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Ostberg et al.

[11] **3,902,893**

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[54] **METHOD FOR MOVING AND STIRRING OF HEAVY METALLURGICAL MELTS**

[76] Inventors: **Jan-Erik Ostberg,** Torps Sateri, Bettna; **Sven Anders Noren,** Klovervagen 3, Bromma, both of Sweden

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[52] **U.S. Cl.** .... **75/61;** 75/93 R; 266/34 A

[51] **Int. Cl.** **C21c 7/00**

[58] **Field of Search** .... 75/61, 93; 266/34 A

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Primary Examiner—L. Dewayne Rutledge
Assistant Examiner—M. J. Andrews

[57] **ABSTRACT**

In order to stir a metallurgical melt and to improve reactions therein, the melt is caused to flow in two substantially toroidal paths which have a substantially common area by reciprocating therein under proper conditions a mechanical stirring member. The stirring member has a side wall of substantial height, and a stroke which is preferably at least 40 percent of the minimum thickness of the body. The two toroidal flows may have a common direction in their meeting area, or may flow in opposite directions in such area.

8 Claims, 7 Drawing Figures

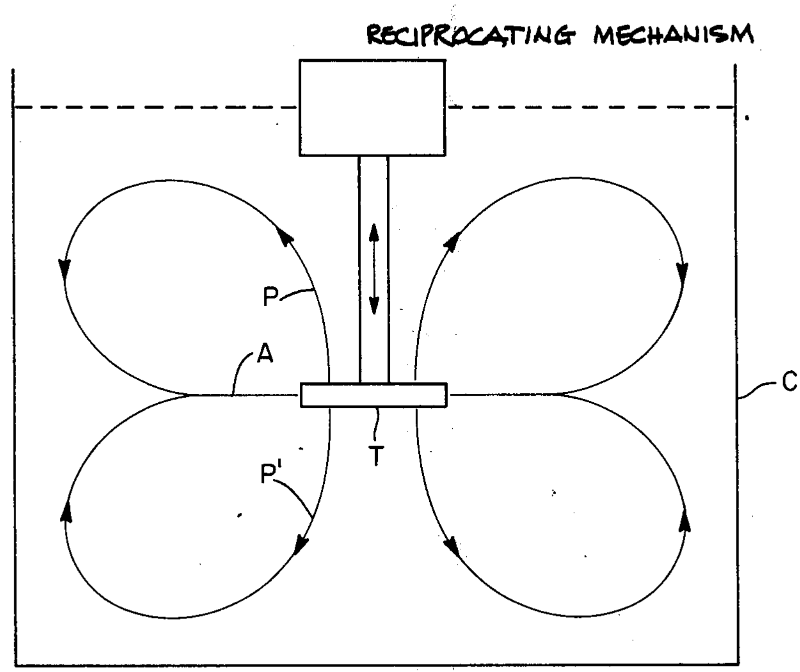


FIG. 1

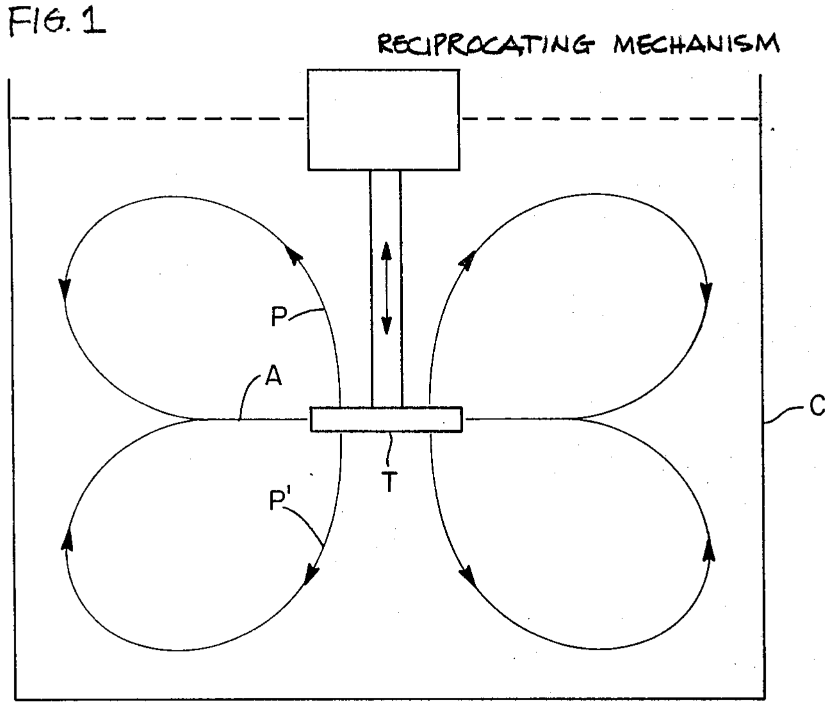


FIG. 2

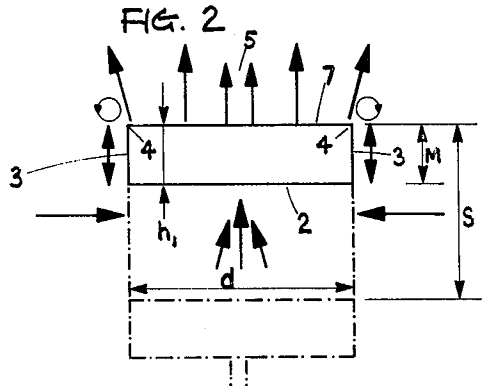


FIG. 3

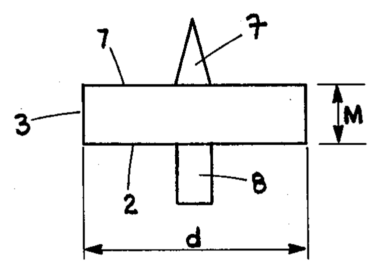


FIG. 4

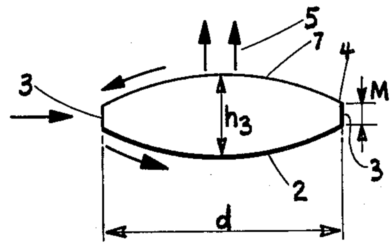


FIG. 5

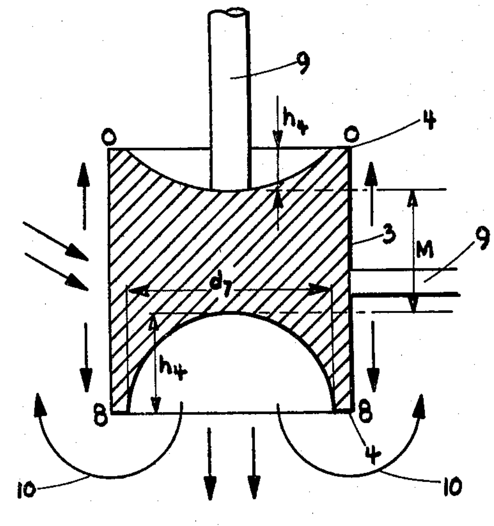


FIG. 6

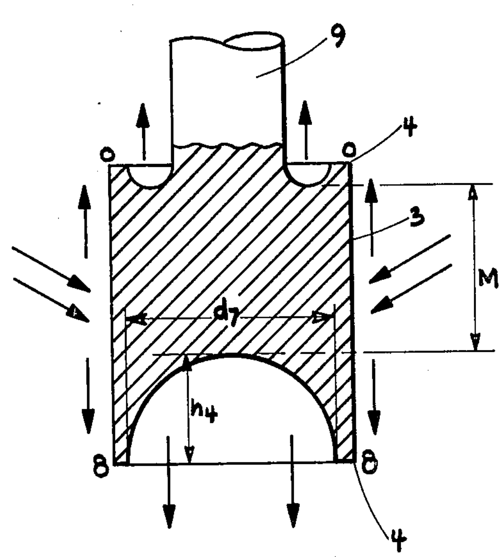
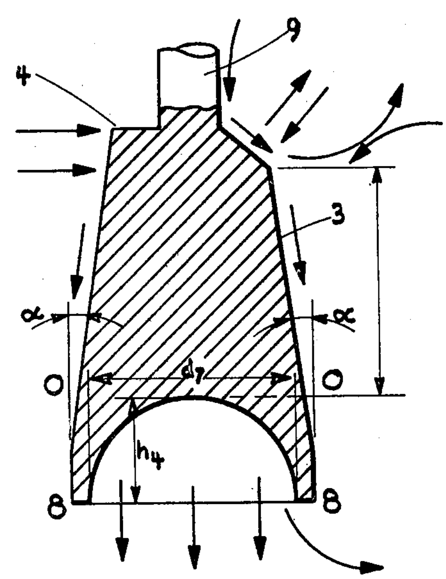


FIG. 7



METHOD FOR MOVING AND STIRRING OF HEAVY METALLURGICAL MELTS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention refers to a method of developing simultaneously a flow in a vertical and a horizontal direction within a metallurgical melt by means of a reciprocating mechanical apparatus. The invention also refers to an apparatus for the realization of this new method.

2. The Prior Art

The understanding that processing of metallurgical melts in practice is possible only if they are stirred or brought into movement by some external means is as old as metallurgical technique as such. This need was originally met by hand tools, but when metallurgy grew to an industry using ever larger furnaces and ladles, and particularly when tendencies developed to semi- or fully continuous processing, gradually non-manual methods have been introduced for the stirring and transport of metallurgical melts. Such methods have in addition been sought in order to eliminate the physical nuisance and strain on the workers, which the manual job implies.

To non-manual devices of this sort belong electromagnetic stirrers and means for the transport of various kinds and methods for the stirring of melts by means of gases flowing through the melt. A number of mechanical methods to this end are also known some of which are characterised by having the container holding the melt perform some type of a movement, which is transferred to the melt or by a tool of some kind, which may be completely or partly submerged in the melt where, because of a rotating, translating or reciprocating movement, it sets the melt in a flow according to a pattern characterizing the particular tool.

SUMMARY OF THE INVENTION

The present invention refers to a method of generating a flow within a metallurgical melt by means of a mechanical tool, which is moved back and forth in the melt, and an apparatus to perform the method. This invention is in a way an improvement of the invention which is described in application Ser. No. 836,918, filed June 26, 1969. The apparatus, which is described in that application will be briefly described as a background to the description of the novel measures and features of design, which are characterizing the present invention.

A stirrer or means for transport according to Ser. No. 836,918 is characterised by a tool, denominated the active body, which is submerged into the fluid, upon which it is intended to act and there move substantially rectilinearly forth and back. The active body has, facing the desired direction of flow, a so-called active surface, which as a rule is concave and which generates an increase in pressure within the fluid, when the active body is moved in the desired direction and a decrease in pressure within the fluid, when the active body is moved in a direction opposite to the desired direction of flow. Both of these effects contribute to the flow in the desired direction. In the preferred design, when the active face is concave, the flow is kept well together and often takes the shape of a jet.

The flow away from the active face of the active body is a function of the stroke and frequency of the reciprocating movement of the active body. When these are large enough, the range of the flow may be considerable. The flow which is directly generated by the active body may give rise to secondary flow patterns, when the originally generated jet rebounds from or in some other way acts together with the side-walls of the container or with other free surfaces. By means of such interaction, the melt may be brought into rotation or a movement into elsewise not easily attainable parts of the volume of the melt may be obtained. In spite of the fact that there is a wide range of possible variation obtainable with this type of stirrer, requirements are quite frequently presented, which cannot be met with an apparatus according to said application.

One such case refers to stirring of the contents of a ladle for iron or steel. A jet may stir horizontally on a certain level or it may stir part of the melt vertically, but very unsatisfactorily vertically and horizontally simultaneously. Another such case refers to the stirring of a melt in a hearth furnace with much greater length than width. It is true that the flow may be brought to cover a great deal of the volume of the contents in the oval hearth even lengthwise by skillfully handling the primary jet but an entirely satisfactory result is normally obtained only by operating more than one stirrer simultaneously.

The present invention gives a most satisfactory stirring, even in such complicated cases, by using just one apparatus, which by itself generates flow circuits in two or more directions.

According to the present invention an active body is moved forth and back within a melt in a substantially rectilinear path, wherein the active body during the return stroke travels a path which is a reversal of the path through which it travelled during the forward stroke. Contrary to the operation according to application Ser. No. 836,918, the active body according to the present invention has two active faces, which are directed opposite to each other and thus one facing in one of the directions in which the active body is moved and the other in the other direction of movement.

The active faces according to the present invention may be shaped differently in different situations. There are some cases, when the pressure which is built up in front of the active body plays the major role, and there are other cases where the predominant effect is the decreased pressure, which is created back of the body. In all cases the result is greatly influenced by phenomena occuring at or near the other faces or edges of the body whereby the common characteristic is that the active body as a result of its movement gives rise to a component of flow sidewise with respect to the active body and thereby already by itself primarily leads to two or more flow circuits. This inflow towards the active body from the sides may be perpendicular to the path of the active body or have a direction which is inclined towards either of the directions in which the active body is moved. From the front of the active faces a flow is initiated, which may be more or less well kept together as a result of the shape which may have been given to the active face, which may be concave, plane or even convex. The sidewise inflow, which is the aim and particular advantage of the present invention, occurs to the most satisfactory extent if the geometry and the dimensions of the active body are consistent with some definite rules and requirements and in some cases only if the active body is moved with a proper length of stroke and frequency. These rules and requirements will be discussed in detail hereinafter.

The object of the present invention is to generate initially a flow within fluid-phases, which are homogeneous as fluids or in which qualities of flow are changing continuously. In a metallurgical system there are normally at least two phases present, that have some importance, namely one heavy metallic phase and one lighter slag-phase. By a heavy metallurgical melt in this context is meant either a metallurgical melt alone or a metallurgical melt associated with a slag, the density of which is at least 1500 kgs/M^3 less than that of the metallurgical melt. From the standpoint of flow this means that parts or particles of the lighter slag-phase, which locally may have been mixed into the metallic phase, are rapidly separated out of the metallic phase, except for very tiny particles. Although local mixing zones may be created or even aimed at, the flow in such a system is characterized by the effects, which the active body creates in the different phases separately.

A reciprocating apparatus, going back and forth in a fluid normally generates in the fluid back and forth intermittent pulsations. There are even stirring apparatuses proposed with the aim of generating such intermittent pulsations and where this effect is accentuated by some particular means such as perforations in the apparatus. The aim of the present invention is however to bring the entire volume of a particular melt, or the major part of it, into a predetermined flow pattern. Intermittent pulsations, which are reciprocating as in the case of perforated tools or in the case of nonhomogeneous fluids, are not desired because they reduce the volume of the flow and lower the efficiency.

According to the present method of stirring and transport, two flow circuits are primarily started out from the active body and in addition a sidewise inflow towards the active body is set up, thus forming toroidal flow patterns. The object may be to mix one or all of the phases present, if there are many phases, and to create mixing zones between the phases. This being so, it is important that the individual flow circuits which are generated should not get isolated from each other but that material may be transferred from one circuit to another. This exchange of material takes place in the areas through which the sidewise inflow is passing. Because of this it is necessary that these areas are not too small in relation to the active body. Otherwise expressed, it is necessary to arrange for so much free space around the active body, that the sidewise inflow covers an interface between the different flow circuits, which has a minimum size. This space around the active body, which is called the free fluid surface, is normally calculated as the cross-section of the fluid in a plane through the center of the active body and perpendicular to the path of its movement. There are some cases, when this whole area is not free in the sense which is considered here. This is for instance true, when for some external reason fluid streams through this area in substantially the same direction that the active body is moved. One such case may occur in a steel ladle, equipped with an electrodynamic stirrer. In the normal arrangement such a stirrer gives a rather vigorous flow vertically. In such a case an area has to be deducted from the calculated free area corresponding to the area influenced by the electrodynamic field of force, because the sidewise inflow towards the active body is obstructed or made entirely impossible within that area. A similar situation will occur in case of local upflow caused by a gas streaming through the melt. The free fluid surface may be nonsymmetrically distributed around the active body. Practical investigation has showed that the average width of the surface, which normally is the distance between the face or edge of the active body and the outer end contour of the free faces, must be at least twice as large as the diameter of the active body. If the cross-section of the active body is not circular, the width has to be twice as large as the largest dimension of the cross-section of the active body. In other words, the diameter of an active body of noncircular cross-section is the reduced diameter as normally calculated. An active body having a diameter of 100 mm should consequently not be used in a cross-section of a melt-volume, which has smaller diameter than 500 mm or a correspondingly large area.

The rules for designing the active body and the requirements with respect to the frequency of the movement and the length of the stroke will not be discussed with reference to FIGS. **1** to **7**, which show cross-sections lengthwise through a few different active bodies. These figures should be understood as being schematic. It is also understood that the active bodies shown have circular or almost circular cross-sections.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is an explanatory diagram showing one flow pattern according to the invention;

FIGS. 2–7 show variations of the mechanical stirring device, with FIG. 7 showing also another type of toroidal movement.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, there is shown a container C with a mechanical tool T which is reciprocated in the interior of the container and is so constructed as to produce in a metallurgical melt or other heavy liquid therein a flow in two toroidal paths P and P′ which have in the area A a common flow path side by side.

FIG. **2** is a schematic and symbolic picture of an active body. The upper part of the figure is drawn in full lines and shows the one end position of the active body during its reciprocating movement. The direction of movement during movement towards this end position is indicated by the arrows **5**. The lower part of the figure is drawn with a broken line and shows the opposite end position of the movement, which is reached after a movement in the direction of the dashed arrows **6**.

The active body has two opposite active faces, the front face **1** and the return or back face **2**. These faces are connected by the side face **3**, which in this case is cylindrical. The active faces meet the side face **3** in a periphery, rim or edge **4**. The dimension of the active body in the direction of movement is called its length and denominated h_1. The stroke of the movement back and forwards is denominated s. The single arrows, which occur in the figure, show characteristic flow directions. The small circles around the upper edges **4** symbolize eddies, which occur in the areas surrounding these edges. The exact position of these eddies will vary.

It is assumed that the first stroke of the active body is directed upwards. This stroke results in an increased pressure within the fluid in front of, or above, the surface **1**. Behind, or below, the back surface **2** arises a decreased pressure. Along the side face some fluid is brought to flow with the active body in its movement although with some delay. The pressure in front of the front face **1** gives rise to a flow which is directed substantially perpendicularly out from this face **1**, but which in addition also has a component parallel to the plane of the front face. This flow may, when it reaches the upper edge **4**, separate in a way, which may differ somewhat from one instance to another, wherein the surface conditions of the active surface, the surface tension of the fluid and its viscosity will bear upon the result. The result will be an eddy or a disturbance somewhere near the edge **4**.

The decreased pressure behind, or below, the back face **2** gives rise to flow towards this surface. Along the edges **4** this flow occurs partly from the fluid surrounding the side face **3** and which is closest to the edge and partly from surrounding fluid more or less perpendicularly to the path of the active body. In the vicinity of the center of the back face the inflow is directed more or less perpendicularly towards the back face.

When the active body has reached the uppermost position shown by the full lines in the upper part of FIG. **1**, it stops and reverses in a movement downwards towards the lower end position. This movement is indicated by the arrows **6**. The active face **2** is now the front face and gives rise to a pressure in the part of the fluid, which is located a short distance in front of, or below, itself, while the active face **1** is now a back face and gives rise to decreased pressure just behind or above itself. These new pressure and subpressure zones create flows in the fluid which correspond to the ones just described. Part of the flows, which were initiated during the foregoing stroke, therefore are given a tendency to reverse. The new tendencies for flow are however influenced by the flows, which were created during the foregoing stroke. This influence will among other things have the following effect:

The inflow towards the new back face will be retarded because of the fact that the outflow which remains from the foregoing stroke upwards must first be retarded and possibly reversed. The inflow of fluid from the areas surrounding the side face may however be promoted because the edge in its movement meets the flow created by friction between the side face and the fluid during the foregoing stroke. The inflow sidewise, which was initiated during the foregoing stroke, will receive new impulses in the original direction from the new decreased pressure.

In front of or below the new front face **2**, the formation of the component of flow parallel to this face will be retarded because of the initially unfinished inflow sidewise. The effect of this tends to make the jet from this face tighter and better kept together, an effect which is however counteracted by the fact that the inflow towards the center of this active surface, which was created during the foregoing stroke, has to be reversed, which mechanism normally increases the component of the flow which is directed parallel to the plane of this active face. The flow along the side face **3** is also bound to be reversed, but before this has happened its influence upon the general flow pattern is not very great. The combined effects of these influences will be that the eddies and disturbances in the neighborhood of the edge **4** will develop immediately as the active body turns back.

After some few strokes back and forth a continuous condition will be established, which is characterised by some movements back and forth, by some eddies particularly in areas near the end positions of the active body, of a continuous flow outwards from both of the active surfaces, which outflow may possibly start only at a short distance in front of each of the active surfaces and finally of an inflow from the sides towards a relatively limited area in the middle position of the active body between the two end positions.

The flow pattern, which the active body primarily creates, will be influenced by other flows in the fluid, which may have been caused by effects due to free surfaces of the fluid or by other external influences. In this context the flow has a particular bearing, which is primarily created by the active body and then redirected, when it faces an obstacle such as the side walls of the container, in which the active body is operating. This redirected flow will be guided back to the center of the side face of the active body and thus reinforce the inflow sidewise.

Changes in the frequency of the reciprocating movement will not per se change the general picture of the flow pattern. At higher frequency more dynamic energy will be transferred upon the field. The movement will then become more vigorous and the flow or jet which issues from the active faces has a prolonged range provided the dimensions of the container make this possible. It is however important that the active body be moved more rapidly than the fluid upon which it is working. This has a great practical bearing for the following reason: The tendency, which has already been referred to for an outflow of fluid from the front face of the active body which is caused by a component of flow parallel to this surface will normally at lower frequencies cause a part of the outflowing fluid to be caught by the tendency to inflow towards the area of lowered pressure in front of the back face of the active body. This mechanism gives rise to an exchange of fluid between the active faces of the active body. The extent of this exchange grows less important at higher frequencies. For all practical purposes it can be disregarded, when the active body is moved with a speed greater than 20 diameters of the active body per second. Normally even lower speed may also be accepted. Usually the tendency for exchange has disappeared at speeds of 15 active body diameters per second.

The length of the active body in relation to its diameter must also be adjusted properly: The flow along the side faces caused by the fact that fluid is carried away by the active body in its movement sometimes will not get a chance to establish a continuous condition of flow because of the reversals. Instead of this eddies are formed around the edges **4** which, as already mentioned, may vary with respect to size and position in relation to the edges **4** as well because of the dimensions of the active body as of the flow characteristics of the fluid. These areas of disturbance are however substantially to be found in the vicinity of the end positions of the movement back and forth of the active body. It turns out that the sidewise inflow is most efficient just where these disturbances disappear. This means that if the length of the active body h_1 is moderate, only one area of sidewise inflow will be established, while two such areas of vigorous sidewise inflow will appear if this length is considerable, each area related to one of the end positions and which areas are separated by an area of moderate sidewise inflow. The flow pattern, which is established in the latter case will not give the metallurgical results which are aimed at with this invention. It will for instance not be possible to get a sufficiently great and rapid transfer of substance from the flow circuit, of which one of these distinct sidewise inflows is a characteristic part and the other flow circuit, of which the second of these distinct inflows is a characteristic part. The size of the active faces also has a bearing upon the extent of the disturbances. The practical result of these facts is that an active body, which has plane active faces necessarily must have a limited length h_1. This dimension must not exceed the dimension d.

When the active faces are otherwise shaped than plane, the phenomena of flow, which have so far been described will have different relative importance than the one which has been described for the plane active faces. The tendency for flow outwards from the center of the face caused by the fact that the inflow towards the back face is reversed when this same face acts as the front face during the following stroke is displayed relatively strongly in all alternative shapes. This effect almost always appears as an irregularity of the flow during the forward stroke. FIG. **3** shows a means of counteracting this tendency. In the center of the active face is arranged an elevation, which may take the shape of a conical plut **7** or a cylindrical plug **8** or have some other guiding shape. This elevation may be shaped in many other ways. The elevation may be characterised as a guiding or regulating device.

The active face may also be convex as shown in FIG. **4**. In front of the front face, even in case of convex active faces, creates pressure, but the component of flow, which goes parallel along the front face or in this case perhaps more properly expressed tangentially to this face, grows relatively larger. A relatively larger quantity of fluid will flow along the face and in addition this flow will separate from the active face at an acute angle towards the side face. Near the back face conditions will also be changed with the result that the inflow from areas around the side face will be more readily obtained. These two factors will work together in decreasing the volume of sidewise inflow, which characterizes this invention. If in the extreme case the active body were a sphere, a movement back and forth between the two faces of active body would be developed and the volume of fluid outside an area near the active body would not be influenced to any large degree. This comparison should make it clear that the disturbances at the edges have a guiding function and that the function cannot be achieved without them. The bearing of this disturbance appears particularly when the active faces are convex, because the decreased pressure behind the back face plays a more dominant role for the operation than with other shapes. These necessary disturbances require to become established that the length of the side face h_2 does not exceed 15% of the diameter d, while simultaneously the height h_3 of the active body is not more than 40% of the diameter d. These requirements also refer to plane-convex active bodies.

The flow of fluid along the side face of the active body, which occurs in the direction of the length of the active body has two causes, one being that fluid is carried along by friction by the active body in the direction of movement and the second being that fluid is sucked towards the back side of the active body. If the active face is concave, the drop in pressure during the return stroke will be particularly strong so that the flow along the side face next to the edges **4** will be more or less continuously directed towards the respective active face. This fact of course does not mean that disturbances in these areas will disappear. Such disturbances may in fact appear simultaneously outside the edges and along the side face. But the fact that the flow is substantially towards the edge and without distruption is not influenced by this fact. This tendency is reinforced and accentuated by the fact that the concave active face has a tendency to keept the flow together. A possible flow forth and back, a pulsation, therefore does not affect the area in direct vicinity of the edge but may take a path as the one at **10** in FIG. **5**. Thus provided at least one of the active faces is made pronouncedly distinctly concave, the length of the active body will be less critical than when the active faces are plane or convex, because a more or less continuous flow is established towards the concave face or faces. This prohibits the establishing of two distinct areas for side wise inflow as has previously been described for active bodies with plane active faces and of great length.

As the present invention refers to a method for heavy metallurgical melts, the active bodies will as a rule have to be made from refractory ceramic material perhaps applied upon some framework of metal. It will rarely be possible to make the active bodies as shown in FIGS. **4, 5** and **6** with sharp rims or edges **4**. A concave body will therefore have a concavity or cup, the diameter of which d_1 is smaller than the diameter d of the full active body, as a rule 70 to 90% of this diameter. With a distinctly concave active face is meant one where the concavity has a depth h_4 which is 20% or more of the dimension d_1. Active faces with a less pronounced concavity than this will be denominated as saucer-like. Even saucer-like active faces have a tendency to guide the flow along the side face in one and the same direction regardless of the direction of movement. Even if only one of the active faces is saucerlike and the other one plane, the length of the active body will not be as critical a dimension as in case both of the active faces are plane. Practical tests have shown that the minimum length of an active body having saucer-like active faces should not exceed 150% of the diameter of the active body.

If the container in which the active body is operating is not symmetrically shaped, or if the active body is not symmetrically located in the container, which are quite frequent conditions, it may be desirable for instance in order to reduce the necessary free area somewhat below the requirement given on page **6** not to direct the sidewise inflow perpendicular to the direction of movement of the active body. FIG. **5** shows an active body where the lower active face is less distinctly concave and also larger than the upper active face, which two circumstances both contribute to direct the sidewise inflow in a somewhat inclined direction as shown by the arrows in the figure. This figure also shows a driving rod **9**, which is connected with an otherwise not shown driving arrangement. This driving rod **9** may be attached either in one of the active faces, whereby it is not necessarily attached to its center, or to the side face. In the first mentioned case it takes up part of the active face. In the latter case an arrangement is obtained, which is very advantageous for working in a ladle. If the driving rod attached to the side face is vertically arranged, the active body moving simultaneously will in addition during operation be moved up and down. Such an arrangement in a ladle normally operates best at very high frequencies and short strokes.

FIG. 6 shows a similar active body, the driving rod of which 9 is large and which for that reason takes up a relatively large proportion of the active face. With this active body as well as with that of FIG. 5 there will appear eddies at the edges as shown in the figure. Some movement back and forth, pulsation, may also appear at the edges.

FIG. 7 shows an active body, where one of the active faces is very dominating and concavely shaped. For the non-dominating active face two alternatives are symbolically shown. The alternative to the left of the figure is an active face directed perpendicularly to the direction of movement of the active body. The alternative to the right of the figure is an active face, which is arranged at an inclined angle to the path of the active body. As a consequence of the fact that the active surfaces have diameters of different size, the side face 3 will be conical either in its full length, or, as shown in the figure, with the exception of a short distance near the edge of the dominating active surface. This fact has in itself not a very favorable effect. During the period when the secondary face is the front face the conical side face will to some extent cooperate with this active face, but the conical shape also gives rise to causing fluid surrounding the conical side face to be turned aside and flare out to the sides. The flow along the side face towards the dominating concave face will for that reason be disturbed by eddies and pulses of specific kind. The side face should because of effects of this kind not make a greater angle (α) with the direction of movement of the active body than 20°.

Because of the active faces in FIG. 7 is so very much dominating, the sidewise inflow is also influenced so that it hits the side face of the active body relatively near the secondary face. In the left part of the figure accordingly the inflow is shown in a direction, which is almost parallel to the driving rod 9. This side of FIG. 7 also shows flow lines, which are directed at a right angle towards the path of the active body, a flow pattern, which may be the result of the primary flow being thrown back from the side walls of the container.

The right side of FIG. 7 showa a secondary active face obliquely directed, which results in an interesting and often efficient flow pattern. At the edge of the upper secondary (subordinate) face is shown both an inflow to the active face from the side and also adjacent to this inflow a flow directed outwards, which is caused by the circumstance that this secondary active face when it is the front face turns the flow obliquely sidewise. In addition to this, this shape makes the radial component of flow relatively vigorous. The final result of these interactions is that the flow circuit, which comprises the larger volume, contains one part directed inwards towards the active body in the vicinity of the upper edge, while the flow circuit, which comprises the smaller volume contains one inwardly directed part along the driving rod and one outwardly directed part in the vicinity of the inflow of the first mentioned flow circuit. These two opposite flows open a valuable possibility for countercurrent reaction. The secondary or subordinate flow circuit may be described as having a guiding function. The angle at which this secondary active face is arranged relatively to the path of the active body is a factor, which establishes the degree of turning aside of the dominating flow circuit. This type of stirrer may for instance be used to advantage in hearth furnace, where it may be introduced through a furnace door. The secondary flow circuit will in this arrangement create a vigorous reaction zone and bring the slag which is carried by a metallurgical melt into a favorable turbulent motion.

In order to obtain the best results, the minimum thickness, that is, the distance between two planes perpendicular to the direction of movement and in which lie the portions of the faces of the upper and lower surfaces nearest each other, should not be less than 10% of the diameter. This distance is represented in FIGS. 2 to 7 by M. This assures the existence of side faces of sufficient extent to ensure the desired effect on the liquid.

The stroke is preferably at least 40% of the minimum thickness *M*.

One example of an operation according to the invention includes a container of 2 meters diameter in which is reciprocated an active body of the type shown in FIG. 2, of a diameter of 10 cm with 25 strokes per second of a length of 10 cm.

We claim:

1. Method of stirring a metallurgical melt in a container which comprises producing in the melt toroidal currents in the upper and lower parts of the melt the paths of which are mingled in side by side relation in the area of the melt in which the currents are adjacent each other by moving an unperforated mechanical stirring member in the melt back and forth in coincident substantially rectilinear paths, in which the diameter of the container in a plane perpendicular to said rectilinear paths is at least about five times as great as the greatest diameter of the stirring member in a plane perpendicular to such path.

2. Method as claimed in claim 1, in which the currents in such area flow in the same direction.

3. A method as claimed in claim 1, in which the interior of the container outside of the path of the stirring member is substantially unobstructed.

4. Method as claimed in claim 1, in which the stirring member has a minimum thickness in a direction parallel to such path at least equal to 10% of and not more than twice the diameter of the stirring member.

5. Method as claimed in claim 1, in which the stirring member has a stroke of at least about 40% of the minimum thickness of the stirring member in a direction parallel to such path.

6. Method as claimed in claim 1, in which the stirring member has a peripheral side wall of a height in a direction parallel to the direction of movement of the stirring member of at least 10% of the minimum dimension of the stirring member transverse to such path.

7. Method as claimed in claim 6, in which the stirring member has a minimum thickness in a direction parallel to such direction of movement at least equal to 10% of and not more than twice the diameter of the stirring member.

8. Method as claimed in claim 7, in which the stirring member has a stroke of at least about 40% of the minimum thickness of the stirring member in the direction of such path.

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