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F. J. MIEHE
LIQUID RHEOSTAT

3,246,276

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2 Sheets-Sheet 1

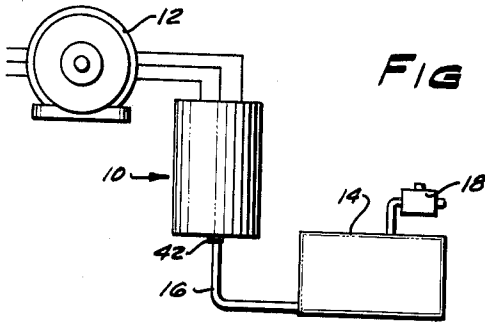


FIG. 2

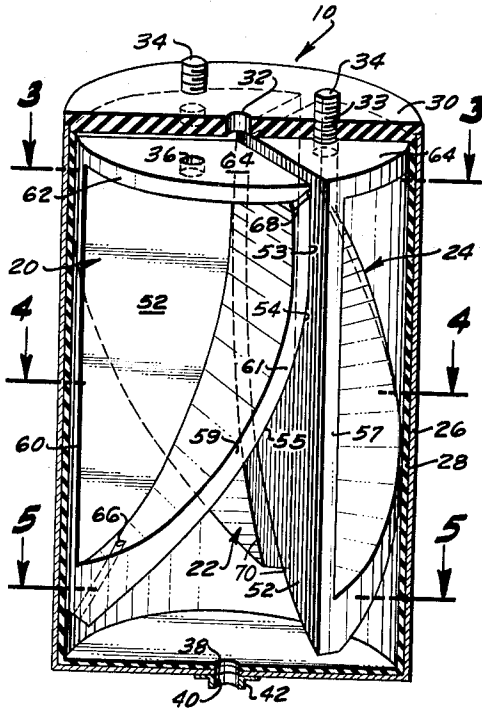


FIG. 6

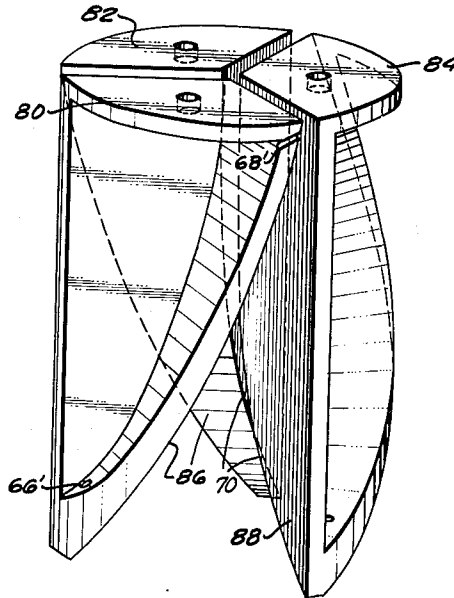
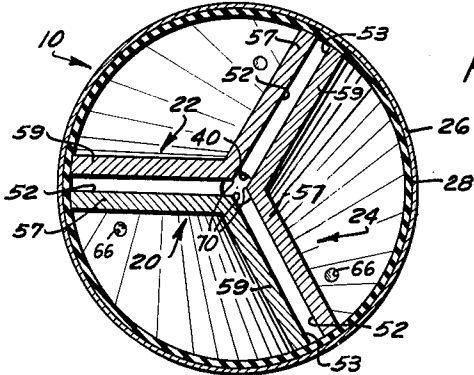


FIG. 3



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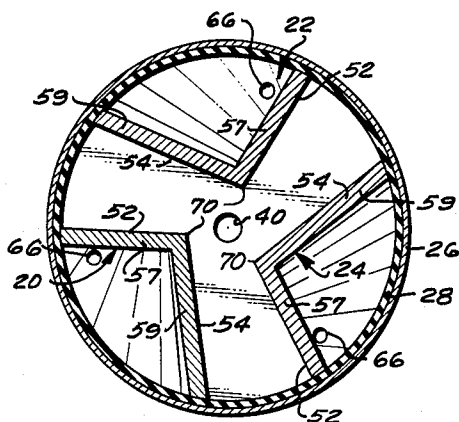
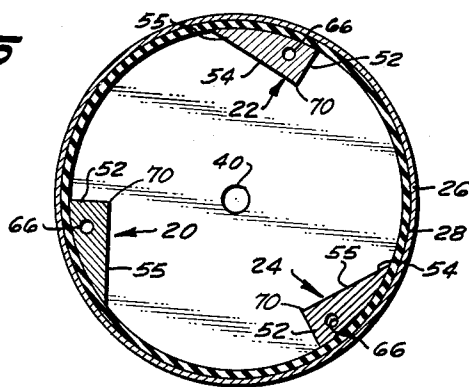


FIG. 4

FIG. 5



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13 Claims. (Cl. 338-86)

This invention relates to liquid rheostats, and more particularly to rheostat plate assemblies.

Liquid rheostats are often used to vary the resistance in the rotor circuit of three-phase induction motors to vary the speed of such motors. Liquid rheostats known hitherto have been large and bulky due primarily to the low current densities hitherto required in order to minimize erosion of the plates. The prior art liquid rheostats also have required edge protectors for the plates in order to prevent erosion of the edges of the plate.

An object of the invention is to provide new and improved liquid rheostats.

Another object of the invention is to provide very compact, small volume liquid rheostats.

Another object of the invention is to provide liquid rheostats having plates capable of use with very high current densities with no erosion.

Another object of the invention is to provide a liquid rheostat whose resistance varies exponentially relative to the liquid height in the rheostat.

Another object of the invention is to provide a liquid rheostat having plates which cause its resistance to so vary with respect to liquid level variation therein as to match the characteristics of an induction motor with which the rheostat is used.

A still further object of the invention is to provide a liquid rheostat electrode assembly in which the electrodes may be composed of cast iron.

In accordance with illustrated embodiments, rheostats of the present invention include a cylindrical tank containing electrodes which extend generally vertically with the electrodes varying in width or spacing from each other proceeding downwardly along the electrodes. Preferably the electrodes are wedge-shaped members arranged relative to each other to form segments of a cylinder with a first surface of each electrode lying in a vertical plane spaced about one-third of a circle from each of the corresponding surfaces of the other electrodes. Each electrode also is preferably provided with a second surface which faces the plane surface of one of the other electrodes and curves away from the adjacent plane surface proceeding downwardly along the electrode, and with both the plane surfaces and curved surfaces decreasing in width proceeding downwardly so that as the liquid level varies in the electrode the resistance of the rheostat varies exponentially relative thereto. The upper portions of the plane and curved surfaces extend parallel to each other in one embodiment of the invention to minimize slip of a motor controlled thereby during full speed operation of the motor.

A more complete understanding of the invention may be obtained from the following detailed description of liquid rheostats forming specific embodiments of the invention, when read in conjunction with the amended drawings, in which:

FIG. 1 is a schematic elevation view showing a liquid rheostat constructed in accordance with the invention connected to control an induction motor, a variable liquid height controlling device being connected to the liquid rheostat;

FIG. 2 is a perspective view of a preferred embodiment of a liquid rheostat constructed in accordance with the invention with portions thereof shown in vertical section;

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FIG. 3 is a horizontal sectional view taken along line 3-3 of FIG. 2;

FIG. 4 is a horizontal sectional view taken along line 4-4 of FIG. 2;

FIG. 5 is a horizontal sectional view taken along line 5-5 of FIG. 2; and

FIG. 6 is a perspective view of an electrode assembly of a liquid rheostat forming an alternate embodiment of the invention.

Referring first to FIG. 1, a liquid rheostat 10 forming one embodiment of the invention is shown connected to the rotor of a variable speed, wound rotor, induction type motor 12 which may be used, for example, to drive a pump (not shown) in a system having a varying demand upon the pump. The rheostat 10 is connected to control the speed of the motor 12 in accordance with the demands thereon by varying the height of the electroconductive liquid or electrolyte in the rheostat, thus varying the resistance of the rheostat. The electrolyte level in the rheostat 10 is varied by transferring electrolyte between the rheostat and a sealed reservoir 14 connected to the rheostat by a conduit 16. To effect electrolyte transfer, the electrolyte in reservoir 14 is placed under selected pressures by a controller 18 of a well known type, which is operated in accordance with the work load required of the motor 12. The controller 18 may be of the type disclosed in Ryden Patent 3,021,789.

Referring now to FIGS. 2 and 3, the rheostat 10 includes an electrode assembly comprising three identical, asymmetrical, conical or wedge-shaped electrodes 20, 22 and 24 mounted in a tank or container 26 of cylindrical shape having a liner 28 of electrical insulation. The container 26 has a top 30 of insulating material having a vent hole 32 and holes 33 through which connector posts 34 project. The connector posts 34 are threaded into tapped bores 36 formed in the electrodes and fixedly support the electrodes at the same level in the container 26 and equally spaced from each other. The liner 28 and container 26 have openings 38 and 40 in the bottoms thereof which are connected by a flanged connection 42 to the conduit 16 for the flow of electrolyte to and from the container 26. Nuts (not shown) may be threaded onto the ends of the connectors 34 to support the electrodes from the top 30.

Each of the electrodes 20, 22 and 24 is provided with a plane, radially parallel, electrode surface 52 facing a curved and twisted electrode surface 54 of the electrode immediately adjacent the surface 52. The surfaces 52 extend in planes spaced 120° from each other and spaced just slightly off the radii of the cylindrical liner 28. The upper portions 53 of each of the surfaces 54 are plane and are parallel to the facing plane surface 52 of the adjacent electrode. The surface portions 53 lie in planes spaced 120° from each other and just off the radii of the liner 28. The upper surface portions 53 and about one-quarter of the length of each of the electrodes in the embodiment of FIGS. 2 to 5. The lower portions 55 of the surfaces 54 curve away from the corresponding lower portions of the surfaces 52. Preferably the surface portions 55 conform substantially to an exponential curve, the purpose of which will be explained subsequently. This curving has the effect of, proceeding downwardly, decreasing the width of the surfaces 54 and also decreases the width of the surfaces 52, as illustrated best in FIG. 2. The surfaces 52 are formed on the faces of thick walls 57 and the surfaces 54 are formed on thick walls 59. The walls 57, 59 of each electrode are formed integrally with a top wall 64 into which the connector 34 is threaded.

The walls 59 and the lower surface portions 55 not only curve away from the surfaces 52, but also twist to further increase the average spacing between the surface portions 55 and the surfaces 52 proceeding downwardly

therealong, as best illustrated by comparison of FIGS. 3, 4 and 5. In FIG. 3, the parallel arrangement of the surfaces 52 and the upper surface portions 53 is illustrated. At the level shown in FIG. 4, proceeding outwardly along the surfaces 54, the surface portions 55 extend angularly away from the surfaces 52. At the level shown in FIG. 5, the surface portions 55 extend outwardly from the facing surfaces 52 at an even greater angle relative thereto. Thus, the portions of the surface portions 55 nearer the liner 28 at the lower portions of the electrodes are spaced farther from the facing surfaces 52 than are the portions of the surface portions 55 spaced farther inwardly from the liner 28. It will be seen, however, that in general the electrodes are wedge-shaped in horizontal cross section.

The walls 57, 59 and 64 are provided with edges 60, 61 and 62, respectively, forming a part of a cylinder and fitting closely against the inner wall of the liner 28 so that the outer corners of the electrode surfaces 52 and 54 are protected by the liner 28 against erosion. The electrodes are provided with drain holes 66 and suitable vent holes are provided near the tops of the electrodes, a grooved vent hole 68 being shown by way of illustration. Any suitable electrolyte such as sodium carbonate may be used for the electrolyte of the liquid rheostat.

The liquid rheostat 10 is particularly well adapted to minimize slip in the motor 12 at full speed operation thereof. When the motor 12 is to be operated at full speed, the controller 18 places the electrolyte in the reservoir 14 under pressure sufficient to force the electrolyte into the rheostat container 26 substantially to the top of the container. In this condition, the rheostat 10 offers a predetermined low resistance to the flow of current therethrough, with substantially the entire area of the surfaces 52 and 54 being utilized to carry the current and with the more closely spaced, parallel upper portions of the surfaces 52 and 54 carrying the major portion of the current. However, when the load of the motor decreases, the controller 18 drops the pressure on the electrolyte substantially linearly with respect to the decrease in load of the motor 12 and electrolyte flows from the container 26 to the reservoir 14 and the height or level of electrolyte in the container 26 is decreased linearly relative to the drop in load. During the initial portion of the drop, which is along the surface portions 53 parallel to the surfaces 52, the resistance of the rheostat 10 increases somewhat greater than linearly relative to the drop in the height of the liquid electrolyte. After the electrolyte is dropped below the parallel portions of the surfaces 52 and 54 and continues to drop, the top of the immersed portions of surfaces 54 move away from the adjacent facing surfaces 52, and each of the surfaces 52 and 54 decreases in width at the top of the electrolyte. Hence, the resistance between each immersed portion of the facing surfaces 52 and 54 increases both because of the average longer separating distance of these immersed portions of the surfaces 52 and 54 and also because of the decreasing average width of the immersed portions of the surfaces 52 and 54. The twist of the lower portions 55 of the surfaces 54 also increases the average separation. Since the increasing spacing is primarily responsible for the change in resistance as the electrolyte level drops, the resistance of the rheostat 10 increases substantially exponentially as the electrolyte level drops. This will in turn effect a proportional change in the speed of the motor 12. As will be apparent by changing the shape of the electrodes 20, 22 and 24, the response of the rheostat to changes in electrolyte level can be varied as desired.

As illustrated best in FIG. 4, as the liquid level drops and the resistance increases, each of the corner 70 formed by the intersecting surfaces 52 and 54 of one of the electrodes is spaced sufficiently far from the electrode behind it, proceeding clockwise, as viewed in FIG. 4, that the current path from that corner to the electrode behind

it is greater than to other portions of the electrode so that whenever the forward electrode is anodic relative to the electrode behind it, the current does not concentrate at the corner of the forward electrode. Thus, the corner 70 formed by the junction of the surfaces 54 and 52 of the electrode 20 is spaced sufficiently far from the electrode 24 as compared to the distance between the surface 54 of the electrode 20 and the surface 52 of the electrode 24 that current density on that corner of the electrode 20 is low and erosion thereof is minimized. Since each electrode is anodic for about one-half the time of operation, this greater spacing of the corners is of assistance in preventing erosion at the corners where current concentrations and erosion ordinarily would be expected.

In FIG. 6 there is shown an electrode assembly of a liquid rheostat comprising three electrodes 80, 82 and 84 also for use in a cylindrical container. The electrodes 80, 82 and 84 are identical with the electrodes 20, 22 and 24 except that electrode surfaces 86 are curved from the top thereof to the bottom thereof and omit portions corresponding to the plane upper portions 53 of the surfaces 54, the electrodes 80, 82 and 84 being adapted to be used where there is no problem of motor slip at full speed operation of the motor. Vertical plane surfaces 88 are provided in facing relationship relative to electrode surfaces 86. The latter surfaces may conform substantially to an exponential curve so that, starting from the very top of the electrodes 80, 82 and 84, the separation between the opposing surfaces 86, 88 increases substantially geometrically proceeding to the bottom ends of the electrodes. The surfaces 86 preferably are twisted like the lower portions 55 of the surfaces 54 of the electrodes 20, 22 and 24.

The electrodes of the invention are conventionally cast of block iron, thus enabling inexpensive manufacture, but may be fabricated from plates.

The electrode assemblies described above are effective to operate at current densities as high as 30 amperes per square inch for extended periods, surprisingly, without substantial erosion. More surprising, no erosion occurs during operations for long periods of time at average current densities greater than 10 amperes per square inch. The rheostats are very compact, light in weight and rugged, the rheostats occupying only a fraction of the space required by rheostats known hitherto. For example, a rheostat made in accordance with the invention and capable of controlling a 150 horsepower wound-rotor induction motor, has a diameter of only about ten inches and a height of only about twenty inches.

It is to be understood that the above-described arrangements are simply illustrative of the application of the principles of the invention. Numerous other arrangements may be readily devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof.

What is claimed is:

1. In a liquid rheostat, at least three vertically oriented, elongated electrodes each having a pair of electroconductive side surfaces, and means disposed at an angle relative to each other, mounting the electrodes in a circle in spaced positions in which adjacent side surfaces of the electrodes face each other, the adjacent side surfaces diverging exponentially away from each other proceeding downwardly along the surfaces.
2. In a liquid rheostat, a container, a liquid electrolyte in the container, three elongated, wedge-shaped electrodes in spaced vertical positions in the container and arranged in a circle and each electrode having a pair of generally radial sides spaced from and in current-transmitting relationship with the more adjacent sides of

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the other two electrodes and tapering from large to small proceeding downwardly,
and means for varying the height of the electrolyte in the container in accordance with a characteristic of the electrical device,

at least one of the pair of sides of each electrode, proceeding downwardly, diverging away from the more adjacent side of the one of the electrodes adjacent thereto.

3. In a liquid rheostat,

an electrode comprising a vertically elongated, electroconductive body wedge-shaped in horizontal cross section,

means for connecting the electrode body to an electrical power supply,

the electrode body having an outwardly facing, vertically extending, plane electrode surface,

the electrode body also having a second, outwardly facing, generally vertically extending, electrode surface curved in the longitudinal direction.

4. An electrode for a liquid rheostat comprising

a first electroconductive wall extending generally vertically,

a second, elongated, generally vertical electroconductive wall extending angularly from the first wall so as to define a conical body,

and means for connecting the electrode to a source of power,

the walls being joined together along a pair of juxtaposed edges,

the outer face of the first wall being a plane, the electrode being wedge-shaped in transverse cross section,

the outer face of the second wall being convex about a generally horizontal axis extending at an oblique angle relative to the plane of the first wall.

5. A wedge-shaped electrode for a liquid rheostat comprising

a wedge-shaped, elongated body defined by a pair of generally vertical electroconductive walls angularly intersecting at one edge of each wall and one of which is formed with a planar outer surface,

means for connecting the electrode to a source of power,

said body being adapted to be disposed in a rheostat with said surface extending vertically,

the other of said walls being curved in the vertical direction and having an outer, convexly curved, surface,

the free edges of said walls defining a segment of a cylinder.

6. In a liquid rheostat,

a cylindrical container,

three wedge-shaped, elongated electroconductive electrodes arranged in generally vertical positions in a circle in the container and spaced from each other, an electrolyte in the container and variable in height therein,

connecting means for varying the height of the electrolyte in the container,

each electrode having a first vertical plane face extending substantially radially relative to the container and a second face facing the plane face of an immediately adjacent electrode and, proceeding downwardly, diverging away from the last-mentioned plane face,

and means for applying electrical power to the three electrodes to cause current flow therebetween.

7. The liquid rheostat of claim 6 wherein each electrode comprises a pair of generally vertical walls wider at the top thereof than at the bottom thereof.

8. The liquid rheostat of claim 6 wherein the connecting means includes three connector posts each fixed to and supporting one of the electrodes,

and means supporting the connector posts from the container.

9. In a liquid rheostat device for use with an induction motor having a variable load and a controller responsive to the load of the motor,

a cylindrical container,

means controlled by the controller for filling the container with an electrolyte to a height varied in accordance with variations in the load of the motor, three elongated, electroconductive electrodes positioned vertically in a circle within the container and spaced from each other,

the electrodes being wedge-shaped in transverse cross section,

each electrode having a first vertical plane face extending substantially radially relative to the container and a second face facing the plane face of an immediately adjacent electrode and, proceeding downwardly, diverging away from the last-mentioned face,

and means for creating a potential difference between each adjacent pair of the electrodes to cause current flow therebetween.

10. In a liquid rheostat,

a cylindrical container having a hole in the lower portion thereof,

a cylindrical liner of electrical insulation in the container,

an electrolyte in the container,

means for withdrawing the electrolyte from the container and supplying the electrolyte to the container through the hole therein,

three elongated, downwardly tapered, electroconductive electrodes arranged in a circle within the container and spaced from each other,

the electrodes being wedge-shaped in transverse cross section and positioned vertically in the container,

each electrode having a first vertical plane wall extending substantially radially relative to the container with the outer edge thereof abutting the liner, and

a second wall facing the plane wall of an immediately adjacent electrode and, proceeding downwardly, diverging away from the last-mentioned plane wall,

the outer edge of the second wall abutting the liner, each electrode having a wedge-shaped top joining the walls and having an outer edge abutting the liner,

and means for applying electrical power to the three electrodes to cause current flow between the electrodes.

11. In combination,

a cylindrical container disposed with its longitudinal axis vertical and having an opening at the bottom thereof,

an electrolyte,

control means for supplying the electrolyte to the container through the opening and withdrawing the electrolyte from the opening to vary the height of the electrolyte in the container,

three elongated, fixed electrodes of generally wedge shape in transverse cross section and arranged in a circle within the container and having generally radial sides adjacent to and facing each other,

the electrodes tapering from large to small proceeding downwardly therealong and the facing sides of the electrodes diverging exponentially from each other proceeding downwardly therealong,

and means for connecting the electrodes to a source of power.

12. The combination of claim 11 wherein the outer surfaces of each of the electrodes form a portion of a cylinder and fit the inner cylindrical surface of the container.

13. The combination of claim 12 wherein the electrodes are hollow and open at the portions thereof adjacent the wall of the container and are provided with

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vent holes at the tops thereof and drain holes at the bottoms thereof.

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