THE BASICS OF OIL AND WATER EMULSION TREATING*

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ABSTRACT

When crude oil is brought to the surface, various amounts of water, gas and other elements are mixed with the oil into a homogeneous mixture referred to as an "emulsion." Before the oil is refined, the water, gas and other elements must be removed from the oil. This removal, or separation process, is referred to as "treating."

A combination of heat, settling and chemical treatment is used to affect "treating." A recent development adds the use of electrostatic grids to improve "treating."

INTRODUCTION

When crude oil is brought to the surface by whatever means, various amounts of water, gas, and other elements are blended with the oil into a homogeneous mixture referred to as an "emulsion." Before being refined, the oil must have the water, gas, and other elements (called "basic sediment and water") removed. This removal, or separation process, is referred to as "treating" or "dehydration."

An emulsion is a combination of two immiscible liquids which will not molecularly disperse into each other. In an emulsion, the liquid which is in the form of minute droplets is called the dispersed liquid or internal phase, and the other liquid in which the dispersed liquid is present is called the continuous or external phase. Oil field emulsions are usually of the water-in-oil type with the size of the dispersed water particles varying in size from large drops down to minute droplets about 1 micron in size.

To produce or form an emulsion, two conditions are required: first, the presence of two liquids which are immiscible such as oil and water, and, second, sufficient agitation to ensure mixing of the two liquids. This mixing action can be the result of the fluids passing through perforations, chokes, orifices, or other restrictions, and by the agitation caused by gas lift or sub-surface pump, especially if the pump is slightly worn. If the emulsion is to be "tight", or stable, it must have in its presence an emulsifying agent or emulsifier. These emulsifying agents are closely associated with the production of oil, water, and gas and vary widely as to composition. They may be asphalts, resins, paraffin waxes, sulphur compounds, organic acids, corrosion products, or solids, such as sand, shale, silt, clay, and gilsonite. The type of emulsifying agent is one of the factors determining the type of emulsion: water-in-oil or oil-in-water.

The problem of emulsions has been the subject of extensive studies ever since it was first recognized. Today's operator is more aware of the complexities of these emulsions and considers each individually, for lease consolidations mean larger volumes of fluid which must be dehydrated efficiently and economically. Therefore, a basic understanding of the treatment of emulsions is a necessity if per-barrel operating costs are to be reduced.

An example of difficult-to-treat emulsions in today's operations consists of the crude emulsions produced by the steam-injection systems now so numerous in California. Since the introduction of this process, the problem of treating thermally produced low gravity-high viscosity crude oil and emulsions has become severe and expensive. The severity of these emulsions is caused by the steam-injection process, which helps create a more stable emulsion through the addition of energy and agitation to the produced fluids, and the continual addition of fresh water to the reservoir and produced fluids.

In order to promote destruction of a crude oil emulsion, it is necessary to displace the emulsifier and its film, to bring about the coalescence of droplets of water, and furnish a means and time period of an undisturbed settling of the coalesced water drops. There are several methods of treatment available for the destruction of oil field emulsions, and as a rule, will be found used in conjunction with each other.

THERMAL: In the Thermal method of treatment, the process involves the application of heat to break the oil-water emulsions by effecting a reduction in the surface tension of the film. While this is considered to be the main effect, it is known that the application of heat also causes thermal currents to be created within the treating vessel and as a result of these thermal movements, small droplets of the fluids will collide, rupture the film, and coalesce.

CHEMICAL: The Chemical method of treatment requires the dispersion of a chemical demulsifier, or emulsion breaker. These demulsifiers, or surface-active agents, migrate to the oil-water interface, rupturing the film, or weakening it sufficiently for the emulsifier to be dispersed back into the oil and for the intermolecular forces of like substances to attract, collide, and coalesce.

MECHANICAL: The Mechanical method of treatment is the simplest of all methods and probably the least understood. It involves the use of baffles arranged and installed inside a vessel so as to permit degassing of the incoming fluid, control direction of fluid flow, limit and control travel of thermal currents, and promote better coalescence of the emulsion droplets.

GRAVITATIONAL: The Gravitational method of treatment is nothing more than allowing the force of gravity to do its job of settling out the droplets. This is a function of time and is dependent upon the degree of stability of the emulsion.

ELECTRICAL: The Electrical method of oil field emulsion treatment involves the use of electrical or electrostatic fields for the purpose of causing small dispersed droplets to move, collide, and coalesce (thus the term "electrical coalescer").

VERTICAL AND HORIZONTAL TREATERS

This is where emulsion treating comes into view, the first of which was a vertical treater (Figure 1). Emulsion enters at the top, or inlet, section of the treater where free gas is released. Degassed fluid then flows down to the bottom section where free water is released.

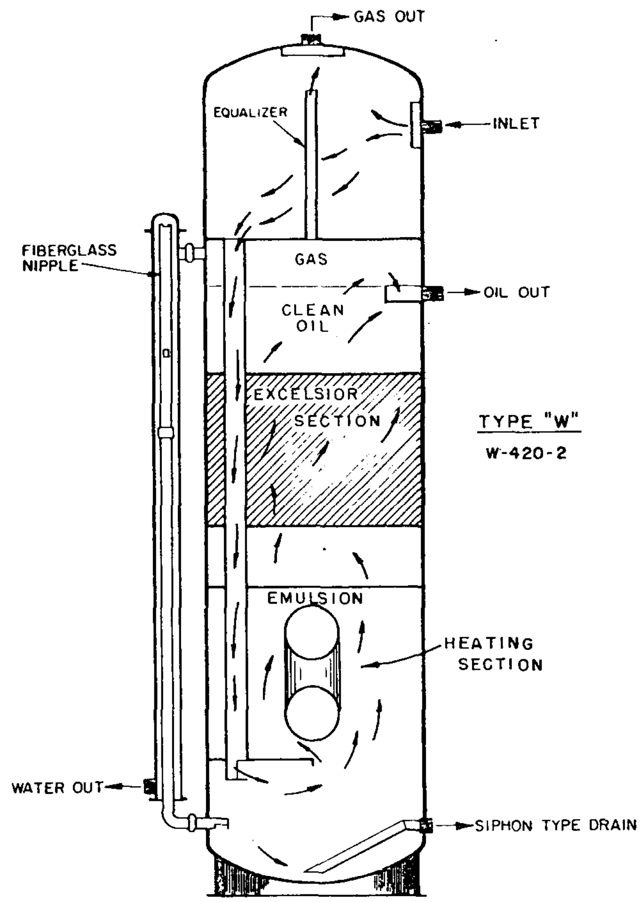

FIGURE 1 VERTICAL TREATER

The fluid now consists of oil and tightly trapped or entrained water and gas. To remove this, the fluid travels upward into the heating section where "treating temperature" is reached. These minute particles of water and gas are physically enclosed or encapsulated with very thin coverings of oil. The emulsion breaker and heat serve to soften this covering. Heat also causes these particles to agitate and, through physical contact, begin to merge into larger more easily separated droplets.

The heated fluid then rises into a coalescing section where it comes into contact with excelsior, a water-absorbent element. This wetted surface causes the water to coalesce or blend into larger drops and separate from the oil. Water flows downward for removal at the bottom, and released gas flows upward through the oil and is removed from the top.

Clean oil is removed from above the coalescing section.

So far we have described the basics of separation, or dehydration, using vessels of vertical configuration.

Production volume capacity of a vertical configuration vessel is limited by its cross-section and the usable size of its coalescing section, combined with the capability of the heating section.

To meet higher production requirements, a preliminary stage, called a flow splitter, was developed. This stage, placed between chemical injection and separation, divides produced fluids among two or more treaters. Flow splitters, with free water knockout and free gas removal capabilities, increase the efficiency and volume handling of treaters.

Continuing efforts to achieve high volume production in a single vessel led to the development of the horizontal treater. Early designs in effect laid a vertical vessel on its side and attempted to establish horizontal flow. Efficiency and volume were unsatisfactory. Problems included a reverse action tendency in the coalescing section, which caused some emulsions to tighten rather than separate, the danger of free gas entering the heat section, and fluctuations in treating temperature and pressure. Understandably, horizontal treaters were not accepted by the industry until the VFH treater (Figure 2), with vertical flow in a horizontal vessel, was developed.

The inlet section of the VFH treater is to the left. Emulsion enters and free gas is released; the fluid flows downward, around a U-shaped hood, to the bottom where free water is released. Free gas, in the upper section, flows through the inverted U-shaped gas equalizer into the heating section.

Degassed fluid rises around the heater section, releasing entrained gas to be discharged with the free gas. Heated fluid flows over a baffle into the coalescing section, where final removal of water occurs.

In addition to be capable of higher volume, VFH systems are more efficient dehydration processors and are more easily adapted to solving specific regional problems, such as those encountered in California's thermal recovery fields. Continuing developments in the internal components of oil dehydration facilities, including electrostatic coalescense, increase both efficiency and volume capabilities of equipment.

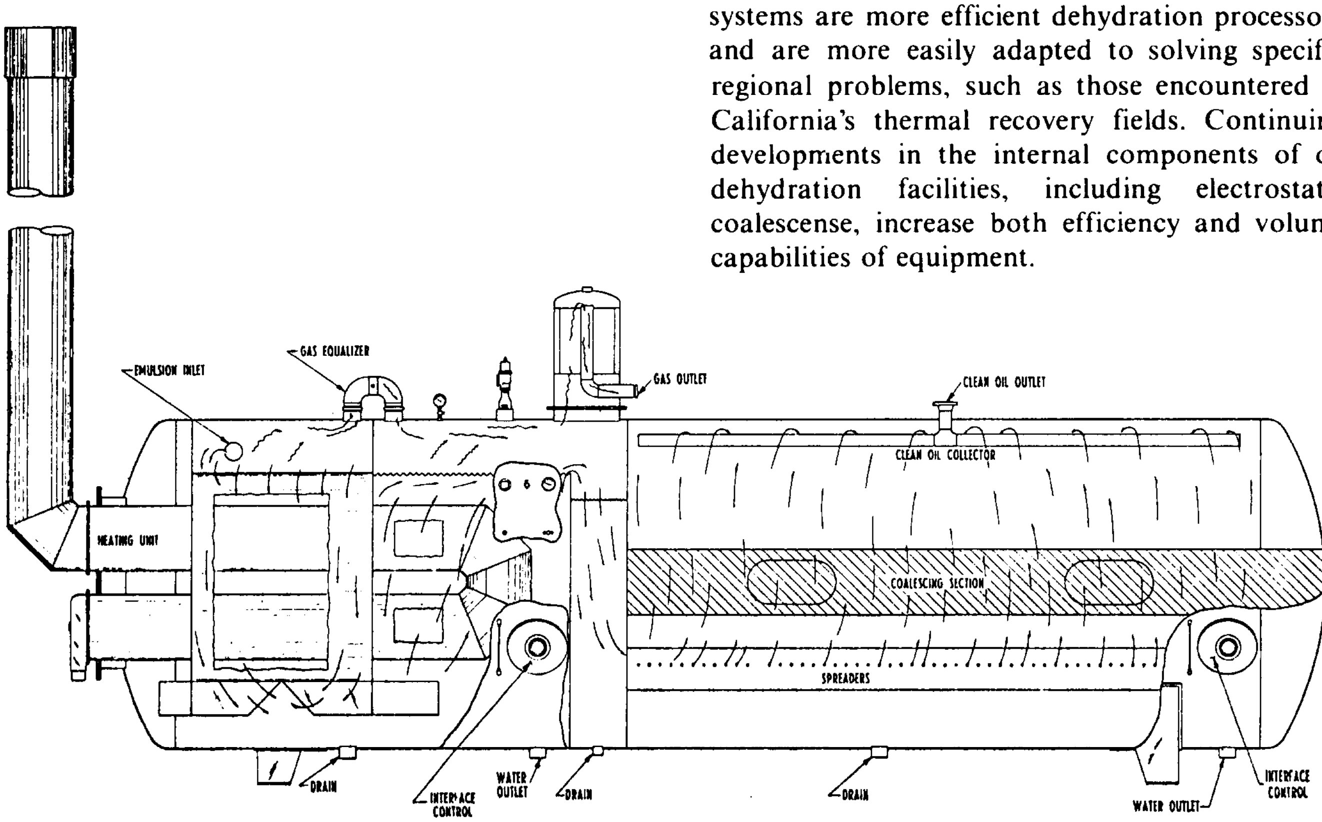

FIGURE 2--VFH OIL PROCESSING UNIT

Basically, those are the processing steps crude oil must undergo from bottomhole, to transportation, to refinery acceptance. A number of specific internal and external controls and modifications may be added to the basic process, each dependent upon the specific requirements of the producing well or wells.

Many factors must be considered in selecting the proper facility to dehydrate crude from a particular well or lease. The first area of consideration is the emulsion. It must be analyzed and an emulsion breaker formulated to meet the particular characteristics of the fluid.

The second consideration is volume: the barrels of oil and the volume of gas to be handled per hour. In general, a vertical flow horizontal unit will handle the same volume as three vertical units of the same cross-sectional area.

Ambient temperature of the emulsion and climatic temperature extremes must also be taken into consideration. The fourth consideration is the flow factor of the emulsion to be treated: its specific gravity and viscosity.

Location, primary and secondary recovery methods, the type of artificial lift (or gas lift)—literally hundreds of factors must be taken into consideration when a dehydration facility is being designed. Time spent in properly analyzing each factor and meeting each problem will assure the operator of profitably delivering salable oil and gas to his markets. And, time spent in an operator's becoming familiar with the facility operations, preventive maintenance, and basic troubleshooting can save downtime later.

Startup procedures for all vertical and VFH units are similar. The proper amounts of water and emulsion should be in the vessel before the heater is fired. Each valve and control has a specific function and should be opened, or shut, in its proper sequence. Exact operating temperature and internal pressures must be maintained.

Daily, check the chemical pump and tank. If you aren't injecting emulsion breaker in the proper proportion, your facility will not function. Turning valves an eighth of a revolution and then returning them to proper setting will prevent a buildup of paraffin or other minute particles of sediment that might cause them to become inoperative, gauge glasses should be flushed and then checked to see if they are indicating the proper level of fluid, and all temperature and pressure indicators checked to determine if the proper operating ranges are being maintained.

Each week the drain valves should be operated to flush out the bottom and drain the safety fuel gas scrubber. Fluctuations in fuel to the heater or a sudden shutoff can mean a long shutdown.

Flame arrestors should be checked monthly. Also the calibration of each pressure, temperature, and liquid-level indicator should be checked.

Once each year the fire tubes should be removed and inspected. At the same time, the coalescing section should be cleaned and checked. If your unit uses excelsior, it should be repacked. All valves, gauges and liquid level controllers should be checked, tested, and calibrated.

Even the best maintained equipment will have an occasional problem. Don't wait too long to contact your service technician, but have some basic information handy. Your daily, weekly and monthly checklists will establish normal operating conditions. But again, start with the well.

Are these changes in flow? Are these changes in downhole additives? When was the last time a bottle test was run on your emulsion? Is the chemical pump working? Is there chemical in the tank?

Is the treater discharging more or less water than normal? Is the level of water in the treater within operating limits?

Circulating a tank bottom probably causes more problems than any other single operating step. You have to "sneak" bottom fluid into the main flow as slowly as possible, almost without letting the treater "know" it's coming in!

Discuss all the "what if's" with your service and chemical technicians when your treater, or more accurately — crude oil dehydrator — is first installed. They will help you draw up your operational checklists and a "what if" checklist.

We've all laughed at stories telling of appliance servicemen answering an emergency call only to plug in the TV or refrigerator or washing machines, but nobody laughs when a service technician makes a long trip into the boondocks, or offshore, only to turn a valve handle, to throw a switch, or to point out an empty chemical tank. It has happened!

In summary, there are many factors which must be taken into consideration when designing and installing a crude oil dehydration facility, just as no single emulsion breaker will work with all emulsions, no single oil dehydrator will handle all problems.

ELECTRICAL COALESCERS

Essentially, there's only one effective method of separating oil and water, and that's by gravity. Water is heavier, and given time, plus favorable conditions, it will fall to the bottom of storage tanks or treaters. Once this separation occurs, the water can be drained off from the bottom for disposal while the dehydrated oil is piped off from the top.

All this sounds quite simple and easy to accomplish, and in its most basic form it is simple. However, water separation by gravity alone requires a lot of time in some crude oils.

Even with the help of baffles or wet excelsior pads to enchance the gravity separation process and even with the application of heat or chemicals, the water content is generally cut from around 5 percent to about 1 percent, which is still not good enough. For even this one percent constitutes a threat of corrosion and a waste of energy in the transmission and treatment stages.

The finer the droplets of water, the more time that is required to separate them by gravity alone. And time is money in the oil business as in any other business. As it turns out, there is a way to speed up the process. It's called "electrostatic coalescing." It was discovered some 65 years ago and applied to the desalting phase of refinery processing. Figure 3 shows an electrostatic coalescer.

The speed with which a droplet of water falls to the bottom in a mixture of oil and water depends chiefly on the size of the droplet. So the real key to speeding up this process is the coalescing, or bringing together, small droplets to form larger droplets.

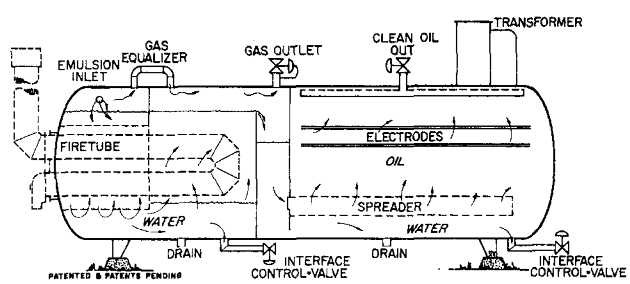

FIGURE 3—FLOW THROUGH ELECTROSTATIC COALESCER

Heat, chemicals and mechanical aids help a little in this respect. But, the most effective aid, by far, is an electrical charge.

When a high voltage from an alternating source is applied to an oil-water emulsion, the small water droplets become induced dipoles. This simply means each droplet will have a negative charge on one end, and a positive charge on the other end. This action causes the droplet to become ellipsoidal instead of spherical. With the negative and positive charges positioned at opposite ends of the water droplet, and each droplet aligned in the same manner, then every two adjacent droplets will have an attraction, that is, negative to positive. This induced electrical attraction causes the droplets to come together and coalesce into larger and larger droplets. The very small water droplets that are too far apart to be affected by this attraction will remain in the oil if they cannot be contacted by other droplets.

During the earlier days of oil production and processing, electrostatic coalescing was pretty much confined to the refinery stage. However, in the past 15 years or so, various forms of this process have shifted to the producing area itself and have gained wide acceptance.

Electrostatic treaters using only 60 Hertz alternating current (AC) generate a force field which acts on the suspended water droplets between the electrodes. This force field helps to elongate and polarize many of the droplets, but alternating current results in the force lines changing directions 120 times a second. Obviously, this gives the droplets a very short time in which to move together and coalesce. Some do manage, but the coalescence is purely random.

The dual polarity electrostatic treater introduces an entirely new dimension. By providing a constant direct-current (DC) electrostatic field at right angles to the AC field, droplets which are virtually unaffected by the rapidly reversing AC field are "trapped" by the DC field and migrate back and forth between opposing DC electrode plates. As the oil leaves the AC field and enters the DC field, half of the droplets present will be repelled from one electrode and attracted by the opposite. This means that these droplets are crossing and criss-crossing each other, and the probability of coalescing is greatly increased.

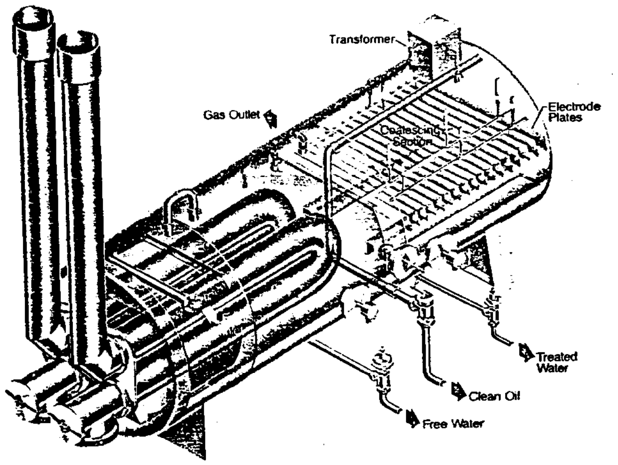

FIGURE 4 —DUAL POLARITY ELECTROSTATIC TREATER

Furthermore, these water droplets in this migrating back and forth will have a better opportunity to come into contact with any emulsion-breaking chemicals that may be added to the system.

Perhaps the most important aspect of this treater is the fact that it results in increased throughput rates at lower operating temperatures. Faster throughput means lower costs per barrel and lower operating temperatures yield more barrels, since less of the lighter hydrocarbons are lost in treatment. To get a better idea of the actual economic benefits of this low-temperature dehydration, take a look at what happened when 10,000 barrels per day of 32.5° gravity crude are processed by a conventional AC electrostatic treater and the same volume is processed by the Dual Polarity electrostatic treater.

The Dual Polarity treater can operate up to 25 degrees F lower temperature than the conventional electrical treater. As this chart illustrates, when the dual polarity treater is operating at a 15 degree F lower temperature, a fuel savings of 22,500,000 BTU per day can be realized. This means a savings of 37,500 standard cubic feet per day at 60-percent efficiency heat transfer.

At a 1977 representative price of $1.50 per thousand cubic feet, this translates into a cash savings of $56.25 a day, or $20,532 a year. Even more important, as seen in this chart, the lower operating temperature results in a 0.25-percent decrease in fluid loss. This translates into a savings of 25 barrels a day in the stock tank. With oil selling at $10 a barrel, this represents some $250 a day or $91,250 a year in additional income. Thus, the total net difference in income between conventional electrostatic treating and the dual polarity treating, in the case of a 10,000 barrel per day throughput of 32.5° oil, comes to $111,782 per year. If you project that over the producing life of the lease, and you can easily see that the economic benefits are quite significant.

What's more, the benefits don't end there. This advanced technique permits the use of smaller vessels and thus makes electrostatic treating practical for offshore platform production for housed artic operations and for terminal operations where large volumes must be handled.

The dual polarity electrostatic treaters have been proven in actual use at field production sites since 1971. One unit was installed on a lease that produces crude emulsion which is particularly difficult to dehydrate. With this unit, 2,000 barrels of oil are produced each day, along with an equal amount of fresh water. The dual polarity treater delivers dehydrated oil with basic sediment and water content no greater than one-tenth of one percent and it does it at operating temperatures up to 25 degrees *lower* than conventional electrostatic treaters.

In another example, three dual polarity electrostatic treaters were used to replace eight conventional VFH type treaters used for treating a steam-flood program. They successfully recovered 12-14 degree API crude *without* additional heat input to the produced stream. The stream was previously treated at a temperature of between 240 and 250 degrees F. By using the dual polarity treaters, they were able to lower the temperatures of the flow-stream to 218 degrees F after the removal of the free water and reduce the cost of fuel gas for their mechanical treaters by $106,000 per year.

CONCLUSION

To sum it all up, the removal of water from crude oil at the production site is more important now than ever before. The basic force employed for this purpose is gravity. But since gravity acts very slowly on widely dispersed, tiny water droplets as small as one thousandth of a millimeter in diameter, something must be done to bring these droplets together and coalesce them into larger drops. Coalescing can be assisted by mechanical means, such as baffles and excelsior packing, heat, demulsifying chemicals, and electrostatic treatment.