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**EXAMINING AND ANALYZING DESALTERS FROM VIEWPOINT OF  
ELECTRIC FIELD FOR DESALINATION OF CRUDE OIL**

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**ABSTRACT**

Salt content may cause prominent damage to crude oil production units, petroleum transfer pipelines as well as refinery and downstream industries. Desalting of crude oil has many advantages including decrease of corrosion in petrol installations, decrease of thermal exchange systems tracts obstruction, protection in practice of catalysts, improving crude oil quality. Using maximum volume of pipes and capacities of refineries and finally preventing energy usage waste in refineries. In this regard present study studies and analyses desalters from viewpoint of electrical field. In this research it is tried with introducing various processes and events that take place in a crude oil desalter to achieve a more accurate understanding from its performance.

**Keyword: Crude Oil, Desalter, Electrical Field**

**INTRODUCTION**

Oil industry is one of the most effective and broadest industry in the world especially in Iran. The oil, in addition to be a prominent source of energy supply in any activity, today it plays a pivotal role in determining national power level and international credit of various countries too. Optimized policy in oil and gas sector in line with providing national profits is considered as one of the key and important objective of

the country within recent years. Energy and particularly oil and gas are considered as one of the influential parameter in producing wealth and power in today world. World economics with all development emerged in the period after the cold war are still dependent to oil and gas and the reason is clear: the energy is propulsion of development for industrial countries and world economic growth.

Meanwhile crude oil refinery due to provide and supply of fuel and energy or in other word energy supply of industrial and social wheel in the countries stands in special position and its development, maintaining and optimization is important whether in term of hardware or in terms of think software.

The crude oil that is extracted from earth is constituted from various chemicals.

From chemical point of view the oil is a mixture of hundreds of molecular compounds that is called hydrocarbon. Hydrocarbons are compounds that are constituted from two element of Carbone C and hydrogen H. of course the oil that is extracted from the well is called crude oil or petroleum that is a brown to black liquid and may be fluid as water or thick as bitumen.

Crude oil is a liquid with different viscosity. The color of crude oil varies from green (Moonie crude oil in Australia) to dark brown (Ghawar crude oil in Saudi Arabia). The odor of crude oil can be similar to hydrogen sulfide, terebantin, or simple hydrocarbon. Chemical compounds of crude oil are extremely complicated and inherently depends on its lifetime. It means complexity of chemical compound regardless to crude oil origin depends on oil field phase extension) [1].

Crude oil may be transferred my pipeline, train, truck or ship to a place called refinery and thereafter desalting and deacidifying take place, the remaining hydrocarbon is refined in order to achieve the required products for energy supply and needed substances. Knowledge about all physical and chemical properties of crude oil identified the type of preliminary refinery (separation of associated gas and consolidation of oil field production), transportation, restoring and pricing [2].

Detailed study of features of oil products are first important technical and economic parameters because it allows to refineries feedstock could be selected for different units in order to separation, transfer and transfer for adjusting operational conditions, and this case causes meeting market requests in the best possible manner.

Extracted crude oil from reservoirs include water content in the form of water emulsion in the oil that contains various types if mineral salts such as sodium, magnesium and calcium chloride. Though water content is often less than 0.5% and salt content fluctuate between 4000-200000 ppm , but existence of the same small amount brings about some problem in oil refinement process among their most important is corrosion of equipment of

refineries and transfer and disabling catalysts [3].

### **Theoretic basics**

The first oil well of the world was dug in 1859 in the Pennsylvania, U.S. where 35 barrel per day was extracted.

First oil well of Iran was dug in Masjed Soleyman in 1908, may 26 with depth of 360m for achieving to the oil. In the 1901 concession of detection, extraction, refinement, transportation and sale of black gold of Iran was ceded to one of the English capitalist called William D'arcy by Mozaffareddin Shah. After a while dominance of foreigner on the country oil resources terminated finally under shadow of endeavors of Dr. Mossadegh in 1950 ,it means near 50 years after ceding the concession by Mozaffaredin shah and a law was approved upon which decision making about the oil would become on the nation and government of Iran. Today it is elapsed more than fifty years from that date. From total of the thousand milliard oil barrel that approximately constitutes known storage of world oil, its 65% is found in Middle East region.

Crude oil is transferred to the refinery by pipeline, train, truck and ship and there after desalination and deacidification, the remaining hydrocarbons are refined to obtain required products for energy supply and substantial materials because the oil

that is extracted from the well always contains some amount of water and gas sediments. In exploitation unit the objective is to separate these substances from the crude oil. The crude oil is transferred to refineries (for refinement) or they can be exported by means of terminals. We know that any refinery is designed according to its feed, in this unit at first some primary experiments is carried out such as measuring the ash, N<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>O on the crude oil. The important point in creating and constructing refineries is selecting kind of materials and metals used in refinery installations, design of refinery units, mass and energy balance, economic studies for sale based on physical and chemical qualities, the kind of necessary product for regional and national usage, problems of environment protection that requires cleaner fuels and etc and these items depend on knowledge about crude oil chemical components.

### **Discussion and findings**

#### **Electrostatic fields**

Types of electrostatic dehydrators devices in order to coagulate between tiny brine water droplets relies on three base on electrostatic fields as follows:

#### **Direct current (DC) field**

In direct current field the droplets after colliding with the electrode become charged and while moving to opposite

electrode collide to each other and they coagulate. Constant and unidirectional properties of this field lead to droplet immigration and make it possible to increase the probability of fine droplet coagulation that are far from each other. Since the droplets become charged through colliding in a DC field this increases the applied electrostatic forces on droplets and lead in increase of droplets coagulation. Unfortunately despite of mentioned advantages due to corrosion consideration and possibility of short circuit in DC field there are many problems with it in practice. Therefore they are not used solely in desalination of oil and they are used just in dehydration of oils that have low conductivity [4].

#### **Alternative current (AC) field**

As it is shown in figure (1), the alternative current field is applied by a transformer attached to horizontal electrodes and is suspended in desalter reservoir. In AC field due to current rapid inverse direction change before obtained products from corrosion can become far from reaction spot, they involves in inverse corrosion process of chemical reaction. Therefore no pure corrosion takes place. Due to corrosion consideration nowadays DC field application is confined to cases including refined products with lower electrical conductivity in respect with crude oil. A

weak AC current is usually establish between the electrode and interface of two phases and a powerful AC field is established between charged electrode and the earth electrode. The mixture of water and oil enters the reservoir from above the two phases interface and at first it coagulates by weak AC field and afterward it coagulates and dehydrates by strong AC field.

AC current field due to efficiency in large changes domain from water associated with the oil as well as its non-electrolyte nature is used by most electrostatic appliance manufacturer.

Electrostatic appliance with AC field type is constituted from a transformer attached to a horizontal electrode suspended under earth electrode. A weak AC gradient is established between energy electrode and interface of water and oil and a strong AC gradient is establish between energy electrode and earth electrode. The water content in the input oil wet begins to coagulate and coalesce just above the interface of water and oil. And finally more coagulation and complete dehydration takes place in upstream field. When the oil stands in a higher position from earth electrode the coagulation is impossible because there is no field above the earth electrode. For higher efficiency of AC type desalters three

AC transformer and three electrode pair can be used according to figure (2).

In this example a deeper and more extensive AC field usually can be used because in oil wet the initial coagulation takes place just in top of the interface where there is weak AC field and more coagulation and separation take place between three electrode where there are high gradient of AC field and as a result desired performance can be achieved.

Among advantages of AC field is existence of bipolar attraction forces, tensile film producing and tolerating higher amount of water in electrodes place and especially about AC field limitations are low level of droplet displacement and particles low charge density.

#### **Synthetic current (AC/DC) fields**

Synthesizing AC and DC makes possible the use of water changes domain with the oil pertaining to AC field together with high efficiency of DC boards. In 1970's a process with trade mark of Dual polarity was addressed and developed for using synthesizing AC/DV field in order to obtaining and using advantages of both types of field and avoiding from DC field corrosion problems [5].

The specific method of electrical connection used in this system establishes an AC field in the place under electrodes and a DC field between vertical adjoining

electrodes, Figure (3). Therefore the direct current field is confined to vertical electrode regions while used structure brings about an AC field in the reservoir too that its duty is preventing corrosion. This structure makes migration and collision of remaining very tiny droplets possible in the DC field so that maximum dehydration level takes place.

In an optimum electrostatic process DC and AC fields can be applied together simultaneously so that the dehydration efficiency increases. AC electrical field is applied in vicinity of water and oil interface, while the DC field is applied in phase oil and between blades. In electrostatic process in double field dehydration operation can be carried out effectively and in lower temperature comparing with other processes and therefore energy usage efficiency is higher. This type of desalters that called bipolar type desalter as well includes array of vertical and parallel electrodes that cover all over the desalter vessel and is shown in Figure (4).

This desalter includes three transformer that each one have an inverter diode pair that establishes DC field between adjacent electrodes that is shown in figure (2).

In AC/DC desalters the AC field is engendered between electrodes lower part and water and oil interface level and just

similar to AC desalters the initial coagulation of big droplets takes place on

top of the interface level due to weak gradient of AC field.

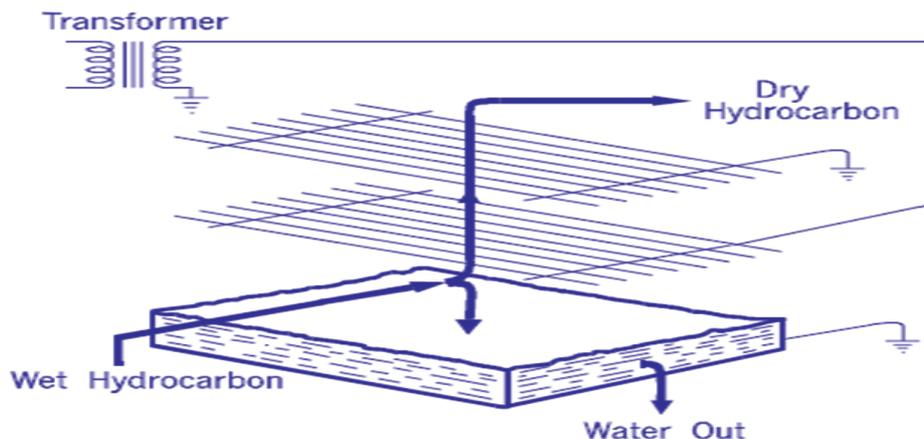


Figure (1): a typical structure of an AC desalter

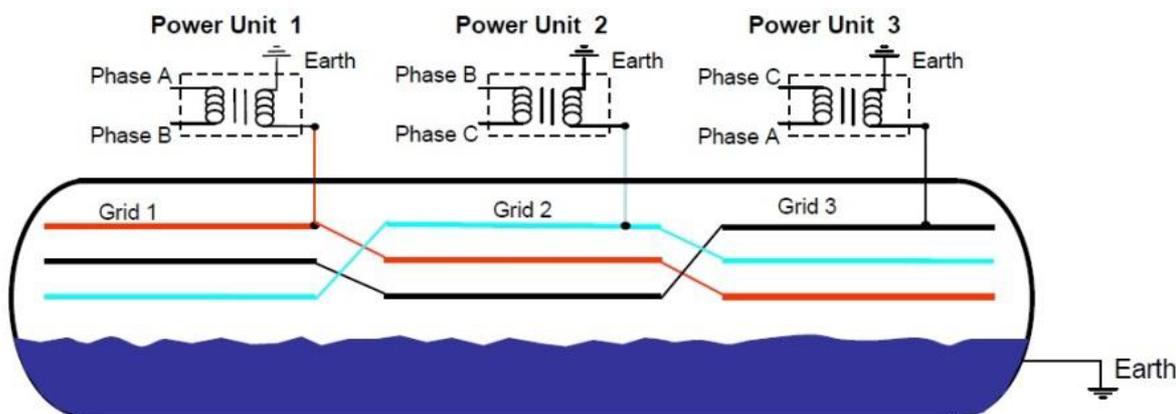


Figure (2): electrostatic appliance with AC type field

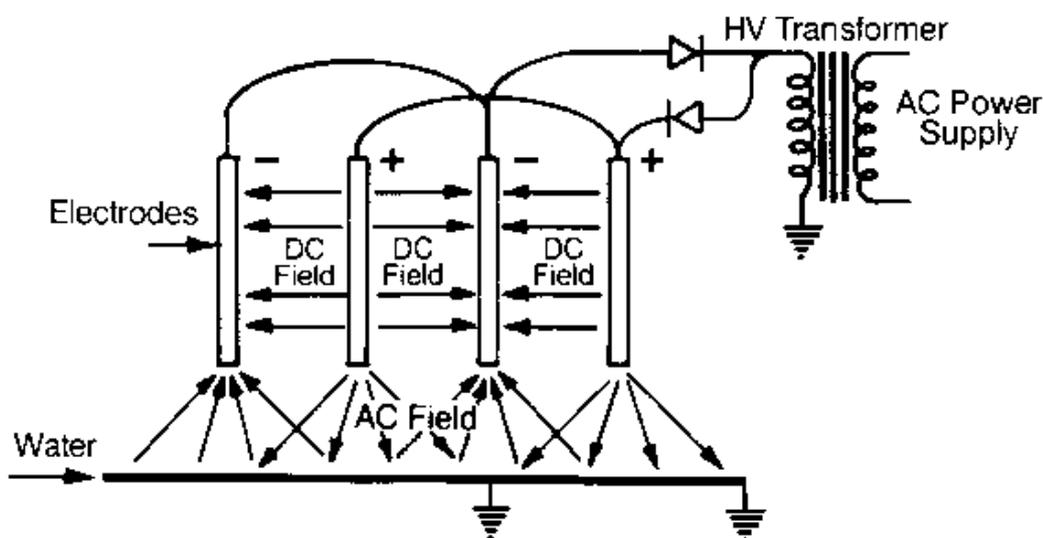


Figure (3): a general structure of (AC/DC) desalter.

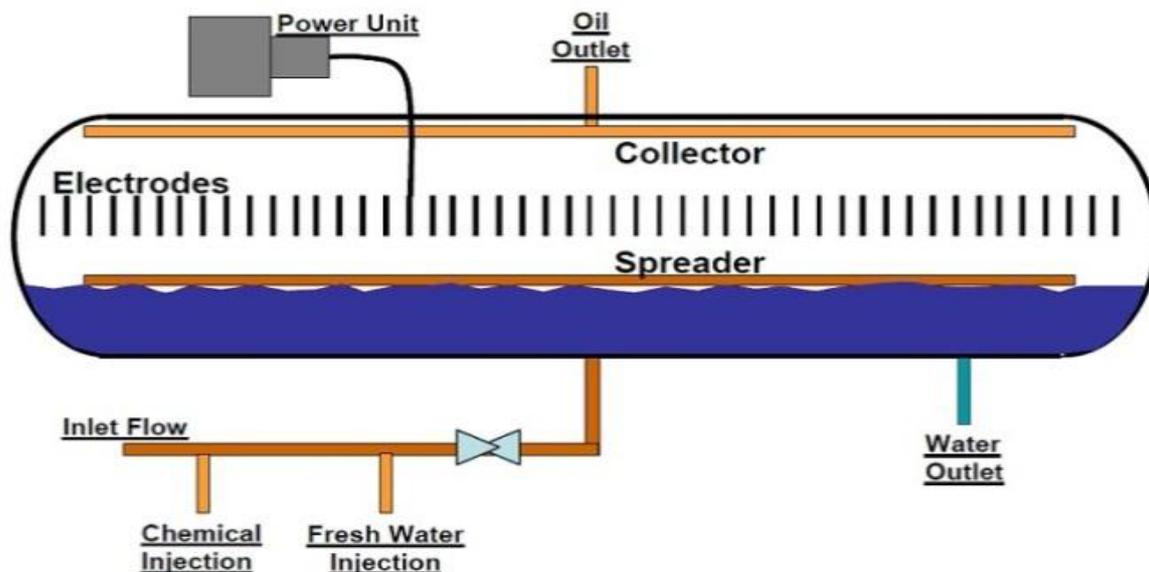


Figure (4): electrostatic appliance with bipolar field type

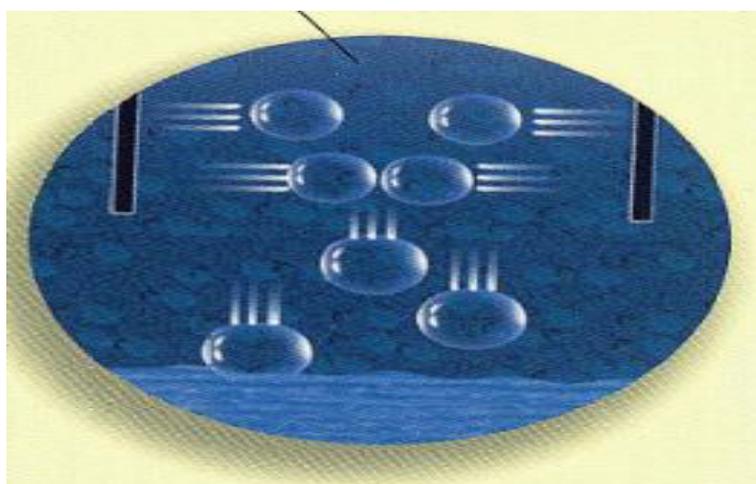


Figure (5): coalescing of vectored particles in DC field

Advantages of dipole field includes AC field advantages in addition to appropriate transfer of droplets, existence of electrostatic charge, deeper sediment field than AC field, desalter reservoir efficiency in lower operational temperature and existence of single force source. In the meanwhile the above field efficiency is tested for all types of crude oil with API degrees. In respect to dipole fields limitations are the same as limitations of AC field although some endeavors are done

for preventing electrolyte reactions and reducing effect of changes in water particles with oil.

Analysis of electrical field in crude oil desalination

With respect to efficiency of electrical separation energy the best way is breaking emulsion and desalination of the oil. therefore in the cases that brine droplet may detach from oil hardly the electricity current is used, to achieve this , desalination appliances are manufactured

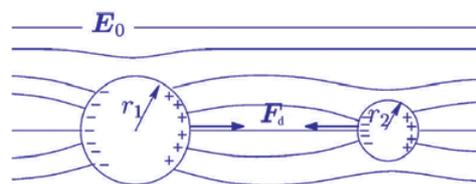
within which there are two positive and negative electricity pole with high voltage (approximately 15000 to 21000 volt). Water molecules that are dispersed in the oil are in spherical form but are deformed under static forces and turned into eclipse and in this state the adjacent droplets integrate with each other and settle down by the gravity force but if the droplet is excessively large the electricity current disintegrate them dramatically and they turn to tinier droplets.

### Principles of electrostatic desalination

A droplet of a liquid that is suspended in another liquid, if no external force is applied to it is considered as complete spherical shape. While if electrical field with high voltage is applied the droplet fails to hold the spherical shape. The positive and negative charges in the droplet aggregate in hemispheres against electrode with opposite charge. With this arrangement this is allegedly polarization of droplet [6].

As it is shown in the figure (6), two adjacent polarized droplets have electric attraction to each other. Positive part of a droplet situated in nearest distance to the negative end of another droplet, therefore there is an attraction force between two end that has the tendency to attract the droplet to each other. If this force is strong enough, the droplets move the external layers of

droplets (oil layer (is broken and allow to droplets to attach to each other and form a larger droplet.



**Figure (6): electric force  $F_d$  between two droplets with radius  $r_1$  and  $r_2$  in the electric field with intensity of  $E_0$**

A suspended droplet between a pair of electrodes is subjected to five different forces. (Figure 4-2). Meanwhile there are two hydraulic type forces. Weight and buoyancy forces that tends to cause moving droplets downward and drag force that is applied from top of the droplets by passing oil flow and tend to rising the droplet toward oil output. If the size of water droplet is greater than the diameter of the droplet stated by stoke relation ( relation 1) , the weight force is greater than drag force and water droplet falls downward and detaches from the oil.

### Relation 1

$$d_{stoke} = \left( \frac{18\mu_o v_v}{g(\rho_w - \rho_o)} \right)^{0.5}$$

In order to enhancing desalination processes efficiency, electrostatic forces should be able to coagulate the small droplets to each other and reach their size to diameters greater than Stoke diameter. Three electrostatic forces exerted to water droplet including: dipole-dipole force,

electrophoretic and di-electrophoretic. Suspended water droplets between a pair of electrode are shown in figure (7) [4].

The dipole force is engendered by orientation of water polarized molecules within the droplet and is proportional to electric field intensity, the drop size and droplets distance [4].

#### Relation 2

$$F_d = \frac{6 K E^2 r^6}{s^4}$$

Electrophoretic force includes both attraction and repulsion that emerges within uniform voltage field and between charged droplets and electrodes. These forces is proportional with field intensity, droplet size and oil transitivity coefficient [4].

#### Relation 3

$$F_e = C \pi^3 \mu_o \varepsilon_o r^2 E^2 e^{(-\sigma_o t / \varepsilon_o)}$$

The di-electrophoretic is attraction type that emerges in a non-uniform field between droplets and electrodes. This force conducts the droplets to stronger electric field and is proportional with droplet size and oil transitivity coefficients [7].

#### Relation 4

$$F_{diel} = 2 \pi r^3 \varepsilon_o \left( \frac{\varepsilon_w - \varepsilon_o}{\varepsilon_w + 2 \varepsilon_o} \right) \nabla E^2$$

As it is shown in relation (2), dipole force depends on water droplet size and distance between them, assuming water droplet size

is uniform and are homogenously distributed. It is obvious that the distance between droplets is inversely proportional to the volume. Therefore relation (4) with integrating (X) propagated water and coagulation of propagated water droplets and separating from the oil, the distances between droplets increases and the bipole force reduces. Also the relation (5) shows that when the diameter of the droplets is increased the distance between droplets is increased too. Therefore over time and by coagulation and coalescing droplets and detaching from oil, the dipole force reduces [7].

#### Relation 5

$$s = r \left( \frac{1.333 \pi}{X} \right)^{0.333}$$

Regarding relation (3) the electrophoretic force is independent from the distance between the droplets, but it depends on crude oil transitivity coefficient and viscosity. Also this relation shows that the electrophoretic force reduces in the crude oil that its transitivity coefficient is high. Regarding the relation (3), di-electrophoretic force is independent from distance between droplets and depends on field intensity gradients and attract larger droplets toward stronger electric field.

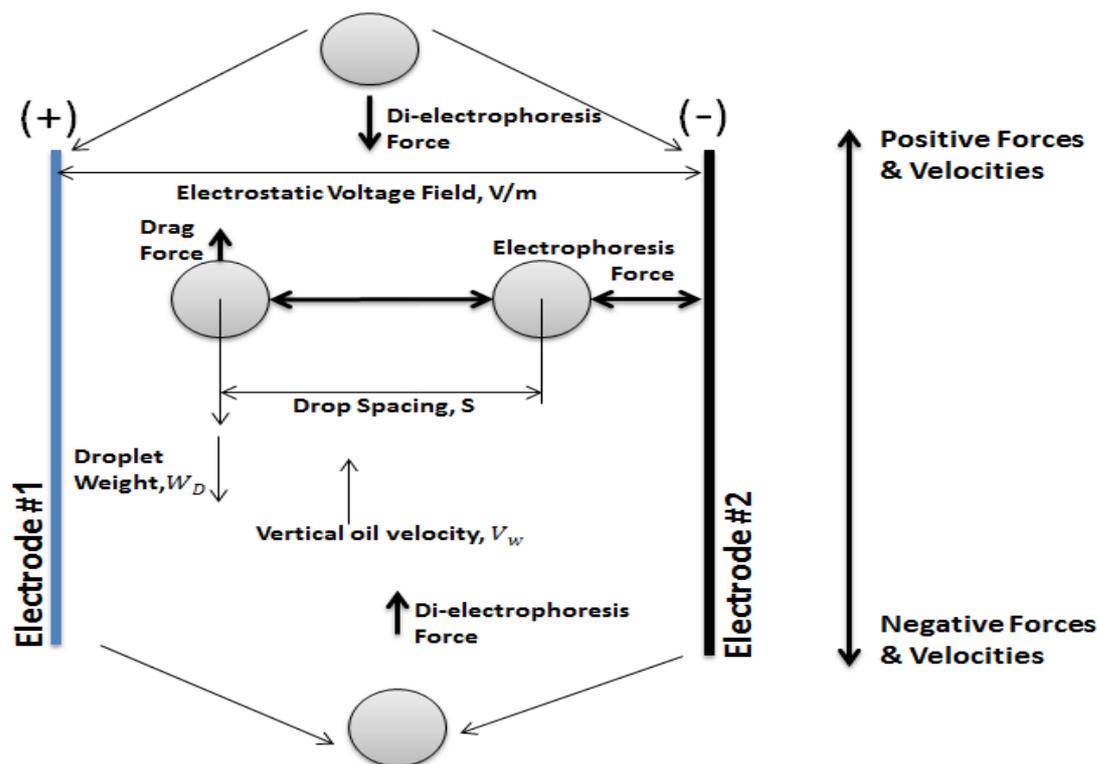


Figure (7): exerted forces on water droplets suspended between a pair of electrode

Two of these five forces are gravity and hydraulic forces. Gravity force equals to water droplet weight in movement to the bottom of desalter vessel. Drag forces is applied due to upward movement of oil through water droplets that cause lift of these droplet toward oil output.

If water droplets diameter is larger than droplets Stoke diameter then the weight force is greater than drag force and water droplets would detach from oil. In order to maximize the desalting process efficiency the electrostatic force must be able to coagulate and constitute droplets with greater diameter form Stoke diameter. Three available electrostatic forces includes dipole force, electrophoretic force and di-electrophoretic force.

Generally design parameters, inter-surface tension and conductivity are three effective factor on electrostatic process efficiency. Inter-surface tension can be measured in terms of (dynes/cm) within range 15 to 25 for ordinary oils. High surface tension makes water droplet coagulation difficult and necessitate the need to applying large coagulator forces.

In low surface tension droplet coagulation is easy but coagulated droplets are highly instable and they easily disintegrate and propagate again. Demulsifier chemicals and electrostatic field reduce surface tension and helps to droplets grow. Excessive level of electrostatic charge and chemical curing reduces surface tension and disintegration of generated droplets and their propagation.

Oil conductivities is in terms of nano simens/meter and varies between 40 to 80. Nevertheless for heavy oils mixed with bitumen the conductivity is reported up to 250. Oil conductivity is due to excessive amount of water content in electrode region, organic and non-organic polarized compounds and presence of conductive solids in the oil. High conductivity of oil have three variant effect on electrostatic processes as follows:

- Firstly increase of oil conductivity leads in oil thermal resistance increase that doesn't help in electrostatic coagulation process. This issue may ensue cost of use of force larger sources for maintaining exploitation and efficiency of electrostatic process for manufacturer.
- Secondly high oil conductivity lead in decrease of electrophoretic that in turn decrease droplet transferability in AC/DC type desalter.
- Thirdly di-electrophoretic forces reduces in both type of AC and AC/DC.

In this manner with manipulating in voltage for AC/DC synthetic desalters conductivity and surface tension may become beneficial. If applied voltage in desalter blades are very high electrostatic forces may exceed

from surface tension forces and cause disintegration and propagation of droplet once more. This voltage is known as critical voltage and include all crude oils types with different degrees of API. Threshold voltage is the voltage in which the droplets begins to be charges and then be coagulated. In threshold voltage the secondary current becomes intense and sharp and it shows that suspended water droplets are electrically charged. Then the current begins to dramatically reduce that shows charged droplets are coagulated. The operation bellow of threshold voltage cannot achieve to provide sufficient electrostatic energy for droplet coagulation. Effective electrostatic operation takes place in a voltage near to threshold voltage because we have maximum constituted droplets diameter.

#### **Effect of temperature degree changes in desalination efficiency (optimum temperature)**

Performance of suspended water droplets between a pair of electrodes is shown in figure (7). The effect of temperature degree changes on desalination efficiency is significant. With increase in temperature particle movement is increase and as a result number of collisions increases over a certain period of time and consequently desalination efficiency increases.

## CONCLUSION

Extracted crude oil from oil field always contains some amount of brine in the form of emulsion. Water content of crude oil depends on establishing manner of phases within reservoir, oil field geographical position (land or sea), reservoir lifetime, extraction method and especially usage of water injection method for enhancing extraction.

Water content of crude oil contains salts that cause many problems in refinery processes. Chloride sodium salt constitutes main part of existing salt in the crude oil. Calcium chloride and magnesium are in the next grade. These salts are usually found in almost all water contents of crude oil. Salts are rarely found in crude oil (organic phase) and in case of presence they are found in the suspended and insolvent form. Almost in all cases available salt in crude oil is found as solved in tiny water droplets and chlorides and sulfates are found as dissolved in water droplets. due to a lot of problems emanating from salt presence, desalination takes place at the beginning in well-head exploitation units up to 10-20(pound per 1000 barrels) and then in refineries before transferring to injection unit up to 5 PTB.

Essentially if salt content level in crude oil exceed from 10PTB, desalination is necessary. Nevertheless many refineries

even in some cases that the salt content is lower than this level engage in desalting the input crude oil.

Salt content leads in prominent damage in crude oil production units, oil transfer pipeline as well as damage in refinery and downstream industries. Eliminating salt form the oil has some advantages such as reduce of corrosion in oil installation, decrease of decrease in thermal exchange systems tracks obstruction, protecting catalysts actions, crude oil quality improvement. Maximum usage of pipes volumes and refineries capacities and finally preventing energy usage waste in refineries.

Essential point for crude oil sale (exportation) and refinement is its desalination and reducing salt content in the oil to permissible and usable limit. Beside this main objective it can be used some compounds as demulsifier with a some attention , sensitiveness and endeavor that has least pollution level in great volume of output water and reduces undesirable and irreparable environmental effects. Regarding high volume of crude oil production and desalted brine, failure in observing environmental considerations in applying appropriate demulsifiers lead in emerging problems and dramatic pollutions in environment.

In this research desalination process is studied as one of the most important stage of crude oil production. Identifying effective factors on desalter performance requires understanding mechanism and examining basic principles of this phenomenon.

Different electric forces exerted to water droplets propagated in crude oil phase are introduced as dipole, electrophoretic and di-electrophoretic forces. Meanwhile dipole force leads to coagulating adjacent droplets and electrophoretic and di-electrophoretic leads to movement of droplets toward electrodes.

Types of electric field used in crude oil desalters including AC and DC field and AC/DC field was examined. The study revealed that the DC field contrary to advantages that may lead to higher efficiency has procedural problems too that makes its application difficult. AC field that has not corrosion problem is widest type. AC/DC synthetic field benefits from both fields simultaneously and is used in crude oil desalters new generation.

Also appropriate emulsion and demulsification among crude oil and brine is examined. At present time combination of multiple methods is used for demulsification between crude oil and brine and detaching brine from it. One of the most essential stages in this operation is use

of demulsifier chemicals. These chemicals should have the best performance in breaking emulsions in crude oil according to different conditions of any kind of crude oil.

Oil emulsions due to additional water content as well as higher viscosity increases transferring costs. From one side due to presence of solved salts in water droplets cause equipment corrosion and deactivation of catalyts. Therefore demulsification is among important processes in refinement industry. With increase of emulsion durability time, sediment yield is increased too so that reaches to a maximum. After that for extra increase sediment yield, higher amount of demulsifier should be used ,though with increase of demulsifier the dehydration- desalination efficiency increases but after reaching to optimum level this procedure halts because with saturation of droplets level by demulsifier and formation of micelle, emulsion stability increases too. Adding water always increases desalination efficiency, but presence of high level of water in emulsion leads to dehydration efficiency reduction duo to water volume fraction increase. Also temperature increase reduces viscosity of oil continuous phase and as a result increases dehydration efficiency, though in these conditions desalination efficiency is lower that dehydration. Mixture time

increase always leads in desalination efficiency increase because leads in more solution of the salt in water phase. In electrical method applied voltage increase to reaching an optimum level is continued but after that sustain decrease rate. In microwave method with increasing time duration of microwave applying demulsification efficiency increases. Generally for desalination efficiency increase in crude oil presence of demulsifiers is necessary.

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