June 1, 1971 R. N. LUCAS 3,582,527

UNIFORM ELECTRIC FIELD TREATING SYSTEM

Filed May 15, 1969 2 Sheets-Sheet 1

Fig. 1

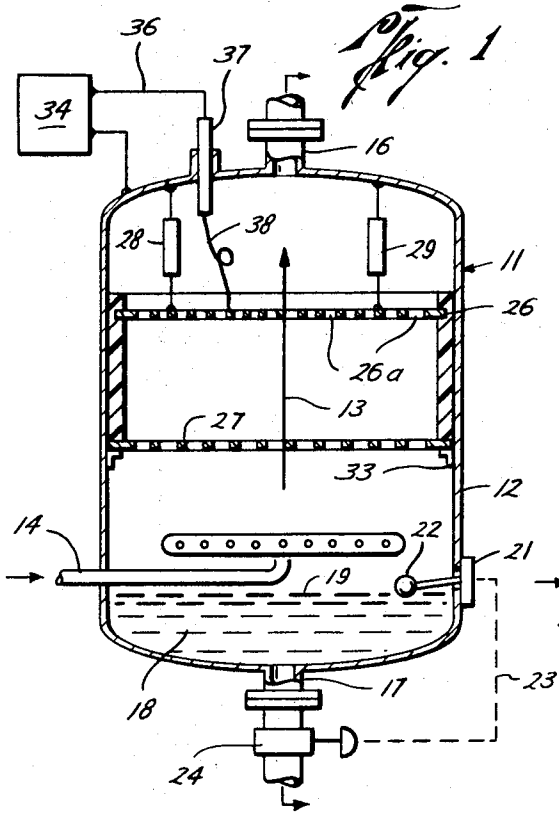
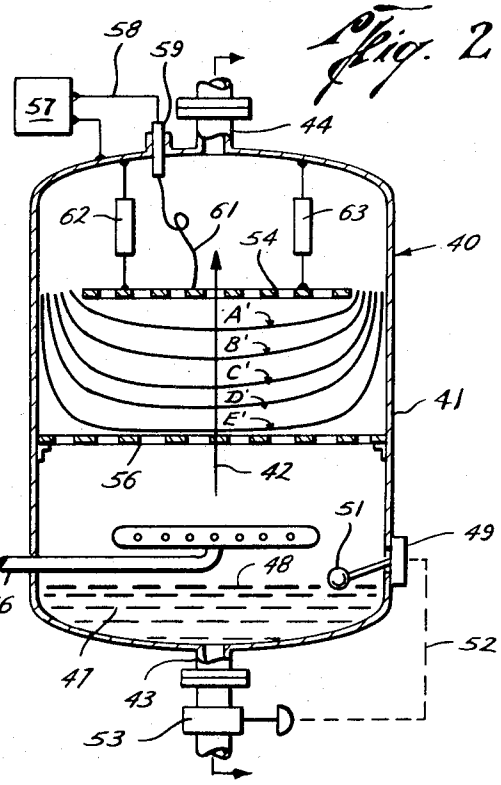


Fig. 2



PRIOR ART

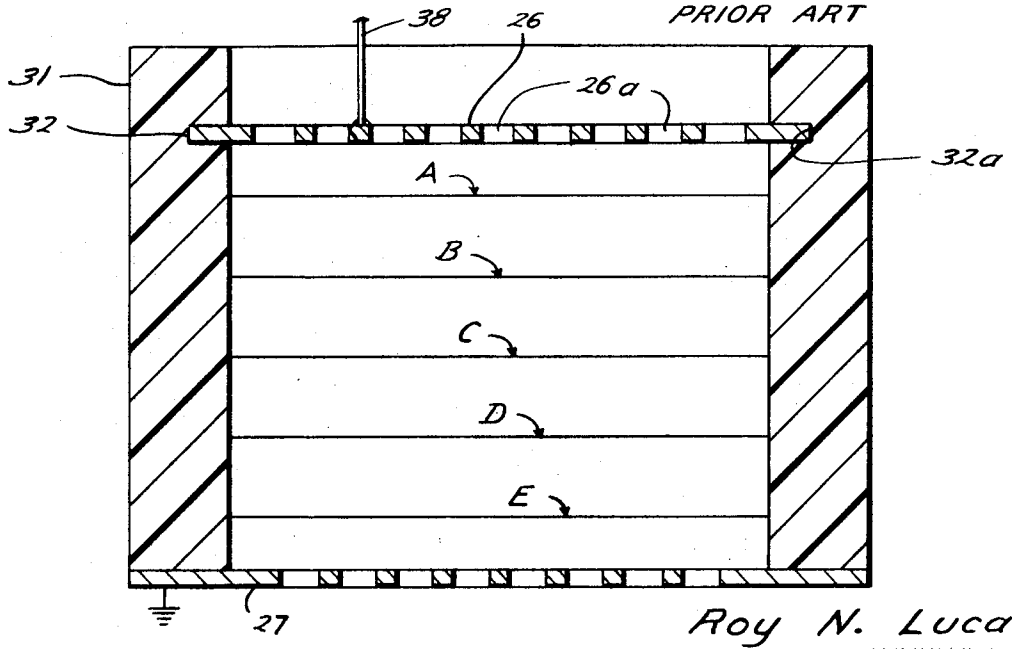


Fig. 3

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UNIFORM ELECTRIC FIELD TREATING SYSTEM

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Fig. 4

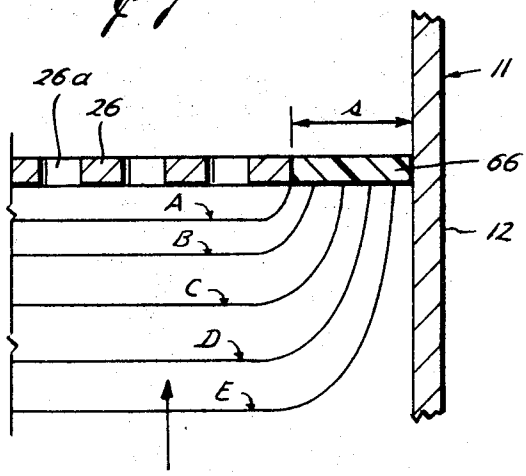


Fig. 5

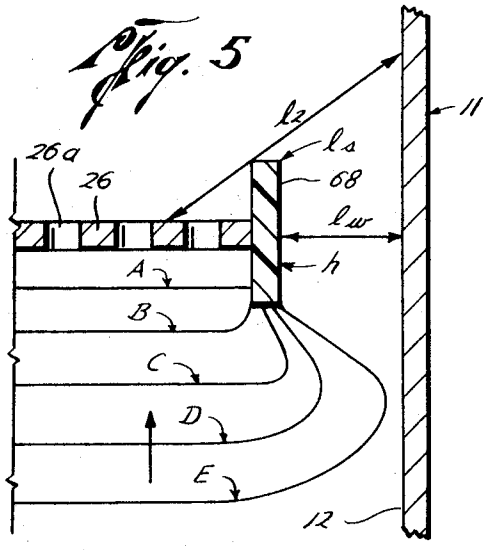


Fig. 7

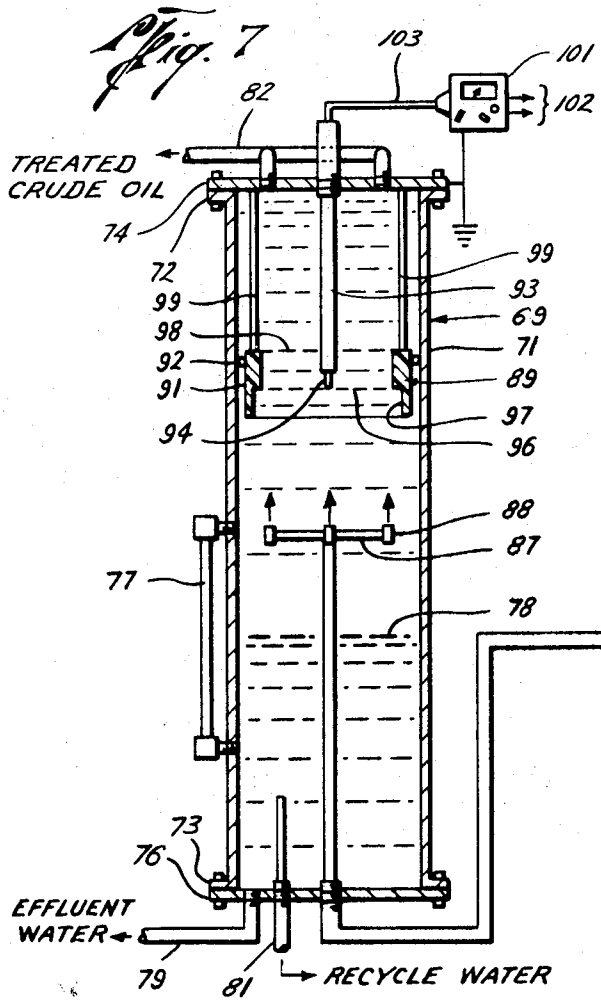
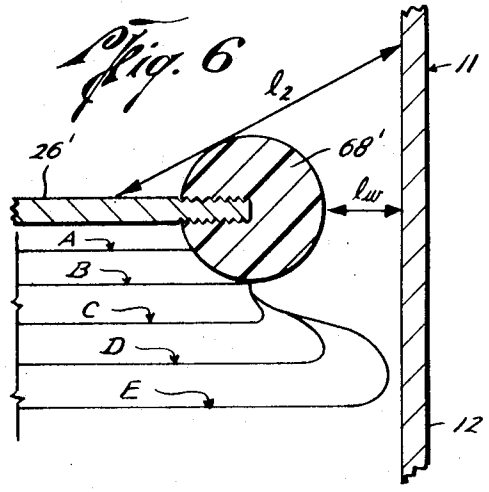
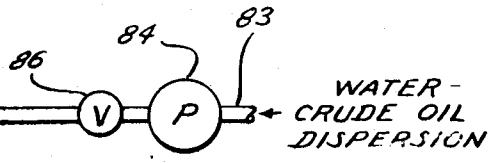


Fig. 6





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3,582,527

UNIFORM ELECTRIC FIELD TREATING SYSTEM

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Int. Cl. B03c 5/02
U.S. Cl. 204—302 9 Claims

ABSTRACT OF THE DISCLOSURE

A system, including apparatus for electrically resolving a dispersion consisting of immiscible and liquid phases. The dispersion flows along a vertical flow axis between inlet and outlet zones. An electric field for resolving the dispersion is established in a region between a horizontally disposed, foraminous electrode and the inlet zone through which region passes substantially all of the fluid. The electric field increases monitonically in potential toward the electrode and has planes of constant potential transverse to the direction of dispersion flow. The phases resolved from the dispersion in the electric field are recovered from the outlet zones.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates to resolving dispersions consisting of immiscible and liquid phases. More particularly, the invention relates to electric field treatment for resolving such dispersions.

(2) Description of the prior art

Electric fields are employed for resolving many dispersions in which the internal phase is an aqueous material such as water, caustic, or acid, etc. and the external phase is an organic liquid such as crude oil. These dispersions are passed between electrodes energized with a high voltage to create an electric field of sufficient intensity to cause the internal phase to coalesce. The term "coalesce" as used herein refers to the agglomeration of the dispersed internal phase while in the continuous external phase. Sufficiently large particle sizes of the internal phase are created which can be readily separated from the external phase by differences in specific gravities.

A large number of designs have been employed in electric treaters. Many methods of operation have been tested for improving the electrical resolution of dispersions. Some of these treaters were designed to employ non-uniform electric fields for effecting dispersion resolution. Other treaters were designed to employ uniform electric fields to effect the desired electrical resolution of dispersions. The latter type of treaters relate more closely to the present invention than treaters employing non-uniform electric fields.

One treater employing uniform electric fields for resolving dispersions is shown in U.S. Pat. 1,440,776. The treater (crude oil dehydrator) was formed of an upright cylindrical metallic vessel in which were mounted horizontally a pair of vertically spaced apart foraminous electrodes. The lower electrode was grounded. The upper electrode was energized to create an electric field between the electrodes. The dispersion was introduced into the lower part of the vessel and passed upwardly through the two electrodes. The electric field caused the aqueous phase to coalesce and fall to the bottom of the vessel for removal through a suitable outlet. The organic phase passed upwardly and was removed through a suitable overhead outlet. As a result of operation of the treater, a stratified field (of undisclosed character) is alleged to be produced in the space between the electrodes.

The electrodes in the treater have a cross-section with a substantial area less than the cross-section in the treater open to fluid flow. Thus, not all the dispersion will flow through the energized electrode. For example, in a conventional similarly designed treater, this area may be in the range of between 10 and 20 percent of the cross-sectional area of the treater open to fluid flow. Thus, incomplete resolution of dispersions could result. Also, a non-uniform electric field exists between the peripheral edge of the energized electrode and the adjacent metallic side walls of the vessel. This non-uniform field does not produce the same resolution of the dispersion as the uniform field which exists in regions directly between the energized and grounded electrodes. Thus, any dispersion which passes through this non-uniform field between the edge of the electrode and the adjacent metal wall of the vessel will not be treated to the same extent as the dispersion which passes through the energized electrode. Thus, the efficiency of the treater in resolving dispersions may be varied when dispersion from uniform and non-uniform electric fields is comingled.

The purpose of the present invention is to employ a uniform electric field for resolving dispersions without passing any significant amount of dispersions through the treater other than through the uniform electric fields.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a system, including apparatus for resolving dispersions with uniform electric fields. More particularly, there is provided a treater formed of a vessel which contains a vertical flow axis within metallic walls. Vertically spaced apart outlets are provided to remove aqueous and organic phases derived from the dispersion. An inlet is provided to introduce the dispersion adjacent to one end of the flow axis. Electrode means are positioned in the vessel for creating an electric field having planes of constant potential oriented normal to the flow axis when the electrode means is energized with potentials capable of resolving the dispersion in the electric field. The electrode means extends the electric field across substantially the entire cross-section of the vessel receiving flow of fluid along the vertical flow axis. As a result, energization of the electrode means produces planes of constant potential normal to the vertical flow axis in a region residing between the electrode means and the inlet. Substantially all of the fluid moved along the vertical flow axis of the vessel passes through this region.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical section taken through a treater embodying the present invention;

FIG. 2 is a vertical section taken through a prior art treater which is arranged graphically to provide a ready comparison to the treater illustrated in FIG. 1;

FIG. 3 is an enlarged view of the energized and grounded electrode assembly of the treater illustrated in FIG. 1;

FIG. 4 is an enlarged fragmentary vertical section of another energized electrode embodiment used in the treater illustrated in FIG. 1;

FIGS. 5 and 6 are enlarged fragmentary vertical sections of other energized electrode embodiments used in the treater illustrated in FIG. 1;

FIG. 7 is a vertical section taken through an experimental treater employed for field testing the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Referring to FIG. 1 of the drawings, there is shown a treater of the present invention which is comprised of a vessel 11 having metallic wall 12 to form a vertical

flow axis which is indicated by the arrowed line **13**. An inlet **14** is provided to introduce dispersion to be treated into the vessel **11** at one end of the vertical flow axis. The dispersion is formed of an organic phase in which is dispersed a more dense aqueous phase. Outlets **16** and **17** to remove the organic and aqueous phases, respectively, are provided at the top and bottom of the vessel **11**. If the organic phase is more dense than the aqueous phase, the treater may be inverted. Then, the organic phase would be removed through the lower outlet.

In operation of the treater, the organic phase obtained from the dispersion passes upwardly and it is removed through the outlet **16**. Aqueous phase material gravitates downwardly and it is collected in a body **18** in the lower portion of the vessel **11**. The aqueous phase body may be withdrawn from the vessel at regulated rates so as to maintain a relatively constant interface **19** between the body **18** of aqueous phase and the dispersion and organic phase thereabove. A level control system may be provided for maintaining the interface **19** at a constant level within the vessel **11**. For this purpose, a controller **21** is actuated by a float **22** for providing a signal (indicated by chain line **23**) to a motor actuated control valve **24** which regulates fluid flow from the outlet **17**. By this means, the aqueous phase can be removed through the outlet **17** at rates sufficient to maintain the interface **19** at any suitable level in the vessel **11**.

Although the inlet **14** is shown as being disposed above the interface **19**, for purposes of the present invention the inlet **14** may introduce dispersion below the interface **19**, immediately at the interface **19**, or at some level thereabove.

A spatial uniform electric field is provided by an electrode means within the vessel **11** so that the dispersion flowing along the vertical flow axis passes perpendicularly through planes of constant potential. In the treater illustrated in FIG. 1, the electric field is established between an energized electrode **26** and an upstream electrical ground, such as a grounded electrode **27**, which are spaced vertically from one another. More particularly, the electrode **26** is constructed of an electrically conductive metal into a foraminous form and is positioned substantially horizontally in the vessel **11**. The electrode **26** has a planar surface presented toward the inlet **14**. Insulators **28** and **29** may support the electrode **26** in electrical isolation from the walls **12** of the vessel **11**. The electrode **26** extends substantially across the entire cross-section of the vessel **11** transverse to the flow of fluid along the vertical flow axis **13**. An insulating sleeve or cylindrical member **31** is interposed between the peripheral edge **32** of the electrode **26** and the adjacent walls **12** of the vessel **11**.

The electrode **26** may be formed of a steel disc provided with a plurality of openings **26***a* through which fluid may flow on passing along the vertical flow axis in the vessel **11**. The cylindrical sleeve **31** is provided with a groove **32***a* to receive the peripheral edge **32** of the electrode **26**. Thus, the electrode **26** and sleeve **31** comprise an integral unit which can be suspended upon the insulators **28** and **29**, or if desired, upon lower wall-mounted supports **33**.

The cylindrical sleeve **31** is formed of a material having a high specific inductive capacity or dielectric constant which provides a barrier of very high resistivity compared to the fluids within the vessel **11**. For substantially all practical purposes, no excessive current flows from the electrode **26** through the cylindrical sleeve **31** to the walls **12**. By excessive current, it is meant a current which is greater than flows between the electrodes **26** and **27**. Suitable materials for forming the cylindrical sleeve **31** may be Teflon, polypropylene and various acrylic and other resinous materials. If desired, ceramic insulative materials may also be employed in the sleeve **31**. The cylindrical sleeve **31** has a certain thickness filling the space between the electrode **26** and walls **12**.

The sleeve **31** may have a lesser thickness but should have at least a minimum thickness which will not be readily punctured at the potentials to which the electrode **26** is energized during operation of the treater. Preferably, the sleeve **31** extends from a short distance above the electrode **26** downwardly throughout the region to the grounded electrode **27**. In this region, the uniform electric field of the present invention is employed for resolving the dispersion.

The grounded electrode **27** is foraminous and may be constructed similar to the energized electrode **26**. The grounded electrode **27** is supported beneath the sleeve **31** by supports **33** secured to the walls **12** of the vessel **11**. Thus, the grounded electrode **27** is planar and disposed parallel to the electrode **26**.

If desired, the grounded electrode **27** may be omitted. In this instance, the distributor connected to inlet **14**, or the aqueous phase interface **19** will serve as an electrical ground spaced vertically from the energized electrode **26**. The electrical field within the sleeve **31** will not be significantly changed. However, the electric field may be somewhat non-uniform in the vicinity of the distributor.

The electrode **26** is energized to potentials adequate for resolving the dispersion which enters the region between the electrodes **26** and **27**. For this purpose an external power source **34** may be provided. This power source supplies suitable potentials (AC or DC) to the electrode **26** for providing the desired result. For this purpose, one terminal of the power source **34** is connected directly to the walls **12** of the vessel **11**. A high voltage conductor **36** is connected between the power source **34** and the electrode **26** through a high voltage bushing **37** mounted upon the upper surface of the vessel **11** and connected with a flexible wire **38** to the electrode **26**. The power source **34** energizes the electrode **26** to sufficiently high potentials to resolve the dispersion in the region between the electrodes **26** and **27**. For example, the electrode **26** may be energized to between 3 and 35 kilovolts AC or DC for this purpose. The exact magnitude of the potential will depend upon the characteristics of the dispersion and also of the spacing between the electrodes **26** and **27**.

Referring to FIG. 3, the arrangement of the electrodes **26** and **27**, and the sleeve **31** is shown in enlarged detail. The energized electrode **26** creates an electric field which extends vertically between the electrodes **26** and **27**. The sleeve **31** substantially reduces current flow to the walls **12** from the electrode **26** in directions parallel thereto. Therefore, substantially all current flows vertically between the electrodes. As a result, a spatially uniform electric field is created in the region between these electrodes which field has planes of constant potential normal to the vertical flow axis in the vessel **11**. A plane of constant potential may be defined as a plane in which the potential is of constant magnitude throughout its extent. The plane is perpendicular to the lines of force of the electric field between the electrodes **26** and **27**. These planes of constant potential are identified by letters A, B, C, D and E for purposes of illustration. The actual spacing between adjacent planes of potential may vary depending upon the electrical characteristics of the fluids which are present in the region between the electrodes and the energizing potential applied to the electrode **26**. The dispersion moves from the electrode **27** towards the energized electrode **26** in an electric field with a monitonically increasing potential. Thus, the dispersion flows at right angles to the planes of constant potential. Its traverse of the planes of constant potential provides for outstanding resolution of the dispersion into its respective aqueous and organic phases. The aqueous phase gravitates downwardly through the electrode **27** and collects into an aqueous phase body **18** in the lower extremity of the vessel **11**. The organic phase with any unresolved aqueous phase passes upwardly through the electrode **26** and moves towards the outlet **16** at the upper extremity of the vessel **11**.

It will be apparent that the sleeve **31** deflects lines of constant potential from an orientation parallel to the ver-

tical flow axis in all flow passages along the vertical flow axis **13** within the treater. Thus, the dispersion must flow vertically at right angles through all planes of constant potential in the region which resides between the electrodes **26** and **27**. Optimum resolution of the dispersion occurs in the uniform electric field under these conditions.

The function of the spatial uniform electric field employed in the present invention may be readily appreciated by reference to prior art treaters. In FIG. 2 there is illustrated a "prior art" treater which is based upon the principles of operation described in U.S. Pat. 1,440,776 earlier described. This "prior art" treater is comprised of a vessel **40** having metallic walls **41** which provide a vertical flow axis indicated by the arrow **42**. The vessel **40** carries aqueous and organic phase outlets **43** and **44**, respectively, at the top and bottom portions thereof. An inlet **46** is provided at one end of the vertical flow axis **42** in the vessel **40**. The electric field established in the vessel **40** produces an organic phase which moves towards the outlet **44** and an aqueous phase which gravitates downwardly into an aqueous phase body **47** in the lower extremity of the vessel **40**. Flow control means remove the aqueous phase at a rate suitable to maintain a relatively constant interface **48** (above the body **47**) at a predetermined level in the vessel **40**. For this purpose, a flow control system **49** is actuated by a float **51** for providing signals indicated by chain line **52** to actuate a motor controlled valve **53** which regulates fluid flow from the outlet **43**. The vessel **40** contains an energized electrode **54** and a grounded electrode **56** which are foraminous. The electrodes are mounted in vertically spaced-apart horizontally oriented relationship. Thus, the electrodes **54** and **56** are substantially identical to the electrodes **26** and **27** in the treater of the present invention illustrated in FIG. 1. However, the energized electrode **54** has its peripheral edge spaced from the metallic walls **41** of the vessel **40** a sufficient distance that excessive currents are not drawn during treater operation. The electrode **54** is energized from a power source **57** which may be of any suitable design. The power source is grounded directly to the metallic walls **41** of the vessel **40**. The power source **57** connects to a conductor **58**, through an insulating entrance bushing **59**, and with a flexible lead **61** to the electrode **54**. The electrode **54** is suspended from insulators **62** and **63** within the vessel **40**. Thus, the electrode may be energized to a suitable operating potential from the power source **57**.

Upon energization of the electrode **54**, a limited uniform electric field for resolving the dispersion which flows vertically through the vessel **40** is created in the central region between the electrodes **54** and **56**. A portion of the current flows vertically between the electrodes **54** and **56** in a uniform portion of the electric field. However, substantial current also flows in directions other than vertically in the region between the electrodes **54** and **56** to create non-uniform portions of the electric field. The uniform portion of the electric field has planes of constant potential normal to the flow axis **42**. For example, if the electrode **54** is a perforated metal disc, the lines of force will be cup-shaped. These lines of constant potential for illustration are labeled A′, B′, C′, D′ and E′. The central part of the region between the electrodes is in the uniform portion of the electric field, and constant potential lines reside in planes transverse to the vertical flow axis **42**. However, as the radial distance from the central region below the electrode **54** increases, the lines of force become divergent in the non-uniform portion of the electric field. Also, the lines of constant potential begin to become more compact in curved surfaces which eventually reach a vertical orientation between the peripheral edge of the electrode **54** and the adjacent metallic walls **41** of the vessel **40**. Efficiency in the treater for resolving the dispersion varies as the lines of constant potential become oriented towards the vertical and become more compact.

The dispersion passing between the peripheral edge of the electrode **54** and the metallic wall **41** of the vessel **40** may be, for example, 10% by volume of all fluids which pass through the vessel **40**. As a result, at least 10% of the dispersion is not resolved to the same extent as centrally between the electrodes. Additionally, the curvature of the lines of constant potential towards the vertical tends to move (by electrophoretic action) unresolved dispersion into the flow passages between the peripheral edge of the electrode **54** and the metallic **41** of the vessel **40**. These effects combine to affect the efficiency of the prior art treater in resolving dispersions relative to the present invention.

In the treater illustrated in FIG. 1, the cylindrical sleeve **31** represents the preferred embodiment of an insulated barrier interposed between the peripheral edge of the energized electrode and adjacent metallic walls of the vessel. However, other embodiments of the insulated barrier may be employed for deflecting lines of constant potential from an orientation parallel to the vertical flow axis within flow passages residing between the energized electrode and the metallic walls of the vessel.

Another embodiment of the insulating barrier is illustrated in FIG. 4. Like parts in the treater in FIG. 4 will be designated by like numerals relative to the treater shown in FIG. 1. The electrode **26** in the vessel **11** is spaced from the metallic walls **12** by a distance *s*. An imperforate insulating barrier is provided between the peripheral edge of the electrode **26** and the metallic walls **12**. The insulating barrier is an annular member **66** formed of a material having a high specific conductive capacity, or dielectric constant, which provides a much higher specific resistance than the fluids which are passed through the electrode **26**. For example, the annular member **66** may be formed of Teflon, or other materials such as were described relative to the sleeve **31**. The member **66** may have any thickness but preferably is substantially identical in thickness to the electrode **26**.

Th lines of constant potential produced in the region between the electrodes **26** and **27** will be substantially planar immediately below the electrode **26** and reside in planes A, B, C, D and E. Outwardly beyond the peripheral edge of the electrode **26**, the lines of constant potential begin to curve upwardly from the planes A, B, C, D and E. These lines terminate perpendicularly along the insulated annular member **66**. The annular member **66**, as a high dielectric constant material, prevents the electric field from encircling the peripheral edge of the electrode **26**. Additionally, the annular member **66** is imperforate and therefore seals the peripheral edge of the electrode **66** to the walls **12** of the vessel **11**. Thus, substantially all fluids must move vertically along the flow axis and through the electrode **26**. Fluids moving adjacent the metallic walls **12** are diverted inwardly by the annular member **66** and must pass through the openings **26***a* of the electrode **26**. These diverted fluids traverse at substantially right angles the lines of constant potential extending between the planes of constant potential A through E and the annular member **66**. Thus, all of the dispersion in the vessel **11** is treated at practically substantially identical conditions with fluid moving normal to the lines of constant potential. For all practical purposes, the embodiments shown in FIG. 1 and 4 produce identical results.

The distance *s* illustrated in FIG. 4 for the annular member **66** is not critical but should be above a certain minimum dimension. Referring momentarily to the prior art treater of FIG. 2, the high-density concentration of the lines of constant potential between the peripheral edge of the electrode **54** and the walls **41** of the vessel **40** cause accumulation of aqueous phase material. This aqueous material causes "chaining effects" or high current paths between the electrode **54** and the walls **41**. In the embodiment of FIG. 4, the annular member **66** prevents this undesired result. Thus, the accumulation of water, between the peripheral edge of the electrode **26** and the walls **12**, is avoided. Excessive current flows beween the

electrode **26** and the walls **12** cannot occur as a result of accumulation of water therebetween.

A certain criterion is employed for determining the minimum spacing or distance *s* for the annular member **66**. It has been found that dispersions tested in the laboratory produce an increase for current conducted through the dispersion proportional to each increase in potential until a certain critical potential is applied. Then, disproportionately larger amounts of current pass through the dispersion over a certain range of applied potentials above the critical potential. At additionally increased applied potentials, the magnitudes of current passed will be several times greater than current flows below the critical potential.

The current-potential curves for any dispersion may be determined with an apparatus to contain the dispersion about an energized electrode. Preferably, a cylindrical container coaxially carrying an energized rod electrode is used. Data is taken with sufficient rapidity that the dispersion is not resolved completely during the application of potential and measurement of the current passed through the dispersion.

The excessive current conducting properties of the dispersion above the critical voltage result from certain physical properties which cannot be presently precisely defined. It is believed that these properties occur about electrodes defining an electric field by the creation of ions, or ionized particles in the dispersion, or any gas, moisture or other impurities carried therein. This conduction may take place essentially through collision ionization (as occurs in gases) or molecular disruption by heating, or both. It has been also suggested that the conduction in the dispersion is of an electrolytic nature. The ionization of the contained gas may be the more likely explanation of this high-current conducting phenomenon since the critical voltage of a dispersion increases as the pressure upon the liquid phase is increased. Thus, for any given dispersion, the potential applied to the energized electrode to create an electric field should not create such a potential gradient between the energized electrode **26** and the adjacent walls **12** over the distance *s* that excessive current flows would result by reaching the critical voltage of the dispersion.

Referring now to FIG. 5, there is illustrated another embodiment of the electrode arrangement employed in the present invention wherein like parts carry like reference numerals to the embodiment illustrated in FIG. 1. The insulating barrier interposed between the peripheral edge of electrode **26** and adjacent walls **12** of the vessel **11** takes the form of an annular band **68** carried on the electrode **26**. The band **68** is formed of a material having a high specific inductive capacity or dielectric constant and with a high resistivity compared to the dispersion being treated. The band **68** has a thickness l_s which may be formed of materials such as described for the sleeve **31** in the embodiment illustrated in FIG. 1. The band **68** is spaced a distance l_w away from the walls **12**. This spacing l_w can be of the same magnitude as the distance *s* shown in the FIG. 4. However, the band **68** provides an additional function that permits the distance l_w to be smaller than the distance *s*.

In a momentary reference to FIG. 4, the shortest distance through the dispersion between peripheral edge of the electrode **26** and the metallic wall **12** is the distance *s*. In FIG. 5, the barrier **68** has a height *h* providing a path of very high resistivity interposed between the peripheral edge of the electrode **26** and the adjacent walls **12**. Thus, the closest electrical or line-of-sight path between the electrode **26** and the walls **12** is the line identified by the dimension l_2. Thus, as long as the dimension l_2 is not so short as *s* to create potental gradients above the critical voltage of the dispersion, the distance l_w may be any desired distance. The distance l_w can be less than the distance *s*.

The band **68** extends vertically away from the electrode **26** a sufficient distance *h* to deflect lines of constant potential from orientation parallel to the vertical flow axis in flow passages residing between the energized electrode **26** and the walls **12** of the vessel **11**. In the region between the electrodes **26** and **27**, and directly beneath the electrode **26**, there will be formed planes A through E of the constant potential lines normal to the vertical flow axis in the vessel **11**. These lines of constant potential as they approach the metallic walls **12** of the vessel are deflected into curved paths. The band **68**, as an insulating barrier, causes these lines of constant potential in the curved path to return to the lower extremity of the band **68**. Thus, the flow passage between the band **68** and the adjacent walls **12** contains an electric field in which the lines of constant potential very closely approach orientation in horizontal planes. Also, the vertically moving fluid intersects nearly twice the number of lines of constant potential as compared to the electric field directly below the energized electrode **26**. The further downwardly a line of constant potential is below the energized electrode **26**, the more closely this line will orient into nearly horizontal planes of constant potential in the flow passage between the band **68** and the walls **12**. For practical purposes, any dispersion flowing in these flow passages will be in an uniform electric field having substantially the same properties as that dispersion which passes vertically through the central portions of the electrode **26**.

Another embodiment of the insulating barrier is illustrated in FIG. 6. Like parts in the treater in FIG. 6 will be designated by like numerals relative to the treater shown in FIG. 1. The energized electrode **26'** is constructed of metal, but unlike electrode **26**, has a horizontal undulated peripheral edge with varying spacing from the adjacent metal walls **12**. The electrode **26'** is foraminous being formed of horizontal metal rods which electrically are substantially equivalent to perforated disc electrode **26**. The rods in electrode **26'** are arranged as shown in U.S. Pat. 2,855,359. Each rod has an end presented to the vessel **11**. As a result, the peripheral edge of the electrode **26'** is variably spaced from the metallic walls **12** since the ends of the rods project radially beyond other parts on the continuous electrode parameter.

Obviously, the entire peripheral edge, where required, could be surrounded by a continuous imperforate insulating barrier such as is illustrated in FIG. 4 or 5. However, the present embodiment produces acceptable results by an individual insulating barrier integrally carried on the radially projecting ends of rods forming the electrode **26'** where its peripheral edge is variably spaced from the metallic walls **12**. This result is shown by constant potential planes A–E. The individual insulating barriers may be in the form of blocks, discs or other structures. However, it is preferred for optimum electrical and hydraulic characteristics to form these individual insulating barriers on the ends of the rods as spheres or ball-like structures.

More particularly, the ball **68'**, forming an individual insulating barrier, is mounted threadedly upon the end of each projecting rod contained in the electrode **26'**. The ball **68'**, as an insulating barrier, may be formed of the same materials as earlier described relative to the annular member **68**. For good results, the ball **68'** can be formed of Teflon.

The ball **68'** is of identical physical dimensions, l_2, l_s, l_w and *h*, in arrangement on the electrode **26'** as was the annular band **68** on electrode **26** as shown in FIG. 5.

Although the ball **68'** provides on the projecting rod ends the same function and results as the annular member **68**, there is obviously a great saving in materials employed in the insulating barrier on these parameter portions of the electrode **26'**.

It will be apparent from the foregoing embodiments illustrated in FIGS. 1, 4, 5 and 6, that the insulating barrier interposed between the peripheral edge of the electrode **26** or **26'** and the adjacent walls **12** may take any

configuration as long as the insulating barrier extends away from the electrode of sufficient distance to deflect lines of constant potential from an orientation parallel to the vertical flow axis in flow passages residing between the electrode **26** and the metallic walls **12**. Where the insulating barrier is so arranged, the electrode produces planes of constant potential normal to the vertical flow axis in a region residing between the energized electrode **26** and the inlet **14** through which region passes substantially all of the fluid moved along the vertical flow axis of the vessel **11**. This results in a substantial improvement in the efficiency of resolving dispersions in treaters of this design.

It has been found within treaters arranged according to the present invention, that the vertical distance between the energized electrode **26** and the grounded electrode **27** may be substantial, and as a result, the electrode **26** can be energized to sufficiently high potentials that not only is the dispersion resolved in the region between the electrodes but any residual dispersed aqueous phase material will be repelled from the electrode **26**. Thus, the function of the electrode means of this invention provides for enhanced resolution of dispersions. Also, these structures provide for applying sufficient potentials to energize the electrode that an electrostatic phenomenon may be produced which repels residual dispersed aqueous phase materials from the outlet zone and in a direction toward the inlet zone in the vessel **11**.

The insulating barrier formed by either the sleeve **31**, annular member **66**, the band **68**, or the balls **68'**, can be delineated as to geometry and composition in terms of the physical properties of the system. The system is comprised of the dispersion having applied thereto a potential to create a current flow adequate to resolve the dispersion. Below the critical voltage, the electrical characteristics conform to a classic mathematical description of

$$\frac{dE}{dI}=R$$

where "R," the resistance (in ohms) depends upon the geometry and the initial physical properties of the system surrounding the energized electrode, the fluid in the vessel **11** and the spacing s from the metallic walls **12**.

In terms of the specific resistivity ρ_o of the fluid surrounding the electrode, at the critical voltage the condition of excessive current flow due to close spacing between the electrode and the wall can be written as $\rho_o \times l_w < R$ where l_w is the linear separation s between the electrode and the wall. To reduce the current flow, an insulating barrier is imposed between the energized electrode and the wall. The barrier must have a specific resistivity ρ_s and thickness l_s such that

$$\rho_s l_s + \rho_o (l_w - l_s) \geq R$$

In addition, the barrier must be of sufficient height h to provide a "line-of-sight" path l_2 of adequate length, i.e.,

$$\rho_o \times l_2 \geq R$$

These restrictions delineate the structure and properties of the insulating barrier which are required to reduce current flow at the critical voltage. Naturally, the vertical spacing l_e between the energized and any grounded electrode must also be such that

$$\rho_o \times l_e \geq R$$

The preceding equations provide a method to determine the distance that the insulating barrier in the form of the cylindrical sleeve **31**, the annular member **66**, the band **68**, or the ball **68'**, has to extend from the peripheral edge of the electrode **26** for deflecting lines of constant potential from an orientation parallel to the vertical flow axis in flow passages residing between the energized electrode **26** and the walls **12**.

In treaters of the present invention, a dispersion is electrically resolved into aqueous and organic phases by several basic steps. The dispersion is passed vertically between inlet and outlet zones formed in the vessel **11** adjacent the aqueous phase and organic phase outlets **16** and **17**, respectively. A monitonically increasing electric field is established in the dispersion by function of the electrodes **26** and **27**. The field has planes of constant potential transverse to the direction of dispersion flow along the vertical flow axis in the vessel **11**. The electric field has sufficient intensity for resolving substantially the dispersion before it passes from the inlet zone into the outlet zone. The organic phase resolved from the dispersion is recovered from the outlet zone. As mentioned, the electric field may be provided by energizing the electrode **26** to a sufficient potential that residual dispersed aqueous phase materials are repelled from the outlet zone. The aqueous phase resolved from the dispersion gravitates downwardly in the electric field and is recovered adjacent the inlet zone.

Although a grounded electrode **27** has been described and shown as a metallic foraminous member, it will be apparent to those skilled in the art that the interface **19** or a grounded distributor, may be employed to serve the purpose of the grounded electrode **27**. This arrangement may be advantageous in circumstances as where the dispersion may be a crude oil containing large amounts of sediment, or for other reasons.

The scientific reasons for the highly effective resolution of dispersions in accordance with the present invention is not fully determined. The advantageous electrical resolution appears to reside in the particular configuration of the electric field employed in the region beneath the energized electrode. Resolution of the dispersion requires coalescence of the aqueous phase into sufficiently large droplets that gravitate downwardly against the upflowing dispersion. It is believed that dispersion flowing along a vertical flow axis normal to planes of constant potential produces this advantageous result. The condition of the dispersed aqueous phase in the dispersion represents an energy barrier to coalescence. The electric field supplies a means for overcoming such an energy barrier. Thus, the electric field plays a similar role in coalescing a dispersion as temperature affects chemical reactions. For example, in chemical reactions reagents may be thermodynamically unstable with respect to the products but do not react at an appreciable rate until a certain temperature level is reached. At this temperature, the desired reaction proceeds in the direction required by thermodynamics. In electrically resolving dispersions, the electrical potential is employed in an analogous fashion to temperature in electrically aided coalescence by raising the droplets to a sufficient energy level so as to allow the coalescence to proceed in the direction required by thermodynamics.

In the specific uniform electric field employed in the present invention, the monitonically increasing electric field provided by planes of constant potential oriented normal to the vertical flow axis of the dispersion produces zones of relatively constant potential having relatively low potential gradients. Thus, one explanation of the exceptionally high resolution of dispersions according to the present invention is that it is the potential level (between these planes of constant potential) which causes resolution of the dispersion. Thus, the electrode **26** would act effectively as a potential barrier to the passage of small droplets since the rate of coalescence of small droplets to large drops is increased by higher potential levels in the neighborhood of the electrode. The large drops gravitate downwardly to fall into the aqueous phase body **18**. As a result, only small amounts of residual dispersed aqueous phase material passes through the electrode **26**.

The present invention may employ either alternating or direct current potentials for energizing the electrode **26**. Unexpectedly, this invention allows the known beneficial results of DC potentials in electrically resolving distillate-type dispersions to be extended to crude ois. For example,

prior art methods for resolving crude oil dispersions alleged that the electric field should be created by alternating current potential. Further, creating the electric field with DC potentials to achieve the same degree of dehydration as the AC potential caused excessive current requirements. However, field testing of the present invention with an experimental treater proved the converse. It was found that crude oil dispersions could be resolved electrically to the same degree of resolution by employing DC potentials instead of AC potentials. Unexpectedly, the current consumption with DC potentials was approximately one-half of that experienced with AC potentials.

Referring now to FIG. 7, there is shown an experimental treater which was taken into an oil field to perform experiments relating to the present invention. The treater was formed of a vesel **69** provided by a steel pipe **71** having approximately a 2 foot exterior diameter and a length of about 9 feet. Flanges **72** and **73** were secured to the ends of the pipe **71**. Cover plates **74** and **76** were secured to the flanges **72** and **73** respectively by bolting to form end covers across the vessel **69**. The sight glass assembly **77** was secured through the sidewalls of the pipe **71** at a region where the crude oil-water interface **78** was maintained. Water resolved from the crude oil accumulated in the lower portion of the vessel **69** and was removed through an effluent water outlet **79**. If desired, water could be removed through a recirculating line **81** and intermixed with the incoming crude oil to form dispersions of increased water content. Treated or dehydrated crude oil was removed from the upper extremity of the vessel **69** through outlet line **82** which connected to a plurality of nozzles passed through the cover **74**. Crude oil from a field source was passed into conduit **83**, moved through pump **84**, and regulated in rate by valve **86** to pass through an inlet distributor **87** which contained a 4-way nozzle assembly **88** that passed the crude oil uniformly into the interior of the vessel **69**.

The water outlet **79** contained a valve (not shown) which regulates flow therethrough for maintaining the interface **78** at a relatively constant level in the vessel **69**. Also, the crude oil outlet **82** contained a backpressure valve (not shown) for maintaining sufficient pressure to prevent undesired gas release from the crude oil in vessel **69**.

An electrode assembly **89** was mounted within the vessel **69** intermediate the distributor **87** and the cover **74**. The electrode assembly **89** was formed by a Teflon ring **91** having a width of approximately 6 inches with an internal diameter of about 14 inches. The Teflon ring **91** was sealed exteriorly to the pipe **71** by means of an O-ring **92**. An insulated feedthrough bushing **93** pased through the cover **74** and extended downwardly to adjacent the electrode assembly **89**. A metal conductor **94** was bolted to a disc-like foraminous steel electrode **96**. The electrode **96** extended into a step **97** formed on the Teflon ring **91**. The bushing **93** supported the electrode assembly **89** within the vessel **69**. A grounded electrode **98** was positioned on top of the Teflon ring **91** by supporting rods **99**.

The grounded electrode **98** was formed of a metal disc containing a plurality of openings similar to that of electrode **96**. Thus, the electrode assembly **89** had the energized and grounded electrodes mounted in the horizontal and transverse to the vertical flow axis through the treater **69**.

The electrode **96** was energized from a power source **101** which was connected to a suitable source of primary power by conductors **102**. The energizing potential was passed through a conductor **103** and entrance bushing **93** to the energized electrode **96**. The power supply **101** was arranged to provide a wide variation in potentials, and either alternating or direct current potentials as was desired. The potentials applied to the electrode **96** and the current it consumed were monitored on the power source **101**.

The spacing between the energized and grounded electrodes was approximately 5 inches. The electrode assembly **89** was constructed so that the fluid flow along the vertical axis 3 inches above and 3 inches below the energized electrode was confined to a horizontal cross-section of 154 square inches. Within this region, the fluid flow was essentially parallel to the principal direction of the electric field and perpendicular to the planes of constant potential. At typical flow rates of 10.6 barrels per day per square foot of electrode **96** in operating the treater, approximately 12 minutes were required for fluids to traverse the region between electrodes **96** and **98**.

Under substantially equivalent operating conditions, the electrode **96** was energized first with AC potentials and then with DC potentials from the power source **101**. Under near identical conditions, the DC potential achieved the same degree of dehydration of the crude oil as the AC potential but with greatly reduced current requirements. It was unexpectedly found that the current consumption with DC potentials was approximately one-half of that experienced with AC potentials applied to the electrode **96**. After the upper portions of the vessel **69** were displaced of the incoming dispersion with dehydrated crude oil, the DC potential applied to electrode **96** began to increase as a result of a higher dielectric constant of the treated crude oil.

The crude oil tested was a 17° API oil produced by thermal recovery techniques in an East Texas oil field. The crude oil as obtained varied in water content between 40 and 80% by volume of intermixed water. An initial phase separation externally of the vessel **69** separated bulk water from the crude oil. The remaining dispersion was heated to above about 180° F. and then supplied to the conduit **83** for the experiment. Samples of treated crude oil were taken from outlet **82** at periodic intervals. The samples were analyzed for the base sediment and water (BS&W) content in volumetric percent. The potentials in kilovolts (kv.) and current in milliamperes (ma.) applied to electrode **96** were taken at the time each sample of treated crude oil was obtained. The results of this field test are shown in following Table 1.

TABLE 1.—FIELD TEST OF AC AND DC POTENTIAL

Test duration, Hour	Flow, B/D/ft.²	AC test			DC test		
		Secondary readings		Product carryover, percent	Secondary readings		Product carryover, percent
		Kv.	Ma.	BS&W	Kv.	Ma.	BS&W
Start	10.6	25			25		
1.0	10.6	21.0	9		26.5	4	2.0
1.5	10.6	21.0	7	1.2	28.0	3	1.2
2.0	10.6	21.0	7	1.0			
2.5	10.6				28.0	3	1.0

Comparison of the AC with the DC potential results demonstrates reduced current levels in the DC system as well as the slight decrease in residual water carryover.

From the foregoing, it will be apparent that there has been provided a system well adapted for electrically resolving dispersions into respective aqueous and organic phases. It will be understood that certain features, and alterations, of the system may be employed without departing from the spirit of the present invention. This is contemplated by and is within the scope of the inventive claims. Additionally, it is intended that the present description is to be taken as a means of illustration of the present system.

What is claimed is:

1. A treater comprising:

(a) a vessel with metallic walls forming a vertical flow axis, and vertically spaced apart outlets to remove therefrom aqueous and organic phases, and an inlet to introduce thereinto a dispersion formed of the aqueous and organic phases adjacent to one end of said flow axis;

(b) electrode means for creating an electric field having planes of constant potential oriented normal to the flow axis in said vessel when said electrode means

are energized with potentials capable of resolving the dispersion in the electric field;

(c) said electrode means extending the electric field across substantially the entire cross-section of said vessel receiving flow of fluid along the vertical flow axis; and

(d) insulating barrier means interposed between said electrode means and the adjacent metallic walls of said vessel, and said insulating barrier means obstructing no substantial portion of said electrode means to the flow of fluid being treated whereby energizing said electrode means produces planes of constant potential normal to the vertical flow axis in a region residing between said electrode means and said inlet through which region passes substantially all of the fluid moved along the vertical flow axis of said vessel.

2. The treater of claim 1 wherein said electrode means is energized with a DC potential.

3. A treater comprising:

(a) a vessel with metallic walls forming a vertical flow axis, and vertically spaced apart outlets to remove therefrom aqueous and organic phases, and an inlet to introduce thereinto a dispersion formed of the aqueous and organic phases adjacent to one end of said flow axis;

(b) a foraminous electrode positioned substantially horizontally in said vessel and having a planar surface presented toward said inlet, said electrode being electrically insulated from said vessel and adapted to be energized from an external power source means to potentials capable of resolving the dispersion in an electric field extending to an electrical ground spaced vertically from said electrode;

(c) said electrode extending across substantially the entire cross-section of said vessel in a plane transverse to the flow of fluid along the vertical flow axis; and

(d) insulating barrier means interposed between the peripheral edge of said electrode and the adjacent metallic walls of said vessel and said insulating barrier means obstructing no substantial portion of said electrode to the flow of fluid being treated, and said insulating barrier means extending away from said

electrode a sufficient distance to deflect lines of constant potential in the electric field adjacent said electrode from orientation parallel to the vertical flow axis in flow passages residing between said electrode and the metallic walls whereby energizing said electrode produces planes of constant potential normal to the vertical flow axis in a region residing between said electrode and said inlet through which region passes substantially all of the fluid moved along the vertical flow axis of said vessel.

4. The treater of claim 3 wherein said electrode is energized with a DC potential sufficient in magnitude to resolve the dispersion in the region residing between said electrode and said inlet.

5. The treater of claim 3 wherein said insulating barrier means is an annular member formed of a dielectric material carried circumferentially about the peripheral edge of said electrode.

6. The treater of claim 5 wherein said annular member is formed of Teflon.

7. The treater of claim 5 wherein said annular member extends radially from the peripheral edge of said electrode to the metallic walls of said vessel for blocking fluid flow between said electrode and said walls.

8. The treater of claim 3 wherein said insulating barrier means comprises at least one individual part formed of a dielectric material carried on protruding edges of said electrode having a horizontally undulating peripheral edge with varying spacing from the adjacent metallic walls of said vessel.

9. The treater of claim 8 wherein said individual part is formed of Teflon integrally carried on the most radially protruding edges of said electrode.

References Cited

UNITED STATES PATENTS

1,440,776	1/1923	Eddy	204—302
2,364,118	12/1944	Wolfe	204—188

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