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DEVELOPMENT OF THE COMBINED RESERVOIR OF MIXTURE OF TECHNICAL COMBUSTIBLE LIQUIDS AS COMPONENT OF ENVIRONMENT PROTECTION TECHNOLOGY

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Abstract

In this study the development, analysis and description of the scheme of environment protection technology for the oil storage were carried out. The proposed scheme is provided for the utilization of vapors of technical combustible liquids stored at the enterprise, namely diesel fuel, gasoline and motor oil, formed during the manifestation of the phenomena of small and large reservoir breathing in significant quantities. Set of initial data and the mass hourly emission of such vapors into the environment were obtained according to an improved approach. Development of a high-pressure storage reservoir for such vapors as the executive device of environmental protection technology for the oil storage according to an improved approach was carried out. Parameters of the reciprocating compressor, which distills the mixture of such vapors from the low-pressure storage reservoir to the high-pressure storage reservoir, compressing them, was selected. Calculation of the reservoir wall thickness based on the theory of strength of closed solid shells was carried out taking into account the mechanical properties of the wall material, namely steel 60, and the value of the pressure of the gaseous fluid in it. Magnitudes of weight of the developed reservoir and the cost of materials for its manufacture were determinated. Design of a combined reservoir for the accumulation of a volley of a mixture of such vapors with a system of intermediate cooling of the mixture after its compression by a reciprocating compressor and the possibility of heating the condensate in the reservoir was developed.

Key words: ecological safety, environmental protection technologies, pollutants emission, vapor of technical combustible liquids, large reservoir breathing, small reservoir breathing, oil depot.

Relevance of the study.

One of the most urgent tasks for Ukraine today is the problem of preserving, improving and restoring the favorable for life of all parts of the trophic chains of ecosystems, including humans, the state of atmospheric air as a component of the environment. Among the priorities that stand out in this context is to address the legal protection of air, especially in industrialized regions, which undoubtedly include the city of Kharkiv [1–4].

At the same time, the documentary basis of legal protection of atmospheric air is the body of relevant regulations establishing limit values of physical quantities that characterize ecological safety (ES) factors, procedures for experimental or calculated obtaining of their values, methods of experimental data processing and more. For obtaining the values of ES factors and comparing them with the normative ones, which is the essence of estimating the ES level, for atypical man-made, primarily industrial, objects it is not possible to use existing methods and criteria mathematical apparatuses, so it is advisable to modify them to upgrade or develop new ones. The main causes of air pollution are the use of technologies, most of which do not meet modern environmental requirements, failure to implement in a timely manner atmospheric air protecttion measures to reduce or eliminate harmful emissions. The current ecological crisis on the territory of Ukraine is objectively the result of the general current unfavorable socio-economic and political situation and ecological management policy in the country developed in previous years. Such information follows from the analysis of ecological passports of such an industrially developed region of Ukraine, as Kharkiv region, from the last decade.

It is also necessary to take into account the fact that air pollution, emissions of thermal energy and toxic substances – pollutants – are transboundary in nature, and cause significant damage to the environment of not single but many countries. A classic example includes consequences of catastrophes of Chernobyl (a cloud of radioactively contaminated gaseous emissions of a volley nature) and Fukushima (a significant spill of radioactively contaminated liquid emissions of a volley nature) nuclear power plants. Atmospheric pollution as a global problem makes Ukraine to take efforts primarily in the international legal field. Ukraine is a party of the most international conventions and other regulations aimed at protecting the air, including the Montreal Protocol, the UN Framework Convention on Climate Change, the Kyoto Protocol, the implemented UNECE Regulations and others. In accordance with international obligations, our state has developed a number of important documents that contribute to the development of national air protection legislation [1–4].

However, despite the positive initiatives being developed and implemented, Ukrainian legislation on air protection requires further development at bringing it in line with the content and requirements of international standards [5–7]. Another area of development of national air protection legislation is its convergence with the relevant legislation of the European Union, as Ukraine's accession to the EU has been declared as one of the main geopolitical vectors of foreign policy of our state [8–17]. The solution of such problems should be based on the appropriate methodological apparatus of the ES management systems (ESMS) [18–19] and the legal basis [20–24].

They use reusable containers as storage reservoirs for technical combustible, chemically active and toxic liquids. It has significant mass and cost indicators, it is subject to weight and inertial mechanical loads of permanent, pulsed or oscillating nature. Liquids of petroleum origin are valuable and irreplaceable energy resource, the vapors of which are toxic, combustible and explosive pollutants, the emissions of which are due to the manifestations of small (SRB) and large (LRB) reservoir breathing. It is safe to say that the relevance of research in this area for the packaging industry is beyond doubt.

Purpose of the study is to increase the ES level of oil storage enterprises by creating an approach to the development of the material basis of the technology of utilization of vapors of technical combustible liquids (TCL), the emission of which is due to SRB and LRB during storage, due to their preliminary accumulation and storage, combustion and utilization of heat.

Object of the study is the system for ensuring of ES level of production activities of the petroleum products storage – oil depot.

Subject of the study is the technical and economic performance of low and high pressure reservoirs as reusable containers and the executive body of environmental protection technology (EPT).

Methods of the study: analysis of scientific, technical and normative literature, the main provisions of the disciplines «Thermodynamics and Heat Engineering», «Technical Mechanics of Liquid and Gas», «Ecological Safety Management Systems», «Environmental Protection Technologies», «Design and calculations in ecological safety systems».

Tasks of the study.

1. Development, analysis and description of the scheme of EPT for the petroleum products storage enterprise.

2. Determination of mass hourly emission of vapors of TCL by the mechanisms of LRB and SRB during their storage in the petroleum products depot in the environment air.

3. Development of a high-pressure storage reservoir for TCL vapors as an executive body of EPT for the petroleum products storage enterprise and determination of its technical and economic indicators.

4. Development of the concept of design of the combined accumulative reservoir for vapors of TCL.

Scientific novelty of obtained results.

The approach to development of schemes of EPT from gaseous emissions of vapors of TCL of the enterprise on their storage and distribution caused by the phenomena of SRB and LRB has received further development. The approach to the design of high and low pressure storage reservoirs for the accumulation and storage of volley emissions of a mixture of vapors of TCL of petroleum origin has received further development.

Practical value of obtained results.

The proposed approach to the development of EPT from gaseous emissions of vapors of TCL of the enterprise for their storage and distribution due to the phenomena of SRB and LRB, allowed to build an appropriate system that can be recommended for implementation in a typical enterprise for storage and distribution of petroleum products.

An improved approach to determining the value of mass and volumetric hourly emissions of liquid petroleum products vapors during storage, caused by the phenomena of LRB and SRB, is suitable for application to other objects – sources of gas emissions.

The proposed approach to the design of storage reservoirs of high and low pressure for the accumulation and storage of volley emissions of a mixture of vapors of combustible liquids of petroleum origin is suitable for use in streamlining the design of this type of device.

1. Development, analysis and description of the scheme of environmental protection technology for storage of petroleum liquids

The developed EPT, in particular the system of utilization of vapors of TCL stored at the oil depot, with the recovery of heat obtained during their combustion by conversion into electricity, is described at the diagram shown at Fig. 1. Sources of negative impact on the atmosphere as a component of environment are reservoirs for storage of TCL (actually, the main technological equipment of the oil depot) – are marked as «A», «B» and «C», and the impact – vapor emissions of such liquids due to the phenomena of SRB and LRB – are marked as «1»–«6». The studied oil depot has such reservoirs for storage of TCL N(DF) = 3 units, N(BF) = 5 units, N(MO) = 2 units [25], all are of the same geometric shape (cylindrical with a diameter of the base D = 10 m and high H = 15 m) and volume W(k) = 1178 m^3 [25]. The receiver of the emission is the atmosphere of the Kharkiv – is marked as «S».

Vapors of TCL, which are stored in the reservoirs of the oil depot, are released by the mechanisms of SRB and LRB of these reservoirs (see marks «1»–«6» at the diagram), enter the atmosphere and make up the emission of pollutants. This pollutant consists mainly of hydrocarbons of various types – saturated, unsaturated, polycyclic – with the formulas from C_5 till C_{20} [25].

Each of the three types of TCL, stored in significant quantities in several reservoirs each, forms above its free surface a layer of saturated vapor with a volume equal to the volume of the reservoir above the free surface of the liquid and the mass determined by excess saturated vapor pressure as a function of temperature liquid. To neutralize the effect of SRB caused by daily fluctuations in temperature of environment air, a double-acting breathing valve – marked as «D» at the diagram – was introduced into the design of their shut-off body (lid, neck). Such a regulator has two springs, one of which is set to the limit value of the positive excess pressure in the reservoir, and the other to the negative value (vacuum). To offset the effect of LRB caused by the displacement of vapors by the liquid when filling the reservoir, the reservoirs have a deflation system separating from the aerosol discharge flow its dispersed phase – liquid droplets which vapors form the dispersed medium of the emission aerosol – marked as «E» at the diagram.

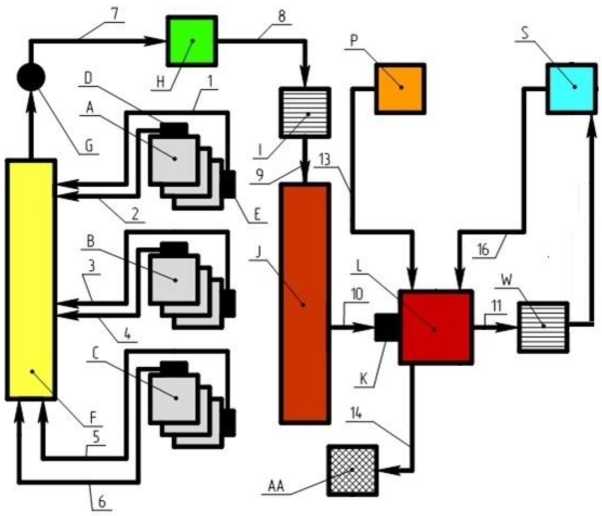


Figure 1 – Technological scheme of the developed environmental protection technology

A – bensine storage reservoires;
B – diesel fuel storage reservoires;
C – reservoires for storage of motor oil;
D – breathing valve of the reservoir;
E – blower system valve;
F – low pressure combustible liquid vapor reservoir;
G – injection pump; H – steam dehumidifier;
I – filter of mechanical impurities;
J – high pressure TCL vapor reservoir; K – torch;
L – solid fuel boiler; S – atmosphere;
W – system for neutralization of pollutants in the RICE EG flow; AA – consumer of thermal energy;
substances: 1, 3, 5 – vapor of combustible substance released during small breathing of the reservoir;
2, 4, 6 – vapor of combustible substance released during LRB;
7 – mixture of vapors of TCL of high pressure;
8 – mixture of combustible vapors, purified from water vapor;
9, 10 – mixture of combustible vapors, purified from particulate matters; 11 – crude exhaust gases;
12 – EG cleaned of particulate matters; 13 – fuel briquettes;
14 – ash in bulk

The breathing valve of the reservoir, which automatically eliminates the phenomenon of its SRB in the traditional way, on the direct course of the shut-off body (i.e. the emission of TCL at a positive value of excess pressure in the reservoir) has a spring set to the threshold value of excess pressure ΔP_{fv+} = 15 kPa. On the return stroke of the shut-off body (i.e. air intake at a negative value of excess pressure in the reservoir) has a spring set to the threshold value of excess pressure ΔP_{fv-} = –5 kPa.

The breathing valve of the reservoir, which automatically eliminates the phenomenon of its LRB in the traditional way – release into the system of blowing or directly into the atmosphere, has only a direct course of the shut-off body, i.e. provides only the release of liquid vapors in storage, or no working spring (opens manually directly or remotely), or it is set to the minimum pressure drop, so the value of its resistance can be neglected.

It is assumed that the vapors of TCL (see marks “1”–“6” at the diagram), leaving the cavities of sealed reservoirs for storage in the oil depot, located above the free surface of liquids, through the breathing valves of reservoirs for both types of breathing, overcoming the springs of these valves and insignificant hydraulic resistance of the tract behind them, periodically flow by gravity into the low pressure reservoir (see mark “F” at the diagram) and are accumulated there for a period of 3 hours. The accumulated mixture of TCL vapors in the low pressure reservoir is stored at ambient temperature and atmospheric pressure.

Every 3 hours, this mixture (see mark “7” at the diagram) is pumped into the high-pressure storage reservoir (see mark “J” at the diagram) by means of a three-stage reciprocating compressor (see mark “G” at the diagram). The vapor mixture is compressed and heated. The accumulated mixture of TCL vapors in the high pressure reservoir is stored at ambient temperature and pressure 2.0 MPa.

On the way to the high-pressure storage reservoir the vapor mixture is cleaned of water vapor (see mark “8” at the diagram) condensed in a drop, in a dehumidifier (see mark “H” at the diagram), as well as from mechanical impurities (see mark “9” at the diagram) in the filter (see mark “I” at the diagram). From the high-pressure storage reservoir, the mixture of TCL vapors (see mark “10” at the diagram) through the gas burner (see marks as “K” at the diagram) is fed as additional fuel into the solid fuel boiler (see mark “L” at the diagram) and burned, releasing heat energy, untreated waste (see mark “11” at the diagram) and powdered solid ash (see mark “14” at the diagram). Air (see mark “16” at the diagram) with oxygen in its composition from the atmosphere (see mark “S” at the diagram) is supplied to the solid fuel boiler to ensure the implementation of exothermic redox reactions. The main fuel for a solid fuel boiler is fuel briquettes (see mark “13” at the diagram) supplied from the warehouse (see mark “P” at the diagram). The thermal energy obtained in the solid fuel boiler is transferred to the consumer (see mark “AA” at the diagram) and is used for the company’s own economic needs. The exhaust gases formed in the solid fuel boiler and in the diesel generator (see mark “11” at the diagram) are an aerosol contaminated with particulate matter, products of incomplete fuel combustion and nitrogen oxides, and also have a significant reserve of thermal energy. The exhaust gas flow is cleaned of the specified legislative normalized pollutants in the pollutant neutralization system in the EG flow of the engine (see mark “W” at the diagram). The exhaust gas flow, purified from particulate matter and products of incomplete combustion of fuel and nitrogen oxides, as well as free from excess thermal energy, is released into the atmosphere.

2. Obtaining of initial data for determination of mass hourly emission of TCL vapors into the atmosphere by mechanisms of large and small machines

LBR with motor fuel is a phenomenon of emission of motor fuel vapor into the environmental air, which has a volley character, due to the displacement of gaseous medium from the reservoir with liquid when it is fully or partially filled (refueling) through or open shut-off special reservoir way the valve in it is adjusted [17].

SBR with motor fuel is a phenomenon of emission of motor fuel vapor into the environmental air, which has a volley character, due to the cyclical change of temperature regime (including daily fluctuations in air temperature and barometric pressure) in operation of vehicle or reservoir, which leads to alternating intensification of evaporation and condensation of motor fuel and a corresponding change in the value of its saturated vapor pressure in the reservoir, the excess and lack of which is compensated by mass exchange with ambient air through a properly configured two-way valve in the shut-off valve.

The mass hourly emission of such a pollutant must be characterized qualitatively and quantitatively.

Regarding the qualitative aspect of the emission, to provide such a characteristic one may use the results of determining the value of the dimensionless indicator of relative aggressiveness of such a pollutant described in the monograph [19], where it is equated to the value of the fuel component of the complex fuel and ecological criterion of prof. Igor Parsadanov A_{fv} = 38.4, which in physical terms is the ratio of the maximum allowable concentration of *k*-th pollutant to the maximum allowable concentration of pollutant, which is selected as a reference, in this case for such we have taken carbon monoxide CO [19,24].

Regarding the quantitative aspect of the emission, to provide such a characteristic, it one may use the traditional approach, namely choosing for this characteristic the value of the mass hourly emission G_{fv} in kg/h, because in terms of mass emission the law of continuity of the flow of gaseous fluid is fulfilled, since its volume is determined by the dependence of its density on temperature [19].

In previous studies, the approach was developed and method of calculating the values of mass hourly emission of vapors of TCL from reservoir for their storage at the oil depot caused by the phenomena of LRB and SRB was created.

The method takes into account both driving forces of the emission:

– increase in evaporation of liquids with heating;

– increase in gas pressure with heating.

To implement the method, information is required on the indicators of evaporation of these TCL and on the value of the daily temperature difference as the driving force of such a process, which is given at Fig. 2,a. The graphs on them are described by the formulas (1)–(3) [19]. The value of the average monthly daily temperature difference in Kharkiv can be approximated by a polynomial of degree 2 (R^2 = 0.851) (see Fig. 2,b) [19,26] – shown with formula (4).

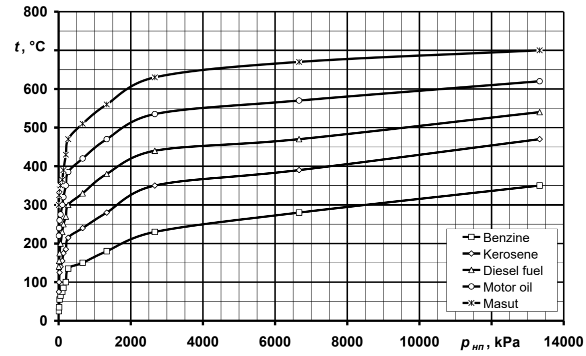
$$p_{нп}(\text{MO}) = \exp((t(\text{MO}) - 75.5) / 55.310),\ \text{kPa}, \quad (1)$$

$$p_{нп}(\text{DF}) = \exp((t(\text{DF}) - 2.5) / 53.439),\ \text{kPa}, \quad (2)$$

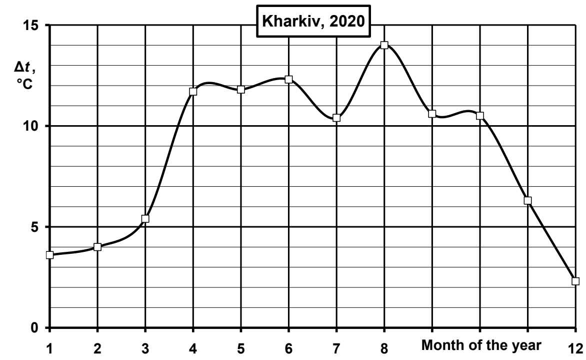
$$p_{нп}(\text{BF}) = \exp((t(\text{BF}) + 91.0) / 40.935),\ \text{kPa}. \quad (3)$$

$$\Delta t_{air} = -3.608 \cdot 10^{-4} \cdot d^2 + 1.342 \cdot 10^{-1} \cdot d,\ ,\ ^{\circ}\text{C}. \quad (4)$$

Assuming that the degree of filling of these reservoirs $\varepsilon(k)$ = 0.25; 0.50; 0.75, temperature of TCL t(k) = 5…20 °C, we have the results of an approximate determination of the values of the mass hourly emission of vapors of *k*-th type of TCL by the mechanism of SRB, which are shown at Fig. 3–8.



a



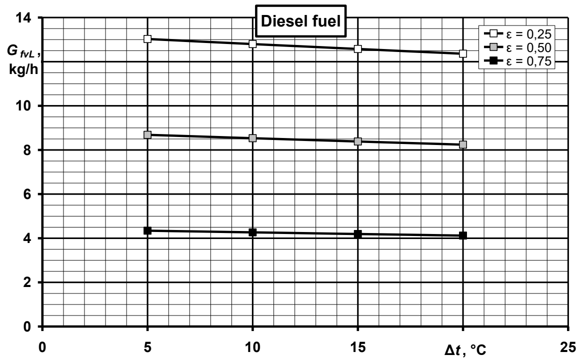
b

Figure 2 – Nomograms of saturated vapor pressure of petroleum products (obtained on the basis of data from the source [19]) (a) and distribution of values of the minimum average monthly temperature of atmospheric air in Kharkiv by months in 2019 (according to the source [19, 26]) (b)

At Fig. 3 graphs of dependence of values are given: mass hourly emission of diesel fuel vapors by the mechanism of LRB $G_{fv}(\text{DF})_L$ from the degree of filling the reservoir with liquid fuel ε and the daily temperature difference of atmospheric air Δt at T_{collL} = 2016 year. At Fig. 3,a, and Fig. 3,b it is seen that the minimum value is the value $G_{fv}(\text{DF})_L$ = 4.120 kg/h acquired at ε = 0.75 and Δt = 20 °C, and the maximum magnitude is value $G_{fv}(\text{DF})_L$ = 13.027 kg/h acquired at ε = 0.25 and Δt = 5 °C.

At Fig. 4,a graphs of dependence of values of mass hourly emission of diesel fuel vapors by the mechanism of SRB $G_{fv}(\text{DF})_S$ from the degree of filling the reservoir with liquid fuel ε and daily temperature difference Δt are given at T_{collS} = 24 hours. At Fig. 4,a it is seen that minimum magnitude is value $G_{fv}(\text{DF})_S$ = 0.347 kg/h acquired at ε = 0.75 and Δt = 5°C, and maximum magnitude is value $G_{fv}(\text{DF})_S$ = 5.018 kg/h acquired at ε = = 0.25 and Δt = 20 °C.

At Fig. 4,b graphs of dependence of values of total mass hourly emission of diesel fuel vapors by the mechanism of SRB and LRB $\Sigma G_{fv}(\text{DF})$ from the degree of filling the reservoir with liquid fuel ε and the daily temperature difference of atmospheric air Δt are given. At Fig. 4,b it is seen that the minimum magnitude is the value $\Sigma G_{fv}(\text{DF})$ = 4.689 kg/h acquires at ε = 0.75 and Δt = = 5°C, and the maximum magnitude is $\Sigma G_{fv}(\text{DF})$ = = 17.378 kg/h acquired at ε = 0.25 and Δt = 20 °C.



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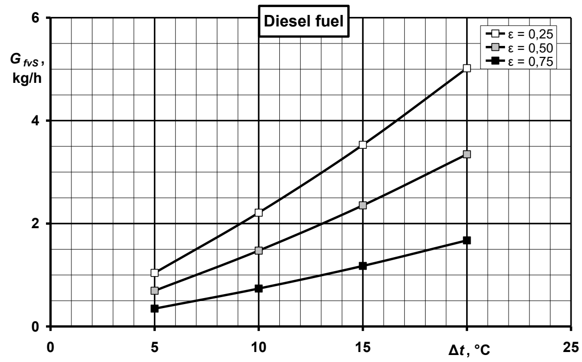
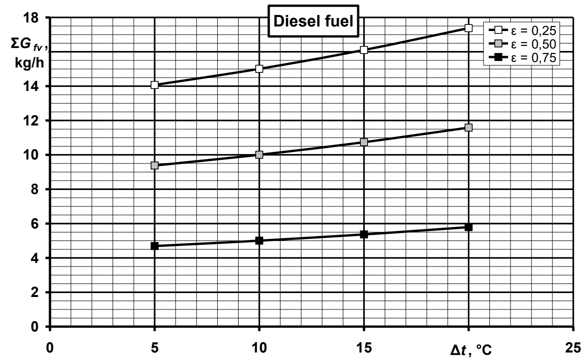


b

Figure 3 – Graphs of dependence of values of mass hourly emission of diesel fuel vapors by the mechanism of LRB $G_{fv}(DF)_L$ (a) and values of mass hourly emission of diesel fuel vapors by the mechanism of SRB $G_{fv}(DF)_S$ (b) from the values of degree of filling the reservoir with liquid fuel ε and daily temperature difference Δt at T_{collL} = 2016 hours and T_{collS} = 24 hours



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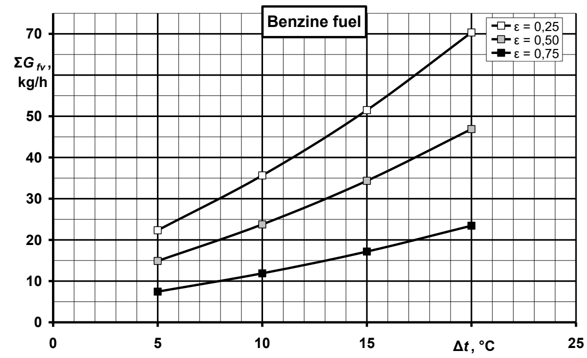
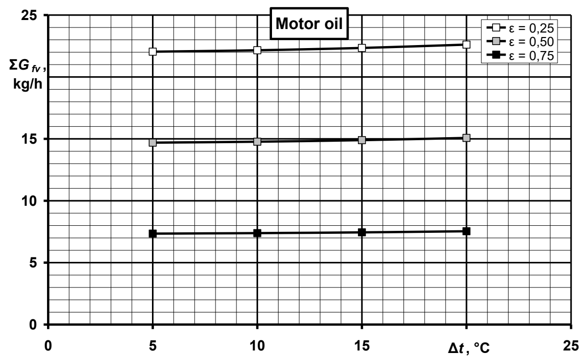


b

Figure 4 – Graphs of dependence of values of total mass hourly emission of diesel fuel vapors on the mechanism of SRB and LRB ΣG_{fv}(DF) (a) and values of total mass hourly emission of gasoline vapors on the mechanism of SRB and LRB ΣG_{fv}(BF) (b) from the values of ε and Δt



a

b

Figure 5 – Graphs of dependence of values of total mass hourly emission of motor oil vapors on the mechanism of SRB and LRB ΣG_{fv}(MO) (a) and total mass hourly emission of vapors of all TCL by the mechanism of SRB and LRB ΣG_{fv} (b) from the values of ε and Δt

At Fig. 6 you may see graphs of dependence of values of total mass hourly emission of vapors of gasoline, motor oil and all TCL, respectively, on the mechanism of SRB and LRB ΣG_{fv}(BF) from the degree of filling the reservoir with liquid fuel ε and the daily temperature difference of atmospheric air Δt. At Fig. 6,a it is seen that the minimum magnitude is the value ΣG_{fv}(BF) = = 7.443 kg/h acquired at ε = 0.75 and Δt = 5 °C, and maximum magnitude is the value ΣG_{fv}(BF) = = 70.328 kg/h acquired at ε = 0.25 and Δt = = 20 °C. At Fig. 7 it is seen that the minimum magnitude is the value ΣG_{fv}(MO) = 7.347 kg/h acquired at ε = 0.75 and Δt = 5 °C, and the maximum magnitude is the value ΣG_{fv}(MO) = 22.614 kg/h acquired at ε = 0.25 and Δt = 20 °C. At Fig. 6,b it is seen that the minimum magnitude is the value ΣG_{fv} = 19.479 kg/h acquired at ε = 0.75 and Δt = 5 °C, and the maximum ΣG_{fv} = = 110.320 kg/h acquired at ε = 0.25 and Δt = 20 °C.

3. Development of high pressure accumulation reservoir for TCL vapors as the executive body of environmental protection technology

Volume of such a reservoir W_{LPR} in m^3 is determined by the total volumetric emission of TCL vapors ΣV_{fv}(k) in m^3/h, the duration of the cycle of accumulation of vapors T_{coll} in hours, defined with the formula (5), and, as we have accepted T_{coll} = 24 hour, then the formula (5) is converted to the formula (6).

Value ΣV_{fv}(k) is determined by the sum of the values of volumetric emissions of TCL V_{fv}(k) in m^3/h, i.e. by formula (7). Values V_{fv}(DF), V_{fv}(BF) and V_{fv}(MO) in turn is the sum of such values for emissions caused by phenomena of SRB $V_{fv}(k)_S$ and LRB $V_{fv}(k)_L$, i.e. by formula (8).

$$W_{LPR} = \Sigma V_{fv}(k) \cdot T_{coll}, \text{ m}^3. \quad (5)$$

$$W_{LPR} = \Sigma V_{fv}(k) \cdot 24, \text{ m}^3. \quad (6)$$

$$\Sigma V_{fv}(k) = V_{fv}(DF) + V_{fv}(BF) + V_{fv}(MO), \text{ m}^3/\text{h}. \quad (7)$$

$$V_{fv}(k) = V_{fv}(k)_S + V_{fv}(k)_L, \text{ m}^3/\text{h}. \quad (8)$$

Volumetric hourly emission values V_{fv}(k) in m^3/h should be obtained at a known mass hourly emission value G_{fv}(k) in kg/h and the density of the vapor mixture of TCL ρ_{fv} in kg/m^3 according to formula (9). To obtain the value of the density of the mixture of vapors of TCL ρ_{fv} in kg/m^3 it can be used the Clapeyron-Mendeleev equation in the form (10). Then the desired value of density ρ_{fv} can be determined by formula (11). Because in the low pressure reservoir vapors of TCL accumulate over time T_{coll} and stored under so-called normal conditions $p_{fv} = p_0$ = 101325 Pa, $T_{fv} = T_0$ = 20 °C (or 293 K), and universal gas constant R = 8.314 J/(mole·K), then the previous formula takes the form (12).

$$V_{fv}(k) = G_{fv}(k) / \rho_{fv}, \text{ m}^3/\text{h}. \quad (9)$$

$$p_{fv} \cdot W_{fv} = m_{fv} / \mu_{fv} \cdot R \cdot T_{fv}. \quad (10)$$

$$\rho_{fv} = m_{fv} / W_{fv} = \mu_{fv} \cdot p_{fv} / (R \cdot T_{fv}), \text{ kg/m}^3. \quad (11)$$

$$\rho_{fv} = \mu_{fv} \cdot p_0 / (R \cdot T_0) = \mu_{fv} \cdot 101325 / (8.314 \cdot 293) = \mu_{fv} \cdot 41.6, \text{ kg/m}^3. \quad (12)$$

To determine the molar mass of mixture of vapors of TCL in a low pressure reservoir, it should be noted that all types of liquids of petroleum origin are mixtures of different hydrocarbons, mainly normal alkanes (saturated) with a chemical formula C_nH_m, where $m = 2 \cdot n + 2$, the typical hydrocarbon in gasoline is octane C_8H_{18}, that is n = 8 and m = 18, in diesel fuel – cetane $C_{16}H_{34}$, that is n = 16 and m = 34, and in motor oil – tetracontan $C_{40}H_{82}$, that is n = 40 and m = 82. Then the molar mass of the hydrocarbon with the chemical formula C_nH_{2n+2} is determined by the formula (13). Therefore, $\mu(C_8H_{18})$ = = 114 g/mole, $\mu(C_{16}H_{34})$ = 226 g/mole, $\mu(C_{40}H_{82})$ = = 562 g/mole. Thus, taking into account the portion composition of the mixture of TCL vapors given above, we have the formula (14). The final value of the value ρ_{fv} is defined by the formula (15).

The value of the mass hourly vapor emission of a single k-th type of TCL G_{fv}(k) in kg/m^3 if available at the oil depot N(k) identical reservoires for their storage, filled to the same part ε(k) and are in the same temperature conditions t(k), from each of which there is a mass hourly emission of vapors $G_{fv}(k)_N = f(\varepsilon(k); t(k))$, should be determined by the formula (16).

$$\mu(C_nH_m) = \mu(C) \cdot n + \mu(H) \cdot m = 12 \cdot n + 1 \cdot m = 12 \cdot n + 1 \cdot (2 \cdot n + 2), \text{ g/mole}. \quad (13)$$

$$\mu_{fv} = \mu(C_{16}H_{34}) \cdot G_{fv}(DF) / G_{fv}(\Sigma) + \mu(C_8H_{18}) \cdot G_{fv}(BF) / G_{fv}(\Sigma) + \mu(C_{40}H_{82}) \cdot G_{fv}(MO) / G_{fv}(\Sigma) = 226 \cdot 0.30 + 114 \cdot 0.50 + 562 \cdot 0.20 = 237.2 \text{ g/mole}. \quad (14)$$

$$\rho_{fv} = \mu_{fv} \cdot 41.6 = 237.2 \cdot 10^{-3} \cdot 41.6 = 9.868 \text{ kg/m}^3. \quad (15)$$

$$G_{fv}(k) = N(k) \cdot G_{fv}(k)_N, \text{ kg/m}^3. \quad (16)$$

The studied oil depot has such reservoirs for storage of TCL N(DF) = 3 psc, N(BF) = 5 psc, N(MO) = 2 psc, all are of the same geometric shape (cylindrical with a diameter of the base D = 10 m and height H = 15 m) and volume W(k), which is determined by the formula (17).

$$W(k) = \pi \cdot D^2 / 4 \cdot H = 3.1416 \cdot 10^2 / 4 \cdot 15 = 1178 \text{ m}^3. \quad (17)$$

The volume of TCL, the emission of which is due to the phenomenon of LRB $V_{fv}(k)_L$, corresponds to the total volume of reservoirs for their storage, divided by the time between full refueling of such reservoirs, i.e. the time of exhaustion of the full volume of stored TCL T_{fill}(k) in hour, defined by the formula (18).

$$V_{fv}(k)_L = W(k) \cdot N(k) / T_{fill}(k), \text{ m}^3/\text{h}. \quad (18)$$

According to time regulations T_{fill}(k) = 3 months = = 12 weeks = 12 · 7 · 24 = 2016 hours and coincides for all of the k-th types of TCL. For gasoline $V_{fv}(BF)_L$ = = 2.922, m^3/h, for diesel fuel $V_{fv}(DF)_L$ = 1.753, m^3/h, for motor oil $V_{fv}(MO)_L$ = 1.169 m^3/h. Then the total volumetric hourly emission of TCL vapors by the mechanism of LRB is determined by the formula (19). Then the total volumetric hourly emission of TCL vapors by the mechanism of LRB is determined by the formula (20). Thus, the volume of such a low pressure reservoir W_{LPR} has the magnitude that is determined by the formula (21).

$$\Sigma V_{fv}(k)_L = V_{fv}(BF)_L + V_{fv}(DF)_L + V_{fv}(MO)_L = 2.922 + 1.753 + 1.169 = 5.844 \text{ m}^3/\text{h}. \quad (19)$$

$$\Sigma G_{fv}(k)_L = \Sigma V_{fv}(k)_L \cdot \rho_{fv} = 5.844 \cdot 9.868 = 57.669 \text{ kg/h}. \quad (20)$$

$$W_{LPR} = \Sigma V_{fv}(k) \cdot T_{coll} = (G_{fv}(DF) + G_{fv}(BF) + G_{fv}(MO)) / \rho_{fv} \cdot T_{coll}, \text{ m}^3. \quad (21)$$

At Fig. 6,a graphs of dependence of values of total volumetric hourly emission of a mixture of vapors of TCL ΣV_{fv}, reduced to normal conditions, from the degree of filling the reservoir with liquid fuel ε and daily temperature difference Δt in normal m^3/h are given.

At Fig. 6,a it is seen that the minimum magnitude is value ΣV_{fv} = 2.220 normal m^3/h acquired for ε = 0.75 and Δt = 5 °C, and the maximum ΣV_{fv} = 16.444 normal m^3/h acquired for ε = 0.25 and Δt = 20 °C.

At Fig. 6,b graphs of dependence of values of total volumetric daily emission of a mixture of vapors of TCL ΣW_{fv}, reduced to normal conditions, from the degree of filling the reservoir with liquid fuel ε and daily temperature difference Δt in normal m^3/age are given.

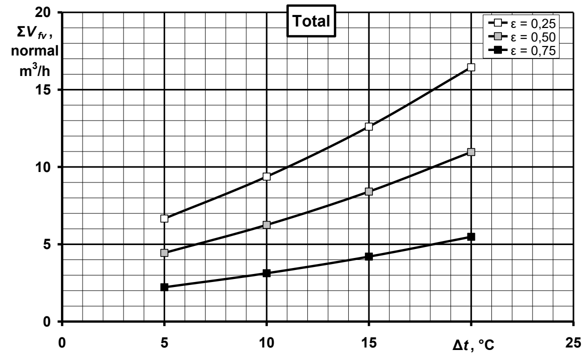
At Fig. 6,b it is seen that the minimum magnitude is the value ΣW_{fv} = 53.285 н.m^3/age acquired for ε = 0.75 and Δt = 5 °C, and the maximum ΣW_{fv} = 394.649 normal m^3/age acquired for ε = 0.25 and Δt = 20 °C.

4. Method of determining the wall thickness of the reservoir

We have carried out the calculation study of the wall thickness of the reservoir based on the theory of strength of closed solid shells, taking into account the mechanical properties of the wall material and the value of the pressure of the gaseous fluid in it. The increase in fluid pressure on Δp leads to additional tension in the reservoir as the pipe, the definition of which is considered during the study of the material disciplines "Resistance of materials" or "Theory of elasticity" [27].

Consider a section of a cylindrical pipe of circular cross section with an inner diameter d and wall thickness δ, loaded with internal pressure (see Fig. 7,a) [27]. A distinction must be made between the stress state of a thin-walled and a thick-walled shell, which can be used to model a real object. A cylinder is considered thick-walled if its wall thickness exceeds 0.1 of the average radius of the cylinder. When calculating thin-walled cylinders, it is assumed that in the circumferential direction the tensions are constant over the wall thickness, and in the radial direction they are absent at all (see Fig.7,b). These assumptions are not valid for thick-walled ones.

Consider the cylinder with an inner radius $r_1 = r = d / 2$ and outer radius $r_2 = r + \delta$. Due to the axial symmetry of the cylinder and the tension and strain loads are also symmetrical about its axis. In a pipe length dz select the element by planes passing through the axis of the cylinder and forming an angle between them dΘ, and two coaxial cylindrical surfaces with radiuses r and r + dr [27].



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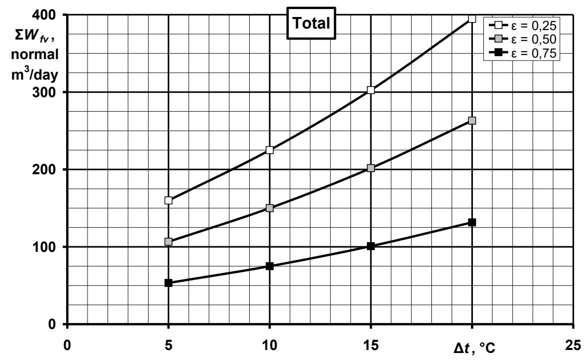


b

Figure 6 – Graphs of dependence of values of total volume hourly emission of a mix of vapors of TCL ΣV_{fv} (a) and total volume daily emission of a mix of vapors of TCL ΣW_{fv} (b), reduced to normal conditions, from the degree of filling the reservoir with liquid fuel ε and daily temperature difference Δt in normal m^3/day

The faces of the element will not be skewed; they are not affected by tangential tensions. Normal tensions on cylindrical surfaces of an element of radiuses r_1 and r_2 are indicated σ_r (radial), on flat faces – σ_Θ (tangential or circumferential). Under internal pressure Δp tensions increase in the interval $r_1 \le r \le r_2$ is described by formulas (22)–(23) [27].

$$\Delta\sigma_r = r_1^2 / (r_2^2 - r_1^2) \cdot (1 - r_2^2 / r^2) \cdot \Delta p, \text{ Pa}, \quad (22)$$

$$\Delta\sigma_\Theta = r_1^2 / (r_2^2 - r_1^2) \cdot (1 + r_2^2 / r^2) \cdot \Delta p, \text{ Pa}. \quad (23)$$

Radial tensions are compressive everywhere, circumferential – tensile, they reach the maximum value on the inner surface of the cylinder (radial modulus is inferior to circumferential) is described by formulas (24)–(26) [27].

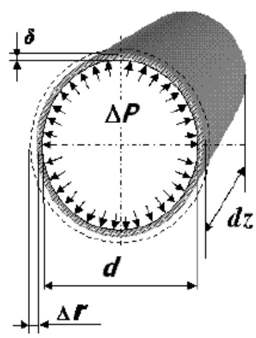
$$\Delta\sigma_r(r = r_1) = -\Delta p, \text{ Pa}, \quad (24)$$

$$\Delta\sigma_\Theta(r = r_1) = (1 + k^2) / (1 - k^2) \cdot \Delta p, \text{ Pa}, \quad (25)$$

$$k = r_1 / r_2. \quad (26)$$

In the absence of longitudinal force N tension σ_z do not occur in cross sections. Then, according to one of the theories of strength, the equivalent tension is determined and the fulfillment of the strength conditions is checked.

Increasing the wall thickness of the reservoir, which in the mathematical sense will mean a decrease in the coefficient k due to the growth of the outer radius r_2, starting with some value, becomes an ineffective way to strengthen the reservoir. Really, for $k = 0.9$ $\Delta\sigma_\Theta = 9.53 \cdot \Delta p$, for $k = 0.8$ $\Delta\sigma_\Theta = 4.56 \cdot \Delta p$, for $k = 0.5$ $\Delta\sigma_\Theta = 1.67 \cdot \Delta p$, for $k = 0.3$ $\Delta\sigma_\Theta = 1.20 \cdot \Delta p$ and then formally with infinite reduction k we receive $\Delta\sigma_\Theta = \Delta p$. However, from the level $k = 0.5$ changes occur at the level of tenths with a significant increase in the size of the reservoir [27].



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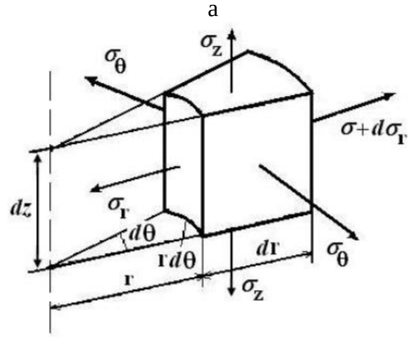


b

Figure 7 – Calculated scheme of the section of the thin-walled cylindrical reservoir (a) and scheme of the stress-strain state of the element of the thin wall of the cylindrical reservoir (b) [27]

Ways to reduce tensions are to use stronger materials or create external pressure on the outer surface of the reservoir. The latter is more theoretical advice than practical, as the operation of reservoirs in real conditions makes certain demands on the designs. More often in systems of storage of fluids under considerable excess pressure there are designs which may, from the point of view of their calculation on durability, be used for thin shells.

For thin-walled cylinders the circumferential tensions σ_Θ remain under the action of internal pressure, the meridional tensions act along the longitudinal axis σ_m, and radial stress σ_r varies from 0 on the outer surface to Δp – on the inner, but it is much inferior to the first two, so they are neglected and we take that the reservoir is in a flat stress state [27].

Due to the thinness of the walls, it is possible to take the appropriate radius of the inner or outer surfaces for calculations [27]. Then we have formulas (27)–(28).

$$\Delta\sigma_\Theta = \Delta p \cdot d / (2 \cdot \delta), \text{ Pa}, \quad (27)$$
$$\Delta\sigma_m = \Delta p \cdot d / (4 \cdot \delta), \text{ Pa}. \quad (28)$$

The relation (28) explains the destruction of pipes along the forming line. As in the previous case, the most dangerous are the circumferential tensions, so their calculations are necessary to determine the consequences of a sharp increase in pressure in the reservoir.

The obtained values of the excess pressure of the mixture of vapors of TCL in the storage reservoir of high pressure Δp depend on the capabilities of the reciprocating compressor placed between it and the low-pressure storage reservoir, and can be used when calculating the wall thickness of the reservoir δ, namely, the condition of strength must meet the condition (29).

$$\sigma \le [\sigma] = \sigma_T \cdot k_z. \quad (29)$$

In the above condition of strength σ_{np} is an indicator that numerically characterizes the mechanical property of the structural material – limit of strength; k_z – strength safety margin factor, in our calculations we accept $k_z = 1.5$.

Then the design calculation for a cylindrical reservoir with a base diameter D, height H and volume W_{HP} should be carried out according to the formula (30).

$$\delta \ge \Delta p \cdot D / (2 \cdot \sigma_T \cdot k_z) = \Delta p \cdot (4 \cdot W_{HP} / (\pi \cdot H))^{1/2} / / (2 \cdot \sigma_T \cdot k_z) = f(\Delta p, \sigma_{np}), \text{ mm}. \quad (30)$$

Magnitude of values σ_T for steel 08 is 196 MPa, for steel 10 is 205 MPa, for steel 15 is 225 MPa, for steel 20 is 245 MPa, for steel 25 is 275 MPa, for steel 30 is 295 MPa, for steel 35 is 315 MPa, for steel 40 is 335 MPa, for steel 45 is 355 MPa, for steel 50 is 375 MPa, for steel 55 is 380 MPa, for steel 60 is 400 MPa [20]. Compressors of different types create excess pressure of the gaseous fluid from 5 to 50 atm, i.e. from 0.5 to 5.0 MPa [28].

The degree of increase in fluid pressure from pressure p_1 to p_2 determined by the formula (31) [28]. The degree of compression of the fluid in the compressor from the volume W_1 to W_2 is determined by the formula (32) [28]. Compression in a reciprocating compressor occurs by a polytropic process, the equation of which is a degree function with a degree n, which is called the polytrope index [28], i.e. formulas (33)–(35) are used. For mixture of vapors of TCL of petroleum origin (mixtures of saturated hydrocarbons) we take $n = 1.4$ [28].

$$\psi = p_2 / p_1. \quad (31)$$
$$\varphi = W_2 / W_1. \quad (32)$$
$$p \cdot W^n = \text{const}, \quad (33)$$
$$p_1 \cdot W_1^n = p_2 \cdot W_2^n, \quad (34)$$
$$\psi = (1 / \varphi)^n. \quad (35)$$

The volume of a portion of a mixture of TCL vapors extracted m times a day from a low-pressure storage reservoir W_{LP}, equal to the volume of such reservoir determined by the formula (36).

$$W_{LP} = \Sigma W_{fv\max} / m, \text{ m}^3. \quad (36)$$

If we accept $m = 8$, which means that the extraction of vapors from the low pressure reservoir to the high pressure reservoir by a reciprocating compressor is carried out every 3 hours, then $W_{LP} = 400 / 8 = 50$ m^3.

Then they need the volume of the high-pressure storage reservoir W_{HP} determined by the formula (37).

$$W_{HP} = W_{LP} \cdot (p_1 / p_2)^n = 50 \cdot (0.1 / p_2)^{1.4}, \text{ m}^3. \quad (37)$$

For $p_2 = 0.5$ MPa $W_{HP} = 2.101$ m^3 (or 2101 l), for $p_2 = 5.0$ MPa $W_{HP} = 0.084$ m^3 (or 84 l), $p_2 = 12$ MPa $W_{HP} = 0.025$ m^3 (or 25 l).

Dependence of the value of the volume of the high-pressure storage reservoir W_{HP} from the desired value of the pressure in it p_2 at different values of the volume of the low pressure storage reservoir W_{LP} (i.e. different number of cycles of vapor extraction per day) and the set value of the pressure in it p_1 are shown at the Fig. 8,a.

In the study it is accepted $p_2 = 2.0$ MPa, then $W_{HP} = 0.754$ m^3 (or 754 l) and round the volume value $W_{HP} = 750$ l. They need to establish the proportions of the main dimensions of the cylindrical reservoir – the diameter of its base D in m and its height H in m. We take the value of the ratio $D / H = 1 / 1.618 = 0.618$ (golden section) for design reasons and information on the size of the site on the territory of the enterprise, which is set aside for the placement of such executive device of EPT. Then at $W_{HP} = 0.750$ m^3 $D = 0.840$ m, and $H = 1.359$ m, round to $D = 0.840$ m and $H = 1.360$ m.

The results of the calculation of the wall thickness of the high pressure reservoir for different types of steel and different values of pressure in it are given at Fig. 8.b.

The mass of the reservoir in the form of a cylindrical barrel with overall dimensions D and H consists of the masses of the bases m_B and side wall m_C is determined taking into account the density of the wall material ρ_{cm} according to formulas (38)–(40).

$$m_{HP} = 2 \cdot m_B + m_C, \text{ kg}, \quad (38)$$
$$m_B = \pi \cdot D^2 / 4 \cdot \delta \cdot \rho_{cm}, \text{ kg}, \quad (39)$$
$$m_C = \pi \cdot (D^2 - (D - 2 \cdot \delta)^2) / 4 \cdot \mathrm{H} \cdot \rho_{cm}, \text{ kg}. \quad (40)$$

In the study the steel 60 with $\sigma_T = 400$ MPa is selected as the material of the reservoir, and therefore at $p_2 = 2.0$ MPa wall thickness δ is 1.4 mm at $k_z = 1.5$.

Influence of the value of the reservoir wall thickness δ on its mass m_{HP} is illustrated at Fig. 9,a. Then the mass of the designed reservoir in the form of a cylindrical barrel m_{HP} is 51.2 kg. Given that the selling price per unit mass is steel now P_{st} is about 20 UAH/kg (or 0.74 $/kg) [29], then the cost of material for the manufacture of 1 reservoir P_{HP} depending on the thickness of its wall δ depends as illustrated at Fig. 9,b. Therefore, the cost of the material for the manufacture of the prepared reservoir P_{HP} is $ 37.95. A sketch of the designed high-pressure storage reservoir for storing a compressed mixture of TCL vapors in the form of a cylindrical barrel is shown at Fig. 10.

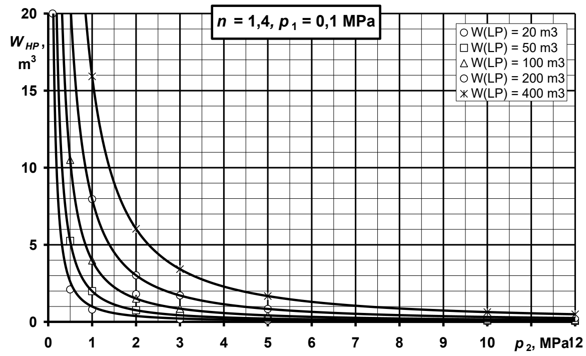
5. Development of combined reservoir for accumulation of the mixture of fuel liquid vapors

Based on the analysis of all the above in the previous results of the study, we may propose the following concept of the design of the combined storage reservoir. Combined reservoir for the accumulation of a mixture of TCL vapors, consists of two cavities – high and low pressure ones. The mixture first enters into the low pressure cavity from the breathing valves of oil storage reservoirs and is stored there at atmospheric pressure. Then it is pumped by a reciprocating compressor into high-pressure reservoir, where is stored at high pressure. Reservoir has the feature that both cavities have a torus-like shape, placed coaxially inside each other – a high-pressure cavity inside the low-pressure one, and along the axis of rotation of the torus there is a cooling cavity with the pipeline of spiral shape, through which air is blown cooling the reciprocating compressor, which pumps a mixture of vapors from the cavity of low pressure into the cavity of high pressure. A sketch of the proposed reservoir is shown at Fig. 10.

It should be emphasized that the scope of development is technogenic and ecological safety, in particular, ensuring regulatory indicators of the level of ES of the storage and distribution of petroleum products. The task of implementing the proposed design concept is solved by improving the cost, layout and mass of the executive device of EPT from volley emissions of TCL of petroleum origin during their centralized storage at the enterprise for distribution of petroleum products caused by phenomena of SRB and LRB, due to the special arrangement of the components of such device and providing the ability to cooling of the compressed vapor mixture in a specially configured pipeline between the cavities of the reservoir and heat the condensate from the heat of the compressed vapor mixture.

The technical result expected in the case of implementation "in metal" of the proposed design concept is as follows: to improve the cost, layout and size of the storage of volley emissions of TCL of petroleum origin, as well as the technical possibility of regulating the temperature of stored high pressure vapor mixture and maintenance the stability of the stored mixture of low pressure vapors.

To complexly overcome the two problems described above, a combined reservoir design is proposed, which is obtained by arranging three cavities of the storage reservoir – low pressure (see mark "A" at Fig. 11), high pressure (see mark "B" at Fig. 11) and cooling (see mark "C" at Fig. 11). The mixture first enters the low-pressure cavity from the breathing valves of oil storage reservoirs through the fitting (see mark "E" at Fig. 11) and the pipe (see mark "D" at Fig. 11) and is stored there at atmospheric pressure (see mark "1" at Fig. 11). Then it is pumped by a reciprocating compressor through the fitting (see mark "F" at Fig. 11) and the outlet hole at the outlet to the low pressure cavity of the reservoir (see mark "G" at Fig. 11) in the high pressure reservoir, where it is stored at high pressure (see mark "2" and "3" at Fig. 11).



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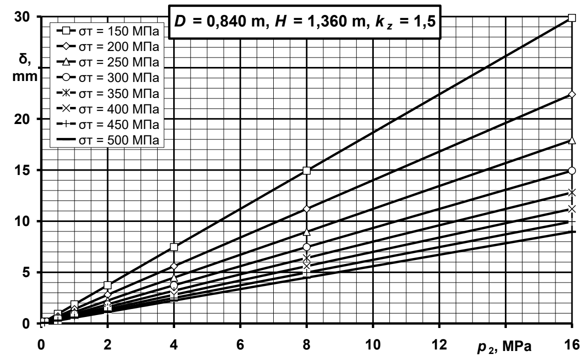

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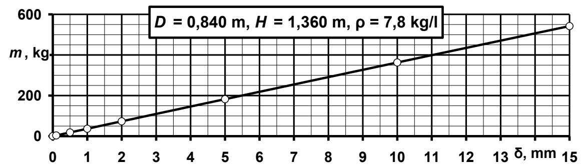
Figure 8 – Graphs of the value of the volume of the storage reservoir of high pressure W_{HP} from the desired value of the pressure in it p_2 at different values of the volume of the low pressure storage reservoir W_{LP} and the set value of pressure in it p_1 (a) and graphs of dependence of values of the minimum wall thickness of the accumulative high-pressure reservoir δ from the value of the fluid pressure in it p_2 and the yield strength of the reservoir material $\sigma_т$ with at D = 0.840 m and k_z = 1.5 (b)



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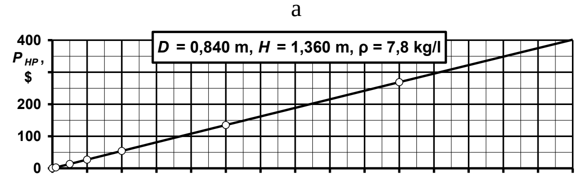

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Figure 9 – Graph of the mass value of the reservoir m_{HP} from the thickness of its wall δ (a) and graph of the price of the material for the manufacture of the reservoir P_{HP} from the thickness of its wall δ (b)

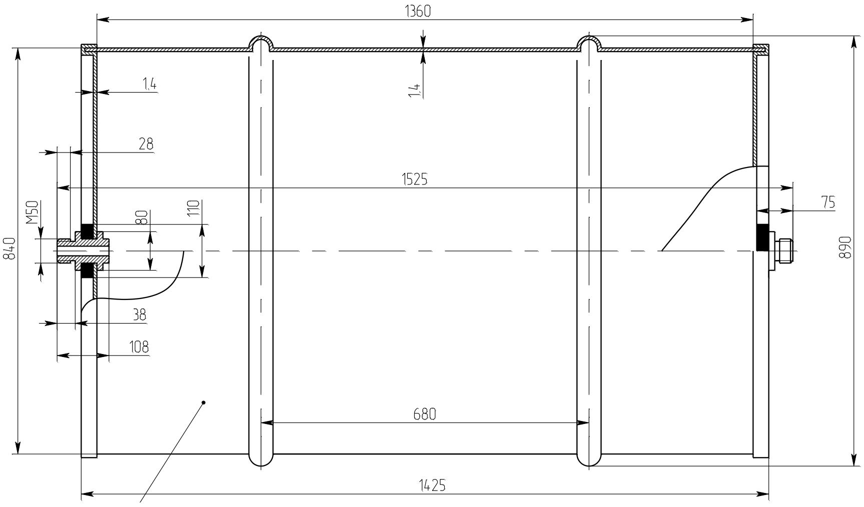
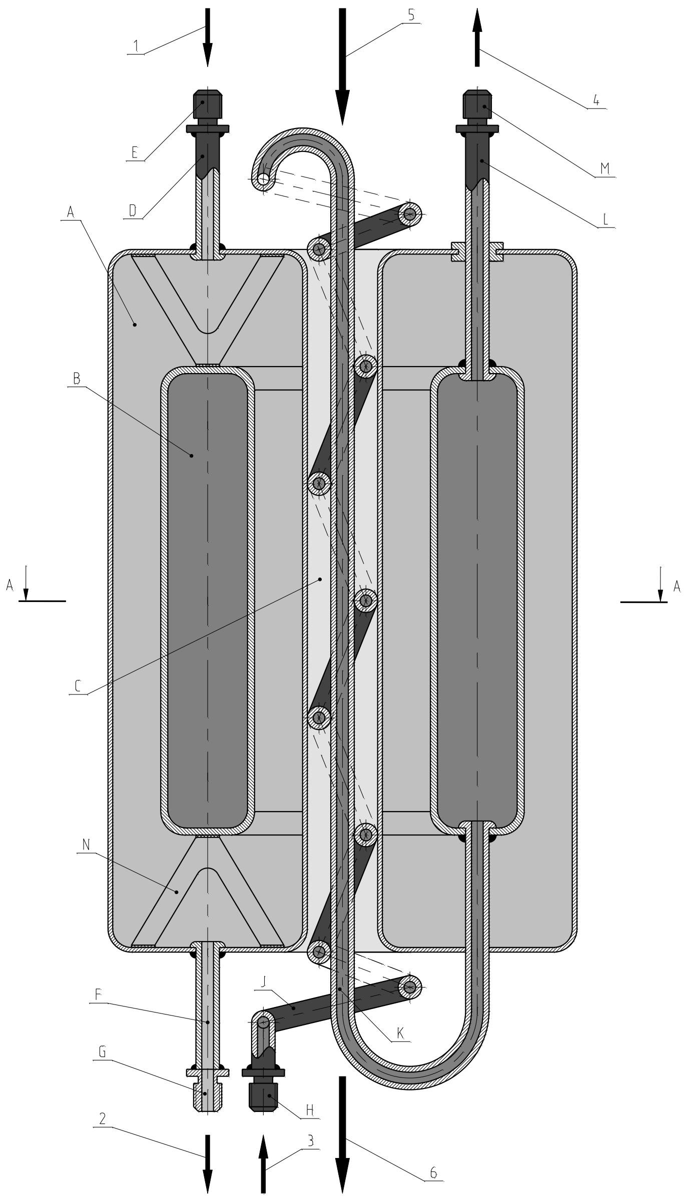


Figure 10 – Sketch of the developed high-pressure storage reservoir for storing of compressed mixture of vapors of TCL in the shape of a cylindrical barrel



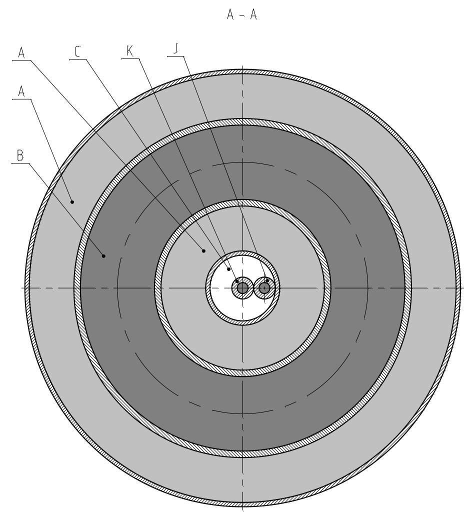


Figure 11 – Sketch of the proposed development of combined tank for the accumulation of a mixture of TCL

A – low pressure cavity of the reservoir; B – high pressure cavity of the reservoir; C – cooling cavity of the reservoir; D – receiving pipe at the entrance to the low pressure cavity of the reservoir; E – fitting of the receiving pipe of the low pressure cavity of the reservoir;
F – outlet hole at the outlet to the cavity of the low pressure reservoir; G – fitting of the outlet pipe of the low pressure cavity of the reservoir; H – fitting of the receiving pipe of the high pressure cavity of the reservoir;
J – coil of the cavity of the cooling cavity of the reservoir;
K – pipeline cavity of the cooling cavity of the reservoir;
L – outlet hole at the outlet to the high pressure cavity of the reservoir; M – fitting of the outlet pipe of the high pressure cavity of the reservoir; N – holding and damping element of the high pressure cavity of the reservoir;

1 – flow of a mixture of vapors of TCL of low pressure from the breathing valves into the cavity of the low pressure of the reservoir;
2 – flow of a mixture of vapors of TCL of low pressure to the reciprocating compressor;
3 – flow of a mixture of vapors of TCL of high pressure from the compressor into the cavity of the high pressure reservoir;
4 – flow of a mixture of vapors of TCL of high pressure to the consumer from the high pressure cavity of the reservoir;
5 – flow of cooling air at the inlet to the cooling cavity of the reservoir;
6 – flow of cooling air at the outlet of the cooling cavity of the reservoir.

Both cavities have a torus-like shape, placed coaxially inside each other – a cavity of high pressure (see mark “A” at Fig. 11) inside the cavity of low (see mark “B” at Fig. 11). Along the axis of symmetry of the torus there is a cooling cavity (see mark “C” at Fig. 11), which houses the pipeline between the cavities of the spiral and straight shape (see mark “J” and “K” at Fig. 11) with a corresponding fitting (see mark “H” at Fig. 11), through which air is blown (see mark “5” and “6” at Fig. 11) cooling the reciprocating compressor, which pumps a mixture of vapors from the cavity of low pressure into the cavity of high pressure.

As needed, the compressed vapor mixture (see mark “4” at Fig. 11) is taken by the consumer from the high pressure cavity through the fitting (see mark “M” at Fig. 11) and the outlet to the high pressure cavity of the reservoir (see mark “L” at Fig. 11). The high-pressure cavity is held in place by an elastic element (see mark “N” at Fig. 11), which also dampens its oscillations. This design provides cooling of the gaseous fluid heated during compression in the reciprocating compressor during pumping between low and high pressure cavities and heating of the condensate formed in the cavities from the heat of the compressed vapor mixture to maintain aggregate stability of the stored vapor mixture.

When moving a mixture of vapors of TCL of petroleum origin as a real viscous compressible fluid in the flowing part of the storage reservoir and its fittings there are hydrodynamic phenomena, the numerical values of which depend on the temperature of these fluids [23], which should be taken into account by electronic control system for the flow of cooling air in the corresponding cavity that washes the configured pipeline.

The obtained positive effects from the implementation of patented constructive measures should be evaluated by conducting a criteria-based assessment [20], based on the results of which it is possible to build feedback in the relevant ESMS.

It also provides regulatory indicators of the level of ES of the operation of the main technological equipment of enterprises for storage and distribution of liquid petroleum products by hydrocarbon content in gas emissions, as well as it provides technical possibility to regulate the temperature of the stored mixture of combustible liquids.

Conclusions

Thus, following main results were obtained in the study.

1. Development, analysis and description of the scheme of EPT for the oil storage were carried out.

The proposed scheme provides for the utilization of vapors of TCL stored at the enterprise, namely diesel fuel, gasoline and motor oil, formed during the manifestation of the phenomena of SRB and LRB in significant quantities. Utilization of the mixture of vapors is carried out by using them as an additional fuel for a solid fuel boiler, the main fuel for which is fuel briquettes. It is also envisaged to obtain such briquettes from solid crushed combustible waste of the enterprise, impregnated with combustible waste of the enterprise. The obtained thermal energy from the solid fuel boiler, cooling of exhaust gases, coolant and engine oil, is converted into electricity and after conversion of its parameters is transferred to the storage or the final consumer. The scheme also envisages cleaning and utilization of by-products of the technology – gaseous (exhaust gases) and solid (ash) and integration into such a system of optional diesel generators, photovoltaic converters and wind turbines.

2. Set of initial data was obtained and the mass hourly emission of TCL vapors was determined by the mechanisms of SRB and LRB during their storage in the oil storage enterprise into the environment according to an improved approach.

It is determined that in total for all TCL stored at the oil depot – diesel fuel in 3 reservoirs, gasoline in 5 reservoirs, motor oil in 2 reservoirs on 1178 m^3 – by the mechanisms of large and small breathing reservoirs for their storage is formed in total 60 kg/h of vapors at the degree of filling of reservoirs 0.50 and daily temperature difference 15 °C, and the maximum value of the total reduced mass hourly emission of vapors of all TCL by both mechanisms is 4236.3 kg/h.

3. The development of a high-pressure storage reservoir for TCL vapors as the executive device of EPT for the oil storage according to an improved approach was carried out.

It is determined that the maximum value of the total hourly volumetric emission of all types of ECL stored at the oil depot is 16.5 m^3/h, and the maximum value of the total daily volumetric emission of all types of TCL – 400 m^3/age. A rational number of extractions of a mixture of TCL vapors from a low-pressure storage reservoir was selected – 8 times, i.e. once every 3 hours, which determines its volume – 50 m^3.

4. The parameters of the reciprocating compressor, which distills the mixture of TCL vapors from the low-pressure storage reservoir to the high-pressure storage reservoir, compressing them, was selected.

It is determined that the pressure in the high-pressure storage reservoir should be 2.0 MPa, and the compression process is a polytrope with a value of degree 1.4, which determines the volume of the high-pressure storage reservoir – 750 l. The shape of the reservoir is chosen – a cylindrical barrel, the ratio of the main dimensions of the reservoir is chosen $D / H = 0.618$ like a golden section.

5. The calculation of the reservoir wall thickness based on the theory of strength of closed solid shells taking was carried out with into account the mechanical properties of the wall material, namely steel 60, and the value of the pressure of the gaseous fluid in it, this value was 1.4 mm. It is determined that weight of the developed reservoir is 51.2 kg, and the cost of materials for its manufacture is 37.95 $. A sketch of a developed high-pressure storage reservoir for storing a compressed mixture of TCL vapors in the form of a cylindrical barrel was developed.

6. The design of a combined reservoir for the accumulation of a volley of a mixture of TCL vapors with a system of intermediate cooling of the mixture after its compression by a reciprocating compressor and the possibility of heating the condensate in the reservoir developed.

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РОЗРОБКА КОМБІНОВАНОГО РЕЗЕРВУАРУ ДЛЯ СУМІШІ ТЕХНІЧНИХ ГОРЮЧИХ РІДИН ЯК КОМПОНЕНТА ТЕХНОЛОГІЇ ЗАХИСТУ СЕРЕДОВИЩА

У цьому дослідженні здійснено розробку, аналіз та описання схеми технології захисту навколишнього середовища для нафтосховища. Запропонована схема передбачає утилізацію парів технічних горючих рідин, що зберігаються на підприємстві, а саме дизельного палива, бензину та моторної олоиви, що утворюються під час прояву явищ малого та великого дихання резервуарів у значних кількостях. Отримано набір вихідних даних та визначено масовий годинний викид таких парів у навколишнє середовище відповідно до вдосконаленого підходу. Розроблено резервуар високого тиску для таких парів, як виконавчий пристрій ТЗНС для нафтосховища згідно з вдосконаленим підходом. Обрано параметри поршневого компресора, який переганяє суміш таких парів з резервуара низького тиску в резервуар високого тиску, стискаючи їх. Виконано розрахунок товщини стінки резервуару на основі теорії міцності закритих суцільних оболонок проводився з урахуванням механічних властивостей матеріалу стіни, а саме сталі 60, і величини тиску газоподібного текучого середовища в ній. Це визначені величини ваги розроблюваного резервуару і вартість матеріалів для його виготовлення. Розроблена конструкція комбінованого резервуара для накопичення залпового викиду суміші таких парів із системою проміжного охолодження суміші після її стиснення поршневим компресором та можливістю нагрівання конденсату у резервуарі.

Ключові слова: екологічна безпека, технології захисту навколишнього середовища, викиди полютантів, пара технічних горючих рідин, велике дихання резервуару, мале дихання резервуару, нафтосховище.

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