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Research Concerning the Manufacture of Flame Arresters Combined with Mechanical Breathing Valves

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Abstract

This paper presents the outcomes of the research regarding the improvement of safety in the use of safety equipment the containers for oil product air storage are provided with. The new solution of coupling the valve and the flame arrester guarantees a high level of safety in exploitation, by means of reducing the wear of the mobile elements of the valve and by protecting the flame arrester against explosive flames with high propagation speeds.

Key work: *flame arrester, combined, breathing valves, drop pressure valve, flow.*

Flame Arrester Combined with a Mechanical Breathing Valve

Today, the mounting technology of the protective equipment on the container stipulates the following order: there shall be mounted the flame arrester and then its valve on the connector of the container, as shown in figure 1.

The assembly of the elements for the safety of the containers in the following order – container connector, line arrester and the blow-off exhaust valve – has the following characteristics:

- if there appears a stationary flame, this is located above the valve and it may cause the blocking of the valve and it has specific consequences;
- the arrester shall arrest only the flames that have passed through the valve from the air.

The flames that have got over the valve shall accelerate their speed up to a medium or even high speed deflagration due to the fact that they have to get through a distance of minimum four diameters up to the flame arrester, which makes the arrest function of the flame by the arresting grid inefficient.

Starting from the current conditions of use of the assembly – flame arrester, safety valve – we have made studies and research in order to find a solution that should sort out the above-mentioned technical characteristics.

In order to avoid the blocking of the safety valve because of the fact that the flame is located above it and to eliminate the conditions of the occurrence of rapid deflagrations, we have chosen the solution to mount the flame arrester after the valve in the flow direction of the gas. The proposed solution is shown in fig. 2 and has the following advantages:

a) the flame arrester, being the last element in the safety system chain, shall arrest the flames that propagate from the air at a high level of probability, because:

b) the flame propagates from the air at constant speed (*unconfined deflagration*) and manifests itself as a low-speed deflagration;

c) due to the fact that it has low speed, according to the Péclé criterion, the output of the heat transfer from the flame to the grid is at its maximum value and, consequently, the flame shall be arrested.

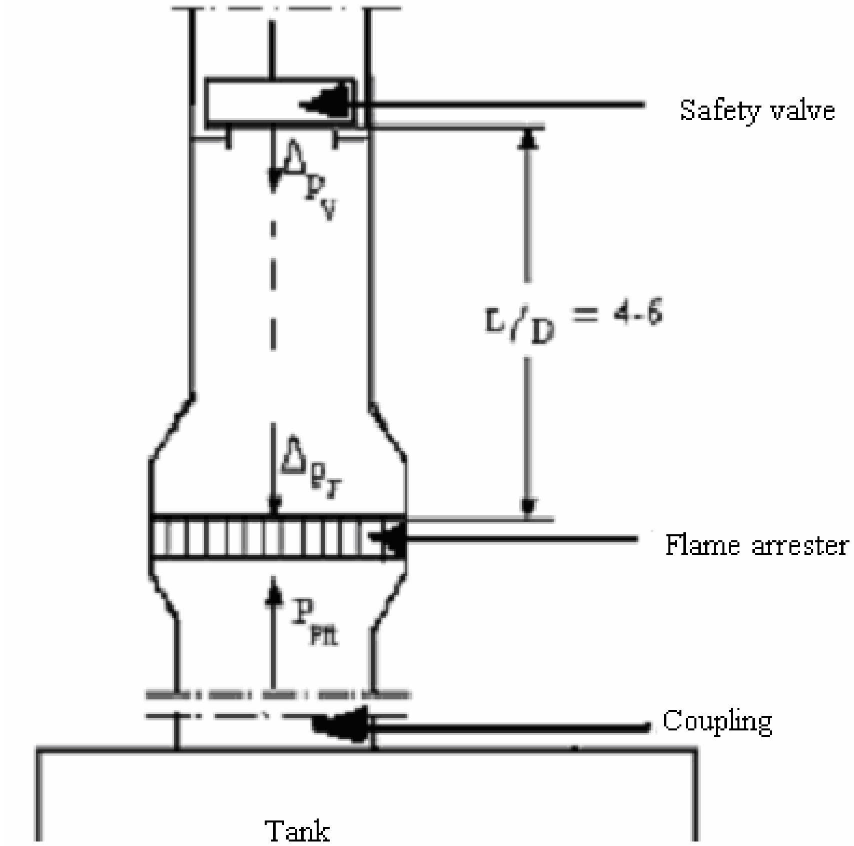

Fig.1 The scheme of pressure drops in its current variant

The risk that the flame should block the blow-off valve is eliminated, because if a flame appears, it should be located on the flame arrester on the exhaust side.

The diagram of pressure drops on the assembly valve-arrester is the following:

Out of figure 2, there can be written:

$$P_{PR} = \Delta P_S + \Delta P_F \tag{1}$$

where : P_{PR} - tank design pressure;

ΔP_v - drop pressure valve;

ΔP_F - drop pressure flame arrester.

If a high hydraulic resistance flame arrester is chosen, the valve shall have a low open pressure, fact which shall improve its reliability, because the weight of the disk shall be low (in inverse ratio to the pressure drop on the arrester) and the specific pressure on the airtight packing shall be reduced at the same time with its wear.

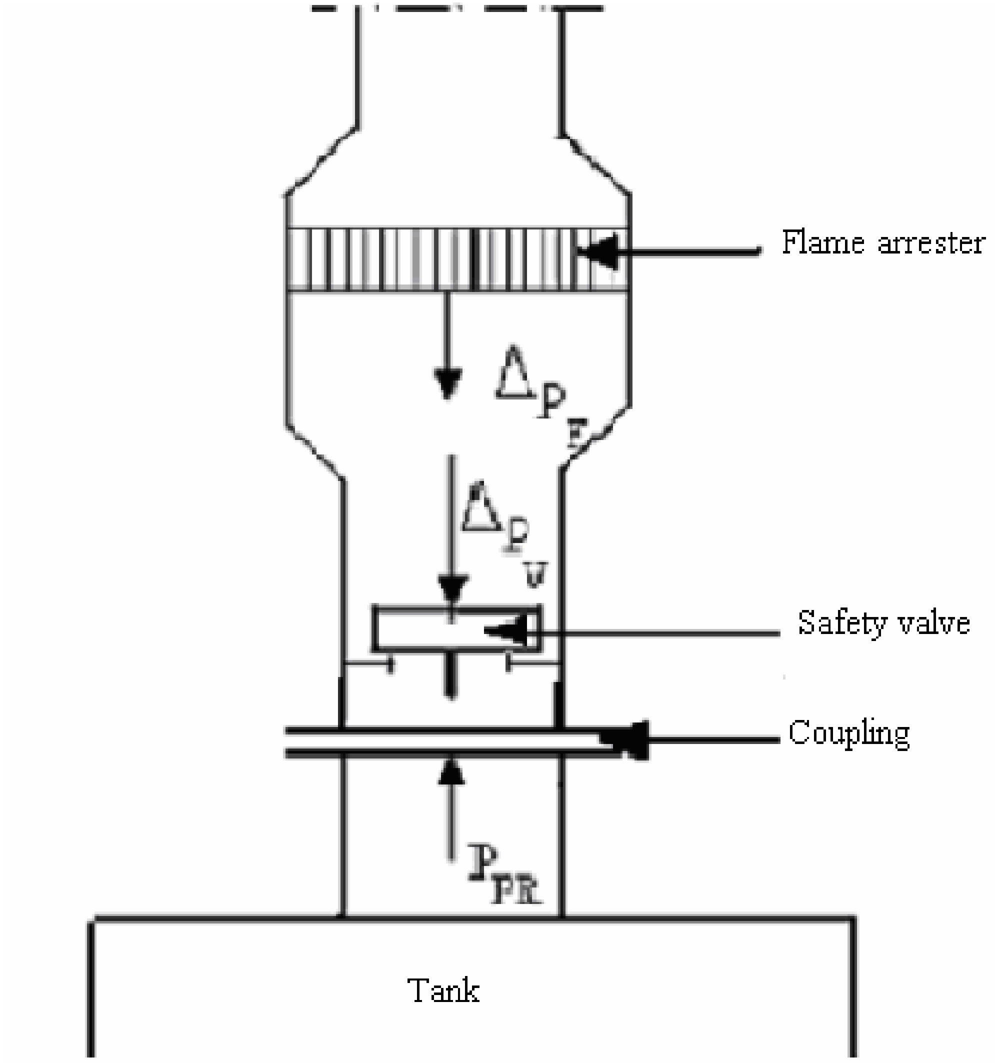

Fig.2 The pressure drop scheme as proposed in the paper

Taking into consideration the above-mentioned technical characteristics, we have studied the possibility of developing a technical variant by means of which the above-mentioned theoretical solution may be tested. The outcome of this solution has been materialized in the development and execution of a blow-off mechanical breathing valve combined with a flame arrester with nominal diameter Dn150 (fig. 3).

The constructive solution consists in the assembling, in the same case, both of the breathing valve and of the arresting grid used in flame arresters Dn150, according to fig.4.

Fig. 5 shows, for the combined valve, the pressure drop diagram obtained by using the regression method, after the laboratory test results have been processed, with the following regression equation:

$$y = 0.0669x^2 + 0.6295x + 0.7611 \qquad (2)$$

and the determination level $R^2 = 0.9959$.

Fig.3. Valve combined with a flame arrester

Fig.4. Arresting grid and protection sieve in the combined valve Dn150mm

Out of the diagram there can be noticed the fact that for 300 Nm^3/h flows the pressure drop (hydraulic resistance) for this assembly is very low, of 3.5 water col. (0.35 mbar), allowing the increase in the exhaust flow from 200 to 300 Nm^3/h.

The maximum speed of the gas in the critical cross sections at the maximum evaluated flow of 300Nm^3/h is:

$$v = \frac{4 \cdot Q}{\pi \cdot d^2} \qquad (3)$$

where: v – the maximum speed of the gas in the critical cross section of the combined valve;
Q – the maximum flow of the gas through the valve;
d – critical diameter of the valve.

For the Dn150 combined valve, we have the following values: Q = 300 Nm^3/h ; d = 144 mm. There results:

$$v = \frac{4 \cdot 300}{\pi \cdot (0.144)^2} = 18430 m/h \quad (4)$$

or :

$$v = \frac{18430}{3600} = 5.12 m/s \quad (5)$$

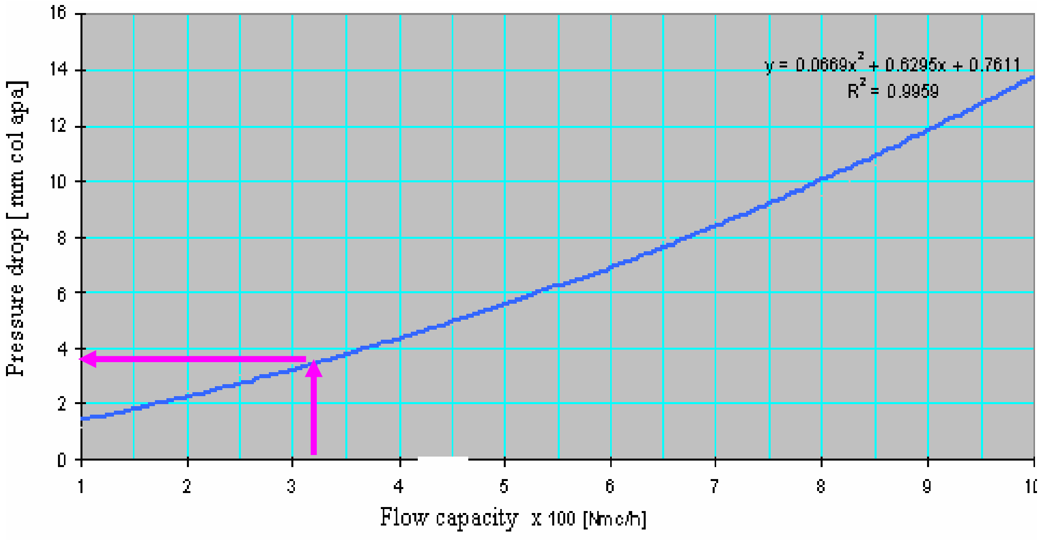

Fig.5. The diagram of pressure drop for the combined valve Dn150
The regression equation: $y = 0.0669 \cdot x^2 + 0.6295 \cdot x + 0.7611$
Determination level : $R^2 = 0.9959$

This speed is approximately seven times lower than the maximum allowed speed in designing safety valves.

Analyzing the exhaust capacity of the valve from this point of view, we may guarantee a maximum flow of 300·7 = 2100 Nm^3/h. At this flow rate, the hydraulic resistance is very high. Using the regression equation which was the basis of setting up the pressure drop diagram for this valve

$$y = 0.0669x^2 + 0.6295x + 0.7611 \;, \quad (6)$$

where: y – valve pressure drop [mm water col],
x – gas flow through the valve [Nm^3/h],
and granting x the value of 2100 Nm^3/h (reduced at the diagram scale) which represents the maximum allowed flow rate, restricted by the self ignition speed and the configuration of the valve, there results the value of the hydraulic resistance for the valve :

$$y = 0.0669 \cdot 21^2 + 0.6295 \cdot 21 + 0.7611 = 43.48 mm.col.H_2O \quad (7)$$

This pressure drop value represents 28.98% of the designed value of the maximum pressure of containers for oil product storage $p_{max} = 150 mmcol.H_2O$. At this value of the pressure drop on the valve, the maximum pressure in the container would reach the value of $179 mmcol.H_2O$, which is an impermissible design value. Due to the fact that the safety hydraulic valve opens to 10% above p_{max}, there results that the combined valve may guarantee a flow which creates a drop pressure on the valve of maximum $\Delta p_s = 15 mmcol.H_2O$, which corresponds to a maximum pressure in the container of $P_{max} = 165 mmcol.H_2O$.

Making the calculations with the help of relation (7), we obtain a pressure drop $\Delta p = 14.74 mmcol.H_2O$, and through the combined valve there must be a maximum flow of $Q_{\max} = 1050 Nm^3 / h$.

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Cercetări privind fabricarea opritorilor de flăcări combinați cu supape mecanice de respirație

Rezumat

Lucrarea prezintă rezultatele cercetării privind îmbunătățirea siguranței în exploatare a echipamentelor de siguranță ce echipează rezervoarele pentru depozitare atmosferică a produselor petroliere. Noua soluție de cuplare a supapei şi opritorului prezintă o siguranță ridicată în exploatare prin reducerea uzurii elementelor mobile ale supapei şi protejarea opritorului de flăcări împotriva flăcărilor de deflagranție cu viteze de propagare mari.