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Reducing the evaporation of stored Iraqi crude oil

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Abstract

In order to reduce the losses due to evaporation in the stored crude oil and minimizing the decrease in °API many affecting parameters were studied (i.e. Different storage system, namely batch system with different types of storage tanks under different temperatures and:or different pressures). Continuous circulation storage system was also studied. It was found that increasing pressure of the inert gas from 1 bar to 8 bar over the surface of the crude oil will decrease the percentage losses due to evaporation by (0.016%) and decrease the change of °API by (0.9) during 96 hours storage time. Similarly using covering by surfactant (potassium oleate) or using polymer (polyurethane foam) decreases the percentage evaporation losses compared with uncovered surface of the blend crude oil. In each surfactants and polymers the layer thickness was (1.0, 1.5, 2.0, 2.5, 3.0 cm), and increasing the thickness of the surfactant to 2.5 cm or of the polymer to 3 cm was found to be best required thickness. Surfactant gave lower percentage evaporation losses than polymer, for fixed roof tank (i.e. 0.299%, 0.383%) for 120 hours evaporation time. Different processed storage tanks namely (fixed roof, external moving roof, fixed and internal moving) were studied and fixed and moving roof was the best in reducing evaporation losses (0.453%) for 120 hours. In continuous circulation for proposed continuous storage system, the percentage evaporation losses for covered with surfactant, covered with polymer, and uncovered surface of blend crude oil were (0.328%), (0.378%), and (0.45%) respectively at 24 °C for 96 hours evaporation time.

Introduction

During storage the losses due to evaporation occurred which means high cost losses especially when the oil prices are high, and also causes pollution. Different types of the storage tanks to minimize hydrocarbons evaporation losses were designed [1, 2], since for example there are half million storage tanks in USA. Other techniques cooling of the surface of the storage tanks by showering water over them with water. This process is still be used now. Painting the external metallic of the storage tank with white paint in order to reflect the heat coming from the sun light. Heat insulation materials are used to minimize the percentage evaporation losses. There are different types of losses such as filling losses (working losses), running losses, breathing losses [3, 4]. Different internal design of storage tanks were considered, similarly different types of polymers were used to minimize evaporation losses. Also different surfactants were used to reduce evaporation. Continuous circulation of the crude oil will increase evaporation losses. In order to capture the volatile escaped, vapour were collected from special vents, cooling the condensed liquid again before recycling to the storage tanks.

Experimental Work

Aim of the Work

1- Decreasing Iraq crude oil evaporation in the storage tank.
2- Studying the effectiveness of Different types of surfactant and polymers to prevent crude oil evaporation.
3- Studying the effect of different storage conditions (i.e. temperature, pressure, space volume, and storage type).
4- Studying the effects of storage type and recycling crude.

Materials Used

1- Iraqi blends crude oil from Dura refinery.
2- Polyurethane foam.
3- Potassium Oleate ($C_{17}H_{33}COOK$).

Apparatus

The apparatus composed of:

1- Cylindrical iron fixed roof storage tank (13.5 cm inside diameter, 14cm outside diameter and 39.5 cm high) which contains cone cover of five hatches in the top of the tank for gas inlet, Digital thermometer, Pressure gauge , one inlet to the tank and one outlet from the tank.
2- Cylindrical iron external moving roof storage tank (13.5 cm inside diameter, 14cm outside diameter and 39.5 cm high) which contains flat external moving roof with its controller.
3- Cylindrical iron fixed and internal moving roof storage tank (13.5 cm inside diameter, 14cm outside diameter and 39.5 cm high) which contains two roofs. One roof is cone cover of five hatches in the top of the tank for gas inlet, Digital thermometer and Pressure gauge and the other roof is flat internal moving roof with its controller.
4- Cylindrical iron storage tanks with different inside diameters (i.e. 12.5 cm, 10 cm, 8.5 cm) which contains flat cover with three hatches in the top of the tank for digital thermometer, pressure gauge, and vent.
5- Water bath.
6- Tank (QVF).
7- Pumps.

Surfactant Testing

The surfactants which were used must not react with crude oil and float on its surface. Therefore, many types of surfactants were tested (which are listed in the used material). 500 ml of blend crude oil was put in each beaker (800ml) and covered with a layer of surfactant and left there for 24 hours. One type of surfactant (potassium oleate) succeeded experimentally. Similarly one type of polymer (polyurethane foam) also succeeds experimentally.

Layer Thickness

Evaporation losses were studied using different polymer thickness and different surfactant thickness (1, 1.5, 2.0, 2.5, and 3.0) cm. The time in each experiment was 24 hours. Differences in Weights of crude oil between before and after the experiment indicate the percentage evaporation losses.

Evaporation Time

Three litters of blend crude oil were put in cylindrical tank with diameter (13.5 cm). Sensitive balance was used to weigh the crude oil at time zero. Then, weighing the crude oil was carried after leaving it for different accumulative times (24, 48, 72, 96, 120) hours. The differences in weight at time zero and the weight at other accumulative times represent the percentage evaporation losses. The crude oil was covered with either potassium oleate surfactant (2.5 cm) thickness or polyurethane foam (3.0 cm) thickness. The differences in weights before and after different accumulative times were evaluated. After each run the (API) gravity was measured using picknometer device (ASTM IP 120/64). Three types of tanks were studied. Similar experimental procedure were used for external moving roof tank and fixed and internal moving roof tank as those described above for fixed roof tank. In external moving roof tank the top roof is moving up and down so that it can cover and close the opening of the tank. Fixed and internal moving roof tank contains two roofs. One movable roof covers the surface of the crude oil and the second roof covers the opening of the tank.

Temperatures of Crude Oil

Three litters of blend crude oil were put in cylindrical tank at constant temperature using water path for 24 hours, and Covered with either potassium oleate surfactant (2.5cm) thickness or polyurethane foam polymer (3.0cm) thickness or uncovered at different Temperatures. Digital thermometer was used to measure crude oil temperature (i.e. 16, 40, 50, 60, 70) °C. Percentage evaporation losses were measured in each case.

Space height above Crude Oil

Different space height (11.5, 18.5, 25, 32)cm, that is different space volumes (1644.5, 2645.5, 3575, 4576) cm^3 were used for studying evaporation losses in tank with and without polyurethane foam or with or without potassium oleate after 24 hours in each experimental tests. Evaporation losses were calculated from the difference of weights of crude oil before and after each experimental test.

Surface Area Effect

Storage tanks of different diameters (8.5, 10.5, 12.5 and 13.5) cm, that is different surface areas (56.7, 78.5, 122.6, 143) cm^2 and different quantity of crude oil covered with either potassium oleate surfactant (2.5cm) thickness or polyurethane foam (3.0cm) thickness or uncovered and at constant space volumes were studied for 24 hours.

Tank Pressure

Storage tank with three liters of blend crude oil covered with either potassium oleate surfactant or polyurethane foam polymer or uncovered were subjected to different Pressure (1, 2, 4, 6, 8 bar) by using nitrogen gas as inert gas. Evaporation losses were evaluated from the differences of crude oil weights between before and after the experiment.

Recycling Time

A continuous recycling unit consists of two storage tanks fixed roof tank and QVF glass tank. Fixed roof tank was connected by plastic pipes to QVF glass tank controlled by manual control valve using two pumps which were controlled by electrical timer board. This continuous circulation process was carried out at different periods of times i.e. (24, 48, 72, 96) hours. Five litters of crude oil was put in the main fixed roof storage tank and then it was pumped to the second storage tank (Discharging process). Then the crude oil returned back to the main storage tank by gravity (Filling process). This circulation process was controlled by valves. The output stream from the main storage tank was closed for 30 seconds to allow the crude oil to return to the fixed roof storage tank (filling process). Then the electrical power of the pumps was switched off. The inlet stream of the main storage tank was closed. Percentage evaporation losses were evaluated for crude oil covered with either potassium oleate surfactant (2.5cm) thickness or polyurethane foam (3.0cm) thickness or uncovered surface.

Results and Discussion

Effect of Layer Thickness of Surfactant and Layer Thickness of Polymer:

Potassium oleate surfactant and polyurethane foam were used because they float over oil surface. Thus only two materials float over the crude oil out of ten materials studied and hence decreasing evaporation losses. Percentage of evaporation losses versus layer thickness of polymer and layer thickness of surfactant are shown in Figs.1 and 2 respectively. The evaporation losses from crude oil using potassium oleate is less than using polyurethane foam. The minimum thickness required to reduce evaporation losses, almost completely was found to be (2.5cm) for potassium oleate, and (3cm) for polyurethane foam. The surfactant layers covered the crude oil surface which separates oil surface from atmospheric air and isolates it. Therefore, it reduced the evaporation losses from crude surface due to the space above. Potassium oleate isolation is more than polyurethane foam due to the differences in permeability and surface tension of the polymer and surfactant used [5,6].

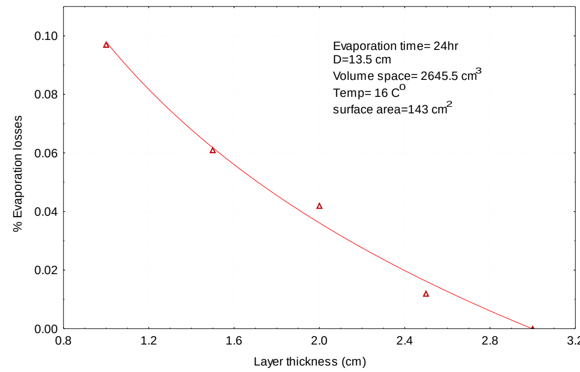

Fig. 1 percentage evaporation losses vs. Layer thickness with polyurethane cover.

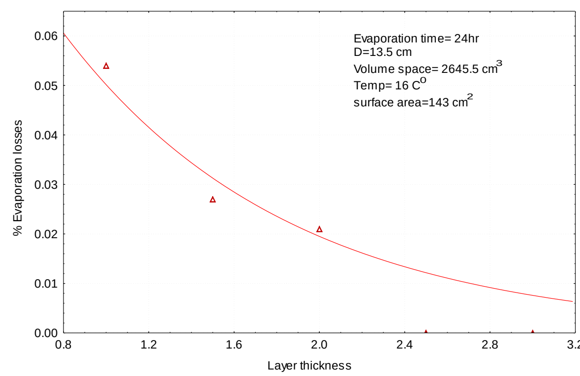

Fig. 2 percentage evaporation losses vs. Layer thickness with potassium oleate cover

Effect of Time

Figs. 3 and 4 show the relation between the percentage evaporation losses of crude oil with time when the surface of crude oil covered with either surfactant or polymer and with neither surfactant nor polymer. Percentage crude oil evaporation losses increases with time due to the evaporation processes proceeding with time. Light components were mainly evaporated during the first (24 hours) from crude oil as indicated by API measurement. Later for the next 24 hours, the evaporation rate decreases with time because the more volatile components evaporate at first. The heavier components take longer time to evaporate, as indicated after 120 hours evaporation. The percentage evaporation losses decrease from 0.50% to 0.35% after 120 hours when the blend crude oil was covered with polymer as shown in Fig.3, in which, the percentage evaporation losses decrease from 0.50% to 0.27% after 120 hours when the blend crude oil was covered with surfactant as shown in Fig.4.

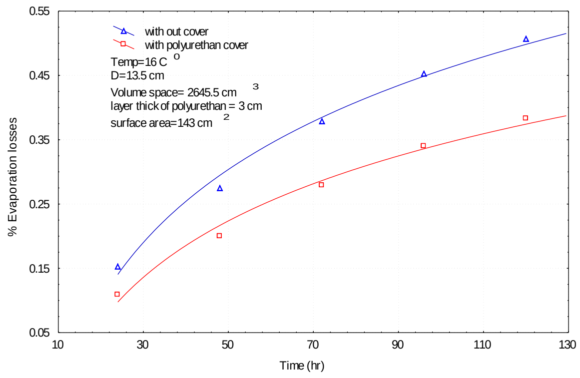

Fig. 3 percentage evaporation losses vs. time.

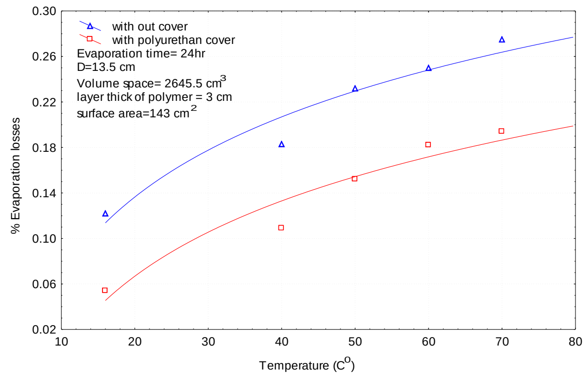

Fig. 5 percentage evaporation losses vs. temperature.

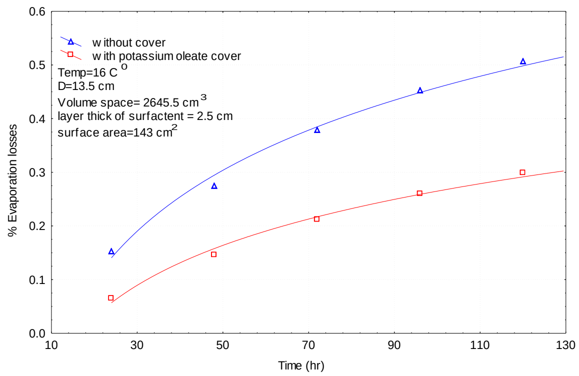

Fig. 4 percentage evaporation losses vs. time.

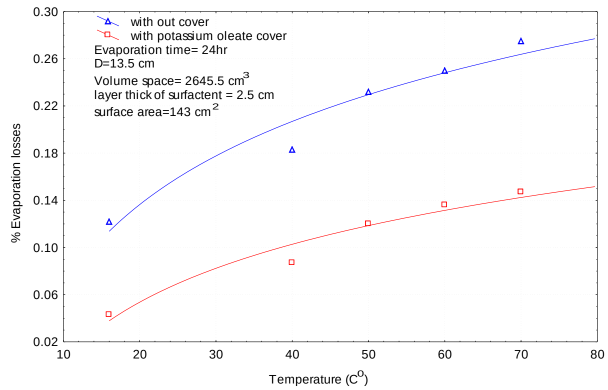

Fig. 6 percentage evaporation losses vs. temperature.

Effect of Temperature

Figs. 5 and 6 represent the relationship between the percentage evaporation losses of crude oil with storage tank temperature. When the temperature increases, the percentage evaporation losses increases, because the temperature of crude oil increased, hence the energy of molecules increases and this leads to increase molecules motion and this may make light component librated[43,44]. The percentage evaporation losses decrease from 0.13% to 0.07% at 20 °C and from 0.27% to 0.18% at 70 °C when the blend crude oil was covered with polyurethane foam. Similar the percentage evaporation losses decrease from 0.13% to 0.05% at 20 °C and from 0.27% to 0.14% at 70 °C when the blend crude oil was covered with potassium oleate. The difference between the behavior of the surfactant and polymer due to the difference in permeability and surface tension [6,8].

4. Effect of Exposed Surface Area:

Figs. 7, 8 shows the relation between percentage evaporation losses of the crude oil with the exposed surface area of the blend crude oil at constant other conditions. Figs. 9, 10 shows the relation between percentage evaporation losses of the crude oil per unit area (cm^2) with the exposed surface area of the blend crude oil at constant other conditions. When the blend crude oil area increases the percentage of the crude oil evaporation losses increases. The contact between the above space and surface of crude oil increases leads to evaporating the more volatile components. The percentage evaporation losses increase from 0.089% to 0.11% when exposed surface area increases from 78.5 cm^2 to 143 cm^2 for polymer. The percentage evaporation losses increase from 0.055% to 0.073% when exposed surface area increases from 78.5 cm^2 to 143 cm2 for surfactant. The percentage evaporation losses per unit exposed surface area (cm^2) decreases from $0.113*10^{-2}$% to $0.077*10^{-2}$% for polymer when exposed surface area increases from 78.5 cm^2 to 143 cm^2 respectively. While the percentage evaporation losses per unit exposed surface area (cm^2) decreases from $0.07*10^{-2}$% to $0.051*10^{-2}$% for surfactant when exposed surface area increases from 78.5 cm^2 to 143 cm^2 respectively. This indicated that other parameters such as height of blend crude oil under the surfactant play some role in changing the percentage evaporation losses [6].

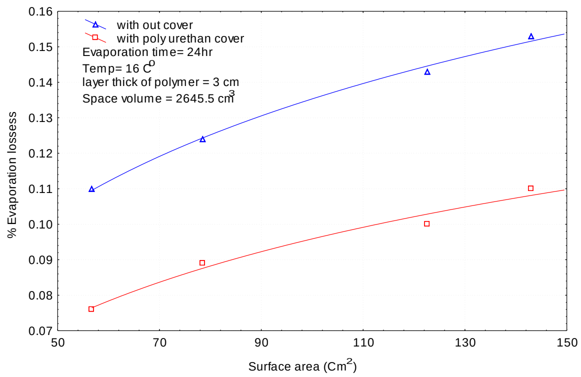

Fig. 7 percentage evaporation losses vs. exposed surface area.

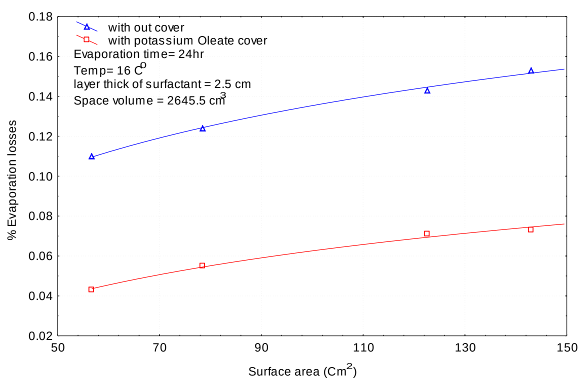

Fig. 8 percentage evaporation losses vs. exposed surface area.

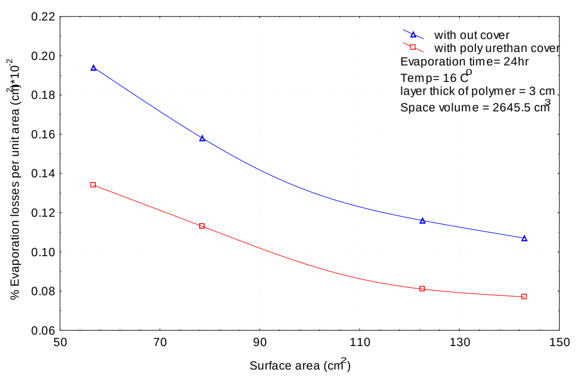

Fig. 9 percentage evaporation losses per Unit area vs. exposed surface area.

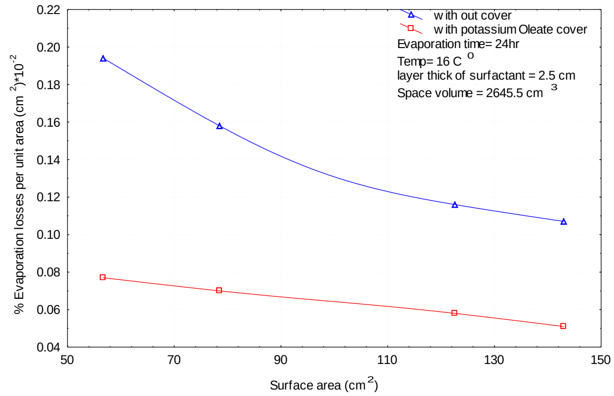

Fig. 10 percentage evaporation losses per unit area vs. exposed surface area.

Effect of Pressure

Figs. 11, 12 illustrate the relation between percentage evaporation losses of the crude oil with pressure in the storage tank using different values of pressure (i.e. between 1to 8 bar). When pressure increases the evaporation losses of the crude oil decreases because of the equilibrium between the liquid crude oil and its vapor which fastly decrease the evaporation losses from crude oil. As indicated by simple perfect equilibrium equation which states ($Pp = x\ p^{*}\ \gamma = y\ p_T\ \Phi$). As pressure increases evaporation decreases, since it reduces molecules movements near the surface of the crude oil since some of hydrocarbons up to C_3, C_4 liquefies at (8 bar) at room temperature (i.e. 25 °C). The percentage evaporation losses decreases from 0.15% to 0.11% and 0.017% when exposed to pressure from 1 bar, 2 bar and to 8 bar respectively when the blend crude oil was uncovered. The percentage evaporation losses decreases from 0.09% to 0.01% when exposed to pressure from 2 bar to 8 bar respectively when the blend crude oil was covered with polymer. The percentage evaporation losses decrease from 0.07% to 0% when exposed to pressure from 2 bar to 8 bar respectively when the blend crude oil was covered with surfactant. The pressure gauge a good control in reducing evaporation rate with or without using either polymer or surfactant as reduce evaporation rate to 0.02% from 0.15% at 8 bar. But the disadvantage with pressure which are high capital operational cost.

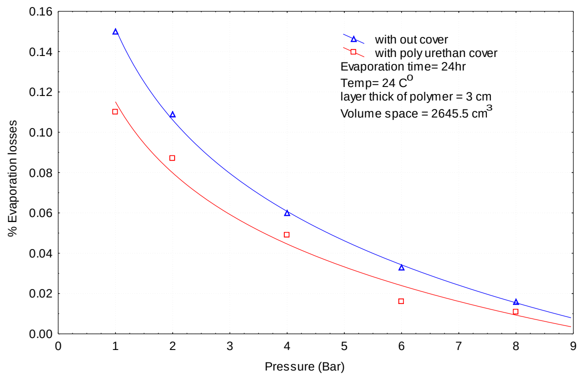

Fig. 11 percentage evaporation losses vs. pressure.

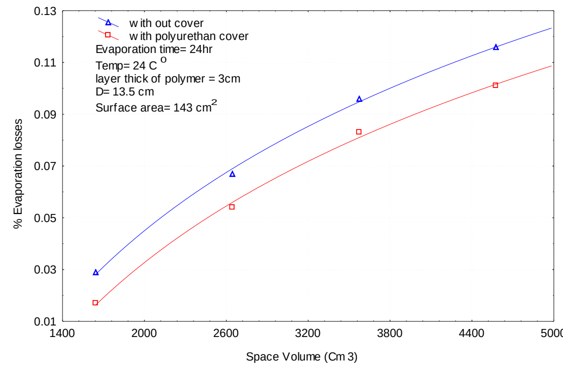

Fig. 13 percentage evaporation losses vs. space volume.

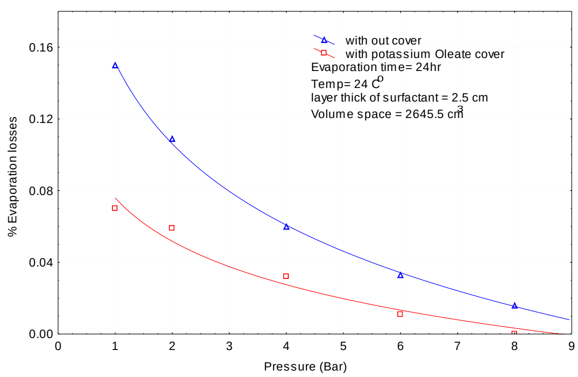

Fig. 12 percentage evaporation losses vs. pressure.

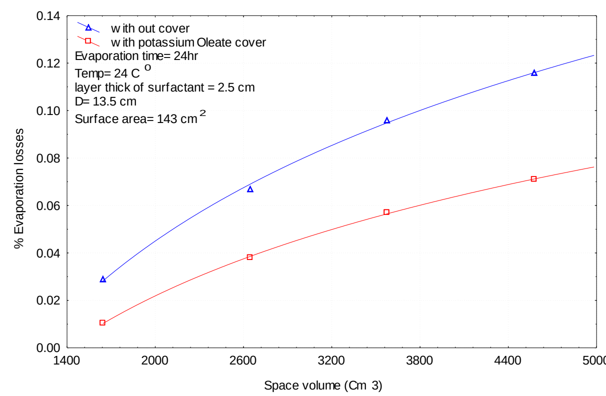

Fig. 14 percentage evaporation losses vs. space volume.

Space Volume above Surface of Crude Oil

Figs.13, 14 represent relation between percentage evaporation losses of the crude oil with the space volume above crude oil surface in the storage tank. When space volume above the crude oil surface in the tank increases the evaporation quantity of crude oil increases due to longer time required to reach the equilibrium between the liquid crude blend oil and its vapour in the space above the surface while when the space volume of storage tank decreases the space above the crude oil will be quickly saturated with its vapour. For closing tank without additions, the evaporation losses were 0.045% to 0.12% for 2000 cm^3 and 5000 cm^3 space volume above blend crude oil respectively at 24 °C. The results indicated decreases in percentage evaporation losses from 0.045% to 0.03% and to 0.02% for uncovered blend crude oil, polymer covered oil, and surfactant covered oil respectively when space volume was 2000 cm^3. Lower results of percentage evaporation losses were obtained from uncovered oil, polymer covered oil, and surfactant covered oil. These percentage evaporation losses were 0.12%, 0.11%, 0.08% respectively when space volume above blend crude oil was 5000 cm^3.

Effect of Recycling

Figs. 15 and 16 represent the relation between the percentage evaporation losses of crude oil with recycling for different times namely 24, 48, 72, and 96 hours. This operation was carried out continuously for above time intervals for uncovered blend crude oil, covered blend oil with polyurethane foam and covered blend oil with potassium oleate. Weighing was carried out for each sample for each interval. In each operation total oil volume was five liters. In the recycle continuous storage system, when the storage time increases the percentage evaporation losses of crude oil increases. Fig.17, compares between the evaporation losses of crude oil in the batch storage tank and continuous storage tank for uncovered blend crude oil, which shows percentage of crude oil in the continuous storage tank more than in the batch storage tank for the same time. The difference in evaporation losses between both cases decreases with storage time, but still there is a difference. The energy of continuous flowing crude oil is more than the static due to forced motions of the crude which are similar to the behavior of filling and discharging. Fig. 18 represents the difference of percentage evaporation losses in the batch and in the continuous storage tank when the surface of crude oil covered with layer of polyurethane foam. Fig.19 represents the difference of percentage evaporation losses in the batch and in the continuous storage tank when the surface of crude oil covered with layer of oleate soap. Figs. 18, 19 show that there is higher rate of evaporation of blend crude oil with continuous recycle compared with batch with storage time for blend oil covered with polyurethane and potassium oleate respectively. The results indicated to an increase of 0.04% in percentage evaporation losses when crude oil covered with polymer compared with 0.05% in percentage evaporation losses when crude oil covered with surfactant. This indicated it is almost the same behavior of the two cases due to energy movements.

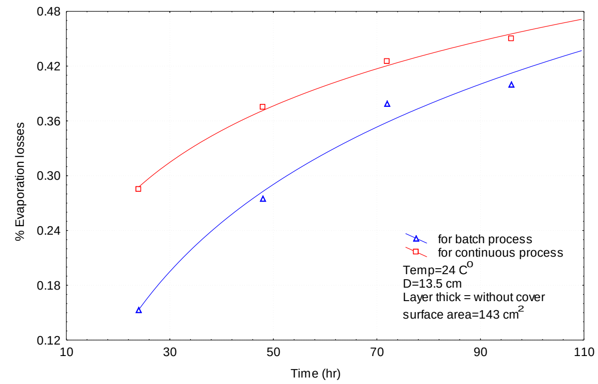

Fig. 17 compares between the evaporation losses of crude oil in the batch and continuous storage tank with out cover

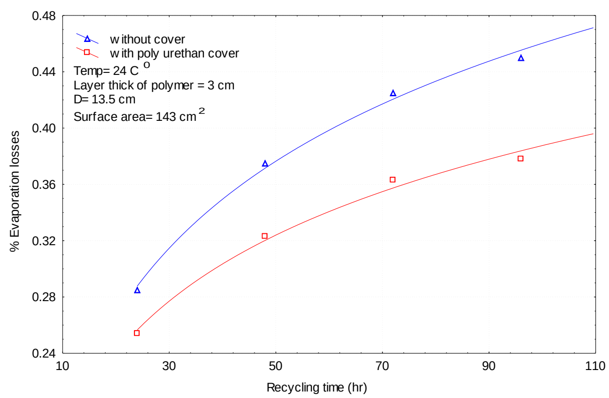

Fig. 15 percentage evaporation losses vs. recycling time.

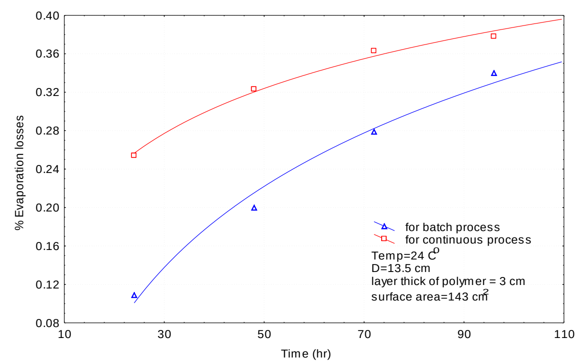

Fig. 18 compares between the evaporation losses of crude oil in the batch and continuous storage tank with polyurethane cover

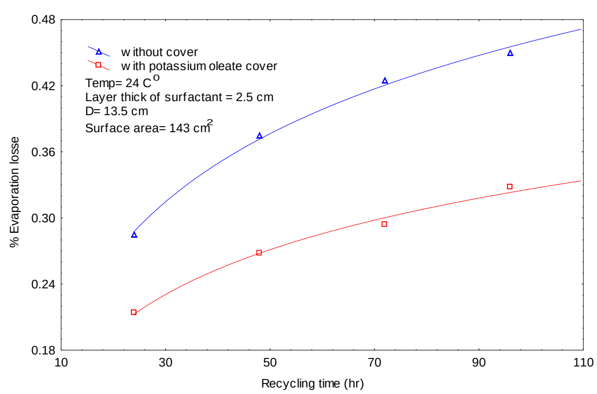

Fig. 16 percentage evaporation losses vs. recycling time.

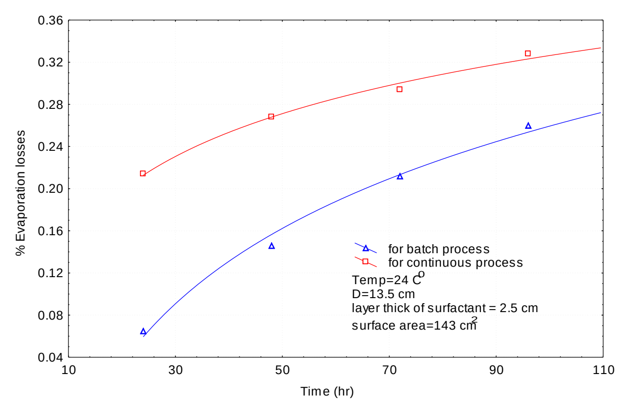

Fig. 19 compares between the evaporation losses of crude oil in the batch and continuous storage tank with potassium oleate cover

Effect of Evaporation on° API

Figs. 20, 21 represent the relation between the °API of crude oil with time. When the time increases, °API of crude oil decreases because °API varies inversely with specific gravity, i.e. When light components evaporate with time, the specific gravity increases and °API decreases. The above figures shows an increase in °API of using surfactant rather than polyurethane foam. Both surfactant and polymer gave high °API after 110 hrs compared with uncovered blend crude oil. The increase in °API was 0.7 which means an increase in the profit of selling crude oil. Therefore two improvements costs were obtained, i.e. high °API of stored crude and less losses of the hydrocarbon vapor from the crude. Figs. 22, 23, 24 represent the relation between evaporation losses with °API. When accumulative evaporation losses increases °API decreases due to the increase in the S.G of crude oil. Initially the percentage evaporation losses was higher than later one. This gaves a higher decrease in °API per unit time than later one. The decrease in °API was reduced when crude oil was covered with polyurethane compared with uncovered crude oil as shown in Figs. 22, 23. The later gave higher decrease in °API than when the crude oil was covered with potassium oleate as shown in Fig. 24.

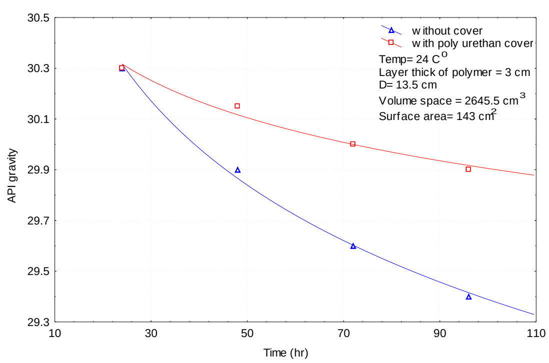

Fig. 20 API gravity vs. time.

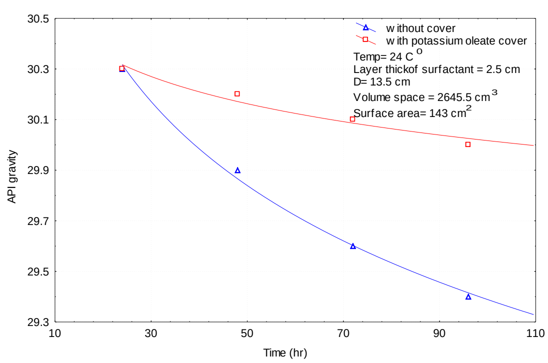

Fig. 21 API gravity vs. time.

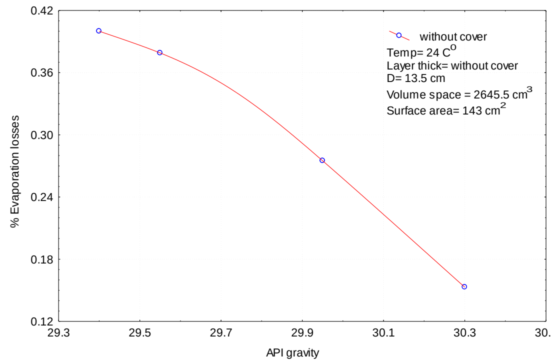

Fig. 22 percentage evaporation losses vs. API gravity with out cover.

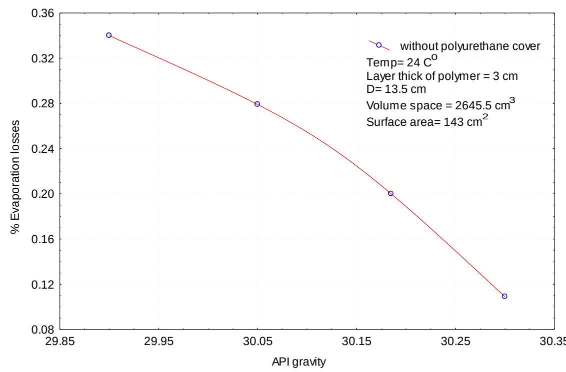

Fig. 23 percentage evaporation losses vs. API gravity with polyurethane cover.

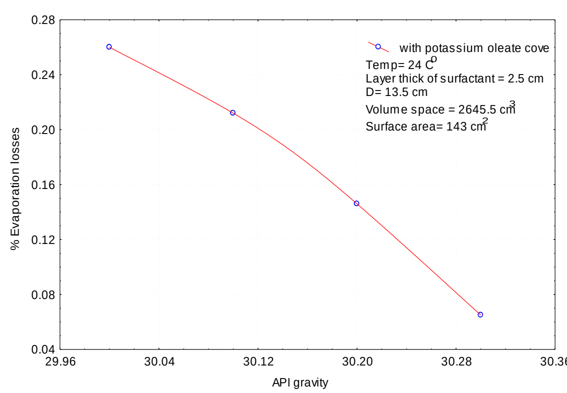

Fig. 24 percentage evaporation losses vs. API gravity with potassium oleate cover.

Conclusions

The following conclusions can be obtained from this experimental research:

1- Some polymers and some surfactant failed to cover over the surface of the blend crude oil and therefore can not be used.
2- The best thickness of polymer and surfactant, which were used to cover the surface of blend crude oil, was 2.5 cm or 3.0 cm respectively.
3- The obtained results indicated that the surfactant (potassium oleate) is better in reducing evaporation losses rather than polyurethane polymer.
4- In batch process, surfactant coverage gave percentage evaporation losses (i.e. 0.147%) less than uncovered blend crude oil (i.e. 0.275%) at 70 °C, surface area 143 cm^2, dead space 2645.5 cm^3, height of crude oil 21 cm , evaporation time 24 hours, for fixed roof tank. In batch process polymer coverage, gave percentage evaporation losses (0.194%) less than uncovered oil (0.275%) at 70 °C, and at the same above conditions.
5- The measured original °API equals (30.3). The °API for crude oil covered with surfactant, covered with polymer, and uncovered blend crude oil were (30.0), (29.9), (29.4) respectively, at 24 °C, 96 hrs evaporation time, and other parameters were the same above (point 4).
6- Increasing the pressure to 8 bar over the surface of blend crude oil covered with surfactant, covered with polymer and uncovered blend crude oil gave percentage evaporation losses (zero%), (0.01%), (0.16%) respectively, at 24 °C, and for 24 hrs evaporation time at the same above conditions (point 4).
7- The percentage evaporation losses for fixed roof , external moving roof, fixed roof with internal moving roof were (0.507%), (0.477%), (0.453%) respectively without surfactant and polymer. But with surfactant or polymer for above three roof types gave (0.299%, 0.388%), (0.283%, 0.365%), (0.266%, 0.347%) respectively at 16 °C, 120 hours evaporation time, for the same above other conditions (point 4).
8- The addition of either polymer or surfactant minimizing the importance of proposed tanks types.
9- In continuous circulation of blend crude oil (i.e. filling and discharge) for crude oil covered with surfactant, polymer and uncovered blend crude oil gave percentage evaporation losses, (0.328%), (0.378%), (0.45%) respectively at 24 °C, 96 hrs evaporation time , 143 cm^2 surface area, 1072.5 cm^3 dead space, 32 cm height of crude oil.

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