An apparatus for collecting and removing gases emitted by an aluminum reduction cell consists of at least one channel extending between a suction inlet and exhaust outlet. At least one curvilinear partition extends within the channel, so as to divide it into respective gas suction zones. Such zones are formed to change the direction of the gas flow from substantially vertical at the suction inlet to substantially horizontal at the exhaust outlet.
Fig. 4

Distance from outlet branch pipe (m)

Vertical velocity component (m/s)
APPARATUS FOR COLLECTION AND REMOVAL OF GASES FROM AN ALUMINUM REDUCTION CELL

FIELD OF THE INVENTION

[0001] This invention relates to non-ferrous metallurgy in general, more particularly to gas collection and removal technology for production of aluminum by electrolysis.

BACKGROUND OF THE INVENTION

[0002] Electrolytic cells are well known in the art of metallurgy and specifically, in the production of aluminum by the electrolysis of alumina. Such an electrolysis cell has a tank which is open at its upper end and whose base is formed by metal bars supporting blocks of carbon. The blocks of carbon are connected by a lining and act as a cathode. The tank contains an electrolysis bath consisting of alumina dissolved in cryolite which is heated to a temperature of about 950°C, to 1050°C. Anodes made of carbon are dipped into the cryolite bath.

[0003] When electric current is passed through the cell, the alumina decomposes into aluminum and forms a metal bath which covers the cathode. Oxygen gas is released during this process. As a result, the lower portion of the carbon paste anode cooks because it is dipped into the high temperature electrolysis bath. Due to the presence of combustible oxygen, the anode becomes burnt while the upper (undipped) portion softens. As the lower part is burnt by the oxygen, the carbon mass has to be pushed downwards to keep the anode/cathode interval constant.

[0004] Combustion of the anode is accompanied by the substantial emission of fumes consisting of gases such as carbon dioxide, carbon monoxide, sulfur dioxide, gaseous hydrofluoric acid, and particles of carbon, alumina, and fluorine-containing compounds. A solid crust typically forms on the top of the electrolytic cells. The crust traps gas in the electrolytic cells forming a buildup of pressure. The crust may break in unpredictable places to alleviate the pressure buildup and allow the built-up gases to escape.

[0005] The gas contains noxious compounds which are detrimental to the health of individuals and the environment. Therefore, the gas must be collected and filtered. The increased volume of production of electrolytic cells is leading to an acute problem with regards to the gas collection and purification. Due to the increased size and volume of production facilities as well as stringent regulations, costs of gas disposal are increasing rapidly. Further, inefficient removal of gases from the electrolytic cell compromises the efficiency of aluminum production and often results in more gases being released into the workroom. Thus, the air of the building is more hazardous to breathe and extensive filters and purification techniques are needed before the air is ventilated to the atmosphere.

[0006] A typical method of collecting gases from the electrolytic cell involves collecting the gases from the roof of a building or contained space. The collection unit will collect gas emitted from many individual electrolytic cells. A large volume of air must be purified before exiting the facility, but the concentration of noxious fumes is generally low enough that it may be breathed, albeit uncomfortably. To purify the amount of air in a large facility requires a vast and expensive filtration system.

[0007] It is desired to filter the air closer to the source of the emission of the noxious fumes so that less air need be filtered and workers inside the facility do not have to breathe the noxious fumes. U.S. Pat. No. 4,668,352 and the USSR Patent Document 1473718 disclose means of providing suction and venting at regular intervals along the electrolytic cell so as to provide predictable and efficient gas diffusion. Each individual vent opens into a cross-section of the electrolytic cell. The venting area of the cell is bisected by horizontally placed walls spaced apart such that those walls higher in the cell extend inward from the vent less distance than those lower in the cell. Suction zones provided are approximately the width of two flaps of the cell exhaust hood. The space between two neighboring partitions is formed by two preset channels for gas removal from each suction zone, which converge into a common collector connected with the central suction device.

[0008] By this design, the inner bore of the electrolytic cell is divided by solid wall-to-wall horizontal bafflers. The bafflers prevent placing or moving an anode busbar or pins in this space. Channel geometry does not impede deposition of alumina present in the flow of gases and thereby causes withdrawal thereof from the cell in significant quantity. While this arrangement provides some improvement over the prior art gas collection systems, it causes formation of pockets of stagnation and does not contribute to the uniform gas collection and removal throughout the cell.

[0009] Further, Russian Federation Patent 2,218,453 discloses a system adapted for collection and removal of gases emitted from an aluminum reduction cell which comprises an anode beam formed with vertical walls, suction windows, and upper and lower stiffening members, so as to define channels adapted for collection and removal of gases. The channels are disposed in the top part of the anode beam, whereas each channel is provided with inclined restrictive members forming a suction slit of constant width and variable height. The height of the channels increases in the direction of an end of the anode beam connected to the gas exhaust system.

[0010] From the detailed mathematical modeling based on a complete three-dimensional mathematical models of turbulent flows it is apparent that these prior art arrangements do not provide uniform gas collection along the length of the cell. For example, in Russian Federation Patent 2,218,453, gas collection is substantially more intensive at the outlet branch pipe of the central suction device than the rest of the system. More importantly, in one-sided gas collection, the gas collection system appears to be practically inoperative at the portions thereof near the outlet end. On the other hand, in the double-sided suction embodiment, three-dimensional models showed that suction was practically non-existent in the central section of the arrangement. The inclined restrictive members forming the suction slit of constant width and variable height not only have actual effect on the uniformity of gas collection in the system, but actually provide highly undesirable additional aerodynamic drag.

SUMMARY OF THE INVENTION

[0011] One aspect of the Invention provides an apparatus for collecting and removing gases emitted by an aluminum reduction cell, and utilizing an anode beam formed with first and second walls spaced from each other so as to define a
substantially hollow space therebetween. The apparatus consists of at least one channel formed within the substantially hollow space between said first and second walls, so as to extend between a suction inlet and an exhaust outlet. The suction inlet is associated with a gas collection system of the aluminum reduction cell. The channel is provided with at least one curvilinear partition extending between proximal and distal ends thereof and adapted to divide the channel into respective gas suction zones, having gradually narrowing cross-section so as to change the direction of a gas flow in the suction zones from substantially vertical at the suction inlet to substantially horizontal at the exhaust outlet.

[0012] According to another aspect of the invention, at least one partition extends between a proximal end thereof situated at the suction inlet and a distal end thereof situated at the exhaust outlet. At least one gas flow regulating device is provided at the distal end of the partition, so as to regulate the gas flow within the respective suction zone. This gas flow regulating device includes a buffer flap which is movable connected to the distal end of the respective partition by a rotary device.

[0013] According to a further aspect of the invention, the first and second walls of the anode beam are substantially vertically oriented. At least one channel is further defined by front and rear curvilinear walls. At least one partition is positioned between the front and rear walls. The buffer flap is movably connected to the distal end of the partition, so as to engage in one position the front curvilinear walls and in another position to engage the rear curvilinear curvilinear wall of the channel.

[0014] As to still another aspect of the invention, the partition is formed by a concave bottom surface and by a convex top surface. These top and bottom surfaces meet each other at the proximal and distal ends thereof. In the channel the concave bottom surface of the partition faces the front curvilinear wall and the convex top surface faces the rear curvilinear wall of the channel.

[0015] As to still further aspect of the invention, upon changing the direction of the gas flow from substantially vertical to substantially horizontal, the gas flow goes through a 90° transformation within the respective gas suction zone. According to this aspect of the invention, multiple channels are formed with the substantially hollow space. The at least one curvilinear partition comprises multiple curvilinear partitions positioned within the respective channels, so as to divide the channels into the respective multiple gas suction zones.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a longitudinal sectional view of one embodiment of the gas collection apparatus of the invention;

[0017] FIG. 2 is a cross-sectional view thereof;

[0018] FIG. 3 is a longitudinal sectional view of another embodiment of the apparatus of the invention; and

[0019] FIG. 4 is a chart illustrating the relationship between the vertical velocity component of the gas flow with respect to the distance between a particular location within the gas channel from the outlet branch pipe.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring now to the drawings in general and to FIGS. 1 and 2 in specific, a multidirectional embodiment of the gas collection and removal device of the invention is depicted. More specifically, these figures illustrate a double-sided gas collection device having two gas collection branches 12 and 14, extending in opposite directions and originating from a common area. Each branch is adapted to collect and remove gases emitted from an aluminum reduction cell. These branches form a part of an anode beam 1 of the respective cell having at least a pair of spaced from each other substantially vertical walls 2 defining substantially hollow gas collection and removal channels 5. Top and bottom stiffness members 3 and 4 are provided to reinforce the channel structure. Each channel extends between an inlet area 16 disposed in the vicinity of a suction window 9 and an outlet area 18 situated near an outlet branch pipe 7. At least one curvilinear partition 6 is provided within the hollow area of each channel 5, so as to divide it into at least two semi-independent sub-channels or suction zones 15. Each curvilinear partition 6 extends within the respective channel from the inlet area 16 to the outlet area 18. In the embodiment of the invention illustrated in FIG. 1 the partitions 6 are formed by concave bottom surface 17 and convex top surfaces 19 which meet at proximal edges 21 and distal edges 23. The cross-section of each channel 5 gradually narrows from the inlet to outlet and the direction of gas flow changes from the vertical to horizontal. In a similar manner, each suction zone gradually narrows and the direction of the respective gas flow changes from substantially vertical to substantially horizontal in an aerodynamic and efficient manner.

[0021] A gas flow regulating device 10 is provided at the distal end 23 of each partition 6 and is adapted to regulate the flow of the gases in the outlet region of the respective suction zone and ultimately within the entire channel. In the preferred embodiment, as illustrated, for example in FIG. 1, the gas flow regulating device 10 is in the form of a buffer flap 24 movably connected to a distal end 23 of the respective partition 6 by the rotary arrangement 26. The length of the flap 24 is enough to partially or fully close the corresponding sub-channel or suction zone 15 upon activation of the rotary arrangement 26.

[0022] Each channel is further defined by front 25 and rear 27 curvilinear walls. The shape of each sub-channel 15 is enhanced by the fact that in one instance the concave bottom surface 17 of the partition faces the convex rear wall 27 and in the other instance the convex top surface 19 of the partition faces the front concave wall 25 of the channel. The partition 6 is positioned between the front and rear walls, whereas the buffer flap 24 is movably positioned at the respective distal end 23 of the partition. Thus, in one mode the buffer flap 24 either moves in the direction of or engages the front curvilinear wall 25 and in another mode it is adapted for movement toward or engagement with the rear curvilinear wall 27.

[0023] In order to maintain the required rate of flow, in each channel 5 gases from the sub-channels or individual suction zones 15 are collected by the gradually narrowing outlet region 18 associated with the outlet branch pipe 7. As the gases rise from the suction windows 9 and inlet area 16 towards the outlet area 18, the rate of gas flow is kept at equilibrium with each suction zone 15 by gradually decreasing cross-sectional area thereof. Further, the configuration of curvilinear walls of the channels and the respective surfaces of partitions enables the invention to smoothly
change the gas flow from a substantially vertical direction to a substantially horizontal direction. More specifically, as illustrated in FIG. 1, in each channel 5 and suction zone 15 the direction of the gas flow goes through about a 90° transformation, i.e. from substantially vertical at the inlet 16 to substantially horizontal at the outlet area 18, before it is fed via an outlet branch pipe 7 into a common collector (not shown) and further to the reduction plant gas collection system.

[0024] The combination of smooth curvilinear walls of the channels with aerodynamically sophisticated design of the partitions 6 minimizes formation of undesirable turbulences, assures a laminar gas flow, and prevents alumina deposition on the walls of gas collection system. In the arrangement of the invention, the channels 5 and the sub-channels or suction zones 15 have no "dead" regions or locations where gas stagnates and crust or residue builds up. As well known from the prior art, such residue impedes flow, changes the dynamic flow of gas, and reduces efficiency of the entire gas evacuation system. In the aluminum production plant, eventually the gas collection and removal system must be stopped, cleaned, and reset. The present arrangement allows for the process of reduction of aluminum to continue unabated for longer periods of time, thus, increasing efficiency of an entire plant.

[0025] Referring now to FIG. 3 of the drawings, wherein a unidirectional embodiment of the gas collection and removal apparatus of the invention is illustrated. This figure depicts a single-sided gas collection device having one gas collection branch provided to collect and remove gases emitted from aluminum reduction cells. Similar to the previously discussed arrangement, this embodiment also forms a part of the anode beam 1 defined by at least a pair of spaced from each other substantially vertical walls 2 forming the substantially hollow gas collection and removal channel 5. Top and bottom stiffness members 3 and 4 are also provided to reinforce the structure. The channel 5 extends between the inlet area 36 formed with multiple suction windows 9 and a common outlet area 38 situated in the vicinity of the branch pipe outlet 7. In the channel, the direction of gas flow changes from vertical to horizontal and the cross-section thereof gradually narrows from the inlet to outlet.

[0026] Multiple curvilinear partitions 6A, 6B, and 6C are provided within the channel 5, so as to form multiple semi-independent sub-channels or suction zones 35A, 35B and 35C. Each curvilinear partition extends from the inlet area 36 toward the outlet area 38. The partitions 6A, 6B, and 6C are formed with somewhat similar concave-shaped bottom surfaces 37A, 37B, and 37C, respectively. However, the shape of the top surface varies from one partition to another. In this respect, the first partition 6A, according to the gas flow direction, is formed with the top surface 39A having a semi-convex configuration with an elongated portion 40A extending toward the distal edge thereof. The top and bottom surfaces meet at proximal and distal edges, so as to define a body having a sophisticated aerodynamic configuration. A hollow interior of the body of the partition is adapted to accommodate ducts 8 which can be used for the installation of anode busbar struts. A cross-sectional configuration of the second partition 6B is somewhat similar to that of the first partition 6A and is formed with an angle-shaped proximal end area. An elongated, substantially flat portion 40B is provided at the distal area thereof or at the intersection between the top 39B and bottom 37B surfaces of the second partition. The elongated portion 40B is oriented within the channel 5 along the direction of movement of the gases and has a substantial length reaching the outlet area 38. The third partition 6C is defined by the top and bottom surfaces 39C and 37C, respectively, so as to form an aerodynamically shaped body having a hollow interior. The elongated portion 40C is oriented in a substantially parallel manner to the elongated portion 40B of the second partition. As illustrated in FIG. 3, the outlet portion of the suction zone 35C formed between the second and third partition extends into the continuous area between elongated portions 40B and 40C. The section zones 35A and 35B merge at the outlet area 38, so that the common portion thereof is arranged in a substantially parallel manner to the outlet portion of the suction zone 35C.

[0027] Similar to the configuration of the respective channel, cross-sections of each sub-channel or suction zone gradually narrows and the direction of the respective gas flow changes from substantially vertical to substantially horizontal in an aerodynamic and efficient manner.

[0028] In a previously discussed manner, the gas flow regulating devices 10 are provided at the distal end of each partition, so as to regulate the flow of the gases in the respective sub-channels or suction zones 35A, 35B, and 35C and ultimately within the entire channel 5. The gas flow regulating devices 10 are in the form of buffer flaps which are movably connected to the distal ends of the respective partitions by the rotary arrangements. The length of the flaps is substantial enough to regulate movement of gases by partially or fully closing the corresponding suction zones. In view of the substantial length of the elongated portions 40B and 40C, the outlet area of the suction zones 35B and 35C have a substantially uniform cross section and are terminated in the close vicinity of the outlet branch pipe 7.

[0029] In the embodiment of FIG. 3, the channel 5 is further defined by the front 25 and rear 27 curvilinear walls. As the gases rise within the respective suction zones from the inner area toward the outlet area, the flow direction is converted from a substantially vertical to a substantially horizontal configuration.

[0030] In the apparatus of the invention the cross-section of each sub-channel or suction zone 15, 35 and the respective channels 5 are adjusted according to a predetermined pattern. The cross-sectional area of the outlet region 18, 38 of the channel is substantially decreased by the virtue of its design in comparison to the rest of the channel. In this manner, the gas flow is accelerated to a higher velocity upon exiting the outlet region. Furthermore, by utilizing the flow controlling arrangement 10 having movable buffer flaps, the gas flow within the respective channels can be further limited to a particular sub-channel or suction zone or a restricted area thereof. As the cross-sectional area of the sub-channel is restricted, the velocity of the gas flow passing therethrough is accelerated even further. Thus, the device of the invention provides a positive impulse for the gas flow, upon its entering into the main duct of the gas evacuation system. In view of the above, the typical amount of energy loss and pressure drop in the main duct is considerably reduced. This is because the energy requirement for the entire gas transportation system has been reduced.

[0031] In the plant evacuation system, gases are conveyed out of the suction zones and into the output duct. In the
device of the invention additional energy is acquired in the sub-channels or suction zones 15 to allow the gas to enter into the output duct at a greater velocity. Thus, the present invention provides a gas transportation system with a considerable reduction of the energy consumption.

[0032] Aluminum reduction provides a level of unpredictability of gas production. Unknown variables include the precise amount, temperature and so forth of the gas itself. Further, external factors such as ambient temperature and precise heat capacity of the electrolytic cell also affect the system. To compensate for these and other factors, as described hereinabove, the gas flow regulating devices 10 can be used to partially or fully close a specific sub-channel or suction zone 15. Doing so allows the gas flow to be diverted to the adjacent sub-channel. Unforeseen or unpredictable gas flow variations can be compensated for by directing the gas flow through various sub-channels to maintain equilibrium. A versatility of the gas evacuation system is increased by partially or fully closing a specific sub-channel or suction zone, so as to increase pressure in that part of the system and decrease flow.

[0033] In the apparatus of the invention gas volume is regulated within the individual sub-channels by the gas flow regulating devices which include buffer flaps movably connected to the distal ends of the curvilinear partitions. The inner spaces of the sub-channels and channels remain free and unobstructed for installation of the automatic feedings system which provides daily alumina stock. Another positive aspect of the apparatus of the invention is that a part of the wall structure remains free for the formation of the windows passing through such walls and provided for installation of anode bar struts.

[0034] Referring now to FIG. 4, a chart illustrating the relationship between the vertical velocity component of the gas flow and the distance between a particular location within the channel from the outlet branch pipe is depicted. The chart illustrates the uniformity of the gas flow within the device of the invention which is based on the results of the detailed mathematical modeling which are in turn based on complete 3-dimensional models of the turbulent flows. The curve 1 of this figure reflects the average vertical velocity at the inlet area of the device. The curve 2 reflects the average vertical velocity in the prior art devices. It is clear from the chart of FIG. 4 that as the distance of a particular location within the channel from the outlet branch pipe increases the gas flow on the device of the present invention corresponds substantially lower vertical velocity component compared to the prior art devices.

What is claimed is:

1. An apparatus for collecting and removing gases emitted by an aluminum reduction cell, said apparatus utilizing an anode beam of said cell formed with first and second walls spaced from each other so as to define a substantially hollow space therebetween, said apparatus comprising:

   at least one channel formed within said substantially hollow space between said first and second walls, said

   at least one channel extending between a suction inlet and an exhaust outlet, said suction inlet being associated with a gas collection system of said single aluminum reduction cell, said at least one channel is provided with at least one curvilinear partition extending between proximal and distal ends thereof and adapted to divide said channel into respective gas suction zones, having gradually narrowing cross-section so as to change the direction of a gas flow in said suction zones from substantially vertical at said suction inlet to substantially horizontal at said exhaust outlet.

2. The apparatus according to claim 1, wherein said at least one partition extends between a proximal end thereof situated at the suction inlet and a distal end thereof situated at the exhaust outlet, at least one gas flow regulating device is provided at said distal end of the partition, so as to regulate the gas flow within the respective suction zone.

3. The apparatus according to claim 2, wherein said at least one gas flow regulating device comprises a buffer flap movably positioned at said distal end of said at least one partition.

4. The apparatus according to claim 3, wherein said buffer flap is movably connected to said distal end of said at least one partition by a rotary device.

5. The apparatus according to claim 4, wherein said first and second walls of the anode beam are substantially vertically oriented, said at least one channel is further defined by a front and rear curvilinear walls, said at least one partition being positioned between said front and rear walls, said buffer flap is movably positioned at said distal end of the partition, so as to engage in one position the front curvilinear walls and in another position to engage the rear curvilinear wall of said channel.

6. The apparatus according to claim 5, wherein said at least one channel is formed by a concave bottom surface and by a convex top surface, said top and bottom surfaces meet each other at said proximal and distal ends of the partition.

7. The apparatus according to claim 6, wherein in said at least one channel said concave bottom surface of the partition faces the front curvilinear wall and said convex top surface faces the rear curvilinear wall of the channel.

8. The apparatus according to claim 1, wherein upon changing the direction of gas flow from substantially vertical to substantially horizontal, said gas flow goes through a 90° transformation within the respective gas suction zone.

9. The apparatus according to claim 2, wherein said at least one partition is formed having substantially hollow interior.

10. The apparatus according to claim 1, wherein at least one channel comprises multiple channels formed with the said substantially hollow space, said at least one curvilinear partition comprises multiple curvilinear partitions positioned within said respective channels, so as to divide said channels into the respective multiple gas suction zones.

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