Chemical-Electrical Dehydration Process

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In virtually all crude oil formations, water is associated with the oil deposit in some way, and the two materials inevitably become mixed during some stage of the production process. The intense mixing encountered in passage of the oil and water -- together through perforations, pumps, restrictive valves, orifices, pipelines, etc. -- results in the formation of emulsions which can remain stable for extended periods, even up to years in time. The reason for this extraordinary stability is the presence in virtually all crude oils of "asphaltic" types of materials which have high surface activity and which adsorb on the oil-water interfaces of the droplets formed by the dispersion processes noted. Consequently the droplets of water, even when they are brought together by agitation or other means, will not coalesce readily. Under conditions free from agitation by thermal or mechanical influences, gravity forces will allow these particles to settle to some extent. However, even then they will not coalesce and will form a "sludge" which contains so much oil that it can no longer be economically discarded as it was in the early days of oil production.

Two general methods of resolving these emulsions have evolved over the past several decades. One is the chemical treating method, in which surface active agents replace the asphaltic emulsifiers by virtue of their greater surface activity and thus allow the droplets to coalesce on contact because the demulsifier film is much less rigid. The other method is electric precipitation in which the powerful forces of an electric field are applied to the droplets to bring them together. The electric field also has a disturbing effect on the protective film but sometimes even this is not sufficient to allow the droplets to coalesce, although the resistance of the films can then be overcome to some extent by the application of heat, which makes them more fluid.

Heating is also often required in the chemical dehydration processes. Electrical methods have not been as widely used for oil field dehydration because of the greater cost of the equipment and because of the requirements for electric utilities. The general practice today is to utilize appropriate chemicals, together with some additional heat, to obtain the most economical dehydration of the crude oil system.

To illustrate the effectiveness of the electric field in coalescing the water particles of a crude oil emulsion the photographs of Figure 1 have been prepared. These are enlargements from frames in a high speed motion picture film which recorded the treating action under a microscope of a crude oil emulsion containing 12 per cent water. The large particles are approximately 20 microns in diameter and the small ones about 2 microns. The horizontal line is an approximation of the voltage existing at the time when the picture was taken; zero is at the center. In Figure 1-A is shown the arrangement of the droplets immediately prior to the application of an alternating electric field, and indicates a fairly uniform distribution of the dispersed water particles. Figure 1-B shows the emulsion six frames (about 1/3 of a cycle or .005 seconds) after the voltage was applied, and it is evident that a considerable amount of coalescence among the particles has already occurred in this short time period. Most of the droplets have been coalesced with their immediate neighbors. Figure 1-C was taken 20 frames (1 cycle or 1/60 second) after application of voltage, and still further coalesence is

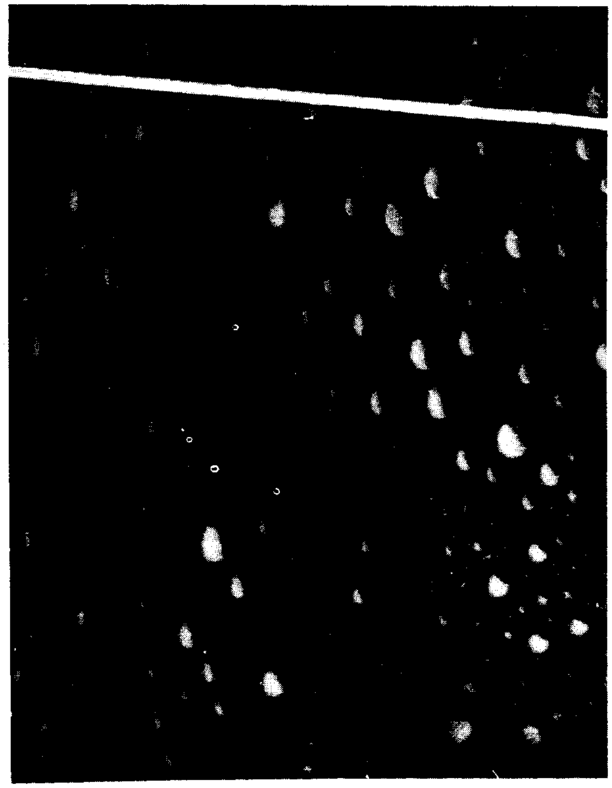

Fig. 1A

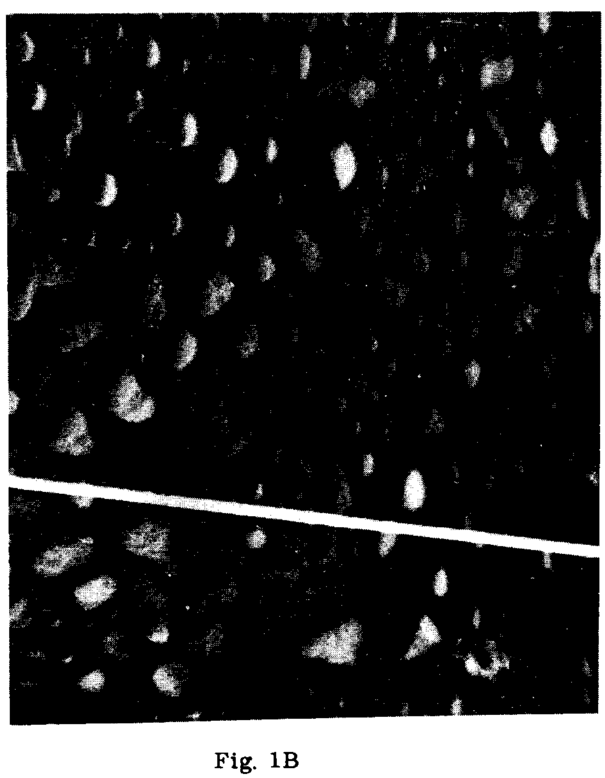

Fig. 1B

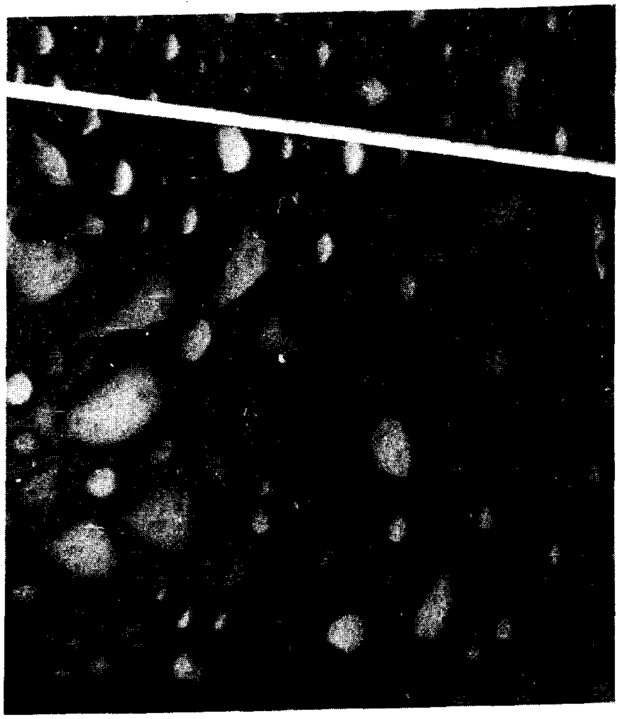

Fig. 1C
Coalescence of Emulsion Particles by Electric Field

evident. Because of the static nature of the system only a moderate amount of additional coalescence subsequently occurred because of the greater distance between droplets and the resistance of movement because of the viscosity of the system. The actual motion picture film section showed that, with each half cycle of the current, the originally round droplets were pulled into ellipsoids and oscillated in this manner at double its frequency. This exceedingly rapid coalescing action is conducive to a high rate of separation of the emulsified water from an oil.

As has been mentioned previously, solids or semi-solid films surround the emulsion particles so that, even when they are brought together by an electric field at normal temperatures, these droplets may not readily coalesce. Consequently, when this situation occurs, heat or chemical or both must be supplied to modify the film. The temperature below which the electric field is not effective is a characteristic of the specific crude oil being processed. This characteristic is attributed to the "melting" of the solid film to permit contact of the water droplets with each other through the liquefied film. The voltage gradients applied in the electric system must be chosen to obtain maximum coalescence but still avoid dispersive effects which may occur under extreme conditions. Such dispersive effects are shown in Figure 2. In 2-A a droplet cluster is shown with no field applied, and in 2-B an excessively high potential field has drawn out the larger drops (formed by coalescence of neighboring smaller ones) to such an extent that actual dispersion occurs from the ends of these droplets; this the system is re-emulsified.

The effect of a chemical demulsifying agent of the commercial type used in oil fields is shown in Figure 3. The film-forming constituents of a crude oil were allowed to adsorb on the interface between a white oil and a water layer. In 3-A a very small amount of chemical demulsifier was added at a point near the center of the interface, and the disturbing effect is indicated by the cracks, formed where the chemical has displaced and pushed back the original rigid film. In 3-B the effect of some additional chemical is observed to caused further displacements. This type of action provides, on the surface of a droplet, areas in which a fluid interface is available for coalescence with other droplets. Normally only very small quantities (in the range of 10-100 ppm) of these highly effective demulsifiers need to be added to the crude oil to displace the stabilizing films and permit coalescence. However here again some elevated temperatures may be required to assist in this replacement action. After destabilization coalescence of the droplets is achieved by proper design of the treating tank to give sufficient agitation to provide opportunity for contact of the droplets. The agitation must necessarily not be excessive since, if too intense, it will prevent growth of the droplets to sufficient size to settle rapidly, thus the separation process is slowed down.

This brief description does of course not tell the whole story of the dehydration process. After the particles

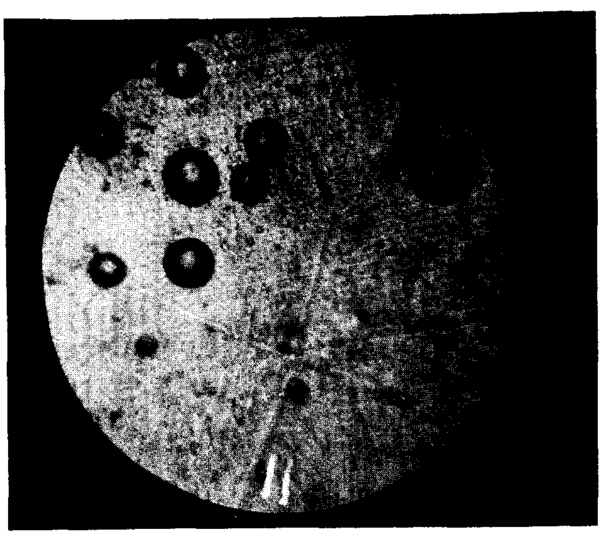

Fig. 2A

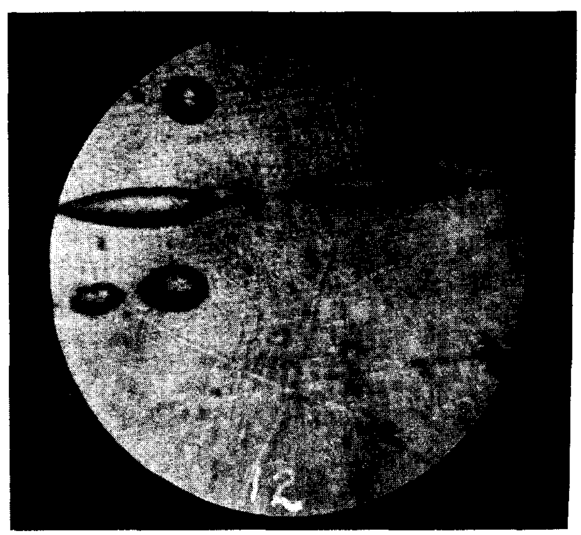

Fig. 2B

Dispersion Effect by Excessive Electric Field

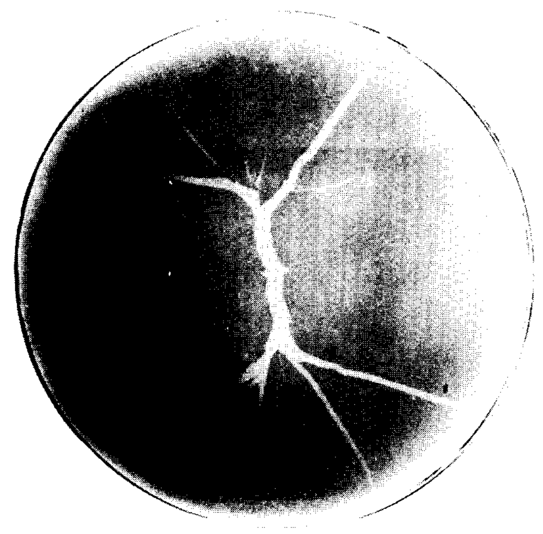

Fig. 3A

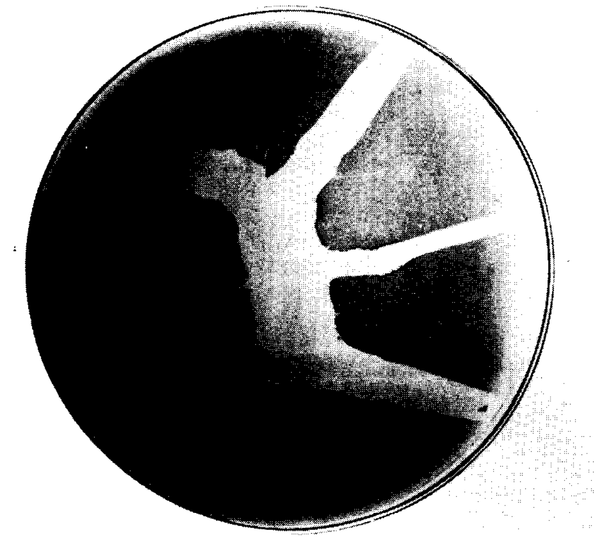

Fig. 3B

Effect of Chemical Demulsifying Agent on Interfacial Films

are brought together they must be coalesced to sufficient size so they can drop rapidly from the oil to the bottom of the treater. As they settle to the oil-water interface, they must join the water layer without the formation of accumulating intermediate layers of sludgy material which would need to be drawn off, usually as oily water bleeds. The amount of residual water in the oil must be small enough to meet pipeline specifications. These requirements are admirably met in the chemical-electric treater. The electric field is particularly effective in rapidly coalescing the water droplets to large sizes; for the chemical, by modifying the interfacial stabilizing agents, allows the droplets to coalesce at lower temperatures. It is also most effective in eliminating sludge accumulations and preventing small oil particles from being carried out with the water draw-off. The newly designed chemical-electric treater takes advantage of all the favorable characteristics of both the chemical and electrical treating processes. In addition, the new treater incorporates the functions of a gas separator for low gas-oil ratio production and can be very economically built because of the relatively small size which the combination makes possible. The design also makes provision for an integral heater where such is desirable.

It must be kept in mind that crude oils differ greatly in characteristics, as do the waters associated with them. Consequently it is necessary to provide specific treating conditions suited to each type of oil in order to obtain effective and efficient dehydration.

Attempts have been made in the past to devise, for crude oil treating, a chemical-electric combination which would be superior to either method alone. However, the additional costs involved have usually militated against the commercial application of such processes. Furthermore, the demulsifying chemicals suitable for straight chemical dehydration were not always those most efficient in aiding the electric field. However, with the increasing cost-consciousness of the oil industry, it is now apparent that justifiable savings can be effected with an effective chemical demulsifier and an appropriately designed electric treater combination. An electric treater can be effective on crude oil emulsions at much lower critical temperatures when a suitable chemical is used. Further, a reduced temperature can also be achieved if electric forces are used to coalesce the particles previously destabilized in a chemical treating system. Such reductions in temperatue by this combination, as contrasted with either method alone, has achieved appreciable savings by reducing oil volume and gravity losses in the oil that was shipped from the producing area. And electrical treating systems

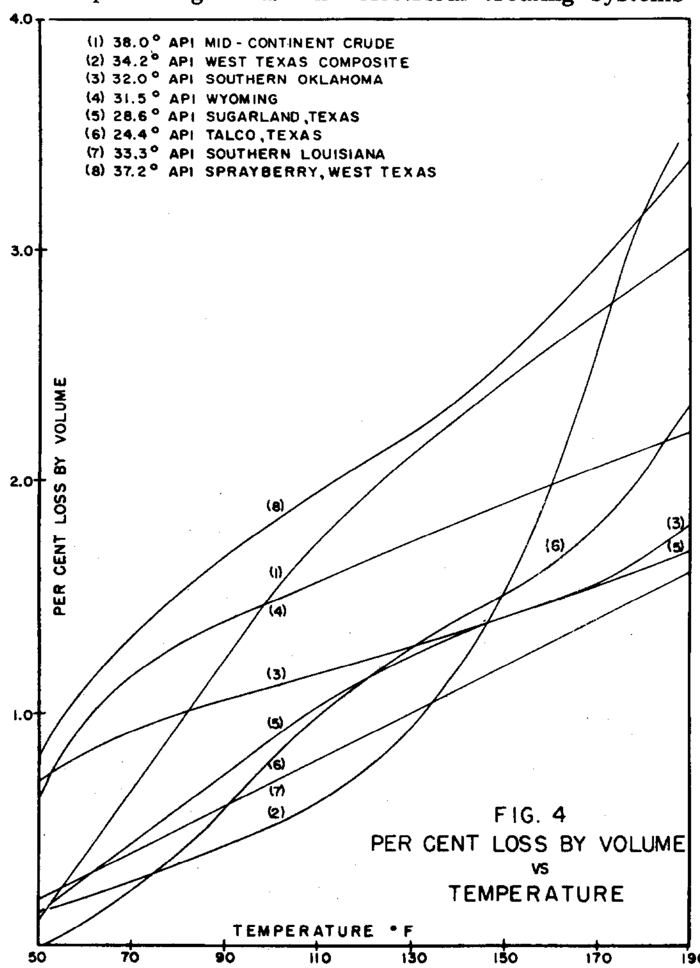

FIG. 4
PER CENT LOSS BY VOLUME
VS
TEMPERATURE

lend themselves well to automatic operation and vapor-tight equipment.

The volume lost by crude oils when exposed to various temperatures at atmospheric pressures for a considerable variety of crude oils is shown in Figure 4. The losses are different for each type and the curves reflect the variations. The volume loss is, of course, translatable directly into dollars corresponding to the reduced recovery.

The corresponding gravity losses are shown for the same oils (Fig. 5). Since there are breaks in crude prices at various gravity levels it can be seen that sometimes a small improvement in these levels

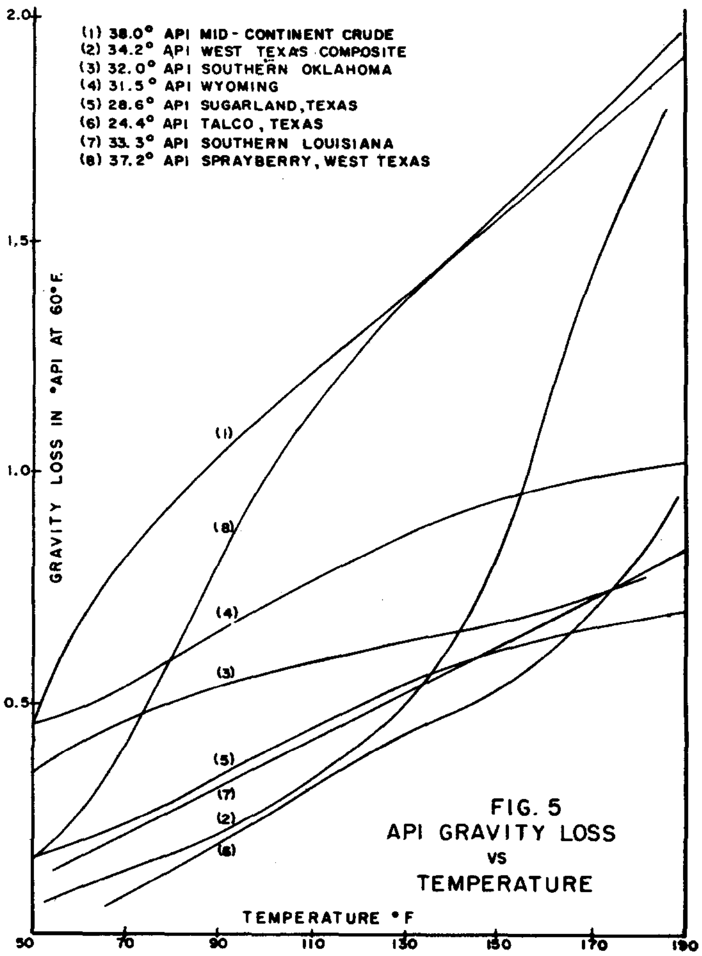

FIG. 5
API GRAVITY LOSS
vs
TEMPERATURE

can mean a considerable extra income for the particular crude involved. Table 1 shows the Oil and Gas Journal price levels for November 27, 1961 and permits a dollar evaluation of the savings for any gravity improvements obtained.

Figure 6 shows the approximate volume loss per cent of the original volume influenced by API gravity loss for crudes from 10 through 40 API gravity range.

A flow diagram to indicate the way in which the chemical-electric treater can be incorporated into the dehydration system is shown in Figure 7. The crude oil emulsion, usually from a number of wells in the area, is brought to a central treating plant location where a chemical pump injects demulsifying chemicals into the emulsion pipeline, usually some distance ahead of the dehydrator. This achieves adequate mixing of the chemical with the oil. If necessary, in the treater, a heater is incorporated to provide a simple and direct method of supplying whatever temperature may be necessary to obtain best results. Gas is separated beyond the heating section, and the electric field then coalesces the water droplets as the emulsion is broken into clean oil and clean water. The dehydrated crude is then taken to storage tanks, etc., and the water is appropriately discarded.

GRAVITY LOSS °API
vs
PER CENT LOSS BY VOLUME

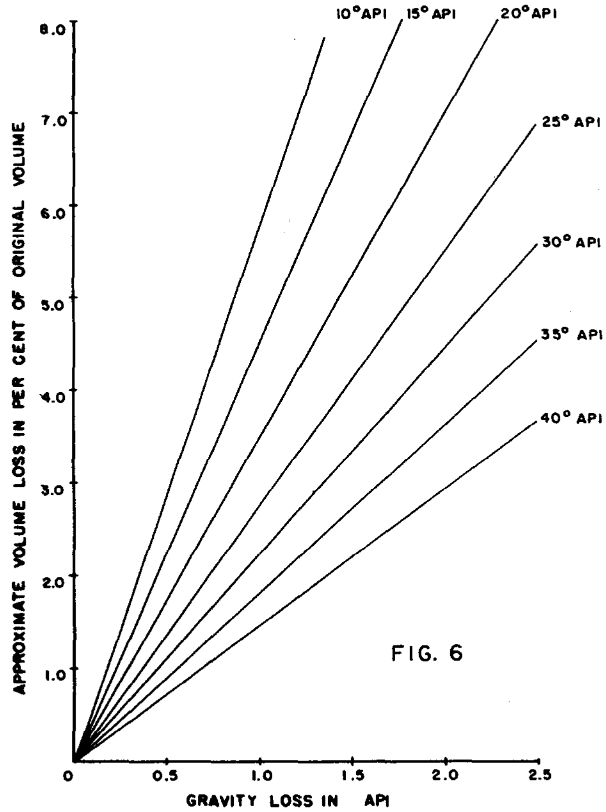

FIG. 6

A photograph of an actual installation is shown in Figure 8. For the purpose of obtaining automatic and trouble-free operation and maximum efficiency, a very simple and compact design has been achieved.

Operational information on three plants in which comparisons are made between conventional dehydrating methods and the Chem-electric treater is shown in the accompanying Tables II, III, and IV.

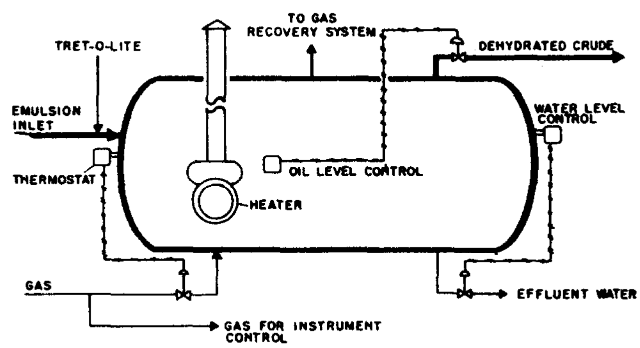

FIG. 7
PETRECO CHEMELECTRIC DEHYDRATOR
FLOW DIAGRAM

TABLE I **CRUDE-OIL PRICES**
Gravity Schedule

	Signal Hill Calif	Okla-homa	West Tex. (Sour)	West Tex. (Inter.)	No.* Texas	Texas Refugio Light	Bayou Sale (La.)	Denver Jules-burg	Wyo. (Sour)
14-14.9	$1.86	.....	.....	.....	.....	.....	.....	.....	.....
15-15.9	1.93	.....	.....	.....	.....	.....	.....	.....	$1.81
16-16.9	2.00	.....	.....	.....	.....	.....	.....	.....	1.86
17-17.9	2.06	.....	.....	.....	.....	.....	.....	.....	1.91
18-18.9	2.13	.....	.....	.....	.....	.....	.....	.....	1.96
19-19.9	2.20	.....	.....	.....	.....	.....	.....	.....	2.01
20-20.9	2.27	$2.49	$2.35	$2.61	$2.29	$2.95	$2.90	$2.38	2.06
21-21.9	2.33	2.52	2.38	2.63	2.33	2.97	2.92	2.40	2.11
22-22.9	2.40	2.55	2.41	2.65	2.37	2.99	2.94	2.42	2.16
23-23.9	2.46	2.58	2.44	2.67	2.41	3.01	2.96	2.44	2.21
24-24.9	2.53	2.61	2.47	2.69	2.45	3.03	2.98	2.46	2.26
25-25.9	2.60	2.64	2.50	2.71	2.49	3.05	3.00	2.48	2.31
26-26.9	2.67	2.67	2.53	2.73	2.53	3.07	3.02	2.50	2.36
27-27.9	2.74	2.70	2.56	2.75	2.57	3.09	3.04	2.52	2.49
28-28.9	2.81	2.73	2.59	2.77	2.61	3.11	3.06	2.54	2.54
29-29.9	2.87	2.76	2.62	2.79	2.65	3.13	3.08	2.56	2.59
30-30.9	2.93	2.79	2.65	2.81	2.69	3.15	3.10	2.58	2.63
31-31.9	3.00	2.82	2.68	2.83	2.73	3.17	3.12	2.60	2.67
32-32.9	3.06	2.85	2.71	2.85	2.77	3.19	3.14	2.62	2.71
33-33.9	3.12	2.88	2.74	2.87	2.81	3.21	3.16	2.64	2.75
34-34.9	3.17	2.91	2.77	2.89	2.85	3.23	3.18	2.66	2.79
35-35.9	3.22	2.94	2.80	2.91	2.89	3.25	3.20	2.68	2.83
36-36.9	3.27	2.97	2.83	2.93	2.93	3.27	3.22	2.70	2.87
37-37.9	3.31	2.99	2.86	2.95	2.95	3.29	3.24	2.72	2.89
38-38.9	....	3.01	2.89	2.97	2.97	3.31	3.26	2.74	2.91
39-39.9	....	3.03	2.92	2.99	2.99	3.33	3.28	2.76	2.93
40-44.9	....	3.05	2.95	3.01	3.01	3.35	3.30	2.78	2.95

* Taken from the OIL AND GAS JOURNAL - November 27, 1961 Issue

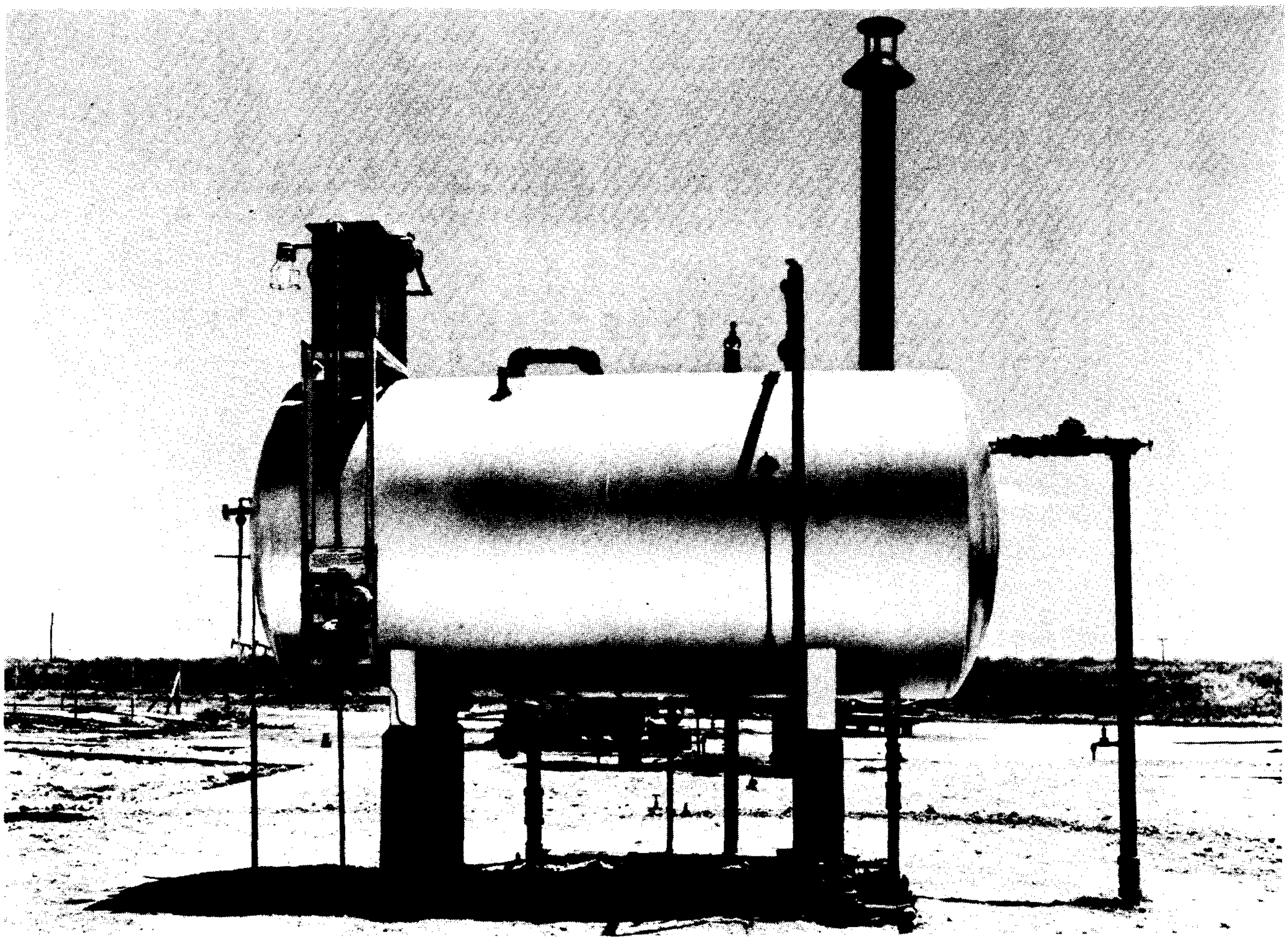

Fig. 8

Petreco Chem-Electric Dehydrator

Table II compares the treating efficiency of a 6 ft x 12 ft chemical-electric dehydrator with that of an existing heater-treater dehydrating a West Texas Devonian crude. The production on the lease was 560 BPD. However, the chemical-electric treater was able to operate at 74 F, whereas the conventional treater required 120° for satisfactory separation. This difference made for a sizeable reduction in amount of gas required for heating purposes, and the reduction in turn produced a $13 per day saving in gas alone. Because of the lower temperature smaller amounts of volatile fractions were lost, increasing the API gravity by 1.3°, which then placed the crude in the next higher gravity bracket, as can be ascertained from the chart of Table I. The corresponding dollar saving of $11 shown in the table was thus made possible. The volume lost by light ends, corresponding dollar saving of $11 shown in the Table I per cent of the oil stream and, at the prevailing price, produced a daily saving of $46. This saving may be considered as an immediate gain because of the increased volume produced and its immediate availability for sale; or if this added production is not desired or not possible because of proration requirements, etc., this amount of oil can be left in the formation for future production. At any rate, a total value of $70 in savings allocatable to to the chemical-electric treating system is apparent.

In Table III the comparison is between two heater-treaters and one chemical-electric treater in a Wyoming installation. The electric unit began operation while the ambient temperature was -31 F. It was possible to increase the treating rate, even with the considerably smaller vessel volume, by 70 per cent and to reduce the treating temperature by 42°. The corresponding savings, as explained in the consideration of Table II, came to a total of $104 per day.

Table IV shows another example in which two heater-treaters were replaced by a single chemical-electric dehydrator in West Texas. In this case heating was required only in the winter and a reduction of 85° in temperature requirements was achieved. The corresponding savings as outlined in the previous tables amounted to about $80 per day for this stream.

These examples clearly show the advantages of the new treating system as a conservation measure as well as an appreciable economic factor in the dehydration of crude oils.

TABLE II

	One Heater Treater	One Chem-electric 6' x 12'	Savings Per Day
Treating Rate BPD	560	560	
Treating Temp. °F.	120	74	
Difference °F.		46	
MCFG Per Day	90	38	
Cost for Gas Per Day	$22.50	$9.50	
Value of Gas Saved			$13.00
Gravity Average API	36.5	37.8	
Gravity Conserved API		1.3	
Increased Value/bbl (Cents)		2.	
Crude Value Increase			$11.20
Volume Savings %		2.8	
Volume Savings BPD		15.7	
Dollar Value/bbl		2.93	
Increased Value/Day Dollars			$46.00
Total Savings/Day			$70.20

TABLE III

	Two Heater-Treaters 6' x 22'	One Chem-electric 8' x 12'	Savings Per Day
Treating Rate BPD	548	936	
Treating Temp. °F.	160	118	
Difference °F.		42	
MCFG Per Day	157	79	
Cost for Gas Per Day	$47.10	$23.70	
Value of Gas Saved			$23.40
Gravity Average API	24.05	25.50	
Gravity Conserved API		1.45	
Increased Value/bbl (Cents)		5	
Crude Value Increase			$46.80
Volume Savings %		1.62	
Volume Savings BPD		15.16	
Dollar Value/bbl.		$2.26	
Increased Value/Day Dollars			$34.26
Total Savings/Day			$104.46

TABLE IV

	Tow Heater-Treaters 6' x 22'	One Chem-electric 6' x 12'	Savings Per Day
Treating Rate BPD	904	947	
Treating Temp. °F.	145	60	
Difference °F.		95	
MCFG Per Day	86	35.2	
Cost for Gas Per Day	$21.50	$8.80	
Value of Gas Saved			$12.70
Gravity Average API	33.6	34.7	
Gravity Conserved API		1.1	
Increased Value/bbl (Cents)		2.0	
Crude Value Increase			$18.94
Volume Savings %		1.8	
Volume Savings BPD		17.0	
Dollar Savings/bbl		$2.83	
Increased Value/Day Dollars			$48.11
Total Savings/Day			$79.75

*Petrolite Corporation, Petreco Division