Chemelectric--The Electrical Coalescing Treater

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The present trend toward lease consolidation and automation coupled with a strong economic influence has brought about the re-introduction of electrical coalescers for the treatment and separation of oil field emulsions. The principle of electrostatic coalescing, now over 50 years old, has been combined with other proven methods of emulsion treating into a highly efficient integral packaged unit called the "Chemelectric Treater." See Figs. 1 and 2.

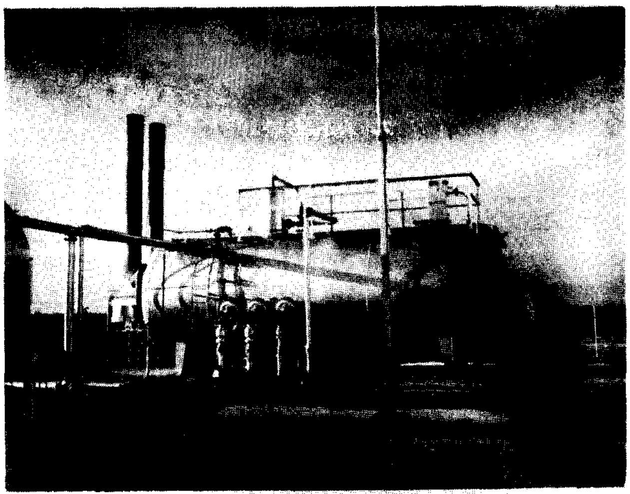


Fig. 2

Other factors influencing the reappearance of electrical coalescers are the degree and availability of electrical power now present throughout the oil field, and the definite need now existing for equipment of the proper design to effectively treat large volumes of fluid with varying field conditions.

EARLY HISTORY OF CRUDE OIL-WATER SEPARATION

The problem of separating water from produced crude oil dates back to around 1850. The objective then was the recovery of salt and not crude oil. To rid the salt water brine of crude oil it was necessary to allow both to settle in an open pit and then skim the crude contaminate from the surface and discard it as waste. With the advent of the petroleum industry in 1865, the salt water became the contaminate and the crude oil the product.

In these early years of the industry the separation of crude oil and water consisted of simply providing sufficient time for the fluids to stratify. A layer of accumulation between the crude oil and water phases was referred to as "sludge" and was removed by flushing from the storage tanks to a pit and burned. It was not until the early 1900's that it was discovered this interface build-up of waste was actually an emulsion of crude oil, water and solid contaminates, and was valuable if the crude could be separated.[1]

EARLY DEVELOPMENT OF THE ELECTROSTATIC PRECIPITATION PRINCIPLE

In an effort to improve the earlier methods of separation many different techniques of emulsion treating were developed and tried. Most methods revolved around ramifications of the use of settling tanks for gravitational separation.

The introduction of the electrical coalescer occurred around 1910 when it was developed and first applied as a method of treating oil field emulsions. In 1911, a basic patent was issued to Dr. F. G. Cottrell, a Professor of Chemistry at the University of California, relating to a process involving the use of an oil submersed high voltage electrostatic field. This field, acting on droplets of water . . . subject to polarization of high potential gradients . . . caused the droplets to link-up and form a chain from one electrode to the other.[2] The patent further stated the effectiveness of the forces was dependent upon the relative potentials and dielectric constants of the materials in contact.

Several of these units were tried in California and the Texas-Louisiana Gulf Coast Areas during the next 10 to 20 years. In the early 1930's, the introduction of an efficient pressure operated "heater-treater" gave operators the treating equipment that satisfied their immediate needs and conditions. This change occurred for two reasons: first, there was virtually no electrical power available in the oil fields; and second, there were increasing quantities of waste gas produced which could be used for fuel.

However, in other areas electrical coalescers continued to be improved and found wide application in refineries for use in crude oil desalting and other processes involving electrical coalescing and precipitation for the separation of solids, liquids, and gases.[3]

THE EMULSION PROBLEM DEFINED

An emulsion is a combination of two immiscible liquids which will not molecularly disperse into each other. In an emulsion, the liquid, 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.

As produced water-to-oil ratios increase, as is the case in secondary recovery water flood operations, there is a tendency towards inverse emulsions of the oil-in-water type. To keep within the scope of this paper it will suffice to say that inverse emulsions are difficult to treat and cause mechanical disposal problems, especially when produced in conjunction with products of corrosion and other solids. The subsequent paragraphs deal primarily with the oil-in-water type emulsions that relate to the merchandising of the oil.

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 insure 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.[4,5]

The degree to which an emulsion will become stable is dependent upon a number of factors. They are:

(1) Film stability of the emulsifying agent.

(2) Size of the dispersed droplets.

(3) Viscosity of external or continuous phase.

(4) Difference in density of the two liquids.

(5) Ratio of dispersed phase to total emulsion.

(6) Age of emulsion.

The emulsifying agent produces a film around the dispersed particle creating a film stability or interfacial tension of varying magnitude. It is this film which comprises a physical barrier around the water droplet that prevents the intermolecular forces between water droplets to bring about coalescence. This film has to be ruptured or discharged by the demulsifier or destabilized to allow water droplets to attract each other causing them to collide and coalesce.

TREATMENT OF EMULSIONS

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.

As far as treatment is concerned the viscosity of the external oil phase affects the oil-water resolution by the rate at which the dispersed de-emulsified water droplets will settle downwardly through the oil.[6] A less viscous and high gravity crude will separate more readily from salt water than will a highly viscous and low gravity crude separate from fresh water.

An example of difficult to treat emulsions in today's operations would be 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.[7]

In addition to droplet size of the dispersed liquid, the ratio of these droplets to the total volume will also determine the degree of stability. An unstable emulsion with 50 per cent oil and 50 per cent water will separate more readily than an emulsion wherein the percentage of the dispersed phase is considerably less than the external phase. This phenomenon has to do with the distance between water particles which directly influences the force of attraction between droplets. The greater the distance between particles, the weaker the force of attraction, and the lesser the probability of coalescence.

A fresh emulsion is usually less difficult to treat than an aged emulsion which has had a chance to set and settle out most of its free water. What remains, after the free water has settled out, is an emulsion with fewer droplets of dispersed water; therefore, there is less chance of colliding and coalescing, and consequently, the emulsion is more stable than when it is first produced.

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. They are as follows:

(1) Thermal
(2) Chemical
(3) Mechanical
(4) Gravitational
(5) Electrical

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.

Another theory held by many is that by heating the fluid droplets they are caused to expand to a point they will rupture their captive films, especially in the presence of surface tension reducers such as chemical demulsifiers or re-agents. This is further supported by the fact that chemical action will take place on an accelerated basis at higher temperatures.

Higher temperatures also mean greater fuel gas consumption and possible additional loss of crude oil gravity and volume. See Figs. 3 and 4. It is for this reason that treating temperatures should be held to the minimum level. For efficient thermal treating the treating equipment must not only treat at the lowest permissible temperature but must also incorporate a means for limiting thermal currents, condensing the hot gas vapors into the oil, and cooling both the gas and the dehydrated oil before flashing to atmospheric storage.

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. The remaining problem is to bring the droplets into contact without excessive agitation, or mixing, that would re-disperse the droplets. Any given chemical emulsion breaker may be excellent and efficient for one emulsion and entirely unsatisfactory for another. It is important, for effective and economical treatment that the operator encourage the chem-

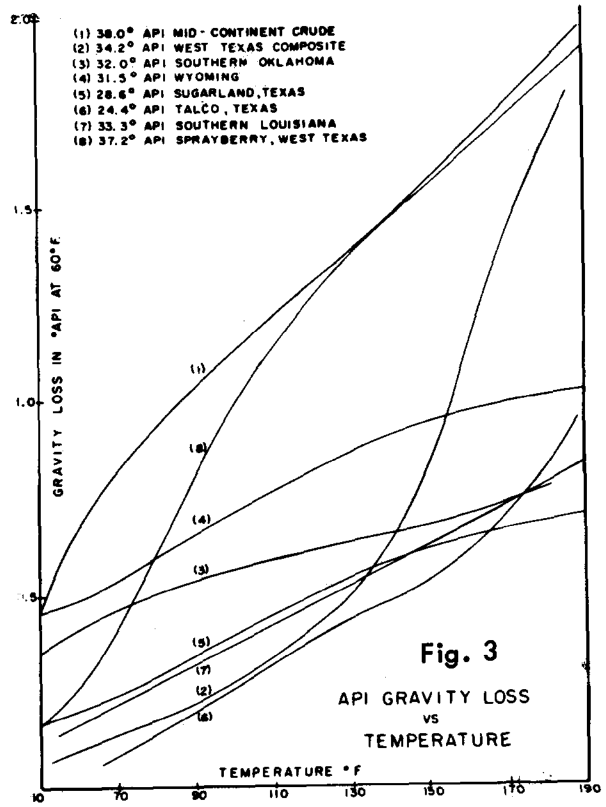


Fig. 3

API GRAVITY LOSS
VS
TEMPERATURE

GRAVITY LOSS °API
VS
PER CENT LOSS BY VOLUME

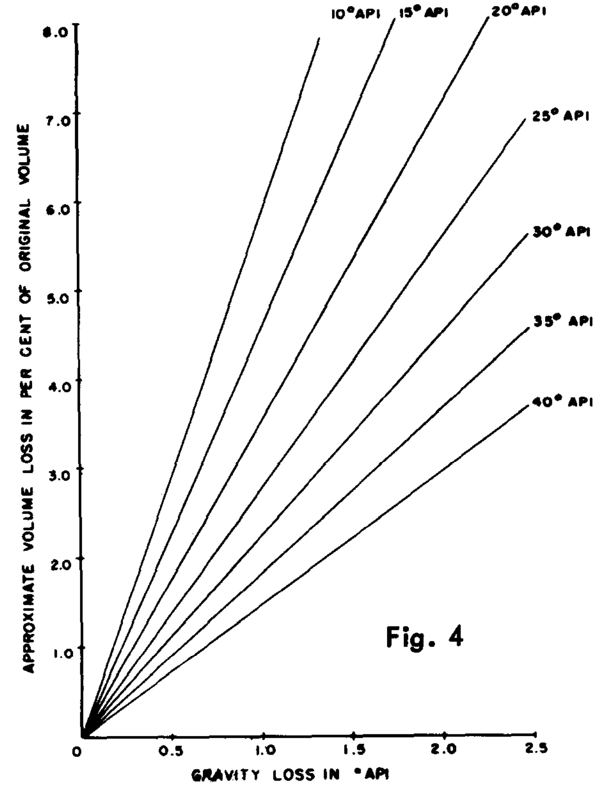


Fig. 4

ical supplier to analyze his specific problem. For further treatment on the subject of chemicals and their use in treating oil field emulsions, consult any of the many textbooks and references now available.

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. These baffles are two-fold in purpose: first, they guide the direction of gas and fluid flow and secure effective degassing and washing action of the fluids, and second, they hold and trap droplets of emulsion, so that they may collide and coalesce with like droplets. The first type of baffle referred to is a "flow" or "deflecting" baffle, and the second type, a "trap" or "retaining" baffle.

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. The time required to treat a barrel of fluid from the time it enters the treating vessel to the time it leaves as treated oil or water, is referred as "residence" or "retention" time. Methods have been developed to accelerate this process, usually by use of a high speed centrifuge, but so far have proved unsatisfactory due to investment and maintenance costs, limited volume throughput, and their difficulty in handling paraffin.

CURRENT THEORY OF ELECTRICAL TREATING

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." This electrical field also performs a second function of overcoming the resistance of the destabilized or ruptured films. This film resistance may be weakened and further ruptured by the stretching action resulting from the elongation of the water droplet when the droplet is exposed to the high potential of the electrical field. It should be noted here that there is a certain temperature at which the responsive characteristics of the film cease to be influenced by a high potential field. This explains why it is necessary to occasionally apply heat to the Chemelectric Treater and to hold the treating temperature above some minimum, especially if a demulsifier chemical is not utilized.

For a more detailed explanation of the effect of these electrical forces, consider a single droplet of water submersed in an oil external phase into which two electrodes have been placed and to which an alternating high electric potential is applied. Immediately, the water droplet has electrical charges acting on it and becomes an induced dipole.[8] A dipole is any object that is oppositely charged at two points or poles. The electrodes form the electrical field to which the droplet is responsive, and since the electrical supply is an alternating 60 cycle system, will cause the droplet to pulsate or elongate at twice the electrical frequency, or 120 times per second. When the power is removed from the electrodes the droplet resumes its original spherical shape. Figure 5a is a microscopic photograph of an uncharged water droplet. Figure 5b is a photograph of the same droplet under the influence of a high potential field.[9] If too high a potential is applied to the electrodes, the water droplets will elongate and stretch to a point where they pull apart and re-disperse into the external oil phase. See Figure 5c. On the other hand, if the potential is too low, the water droplets will line up and form a chain from one electrode to the other resulting in a short circuit and loss of electrical coalescing treatment. Conductance between water droplets reduces their attraction for one another and consequently, reduces their movement to a point where coalescence will cease.

Figure 6 shows the water droplets in an emulsion as recorded under a microscope with a high speed camera just prior to application of power. Figure 7 shows the same emulison 1/60 of a second later. It is the rapidly changing high potential of the electrodes, that induces charges upon the water droplets, and the intermolecular forces of attraction of the charged water droplets that together cause a fast movement and physical distortion of the droplets, resulting in their colliding and coalescing with

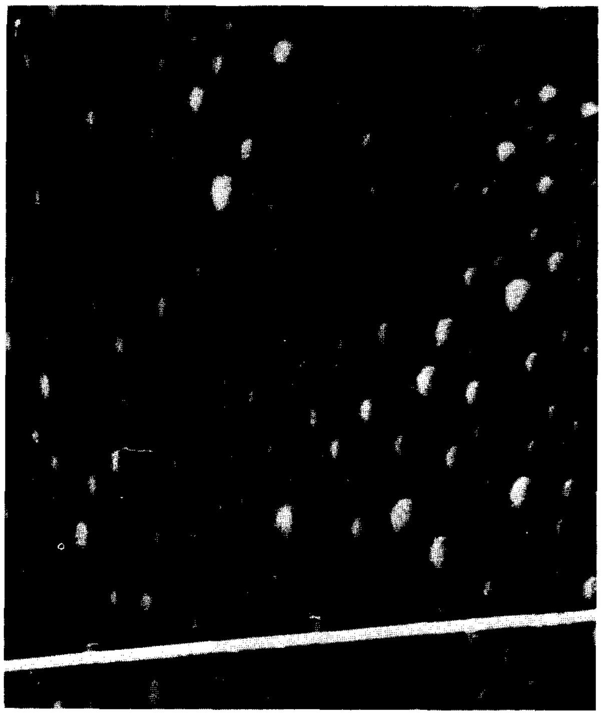


Fig. 6

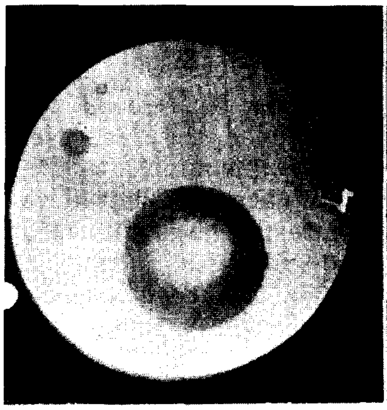


Fig. 5A

Fig. 5B

Fig. 5C

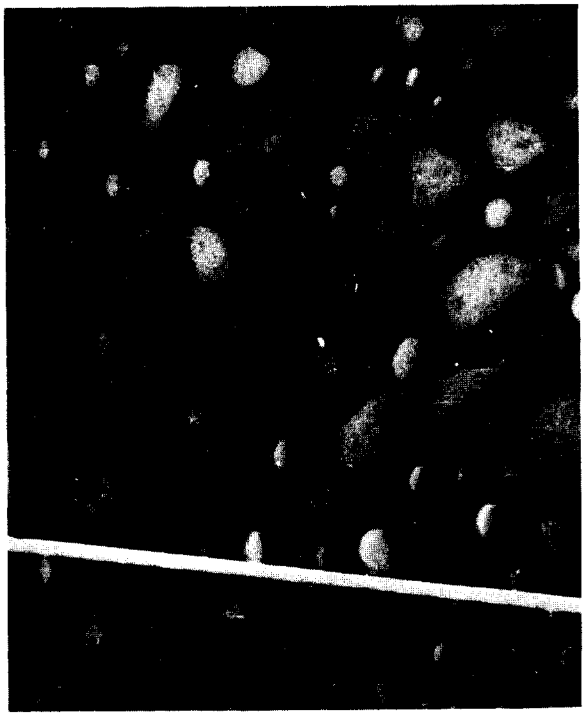


Fig. 7

other droplets. The intermolecular attracting forces between these droplets increase as the droplet size increases and as the distance between them decreases.

THE CHEMELECTRIC TREATER

Because of the need for improvement in operating economics, and the inherent advantages of the electrical coalescing method of treatment, the electrical coalescer was reintroduced in 1960 at the field production level in a new package referred to as the Chemelectric Treater. This unit combines several of the various methods of treatment with a new approach in fluid flow patterns of vertical flow in a horizontal vessel. Since effective emulsion depends upon the separation and coalescence of fluids it is essential that a vertical flow pattern be established. It has been within the last few years that a horizontal treater of this type has been developed, which not only has the advantages of a horizontal vessel, such as more interface area, but retains the necessary vertical flow characteristics.[10]

The Chemelectric is divided into several compartments as shown in Fig. 8. The incoming emulsion enters the treater at the side of the vessel near the top through an internal distributor into a de-gasing chamber. After degassing, the emulsion then travels down and up across the firetube for initial and final heating. In this down and up vertical flow pattern, some of the water droplets, which have become free due to the application of heat and their intermolecular attraction, are caused to coalesce and settle out to the free water interface. The free water is removed as it accumulates from the vessel through a water discharge valve controlled by the interface level control.

The emulsion enters the next compartment via a spillover weir for final removal of gas bubbles which may have developed as a result of the heating application. Emulsion then enters the bottom of the last compartment through a distributor. The distributor spreads he emulsion over the entire interface area of the coalescing compartment.

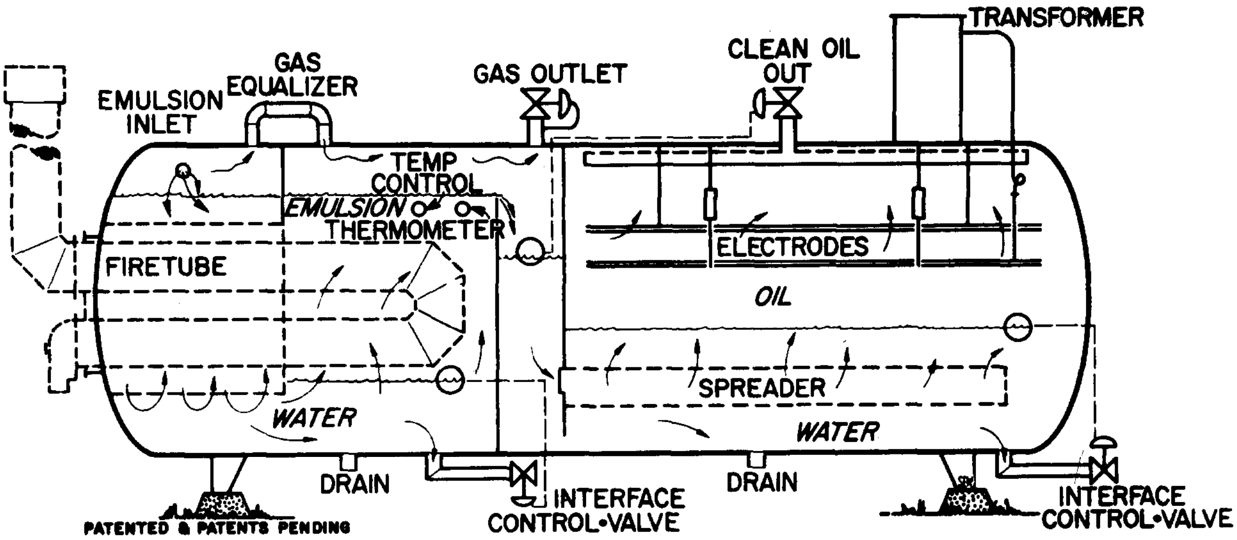
The interface level is regulated by the interface level control and water discharge valve. As the water rises, the water control valve will throttle open and discharge the free water from the bottom of the treater thereby dropping the level of the interface.

The emulsion continues upward into the electrical grid system where the remaining water droplets are coalesced and removed. The clean oil is then removed from the top of the vessel through a pipe running the length of the coalescing compartment and out through the oil valve to the tanks.

This oil outlet valve is regulated by a level control which discharges the oil at a rate equal to the emulsion entering the coalescing compartment, less that amount of water leaving the coalescing zone via the coalesced water discharge valve. The coalescing compartment is maintained in a fluid packed state during normal operation.

Should the treater experience a malfunction in the coalescing section, the electrical grid system is so designed and equipped to trip a safety shut-down. This electrical shut-down is required to minimize the possibility of any damage to the electrical system. Once the cause of the malfunction has been established and corrected the treater can be returned to service.

The Chemelectric employs an electrical a.c. field with an electrode potential of over 10,000 volts. This voltage is supplied by means of a step-up transformer. Input voltages can be



NATIONAL-PETRECO® CHEMELECTRIC® DEHYDRATOR

Fig. 8

either 220 or 440 volts a.c. single phase. The electrodes, or grids, are so designed to give maximum treating capabilities and electrostatic field efficiency together with complete and safe unattended operation. This optimum potential gradient to use for various oils is a result of 55 years of work in the field of electrical coalescers. Power consumption will be dependent upon several factors, but primarily will vary according to the conductivity of the fluid medium surrounding the electrodes. In the Permian Basin Area, this power consumption has amounted to as little as $0.15 per day up to as high as $1.00 per day on higher capacity units.

Table I lists a few of the Chemelectric installations throughout the Permian Basin. In several instances data was also available on the treating system in use prior to installtaion of the Chemelectric. While data on the Chemelectric is somewhat incomplete it can be noted that a definite improvement in treating temperatures, and in many cases, an improvement in gravities is realized. While it is known that the gravity of any given crude oil cannot be improved over its original formation gravity it can be maintained at a higher volume than is usually realized in present oil field operations.

This can be accomplished through the use of efficient gas separating equipment, lower treating temperatures, and/or an efficient treating system which will render the crude oil to the pipe line with as little BS&W content as possible. Even a small BS&W content will reduce the overall gravity of the product, thereby penalizing the product both quantitatively and qualitatively. Dollar savings as a result of lower operating costs, and increased income resulting from a higher quality product, have resulted in an added income ranging from a few dollars per day to several thousand dollars per month.

Date		County	Pay	Treating System No. and size	Production Bbls / day Average		Temperature °F. Average				BS&W Average %		Chem Used Qts/100 Bbls.	Gravity API Corr. Avg.	Estimated Cost Per Day $		
Mo	Yr	Status			Oil	Water	Amb	In	Out	Unit	In	Out			Gas	Chem	Elec
		YOAKUM															
Nov	64	Before	SA	*1-30"x10'	776	24	20	NA	115	165	3.0	0.8	1	33.0	NA	NA	NA
Nov	64	After	SA	1- 6'x15'	799	51	34	95	90	95	6.0	0.3	1	34.0	NA	NA	NA
		ECTOR															
Jun	65	Before	Gray	*1- 8'x27½	160	3	84	95	120	125	2.0	0.1	0	34.0	NA	NA	NA
Jun	65	After	Gray	1- 6'x15'	160	3	84	95	100	F.O.	2.0	0.1	0	35.0	NA	NA	NA
		GAINES															
Jan	65	Before	Dev	** Various	9900	2100	NA	NA	NA	120	17.5	0.4	1½	39.9	26.80	5.00	0.00
Mar	65	After	Dev	1-12'x60'	9900	2100	30	50	70	75	17.5	0.2	0	40.5[1]	13.25	0.00	1.00
Jun	65				9900	2100	NA	NA	NA	F.O.	17.5	0.2	0	39.7[1]	0.00	0.00	1.00
		COCHRAN															
Oct	65	Before	SA	***Various	300	75	NA	NA	NA	130	20.0	0.4	½	NA	1.00	0.55	0.00
Nov	65	After	SA	1- 8'x15'	300	75	NA	NA	NA	80	20.0	0.1	¼	NA	0.60	0.28	NA
		ECTOR															
Aug	65	Before	Gray	*1- 8'x20'	2200	100	NA	NA	NA	125	4.3	1.9	½	33.7	2.04	5.00	0.00
Oct	65	After	Gray	1- 8'x15'	2600	300	NA	75	80	F.O.	10.1	0.1	¼	35.3	0.00	2.00	0.20
Jan	66				1500	200	26	52	71	100	11.5	0.6	¼	35.9	1.63	2.00	0.20
		HOWARD															
Jul	64	Before	Clear	Various[2]	NA	NA	NA	NA	NA	130	60.0	0.3	NA	31.0	NA	NA	0.00
Oct	64	After	Clear	1- 8'x15'	400	725	NA	NA	75	90	64.4	0.3	NA	32.4	NA	NA	0.03
		ANDREWS															
Aug	64	Before	Wolf	Various[2]	NA	NA	NA	NA	NA	125	NA	NA	NA	39.0	NA	NA	0.00
Sep	64	After	Wolf	1- 8'x20'	1800	500	NA	NA	NA	90	22.6	0.2	¼	40.0	NA	3.00	0.17
Jan	66				1700	500	40	60	80	100	21.6	0.2	¼	40.1	NA	3.00	0.17
		MIDLAND															
Jun	65	Before	Spra	Various[2]	1000	1000	NA	NA	NA	155	NA	NA	NA	31.0	NA	NA	NA
Aug	65	After	Spra	1- 8'x20'	1100	1400	82	70	75	85	NA	0.2	¼	32.0	NA	NA	NA
Jan	66				1200	1600	38	44	75	105	48.0	0.4	¼	35.0[3]	NA	NA	NA

* - Direct fired heater or conventional vertical heater treaters.
** - Before lease consolidation - one 10'x27½', three 8'x27½', and three 6'x27½' treaters.
*** - Before lease consolidation - five 6'x27½' and one 4'x27½' treaters.
1 - With vapor recovery unit in operation. No vapor recovery before consolidation.
2 - Before consolidation. Number and size of treaters not available.
3 - Gravity of oil sold to pipe line. Actual corrected gravity from treater was 37.7°API.

Table 1

SUMMARY AND CONCLUSIONS

The modern electrostatic coalescer is an extremely valuable addition to the methods of dehydrating crude oils. Wherever it is applicable the electrostatic coalescer offers definite advantages in . . .

(1) Dehydration at lower temperatures which offer . . .
   (a) Fuel gas conservation. This means more gas is available for direct sale or plant processing.

   (b) Increased stock tank recovery per increment of well effluent which extends the production life of the well or lease.

   (c) A gravity increase that can mean more money per barrel.
(2) Accelerated coalescence of water droplets over vessels without the electrostatic aid which means . . .

   (a) More capacity per vessel.

   (b) Fewer vessels and less hook-up expense.

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