

[54] **METHOD FOR REGULATING ANODE-CATHODE SPACING IN AN ELECTROLYTIC CELL TO PREVENT CURRENT OVERLOADS AND UNDERLOADS**

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[56] **References Cited**
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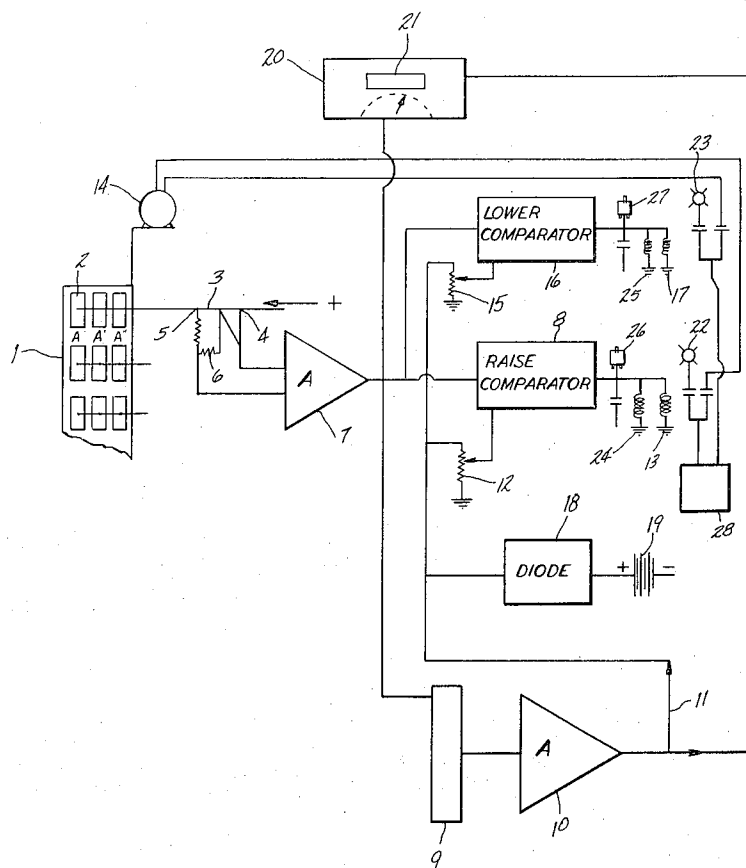
3,574,073	4/1971	Ralston, Jr.	204/225 X
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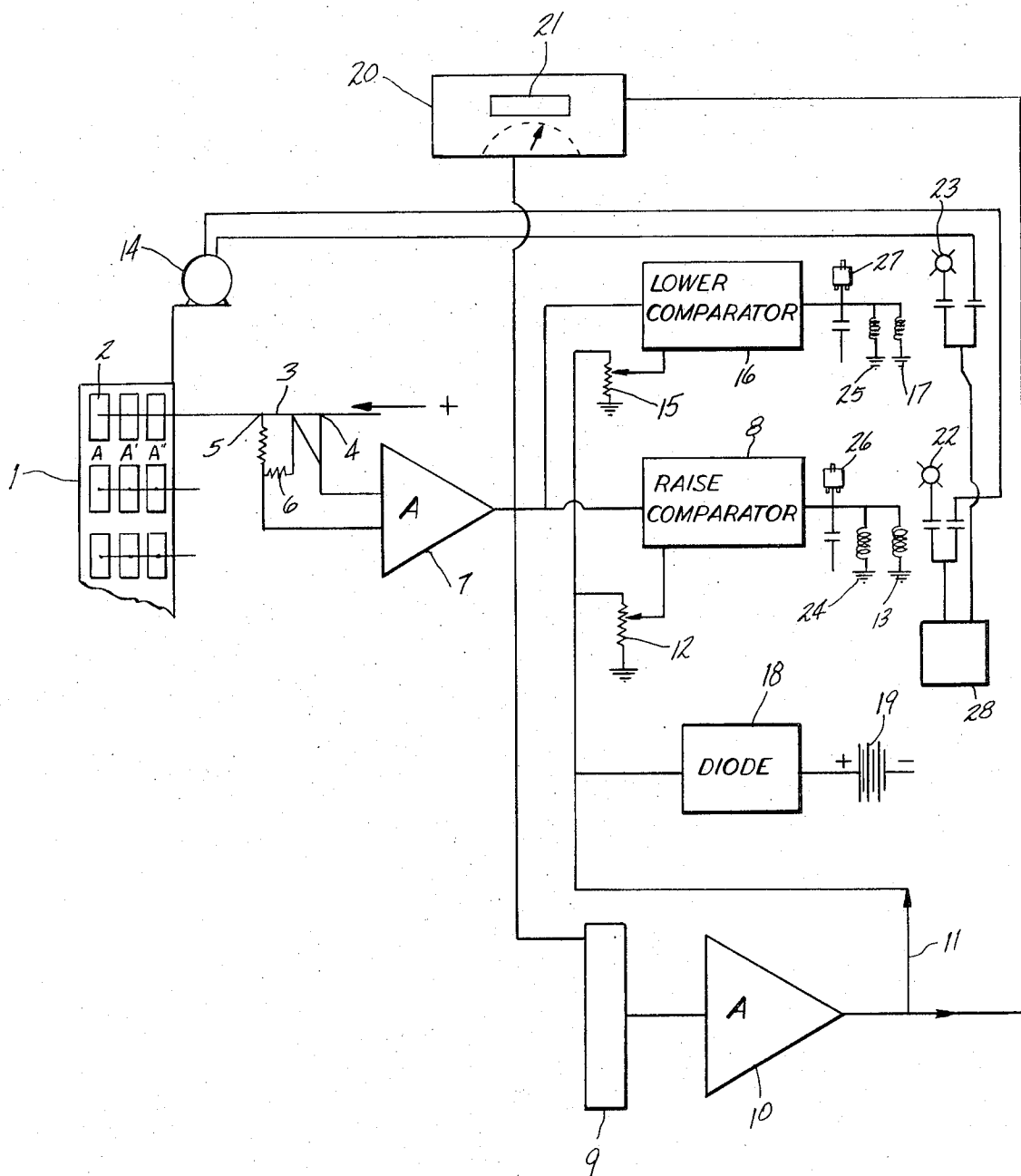
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[57] **ABSTRACT**

An improved method and apparatus for adjusting the space between an adjustable anode set and a cathode in an electrolytic cell to protect the electrodes from current overloads and current underloads wherein an amplified current signal for each anode set is obtained, an average current determined, and a collective current, proportional to the average current, generated. A first portion of the collective current is individually selected for each anode set as an upper reference signal and a second portion of the collective current is individually selected for each anode set as a lower reference signal, the difference between the upper reference signal and the lower reference signal being the operating current range. Comparison of the amplified current signal for an anode set is made with its upper and lower reference signals and the anode-cathode spacing adjusted when the amplified signal falls outside of the operating current range.

10 Claims, 1 Drawing Figure





METHOD FOR REGULATING ANODE-CATHODE SPACING IN AN ELECTROLYTIC CELL TO PREVENT CURRENT OVERLOADS AND UNDERLOADS

The present invention relates to a method and apparatus for adjusting the anode-cathode spacing in an electrolytic cell. In particular, the invention relates to a method for adjusting the anode-cathode spacing in an electrolytic cell for the electrolysis of alkali metal chlorides such as sodium chloride.

More particularly, the invention relates to a new method and apparatus for detecting current overloads or underloads and automatically adjusting the anode-cathode spacing in horizontal mercury cells.

In electrolytic cells with adjustable electrodes, the control of the inter-electrode distance between the anode and the cathode is economically important. The anode-cathode spacing should be as narrow as possible to maintain the voltage as close to the decomposition voltage of the system being electrolyzed as possible. Careful control of the anode-cathode spacing means the reduction of wasteful consumption of energy, for example, in the production of heat, and the avoidance of short circuiting and its accompanying problems, for example, destruction of anode surface and the contamination of the electrolytic products, among others.

Current overloads can result from several conditions including the maladjustment of the anode-cathode spacing, undulation of the liquid cathode surface as a result of irregular pump operation, alterations in the depth of the cathode layer as a result of variations in the feed rate, and the presence of impurities on the cathode surface.

As a result of these conditions, an excessive flow of current in the anode set, anode leads and the conductor serving the anode set takes place with subsequent overheating of each of these components and a waste of electrical power.

Current underloads can result from conditions such as uneven consumption of anodes, the maladjustment of the anode-cathode spacing, or the malfunction of electrical components. When current underloads occur, electrolysis proceeds at inefficient rates.

Numerous techniques have been developed to adjust the anode-cathode gap in electrolytic cells. For example, U.S. Pat. No. 3,574,073, issued Apr. 6, 1971, to R. W. Ralston, Jr., discloses adjustment means for anode sets in such cells wherein means responsive to changes in the flux of the magnetic field, generated by current flow in a conductor supplying the anode sets, controls the opening and closing of an electrical circuit, activating hydraulic motors effective to raise or lower the anode sets.

Devices employing magnetic means for current overload detection, while satisfactory, are difficult to accurately adjust and calibrate. Being physically located on the electrical conductors of the electrolytic cell, they are subject to the ambient influences of stray magnetic fields, heat and possible corrosion.

U.S. Pat. No. 3,723,285, issued Mar. 27, 1973, to G. A. Daga et al, discloses detecting overloads in mercury cells by measuring the current on conductors to anode sets in a cell, averaging the current for the anode sets, and determining the highest current for any single anode set in the series. The difference between the highest current and the average current is obtained and

when this difference falls outside of a specified range, an alarm system is activated. No provision is made in this technique for the individual characteristics of each anode set, and only the anode set with the highest current deviation from the average current is considered.

In co-pending application U.S. Ser. No. 272,240, pending filed July 17, 1972, by Richard W. Ralston, Jr., a digital computer is used to periodically scan, in serial order, the anode sets in an electrolytic cell to detect current overloads. The current reading for the anode set is compared with a standard value stored in the computer and the anode set raised when the current reading exceeds the standard value by a predetermined limit.

The above application discloses a non-continuous method of detecting current overloads to anode sets in a prescribed order. In addition, the method requires a digital computer for successful operation.

It is an object of the method and apparatus of the present invention to continuously detect current overloads and underloads and automatically adjust the anode-cathode spacing in electrolytic cells having a liquid cathode.

An additional object of the method and apparatus of the present invention is the automatic adjustment of the anode-cathode spacing in a horizontal mercury cell to protect against current overloads and underloads while permitting the current requirements for each anode set in a cell to be individually selected.

A further additional object of the method and apparatus of the present invention is the protection of anode sets against current overloads and underloads in which the reference values selected to indicate current overloads and underloads are automatically adjusted with changes in the total cell current.

These and other objects of the invention will be apparent from the following detailed description of the invention.

The novel method of this invention protects against current overloads or underloads in an electrolytic cell containing an electrolyte decomposable by electric current, where the electrolyte is in contact with electrodes. The electrodes are comprised of at least one adjustable anode set and a liquid cathode in spaced relationship. A current is applied to the anode set through at least one conductor. A signal corresponding to the current in the conductor is detected and compensated for temperature variations in the conductor to produce a temperature-compensated signal. This temperature-compensated signal is then amplified and the amplified signals from each anode set in the cell are averaged. The improved method of this invention comprises:

- a. generating a collective signal proportional to the average signal,
- b. selecting individually for each anode set a first portion of said collective signal as an upper reference signal,
- c. selecting individually for each anode set a second portion of said collective signal as a lower reference signal, the difference between said upper reference signal and said lower reference signal representing the operating current range for said anode set,
- d. comparing said amplified signal with said upper reference signal and said lower reference signal, and

e. adjusting the space between said anode set and said cathode when said amplified signal falls outside said operating current range.

The novel apparatus of the present invention is illustrated in the accompanying FIGURE.

The accompanying FIGURE represents the circuit for protecting anode sets from current overloads or underloads employing the method and apparatus of the present invention. Electrolytic cell 1 contains a plurality of anode sets, represented by anode set 2 having anodes A, A' and A''. Current is supplied to anode set 2 by conductor 3. Terminals 4 and 5 along conductor 3 generate a signal representing the current flow to anode set 2. Thermistor circuit 6 provides temperature compensation to the current signal generated between terminals 4 and 5. Amplifier 7 receives the temperature compensated current signal from thermistor circuit 6 and supplies an amplified current signal to raise comparator 8. Averaging circuit 9 also receives the amplified current signal from amplifier 7 and averages the amplified current signals from all anode sets in the electrolytic cell. Scaler amplifier 10 receives the averaged current signal from averaging circuit 9 and produces a collective signal supplied to conductor 11. Raise potentiometer 12 is set to select an upper reference signal representing the individual current requirements of anode set 2, which is a portion of the collective signal in conductor 11. Raise comparator 8 receives the upper reference signal for anode set 2 from raise potentiometer 12 and compares it with the amplified signal from amplifier 7. When the amplified signal exceeds the upper reference signal, raise relay 13 is activated and motor voltage source 28 energizes motor 14 to raise anode set 2 a predetermined amount. Lower potentiometer 15, which also receives the collective signal through conductor 11, is set to provide an individually selected lower reference signal for anode set 2 to lower comparator 16. Lower comparator 16 also receives the amplified signal from amplifier 7. Upon comparing the amplified signal with the lower reference signal from lower potentiometer 15, if the amplified signal is less than the reference signal lower relay 17 is activated and motor voltage source 28 energizes motor 14 to lower anode set 2 a predetermined amount.

In a preferred embodiment, diode 18 is connected to power source 19 and to conductor 11. Diode 18 supplies voltage to conductor 11 when the collective signal from scaler amplifier 10 falls below that of voltage power source 19.

A further embodiment employs multiple switch 20 which selectively receives the amplified current signal from anode set 2 in addition to the amplified signals from all other anode sets. Multiple switch 20 also receives the collective signal from scaler amplifier 10. Digital volt meter 21 is connected to multiple switch 20 and visually displays the signal selected by multiple switch 20.

In another embodiment, lamp 22 is connected to raise relay 13 and is turned on when this relay is activated, indicating that the anode set is being raised. Similarly operated is lamp 23 connected to lower relay 17. These lamps are inactivated when movement of the anode set is discontinued. Also connected to raise relay 13 and lower relay 17 are latching relays 24 and 25, respectively, which energize annunciator lamps 26 and 27, respectively. Annunciator lamps 26 and 27 remain

energized until latching relays 24 and 25, respectively, are manually reset.

Where an anode set is supplied with current by more than one conductor, the current signal from each conductor is temperature compensated and the temperature compensated signals for the anode set can be averaged in an averaging circuit (not shown) with the averaged current signal being supplied to amplifier 7. Preferably, a separate circuit containing a thermistor circuit, amplifier, raise comparator, raise potentiometer, lower comparator and lower potentiometer is used for each current conductor supplying current to an anode set. This latter method provides more reliable protection to an anode set from current overloads and underloads.

The method and apparatus of the present invention permits the use of anode sets of differing materials of construction to be used in the same cell.

The method of the present invention may be used on a variety of electrolytic cell types used for different electrolysis systems. It is particularly useful in the electrolysis of alkali metal chlorides to produce chlorine and alkali metal hydroxides. More particularly, it is highly suitable to horizontal electrolytic cells having a liquid metal cathode such as mercury, as disclosed, for example, in U.S. Pat. Nos. 3,390,070 and 3,574,073.

As indicated in U.S. Pat. No. 3,574,073, issued Apr. 6, 1971, to Richard W. Ralston, Jr., horizontal mercury cells usually consist of a covered elongated trough sloping slightly towards one end. The cathode is a flowing layer of mercury which is introduced at the higher end of the cell and flows along the bottom of the cell toward the lower end. The anodes are generally composed of rectangular blocks of graphite or titanium rods coated with a metal oxide. The anodes are suspended from conductive lead-ins, for example, graphite or protected copper tubes or rods. The bottoms of the anodes are spaced a short distance above the flowing mercury cathode. The electrolyte which is usually salt brine, flows above the mercury cathode and also contacts the anode. In each anode set, one anode lead is secured to a conductor, and the other lead is secured to a second conductor. Each conductor is adjustably secured at each end to a supporting post. Each supporting post is provided with a drive means such as a sprocket which is driven through a belt or chain or directly by a motor such as an electric motor, hydraulic motor or other motor capable for responding to electric signals.

Although the invention is particularly useful in the operation of horizontal mercury cells used in the electrolysis of brine, it is generally useful for any liquid cathode type electrolytic cell where adjustment of the anode-cathode space is necessary.

The number of electrolytic cells controlled by the method and apparatus of this invention is not critical. Although a single electrolytic cell can be controlled, commercial operations containing more than 100 cells can be successfully controlled.

Each electrolytic cell may contain a single anode, but it is preferred to apply the method and apparatus of this invention to electrolytic cells containing a multiplicity of anodes. Thus, the number of anodes per cell may range from 1 to about 200 anodes, preferably from about 2 to about 100 anodes.

It is preferred, particularly on a commercial scale to utilize anode sets when adjusting the space between the cathode and anodes of electrolytic cells. An anode set

may contain a single anode, but it is preferred to include from 2 and about 20 anodes and preferably between from about 3 and about 12 anodes per anode set.

In accomplishing the adjustment of the anode-cathode spacing by the method of the present invention, at least one electrical signal is generated and measured for each anode set. The signal represents the current flow in conductor 3 for anode set 2 and may be obtained by measuring the voltage drop between a plurality of terminals, preferably two, spaced apart a suitable distance along the conductor. The spacing suitably varies between 3 and 100 inches, for example, about 30 inches, but should be the same distance for all conductors. It is desirable that the terminals be located laterally in the middle of the conductor, in a straight segment of conductor of uniform dimensions. Current measurements may also be obtained using other well-known methods such as by the Hall effect or other magnetic detection devices. A current signal for each individual anode set in each cell is obtained continuously.

The current signal is of the magnitude of from about 10 to about 50 and usually from about 20 to 30 millivolts. It is compensated for temperature changes in the conductor by thermal resistor 6 being embedded or otherwise attached to the section of conductor 3 being used as the source of the current signal.

The temperature-compensated signal is passed through an amplifier 7 having a gain of from about 200 to about 300 where the signal is amplified.

The amplified signal is used by several components of the apparatus of the present invention including:

averaging circuit 9, raise comparator 8, and lower comparator 16, and multiple switch 20 connected to a visual display device.

The averaging circuit 9 receives an amplified signal from each anode set in the electrolytic cell. It is, for example, a network of resistors which determines the average amplified signal for the anode sets served and transmits this average signal to a scaling amplifier 10.

The scaling device 10 is, for example, an amplifier which increases the level of the average signal to provide a collective signal. The increase can be any convenient level of amplification. For example, the average signal can be multiplied by a factor equal to the number of amplified signals being averaged in the cell to give a collective signal corresponding to that of the total cell current or by a factor equal to the number of anode sets in the cell. This collective signal is fed to a collective signal conductor 11. The collective signal conductor 11 supplies the collective signal to a series of potentiometers with at least one raise and one lower potentiometer serving each anode set in the cell. The raise and lower potentiometers are each set by means of a calibrated dial to individually select a proportion of the collective signal as a reference signal for the particular anode set it serves. Raise potentiometer 12 selects a portion of the collective signal as the upper reference signal and lower potentiometer 15 selects a portion of the collective signal as the lower reference signal. The upper and lower reference signals are individually selected for each anode set in a cell. The difference between the upper reference signal and the lower reference signal represents the operating current range for each anode set. The potentiometers can be calibrated to provide a reference signal, for example, reading directly in kiloamperes or as a percent of the collective signal. The latter is preferred, as changes in the collec-

tive signal will be automatically compensated for in the reference signals received by the potentiometers without having to adjust their set points. In the case of an electrolytic cell having 10 anode sets, the upper reference signal can represent a portion of from about 11 percent to about 20 percent, and preferably from about 13 percent to about 17 percent of the collective signal. The lower reference signal can represent a portion of from about 1 percent to about 9 percent and preferably from about 2 percent to about 8 percent of the collective signal. The reference signals selected by the raise and lower potentiometers serving an anode set are supplied to the raised and lower comparators respectively.

As previously mentioned above, the amplified signal from the anode set is also supplied to at least two comparators. There is a separate raise and lower comparator for each anode set. In addition to the amplified signal, each comparator also receives a reference signal from the particular potentiometer serving it. A comparator is, for example, an amplifier which is biased in the off position and which compares the amplified signal from the anode set conductor with the reference signal from the potentiometer. When the amplified signal to the raise comparator exceeds the reference signal the amplifier will switch to the on position, energizing a relay 13 which provides power to the raise mode of the motor 14 controlling the particular anode set 2. As the anode set 2 is raised, the current, and thus the amplified signal decreases. The anode set 2 is raised until the amplified signal falls below that of the reference signal by a predetermined amount. At this point, the comparator 8 is turned off, stopping the motor and thus the anode set movement.

Similarly, when for a particular anode set the amplified signal to the lower comparator 16 is less than the reference signal from the lower potentiometer 15, the comparator will switch to the on position and energize a relay 17 which provides power to the lower mode of the motor 14 controlling the particular anode set 2. As the anode set 2 is lowered, the current and thus the amplified signal increases. Lowering of the anode set is continued until the amplified signal exceeds the reference signal by a predetermined amount. The comparator switch is turned off, stopping the motor 14 lowering anode set 2.

When an anode set is raised or lowered, it should be moved a sufficient distance so that its new amplified signal falls within the operating range for that particular anode set by a predetermined amount. This predetermined amount can be, for example, a selected range of kiloamperes or it can be a portion of the value of the particular reference signal to which it is being compared. Preferably, the predetermined amount is a value of from about 1 to about 35 and preferably from about 5 to about 30 percent of that of the reference signal to which it is being compared.

In a preferred embodiment, the collective signal conductor 11 is connected to a diode 18 which is in turn connected to a voltage supply 19. If the signal supplied by the collective signal conductor 11 should fall below the level required by the potentiometers to hold the system in operation, then voltage will be supplied through the diode 18 to the collective signal conductor 11 so that the signal level supplied to the potentiometers is maintained at the minimum level. The voltage can be any convenient amount representing a percentage or proportion of the collective signal, for example,

from about 20 percent to about 70 percent of the signal.

In another preferred embodiment, the amplified signals from each anode set or the collective signal can be visually displayed by supplying the signals to a multiple switch which is connected to a display device, such as a digital voltmeter. By selecting the desired anode set, the selected signal is displayed directly as a series of numbers. This is particularly advantageous with respect to properly adjusting the anode-cathode spacing, for example, after the anode has been raised to avoid damage from an overload of current.

It may also be desirable to connect a series of indicators, for example, lamps or alarms, to the relays which energize the motors which control the movement of the anode set. Various types of indicators can be used. In a preferred embodiment, each raise or lower relay is also connected to two indicators, for example, lamps which are turned on when the relay is activated. One lamp is turned on only during the period of time when the anode set is actually being moved and automatically turns off when the anode set stops movement. The second lamp is turned on by a latching relay when the anode set is being moved but remains lit after anode movement stops. It is only turned off when the latching relay is deliberately reset. Such a system can be used to alert operating personnel to the number of times that an anode set has been automatically adjusted and perhaps serving as a guide for required cell maintenance.

Using the method and apparatus of the present invention, anode sets can be operated at any desired current level. The total cell current, number of anode sets, the location of the anode sets in the cell and the condition of the anodes are among the factors which will affect the distribution of current among the anode sets in a cell and thus the operating current range for a specific anode set. For example, in a horizontal mercury cell having a total cell current of 150 kiloamperes, and ten sets of anodes, the operating current range for an anode set can be from about 1 to about 20, and preferably from about 5 percent to about 15 percent of the total cell current. Very low currents, such as 1 kilampere, can be employed, for example, to permit a faulty anode set to continue operating until corrective action can take place.

The method and apparatus of the present invention for protecting electrodes from current overloads or underloads, are particularly useful when employed with a system which adjusts the anode-cathode spacing to provide the optimum use of current and voltage in an electrolytic cell, such as disclosed in copending application U.S. Ser. No. 272,240, filed July 17, 1972, by Richard W. Ralston, Jr.

The present invention provides protection to electrodes against current overloads and underloads for all ranges of the total cell current. Operating current

ranges can be tailored to meet the specific requirements of each anode set by the individual selection of the set points for the upper and lower reference signals. These set points are readily changed by means of a dial, calibrated, for example, in kiloamperes or as a percent of the collective signal. With the latter method, the set points are automatically modulated with a change in the total cell current. A high degree of control accuracy is obtained using inexpensive components, most of which can be located outside of the electrolytic cell room atmosphere.

The following example is included to further illustrate the present invention.

EXAMPLE

A horizontal mercury cell for electrolyzing aqueous sodium chloride to produce chlorine containing 10 anode sets of 5 graphite anodes per set was equipped with apparatus similar to that shown in the accompanying FIGURE. Each anode set was supplied with current by two conductors. A signal representing the current from each conductor was selected and temperature compensated for temperature changes in the conductors. The two signals for each anode set were then averaged in an averaging circuit (not shown) and the signal supplied to an amplifier. The amplified signal was supplied to the lower and raise comparator for each anode set and also to the averaging circuit. The average signal for the 10 anode sets was 7.24 kiloamperes. This signal was fed to a scaling device where the signal was multiplied by a factor of 20 to give a collective signal corresponding to 144.8 kiloamperes. The collective signal was fed to a collective signal conductor where a raise and lower potentiometer for each anode set selected an upper and lower reference signal respectively. These values of the individually selected reference signals are given in Table 1 below. The upper and lower reference signals for each anode set were fed to the raise and lower comparators respectively. The comparators compared the amplified signal for the anode set with the reference signal received. Whenever an amplified signal exceeded the upper reference signal, the comparator activated a relay energizing the raise mode of a motor and the particular anode set was raised until the amplified signal fell to a value of about 10 percent below that of the upper reference signal.

Similarly, where the amplified signal for an anode set fell below the lower reference signal of a lower comparator, the comparator activated a relay energizing the lower mode of a motor and the anode set was lowered until the amplified signal exceeded the lower reference signal by a value of about 10 percent above the lower reference signal. Whenever a motor was energized to raise or lower an anode set, an indicator lamp was switched on the control panel.

TABLE 1

Anode Set No.	Anode Signal (1) (kiloamperes)	Upper Reference Signal (kiloamperes)	Lower Reference Signal (kiloamperes)
1	7.13	8.90	5.35
2	7.65	9.55	5.75
3	8.745	10.95	6.50
4	8.065	10.00	6.00
5	7.735	9.70	5.80
6	6.575	8.25	5.00
7	5.985	7.50	4.50
8	6.365	7.95	4.80
9	7.24	9.05	5.45
10	6.905	8.65	5.20

(1) Anode signal was the average of the signals from two conductors to the anode set.

What is claimed is:

1. In a method for continuously protecting electrodes against current overloads or underloads in an electrolytic cell containing an electrolyte decomposable by electric current, said electrolyte being in contact with said electrodes, said electrodes being comprised of at least one adjustable anode set and a liquid cathode in spaced relationship, applying a current to each said anode set through at least one conductor, detecting a signal corresponding to said current in said conductor, compensating said signal for temperature variation in said conductor to produce a temperature-compensated signal, amplifying said temperature-compensated signal to produce an amplified signal, generating an average signal representing amplified signals from each said anode set in said cell, the improvement which comprises:

- a. generating a collective signal proportional to said average signal,
- b. selecting individually for each anode set a first portion of said collective signal as an upper reference signal,
- c. selecting individually for each anode set a second portion of said collective signal as a lower reference signal, the differences between said upper reference signal and said lower reference signal representing the operating current range for said anode set,
- d. comparing said amplified signal with said upper reference signal and said lower reference signal, and
- e. adjusting the space between said anode set and said cathode when said amplified signal falls outside said operating current range.

2. The method of claim 1 in which said space between said anode set and said cathode is increased when said amplified signal is greater than said upper reference signal.

3. The method of claim 1 in which said space between said anode set and said cathode is decreased when said amplified signal is less than said lower reference signal.

4. The method of claim 1 in which said collective signal is a multiple of said average signal, said multiple being the number of signals being averaged.

5. Apparatus for adjusting the space between electrodes in an electrolytic cell, said electrodes being comprised of at least one adjustable anode set and a liquid

cathode in spaced relationship, said anode set being supplied with current by at least one conductor, said apparatus comprising in combination:

- a. means for continuously detecting a signal representing said current supplied to said anode set by said conductor,
- b. means for compensating said signal for temperature variation in said conductor to produce a temperature compensated signal,
- c. means for amplifying said temperature compensated signal to produce an amplified signal,
- d. means for generating an average signal representing said amplified signals from each anode set in said cell,
- e. means for generating a collective signal proportional to said average signal,
- f. means for selecting individually for each said anode set a first portion of said collective signal as an upper reference signal,
- g. means for selecting individually for each said anode set a second portion of said collective signal as a lower reference signal,
- h. means for comparing said amplified signal with said upper reference signal and said lower reference signal,
- i. means for activating motor means to raise said anode set when said amplified signal is greater than said upper reference signal, and
- j. means for activating motor means to lower said anode set when said amplified signal is less than said lower reference signal.

6. Apparatus of claim 5 having means for supplying a voltage to said collective signal when said collective signal falls below a predetermined limit.

7. Apparatus of claim 5 having means for energizing an indicator when said motor means are activated to adjust said space between electrodes.

8. Apparatus of claim 5 having means for visually displaying said amplified signals for each said anode set.

9. Apparatus of claim 5 having means for visually displaying said collective signal.

10. The method of claim 1, in which a voltage is supplied to said collective signal when said collective signal falls below a predetermined limit.

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