Jan. 20, 1970 J. L. DEWEY 3,491,002

ADJUSTING ANODE BLOCKS IN AN ELECTROLYTIC CELL

Filed Sept. 21, 1964 2 Sheets-Sheet 1

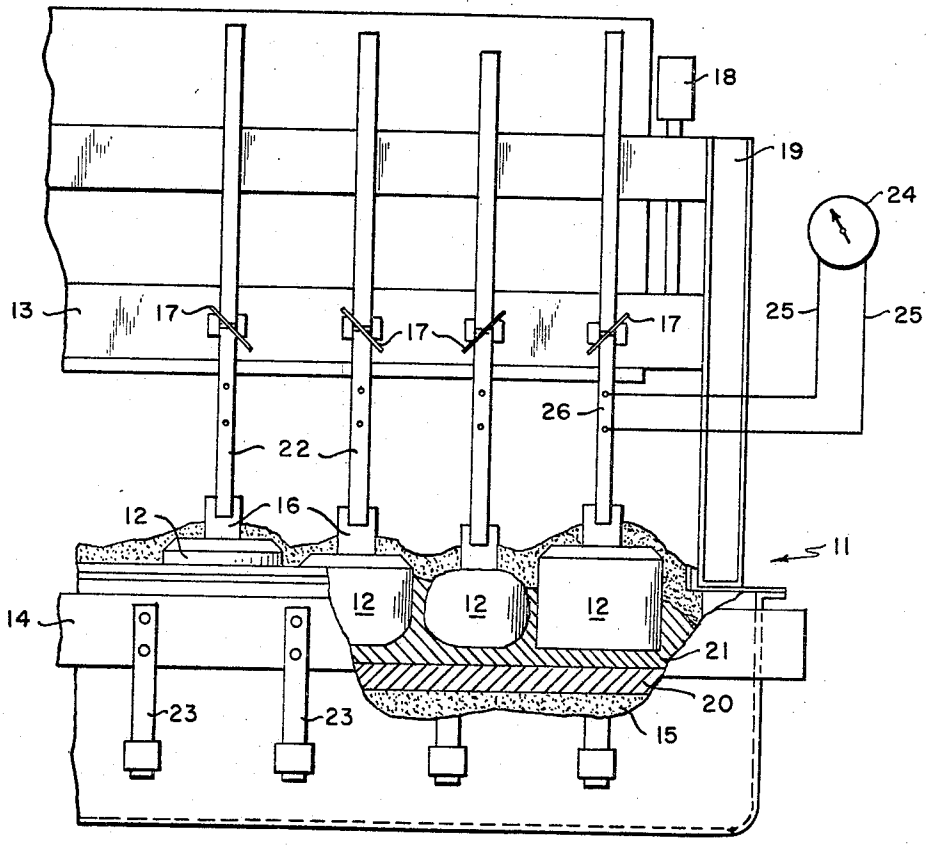

FIG. 1.

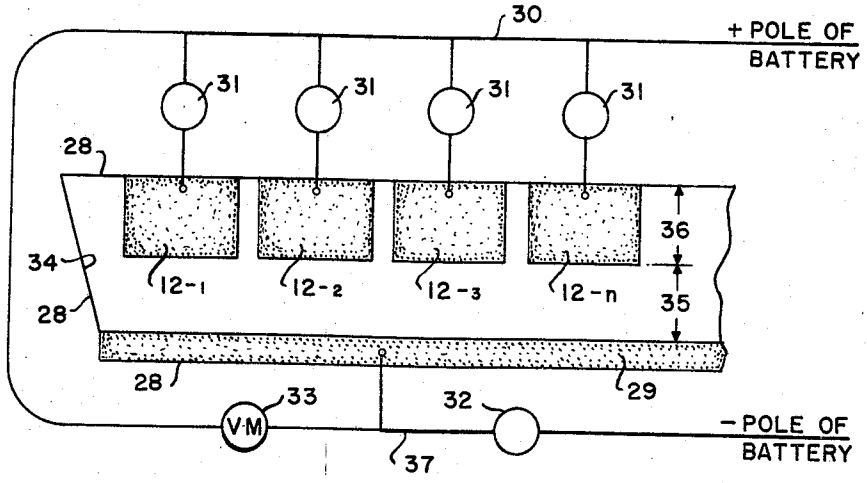

FIG. 2.

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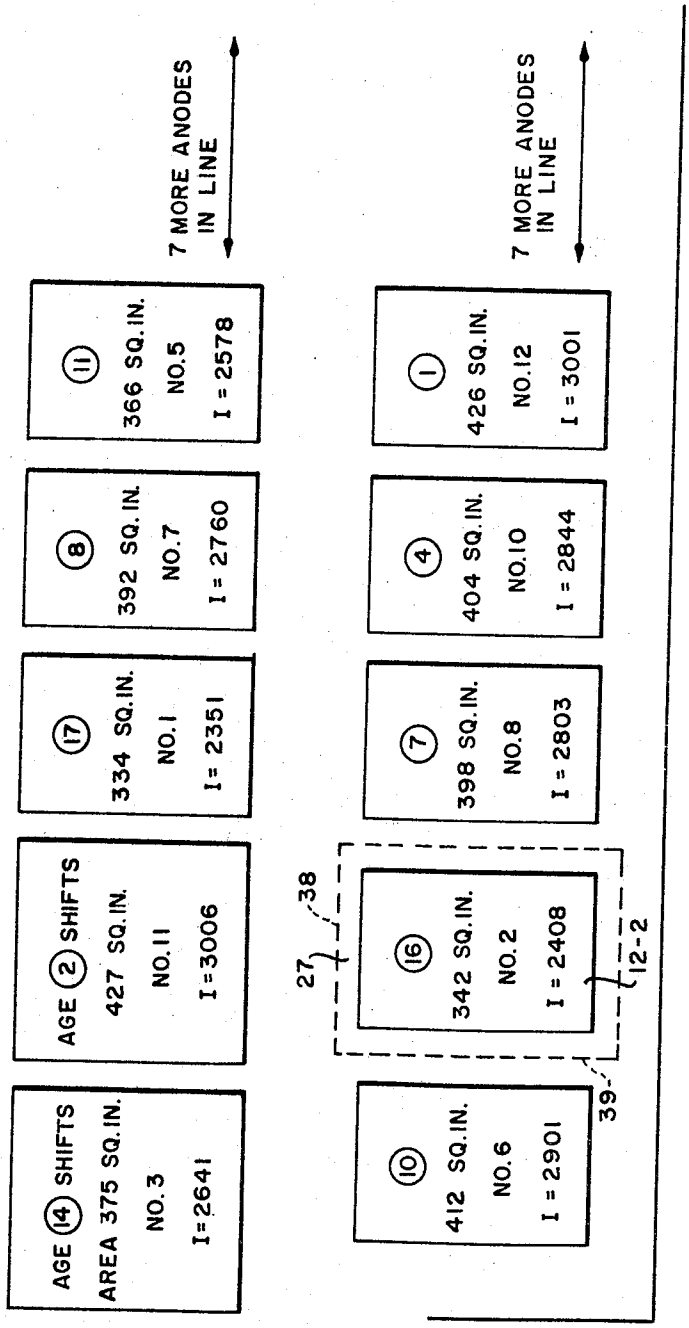

FIG. 3.

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United States Patent Office 3,491,002
Patented Jan. 20, 1970

3,491,002

ADJUSTING ANODE BLOCKS IN AN ELECTROLYTIC CELL

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Filed Sept. 21, 1964, Ser. No. 397,755
Int. Cl. B01k 3/00; C22d 3/12
U.S. Cl. 204—67 5 Claims

ABSTRACT OF THE DISCLOSURE

A method of adjusting individual anodes in a multiple anode reduction cell by first determining for each anode the size of a pseudo-area corresponding to the effective conduction area of that particular anode. Each pseudo-area may be determined by means of two-dimensional analogue models of the cell representing orthogonal vertical cross-sections thereof. A determination is made of the resistance value between each anode and the cathode of each model and these resistance values are related to a linear dimension corresponding to a side of each anode block's pseudo-area. The vertical position of each anode is adjusted so that the current therethrough bears substantially the same relation to the total current through all of the anode blocks as that particular block's pseudo-area bears to the sum of all of the pseudo-areas.

This invention relates to a method of and apparatus for adjusting the anode blocks in a reduction cell. More specifically, although not limited thereto, this invention relates to a method for adjusting the individual carbon anode blocks of a multiple anode alumina reduction cell to the natural current-carrying capacity of each block, whereby full advantage may be taken of the natural tendency of the anodes to self-adjustment and whereby variations in anode-to-cathode spacings among the blocks may be eliminated.

As far as known there is no similar method in the art. General reference is made to U.S. Patent 2,930,746 to Cooper and to U.S. Patent 2,958,641 to Reynolds which show alumina reduction cells.

The principal object of this invention is to provide a method of and apparatus for adjusting carbon anodes in a reduction cell or cells.

Another object is to provide a method of adjusting carbon anode blocks in an alumina reduction cell.

Yet another object is to provide a method of adjusting carbon anode blocks in a multiple anode alumina reduction cell to the natural current-carrying capacity of each block whereby variations in anode-to-cathode spacings among the blocks may be eliminated.

Still another object is to provide a method of preparing an electrical analog model of a reduction cell.

Other objects and advantages will clearly appear from a description of a preferred embodiment as shown in the accompanying drawings, in which:

FIG. 1 shows schematically an alumina reduction cell having multiple anodes;

FIG. 2 depicts an electrical analog of an alumina reduction cell; and

FIG. 3 represents pseudo-areas of anodes.

Similar reference characters are applied to similar elements throughout the drawings.

As is well known in the industry, the carbon from the anode of a reduction cell is converted into carbon dioxide gas during the electro-chemical reduction process so that the carbon blocks or anodes must be replaced periodically. Generally it is presently the practice to selectively replace one or more of the carbon blocks in each plural

anode cell during each work shift. A carbon block replacement schedule is followed so that the average age of the carbon blocks in each section of the cell is maintained substantially constant. Where a pot line includes a large number of multiple anode cells, for instance 140 cells each having twenty-four carbons, anode positioning and replacement is a constant and costly process that permits much error and inefficient cell operation.

Those skilled in the art recognize that at perfect adjustment substantial differences in current carrying capacity exist among the several blocks that comprise the multiple-block anode, but in conventional practice the operator still adjusts each block to about the same current loading, primarily because he has no method of accurately predicting what the current loading should be for each block, and because he has relied upon the natural tendency of the system to adjust itself during operation. I have found, however, that self-adjustment proceeds so slowly and is so frequently upset by attempts of the operator to adjust the individual blocks of a multiple block anode that a high degree of adjustment cannot be maintained and full benefit cannot be taken of the natural tendency of the anode to self-adjust. Even after the operator has attained an apparently satisfactory adjustment of the blocks he often finds, after he has had occasion to reduce the anode-to-cathode spacing, that the anode blocks are no longer in adjustment.

When the individual blocks of the anode have been adjusted to their natural current-carrying capacity in accordance with this invention the anode maintains its adjustment over long periods of time. The need for frequently adjusting the level of individual blocks is substantially reduced, and the anode-to-cathode distance may be changed as desired without the appearance of sodium flames or other manifestations of maladjusted anodes.

An important type of alumina reduction cell, indicated generally by the numeral **11**, is shown schematically in FIG. 1. This type of cell, known in the industry by various names such as "prebaked," "Niagara," etc., is particularly distinguished from other types of reduction cells by virtue of its anode. The anode in this type of cell comprises a plurality of carbon blocks **12**, each of which are individually connected to the positive side of a source of direct current electricity represented in FIG. 1 as an anode bus **13**. Each carbon block **12** is individually adjustable with respect to a carbon cathode **15**, and the set of carbon blocks that comprise the anode is vertically adjustable with respect to the cathode **15** in such a manner that the position of each block relative to the other blocks of the set is unchanged.

Each carbon block **12** is connected through an iron stub **16** cast in the block to a copper anode rod **22** which in turn is clamped to anode bus **13** by a hand operated clamp **17**. Anode bus **13** is supported at each end by a bridge jack **18** attached to cell frame **19** whereby the anode bus **13** is raised or lowered with respect to the carbon cathode **15** and a layer of molten aluminum **20** which overlies the cathode **15**, effecting a uniform increase or decrease respectively in the thickness of a layer of molten cryolite **21** disposed between the neighboring surfaces of the carbon blocks **22** and the molten aluminum **20**. Individual carbon blocks **12** may be raised or lowered by an operator with respect to the anode bus **13** and cathode **15**, after loosening the appropriate clamp **17**, with a conventional hand jack (generally used by the industry) that operates between clamp **17** and rod **22**.

The electrical circuit through the cell consists (in the order named) of the anode **13**, the anode rod **22**, the stub **16**, carbon blocks **12**, the molten cryolite layer **21**,

molten aluminum layer **20**, carbon cathode **15**, current collecting members **23**, and the cathode bus **14**. The anode bus **13** and the cathode bus **14** are connected to a suitable source of DC power (not shown). The major resistance to electrical current flow resides in the molten cryolite layer **21**, and the total cell current distributes itself among the plurality of parallel-connected carbon blocks **12** in inverse relation to the thickness of the molten cryolite layer **21** between each of the carbon blocks and the molten aluminum layer **20**.

The current flowing in each of the anode rods **22** may be measured with a suitable current-measuring means which in this embodiment comprises a suitable millivoltmeter **24** connected by suitable circuit elements **25** to opposite ends of precalibrated lengths **26** of the anode rod **22**. The relationship between the reading of the millivoltmeter **24** and the current flowing through section **26** of rod **22** is readily determined before installation in the cell by passing a known current through rod **22** while noting the reading on millivoltmeter **24**. Various other means known to the industry may be used to measure the current in rod **22**.

FIG. 3 shows the respective pseudo-areas and current loads of a representative portion of the blocks of a 24-carbon anode as determined at a time when the blocks had attained the listed ages expressed in units of 8-hour shifts. The cell was operating at 65,000 amperes of an 18-shift carbon changing schedule. The dashed box **27** represents the size of a pseudo-area having a short side **38** and a long side **39**. Each anode has a corresponding pseudo-area.

The method of adjusting each of the individual blocks to its natural current-carrying capacity comprises the steps of:

(a) Determining the size of a pseudo-area for each of the individual blocks of the anode;

(b) Adjusting the vertical position of each block so that the current through each block bears the same relationship to the total current as the pseudo-area of each block bears to the sum of all the pseudo-areas.

The current may be measured for each individual block by means of the meter **24**, and the adjustment of the block may be made by means of a hand jack after loosening the hand clamps **17**.

The size of the pseudo-area **27** for each block may be accurately determined from electrical analog models of the anode and cell, constructed in accordance with the principles used in the construction of such models for the determination of the electrical or thermal conductance of complex shapes. The pseudo-area **27** may be determined in accordance with the electrical analog model of FIG. 2 so that the pseudo-area is equivalent to the cross-sectional area of a hypothetical column of molten electrolyte, equal in height to the anode-to-cathode distance of the cell. Values of the pseudo-area **27** determined from such a model, and the desired current loadings of each block calculated therefrom, are shown for each of the blocks represented in FIG. 3. It is evident that the natural proportion of the total current that each block should carry properly adjusted is strongly dependent on the environment of the block as well as on its age, and that if the blocks are adjusted to carry substantially an average current load as in the conventional manner substantial variations of anode-to-cathode distance must exist under the set of blocks that comprise the anode.

To properly position the individual blocks **12** according to this invention the current in anode rod **22** is measured with a suitable current measuring means, for example the calibrated section **26** and millivoltmeter **24**, and the block **12** raised or lowered as needed so that the ratio of the current in rod **22** of said block **12** to the total current of the cell is equal to the ratio of the pseudo-areas **27** of said block **12** to the sum of the pseudo-areas **27** for all of the blocks **12** in the cell.

When first applying this invention to a cell in which the blocks **12** have been adjusted in the conventional manner, it is preferred to make a first partial adjustment of all the blocks **12**, raising or lowering each block about two-thirds of the amount needed, and then to make a second adjustment of each of the blocks **12**, bringing each to its natural current loading. When a new block **12** is set in a cell which has been adjusted according to this invention it is adjusted to about 90 percent of its natural current loading three hours after setting and to 100 percent of its natural current loading four hours after setting. Usually the adjustment at three hours is all that is necessary.

When the blocks **12** of a cell have been adjusted according to this invention no further adjustment is required unless the position of one or more of the blocks is mechanically disturbed, for example, by slippage of clamp **17** or by bending of an anode rod **22**. The anode-to-cathode distance of the set of blocks **12** can be adjusted substantially at will by operating bridge jack **18** without the appearance of sodium flames or other manifestations of carbon maladjustment.

The method of estimating an area $YnZn$ which is proportional to the pseudo-area **27** of block n is illustrated in FIG. 2 in which is shown schematically a vertical plane passing lengthwise of the cell and near the centers of blocks **12** along one side of the cell. The elevation view is drawn to scale on electrically conductive paper outlined by the borders **28**. The anode blocks **12–1**, **12–2**, **12–3**, **12–*n*** and the aluminum metal cathode **29** are painted on the paper with electrically conductive silver paint. Each block **12–1** . . . **12–*n*** is connected in parallel with, say, the positive pole of a source of electrical potential (not shown) through a bus **30**. In series with each block is a milliammeter **31**. The aluminum metal cathode **29** is connected with the negative pole of said electrical source through a negative bus **37**. A milliammeter **32** may be inserted in negative bus **37** if desired, for use in checking the readings and the computations. Voltmeter **33** is across the supply. The edge **34** of the paper is cut to represent, in accordance with measurements, the end-wall ledge of the reduction cell. The anode-to-cathode distance is represented by the dimension **35** and the height of molten electrolyte on the vertical surface of the carbon blocks is represented by the distance **36**. The electrical potential E between positive bus **30** and the negative bus **37** is measured by voltmeter **33**. The blocks **12** are shown as rectangles **12–1**, **12–2**, **12–3**, **12–*n*** for ease of illustration. However, the precision of carbon adjustment may be improved as the shape of the blocks **12–*n*** more nearly conforms to the observed shape of the blocks **12** of the reduction cell.

When the busses **30**, **37** are energized the resistances R–1, R–2, R–3, R–*n* of the parallel circuits through blocks **12–1**, **12–2**, **12–3**, **12–*n*** are readily calculated as the ratio of the voltage read on voltmeter **33** to the individual circuit currents read on ammeters **31**. From the resistivity R_0 of the paper and the length (X) of the dimension **35**, a length (Y) which is proportional to the length of the side **38** of pseudo-area **27** of FIG. 3 is obtained from the relation $Y_n=R_0X/R_n$. Values of Y_1, Y_2, Y_n are similarly calculated for all of the blocks **12** represented in FIG. 2, which may comprise all of the blocks **12** along one side of the reduction cell.

Values of Y_n for the blocks along the other side of the reduction cell are determined in the same manner from a similar model wherein the blocks **12** are drawn according to the shape of the blocks on said other side.

Values of Z_1, Z_2, Z_3, Z_n, which are proportional to the length of side **39** of pseudo-area **27**, are determined in the same manner from scale models of planes bisecting opposite carbons in the rows, for example, carbons **3** and **6**, carbons **11** and **2**, etc., of FIG. 3.

The pseudo-area **27** is representative of the effective conduction area of the corresponding carbon block (n),

and, is proportional to the product of Z_n and Y_n and the proportion of the total cell current I to be carried by carbon block (n) is given by the ratio of Y_nZ_n to $\Sigma_i[(Y_i)(Z_i)]$ wherein the summation i is taken over all the blocks in the cell.

The block (n) in the cell is set in a vertical position, in accordance with the reading of the rod meter **24**, to the current given by the relation $I_n=I\cdot Y_nZ_n/\Sigma_i(Y_iZ_i)$ whereby the block (n) is set to its natural current-carrying capacity.

Values of the ratios may be determined, as set forth above, for the set of blocks at various ages over the carbon-setting cycle. These values may then be used repetitively for setting the carbons during each successive cycle so long as the carbon-setting cycle is not changed.

This invention rests on the discovery that the natural current-carrying ability of an anode which in operation shows a substantial electrochemical overvoltage, about 30 percent of the cell voltage for alumina reduction cells, can be determined in the same manner as the natural current-carrying ability of an electrochemically inert system, thereby eliminating the difficulty which has heretofore forestalled advances in the methods of operating electrochemical cells.

Those skilled in the art, being apprised of this discovery by virtue of my detailed description of one embodiment of this invention, may readily devise other means of practicing this invention without departing from the concepts of discovery and teaching. Accordingly, it will be apparent that the embodiment shown is only exemplary and that various modifications can be made within the scope of my invention as defined in the appended claims.

What is claimed is:

1. A method of adjusting individual carbon blocks of an anode that is adustably spaced with respect to the cathode of a reduction cell comprising the steps of:

determining for each anode block the size of a pseudo-area corresponding to the cross sectional area of a column of molten electrolyte having a height equivalent to the distance between the anode and cathode of said cell and a resistance equivalent to the resistance between the particular anode block and the cathode, said determination of each such pseudo-area comprising the steps of:

(i) determining a first resistance value between each individual anode block and the cathode, said first resistance value being determined for a first vertical cross section of said cell;

(ii) relating each of said first resistance values to a first linear dimension for each of said anode blocks, each of said first linear dimensions representing a first side of the corresponding anode block's pseudo-area;

(iii) determining a second resistance value between each individual anode block and the cathode, said second resistance value being determined for a second vertical cross section of said cell orthogonal to said first vertical cross section;

(iv) relating each of said second resistance values to a second linear dimension for each of said anode blocks, each of said second linear dimensions representing a second side of the corresponding anode block's pseudo-area;

(v) multiplying each of said first linear dimensions by the second linear dimension corresponding to the same anode block so as to determine each anode block's pseudo-area; and

adjusting the vertical position of each individual anode block so that the current therethrough bears substantially the same reltionship to the total current through all of said anode blocks as the respective pseudo-area of each anode block bears to the sum of all said pseudo areas.

2. The method of claim **1** wherein said pseudo-areas are determined by means of analogue models.

3. The method of claim **2** including the steps of:

constructing a first two-dimensional analogue model of said cell representing said first vertical cross section thereof; and

constructing a second two-dimensional analogue model of said cell representing said second vertical cross section.

4. The method of claim **3** wherein the determination of the resistance value between each of said anodes and the cathode of said analogue models includes the steps of:

connecting a source of electrical power across said analogue models;

measuring the current and voltage values between each anode and the corresponding cathode of the analogue models; and

dividing each voltage value by the corresponding current value.

5. The method of claim **3** wherein the relating of each said resistance value to each said corresponding linear dimension comprises the steps of:

determining the resistivity between the related anode and the cathode of the corresponding model;

determining the anode-to-cathode distance of the corresponding model; and

dividing the product of said resistivity and said anode-to-cathode distance by said corresponding resistance value.

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U.S. Cl. X.R.

204—1, 225, 243; 235—61.5