

June 1, 1971

M. O. SEM

3,582,483

PROCESS FOR ELECTROLYTICALLY PRODUCING ALUMINUM

Original Filed June 29, 1962

3 Sheets-Sheet 1

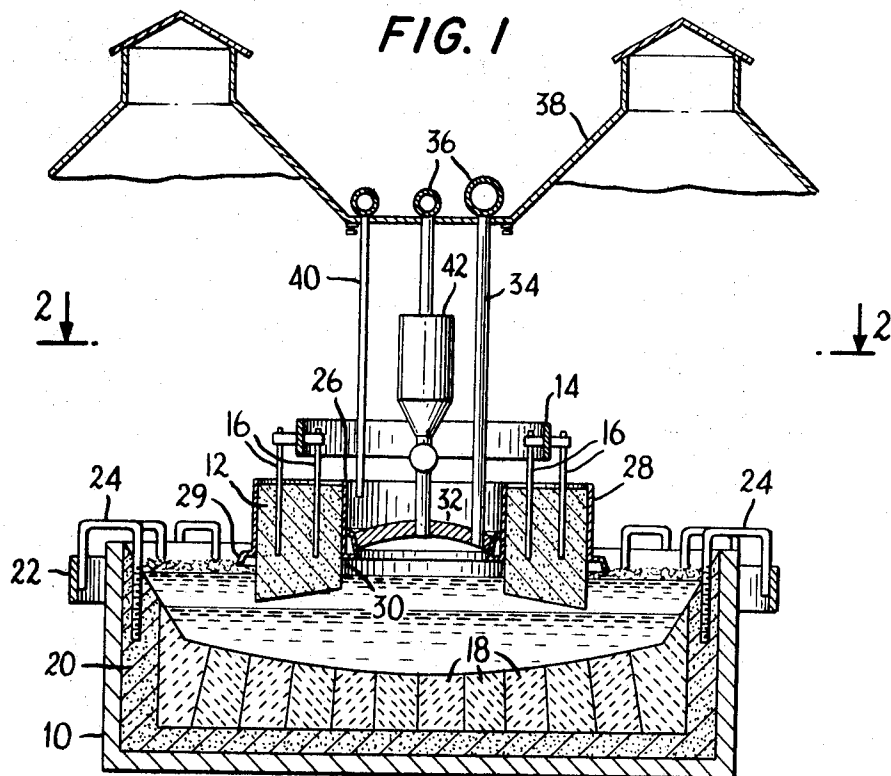
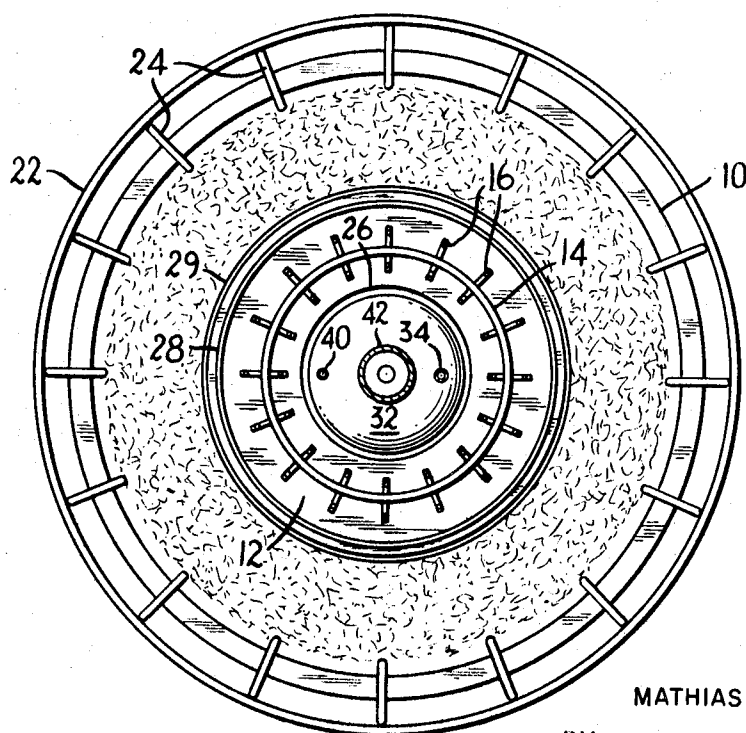


FIG. 2



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3 Sheets-Sheet 2

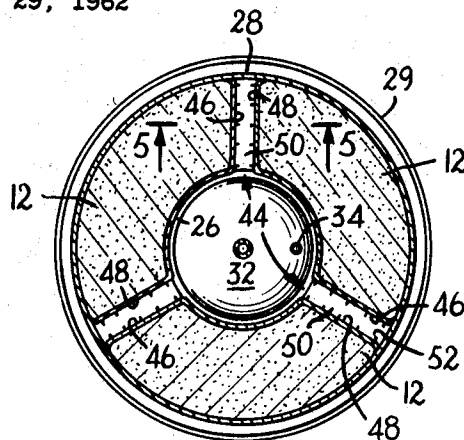


FIG. 3

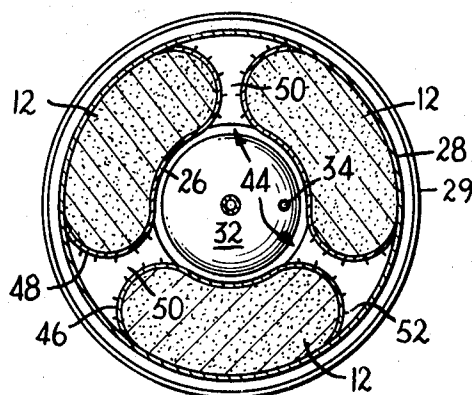


FIG. 4

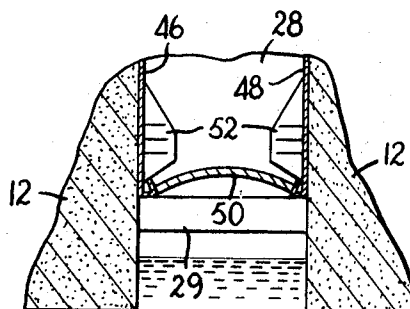


FIG. 5

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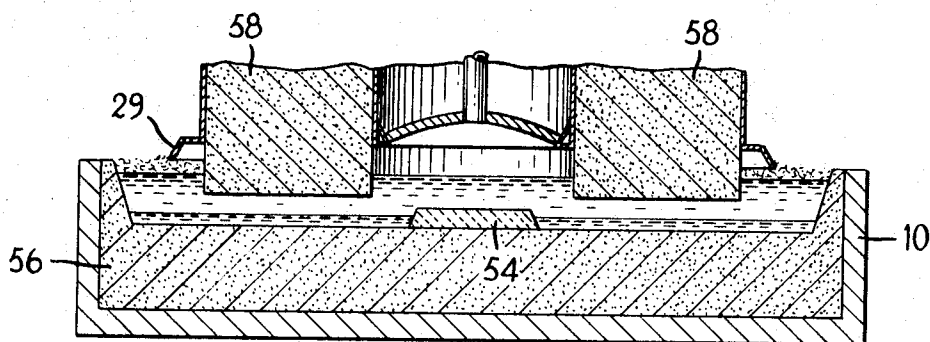


FIG. 6

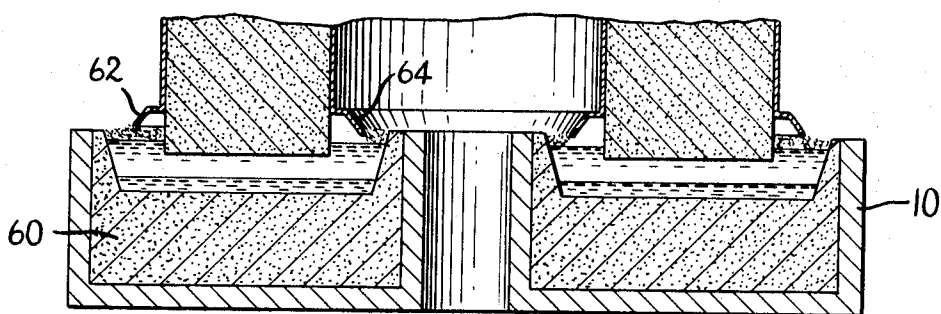


FIG. 7

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3,582,483 PROCESS FOR ELECTROLYTICALLY PRODUCING ALUMINUM

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Original application June 29, 1962, Ser. No. 210,289, now
Patent No. 3,368,960, dated Feb. 13, 1968. Divided
and this application Sept. 18, 1967, Ser. No. 669,360
Int. Cl. C22d 3/02, 3/12
U.S. Cl. 204—67 4 Claims

ABSTRACT OF THE DISCLOSURE

An electric furnace for production of aluminum by melt electrolysis is provided with an overhead annular Soderberg anode having a hollow center coextensive with the longitudinal anode axis. The furnace is operated under a load above 100,000 amperes and up to about 500,000 amperes, said high load being made possible by the annular configuration of the anode.

This application is a division of my copending application Ser. No. 210,289, filed June 29, 1962, now U.S. Letters Pat. No. 3,368,960 issued Feb. 13, 1968.

Since the invention of the continuous Soderberg anode for production of aluminum by melt electrolysis, considerable development work has been carried out to increase the capacity of commercial furnaces.

The shape of the anode is one of the most important factors to consider in determining the capacity of the furnace. Early anodes were in the form of cylinders which are still used today in small furnaces of limited capacity. For efficient commercial operation the diameter of the cylinder is limited to a maximum of about 2.5 meters and the load to about 30,000 amperes.

A tremendous improvement in furnace capacity was achieved by means of rectangular or oblong shaped anodes. These anodes were able to carry much larger ampere loads and there are commercial furnaces in operation today in which the rectangular anode carries a load of about 120,000 amperes. The rectangular anode in such a furnace is about 2.5 meters wide and 12.5 meters long. Still larger rectangular anodes capable of carrying a load of 150,000 amperes have been proposed but difficulties have been experienced in operating the large furnaces.

Rectangular anodes are most efficiently operated when the anode is about five times as long as it is wide and in the larger furnaces having a capacity of 120,000 amperes or more the anode is so long that it is extremely difficult to obtain even current loads in both ends of the anode. Uneven current loads tend to interfere with the efficiency of the furnace and a further drawback is experienced in that an uneven current load causes uneven stresses and strains in the bottom of the furnace and the furnace lining has a considerably shorter life than that in the smaller size furnaces. The life of the furnace lining in the smaller size furnaces of about 50,000 amperes will usually average about four years whereas the life of the furnace bottom in the larger furnaces seldom lasts more than two years. Experience has shown that the larger furnaces can not be economically operated and today the tendency in the aluminum industry is to limit the load on the anode to about 80,000 to 100,000 amperes.

In accordance with the present invention there has now been devised an electric furnace for the production of aluminum by melt electrolysis which utilizes an annular or ring shaped anode capable of operating under a load of 250,000 amperes or more. In a preferred form of structure the outside diameter of the anode is about 7.0 meters and the inside diameter is about 2.0 meters giving an

anode width of about 2.5 meters throughout. Such an anode under a load of 250,000 amperes will have a current density of about 0.75 ampere per square centimeter.

The symmetrical construction of the present invention has many advantages which tend to reduce the cost of construction and operation of the furnace. For example, the symmetry of the structure makes it possible to provide a uniform current load in the anode which will eliminate stresses and strains in the lining of the furnace bottom caused by the uneven current load experienced with anodes in rectangular furnaces. A uniform current load also provides well balanced operating conditions in the furnace which are important for efficient operation and under such well balanced conditions the annular anode and circular cathode will both tend to keep their shape without using those expensive reinforcements required in rectangular furnaces.

The hollow space in the center of the anode may be used to advantage for automatic and continuous charging of alumina and if desired the hollow space may be covered with a roof and all or only a part of the furnace gases may be collected beneath the roof in the hollow space of the anode. If all of the gas is to be collected beneath the cover in the hollow space, one or more channels are arranged in the anode to connect the peripheral part of the furnace with the hollow space in the center of the anode.

Collection of gas is helped by sloping the bottom surface of the anode upwardly toward the hollow space in the center of the furnace. When this is done furnace gases which ordinarily tend to collect on the bottom surface of the anode will have a natural tendency to flow upwardly into the hollow space. The slope or taper on the bottom surface of the electrode is readily achieved by distributing the current in the anode in such a way that there is a higher amperage maintained in the inner portion of the anode than in the outer portion. This may be done for example by positioning a greater number of contact rods in the inner portion of the anode than there are in the outer portion.

The current may be led away from the furnace bottom in known manner as for example by means of iron reinforcements embedded in an electrically conductive furnace bottom. The current may if desired also be led away only through the peripheral portion of the furnace bottom as for instance by means of an annular member of electrically conductive material such as blocks of coal or graphite or materials like TiB_2 , ZrB_2 , etc., which are not subject to attack by liquid aluminum at the temperatures experienced in operation. By leading the current away through the peripheral portion of the furnace bottom there is no need for metallic reinforcements normally used in the bottom of the furnace. If the current is led away from the peripheral portion of the furnace the remainder of the furnace bottom is lined with conventional refractory material which will not conduct electricity.

As is known the best possible electromagnetic conditions in an aluminum furnace are obtained when the current path between the anode and cathode is as close to a vertical line as possible. With the annular anode of the present invention, it will be difficult to obtain vertical current paths in the center of the furnace below the hollow space in the anode. This situation may be greatly improved by positioning a block of electrically non-conductive or poorly conductive material on the cathode below the hollow space of the anode. The block may consist of Carborundum of such height that the top of the block is above the highest level of liquid aluminum in the furnace. The liquid melt will then form in a ring on the furnace bottom directly below the annular anode. In really large furnaces of 400,000 to 500,000 ampere load the hollow space in the center of the anode may

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have a diameter of 4 to 5 meters or more. In such case it may be desirable to employ an annular furnace pot.

The furnace of the present invention may be tapped in known manner and in the case of the large size furnaces tapping should be carried out continuously which may be done for example through pipes or refractory materials such as TiB_2 or ZrB_2 .

Conventional furnace bottoms are usually constructed of blocks of baked carbon which may be employed to line the bottom of the furnace of the present invention. These baked blocks however expand when the furnace is heated up to operating temperature and movement in the furnace bottom caused by expansion tends to reduce the life of the bottom. In accordance with the present invention applicant has found that such movement may be avoided by using a mixture of baked and unbaked blocks of graphite or carbon electrode paste. The unbaked blocks will during the heating period shrink and as a practical matter the shrinkage will so closely correspond to the thermal expansion of the baked blocks that the furnace bottom will show little or no expansion while the furnace is heated to operating temperature. In some cases it may be desirable to adjust the arrangement of the blocks so as to obtain a very slight thermal expansion during the heating period.

These and other advantages and the details of the structure of the present invention are schematically illustrated in the drawings in which

FIG. 1 is a vertical section through one form of furnace

FIG. 2 is a top view taken on line 2—2 of FIG. 1
FIGS. 3 and 4 are horizontal sections through modified forms of annular anode

FIG. 5 is a sectional view taken on line 5—5 of FIG. 3 which illustrates a channel through the anode

FIGS. 6 and 7 are vertical sectional views illustrating modified forms of furnaces.

In the drawings 10 is the furnace shell while 12 is the annular anode which may be suspended by any convenient means. As illustrated in the drawing the anode is suspended from an annular bus bar 14 by means of contact studs 16 which supply current to the anode. The contact studs are the type conventionally used for suspending the ordinary type of continuous Soderberg anode. As in conventional furnaces the vertical position of the anode is changed during operation of the furnace by changing the position of the bus bar by means of jacks (not shown). Two rows of contact studs 16 are shown in the drawing but any desired number of rows may be employed and the studs need not be symmetrically arranged in the anode.

The bottom of the furnace is lined with blocks 18 which are shaped to form a spherical surface and in the preferred form of structure a keystone block such as that employed in stone bridges (not shown) may be employed to guard against the bottom rising up in the furnace.

In the form of structure shown blocks 18 are made of conventional refractory material which will not conduct electricity. The current is led away by means of an annular member 20 (cathode) which consists of graphite blocks electrically connected to an annular metal cathode bar 22 by means of iron rods 24 which are preferably screwed into the graphite ring so that they may be readily removed and replaced without disturbing or discontinuing furnace operation. In the structure of the furnace shown in FIG. 1 electromagnetic forces will cause the molten aluminum to move toward the central part of the furnace. Because of this movement the bottom surface of the anode will be shaped to slope upwardly toward the central part of the furnace. This slope on the bottom surface of the electrode is of advantage in that gas bubbles which ordinarily collect on the bottom surface of the anode will tend to move into the hollow space in the center of the anode.

The anode is molded by feeding conventional electrode paste into the annular space between an inner and an

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outer permanent metallic casing 26 and 28 respectively.

The electrode paste is baked as it slides down through the space between the permanent casings in a manner similar to the way in which the paste is baked in a conventional circular continuous Soderberg anode. Additional unbaked paste is fed in at the top as the anode is consumed during furnace operation. The outer and inner permanent casings may be suspended in the furnace in any convenient manner as for example by metal straps (not shown) attached to the casings and to the roof or support beam in the furnace building or any conventional suspension mechanism may be employed.

Outer casing 28 is equipped with a circular gas hood 29 in which furnace gases are collected. The gas hood is of known construction and the gases may be withdrawn from the hood by one or more pipes (not shown). One example of such a gas hood is described in U.S. Letters Pat. No. 2,526,876.

The inner casing 26 is preferably equipped with an annular flange 30 which supports a roof 32 that covers the hollow space in the center of the anode in which furnace gases collect. The furnace gases in the hollow space are withdrawn by means of a pipe 34 which connects the hollow space with a manifold 36 which is most conveniently arranged on the roof of the furnace building 38. Thereafter the furnace gases are processed in conventional manner. Air is injected into the hollow space above roof 32 by means of a pipe 40 in order to cool the inner casing. Alumina is fed into the hollow space in the center of the anode by means of conventional feeding equipment indicated at 42. The furnace may be tapped in conventional manner or continuously tapped by pipes of TiB_2 (not shown) arranged in the bottom of the furnace.

Modified forms of the anode of the furnace of FIG. 1 are illustrated in FIGS. 3 to 5. As there shown gas channels 44 are cut through the annular anode 12 to connect the hollow space under the gas hood 29 with the hollow space under roof 32 in the center of the furnace. The walls of channels 44 are formed by metal casing members 46 and 48 which connect the inner casing 26 with the outer casing 28. As best shown in FIG. 5 the channels through the anode are provided with a cover or roof 50 which connects the base of the casing members 46 and 48. Air supplied by pipe 40 will be circulated through channels 44 above roof 50 and the casing members 46 and 48 are provided with fins 52 which assist in cooling the casing members. In this way the furnace gases which collect in the gas hood 29 pass through the channels 44 and all of the furnace gas is withdrawn from the hollow space in the center of the anode. Alumina may also be fed into the furnace through suitable openings (not shown) in the roof of the channels to effect a more even distribution of the charge. The form of anode illustrated in FIG. 4 is identical with that of FIG. 3 with the exception that the three separate anode casings are rounded off to an approximate elliptical shape.

FIG. 6 illustrates the use of an annular anode and cathode equipped with a block of electrically non-conductive or poorly conductive material positioned below the hollow space of the anode. As there shown a circular block of Carborundum 54 is positioned on the cathode 56 below the hollow space in the center of anode 58. The block extends above the level of the liquid molten aluminum which forms a ring of liquid below the anode to provide substantially vertical current paths in the furnace. The remainder of the furnace may be constructed in accordance with the furnace shown in FIG. 1 and the annular anode may be provided with one or more radial channels shown in FIG. 3. Cathode 56 is made of conventional material which is electrically conductive.

The furnace pot illustrated in FIG. 6 is in the form of an annular ring 60 having an open hollow space in the center thereof. In this case the outer and inner anode casings are each provided with circular hoods 62 and

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64 respectively for collection of furnace gases. Air is preferably circulated in the hollow space in the center of the furnace to cool the furnace parts.

While the structure of the present invention is of particular advantage in connection with continuous Soderberg anodes it will be understood that the anode may if desired be prebaked in the form of an annular ring or sections thereof.

It will be understood that it is intended to cover all changes and modifications of the preferred form of structure herein chosen for the purpose of illustration which do not constitute a departure from the spirit and scope of the invention.

What I claim is:

1. A method of operating an aluminum melt electrolysis furnace which includes a cathode, a furnace bottom and a Soderberg anode having an annular configuration comprising the steps of applying an electric current at least equal to 100,000 amperes and up to 500,000 amperes to said anode, distributing said current in said anode so that a greater current is applied to the radially inner portion of the operative end of said anode than the radially outer portion to cause said inner portion to be consumed more rapidly than said outer portion to form a sloping surface between said inner and outer portions wherein said outer portion is longer axially than said inner portion, placing an electrically insulative barrier adjacent said cathode in a position below the hollow material of said anode, said barrier being effective to prevent current flow between said anode and said insulative barrier to reduce the area of electrolytic production of aluminum to the portion of said furnace external to said insulative barrier to substantially eliminate current paths from said anode through the area occupied by said insulative barrier to the cathode.

2. A method of operating an aluminum melt electrolysis furnace which includes a cathode, a furnace bottom and a Soderberg anode having an annular configuration comprising the steps of applying an electric current at least equal to 100,000 amperes and up to 500,000 amperes to said anode, distributing said current in said anode so that a greater current is applied to the radially inner portion of the operative end of said anode than the radially outer portion to cause said inner portion to be consumed more rapidly than said outer portion to form a sloping surface between said inner and outer portions wherein said outer portion is longer axially than said inner portion, supplying charge material to said furnace, passing said current through said charge to said cathode to

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generate heat, and differentially expanding and shrinking different portions of the furnace bottom in predetermined manner in response to said heat to prevent any substantial thermal expansion of said furnace bottom.

3. A method of operating a melt electrolysis furnace which includes a cathode and a Soderberg anode having an annular configuration with a hollow interior comprising the steps of applying an electric current of at least 100,000 amperes and up to 500,000 amperes to said anode, placing an electrically insulative barrier adjacent said cathode in a position below the hollow interior of said anode, said barrier being effective to prevent current flow between said anode and said insulative barrier to reduce the area of electrolytic production of aluminum to the portion of said furnace external to said insulative barrier to substantially eliminate current paths from said anode through the area occupied by said insulative barrier to the cathode.

4. A method of operating an aluminum melt electrolysis furnace which includes a cathode, a furnace bottom having a lining and a Soderberg anode having an annular configuration comprising the steps of supplying charge material to said furnace, applying an electric current of at least 100,000 amperes and up to 500,000 amperes to said anode, passing said current through said charge to said cathode to generate heat, and differentially expanding and shrinking different portions of the furnace bottom in predetermined manner in response to said heat to prevent any substantial thermal expansion of said furnace bottom.

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HOWARD S. WILLIAMS, Primary Examiner

U.S. Cl. X.R.

204—243