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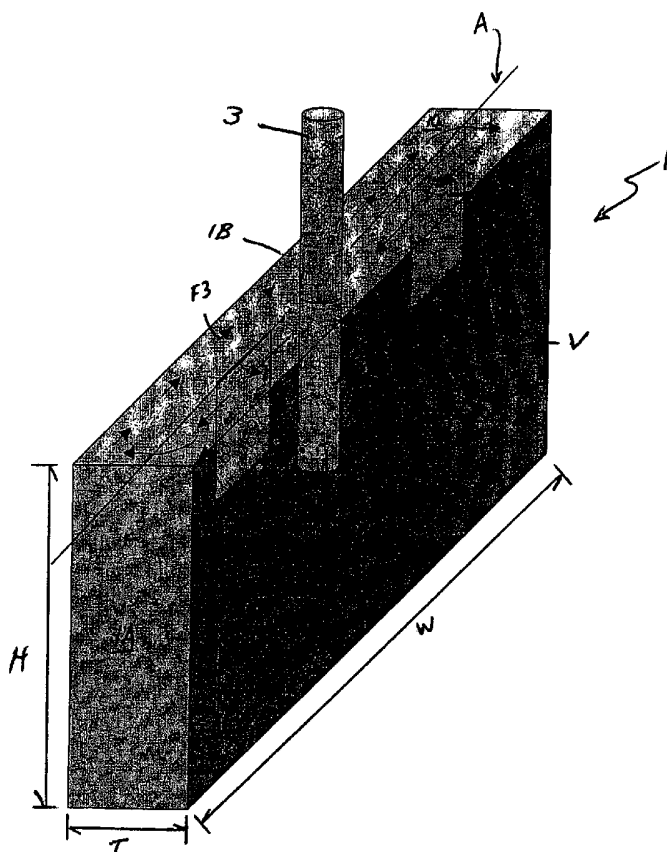
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(54) Title: METHOD AND APPARATUS FOR MELT FLOW CONTROL IN CONTINUOUS CASTING MOLD



(57) Abstract: A method and apparatus for continuous casting of metal. The flow of molten metal is altered to eliminate or reduce the transfer of entrained mold flux slag and non-metallic particles to the vicinity of solidifying metal near the mold walls, thereby resulting in significantly reduced sliver and related defects. Flow modifier members are placed such that their larger surface is more aligned with the larger dimension of the interior volume of the vessel in which the member is placed. In a particular form, the members may be shaped as rectangular plates and placed substantially parallel to the longer interior wall of the vessel.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD AND APPARATUS FOR MELT FLOW CONTROL IN CONTINUOUS CASTING MOLD

5 The present invention relates generally to the field of continuous casting of steel, and more particularly to a device and method for flowing molten metal in continuous castings that produces fewer defects in the cast product.

 In continuous casting of steel (such as plain carbon steel), molten metal is poured from a ladle or tundish into a water-cooled copper mold vessel by using a submerged entry
10 nozzle (SEN). In the continuous casting process, steel begins to solidify as it comes in contact with the walls of the copper mold, the slab descending down the height of the vessel. The thickness of slabs produced in such a mold typically is about 9 to 12 inches (~230 to 300 mm), whereas in a thin slab caster the thickness is only about 2 to 4 inches (~50 to 100 mm), while the width is much larger, typically 60 to 72 inches (1500 to 1830
15 mm) and even up to 100 inches (2540 mm). A layer of mold flux (typically a metal oxide) is maintained at the free surface of the molten metal in the mold. This flux serves a couple of purposes; first, it protects the hot metal from atmospheric oxidation, and second provides a thin lubricating layer between the descending slab and the mold walls to inhibit bonding between the two.

20 Traditionally, the molten metal was the only thing introduced into the mold through the SEN. In more recent variations, argon gas has also been injected with molten metal, so metal and gas exit the SEN ports. The presence of gas has been found to be beneficial in that it prevents inclusions (such as alumina) inherent in the metal from clogging up the SEN as it passes through. Additionally, the gas helps push inclusions
25 present in the molten metal upward to a free molten metal surface. Nevertheless, the presence of gas also changes the molten metal flow in the mold, as part of the molten metal is carried in the wake formed by the rising gas bubbles. Several fluid flow studies of continuous casting molds have shown that the flow of molten metal in a mold has a large influence on the surface and subsurface quality of the resultant cast metal. Factors
30 that influence molten metal flow in the mold include casting rate, mold width and thickness, SEN design parameters and submergence depth. Among the SEN design parameters are SEN internal configuration, port size, number and location of ports, port tilt angle and SEN rotation angle. One way to deal with the differing flow patterns produced

by the introduction of gas has been to rotate the angle of the SEN about a vertical axis such that the traditional flow of molten metal could be made to contact the walls of the mold in different locations. In such rotated SEN configurations, metal flow would not be substantially parallel to the wider of the mold walls; this asymmetric flow condition
5 produces significantly different flow patterns that if left unchecked have the ability to exacerbate rather than correct slab contamination through flux slag entrainment.

One especially troublesome flow pattern for the continuous casting of steel under such asymmetric flow conditions involves the tendency of the gas and molten metal that exits the SEN to contact the wider walls of the mold, after which they ascend to the free
10 surface of metal. Once it reaches the free surface, it flows across the thickness (i.e., the shorter dimension) of the mold at the interface between the molten metal and the flux with a relatively high velocity. This high velocity can cause shearing of the mold flux and the non-metallic inclusions from the interface, which in turn could be carried downward to the solidifying metal slab when molten metal contacts the opposing wall.

15 Regardless of whether the SEN is in a rotated or non-rotated configuration, it is important when operating a SEN to dispense mixtures of molten metal and gas to avoid high surface flow velocities and the resultant downward carrying of impurities along the walls of the casting vessel. Accordingly, there exists a need for a device and method of continuous casting that reduces contamination of the slab being cast.

20 These needs are met by the present invention, wherein a continuous casting system and a method of operating the system that incorporates the features discussed below are disclosed. By the present invention, the flow of metal is altered in such a way so that it reduces the transfer of the entrained mold flux slag and non-metallic particles to the vicinity of solidifying metal near the mold walls, thereby significantly reducing sliver and
25 other defects. Although described with respect to the field of steel casting, it will be appreciated that similar advantages of cleaner metal casting with reduced defects, along with other advantages, may apply to other applications of the present invention. Such advantages may become apparent to one of ordinary skill in the art in light of the present disclosure or through practice of the invention.

30 In accordance with a first aspect of the present invention, the system includes a mold vessel configured to contain and dispense a molten metal for casting. The vessel includes numerous inner surfaces that define an interior volume between them, where the

interior volume includes height, width and thickness dimensions, where at least the width and thickness dimensions generally correspond to a respective width and thickness of a slab of metal produced within the vessel. A SEN is situated within the vessel, and is arranged within the interior volume and extends below a molten metal upper surface
5 formed upon introduction of the molten metal into the interior volume. The SEN includes one or more discharge ports adapted to dispense a mixture of gas and the molten metal into the interior volume. One or more flow modifier members are disposed between the walls of the vessel to control the flow of molten metal. In contrast to conventional flow modifier members (which have an elongate dimension aligned substantially parallel to the
10 narrower (i.e., thickness) dimension of the casting vessel), an elongate dimension of the one or more flow modifier members is aligned substantially parallel to the more broad widthwise dimension, thereby inhibiting flow along the thickness dimension of the vessel.

Optionally, the major surface is angularly aligned substantially parallel to the wider of the width and thickness dimensions of the interior volume. In a preferred option,
15 the interior volume of the vessel is rectangular shaped. Additionally, the one or more flow modifier members extend below the molten metal upper surface. Moreover, each of the flow modifier members can be disposed between the submerged entry nozzle and the narrower of the width and thickness dimensions of the interior volume. The flow modifier member (or members) preferably extends upwardly at least into a flux layer that is situated
20 substantially on top of the molten metal upper surface. In another option, the height, width and thickness dimensions of the flow modifier member(s) are such that they define a plate, where in a particular form, the plate is substantially planar. In a particular form, the discharge port of the submerged entry nozzle extends below the flow modifier member. In another, the discharge port is adapted to dispense the mixture of gas and molten metal into
25 the interior volume at an angle relative to both the width and thickness dimensions of the vessel's interior volume. In an alternate variation, the discharge port (or ports) is adapted to dispense the mixture of gas and molten metal substantially parallel to the interior volume width dimension. More particularly, there are a group of flow modifier members. The group is configured such that individual flow modifier members in the group are
30 spaced apart from one another substantially along a through-the-thickness axis of the members. In such a configuration, at least a majority of the mixture of gas and molten metal exiting the discharge port flows substantially between the individual flow modifier

members in the group. More preferably, the individual flow modifier members within the group are substantially parallel to one another.

According to another aspect of the invention, a flow modifier member configured for use in a continuous casting system, the flow modifier comprising at least one first surface and at least one second surface, the at least one first surface covering a larger surface area than the at least one second surface, the flow modifier member configured such that upon placement into a substantially rectangular casting vessel defining a width dimension and a thickness dimension such that the width dimension is greater of the two, the at least one first surface is angularly aligned closer to the width dimension while the at least one second surface is angularly aligned closer to the thickness dimension of the vessel. Optionally, the flow modifier member is made from a refractory material, such as a ceramic. In another option, at least one joiner disposed between adjacent ones of the flow modifier members, the at least one joiner sized to block the substantial entirety of space defined between the adjacent ones of the flow modifier members.

According to yet another aspect of the invention, a method for controlling the flow of molten metal in a continuous casting system is disclosed. The method includes configuring a vessel to comprise a plurality of walls to produce an interior volume of the vessel in which casting of the molten metal takes place. The walls have height, width and thickness dimensions, where the width dimension is of greater size than the thickness dimension. Additionally, the method includes introducing a mixture of molten metal and gas into the interior volume such that a molten metal upper surface is defined by the top of the quantity of molten metal within the vessel's interior volume. Another part of the method includes placing a flow modifier member such as those previously described in a location within the interior volume between where the mixture introduction occurs and the wall that defines the thickness dimension of the interior volume. The orientation of the flow modifier member is such that a major surface (i.e., a larger surface) is angularly aligned closer to the wall that defines the vessel's width dimension. In this way, the velocity of molten metal flowing adjacent the molten metal upper surface is reduced.

Optionally, the mixture introduction occurs through a submerged entry nozzle such as that previously discussed. More particularly, the submerged entry nozzle can be angled about its vertical axis relative to the interior volume. In this way, the introduced mixture exits the discharge port of the nozzle at an angle relative to both the width and thickness

dimensions of the interior volume, thereby producing an asymmetric flow pattern when viewed from above. In another particular form, the flow modifier member is made up of a pair of flow modifier members, each arranged on opposite sides of the submerged entry nozzle such that each is disposed between the submerged entry nozzle and the narrower walls of the vessel that define the vessel thickness dimension. In another option, the flow modifier member is made up of numerous flow modifier members arranged in one or more groups. Thus, that individual flow modifier members within each group are spaced apart from one another substantially along a through-the-thickness axis of the members. In this way, at least a majority of the mixture of gas and molten metal exiting the discharge port flows substantially between the individual flow modifier members in each group.

FIG. 1 shows a front section elevation view of a conventional continuous casting system, including a general melt flow pattern without gas injection in a continuous casting mold;

FIG. 2 shows a front section elevation view of a conventional continuous casting system showing a general melt flow pattern with relatively low volume of gas injection in a continuous casting mold;

FIG. 3 shows the continuous casting system of FIG. 2 with higher volume of gas injection;

FIG. 4 shows the continuous casting system of FIG. 2 with a still higher volume of gas injection;

FIG. 5A shows a SEN with rotated orientation relative to the narrow and broad walls of a conventional casting vessel;

FIG. 5B shows a SEN with a non-rotated orientation relative to the narrow and broad walls of a conventional casting vessel;

FIGS. 6A and 6B show respectively a perspective and plan view of a conventional continuous casting system, including flow of injected gas and liquid metal in a mold with rotated SEN;

FIG. 7 shows a side (i.e., through the thickness) section elevation view of a conventional continuous casting system, including showing a general melt flow pattern of injected gas and associated metal in the conventional continuous casting system FIGS. 6A and 6B;

FIG. 8 shows a perspective view of a continuous casting system including a pair of surface flow modifier members in accordance with an embodiment of the present invention to reduce the problems associated with the system of FIGS. 6A, 6B and 7;

FIGS. 9A through 9C show respectively a plan and front and side elevation views of the system of FIG. 8;

FIG. 10 shows how a general melt flow pattern of injected gas and associated metal is changed by the surface flow modifier members of FIG. 8;

FIGS. 11A through 11C show a front sectioned elevation view of the SEN having respectively a downward, horizontal and upward discharge ports;

FIG. 12A and 12B show respectively a perspective and plan view of a conventional continuous casting system, including flow of injected gas and liquid metal in a mold with a non-rotated SEN;

FIG. 13 shows a side sectioned elevation view of a continuous casting system of FIGS. 12A and 12B, showing a general melt flow pattern of injected gas and associated metal;

FIG. 14 shows a perspective view of a continuous casting system including groups of cooperating surface flow modifier members in accordance with an alternate embodiment of the present invention to reduce the problems associated with the system of FIGS. 12A, 12B and 13;

FIGS. 15A through 15C show respectively a plan and front and side elevation views of the system of FIG. 12;

FIG. 16 shows how a general melt flow pattern of injected gas and associated metal is changed by the surface flow modifier members of FIG. 14;

FIG. 17 shows a variation on the embodiment of FIG. 14, where the groups of cooperating flow modifiers are replaced with substantially non-planar members; and

FIGS. 18A through 18C show respectively a plan and front and side elevation views of the system of FIG. 17.

Referring first to FIG. 1, an elevation view of a conventional continuous casting system showing a general flow pattern in vessel (also referred to as a mold or mold vessel) 1 is shown. Molten metal 2 emerges from discharge ports 3A in SEN 3 and enters the vessel 1, flowing generally along flow lines 4A, 4B and 4C (collectively referred to as flow lines 4). Molten metal 2 then emerges from the vessel 1 as a partially solidified slab

5 in the shape of the vessel 1, which is typically rectangular with a thickness dimension **T**, height (or length) dimension **H** and a width dimension **W** (not presently shown). As the molten metal 2 progresses through the vessel 1, a layer of solidified steel 6 is formed against the interior surfaces 8 of the vessel 1, resulting in the formation of a shell over the freshly cast slab 5. One or more flow modifier members (not presently shown) may be located on either side of the SEN 3, and have traditionally been used to prevent or minimize downward liquid metal flow near the mold walls. This in turn reduces the likelihood of entrapment of the liquid flux or non-metallic inclusion (i.e., that which is carried with the liquid metal from metal/flux interface) in the solidifying metal shell.

10 Normally, a molten metal upper (i.e., free) surface 10 will bear an oxidation-preventing flux layer (for example, based on a metal oxide), while the flow modifier members will extend into one or both of the flux layer and the molten metal. In one form, the flux is placed in powder form onto the molten metal upper surface 10; the heat from the molten metal then striates the flux into a powdered top layer and a liquid lower layer such that an

15 interface between the top of the molten metal and the bottom of the liquid flux is formed (all shown and described later). The downward movement of the metal through the vessel 1 is facilitated by a layer of flux 9 that is situated on top of the molten metal upper surface 10 that extends between the interior surfaces 8 and the layer of solidified steel 6.

The molten metal 2, with no gas injection, exits SEN 3 at an angle relative to the horizontal and impinges on the narrower wall 1A of vessel 1 that corresponds to the thickness dimension of the formed slab. This flow impingement results in the formation of upper and lower recirculating flow lines 4A, 4B. The upper recirculation flow lines 4A cause a standing wave at the molten metal upper surface 10. The height of the wave typically oscillates with time. The oscillating standing wave and associated turbulence at

25 the molten metal upper surface 10 is considered to be one of the reasons for most of the defects in cast slabs made by this process.

Referring next to FIGS. 2 through 4, the introduction of a metal and gas mixture into the vessel 1 through SEN 3 is shown. As mentioned above, the nature of the surface standing wave and turbulence changes with different levels of gas injection. FIG. 2 shows

30 that at relatively small gas flow ratio, the upper recirculation flow lines 4A still remain counter-clockwise on the right side of the vessel 1, while the height of the surface standing wave is reduced as some molten metal 2 is carried to the upper surface 10 by gas bubbles

11. FIGS. 3 and 4 show altered upper recirculation lines **4A** with increasing gas flow ratios, where at large gas flow ratios (FIG. 4), upper recirculation lines **4A** are completely reversed and one large loop forms on each side of the vessel **1**. While the increased gas flow is desirable for reducing standing waves and for conveying some of the inclusions upward and away from the solidifying slab **5**, it can be detrimental in that it allows relatively high velocity molten metal on the upper surface **10** to capture and drag flux or other surface contaminants downward near the solidifying slab **5**.

Referring next to FIGS. 5A and 5B, the difference in molten metal flow exiting the SEN **3** can be seen for non-rotated (FIG. 5A) and rotated (FIG. 5B) conditions. In the non-rotated embodiment of FIG. 5A, the flow of the molten metal is generally parallel to the widthwise dimension of the vessel **1**, while in the rotated embodiment of FIG. 5B, SEN **3** is rotated about its longitudinal (vertical) axis such that the flow is angled relative to a central axis **A** by an angle θ and produces an asymmetric (when viewed from above) profile.

Referring next to FIGS. 6A, 6B and 7, the gas/liquid jet exiting from the rotated SEN **3** of FIG. 5B would contact the more broad wall **1B** of the vessel **1** and rise to the molten metal surface of metal. Referring with particularity to FIGS. 6A and 6B, the width, thickness and height dimensions **W**, **T** and **H** of the vessel **1** define an interior volume **V** into which molten metal **2** is placed and slab **5** (not presently shown) is formed. In particular, the flow **F** of the gas and molten metal mixture is divided into numerous regions, including **F1** through **F4**. In the first region **F1**, gas and liquid flow **F** that exits the discharge port **3A** of SEN **3** first contacts the more broad (i.e., wider) wall **1B** of vessel **1**. In the second region **F2**, the buoyancy of the gas **11** causes the mixture to travel upward to the surface **10**. In the third region **F3**, the flow **F**, upon reaching the surface **10**, travels horizontally across the surface and toward the opposing wall **1B**. Depending on the velocity of this horizontal flow **F3**, the flux layers **12A**, **12B** can shear, which causes a disruption of inclusions or other contaminants that have settled on the surface **10**. Upon reaching region **F4**, the flow **F** can capture and drag these contaminants downward into the shell **6** and the as yet unsolidified molten metal **2**, where they can corrupt the formed slab **5** (not presently shown). A side view (i.e., looking along the widthwise dimension of the vessel **1**) of regions **F2**, **F3** and **F4** of the flow **F** is shown in FIG. 7 with the relative position of the molten metal upper surface **10** and flux **12**, where the latter is made up of a

powdered flux layer **12A** and a liquid flux layer **12B**. FIG. 7 further indicates that with the relatively small thickness dimension **T** (and concomitant inability to allow for geometric spreading of the flow) of vessel **1**, the velocity of the liquid metal increases along the interface **14** of the molten metal **2** and liquid flux **12B**. These high velocities can cause shearing of the flux **12** and any non-metallic inclusions present on the interface **14**.

Referring next to FIGS. 8 through 11C, an embodiment of the present invention is shown where the SEN **3** is rotated such that the discharge of the gas and molten metal mixture from the discharge ports **3A** is angled relative to the narrow and broad walls **1A** and **1B** of the vessel **1**. In the present embodiment, the mixture exits as flow **F** through the discharge ports **3A** (only one of which is shown) at an angle relative to the central axis **A**. Referring with particularity to FIG. 8, the unique orientation of the flow modifier members **15** reduces the tendency of the flow of molten metal **2** to shear the flux **12** at the interface **14**, instead causing the horizontal flow region **F3** to form a predominantly circumferential flowpath along the molten metal upper surface **10**. This eliminates or significantly reduces downward flow region **F4** of the mixture, as well as any entrained inclusions or other contaminants from the flux **12**, thereby reducing the likelihood of introducing such into the molten metal **2** and solidifying metal slab **5** (not presently shown) at the vessel walls **1A**, **1B**. Three views of the placement and orientation of flow modifier members **15** in a vessel **1** are shown in FIGS. 9A through 9C. As before, the width, thickness and height dimensions **W**, **T** and **H** define an interior volume **V** of the vessel **1**. The narrow walls **1A** are formed by a plane made up of the height and thickness dimensions **H**, **T**, while the more broad walls **1B** are formed by a plane made up of the height and width dimensions **H**, **W**. In addition, the plates **15** extend both above the molten metal upper surface **10**, as well as below the surface such that they project into the layer of molten metal **2**. As shown, the lower edge of the plates **15** do not project below the bottom of SEN **3**, although a configuration where the lower edges do extend below the discharge ports of SEN **3** is within the scope of the present invention. Referring with particularity to FIG. 10, a side view of the flow of metal through vessel **1** with flow modifier members **15** is shown. Downward flow near the wall is significantly reduced or eliminated as a result of the placement of the flow modifier members **15**. As can be seen with particularity in FIGS. 11A through 11C, the tilt angle of the discharge ports **3A** can be horizontal,

downwards or upwards, for example, up to approximately twenty degrees in either direction. Such can be used to control the amount of first region F1 flow in vessel 1.

As shown, the flow modifier members 15 are rectangular-shaped plates, although it will be appreciated that any shape capable of causing significant changes in molten metal flow could be adopted. In addition, the plates 15 are generally positioned centrally within the vessel 1 and parallel to the longer wall dimensions 1B and are oriented in-line with respect to each other on opposite sides of the SEN 3 on the central axis A extending through the center of the SEN 3. As shown with particularity in FIG. 10, in a variation of the embodiment depicted in FIG. 8, the plates 15 may also be positioned parallel to the longer walls 1B but off-set of the central axis A. In yet another variation (not shown), the plates 15 may be positioned at an angle relative to the central axis A. For example, the plates 15 can be angled up to approximately forty degrees relative to the central axis A and still maintain a significant flow modification function. The plates 15 are generally positioned such that they are placed centrally of the space between the SEN 3 and the narrow walls 1A of vessel 1, but they may be located closer or farther from the SEN 3. The size of plate 15 would depend upon the width W of vessel 1 and volume of injected gas. Preferably, each plate 15 is sized to cover most of the width of gas and molten metal mixture that is rising up to the molten metal upper surface 10.

Experiments conducted by the inventor have shown that the design of the plates 15 is independent, to some extent, of the width W of the vessel 1, gas flow rate and metal casting rate. Thus during a normal casting operation, any fluctuations in the gas and liquid metal flow rates should not have any effect on the plate 15 operation in controlling the metal flow. FIG. 8 shows that the predominant vertical metal flow of FIG. 2 is transformed by the presence of plates to a large horizontal metal flow at the surface 10. In addition to reducing surface flow velocity, this is also good for uniform distribution of mold flux powder placed on the surface 10. The flow instabilities, which are inherent in any normal mold flow operation and are mainly responsible for the casting defects, seem to have significantly reduced with the installation of plates 15.

Referring next to FIGS. 12A through 16, a non-rotated SEN 3 and another embodiment of the invention useable with such a SEN 3 configuration is shown. Referring with particularity to FIGS. 12A, 12B and 13, which are a variation of the device shown in FIGS. 6A, 6B and 7, the flow F of the gas and molten metal mixture exiting SEN

3 is shown. The particular flow regions **F1** through **F4** differ. For example, in the present embodiment, the first region **F1** transitions to the second region **F2** without hitting the broad walls **1B**. Thus, by the time the horizontal flow region **F3** commences on the surface **10**, it can extend in both directions along the thickness dimension **T** of vessel **1**, after which it drops downward as shown by the fourth region **F4**. Referring with particularity to FIG. 14, in situations where there is little or no rotation of the SEN **3** about its vertical axis, two plates **15** may be grouped together to be used on either side of the SEN **3**. In this embodiment, the plates **15** in each group **15A** and **15B** are typically arranged parallel to both each other as well as to the longer walls **1B** of the mold. Moreover, they are in-line with each other along central axis **A**. Although not shown, it will be appreciated that the plates **15** may be positioned at an angle with each other. In the variant shown in the figures, the plates **15** are spaced apart by a distance which is approximately the same as the cross-sectional dimension of the SEN **3**. As with the embodiment described in FIGS. 8 and 9, it is possible for the plates **15** in each group **15A**, **15B** to be positioned parallel to the broad walls **1B** but off-set of the central axis **A**. Alternatively, the plates **15** may be positioned at an angle (not shown) to the central axis **A**, for example up to approximately forty degrees. The plates **15** are generally positioned such that they are placed centrally of the space between the SEN **3** and the narrow walls **1A**, but may also be located closer or farther from the SEN **3**, depending on the need. FIGS. 15A through 15C show three views of the system configuration shown in FIG. 14. Because the SEN **3** is not rotated, most of the gas exiting its discharge ports **3A** may be contained between the plates **15** of each group **15A**, **15B**. This arrangement reduces the downward flow **F4** near the broad walls **1B** of the vessel **1**, as shown in FIG. 16, as the flow **F** of the gas and molten metal mixture is carried to the surface **10** in between plates **15**, thereby keeping it substantially within the middle of the mold rather than near the broad walls **1B**.

Referring with particularity to FIGS. 17 and 18, yet another embodiment of the design of the system with flow modifier members **15** is shown. Here, each group **15A**, **15B** of plates are joined together by joiner **16** at one end near the narrow wall **1A** of the mold. This is schematically shown in a three-dimensional representation in FIG. 17 and two-dimensional views in FIG. 18. As with the previous embodiments, the orientation options of the plates **15** can also be varied, depending on the need. As with the

.12-

embodiment of FIG. 12, the present embodiment is particularly well-suited to systems where the SEN 3 is in a non-rotated position, so that most of the gas and molten metal mixture exiting the SEN 3 may be contained between the two plates 15 of each group 15A, 15B. This design would be preferred when the gas volume is high enough to cause a single loop flow shown in FIG. 4. This flow modifier would also prevent flow of liquid metal near the mold narrow wall.

Having described the invention in detail and by reference to preferred embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims. More specifically, although some aspects of the present invention are identified herein as preferred or particularly advantageous, it is contemplated that the present invention is not necessarily limited to these preferred aspects of the invention.

CLAIMS

1. A continuous casting system comprising:
 - a mold vessel adapted to receive a flow of molten metal therein, said vessel
 - 5 comprising a plurality of inner surfaces such that an interior volume is defined thereby, said interior volume comprising a width dimension and a thickness dimension that generally corresponds to a respective width and thickness of a slab of metal produced by said system;
 - a submerged entry nozzle arranged within said interior volume and extending
 - 10 below a molten metal upper surface formed upon introduction of said molten metal into said interior volume, said submerged entry nozzle comprising at least one discharge port adapted to dispense a mixture of gas and said molten metal into said interior volume; and
 - at least one flow modifier member disposed in said interior volume, said at least one flow modifier member having a height dimension, a width dimension and a thickness
 - 15 dimension such that at least one major surface and at least one minor surface is defined thereby, said at least one major surface defining a larger surface area than said at least one minor surface, said major surface angularly aligned closer to the wider of said width and thickness dimensions of said interior volume.
- 20 2. The system of claim 1, wherein said major surface is angularly aligned substantially parallel to the wider of said width and thickness dimensions of said interior volume.
3. The system of claim 1, wherein said at least one flow modifier member extends
- 25 below said molten metal upper surface.
4. The system of claim 1, wherein said interior volume comprises a rectangular shape.
- 30 5. The system of claim 4, wherein each of said at least one flow modifier members is disposed between said submerged entry nozzle and the narrower of said width and thickness dimensions of said interior volume.

6. The system of claim 1, wherein said at least one flow modifier member extends upwardly at least into a flux layer disposed substantially on top of said molten metal upper surface.
- 5
7. The system of claim 1, wherein said height, width and thickness dimensions of said at least one flow modifier member are such that said at least one flow modifier member defines a plate.
- 10 8. The system of claim 7, wherein said plate is substantially planar.
9. The system of claim 1, wherein said discharge port of said submerged entry nozzle extends below said flow modifier member.
- 15 10. The system of claim 1, wherein said at least one discharge port is adapted to dispense said mixture of gas and molten metal into said interior volume at an angle relative to said interior volume width and thickness dimensions.
11. The system of claim 1, wherein said at least one discharge port is adapted to
- 20 dispense said mixture of gas and molten metal substantially parallel to said interior volume width dimension.
12. The system of claim 11, wherein said at least one flow modifier member comprises a group of flow modifier members, said group configured such that individual flow
- 25 modifier members in said group are spaced apart from one another substantially along a through-the-thickness axis thereof such that at least a majority of said mixture of gas and molten metal exiting said discharge port flows substantially between said individual flow modifier members in said group.
- 30 13. The system of claim 12, wherein said individual flow modifier members within said group are substantially parallel to one another.

14. A flow modifier member configured for use in a continuous casting system, said flow modifier comprising at least one first surface and at least one second surface, said at least one first surface covering a larger surface area than said at least one second surface, said flow modifier member configured such that upon placement into a substantially
5 rectangular casting vessel defining a width dimension and a thickness dimension such that said width dimension is greater of the two, said at least one first surface is angularly aligned closer to said width dimension while said at least one second surface is angularly aligned closer to said thickness dimension of said vessel.
- 10 15. The flow modifier member of claim 14, wherein said flow modifier member comprises a refractory material.
16. The flow modifier member of claim 15, wherein said refractory material is a ceramic.
15
17. The flow modifier member of claim 14, further comprising at least one joiner disposed between adjacent ones of said flow modifier members, said at least one joiner sized to block the substantial entirety of space defined between said adjacent ones of said flow modifier members.
- 20 18. A method for controlling the flow of molten metal in a continuous casting system, said method comprising:
- configuring a vessel to comprise a plurality of walls comprising a height dimension, a width dimension and a thickness dimension to define an interior volume
25 thereby, said width dimension being greater than said thickness dimension;
- introducing a mixture of molten metal and gas into said interior volume such that a molten metal upper surface is defined within said interior volume; and
- placing a flow modifier member in a location within said interior volume between where said mixture introduction occurs and said wall that defines said thickness
30 dimension, said flow modifier member comprising a height dimension, a width dimension and a thickness dimension such that at least one major surface and at least one minor surface is defined thereby, said at least one major surface defining a larger surface area

than said at least one minor surface, said major surface angularly aligned closer to said wall that defines said width dimension such that the velocity of molten metal flowing adjacent said molten metal upper surface is reduced.

5 19. The method of claim 18, wherein said mixture introduction occurs through a submerged entry nozzle.

20. The method of claim 19, wherein said submerged entry nozzle is angled relative to said interior volume such that said introduced mixture exits said submerged entry nozzle at
10 an angle relative to both said width and thickness dimensions of said interior volume.

21. The method of claim 20, wherein said flow modifier member comprises a pair of flow modifier members, each arranged on opposite sides of said submerged entry nozzle such that each is disposed between said submerged entry nozzle and said walls of said
15 vessel that define said thickness dimension thereof.

22. The method of claim 18, wherein said flow modifier member comprises a plurality of flow modifier members arranged in at least one group such that individual flow modifier members within each said at least one group are spaced apart from one another
20 substantially along a through-the-thickness axis thereof such that at least a majority of said mixture of gas and molten metal exiting said discharge port flows substantially between said individual flow modifier members in said at least one group.

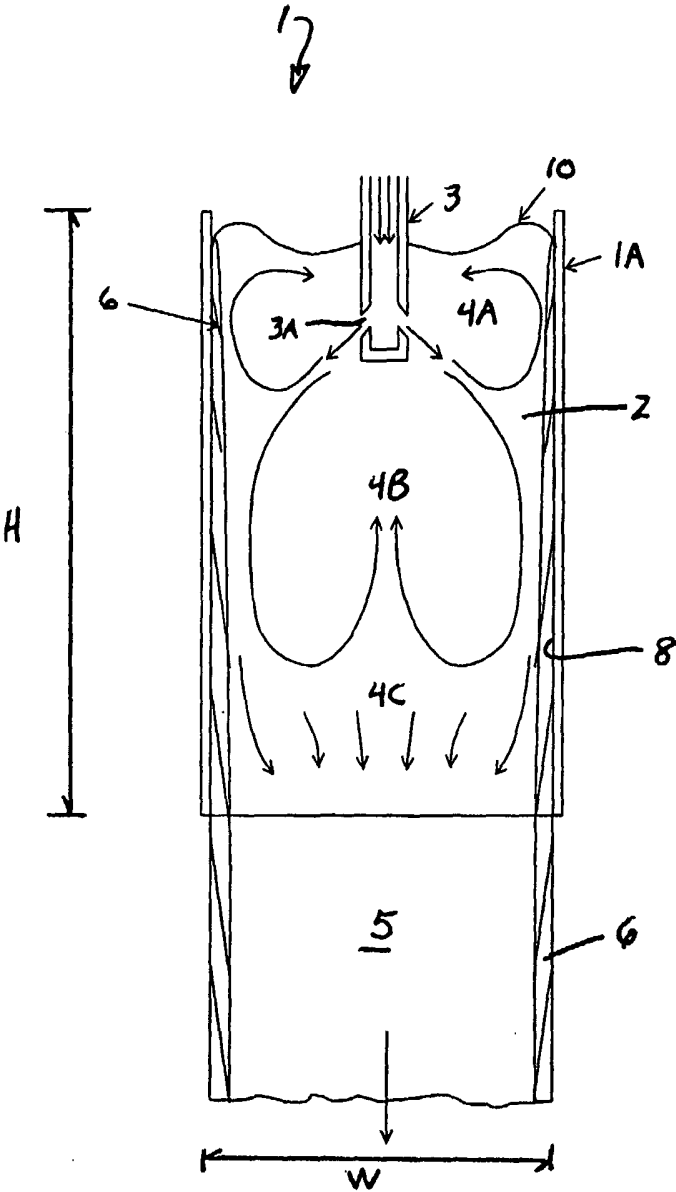


FIG. 1

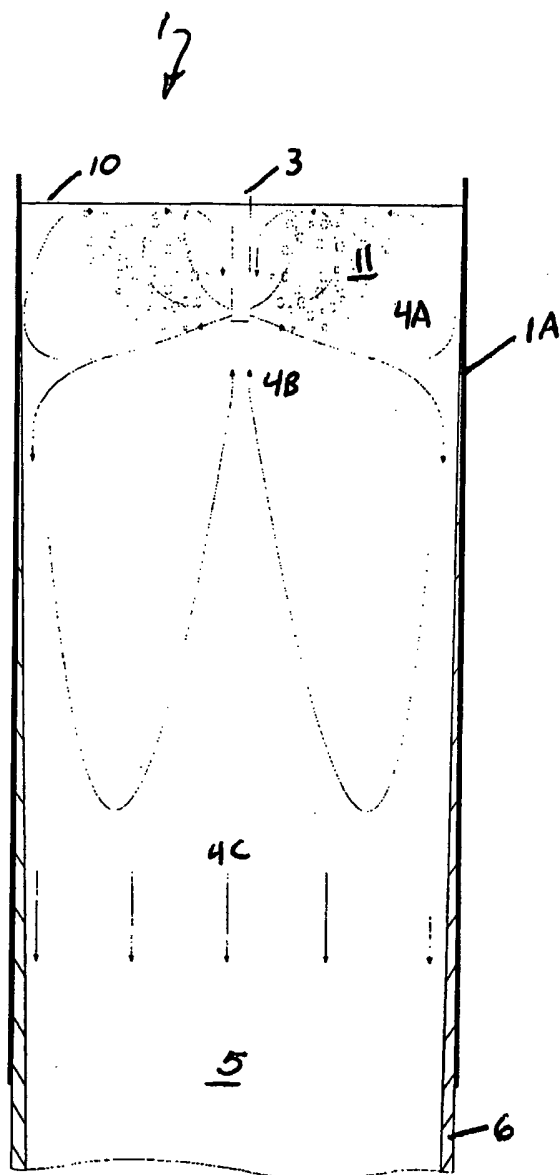


FIG. 2

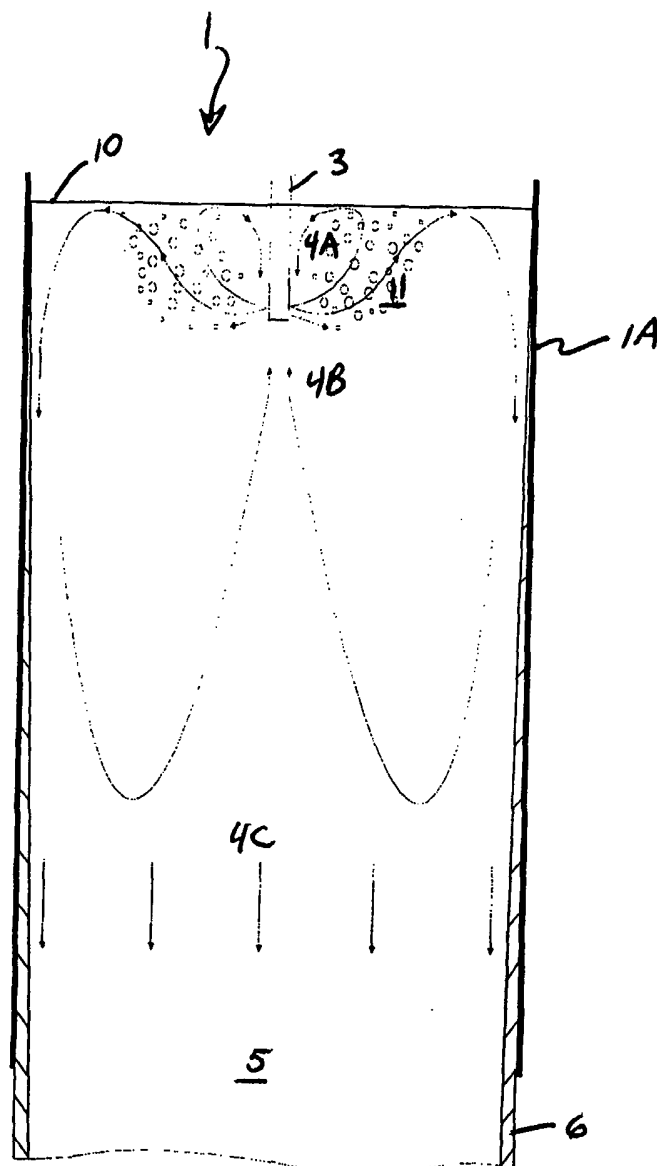


FIG. 3

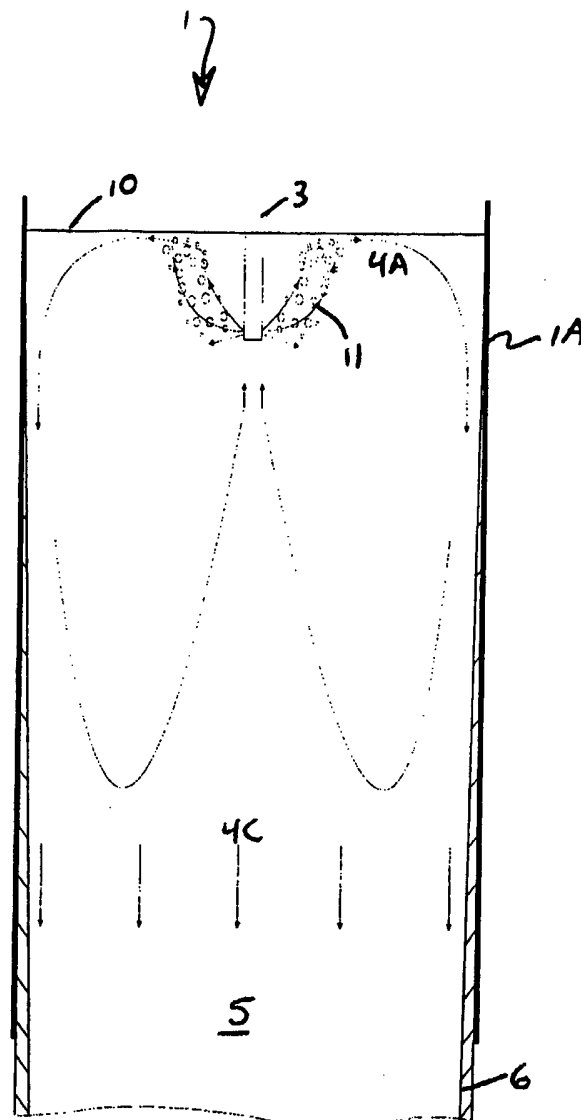


FIG. 4

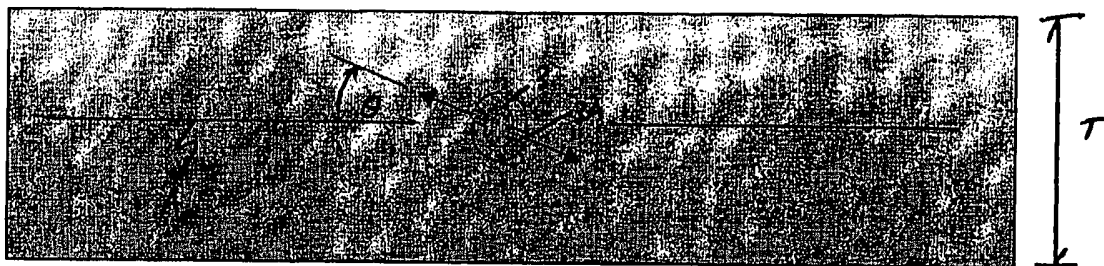


FIG. 5B

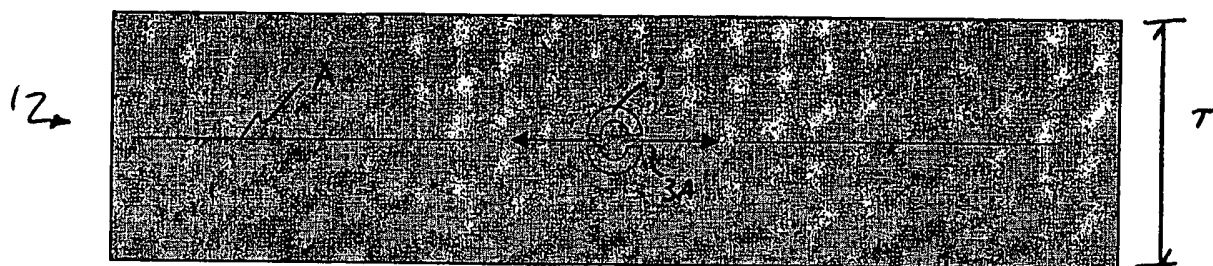


FIG. 5A

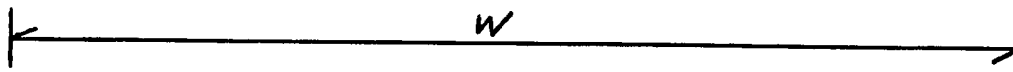


FIG. 6B

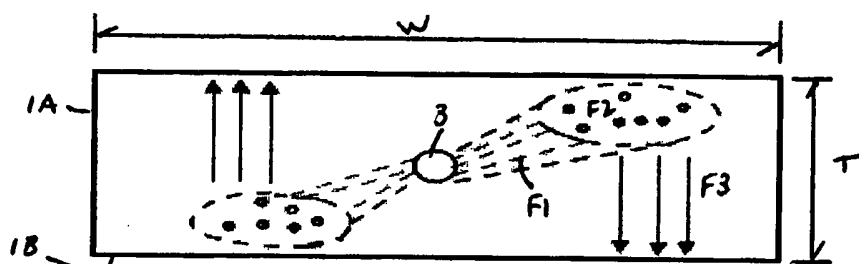
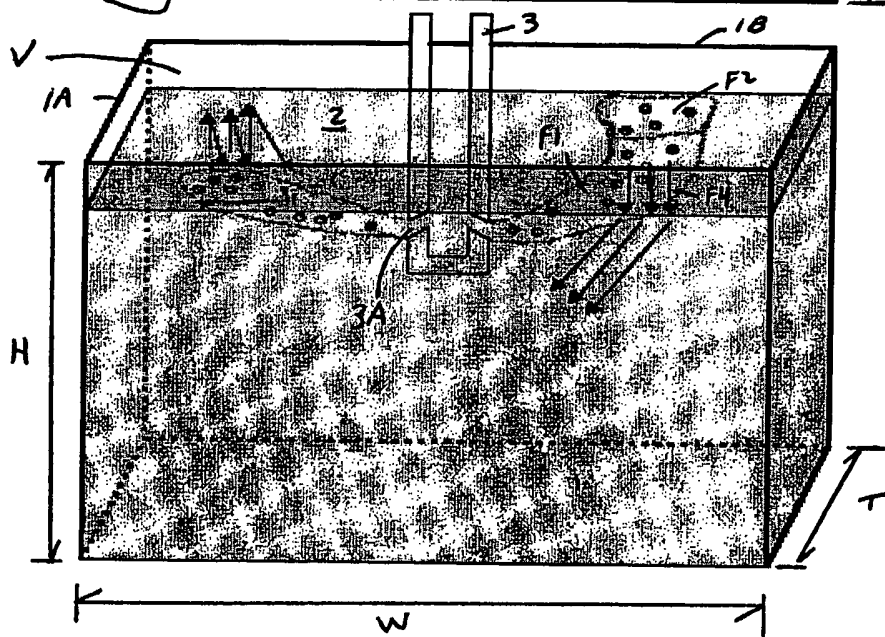


FIG. 6A



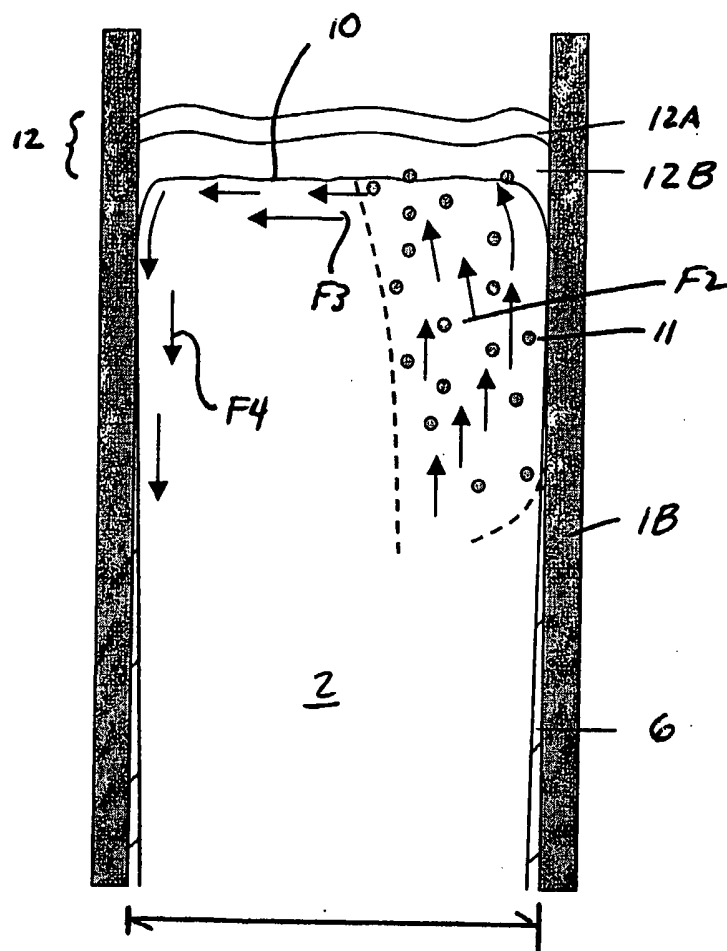
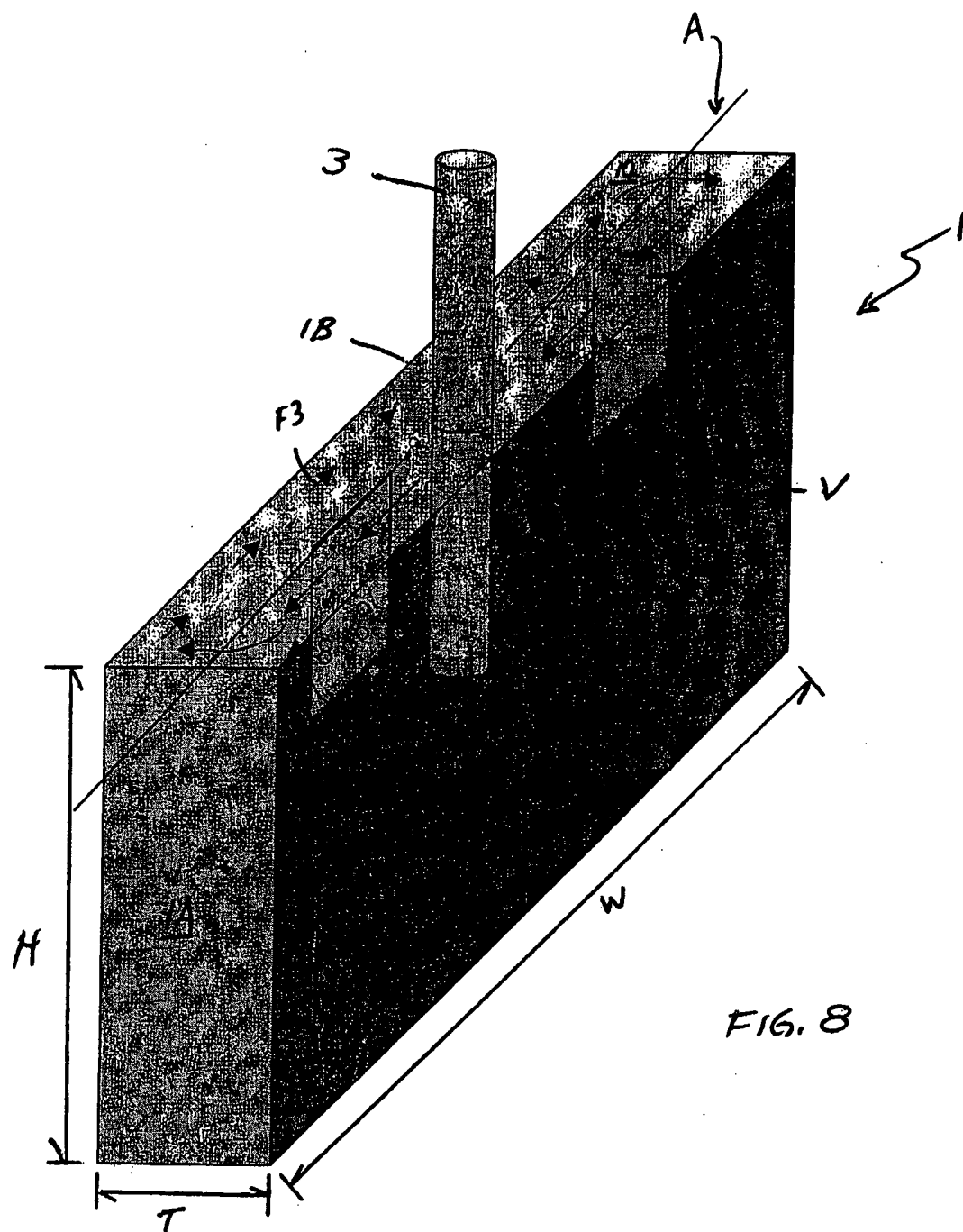
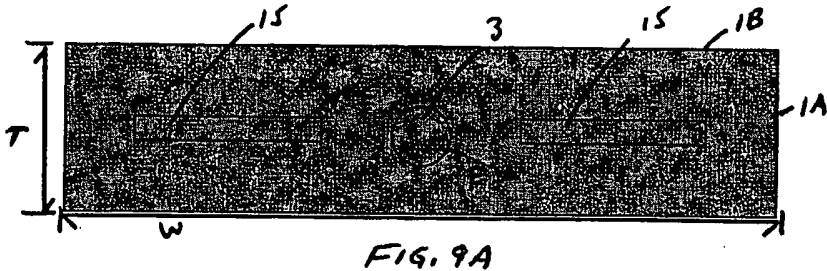
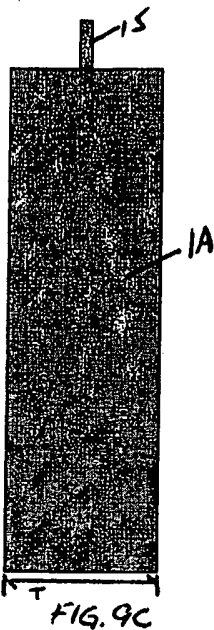
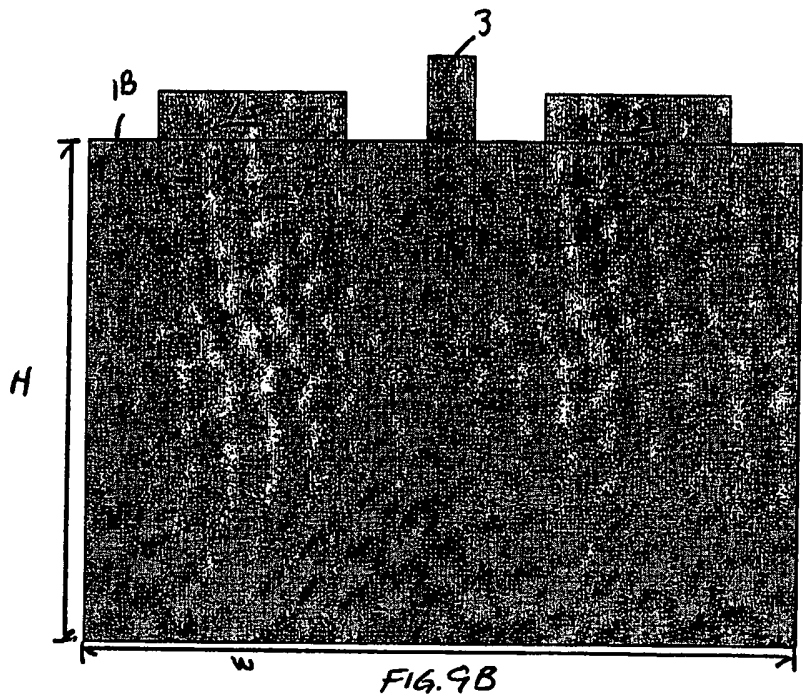


FIG. 7





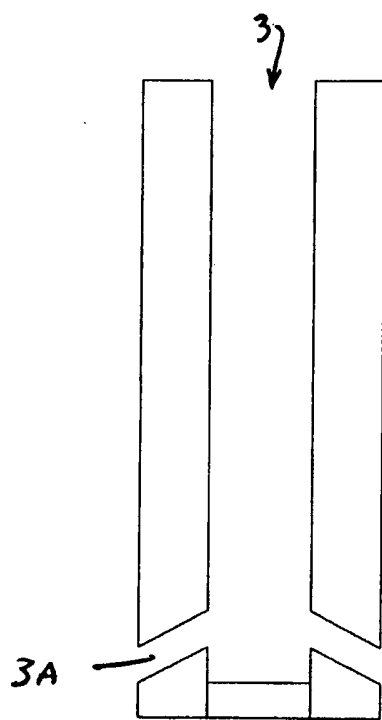


FIG. 11A

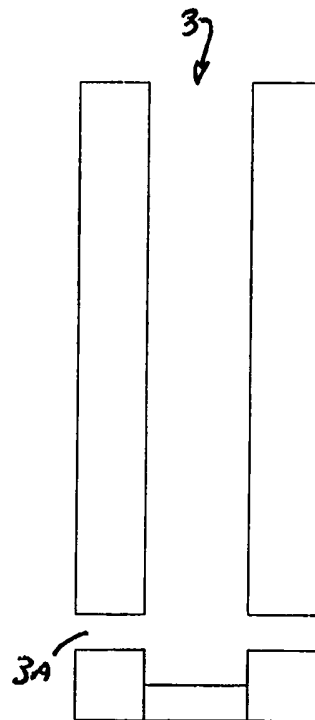


FIG. 11B

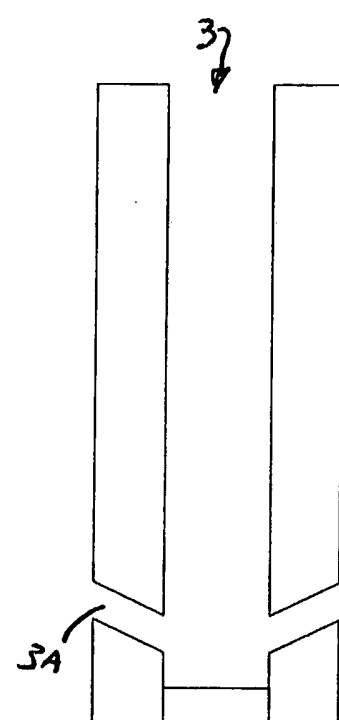
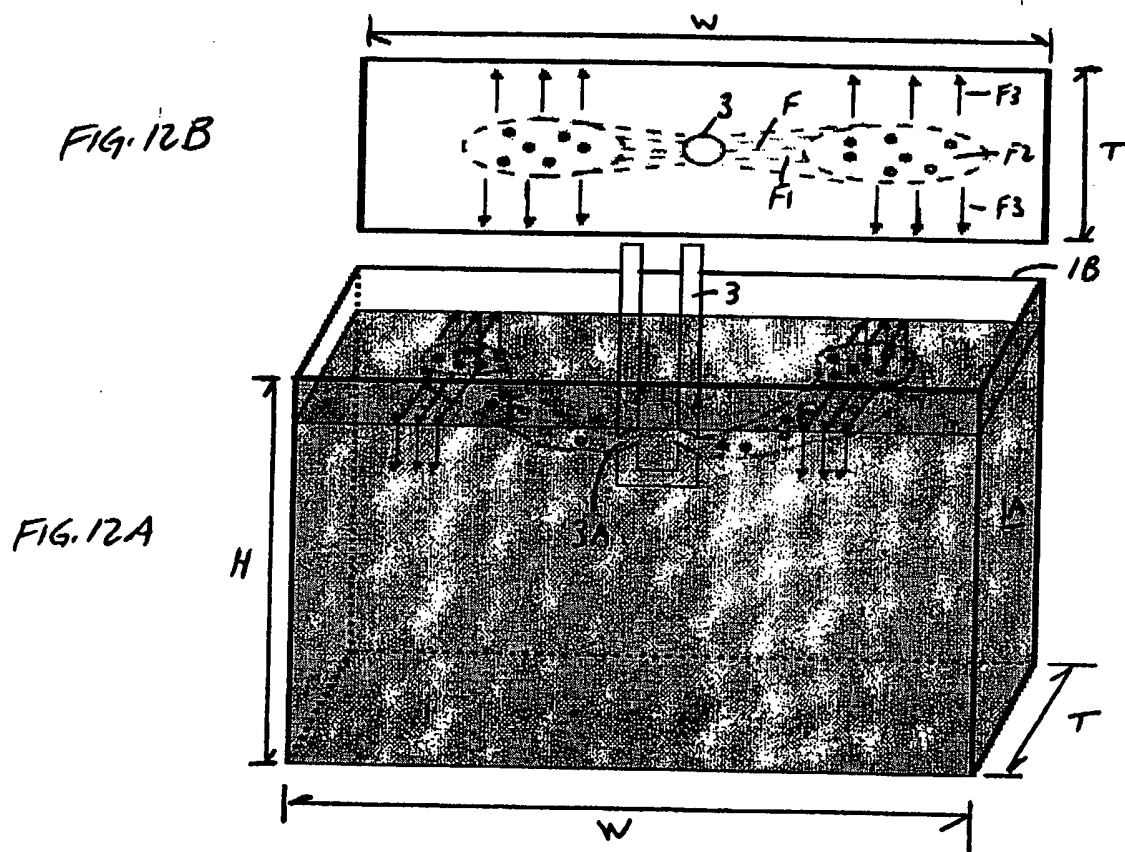


FIG. 11C



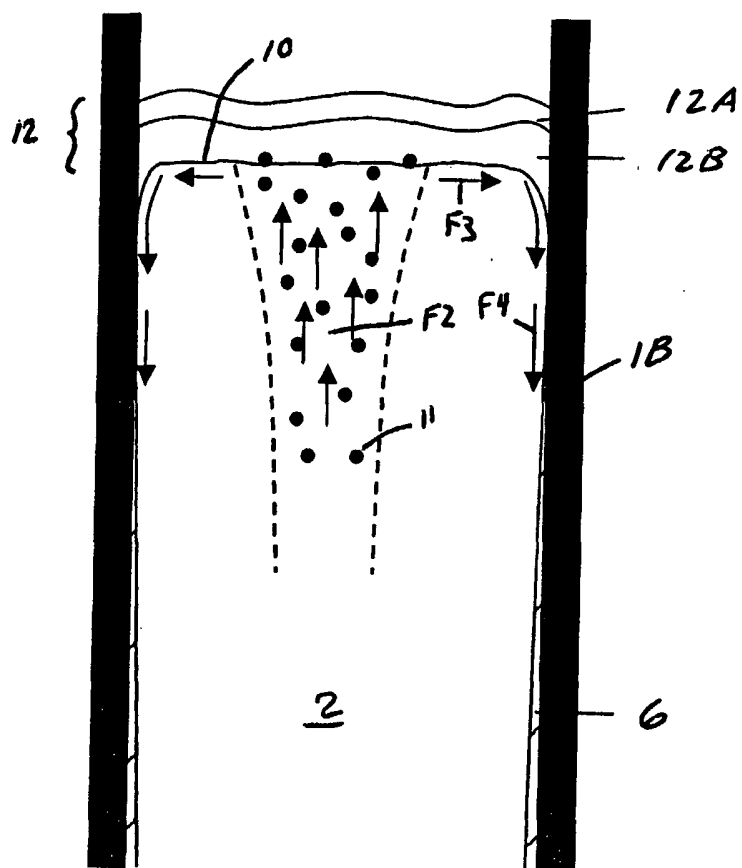
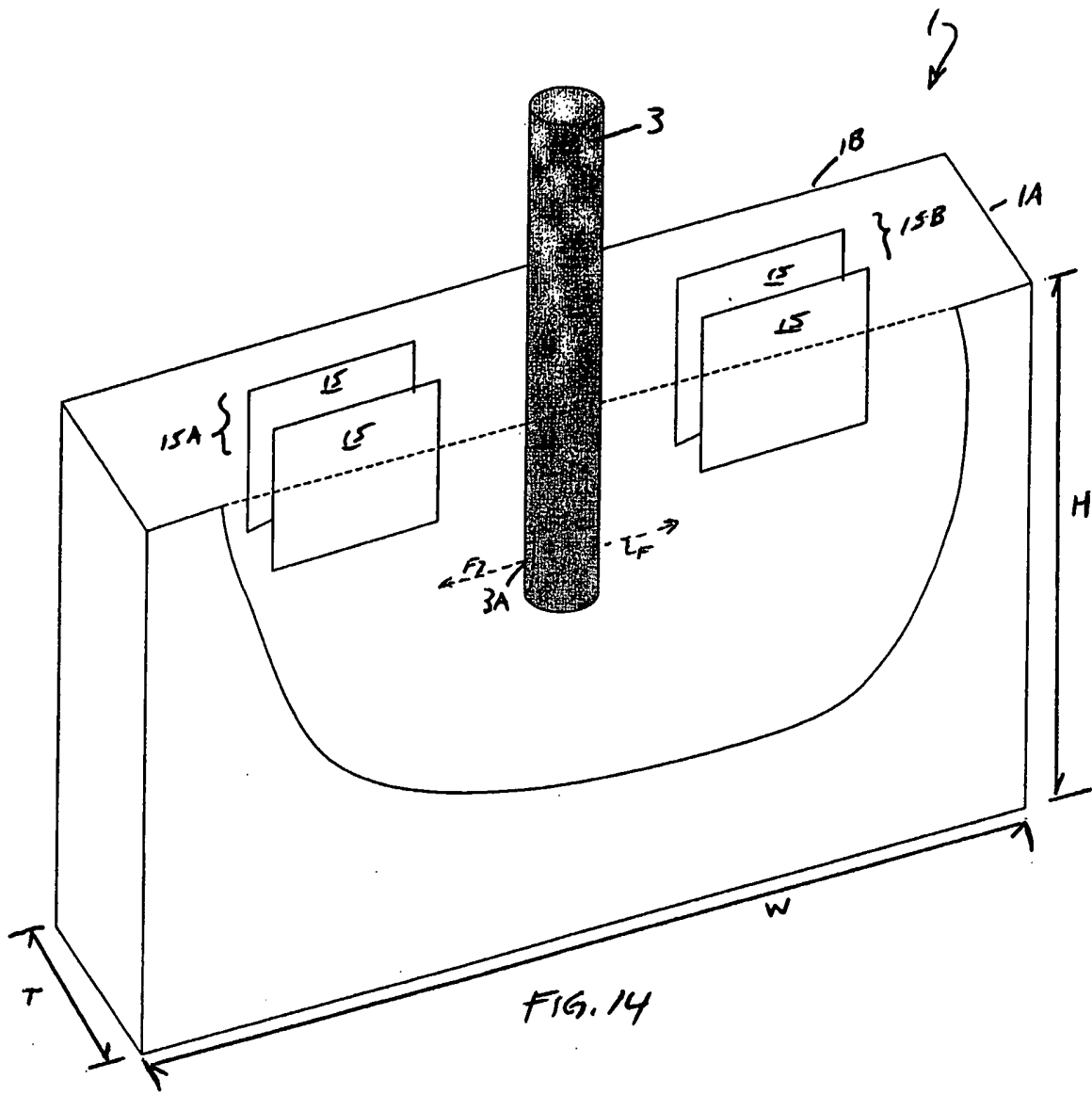
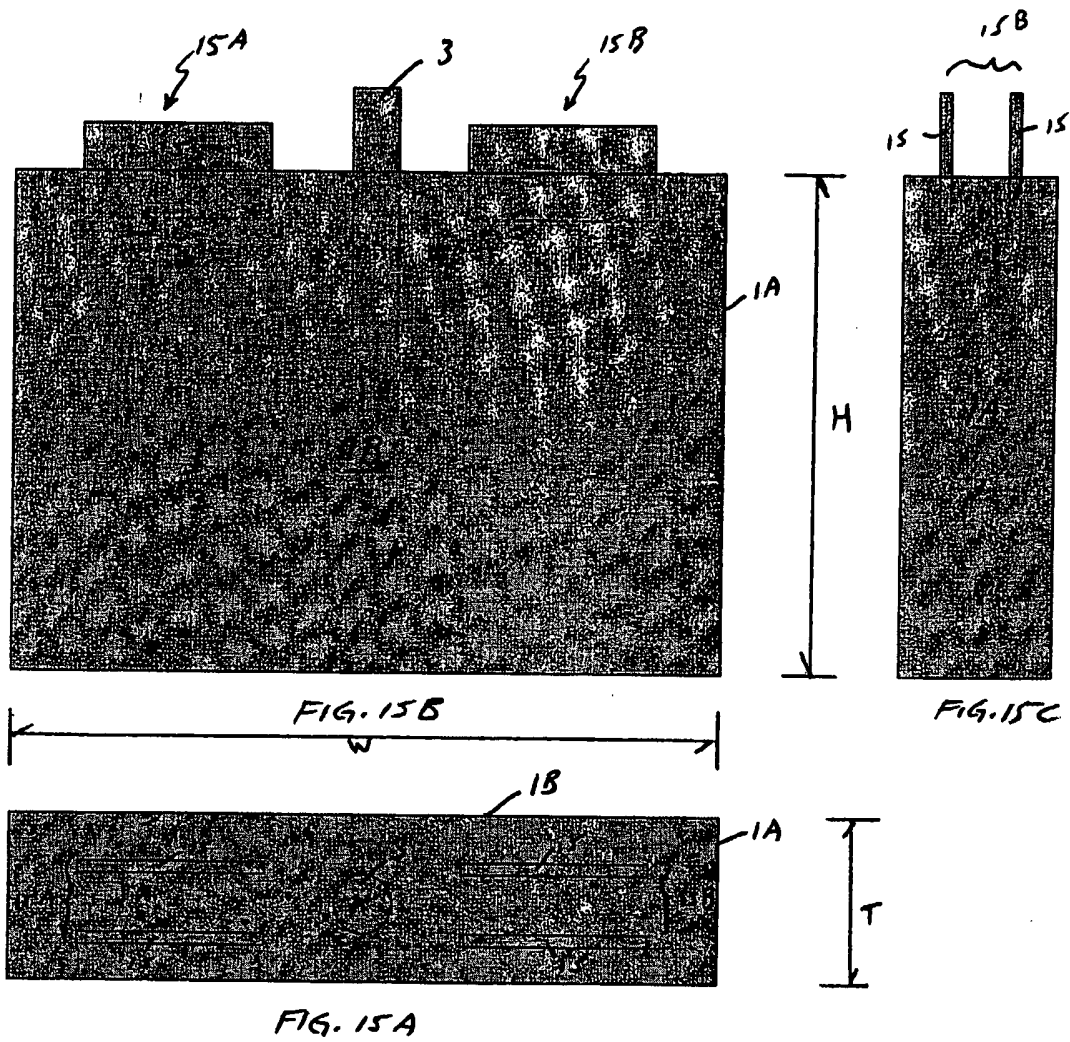


FIG. 13





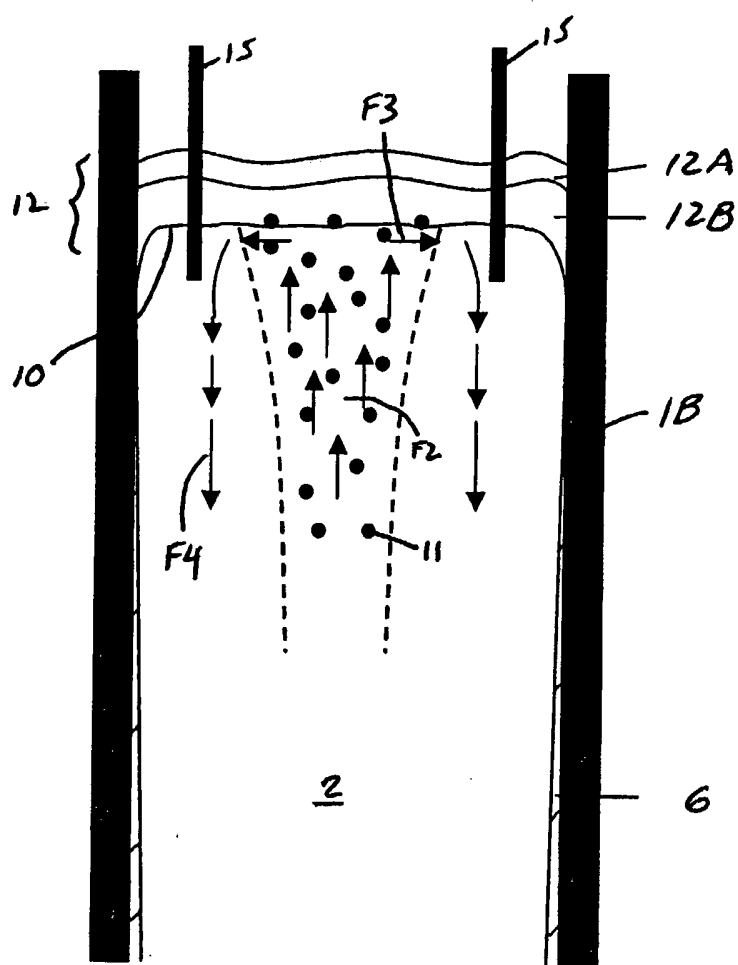


FIG. 16

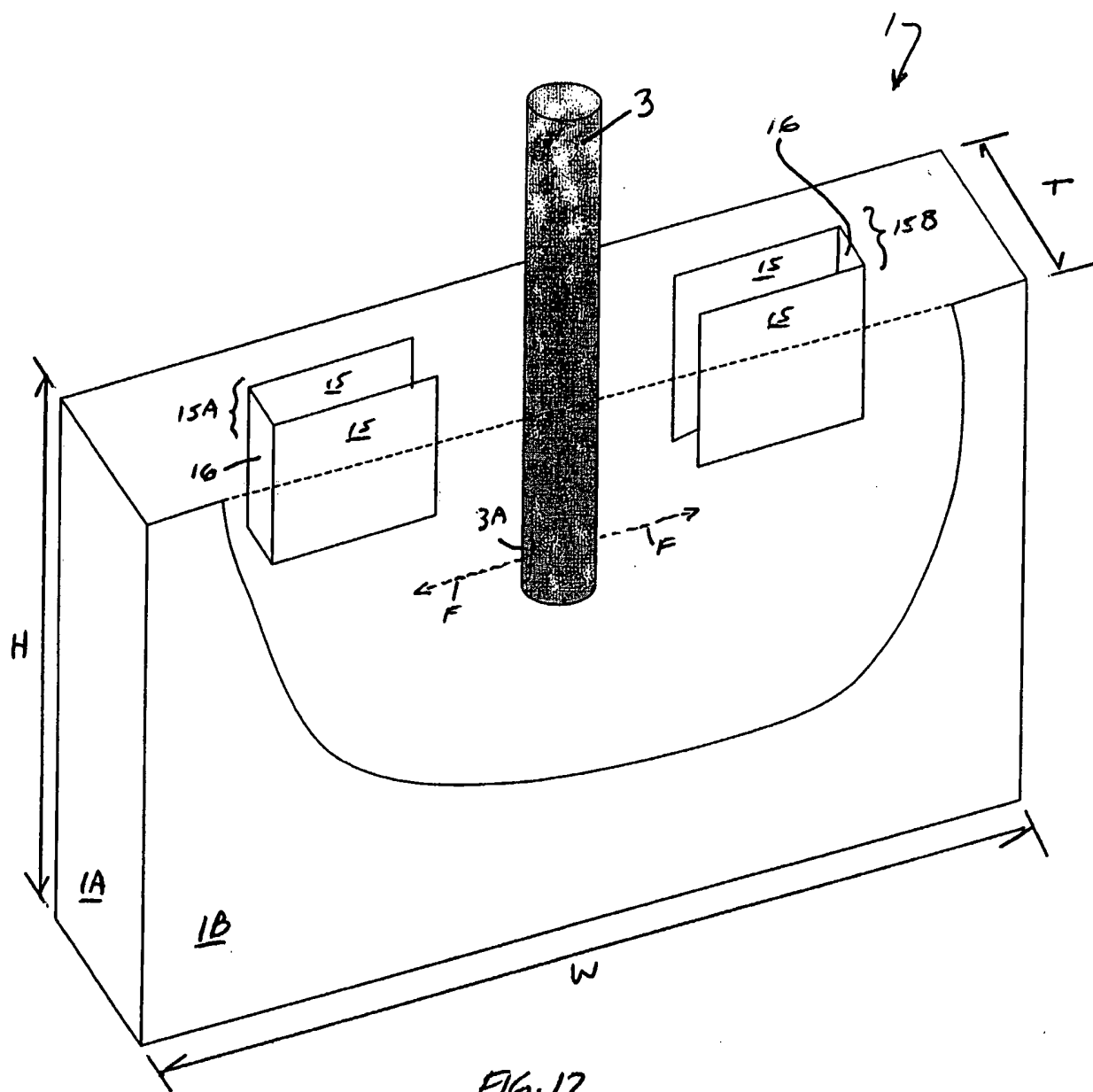


FIG. 17

