer 80.80.8 with protruding arm turned towards the inner side of the tank. Horizontal and vertical welds are butt welded in the field. Roof construction of cylindrical tank consists of 24 main bearers which are leaned on the central pillar and boundary angle of the tank mantle. Main bearers are mutually connected with connecting bearers upon which secondary and radial bearers lean on. Roof cover is made of 4 [mm] thick sheet with side slope of ~5°, which are mutually lap welded. The tank contains outer spiral stairs with railing, inner ladder, roof railing, entry slots on mantle and roof, mechanical level indicator, slot for sampling, residue dish and connection for loading and unloading [2].

2. TECHNICAL REQUIREMENTS FOR WORKS

2.1. Material

Material used for tank consists of sheets of S.0361 quality, with dimensions predetermined by the project. In construction of groove welds, the sheet edges can be prepared by application of gas burner or cutting with air hammer. When plates are prepared with gas burner, cutting surface must be uniformed, smooth, without peels and cut areas. All irregularities must be removed with rasp or grinding machine. Fine, thin layer of rust that occurs after cleaning with steel brush on cut or trimmed edges that should be welded, does not have to be removed. Jacket sheets should be modeled to predetermined curve by cold rolling and trimmed to exact rectangular shape.

2.2. Welding procedure

For welding procedure, all types of electrodes can be used, which agree with base material and provided welding standards. Welding needs to be conducted according to the predetermined welding plan, which should contain all directions for sequence and procedure, as well as the modes of maintaining plates in the design position during the welding. Welding sequence should enable welding with the procedure which will result in the smallest strain due to shrinkage. Welding surfaces need to be metal clean, cleaned from water, oil, grease, paint, corrosion, etc. During welding in several layers, the seam must be well cleaned of slag after each weld. "Tacking" needs to be conducted with the same electrodes with which it will be welded. The lenght of the "tack" is 20-50 [mm], whereas "tack" step should be 250–300 [mm].

Welding procedure can be performed without any special measures, if surrounding temperature is higher than 0 ^{0}C, and if there are no wind or rain. Otherwise, proper measures for wind and rain protection should be conducted. With temperatures ranging from 0 °C to 5 ^{0}C, preheating of base material should be applied. With temperatures lower than –5 ^{0}C welding should be stopped. During the welding procedure, the welder needs to keep a welding log, in which all specific data are entered, such as: atmospheric conditions, surrounding temperature, name and type of welding, electrode type, and all other data important during the welding procedure.

2.3. Welding testing and control

Welding control is conducted during the preparation, during the welding process and after welding is finished. The control during preparation should include base and added material, as well as shape and regularity of the estimated joint, condition of edges for welding, regularity of edge slope, cleanliness of the edge and welding surface in general, regularity of the distance between the plates, etc.

The control during the welding process should include welding type and seam shape, electrode diameter, current intensity, arch size, regularity of the applied weld, compliance with the sequence predetermined by the welding plan, and achieving continuity and homogeneity of the seam. The control during the welding process is the responsibility of the contractor in agreement with the supervising body of the employer.

The control of seams after welding process should include seam features, regularity of seam circumference (seam height and width), existence of cracks, pores, irregular craters and other mechanical flaws that can be determined with visual examination of the seam. The contractor is required to remove all detected flaws. Testing of vertical, horizontal and cruciform welded joints is conducted by radiographic testing.

2.4. Testing for tightness

The testing of the bottom should be conducted when the bottom is completely welded. It is tested for tightness with vacuum pump or magnetoflux. Testing with vacuum pump is conducted so that all welds are coated with strong soap solution or linseed oil, where, by creating vacuum, existence of bubbles indicates all unwelded spots. These spots are marked, grinded with electrical grinder and welded again, followed by another testing with vacuum pump.

When installation and welding of mantle and roof are completed, testing for tightness is the next step. The most convenient testing method is cold water pressure testing, so that all joints on the inside are coated with strong penetrating oil, such as oil for automobile springs, and then within the tank the pressure is reached that is 1,5 times higher than the pressure of the safety valve opening. Unless joints are welded properly, oil will appear on the outside, thus revealing any irregularities. Poorly conducted welded joints have to be removed and welded again. In order to test roof joints it is necessary to coat them on the outside with strong soap solution or linseed oil, and then within the tank the pressure is reached that is equal to pressure 1,5 times higher than the pressure of the safety valve opening. Possible leaks can also be welded mechanically.

3. STATIC CALCULATION OF THE TANK BASE MODEL

Static calculation of the tank was conducted according to API and JUS standards. Due to limited spatial potential, this paper describes only portion of the tank base model calculation [2].

3.1. Disposition

External dimensions of the tank are Ø 24.384 x 11.500 [mm].

Surface of the tank bottom is calculated as: $$S = \frac{\pi \cdot D^2}{4} = \frac{3{,}14 \cdot 24{,}384^2}{4} = 466{,}74\ [\mathrm{m}^2] \qquad (1)$$

Tank volume is: $$V = S \cdot h = 466{,}74 \cdot 11{,}5 = 5.367{,}51\ [\mathrm{m}^3] \qquad (2)$$

3.2. Mantle calculation

To calculate mantle sheet thickness, the following expression is used:

$$s = \frac{D}{20 \cdot \sigma_{doz} \cdot k} \cdot 98 \cdot \rho \cdot (H - 0{,}3) + c\ [\mathrm{mm}] \qquad (3)$$

where:

- s - calculated minimum sheet thickness [mm],
- ρ - density of stored media [kg/m^3], but not less than 1.000 [kg/m^3],
- D - internal diameter of the tank [mm],
- σ_{doz} - allowable design stress of the material S.0361, 165 [MPa],
- H - height from the centerline of the lower joint of the observed mantle band to the top of upper angle [mm],
- k - seam quality coefficient; calculated as k=0,85 for radiographic control circumference,
- c - addition on corrosion.

Table 1 Values of jacket nominal thickness

Nominal diameter of the tank [m]	Lowest nominal thickness of the jacket [mm]
to 15	5
above 15 to 35	6
above 35 to 45	7
above 45 to 60	8
over 60	10

Nominal thickness, given in Table 1, is determined based on construction reasons and contain addition on corrosion. Tanks with up to 25 [m] diameter have jacket sheet width at least 1.500 [mm]. The jacket of one-chamber tank contains seven sheet sections (I...VII) of different thickness (Table 2).

Mantle thickness, according to API regulations [4], is calculated as: S = 0,0001456 · D · (H_1 - 1), where H = H_1.

Table 2 Parameters for sheet thickness calculation according to JUS M.Z3.054

Lamella	Density ρ [kg/m^3]	Lamella width H_1 [mm]	Tank diameter D [mm]	Allowable stress $\sigma_{dozv.}$ [MPa]	Lamella sheet thickness [mm]
I		11.890			12
II		9.900			10
III		8.110			9
IV	1.000	6.320	24.384	165	8
V		4.520			7
VI		3.040			7
VII		1.550			6

Mantle sheet thickness of lamellas, calculated according to API regulations [4], are given in Table 3.

Table 3 Parameters for sheet thickness calculation according to API regulations

Lamella	Tank diameter D [foot]	Lamella width L [mm]	Lamella width L [foot]	Lamella sheet thickness s [foot]	Lamella sheet thickness [mm]	Accepted lamella sheet thickness s [mm]
I		11.890	39,06	0,443	11,25	12
II		9.900	33,19	0,375	9,53	10
III		8.110	26,67	0,299	7,60	8
IV	80	6.320	20,80	0,231	5,87	6
V		4.520	14,92	0,162	4,12	5
VI		3.040	10,04	0,105	2,67	5
VII		1.550	5,15	0,048	1,22	5

4. CONCLUSION

The former tables clearly indicate that sheets used for tank jacket are of different thickness, and that the maximum thickness is at the very bottom of the tank (lamella I), 12 [mm], which was to be expected, whereas it decreases moving towards the top of the cylindrical tank with lower hydrostatic pressure of only 6 [mm] (lamella VII). Accepted dimension of the tank central pillar upon which complete roof construction leans is Ø 323,8 x 9,5 [mm]. In this way, the basic geometric sizes of 5.000 [m^3] volume cylindrical tank without partitions are defined, which should as well be the basis for the development of multi-chamber tank construction (four chambers) of the same volume.

Based on the construction solution defined in previous researches [1], we have introduced vertical partition walls made of 12 [mm] thick sheets. In order to increase bending strength and disable bending strain, partition walls are reinforced on both sides with horizontal and vertical bearers, built of standard profiles I-32. This solution with I profiles, i.e. reinforcement with setting of 8x7 fields, proved to be optimum, which was later confirmed by corresponding numerical testing [3]. Distances between horizontal bearers are equal, and amount to 1.800 [mm], whereas distance between vertical bearers are variable. The smallest distance between vertical bearers are near the tank jacket and are equal to 1.000 [mm], with the purpose of elimination of expected stress concentration in the nodal point area (welded joint of partition and jacket).

Moving towards central pillar, these distances increase in a way that each following vertical bearer is at distance increased for 200 [mm] in relation to the distance of the previous bearer to tank jacket. Construction solution of vertical partition walls, with the assumption of selection of the optimum welding technology (REL procedure with electrode EVB 50 with preheating), leads the most critical nodal points of the multi-chamber tank to stress condition whose values are bellow allowable stress values, σ_{doz}=165 [MPa].

5. REFERENCES

[1] Fadil Islamovic: Master’s thesis, Faculty of Mechanical Engineering, Zenica, 2001.

[2] The Chief mechanical project of 5.000 [m^3] volume R-5 tank, TTT S-105 Bihac, (VI/1975).

[3] Fadil Islamovic: Doctoral dissertation, Faculty of Mechanical Engineering, Tuzla, 2006.

[4] API (American Petroleum Institute): Standard 620 ″Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks″, 7th ed. Rev. 1, 1985