Sept. 7, 1965 R. W. STENZEL ETAL 3,205,160

ELECTRIC TREATER FOR DISPERSIONS

Filed Oct. 16, 1962 2 Sheets-Sheet 1

Fig. 1.

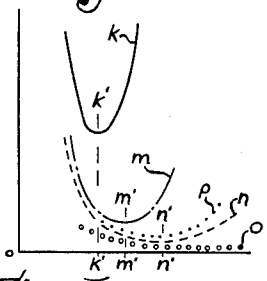


Fig. 2.

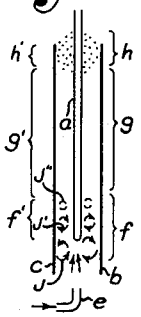


Fig. 3.

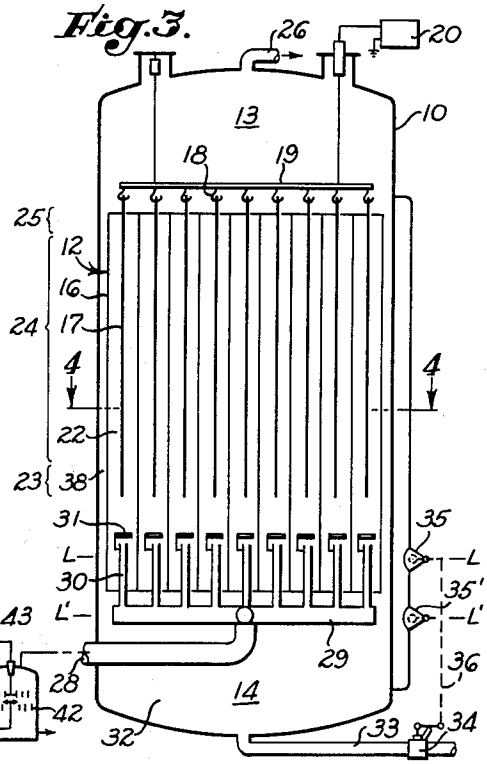


Fig. 4.

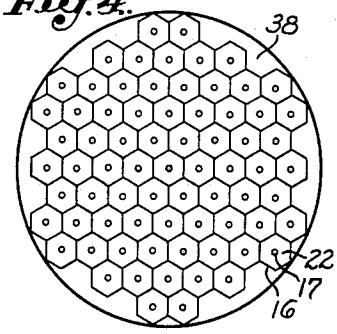


Fig 6

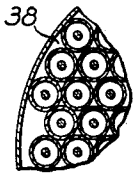


Fig. 8.

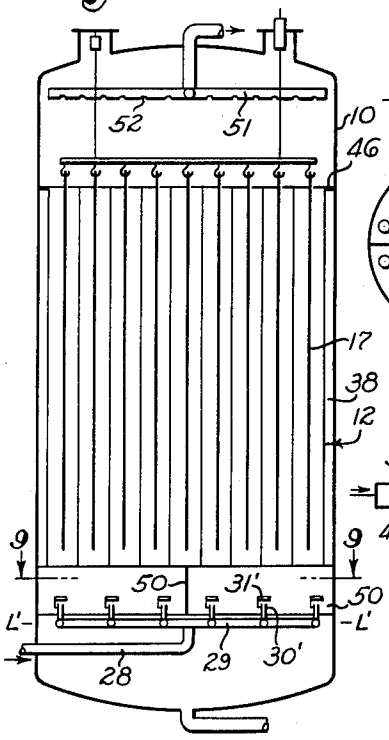


Fig. 9.

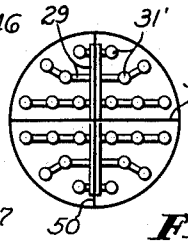


Fig. 7.

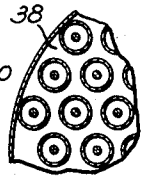


Fig. 5.

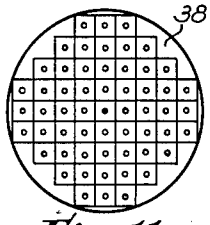


Fig. 10.

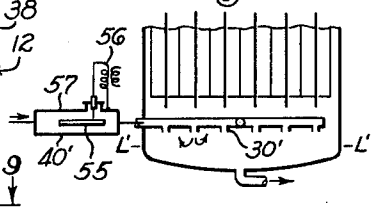
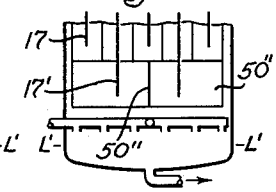


Fig. 11.



INVENTORS.
RICHARD W. STENZEL
DELBER W. TURNER

BY THEIR ATTORNEYS.
HARRIS, KIECH, RUSSELL & KERN

Sept. 7, 1965 R. W. STENZEL ETAL 3,205,160

ELECTRIC TREATER FOR DISPERSIONS

Filed Oct. 16, 1962 2 Sheets-Sheet 2

Fig. 13.

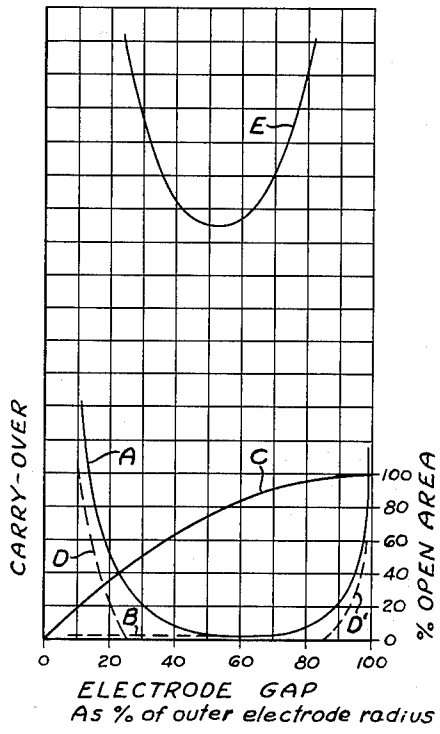
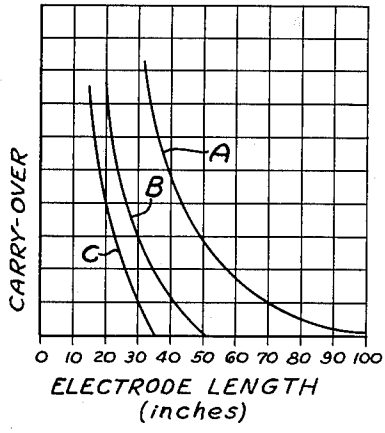


Fig. 12.



INVENTORS.
RICHARD W. STENZEL
DELBER W. TURNER

BY THEIR ATTORNEYS.
HARRIS, KIECH, RUSSELL & KERN

United States Patent Office 3,205,160 Patented Sept. 7, 1965

3,205,160

ELECTRIC TREATER FOR DISPERSIONS

Richard W. Stenzel, Palos Verdes Estates, Calif., and Delber W. Turner, Houston, Tex., assignors to Petrolite Corporation, Wilmington, Del., a corporation of Delaware

Filed Oct. 16, 1962, Ser. No. 230,978
Claims priority, application France, Oct. 19, 1961, 876,376
20 Claims. (Cl. 204—302)

The present application is a continuation-in-part of our copending application Serial No. 64,574, filed October 24, 1960, now abandoned.

This invention relates to a more efficient and effective electrical method and apparatus for treating dispersions in which small particles are dispersed in an oil that is relatively nonconductive as compared with the particulate material. The dispersions may be such that most of the particles would settle by gravity if given sufficient time or they may be more permanent dispersions or emulsions from which the particles will settle very slowly or not at all.

In known processes and equipment for electrically resolving such dispersions great difficulty has been encountered in producing treated oils containing only small amounts of residual dispersed material. Only in recent years and by use of smooth-flow treaters employing unidirectional electric fields has it been possible on some dispersions to reduce the residual material to a few thousandths or a few hundredths of a percent. On other dispersions reductions only to about .5–1% are possible in older equipment. By the present invention used on the same dispersions it becomes possible to produce treated oils containing only a small fraction of such residuals, usually one-half or one-fourth or less and often only a few parts per million. In some instances complete removal (within the limits of accuracy of the usual analytical methods) of the dispersed phase can be achieved.

The invention contemplates an improvement in the older commercial process of electrically resolving oil-continuous dispersions wherein the dispersion flows longitudinally along relatively short interelectrode treating spaces of relatively small length-to-gap ratio between pairs of plate electrodes or large multiple concentric cylindrical electrodes while there is an electric field of high voltage gradient in the interelectrode treating spaces, the improvement being characterized by advancing the dispersion longitudinally along a much longer interelectrode treating space of much larger length-to-gap ratio between the inner wall of a long and narrow cell forming an outer electrode and a long inner electrode near the central axis of the cell while there is between such outer and inner electrodes a unidirectional high-voltage electric field acting upon the dispersed particles of the dispersions. In many commercial forms the invention contemplates division of the dispersion into a number of small streams flowing longitudinally through respective cellular passages of a cellular electrode each having its own high-voltage inner electrode.

It has now been found that the length of the treating field in smooth-flow treaters has an unexpected effect on the treating effectiveness, particularly where the field is relatively narrow in all directions transverse to the flow. Quite unexpected results have been found to flow from the use of relatively long cellular passages particularly at higher applied voltages. These results are evidenced by substantially less residual material in the effluent oil, production of haze-free oils, substantially higher throughput capacities and lower treating costs. Further the treaters of the invention give more stable operation and

can be made much smaller than existing smooth-flow treaters. On light oil dispersions such as petroleum distillates that have been treated with an alkali the invention effects an improvement of the order of ten fold or more as compared with the older treatment, evidenced by a greater throughput while producing a treated oil containing about the same residual dispersed material, by a treatment producing a lower residue of dispersed material at about the same throughput or in most instances by a lower residue at a very much higher throughput.

Dispersed particles of an oil-continuous dispersion can be acted upon by a high-voltage unidirectional electric field to coalesce or electrophorese them. Coalescence or agglomeration brings the particles together into larger masses that settle from the oil. Electrophoretic action moves the particles toward one or both the electrodes along paths therebetween and may induce deposition on one or both electrodes or coalescence of particles migrating in such paths. The coalescing and electrophoretic actions are influenced in part by the relative areas, curvature and the polarity of the electrodes bounding the treating space, the electric field being more concentrated adjacent the electrode of small area or higher curvature. The population density of the particles is an important factor in determining whether separation of the dispersed particles will proceed predominantly by coalescene or agglomeration, or by electrophoretic deposition. Where the population density is relatively high the action of the electric field will be predominantly one of coalescence in situ in the oil, if the dispersed particles are liquid, particularly as concerns the larger particles. In the case of dispersed solids, agglomeration in situ may also occur along with electrophoretic deposition. When the population density is relatively low the electrophoretic action usually predominates in both cases. In order to simplify the description following, the nomenclature usually applicable to emulsions will be used but it is understood that, in the case of solids, agglomeration instead of coalescence may occur, although the electrophoretic movement of the solids will be qualitatively similar to that of the dispersed liquid particles.

The invention contemplates use of electrodes of sufficient length and sufficiently large length-to-gap ratio that the treating actions will be predominantly by coalescence and electrophoresis in successive sections of the interelectrode space under the field patterns present in the one or more cells employed. Stated in other words the invention contemplaes an initial predominantly coalescing or agglomerating treatment within or ahead of a first portion of the interelectrode space followed by a subsequent predominantly electrophoretic treatment in a later portion of the same cell. Once the population density is reduced to a low value the electrophoretic action is counted on to produce a clean-up treatment that reduces the residual amount of dispersed material to values many fold less than with the aforesaid older commercial treaters employing parallel plate or multiple concentric cylinder electrodes. It is generally desirable that the electrode at which the gradient of the electric field is lower, e.g. the outer electrode of a cell, should be of such polarity that the particles tend to migrate toward it.

Turbulence is also a factor in determining the effectiveness of coalescing and electrophoretic actions. Turbulence may be a purely hydraulic turbulence induced by flow or may be induced by movement of the particles in the oil as a result of the electric field, being in this latter respect a function of the population density. From whatever source, turbulence may aid in coalescence by bringing particles into contact or closer together to be coalesced by the action of the electric stress. However turbulence

is detrimental in electrophoretic separation of the particles. The long electrodes of the invention damp out hydraulic turbulence in the electrophoretic section of the interelectrode space and electrically induced turbulence in such section is very small because the population density is low.

From purely hydraulic considerations prior commercial treaters with parallel plate or multiple concentric cylinder electrodes do not always produce the desired results at economically desirable rates. Close spacing of such electrodes tends to damp out local circulations or eddies tending to form because of forward flow of the dispersions but only those in planes that are parallel both to the flow direction and to the lines of force of the electric field. Such circulations or eddies tend also to be established in planes that are parallel to the flow direction but at right angles to the lines of force and with the aforesaid multiple concentric cylinder or parallel plate electrodes there are no close electrode surfaces to impede the latter circulations, such circulations being in planes parallel to the electrode surfaces. The one or more cellular spaces of the invention largely damp out the latter circulations or eddies as well as those earlier mentioned.

In vertical spaces between parallel plate or concentric cylinder electrodes any thermal disturbances upset the desired equal velocity of the dispersion in all the spaces. For example a localized difference in temperature in such laterally unrestricted spaces slows or accelerates flow in a localized path as compared with laterally displaced paths. As a further example, if in a treater of the older type the flow of the dispersion is switched from one tank to another tank which is at a somewhat higher temperature it will not only cause turbulence or rolling but will tend to channel selectively into some of the treating spaces of the treater, causing a decreased upward flow in other treating spaces or even a temporary down flow therein. Treatment in the one or more cells of the invention substantially prevents this differential flow and gives a much more stable operation.

Likewise unequal hydraulic flow, thermal effects and the electro-hydraulic effects to be discussed tend to establish long circulations in an upright interelectrode space, e.g. a tendency toward an upward flow adjacent one electrode from end to end thereof and a corresponding downward flow adjacent the other. Even if the upwardly advancing dispersion stream prevents an actual down flow the force tending to induce it slows a localized portion of the stream adjacent one electrode and tends to establish swirling in the field. Such actions are sometimes localized or more pronounced in one longitudinal zone adjacent an electrode than in a laterally adjacent longitudinal zone, tending likewise to create circulations adjacent the electrode itself. The one or more long cellular electrodes of the invention offer additional insurance against such long or local circulations due both to increased length of the interelectrode space and to the confinement of the dispersion in all lateral directions.

In the accompanying drawing FIG. 1 shows typical characteristic treating curves of the new and old treaters. FIG. 2 illustrates electro-hydraulic effects in the end portions of a treating field. FIG. 3 is a longitudinal sectional view of a typical treater embodying the invention, FIG. 4 being a cross-section taken as indicated. FIGS. 5, 6 and 7 show alternative cellular patterns. FIG. 8 is a longitudinal sectional view of an alternative treater, FIG. 9 being a cross-section taken as indicated. FIGS. 10 and 11 illustrate alternative inlet arrangements. FIGS. 12 and 13 are graphical representations of the operation of the invention and critical characteristics thereof.

Electro-hydraulic effects at the end portions of an interelectrode space are illustrated diagrammatically in FIG. 2 in which a central high-voltage electrode *a* is disposed between electrodes *b* and *c* that are at ground potential, the dispersion entering through *e* and flowing successively through entrance end zone *f*, intermediate zone *g* and exit end zone *h*, the interelectrode space being composed of an entrance portion *f'*, an intermediate portion *g'*, and an exit portion *h'*. The electrode *a* may be considered as a cylindrical electrode between cylindrical electrodes *b* and *c*, these electrodes being considered as shown in section, or the electrode *a* may be considered as a rod between opposite sections *b* and *c* of a tubular electrode of circular or other cross-section.

The field pattern of the high-voltage electric field is necessarily different in end zones *f* and *h* and portions *f'* and *h'* as compared with the intermediate zone of portion *g* and *g'*, due to the edge effects in the former which concentrate the field near edges or ends of an electrode. Considering electrical phenomena alone, the dispersion issuing from *e*, being normally of higher dielectric constant than the surrounding partially-treated liquid, displaces the latter and is attracted into the zone of higher voltage gradient adjacent the end of *a*. It has been found that this and the sideward electric blast action from *a* near the end thereof tend to establish ring-like circulations *j* which in turn establish lesser circulations *j'* and *j''* within the interelectrode space. The field at the end of *a* coalesces some of the dispersed particles into larger masses which settle out but the turbulence created by the field, exemplified as circulations *j*, *j'* and *j''*, are detrimental to the desired smooth flow in the intermediate portion *g'*. Such turbulence rises to greater heights in the interelectrode space as the applied voltage is increased. These effects are superimposed on turbulence in the entrance end zone *f* due to hydraulic action alone. The resulting electro-hydraulic turbulence is a limitation on the effectiveness of smooth-flow treatment in the intermediate portion *g'*.

The edge effect in the exit end zone *h* is somewhat different, being dependent both upon the field pattern and the dispersion flowing from the exit end, particularly the population density, particle size and character of the residual dispersed material that has not been treated out in the intermediate portion *g'*. It has been found that the field pattern at this end zone *h* also creates turbulence in a zone indicated by the dots of FIG. 2 and that this turbulence extends progressively downward in the interelectrode space as the applied voltage and the population density increases. It has been found that turbulence from such electrohydraulic effects in the exit end zone can be minimized and made much less than in existing treaters if the effluent oil contains only minute amounts of residual dispersed material.

The full-line curve *k* of FIG. 1 is the known characteristic treating curve of a conventional electric treater, illustrating the effect on carryover (the amount of residual dispersed material remaining in the treated oil), plotted as ordinates, when the applied voltage gradient, plotted on the abscissae scale, changes. Curve *k* is typical of an electric treater having multiple concentric cylindrical electrodes or parallel plate electrodes energized by a variable source of unidirectional potential, the electrodes being spaced 3 inches apart and providing interelectrode spaces 15 inches long, this being substantially the longest spaces commonly used in commercial treaters of this type. As voltage is applied to the treater, treatment progressively improves with increased gradient to *k'*—*k'* but then deteriorates rapidly as indicated by the upward sweep of the curve beyond this optimum region, the curve *k* having a relatively narrow base near *k'*—*k'*. With the same dispersion passing through a cell-and-rod system having an interelectrode space 3 inches wide and 15 inches long, the forward flow being at the same rate, the characteristic treating curve will be about the same but the treater will be much more stable under changing conditions of temperature, flow rates and other sources of hydraulic disturbances.

The rise in the curve *k* beyond *k'*—*k'* has heretofore been thought to be the result of electric dispersion of the dispersed material due to the increasing voltage gradients

adjacent one or both electrodes and no way has heretofore been found to eliminate this rise. The present invention is based to a large extent on the discovery that by using a cellular electrode and increasing the length of the interelectrode spaces the shape of the characteristic treating curve changes quite unexpectedly. For example, with the same cell-and-rod electrode system mentioned above and with all other conditions the same with the exception that the interelectrode spaces within the cells are made 24 inches long, the characteristic treating curve is changed to dot-dash curve *m* which not only has a minimum much lower than *k* but which usually reaches its minimum at a substantially higher applied voltage gradient as suggested at *m'*—*m'*. Likewise if conditions are the same and the interelectrode spaces within the cells are made about 40 inches long the characteristic treating curve will be as represented by the dot curve *n* which reaches an even lower minimum at *n'*—*n'* at an even higher applied voltage gradient.

It will be noted that the curves *m* and *n* have a much broader base than the curve *k* of the older process, evidencing that near-minimum amounts of residual material can be obtained over a wider range of applied voltages or voltage gradients. This is a characterizing feature of the invention even in these instances in which the minima *m'*—*m'* and *n'*—*n'* of curves like *m* and *n* are closer to or about the same as *k'*—*k'* as is true in some instances. The same is true in starting with a dispersion of lower content of dispersed material which when treated in accordance with the invention will often produce a curve *o* indicated by circles and which extends substantially parallel to the abscissae axis with little or no rise with increasing applied voltage gradients within the ranges currently tested. It will thus be seen that substantially better treatment results through use of cellular electrodes when operated in a range considerably higher than the *k'*—k' value.

In most instances, such for example as in the treatment of petroleum distillates with alkaline solutions, the minima of the characteristic treating curves of conventional parallel-plate or multiple concentric cylinder commercial treaters fall in the range of 3–6 kv./inch. However with the long cellularized electrodes of the invention the minima are often at applied voltage gradients at least twice as high as they would be with the older treaters. Since the treating forces increase approximately as the square of the applied voltage gradient the improved treatment with the cellular electrodes thus results in considerable measure from the higher optimum voltage gradient which can be applied with this system.

The curves *k*, *m* and *n* of FIG. 1 are all at the same forward velocity of the liquid in the interelectrode space. Even with substantially higher forward velocities through the longer cellularized electrodes the curves *m* and *n* will have minima substantially below that of curve *k* and at values of applied voltage the same as or higher than *k'*—*k'*. For example approximately doubling the rate of advancement along the interelectrode space under the conditions of curve *n* will shift the rise of the curve only to that approximated by the dot curve *p*, evidencing a many fold increase in treating effectiveness even at higher throughputs as compared with the older processes.

The time in the field depends on the forward velocity but it is often found that treating results are better even if the time in the field when using the long cellular electrodes is less, compared with the time in the field of curve *k* resulting from use of conventional electrodes. To further illustrate this, a test was made under comparable conditions and at optimum voltage gradients to compare the performance of (I) a treater of a type conventionally and widely employed commercially, having concentric cylinder electrodes providing an electric field 15 inches long and 3 inches wide, (II) a treater with a cellular arrangement having a field also 15 inches long and 3 inches wide, and (III) a treater with another cellular arrangement having a field 3 inches wide but 40 inches long. The results of those particular tests were as follows:

	Upward velocity (in./min.)	Time in field (min.)	Carryover, (p.p.m.)
Treater I	4.4	3.4	16.8
Treater II	4.0	3.8	19.6
Treater III	14.0	2.8	.56

It can readily be seen that with 3½ times greater upward velocity and about 30% less time in the field, the longer cellular electrode produced carryovers that were only 1/30 as much as the other arrangements, and practically perfect from a commercial standpoint. Furthermore the effluent from treater III was perfectly clear, whereas the others were unsatisfactorily cloudy. This also indicates that the long cellularized electrodes have much greater throughput capacity and that treaters thus equipped can be made smaller and cheaper than if equipped with the older multiple cylinder or parallel plate electrodes, thus being commercially far superior.

As another example of the highly beneficial effect produced by increasing the electrode length, a kerosene-water stream was treated in an 8 inch cellular electrode system employed with 2 inch rods of different length at an upward flow velocity of 30 inches/minute. With an interelectrode treating space or rod length of 15 inches the system produced an oil having a carryover of 36 p.p.m. of water whereas with an interelectrode space 48 inches long the electrode system carried over only 0.5 p.p.m This is a dramatic improvement in efficiency which is highly desirable for commercial use. In addition, the first stream was very turbid and that from the long electrode system bright and clear. Because of consumer resistance to cloudy oils the improved commercial acceptability of the clear product is obviously a great economic advantage to the refiner. Attempts to obtain a clear oil with the shorter 15 inch interelectrode space by reducing the rate of flow were fruitless, and even at only a 6 inch per minute vertical rise a 3 p.p.m. carryover and a cloudy oil was still obtained. This clearly demonstrates, as did the example above, that time in the field is not the crucial criterion for determining the effectiveness of the electric treating system but that the electrode configuration itself must be fully taken into account because of the other disturbing effects such as the electric pumping, windage, etc. mentioned above.

In general, the invention contemplates that each cell shall be of sufficient length in the flow direction to prevent the electro-hydraulic turbulence in end zones *f* and *h* from pervading or meeting in the interelectrode zone *g*. The interelectrode space is made long enough that the electro-hydraulic turbulence in its end portions *f'* and *h'* are separated by an intermediate portion *g'* in which the dispersion advances smoothly and in substantial laminar flow. In these ways, and particularly at the higher applied voltage gradients between *k'*—*k'* and *n'*—*n'* of FIG. 1 or beyond *n'*—*n'*, the treatment in intermediate portion *g'* is effective in removing so much of the dispersed material by coalescence and electrophoretic effects that the electro-hydraulic turbulence in the exit end zone *h* is minimized and becomes negligible. In this connection the present invention reduces the residual dispersed material in the effluent oil from two to ten-fold or more as compared with prior commercial treaters. For example, on distillate dispersions it is not uncommon to produce effluent oils of 40 p.p.m. (parts per million) with the older electrodes and 2–10 p.p.m. with the cellular electrodes of the invention under the same conditions of flow and with the same dispersion. When it is required that carryovers of less than one p.p.m. be produced and when a bright oil is required the cellular system of the invention can often meet such requirements when it is impossible to do so with the older electrode types.

Large throughput treaters preferably include a cellular electrode structure occupying substantially the entire cross-section of an electrode zone of a flow passage and providing a plurality of the aforesaid long cells extending side-by-side in the direction of flow of the dispersion. Each cell provides a tubular passage with an inner electrode of opposite polarity, forming between the cell walls and the central electrode an annular treating space. The walls of the cell passages are desirably smooth-surfaced as it is desirable that at least the outer electrode surface should have a smooth surface to avoid protuberances or projections transverse to the flow direction that would tend to concentrate the electric field or destroy laminar flow. It is desirable that the electrodes should be free of dielectric coatings so that the dispersion bridges the electrode surfaces.

Each cell is of a length that is from 2–10 times or more the length, measured in the direction of flow, of conventional electrodes used in commercial emulsion resolving processes. The cells or tubular passages of the invention for best operation are usually of a length of about 24–120 inches. Improvements become marginal as the length of the interelectrode treating space or of the tubular electrode are increased above about 100–120 inches and lengths above about 120 inches are not of practical significance for this type of treating system.

The effect of electrode length on carryover, measured at the voltage which gave the lowest carryover for each system, at different forward velocities in the field is illustrated in FIG. 12. The results here shown are with outer electrodes or cells of 8 inch inside diameter and inner electrodes of 1 inch external diameter used on a dispersion of water in kerosene produced in the water washing of a kerosene stream. Curve B shows results at a forward velocity of 30 inches/minute. It is clearly seen that complete removal of the dispersed phase is obtained when the interelectrode space was about 50 inches long but that with shorter lengths increasingly higher carryovers were obtained. Curve C illustrates the test results when the forward velocity was reduced to 20 inches/minute and shows that a length of about 36 inches was sufficient to give complete removal. Curve A shows the results when the forward velocity was increased to 52.5 inches/minute and indicates the much longer interelectrode spaces required to reduce the carryover to small values. Curve A also illustrates the marginal results from increasing the length above about 100 inches on this kerosene-water system. Dispersions that are more difficulty treatable require longer cells or interelectrode treating spaces for the low carryovers suggested in FIG. 12. At forward velocities less than the 20 inch/minute of curve C it becomes impossible to produce zero carryovers under the conditions of the above runs even through the residence time in the interelectrode space is greater. If the length of the cellular interelectrode space is too short the time in the field becomes of no controlling significance and even extremely long residence times will not produce the low carryovers evidenced by the lower portions of curve C. If the same dispersion is treated at such lower forward velocities of less than 20 inches/minute in conventional treaters between concentric cylinder or parallel plate electrodes it is likewise impossible to obtain the low carryovers evidenced by the lower reaches of curve C.

The width or distance across each cell passage will usually range from about 2–12 inches, sometimes as high as 16 inches and even up to 18–24 inches in some instances. With cross-sections greater than 12–16 inches convection and turbulence factors often become troublesome and often tend to cause arcing at the desirable high voltage gradients, which factors reduce the efficiency of the treating system. The number of cells or passages employed will depend on the throughput desired and while a single cell treater can be used to treat a relatively small stream up to several hundred barrels per day the capabilities of the invention are best utilized in multi-cell treaters often containing five cells or more up to several hundred. The size and number of cells are usually related to the size of the treater.

The inner electrodes within the cells are commonly rods of solid or hollow cross-section. The specific diameter thereof is not particularly critical. Rods ranging in diameter from about ¼ inch to a large fraction of the width of the passage are usable. Rods of a diameter less than about ½ inch are not nearly as effective in the invention and their use is not desirable if high-efficiency treatment is to be achieved. The inner electrodes are desirably centered in the cells but small deviations from this central position will not destroy the effectiveness of the treatment.

In most instances the cells will be oriented vertically and the rods will be hung centrally therein. In this way all of the rod electrodes will be parallel with respect to the individaul cells. However other electrode supports can be employed and will be required if the passages of the cellular electrode are inclined or substantially horizontal.

Interelectrode treating spaces of a length:gap ratio that is at least in the range about 8:1–30:1 can be employed. In commercial practice the ratio is preferably in the range of about 12:1–25:1.

With the treaters of the invention the forward velocity of the dispersion in the electric field within the one or more cells will be at least several inches per minute, e.g. at least 4 inches per minute, with heavier oils such as crude oils or lubricating oils, and normally 10 inches per minute or higher for lighter oils, such as gasoline and kerosene, velocities up to 50 inches per minute or more being practical with many of these lighter oils. These forward velocities are to be compared with maximum velocities in the neighborhood of a fraction of an inch per minute with heavier oils and about 5–6 inches per minute for the lighter oils when treating such oils in treaters with electrodes of conventional types. With the treaters of the invention voltage gradients of about 6–30 kv./inch or more are commonly used, voltage gradient figures expressed in kv./in. being the voltage in kilovolts between the opposed electrodes divided by the gap width therebetween in inches.

The above discussion has considered the use of circular cells with concentric rod electrodes, but the shape of the outer electrode is not particularly critical, and may be in the form of a square or hexagonal cross section etc. We have found that these various sections are usually not quite as effective as the circular ones but that the differences are small and can usually be quite negligible for commercial purposes. Such small deficiencies can be compensated for by increasing the number of cells used or decreasing the forward flow velocities slightly etc. For purposes of the graphs and illustrations given, the square or hexagonal sections can be considered as circles having the same cross sectional area.

With cells that are circular, square or hexagonal in cross section best results will be obtained when the inner and outer electrodes have a form factor F of at least about .8 and preferably between about .8 and .98 in the following equation:

$$F=\left[\frac{2(R_t-R_e)}{(R_t+R_e)\log_e\left(\frac{R_t}{R_e}\right)}\right]^{1/2} \qquad (A)$$

where R_t is the radius of the inner wall of a circular outer electrode or a circle having the same area as the interior cross section of a square or haxagonal outer electrode, and R_e is the radius of the inner electrode.

Some of the numerous factors which enter into the consideration of optimum performance of this cellular type of electrode structure are best illustrated by reference of FIGURE 13. In this particular illustration the carryover is plotted as ordinates in terms of parts per million,

the abscissa scale showing the gap in the electrode system as a percent of the outer electrode radius. Curve A shows the relationship between this gap ratio and the carryover obtained in the cell electrode system, which in this particular system had an outer electrode diameter of 8 inches and a length of 48 inches. The carryover was measured at the voltage which gave the lowest results for each inner electrode diameter. The vertical flow rate in this case was 30 inches/minute for all the tests, and the best runs gave a carryover of only a few tenths of a part per million in the region in which the gap ratio was between 40 and 80%. As the inner electrode diameter became smaller (increasing gap ratio) the carryover gradually rose until about the 95% figure it became quite high and therefore commercially unattractive. The reason for this is ascribable to the fact that for any particular voltage applied between the electrodes the gradient at the smaller electrode begins to become very high as its diameter gets very small. This high gradient causes dispersion of droplets from the electrode surface which then, because of their reduced size, can be carried through the treating zone before they can be redeposited on the walls or recoalesced. Consequently very small electrode diameters are to be avoided and we prefer to operate with a maximum gap ratio of about 95%, and preferably about 85% in order to obtain maximum efficiency. Beyond the 95% ratio the treater operation becomes erratic and undesirable from a commercial standpoint.

On the other hand, as the inner electrode became larger, the electrode gap and the gap ratio becoming smaller, there is also an increase in carryover. At first blush it would seem that the carryover should remain low with increasing electrode diameter, as indicated by the dotted line B, since the field becomes more uniform. It has been discovered however that there is a critical gap distance below which the treater system shows decreasing effectiveness in removal of the dispersed material. This critical distance depends somewhat upon the nature of the dispersed matter. It cannot be expressed accurately as a gap ratio figure but can be generally expressed as an absolute distance. We have found that a gap below about ½ inch shows disturbing effects and we prefer gaps that are at least about one inch.

The percentage of open area represented by a cell electrode system with varying electrode gap ratios is shown by the curve C of FIGURE 13. It will be obvious that in order to utilize the maximum area and therefore obtain the highest efficiency, it is desirable to operate in the right-hand portion of the curve C.

Curve A of FIG. 13 is shown for a system which gave a very low carryover under best conditions at a forward velocity of 30 inches/minute. When the rate was decreased to 20 inches/minute the resulting data were plotted as shown in dotted-line curve D–D¹. In other words, complete removal of the dispersed phase was possible between gap ratios of 25 and 85 at this rate. If the velocity is increased above 30 inches/minute curve A is merely transposed to higher values of carryover, generally still maintaining this characteristic shape.

When the tests were made with all conditions identical except that the length of electrode was 15 inches instead of 48 inches, the results of curve E were obtained. This shows the very real and important factor which the electrode length plays in obtaining the new results of the practice of this invention. The rapid rise of the carryover in the right-hand portion of the curves A and D–D' of FIG. 13 can be ascribed to the adverse effects of a low form factor (high local gradients at the center electrode) and it is therefore desirable to operate with electrode diameter ratios in which F is as high as possible, preferably above 0.8, taking into account however the adverse effect of gaps smaller than ½ inch, as previously pointed out.

The attached drawing suggests various commercial embodiments. In the embodiment of FIGS. 3 and 4 an upright cylindrical container **10** forms an upright passage the cross-section of which is substantially completely occupied by a cellular electrode **12** disposed between upper and lower zones **13** and **14** of the container. The cellular electrode **12** provides a multiplicity of hexagonal cells **16** arranged in close proximity each with a rod electrode **17** depending therein. The rod electrodes may be suspended from hooks **18** depending from a foraminous structure **19** electrically insulated from the container **10** and connected to one terminal of a high-voltage source of unidirectional potential **20**, the other terminal being grounded and thus electrically connected to the cellular electrode **12**.

The dispersion to be treated is caused to flow longitudinally along annular treating spaces **22** within the cells around the rods, entering an end portion **23** of each cell, flowing smoothly and substantially nonturbulently along an intermediate portion **24** and exiting adjacent an end portion **25** adjacent the exit end of each cell. The coalescing section in which treatment is predominantly one of coalescence starts below the rod electrodes and occupies a part of the intermediate portion **24**. The electrophoretic section is here the upper or remaining part of the intermediate portion **24** wherein treatment is predominantly the result of electrophoretic effects. The purified oil is withdrawn at **26**.

Substantially equal increments of the incoming dispersion should enter and flow along the respective treating spaces **22**. In the arrangement of FIG. 3 the incoming dispersion in pipe **28** is divided by a manifold system **29** into a plurality of substantially equal streams which discharge directly into the cells at positions above the lower ends thereof through open-ended pipes **30**. Spreaders **31** may be mounted above the open ends of the respective pipes.

The streams rising in the individual cells are first subjected to the electric and electro-hydraulic effects in and below the end portion **23** wherein considerable coalescence of the dispersed particles takes place to such an extent that the stream advancing along the intermediate portion **24** contains residual dispersed particles in substantially decreased population density. The high-voltage electric field in the upper section of the intermediate portion **24** acts on the smooth-flowing dispersion by electrophoretic action, this intermediate portion **24** being sufficiently long and the applied voltage sufficiently high that the treated oil entering the exit portion **25** contains only very little residual dispersed material so that the electro-hydraulic action in the end portion **25** has substantially no redispersive effect and creates a minimum of turbulence. The coalesced or electrophoresed dispersed-phase material progressively settles through the rising streams and collects as a body **32** from which the material is withdrawn under the control of a valve **34**.

It is often advantageous to extend the cellular electrode **12** into this body **32**, e.g. to maintain the level of the body at a position L—L above the lower ends of the cells. This can be accomplished by a level control device **35** operatively connected to the valve **34** as suggested by the dotted line **36** to maintain the bottoms of the open cells constantly submerged in the heavier liquid of the body **32**. This liquid thus forms a hydraulic seal between adjacent cells and between the outermost cells and any portions **38** of the interior of the container not occupied by the hexagonal cells, which portions can then be left open at top and bottom. By suitable distributor design and adjustment, it is thus possible to feed the same amount of emulsion to each cell, thus avoiding any differential flows therein such as might otherwise occur because of thermal or hydraulically induced currents in conventional cross-pipe distributor arrangements. Adequate results can be obtained under some conditions by maintaining the level at a position L'—L' below the bottoms of the cells, as by associating the operative connection **36** with a lower-positioned control device **35'**. Flow of the en-

tering dispersion into unoccupied portions 38 can then be avoided by extending the pipes 30 a considerable distance into the respective cells or the tops of these unoccupied portions 38 can be blocked off.

The treaters of the invention operate best if the dispersion entering the entrance ends of the interelectrode spaces contains only a relatively small amount of dispersed material, usually less than about 0.5%, although they are operative and give improved results over existing treaters with dispersions having larger amounts of dispersed material. In many instances improved results and economies in treater design can be achieved if some of the dispersed material is first preliminarily separated, such as by flow through an electric treater 40 which may be a high-turbulence treater in which the dispersion is discharged outwardly between edges of upper and lower electrodes 41 and 42 energized by a high-voltage transformer 43. As an example, a kerosene-water mixture was treated in a cellular type treater at a very high velocity of 35 inches/min., a velocity about six times that used in older commercial treaters of the multiple concentric cylinder or parallel plate type when treating the same dispersion. When the water content of the emulsion discharging into the cell was 7.5%, an overhead carryover of 38 p.p.m. of water occurred at the optimum voltage gradient. When the water content of the emulsion was reduced to 0.5%, the carryover was 11 p.p.m. and when reduced to 0.1%, it was 5 p.p.m. As another example a light catalytic cycle oil mixed with 6% strong caustic solution produced a treated oil containing 2 p.p.m. carryover when advancing at a rate of 20 inches/min. in a cell 8 inches square having an inner electrode 2 inches in diameter at a gradient of 13.5 kv./inch. When the incoming dispersion contained only about .5% dispersed material the treated oil contained only about 0.3 p.p.m. at 20 or 30 kv./inch even at a rate of 39 inches/min., the characteristic treating curve being similar in shape to curve *o* of FIG. 1.

The cellular passages may be circular, oval, triangular, square, rectangular, polygonal or arcuate in cross-section. If rectangular, it is desirable that the longer dimension of each cell in any cross-sectional plane should not be more than about twice the shorter dimension thereof in order to block effectively the aforesaid circulations in planes transverse to the lines of force. It is desirable that the longest distance from the center of each passage in any cross-sectional plane thereof measured to the cell wall have a ratio between 1:1 and about 2.5:1 with respect to the shortest such distance. FIG. 5 shows a pattern of square cells that is often advantageous. Regardless of shape, the cells may be tubes or may be a part of a built-up unit. FIG. 6 shows circular cells made of tubes in contact with each other and FIG. 7 shows such tubes with peripheries slightly spaced in which event the unoccupied spaces 38 may be closed by headers supporting the tubes. The closely packed cells of any of the described arrangements occupy substantially the complete cross-sectional area of the container passage in which they are positioned. Any unoccupied spaces 38 between the cells or between the outermost cells and the container constitute cell-blanketing spaces thermally insulating the cells in which the main treatment takes place.

In the embodiments of FIGS. 8 and 9 the cells of the cellular electrode 12 may have any of the previously described cross-sectional shapes, the unoccupied portions 38 being closed at the top by a header 46. The entering dispersion here discharges at a level below the lower ends of the cells through a smaller number of shorter pipes 30' providing dispersion-discharging orifices respectively below spreaders 31'. The zone of the treater passage adjacent the pipes 30' is divided by barriers 50 into quadrants or smaller sections which may be of sectorial or other shape, the discharge into any particular quadrant or section being channeled upward by the barriers to a particular group of interelectrode spaces. The barriers 50 may extend upward to the bottoms of the cells as shown or may terminate a short distance therebelow. The inner electrodes or rods 17 in this embodiment may terminate within the respective cells or at the ends thereof or may extend a distance therebelow. In the latter instances preliminary treating fields will be established between the rods and the barriers and between the rods and the distribution system, these fields preliminarily treating the dispersion in much the same manner as the electric treater 40 of FIG. 3. This embodiment has the advantage that a lesser number of pipes 30' can be used but one or a plurality of these should discharge into each quadrant or section and should be arranged in such pattern that the forward velocity in each of the cells fed by such quadrant or section should be substantially equal. The treated oil is collected by a network of pipes 51 having a large number of orifices 52 distributed across the cross-section of the treater passage. This type of collector can be used in any of the exemplified treaters and serves better than the single outlet 26 of FIG. 3 to insure that the streams in all cells have substantially equal forward velocity.

In FIG. 10 the inner electrodes may either extend from the ends of the cells as shown or may terminate at these ends. The incoming dispersion issues downwardly from orifices provided by short pipes 30'. Here may be used a preliminary electric treater 40' of the pipeline type having a central electrode 55 energized from a high voltage transformer 56 and disposed within a pipe 57. In this pre-treater 40' the flow is highly turbulent to prevent chaining-up of the particles and thus short-circuiting of the electrodes. Consequently little if any settling of coalesced dispersed material takes place in such a treater. However the coalesced material in this instance settles in the main treater immediately upon discharge from the short pipes 30'.

In FIG. 11 most of the inner electrodes 17 terminate within the respective cells but an electrode 17' near the center of a group of cells extends downward into the quadrant or section defined by baffles 50''. A wider field of lower intensity is thus established between the extension of each electrode 17' and the adjoining baffles 50'', this field serving initially to treat the incoming dispersion before it enters the smaller cells and thus serving somewhat the same function as the treaters 40 and 57. The barriers 50'' may be extensions of some of the cell walls.

The foregoing statement of the invention will suggest to those skilled in the art various changes and modifications which can be made without departing from the spirit of the invention as defined in the appended claims.

We claim:

1. Apparatus for electrically treating dispersions containing small amounts of heavier material suspended in oil to remove substantially all of such heavier material therefrom, said apparatus including:

a container providing a lower entrance zone and an upper exit zone spaced from each other in an axial direction with an intermediate zone therebetween of a height of at least about 24'', a major portion of the cross-section of said intermediate zone being an electrode zone;

electrode walls forming a plurality of closely-adjoining side-by-side cellular treating passages in said electrode zone extending in said axial direction having entrance and exit ends respectively communicating with said lower entrance zone and said upper exit zone and forming the sole communication therebetween throughout the cross-section of said electrode zone, said treating passages being of the same cross-sectional size and of an upright length of at least about 24'', said electrode walls being electrically connected together and to said container;

a plurality of elongated rod-like electrodes and means for supporting same substantially centrally in said treating passages, said last-named means including means for electrically connecting said elongated elec-

trodes and electrically insulating same from said electrode walls, said elongated electrodes forming with said electrode walls interelectrode treating spaces each of an upright length of at least about 24" and of substantially uniform cross-sectional area at all levels between the entrance and exit ends thereof, the ratio between such length of each interelectrode treating space and the gap between the elongated electrodes and their electrode walls being at least in the range of about 8:1–30:1;

a high-voltage source of unidirectional potential connected between said electrode walls and said elongated electrodes for establishing in said interelectrode treating spaces high-voltage unidirectional electric fields of a voltage gradient of at least about 6–30 kv./inch;

means for advancing streams of said dispersion along said interelectrode treating spaces in a direction from said entrance ends to said exit ends thereof in bridging relationship with the electrode walls and the elongated electrodes thereof, producing a treated oil substantially free of said heavier material issuing from said exit ends into said exit zone and producing a body of separated heavier material in the bottom of said entrance zone; and

means for withdrawing said treated oil from said exit zone and said separated heavier material from the bottom of said entrance zone.

2. Apparatus as defined in claim **1** in which said major portion of the cross-section of said intermediate zone constitutes the central portion thereof, there being a minor portion of said cross-section of said intermediate zone comprising a blanketing space between said container and those outermost electrode walls forming the outermost of said plurality of treating passages, said space communicating downwardly at its lower end with said entrance zone.

3. Apparatus as defined in claim **1** in which each treating passage is of a cross-sectional width of about 2–16 inches, in which each of said elongated electrodes is of a cross-sectional width of at least ¼ inch, and in which said gap has a minimum width of ½ inch.

4. Apparatus as defined in claim **1** in which each treating passage is a peripherally closed passage of such cross-sectional shape that the longest distance between the center of such passage in any cross-sectional plane thereof measured to the electrode wall thereof has a ratio between 1:1 and about 2.5:1 with respect to the shortest such disance.

5. Apparatus as defined in claim **1** in which each treating passage is of a cross-sectional shape selected from the class consisting of circular, square and hexagonal shapes, each interelectrode treating space having a form factor, defined in equation A of about .8–.98.

6. Apparatus for electrically treating dispersions containing small amounts of heavier material suspended in oil to remove substantially all such heavier material therefrom, said apparatus including:

a deep grid electrode structure having an upright axis and long axially-extending electrode walls bounding a plurality of closely-adjoining similarly-sized upright cellular treating passages having central axes that are parallel to and spaced laterally from said upright axis with one of said central axes being substantially coaxial with said upright axis, said electrode walls laterally baffling each treating passage from laterally-adjoining treating passages, said electrode walls being electrically connected together, said treating passages extending from end to end of such deep grid electrode structure and being of substantially uniform cross-sectional area at all levels between such ends, each treating passage being of an axial length of at least 24 inches and of a cross-sectional width of about 2–16 inches;

a foraminous framework near but spaced from one end of said deep grid electrode, there being means for electrically insulating said framework from said deep grid electrode structure;

a plurality of vertically elongated rod electrodes each of a cross-sectional width of at least ¼ inch attached to and electrically connected to said framework extending axially into and along said treating passages forming interelectrode treating spaces between the outer surfaces of said elongated electrodes and the surfaces of the corresponding passage-bounding electrode walls, each interelectrode treating space being of an axial length of at least about 24 inches, each interelectrode treating space being of substantially uniform cross-sectional area at all levels between the ends thereof, the ratio between the lengths of said interelectrode treating spaces and the gap between the electrode walls and the outer surfaces of said elongated electrodes being at least in the range of about 8:1–03:1;

a high-voltage source of undirectional potential connected between said electrode walls and said framework for developing in said interelectrode treating spaces high-voltage unidirectional electric fields;

flow means for advancing streams of said dispersion at substantially equal upward flow rates upwardly along said interelectrode treating spaces in bridging relation with the surfaces of said electrode walls and said elongated electrodes;

means below said deep grid electrode structure collecting and withdrawing heavier material separating from said dispersion; and

means above said deep grid electrode structure receiving and withdrawing treated oil from the upper ends of said treating passages.

7. Apparatus as defined in claim **6** in which said gap is of a width between about ½ inch and about 95% of the radial distance between the center of the corresponding treating passage and the electrode wall thereof.

8. Apparatus as defined in claim **6** in which each treating passage is of such shape that the longest distance from the center of such passage in any cross-sectional plane thereof measured to the electrode wall thereof has a ratio between 1:1 and about 2.5:1 with respect to the shortest such distance measured in such plane.

9. Apparatus as defined in claim **6** in which each treating passage is of a cross-sectional shape selected from the class consisting of a circular, square and hexagonal shapes, each interelectrode treating space having a form factor, defined in Equation A of about .8–.98.

10. Apparatus as defined in claim **6** in which said deep grid electrode structure comprises a plurality of tubes of substantially uniform diameter from end to end, the walls of said tubes forming said electrode walls, and including means for rigidifying said tubes in side-by-side relation, the distance between the walls of adjacent tubes being less than the outer diameter of said tubes.

11. Apparatus as defined in claim **6** in which said upright treating passages are immediately adjoining, pairs of immediately-adjoining treating passages being separated by a single electrode wall therebetween.

12. Apparatus as defined in claim **6** in which said flow means includes means for flowing said dispersion along each of said interelectrode treating spaces at a rate of at least about 4"/min. for dispersions of heavier oils having gravities in the range of crude oils and lubricating oils and of at least about 10"/min. for dispersions of lighter oils having gravities in the range of gasoline and kerosene.

13. Apparatus as defined in claim **6** in which said means below said deep grid electrode structure includes walls defining an entrance chamber, the lower ends of all of said treating passages opening downwardly on said entrance chamber, and in which said flow means includes means for introducing the dispersion to be treated into said entrance chamber at a plurality of positions in a horizontal plane relatively close to said lower ends of said treating passages.

14. Apparatus as defined in claim 13 in which at least some of said elongated electrodes provide lower end portions protruding downwardly below the lower ends of their corresponding treating passages, said high-voltage source establishing electric fields adjacent said lower end portions electrically treating the dispersion before entry into the lower ends of said interelectrode treating spaces.

15. Apparatus for electrically treating dispersions containing small amounts of heavier material suspended in oil to remove substantially all such heavier material therefrom, said apparatus including:

a deep grid electrode structure made up of electrode walls disposed at right angles to each other forming a plurality of side-by-side upright treating passages each of substantially square and equal cross section at all levels between upper and lower ends thereof, each treating passage being of a width of about 2–16" and of a length of at least about 24", all of said electrode walls being electrically connected together;

a plurality of elongated electrodes each of a length of at least about 24" and of a cross-sectional width no less than about ¼ inch extending axially into and along said upright treating passages, said elongated electrodes being electrically connected together and forming with said electrode walls interelectrode treating spaces each of a length of at least about 24", the ratio between the actual length of each interelectrode treating space and the gap between the elongated electrode and the electrode walls bounding such interelectrode treating space being at least in the range of about 8:1–30:1, the distance across said gap being no less than about ½";

a high-voltage source of unidirectional potential connected between said electrode walls and said elongated electrodes;

flow means for advancing streams of said dispersion at substantially equal flow rates upwardly along said interelectrode treating spaces in bridging relation with the surfaces of said electrode walls and said elongated electrodes;

means below said deep grid electrode structure collecting and withdrawing heavier material separating from said dispersion; and

means above said deep grid electrode structure receiving and withdrawing treated oil from the upper ends of said treating passages.

16. An electric treater for treating dispersions having a continuous phase of oil with small amounts of dispersed particles therein consituting a dispersed phase to remove substantially all of such dispersed phase material, said electric treater including in combination: a grounded tubular electrode of an axial length of about 24–120 inches and a diameter of about 2–16 inches; a rod electrode extending along the central axis of said tubular electrode and cooperating therewith in defining an annular interelectrode treating space of a length of about 24–120 inches between entrance and exit portions thereof, said rod electrode being of a minimum diameter of about ½ inch, the length-to-gap ratio of said annular treating space being at least in the range of about 8:1–30:1, the width of said annular treating space between the surfaces of said rod electrode and said tubular electrode being between about ½ inch and about 95% of the radius of said tubular electrode, means for electrically insulating said rod electrode from said tubular electrode; a high-voltage source of unidirectional potential electrically connected to said tubular and rod electrodes, said source establishing a unidirectional electric field in said treating space of a voltage gradient of about 6–30 kv./inch; walls defining an entrance chamber communicating with said entrance portion of said treating space adapted to collect in the bottom thereof a body of separated dispersed phase material separating from said dispersion in said treating space; means for delivering a stream of the dispersion to said entrance chamber at a position above said body and spaced from the end of said rod electrode, said dispersion flowing from said position toward the lower end portion of said rod electrode into said entrance portion of said treating space for treatment during flow longitudinally along said treating space to produce a treated oil substantially free of residual dispersed particles issuing from said exit portion of said treating space; walls defining an exit chamber communicating with said exit portion of said treating space and receiving the treated oil therefrom; a treated-oil outlet means communicating with said exit chamber for withdrawing the treated oil therefrom; and an outlet means communicating with said body in said entrance chamber for withdrawing separated dispersed material therefrom.

17. An electric treater as defined in claim 16 in which said treating space has a form factor, defined in Equation A, of about .8–.98.

18. An electric treater as defined in claim 16 in which said stream delivery means includes means for flowing said dispersion along said interelectrode treating space at a rate of at least about 4"/min. for dispersions of heavier oils having gravities in the range of crude oils and lubricating oils and of at least about 10"/min. for dispersions of lighter oils having gravities in the range of gasoline and kerosene.

19. Apparatus for electrically treating dispersions of oil in which particles of a material of greater density and higher electrical conductivity are dispersed, said apparatus including: a container providing entrance and exit zones spaced from each other along an axis, there being an intermediate zone therebetween of an axial dimension of at least 24 inches; a plurality of electrically-connected cells disposed side by side in said intermediate zone, each cell being of an axial length at least 24 inches, each cell having entrance and exit portions respectively communicating with said entrance and exit zones, said cells being of substantially equal size in width and axial length, each cell being of substantially uniform cross-sectional area throughout its length; a central electrode in each cell insulated therefrom and providing a treating space therewithin of a high length-to-gap ratio that is at least in the range of about 8:1–30:1 and of an axial length of at least 24 inches, said central electrodes being electrically connected together; a source of high-voltage unidirectional potential connected between said cells and said central electrodes establishing electric fields in said treating spaces; means for flowing separate streams of the dispersion axially along said treating spaces from said entrance portions to said exit portions, said last-named means including a dispersion distributor in said entrance zone comprising a pipe network and a plurality of short dispersion-discharge pipes corresponding in number to said cells and having end portions respectively extending into the entrance portions thereof; and means for withdrawing treated oil from said exit zone.

20. Apparatus for electrically treating dispersions of heavier material suspended in oil, said apparatus including: a container providing a flow passage having upper and lower zones adapted respectively to contain separated bodies of oil and said heavier material; effluent means respectively opening on said bodies to withdraw oil and heavier material therefrom; means controlling such effluents to maintain a level of said body of heavier material substantially a uniform distance above the bottom of said container; a cellular electrode having a plurality of side-by-side cells of substantially equal cross-sectional area, each cell having a lower entrance portion and an upper exit portion respectively communicating with said lower and upper zones; means for mounting said cellular electrode within said container with the lower ends of said cells below said level whereby the body of heavier material forms a liquid seal separating the interiors of said cells; means for introducing streams of the dispersion into said cells; a plurality of long central electrodes in said cells forming with the cell walls interelectrode treating spaces each of a length of at least about 24", the ratio between

such length of each interelectrode treating space and the gap between the central electrode and the cell walls being at least in the range of about 8:1–30:1; and a high-voltage source of unidirectional potential connected between said cells and said central electrodes for establishing high-voltage unidirectional electric fields in said interelectrode treating spaces.

References Cited by the Examiner

UNITED STATES PATENTS

1,838,929	12/31	Fisher	204—188
1,931,725	10/33	Girvin	204—299 X
2,033,137	3/36	Fisher	204—188
2,042,887	6/36	Fisher	204—299
2,539,074	1/51	Grove	204—188
2,588,111	3/52	Ameman	204—302
2,659,438	10/53	Wintermute	204—302
2,665,246	1/54	Bates	204—188
2,855,356	10/58	Stenzel	204—299 X
2,894,895	7/59	Turner	204—302

FOREIGN PATENTS

88,004	3/58	Netherlands.

WINSTON A. DOUGLAS, *Primary Examiner.*

MURRAY TILLMAN, *Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,205,160 September 7, 1965

Richard W. Stenzel et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 56, for "dispersions" read -- dispersion --; column 3, line 33, for "rolling" read -- roiling --; column 7, line 48, for "difficulty" read -- difficultly --; line 53, for "through" read -- though --; column 8, line 69, for "haxagonal" read -- hexagonal --; line 74, for "of" read -- to --; column 9, line 14, after "until" insert -- at --; column 14, line 18, for "8:1-03:1" read -- 8:1-30:1 --; column 15, lines 63 and 64, for "electrode," read -- electrode; --.

Signed and sealed this 5th day of April 1966.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

EDWARD J. BRENNER

Commissioner of Patents