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Watts

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[54] **CONTINUOUS CASTING APPARATUS WITH RESILIENT GRAPHITIC SEALING ELEMENT**

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[52] **U.S. Cl.** ..... **164/260**; 164/281; 164/283 M

[51] **Int. Cl.**[2] **B22D 11/02**

[58] **Field of Search** ..... 164/83, 260, 261, 281, 164/73, 283 M

[56] **References Cited**

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[57] **ABSTRACT**

Apparatus for continuous casting of metals including a cooled axial mold wall defining at least part of a mold cavity and a wall structure extending transversely of the axial wall and located therein, provided with a solid cooled sealing element of resilient graphitic material extending therearound and internally abutting the axial wall which is moved on its axis relatively to the transverse wall. On the face thereof which contacts molten metal and covering a portion of the sealing element in overlapping relation, such transverse wall has a refractory element having an outer surface portion thereof adjacent the axial mold wall disposed at an angle to the last-mentioned wall. There is also provided a nozzle structure having improved thermal characteristics for delivering molten metal to a mold cavity for continuous casting.

11 Claims, 3 Drawing Figures

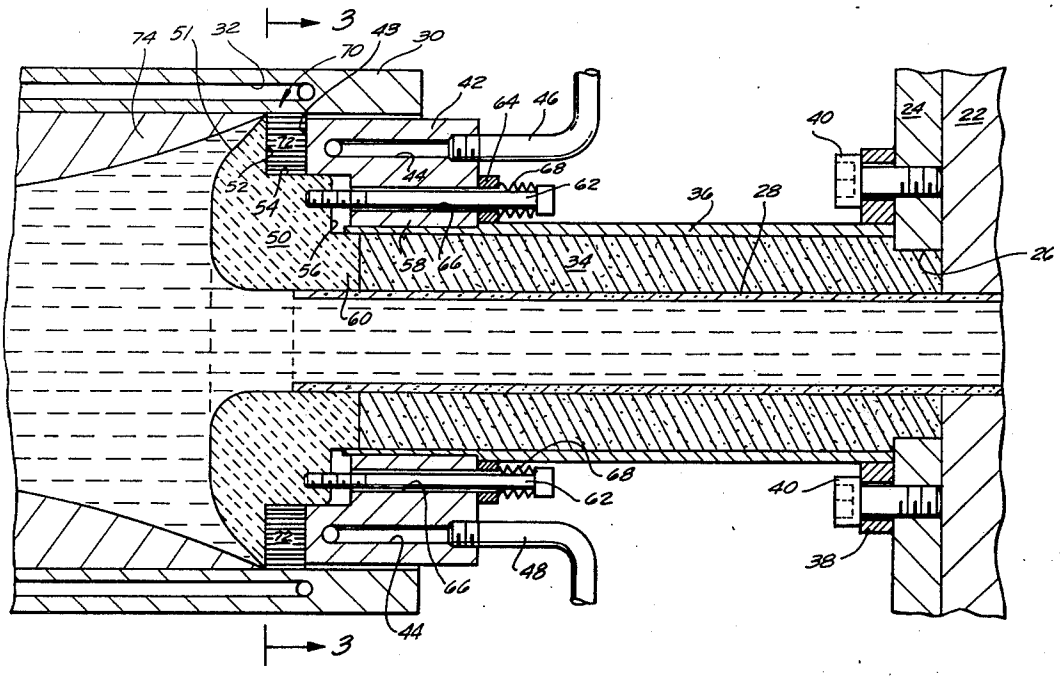


FIG. 1

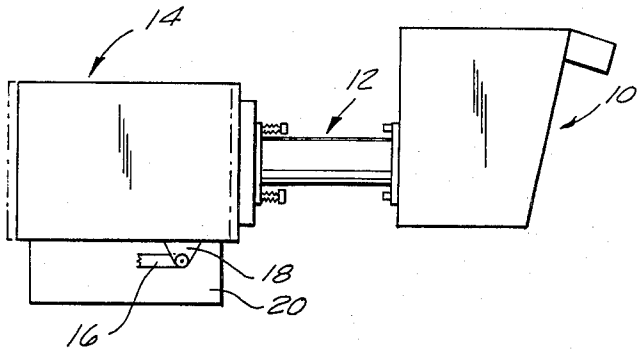


FIG. 3

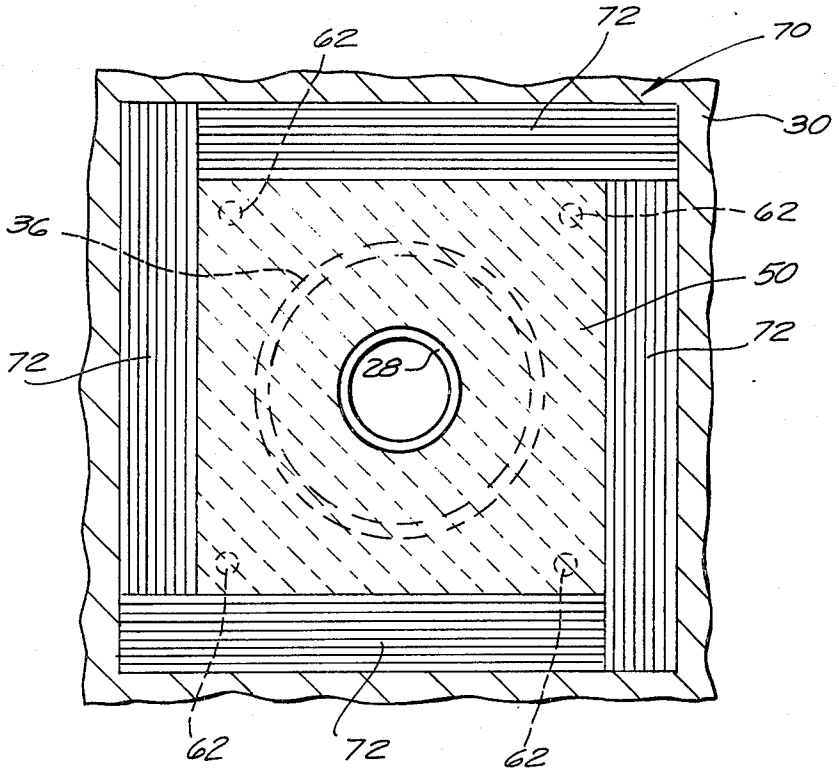
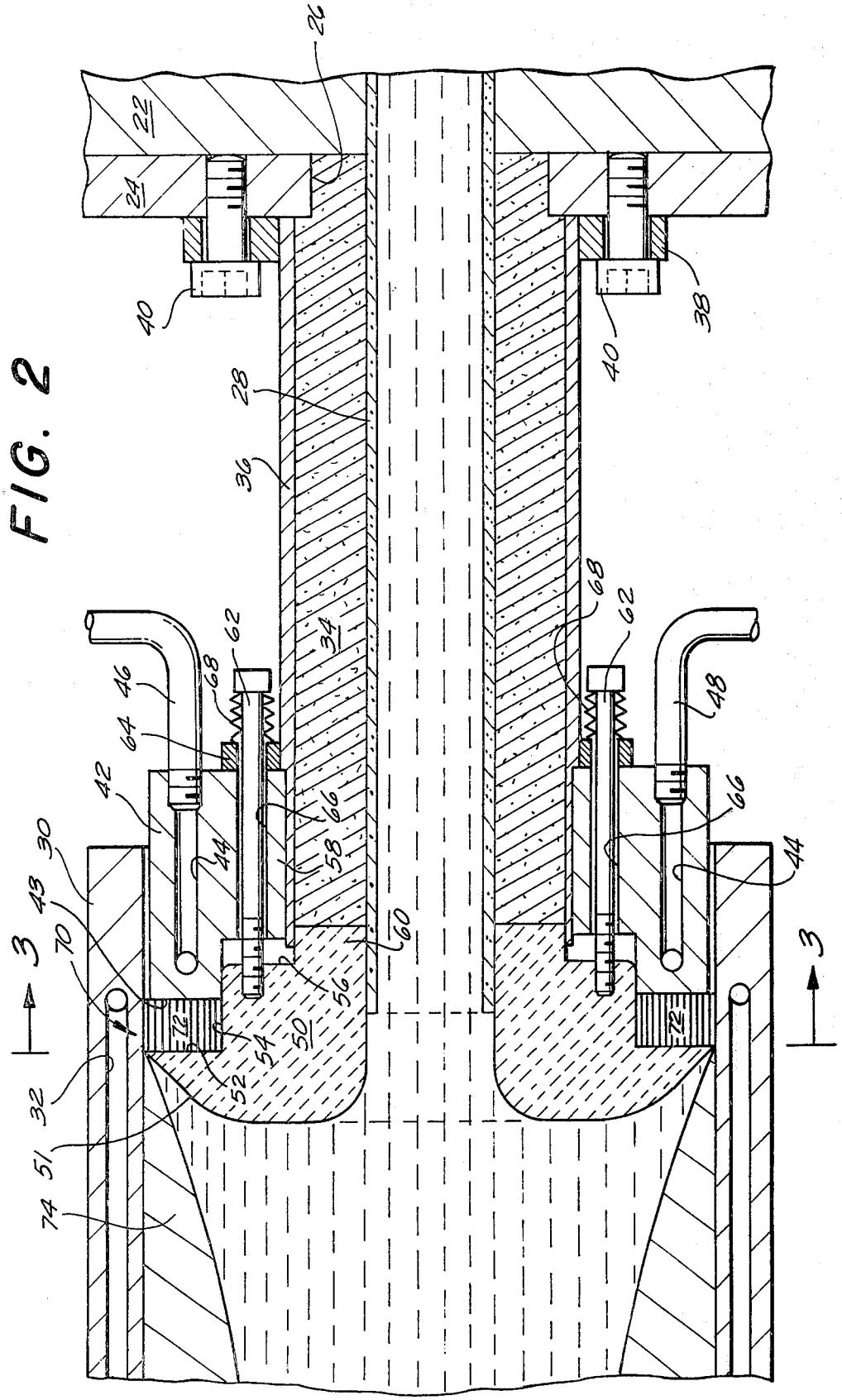


FIG. 2


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CONTINUOUS CASTING APPARATUS WITH RESILIENT GRAPHITIC SEALING ELEMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to apparatus for continuous casting of metals, and relates more particularly to a dynamic seal in such apparatus and elements associated with the seal for casting metals having relatively high melting points.

2. Prior Art

Improvements in apparaus apparatus continuous casting of metal have created a need for a solid dynamic seal for exposure to and occlusion of such metals in molten condition. Difficulty has been encountered in providing in apparatus for casting metal such as steel, iron, nickel, cobalt and alloys thereof, for example, a dynamic seal for exposure to such metals by reason of the physical and chemical limitations of sealing materials in such environment. For example, **1020** carbon steel has a melting point of approximately **2780°F.** With the addition of super-heat to such molten metal, a seal exposed to such metal is required to function at a temperature range of approximately **2800°**– 2900°F. At this temperature, such metal is highly active and will react chemically with hitherto known solid seals having the characteristics of flexibility and resilience, thereby destroying the sealing properties of such seals. Further seal requirements are impermeability to and non-wettability by by such molten metals. If the surface portion of this seal which is in contact with the metal being cast is below the freezing point of such metal, the solidifying metal solidifies on the seal rendering the latter inoperative. Of further concern in the provision of such a dynamic molten-metal-tight seal are the thermal expansion and warpage of a surface with which the seal is in sealing contact. Moreover, the seal and the elements associated therewith in the sealing assembly should be of simple and inexpensive construction and reliable and durable in use. The seal of the invention meets these requirements.

SUMMARY OF THE INVENTION

One object of the invention is to provide an effective and reliable dynamic seal of a solid type in apparatus for continuous casting of metals having relatively high melting points, which seal is exposed to such metals in molten condition, and which seal exhibits, among other characteristics, flexibility and resilience. Such a seal is advantageously employed between a chilled axial mold wall which is oscillated in operation and a transverse wall within the axial wall and with reference to which the axial wall is moved during oscillation. Such transverse wall may be embodied in a molten-metal delivery nozzle for an open-ended mold in contact therewith or in a closed end or plug for a mold, having relatively movable contact with an axial mold wall.

In accordance with the invention, there is provided a solid cooled sealing element of resilient graphitic material extending around such transverse wall and internally abutting such axial wall. On the face thereof which contacts molten metal and covering a portion of the seal in overlapping relation, such transverse wall has a refractory element having an outer surface portion thereof adjacent the axial mold wall disposed at an angle to the last-mentioned wall.

Other objects of the invention will be apparent from the following detailed description of the presently preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a diagrammatic side elevational view of a nozzle embodying the invention and illustrating the same in association with a supply vessel for supplying molten metal through the nozzle to a mold;

FIG. **2** is a fragmentary side elevational view in median section of the apparatus of FIG. **1**; and

FIG. **3** is a fragmentary sectional view taken on line **3—3** of FIG. **2.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. **1**, the supply vessel of molten metal is indicated generally at **10** having a delivery nozzle assembly, indicated generally at **12,** associated therewith to convey molten metal from the vessel **10,** in this form laterally, to a mold indicated generally at **14.** More particularly, in the illustrated form the vessel **10** is in the form of a tundish to receive molten metal from a nonillustrated ladle. The flow of molten metal from the tundish **10** through the nozzle is for the continuous casting of an elongated article of a length longer than the mold **14.** The ends of the mold are open and the axial wall structure is chilled, as will appear more fully hereinafter, so that the molten metal on contact with the chilled axial mold wall forms a solidifying shell of the molten article with a molten metal core, which article is withdrawn at an average casting speed by nonillustrated driving rollers. Withdrawal of such article from the mold is commenced in a conventional manner utilizing a dummy bar. The casting direction is to the left as viewed in FIG. **1.** The mold is oscillated axially during a casting operation by a linkage **16** pivotted to a flange **18** of the mold, the mold reciprocating, as indicated by the broken line position thereof, in slidiing relationship to a mold support **20.**

As indicated in FIG. **2,** the tundish has an inner refractory lining **22** and an outer wall structure **24** formed of steel. The tundish has a discharge opening in the wall thereof receiving one end of an inner tube **28** of the nozzle assembly **12.** Such discharge opening is enlarged, as at **26,** in the metal outer wall structure so that the last-mentioned wall structure does not contact the tube **28.** The last-mentioned end of the tube **28** is supported from the refractory lining **22** of the tundish to permit thermal expansion of tube **28.** Molten metal from the tundish **10** flows through the nozzle tube **28** which is structured of refractory material. The other end of the nozzle tube **28** extends into the near open end of the mold **14** which has an axial wall structure **30** formed of copper and provided with a coolant passageway **32.**

A body **34** of sand in a free state, that is, in a noncohesive condition, surrounds the tube **28** throughout the major portion of its length, the body being supported externally by a housing member **36** which may take the form of a sleeve structured of steel. The body **34** is internally exposed to the refractory tube **28** and provides the latter with a somewhat yieldable support which also has thermal insulating characteristics. Of course, the refractory tube **28,** though thin walled, also has thermal insulating properties so that in the normal

operation of the nozzle the body 34 is not exposed to the temperature of the molten metal flowing through the tube 28. The sand chosen for the body 34 should preferably be free of bonding agents and must have a sintering point somewhat above the temperature to which it is exposed on the flow of the particular molten metal through the nozzle tube 28. On the other hand, the sintering point of the sand must be low enough to sinter locally on exposure to the molten metal around any cracks or rupture of the refractory tube 28 which may take place during operation, so as to seal any leak. For example, for pouring steel, iron, nickel, cobalt or alloys thereof through the nozzle the composition of the sand body 34 may be zirconium oxide.

The sleeve 36 concentrically spaced from the tube 28 has a radial flange 38 fixed thereon for securement of the rear end of the nozzle assembly 12 to the tundish 10 as by bolts 40. Substantially filling the space between and around the sleeve 36 at the forward end portion thereof and the internal surface of the axial mold wall 30 is a copper block 42 having a coolant passageway 44 therethrough one end of which is connected to a flexible coolant inlet conduit 46. A flexible coolant outlet conduit 48 is connected to the other end of the passageway 44. The block 42 is mounted for limited axial sliding movement on the sleeve 36.

Forwardly of the body 34 of sand is a refractory member 50 encircling the forward end portion of the refractory tube 28 and dimensioned to extend close to and around the internal surface of the axial mold wall 30 with a surface inclined, as at 51, to the mold wall 30. The member 50, which may be conveniently structured of boron nitride or alumina graphite, constitutes the nozzle tip in this embodiment of the invention. On the periphery thereof, the member 50 has a rearwardly facing shoulder providing a planar surface 52 in a plane normal to the axis of the mold wall 30 and also a planar surface 54 in a plane parallel to such axis as indicated in FIG. 2.

The surface 54 extends rearwardly a distance sufficient to slide below in an axial direction the undersurface of a forward overhang of the block 42 having a forward planar surface 43 opposing the surface 52. Adjacent the rear extremity of the surface 54, the refractory member 50 has a surface 56 lying in a plane substantially parallel to the surface 52 thereof and spaced forwardly of a radially inwardly extending integral part 58 of the block which part 58 is slidable on the sleeve 36 as previously indicated. Radially inwardly of the surface 56, the member 50 is provided with a rearward extension 60 encircling the forward end portion of the refractory tube 28 in axially sliding relation thereon and extending in sliding relationship into the forward extremity of the sleeve 36. Thermal expansion of the refractory tube 28 is permitted by this construction and arrangement. The rearward extremity of the extension 60 is in contact with the body 34 of sand as indicated in FIG. 2. The axial mold wall 30 is of square cross section as indicated in FIG. 3 and it will be understood that the copper block 42 in the ceramic tip member 50 are also of square cross section, though the sleeve 36 and the refractory tube 28 are of circular cross section as shown in the last-mentioned view.

A plurality of tie bolts 62 in circular array extend forwardly through a radial flange 64 fixed externally as by welding to the sleeve 36 rearwardly of the block 42. The bolts 62 pass with clearance through holes in the flange 64 and holes 66 formed in the block 42, the bolts being threaded into the refractory tip member 50 as indicated in FIG. 2. Compression springs 68 are compressed between the respective bolt heads and the flange 64, urging the tip member 50 rearwardly, and also urging rearwardly through a seal, indicated generally at 70, the block 42. Rearward movement of the block 42 is limited by the flange 64. The compression of the springs 68 may be adjusted as desired by appropriate threaded adjustment of the bolts 62. From the foregoing it will be understood that the seal 70, which is in engagement with the axial mold wall 30 and bottoms on the surface 54 of the member 50, is clamped in stationary position between the surface 52 of the member 50 and the surface 43 of the block 42 by the spring action.

As shown in FIG. 3, the seal 70 may be formed conveniently of segments 72, four such segments being shown. The segments 72 may have mitered ends for the cooperation of the end of one segment with the end of another but in the illustrated form the segments have square ends for flatwise engagement with one another in the manner shown. The seal segments 72 are structured of graphitic material which does not exhibit the characteristics of a refractory material with reference to metals having such a high melting point and an affinity for carbon as steel, iron and nickel which may be cast in accordance with the invention.

More particularly, each seal segment 72 is a laminated structure which gives the segment yieldability and resiliency not normally associated with graphitic materials. It is essential in the use of such material, which is available commercially under the trademark Grafoil, that the laminations or foliations of each such segment be arranged with reference to the axial mold wall 30 so as to be parallel thereto as thermal transfer of the material in such parallel direction is much higher than thermal transfer in a direction transversely of the laminae. Thermal dissipation from such seal segments 72 by the cooled block 42 engaged therewith is essential to prevent the graphitic material on exposure to such molten metals from entering into solution with such metals at their elevated temperatures. In FIG. 2, the nozzle and the mold are shown full of the metal being cast and a solidifying shell or skin of such metal within the mold is indicated at 74 with the remainder of the metal being cast being indicated to be in the molten state.

As indicated in the last-mentioned view, the nozzle tip member 50 covers to a substantial extent and in the manner of a retainer for the seal segments 72 but a small portion of each seal segment is exposed to molten metal within the mold. As previously indicated the material of the seal is anisotropic in the characteristics thereof with highly preferential directional thermal properties. The values for this material at 70 lbs./cu. ft. density are as follows at 70°F: in a direction parallel to the laminae 80 B.T.U./ft./ft.^{2} /hr./°F and in a direction transverse to the laminae 3 B.T.U./ft./ft.^{2} /hr./°F.

As previously indicated the axial mold wall 30 is oscillated during a casting operation. It is important to assure uniform bearing of the seal 70 against the face 43 of the cooled block 42. Uneven contact may result in localized reduction of heat transfer between the seal and the cooled block 42. In the latter event, the temperature of the graphitic material in this area may rise above the solution point and erosion of the seal may oc-

cur. The spring loading of the seal assures proper contact of the seal with the block **42** together with sufficient flatness of the surfaces **43** and **52** as well as the corresponding surfaces of the seal **70.** The thickness of the seal **70** in a direction axially of the mold wall **30** should be held to a minimum compatible with the strength requirements of the seal so as to enhance heat dissipation from the seal during operation. At the start of a cast, the seal **70** has an interference fit with the internal surface of the mold wall **30.** It will be apparent that the graphitic material of the seal is self-lubricating. Furthermore, the seal occludes molten metal from between the nozzle assembly **12** and the mold wall **30,** while permitting gases within the mold to escape past the seal.

After the completion of a casting run, the mold is removed from the nozzle assembly **12** and the refractory tube **28** is visually inspected while remaining assembled to the tundish **10** to ascertain if the tube **28** has been damaged as by erosion or a rupture. If the tube **28** has not been damaged, and only the sealing elements require replacement, the spring-pressed bolts **62** secured to the seal retainer **50** are thrust forward in a manner to release the clamping engagement on the seal elements **72** to permit them to be lifted out of the nozzle assembly **12.** While the retainer **50** is in the inoperative position thereof, new seal elements **72** are inserted in the nozzle assembly **12** and the spring-pressed bolts are released to enable to retainer **50** to clamp the new seal elements **72** against the block **42.** The mold may then be reassembled with the nozzle assembly **12.**

If the refractory tube **28** shows signs of damage, the nozzle assembly is removed from the tundish **10** and replaced by another nozzle assembly. The damaged tube **28** of the removed nozzle assembly may be readily replaced by another such tube around which the body **34** of sand is replaced. The seal elements **72** are replaced in the aforementioned manner. After these steps, the nozzle assembly is in condition for later use.

It will be evident from the foregoing that the peripherally cooled block **42** and the refractory cover member **50** form together a transverse wall within the axial wall **30** which, through the seal **70,** is in sealing engagement with such mold wall which is movable. This is significant, whether or not such transverse wall forms part of a nozzle construction having a discharge opening for molten metal therethrough, and such a sealing wall without such opening has significant utility in a mold for continuous casting of metals, which mold is of the type having a closed end, that is, impermeable to molten metal. Such a mold having an axial wall oscillatable with reference to a closed end of plug therein is illustrated and described in my copending U.S. patent application Ser. No. **268,977,** filed July **5, 1972,** now U.S. Pat. No. **3,814,166** and assigned to the assignee of the present invention.

While the presently preferred embodiments of the invention have been illustrated and described, it will be apparent, especially to those versed in the art, that the invention may take other forms and is susceptible of various changes in details without departing from the principles of the invention.

What is claimed is:

1. Apparatus for the continuous casting of a metal article comprising, in combination:

a cooled axial mold wall having a forward exit for the article and movable on its axis and defining at least in part a mold cavity;

a wall structure extending transversely of said axial wall and located therein and which is exposed to molten metal in a casting operation, said transverse wall comprising a cooled peripheral portion having a face toward said exit extending transversely of said axial wall;

means to oscillate said axial wall with reference to said transverse wall; and

a solid dynamic sealing element of resilient graphitic material carried by said transverse wall and extending therearound forwardly of and in contact with said cooled face to be cooled thereby, said sealing element being in internal sealing contact with said axial wall; and

said transverse wall having a forward refractory cover element thereon exposed to molten metal in said mold cavity, said cover element substantially overlapping the foremost portion of said sealing element for thermal insulation of it.

2. Apparatus as defined in claim **1,** wherein: said sealing element seats on a surface of said cover element extending at least generally parallel to said axial mold wall, said sealing element having a planar surface portion which is in flatwise contact with said cooled face.

3. Apparatus as defined in claim **1,** wherein: the dimension of said sealing element in contact said axial mold wall in a direction parallel thereto is substantially equal to the longest dimension of said sealing element in said parallel direction.

4. Apparatus as defined in claim **1,** wherein: said sealing element has planar surface portions facing in opposite directions which are respectively engaged in flatwise relation by said cover element and said cooled face.

5. Apparatus as defined in claim **1,** wherein: said cover element is a retainer for said sealing element and is spring biased to clamp said sealing element against said cooled face.

6. Apparatus as defined in claim **1,** wherein: said sealing element in cross section parallel to said axial wall is rectangular.

7. Apparatus as defined in claim **1,** wherein: said transverse wall has an opening therethrough axially of said axial mold wall for delivery of molten metal to said mold cavity.

8. Apparatus as defined in claim **1,** wherein: said sealing element comprises seal segments arranged to abut one another in array around the internal surface of said axial mold wall.

9. Apparatus as defined in claim **1,** wherein: said sealing element comprises laminated graphite the foliations of which are arranged in parallelism with said axial mold wall.

10. Apparatus as defined in claim **1,** wherein: said sealing element comprises laminated graphite the foliations of which are arranged in parallelism with said axial mold wall, and said sealing element comprises seal segments abuting one another in array around the internal surface of said axial mold wall.

11. Apparatus as defined in claim **1,** wherein: said transverse wall has an opening therethrough axially of said axial mold wall for delivery of molten metal to said mold cavity, said cover element having a non-planar portion extending into said mold cavity.

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