Tikrit University

The College of Petroleum Processes Engineering

Petroleum Systems Control Engineering Department

Petroleum Refining Processes

Fourth Class

Lecture 7 & 8

By

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Oil Emulsion

- The fluid produced at the wellhead consists usually of gas, oil, free water, and emulsified water (water–oil emulsion).
- Before oil treatment begins, we must first remove the gas and free water from the well stream. This is essential in order to reduce the size of the oil–treating equipment.
- The gas and most of the free water in the well stream are removed using separators.
- Gas, which leaves the separator, is known as **"primary gas."** Additional gas will be liberated during the oil treatment processes because of the reduction in pressure and the application of heat. Again, this gas, which is known as **"secondary gas,"** has to be removed.
- The free water removed in separators is limited normally to water droplets of 500 μm and larger. Therefore, the oil stream leaving the separator would normally contain free water droplets that are 500 μm and smaller in addition to water emulsified in the oil.
- This oil has yet to go through various treatment processes (dehydration, desalting, and stabilization) before it can be sent to refineries or shipping facilities.
- First specialist has deals with the of treatment. The objective of dehydration stage treatment is first to remove free water and then break the oil emulsions to reduce the remaining emulsified water in the oil.
- Depending on the original water content of the oil as well as its salinity and the process of dehydration used, oil-field treatment can produce oil with a remnant water content of between 0.2 and 0.5 or 1%. The remnant water is normally called **the basic sediments and water (B.S. &W.)**. The treatment process and facilities should be carefully selected and designed.

The basic principles for the treating process are as follows:

1) Breaking the emulsion, which could be achieved by either any, or a combination of the addition of heat, the addition of chemicals, and the application of electrostatic field.

2) Coalescence of smaller water droplets into larger droplets.

3) Settling, by gravity, and removal of free water.

Salt water is thus produced with oil in different forms as illustrated in Figure 5.

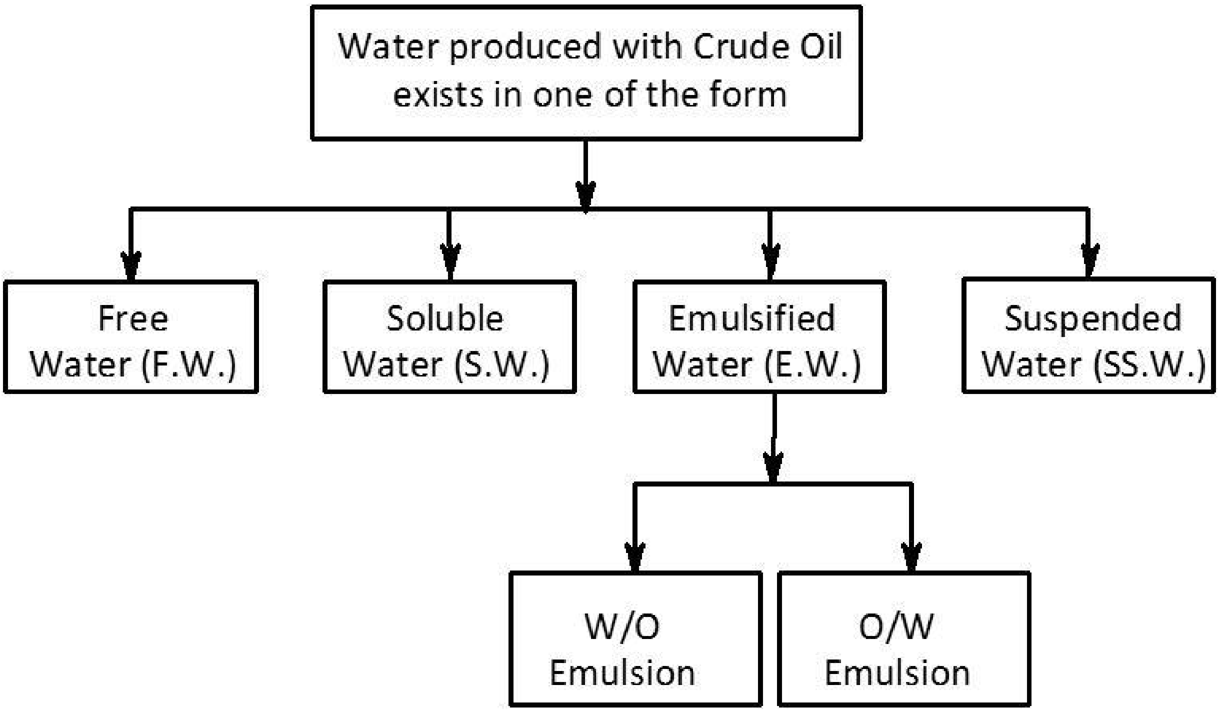


Figure 5: Forms of saline water produced with crude oil.

- Apart from free water, emulsified water (water-in-oil emulsion) is the one form that poses all of the concerns in the dehydration of crude oil.
- Oil emulsions are mixtures of oil and water. In general, an emulsion can be defined as a mixture of two immiscible liquids, one of which is dispersed as droplets in the other (the continuous phase), and is stabilized by an emulsifying agent. In the oil field, crude oil and water are encountered as the two immiscible phases together. They normally form water-in-oil emulsion (W/O emulsion), in which water is

dispersed as fine droplets in the bulk of oil. This is identified as type C in Figure 6. However, as the water cut increases, the possibility of forming reverse emulsions (oil-in-water, or O/W emulsion) increases. This is type B in Figure 6.

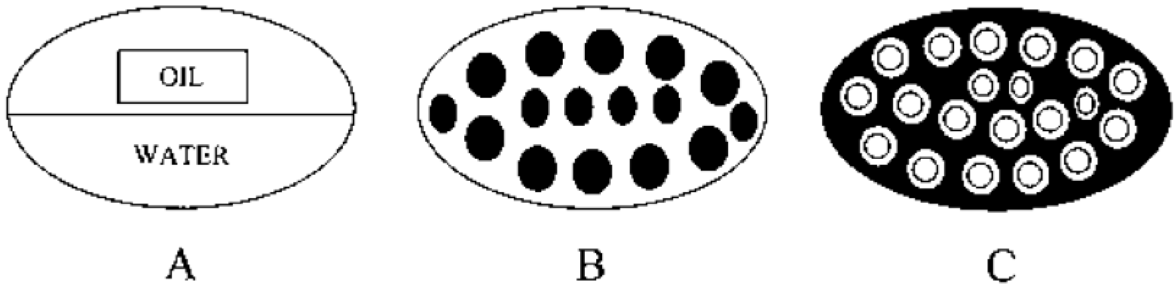


Figure 6: Schematic representation of (A) a non-dispersed system, (B) an O/W emulsion, and (C) a W/O emulsion.

For two liquids to form a stable emulsion, three conditions must exist:

1) The two liquids must be immiscible.

2) There must be sufficient energy of agitation to disperse one phase into the other.

3) There must be the presence of an emulsifying agent.

Emulsifying Agents

Emulsifying agents, which are commonly found in crude oil or water in the natural state or introduced in the system as contaminants during drilling and/or maintenance operations, create this film. Some of the common emulsifiers are as follows:

1) Asphaltic materials;

2) Resinous substances;

3) Oil-soluble organic acids;

4) Dispersed solid materials such as sand, carbon, calcium, silica, iron, zinc, aluminum sulfate, iron sulfide, and so on. These emulsifying agents support the film formation encasing the water droplets, hence the stability of an emulsion.

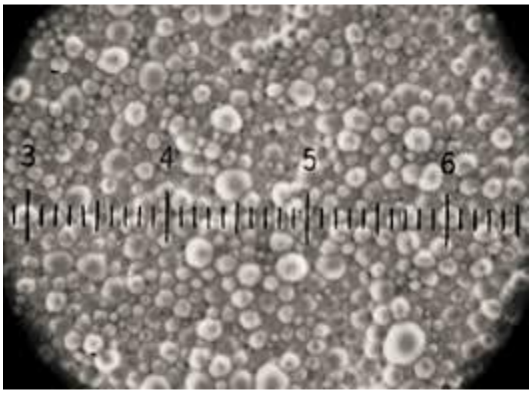


Figure 7: Photomicrograph of loose emulsion containing about 30% emulsified water in the form of droplets ranging in diameter from about 60 μm downward.

A very stable emulsion is known as a ‘‘tight’’ emulsion and its degree of stability is influenced by many factors. Accordingly, we can best understand the resolution problem and, hence, **the treatment procedure if we consider the following factors:**

1. Viscosity of oil
2. Density or gravity difference between oil and water phases
3. Interfacial tension between the two phases (which is related to the type of emulsifying agent)
4. Size of dispersed water droplets
5. Percentage of dispersed water

The method of treating ‘‘wet’’ crude oil for the separation of water associated with it varies according to the form(s) in which water is found with the crude. Free-water removal comes first in the treating process, followed by the separation of ‘‘combined’’ or emulsified water along with any foreign matter such as sand and other sediments. The basic approaches of handling ‘‘wet’’ crude oils are illustrated in Figure 8.

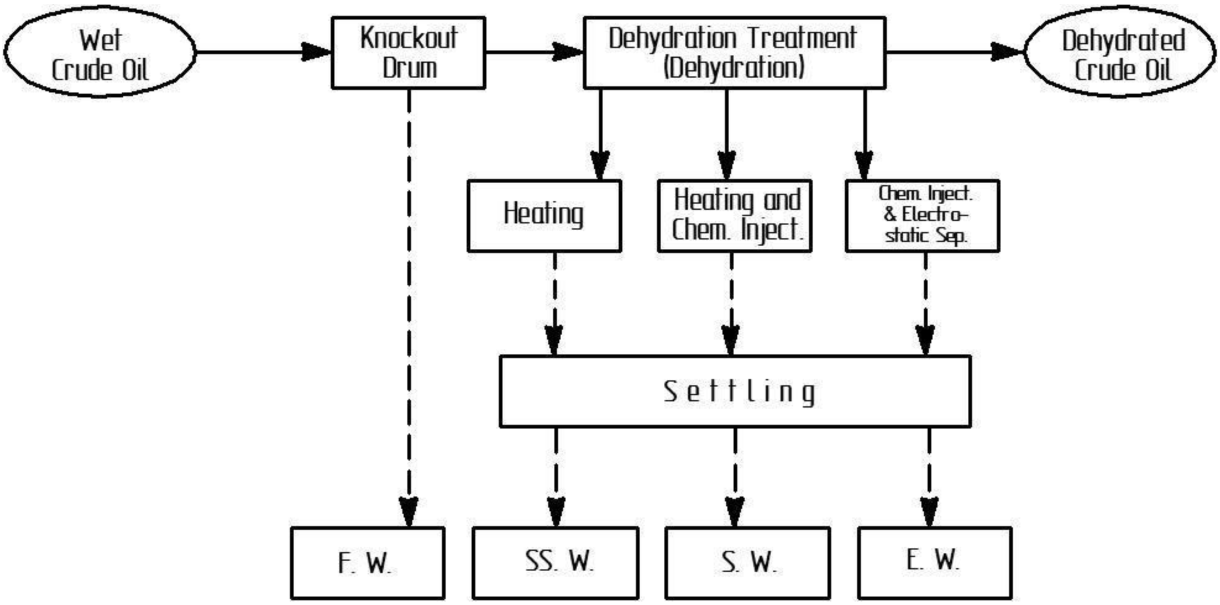


Figure 8: Basic approach of handling wet crude oil (F.W. = free water, SS.W. =suspended water, E.W. = emulsified water).

Dehydration Process

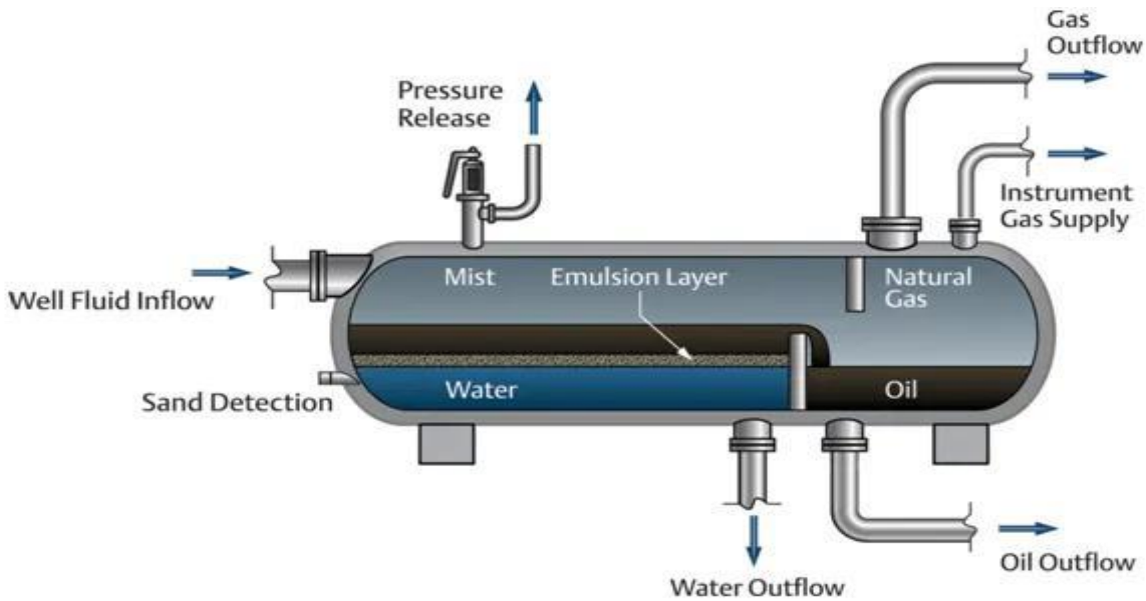
- Crude oil from separators normally contains up to 2% produced water in addition to water emulsified in the oil.
- When the product specification calls for a BS&W less than 0.5 %, electrostatic coalescer is commonly used.
- In dehydration stage by electrostatic coalescer, up to 10% water in inlet oil reduces to less than 0.2% volume water in oil after coalescing.

Successful dehydration of crude oil is carried out in three step:

- **Destabilization of the emulsion**
- **Coalescence of small drops into large drops**
- **Settling out of large drops and separation of the two phases.**

Destabilization of the Emulsion

- During crude oil production and processing, unfavorable formation called emulsion is formed due to dispersion of a liquid (dispersed phase) in the form of droplets, entirely in another liquid (continuous phase).
- Emulsion is an unwanted formation that causes serious corrosion in pipelines, processing equipment, and increase in operational and capital cost.



Stable inter-facial films can be broken down by:

- Chemical demulsifiers
- Heat treatment
- PH treatment
- Increased salinity.

Coalescence of water droplets

This is achieved by introduction of electric field into the oil–water emulsion. When the emulsion passes through the electric field, the water droplets are electrically charged, and then dipole will be created. Dipole attraction between water droplets causes the coalescence of droplets. The attraction between water droplets in an electric field is given by:

$$F = \frac{K_s \varepsilon^2 (d_m)^6}{S^4} \; with \; S \geq d_m$$

F: attractive force between droplets

Ks: constant for system

ε: voltage gradient

dm: diameter of droplets

S: distance between droplets

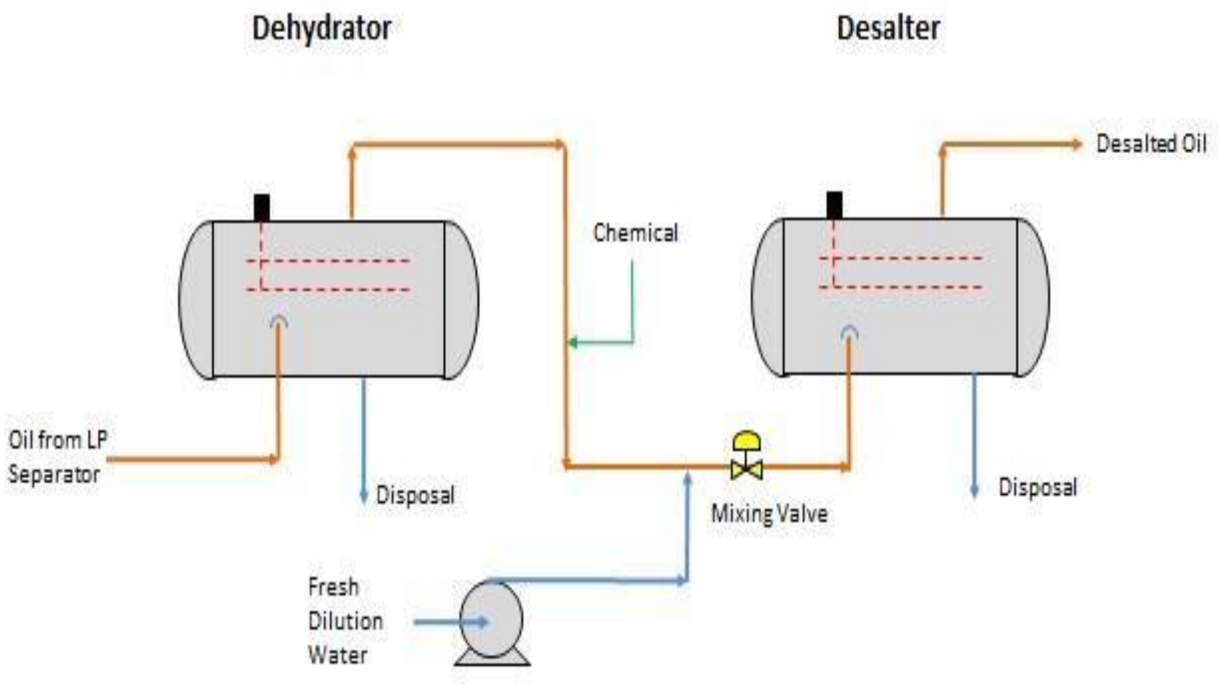


Figure 9: Typical Dehydrator and Desalter Arrangement.

Why crude dehydration?

Crude oil often contains water, inorganic salts, suspended solids, and water-soluble trace metals. As a first step in the refining process, to reduce corrosion, plugging, and fouling of equipment and to prevent poisoning the catalysts in processing units, these contaminants must be removed by desalting (dehydration).

Mimic diagram

- A line diagram of a pipe system or items of equipment which includes miniature alarm lights or operating buttons for the relevant point or item in the system.
- The mimic diagram provides the operator with an overview of the status of the power system.
- The dynamic data shown on the mimic is updated automatically.
- The mimic diagram can also accommodate analog meters, digital displays, directional power flow indicators and chart recorders.

Benefits

- The operator is able to scan the overall status of the complete power system at a glance.
- The mimic diagram provides a pictorial view of the power system network.

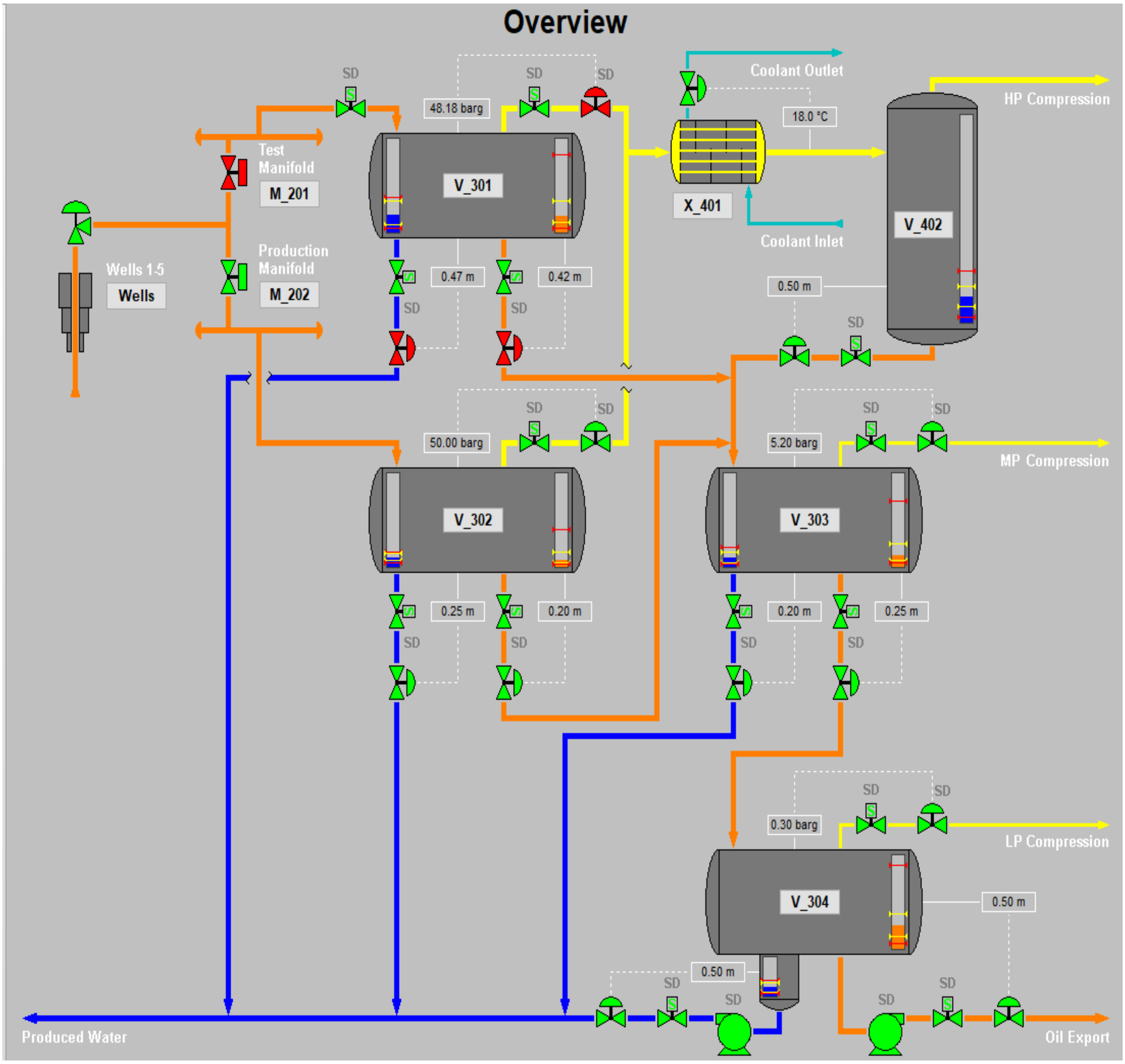


Figure 10: Mimic diagram for typical oil and gas separation train.

Desalting of crude oil

- The removal of salt from crude oil for refinery feed stocks has been and still is a mandatory step. This is particularly true if the salt content exceeds 20 PTB (pounds of salt, expressed as equivalent sodium chloride, per thousand barrels of oil).
- The most economical place for the desalting process is usually in the refinery. However, when marketing or pipeline requirements are imposed, field plants are needed for processing the salty oil prior to shipping.
- Salt in crude oil is, in most cases, found dissolved in the remnant brine within the oil. The remnant brine is that part of the salty water that cannot be further reduced by any of the dehydration methods

Table 1 shows the amount of salts found in oils for various regions in the world

Table 1: Average Values for the PTB for Some Typical Crude Oils.

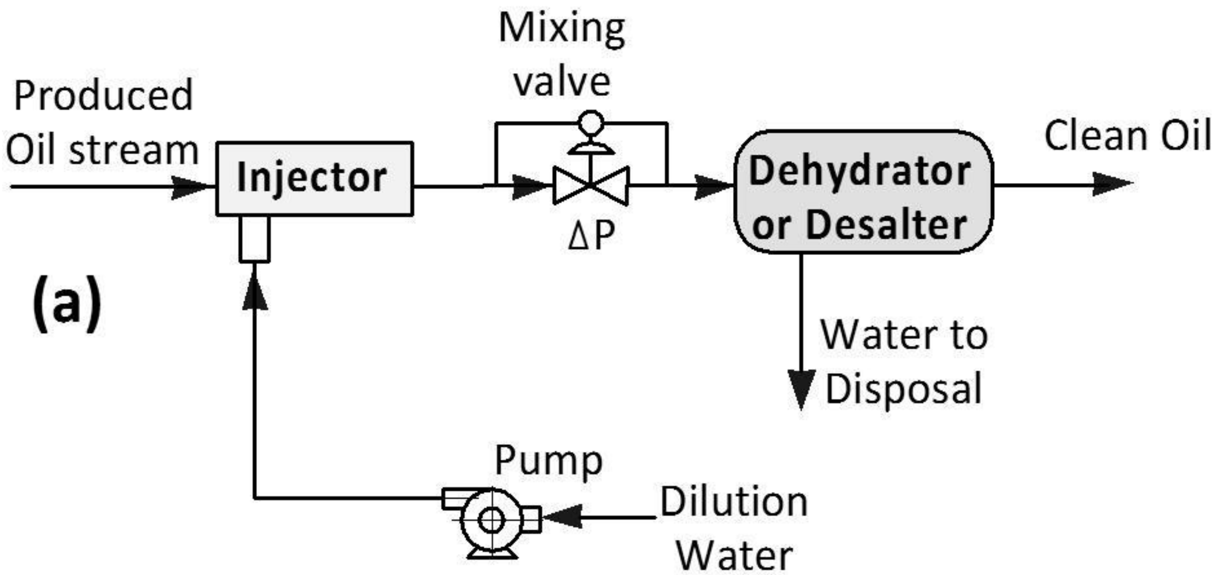
Source of oil	Avg. salt content (PTB)
Middle East	8
Venezuela	11
United States	
Pennsylvania	1
Wyoming	5
East Texas	28
Gulf Coast	35
Oklahoma and Kansas	78
West Texas	261
Canada	200

- The amount of salt in the crude oil is a function of the amount of the brine that remains in the oil WR (% B.S.&W.) and of its salinity SR in parts per million (ppm).
- The method of reducing the PTB by lowering the quantity of remnant water WR is usually referred to as the treating process of oil dehydration.

- The other alternative of reducing the PTB is to substantially decrease the dissolved salt content of the remnant water (i.e., its concentration, SR). This practice is known as desalting.
- Desalting of crude oil will eliminate or minimize problems resulting from the presence of mineral salts in crude oil. These salts often deposit chlorides on the heat transfer equipment of the distillation units and cause fouling effects.
- The removal of these salts is aimed at providing an economical operating cycle in the refining process of crude oil. The reduction of salt content down to 5 PTB is feasible.

Description of the desalting process

- We cannot economically achieve a satisfactory salt content in oil by using dehydration only (single stage). This is particularly true if the salinity of the water produced with oil is much greater than 20,000 ppm (formation water has a concentration of 50,000–250,000 mg/L). Accordingly, a two-stage system (a dehydration stage and a desalting stage) is shown in Figure 11 . Under certain conditions, however, a three-stage system may be used which consists of a dehydration stage and two consecutive desalting units as shown in Figure 11(b).



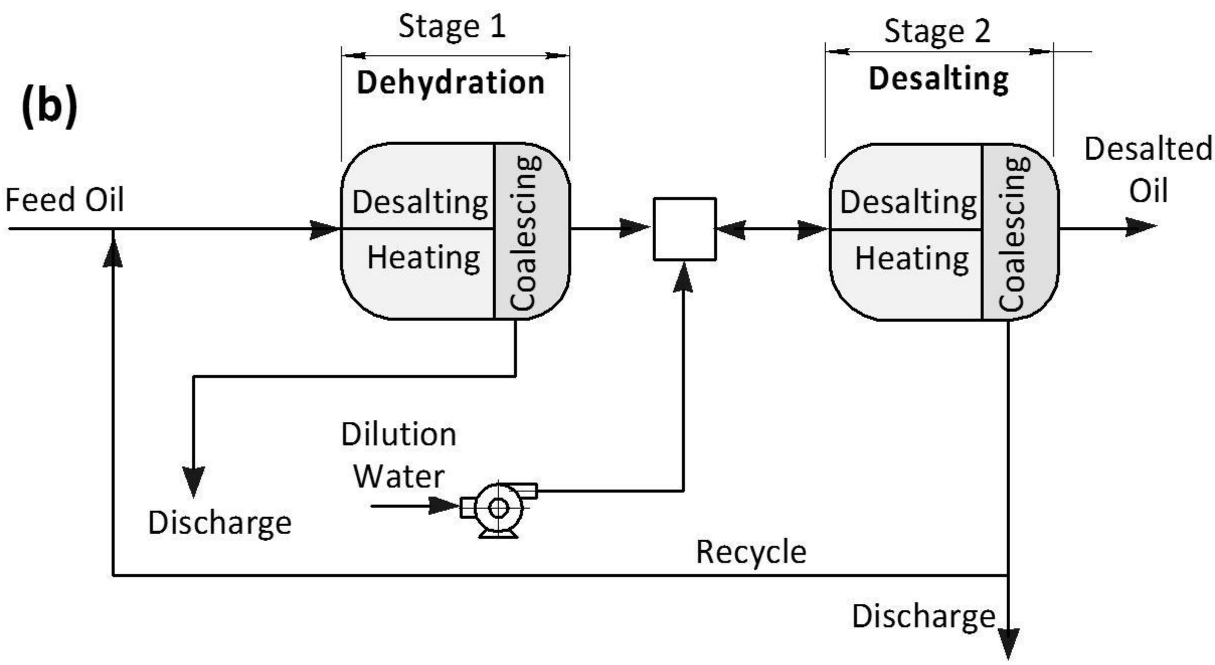


Figure 11: (a) Single-stage desalting system (from Ref. 5). (b) A twostage desalting system.

- Wash water, also called dilution water, is mixed with the crude oil coming from the dehydration stage. The wash water, which could be either fresh water, or water with lower salinity than the remnant water, mixes with the remnant water, thus diluting its salt concentration. The mixing results in the formation of water–oil emulsion. The oil (and emulsion) is then dehydrated.
- The separated water is disposed of through the field-produced water treatment and disposal system.
- In the two stage desalting system, dilution water is added in the second stage and all, or part, of the disposed water in the second stage is recycled and used as the dilution water for the first desalting stage. Two-stage desalting systems are normally used to minimize the wash water requirements.
- The mixing step in the desalting of crude oil is normally accomplished by pumping the crude oil (which is the continuous phase) and wash water (which is the dispersed phase) separately through a mixing device. The usual mixing device is

simply a throttling valve. The degree of mixing can be enhanced if the interfacial area generated upon mixing is increased.

- The chemical desalting process involves adding chemical agents and wash water to the preheated oil, followed by settling, is shown in Figure 12. The settling time varies from a few minutes to 2 h. Some of the commonly used chemical agents are sulfonates, long-chain alcohols, and fatty acids.

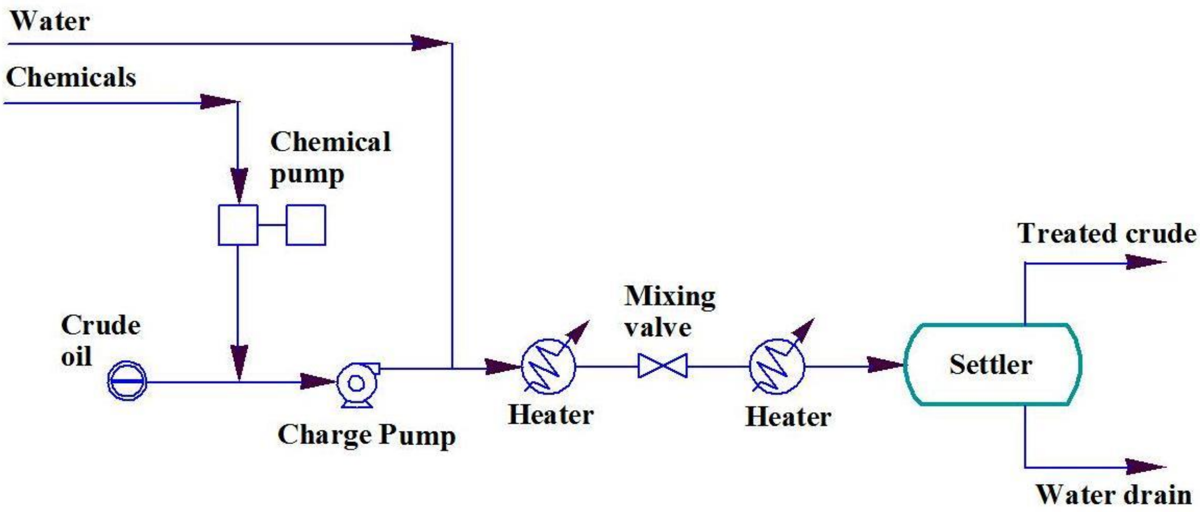


Figure 12: Chemical desalting.

Electrostatic Desalting

In this case, an external electric field is applied to coalesce the small water droplets and thus promote settling of the water droplets out of the oil. The electric field may be applied in any of the following manners:

1. ac field devices for water-rich emulsions.
2. ac/dc field for maximum dehydration
3. Variable gradient field for maximum salt reduction.

In the electrical desalting process, a high potential field (16,500–33,000 V) is applied across the settling vessels to help coalescence, as shown in Figure 13.

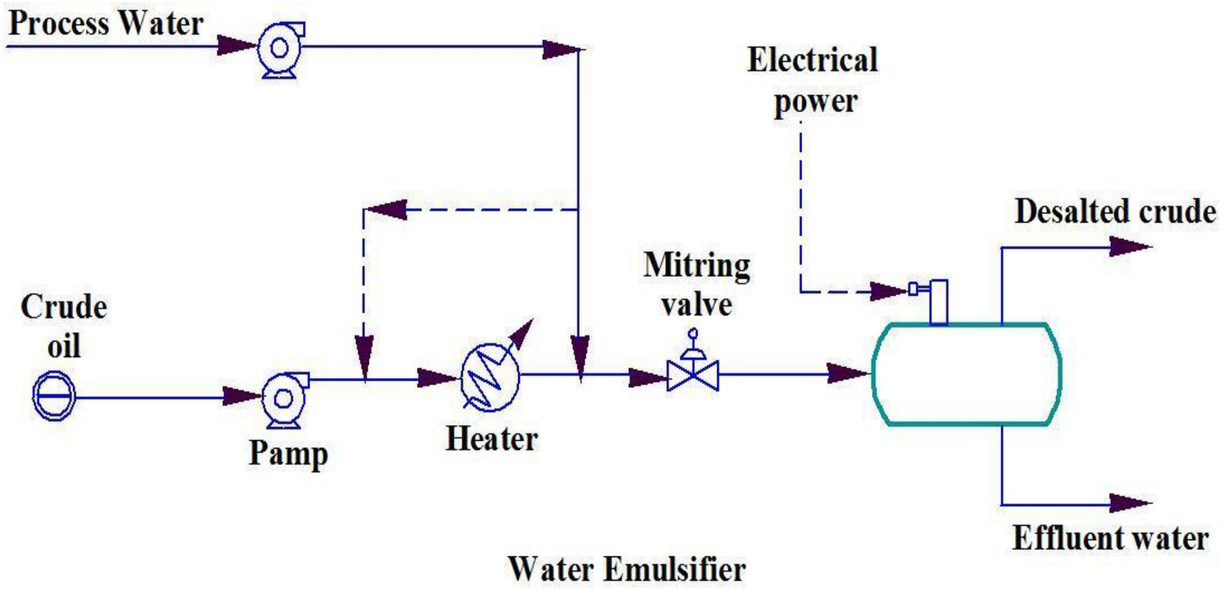


Figure 13: Electrical desalting.

The chemielectric concept utilizing both chemical agents and electrical field is schematically illustrated in Figure 14. In the desalting process, it is a common practice to apply enough pressure to suppress any loss of hydrocarbon due to vaporization of the oil. The pressure normally used in a desalting process is in the range 50–250 psi.

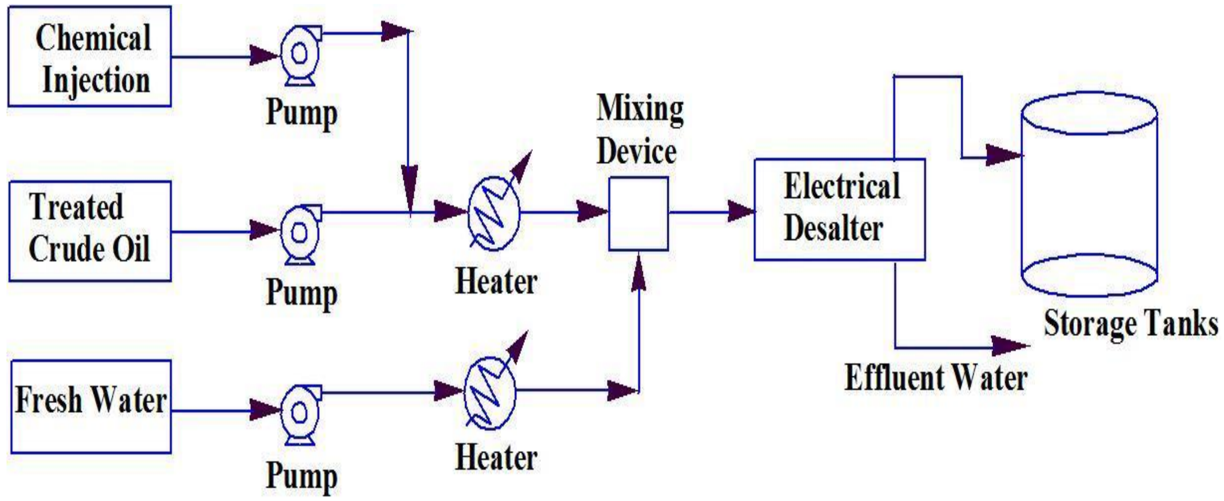


Figure 14: A typical desalting system utilizing chemelectric approach.

The efficiency of desalting is dependent on the following parameters:

1. Water–crude interface level.
2. Desalting temperature.
3. Wash water ratio.
4. Pressure drop in the mixing valve.
5. Type of demulsifiers.

Table 2: Average Desalting Conditions.

Crude gravity (°API)	Desalting temperature (°C)	Minimum water ratio (vol%)
>40	110	2–4
30–40	110	4–8
	120	4–7
<30	130	8–10
	140	>10

Storage Tanks

Storage tanks for crude oil are needed in order to receive and collect oil produced by wells, before pumping to the pipelines as well as to allow for measuring oil properties, sampling, and gauging (Figure 15).

Figure 15: Storage tanks.

The design of storage tanks for crude oil and petroleum products requires, in general, careful consideration of the following important factors:

- The vapor pressure of the materials to be stored.
- The storage temperature and pressure.
- Toxicity of the petroleum material.

Types of Storage Tank

The main features of some of the common types of storage tank used by the petroleum industry in general are presented in Table 3.

Table 3: Summary of Refinery Storage Tanks.

Characte-ristics	Standard Storage Tanks	Conservation-Type Storage Tanks		
		I (Floating Roofs)	**II (Variable-Vapor-Space)**	**III (Pressure Storage)**
Evaporation losses	High	Significantly reduced	Significantly reduced	Prevented or eliminated
Operating conditions	Recommended for liquids whose vapor pressure is atmospheric or below at storage conditions (vented).	Allow no vapor space above the liquid: level (no venting)	Allow the air-vapor mixture to change volume at constant or variable pressure (no venting)	Allow the pressure in the vapor space to build up. Tanks are capable of withstanding the maximum pressure without venting.
Sub-classification	1.Rectangular 2.Cylinderical: a) Horizontal b) Vertical	-	1. Lifter roof, which is a gas holder mounted on a standard storage tank. 2. Vapor-dome	1.Low-pressure storage normally designed for 2.5-5 psig and up to 15 psig (0.14 – 0.34 bar and up to 1.02 bar) 2.High pressure storage: 30-200 psig (2 – 13.5 bar)
Typical types	Cone-roof-vertical (cylinderical tanks)	Floating-roof. wiggins-Hidek type	Lifter roof tanks. wiggins dry seal type	Spheroids and hemispheroids for low pressure storage, spheres for high pressure storage
Applications	Heavy refinery-products	Sour crude oils, light crude oils, light products.	Light refinery product and distillates	Spheroids are used to store aviation, motor, jet fuels. Spheres are used to store natural gasoline and LPG.