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METHOD AND ARRANGEMENT FOR REGULATING THE ELECTRICAL EFFECT TO ELECTROLYSIS FURNACES COUPLED IN SERIES, PARTICULARLY FOR THE PRODUCTION OF ALUMINIUM

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FIG. 1.

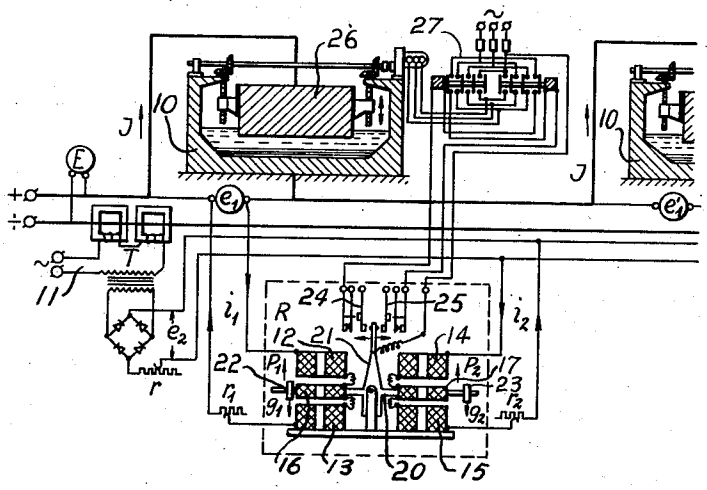
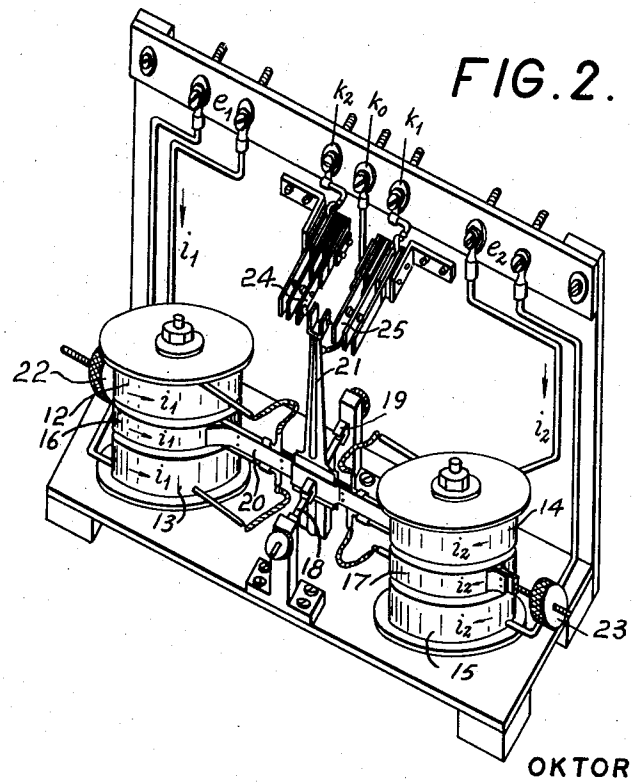


FIG. 2.



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METHOD AND ARRANGEMENT FOR REGULATING THE ELECTRICAL EFFECT TO ELECTROLYSIS FURNACES COUPLED IN SERIES, PARTICULARLY FOR THE PRODUCTION OF ALUMINIUM

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3 Claims. (Cl. 204—225)

The present invention relates to electrolysis furnaces coupled in series, particularly for the production of aluminium.

When operating with furnaces the individual regulation of each furnace is carried out by varying the distance between the electrodes. The object of such regulation of the electrode distance is to maintain the mean distance between metal surface and the under side of the anode, being once determined for the furnace type, as constant as possible during the operation. During the production process the level of metal in the furnace will rise between two discharges, from a lower value corresponding to the reserve of metal to a higher value, which should not be exceeded due to the construction of the furnace.

Simultaneously that part of the anode which is positioned in the electrolysis bath and facing the metal surface, will be consumed, and cause a shortening of the anode in the vertical direction of the bath.

The rise of the metal level and the shortening of the anode will thus act against each other and the result is in the commonly used furnace types that the anode with intervals must be descended in order to maintain a constant distance between the metal surface and the under side of the anode.

This adjustment of each furnace in the period between two discharges of metal is usually called the "daily adjustment." After each discharge a readjustment is likewise necessary, as the anode then must be lowered as much as the level of metal has decreased during the discharge.

The control of the adjustment is made by a voltmeter, which should indicate a predetermined value after each adjustment as long as the current through the furnace—otherwise under the same condition—is the same as before the adjustment.

Usually the regulation is done manually by means of a hand wheel and a worm screw or by means of a reversible gear motor controlled by a contactor and press buttons.

When the distance between the electrodes in one of these ways is increased or diminished a corresponding increase or decrease in the part of the total electrical resistance of the furnace results, which is due to the electrolytic bath between the metal surface and the anode. This means that the regulation can only influence a part of the voltage of the furnace. By electrolysis of aluminium this part may for instance amount to about $\frac{2}{5}$ of the total furnace voltage. The remaining part consists in a constant part being about $\frac{1}{3}$ of the total furnace voltage and representing the chemical decomposition voltage and a part being about $\frac{1}{15}$ of the total furnace voltage and representing the ohmic drop in voltage in the anode and the cathode, the conducting bars and their connections to the furnace.

As the production of metal in an electrolysis furnace is proportional to the value of the electrical current passing through the furnace, it is normally desired to operate the furnace with a current as closely as possible to the desired value.

The predetermined normal current is desired to be kept as constant as possible and in order to obtain this the electrical equipment transforming the current from alternating to direct current is provided with regulators of different kind and construction.

Common to such regulators in rectifying plants of modern construction is that they are all automatic and that their action is based upon a device sensitive to current variations regulating the voltage of the whole of series of furnaces when the total electrical resistance of the series of furnaces increases or decreases during the operation.

At constant voltage of the alternating current of the rectifier plant the direct current is generally regulated coarsely by hand in regulating transformers and regulated finely by means of the said automatic regulators inside the single voltage steps of the regulating transformers.

Experience from existing plants in aluminium factories have, however, shown that usually during operation so large variations in the electrical resistance of the furnaces occur that it has not hitherto been possible by means of the described manual regulation for each furnace and the automatic regulation of the whole series of furnaces to keep the current in the furnace as constant as desired for economic production.

Variation in the current of up to 5 and 10% is thus not usual even in modern plants. The main cause for the variations in the electrical resistance of the furnaces by the electrolysis of aluminium is the anode effect characteristic for this electrolysis resulting in tension of a furnace at certain intervals suddenly rising to a value many times the normal (up to 10 times) and with a duration of 5 to 10 minutes for each furnace.

When this anode effect, also called "lighting" occurs simultaneously at several furnaces of a series, the total resistance can increase to such an extent that automatic fine regulator is incapable of increasing this voltage sufficiently for maintaining the normal current through the furnaces. The result is thus that the current decrease and the production is reduced for the duration of the anode effect.

Another cause of variations in the electrical resistance of the furnaces is the bath temperature.

When the temperature of the bath for a reason, for instance lowering of the current decrease, the resistance of the bath increases and the voltage of the bath will increase when the current is kept constant. The opposite will occur if the temperature for some reason increases.

Among other causes for variation in the resistance, apart from the variation in the distance between the metal surface and the underside of the anode caused by the operation, can be mentioned the chemical composition of the electrolytic bath and the condition of the places of contact between the conducting bars and the places of contact between these bars and the anode and the cathode.

The described problems of operation of electrolysis furnaces for aluminum, show that method of regulation used hitherto with manual regulation of the voltage of each furnace by varying its voltage cannot be said to satisfy the operational requirements demanded of an automatically operated servo-technical system, being incapable of utilizing the installed production capacity under variable operation condition as well as desirable.

The present invention has the object of eliminating the described deficiencies of the regulating means now in use through the introduction of an automatic regulator for each furnace with properties enabling it in addition to

regulating the resistance of the furnace it is controlling also in cooperation with the regulators of the other furnaces of the series to influence the total resistance of the series so that this is kept constant during varying operation conditions.

The arrangement according to the invention presupposes that each furnace is provided with a mechanism for regulating the electrode distance an electrical drive for reversible movement of said mechanism and a reversing contactor for reversing the drive. The characteristic feature of the arrangement consists therein that for each furnace there is provided two control circuits for said contactor and a regulator for closing and opening of these circuits which regulator is supplied partly with a voltage equal to or proportional to the voltage of the furnace and partly with a reference voltage proportional to the current and containing a circuit breaker closing the one or the other of the said control circuits when the difference between the said voltage supplied to the regulator exceeds a predetermined value and that a means common to all the furnaces is producing the reference voltage proportional to the power of the current.

The invention also comprises a regulator for an arrangement according to the invention. The particular feature of this regulator is that it contains partly two coil systems, each with two fixed and one movable coil arranged as a "Lord Kelvins current balance," the movable coils being attached one to each end of a swingably supported lever arm, and two by swinging of the said lever operated circuit breakers, one coupled to each of said control circuits.

Further features of the regulator will be described below.

The invention further comprises a method for the operation of the electrolysis furnaces coupled in series using an arrangement and regulator according to the invention, and will in the following be described more closely in connection with the drawing in which:

Fig. 1 schematically illustrates an arrangement according to the invention, showing only of the electrolysis furnaces coupled in series together with its reversing contactors and regulator.

Fig. 2 is a perspective view of the regulator shown schematically in Fig. 1.

In Fig. 1:

E=the total busbar voltage of the series of furnaces **10**, which is presupposed to be constant and adjusted by means of for instance regulating transformers (not shown) to a value considered required for the number of furnaces in operation.

I=the current through the furnaces **10**.

T=a current transformer **11** gives a reference voltage e_2 proportional to the current I and which can be varied by means of the resistance r to the value desired at the moment.

R=the regulator described above coupled to furnace No. 1.

r_1 and r_2=adjusting resistances permitting individual adjustment of the desired furnace voltage if this should be required due to the bath temperature or other causes.

p_1 and p_2=forces produced by the currents i_1 and i_2 in the system of coils in the regulator.

The mode of action of the apparatus will better be understood from a closer description of the regulators.

Fig. 1 shows the principal and the vital parts of the regulator consisting mainly of two equal systems of coils and a system of contacts. The two systems of coils are constructed in a manner known per se as a "Lord Kelvin's current balance" with four fixed coils **12**, **13**, **14** and **15** and two movable coils **16** and **17** mounted symmetrically on a lever **20**, a horizontal axle **18**, which may be supported by pivots in jewel bearings or as shown on the drawing by means of flexible bands **19**. The shown method of support results in, apart from great sensibility, in the vertical contact arm mounted **21** at the middle of and at right angle to the lever arm keeping in the dead zone without extra springs when the two systems otherwise are in balance.

The two fixed and the one movable coil e.g. **16** at each end of the middle axis are coupled in series in such a way that the resulting force between the current carrying coils e.g. **12** and **13** is direcetd upwards.

Each of the movable coils is also provided with an adjustable counter weight **22** and **23** acting in opposition to the force caused by the current in the corresponding system of coils. In order to simplify the description it is supposed that the two counter weights are equally large and that adjustment of their torque is carried out by varying the length of the arm they are acting upon.

If the same voltages e_1 and e_2 are impressed upon the two systems of coils, the resulting currents i_1 and i_2 will also be the same if the number of turns and section of the wire is the same in both systems. With the same adjustment of the counter weights the forces g_1 and g_2 causing the turning movement of the two systems in respect of the middle axis will be alike and opposed so that the contact arm **21** will keep stationary in the dead zone as shown on the drawing.

When the voltages e_1 and e_2 are different and/or when counter weights **22** and **23** are adjusted differently a turning torque in respect of the middle axis will result, which, if the difference exceeds the sensitivity of the current balance, will cause the contact lever **21** to turn to the one or the other side from the middle position until it connects with the nearest contact spring **24** or **25** which through a holding contact coupled in series in a manner known per se closes the circuits either in an intermediate relay or directly in the one of the control circuits operating the reversing contactor **27**.

If the resulting torque to the one or the other side exceeds a limiting value determined by the spring loading of the contacts, which can be adjustable, the said holding contact coupled in series will open and the current in the control circuit will be interrupted until the torque falls below the said limiting value.

The mode of operation of the arrangement on Fig. 1 will now be described:

The furnace voltage is lead directly or through a variable resistance to the terminals of the one system of coils marked e_1, and the voltage from an outside source, also called the reference voltage, is lead in the same way directly or through a variable resistance to the terminals for the other system of coils marked e_2.

The three terminals of the contact system marked K_0, K_1 and K_2 are connected in a manner known per se to the operating coils of the reversing contactors for the motor supposed to be mounted on the furnace for raising and lowering the anode.

Supposing firstly that the counter weights are so adjusted that the torque g_1 exceeds g_2 by an amount equal to but opposed to the torque caused by the voltage of chemical decomposition, then the regulating curves for the two systems of coils will be exactly alike. This will mean that at constant current through the furnace **10** a variation up or down of the reference voltage e_2 will result in an equal increase or decrease of the furnace voltage e_1 and at constant reference voltage e_2 a variation up or down of the current will result in a regulation up or down of the bath resistance **26** until the furnace voltage e_1 has assumed the same value as before the current was varied.

With a different adjustment of the counter weight the regulator can at will be given over- or under-regulating properties so that a variation up or down of the reference voltage will cause a larger or smaller variation of the furnace voltage. This again will mean that at constant reference voltage a variation up or down of the current through the furnace will cause a regulation up or down of the bath resistance until the furnace voltage has as-

sumed a value smaller or larger than before the current was varied.

The purpose of the holding contacts coupled in series is that the regulating means for instance the motor is to be uncoupled each time the furnace voltage exceeds or falls below certain limiting values, for instance when the furnace assumes the "lighting" condition or when a conductor to the regulator is broken.

By use of the regulator for the operation of aluminium furnaces coupled in series, the counter weights are according to the invention adjusted in such a way that the torque g_2 is larger than the torque g_1 and that the difference together with the torque from the current caused by the voltage of chemical decomposition causes a reduction in the bath resistance when the current through the furnaces and the reference voltage proportionated here to falls below the predetermined normal value due to an increase in the resistance of one or more furnaces caused for instance by the anode effect. Inversely an increase of the bath resistance is obtained when the current through the furnaces for one reason or another exceeds the predetermined value.

With a correct adjustment of the counter weights the regulator will in this way be able to compensate all variations in the total resistance of the series of furnaces which would be sufficient for reducing the current through the furnaces.

Otherwise expressed the regulator coupled to each furnace of a series has a double purpose of in addition to making the required regulation of the anode distance in the furnace it is controlling, also co-operating with the regulators of the other furnaces for the purpose of keeping the combined bath resistance of the series of furnaces constant.

It can be mentioned that for the use of the regulator described above, actually one counter weight is sufficient for instance g_2 giving a turning torque in the same direction as that caused by the voltage of chemical decomposition.

The combination of these torques gives the device the property of lowering the anodes of the furnaces, which are not blazing, so much that the increase in the voltage of the furnaces, which are "lighting" is compensated as far as possible. When $g_2=0$ the compensation is very small and full compensation is really only obtained when g_2 is infinitely large.

If it is desired to use the regulator also for regulating one single furnace at constant anode distance, only one counter weight is necessary but then g_1 is given such a value that its torque is equal but opposed to the torque caused by the voltage of the chemical decomposition.

Other means than the proposed counter weights can be used for obtaining the desired effect for instance the force from supplementary coils with an independent source of voltage or from permanent magnets, but these means have the disadvantage that their magnetic field may disturb the electromagnetic fields of the system of coils of the regulator.

I claim:

1. An arrangement for regulating the electrical effect for a plurality of electrolysis furnaces coupled in series, particularly for the production of aluminum, comprising a means common for all the furnaces for producing a reference voltage proportional to the current through the furnaces and comprising further a mechanism for each furnace for regulating the electrode distance, said mechanisms each comprising an electric drive for reversible movement of the said mechanism, a reversing contactor for the drive, two circuits connected to said reversing contactor for controlling the reversing contactor, and a differential relay in said two circuits for closing and opening these circuits, which relay comprises a first coil supplied with a voltage proportional to the voltage of the furnace, and a second coil supplied with a reference voltage proportional to the current, and a rotatable lever carrying one of said coils and a circuit breaker for closing one of the control circuits when the difference between said voltages supplied to the relay exceeds a predetermined value, and said lever carrying further adjustable means for applying to said lever a torque adjustable independent of said voltages.

2. A regulator for regulating the electrical effect for a plurality of electrolysis furnaces coupled in series, comprising a rotatably supported lever, a coil system at each end of said lever, each system comprising a coil attached to said lever at one end thereof, and two stationary coils mounted adjacent the end of said lever, one coil being on one side of the coil on said lever and the other coil being on the other side of the coil on said lever with said two coils spaced from and aligned with the coil on the end of said lever and with each other for causing a force tending to rotate said lever by the resistance of the forces produced when said coils are energized, the coil system at the one end of the lever being supplied with a voltage proportional with the voltage of one of the furnaces and the other coil system being supplied with a voltage proportional to the current through the furnace, said regulator further comprising a weight adjustably mounted on said lever, two contacts attached to the lever and two stationary contacts mounted adjacent said lever, one for cooperation with one of the movable contacts, each two cooperating contacts constituting a circuit breaker for closing and opening circuits for controlling a mechanism for regulating the electrode distance in the furnace.

3. A regulator according to claim 2, in which a holding contact for each circuit breaker is mounted adjacent said lever and is closed by the swinging of the lever, said holding contact being opened again if the turning torque upon the lever exceeds a predetermined value.

References Cited in the file of this patent

UNITED STATES PATENTS

2,545,411	Perret-Bit	Mar. 13, 1951
2,545,412	Perret-Bit	Mar. 13, 1951
2,545,413	Perret-Bit	Mar. 13, 1951
2,757,137	Petrovich et al.	July 31, 1956