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(54) **METHOD AND APPARATUS FOR ELECTROMAGNETIC CONFINEMENT OF MOLTEN METAL**

VERFAHREN UND VORRICHTUNG ZUM ELEKTROMAGNETISCHEN EINDÄMMEN
SCHMELZFLÜSSIGER METALLE

PROCEDE ET APPAREIL POUR LE CONFINEMENT ELECTROMAGNETIQUE DE METAL EN
FUSION

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(73) Proprietor: **Alcoa Inc.**
Pittsburgh, PA 15212-5858 (US)

(72) Inventor: **BHAMIDIPATI, Jagan**
Fremont, CA 94538 (US)

(74) Representative: **W.P. THOMPSON & CO.**
Eastcheap House
Central Approach
Letchworth, Hertfordshire SG6 3DS (GB)

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Description

Technical Field

[0001] The present invention relates to the continuous casting of metals, and more particularly, to the electromagnetic confinement of molten metal in a twin belt casting system.

Background Art

[0002] The continuous casting of thin metal strip has been employed in the prior art but with only limited success. Prior techniques for the continuous casting of metal strip have been limited to a relatively small number of alloys; it has been found that if the alloy content of various metals such as aluminum alloy are increased, the as-cast surface quality of the strip deteriorates.

[0003] One approach employed by the prior art in the strip cast of metals has been what has become known in the art as the twin drum caster. Such devices include a source of molten metal supplied to the space between a pair of counter-rotating, internally cooled drums. The molten metal thus solidifies when it comes into contact with the drums to form a cast metal strip; the drums also assert a compressive force on the solidified metal, and effect hot reduction of the cast alloy immediately after freezing. Such twin drum casters have enjoyed the greatest extent of commercial utilization in the strip casting of metals. Nonetheless, they offer some serious disadvantages arising from the fact that the output of such casting systems is substantially lower than that for other strip casting techniques. In addition, twin drum casting, while providing acceptable surface quality in the casting of high purity aluminum (e.g., foil), suffers from the disadvantages of poor surface quality when used in the casting of aluminum having a high alloy content. In addition, twin drum casters also suffer from the problem of centerline segregation of the alloy due to deformation during solidification,

[0004] Another conventional technique is the strip casting of metals, and particularly aluminum, involving a twin belt strip casting technique in which two endless moving belts are positioned adjacent each to the other to define a moving molding zone between them. Cooling of the belts is typically effected by contacting a cooling fluid with the side of the belt opposite of the side in contact with the molten metal. Such twin belt strip casting machines have the advantage over twin drum casting machines of providing significant output of cast metal. However, because cooling is typically effected by having a cooling fluid in contact with one side of the belt while either molten metal or a hot cast metal strip is in contact with the other side of the belt, such casting systems give rise to high thermal gradients over the thickness of the belt. Those thermal gradients, dynamically unstable, cause distortion in the belt and, as a result, neither the upper nor the lower belt is substantially flat. The result

is that the product thus produced has areas of segregation and porosity.

[0005] Substantial improvements in the strip cast of metals have been achieved as described in US-A-5515908 and US-A-5564491. Those patents describe a substantially improved method and apparatus for use in the strip casting of metals using a twin belt technique in which use is made of two endless belts positioned adjacent each to the other to define a molding zone therebetween. At one end of the machine, the belts each pass over an entry pulley which defines a curved surface as each belt passes around the entry pulleys. The molten metal, as disclosed in US-A-5515908, is supplied to the curved surface of both of the belts in the molding zone at a time when the belts are supported by the pulleys over which they are advanced, thus, preventing any initial warping of the belts as molten metal is supplied thereto. Thereafter, the cast metal strip is carried between the belts, and supported by the lower belt whereby both the molten metal and the hot cast strip transfer heat to the belts. That heat is then removed from the belts at a time when the belts are not in contact with either the molten metal or the hot cast metal strip to substantially prevent, minimize or eliminate the high thermal gradients which have plagued the prior art. Further improvements in the techniques described in US-A-5515908 are disclosed in US-A-5564491 in which there is provided a system to control the spacing between the entry pulleys whereby the entry pulleys exert a compression force on the substantially frozen cast strip at the nip of the entry pulleys, that compressive force being sufficient to cause elongation of the cast strip to ensure that the cast strip is in compression in the direction of travel after exiting from the nip to minimize cracking of the cast strip.

[0006] The strip casting techniques as described above and other strip casting techniques require the use of a containment system to maintain molten metal in the gap between the rolls of the caster. Up to the present, the casting system has employed mechanical edge dams to provide containment of the molten metal. One of the principal advantages of the strip casting system as described in the foregoing patents is that the system is capable of operation at tremendously high speeds. As a result, however, the mechanical edge dams heretofore employed have a short life. They tend to be worn out rapidly by erosion of the hot metal flowing at high velocities in contact with such mechanical edge dams. In addition, such mechanical edge dams provide sites for the formation of skull which has a tendency to be sheared off and thus enters the cast to render the microstructure metallurgically undesirable.

[0007] Electromagnetic edge dams have been employed in the prior art in the strip casting of metals such as aluminum in twin drum casting systems. Such systems have been generally categorized into one of two distinct systems. The first are those systems that use a combination of a magnet assembly and an AC coil to

generate confinement forces and those systems that rely solely on an AC coil to generate the containment forces.

[0008] The magnetic systems use a magnetic member which comprises a yoke or core connecting two pole faces disposed on either side of the gap on which the molten metal is to be confined. The magnetic member is made of a ferromagnetic material and surrounded over the given length of the yoke by a coil carrying an AC current. The magnetic flux generated by the flow of the current in the coil is transmitted to the poles of the magnet through the yoke, and when the flux lines pass through the molten metal, they cause the flow of induced currents in the molten metal. The interaction between the applied field and these induced currents establishes containment forces at the metal surface in the gap.

[0009] Typically, in systems of that type, part of the magnetic member is covered with an electrically conductive shield to minimize leakage of flux in a direction away from the gap. Such magnetic confinement systems have the advantage that the confinement current need not be as high as compared to those systems using solely an induction coil. If a stronger magnetic field is required, it can be achieved with the same current level by reducing the area of the pole faces. Such systems are not without disadvantages, however. Such systems typically have poor operating efficiency by reason of core losses and losses due to magnetic hysteresis when an AC current is applied to the magnetic material. In addition, high amounts of heat are generated, necessitating the need for cooling systems to avoid damage to the magnetic system.

[0010] The induction coil type confinement system typically employs a shaped inductor positioned close to the gap in which the molten metal is to be contained. The AC current flowing in the inductor generates induced currents in the molten metal as well as a time-varying magnetic field on the surface of the molten metal. The current-magnetic field interaction provides the containment forces. Such induction coil systems are generally simpler in design than the magnetic systems. However, the induction coil type systems are limited in terms of maximum metallostatic head which can be supported. That is because very high inductor currents are needed to provide the necessary containment forces, and such high currents are accompanied by extremely high heat which in turn hinders or slows the solidification process.

[0011] One such magnetic confinement system is disclosed in US-A-4936374 illustrating a magnetic type confinement system to support molten metal in the gap between the rolls of a vertical twin roll caster. Other electromagnetic confinement systems are disclosed in US-A-4974661, US-A-4986339, US-A-5197534, US-A-5385201 and US-A-5487421. Each of the systems disclosed in the foregoing patents is directed to an electromagnetic containment system for use with twin drum casting apparatus as distinguished from twin belt cast-

ing apparatus. Thus, the containment forces need only be great enough to support the metallostatic head in the reservoir of molten aluminum maintained above the nip between the twin drums of the twin drum casting system.

In contrast, twin belt casters of the type described in US-A-5515908 and US-A-5564491 present different types of containment problems because of their unique configuration. For example, electromagnetic edge containment systems for use in US-A-5515908 and US-A-5564491 must be capable of addressing the unique problem arising from the squeeze pressure arising from belts positioned in a generally horizontal plane. Thus, there is a need to provide electromagnetic containment systems capable of use with twin belt casting systems of the type described in the foregoing patents.

[0012] It is accordingly an object of the invention to provide an alternative technique for edge containment which overcomes the foregoing disadvantages.

[0013] It is a more specific object of the invention to provide a technique for edge containment which is electromagnetic to produce containment involving no physical contact between the molten metal and the containment element.

[0014] It is yet another object of the invention to provide apparatus for use in the strip casting of molten metal utilizing a pair of endless belts equipped with edge containment apparatus to efficiently provide edge containment of the molten metal.

[0015] The present invention provides an apparatus according to independent claims 1 and 25, to which reference should now be made.

[0016] Preferred yet optional features of the invention are defined in dependent claims 2 to 24 and 26 to 45, to which reference should also be made.

[0017] The present invention further provides a method according to claim 46, to which again reference should be made.

[0018] The separation of claims 1, 25 and 46 into pre-characterising and characterising parts is on the basis of US-A-5515908, to which reference has already been made.

[0019] The concepts of the present invention reside in electromagnetic edge containment apparatus for use in the strip casting of molten metal by means of a casting belt, preferably a pair of endless belts. In the practice of the invention, a pair of endless belts may be positioned adjacent each to the other to define a molding zone therebetween. Each belt may pass over an entry pulley and defines a curved surface on the belt adapted to receive molten metal. The apparatus may also include means for supplying molten metal to the curved surfaces of each of the belts, the molten metal being confined on each of the lateral edges of the belts by electromagnetic apparatus positioned preferably on each side of the belts adjacent to the molding zone. Thus, the electromagnetic apparatus serves to electromagnetically confine the molten metal in the molding zone in contact with the curved surfaces.

[0020] The apparatus of the invention includes a magnetic member having a first pole and a second pole and an induction coil wound about a core portion of the magnetic member whereby magnetic lines of force pass from one of the poles to the other. The magnetic member is positioned adjacent a lateral edge of the belt in the area of the molding zone so that the upper and lower pole faces allow the magnetic lines of force to pass through the lateral edge of the belt to establish containment forces at the edge of the belt to contain the molten metal in the molding zone.

[0021] It has been found in a preferred form of the apparatus that by positioning the magnetic member adjacent to the edges of each of a pair of upper and lower ferromagnetic belts in the molding zone, the magnetic lines of force from the poles of the magnetic member are attracted to the ferromagnetic upper and lower belts and thus serve to focus containment forces on the molten metal maintained in the molding zone between the upper and lower belts. The attraction of the ferromagnetic member, that is the magnetic belts, thus serves to direct and conserve the energy and hence the confinement forces, focusing those forces on the liquid metal in the molding zone at the edges of the belt.

[0022] In contrast, such electromagnetic edge containment apparatus as used in the prior art with twin drum casters typically involve loss of substantial energy because the magnetic flux could become dissipated to the drum. In this preferred form of the present invention, the belts, formed of a magnetic metal, serve to focus the magnetic lines of force at the edge of the belts to ensure adequate containment forces without substantial loss of energy.

[0023] In preferred aspects according to the present invention, pole faces can have (1) a positive angle relative to the horizontal so that the inter-pole-face gap is larger at the outside edge of each pole face than at the inside edge of each pole face, (2) no angle relative to the horizontal so that the inter-pole-face gap is the same at the outside edges of each pole face as at the inside edge of each pole face, (3) a negative angle relative to the horizontal so that the inter-pole-face gap is smaller at the outside edge of each pole face than at the inside edge of each pole face, or (4) a combination thereof. The configuration of the pole faces should be chosen so as to create a strong magnetic field and a steep magnetic field gradient across each pole face.

[0024] In some embodiments of the present invention, a mechanical edge dam precedes the electromagnetic edge dam so that both dams confine the molten metal in the molding zone. In other embodiments, the electromagnetic edge dam is extended to completely replace the mechanical edge dam.

[0025] According to the present invention, the magnetic member having the pole faces can be formed from layers that are bonded together, layers that are mechanically held together, or a solid core that is cut to form the inter-pole-face gap. In addition, the magnetic member

can be formed so that the upper and lower halves of the member are removably attached so as to facilitate the repair and maintenance of the containment system.

[0026] Embodiments of the invention will now be described by way of example with reference to the drawings, in which:

Fig. 1 is a side view in elevation of a twin belt caster equipped with an electromagnetic edge dam apparatus,

Fig. 2 is a sectional view taken along the lines 2-2 in Fig. 1,

Fig. 3 is a sectional view of the electromagnetic edge dam apparatus of Fig. 2 illustrating the path of the magnetic lines of force in relation to the belts of the caster and the molten metal therebetween,

Fig. 4 is a view in perspective of one magnetic member suitable for use in an embodiment of the present invention,

Fig. 5 is a sectional view of an electromagnetic edge containment apparatus in accordance with another embodiment of the invention,

Fig. 6 is a sectional view of another embodiment of the invention illustrating the use of contoured belts,

Fig. 7 is a perspective view of an alternative embodiment illustrating a magnetic member having stepped pole faces,

Fig. 8 is a cross-sectional view like Fig. 3 illustrating another embodiment of the invention utilizing cooling channels within the core winding,

Figs. 9, 10, 11, and 12 illustrate different pole face angles and orientations in different embodiments of the present invention,

Fig. 13 illustrates a further embodiment of the present invention wherein a mechanical edge dam is used in conjunction with an electromagnetic edge dam,

Fig. 14 illustrates a solid structure from which a magnetic member for use in an embodiment of the present invention can be formed,

Fig. 15 illustrates yet another embodiment of the present invention wherein a magnetic member has a split core design, and

Fig. 16 illustrates a further embodiment of the present invention wherein a magnetic member has two regions.

[0027] The apparatus embodied in the practice of the invention is illustrated overall in Figs. 1 and 2 of the drawings illustrating a strip caster employing the concepts of US-A-5515908 and US-A-5564491 and equipped with electromagnetic edge containment apparatus in accordance with the practice of this invention. As there shown, the apparatus includes a pair of endless belts 10 and 12 carried by upper pulley 14 and lower pulley 16. As will be appreciated by those skilled in the art, the belts 10 and 12 are likewise supported by additional pulleys as disclosed in the foregoing patents

which are not illustrated in the present drawings for purposes of simplicity. The pulleys are of a suitable heat resistant type, with one of the pulleys in each pair being driven by suitable motor means likewise not illustrated in the drawings for purposes of simplicity. Each of the belts 10 and 12 is an endless belt and is preferably formed of a magnetic metal which has low reactivity or is nonreactive with the metal being cast. A number of suitable metal alloys, as is understood by those skilled in the art, may be employed, including steel belts.

[0028] As illustrated in Fig. 1, pulleys 14 and 16 are positioned one above the other whereby the belts 10 and 12 passing over those pulleys define curved surface 18 and 20 as the belts 10 and 12 pass over the pulleys 14 and 16, respectively. Thus, the belts, and particularly the curved surface 18 and 20, define a molding zone therebetween, with the minimum gap between them dimensioned to correspond to the desired thickness of the metal strip being cast. As will be appreciated by those skilled in the art, the thickness of the metal strip being cast is determined by the dimensions of the nip between belts 10 and 12 passing over pulleys 14 and 16 along a line through the axis of pulleys 14 and 16 perpendicular to belts 10 and 12.

[0029] While it is not illustrated in Fig. 1 for purposes of simplicity, it is some times desirable to include, as disclosed in US-A-5564491, an apparatus to rigidly fix the relative positions of pulleys 14 and 16. As described in the foregoing patent, means to fix the relative positions of those pulleys may be a tension member, which is either fixed or adjustable, such as a turn buckle, a pillow block or a hydraulic cylinder as disclosed in US-A-5564491. As described in that patent, the means controlling the spacing between entry pulleys 14 and 16 serves to effect a compressive force on the substantially frozen cast strip at the nip between pulleys 14 and 16 to cause elongation thereof so that the cast strip is in compression in the direction of travel after exiting from the nip to minimize cracking of the cast strip.

[0030] Molten metal to be cast is supplied to the molding zone through suitable metal supply means 22 such as a tundish, substantially corresponding in width to the width of the narrower of the belts 10 and 12. As will be appreciated by those skilled in the art, the tundish is a conventional means of supplying molten metal to strip casters.

[0031] Thus, the molten metal flows into the molding zone defined between the curved surface 18 and 20 of belts 10 and 12, respectively, passing substantially horizontally from the tundish to fill the molding zone between the curved surface 18 and 20. As is described in US-A-5515908, the molten metal begins to solidify and is substantially solidified by the point at which the cast strip reaches the nip of pulleys 14 and 16. As is described in US-A-5515908, the molten metal flows substantially horizontally to provide a flowing stream of molten metal to the molding zone where it is in contact with the curved surface 18 and 20 of belts 10 and 12, respec-

tively, as those belts pass around pulleys 14 and 16. That serves to limit distortion of the belts and maintain better thermal contact between the molten metal and each of the belts as well as improving the quality of the top and bottom surfaces of the cast strip.

[0032] In accordance with the concepts of the invention, the casting apparatus is equipped with a pair of electromagnetic edge dams 24 and 26 positioned immediately adjacent the molding zone defined by the curved surface 18 and 20 on each lateral edge of the belts 10 and 12 as illustrated in Fig. 2. Electrical current to the electromagnetic edge dam is supplied by means of electrical conduits 26 as illustrated in Fig. 1.

[0033] The details of the electromagnetic edge dam apparatus are illustrated in detail in Fig. 3 of the drawing representing a sectional view of the edge dam apparatus 24 illustrated in Fig. 2. In the preferred practice of the invention, the electromagnetic edge containment apparatus employed in the practice of the invention is a magnet type of confinement system as described above and includes a generally C-shaped magnetic member 30 as illustrated in Fig. 3. The magnetic member 30 thus includes a core 32 having an upper arm or pole 34 and a lower arm or pole 36 extending therefrom to define a generally C-shaped cross-section. As illustrated in Fig. 3, an induction coil winding 38, composed of a plurality of turns 40, is wound around the core 32 of the magnetic member 30.

[0034] As is also disclosed in Fig. 3, the upper arm 34 terminates in a pole face 42 whereas the lower arm 36 terminates in a pole face 44 positioned adjacent belts 10 and 12, respectively with the molten metal 46 being maintained therebetween. The pole faces 42 and 44 thus define the surface from which the magnetic lines of force generated by the magnetic element 30 with its induction coil 38 pass from one of the pole faces 42 to the other pole face 44 as illustrated by the magnetic lines of force 48 as shown in Fig. 3. It is not important in the practice of the present invention whether the magnetic lines of force pass from the upper pole face 42 to the lower pole face 44 or vice versa.

[0035] In one practice of the invention, the magnetic member 30 is formed from a ferromagnetic material such as silicon steel, and can be formed from a solid piece of such ferromagnetic material. Alternatively, the magnetic member 30 can be formed from a series of laminated elements machined and secured together using mechanical means, an adhesive or like means to yield the desired configuration. In many instances, the use of such laminates is preferable since such laminates serve to more uniformly distribute the flux lines in the magnetic member and reduce loss due to saturation of the magnetic member. In addition, for a magnetic member made of laminated ferromagnetic material, the electrical energy dissipated as heat is also more evenly distributed and more easily removed, particularly where the adhesive employed to hold the laminate elements together has good thermal conductivity.

[0036] Surrounding the magnetic member 30 is an outer shield 50, which is preferably made of a material, and most preferably a metal, having structural rigidity and extremely high electrical and thermal conductivities. Particularly good results are obtained when the outer shield 50 is fabricated of copper, although other metals such as silver and gold can likewise be used. The high electrical conductivity of the outer shield 50 aids in containing the magnetic lines of force within the magnetic member while the good thermal conductivity aids in the dissipation of heat from the overall apparatus. As will be appreciated by those skilled in the art, the outer shield 50 may be provided with cooling channels therein or brazed tubes thereon to distribute cooling fluid through or at the surface of the outer shield to further aid in the removal of heat generated by the electromagnetic field. For example, an inlet 52 can be employed to pass a cooling fluid through the outer shield for removal from a discharge port 54 as illustrated in Fig. 3 when additional cooling capability is required. Thus, the cooling fluid can be passed through a conduit within the outer shield to remove heat generated by the electromagnetic field.

[0037] The electromagnetic edge dam employed in the practice of the present invention also includes an inner shield 56 dimensioned to fit within the C-shaped configuration of the magnetic member 30 as illustrated in Fig. 3. The inner shield 56 likewise serves to contain the magnetic lines of force generated by the coil 38 of the magnetic member 30, insuring that the magnetic lines of force are maintained within the magnetic member 30. In addition, it is also possible, and some times desirable, to include within the inner shield conduit means for the passage of a cooling fluid therethrough where it is desired to increase the ability to dissipate heat from the magnet. It is also possible to do away with the inner shield; especially so when using grain oriented silicon steel laminates where the field lines prefer to flow within the laminates.

[0038] The relationship between the electromagnetic edge containment apparatus and the belts is also illustrated in Fig. 3 of the drawings. As can be seen there, the upper belt 10 and the lower belt 12 define a molding zone with the molten or liquid metal 46 being positioned therebetween. The lateral edges of the belts 10 and 12 are positioned adjacent to the inner shield so that the magnetic lines of force passing out of one of the upper pole face 42 and the lower pole face 44 pass through the upper and lower belts 10 and 12 and the liquid metal 46. The magnetic field lines thus establish the containment force preventing the liquid metal from spilling over the edges of the upper and lower belts 10 and 12, respectively.

[0039] As indicated above, the belts employed in the practice of the present invention have ferromagnetic characteristics, causing them to attract flux lines to themselves and thereby minimizing field losses between the poles 42 and 44. That in turn maximizes the field available at the space between the belts. The mag-

netic nature of the belts also minimizes the gradient of the magnetic field reducing the magnetic pressure that can be generated. In accordance with the preferred practice of the invention, it is important to embody a high gradient magnetic field on the belt to produce sufficient magnetic pressure after allowing for the reduction of the field gradient due to the magnetic nature of the belts. To produce that desired high magnetic field gradient at the belts, it is preferred to orient the poles at an angle relative to the belts. The lines of force illustrated in Fig. 3 illustrate the effects of the belts in modifying the field line distribution in the vicinity of the molding gap.

[0040] The exact placement of the lateral edges of the belts relative to the electromagnetic dam is not critical to the practice of the invention, and can be varied. It is generally sufficient that the lateral edges of belts 10 and 12 be positioned such that most, if not all, the magnetic lines of force pass substantially immediately through belts 10 and 12. That ensures that sufficient containment forces will be generated to prevent the liquid metal from spilling over the lateral edges of the belt adjacent to the electromagnetic containment apparatus.

[0041] The configuration of one embodiment of the magnetic member 30 is shown in Fig. 4 of the drawing which includes the base portion or core 32 about which the coil is wound, the coil winding having been omitted from Fig. 4 for purposes of simplicity. The magnetic element 30 also includes upper and lower arms or poles 34 and 36, respectively, which are formed integrally with the core 32, whether the magnetic element 30 is a solid piece of metal or a laminated structure as described above. Formed in the leading edges of the arms or poles 34 and 36 are the pole faces 42 and 44.

[0042] The magnetic member 30 is preferably formed from a ferromagnetic material such as silicon steel. The magnetic member 30 can be formed from layers that are bonded together, layers that are mechanically held together, or from a solid core. In some instances, the use of laminates is preferred because there is a more uniform distribution of flux lines in the magnetic member and less loss due to saturation. If the laminate has good thermal conductivity, the heat is more evenly distributed and easier to remove. In other instances, it is better to mechanically hold the layers together.

[0043] As shown in Fig. 4, the pole faces 42 and 44 have a curvature corresponding substantially to the curvature of the belts 10 and 12 adjacent to the electromagnetic containment apparatus. It has been found that best results are generally obtained when the pole faces have an arcuate or curved configuration so as to maintain a constant distance between the belts 10 and 12 as they pass around their respective pulleys and the pole faces themselves.

[0044] As shown in Fig. 4, the pole faces of the magnetic member 30 have a substantially smooth surface corresponding to the curvature of the belts passing around the respective entry pulleys. As will be appreciated by those skilled in the art, however, it is also pos-

sible, and sometimes desirable from the standpoint of economies in manufacture, to approximate a smooth curved surface with a surface formed of a series of stepped elements. A magnetic member utilizing such stepped pole faces is illustrated in Fig. 7 of the drawing.

[0045] As shown in that figure, the pole faces 42 and 44 are formed of a series of discrete substantially rectangular faces 45 which approximate the smooth curved pole faces as illustrated in Fig. 4. As will be appreciated by those skilled in the art, the use of such stepped pole faces represents a distinct advantage in economies in manufacture of the magnetic member 30. As shown in that figure, the core 32 may be equipped with a cooling conduit 47 extending therethrough; in that way, a cooling fluid can be passed through the cooling conduit 47 to aid in the dissipation of heat generated by the electromagnetic field.

[0046] In the preferred embodiment as shown in Fig. 3, the positioning of the lateral edges of the belts 10 and 12 relative to the pole faces 42 and 44 can conveniently be controlled by utilizing pulleys 14 and 16 having a belt engaging surface 58 which is axially of diminished width as compared to the remainder of the pulley 14. In that way, the belts 10 and 12 can be positioned in closer proximity to the electromagnetic containment apparatus by dimensioning the belts to extend beyond the belt supporting surface 58 of the pulleys 14 and 16 as illustrated in Fig. 3. In an alternative embodiment, it is sometimes preferable as shown in Fig. 5 to provide an annular copper ring 60 between the pulleys 14 and 16 and the electromagnetic containment apparatus. That copper ring modifies the magnetic field in the vicinity of the molding zone to prevent the magnetic lines of force from entering the rolls 14 and 16.

[0047] In accordance with another variation of the present invention as shown in Fig. 6, it is sometimes desirable to configure the belts 10 and 12 with lips 62 and 64, respectively. Those lips can simply be formed by increasing the thickness of the lateral edges 66 and 68 of belts 10 and 12, respectively, so as to provide a lip area of increased belt thickness at the lateral edges of the belts. As shown in Fig. 6, providing belts with increased thickness toward lateral edges improves the magnetic field strength as well as the field distribution region between the belts 10 and 12, thereby maximizing the containment forces near the molding zone.

[0048] In designing the electromagnetic containment apparatus employed in the practice of this invention, a number of different techniques can be employed in dissipating heat generated by the electromagnetic field. In the embodiment illustrated in Fig. 3, the core windings 40 about the core 32 can be, as illustrated in Fig. 3, made of solid metal such as copper wire. Alternatively, as shown in Fig. 8, the windings 40 may be formed of an annular conductor having a central opening 41 extending therethrough. Thus, cooled water can be passed through the central opening of the windings 40 to aid in the dissipation of heat generated by the elec-

tromagnetic field.

[0049] Figs. 9, 10, 11, and 12 illustrate different pole face angles and orientations in accordance with the present invention. Fig. 9 illustrates a cross section of a magnetic member 30 wherein the pole faces 42 and 44 have a positive angle relative to the horizontal. The positive angle means that the inter-pole-face gap 43 increases as the distance from the core increases, i.e. the inter-pole-face gap 43 is greater at the outside edge of each pole face than at the inside edge of each pole face. The angle of the pole faces should be chosen so as to create a strong magnetic field and a steep magnetic field gradient across the pole face. A pole face can have any desired angle such as 5, 10, 15, 20, 25, or 30 degrees relative to the horizontal. It will be appreciated by those skilled in the art that as the inter-pole-face gap 43 increases, the strength of the field across the gap decreases. As a result, the containment forces created by the magnetic member shown in Fig. 9 are stronger at the inside edge of each pole face than at the outside edge of each pole face.

[0050] Fig. 10 illustrates a cross section of a magnetic member 30 wherein the pole faces 42 and 44 have no angle relative to the horizontal. The zero angle means that the inter-pole-face gap 43 is the same at the inside edge of each pole face and the outside edge of each pole face. As a result, the magnetic field created by the magnetic member shown in Fig. 10 is relatively uniform across each pole face.

[0051] Fig. 11 illustrates a cross section of a magnetic member 30 wherein the pole faces 42 and 44 have a negative angle relative to the horizontal. The negative angle means that the inter-pole-face gap 43 is less at the outside edge of each pole than at the inside edge of each pole face. As a result, the containment forces created by the magnetic member shown in Fig. 11 are stronger at the outside edge of each pole face than at the inside edge of each pole face.

[0052] Fig. 12 illustrates a cross section of a magnetic member 30 having a reverse angle configuration. The pole faces 42 and 44 are parallel in part and not parallel in part. The inside region of the pole faces 42 and 44 have a negative angle relative to the horizontal. The magnetic member shown in Fig. 12 and the magnetic member shown in Fig. 11 both result in a narrower strip than the magnetic member shown in Fig. 9. When the magnetic member shown in Fig. 9 is used to contain molten metal, the magnetic forces are at a maximum at the very edge of the belt. When the magnetic member shown in Figs. 11 or 12 are used to contain molten metal, the magnetic forces are at a maximum farther into the belt. As a result, the strip width would be lower when using magnets with a design as shown in Fig. 11 and 12 as compared to the designs shown in Fig. 9 and 10.

[0053] Fig. 13 illustrates an exemplary embodiment of the present invention wherein a mechanical edge dam 55 is used in conjunction with an electromagnetic edge dam having a magnetic member 30. The magnetic

member 30 is preceded by the mechanical edge dam 55. It is possible to replace the mechanical edge dam 55 completely. However, as mentioned above, the electromagnetic edge dam should curve to mirror the curved surface of the belts. When the pole faces 42 and 44 spread apart to mirror the curved surface of the belts, the inter-pole-face gap 43 increases and the strength of the magnetic field across the gap decreases. For this reason, the mechanical edge dam 55 is used in conjunction with the extended magnetic member 30 at the point where the magnetic field is the weakest. The mechanical edge dam 55 shown should ideally have a ceramic-less surface and comprise magnetic material to reduce the reluctance at the mouth of the molding zone. A ceramic material may also be used to make mechanical edge dam 55 if process conditions preclude the use of a metallic material.

[0054] Fig. 14 illustrates a solid structure 70 from which a magnetic member 30 in accordance with the present invention can be formed. As mentioned above, the magnetic member 30 can be formed from layers that are bonded together, layers that are bolted together, or a solid core that is cut to form the inter-pole-face gap. It will be appreciated by those skilled in the art that currents can be induced in the individual laminates and that the currents can lead to the generation of heat. For this reason, it may be advantageous to cut the magnetic member from a solid core. If, for example, a silicon steel sheet is wound into a racetrack-like shape 70 that corresponds to the external shape of the magnet 30, the pole faces 42 and 44 can be formed from the block 70 by removing a piece of metal 71 from the region where the inter-pole-face gap should be located, see the open region or gap in figure 15. This method of manufacturing the magnetic member 30 is usually less expensive than other methods of manufacturing. More importantly, when the silicon steel is very thin (approximately 1 mil thick) this method minimizes the heat induced in a stacked design and facilitate the cooling of the magnetic member 30.

[0055] Fig. 15 and 16 illustrate an exemplary embodiment of the present invention wherein a magnetic member 30 has a split core design. It will be appreciated by those skilled in the art that as the containment system is used, insulation around the induction coil 40 begins to deteriorate and has to be replaced. In conventional systems, the coil 40 is replaced by dismounting the magnet 30 from the belt caster, cutting the coil 40, removing the coil 40, and winding a new coil (not shown) around the magnet 30. In addition, if the magnet 30 is damaged by one of the endless belts, it is necessary to replace the entire magnet 30.

[0056] According to the embodiment shown in Fig. 15, the magnetic member 30 has a split core design wherein the magnetic member 30 has an upper region 81 and/or a lower region 82 that is removably attached to the central region 80 to form the C-shaped magnetic member 30. As a result, it is significantly easier to replace

the induction coil 40. If the upper region 81 or the bottom region 82 is removed from the central region 80, it is possible to remove the induction coil 81 and insert a new pre-wound coil (not shown). Furthermore, if the upper region 81 or bottom region 82 is damaged by one of the belts, it is not necessary to replace the entire magnet 30. The top and bottom regions 81 and 82 can be replaced by connecting a new top or bottom region (not shown) to the central region 80.

[0057] In the embodiment shown in Fig. 16, the magnetic member 30 has a split core design wherein the magnetic member 30 is formed of laminates and has an upper region 83 and/or a lower region 84 that attach to form a C-shaped magnetic member 30. It is easier to replace the induction coil in this design; the magnetic member is first disassembled, and a new pre-wound coil inserted before the magnetic member is reassembled. As stated above, if the upper region 83 or bottom region 84 is damaged by one of the belts, it will not be necessary to replace the entire magnet 30. The damaged half of the magnetic member can be replaced by connecting a new top 83 or bottom region 84. The upper 83 and lower 84 regions are mechanically held together to maintain the proper orientation. For example, bolts 85, 86 are used to hold the laminates of each half together. Thereafter, plates 87 on each end attach to the two bolts 85, 86 and keep the two regions together. It is preferred that the bolts and plates be made of non-magnetic material, preferably stainless steel.

[0058] It will be understood that various changes and modifications can be made in the details of construction and use without departing from the scope of the invention, as defined in the following claims.

Claims

1. An apparatus for belt casting molten metal, the apparatus including a casting belt (10, 12) and an edge containment device:

characterised in that the edge-containment device comprises:

a magnetic member (30) having a first pole (34), a first pole face (42), a second pole (36), and a second pole face (44); and
a coil (38) that generates magnetic lines of force (48) in the magnetic member when current is supplied to the coil, the magnetic lines of force (48) passing from the first pole face (42) through an edge of the casting belt (10, 12) to the second pole face (44).

2. An apparatus according to claim 1, having an outer shield (50) surrounding the magnetic member (30) so as to contain the magnetic lines of force (48) within the magnetic member.

3. An apparatus according to claim 1 or 2, having an inner shield (56) positioned within the magnetic member (30) so as to contain the magnetic lines (48) of force within the magnetic member.
4. An apparatus according to any of claims 1 to 3, wherein the magnetic member (30) includes a cooling passage (52, 54; 47) for cooling the magnetic member.
5. An apparatus according to any of claims 1 to 4, wherein the first pole face (42) is not parallel to the second pole face (44).
6. An apparatus according to any of claims 1 to 4, wherein the first pole face (42) is parallel to the second pole face (44).
7. An apparatus according to any of claims 1 to 4, wherein the first pole face (42) and the second pole face (44) have a first opposed surface parallel to each other and a second opposed surface not parallel to each other.
8. An apparatus according to claim 5, wherein the distance (43) between the first pole face (42) and the second pole face (44) is greater at an outside edge of each pole face than at an inside edge of each pole face.
9. An apparatus according to claim 5, wherein the distance (43) between the first pole face (42) and the second pole face (44) is greater at the inside edge of each pole face than at an outside edge of each pole face.
10. An apparatus according to any of claims 1 to 9, wherein the magnetic member (30) is formed of a ferromagnetic material from a stack of bonded elements.
11. An apparatus according to any of claims 1 to 9, wherein the magnetic member (30) is formed of a ferromagnetic material from a plurality of sections (83, 84) that are mechanically held (85, 86, 87) together.
12. An apparatus according to any of claims 1 to 9, wherein the magnetic member (30) is formed from a solid core of ferromagnetic material.
13. An apparatus according to any of claims 1 to 12, wherein the first pole (34) and/or the second pole (36) is removably attached to the magnetic member (30) so as to facilitate replacement of the coil.
14. An apparatus according to any of claims 1 to 13, wherein the pole faces (42, 44) are not smooth.
15. An apparatus according to any preceding claim, having two belts (10, 12) that mold the molten metal (46) therebetween.
16. An apparatus according to claim 15, wherein, in use, the magnetic lines of force (48) contain the molten metal (46) in an edge region between the two belts (10, 12).
17. An apparatus according to claim 15 or 16, wherein the two belts (10, 12) have a curved region and a linear region.
18. An apparatus according to claim 17, including a pulley (14, 16) defining the curved region and a shield (60) positioned between the magnetic member (30) and the pulley to shield the pulley from the magnetic lines of force.
19. An apparatus according to claim 17 or 18, wherein the magnetic lines of force (48) contain the molten metal (46) in a region between the curved region of the two belts (10, 12).
20. An apparatus according to any of claims 17 to 19, wherein the belts (10, 12) have a curved region (18, 20) in a gap between the first pole face (42) and the second pole face (44).
21. An apparatus according to claim 20, wherein the first pole face (42) and the second pole face (44) become farther apart along the curved region.
22. An apparatus according to claim 20 or 21, wherein a mechanical edge dam (55) is located in a region along the belts where a gap between the first pole face and the second pole face is at a maximum.
23. An apparatus according to any of claims 15 to 22, wherein each belt (10, 12) has an edge that passes within a region between the first pole face (42) and the second pole face (44).
24. An apparatus according to any of claims 15 to 23, wherein the belts have a thickness (62, 64) which increases towards an outer edge (66, 68) thereof.
25. An apparatus for strip casting of molten metal comprising:
 - (a) a pair of endless metal belts (10, 12) positioned adjacent each to the other to define a molding zone therebetween, with each belt passing over an entry pulley (14, 16) to define a curved surface (18, 20) adapted to receive molten metal (46) thereon,
 - (b) means (22) for supplying molten metal to the curved surfaces (18, 20) of each of the belts

(10, 12) to supply molten metal thereto, and
(c) a respective edge containment device positioned on each side of the molding zone to contain the molten metal (46) in the molding zone in contact with the curved surfaces,

characterised in that

each edge containment device includes a magnetic member (30) having an upper pole (34) and a lower pole (36), an induction coil (38) wound about a portion (32) of the magnetic member to generate magnetic lines of force (48) passing from one of the upper and lower poles to the other, with the magnetic member being positioned such that the upper and lower poles direct magnetic lines of force through the edges of each of the belts (10, 12) to establish containment forces at the edges of the belts to contain the molten metal therebetween.

26. An apparatus according to claim 25, including an outer shield (50) positioned about the magnetic member (30) to contain the magnetic lines of force (48) within the magnetic member.
27. An apparatus according to claim 25 or 26, including an inner shield (56) positioned within the magnetic member to contain the magnetic lines of force (48) to the magnetic member.
28. An apparatus according to any of claims 25 to 27, wherein the magnetic member (30) has a generally C-shaped configuration, including a core portion (32) and parallel poles (34, 36) integral with and extending therefrom.
29. An apparatus according to claim 28, wherein the poles (34, 36) of the magnetic member (30) terminate in pole faces (42, 44) positioned adjacent the endless belts whereby the magnetic lines of force pass from one of the pole faces through the belts and to the other of the pole face to thereby establish containment forces for molten metal maintained in the molding zone between the endless belts.
30. An apparatus according to claim 29, wherein the pole faces (42, 44) are positioned adjacent to and at an angle with respect to the endless belts to ensure a gradient of magnetic flux at the lateral edges of the endless belts.
31. An apparatus according to any of claims 25 to 30, wherein the induction coil (38) is wound about the core of the magnetic member.
32. An apparatus according to any of claims 25 to 31, including shield means (60) positioned between the magnetic member and the entry pulleys to shield the entry pulleys from the magnetic lines of force.

33. An apparatus according to any of claims 25 to 32, wherein the belts (10, 12) each have a lip (62, 64) formed by gradually increasing the thickness of the belts at their lateral edges (66, 68) adjacent the edge containment apparatus, said lips serving to modify the strength and distribution of the magnetic lines of force to confine liquid metal between the belts.

34. An apparatus according to any of claims 25 to 33, wherein the magnetic member (30) is formed of a ferromagnetic material from a series of laminated elements secured together.

35. An apparatus according to any of claims 25 to 33, wherein the magnetic member (30) is formed of a ferromagnetic material from a stack of bonded elements.

36. An apparatus according to any of claims 25 to 33, wherein the magnetic member (30) is formed of a ferromagnetic material from a plurality of sections (83, 84) that are mechanically held (85, 86, 87) together.

37. An apparatus according to any of claims 25 to 36, wherein the magnetic member (30) is formed from a solid core of ferromagnetic material.

38. An apparatus according to any of claims 25 to 37, wherein the pole faces (42, 44) are parallel.

39. An apparatus according to any of claims 25 to 37, wherein the pole faces (42, 44) are not parallel.

40. An apparatus according to any of claims 25 to 37, wherein the pole faces (42, 44) have a first opposed surface parallel to each other and a second opposed surface not parallel to each other.

41. An apparatus according to any of claims 25 to 37, wherein the distance between the pole faces (42, 44) is greater at the outside edge of each pole face than at the inside edge of each pole face.

42. An apparatus according to any of claims 25 to 37, wherein the distance between the pole faces (42, 44) is greater at the inside edge of each pole face than at the outside edge of each pole face.

43. An apparatus according to any of claims 25 to 42, including a mechanical edge dam (55) that is positioned in a region along the belts where the magnetic lines of force are the weakest.

44. An apparatus according to any of claims 25 to 43, wherein either the upper (83) or the lower (84) half of the magnetic member is removable so as to fa-

cilitate replacement of the induction coil (32).

45. An apparatus according to any of claims 25 to 44, wherein the pole faces (42, 44) are not smooth.

46. A method of containing molten metal (46) between two belts (10, 12) in a strip casting system, said method comprising the steps of:

delivering molten metal to a molding zone at an upstream end of the belts;
solidifying the molten metal into a strip between the belts and conveying the strip between the belts in a downstream direction; and
containing molten metal at lateral edges of the belts in the molding zone;

characterised by

containing of the molten metal is by winding a coil (38) around a magnetic member (30) having an upper pole face (42) and a lower pole face (44);
positioning the magnetic member so that the upper pole face and the lower pole face overlay a lateral edge of each belt (10, 12); and
providing electrical current to the coil to generate magnetic lines of force which contain the molten metal.

Patentansprüche

1. Vorrichtung zum Bandgießen von geschmolzenem Metall, wobei die Vorrichtung ein Gießband (10, 12) und eine Kanteneinschließungsvorrichtung aufweist;

dadurch gekennzeichnet, dass die Kanteneinschließungsvorrichtung folgendes umfasst:

ein Magnelement (30) mit einem ersten Pol (34), einer ersten Polfläche (42), einem zweiten Pol (36) und einer zweiten Polfläche (44); und einer Spule (38), die magnetische Kraftlinien (48) in dem Magnelement erzeugt, wenn der Spule Strom zugeführt wird, wobei die magnetischen Kraftlinien (48) von der ersten Polfläche (42) durch eine Kante des Gießbands (10, 12) zu der zweiten Polfläche (44) verlaufen.

2. Vorrichtung nach Anspruch 1, mit einer äußeren Abschirmung (50), welche das Magnelement (30) umgibt, so dass die magnetischen Kraftlinien (48) in dem Magnelement eingeschlossen werden.

3. Vorrichtung nach Anspruch 1 oder 2, mit einer inneren Abschirmung (56), die in dem Magnelement (30) positioniert ist, so dass die magnetischen Kraftlinien (48) in dem Magnelement eingeschlossen werden.

4. Vorrichtung nach einem der Ansprüche 1 bis 3, wobei das Magnelement (30) einen Kühldurchgang (52, 54; 47) zum Kühlen des Magnelements aufweist.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, wobei die erste Polfläche (42) nicht parallel zu der zweiten Polfläche (44) ist.

6. Vorrichtung nach einem der Ansprüche 1 bis 4, wobei die erste Polfläche (42) parallel zu der zweiten Polfläche (44) ist.

7. Vorrichtung nach einem der Ansprüche 1 bis 4, wobei die erste Polfläche (42) und die zweite Polfläche (44) eine erste entgegengesetzte Oberfläche aufweisen, die zueinander parallel sind, und eine zweite entgegengesetzte Oberfläche, die zueinander nicht parallel sind.

8. Vorrichtung nach Anspruch 5, wobei der Abstand (43) zwischen der ersten Polfläche (42) und der zweiten Polfläche (44) an einer Außenkante jeder Polfläche größer ist als an einer Innenkante jeder Polfläche.

9. Vorrichtung nach Anspruch 5, wobei der Abstand (43) zwischen der ersten Polfläche (42) und der zweiten Polfläche (44) an der Innenkante jeder Polfläche größer ist als an einer Außenkante jeder Polfläche.

10. Vorrichtung nach einem der Ansprüche 1 bis 9, wobei das Magnelement (30) aus einem ferromagnetischen Material aus einem Stapel verbundener Elemente gebildet wird.

11. Vorrichtung nach einem der Ansprüche 1 bis 9, wobei das Magnelement (30) aus einem ferromagnetischen Material aus einer Mehrzahl von Abschnitten (83, 84) gebildet wird, die mechanisch zusammengehalten (85, 86, 87) werden.

12. Vorrichtung nach einem der Ansprüche 1 bis 9, wobei das Magnelement (30) aus einem festen Kern aus einem ferromagnetischen Material gebildet wird.

13. Vorrichtung nach einem der Ansprüche 1 bis 12, wobei der erste Pol (34) und/oder der zweite Pol (36) entfernbar an dem Magnelement (30) angebracht ist, um den Austausch der Spule zu erleichtern.

14. Vorrichtung nach einem der Ansprüche 1 bis 13, wobei die Polflächen (42, 44) nicht glatt sind.

15. Vorrichtung nach einem der vorstehenden Ansprü-

che, mit zwei Bändern (10, 12), die das geschmolzene Metall (46) dazwischen formen.

16. Vorrichtung nach Anspruch 15, wobei die magnetischen Kraftlinien (48) im Einsatz das geschmolzene Metall (46) in einem Kantenbereich zwischen den beiden Bändern (10, 12) einschließen. 5
17. Vorrichtung nach Anspruch 15 oder 16, wobei die beiden Bänder (10, 12) einen gekrümmten Bereich und einen geradlinigen Bereich aufweisen. 10
18. Vorrichtung nach Anspruch 17, mit einer Riemenscheibe (14, 16), die den gekrümmten Bereich definiert, und mit einer zwischen dem Magnetelement (30) und der Riemenscheibe positionierten Abschirmung (60) zur Abschirmung der Riemenscheibe vor den magnetischen Kraftlinien. 15
19. Vorrichtung nach Anspruch 17 oder 18, wobei die magnetischen Kraftlinien (48) das geschmolzene Metall (46) in einem Bereich zwischen dem gekrümmten Bereich der beiden Bänder (10, 12) einschließen. 20
20. Vorrichtung nach einem der Ansprüche 17 bis 19, wobei die Bänder (10, 12) einen gekrümmten Bereich (18, 20) in einem Zwischenraum zwischen der ersten Polfläche (42) und der zweiten Polfläche (44) aufweisen. 25
21. Vorrichtung nach Anspruch 20, wobei die erste Polfläche (42) und die zweite Polfläche (44) entlang des gekrümmten Bereichs einen zunehmenden Zwischenabstand aufweisen. 30
22. Vorrichtung nach Anspruch 20 oder 21, wobei ein mechanischer Kantendamm (55) in einem Bereich entlang der Bänder angeordnet ist, in dem ein Zwischenraum zwischen der ersten Polfläche und der zweiten Polfläche maximal ist. 35
23. Vorrichtung nach einem der Ansprüche 15 bis 22, wobei jedes Band (10, 12) eine Kante aufweist, die in einem Bereich zwischen der ersten Polfläche (42) und der zweiten Polfläche (44) verläuft. 40
24. Vorrichtung nach einem der Ansprüche 15 bis 23, wobei die Bänder eine Dicke (62, 64) aufweisen, die in Richtung einer Außenkante (66, 68) der Bänder zunimmt. 45
25. Vorrichtung zum Stranggießen von geschmolzenem Metall, wobei die Vorrichtung folgendes umfasst: 50
 - (a) ein Paar von Endlosbändern aus Metall (10, 12), die angrenzend aneinander positioniert

sind, so dass eine Formzone dazwischen definiert wird, wobei jedes Band über eine Eintritts-Riemenscheibe (14, 16) verläuft, so dass eine gekrümmte Oberfläche (18, 20) definiert wird, die darauf geschmolzenes Metall (46) aufnehmen kann;

(b) eine Einrichtung (22) für die Zufuhr von geschmolzenem Metall zu den gekrümmten Oberflächen (18, 20) jedes der Bänder (10, 12), um diesen geschmolzenes Metall zuzuführen; und

(c) eine entsprechende Kanteneinschlussvorrichtung, die an jeder Seite der Formzone positioniert ist, um das geschmolzene Metall (46) in der Formzone in Kontakt mit den gekrümmten Oberflächen zu halten; **dadurch gekennzeichnet, dass:**

jede Kanteneinschlussvorrichtung eine Magnetkammer (30) mit einem oberen Pol (34) und einem unteren Pol (36) aufweist, wobei eine Induktionsspule (38) um ein Teilstück (32) des Magnetelements gewickelt ist, um magnetische Kraftlinien (48) zu erzeugen, die von einem der oberen und unteren Pole zu dem anderen Pol verlaufen, wobei das Magnetelement derart positioniert ist, dass die oberen und unteren Pole die magnetischen Kraftlinien durch die Kanten jedes Bands (10, 12) drücken, so dass an den Kanten der Bänder Einschlusskräfte erzeugt werden, so dass das geschmolzene Metall dazwischen gehalten wird.

26. Vorrichtung nach Anspruch 25, mit einer äußeren Abschirmung (50), die um das Magnetelement (30) herum positioniert ist, so dass die magnetischen Kraftlinien (48) in dem Magnetelement eingeschlossen werden.
27. Vorrichtung nach Anspruch 25 oder 26, mit einer in dem Magnetelement positionierten inneren Abschirmung (56) zum Einschließen der magnetischen Kraftlinien (48) in dem Magnetelement.
28. Vorrichtung nach einem der Ansprüche 25 bis 27, wobei das Magnetelement (30) eine allgemein C-förmige Konfiguration aufweist, mit einem Kernteilstück (32) und parallelen, integralen und sich von dem Teilstück erstreckenden Polen (34, 36).
29. Vorrichtung nach Anspruch 28, wobei die Pole (34, 36) des Magnetelements (30) in Polflächen (42, 44) enden, die angrenzend an die Endlosbänder positioniert sind, wodurch die magnetischen Kraftlinien von einer der Polflächen durch die Bänder und zu der anderen Polfläche verlaufen, so dass Ein-

schlusskräfte für das geschmolzene Metall erzeugt werden, das in der Formzone zwischen den Endlosbändern gehalten wird.

30. Vorrichtung nach Anspruch 29, wobei die Polflächen (42, 44) angrenzend an die Endlosbänder und in einem Winkel zu diesen positioniert sind, um einen Verlauf des Magnetflusses an den lateralen Kanten der Endlosbänder zu gewährleisten. 5
31. Vorrichtung nach einem der Ansprüche 25 bis 30, wobei die Induktionsspule (38) um den Kern des Magnetelements gewickelt ist. 10
32. Vorrichtung nach einem der Ansprüche 25 bis 31, mit einer Abschirmungseinrichtung (60), die zwischen dem Magnetelement und den Eintritts-Riemenscheiben positioniert ist, um die Eintritts-Riemenscheiben vor magnetischen Kraftlinien abzusichern. 15
33. Vorrichtung nach einem der Ansprüche 25 bis 32, wobei die Bänder (10, 12) jeweils eine Lippe (62, 64) aufweisen, die durch die allmählich zunehmende Dicke der Bänder an ihren lateralen Kanten (66, 68) angrenzend an die Kanteneinschlussvorrichtung gebildet werden, wobei die genannten Lippen dazu dienen, die Stärke und die Verteilung der magnetischen Kraftlinien zum Einschließen von flüssigem Metall zwischen den Bändern zu modifizieren. 20
34. Vorrichtung nach einem der Ansprüche 25 bis 33, wobei das Magnetelement (30) aus einem ferromagnetischen Material aus einer Reihe aneinander befestigter, laminierter Elemente gebildet wird. 25
35. Vorrichtung nach einem der Ansprüche 25 bis 33, wobei das Magnetelement (30) aus einem ferromagnetischen Material aus einem Stapel verbundener Elemente gebildet wird. 30
36. Vorrichtung nach einem der Ansprüche 25 bis 33, wobei das Magnetelement (30) aus einem ferromagnetischen Material aus einer Mehrzahl von Abschnitten (83, 84) gebildet wird, die mechanisch zusammengehalten (85, 86, 87) werden. 35
37. Vorrichtung nach einem der Ansprüche 25 bis 36, wobei das Magnetelement (30) aus einem festen Kern eines ferromagnetischen Materials gebildet wird. 40
38. Vorrichtung nach einem der Ansprüche 25 bis 37, wobei die Polflächen (42, 44) parallel sind. 45
39. Vorrichtung nach einem der Ansprüche 25 bis 37, wobei die Polflächen (42, 44) nicht parallel sind. 50

40. Vorrichtung nach einem der Ansprüche 25 bis 37, wobei die Polflächen (42, 44) jeweils eine erste entgegengesetzte Oberfläche aufweisen, die parallel zueinander sind, und eine zweite entgegengesetzte Oberfläche, die nicht zueinander parallel sind.

41. Vorrichtung nach einem der Ansprüche 25 bis 37, wobei der Zwischenabstand zwischen den Polflächen (42, 44) an der Außenkante jeder Polfläche größer ist als an der Innenkante jeder Polfläche.

42. Vorrichtung nach einem der Ansprüche 25 bis 37, wobei der Zwischenabstand zwischen den Polflächen (42, 44) an der Innenkante jeder Polfläche größer ist als an der Außenkante jeder Polfläche.

43. Vorrichtung nach einem der Ansprüche 25 bis 42, mit einem mechanischen Kantendamm (55), der in einem Bereich entlang der Bänder positioniert ist, in dem die magnetischen Kraftlinien am schwächsten sind.

44. Vorrichtung nach einem der Ansprüche 25 bis 43, wobei entweder die obere (83) oder die untere (84) Hälfte des Magnetelements entfernbar ist, um den Austausch der Induktionsspule (32) zu erleichtern.

45. Vorrichtung nach einem der Ansprüche 25 bis 44, wobei die Polflächen (42, 44) nicht glatt sind.

46. Verfahren zum Einschließen von geschmolzenem Metall (46) zwischen zwei Bändern 810, 12) in einem Stranggussystem, wobei das genannte Verfahren die folgenden Schritte umfasst:

Zuführen des geschmolzenen Metalls in eine Formzone an einem oberen Ende der Bänder; Verfestigen des geschmolzenen Metalls in Streifen zwischen den Bändern, und Befördern des Streifens zwischen den Bändern in eine Abwärtsrichtung; und Einschließen von geschmolzenem Metall an lateralen Kanten der Bänder in der Formzone;

dadurch gekennzeichnet, dass:

das Einschließen des geschmolzenen Metalls durch Wickeln einer Spule (38) um ein Magnetelement (30) mit einer oberen Polfläche (42) und einer unteren Polfläche (44) erfolgt; das Magnetelement derart positioniert wird, dass die obere Polfläche und die untere Polfläche eine laterale Kante jedes Bands (10, 12) überlagern; und der Spule elektrischer Strom zugeführt wird, um magnetische Kraftlinien zu erzeugen, welche das geschmolzene Metall einschließen.

Revendications

1. Appareil de coulée en continu de métal en fusion, l'appareil comprenant une courroie de coulée (10, 12) et un dispositif de confinement latéral :

caractérisé en ce que le dispositif de confinement latéral comporte :

un élément magnétique (30) ayant un premier pôle (34), une première face polaire (42), un second pôle (36), et une seconde face polaire (44) ; et

une bobine (38) générant des lignes magnétiques de force (48) dans l'élément magnétique lorsqu'un courant est délivré à la bobine, les lignes magnétiques de force (48) passant depuis la première face polaire (42) à travers un bord de la courroie de coulée (10, 12) jusqu'à la seconde face polaire (44).

2. Appareil selon la revendication 1, possédant un écran extérieur (50) entourant l'élément magnétique (30) de manière à confiner les lignes magnétiques de force (48) à l'intérieur de l'élément magnétique.

3. Appareil selon la revendication 1 ou 2, possédant un écran interne (56) disposé à l'intérieur de l'élément magnétique (30) de manière à confiner les lignes magnétiques (48) de force à l'intérieur de l'élément magnétique.

4. Appareil selon l'une quelconque des revendications 1 à 3, dans lequel l'élément magnétique (30) comprend un passage de refroidissement (52, 54 ; 47) afin de refroidir l'élément magnétique.

5. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel la première face polaire (42) n'est pas parallèle à la seconde face polaire (44).

6. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel la première face polaire (42) est parallèle à la seconde face polaire (44).

7. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel la première face polaire (42) et la seconde face polaire (44) possèdent une première surface opposée parallèle l'une à l'autre et une seconde surface opposée non parallèle à l'autre.

8. Appareil selon la revendication 5, dans lequel la distance (43) entre la première face polaire (42) et la seconde face polaire (44) est plus grande sur un bord extérieur de chaque face polaire que sur un bord intérieur de chaque face polaire.

9. Appareil selon la revendication 5, dans lequel la dis-

tance (43) entre la première face polaire (42) et la seconde face polaire (44) est plus grande sur le bord intérieur de chaque face polaire que sur un bord extérieur de chaque face polaire.

10. Appareil selon l'une quelconque des revendications 1 à 9, dans lequel l'élément magnétique (30) est constitué d'un matériau ferromagnétique à partir d'un empilage d'éléments liés.

11. Appareil selon l'une quelconque des revendications 1 à 9, dans lequel l'élément magnétique (30) est constitué d'un matériau ferromagnétique à partir d'une pluralité de sections (83, 84) qui sont solidarisées mécaniquement (85, 86, 87).

12. Appareil selon l'une quelconque des revendications 1 à 9, dans lequel l'élément magnétique (30) est constitué d'un noyau solide de matériau ferromagnétique.

13. Appareil selon l'une quelconque des revendications 1 à 12, dans lequel le premier pôle (34) et/ou le second pôle (36) est fixé de façon amovible à l'élément amovible (30) de manière à faciliter le remplacement de la bobine.

14. Appareil selon l'une quelconque des revendications 1 à 13, dans lequel les faces polaires (42, 44) ne sont pas lisses.

15. Appareil selon l'une quelconque des revendications précédentes, possédant deux courroies (10, 12) qui moulent entre elles le métal en fusion (46).

16. Appareil selon la revendication 15, dans lequel en utilisation, les lignes magnétiques de force (48) retiennent le métal en fusion (46) dans une région de bord entre les deux courroies (10, 12).

17. Appareil selon la revendication 15 ou 16, dans lequel les deux courroies (10, 12) possèdent une région courbe et une région linéaire.

18. Appareil selon la revendication 17, comprenant une poulie (14, 16) définissant la région courbe et un écran (60) disposé entre l'élément magnétique (30) et la poulie afin de protéger la poulie des lignes magnétiques de force.

19. Appareil selon la revendication 17 ou 18, dans lequel les lignes magnétiques de force (48) retiennent le métal en fusion (46) dans une région entre la région courbe des deux courroies (10, 12).

20. Appareil selon l'une quelconque des revendications 17 à 19, dans lequel les courroies (10, 12) possèdent une région courbe (18, 20) dans un intervalle

entre la première face polaire (42) et la seconde face polaire (44).

21. Appareil selon la revendication 20, dans lequel la première face polaire (42) et la seconde face polaire (44) s'éloignent l'une de l'autre le long de la région courbe. 5
22. Appareil selon la revendication 20 ou 21, dans lequel une digue latérale mécanique (55) est située dans une région le long des courroies où un intervalle entre la première face polaire et la seconde face polaire est maximum. 10
23. Appareil selon l'une quelconque des revendications 15 à 22, dans lequel chaque courroie (10, 12) possède un bord passant à l'intérieur d'une région entre la première face polaire (42) et la seconde face polaire (44). 15
24. Appareil selon l'une quelconque des revendications 15 à 23, dans lequel les courroies ont une épaisseur (62, 64) qui augmente vers un bord extérieur (66, 68) de celles-ci. 20
25. Appareil pour la coulée en bande de métal en fusion comprenant : 25
- a) une paire de courroies métalliques sans fin (10, 12) disposées adjacentes l'une à l'autre pour définir une zone de fusion entre elles, chaque courroie passant au-dessus d'une poulie d'entrée (14, 16) pour définir une surface courbe (18, 20) apte à recevoir du métal en fusion (46), 30
 - b) des moyens (22) pour délivrer du métal en fusion aux surfaces courbes (18, 20) de chacune des courroies (10, 12) pour y délivrer du métal en fusion, et 35
 - c) un dispositif de confinement latéral respectif situé sur chaque côté de la zone de fusion pour contenir le métal en fusion (46) dans la zone de moulage en contact avec les surfaces courbes, 40
- caractérisé en ce que** 45
- chaque dispositif de confinement latéral comprend un élément magnétique (30) possédant un pôle supérieur (34) et un pôle inférieur (36), une bobine d'induction (38) bobinée autour d'une partie (36) de l'élément magnétique pour générer des lignes magnétiques de force (48) passant depuis l'un des pôles supérieur et inférieur à l'autre, l'élément magnétique étant situé de telle sorte que les lignes magnétiques directes de force des pôles supérieur et inférieur à travers les bords de chacune des courroies (10, 12) afin d'établir les forces de confinement sur les bords des courroies afin de retenir entre elles le métal en fusion. 50 55

26. Appareil selon la revendication 25, comprenant un blindage extérieur (50) disposé autour de l'élément magnétique (30) pour retenir les lignes magnétiques de force (48) à l'intérieur de l'élément magnétique.
27. Appareil selon la revendication 25 ou 26, comprenant un blindage interne (56) situé à l'intérieur de l'élément magnétique pour retenir les lignes magnétiques de force (48) dans l'élément magnétique.
28. Appareil selon l'une quelconque des revendications 25 à 27, dans lequel l'élément magnétique (30) possède une configuration généralement en forme de C, comprenant un noyau (32) et des pôles parallèles (34, 36) faisant corps avec et s'étendant depuis celui-ci.
29. Appareil selon la revendication 28, dans lequel les pôles (34, 36) de l'élément magnétique (30) se terminent dans des faces polaires (42, 44) situées adjacentes aux courroies sans fin de telle sorte que les lignes magnétiques de force passent de l'une des faces polaires à travers les courroies et vers l'autre des faces polaires pour ainsi établir des forces de confinement pour le métal fondu maintenu dans la zone de moulage entre les courroies sans fin.
30. Appareil selon la revendication 29, dans lequel les faces polaires (42, 44) sont disposées adjacentes et angulairement par rapport aux courroies sans fin pour assurer un gradient de flux magnétique sur les bords latéraux des courroies sans fin.
31. Appareil selon l'une quelconque des revendications 25 à 30, dans lequel la bobine d'induction (38) est bobinée autour du noyau de l'élément magnétique.
32. Appareil selon l'une quelconque des revendications 25 à 31, comprenant un blindage (60) situé entre l'élément magnétique et les poulies d'entrée pour protéger les poulies d'entrée des lignes magnétiques de force.
33. Appareil selon l'une quelconque des revendications 25 à 32, dans lequel les courroies (10, 12) possèdent chacune une lèvre (62, 64) formée en augmentant progressivement l'épaisseur des courroies sur leurs bords latéraux (66, 68) adjacents à l'appareil de confinement latéral, lesdites lèvres servant à modifier l'intensité et la répartition des lignes magnétiques de force pour confiner le métal liquide entre les courroies.
34. Appareil selon l'une quelconque des revendications 25 à 33, dans lequel l'élément magnétique (30) est constitué d'un matériau ferromagnétique à partir

d'une série d'éléments stratifiés solidarisés.

35. Appareil selon l'une quelconque des revendications 25 à 33, dans lequel l'élément magnétique (30) est constitué d'un matériau ferromagnétique à partir d'un empilage d'éléments liés. 5
36. Appareil selon l'une quelconque des revendications 25 à 33, dans lequel l'élément magnétique (30) est constitué d'un matériau ferromagnétique à partir d'une pluralité de sections (83, 84) solidarisés mécaniquement (85, 86, 87). 10
37. Appareil selon l'une quelconque des revendications 25 à 36, dans lequel l'élément magnétique (30) est constitué d'un noyau solide de matériau ferromagnétique. 15
38. Appareil selon l'une quelconque des revendications 25 à 37, dans lequel les faces polaires (42, 44) sont parallèles. 20
39. Appareil selon l'une quelconque des revendications 25 à 37, dans lequel les faces polaires (42, 44) ne sont pas parallèles. 25
40. Appareil selon l'une quelconque des revendications 25 à 37, dans lequel les faces polaires (42, 44) possèdent une première surface opposée parallèle l'une à l'autre et une seconde surface opposée non parallèle à l'autre. 30
41. Appareil selon l'une quelconque des revendications 25 à 37, dans lequel la distance entre les faces polaires (42, 44) est plus grande sur le bord extérieur de chaque polaire que sur le bord intérieur de chaque face polaire. 35
42. Appareil selon l'une quelconque des revendications 25 à 37, dans lequel la distance entre les faces polaires (42, 44) est plus grande sur le bord intérieur de chaque face polaire que sur le bord extérieur de chaque face polaire. 40
43. Appareil selon l'une quelconque des revendications 25 à 42, comprenant une digue latérale mécanique (55) qui est située dans une région le long des courroies où les lignes magnétiques de force sont les plus faibles. 45
44. Appareil selon l'une quelconque des revendications 25 à 43, dans lequel soit la moitié supérieure (83), soit la moitié inférieure (84) de l'élément magnétique est amovible de manière à faciliter le remplacement de la bobine d'induction (32). 50
45. Appareil selon l'une quelconque des revendications 25 à 44, dans lequel les faces polaires (42, 44) ne

sont pas lisses.

46. Procédé de confinement de métal en fusion (46) entre deux courroies (10, 12) dans un système de coulée en bande, ledit procédé comprenant les étapes consistant à :

délivrer du métal en fusion à une zone de moulage à une extrémité amont des courroies ;
solidifier le métal en fusion en une bande entre les courroies et acheminer la bande entre les courroies vers l'aval ; et
confiner le métal en fusion sur les bords latéraux des courroies dans la zone de moulage ;

caractérisé par

le confinement du métal en fusion par bobinage d'une bobine (38) autour d'un élément magnétique (30) ayant une face polaire supérieure (42) et une face polaire inférieure (44) ;

le positionnement de l'élément magnétique de sorte que la face polaire supérieure et la face polaire inférieure recouvrent un bord latéral de chaque courroie (10, 12) ; et

la délivrance d'un courant électrique à la bobine pour générer des lignes magnétiques de force qui retiennent le métal en fusion.

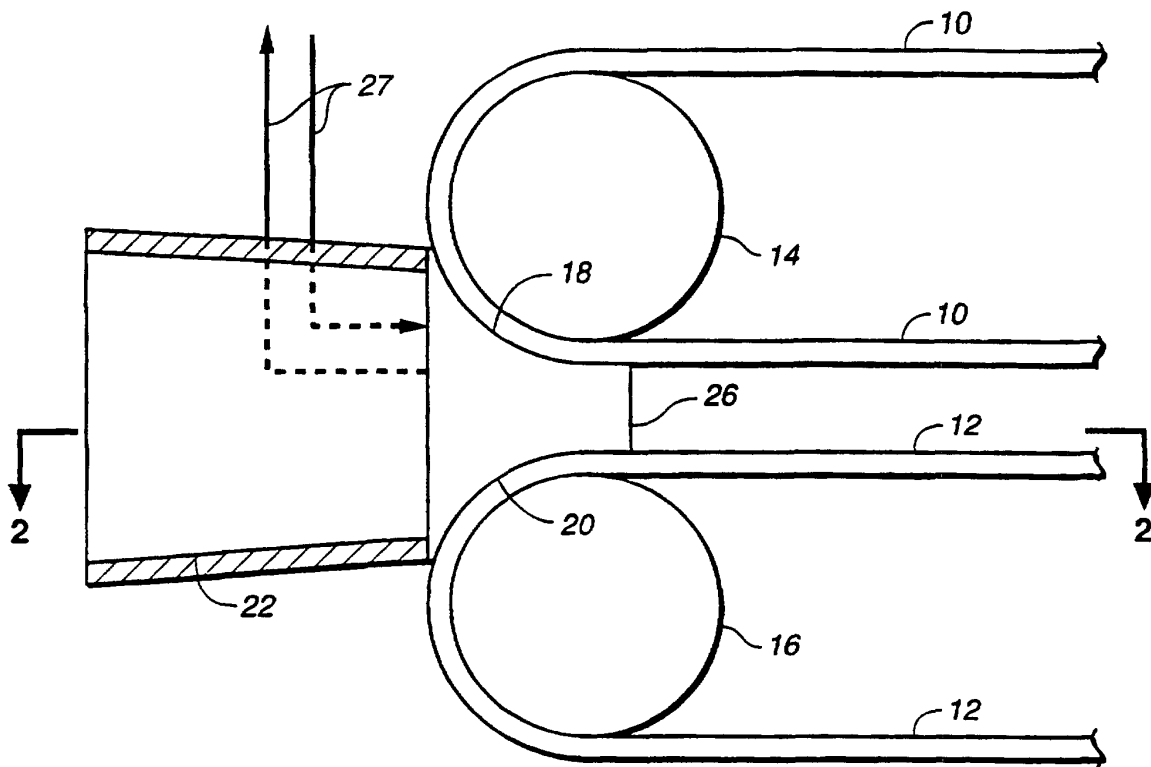


FIG. 1

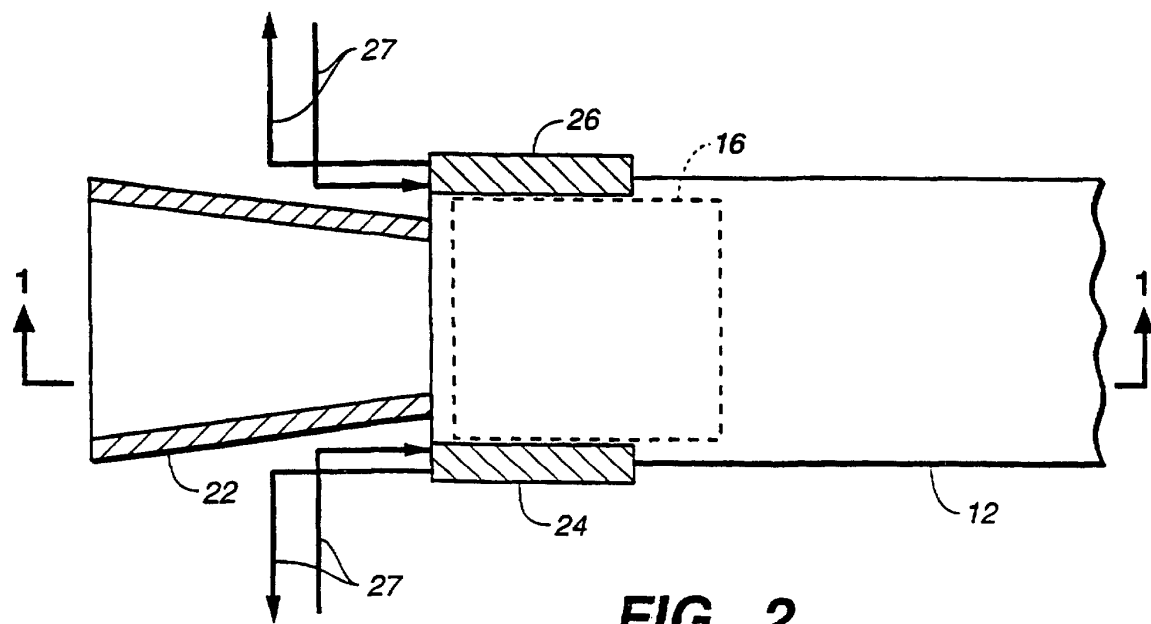


FIG. 2

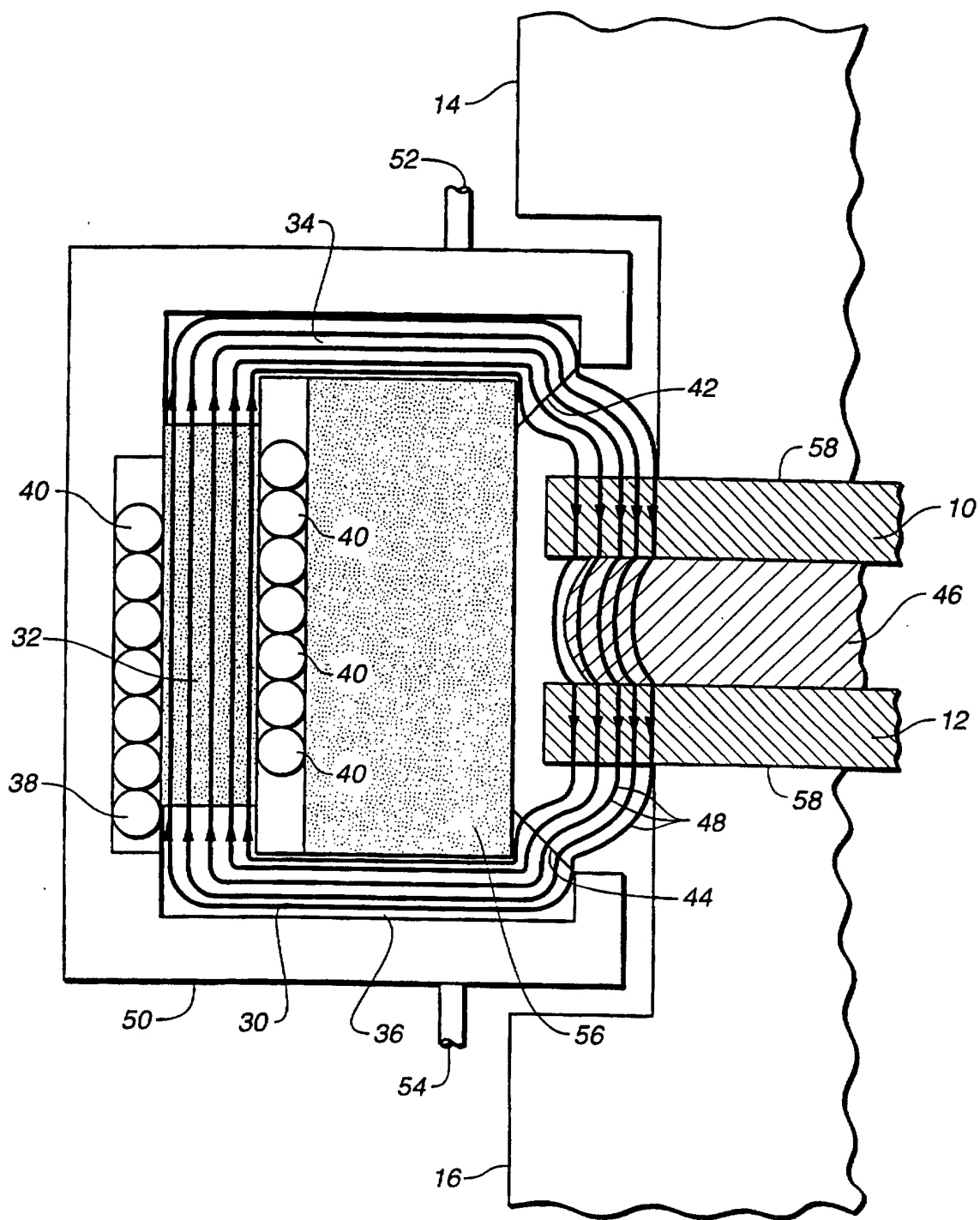
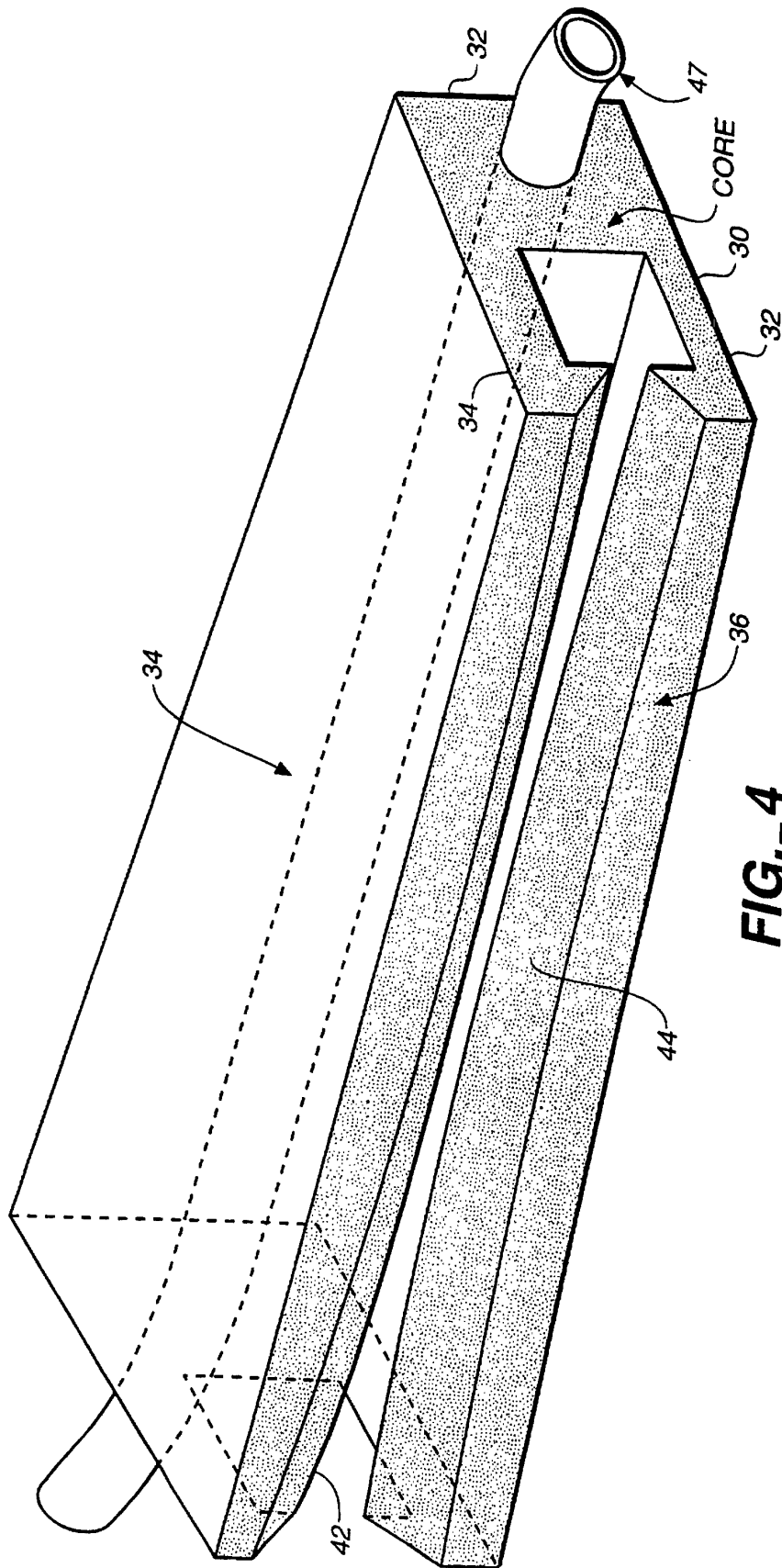


FIG. 3



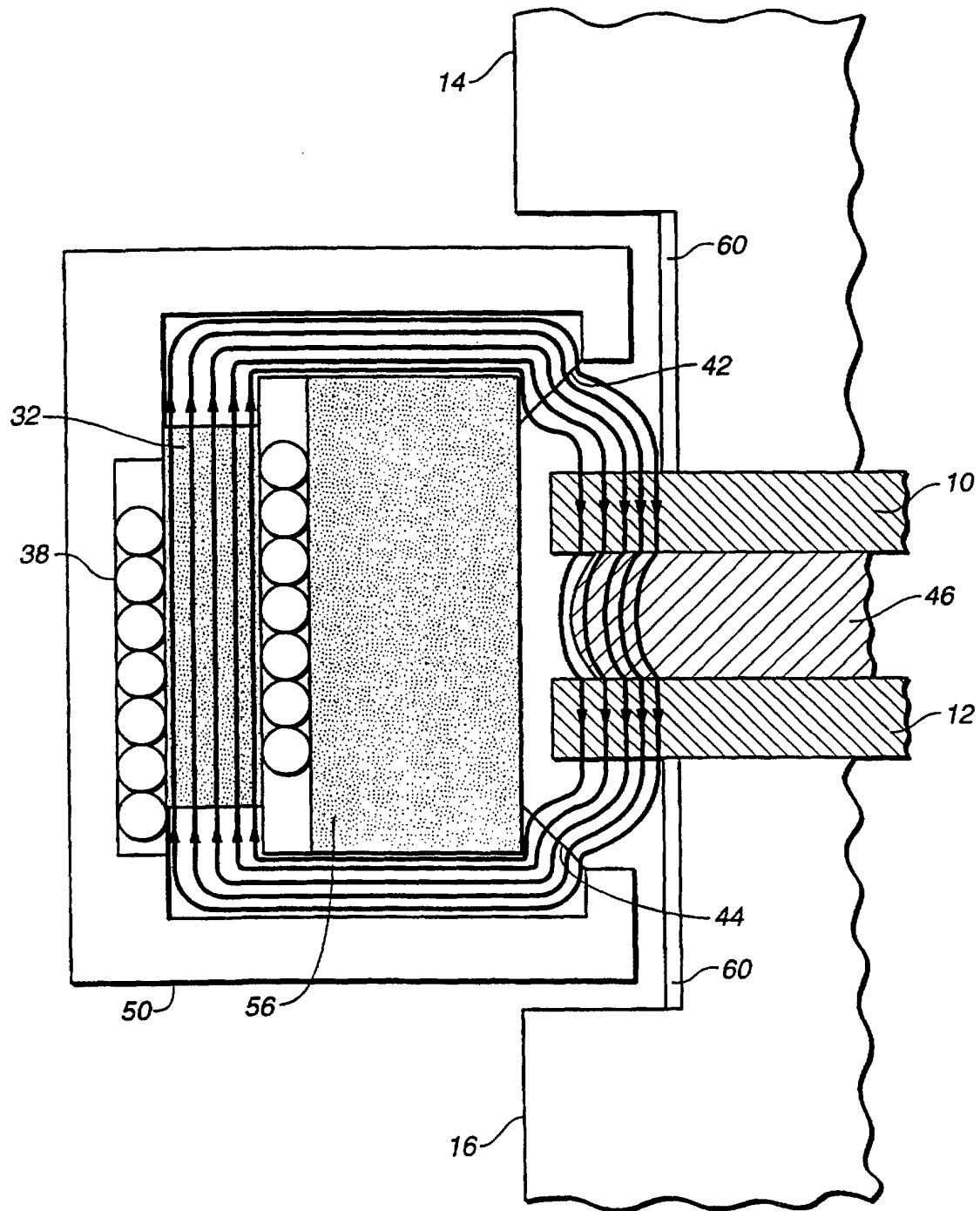


FIG._5

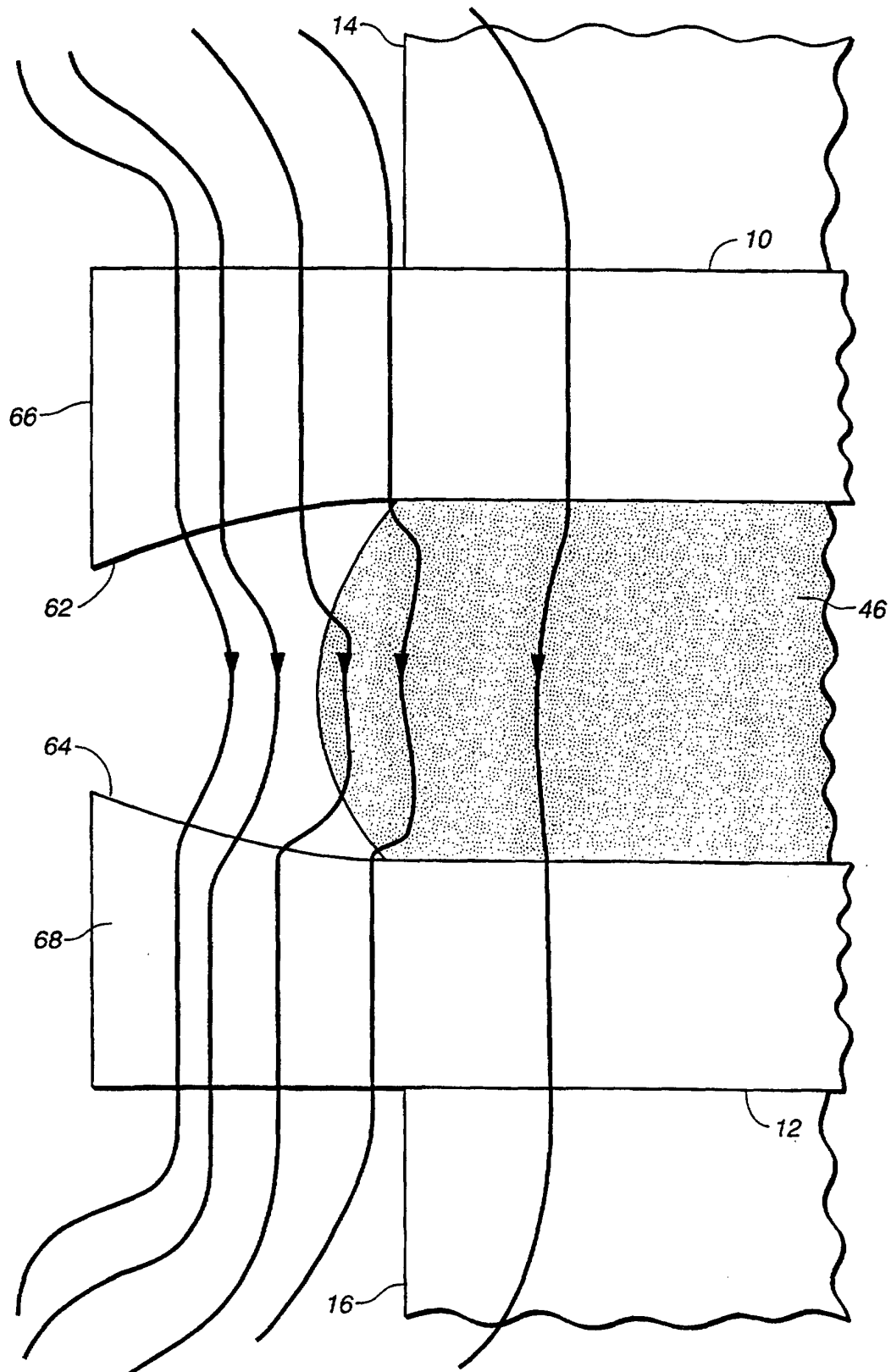
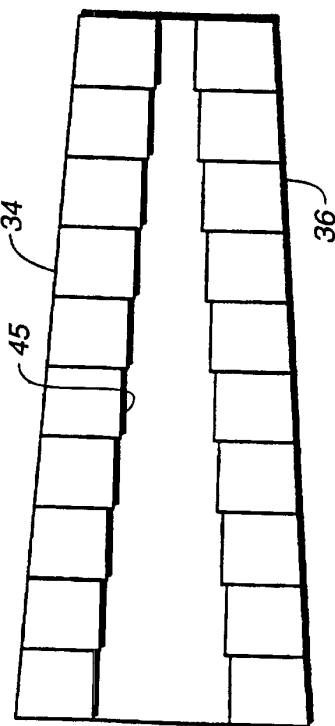
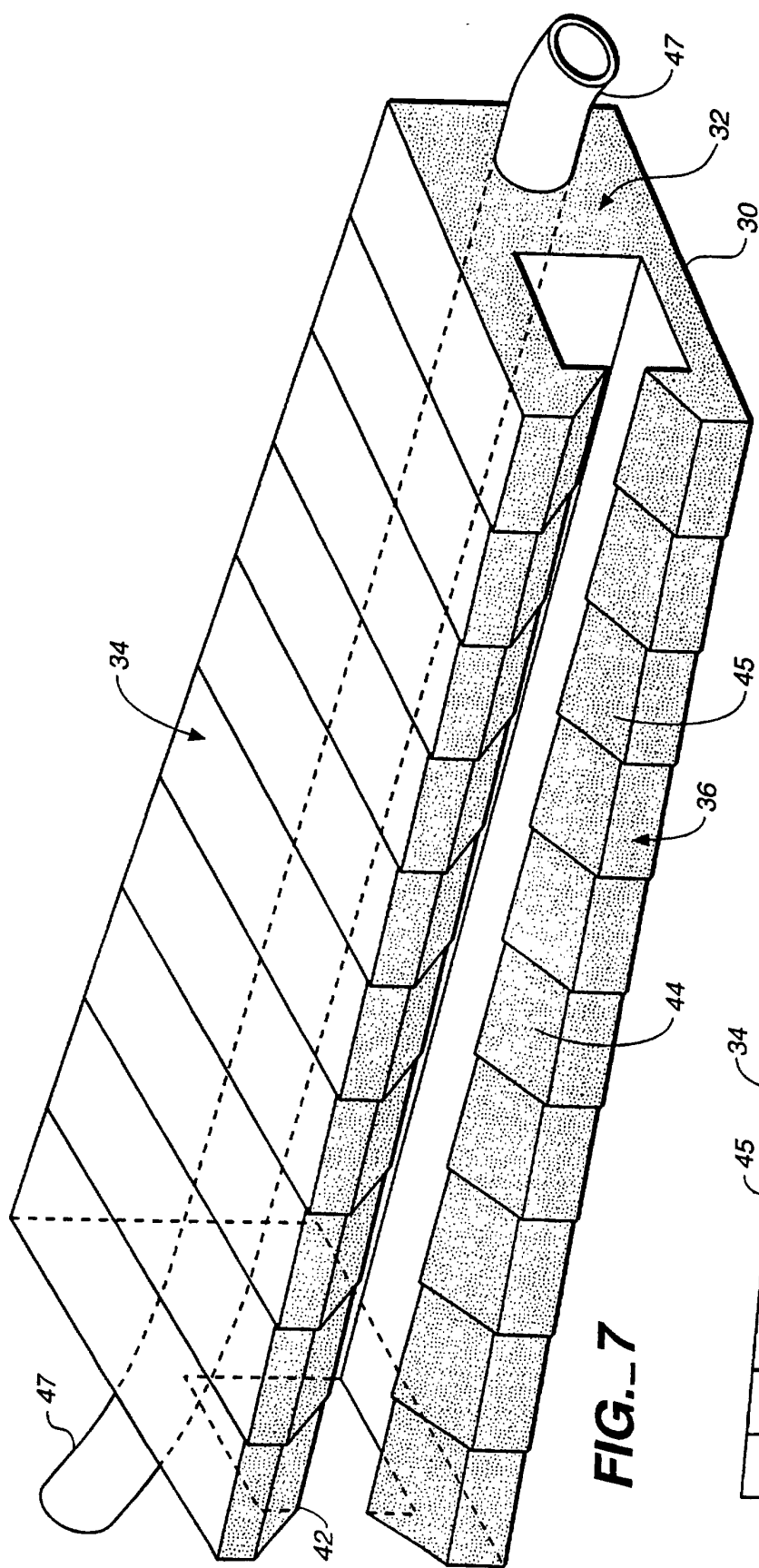


FIG._6



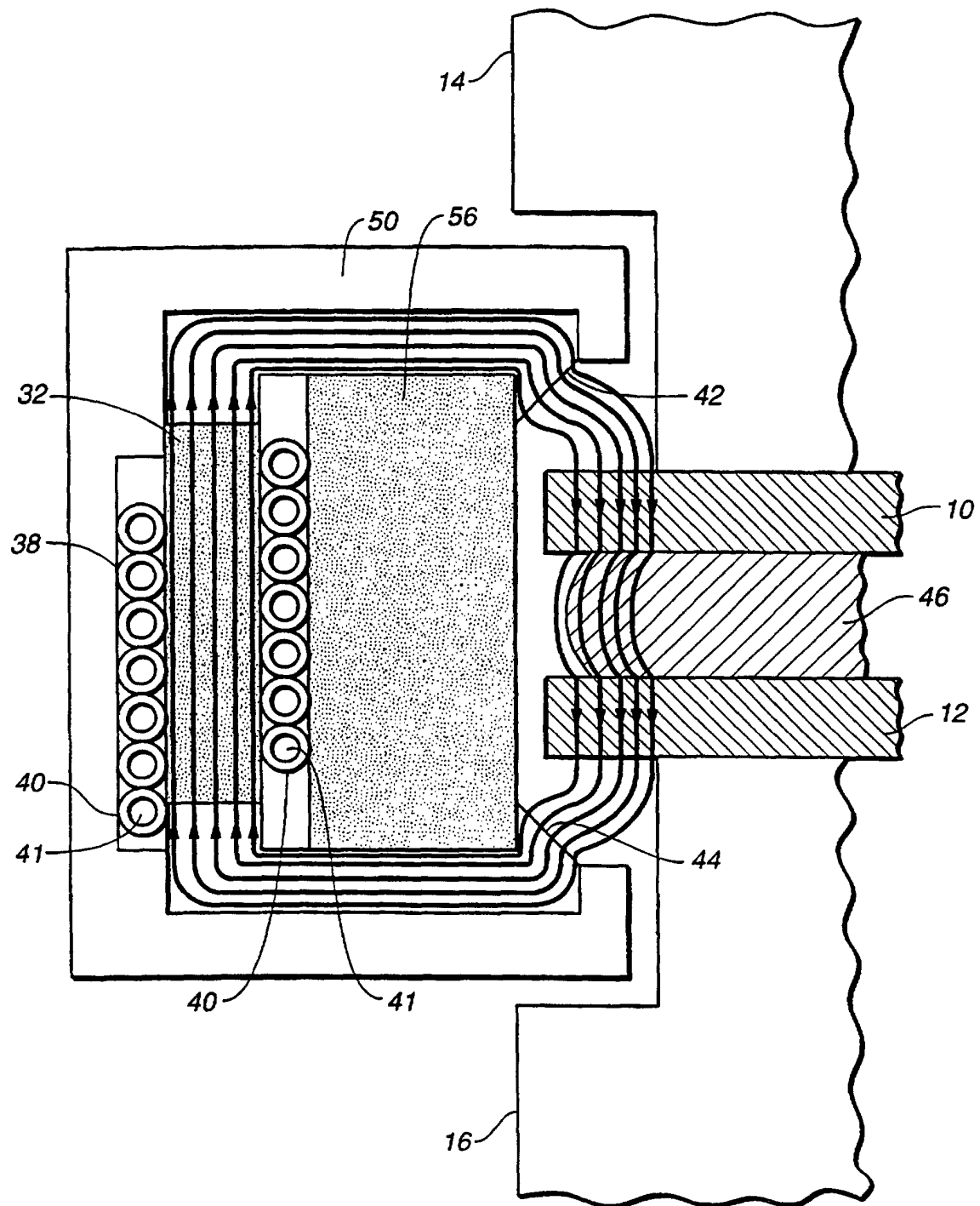


FIG. 8

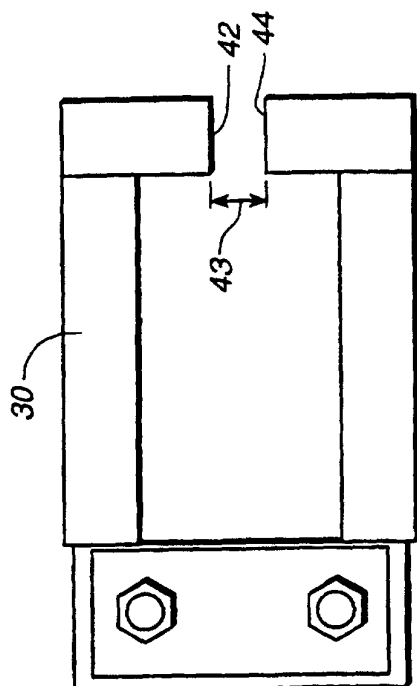


FIG._10

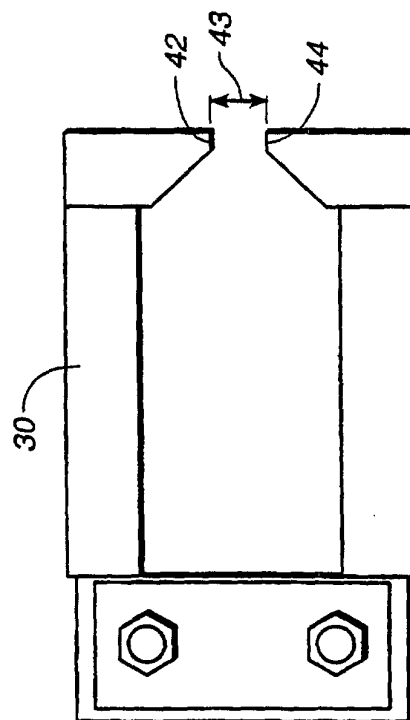


FIG._12

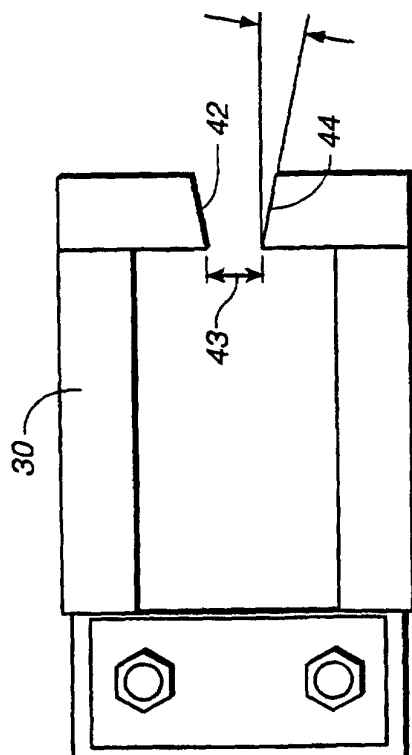


FIG._9

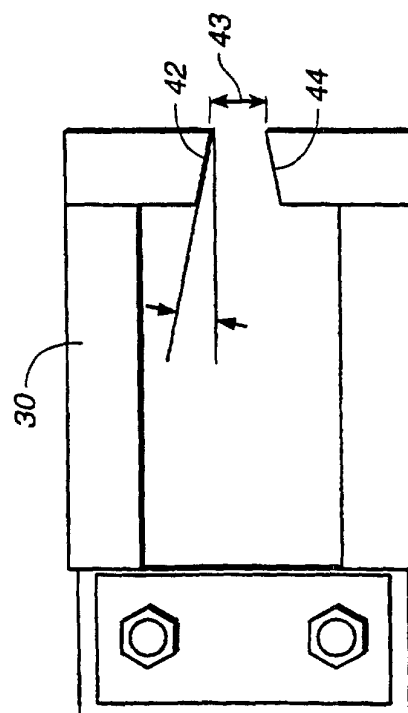
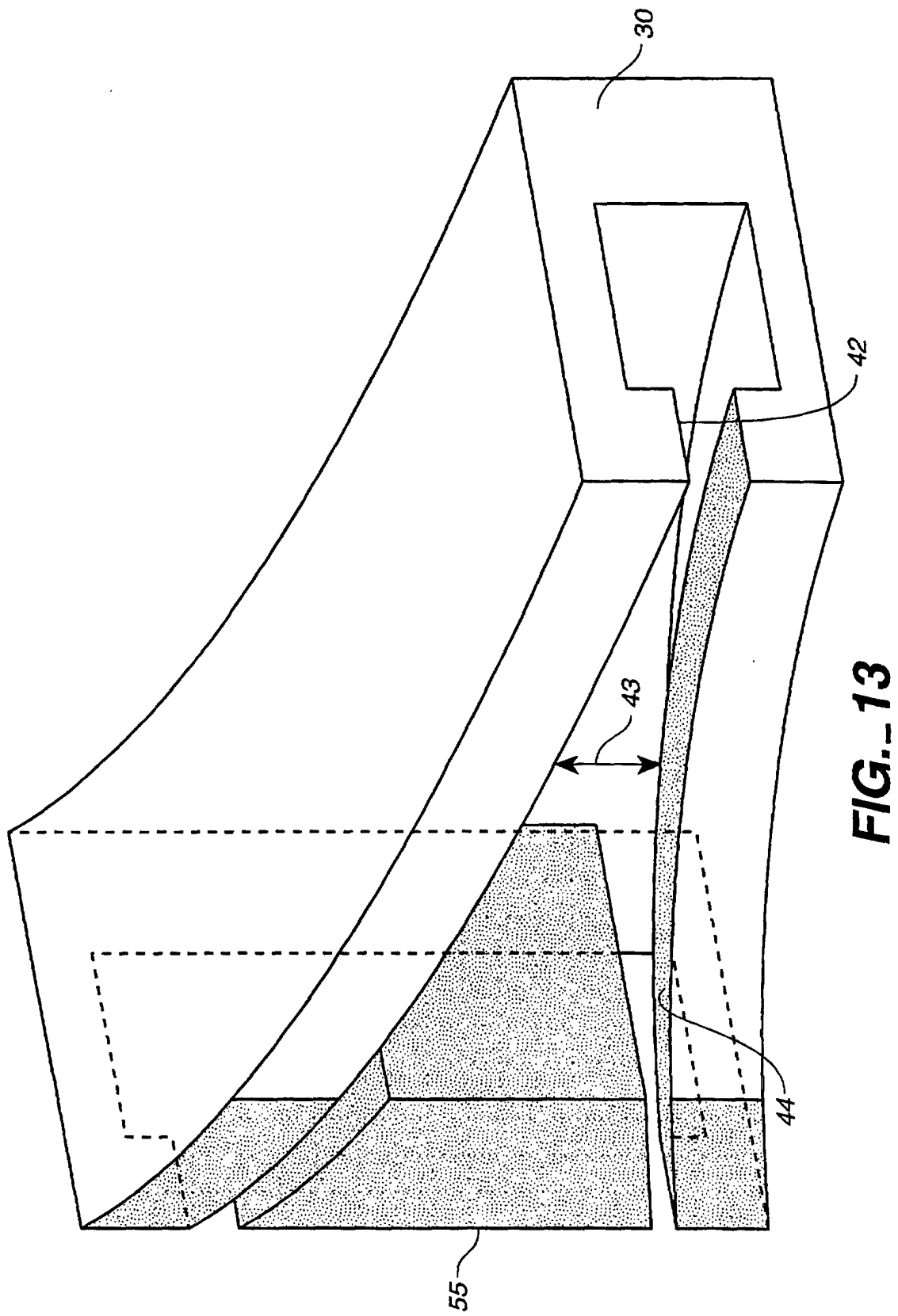


FIG._11



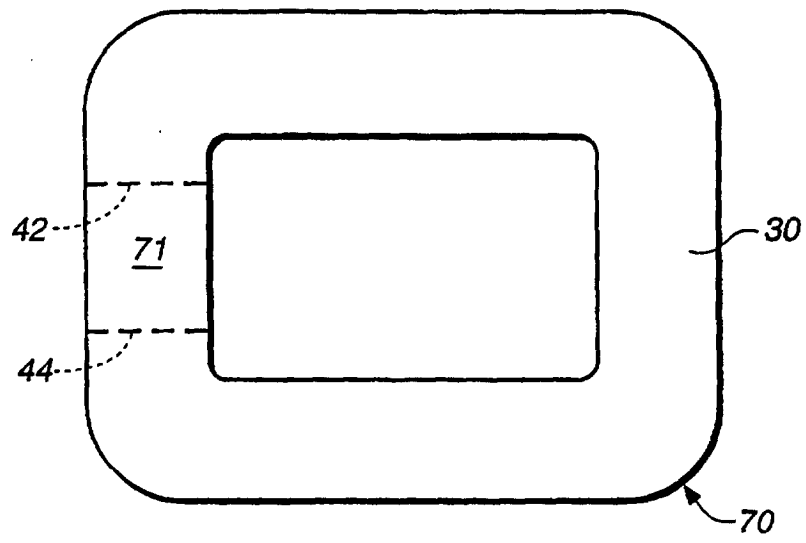


FIG._14

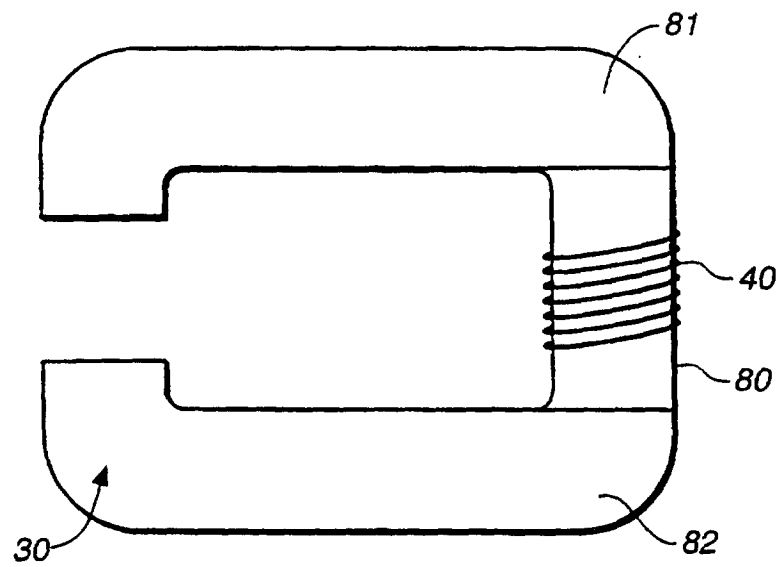


FIG._15

