Determining Fuel Losses in Storage Tanks Based on Factual Saturation Pressures

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Abstract. At present, evaluation of fuel evaporative losses is based on a number of indirect parameters. Accuracy of such methods leaves much to be desired. The paper presents a method developed following the author’s laboratory tests. An effective operation range of pressure vent valves in various tanks is provided, as well as low A92 gasoline losses for horizontal steel tanks at all operation temperatures.

1. Introduction
More than half of the operational losses are evaporative losses. They can be classified into two types: quantitative, caused by evaporation and qualitative, caused by changes in fluid composition. To assess qualitative losses a lab test of the substance composition must be carried out, but assessment of quantitative losses is done, as a rule, by calculation. To obtain factual values rather than calculated it is necessary to measure the volume of the displaced gas-vapor mixture and its vapor concentration. Such measurements must be conducted constantly over the entire life of the tank, which is connected to some technical complexity.

Thus, for instance, using air flowmeters is not always justified as the displaced mixture volume may be relatively small at small breathing and not fall within the flowmeter operating capacities. Determining vapor concentration in the displaced mixture requires constant sampling with subsequent lab analysis, which can be unprofitable and highly labor-intensive.

When determining oil and petroleum products emissions, Russian scientists F.F. Abuzova, P.A. Rybakov, N.I. Tikhonov and other researchers based their calculation methods on such parameter as saturated vapor pressure which was used to determine hydrocarbon tendency towards evaporation. [1,2]

Saturated vapor pressure (SVP) is a parameter that essentially depends on hydrocarbon composition, phase ratio and temperature and is described by the following dependences:

1. Simplified calculation of SVP within the temperature range from –30 to +100 °C according to P.A. Rybakov: \[ P_{SV} = p_{38} \cdot 104.6 - 1430/T \], mm of mercury.
2. Dependence of petroleum products SVP on phase ratio, according to N.I. Tikhonov
\[
P_{SVt} = P_{38} \left( \frac{14}{10+V_V/V_L} \right)^{0.31} \times 10^{4.0283-1252/T}
\]

3. According to F.F. Abuzova,
\[
P_{SVt} = 1.29(t/38)^{0.69}(N_V/N_L)^{0.19} P_{38}
\]

where \( T\), \( t\) – the temperature of the liquid, \( P_{SVt} \) – the saturated vapor pressure, \( V_V \) – the gas phase volume, \( V_L \) – the liquid phase volume.

However, these dependences are significantly simplified. For example, P.A. Rybakov determines SVP depending on temperature but irrespective of phase ration. F.F. Abuzova and N.I. Tikhonov...
determine SVP depending on temperature and phase ratio, but in some cases the obtained dependences have a narrow temperature range. There is also SVP dependence obtained by the CSRL (Central science and research laboratory) which is directly proportional to temperature. However, the experimental data are outdated and require updating due to a significant change in hydrocarbon composition.

2. Research object
To estimate the amount of losses we suggest determining the saturated vapor pressure (SVP). This value, with minimum indirect measurements, allows us to predict quantitative changes when storing fuel. Such multi-component substances as petroleum products have an extremely complex composition due to which their phase transformation happens in a more complicated way than that of chemically homogeneous substances. During vaporization, lighter cuts gradually evaporate and liquid phase becomes heavier. Thus, partial pressures of single hydrocarbons also change and total petroleum products saturated vapor pressure is always 10-30% higher than can be expected according to the law of additivity.

To determine motor spirits SVP based on the government standard an experimental unit was designed that allowed determination of pressure exerted by the gas-vapor mixture in a model tank at various phase ratios. The temperature of the tested motor spirits was changed within the operation range by means of a hydronic cryothermostat LOIP FT-311-80.

A series of lab tests was conducted to determine motor spirits SVP depending on temperatures at various phase ratios within the operation range (figure 1). A full-scale experimental study involved placing gasoline А 92 in vertical cylindrical tanks 3000 m³ in nominal volume.

![Figure 1. Dependence of gas-vapor mixture pressure (kPa) on temperature (°C) when the tank is 20-95% filled.](image)

For the purpose of precision, factual losses were measured in tanks with the same type pressure vent valves located at the same tank battery and within the same time and temperature interval.

3. Results and discussion
The study produced experimental data on changes in the gas space pressure and gas-vapor mixture volume.
The data were processed considering hydrocarbon concentration in the gas-vapor mixture and lost product masses were obtained (figure 2).

From the graphs we can see that gasoline has a high level of evaporation due to lack of means to reduce hydrocarbon losses in the test tanks. It should also be mentioned that the obtained test data strongly depend on temperature. Natural loss norms for petroleum products do not have such dependence.

![Figure 2. Gasoline vapor emissions in storage tanks.](image)

Curves of factual gasoline losses are higher than the normative losses determined by the order № 364 "On establishing the norms of natural losses of petroleum products during storage" beginning from -15 °C.

Moreover, constructing a dimensional graph of hydrocarbon vapor pressure dependence on temperature and phase ratio for gasoline A92 (figure 3) we see that pressure vent valves are not always efficient. Their effective operation range (green area in the picture) is from 0 to –25 degrees Celsius depending on phase ratio for vertical steel tanks (VST) and from –25 to +25 degrees Celsius for horizontal steel tanks (HST).

Figure 3 also demonstrates that utilizing HSTs hydrocarbon vapor emissions can be eliminated without burying them underground.
Figure 3. Effective zone of a tank breather valve (gasoline A92)

4. Summary
The obtained saturated vapor pressure dependences on temperature show that if there is even a slight change in average temperature for as little as 5 degrees Celsius, SVP can increase up to 100%. This results in a great error of the averaged norms.

The indirect dependence of natural petroleum product loss norms on temperature causes distortion of real hydrocarbon losses during storage.

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