April 28, 1970 M. E. GOODING 3,509,030

CASING LINER

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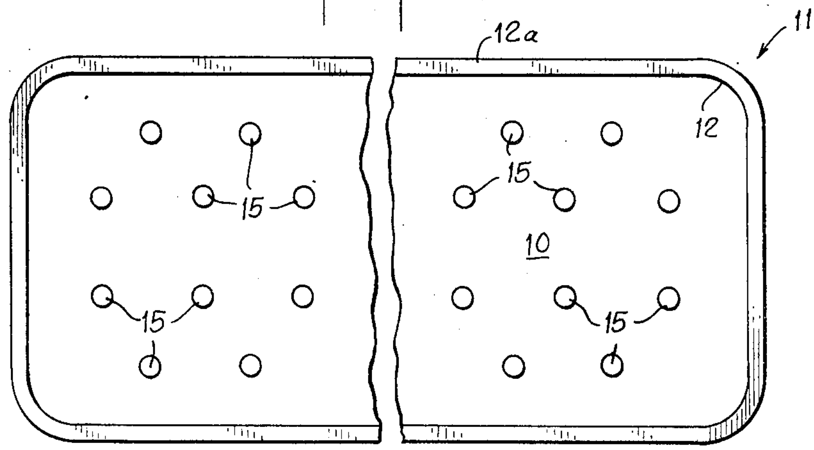
Fig. 1.



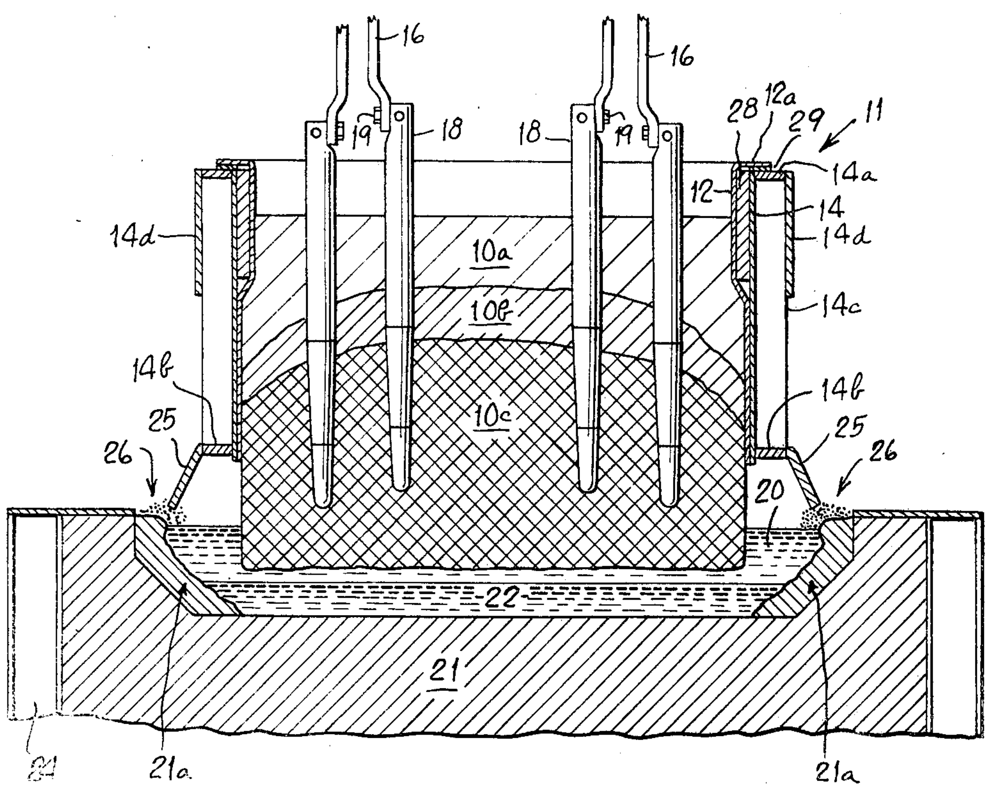


Fig. 2.

INVENTOR.
MATTHEW ERNEST GOODING
BY
Robert S. Dunham
ATTORNEY

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Fig. 3.

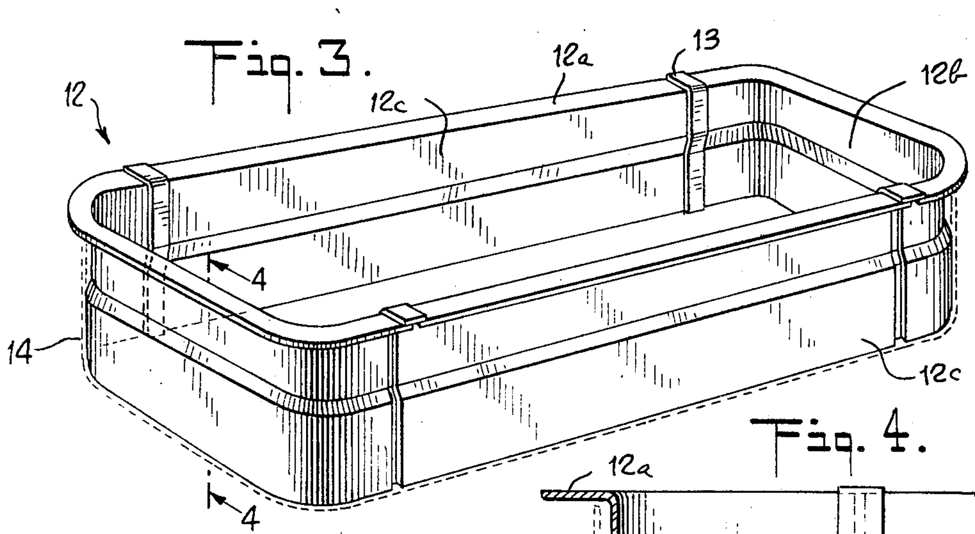


Fig. 4.

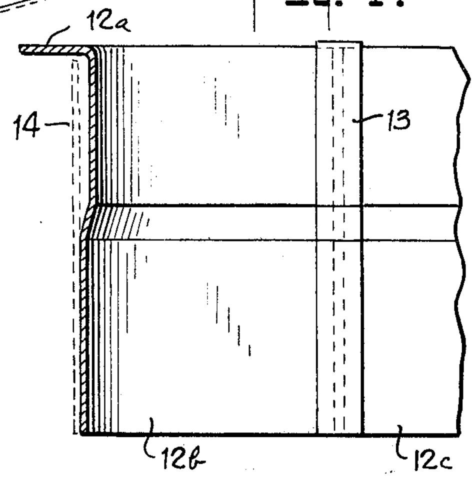


Fig. 6.

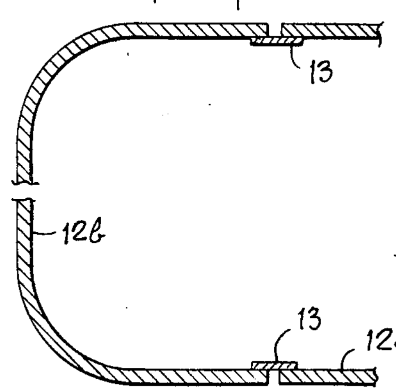
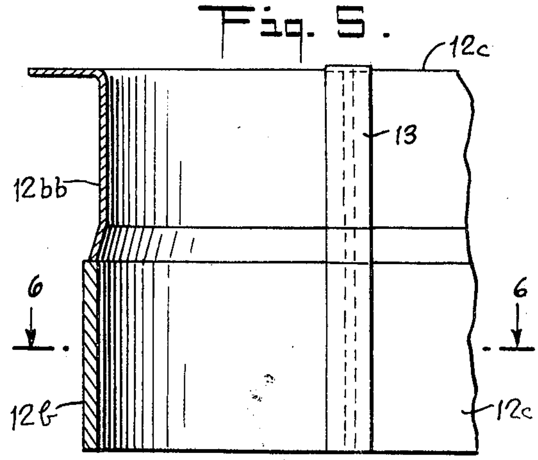


Fig. 5.



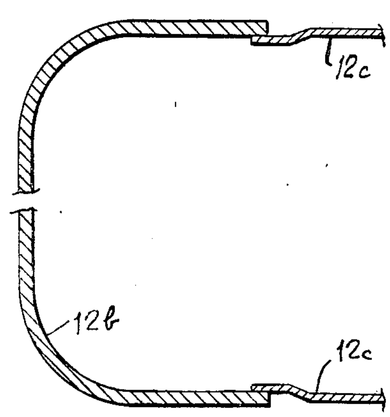


Fig. 7.

INVENTOR.
MATTHEW ERNEST GOODING
BY
Robert S. Dunham
ATTORNEY

United States Patent Office

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CASING LINER

Matthew Ernest Gooding, Kitimat, British Columbia, Canada, assignor to Alcan Research and Development Limited, Montreal, Quebec, Canada, a corporation of Canada

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U.S. Cl. 204—67 19 Claims

ABSTRACT OF THE DISCLOSURE

In the production of aluminum employing a vertical stud anode improved results are obtained by providing the anode casing which supports the anode and within which the anode moves vertically downward with a liner made up of a metal having a greater heat conductivity than the material making up the anode casing. Specifically, improved results are obtained by providing a steel anode casing with an aluminum liner. The liner is in contact with and substantially conforms to the shape or configuration or dimensions of the interior of the lower portion of the anode casing but is spaced from the interior of the upper portion of the anode casing to provide space between the upper portion of the anode casing and the liner for the introduction of suitable insulating material therebetween. By providing the anode casing with a metal liner, a more uniform temperature distribution is obtained within the anode and the formation of frozen anode paste rims and "corns" which tend to interfere with the lowering of the anode during the aluminum production operation is avoided. Additionally, the metal liner, particularly an aluminum metal liner, provides a surface to which the baked anode is less adherent, thereby permitting easier downward movement of the anode within the casing for maintaining contact with the electrolyte and reducing the likelihood of anode paste leaks into the electrolyte.

This invention relates to an anode casing structure useful in the electrolytic process for the manufacture of aluminum. In the electrolytic process for the manufacture of aluminum electric current is passed through a carbonaceous anode, a molten alumina-containing electrolyte and a cathode with the resulting formation of molten elemental aluminum at the cathode; for more details of the electrolytic process for the manufacture of aluminum see U.S. Patents 3,024,178 and 3,251,763, the disclosures of which are herein incorporated and made a part of this disclosure. During the production of aluminum the anode is oxidized and gradually consumed and must be replaced.

One technique for the manufacture of aluminum by the electrolytic process involves the use of a so-called vertical stud (V.S.) anode. In a vertical stud anode, anode material or paste is added to the top of an open-end steel casing, generally rectangular in cross section, which contains the anode and within which the anode moves downwardly into contact with the alumina-containing electrolyte and is gradually consumed. Vertical studs or conductors are implanted into the anode to support it and supply it with electrical energy. They move downward with the anode, and as they approach the molten electrolyte they are removed from the anode and reimplanted in the anode, this time at a greater distance from the electrolyte. From time to time anode paste is added to the anode within the casing to replace that portion of the anode consumed in the aluminum production process. The amount of anode paste added to the anode is substantially at the rate at which the anode is consumed during the aluminum production process.

The anode material or paste added to the anode casing is a mixture of a binder, such as pitch or tar in an amount usually in the range 20–40% by weight of the paste, and a solid carbonaceous material, such as petroleum coke or anthracite and mixtures thereof. The anode paste thus supplied to the anode is usually substantially solid in appearance, particularly at room temperature, since the melting point of the binder material is about 100° C. more or less. More fluid or paste-like anode material may be employed by employing a lower melting point pitch or tar as the binder.

As the anode moves downwardly within the anode casing into contact with molten alumina-containing electrolyte which is usually maintained at a temperature in the range 930–1000° C., such as a temperature of about 950–970° C., and is consumed, the anode paste within the anode casing is gradually heated. Although at first the anode paste appears solid, upon heating it becomes more fluid and tends to flow and uniformly fill the anode casing. As the, now more fluid, anode paste moves downwardly within the anode casing, it is subjected to still higher temperatures and at a temperature of about 300–400° C. the anode paste tends to lose some of the more volatile constituents and becomes baked to a hard, somewhat porous, electrically conductive, carbonaceous mass.

This hard, baked carbonaceous mass then moves downwardly within the anode casing for eventual contact with the alumina-containing electrolyte where it is consumed.

In commercial operations employing a vertical stud anode in the electrolytic process for the manufacture of aluminum difficulty frequently arises due to the movement of the anode within the anode casing or the failure of the anode to move within the anode casing. For example, a steel casing is regularly employed as the casing for a vertical stud anode. Sometimes the baked anode material due to localized overheating tends to form hard carbonaceous masses or "corns" which adhere very tenaciously to the steel casing and prevent or make very difficult the downward movement of the anode. Sometimes when these corns are formed and the anode material broken away from the corns and moved downwardly within the casing, the more fluid anode material in the upper portion of the anode casing leaks through and flows into the hot alumina-containing electrolyte. When this occurs the aluminum production cell does not operate efficiently for some time thereafter.

It is an object of this invention to provide an anode casing structure particularly useful in connection with a vertical stud anode for use in the electrolytic process for the manufacture of aluminum.

Another object of this invention is to provide an improved anode casing structure which tends to reduce or eliminate "corns" and anode paste leaks.

Still another object of this invention is to provide an anode casing structure for a vertical stud anode which makes possible better and more uniform temperature control of the anode paste and the anode material within the anode casing.

Yet another object of this invention is to provide an anode casing structure which presents a surface to the anode material within the casing which permits an easier movement of the anode within the anode casing.

How these and other objects of this invention are achieved will become apparent in the light of the accompanying disclosure and drawings wherein:

FIG. 1 is a broken plan view of a vertical stud anode casing structure showing the liner, the anode material and the vertical studs;

FIG. 2 is a transverse cross sectional view of a vertical stud anode as employed in an electrolytic cell for the manufacture of aluminum;

FIG. 3 is a perspective view of a liner suitable for use as the liner of a vertical stud anode casing, the casing portion with respect to the liner being outlined by dashed lines;

FIG. 4 is a fragmentary cross sectional view taken along lines **4—4** of FIG. 3, illustrating a liner made up of a material of uniform thickness;

FIG. 5 is a cross sectional view similar to FIG. 4 illustrating an embodiment in accordance with the practice of this invention wherein the lower portions or sections of the liner structure have a greater thickness than the upper portions or sections;

FIG. 6 is a cross sectional view taken along lines **6—6** of FIG. 5; and wherein

FIG. 7 is a cross sectional view similar to that of FIG. 6 wherein the lower portions of the end sections of the casing liner have a greater thickness than the other portions or sections of the liner.

In at least one embodiment of the practice of this invention at least one of the foregoing objects will be achieved.

In accordance with this invention it has been found that improved results in the production of aluminum by the electrolytic method employing a vertical stud anode are obtainable by providing the anode casing with a liner, desirably a liner made up of a material or metal having a heat conductivity greater than that of the material or metal making up the anode casing or the outer shell of the anode structure. In accordance with a specific embodiment of the practice of this invention a steel anode casing of a vertical stud anode is provided with an aluminum metal liner of suitable size and shape fixed to the steel casing such that the anode material making up the anode comes into contact substantially only with the aluminum liner.

Aluminum is particularly useful as the material making up the anode casing liner since the anode material, i.e. the Soderberg or anode paste, liquid or baked, does not readily bond or adhere to aluminum, particularly as compared to steel. Additionally, aluminum has a much higher thermal conductivity than steel and therefore improves the temperature distribution of the anode material within the anode casing structure to the most desirable condition for efficient operation. By using a liner made up of a metal having a higher thermal conductivity than the casing or the outer shell of the anode structure, heat is readily conducted away from the lower, relatively hot portions of the anode, particularly those portions of the anode closest to and/or in direct contact with the hot gases covering the molten alumina-containing electrolyte and in contact with the electrolyte itself which is usually maintained at a temperature in the range 930°–1000° C. during the aluminum production operation. The use of a high heat conductivity metal liner within the anode casing, such as an aluminum liner, which presents a surface which does not readily bond or adhere to the anode material within the casing, permits a more easy downward movement of the anode within the casing structure. The liner also provides for the conduction of heat from the lower, hotter portions of the anode to the upper cooler portions of the anode, thereby not only eliminating most or all of the troubles heretofore experienced with cold or frozen Soderberg or anode paste rims during cold weather but also reducing sticking of the anode material within the casing structure. The use of the liner also greatly reduces or eliminates the likelihood of formation of "corns" adhering to the inside of the anode casing structure which sometimes cause paste leaks with resultant reduction in cell efficiency and increased cost. The use of a liner in the anode casing for aluminum production in accordance with this invention also makes possible an appreciable saving in the Soderberg or anode paste binder because of the improved temperature uniformity in the soft or relatively fluid paste zone of the anode material within the anode casing.

Experiments have demonstrated that Soderberg or anode paste, upon baking, does not stick to an aluminum metal surface as easily or as readily as to a steel surface. Also, if the baking anode paste does adhere to the aluminum metal surface the bond between the anode material and the aluminum surface can readily be broken, leaving a clean aluminum surface. In contrast, baking anode paste material tends to strongly adhere to a steel surface and the bond between the steel surface and the anode material tends to be stronger than the baked anode material itself. Accordingly, when a fracture occurs during an attempt to move the anode material downwardly within a steel casing, there is left behind on the steel surface of the casing a rough surface of baked anode material which tends to prevent free sliding or movement of the anode within the casing.

In accordance with another embodiment of the practice of this invention, by employing in the anode casing structure a metal liner made up of a metal having a higher heat conductivity than the material, usually steel, making up the anode casing or outer shell of the anode casing structure and by spacing the liner from the interior of the upper portion of the anode casing and introducing insulation material, such as plywood, asbestos, rock wool, fiberglass and the like, into the annular space between the liner and the casing in the upper portion of the anode structure, a very improved and more uniform temperature distribution within the anode material is obtained. Merely providing an annular air space without any insulation material therein or only partially filling the annular space with insulated material would appear to yield improved results. By means of an anode casing structure of the type in accordance with this invention, most of the problems usually encountered in the operation of large vertical stud anodes, particularly those with relatively high current densities or wider than 80", and especially when employing a high melting point binder for the anode paste material, are substantially reduced or eliminated.

In the special embodiment in accordance with this invention wherein an aluminum metal liner is provided within a steel anode casing, the aluminum liner more readily removes heat from those areas of the anode exposed to high temperatures, such as that portion of the anode material closer to the hot, molten electrolyte, and conducts and distributes this heat to those portions of the anode material requiring more heat and an increased temperature for a more efficient operation. An anode casing structure in accordance with this invention tends to eliminate or reduce overheating of the anode material and excessive baking of the anode material with the resulting formation of carbon "corns" which tend to firmly attach themselves to the interior of the anode casing structure and cause anode paste leaks and other related troubles. An anode casing structure in accordance with this invention also serves to keep the Soderberg or anode paste within the upper portion of the anode casing more fluid and relatively uniform in surface temperature and also in good consistency for the planting and reimplanting of the vertical studs used to supply the electrical energy to the anode. An anode casing structure in accordance with this invention tends to eliminate rims of frozen paste which usually adhere to the casing during wintertime operations, thereby permitting a reduction in the proportion of anode paste binder used in the preparation of the anode paste and removing non-conformities from the sliding zone of the anode. An anode casing structure in accordance with this invention assures the supply of enough heat, and a sufficiently high temperature, to the bottom corners or ends of a relatively low current density, wide vertical stud anode casing so as to bake the Soderberg or anode paste adequately before it emerges from the anode casing structure for eventual contact with the hot molten electrolyte.

By varying the thickness of the metal making up the anode casing liner and the size and shape of the casing liner relative to the casing and by the use of more or less insulating material or more or less efficient insulating material within the annular space between the metal liner and the casing or outer shell of the anode structure, the desired heat conservation and temperature control with respect to the anode material within the anode casing is effected. This permits attainment of more uniformity with respect to temperature at various levels within the anode.

Although emphasis in this disclosure has been placed upon the use of a steel anode casing in combination with an aluminum metal liner, a number of metals or materials making up the anode casing and the liner, as indicated herein, may be employed. Desirably in accordance with this invention the material or metal making up the casing liner has a higher heat conductivity than the material or metal making up the anode casing or outer shell of the anode casing structure. As indicated hereinabove, primarily because of its strength and availability, steel is the preferred material for the fabrication of the anode casing or outer shell of the anode casing structure. For the liner aluminum metal and its alloys are preferred. Other metals which would appear to be useful for the fabrication of the anode casing liner, particularly in combination with a steel casing, include titanium, copper, magnesium and their alloys.

Referring now to the drawings which illustrate the practices of this invention, and particularly to FIGS. 1 and 2 thereof, there is illustrated a vertical stud anode assembly or arrangement used in the electrolytic process for the manufacture of aluminum. Anode **10** is contained within an anode casing assembly or structure generally indicated by reference numeral **11**. The anode casing structure is made up of a casing liner **12** supported on and fixed to casing **14**. Vertical stud conductors **15** are schematically illustrated in FIG. 1. The vertical stud conductors, illustrated in greater detail in FIG. 2, are made up of electrical conductors **16** fixed to studs **18** by suitable fasteners **19**. Studs **18** are implanted in anode **10** which, from a temperature and physical point of view, may be considered to be comprised of three zones or sections, the upper zone or section **10*a*** of the anode being made up of substantially fluid paste at the lowest temperature, with the intermediate zone **10*b*** beneath consisting of semi-baked and baking paste, at a higher temperature and substantially solid in appearance, although containing a high proportion of unbaked hydrocarbons. In the lowermost zone anode section **10*c*** is made up of baked anode paste and is relatively hard, solid, self-supporting, electrically conductive material and is at a substantially higher temperature than the remaining portions **10*a*** and **10*b*** of the anode material. The lowermost portion of anode **10**, section **10*c***, is shown in contact with a bath of alumina-containing electrolyte **20**.

In the manufacture of aluminum, current is passed through conductors **16**, vertical studs **18** and anode **10** through molten alumina-containing electrolyte **20** to cathode **21** with its sides covered by frozen electrolyte and almina **21*a*** which is contained within cell supporting structure **24** with the resulting production of a body or pool **22** of molten aluminum. From time to time a portion of the molten aluminum is removed by means not shown.

As molten aluminum is produced at cathode **21** the bottom of anode **10** is in direct contact with the molten alumina-containing electrolyte and is oxidized as a part of the reaction and is slowly consumed. Gases generated are prevented from escaping and are collected for removal by means of a skirt or shroud **25** and alumina seal **26**.

As illustrated in FIG. 2 casing liner **12** is in direct surface-to-surface contact with the lower portion of casing **14**, casing liner **12** being substantially contiguous and coterminus with the casing **14**.

The upper portion of casing liner **12** is spaced inwardly away from casing **14** so as to provide annular space **28** therebetween. Annular space **28** may be unoccupied or filled with suitable heat insulating material, such as plywood, asbestos or rock or glass wool, or any other suitable material, having the desired heat insulating properties and the ability to resist the conditions in this area. The purpose of providing annular space **28** between the upper portions of casing liner **12** and casing **14** is for heat conservation so as to better conserve and utilize heat withdrawn from the hotter portions of anode **10**, i.e. portions **10*c*** and **10*b***, and from the hot gases covering electrolyte **20** to the uppermost zone **10*a*** of the anode. This arrangement in accordance with this invention has been found to provide a more uniform heat and temperature distribution within anode **10**, particularly in the upper zones **10*a*** and **10*b***.

The separation between casing liner **12** and casing **14** commences at about midway of casing **14**. If desired, however, annular space **28** between casing liner **12** and casing **14** may include only the upper ⅓ or upper ¼ of the height of casing **14**. On the other hand, annular space **28** may include as much as or ⅔ or ¾ of the upper portion of casing **14**, but must terminate above the baked zone **10*c*** and preferably above the semi-baked zone **10*b***. The height of annular space **28** depends upon the size of casing **14**, the operating conditions of the cell for the manufacture of aluminum, the composition of the anode paste, the size of casing **14** and casing liner **12** both with respect to length and the thickness making up the casing and liner and the temperature conditions desired within anode **10** and the levels and extent of the various zones **10*a***, **10*b*** and **10*c*** making up anode **10**. For example, the thickness of the material or metal making up casing liner **12** may be in the range ⅛" to about 1" more or less and the width of annular space **28** separating casing liner **12** from casing **14** may be in the range ⅛" to about 1½", such as ½", ¾" or 1".

As illustrated in FIG. 2 the upper end of casing liner **12** is provided with a flange portion **12*a*** which is fixed to and/or supported on flange portion **14*a*** of casing **14**. There is conveniently provided between liner flange **12*a*** and casing flange **14*a*** a sealing strip **29** of suitable material, such as heat insulating material. The lower end of casing **14** is provided with a bottom flange **14*b*** which supports gas collecting shroud or skirt **25**. Also, as illustrated in FIG. 2, the lower casing flange **14*b*** may be suitably provided with fins **14*c*** for temperature control, fins **14*c*** serving to radiate or dissipate excess heat from casing **14** of the anode structure or assembly. Around the upper portion of the casing **14** in the region of the soft paste **10*a***, and particularly at the corners of the casing, it may be desirable to provide additional thermal shielding or insulation in the form of a metal shield **14*d*** on the outside of the casing structure **14** or suitable insulation incorporated in or around the anode casing structure.

Referring now to the remaining figures of the drawings, viz FIGS. 3–7, which illustrate various embodiments of the casing liner, FIGS. 3 and 4 show casing liner **12** in accordance with one embodiment of this invention wherein the material, such as aluminum, making up casing liner **12** is of uniform thickness, such as a thickness of 0.25". As ilustrated, end portions **12***b* are joined to side portions **12***c* by means of straps **13** of about the same thickness as end and side portions **12***b* and **12***c* and which are attached or otherwise fixed to ends **12***b* and or the sides **12***c*. The gap covered by straps **13** separating ends **12***b* and sides **12***c* may be any suitable dimension to suit differential thermal expansion of aluminum and steel or other metals, such as 0.5–1.5", e.g. 1". The outline of casing **14** and its relationship to liner **12** is indicated by dashed lines. Instead of straps **13** fastening portions **12***b* and **12***c*, these portions can be overlapped and then fastened together with bolts with enlarged holes to allow for expansion.

FIGS. 5 and 6 illustrate another embodiment of a casing liner in accordance with this invention wherein liner sides **12***c* and the bottom sections of liner ends **12***b* are of the same, uniform thickness but wherein the upper portions of the liner ends **12***bb* have a smaller thickness than the lower portions **12***b*. Straps **13** joining liner sides **12***c* and liner ends **12***b* and **12***bb* may have any suitable thickness, such as the thickness of liner sides **12***c* or the thickness of the material making up liner end portions **12***b* or **12***bb*.

FIG. 7 illustrates yet another embodiment of a casing liner in accordance with this invention wherein liner ends **12***b* are made up of a material of uniform thickness but a thickness greater than the material making up liner sides **12***c* and wherein ends **12***b* and sides **12***c* overlap and are joined as described before.

As will be apparent to those skilled in the art in the light of the foregoing disclosure many modifications, alterations and substitutions are possible in the practice of this invention without departing from the spirit or scope thereof.

I claim:

1. A structure useful for supporting and containing the anode material of a vertical stud anode employed in the electrolytic process for the manufacture of aluminum comprising an open-end casing, said casing being substantially rectangular in cross section, and a metal liner fixed to and provided within said casing, said liner being in contact with and substantially conforming to the inner surface of said casing within the lower portion or end thereof and said liner being spaced from the inner surface of said casing within the upper portion or end to provide space between said liner and said casing, said metal liner being made up of a metal having a greater heat conductivity than the material making up said casing.

2. A structure in accordance with claim **1** wherein said space between said liner and said casing is occupied at least in part with themal insulation material.

3. A structure in accordance with claim **1** wherein said space between said liner and said casing is occupied at least in part with asbestos-containing material.

4. A structure in accordance with claim **1** wherein said space between said liner and said casing is occupied at least in part with plywood.

5. A structure in accordance with claim **1** wherein said casing is a steel casing and wherein said liner is a metal liner selected from the group consisting of magnesium, aluminum, titanium and alloys thereof.

6. A structure in accordance with claim **1** wherein said casing is a steel casing and wherein said metal liner is made up of aluminum.

7. A structure in accordance with claim **1** wherein said casing is a steel casing and wherein said metal liner is made up of aluminum, the aluminum making up said liner being uniform in thickness.

8. A structure in accordance with claim **1** wherein said casing is a steel casing and wherein said metal liner is made up of aluminum, the thickness of the aluminum making up said liner within the lower portion or end of said casing being greater than the thickness of the aluminum making up said liner within the upper portion or end of said casing.

9. A structure in accordance with claim **1** wherein said casing is a steel casing and wherein the metal liner is made up of aluminum, the thickness of the aluminum in contact with the ends of the lower portion of said casing being greater than the thickness of the aluminum making up the other sections or sides of said liner.

10. In the electrolytic process for the manufacture of aluminum employing a vertical stud anode wherein the vertical stud anode is provided within a substantially rectangular anode casing and wherein current flows through said anode and a high temperature molten alumina-containing electrolyte in contact with the bottom of said anode with the resulting production of molten elemental aluminum at the cathode in contact with said electrolyte and wherein the anode paste is introduced into the upper portion of said anode casing to provide said anode therein and wherein the paste thus-introduced into said casing becomes more fluid and is baked to a hard, electrically conductive carbonaceous material which moves downwardly within said casing while being subjected to higher temperatures therein and into contact with said electrolyte and is consumed during the electrolytic process for the manufacture of aluminum, the improvement which comprises providing said casing with a metal liner substantially conforming to and in contact with the interior of the lower portion of said casing but spaced from the interior of the upper portion of said casing to provide a space therebetween, said metal liner being substantially contiguous with said casing and being positioned within said casing so that said paste comes into contact only with said liner and not with said casing, the metal making up said liner having a higher heat conductivity than the material making up said casing.

11. A process in accordance with claim **10** wherein the material making up said casing is steel of substantially uniform thickness and wherein the metal making up said liner is aluminum.

12. A process in accordance with claim **10** wherein the material making up said casing is steel of substantially uniform thickness and wherein the metal making up said liner is aluminum and wherein the thickness of said aluminum liner is greater than the thickness of the steel making up said casing.

13. A method in accordance with claim **10** wherein the metal making up said liner is a magnesium alloy.

14. A method in accordance with claim **10** wherein the metal making up said liner is an aluminum alloy.

15. A method in accordance with claim **10** wherein the metal making up said liner is a titanium alloy.

16. A method in accordance with claim **10** wherein the metal making up said liner is a copper alloy.

17. A method in accordance with claim **10** wherein the metal making up said liner is aluminum, the lower portion of the aluminum metal making up said liner having a thickness greater than the aluminum metal making up the upper portion of said liner.

18. A method in accordance with claim **10** wherein the metal making up said liner is aluminum and wherein the thickness of the aluminum liner is uniform.

19. A method of improving the operation of a vertical stud anode in the electrolytic process for the manufacture of aluminum wherein the anode prepared from anode paste is contained and supported within an open-end substantially rectangular casing which comprises providing said casing with a metal liner substantially conforming to and in contact with the interior of the lower portion of said casing, the metal making up said liner having a higher heat conductivity than the material making up said casing, maintaining said casing in direct contact with said liner around the interior of the lower portion of said casing and insulating the interior of the upper portion of said casing from said liner by providing a space intermediate said liner and the upper portion of said casing, the combination of said metal liner in contact with the lower portion of said casing and the conservation of heat in said anode by providing insulating space intermediate said liner and the upper portion of said casing serving to provide a more uniform heating of said anode and temperature distribution within the anode within said casing.

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JOHN H. MACK, Primary Examiner

D. R. VALENTINE, Assistant Examiner

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