March 17, 1953 B. B. A. LUZZATTO 2,631,972

PROCESS AND APPARATUS FOR THE ELECTROLYTIC PRODUCTION OF MATERIALS

Filed June 28, 1948 3 Sheets-Sheet 1

FIG. 1.

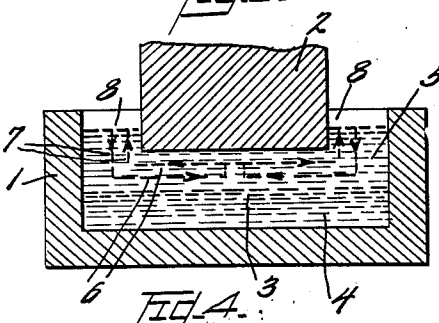


FIG. 3.

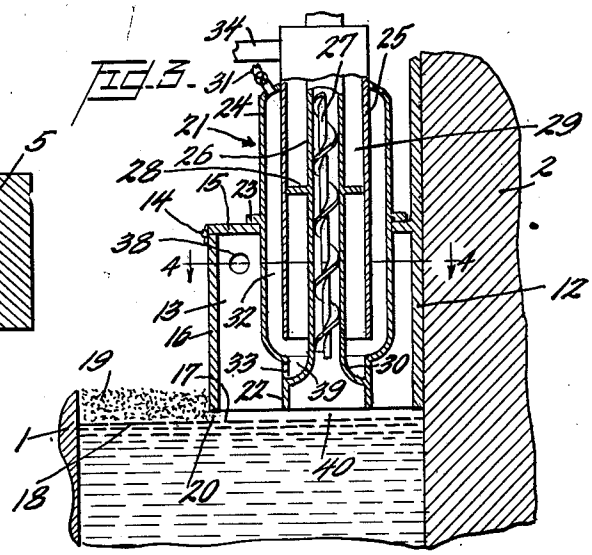


FIG. 4.

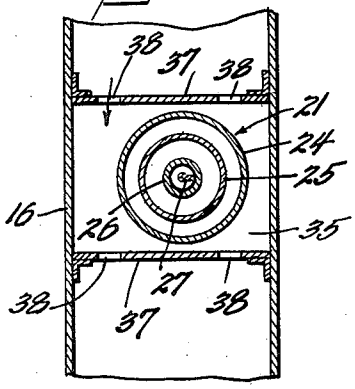


FIG. 5.

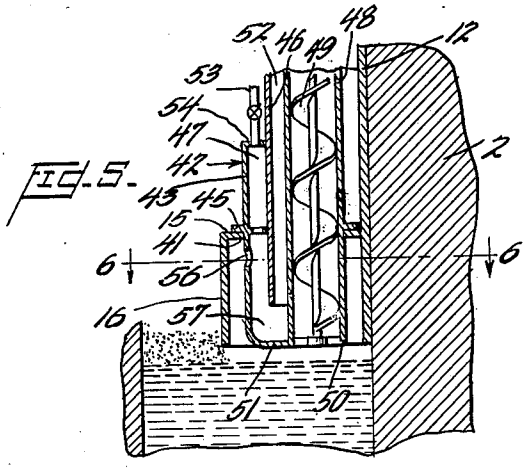


FIG. 2.

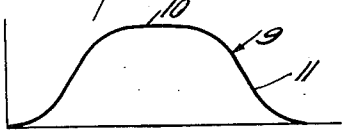


FIG. 7.

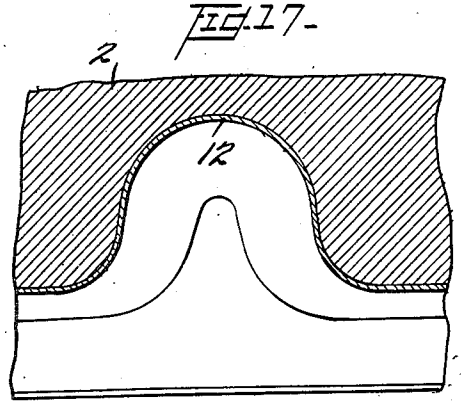
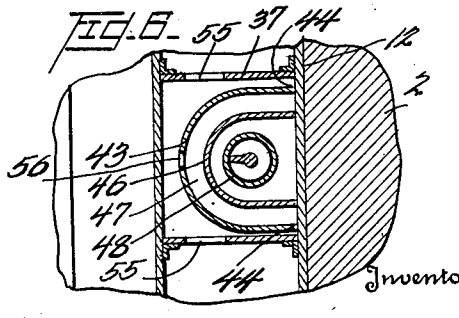


FIG. 6.



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PROCESS AND APPARATUS FOR THE ELECTROLYTIC PRODUCTION OF MATERIALS

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FIG. 7.

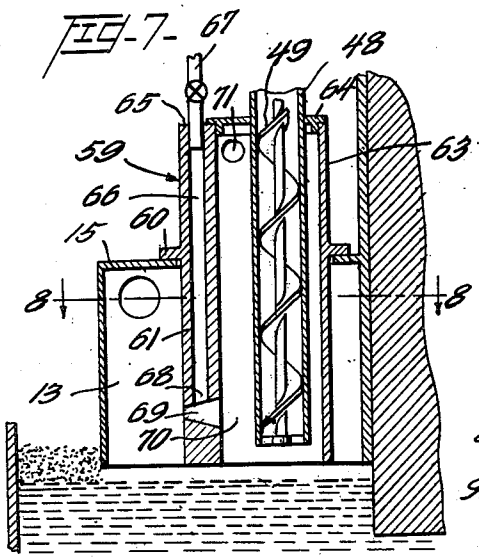


FIG. 9.

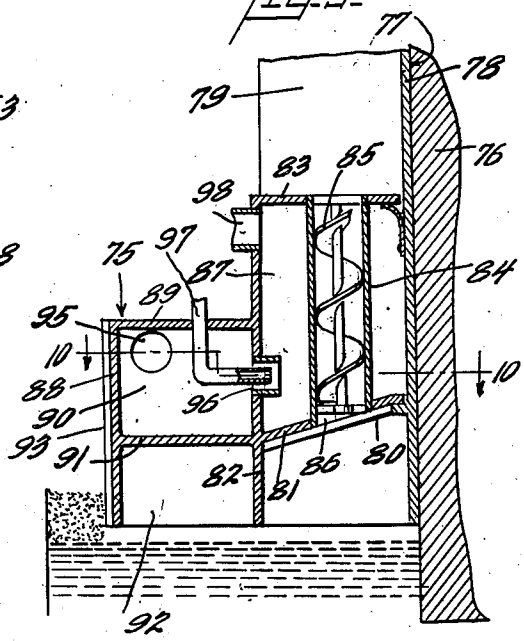


FIG. 8.

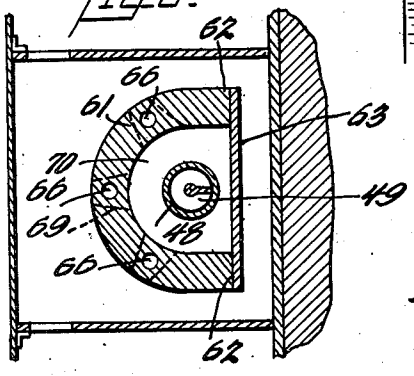


FIG. 10.

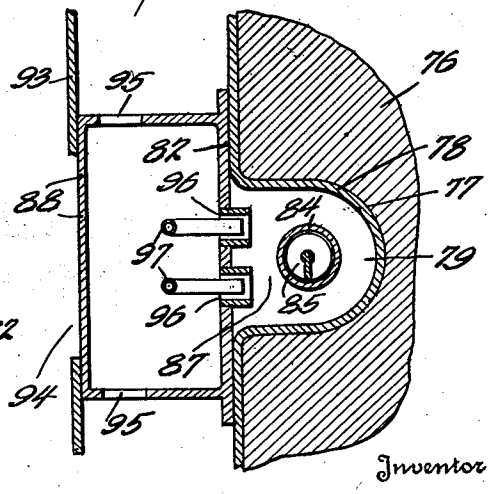
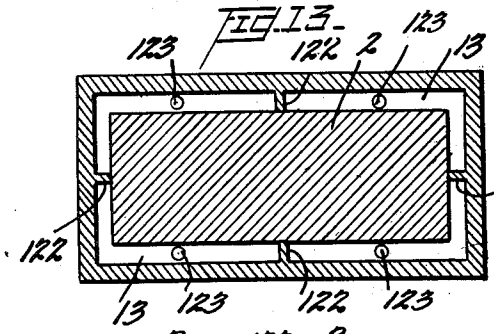


FIG. 13.



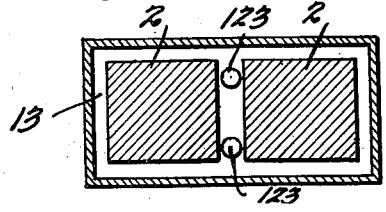


FIG. 14.

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PROCESS AND APPARATUS FOR THE ELECTROLYTIC PRODUCTION OF MATERIALS

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FIG. 11.

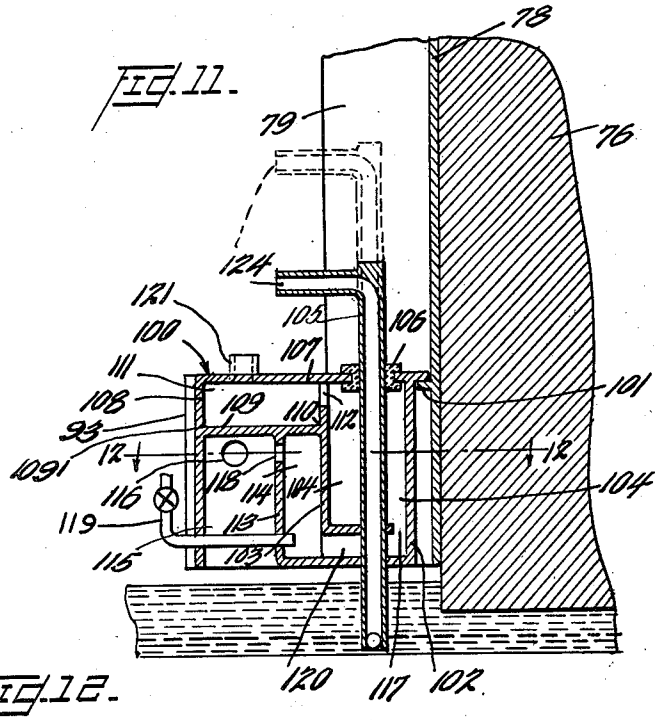


FIG. 12.

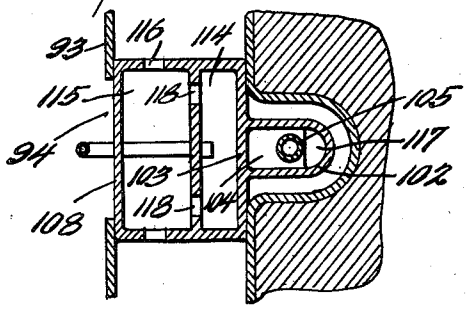
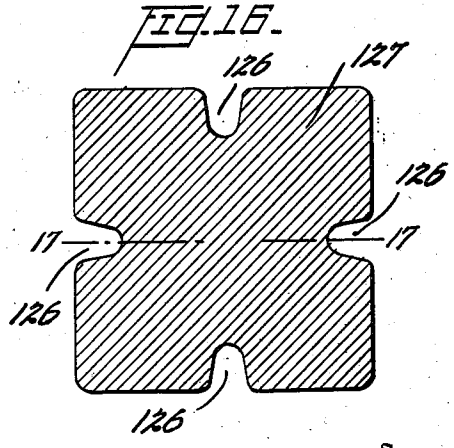


FIG. 16.



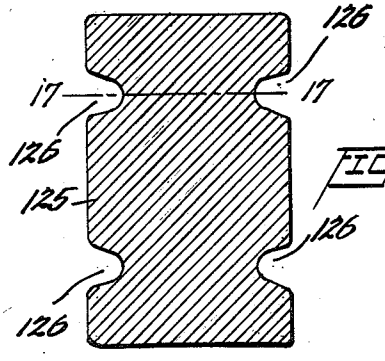


FIG. 15.

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Patented Mar. 17, 1953

2,631,972

UNITED STATES PATENT OFFICE

2,631,972

PROCESS AND APPARATUS FOR THE ELECTROLYTIC PRODUCTION OF MATERIALS

Bruno B. A. Luzzatto, Washington, D. C.

Application June 28, 1948, Serial No. 35,646

18 Claims. (Cl. 204—67)

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This invention relates to the art of electrochemistry. More particularly it pertains to electrolytic operations involving the utilization of electrode furnaces or cells adapted for the electrochemical production of a substance through the expedient of an appropriate electrolyte. In its preferred adaptations, it is directed to the electrolytic production of aluminum from compounds thereof, preferably alumina, including within its purview both procedural and apparatus features.

In order to facilitate a comprehensive consideration of the features of the invention, the following description is illustratively presented with reference to the aforesaid preferred embodiment thereof, the electrolytic production of aluminum from a fused bath containing alumina, in an electrolytic furnace or cell which preferably involves the adaptation of the so-called self-baking type of electrode. It will however be understood that the invention herein is not restricted in its scope to such optimum embodiment, either with respect to the materials indicated, features of procedure, or electrolytic furnace or cell characteristics, since it is of substantial latitude in its sphere of adaptation and field of application.

The production of aluminum from a fused bath containing an aluminum oxide, such as alumina, and a fluoride, desirably cryolite, by electrolysis of said bath in a self-baking electrode type of cell or furnace has afforded the prior art certain advantages. Nevertheless various shortcomings and disadvantages have persisted, serving to accentuate the necessity for substantial improvement and increased efficiency. Among the problems encountered, by way of illustration, has been that applicable to the above referred self-baking electrode, also known as the Soderberg or continuous type of electrode. These electrodes are generally recognized in the art and have been described in such early patents of Soderberg as No. 1,442,031 and No. 1,670,052. Usually these electrodes are of carbonaceous derivation and comprise a plastic or fluid composition, such as in the form of a paste which passes through a molding casing appropriately positioned relative to the electrolyte for use of the electrode during the course of its formation. The heat of the furnace or electrolytic operation bakes and hardens the lower portion of electrode, thereby adapting it for its function. Various contact adaptations are resorted to for these electrodes, and desirably they are of the vertical type, as illustratively shown in the patent to Manfredini

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No. 2,224,739 and that to Trematore No. 2,100,927, both of which are further indicative of the use of the self-baking electrode in connection with the electrolytic production of aluminum.

Excessive corrosion of the self-baking electrode has been manifested as a result of the access of heated air to the lower portion thereof, which is at a comparatively high temperature—substantially the maximum attained at any part of the electrode during the electrolytic operation. Thus the maximum temperature is influenced by the proximity of the electrode to the bath, the highest temperature of the bath occurring under the electrode where the interpolar distance is a minimum.

Moreover both the baking of the electrode, which normally contains a substantial proportion of hydrocarbons in its initial composition, and the electrolytic process per se give origin to gases which are obnoxious and toxic in their characteristics, notwithstanding their content of valuable constituents, and their segregation and collection pursuant to the prior art has presented elements of inexpediency and inefficiency. This is attributable primarily to a dispersion or loss of the evolved gases as a result of the characteristics of the electrode and the cell or furnace structure, as well as a loss of heat value attainable from these gases.

An additional difficulty has been encountered in the prior art with respect to the supply of the raw material, such as alumina and/or cryolite to the cell or furnace, particularly in view of the tendency of crust formation during the electrolysis. The said crust formation is generally conceded to be attributable to the surface solidification of the electrolyte bath, as a result of the lower temperature prevailing at this area compared with the temperature of the cell operation. It functions as an obstruction impeding the supply of raw materials to the cell or furnace, especially where any continuous feeding is contemplated, and obstructs the controlled removal of gases evolved by the electrolytic operation, free from excessive extraneous diluents, such as air, at predetermined collecting zones.

Thus the usual manner of supplying raw materials to the electrolytic bath has heretofore necessitated the physical crushing of its encrusted surface, with an attendant impairing of the efficiency of cell operation. For example it has rendered the effective control of the temperature of cell operation quite impracticable, and has in substantial measure prevented any expedient

continuous operation. This is emphasized by the recurrent and substantially uncontrolled development of the so-called "anodic effect" in electrolytic cell operations, the said effect being coincident with the reduction of the alumina content in the electrolyte bath to a minimum, at which time steps must be taken to replenish the essential raw materials. The development of this "anodic effect" with attendant low concentration of alumina causes an increase in the cell voltage, which by way of illustration may be from a value of 5 volts required for normal operation of a given cell to 50 volts attributable to the extenuating circumstances prevailing as a result of the said "anodic effect." It will accordingly be apparent that the optimum conditions of temperature applicable to a given cell operation cannot be maintained under such circumstances, and the efficiency of the cell, particularly in view of the intervening substantially uncontrollable "anodic effect," is subject to substantial disturbance.

Objections similar to that which pertain in connection with the feeding of raw materials to the cell have prevailed with respect to the withdrawal of aluminum from the cell or furnace. In the case of comparatively small electrolytic installations the removal of the product of electrolysis is in many cases manually accomplished by resort to a cast iron "flower" pot into which the molten metal is permitted to flow from the bottom portion of the cell or furnace beneath the electrolytic bath which is present as an upper stratification of molten material in the cell or furnace. The metal may then be subjected to hand ladling, while in larger cell or furnace installations, a suction system has been utilized for withdrawal of the molten aluminum, this manipulation has necessitated a preliminary breakage of the crust or film formation normally prevailing on the surface of the bath, and as a result thereof, the removal of the molten metal has usually been resorted to during the time interval of feeding alumina or the like to the bath at the time of the development of the above referred to "anodic effect," in order to thereby avoid duplication of the interruption of the cell or furnace operation. Thus in general the removal of the products of electrolysis has not lent itself to any efficient continuous operation, and has involved various problems as indicated.

Efforts to circumvent difficulties of the type indicated have afforded an element of improvement. A development in this connection has been the coordination with the self-baking electrode of a so-called double-ring chamber determining a compartment adapted to segregate and remove the gases evolved by the electrolytic operation from a zone peripherally adjacent the electrode and contiguous the bath surface. This has permitted the withdrawal of a substantial portion of the gases resulting from the cell operation, and has afforded in a measure the utilization of some of the heat values attainable from the said gases. Thus the positioning of this zone at the lower portion of the self-baking electrode adjacent the electrolyte bath, thereby embracing a zone of maximum temperature during the cell operation, has to some extent contributed in retaining a comparatively restricted portion of the bath surface in molten condition or with a comparatively limited crust formation, such as in the form of a thin film. For a conventional type of cell or furnace, the extent of the molten area of bath surface attainable through this expedient has been for a distance of one inch and up to a maximum of approximately two inches from the electrode.

Consideration has been given to the supply of raw materials, such as alumina, during the cell operation by feeding the same to the aforesaid restricted molten zone immediately adjacent the electrode and embraced by the double-ring chamber. However this has been subject to shortcomings because of the uncertainty and limitations of the extent of the said molten area adjacent the electrode. Thus notwithstanding the improvement attainable with the double-ring chamber, efforts directed to an efficient operation of an electrolytic cell or furnace have not been free from criticism and objection, especially from the standpoint of attaining a dependable, regulated supply of raw materials, and/or withdrawal of the products of electrolysis, such as that commensurate with a reasonably continuous efficient operation, including the desirability for a controlled maintenance of optimum temperature conditions.

It is an object of this invention to obviate such difficulties and uncertainties as hereinabove indicated.

Another object is to improve the efficiency of an electrolytic cell or furnace operation wherein the electrolyte utilized manifests a tendency to surface solidification at the prevailing conditions of procedure, and adapting the same for a continuity of operation.

An additional object is to improve the performance of an electrochemical procedure involving an electrolyte which manifests a tendency to surface solidification, by maintaining a predetermined area of electrolyte surface in substantially molten state during the electrolytic operation for the facilitated supply of raw material to and/or withdrawal of reaction products from the said electrolyte.

A further object is to enhance the operation of an electrochemical procedure wherein the electrolyte manifests a tendency to surface solidification, by retaining one or more predetermined areas of bath surface in substantially molten state during the electrolytic operation for the supply of raw material to and/or the withdrawal of reaction products from said bath, through the concentration at said area or areas of heat values attainable in any expedient manner.

An important object is to attain an improved production of aluminum in an electrochemical procedure involving an electrolytic bath which manifests a tendency to surface solidification, by maintaining one or more predetermined areas of bath surface in substantially molten state during the electrolytic operation for the supply of raw material to and/or the withdrawal of reaction products from said bath, through the concentration at said area or areas of heat values attainable from gases evolved by the electrolytic operation, supplemented if desired by the addition of heat values from an extraneous source, such as by the supply of added combustible gases.

Another important object is to afford an increased efficiency of aluminum production in an electrochemical procedure involving an electrolytic bath which manifests a tendency to surface solidification, by maintaining one or more predetermined areas of bath surface in substantially molten state during the electrolytic operation for the supply of raw material to and/or the withdrawal of reaction products from said bath,

through the concentration at said area or areas of heat values attainable from gases evolved by the electrolytic operation, supplemented if desired by the addition of combustible gas from an extraneous source, said heat values preferably being subject to a coordinated heat exchange relationship with the aforesaid supply and/or withdrawal of materials.

A significant object is to provide an improved electrochemical procedure for the production of aluminum from a molten alumina-containing electrolyte which manifests a tendency to surface solidification and wherein the electrolytic operation involves the adaptation of a self-baking type of electrode, by maintaining one or more predetermined areas of bath surface in substantially molten state during the electrolytic operation for the supply of raw material to and/or the withdrawal of reaction products from said bath, through the concentration at said area or areas of heat values attainable from gases evolved by the said electrolytic operation including the combustion of said gases, said gases if desired being augmented by combustible gas from an extraneous source, said heat values preferably being subject to a coordinated heat exchange relationship with the aforesaid supply and/or withdrawal of materials.

Another primary object of the invention is to devise apparatus adapted to afford the various features of procedure contemplated by the invention.

A significant object is to devise apparatus adapted to afford an improved efficiency of electrolytic operation including the various procedural features of the invention.

An added object is to produce an expedient electrolytic furnace or cell adapted to afford predetermined areas of heat concentration on the surface of the electrolyte utilized.

A still further object of the invention is an electrolytic furnace or cell combination particularly applicable wherein the electrolytic bath manifests a tendency to surface solidification during the cell or furnace operation, including means for concentrating heat values at a predetermined area or areas of bath surface for maintaining said area or areas in a substantially molten state, and means for conveying raw material to and/or withdrawing reaction products from said bath.

Another significant object is an electrolytic furnace or cell combination manifesting an improved efficiency of operation particularly applicable wherein the electrolytic bath manifests a tendency to surface solidification during the cell or furnace operation, including a chamber for segregating gases evolved by the electrolytic operation and means for concentrating the attainable heat values of said gases embracing means for burning of the combustible content thereof at a predetermined area or areas of bath surface for maintaining said area or areas in a substantially molten state.

Another object is an electrolytic furnace or cell combination including a self-baking type of electrode, a chamber correlated with said electrode for segregating gases evolved by the electrolytic operation, means for concentrating the attainable heat values of said gases and for burning the combustible content thereof contiguous a predetermined area or areas of bath surface for maintaining said area or areas in a substantially molten state, and means for conveying raw material to and/or withdrawing reaction products from said bath, said conveyor or withdrawal means being in coordinated heat exchange relationship with said means for concentrating the gaseous heat values.

An additional important object is an attachment for an electrolytic furnace or cell particularly applicable to operations wherein the electrolytic bath manifests a tendency to surface solidification, said attachment being removably positionable relative to the electrolytic bath and adapted to concentrate at a predetermined area or areas of bath surface heat values attainable from gases including the burning of the combustible content of said gases.

Another object is to provide an electrolytic furnace or cell combination particularly applicable to operations wherein the electrolyte manifests a tendency to surface solidification, including a self-baking type of electrode, a chamber coordinated with said self-baking electrode for segregating gases evolved by the electrolytic operation, a burner attachment removably positionable within said chamber to concentrate the heat values attainable from said gases and burn the combustible content thereof contiguous a predetermined area or areas of bath surface, thereby maintaining said area or areas in substantially molten state, and conveyor means for supplying raw materials to and/or means for withdrawing reaction products from said bath at said predetermined area or areas, said conveyor or withdrawal means being in coordinated heat exchange relationship with said burner attachment.

Another expedient object is a burner attachment for an electrolytic furnace or cell particularly applicable to operations wherein the electrolytic bath manifests a tendency to surface solidification, said attachment being removably positionable relative to the electrolytic bath and adapted to concentrate at a predetermined area or areas of bath surface heat values attainable from gases including the burning of the combustible content of said gases, said attachment including in integrally removable relationship means for conveying raw material to the bath at said area or areas and/or withdrawing reaction products therefrom.

An added object of importance is a self-baking electrode of novel structure adapted to afford an enlarged zone of maximum heat concentration relative to the adjacent surface of an electrolyte in coordinated association with said electrode.

Other objects, attributes and features of the invention will become apparent from the description read in connection with the accompanying drawings in which similar elements are designated by like numerals.

Fig. 1 relates to a fragmentary vertical section diagrammatically showing the relationship of electrode with molten bath and indicating the zone of maximum heat concentration, which corresponds with the zone of maximum current intensity in the bath.

Fig. 2 comprises a curve illustrating the prevailing temperature conditions in the bath, especially as it pertains to the interpolar zone of Fig. 1.

Fig. 3 represents a diagrammatic fragmentary vertical section of an electrolytic furnace or cell embracing means for segregating the gases from the electrolytic operation in combination with a self-baking type of electrode, and coordinated with an attachment for concentrating the heat values obtainable from these gases at a predetermined zone of the bath, the said attachment including a conveyor for supplying raw material to the bath at said predetermined zone.

Fig. 4 is a horizontal section taken along line 4—4 of Fig. 3.

Fig. 5 represents a combination analogous to that shown in Figs. 3, 4 and of similar sectional view, differing in the details of the attachment device modification, but including corresponding fundamental structural features for collecting the gases, burning the combustible ingredients thereof, concentrating the attendant heat values at a predetermined zone of the electrolyte bath surface, and including correlated means for feeding the raw material at the said predetermined bath zone.

Fig. 6 is a horizontal section of the apparatus shown in Fig. 5, taken along line 6—6 of the latter figure.

Fig. 7 provides an additional modification of apparatus combination of gas collector, burner and feeding means correlated with a self-baking type of electrode, applicable to a predetermined zone of heat concentration within the collector, this combination likewise shown as a diagrammatic vertical section.

Fig. 8 is a cross-sectional view taken along line 8—8 of Fig. 7.

Fig. 9 is directed to a further structural modification of the invention also shown in sectional elevation, including the chamber for collecting evolved gases coordinated with a longitudinally slotted self-baking type of electrode, the burner-conveyor attachment being positioned essentially within an aforesaid electrode slot.

Fig. 10 is drawn to a cross-sectional view taken along line 10—10 of Fig. 9.

Fig. 11 relates to another modification of the electrolytic cell combination combining gas collecting chamber, longitudinally slotted self-baking electrode and burner attachment correlated with an electrode slot, this burner attachment including means for withdrawing the products of electrolysis in lieu of the conveyor for supplying raw materials shown in the previous modifications.

Fig. 12 is indicative of a horizontal cross section of the structure of Fig. 11, taken along line 12—12.

Fig. 13 pertains to a diagrammatic plan section of an electrode provided with a gas collecting or double-ring chamber subdivided into four compartments, each compartment having positioned therein a device of the type described in any of Figs. 4–12.

Fig. 14 is another schematically indicated horizontal section of a differentiated association of double-ring chamber with an attachment device of the type disclosed, the device being shown positioned between two electrodes.

Fig. 15 pertains to an electrode modification in vertical section, preferably of the self-baking type, indicating a plurality of slots or channels extending longitudinally of its perimetric surface.

Fig. 16 shows an additional longitudinally slotted electrode modification.

Fig. 17 is directed to a horizontal fragmentary section taken along line 17—17 of the electrode modifications shown in either Fig. 15 or Fig. 16, together with a curve of the heat or temperature characteristics applicable to the lower portion of the slotted zone or area determined by the adjacent electrode wall surface.

Without intending to be restricted to any particular theory or explanation it is generally recognized that optimum conditions are applicable for the efficient operation of a given electrolytic furnace or cell, dependent upon the characteristics of the said cell or furnace as well as the nature of the reaction involved. Similarly and as a corollary to the furnace or cell operation it is well recognized that the electrode chemical procedure per se is usually subject to optimum conditions of reaction.

In connection with such optimum conditions of operation and reaction, there are definite indications to the effect that the temperature involved may be of critical importance, and this is illustrated by reference to the electrolytic production of aluminum from a molten bath comprising cryolite and alumina as the electrolyte. Thus a temperature materially in excess of that pertaining during optimum conditions of operation results, among other objections, in an undue energy loss and an adverse effect on the structural facilities. Conversely an excessive reduction of temperature may detrimentally affect the reaction and cell operation since it tends to increase the viscosity of the electrolytic bath with an attendant decrease or retardation of the solubility of the raw materials supplied thereto, particularly alumina. In this connection while a highly fluid bath is conducive to a comparatively rapid source of alumina added to the electrolyte, as the bath viscosity increases the solubility characteristics of the alumina therein are diminished. Moreover the increase of electrolyte viscosity manifests an objectionable effect on the electrolysis, and as the temperature is unduly permitted to decrease there is a more or less progressive tendency of the electrolyte to assume the condition of a viscous paste and ultimately even an essentially solidified state.

It is noteworthy that even with efficient operation and optimum prevailing temperature, the electrolysis of an alumina-cryolite bath manifest a tendency to surface crust formation. Thus this characteristic surface crust, it is believed, may function in the capacity of a heat insulator with the temperature within the body of the bath below the crust being retained at an appropriate value for optimum conditions of electrolysis. Despite this possibility of retaining an element of efficiency in view of the said characteristic crust formation, from a practical standpoint the maintenance of an efficient operation has proved to be difficult if not impossible. This is illustrated by the necessity for crushing the surface crust, usually by manual efforts, as a preliminary to feeding the raw materials to the bath, thereby disturbing the efficiency of the reaction. Moreover the practice in the art has been to avoid such disturbance of the reaction until the interval that a so-called "anodic effect" develops, this being indicative of a drop in the content of raw material, especially alumina, required for continuing the electrolysis. At the interval of the "anodic effect" manifestation, the bath temperature rises quite abruptly to a value materially above the optimum temperature conditions, and the supply of raw material to the bath during this interval causes a material drop in temperature due to heat losses from the bath surface as well as in view of the heat values required for bringing the raw materials up to the bath temperature. In summary the supply of alumina to the bath at the time that an "anodic effect" has developed per se results in a significant heat loss, and together with the inevitable losses attendant the intermittent necessity for breaking the crust to feed raw materials, substantially impairs the efficiency of operation.

This objectionable disturbance of optimum

temperature conditions is not subject to obviation by resort to a mechanical agitation in an effort to prevent crust formation, since such recourse introduces the objections of localized cooling of the bath and the aforesaid tendency to a development of an excessive electrolyte viscosity, with the disadvantages indicated above. On the other hand, resort to temperature values materially above the level of optimum efficiency on its face is inconsistent with practical and expedient cell operation.

Within the purview of the present invention, it has been found that the requisite operative efficiency may be attained by the expedient of providing or retaining a predetermined restricted area or areas of electrolyte or bath surface in an essentially molten state, or susceptible to conversion to such a state, during the operation of the furnace or cell under optimum conditions, including that of preferred temperature values. Under such circumstances, the raw or make-up materials may be supplied to the bath, or reaction products withdrawn therefrom, at the aforesaid molten area or areas without the necessity of intermittently crushing the surface crust formation or resorting to objectionable mechanical stirring, and generally without disturbing the optimum conditions of cell operation. Moreover it has been further ascertained that the desired localized molten areas of bath surface may be expediently provided by appropriate concentration of heat at such points, and that the gases evolved by the electrolytic operation per se, or supplemented by gases from any predetermined extraneous source, may effectively supply the required heat values. Similarly if desired, the requisite heat may be attained exclusively through the expedient of a heating medium or vehicle derived from a source outside of the electrolytic operation.

The following is illustrative of the heat values attainable from the operation of a given cell in the production of aluminum by the electrolysis of an alumina-cryolite bath, wherein the energy requirements have been approximately 18 kilowatt hours per kilogram of aluminum produced. The optimum temperature for the cell operation within the body of the molten electrolyte is approximately 920° C. to 925° C., this minimum temperature value being scarcely 20° above the solidification point of the bath and corresponding with a maximum current efficiency. It will be noted, however, that a requisite for efficient electrolytic operation of the cell is the maintenance of a temperature which will afford expedient solubility of alumina in the electrolytic bath at the points where alumina is added thereto. In view thereof, a temperature of approximately 960° C. is required for operation of the said given cell in accordance with conventional practice. The said temperature of 960° C. involves a reduction in current efficiency and an increase in energy requirements per kilogram of aluminum obtainable, in order to attain expedient solubility of alumina in the bath, other conditions of operation being equal. However, pursuant to the present invention, the temperature of the localized area of feeding is maintained irrespective of that of the bath as a whole at a value sufficient to afford the requisite molten state for the feeding and solution of the alumina, thereby permitting the bath temperature otherwise, i. e. at other areas, to be lower such as at a value of 920° C. to 925° C., with an improved efficiency of operation.

Referring to electrolytic operations involving the use of a self-baking type of carbonaceous electrode, the paste compositions normally utilzed contain a hydrocarbon binder, such as coal tar or the like, which represents approximately 20% to 30% of the electrode composition. Moreover it has been noted that approximately one-half (50%) of the said hydrocarbon is evolved from the said electrode paste composition during the baking process as volatile or gaseous constituents, and the attendant consumption of carbonaceous paste may comprise about 0.55 kilogram per kilogram of aluminum produced. Accordingly with the hydrocarbon binder content in the electrode composition being for example approximately 22%, the amount of volatiles or gases obtainable primarily from the binder of the self-baking electrode during the cell operation will be approximately 0.06 kilogram

$$(\text{i. e., } 1\times 0.22\times 0.55\times 0.50=0.06)$$

per kilogram of aluminum obtained.

Assuming the calorific value of these volatiles or gases through their combustion as approximately 9000 calories per kilogram, it will be seen that an approximate value for the available heat from this source is in the vicinity of 540 calories per kilogram of aluminum produced, this corresponding to 0.63 kilowatt hour of electrical energy. On the basis of an energy intake of 18 kilowatt hours, estimated as the requirement for the given electrolytic cell operation in accordance with prevailing practice, the available heat content of the gaseous constituents thus attainable from the hydrocarbon or similar content of the self-baking electrode may comprise approximately 3.4% of the total energy requirements applicable to the operation of said cell.

In addition to this source of available heat, the gases emanating from the electrochemical cell afford a substantial source of additional heat values as a part of the electrolytic operation. Thus the cell gases may essentially comprise a mixture containing fluorine, carbon dioxide and carbon monoxide. In view of the comparatively small proportion of fluorine present, this gaseous mixture may to all intents and purposes be assumed for present consideration as comprising approximately 70% CO_2 and substantially 30% CO. However it should be realized that the amount of CO may be considerably higher and as much as 60% of the gas mixture, thereby affording a corresponding advantage in heat conservation.

The actual amount of electrode carbon consumed during the electrolytic operation, as by combination with anodic oxygen from accessible or infiltrated air, to form the aforesaid CO_2 and CO mixture ordinarily comprises approximately 0.50 kilogram per kilogram of aluminum produced. A stoichiometric determination of the carbon content in one kilogram of the aforesaid CO_2-CO mixture in the proportion of 70%:30% is approximately 0.285 kilogram. Accordingly on the basis of the above indicated consumption of 0.50 kilogram of carbon per kilogram of aluminum obtained, 1.75 kilograms of gases are generated

$$\left(\text{i. e. } \frac{0.50}{0.285}\right)$$

for each kilogram of aluminum attainable. With the CO content of the gas mixture 30% as indicated, the proportionate weight thereof per kilogram of aluminum will be approximately 0.52 kilogram.

The combustion of CO to CO_2 yields approximately 2430 calories per kilogram of the said CO. Accordingly 0.52 kilogram of CO, attendant the production of 1 kilogram of aluminum as above indicated, is adapted to provide aproximately 1270 calories or substantially 1.47 kilowatt hours of energy in its conversion to CO_2. This latter value represents approximately 8% of the prevailing energy consumption of 18 kilowatt hours per kilogram of aluminum produced.

Combining the potentially available heat effect attendant the volatiles from the self-baking electrode, estimated as 3.4% of the total energy intake of the given cell, and that attributable to the electrolytic cell gases, represented by the estimate of 8% of the energy requirements, the total heat available from the cell operation may comprise approximately 11.5% of the input energy requirements. Differently stated, on the basis of 18 kilowatt hours energy requirements, the energy equivalent of the gas volatiles from the self-baking electrode may comprise an estimated 0.63 kilowatt hour, and the energy equivalent of the electrolytic cell gases may be approximately 1.47 kilowatt hours, these together representing a total of about 2.10 kilowatt hours of the original energy input.

Thus it should be noted that this estimate of heat conservation is subject to being supplemented by the inherent heat characteristics of the evolved gases in view of the comparatively high cell temperature prevailing in the zone of their evolution. This added available heat content of the gases may amount to as much as approximately 0.30 kilowatt hour of energy per kilogram of aluminum produced. In this connection, while the CO_2 content of the gases does not provide heat values through the expedient of combustion, the inherent temperature characteristics of this gas will nevertheless contribute to the over-all conservation of heat within the scope of the present invention.

The importance of the aforesaid heat conservation is emphasized by the realization that of the 18 kilowatt hours input to the cell for the production of 1 kilogram of aluminum, approximately 30% or 5 to 5.5 kilowatt hours are ordinarily dissipated through the electrolyte surface, such as the crust covering the same. By the adaptation of the aforesaid recuperated heat equivalent exceeding approximately 2 kilowatt hours, represented by the above referred to available heat from the gas volatiles evolved by the decomposition of the self-baking electrode and that obtainable from the electrolytic operation, to predetermined restricted areas of bath surface, effective molten areas may be expediently maintained and coordinated with raw material supply.

In this manner resort to manual deincrustation as a prerequisite to the feeding of raw material to the bath or the withdrawal of aluminum therefrom may be substantially obviated, and the development of any "anodic effect" essentially controlled. Similarly the features of the invention lend themselves to an expedient continuity of operation under optimum conditions including that pertaining to temperature values applicable to an efficient cell operation.

As previously indicated, the foregoing consideration and explanations are not intended to be restrictive to any particular theory or example, these being merely illustrative of the features of the invention as herein described. Effective means for concentrating the heat available through the operation of the cell in accordance with the present invention will be apparent from the further detailed consideration of the preferred modifications of devices shown in the various figures of the drawing.

The normal operative conditions which are believed to prevail in the cell, with illustrative reference to the production of aluminum by the electrolysis of an alumina-cryolite bath, are indicated in Fig. 1 wherein the cell designated as **1**, desirably comprises the cathode, while a fragmentary portion of the anode **2** is shown appropriately positioned relative to said cathode. It will be noted that the term "cell" is intended herein to be of generic purport, embracing within its scope electrolytic furnaces or the like embodying the use of electrodes for effecting an electrolytic operation. Desirably the said anode is of the self-baking carbonaceous type, and the interpolar area generally indicated as **3** embraces the interpolar zone between the electrodes. The layer **4** at the bottom of cell **1** refers to metallic aluminum resulting from the electrolysis reaction, while the strata **5** represents the electrolyte. The broken arrow lines **6** are indicative of the circulation of the molten electrolyte within interpolar area **3**, and the upwardly directed lines **7** are suggestive of the course of the gases evolved by the electrolysis. Thus the said zone **3** substantially comprises a comparatively narrow interpolar area or zone wherein maximum electric current and temperature conditions prevail and within which the optimum tendency toward retention of molten conditions in the bath is afforded. Under the conditions which pertain in the ordinary operation of a cell of this type, the lateral extent of area **8** on the perimeter of zone **3** from the walls of self-baking electrode **2**, where the temperature at the bath surface is sufficient to provide a substantially molten area or zone, may be approximately one to two inches. Beyond this area **8** the tendency toward crust formation exists and the extent thereof progressively increases with the distance from the electrode and the said zone **3**.

The curve **9** shown in Fig. 2 illustrates the aforesaid temperature characteristics of zone **3**, the upper portion **10** of said curve representing the maximum temperature occurring within interpolar area **3**, and the progressive reduction of temperature with attendant increase in crust forming tendency being indicated by portion **11** of the said curve **9**.

The various apparatus modifications shown, illustrative of preferred embodiments of the invention, are adapted to utilize the gas resulting from the electrolytic operation as above indicated. Thus by concentrating, at a predetermined area or areas of bath surface, the heat values obtainable from the gases evolved by the electrolytic operation, including that provided by the electrode decomposition, such as the volatiles from the self-baking electrode and the combustible gases emanating from the electrolytic reaction, desirably in a zone contiguous the said electrode, a comparatively enlarged molten area or areas of bath surface may be maintained. By coordinating this heat utilization with the supply to the bath of raw materials, such as alumina, or with the removal of aluminum formed by the electrolytic reaction, the continuity of cell operation is rendered expedient, not only without impairing the efficiency of operation but actually resulting in an enhanced efficiency.

Referring more particularly to the features of

invention embodied in the modifications shown by the various figures of the drawings, the means for maintaining a localized area or areas of bath surface in molten state is desirably a removable attachment adapted to function as a burner device and preferably coordinated with a chamber adapted to segregate the gases evolved by the electrolytic operation. Desirably this gas collecting chamber peripherally extending around the electrode may be the double ring chamber expediently correlated with the mold casing of a self-baking electrode. Advantageously the attachment device includes a conveyor means for supplying raw material to the bath, or means for withdrawing the product of the electrolytic reaction, and such means may be either permanently or removably associated with the attachment. Thus the concentration of the inherent heat content of the gas mixture from the double ring chamber passing through the attachment device as well as the heat developed by burning the combustible content of said gases within said device serves to retain an appropriate area of bath surface in substantially molten state, and may be adapted for facilitating the baking of the electrode composition, as well as for preheating the raw material supplied through the molten zone or for effectuating the invention.

As shown in Fig. 3, the double ring chamber 13 is determined by a plate member 15 extending horizontally from the mold casing 12 of electrode 2 to which it is integrally attached. The dimension of said plate 15 is essentially determined by the lateral extent of the area at which the concentration of heat resulting from gas combustion is to be directed, and may expediently be approximately 6 to 9 inches. Depending from plate 15, desirably by a hinge attachment 14 is flange or plate member 16, which extends downwardly to a point substantially contiguous the surface 17 of the electrolytic bath. The portion 18 of the said electrolytic bath surface between said flange member 16 and the walls of cell 1 are usually provided with a crust formation, over which is positioned raw material 19, such as alumina. This material serves to function as a seal for the space 20 between the lower end of flange 16 and the bath surface 17. Accordingly as the electrolytic reaction proceeds, the gases evolved including that attributable to the binder material and decomposition of electrode 2 will be essentially collected in double ring chamber 13.

The aforesaid horizontal plate member 15 comprising the top of the double ring chamber is provided with an opening through which the attachment device 21, which may be termed a burner device, is inserted. This attachment 21 is provided with a peripheral flange member 23 for removably supporting and seating the same in predetermined position on plate member 15. While the removable association of the burner device 21 with the double ring chamber 13 may involve elements of preference, it will be understood that the attachment may be permanently affixed to the cell, the requisite being its expedient positioning relative to the bath surface. As shown in Fig. 3 as well as in the other modifications, the lower end 22 of the attachment desirably extends within the double ring chamber nearly to the bath surface, the distance between the said attachment portion 22 and electrolyte being subject to the dictates of expedience.

The said attachment comprises in integral association a housing 24 having therein and desirably affixed thereto in any expedient permanent manner, conduit 25. Conveyor tube 26 is shown as concentrically positioned relative to conduit 25 and is provided with a conveyor element 27 therein. The said conveyor tube 26 may likewise be affixed in any expedient manner to conduit 25, desirably in a permanent coordination, as by a spider element 28 and defines therewith passage 29. The said conveyor element 27 is similarly subject to any suitable manner of support within tube 26, being of practicable adaptation either as a permanent or as a removable member. In the latter event, the conveyor element may be replaced within conduit or tube 26 by any expedient means for withdrawing from the bath products of reaction, such as molten aluminum, as will be further considered hereinbelow. Alternatively in lieu of the screw conveyor 27, a gravity feed may be relied upon in which event tube 26 may be free from any positive conveyor element therein.

The lower end 30 of conveyor tube 26 is flanged outwardly to provide an enlarged outlet essentially coinciding with the dimension at the lower outlet portion 22 of housing 24. As shown, end 30 is permanently affixed to said lower portion 22 of housing 24, but as above indicated, this attachment may be of a removable type.

The housing 24 is shown provided with ducts 31 which may be valve-controlled if desired, and through which air may be supplied into the space 32 determined by housing 24 and the concentrically positioned conduit 25 therein. Similarly the lower end of housing 24 at the portion 22 thereof is afforded with ducts 33 through which the gases from double-ring chamber 13 pass into the said space or zone 32.

At the upper end of conduit 25, a conduit 34 is indicated through which a predetermined suction may be manifested within said conduit 25, by any expedient source of aspiration or suction not shown. Thus conduit 34 in effect comprises the gas outlet of attachment device 21.

As a matter of practical expediency, the burner device of any of the modifications shown may be positioned within a segregated compartment of the double-ring chamber. As shown in Fig. 4, the device 21 is located in a compartment 35, defined by wall members or partitions 37 projecting downwardly from top 15 of the double-ring chamber. The ports 38 permit the ingress of the gases from the double-ring chamber into compartment 35, whence the gases are drawn into the burner device. While the said partitions may be desirable, it should however be understood that they are not required for an effective operation of the burner assembly.

In the operation of attachment 21, as a result of the suction or vacuum effect manifested through conduit 34, a predetermined suction is provided within conduit 25. Thus gas from compartment 35 is drawn through duct 33 and becomes admixed in zone 39 with air supplied from ducts 31 through passage 32. The combustion of this gas mixture, if necessary by resort to ignition results in a substantial heat generation which is radiated from the combustion zone 39 towards the bath surface below, as through the lower portions 30 and 22 of the attachment device.

As a result of the aforesaid gas combustion and heat evolution, a localized area 40 of electrolyte surface is expeditiously maintained in molten state, notwithstanding the prevailing tendency to surface crust formation in the remaining or bordering areas of bath surface. It will be seen that this area 40 liberally embraces the end 22 of

the attachment assembly through which material is fed to the bath or withdrawn therefrom.

Thus illustratively referring to the showing of Figs. 3 and 4, raw material such as alumina may be supplied in controlled quantities by the screw conveyor 27 through conduit 26 into molten area 40 of the bath, without materially disturbing the electrolytic operation or necessitating any breaking of surface crust. Moreover the raw material is preheated in its passage to the molten bath area, in view of its flow in heat exchange relationship with the gaseous products of combustion, which are withdrawn upwardly from combustion zone 39 through conduit 25 and out through conduit 34.

It should be apparent that the attachment assembly 21 lends itself to variable adaptations, and the details for attaining the requisite heat values are likewise subject to variations. Thus where the prevailing conditions suggest the desirability, the gases from the electrolytic operation may be supplemented by combustible heating gases from any extraneous source. These supplementary gases may expediently be supplied to the double-ring chamber, as by a valve controlled inlet fitted to the top plate member 15, although the point of entry may be subject to change pursuant to the discretion of the operator, such as by the addition of the supplementary gases to passage 32 of attachment assembly 21, as by preliminary admixture with air through duct 31.

This extraneous gas, which may be of any inflammable type adapted to burn exothermically including volatilizable hydrocarbons, ultimately becomes admixed with gases resulting from the electrolytic operation, the consummated mixture then being ignited and burned in the aforesaid zone 39 for appropriate concentration and radiation of heat values relative to the predetermined area of bath surface.

It is further within the contemplation of the invention to supply an inert gas, such as N_2 or CO_2, for admixture with the combustible heating gas, thereby controlling the combustion of these gases. The introduction of the inert gas may likewise be directly into the double ring chamber, wherein it becomes admixed with the gases resulting from the electrolysis operation. Moreover the resort to inert gases in excess may be expedient where any emergency situation develops with respect to the combustible gas mixture contemplated for the heat development through burning within the attachment assembly 21.

Generally the operation pursuant to the invention may be controlled in a manner to afford a slight positive pressure within the double ring chamber 13. The provision of such pressure conditions is facilitated where the supplementary gases, whether combustible or inert, are fed into this chamber. It is through this pressure expedient that any tendency of uncontrolled air leakage into admixture with electrolytically evolved gases is minimized, and this factor together with the contributing effect of inert gases added, results in substantially minimizing the possibility of corrosion ordinarily applicable to the electrode 2.

Irrespective of the fundamental structural features of the device as shown in Figs. 3 and 4, it will be understood that the details thereof may be subject to substantial variation dependent upon the dictates of expediency and preference of one versed in the art, and the same pertains to the general configuration of the the device. Thus the width of the double-ring chamber may be enlarged or diminished, this being essentially determined by the dimensions of the top or horizontal plate member 15 and the vertically disposed plate or flange member 16 integral therewith, although as previously indicated, desirably in hinged attachment thereto. Moreover and by the same token, the double-ring chamber need not be uniform in its configuration, since the shape thereof will be subject to the relative positioning of the walls or plate members, such as 15 and 16, partition members as 37, as well as the electrode mold casing, designated in Figs. 3 and 4 by the numeral 12, all of which are determinative of the double-ring chamber characteristics. The effect of the electrode mold casing on the chamber design is indicated in Figs. 9 and 10 by way of example, where this casing conforms with a novel type of electrode having a distinctive peripheral structure. In brief the dimensional characteristics and configuration of the double-ring chamber are such as to permit the expedient segregation of gases resulting from the electrolytic operation and to conform with the desirable coordinated association of the double-ring chamber with the burner device, in view of the function of the latter directed to the ultimate purpose of an improved structure and procedure for the electrolytic production of aluminum.

The burner modification shown in Figs. 5 and 6 embraces the fundamentals of structure and function contemplated by the device of Figs. 3 and 4. The double-ring chamber 13 and its formation through plate members 15 and 16 together with their attachment to or coordination with electrode 2 and its casing 12 generally correspond with that described hereinabove. However in view of the characteristics of the removable burner device in this modification, the opening 41 in the top member 15 is designed to aptly receive the burner assembly generally designated as 42. It will be seen that the edge of plate member 15 adjacent the electrode should be adapted to permit the passage therethrough of the end wall portions of conduits 43 and 46, and desirably this may be provided for by accommodating slits in said edge plate portion 15 which extend from the above referred to opening 41 therein.

This assembly 42 essentially comprises a U-shape housing 43, the ends 44 of which extend to a frictional engagement with mold casing 12 in order to provide an enclosed zone between said housing and mold casing. Nevertheless this frictional closure is not such as to unduly interfere with the removal of burner assembly 42 from opening 41. On the outer or peripheral surface of housing 43 a flange member 45 is provided for supporting the assembly on the top plate member 15 of the double-ring chamber, and desirably the said flange member 45 conforms with the U-shaped configuration of the housing 43 to which it is attached. Positioned within housing 43 is a second U-shaped conduit 46, and the relative association of 45 and 46 corresponds in a sense with a concentric arrangement determining the chamber or zone 47 through which air may be admitted to the burner assembly for admixture with gases from the double-ring chamber.

The said conduit 46 is preferably in integral attachment with housing 43. Within conduit 46 is located conveyor conduit 48 having a screw conveyor 49 operatively positioned therein. The said conveyor conduit 48 may be permanently attached at its lower end 50 to the bottom portion 51 of housing 43, and the relative association

of the said conveyor tube with conduit 46 defines the suction zone or chamber 52. A valve controlled air inlet tube 53 is provided at the upper end 54 of zone or chamber 47.

The support of the screw conveyor 49 within its conduit 48 may be in any manner expedient to a removable association, although if desired the screw conveyor may be permanently affixed in position. Similarly the support of the said conveyor tube 48 within conduit 46 may be augmented by a spider means. If the conduit 48 is intended to be removably supported relative to conduit 46, a conventional spider flange attached to the peripheral surface of conduit 48 may be resorted to for seating on a flange extending from the inner surface of conduit 46; at the same time conveyor conduit 48 will not be in permanent attachment at its lower end 50 with portion 51 of the assembly housing.

In the operation of this device, the gases from the double-ring chamber will be drawn through openings or ducts 55 in partition members 37, thence through port 56 of housing 43 for admixture in zone 47 with air supplied in controlled amounts through tube 53. The gas and air admixture is caused to burn as by ignition at the lower portion of zone 47 designated in the drawings as 57. The heat of combustion is radiated from this zone to the bath surface below, and the gaseous products of combustion are withdrawn through zone or chamber 52, which provides an element of heat exchange with alumina or raw materials being supplied in controlled amount through conveyor conduit 48. The suction manifested on the assembly is exerted through conduit 52 by a means not shown.

The same variations as to details of operation involving the supply of auxiliary combustible or inert gas as considered hereinabove with reference to Figs. 3 and 4 are likewise applicable to the modification of Figs. 5 and 6. Similarly other possible variations in structure and procedure as previously considered are to the same extent generally pertinent to this apparatus modification.

An additional effective burner modification is that presented in Figs. 7 and 8, generally designated as 59. This assembly is supported through the expedient of a flange 60 integral with the outer peripheral wall of the assembly and adapted to seat on top plate member 15 of the double-ring chamber 13. It will be seen that essentially the structure involves a U-shaped wall 61 with the ends thereof 62 fixed to a rear wall member 63 to desirably constitute a weldment assembly, although any expedient attachment may be resorted to. The conveyor conduit 48 with the screw member 49 therein is shown supported by means of flange member 64 integrally attached to the upper portion thereof, this flange member being adapted to seat on the upper end 65 of the aforesaid U-shaped wall 61. Thus the conveyor tube is indicated as removably supported, although it will be understood that alternatively a permanent attachment may be resorted to. Extending longitudinally within wall 61 are passages 66 into which extend valve controlled air tubes 67. The number of such passages is clearly subject to variation, three being shown in the modification indicated. The lower end 68 of passages 65 terminates in a conical shaped port 69 extending between the double-ring chamber compartment 35 and suction passage or zone 70 determined by the inner surface of wall members 61 into outer surface of conveyor tube 48. The suction is manifested at the opening 71 of said zone or chamber 70.

The operation of this device is generally similar to that of the previous devices described. The gas from the electrolytic operation enters the double-ring compartment 35 through opening 38, and is drawn into the aforesaid duct 69 by the suction manifested within zone 70. In passing through said duct 69, the gases become admixed with a regulated quantity of air and, as previously are caused to ignite and burn adjacent the lower portion of the assembly and the surface of the bath. Thus the heat of combustion is adapted to obviate any tendency to crust formation at a localized area of bath surface conforming with the lower end of the assembly 59. Accordingly the raw materials may be supplied in regulated amounts through conveyor tube 48 without the necessity for resorting to any manual crushing of solidified bath surface. The gaseous products of combustion are drawn upwardly in heat exchange relationship with the supply of raw materials to the bath through conduit tube 48 and are passed out of the assembly through opening 71. Concerning the possible variations as to details of operation and structure, generally the same latitude is contemplated by the scope of the invention as illustratively considered with respect to the modification of Figs. 3 and 4 above.

Another effective assembly comprises that of Figs. 9 and 10. This assembly 75 involves the coordination of a desirable burner construction with a preferred modification of electrode, desirably of the self-baking type. The electrode 76 is provided with longitudinally extending slots or recesses 77 and is fitted within the mold casing 78, which conforms with the configuration of the electrode including the aforesaid slots. Thus the zone 79 corresponds with that portion of the electrode casing 78 which is fitted in the longitudinal slot 77 and affords an enlarged surface area contiguous of the electrode with the possibility substantially concentrated heat radiation and an attendant increased conservation of heat values in the vicinity of the bath surface within zone 79, quite irrespective of the effect of the burner device correlated with this electrode zone. By coordinating this zone 79, which is in effect defined by the surface of the electrode determining the aforesaid recess or slot, with a double-ring chamber and burner device, pursuant to the present invention, an especially effective heat utilization and efficiency of cell operation is attainable.

Referring to the structural features of this modification, a U-shaped ledge 80 projects from an appropriate location on the peripheral surface of electrode casing 78 within said zone 79, this ledge being adapted to function as a seat for the assembly device 75. The device comprises a U-shaped bottom member 81 which conforms with the aforesaid ledge 80 as to configuration and is removably seated thereon. Wall member 82 extends vertically from adjacent the bath surface to the top 83 of the burner assembly, said top being seated on the upper end of said wall 82. Substantially concentrically positioned between the said wall member 82 and electrode casing 78 is the conveyor conduit 84 having the usual screw conveyor 85 operatively positioned therein, and the said conveyor tube 84 is affixed at one end to U-shaped bottom member 81 to provide the opening 86 at that point. The upper end of the conveyor tube is likewise attached to the aforesaid top member 83 at opening 86 therethrough.

Thus the conveyor tube 84 is located within zone or chamber 87.

Vertical wall member 88 extends from a point adjacent the surface of the bath parallel to said wall member 82, although terminating at a length less than that of the latter wall member, as at horizontally extending plate member 89 which is integrally attached at one end to wall member 88 and at the other end to wall member 82, thereby determining the top of compartment 90. The base of the said compartment comprises plate member 91 which is essentially parallel to said top member 89, and similarly may be in unitary attachment at one end with wall member 88 and at the other end with wall member 82. Thus the lower portion of said wall members 88 and 82 together with plate member 91 determine the equivalent of a double-ring chamber compartment 92. Although the outer wall 93 of the double-ring chamber is open at 94 the positioning of the assembly 75 in the predetermined coordinated relationship with slotted zone 79 of the electrode results in wall 88 of the device functioning as the outer closure of the double-ring chamber at said opening 94.

In the operation of this device modification, gases from the double-ring chamber pass through openings 95 into compartment 90 and are caused to flow through duct 96 into housing or chamber 87, desirably positioned in proximity to the surface of the electrode defining the recess or slot 77, and as shown being in effect within the said recess or the zone determined thereby. The supply of air in controlled quantity is attained through valve regulated tubes 97, the air being admixed with the gases at the outlet of tube 97 within duct 96, the mixture passing into chamber 87 where it is adapted for combustion, by ignition if necessary. The heat of combustion is radiated through the aforesaid member 81, which in essence comprises an area positioned within zone 79, while the products of combustion are directed upwardly through chamber 87 in heat exchange relationship with conveyor conduit 84 and thence out through conduit 98. It will be understood that during the said combustion directed to maintaining the bath surface below plate member 81 in essentially molten state, raw materials, such as alumina, may be supplied in regulated amounts through the expedient of screw conveyor 85. It is of interest to note that the flow of gases from compartment 90 into compartment 87 may be effectuated by the injector relationship of air tubes 97 to ducts 96. However suction may be expediently relied upon to withdraw the products of combustion from zone or chamber 87 through conduit 98. As repeatedly emphasized hereinabove, the various ramifications of procedural and structural variations, such as considered in detail in the discussion relative to the modification of Figs. 3 and 4 are also applicable with respect to the present burner attachment. It is noteworthy that this attachment, as distinguished from those preceding, in effect embodies double-ring chamber compartment as an integral part thereof, whereas in the previous device the double-ring chamber compartment is shown integral with the double-ring chamber and separable from the attachment assembly.

The modification of Figs. 11 and 12 likewise includes the combination of burner device and double-ring chamber compartment as an integral assembly 100. This assembly is as in the case of the modification of Figs. 9 and 10 coordinated with slotted zone 79 of mold casing 78 in which electrode 76 is molded and utilized. A U-shaped ledge 101 integral with casing 78 within zone 79 functions as a seat for the said assembly attachment 100. Among the integral parts of the assembly are the U-shaped conduits 102 having the ends thereof integrally attached to vertical wall portion 103. Thus the said conduit 102 in effect determines zone or chamber 104 through which tube 105 may project into the aluminum within the electrolytic bath. Said tube 105 passes through an electrical insulator 106 integral with top plate member 107 of the assembly which is seated on the aforesaid ledge 101. It will be seen that the said tube 105 is adapted for vertical movement through the said electrical insulator 106. Depending from the outer extremity of top plate member 107 is vertically extending end wall 108 which projects to a point contiguous the bath surface and determinative of the lower end of the assembly. A horizontally extending plate member 109 attached at end 109' to vertical wall 108 and at the other end 110 to wall portion 103 defines with top plate member 107 a chamber or zone 111, this zone being connected with zone 104 through duct 112. Integral with and projecting from the under side of plate member 109 is the angular shaped member 113, the horizontal portion thereof being affixed to U-shaped conduit 102. Thus the vertical portion of member 113 defines with wall portion 103 zone or chamber 114, while zone 115 is determined by the said vertical portion of member 113 and wall 108. As in the case of the modifications shown in Figs. 9 and 10, outer wall 108 of the attachment serves as a closure for opening 94 in the outer wall 93 of the double-ring chamber.

In the operation of this device modification, gases from the double-ring chamber flow through openings 116 into compartment 115, thence through ducts 118 into zone 114. At the same time, air may be supplied in controlled quantity through valve controlled tube 119 for admixture with the gas within chamber 114, and the ignition together with attendant combustion of the resultant gas mixture affords the desired heat evolution which is radiated through the horizontally extended portion of angular member 113 to the surface of the bath therebelow. The products of combustion are withdrawn from combustion zone 120 through port 117 into chamber or zone 104 embracing the aforesaid tube 105, thereby utilizing the heat values of the exhausting gases over a substantial surface of the said tube 105. The significance of this heat exchange is that the said tube 105 is utilized for withdrawing molten aluminum from the lower strata of the electrolytic bath, as by applying suction at the end 124 thereof, and the said aluminum is thereby retained in molten condition in view of the indicated heat exchange. The gaseous products of combustion are withdrawn through chamber 111, which may desirably envelop the electrode portion and its attendant casing in a heat exchange relationship. Thence the gas flows through conduit 121 which affords a maximum zone of contact with the said electrode portion casing, in order to contribute an efficient heat exchange effect relative to the self-baking aspects of the electrode.

Desirably the said aluminum withdrawal tube 105 is removable relative to the attachment and may for example be replaced by a tube for the supply of raw material to the electrolytic bath. This concept of replacing raw material conveyor

by means for withdrawing the products of the electrolytic operation, it will be seen, is generally applicable to the other modifications described hereinabove, subject to slight changes in the construction without avoiding the scope of the present invention. It should be added that as previously stated with respect to all of the other devices, the adaptation of auxiliary combustible or inert gases to the procedural aspects of the invention or the various other changes applicable to either the procedure or details of apparatus in similar measure pertain to the presently discussed assembly attachment.

A desirable adaptation of the features of the present invention is schematically indicated in the horizontal cross sectional view of Fig. 13. In this arrangement, the electrode 2 is embraced by double-ring chamber 13 which, through the expedient of wall members 122, similar to partitions 37 referred to hereinabove, is divided into 4 compartments by way of illustration. Within each of these compartments, one or more, as desired, of a preferred type of burner assembly 123, such as those exemplified by the illustrations hereinabove described may be positioned. It will be understood that each assembly 123 is independently operative relative to the other assemblies utilized, and it is not necessary to adhere to any one type of assembly, since, in view of its independent function, each asembly 123 may be of a different type corresponding with the predetermined desire and conditions of operation. Moreover and in similar vein, while one assembly 123 may include a raw material feed conveyor means, another assembly may involve the use of a conduit for removal of the product of electrolysis, such as aluminum.

Another diagrammatic sectional showing of arrangement of devices within the scope of the present invention is shown in Fig. 14. In this embodiment two electrodes 2 are presented within double-ring chamber 13. Two devices 123 of the present invention are shown positioned between the respective electrodes. The showings of Figs. 13 and 14 are merely indicative of the fact that the invention is subject to substantial variation in its adaptation, as with respect to the number or positioning of the devices of the type described herein. Moreover the resort to separate compartments for each unit 123, as described in connection with the various modifications, may be within the contemplation of the variations applicable to the positioning of the devices, and conversely the adaptation of such compartments may be avoided.

Electrode 125 of Fig. 15 provides a cross-sectional indication of a desirable modification of anode wherein a plurality of slots or recesses are contemplated. In this showing, 4 slots or recesses 126 are indicated, but this is subject to substantial variation in accordance with preference and the dictates of the conditions of operation. Thus as provided for in Fig. 16, the configuration of the electrode 127 is distinguished from that of Fig. 15, although 4 slots 126 are likewise contemplated by this electrode modification. Thus it will be seen that the scope of the invention includes features of electrode construction, both with respect to configuration and provision of surface irregularities or slots, which render the electrodes particularly adaptable for coordination with the features of the invention relating to the concentration of heat values at predetermined areas of bath surface and the correlated supply of raw material or withdrawal of products of electrolysis from the bath. In this connection, it will be understood that the electrodes within the contemplation of Figs. 15 and 16 may desirably be of the self-baking type, it merely being requisite that the steel casing through which the electrodes pass during their utilization conform with the configuration of the respective electrode to which they apply.

It will accordingly be seen that the features of the present invention include within their scope an electrolytic procedure adapted for the expedient and efficient electrolysis of materials, such as alumina, in the production of a predetermined product, exemplified by aluminum. Pursuant to this procedure the efficiency of operation is substantially enhanced by the control of the temperature conditions prevailing, by the utilization of heat values available by virtue of the gases evolved by the electrolytic operation, and through the coordination therewith of a predetermined supply of raw materials to the electrolytic bath or withdrawal therefrom of products of electrolysis, thereby facilitating a continuity of procedure.

In addition to the novelty in procedure, an important adjunct of the invention embraces features of apparatus including the various elements described as well as the combination of means for collecting the gases evolved by the electrolytic procedure and the means for their combustion in predetermined zones adapted to retain given surface areas of bath under molten condition, with the heat development coordinated with the means through which the raw materials may be supplied or through which the products of electrolysis may be removed during the course of cell operation.

In summary, the following are illustrative of the various features and attributes of the invention with particular reference to the electrolytic production of aluminum:

1. An improved efficiency of operation resulting in the minimizing of energy requirements and the reduction in manpower requisites.

2. An expedient continuity of operation under controlled conditions both with respect to the effective supply of raw materials, such as alumina, during the operation, or the withdrawal of reaction products, such as aluminum.

3. An optimum minimum temperature of operation under conditions of optimum acceptance by the proceeding reaction of raw materials, such as effective solubility of alumina in the electrolytic bath.

4. The conservation of heat values available from the electrolytic reaction as by the appropriate adaptation of the gases evolved for retaining predetermined areas of bath surface in essentially molten state.

5. The substantial control over any "anodic effect development" with the attendant improved efficiency of operation.

6. The substantial replacement of manual requirements by mechanical facilities in the performance of the operation, while maintaining the enhanced operative efficiency.

7. The substantial obviation of uncontrolled corrosion of the electrodes, especially the anode, during the electrolysis.

8. The development of novel devices, including electrodes, for concentrating the available heat values of the gases resulting from the electrolytic operation at predetermined areas of bath surface.

9. Feature of procedural novelty as described hereinabove.

Thus, pursuant to the invention, there is pro-

vided a novel procedure for efficient electrolytic operation especially adapted for the production of aluminum from alumina. Similarly afforded are expedient apparatus means of distinctly efficient operative adaptation notwithstanding the simplicity and sturdiness of structure involved. It should be understood that the details of disclosure, including the various figures of the drawings, are directed to preferred or optimum adaptations of the invention, and are primarily illustrative and not in any way restrictive of the scope of the invention, which is subject to substantial latitude as to its ramifications and variations.

While I have described my invention in accordance with desirable embodiments, it is obvious that many changes may be made in the details of construction and procedure, in the combination of parts and materials as well as in the steps of the process, without departing from the spirit of the invention as defined in the following claims.

Having thus set forth my invention I claim:

1. The method of performing an electrolytic process involving the evolution of combustible gases in a cell having a carbonaceous electrode and a molten electrolytic bath having a surface manifesting a tendency to crust formation, which comprises collecting the gases evolved by the electrolysis in a zone directly above the bath surface, the said gas collecting zone extending laterally from the said carbonaceous electrode and less than to the peripheral edge of the electrolytic bath, conducting said gases adjacent to at least one relatively limited area of the bath surface, said area being within the said gas collecting zone and comprising a portion of the bath surface within the said zone, admixing an oxygen containing gas with the said gases, burning said gaseous admixture adjacent to the said area of bath surface to facilitate the retention thereof in a substantially molten state, the said area being adapted for the conveyance of material to and from the said electrolytic bath at the said area, and maintaining the conditions of electrolysis such that the bath surface, externally of the said gas collecting zone, is in a substantially solidified state.

2. A process as in claim 1, wherein the gases evolved by the electrolysis, prior to burning the same, are supplemented by the admixture therewith of additional combustible gas, the said admixed oxygen containing gas being sufficient to completely burn the resultant combustible gaseous mixture.

3. The method as in claim 1, wherein the electrode comprises a self-baking carbonaceous anode, and wherein the raw material for electrolysis is supplied to the electrolytic bath at said molten area.

4. The method as in claim 3, wherein the gaseous products of combustion are withdrawn in heat exchange relationship with the supply of raw material to the electrolytic bath at said molten area.

5. The method as in claim 3, wherein the electrode is provided with at least one recess extending to the end thereof contiguous the bath surface and affording a zone of substantially concentrated heat radiation, and the area to which the gases are conducted for burning is in proximity to the surface of the said electrode determining the said recess.

6. The method of electrolytically producing aluminum which comprises subjecting to electrolysis an electrolyte containing aluminum oxide in a cell having a carbonaceous electrode, collecting the gases evolved by the electrolysis in a zone directly above the bath surface, the said gas collecting zone extending laterally from the said carbonaceous electrode and less than to the peripheral edge of the electrolytic bath, conducting said gases adjacent to at least one relatively limited area of the bath surface, said area being within the said gas collecting zone and comprising a portion of the bath surface within the said zone, admixing an oxygen containing gas with the said gases, burning said gaseous admixture adjacent to the said area of bath surface to facilitate the retention thereof in a substantially molten state, the said area being adapted for the conveyance of material to and from the said electrolytic bath at the said area, and maintaining the conditions of electrolysis such that the bath surface, externally of said gas collecting zone, is in a substantially solidified state.

7. A process as in claim 6, wherein the gases evolved by the electrolysis, prior to burning the same, are supplemented by the admixture therewith of additional combustible gas, the said admixed oxygen containing gas being sufficient to completely burn the resultant combustible gaseous mixture.

8. The method as in claim 6, wherein the electrode comprises a self-baking carbonaceous anode, and aluminum oxide containing material is supplied at the said molten area.

9. The method as in claim 8, wherein the electrolyte contains cryolite and the gaseous products of combustion are withdrawn in heat exchange relationship with the supply of aluminum oxide containing material to the said molten area.

10. The method as in claim 8, wherein the electrode is provided with at least one recess extending to the end thereof contiguous the bath surface and affording a zone of substantially concentrated heat radiation, and the area to which the gases are conducted for burning is in proximity to the surface of the said electrode determining the said recess.

11. In combination with an electrolytic cell comprising a container for an electrolytic bath having a downwardly dependent electrode coordinated with the said bath, said electrode being supported from above the container and extending into the electrolyte, a downwardly open chamber mounted adjacent to and extending from the electrode and adapted to closely overlie the upper surface of the bath in said container, the sides and top of said chamber being closed, said chamber being adapted for collecting combustible gases evolved by the electrolytic operation, a burner assembly comprising a housing at least partially within said chamber, a portion of said housing extending substantially to the open end of said chamber and providing a combustion zone adjacent to a comparatively restricted area of bath surface, a duct for conveying the collected gases from said chamber into said housing and to the combustion zone thereof, an air inlet communicating with said housing for admixture of air with and for the burning of said gases at said combustion zone adjacent to the said area of bath surface, the said housing having a passage extending therethrough and adapted for the transfer of materials relative to the said bath at the said restricted area, a conduit extending from within said housing for removing the products of combustion from said housing, and means for effecting the flow of said combustible gases

and air into the said housing and for the removal of the products of combustion through said conduit.

12. An apparatus as in claim 11, wherein conveyor means for the transfer of materials relative to the said bath at the said restricted area extends through said housing in heat exchange relationship with said conduit for removing the products of combustion.

13. An apparatus as in claim 12, wherein the conveyor means comprises a conduit having a screw conveyor therein for mechanically controlling the supply of material therethrough, and the said conveyor means is positioned within and extends through the said conduit for removal of the products of combustion.

14. An apparatus as in claim 11, wherein the passage comprises a conduit for the suction withdrawal of molten products of reaction from the bath.

15. An apparatus as in claim 11, wherein the housing extends from without the chamber into the same and is supported thereby at the closed top thereof.

16. An apparatus as in claim 11, wherein the housing is removably supported at the closed top of the chamber.

17. An apparatus as in claim 11, wherein the electrode comprises a self-baking carbonaceous anode provided with at least one peripheral recess extending longitudinally to the end thereof contiguous the bath surface, and the said housing is supported in proximity to the surface of the electrode determining the said longitudinal recess thereof.

18. An apparatus as in claim 11, wherein the said chamber is sub-divided to afford a plurality of compartments with a port for the passage of the collected gases to each said compartment from the said chamber, and wherein a housing is mounted at least partially within each said compartment.

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