The Evaluation of the Influence of Geographic and Meteorological Factors on Heat Transfer in the Case of Crude Oil Storage in Overground Tanks

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The study aims to analyze the main factors that influence the transfer of heat in the case of crude oil storage. A model based on the computing relations taken from specific publications was developed. The case studies were conducted on the basis of experimental research on several oil storage tanks, located in an oil transit station in Romania. The following two cases were analyzed, i.e., when the crude oil is heated and stagnates in the storage tank, and when it only stagnates, respectively. The analysis and application of the developed standard model facilitated the establishing of the factors that influence heat transfer. The influence of the geographic position and meteorological factors was also analyzed, which led to the formulation of conclusions with respect to the heat loss that occurs through the walls of the tanks.

Keywords: tank, crude oil, storage, heat transfer, meteorological factors

We are witnessing unusual climatic changes, characterized by dynamism and extreme phenomena, such as large amounts of precipitation, diurnal changes of atmospheric pressure and temperature, wind speed increase, etc. In Romania there are regulations regarding extreme environmental or meteorological factors and various studies on climate changes [1].

The infrastructure systems for the production, transmission and distribution of natural gas, crude oil, electricity, water, etc. are spread throughout the entire territory of Romania. As a result, their design as well as their operation and management require geographic and climatic parameters.

Climatic parameters represent primary values essential to the energetic evaluation of the energy performance of industrial and/or civil objectives. The climatic parameters are as follows: external air temperature, dew point temperature, wind speed, solar radiation intensity in a horizontal plane, the intensity of the diffuse horizontal radiation, and air absolute and relative humidity [2].

The national oil transportation / distribution system facilitates the transportation of crude oil from national exploitation areas and import to the established refinery checkpoints. It includes pipelines and transit stations. Storage is done in oil exploration and exploitation stations or in crude oil transit stations. The transit station is required for temporary storage in tanks, as well as for crude oil pumping. A transit station consists of the following facilities: crude oil tank parks, pump and related keyboard, decanter, tanks containing industrial water and water in case of fire and other auxiliary facilities. The crude oil is delivered, through discharge, from the pumps to the refineries. As regards the time intervals are concerned, storage can be temporary (conjuncture tanks) or long term (backup tanks).

The thermodynamic storage conditions can be categorized as follows [3, 4]:

-depending on temperature (equal to, less than or greater than the atmospheric temperature);

- depending on pressure (equal to, less than or greater than the atmospheric pressure).

As far as the destination is concerned, crude oil is stored in specific recipients, such as: tanks, cistern cars, tank trucks, drums, cars, etc. Crude oil storage tanks can be classified according to several criteria. From the multitude of possible criteria, only a handful of relevant ones were selected, namely:

- depending on location, tanks can be: aboveground, semi-underground or underground;
- depending on inner fluid pressure: low, medium (< 10 bar) and high atmospheric pressure tanks;
- depending on the temperature of the stored fluid (for warm and refrigeration fluids);
- depending on the insulation (insulated or uninsulated);

In the case of crude oil storage in aboveground tanks, in the context of a transit station, it is necessary to highlight factors that influence heat transfer, including: the quantity of crude oil pumping (pumping scenario), the temperature of the oil in the tank, the thermophysical properties of crude oil (viscosity, gelation temperature, density, thermal conductivity, kinematic viscosity, density, specific heat), the amount of time the crude oil stagnates in the tank and the amount of time the crude oil is pumped.

With regard to the study of heat transfer, the following criteria must be taken into account: the geographical location of the storage tanks, regional climatic parameters and the characteristics of the soil on which the site is located.

The present paper forwards a calculation model that relates to the thermoenergetic analysis of hot crude oil storage in aboveground vertical cylindrical tanks. The calculation model includes first and foremost the equations of mass and energy conservation. The present study relies on a defined outline (imaginary enclosed surface) around the tank, on which the respective ingoing and outgoing flows of mass and energy are applied and analyzed.

Mass conservation equations

The mass flows specific to the outlines of a crude oil storage tank are: crude oil $\Longrightarrow$ crude oil, respectively steam condens. Figure 1 represents the diagram of a mass flow specific to the outlines of a crude oil storage tank, and

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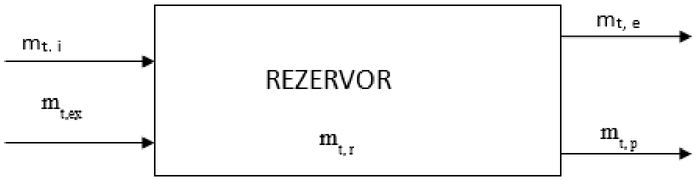

Fig. 1 Schematicrelating to oil mass conservation

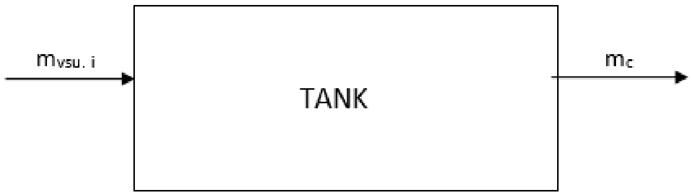

Fig. 2 Schematic of the material result of the steam circuit required for tank heating

figure 2 – the diagram of the material result of the steam circuit required for the heating of the tank.

The mathematical expressions of the equations of mass conservation, for a tank – taking into account the fact that at the time of filling there is oil in the tank and, after evacuation, there still remains a quantity of crude oil in the tank are:

$$m_{t,i} + m_{t,ex} = m_{t,e} + m_{t,r} + m_{t,p} \qquad (1)$$

The equation of conservation of saturated moist vapor mass is as follows:

$$m_{vsu,i} = m_c \qquad (2)$$

The equation of energy conservation, applied to the crude oil storage tank is [3]:

$$Qi = Qe \qquad (3)$$

where Q_i is the ingoing energy and is comprised of all energy forms or energy exchange forms that are introduced or generated by the chosen thermal outline and Q_e - energy upon discharge, comprising all the thermal energies that are discharged, i.e., are dissipated (lost) from the outline into the environment.

Figure 3 details the main constructive dimensions and sizes of the thermal calculation for a tank of heated product.

The energies and forms of energy exchange upon entering the outline are the following:

$$Qi = Q_{t,i} + Q_{vsu,i} + Q_{t,ex} \qquad (4)$$

- The sensitive heat that is introduced with the crude oil is calculated as follows: [5]:

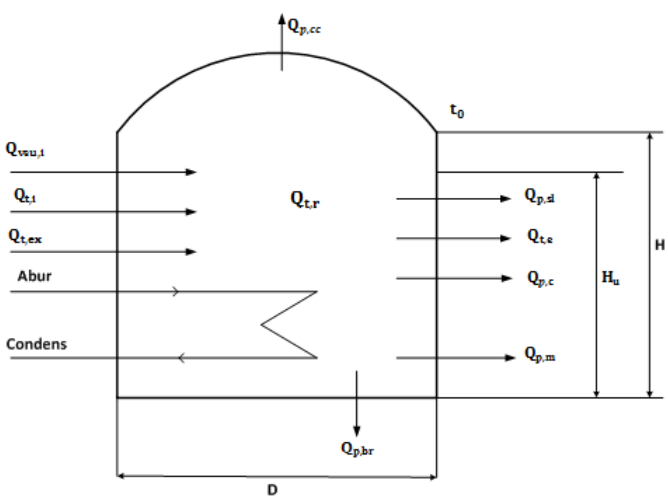

Fig. 3 Overground tank for heated crude oil storage

$$Q_{t,i} = m_{t,i} \cdot h_{t,i} = m_{t,i} \cdot c_{p,t} \cdot t_{t,i} \qquad (5)$$

- The heat of the saturated moist vapors:

$$Q_{vsu,i} = m_{vsu,i}\, h_{v\,abur\,sat.umed} \qquad (6)$$

where saturated steam enthalpy is obtained from the relation [5]:

$$h_{v\,abur\,saturat\,umed} = h' + x\,(h'' - h') \qquad (7)$$

- The initial heat of the crude oil already in the tank at the start of the filling operation:

$$Q_{t,ex} = m_{t,ex} \cdot h_{t,ex} = m_{t,ex} \cdot c_{p,t,ex} \cdot t_{t,ex} \qquad (8)$$

The energies and energy exchange forms upon discharge from the outline are:

$$Qe = Q_{t,r} + Q_{t,e} + Q_{p,c} + Q_{p,s} + Q_{p,m} \qquad (9)$$

- Heat $Q_{t,e}$ necessary for the heating of mass , kg upon tank discharge is:

$$Q_{t,e} = m_{t,e} \cdot h_{t,e} = m_{t,e} \cdot c_{p,t} \cdot t_{t,e} \qquad (10)$$

The heat dissipated from the crude oil in the tank into the environment

- $QP_{surface}$ heat dissipated from the tank into the environment is calculated as follows:

$$Q_{p,s} = \dot{Q}_{p,s} \cdot \tau_{stationare} \qquad (11)$$

$$\dot{Q}_{p,s} = \dot{Q}_{p,sl} + \dot{Q}_{p,cc} + \dot{Q}_{p,br} \qquad (12)$$

$$\dot{Q}_{p,sl} = k_{sl} \cdot S_{sl}(t_{t,rez} - t_0) \qquad (13)$$

The terms involved in relations (11)…(13) are the overall coefficient of heat exchange k_{sl} through the lateral surface is calculated using the relation [5]:

$$k_{sl} = \frac{1}{\frac{1}{\alpha_{int}} + \frac{\delta}{\lambda} + \frac{1}{\alpha_{ext}}} \qquad (14)$$

The wall-environment convection coefficient, α_{ext}, is calculated using the following relation:

$$\alpha_{ext} = 10 + 6\sqrt{v} \qquad (15)$$

The lateral surface S_{sl} is the area of the side of a cylinder of radius equal to the radius of the tank and with a tank height of 0.8 of the height (the degree of filling is approximately 80%).

$$S_{sl} = 2\pi R \cdot H_u = 2\pi R \cdot 0.8 \cdot H \qquad (16)$$

$$\dot{Q}_{p,cc} = k_{cc} \cdot S_{cc}(t_{t,rez} - t_0) \qquad (17)$$

The overall coefficient of heat exchange through the top, k_{cc} is calculated using the relation:

$$k_{cc} = \frac{1}{\frac{1}{\alpha_{t-g}} + \frac{1}{\alpha_{g-cc}} + \frac{\delta}{\lambda} + \frac{1}{\alpha_{cc-pl}}} \qquad (18)$$

The product-atmospheric gas convection coefficient, α_{t-g}, is calculated using the relation:

$$\alpha_{t-g} = 3.26 + \sqrt[4]{t_{t,rez} - t_g} \qquad (19)$$

The gas atmosphere-top convection coefficient, α_{g-cc} is calculated using the relation below:

$$\alpha_{g-cc} = 1.31 + \sqrt[4]{t_g - t_{cc}} \quad (20)$$

Top temperature t_{cc} is determined as an arithmetic mean between gas temperature, t_g, and environment temperature, t_0.

The top-lateral wall convection coefficient, α_{cc-pl}, is calculated using the following relation:

$$\alpha_{cc-pl} = 3.26 + \sqrt[4]{t_{cc} - t_0} \quad (21)$$

$$S_{cc} = \pi R^2 + 2\pi R \cdot (H - H_u) \quad (22)$$

$$\dot{Q}_{p,br} = k_{br} \cdot S_{br}(t_{t,rez} - t_{sol}) \quad (23)$$

$$S_{br} = \pi R^2 \quad (24)$$

Calculation relations (15)...(21) are derived from [6]. It is also worthwhile to mention that no paraffin was formed upon product depositing under the analyzed conditions.

- The heat discharged with condensation:

$$Qp_c = m_c \cdot h_{c,g} = m_c \cdot c_{p,apa} \cdot t_{c,g} \quad (25)$$

- The heat dissipated due to mass loss:

$$Qp_m = m_{p,m,t} \cdot h_{p,m,t} = m_{p,m,t} \cdot c_{p,t} \cdot t_{t,i} \quad (26)$$

- $Q_{t,r}$ - heat of the oil left in the tank after crude oil discharge:

$$Q_{t,r} = m_{t,r} \cdot h_{t,r} = m_{t,r} \cdot c_{p,t} \cdot t_{t,r} \quad (27)$$

Experimental part

On the basis of the mathematical model, the evaluation of the influence of two of the climatic parameters upon heat transfer is required: outside air temperature, $t_{ext,}$ and wind speed, *v.*

From the point of view of conventional external calculation temperatures, Romania can be divided into four areas, listed in table 1. Depending on wind speed, Romania is comprised of four areas. Conventional wind speed values depending on the area and the location of the facility in regard to the area are presented in table 2 [1].

The evaluation was carried out for the four temperature values corresponding to the four temperature zones and, respectively, for the four wind speed values corresponding to the four areas, in the context of a transit station, located outside the city, which temporarily stores crude oil in two tanks, A and B.

The technical characteristics of crude oil storage tanks (fig. 4) are presented in table 3.

During the investigation period, X type crude oil was stored in tank A and in tank B Y type crude oil. The

Table 1

EXTERNAL CALCULATION TEMPERATURES

Area	Temperature, °C
I	-12
II	-15
III	-18
IV	-21

Table 2

WIND SPEED [1]

Wind area	Location			
	locality		outside	
	v, m/s	v, km/h	v, m/s	v, km/h
I	8	28.8	10	36
II	5	18	7	25.2
III	4.5	16.2	6	21.6
IV	4	14.4	4	14.4

Fig. 4 Crude oil storage tanks which have undergone experimental research

Table 3

TECHNICAL CHARACTERISTICS OF CRUDE OIL STORAGE TANKS, SUBJECTED TO INVESTIGATION

Characteristics		Tank A	Tank B
Main dimensions	Diameter, m	15.50	12.35
	Height, m	11.08	8.87
Effective capacity, m^3		1898	1049
Cover type		fixed	fixed
No. Shells sheet		5	6
Shells sheet mounting		Rivets	Welding
Thick shells sheet, m		0.015	0.015
Material		OL 37.4K STAS 500/2-68	OL 37.4K STAS 500/2-68
Foundation		Sand	Sand
No. Safety valves		1	1
No. Flame arresters		1	1
Valves and flame arresters diameter, inch		4	1
Shells sheet thermal conductivity, W/m K		57	57

Table 4

THERMOPHYSICIAL PROPERTIES OF STORED CRUDE OIL TYES

Property	Symbol, Measure Unit	Tank	
		A	B
Oil density	ρ, kg/m^3	847.5	846.2
Relative density	ρ_4^{20},-	0.8475	0.8462
Relative density of the oil remaining in the tank at the time of filling	ρ_4^{20},-	0.8473	0.8460

Characteristic	Symbol, Measure Unit	Tank	
		A	B
Saturated steam parameters at p = 2 bar (t = 120,23°C)	h', kJ/kg	504.8	
	h'', kJ/kg	2707	
Title wet saturated vapor	-	0.8	
Pressure	p, bar	1	
Steam absolute pressure	p_{ab}, bar	2	
Temperature	°C	110 - 150	
Mass flow of saturated wet steam	$\dot{m}_{v,i}$, t/h	0.1	0.15
Output condenser water temperature	$t_{c\ e}$, °C	40	

Table 5
CHARACTERISTICS OF THE HEATING AGENT

characteristics of the crude oil types stored in storage tanks are detailed in table 4.

So as to be able to heat the crude oil, the storage tanks are equipped with internal steam coils. The moist saturated steam, (table 5) is being produced by ABA 0.7-type boilers.

Taking into consideration the fact that crude oil undergoes two types of processes while inside the storage tank, the heat transfer for both stages was analyzed:

- Stage 1 - storage stage for tank A
- Stage 2 - storage and heating stage for tank B.

Table 6 conveys production data for the first status, whereas table 7 – for the second type of status. The

Table 6
THE CHARACTERISTICS OF THE PERIOD IN WHICH THE EXPERIMENTAL RESEARCH WAS CONDUCTED (STATIONARY STATUS)

Tank	Oil Type	Date / hour	Operations Performed	Pumping Interval	Amount Received, t	Amount Pumped, t	Tank Level,cm
A	X	13.01.2015/12:00 13.01.2015/17:15	Power tank		235		357 504
A	X	14.01.2015/4:00 14.01.2015/8:00	Drain tank	4:00 – 8:00		104 (with one pump)	504 438

Table 7
THE CHARACTERISTICS OF THE PERIOD IN WHICH THE EXPERIMENTAL RESEARCH WAS CONDUCTED (STATIONARY AND HEATING STATUS)

Tank	Oil Type	Date / hour	Operations Performed	Pumping Interval	Amount Received, t	Amount Pumped,t	Tank Level cm
B	Y	12.12.2014/14:25 12.12.2014/21:00	Power tank		322		42 364
B	Y	12.12.2014/23:58 12.12.2014/8:00	Drain tank	23:58-8:00		319 (Gravity drain)	364 45

No.	Investigations	Symbol, Measure Unit	Tank	
			A	B
1	Oil temperature input	$t_{t,i}$, °C	27	19
2	Oil output temperature	$t_{t,e}$, °C	27	20.25
3	Oil temperature in the tank	$t_{t\ ex}$, °C	30	16
4	Temperature of oil remaining in the tank	$t_{t\ r}$, °C	27	20.25
5	Temperature of the oil in the tank, after filling	$t_{t,rez}$, °C	27	20.25
6	Time filling tank	τ_u, min	195	405
7	Time emptying the tank	τ_e, min	240	482
8	Time stationary oil	$\tau_{stationare}$, min	645	-
9	Time heating oil	$\tau_{incalzire}$, min	-	1045
10	Outside air temperature	t_{ext}, °C	-2	-2.25
11	Soil temperature	t_{sol}, 0C	0	0
12	Tank level	Before filling, cm	357	42
		Filled, cm	504	364
		After discharge, cm	438	45
13	Oil amount received	$m_{t,i}$, t	235	322
14	Oil amount discharged	$m_{t,e}$, t	104	319
15	Measurements to calculate heat dissipation from the tank to the environment	H, m	11.08	8.87
		H_u, m	8.86	7.096
		R, m	7.75	6.175

Table 8
EXPERIMENTAL INVESTIGATION RESULTS

measurements shown in table 8 were carried out in order to complete the research investigations.

As far as the analysis of the influence of wind speed on heat exchange is concerned, the study made use of the value of the coefficient of convection between the product and the lateral wall of the tank, α_{int}=24.7W/m$^{2}\cdot$K.

For the analysis of the influence of temperature on heat transfer the overall coefficient of heat exchange for the lateral surface was taken into consideration, k_{sl}=10W/m$^{2}\cdot$K. As far as the analysis of the influence of wind speed is concerned, the overall coefficient of heat exchange was calculated according to relation 14. The overall coefficient of heat exchange for the top was calculated according to relations (18)... (21) [6]. The temperature of the gas atmosphere from the reservoir was determined via interpolation. The heat exchange coefficient for the tank was considered to be as follows: k_{br}=0.13W/m$^{2}\cdot$K. [6].

The heat dissipation through the walls of the tanks, calculated for the average temperature of -2°C, as recorded during experimental research, is detailed in table 10.

Results and discussions

The results of the calculations relating to the components of the equations of mass and energy conservation are presented in table 9.

The calculation results relating to the components of the crude oil mass balance and, respectively, of saturated moist vapors are shown in tables 11 and 12. Table 13

Table 9
THE RESULTS OF THE PROPOSED CALCULATION MODEL

No.	Name	Symbol, Measure unit	Tank	
			A	B
1	Specific heat at constant pressure, of the oil at the input	$c_{p,t,i}$, J/kg K	1930.28	1902.36
2	Specific heat at constant pressure of the existing oil	$c_{p,t,ex}$, J/kg K	1941.52	1891.56
3	Specific heat at constant pressure of the remaining oil in tank	$c_{p,t,r}$, J/kg K	1930.28	1906.96
4	Specific heat at constant pressure, of the oil to discharge	$c_{p,t,e}$, J/kg K	1930.28	1906.96
5	Oil input enthalpy	$h_{t,i}$, kJ/kg	52.118	36.144
6	Oil discharge enthalpy	$h_{t,e}$,kJ/kg	52.118	38.615
7	Enthalpy of oil remaining in the tank	$h_{t,r}$, kJ/kg	52.118	38.615
8	Enthalpy oil in the tank	$h_{t,ex}$, kJ/kg	52.245	30.264
9	Weight oil losses	$m_{t,p}$, kg	671.2	303.68
10	Weight oil in the tank	$m_{t,ex}$,kg	570766.7	42562.26
11	Weight oil remaining in the tank	$m_{t,r}$, kg	700433.3	45610.18
12	Occupied volume by existing oil before filling the tank	$V_{t,ex}$, m^3	673.63	50.31
13	Occupied volume by oil remaining in the tank, after draining	$V_{t,r}$, m^3	826.47	53.9
14	Saturated wet vapour enthalpy	h_{vsu},kJ/kg	2266.56	2266.56
15	Enthalpy of condenser water output	$h_{c,e}$, kJ/kg	167.2	167.2
16	Specific heat of water	$c_{p,apa}$ kJ/kg K	4.18	4.18
17	Enthalpy of loss weight oil	$h_{p,m,t}$ kJ/kg	52.118	36.144
18	Lateral surface of tank	$S_{s,l}$, m^2	431.63	275.32
19	Top surface of tank	S_{cc}, m^2	482.8	188.62
20	Base surface of tank	S_{br}, m^2	188.69	119.79

Table 10
CALCULATION RESULTS OF HEAT DISSIPATION THROUGH TANK WALLS

Heat loss	Measure unit	Tank A	Tank B
$\dot{Q}_{p,sl}$	W	125172.7	61947
$\dot{Q}_{p,cc}$	W	21001.8	6365.9
$\dot{Q}_{p,br}$	W	662.3	315.35
TOTAL	W	146836.8	68628.25

Mass	Symbol	Measure unit	Tank A	Tank B
INPUT				
Oil input	$m_{t,i}$	kg	235000	322510.92
		%	29.16	88.34
Weight oil in the tank	$m_{t,ex}$	kg	570766.7	42562.26
		%	70.84	11.66
Total input	m_i	kg	805766.7	365073.18
		%	100	100
OUTPUT				
Oil discharge	$m_{t,e}$	kg	104000	319000
		%	12.91	87.38
Oil remaining in the tank	$m_{t,r}$	kg	700433.3	45610.18
		%	86.93	12.49
Oil losses	$m_{p,t}$	kg	671.2	463
		%	0.08	0.13
Total output	m_e	kg	805766.7	365073.18
		%	100	100

Table 11
COMPONENTS SPECIFIC TO THE CRUDE OIL MASS BALANCE

Mass	Symbol	U. M.	Tank A	Tank B
INPUT				
Saturated wet vapour	$m_{vsu,i}$	kg	1075	2611.5
		%	100	100
Total input	m_i	kg	1075	2611.5
		%	100	100
OUTPUT				
Condenser water	m_c	kg	1075	2611.5
		%	100	100
Total output	m_e	kg	1075	2611.5
		%	100	100

Table 12
QUANTITIES CORRESPONDING TO THE MASS BALANCE OF MOIST SATURATED VAPORS

Table 13
THE RESULTS OF THE APPLICATION OF THE EQUATIONS FOR THE CONSERVATION OF ENERGY.

Thermal energy		Measure unit	Tank A	Tank B
INPUT				
Sensible heat introduced with oil	$Q_{t,i}$	kJ	12247626	11638638.48
		%	25.55	61.75
Saturated wet vapour heat	$Q_{vsu,i}$	kJ	2436552	5919121.44
		%	5.08	31.41
Existing oil heat	$Q_{t,ex}$	kJ	33244648.9	1288145.096
		%	69.37	6.84
Total input	Qi	kJ	47928826.9	18845905.02
		%	100	100
OUTPUT				
Oil evacuated heat	$Q_{t,e}$	kJ	5420226	12318484.86
		%	11.31	65.36
Oil left in the tank heat	$Q_{t,r}$	kJ	36504858.9	1761279.97
		%	76.16	9.35
Loss weight heat	$Q_{p,m}$	kJ	34970.88	16734.8
		%	0.07	0.09
Dissipated to tank walls heat	$Q_{p,s}$	kJ	5682584.16	4302991.28
		%	11.86	22.83
Condenser water heat	$Q_{p,c}$	kJ	179740	436642.8
		%	0.38	2.32
Other heat losses	Q_{ap}	kJ	106447	9771.31
		%	0.22	0.05
Total output	Qe	kJ	47928826.9	18845905.02
		%	100	100

Table 14
HEAT FLOW DISSIPATED THROUGH THE WALLS OF THE TANKS

Heat dissipation		Temperature area			
		I	II	III	IV
$\dot{Q}_{p,sl}$, W	Tank A	168335.7	181284.6	194233.5	207182.4
	Tank B	107374.8	115634.4	123894	132153.6
$\dot{Q}_{p,cc}$, W	Tank A	26172.59	28591.41	31068.18	33834.62
	Tank B	10225.09	11170	12137.7	13218.49
$\dot{Q}_{p,br}$, W	Tank A	662.3			
	Tank B	315.35			
Total	Tank A	195170.59	210528.31	225963.98	241679.32
	Tank B	117915.24	127119.75	136347.05	145687.44

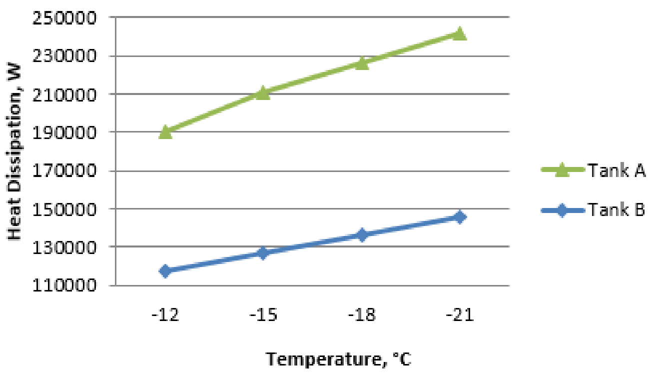

Fig.5. Heat dissipation variation with temperature, for analysed tanks

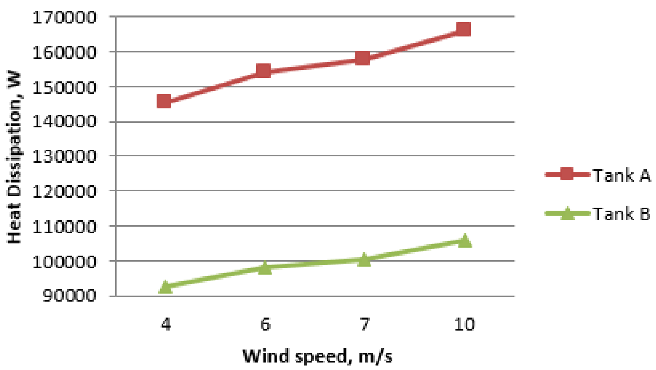

Fig. 6. Heat dissipation variation determined by wind speed for analysed tanks

Table 15
HEAT DISSIPATION THROUGH THE TANK WALLS DETERMINED BY WIND AREAS

Wind area	α_{wall}, W/m² K	k, W/m² K	$\dot{Q}_{p,sl}$, W	
			Tank A	Tank B
I	28.97	13.28	166229.34	106031.24
II	25.87	12.59	157592.43	100522.08
III	24.69	12.30	153962.42	98206.64
IV	22	11.60	145200.33	92617.65

includes the results of the application of the equations for the conservation of energy.

Heat dissipation through the walls of the tanks calculated for each analyzed temperature climate zone (according to table 1) is detailed in table 14. These correlations are subsequently detailed in figures 5.

Heat dissipation for the two tanks through the lateral surface, determined for each wind area, is detailed in table 15. The variation determined by wind speed is presented in figure 6 for tanks A and B.

Conclusions

The investigations carried out have necessitated significant financial efforts and competent personnel involved in these activities.

The proposed calculation model, based on relations from the literature, enables detection of the factors that heat transfer depends on in the case of warm product storage in a cylindrical aboveground tank.

Thus, the influence of temperature and wind speed can be evaluated.

It has been found that an increase of wind speed to 4 m/s (14.4 km/h) up to 10 m/s (36 km/h) results in an outward increase in heat dissipation from approx. 145.2 kW up to 166.2 kW for tank A and from approx. 92.6 kW up to 106.03 kW for tank B.

The lowering of the exterior temperature from -12°C to -21°C has led to an increase in heat dissipation through the tank walls from approx. 195.2 kW to 241.7 kW for tank A and from approx. 117.9 kW to 145.7 kW for tank B.

Both the design and operation of industrial and civil constructions alike require the evaluation of the influence of meteorological factors. Energy management and the energy saving strategies of companies are considerably influenced by such an evaluation.

The highlighting of factors that influence heat transfer in the case of crude oil storage in tanks and the case studies regarding the importance of heat dissipation caused by the geographical and climatic conditions are deemed useful in such cases.

Nomenclature

c_p – Specific heat, kJ/(kg K)
h – Mass enthalpy, kJ/kg
h' – Saturated liquid enthalpy, kJ/kg
h'' – Dry saturated vapor enthalpy, kJ/kg
k – Overall cofficient of heat transfer, W/(m² K)
H – Height, m
m – mass, kg
$\dot{m}$ – mass flow, kg/s
Q – Thermal energy, J
$\dot{Q}$ – Thermal flow, W
T – Temperature, K
R – Tank radius, m
x – Title wet saturated vapor, -
v – wind speed, m/s

Greek letter

α – convection coefficient, W/(m² K)
δ – thickness, m

λ – thermal conductivity, W/(m K)
τ – time, s

Simbol subscript

ap – other losses
apa – water
br –tank base
c – condens
cc - cap
e – exit
ex – existing
ext – external
g - gas
i – input
int- internal
m – mass
p – loss
pl - side wall
r –remaining
rez – tank
s – area
sl – lateral area
sol - soil
t – oil
u – wet
v – vapour
vsu – wet saturated vapor.

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