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Modern Systems for Control and Extinguishing Fires at Petroleum Storage Tanks

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Abstract

The paper presents systems and facilities to ensure fire safety at petroleum storage tanks, issues related to new technological solutions used in control and extinguishing fire installations, respectively horizontal and vertical bladder tanks for foam agent. Also, there are presented experimental test results on behavior shell bladder tank performed by the electric resistive tensometry method.

Key words: *bladder, tank, strain gauges, mechanical stresses, linear strains*

Introduction

Various events manifested over time, demonstrated that, in particular, within the parks of tanks for the storage of petroleum products, in certain circumstances, be conditions to produce fires, given the risks involved, particularly generated by large quantities of combustible and highly favourable characteristics like inflammability and formation of explosive mixtures.

A feature of most flammable and combustible liquids is of organic origin, which determine their flammability.

It is obvious that due to the permanent need for petroleum products, frequency of loading - unloading storage tanks is very high, leading to the achievement of favourable conditions for formation of a potentially explosive mixtures.

Systems for Detection, Control and Extinguishing Fires at the Storage Tanks of Petroleum Products

An essential role in achieving an operative intervention to limit and extinguish a fire, in the case of storage tanks for petroleum products too, is represented by early detection and alarm.

In the particular case of the combustion of petroleum products, the first manifestations of a fire are the occurrence of flames and temperature rise in the affected area.

Due to the large size of storage tanks diameters, a viable solution for surveillance of their entire perimeter is linear heat detection.

This can be achieved with linear heat detectors, in various models.

Linear heat detector types:

- tube sensor - determining pressure variations with temperature increase; sensing pressure changes in the tube;
- digital linear heat detector - operating with changing resistance principle with rising temperature.

The extinguishing of the flames can be generated by non-existing balance between evaporation and flammable mixture formation.

To remove the causes of fire is always present concerns. They are developed standards, regulations and rules which lay down specific conditions for fire prevention.

However, if they occur, it is necessary to have the conditions necessary to limit the spread of fire and extinguished its into the initial stage of development.

Upgrading of Firefighting Foam Systems

To satisfy the demands of cost effectiveness, insurance companies and legal regulations on the prevention and firefighting, urgent measures are needed to upgrading and rehabilitation of existing facilities, worn and outdated.

It is necessary to analyze each case and to determine the possibilities of modernization, which are:

- reconsidering assumptions sizing and reducing the number of in-line mixers;
- transformation these into mini stations with bladder tank and automatic proportioner with variable flow, eliminating all in-line mixers.

Foam bladder tanks can be constructed, depending on the necessary quantities of extinguishing substance, conditions of location, in vertical type on legs or horizontal type on saddles.

Bladder tank is a carbon steel pressure vessel (stainless steel construction optional) containing an elastomeric separation bladder/hypalon-neoprene between the water and foam concentrate.

The bladder permits water pressure to be transferred to the foam concentrate without the two fluids mixing together.

A ratio controller generates a water pressure drop by means of a reduced cross section where the water stream passes through it.

As the foam concentrate pressure is higher than the pressure at the ratio controller, the foam starts flowing towards the water and mixing at a calibrated rate, which is dependant on the water flow rate.

The bladder tank, together with ratio controllers, form a balanced pressure proportioning system used to mix water and fire fighting foam together to generate an effective extinguishing medium.

The bladder tank technology is a reliable and precise mixing method that is widespread in the fire fighting industry.

This method allows the water/foam ratio to remain stable by automatically adjusting to the variable flow rates and pressure conditions that may occur during system operation.

This feature makes bladder tanks particularly suitable for multiple hazard systems.

The main advantages of using bladder tanks are:

- reducing installation costs by eliminating foaming pump;
- internal water distribution pipe to equalize the water pressure everywhere avoiding damage to the bladder and to drain the tank under any condition;
- water / foam inlet and vent plugged;

- it can be used for multi-hazard protection;
- it is easy to install being provided with fixing holes, and having a wide range of pre-installed tubes;
- has materials and optional accessories.

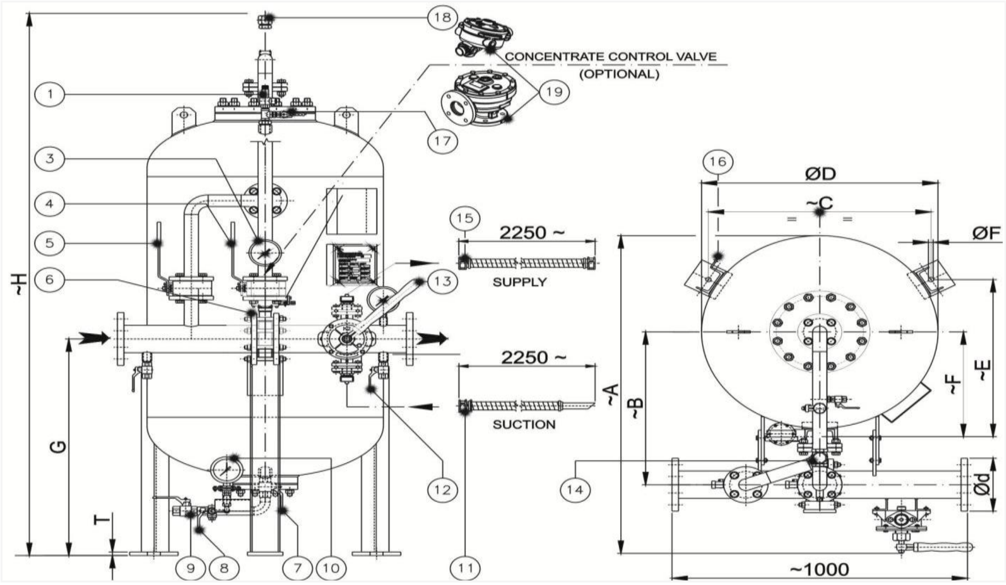

Fig. 1. Vertical bladdertank with proportioner
1. Thermal relief valve; 2. Tank; 3. Tank pressure gauge; 4. Foam concentrate shut-off valve; 5. Water shut-off valve; 6. Wide range ratio controller model Vrind; 7. Water drain valve; 8. Foam level indicator valve; 9. Foam concentrate fill/drain valve; 10. Analog level indicator; 11. Foam pump suction hose (optional); 12. Ratio controller drain valve; 13. Foam filling pump (optional); 14. Check valve; 15. Foam pump delivery hose (optional); 16. Earth lug; 17. Water vent valve; 18. Foam vent valve; 19. Foam concentrate control valve (optional)

Experimental Research on the Behavior of Bladder Tanks Using Electrical Resistive Tensometry Method

Measurements using tensometric resistive sensor is based in principle on the fact that when an electrical conductor (or semiconductor) constituting the sensing element, lengthens or shortens, its electrical resistance changes.

If the sensor element is fixed on a portion of a piece that is deformed due to a mechanical stress, it will deform as the piece.

By measuring the change of the sensing element resistance, with electrical or electronic means, which is proportional to deformation, the deformation can be determined in the portion of studied on the basis of an initial calibration.

Description of experimental stand:

1. vertical bladder tank; foam capacity 200 liters; mounted on three legs welded to the tank shell;
2. general use strain gauges to measure mechanical stresses, Hottinger Baldwin Messtechnik GmbH manufacturer, "rosette type" model 10/120 RY91 with transducers electroresistive on three directions (0^o, 45^o, 90^o), 5 pieces;
3. compensating strain gauge, 10/120 LY11 type, Hottinger Baldwin Messtechnik GmbH manufacturer, one piece;

4. two component epoxy adhesive, X60 type, Hottinger Baldwin Messtechnik GmbH producer; temperature limits -200 ºC and +80 ºC;
5. protectiv coatings ABM 75 type, Hottinger Baldwin Messtechnik GmbH manufacturer; temperature limits -196 ºC and +75 ºC;
6. IT1 measuring device type, Huggenberger Zurich manufacturer;
7. 200 litres of foam; Fomtec ARC 3x6; is a high efficiency multi purpose film forming;
8. manual pump;
9. various equipments and accessories.
10. Experimental stand was create as follows:
11. measurement locations were chosen after analyzing the geometry of the reservoir, its operation and mechanical stress; were chosen the points considered critical/sensitive;
12. the rosette transducers was chosen to determine the state plane stress;
13. the area where the transducers were to be glued was cleaned, up to metallic gloss on a large enough surface to allow adequate bonding; the surface is chemically cleaned to remove residues of humidity, dirt, grease or oil;
14. the transducers were glued, with specially designed adhesive, aiming easier and more uniform pressing at the sensor element;
15. it was envisaged achieving a scheme with the position of each electroresistive transducer for correct recording and interpretation of the values obtained;
16. the transducers were dried and over them was applied a putty for thermal protection;
17. the circuit was carried out and was proceeded to the introduction of an compensator transducer to remove the unbalancing caused by the temperature variation.

Strain gauges were placed near the welds and one of the supporting legs.

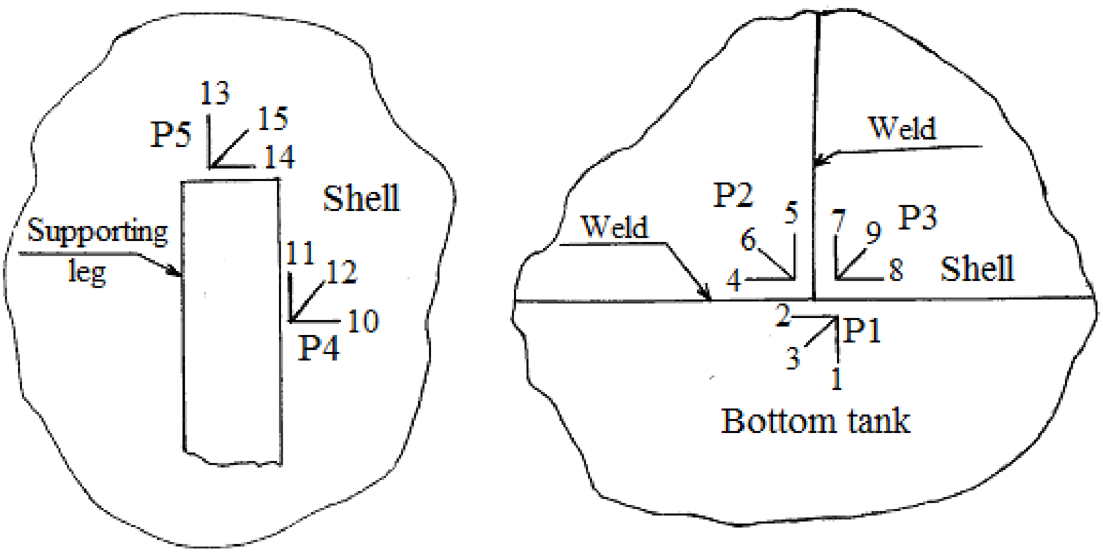

Fig. 2. The location of strain gauges

The tank was tested in hydraulic pressure. There were values indicated with empty tank and bladder.

The pressure was boosting in 4 steps (3, 6, 9 and 12 bar) and depressurization at the same pressure steps, in reverse order.

The results obtained were recorded and at increasing pressure from 0 to 12 bar.

The values recorded for P4 and P5 points near at one of supporting legs are given in Table 1. In these areas are large concentrations of mechanical stresses.

Table 1. The values recorded for P4 and P5 points at increasing pressure from 0 to 12 bar

PMT nr.	TER nr.	Empty tank	Pressure steps in bar										
			0	3	6	9	12	9	6	3	0	12	0
The readings of specific linear strains in µm/mm													
4	10 (X,V)	14360	14350	14355	14360	14380	14405	14385	14370	14350	14335	14432	14345
	11 (Y,H)	15120	15070	15155	15270	15380	15495	15395	15290	15180	15080	15520	15080
	12 (E)	15769	15740	15780	15840	15900	15960	15900	15850	15790	15740	15970	15740
5	13 (X,V)	14485	14465	14545	14610	14670	14735	14670	14610	14550	14490	14730	14480
	14 (Y,H)	14865	14860	14930	15005	15070	15150	15075	15005	14950	14870	15145	14865
	15 (E)	14765	14755	14825	14890	14950	15025	14950	14895	14830	14770	15015	14760

PMT= Measurement Point Tensometry (Tensometry gauge);
TER=Electro-resistive transducer;
X=Orthogonal vertical axis (Directorate Meridian);
Y=Orthogonal horizontal axis (Circumferential direction);
E=bi Directorate (tilt at a 45 degrees angle).

With values from Table 1 were calculated mechanical stresses into the tank shell in P4 and P5 points shown in Figure 2.

When calculating the mechanical stresses was considered the following issues:

1. benchmarks of specific linear strains produced by the weight of the water are those from Table 1 „empty tank" column;
2. benchmarks of specific linear strains produced by pressure are those corresponding to the first column where pressure is zero.

The main stress value was calculated by:

$$\sigma_{1,2} = \frac{E}{1-\mu}\frac{\varepsilon_a + \varepsilon_b}{2} \pm \frac{E}{\sqrt{2}(1+\mu)}\sqrt{(\varepsilon_a - \varepsilon_c)^2 + (\varepsilon_b - \varepsilon_c)^2} \qquad (1)$$

where:

E - the modulus of elasticity of the material of the vessel;
μ - Poisson's ratio;
ε_a, ε_b, ε_c - correspond to directions from Figure 3.

The equivalent stress according to von Mises criterion was calculated using the following equation:

$$\sigma_{ech} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2}\ . \qquad (2)$$

The higher equivalent stress values caused by the weight of water and pressure are shown in Table 2.

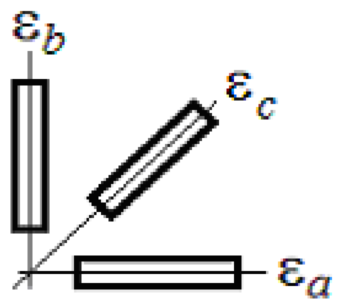

Fig. 3. ε_a, ε_b, ε_c directions

Table 2 The higher equivalent stress values

Pressure MPa	**Measurement Point**	
	P4	**P5**
	σ_{ech}^{max} **, MPa**	
0	10,6	4,35
0,3	28,19	26,94
0,6	51,84	47,94
0,9	74,97	66,71
0,12	99,45	88,45
0,9	78,37	67,51
0,6	56,28	47,88
0,3	33,21	30,84
0	3,64	5,70

Figure 4 includess a graphical representation of the values from Table 2 for measurement point P4.

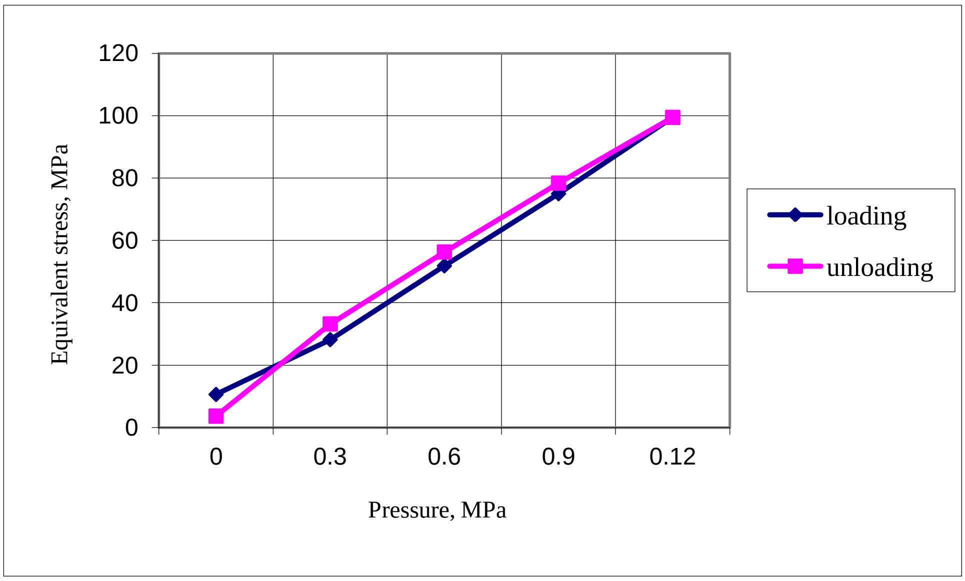

Fig. 4. Equivalent stress variation for measurement point P4

Figure 5 shows a graphical representation of the values from Table 2 for measurement point P5.

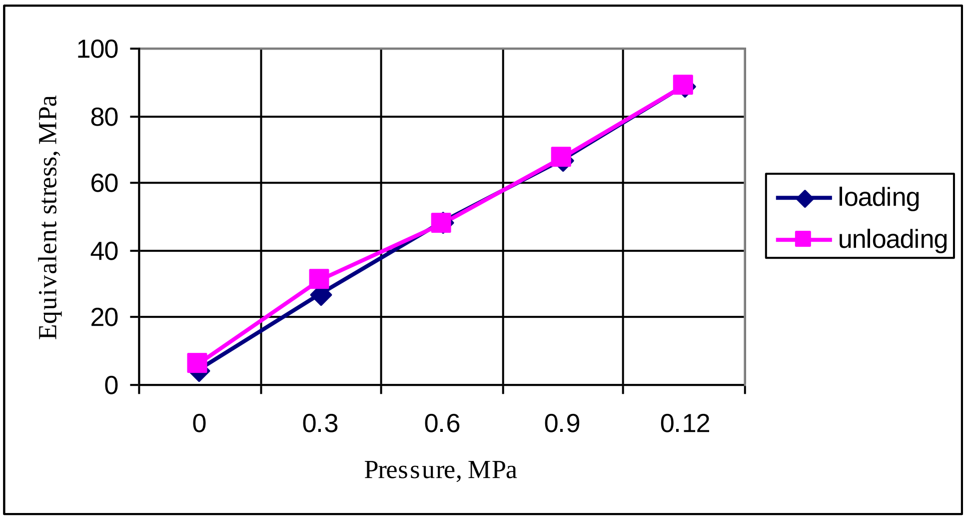

Fig. 5. Equivalent stress variation for measurement point P5

If we do not take into account the pressure generated by water and we consider the tank pressurized at 12 bar, the circumferential stress in its cylindrical area is:

$$\sigma_\theta = \frac{pD}{2t} = \frac{1,2 \cdot 600}{2 \cdot 5} = 72 \text{ MPa} \tag{3}$$

where:

p – pressure, MPa;
D – tank diameter, mm;
t – tank shell thickness, mm.

To achieve effective for extinguishing fires, have been developed and tested extinguishing solutions combined such as:

- extinguishing system with foam and dry powder;
- extinguishing system with foam and inert gas (act by reducing the content of oxygen in the burning zone);
- extinguishing system with foam and and aerosol generating units (act by lowering the temperature in the burning zone).

Of course, these alternatives are optional. Its are not subject to mandatory fitting of petroleum tanks. The deciding factor on the maximum required level of security is at the discretion of the owner.

Conclusions

1. Firefighting foam systems are constantly evolving, once with existing hazards, requirements imposed by insurers, but also by the economy of materials and energy consumed in almost any process.
2. Firefighting foam systems from petroleum storage tanks requires careful consideration in terms of correct choice of components, many of those already in use is outdated both physically and morally.
3. To reduce operating costs, but also to increase the efficiency of these systems, a viable solution is systems with bladder tank, vertical type on legs or horizontal type on saddles, with storage capacities of fire outbreaks linked to existing protected targets.

4. From raw data resulting from experimental research, is not resulting major deformation into the shell tank.
5. The maximum equivalent stresses values in P4 and P5 points, located near at one of supporting legs, are greater than those of the analytic stress because in this area the higher concentration of forces.

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Sisteme moderne pentru limitarea și stingerea incendiilor la rezervoarele de depozitare a produselor petroliere

Articol de față prezintă sisteme și instalații pentru asigurarea securității la incendiu a rezervoarelor pentru produse petroliere, aspectele referitoare la soluții tehnologice noi utilizate în instalațiile de limitare și stingere a incendiilor cu spumă, respectiv rezervoare cu membrană, orizontale și verticale. Totodată, sunt prezentate și rezultatele încercărilor experimentale efectuate prin metoda tensometriei electrice rezistive, privind comportarea rezervoarelor cu membrană.