REPAIRING WORKS IN RIVETED STEEL TANK WITH 5000 m^3 CAPACITY

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Science conference UACG' 2008

Key words: *cylindrical steel tank, riveted shell, bottom, inspection, corrosion, repairing works*

Cylindrical steel tanks for oil and oil products storage have a limited time for exploitation. Under the influence of the storage product, external environment, settlement of foundation, their working condition continuously goes to be worse. In this case the tanks should be periodically inspected, analyzed and if it is necessary – to be repaired or to be out of service.

When the steel tanks are inspected and analyzed correctly and on time, damaged elements could be repaired or replaced. The time for exploitation could be elongated and could be several times bigger than design period of exploitation.

1. INTRODUCTION

The inspected steel cylindrical tank has V = 5000 m^3 capacity and is situated in the base of "Petrol" – Varna, approximately at 100m from the see shore. It is designed to store oil products. Its roof is spherical and its supporting structure is build from steel girders with tight elements. The cover plates are not connected to the roof construction. Probably it has been done in order to assure brittle destruction of the roof in case of fire or tank explosion.

All constructive sheet's elements (bottom, shell, roof's cover plates) of the tank are connected with rivets. The existing ladder for access to the roof is vertical.

The walls of protective catching basin around the tank were made from bricks and are destructed later.

The device has been successfully used for long years but a leak appeared and for this reason it has been emptied and put out of exploitation. After that the tank remained empty without any maintenance. Its condition before the repairing works can be seen (fig. 1).

fig. 1 Tank's condition before the repairing works

Project data for this tank are missing – stored product, maximum liquid level, over pressure and negative pressure in the tank, used steel, thickness of the constructive elements. Unknown is also the year of the beginning of exploitation. Proceeding only from the fact that the bottom, the shell and the roof are connected with rivets (fig. 2), we can presume that this tank has at least 60 years.

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fig. 2 Connection of the sheets with rivets

2. INSPECTION AND RESULTS

After emptying of the tank the inspection has been done [1]. It has been focused on visual examination of the elements of the tank and determination of the thickness of bottom, first and second course of the shell, and roof cover plates. Inspectors did not measure full thickness of all shell courses. They did not measure deviation of the shell from the projected cylindrical form and the settlement of the foundation.

Chemical analysis of the used steel has been done. According to the analysis the steel matches the characteristics of Ст3кп (S235 that is not killed and could not be welded).

Checking calculations for determining of the maximum level of tank filling have been done, according to the measured thickness of the two shell courses.

As we miss our normative document for regulation those calculations are made according to [3]:

(1) $$H_t = \frac{t_{\min}.E.S}{4{,}9.D.G + 0{,}3},$$

where:

H_t is the height of the maximum level of liquid up to the lower joint of the inspected course, m;

D = 23,5 m – nominal diameter of the tank, m;

t_{min} – the smallest measured thickness in the relevant course of the shell. The different corrosion damages are situated at a big distance one from another;

G = 1,0 t/m^3 – design specific weight of the stored oil product;

S = 148 MPa – design strength of material in the tank's shell;

E = 0,6 – coefficient of effectiveness of the vertical joint in the shell with two lines of rivets [3].

The design calculations and the analysis of the other constructive elements in the tank show that :

- maximum liquid level H_{max} = 9,35 m when the density of the stored product is $G \leq 1{,}0$ t/m^3;
- total replacing of the bottom is necessary;
- old roof cover plates shall be replaced with new plates;
- existing vertical ladder shall be changed with spiral ladder.

Having in mind that the construction is obsolete, there is a considerable wearing of the main constructive elements and there is a need of expensive replacement of the considerable part of the tank, it is recommendable to destruct this device. After that a new tank will be erected on the same place according to the latest design and technological requirements.

The owner of the tank, company "Petrol", did not agree to destruct the tank and design and erect a new one. That means that the most damaged tank elements to be replaced because partial repairing works are impossible.

3. REPAIRING WORKS OF THE TANK

For repairing of the tank's main damages the above mentioned necessary repairing works have been done – replacement of the damaged bottom and cover plates, and mounting of spiral stairway.

Ones of the most interesting repairing works are the operations for replacement of the bottom.

The lower supporting joint where by rivets are joined bottom and shell plates (fig.3) is mounted with the aid of the additional angle section, put inside in the shell (fig. 4). This angle section bears the additional bending moments caused by change of strain and deformed status which appears in this zone.

fig. 3 Joint of shell and bottom plates of the tank

Because the jointing angle section in the lower supporting joint is extremely corroded we can not relay on its bearing capacity. It shall be removed or appropriately strengthen. Scheme for initial joint shell-bottom as well as examined versions for replacing of the bottom is shown on fig. 4:

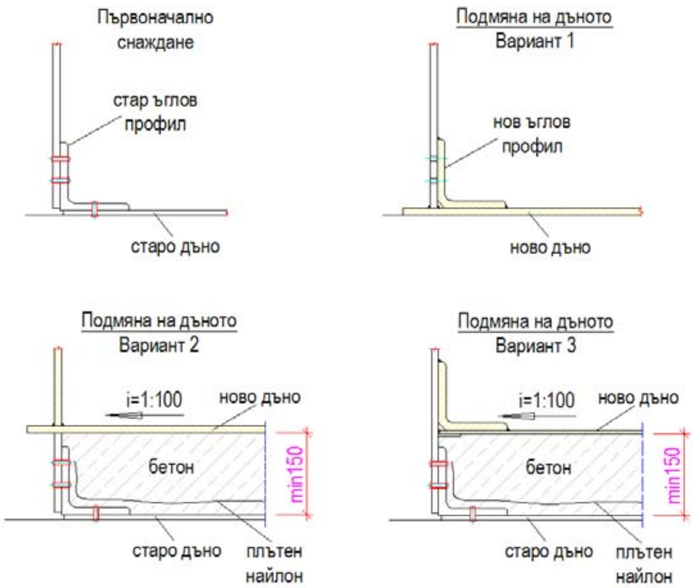

fig. 4 Versions for new joint bottom –shell

Bottom replacement has been done according to the Version 3 which specialties for execution are:

- thickness of sheets in the new bottom is $t_b = 6$ mm and it is determined according to [2];
- steel for the annular bottom plates is S355, and for the central part – S235;
- bottom sheets are welded to the shell with butt weld with full penetration. Under new bottom plates are used steel plates to ensure welding of root of the butt weld;
- new joint between the bottom and shell is reinforced through additional angular section L120x10, which shall decrease the tensions caused by the bending in the joint shell –bottom. The end of the section is beveled in order that the butt joint shell – bottom will be done with smooth transition to the shell.

The advantages of such a solution are:
- the shell is not cut;
- the threat of displacing of the rivets in the shell joint and the possible leak is led to minimum ;
- with new concrete slab we can make a new bottom slope which is different from the initial project or actually measured .

The disadvantages are:
- above the old bottom shall be put additional concrete layer with minimum thickness of 150 mm and thick nylon. Their function is to separate old bottom from new bottom in order to prevent accelerated corrosion process between them, which will cause fast damages on the new [4];
- every peripheral bottom sheet must be cut by individual radius according to the real radius of the shell where the welding works will be done ;
- welding joint between the shell and new bottom shall be done with full penetration, which require strong control on the technological process and executed joints.

After the termination of the repairing works the rivet tank is filled with water and a water check is done. The purpose is to check weather the tank is ready for exploitation.

The device passed almost successfully this test. The noticed departure from the standard is a small leak around some rivets in the shell. The probable reason for this leak is tank's serious corrosion damages and because the smallest vibrations or/and temperature impact lead to the opening of the rivets joint i.e. leaks.

4. CONCLUSION

When the riveted tanks are very old and damaged because they are long time in service, all kind of vibrations during repairing works and/or temperature impact by welding process can cause the displacement of rivets and leak. In this reason all repairing works in the shell must be done with smallest possible intensity and influence on the other elements.

The shown solution has been imposed by the necessity that the displacement in the shell will be minimal. On the other hand it is an alternative of the detail shown in [3]. If the thickness of the new bottom is appropriate, the reinforcing angle section is applied and appropriate welding material are used it is not necessary to cut the shell and it will make easier the mounting of new bottom.

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