April 19, 1960 E. W. GREENFIELD 2,933,440

METHOD AND APPARATUS FOR DETECTION OF ANODE EFFECT

Filed Oct. 9, 1956 3 Sheets-Sheet 1

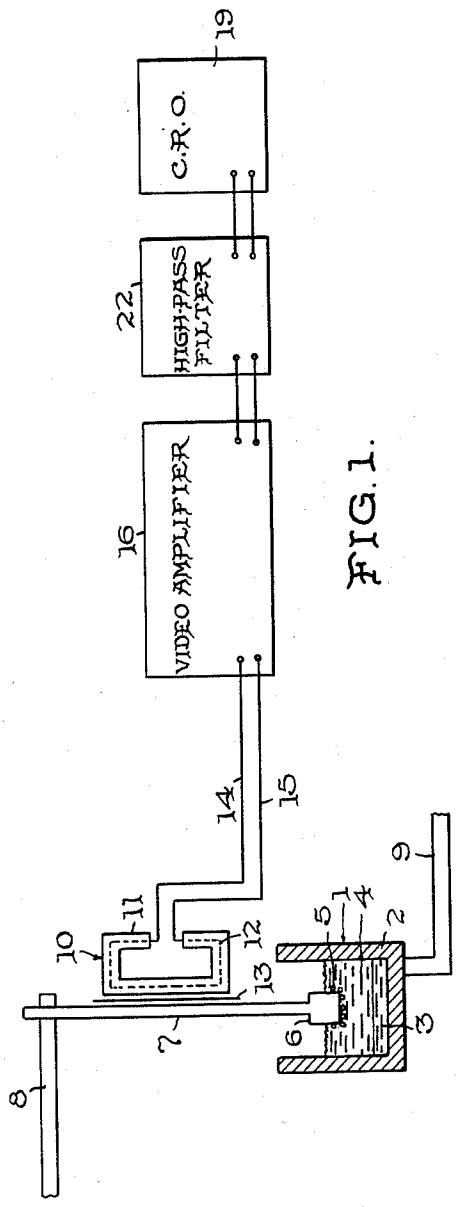


FIG. 1.

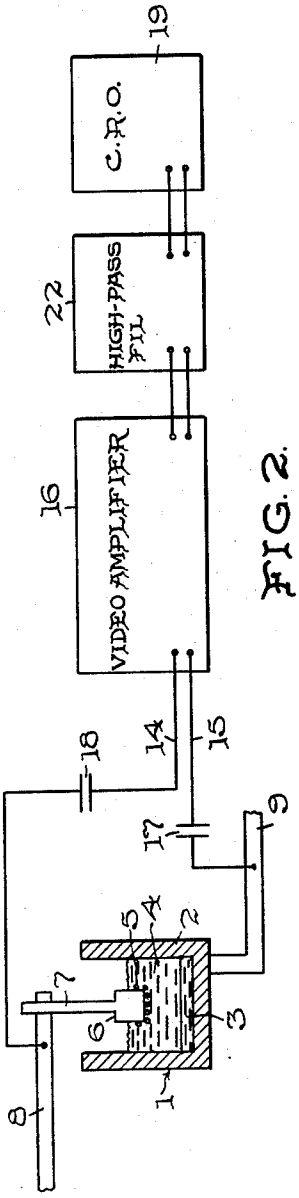


FIG. 2.

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METHOD AND APPARATUS FOR DETECTION OF ANODE EFFECT

Filed Oct. 9, 1956 3 Sheets-Sheet 2

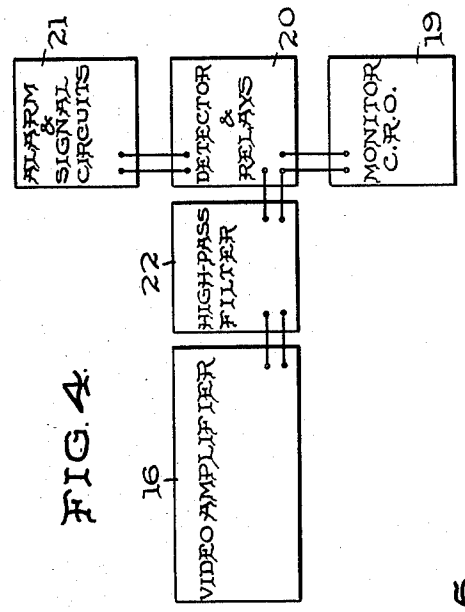


FIG. 4.

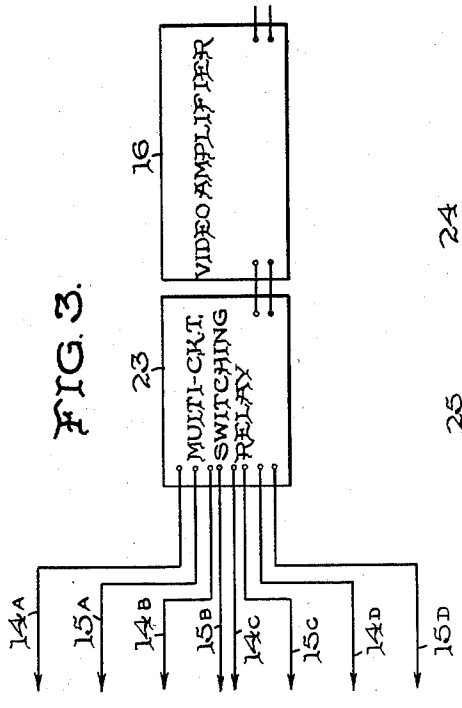


FIG. 3.

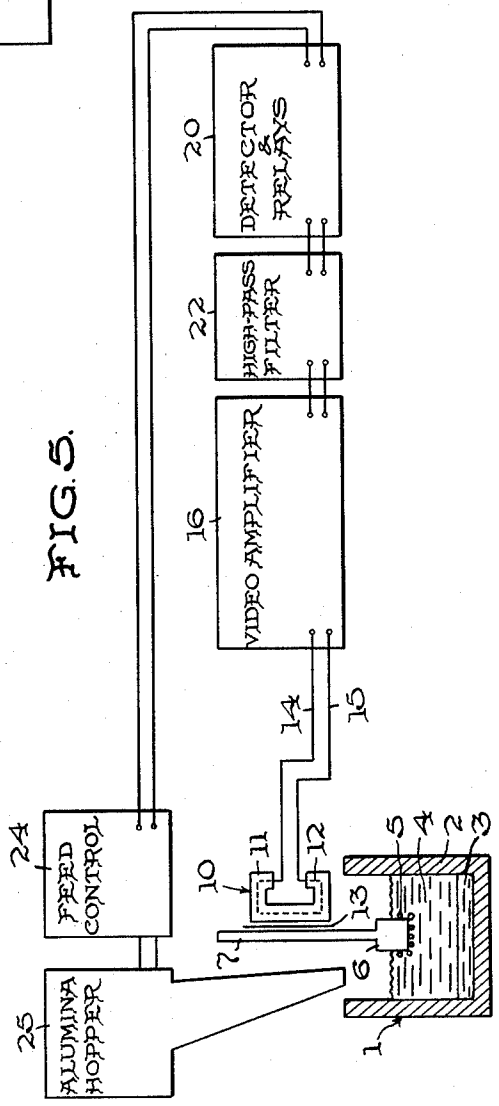


FIG. 5.

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METHOD AND APPARATUS FOR DETECTION OF ANODE EFFECT

Filed Oct. 9, 1956 3 Sheets-Sheet 3

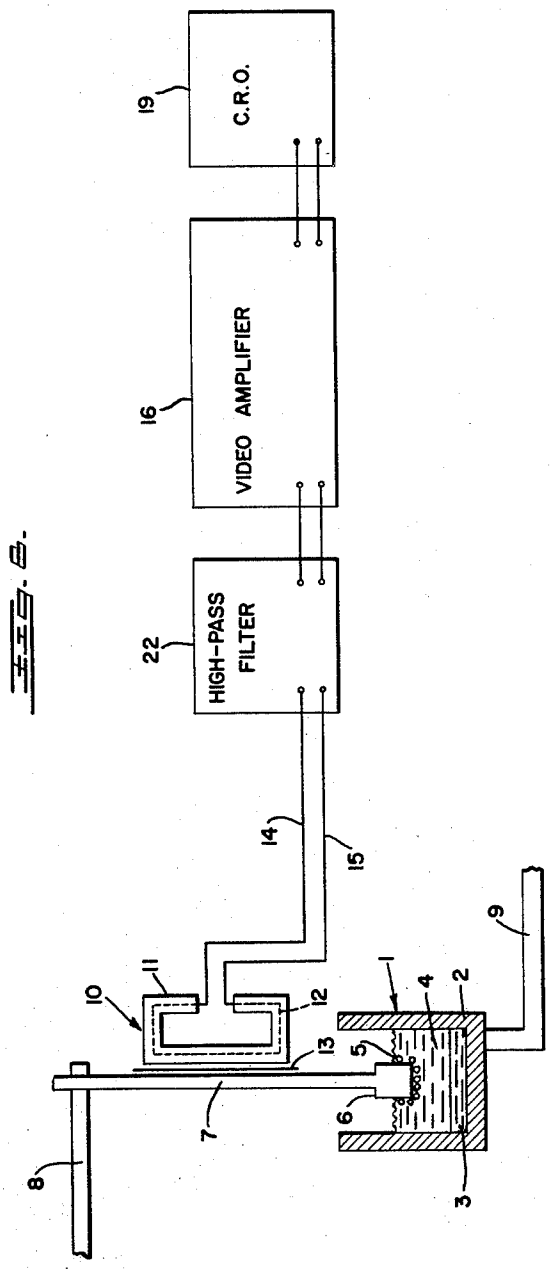


Fig. 2.

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United States Patent Office 2,933,440 Patented Apr. 19, 1960

2,933,440

METHOD AND APPARATUS FOR DETECTION OF ANODE EFFECT

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Application October 9, 1956, Serial No. 614,961

22 Claims. (Cl. 204—67)

This invention relates to fused bath electrolytic cells and methods of operating such cells. More particularly, this invention relates to methods of and apparatus for detecting the onset of the phenomenon known as anode effect in fused salt bath electrolytic cells susceptible thereto and for utilizing the detected information to maintain normal operation of such cells. A specific embodiment of the present invention contemplates a detection system and method of operation for use in conjunction with aluminum reduction electrolytic cells and the utilization of the detected information to control the operation of such cells to suppress or prevent anode effect.

This application is a continuation-in-part of my copending application, Serial Number 445,093, filed July 22, 1954, now abandoned.

During the normal operation of fused bath electrolytic cells, the electrolytic action causes the conductive surface of the anode to be surrounded by gas bubbles which smoothly evolve and are removed from the reaction. The phenomenon known as anode effect results in a considerably higher net voltage drop between the electrodes of the electrolytic cell and consequent reduction in cell efficiency, and has been observed in electrolytic cells having fused salt electrolytes containing halides of lead, cadmium, silver, and alkali and alkaline earth metals, magnesium, cerium and aluminum; with complex electrolytes of aluminum fluorides and with commercial fused salt electrolytes. It is theorized that anode effect is caused by the building up of a relatively high-resistance ionized gas film or layer on the anode of the cell, and that once such gas layer has become established, the anode effect tends to perpetuate itself since continued current flow is by arcing through such layer. The disadvantages of anode effect are many and vary with the material being electrolyzed. One of the major disadvantages is that the high watt dissipation in the film causes overheating which together with erosion caused by arcing in turn causes very rapid consumption of the anode. This sometimes burns off above the level of the electrolyte, and will cause a lower yield of product. Further, the large quantity of gas surrounding the anode may have a deleterious effect on the anode, such as in cells used for the production of fluorine. Another very important result of the anode effect is a large unproductive power consumption.

In the operation of a conventional cell for the production of aluminum an electrolytic cell is formed between one or more carbon anodes, an electrolyte consisting essentially of alumina dissolved in cryolite, and a molten aluminum cathode. Direct current flow through such a cell enables electrolysis to proceed in such a manner as to reduce the alumina to metallic aluminum.

Normally, a commercial electrolytic cell for reduction of alumina operates at 50,000 to 60,000 amperes of direct current and a voltage drop through the electrolyte on the order of 4 to 6 volts. It has been observed that anode effect in such a cell is related to concentration of alumina in the electrolyte. As the alumina is electrolytically reduced, the concentration of alumina in the fused electrolyte decreases until finally a critical minimal concentration of alumina is reached at which the overall resistance of the electrolyte becomes more or less suddenly increased by a factor of approximately 10 times. The voltage across the cell thus rises to approximately 50 volts and the anode effect is established. Heretofore, this change in voltage was indicated by connection of an incandescent lamp across the terminals of the cell, the glow of the lamp being proportional to the D.C. voltage across the cell. Counteraction of the anode effect and restoration of the low voltage drop is normally accomplished in this type of electrolytic cell by breaking the crust on top of the electrolyte and permitting additional alumina to enter the molten bath. At present there are no known prior art devices or methods for reliably predicting the anode effect prior to its actual occurrence. While the use of an incandescent lamp as above described serves to call attention to a cell that is undergoing an established anode effect, it gives no indication until there is a substantial increase in voltage drop with all the disadvantages attending such an increase. Anode effect can be partially eliminated in practice by periodic "feeding" of alumina to the cell to maintain its concentration above the critical value. However, if too much alumina is fed to the cell the alumina falls to the bottom, obstructing normal flow of current through the cell and adversely affecting the cell operation. For this reason, it has been conventional practice to allow each cell to undergo as much as one anode effect per day, as a safety precaution against overfeeding of alumina.

Allowing each cell to undergo anode effect periodically, intentionally or otherwise, has many disadvantages. In the first place, an electrolytic cell having an anode effect is not productive while such effect exists. Further, in the case of commercial installations for production of aluminum for example, electrolytic cells are connected in a line or series so that the current flows from each cell to the next and a D.C. voltage of 200 to 600 volts is impressed across the line, depending on the design and number of cells in the line. Since the cells in a given line are all respectively in series, a sudden increase in resistance and voltage drop across one cell reduces the voltage available to the remaining cells in the line, since the voltage applied to the line remains constant. This causes serious reduction of current through the entire line and consequently production of the cells in the line which are not in anode effect is reduced as well. A further disadvantage lies in the fact that a cell in anode effect requires the complete attention of an operator for a period of time in order to restore normal operation of the cell. Additionally, multiple anode effects occurring in the line of cells can cause serious fluctuations or surges in power load in the plant rectifier and/or generator equipment. On occasion, such deviation in power load can be severe enough to require removal of power from the line, thereby necessitating a shut-down of the entire line.

Accordingly, it is an object of this invention to provide a novel system and method for detecting the onset of anode effect in fused salt bath electrolytic cells and to provide various methods and means for utilizing such detected information to prevent any substantial increase in voltage across such cell.

A further object of this invention is to provide a method and apparatus for anticipating anode effect prior to the actual increase in voltage drop across a given electrolytic cell, to provide an indication of such, and to control means for suppressing or correcting said anode effect.

A further object of this invention is to provide a novel method and apparatus for detecting the onset of anode effect prior to the actual increase in voltage across an electrolytic aluminum reduction cell whereby said detec-

tion device may be employed to operate an indicating device, a suppression device for suppressing said anode effect, and in addition operate an automatic device for feeding alumina to said aluminum cell.

A further object of this invention is to avoid the periodic reduction in production of aluminum from an aluminum cell due to the great increase in voltage drop across said cell as a result of depletion of alumina in said cell below a critical concentration.

A further object of this invention is to prevent reduced production from a series of aluminum cells occasioned by the periodic increase in voltage of one or more of said cells as a result of depletion of alumina in said cell below a critical concentration.

A further object of this invention is to eliminate the possibility of breakdown in rectifier and/or generator equipment for electrolytic cell lines occasioned by large variations in power drain which result from periodic increased voltage in said cells due to anode effect.

A further object of this invention is to avoid the periodic reduction in production from an electrolytic cell due to the great increase in voltage drop across said cell as a result of anode effect.

The present invention contemplates detection of the onset of anode effect in an electrolytic cell by the detection of high frequency current component fluctuations which superimpose themselves on the D.C. current passing through said cell. Said high frequency current components are caused by abnormal cell behavior and appear just prior to the actual large increase in D.C. voltage across the cell indicating established anode effect. As previously pointed out, it appears that these fluctuations are the result of the formation of ionized gas bubbles at the anode which normally rapidly evolve from the system. However, when the anode effect is occurring, examination reveals that the whole of the surface of contact between each anode and the electrolyte is covered by a continuous gaseous film or envelope. This buildup of gas on the anode occurs gradually, involving at first only some anode areas. As a result, some ionization of the gaseous phase at the anode interface takes place prior to any substantial increase in the overall voltage drop. This ionization results in the formation of small, ever-changing discharges between the anode and the electrolyte which produce fluctuations in the D.C. current passing through the cell. These discharge wave forms have been found to contain almost every discrete frequency up into the megacycle range, depending on the impedance of the current paths through which they flow. Part of this high frequency energy is radiated from the cell surface, the anode and the bus bars or conductors.

As the preliminary phases of the anode effect advance, more and more of the total carbon area becomes involved in the ionization process so that the amount of high frequency energy increases. When sufficient gas has accumulated at the interface to withstand an appreciable potential, the anode effect is suddenly complete and the interface gas complex can support a voltage drop of about 50 volts. Thus high frequency impulsive current fluctuations become superimposed on the direct current input energy delivered to the cell an appreciable time before the anode effect is established. The amplitudes of these high frequency current fluctuations increase steadily until the anode effect is completely established, whereupon the D.C. voltage suddenly rises and the productivity of the cell is severely reduced. Therefore, onset of measurable high frequency current fluctuations provides a means for detecting the onset of anode effect prior to the increase in voltage drop across the cell. A measurement of the average amplitude of said current fluctuations may then be related to the time which will elapse before establishment of the anode effect.

The present invention contemplates detection and measurement of the above high frequency current fluctuations produced at a cell anode by providing a suitable selective high frequency pick-up unit, which may be coupled to the cell either capacitatively or electromagnetically. The selected high frequency alternating currents developed by the pick-up unit may then be amplified by suitable means such as a wide-band video amplifier. The output of such amplifying means may be utilized to actuate a suitable indicating device or it may be utilized to operate suitable relay systems for controlling suitable supervisory control devices. Thus, by the method and apparatus of my invention, the initial discharges of the anode effect process can be detected, measured, recorded and/or employed to operate a supervisory control sequence.

In the accompanying drawings is shown an illustrative embodiment of the invention, as applied to a typical electrolytic cell for the production of aluminum. In the drawings:

Figure 1 shows in schematic form a diagram of an electronic anode effect detection device according to the invention employing inductive coupling, a video amplifier, a cathode ray oscilloscope and a high pass filter positioned between the amplifier and the oscilloscope.

Figure 2 shows in schematic form a diagram of an electronic anode effect detection device according to this invention employing capacity coupling.

Figure 3 shows in schematic form a diagram of an electronic anode effect detection device according to this invention when employed in conjunction with a multi-circuit relay for sequentially switching a single amplifier to several pick-ups, each of which is employed in conjunction with a different cell.

Figure 4 shows in schematic form the use of the amplified signal picked up by the pick-up device to operate relays which in turn operate alarm and signal circuits, as well as an indicating cathode ray oscilloscope.

Figure 5 shows in schematic form a system employing an automatic alumina feed mechanism controlled by the electronic anode effect detection device according to the present invention.

Figure 6 shows in schematic form a diagram of an electronic anode effect detection device according to the invention employing inductive coupling, a video amplifier, a cathode ray oscilloscope and a high pass filter positioned between the inductive coupling and the amplifier.

Referring now to the accompanying drawings in which the same reference numerals have been applied to various corresponding parts and circuit elements of the various views, it will be apparent that the amplifying, filtering and relay circuits or networks as well as indicating devices are schematically represented. Those skilled in the art of electronics and instrumentation are well acquainted with the specific nature of such apparatus. In the figures, the numeral **1** schematically denotes an aluminum reduction cell. Said reduction cell **1** is a conventional cell comprising a carbon cell lining or cathode **2**, a carbon anode **6**, an electrolyte **4** consisting essentially of alumina dissolved in cryolite, and a molten aluminum cathode **3**. The current is conducted by bus **8**, through support rod **7** to anode **6** from which it passes through the alumina and cryolite electrolyte **4**, molten aluminum **3** to cell lining or cathode **2** and out bus bar **9**. Passage of such direct current through said cell **1** in the manner described enables electrolysis to proceed in such a manner as to reduce the alumina to metallic aluminum. The oxygen thus liberated ultimately reacts with the carbon electrode **6** to form CO_2 and CO which eventually escape from the system. Also, some fluorides are liberated as a result of thermal decomposition and secondary electrolytic reactions of the cryolite and these also eventually escape from the system. The molten aluminum **3** forms at the bottom of the cell and electrically becomes part of the cathode. Hence, during normal operation a vertical section through an aluminum cell as shown in the drawing reveals a carbon cell lining or cathode **2**, the cathodic layer of molten aluminum **3**, a layer of molten alumina-cryolite

mixture 4 and finally a thin layer of gas 5 on the carbon anode 6.

While the cell 1, as illustrated in the drawing, represents an aluminum reduction cell, other cells, such as cells for the production of fluorine, where anode effect presents a problem, may be substituted for the aluminum cell shown.

In accordance with the embodiment of this invention illustrated in Figure 1, the high frequency pickup unit 10 is coupled to the cell 1 electromagnetically. This pick-up 10, in a specific embodiment, consists of a coil 12 shielded by shield 11 and positioned in close proximity to an electrical feeder for cell 1 such as a supporting rod 7 connected to an anode 6, said coil being insulated from said supporting rod 7 by insulation 13. The high frequency energy picked up by the coil 12 is fed through leads 14 and 15 to the input of the high gain wide-band amplifier 16. This amplifier 16 preferably is a video amplifier of a properly matched input impedance which for the electromagnetic coupling of this embodiment would be a low impedance. The output of video amplifier 16 is preferably fed to a means for selecting the most suitable band of frequencies such as a high pass filter 22. While high pass filter 22 is indicated in Figure 1 as following video amplifier 16, alternatively the high pass filter may precede the video amplifier as shown in Figure 6. The output of filter 22 may then be fed to suitable indicating means such as a cathode ray oscilloscope.

In the embodiment of this invention illustrated by Figure 2, pick-up is accomplished by connecting the leads 14 and 15 directly to anode bus 8 and cathode bus 9 using suitable capacitors 17 and 18 in each lead to block the direct current. The high frequency energy developed in this manner is fed to the input of a video amplifier 16 of a properly matched input impedance which for the capacitive coupling of this embodiment is a high impedance. In a specific application of this invention to a reduction cell, the gain in video amplifier 16 was approximately 1,000 and capacitors 17 and 18 were 3 mfd. oil filled capacitors.

In lieu of having a separate amplifier 16, filter 22, and cathode ray oscilloscope 19 for each electrolytic cell 1, a multi-circuit switching relay 23, as shown in Figure 3, may be employed whereby a single amplifier 16, filter 22 and indicator 19 may be employed for a line or series of such cells 1. According to this embodiment, each cell 1 has a pick-up device of either the type disclosed in Figure 1 or the type disclosed in Figure 2, and each pick-up device feeds through a pair of leads 14*a* and 15*a*, 14*b* and 15*b*, 14*c* and 15*c*, 14*d* and 15*d*, etc., respectively, to the multi-circuit switching relay 23. This switching relay 23 provides sequential connection between the input of amplifier 16 and each pick-up by switching in sequence each pair of leads 14*a*, 15*a*, 14*b*, 15*b*, etc., such that only one pick-up is connected to said amplifier 16 at a time. Such multi-circuit switching relay apparatus and circiut is not shown but such selector or switching relays are well known to those skilled in the art of electrical devices. It is to be distinctly understood that the multi-circuit switching relay 23 affects the video amplifier 16 only insofar as it determines which pick-up device on which aluminum reduction cell 1 is connected to the input of video amplifier 16.

The output of video amplifier 16 in any of the embodiments above described is fed into a suitable low loss high-pass filter 22 or alternatively a low loss high pass filter may be employed at the input of video amplifier 16 as shown in Figure 6.

For purposes of detecting the onset of anode effect in order to take steps to prevent the large increase in voltage drop, a cathode ray oscilloscope 19 of suitable high frequency response may be employed. The output voltage of the high-pass low-loss filter 22 is impressed on a set of deflection elements of said cathode ray oscilloscope 19. In a preferred embodiment, the output voltage of the high-pass filter will be impressed upon the vertical deflection elements of the cathode ray oscilloscope, while a sawtooth horizontal sweep oscillator applies voltages to the horizontal deflection elements of the oscilloscope 19. The use of said oscilloscope will serve to visually indicate the onset of the anode effect mechanism. With the components properly shielded and a full gain the trace of oscilloscope 19 when horizontal sweep is employed will be a horizontal line up to the onset of anode effect. At this moment small pips of various amplitudes and periodicity will appear along the trace. These fluctuations will continuously increase in complexity and average amplitude as gas accumulates on the anode. Experienced personnel may then determine by viewing the screen of the oscilloscope 19 at what time to take proper steps to prevent the large increase in voltage drop characteristic of completed anode effect, such as actuation of suitable correction means. In the case of aluminum reduction cells this amounts to adding the proper amount of alumina feed to the cell 1.

In order to avoid the necessity of relying on the human element to constantly or periodically view the screen of the oscilloscope, warning devices may be employed in lieu of or in addition to cathode ray oscilloscope 19. For this purpose, the output of the detection device can be fed into a detector and sensitive grid-controlled thyratron relay which in turn can actuate a heavy current relay when the rectified signal from filter 22 reaches a predetermined average amplitude. Said heavy current relay may be employed to actuate such things as alarm and signal circuits as schematically represented in Figure 4 by the numeral 21. Since detectors, thyratron relays, heavy current relays, etc., are well known to men skilled in the electrical arts, such detector and relays are indicated schematically by numeral 20. In Figure 4, the output of the video amplifier 16 is used to feed such a detector and relays 20 which in turn operate alarm and signal circuits 21 and in addition, the output of the video amplifier 16 operates a monitor cathode ray oscilloscope 19 for visual indications. In addition, said detector and relays 20 may be employed to initiate the operation of an anode effect suppression device substantially as disclosed in my copending application, Serial Number 447,846.

As shown in Figure 5, the output of detector and relays 20 may be employed to operate an automatic feed control 24 connected to an alumina feeding device 25 whereby the desired quantity of alumina is automatically fed to the aluminum reduction cell 1 upon detection of onset of anode effect by the detection device of this invention. An example of an alumina feeding device is shown and described in U.S. Patent 2,713,024 and German Patent 895,379.

One example of the practice of this invention pertains to the detection of anode effect in an electrolytic aluminum reduction cell employing four conventional pre-bake anodes. It is to be distinctly understood that this is by way of example rather than limitation.

The apparatus used employed a small shielded pick-up coil which was located on the aluminum feeder bus of the aluminum reduction cell adjacent to where the anode bars are clamped thereon. This coil consisted of 100 turns of number 36 wire. The signals induced in the coil were amplified by a video amplifier having an overall voltage gain of 1000 and designed for a frequency range of 10,000 to 50,000 cycles per second at an input voltage of approximately 2 millivolts. The output of the video amplifier was fed into a cathode ray oscilloscope for visual indication.

It was found that rectifier power supplies generate A.C. voltages which are harmonics of the supply voltage frequency. These must be filtered out because they obscure the anode effect signals. In order to remove these harmonics which were masking the desired signals a variable band pass filter was inserted between the oscilloscope and the video amplifier. The minimum fre-

quencies which could be passed by this filter could be set at 10,000, 20,000 and 30,000 cycles per second. It was found that when all signals below 20,000 cycles per second were eliminated a satisfactory pattern for viewing on an oscilloscope was produced.

An actual test for anode effect was made over a two day period. Six anode effects took place and the onset of each was detected from 27 to 54 minutes in advance of substantial voltage rise or completed anode effect. The indications of anode effect as observed on the oscilloscope are an increase in the size of the normal hash pattern plus a series of spiked patterns of large amplitude and short duration. These latter are referred to as gas bursts. It should be noted that no signal was noticeable on the oscilloscope screen at 2 hours before anode effect. The cell generally went into anode effect when alumina concentration dropped to 1%. The following is a résumé of test results as observed on the oscilloscope screen:

First day
- 10:37 A.M.—increased hash and occasional gas bursts
- 11:31 A.M.—anode effect
- 12:58 P.M.—pronounced gas bursts and increased hash
- 1:25 P.M.—anode effect
- 2:05 P.M.—large gas bursts and increased hash
- 2:44 P.M.—anode effect
- 3:20 P.M.—gas bursts and increased hash
- 4:01 P.M.—anode effect

Second day
- 11:37 A.M.—gas bursts and increased hash
- 12:30 P.M.—anode effect
- 2:44 P.M.—gas bursts and increased hash
- 3:20 P.M.—anode effect

The results of the tests indicate that anode effect onset can be detected by visual observations of the oscilloscope pattern well in advance. It can be seen that with the anode effect detection device of this invention more than adequate time is provided to break the crust and add alumina to the aluminum reduction cell thereby restoring the cell to normal operation prior to the substantial voltage increase characteristic of a completed anode effect.

While several embodiments of this invention have been shown and described, it will be apparent to one skilled in the art that the invention is by no means limited thereto, but that many modifications may be made without departing from the scope thereof.

What is claimed is:

1. In the art of fused bath electrolysis wherein the problem of anode effect is encountered, the improvement comprising the steps of detecting high frequency impulsive current fluctuations superimposed upon the direct current employed for said electrolysis due to onset of anode effect, and correcting the cause of said detected fluctuations before said cause produces undesirable effects upon said electrolysis.

2. The method of electrolysis comprising the steps of passing a direct current through a fused bath electrolytic cell, electrically detecting high frequency current fluctuations superimposed on said direct current as a result of the onset of anode effect in said cell and restoring said cell to normal operation prior to completion of said anode effect.

3. A method of detecting the onset of anode effect in electrolytic aluminum reduction cells, comprising the steps of electrically detecting high frequency current fluctuations superimposed on the direct current through said electrolytic cell due to onset of anode effect, amplifying said detected fluctuations, and visually indicating the amplitude of said fluctuations.

4. The method of detecting the onset of anode effect in electrolytic aluminum reduction cells, comprising the steps of electrically detecting high frequency current fluctuations superimposed on the direct current through said electrolytic cell due to onset of anode effect, filtering the low frequency components from said current fluctuations, amplifying said detected fluctuations and visually indicating the amplitude of said fluctuations.

5. The method of detecting the onset of anode effect in electrolytic aluminum reduction cells, comprising the steps of electrically detecting high frequency impulsive current fluctuations superimposed on the direct current through said cell due to onset of anode effect, amplifying the current fluctuations so detected, filtering the low frequency components from said current fluctuations, and impressing a selected group of high frequency components upon a suitable relay system to operate a supervisory control device at any predetermined average current level.

6. In a fused bath electrolytic cell system subject to anode effect, the improvement which comprises means for detecting high frequency current fluctuations superimposed on the direct current passing through said electrolytic cell as a result of the onset of anode effect in said cell, and means for employing said detected high frequency current fluctuations to aid in maintaining normal operation of said cell.

7. A fused bath electrolytic cell system, comprising an anode, a cathode, means for passing direct current through said electrolytic cell, means for detecting high frequency current fluctuations due to onset of anode effect superimposed on the direct current passing through said cell positioned in close proximity to said cell, means for amplifying said current fluctuations, and means for indicating the amplitude of said current fluctuations.

8. An electrolytic aluminum reduction cell system employing an electrolyte of molten cryolite having aluminum oxide dissolved therein comprising a cathode, an anode means for conducting direct current through said cell, means for detecting high frequency current fluctuations superimposed on the direct current passing through said cell due to onset of anode effect positioned in close proximity to said cell, means for amplifying said current fluctuations, means for selecting the most suitable band of frequencies, and means for visually indicating the amplitude of said current fluctuations.

9. An electrolytic cell system employing a fused bath electrolyte comprising an anode, a cathode and means for conducting direct current through said electrolytic cell, means for detecting high frequency current fluctuations superimposed on direct current passing through said cell, due to onset of anode effect positioned in close proximity to said cell, means for amplifying the current fluctuations detected by said detecting means, means for selecting the most suitable band of frequencies, and control means operated by the amplified current fluctuations for actuating a supervisory control device.

10. A system for detecting the onset of anode effect in a fused bath electrolytic cell comprising means for detecting high frequency current fluctuations superimposed on the direct current passing through said cell as a result of the onset of anode effect in said cell positioned in close proximity to said cell, and means for utilizing said detected current fluctuations to continue normal operation of said cell.

11. A system for detecting the onset of anode effect in a fused bath electrolytic cell comprising means for detecting high frequency current fluctuations superimposed on the direct current passing through said cell due to onset of anode effect positioned in close proximity to said cell, means for amplifying said current fluctuations, means for selecting the most suitable band of frequencies, and means for indicating the amplitude of said current fluctuations.

12. The system of claim 11 wherein the indicating means employed is a cathode ray oscilloscope.

13. A system for detecting the onset of anode effect in an electrolytic aluminum reducting cell, comprising

means for detecting high frequency current fluctuations due to onset of anode effect superimposed on the direct current passing through said cell positioned in close proximity to said cell, means for amplifying said current fluctuations, means for selecting the most suitable band of frequencies, and means for indicating the amplitude of said current fluctuations.

14. A system for detecting the onset of anode effect in a fused bath electrolytic cell comprising an electromagnetic type pick-up coil positioned in close proximity to said cell, means for amplifying currents induced in said induction coil, and means for indicating the amplitude of the currents so amplified.

15. A system for detecting the onset of anode effect in a fused bath electrolytic cell comprising an electromagnetic type pick-up coil positioned in close proximity to said cell, means for selecting the most suitable band of frequencies, means for amplifying currents induced in said induction coil, and means for indicating the amplitude of the currents so amplified.

16. A system for detecting the onset of anode effect in a fused bath electrolytic cell comprising video frequency amplifying means, conductive capacitative coupling means connecting the input of said amplifying means across said electrolytic reduction cell to detect high frequency current fluctuations due to onset of anode effect in said cell, and indicating means connected to the output of said video frequency amplifying means for indicating the amplitudes of said high frequency current fluctuations.

17. A system for detecting the onset of anode effect in a fused bath electrolytic cell, comprising video frequency amplifying means, conductive capacitative coupling means connecting the input of said amplifying means across said electrolytic reduction cell to detect high frequency current fluctuations due to onset of anode effect across said cell, means for selecting the most suitable band of frequencies and indicating means connected to the output of said video frequency amplifying means for indicating the amplitudes of said high frequency current fluctuations.

18. A system for detecting the onset of anode effect in a fused bath electrolytic cell, comprising means for detecting current fluctuations superimposed on the direct current passing through said cell, means for amplifying said current fluctuations, high pass filter means for selecting the high frequency components of said current fluctuations, and detection and relay means energized by said high frequency components for actuating a supervisory control device.

19. The system of claim 18 wherein the detection and relay means is employed to actuate an alarm system.

20. A system for detecting the onset of anode effect in electrolytic aluminum reduction cells, comprising means for detecting high frequency current fluctuations superimposed on the direct current passing through said cell due to onset of anode effect, means for amplifying said current fluctuations, means for selecting the most suitable band of frequencies, detection and relay means energized by amplified current fluctuations of a predetermined average amplitude, and automatic alumina feeding means actuated by said detection and relay means for replenishing the alumina content in the electrolyte of said cell.

21. In the art of producing aluminum in an electrolytic reduction cell by passing a direct current through an electrolyte of molten cryolite having alumina dissolved therein, the improvement comprising the steps of electrically detecting high-frequency impulsive current fluctuations superimposed upon said direct current due to onset of anode effect caused by reduction in concentration of the alumina in said electrolyte, and replenishing the alumina in said electrolyte as a consequence of said current fluctuations to maintain the normal operation of said cell.

22. In the art of producing aluminum by the reduction of aluminum oxide in a fused bath electrolytic cell having an anode, a cathode, and an electrolyte of molten cryolite having aluminum oxide dissolved therein by passing a direct current through said molten cryolite, the improvement comprising the steps of electrically detecting high-frequency impulsive current fluctuations superimposed on said direct current as the result of gas accumulation on the surface of said anode caused by depletion of aluminum oxide in the molten cryolite, and feeding aluminum oxide to said molten cryolite before said gas accumulation is sufficient to cause an abnormal increase in average voltage across said cell.

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