INTRODUCTION IN DESIGN OF ABOVEGROUND CYLINDRICAL STEEL TANKS
SELECTED TOPICS:

Chapter 1
GENERAL CONDITIONS
1.1 Purpose of tanks. Types ................................................................. 6
1.2 Main constructive elements of tanks .................................................. 6
1.3 Methods for calculations of shell of steel vertical tanks ...................... 7
1.4 Tank’ construction development in Bulgaria ........................................ 8

Chapter 2
MATERIALS
2.1 Hot rolled sheets .............................................................................. 9
2.2 Steel sections ................................................................................... 12
2.3 Steel pipes ....................................................................................... 12
2.4 Welding materials ............................................................................ 12

Chapter 3
CHOICE OF GENERAL TANKS’ DIMENSIONS
3.1 Optimum shell height ....................................................................... 13
3.2 Roof height ..................................................................................... 15

Chapter 4
ROOFS OF TANKS
4.1 Determination of the roof type ............................................................ 16
4.2 Design of the elements of fixed roofs ................................................... 25
4.3 Efforts in top angle and determination of the geometrical characteristic in the tanks with fixed roofs ................................................................. 35
4.4 Efforts in the central ring of tank’s roof ............................................... 38
4.5 Design of the elements of floating roofs ............................................. 39

Chapter 5
SHELL OF TANKS
5.1 Stress calculations ............................................................................ 59
5.2 Check of the shell for stability loss ..................................................... 53
5.3 Minimum section modulus of the main wind girder in open above tanks ... 59

Chapter 6
TANK’S BOTTOM
6.1 Annular bottom plates .................................................................... 62
6.2 Central bottom plates ....................................................................... 67

Chapter 7
EARTHQUAKE DESIGN
7.1 Main damages on the tanks due to seismic impact ............................... 68
7.2 Behavior of the liquid in the tank during the earthquake ....................... 68
7.3 Overturning moment during the earthquake ....................................... 69
7.4 Horizontal efforts during the earthquake ............................................ 71
7.5 Maximum height of liquid wave $A_L$ ................................................ 71
7.6 Stability of the tank against overturning .......................................... 72
7.7 Maximum admissible longitudinal efforts in the tank’s shell ............... 73
7.8 Stability of the tank against sliding due to the seismic impact ............ 75
Chapter 8
STABILITY OF THE POSITION
8.1 Check for uplift of the tank ................................................................................................ 76
8.2 Check for overturning of the tank ...................................................................................... 77
8.3 Check for sliding of the tank ............................................................................................ 78
8.4 Necessary measurements when the some of checks does not show satisfactory results .. 78

Chapter 9
ANCHORING OF THE TANKS
9.1 Design of anchor bolts ................................................................................................. 79
9.2 Measurement of the anchor chair ................................................................................... 80
9.3 Construction of the anchors .......................................................................................... 82

Chapter 10
FOUNDATION CONSTRUCTION
10.1 Bottom section............................................................................................................. 83
10.2 Preliminary data for design .......................................................................................... 83
10.3 Types of foundation construction .................................................................................. 84

Chapter 11
CREATING AND REINFORCING OPENINGS
11.1 Adding openings without supplementary reinforcement of the shell with sheets ......... 88
11.2 Opening in the shell reinforced through inserted sheets .......................................... 89
11.3 Opening in the shell reinforced through overlap sheets ........................................... 91

Chapter 12
PROTECTION OF STEEL TANKS AGAINST CORROSION
12.1 Anticorrosion lining ...................................................................................................... 92
12.2 Secure the reliability of construction with corrosion allowance ............................ 93

CONCLUSION .................................................................................................................... 96

LITERATURE...................................................................................................................... 97
INTRODUCTION

The current thesis examines aboveground vertical steel cylindrical tanks made by carbon or low alloy steels with volume from 100 m³ up to 100 000 m³ for water, condensate, spirits, milk, oil and oil products. The tanks have welded shell and bottom and are not used when there is an additional internal pressure more than 2,5 kPa and negative pressure (vacuum) till 0,5 kPa. Maximum design temperature of the metal does not exceed 300 °C. When the design temperature is more than 100 °C the changes in mechanical properties of the steel must be considered.

The here described researches and the calculated correlations are valid for aboveground cylindrical steel vertical tanks for another stored product but are not valid for isothermal tanks and tank for storage of aggressive chemical products.

The current document generalizes the author’s researches on the tank construction but also knowledge and experience of different organizations working in field of designing, execution, exploitation, inspection, repairing works and reconstruction of vertical steel cylindrical tanks.

During the preparation of the thesis, author made analysis and reported:
- accessible literature concerning the theme, as particular accent has been put on the European standards;
- experience in design, repairing works, mounting and exploitation of the tanks;
- results from the inspections of steel tanks;
- data obtained from the failures of steel tanks.

Referring the co-ordination of the Bulgarian and end European Union laws the author focused its attention on the last editions of the European standards in this field - EN 1993-4-2 и EN 14015:2004. After its admission as Bulgarian National Standards all steel tanks must be designed in accordance with its prescriptions and requirements.

On the other hand, the tanks which are in service now, are designed following another conception, standards and methodology. The author signed particular parts of them because of following reasons:
- to facilitate the transfer from the old Russian standards to new European ones;
- to compare the Russian and European methodology for tank’s design and the calculated through them results;
- to aid the assessment of the conditions of tanks in service. In order to make a correct assessment of the real conditions of tanks and internal processes, we need to know design basis, rules and tradition according to which the tanks have been designed.

A minimum of requirements for safety and constructive integrity of new built tanks have been mentioned in this thesis. The mentioned here requirements are limited to the following elements:
- Foundation construction, bottom, shell, roof, stair, platforms and handrails, attached assistant technological equipment and nozzles till faces of first flange.

The shared here ideas and scientific researches, obtained results and analyses can help the students specialty “Structural Engineering” in UACG, Sofia as well as the organization which:
- prepare documentations for design of new built tanks;
- produce and/or mount tank’s construction;
- prepare documentations for design or repairing works, changes and reconstruction of the tanks;
- execute repairing works, changes and reconstruction of the tanks in service.
CONCLUSION

The steel tanks are engineer facilities which must be safety and reliable, and which work almost incessantly under maximum exploitation loads. The destruction of such a facility brings big material, ecological, technological and financial loss. Due to this reason to guarantee more safety of products storage and to prevent failures is a trend in all developed countries.

The intensive development of tank’s construction in Bulgaria and abroad, and experience gained from tanks failure, help us to make a conclusion that tanks designed and constructed according to increased requirements for their endurance and exploitation safety are not perfect and supplementary researches are needed in the stages of design, construction and exploitation.

The tanks designed according to the last achievement of science and practice can be damaged and can be destructed due to action or the lack of action during the exploitation.

To increase tank safety we need to undertake different by their type but connected between themselves organizational, technological, constructive and chemical activities

To assure the steel tanks reliability during their exploitation is connected with:
- incessant extension of knowledge for real work of sheets construction and introducing the last achievement of science and practice;
- control on the quality of producing and mounting operations, necessary for tanks building;
- the devices mounted on the tanks must have high level of precision and safety;
- periodical activities for outside, partial and entire tanks inspection for assessment of their real condition;
- expert assessment of the results obtained during the inspection;
- determination of remaining resource and admissible regime of exploitation of steel vertical tanks;
- execution of necessary repairing works of tanks or stop their exploitation if necessary;
- incessant training of all participants in design, producing, mounting, exploitation, inspection and repairing works of the tanks.
LITERATURE

1. Technical literature

1. BARZOV P., Korozia na vtryeshnata povr'xnost na stostanenite rezervoari za nef'toproduktsi, Neft i khimia, 1, 1981.
10. KOSTADINOV Y. K., STANCHCHEV C., Opit' na KZU pri izpousto na rezervoari po rul'nen metod, 1976.
17. RUSEV S. S., Zdravkov L. A., Dop'lnitelnye konstruktivnye resheniya za e'dopolubnye pлаващи покриви при gol'mogabartitnye rezervoary, konferentsiya na IASS, Var'n, 2006.
2. Normative documents and standards

30. Инструкция за изготвяне и технология на монтажа и заваряването на СВР с обем от 100 до 10 000 m³ за системата на енергетиката, Енергопроект, 1995.
31. Инструкция за проектиране на СВЦР с обем от 100 до 10 000 m³ за системата на енергетиката, Енергопроект, 1995.
32. Инструкция по проектираню, изготвяне и монтаж на вертикални цилиндрически стъклени резервоари за нефти и нефтепродукти, Норми Республика Казахстан, 01.01.2005.
33. НАРЕДБА №3 за основните положения за проектиране на конструкциите на строежите и въздействията върху тях, ДВ, бр. 92 от 2004
34. НАРЕДБА №2 за проектиране на сгради и съоръжения в земетръсни райони, ДВ, бр. 68 от 2007 г
35. Норми за проектиране на стоманени конструкции, КТСУ, 1986.
37. Правила устройства вертикальных цилиндрических стальных резервуаров для нефти и нефтепродуктов, ПБ 03-381-00, 2000.
38. Рекомендации по расчету стальных вертикальных цилиндрических резервуаров на сейсмические воздействия, ЦНИИСК, 1994.
40. Сооружения промишленых предприятий, СНиП 2.09.03,1985.
41. Типова работна документация на СВР с обем от 100 до 10 000 m³, изградени по рулонен метод, МССМ, 1977.
43. API Std 653, Tank Inspection, Repair, Alteration and Reconstruction, 2001.
44. BS 2654:1989, Manufacture of vertical steel welded non-refrigerated storage tanks with butt – welded shells for the petroleum industry.
45. DIN 4119, Oherirdische zylindrische Flachboden Tank, buwverke aus metalischen Werkstoffen, 1980.
47. EN 1993-4-2: Design of Steel Structures, Part 4-2: Tanks, February 2007.