March 30, 1971 G. P. DIRTH ET AL 3,573,179

METHOD AND APPARATUS FOR THE CONTROL OF ELECTROLYTIC REFINING CELLS

Filed Dec. 14, 1965 4 Sheets-Sheet 1

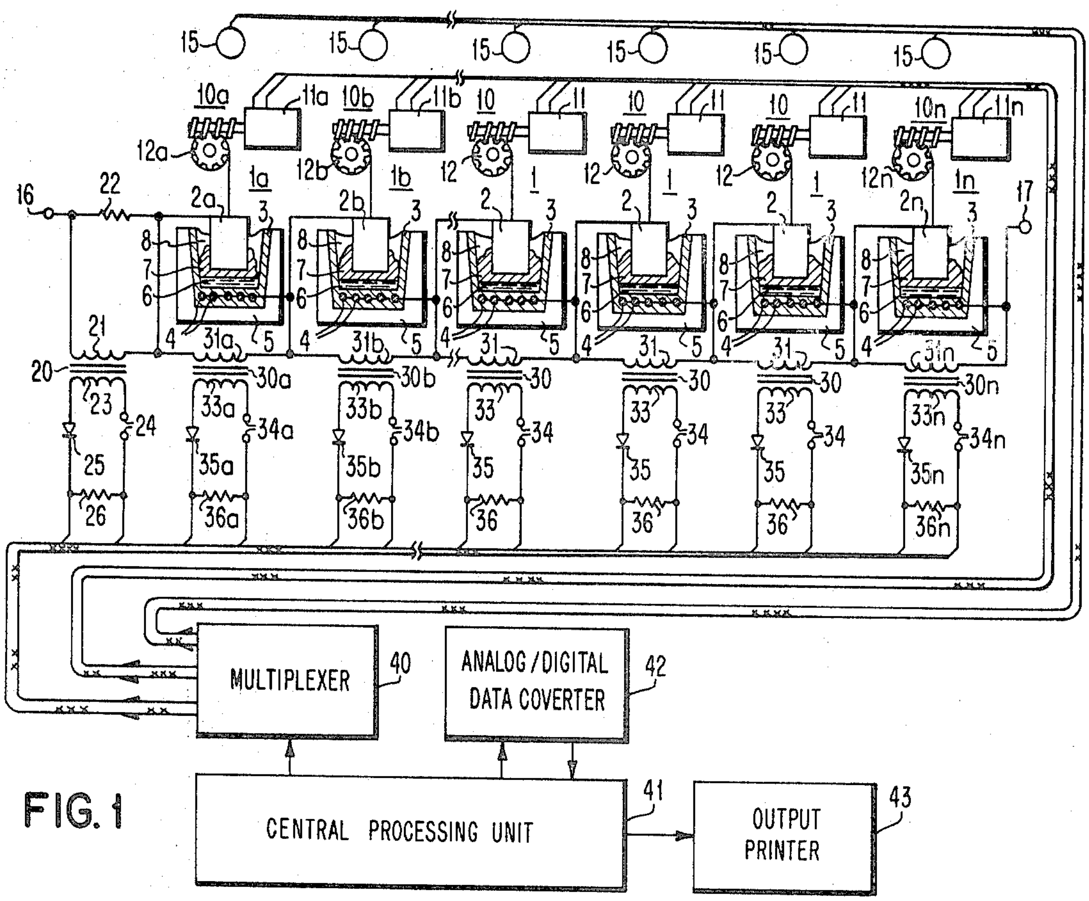

FIG. 1

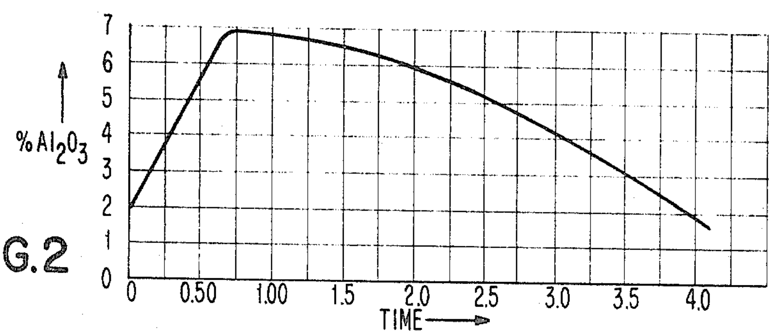

FIG. 2

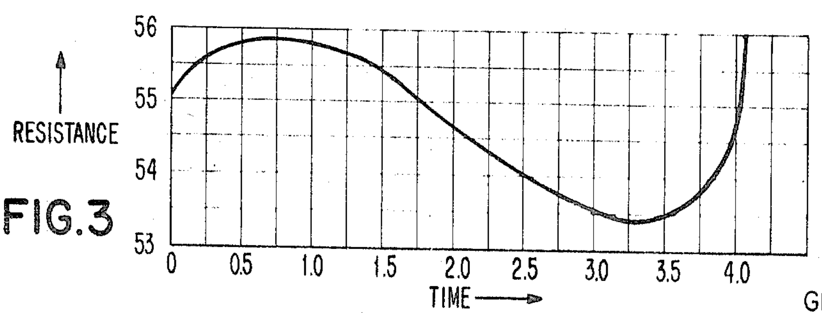

FIG. 3

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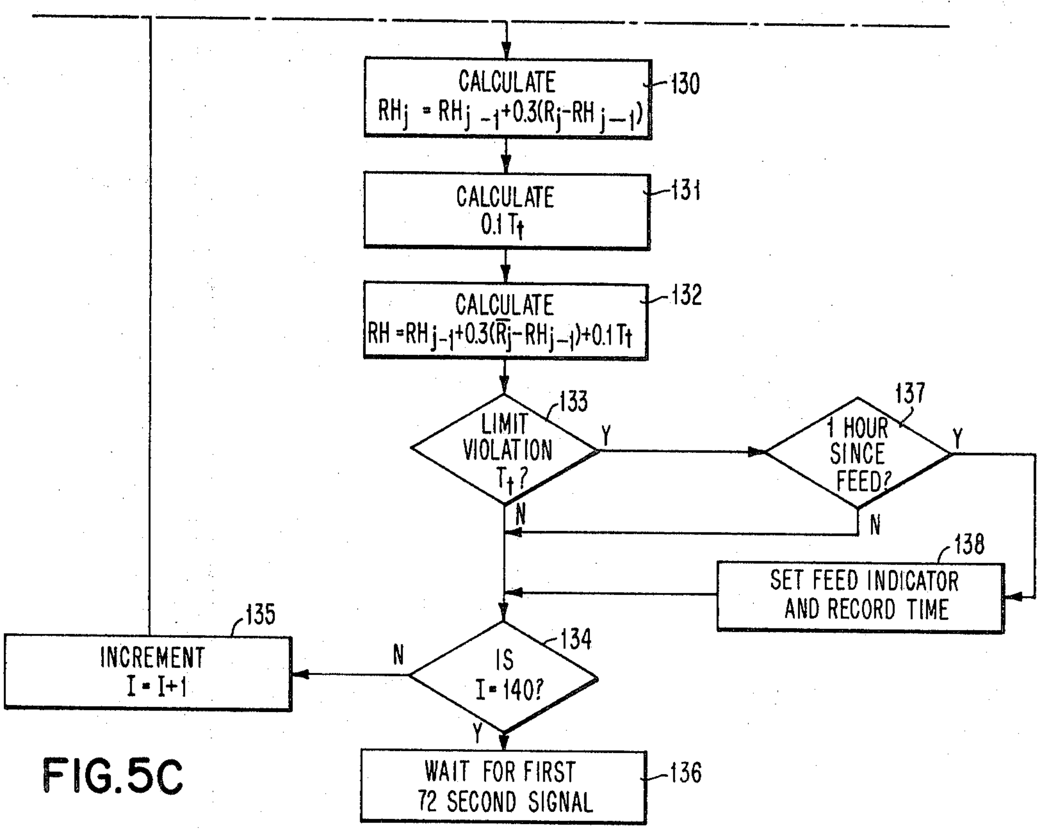

CALCULATE
RHj = RHj -1+0.3(Rj-RH j-1)
130
CALCULATE
0.1 Tt
131
CALCULATE
RH = RHj-1+0.3(R̄j-RHj-1)+0.1 Tt
132
LIMIT VIOLATION Tt?
133
Y
N
1 HOUR SINCE FEED?
137
Y
N
SET FEED INDICATOR AND RECORD TIME
138
INCREMENT I = I+1
135
IS I = 140?
134
N
Y
WAIT FOR FIRST 72 SECOND SIGNAL
136

FIG.5C

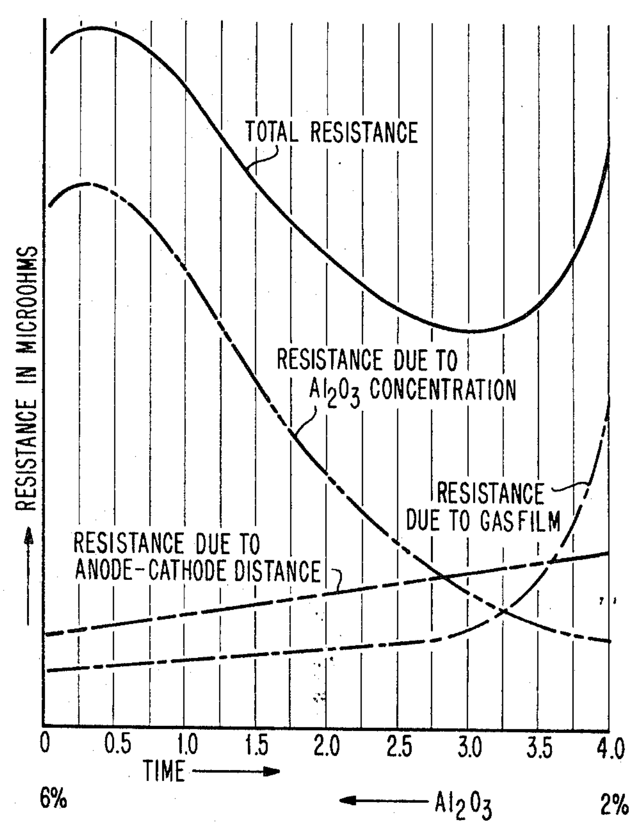
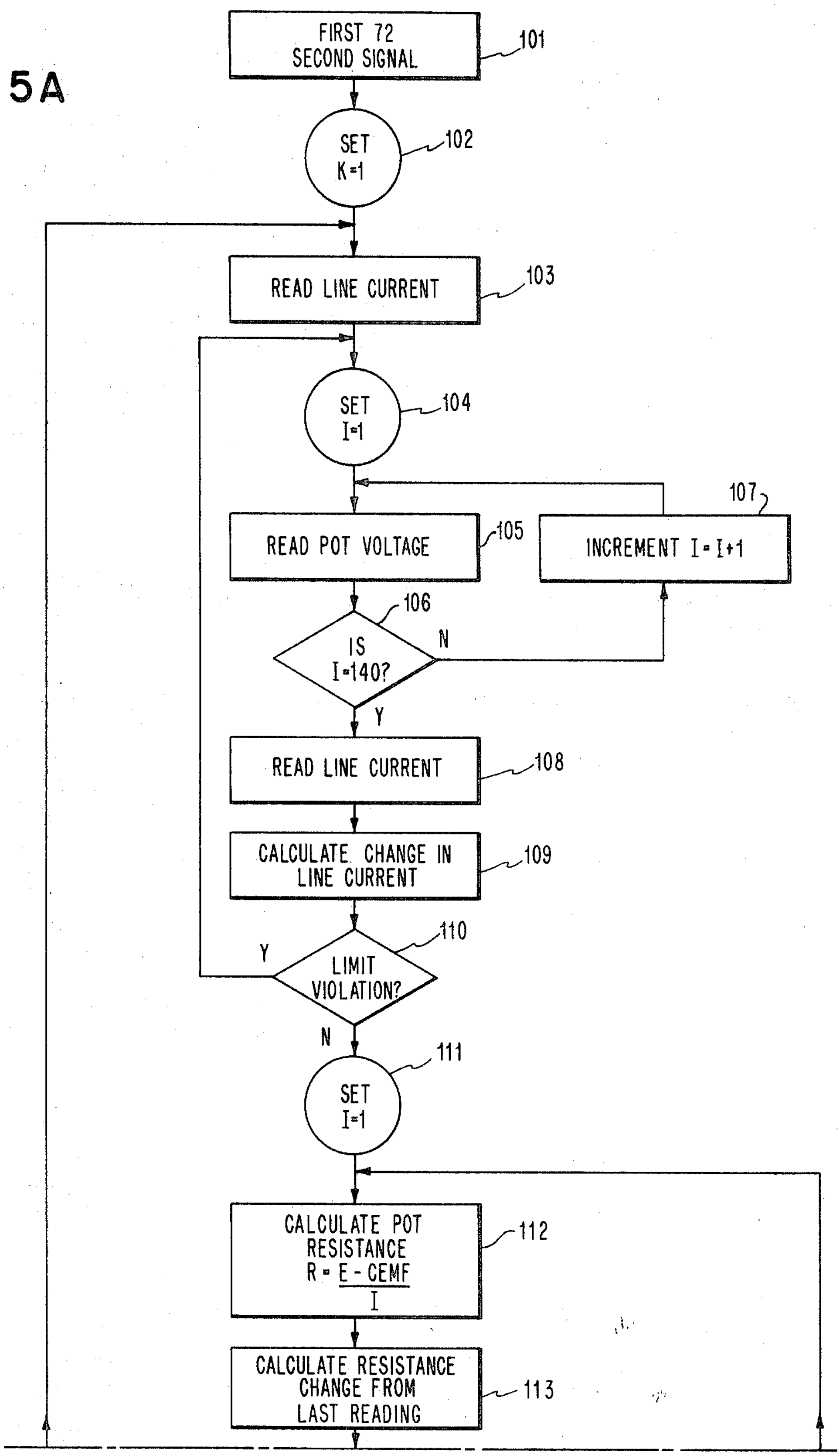

TOTAL RESISTANCE
RESISTANCE DUE TO Al2O3 CONCENTRATION
RESISTANCE DUE TO GAS FILM
RESISTANCE DUE TO ANODE-CATHODE DISTANCE
RESISTANCE IN MICROOHMS
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
TIME
6%
Al2O3
2%

FIG. 4

FIG. 5A


FIRST 72
SECOND SIGNAL
101
SET
K=1
102
READ LINE CURRENT
103
SET
I=1
104
READ POT VOLTAGE
105
107
INCREMENT I=I+1
106
IS
I=140?
N
Y
READ LINE CURRENT
108
CALCULATE CHANGE IN
LINE CURRENT
109
110
Y
LIMIT
VIOLATION?
N
111
SET
I=1
CALCULATE POT
RESISTANCE
R = E - CEMF / I
112
CALCULATE RESISTANCE
CHANGE FROM
LAST READING
113

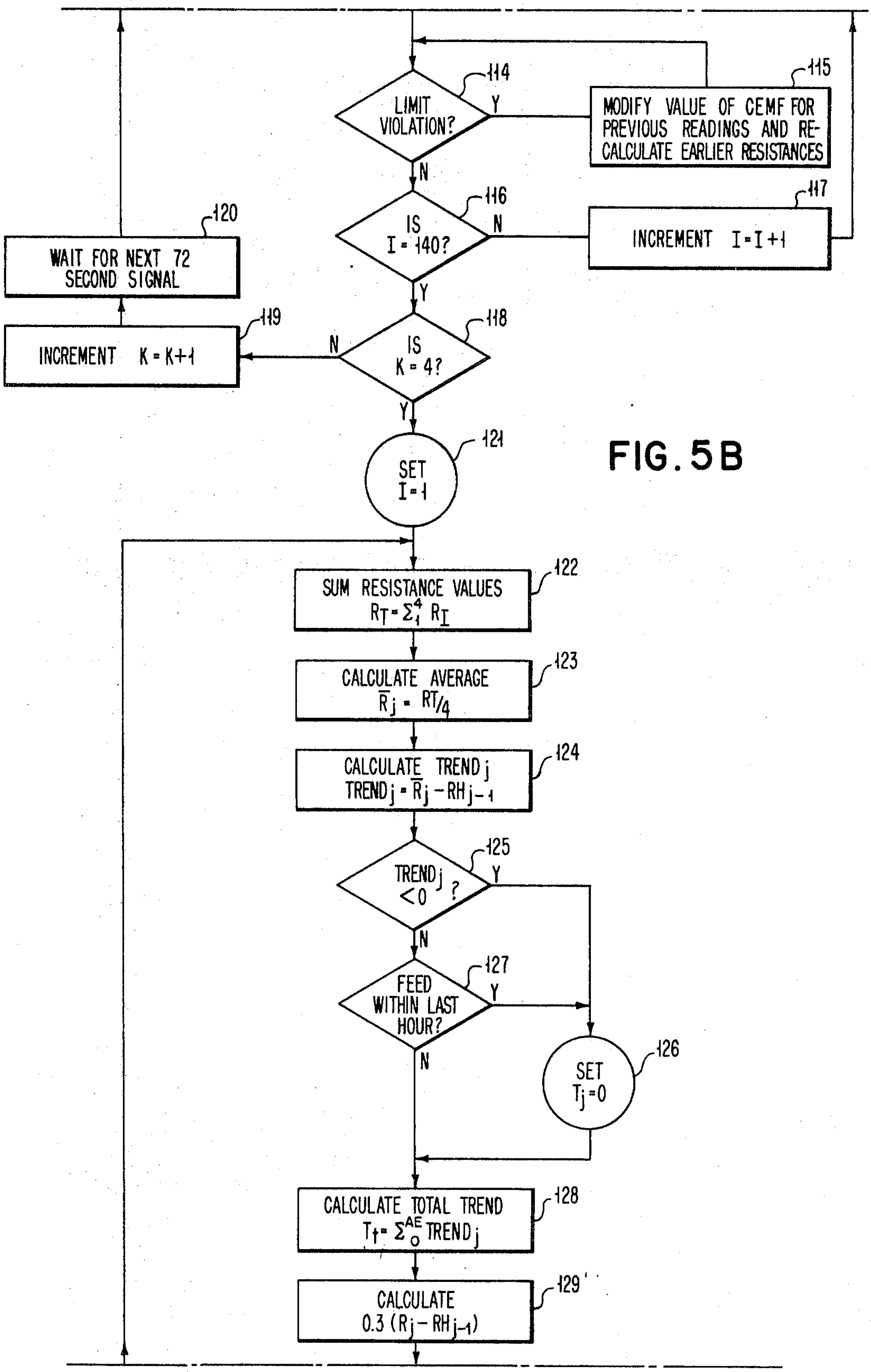

114
LIMIT VIOLATION?
Y
N
115
MODIFY VALUE OF CEMF FOR PREVIOUS READINGS AND RE-CALCULATE EARLIER RESISTANCES
116
IS I = 140?
N
Y
117
INCREMENT I = I + 1
120
WAIT FOR NEXT 72 SECOND SIGNAL
119
INCREMENT K = K + 1
118
IS K = 4?
N
Y
121
SET I = 1
122
SUM RESISTANCE VALUES $R_T = \Sigma_1^4 R_I$
123
CALCULATE AVERAGE $\overline{R}_j = R_T/4$
124
CALCULATE TREND j
$TREND_j = \overline{R}_j - RH_{j-1}$
125
$TREND_j < 0$?
Y
N
127
FEED WITHIN LAST HOUR?
Y
N
126
SET $T_j = 0$
128
CALCULATE TOTAL TREND $T_t = \Sigma_0^{AE} TREND_j$
129
CALCULATE $0.3(R_j - RH_{j-1})$

FIG. 5B

United States Patent Office

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3,573,179

METHOD AND APPARATUS FOR THE CONTROL OF ELECTROLYTIC REFINING CELLS

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Int. Cl. C22d 3/02, 3/12

U.S. Cl. 204—67 7 Claims

ABSTRACT OF THE DISCLOSURE

Method and system for controlling the addition of alumina to electrolytic aluminum refining cells to avoid the occurrence of "anode effects" therein. Control of individual refining cells is based upon the slope or trend of the bath resistance profile instead of actual measured resistance values. The bath resistance values are accumulated over a period of time and the average rate of change or trend of the resistance curve determined. When the slope or trend reaches a predetermined value, the requirement for addition of alumina to the bath is indicated.

This invention relates to a control system and particularly to a control system for an electrolytic refining operation such as the process which provides aluminum by the electrolytic reduction of aluminum oxide dissolved in molten cryolite.

The electrolytic reduction of alumina to raw aluminum is conducted in a series of cells or pots. Each pot includes a carbon anode which is immersed into a bath of molten cryolite having aluminum oxide dissolved therein, and a container of heat insulating material surrounding a conductive cathode pan having a plurality of conductors imbedded in the bottom thereof. A typical commercial operation would consist of 120 to 140 such pots connected in series with sufficient voltage impressed across the line so that the voltage drop across each pot is from 4½ to 5 volts, and the resulting line current between 50 and 100 kiloamperes.

While carbon is universally used as an anode material, two configurations exist. The first is the Soderberg anode in which an open ended steel shell is loaded with carbon paste. As the lower portion of the anode is depleted, more paste is added. The heat liberated during the refining operation bakes the paste as it sinks toward the reaction zone. The heat from the pot substitutes for the baking furnace. The Niagara anode is a baked block carbon anode which is prepared in the special furnace. The Niagara anodes are replaced as they become depleted. During the refining operation a crust of frozen cryolite forms over the reaction bath. This crust must be broken in order to enter fresh aluminum oxide (alumina). The presence of this crust necessitates that feeding be done in discrete batches rather than on a continuous basis. The crust also renders it extremely difficult to determine just how much alumina goes into the cryolite solution after the pot is fed.

In the operation of a cell it is necessary to maintain the alumina concentration within definite limits, usually considered to be two percent to eight percent by weight. At the upper limit a sludge of alumina forms at the cathode, thereby reducing current efficiency. In this condition the pot is said to be sick. When the concentration reaches the lower limit, the bath itself begins to reduce causing a gas film to form about the anodes. The increased resistance caused by the film results in a sharp increase in the pot voltage drop and a corresponding drop in the line current. During an anode effect, as this phenomenon is called, the pot voltage drop will increase from five to

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about thirty volts. The anode effect is in general a less serious commercial problem than overfeeding. Industrial practice is to operate in the lower part of the feasible concentration range to avoid the sick pot condition.

It is common practice to connect an electric light bulb across each of the pots. The bulbs become illuminated during an anode effect due to the increased voltage drop across the pot. The operator of the pot line responds to the illuminated bulb by breaking the crust of the pot and introducing more alumina. The amount which is added is usually estimated conservatively to avoid placing the pot in the sick condition. Operation of the pot near the anode effect results in a reduced efficiency over that which might be achieved by operating the pot closer to the sick condition.

Systems have been devised to anticipate the occurrence of an impending anode effect. However, these are generally unreliable and are based on side effects which may or may not occur in all pot lines. It will be appreciated that the periodic anode movements and the resulting changes in voltage drop across the pot, render it impossible to predict the time of the anode effect by a simple measurement of the voltage across each pot. While automatic anode positioners have accomplished a great deal in stabilizing the operating of an aluminum pot line, they do not solve the problem of the anode effect or the sick pot.

Accordingly, it is an object of our invention to provide an improve means for measuring the operation point of a pot to provide an anticipatory signal to an impending anode effect.

It is another object of our invention to provide an improved and more reliable method of determining the time at which additional alumina should be added to a pot.

It is still another object of our invention to provide means for maintaining the alumina concentration in the cryolite bath within the desired optimum limits.

Still another object of our invention is to provide a means for determining the operating point of a refining cell which is not upset by a change in the anode position.

In this invention, control of the individual pot is based upon the slope or trend of the bath resistance profile instead of actual measured resistances. To determine this slope, the total line current is measured as well as the IR drop across the individual pots. From these values, the individual bath resistance values may be computed. These values are accumulated over a period of time, for example 5 minutes, and the average rate of change or slope of the resistance curve is determined. When this slope or trend reaches a predetermined value, additional alumina should be added to that particular cell. It should be noted that the anode-cathode distance, which substantially affects the absolute value bath resistance, may determine the offset in the absolute value of the resistance profile, but does not materially affect its shape. In our system, the effect of absolute resistance changes due to anode movement is eliminated. When an anode movement is made during the period of time over which the measurements are to be averaged, the previous measurements are corrected or normalized to bring them in line with the measurements subsequent to the anode movement.

In addition to determining the optimum time at which ore is to be added to the pot, it will be recognized that the absolute value of resistance may be used to control the anode cathode distance as in conventional controllers. Furthermore, current efficiency may be calculated by the system by recording the ore consumption of the pot. This may be achieved by determining the average current flow through the pot and the amount of aluminum produced by the individual pot. The former value is easily maintained by data logging equipment, but the latter must be estimated by some indirect means such as the weight of charge of alumina over a long period of time.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiment of the invention as illustrated in the accompanying drawings.

FIG. 1 is a pictorial schematic diagram of a control system embodying our invention.

FIG. 2 is a graph illustrating the variation in Al_2O_3 concentration with time for a typical pot.

FIG. 3 is a graph illustrating the change in pot resistance for the same pot as FIG. 2.

FIG. 4 shows the various components which make up the pot resistance.

FIGS. *5a, 5b* and *5c* are data flow diagrams for a computer program used in the system of FIG. 1.

With reference to FIG. 1, the line to be controlled includes a string of series connected pots **1**, having anode elements **2**, a conductive cathode pan **3**, having rods **4** imbedded therein, and an insulating shell **5**. Each pot normally contains a pool **6** of molten aluminum at the bottom of a bath **7** of cryolite and dissolved alumina. Loss of heat from the surface of the bath causes a crust **8** to form.

Each pot has an anode positioning device **10** shown in schematic form as a motor **11** and associated reduction gears **12**. The position of anode **2** relative to the upper surface of molten aluminum pool **6** may be adjusted by means of motor **11**.

Each pot **1** has associated therewith feed indicating means shown as light **15**. In a conventional control arrangement, light **15** would be connected directly across the cell. A large increase in the voltage across the cell caused by too little aluminum oxide in the cryolite bath, commonly referred to as an anode effect, increases the current through the light to signal the pot line operator that feeding is necessary. In this system light **15** is not connected across the pot, but is controlled by other means.

The pots are series connected, each of the intermediate pots having a bus from the anode **2** to the preceding cathode rods **4**. The end pots are connected to a suitable source of direct current represented by terminals **16** and **17**. Assuming a line of 140 pots, the D.C. source voltage would lie between 600 and 700 volts. The current through the line would lie between 50 and 100 kiloamperes.

The line current is measured by means of magnetic amplifier **20**, having control winding **21** connected across a current shunt **22**. Output winding **23** is energized from an A.C. source connected to terminals **24**. The output **23** is connected to rectifier **25** to develop a D.C. voltage across load resistor **26** which is proportional to the D.C. current flowing in the pot line.

The voltage across each pot is measured by means of a magnetic amplifier **30** having a control winding **31** connected across the pot to be energized by the voltage drop across the pot. Output winding **33** is energized from an A.C. source connected to terminals **34**. Rectifier **35** is connected to output winding **33** to provide a D.C. signal across load resistor **36** which is proportional to the voltage drop across the associated pot.

The signal voltages developed across load resistors **26** and **36*a*–36*n*** are scanned by multiplexer or signal transfer means **40** under control of a computer or central processing unit **41** and converted into digital form by analog to digital converter **42**. The resulting digital values are utilized by central processing unit **41** to determine the proper time for feeding the pots. An output printer **43** allows the operator to monitor the process variables.

FIGS. 2 and 3 illustrate the change in alumina concentration and pot resistance as a function of time for a typical pot. The pot is fed at time 0. The concentration of alumina beings to rise immediately, increasing to a maximum of approximately 7% after 45 minutes. The resistance increases during the same period, going from 55 to almost 56 microohms. For the next two hours, both alumina concentration and resistance decrease steadily. Some three hours after feeding the pot, the resistance exhibits a reversal of the downward trend and begins to rise at an increasing rate. If this trend is allowed to proceed unchecked the pot goes into an anode effect.

FIG. 4 is an analysis of the resistance profile. The most significant component in the period immediately after feeding is the resistance due to dissolved alumina (Al_2O_3) concentration. The slope of the total resistance closely parallels the contribution of the alumina concentration until three hours have passed.

Just beyond the three hour point the contribution due to the gas film rises abruptly and becomes the most significant component of the total resistance curve. The change in resistance due to burn off of the anode is relatively small during this period.

Another factor, not shown on FIG. 4, is the effect of an anode movement on the pot resistance. While such a movement introduces an abrupt change in the absolute resistance value, it does not materially affect the shape of the curve. Neither does it change the steepness of the rise in resistance due to the formation of a gas film at the anode, just prior to an anode effect. A typical anode movement produces a resistance change that makes the rapid rise in resistance prior to the anode effect more difficult to detect.

The curves of FIG. 4 are idealized in that the noise which exists on the pot line has been removed. The presence of noise complicates the problem of detecting an impending anode effect and requires that some form of filtering be used to condition the signal.

The analysis of the resistance profile of a pot is a problem well suited for computer solution. While our method of control for an electrolytic refining cell incorporates the assistance of a computer, it will be recognized that the same measurements and analysis could be performed by other, such as manual, means.

The detailed expression of a computer program depends on the particular computer for which the program is written. A more useful form of expression is the data flow chart such as shown in FIG. 5. Such charts are commonly prepared by programmers before the detailed program is written. Since the charts are related only to the operations being performed and are independent of any instruction set, they may be used equally well in the preparation of programs for any computer.

In FIG. 5, rectangles are used to designate computer manipulation of data such as calculating and recognizing time signals. The circles are used to indicate computer operations where certain counters or terms are set to predetermined values. A diamond shape indicates that a test is performed and the program may take either of two paths depending on the result of the test.

The control operation begins with a time signal as indicated in block **101**. The first occurrence of the recurrent 72 second time signal operates to set a first, or K, counter to the value of 1 as shown in block **102**. This counter will normally be a register within computer **41** and is used to keep track of the number of times the pot resistance values have been determined.

When the counter K has been set to 1, the computer moves to the next step of the method. Block **103** indicates that the pot line current is read. In the embodiment of FIG. 1, this operation would involve computer instructions which cause multiplexer **40** to connect the output of magnetic amplifier **20** to analog to digital converter **42**. The resulting digital value is transferred to central processing unit **41** where it is stored for future use.

Block **104** indicates that a second, or I, counter is set to the value of 1. This counter is similar to K counter mentioned previously and will normally be a register within the computer. The register could be discrete hardware or simply a location in storage which is handled like a register. The I counter is used to keep track of the particular pot which is being scanned. The use of the I counter for this purpose allows certain program steps to be modified and used over and over for all pots without the necessity for repeating the storage for all instructions for every pot.

Having established the number of the pot to be serviced, by setting the I counter to the initial value, block **105** specifies that the voltage across the specified pot will be read. Similar to the previously described operation for reading the line current, this operation involves a signal from central processing unit **41** to multiplexer **40** which connects the output of magnetic amplifier **30***a* to analog to digital converted **42**. The digital value representing the voltage across cell **10***a* is then placed in the storage associated with central processing unit **41**.

Subsequent to this operation a check of the status of the I counter is made as shown by block **106**. When the value in the I counter is not equal to **140**, which is the number of pots in the line being controlled, the No output from block **106** is followed and the branch to block **107** is made. This branch indicates that all pots in the line have not been serviced and the I counter must be incremented to read the next pot. The operation of block **107** adds 1 to the value in the I counter and returns the sequence to the input of block **105** where the next pot voltage is read.

The loop comprising blocks **105**, **106** and **107** is repeated until the I counter reaches **140** indicating that all pot voltages have been read and the values are in the storage of central processing unit **41**. The exit from the loop is made through the Yes output of block **106** to block **108** which causes the pot line current to be read again and the value placed in storage. In block **109**, the value representing the first read line current (block **103**) is substractred from the second reading of line current (block **108**) to determine what change occurred during the period in which the pot voltages were read.

The change in current, as determined in the step of block **109**, is compared against a permissible limit in block **110** to determine whether the accumulated data may be processed further. Since the resistance value for each pot is to be calculated by dividing the line current by the pot voltage, a wide fluctuation in line current while reading pot voltages would make the calculation meaningless. Where pot voltages cannot be read in a very short period it may be necessary to reduce the number of pots read in one pass and break the line into three or four segments of 35 to 50 pots each.

In the event that the line current has changed appreciably during the time that blocks **104–108** were being executed, the Yes signal from block **110** indicates a limit violation and the branch is made to the input of block **104**. All the pot voltages are again read through blocks **105–107**, and the line current read at block **108** and compared, in blocks **109**, **110**, to the value obtained in the previous reading in block **108**. Assuming that the limit for change in line current is not violated, the No output of block **110** leads to block **111** which operates to set the I counter to 1 in preparation for calculation of resistance values for the individual pots. The resistance calculation designated by block **112** takes the form of

$$R=E-CEMF/I$$

where R is the pot resistance, E is the measured voltage across the pot, I is the measured line current and CEMF is the counter electromotive force of the pot. The CEMF is initially set to a theoretical value but is later modified by data obtained from the measured values.

After the resistance value for the pot designated by the I counter has been calculated in block **112**, block **113** operates to substract the present value from the last calculated value. The change in resistance is tested against a limit in block **114**. In the event that the change is greater than the limit, the Yes signal of block **114** is followed to the block **115**. This block increments or decrements the CEMF value and recalculates the previously calculated resistance values until they come within the limit established by block **114**.

This manipulation of the CEMF provides for accommodation of anode movements without affecting calculations of the change in pot resistance due to variations in dissolved alumina concentration. All preceding calculations since the last anode effect are normalized to the new anode position by recalculating with an adjusted CEMF. The increments must be small enough to enable satisfaction of the limit test.

When the resistance values fall within the established limit, the No signal from block **114** is followed to block **116** which tests the value in the I counter. If the I counter value is less than **140**, the No signal from block **116** is followed to block **117** which increments the I counter and re-enters the loop including blocks **112–116** for calculation of another pot resistance.

The existence of **140** in the I counter provides an exit by the Yes signal from block **116** to the test of the K counter indicated by block **118**. As mentioned previously, the K counter operates to keep track of the number of times the pot voltages have been measured and the individual resistance values calculated. In this particular embodiment, four readings are taken at 72 second intervals. The purpose of taking more than one reading is to achieve a measure of filtering of the input data.

In the event that four satisfactory readings of pot voltages and the associated calculations have not been performed, the K counter value will be less than four and the No signal from block **118** will lead to block **119** to increment the K counter. The operation would await the next 72 second signal as shown in block **120**. At the occurrence of the next 72 second signal an entry to block **103** would occur and a scan and calculation routine would follow.

After four satisfactory scan and calculate routines have been performed the K counter stands at 4. This results in an exit from block **118** according to the Yes signal leading to block **121**. The I counter is reset to 1 by this block preparatory to the final calculations of the resistance profile.

The first step of the resistance profile calculation for the pot indicated by the I counter occurs at block **122** where the resistance values obtained in the four scans established by the K counter are summed to provide a value $R_T=\Sigma_1^4 R_I$. From the value R_T, block **123** provides an average

$$\overline{R}_j=\frac{RT}{4}$$

In the next step, block **124** specifies a calculation of the value designated Trend *j*. This value is equal to the difference between the average $\overline{R}_j$, calculated at block **123** and the composite resistance value calculated the previous run, RH_{j-1}.

The sign of Trend *j* may be either positive or negative depending on whether the pot resistance is increasing or decreasing. Since the resistance tends to decrease after a feed operation the existence of a negative sign for the value of Trend *j* is indicative of a high alumina concentration and no danger of an anode effect exists. Block **125** senses the sign of Trend *j*. When the value is less than zero, indicating a negative sign, the Yes signal leads to block **126** which resets the value of Trend *j* to —zero. If this reset operation did not occur, an accumulation of negative values would occur, complicating the detection of an impending anode effect.

The solution of a freshly introduced alumina is complete within an hour after feeding. The No output from block **125**, indicating a positive value of Trend *j* leads to block **127**. Block **127** prevents Trend *j* from accumulating a positive value sufficient to signal a feed operation during the one hour period while the fed alumina is going into solution by testing to see whether a feed has been signaled within the past hour. If a feed has occurred, the Yes signal leads to block **126** where T_j is set to zero just as it was for negative values of T_j. If a feed has not been signaled within the past hour, the No signal exits from block **127** to block **128** where the Trend calculation is completed.

In block **128** all the Trend *j* values, which are not negative and have occurred more than one hour after the most recent feed was signaled, are summed to provide a

$$\text{Trend } T_t = \sum_{0}^{AE} \text{Trend } j$$

representing the summation of positive values of Trend *j* between impending anode effects more than one hour after a feed operation was signaled.

Additional calculations are performed in block **129** as a step in calculating the new value for the filtered resistance of the pot RH_j. The step set forth in block **129** calculates .3 of the difference between $\overline{R}_j$ which is the raw average resistance of block **123** and RH_{j-1} which is the calculated filtered resistance for the preceding 288 second period.

The next step in the calculation, set forth in block **130**, provides for a preliminary calculation of the new RH_j by adding the result of block **129** to the value of RH_{j-1}. This manner of combination provides a filtering action since only .3 of the change between the raw average and the last calculated value is used to modify the calculated value.

Block **131**, the next step, calculates the value of .1 of the total trend T_t which was calculated at block **128**. In block **132** the value T_t is added to the preliminary value of RH_j obtained in block **130** to give the final value of RH_j.

Having completed the calculations associated with evaluation of the resistance trend a test is made at block **133** to determine whether or not the previously obtained value of T_t, block **128**, is in excess of an established limit for the particular pot. If there is no violation, the No signal exits to block **134** which tests the I counter to see whether all pots have been considered. If the I counter value is less than 140, the No signal exits to block **135**, which increments the I counter and re-enters the loop at the input to black **122**. If the I counter stands at 140, all pots have been serviced and the Yes signal exits to block **136** which provides for re-entry of the routine upon receipt of the first 72 second signal as shown at block **101**.

In the event that a trend violation has occurred, indicating that an anode effect is impending, exit from block **133** is according to the Yes signal leading to block **137** which gain tests to see whether one hour has elapsed since the last feed was signaled. If the No signal is present, indicating that a feed was signaled within the last hour, exit occurs to block **134** and no further action is taken on the particular pot.

Where an hour has passed since the last feed operation was signaled, exit from block **137** occurs through the Yes signal leading to block **138**. An indicator which signals the necessity for a feed operation is activated by the operation set out in block **138**. With reference to the System of FIG. 1, central processing unit **41** would signal multiplexer **40** to turn on the light **15** over the pot which needs feeding. The operator turns the light off when he feeds the pot. The operation of block **138** is such that a record of the time when the light is turned on is retained. The assumption is made that feeding occurs within a few minutes from this time.

The exit from block **138** leads to block **134** which has been described.

The foregoing system contemplates the use of a digital computer for performance of the required calculations but the same calculations could be performed by other means. For example, the necessary measurements of line current and pot voltage may be taken with existing or conventional meters designed for the appropriate current and voltages involved. The calculations on this data may be done by means of a desk calculator or even by hand if necessary. It will be recognized that the speed of data acquisition and the ensuing calculations will determine the number of pots which can be handled in a group.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In the process of refining aluminum from alumina in an igneous electrolysis bath in an electrolytic refining cell, the method of controlling the alumina content of said bath by signalling a feed operation to feed additional alumina into said bath prior to the occurrence of an anode effect therein comprising the steps of:

(1) measuring by an instrumentality the operating electrical current and voltage of said electrolytic refining cell at predetermined time intervals, and responding thereto to develop signals representing the value of total pot resistance of said cell at said predetermined time intervals,

(2) comparing by an instrumentality said signal representing the current resistance value with a signal representing the most recent previous resistance values derived from previous measurements to supply signals representing the time rate of change of said total pot resistance,

(3) signalling by an instrumentality said feed operation when said signals representing time rate of change of said total pot resistance reach a predetermined limit.

2. A method according to claim **1** wherein step 1 comprises the steps of:

(A) measuring by an instrumentality the current through the cell to develop a signal representing the value of said current,

(B) measuring by an instrumentality the voltage across the cell to develop a signal representing the value of said voltage,

(C) responding to said current and voltage value representing signals by an instrumentality to develop thereby signals representing the value of total pot resistance from said measured values at said predetermined time intervals.

3. A method according to claim **2** wherein said development of signals representing the value of total pot resistance from said measured values in step C comprises the steps of:

(A) Developing by an instrumentality said cell resistance signals according to the relationship

$$R = \frac{E - \text{CEMF}}{I}$$

where

R is the cell resistance;

E is the measured voltage value;

I is the measured current value;

CEMF is a value for the counter-electromotive force of the cell;

(B) detecting by an instrumentality the difference between the resistance signal developed according to the preceding step and the resistance signal previously developed;

(C) testing by an instrumentality the difference against a limit;

(D) redeveloping by an instrumentality the resistance signals of step A according to an altered value for CEMF when the limit is violated;

(E) repeating steps B–D until the difference lies within the limit.

4. A method according to claim 1 wherein determination of said time rate of change of said total pot resistance of step 2 comprises the steps of:

(A) supplying by an instrumentality a signal representing the average previous resistance value from a predetermined number of signals representing the most recent previous resistance values,

(B) subtracting by an instrumentality a signal representing the filtered value of said current resistance value from said signal representing said average previous resistance value to obtain signals representing the time rate of change of said total pot resistance,

(C) accumulating by an instrumentality the positive values of said time rate of change signals obtained in step B.

5. A method according to claim 4 including the additional steps of:

(A) calculating by an instrumentality a new filtered value of resistance for each pot.

6. In a system for the electrolytic refining of aluminum from alumina by means of a plurality of serially connected cells, apparatus for controlling the alumina content of each of said cells by signalling feed operations to feed additional alumina into individual ones of said cells prior to the occurrence of an anode effect therein comprising:

current sensing means for developing a signal representing the current in said cell line,

voltage sensing means for developing a signal representing the voltage across a cell,

signal transfer means,

a plurality of feed indicator means, each associated with one of said cells, for indicating that a feed operation is required for the associated cell,

control means for said sensors, said signal transfer means and said feed indicator means,

said control means including a digital computer arranged to comprise:

(1) means for operating sid signal transfer means to effect periodic interrogation of said sensors by said signal transfer means and transfer of said current and voltage signal data to said computer;

(2) means responsive to said transferred current and voltage signal data to develop signals representing the value of total pot resistance of each cell at said periodic time intervals;

(3) means responsive to said signals representing the value of total pot resistance at said time intervals to compare said signal representing the current resistance value of a cell with a signal representing the most recent previous resistance values of said cell to determine the time rate of change of said total pot resistance for each of said cells; and

(4) means for operating said feed indicator means for a cell when said time rate of change of said total pot resistance for said cell exceeds a predetermined value.

7. A system according to claim 6 having analog to digital converter means operable in accordance with said control means for converting the analog output of said sensors to digital form for transfer to said computer.

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204—243R, 244, 245

Notice of Adverse Decision in Interference

In Interference No. 98,399, involving Patent No. 3,573,179, G. P. Dirth and T. K. McMahon, METHOD AND APPARATUS FOR THE CONTROL OF ELECTROLYTIC REFINING CELLS, final judgment adverse to the patentees was rendered June 16, 1976, as to claims 1, 2, 4, 5, 6 and 7.

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