Dec. 10, 1968 J. D. SHARP 3,415,427

NOZZLE AND STOPPER ASSEMBLIES FOR TEEMING LIQUID METAL

Filed Aug. 30, 1966 2 Sheets-Sheet 1

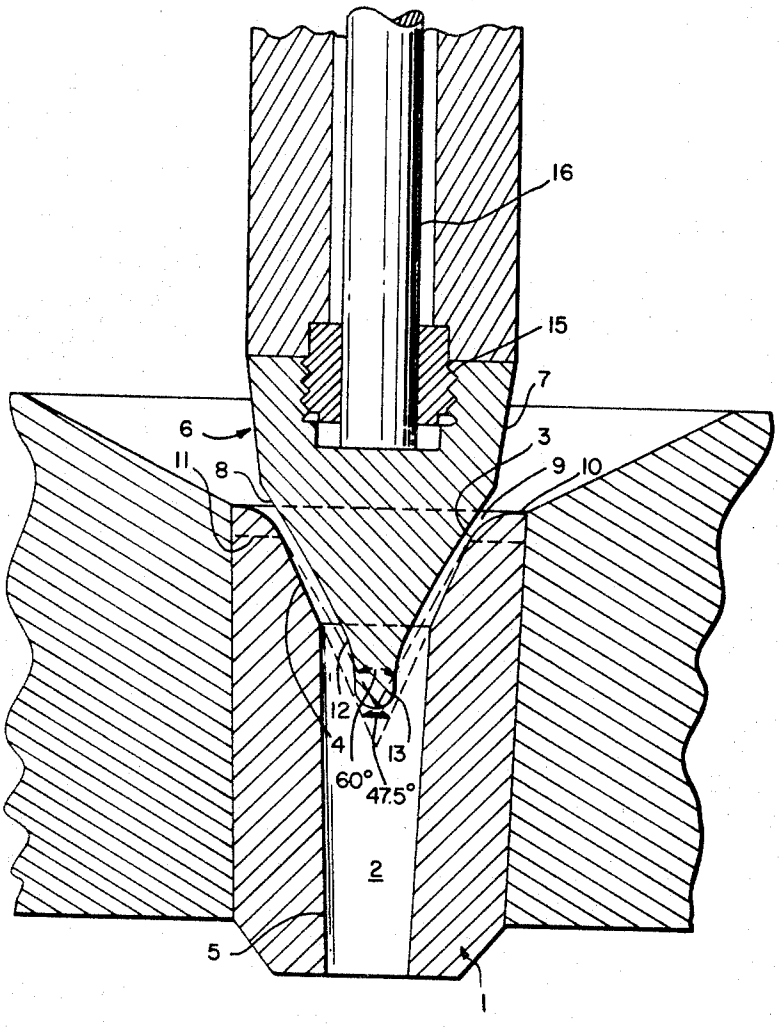


FIG. 1.

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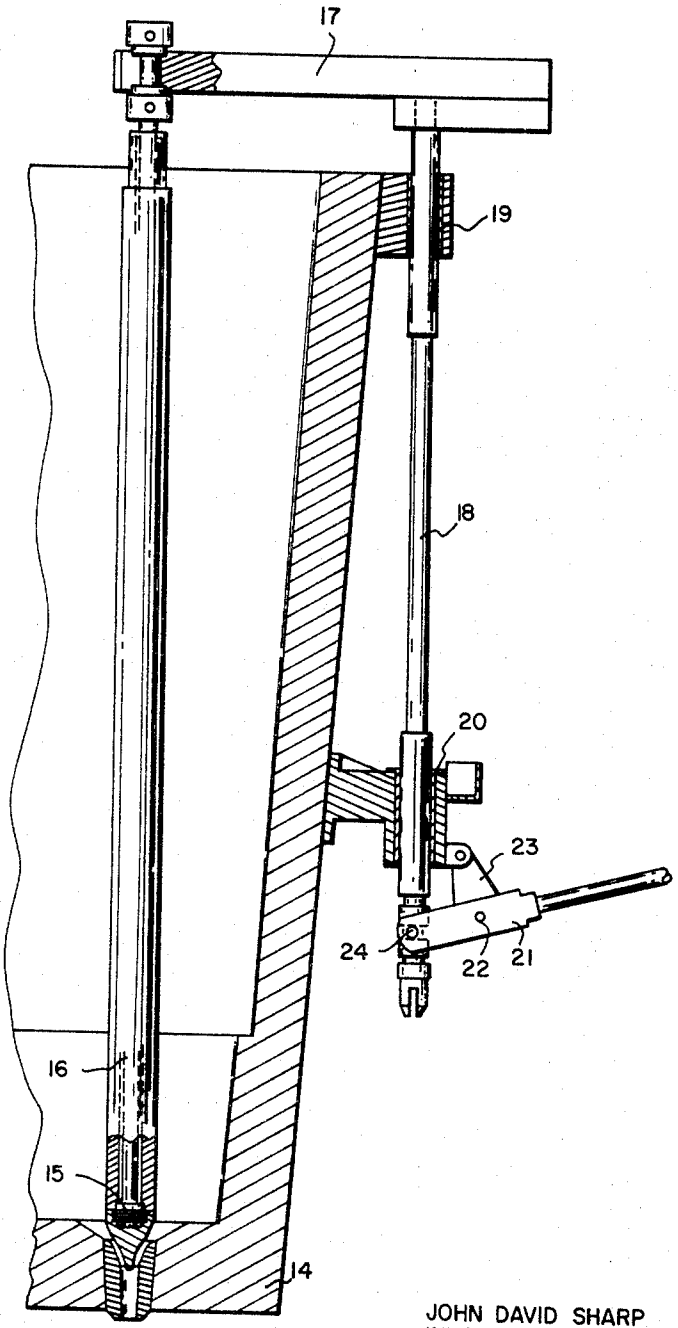


FIG. 2.

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United States Patent Office 3,415,427 Patented Dec. 10, 1968

3,415,427

NOZZLE AND STOPPER ASSEMBLIES FOR TEEMING LIQUID METAL

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Filed Aug. 30, 1966, Ser. No. 576,082
5 Claims. (Cl. 222—509)

ABSTRACT OF THE DISCLOSURE

A nozzle and stopper assembly for teeming of molten steel from a bottom-pour ladle includes a refractory stopper penetrating deeply into the bore of a refractory nozzle. Both the stopper and nozzle are tapered downwardly, but the taper of the nozzle has a portion with a greater included angle than a corresponding portion of the stopper so that the stopper, which makes line contact with the nozzle when stopping molten metal flow, when raised provides an annular space which increases in cross sectional area to accurately control the flow of molten metal. There is an outwardly flaring surface on the nozzle immediately above the area of contact to avoid metal being trapped between the stopper and nozzle when the stopper is moved into the closed position. The nozzle is made from a refractory material in the green dried but unfired state, preferably dead-burnt magnesite containing at least 85% magnesium oxide. A stopper lifting mechanism includes a limit stop so the stopper cannot be completely lifted out of the bore of the nozzle.

This invention relates to nozzle and stopper assemblies used in the teeming of liquid steel or other liquid metal through bottom-pour ladles. In the teeming process the metal flows through one or more nozzles fixed in the bottom of the ladle and each nozzle is normally closed by a refractory stopper. Teeming is started by raising the stopper from its seat on the nozzle.

In all teeming processes, it is desirable that the rate of teeming should be constant or controllable. The actual teeming rate normally depends mainly on the bore of the nozzle, and on the head of metal in the vessel above the nozzle, which in teeming steel is termed the ferrostatic head. During the progress of teeming, the bore of the nozzle normally tends to increase as a result of physical erosion and chemical attack by the constituents of the metal, particularly when this is steel, and in teeming from a ladle the ferrostatic head decreases.

There are a large number of designs of nozzle and stopper assemblies currently in use. Substantially all have certain features in common; the nozzle consists essentially of a refractory body having a cylindrical bore that opens out into a flared trumpet-shaped orifice at the upper end of the bore, and the seat of the stopper is hemispherical. With this arrangement, the flow of liquid metal will start immediately when the stopper is raised from its seat, and the flow of metal will be stopped when the stopper is lowered onto its seat; the mating surfaces will work satisfactorily even if there has been considerable wear on the nozzle by the flowing metal. All these existing assemblies of nozzles and stopper work on the on-off principle.

A stopper having a hemispherical head is unsuitable for control of the rate of flow of metal since a small movement of the stopper produces a large change in the space between the stopper and nozzle. Certain attempts have been made in the past to design a nozzle so that the fall in ferrostatic head is compensated for by the wear on the nozzle, and a constant teeming rate is achieved. These have not been entirely successful, and raise further

difficulties in that different nozzle characteristics are required for each type of steel and for each temperature of teeming.

For the purpose of preventing the liquid stream disintegrating on leaving the nozzle, it has also been proposed in British Patent No. 917,565 to make the stopper penetrate into the nozzle, the bore of the nozzle contracting downstream and the stopper tapering with a taper angle smaller than that of the contracting part of the bore.

In this invention the stopper penetrates into the nozzle but the stopper and the bore of the nozzle both so taper downwardly as to form, when lifted from the nozzle, an annular space which increases in cross-sectional area as the stopper is lifted. Because the annular space thus varies in cross-sectional area as the stopper is lifted it is possible to control the flow of the liquid metal by lifting the stopper. The stopper and the bore of the nozzle make contact with one another over a small area at or close to the top of the bore in a closed position, the surfaces of the stopper and the bore of the nozzle diverge downwardly immediately below the area of contact in the closed position and the surface of the nozzle flares outwardly away from the stopper immediately above that area. The fact that the stopper and the bore of the nozzle diverge downwardly from the area of contact is extremely important in practice since we have found that if the taper of the stopper is less than that of the bore of the nozzle, metal is caught in the bore of the nozzle around the stopper when teeming is stopped and tends to freeze so that the stopper can no longer be lifted. It is important that no metal should thus be trapped, but rather that all metal that has passed the area of contact should be free to flow downwardly. Moreover if the area of contact is large, as would be the case if a deep stopper and the bore of the nozzle were frusto-conical with the same included conical angle, a film of metal tends to be trapped between the stopper and nozzle and similarly to freeze. The depth of the area of contact is therefore small in relation to the total length of the stopper. If the profiles of the stopper and the bore of the nozzle are curved over the area of contact, this area will theoretically be no more than a line. Preferably, however, the stopper and the bore of the nozzle are frusto-conical with the same included conical angle over the area of contact, and immediately below this both are also frusto-conical but the included conical angle of the bore is less than that of the stopper.

Although any metal above the area of contact when the stopper is moved into its closed position is in contact with the main mass of molten metal left in the ladle, it is still important not to permit any narrow space in which metal might rapidly cool to exist above the area of contact, and accordingly this area is at or close to the top of the bore of the nozzle and immediately above it the surface of the nozzle flares outwardly away from the stopper.

If the flow is to be accurately controlled by the stopper, it is essential that the bore of the nozzle should be made to precise dimensions and should not wear or skull as teeming proceeds. The refractory materials of which nozzles and stoppers are made vary considerably. Some materials are rapidly eroded by liquid steel, whereas others tend to skull, i.e. become coated with solid steel. The nozzles and stoppers are normally fired, and in the course of the firing commonly shrink and may become distorted. It is therefore difficult to make them to precise dimensions, say to greater accuracy than +2%.

Although it has always been supposed that a nozzle must be fired before use, we have surprisingly found that nozzles may be made of unfired refractory materials and yet will have sufficient strength to be used in teeming and will retain their shape. Such unfired nozzles can be made to precise dimensions. Preferably therefore the noz-

zle of the assembly is made of a refractory material in the green dried but unfired state, and then the nozzle can be made to the desired precise dimensions. There is the further advantage that unfired nozzles are cheaper than fired nozzles of the same refractories, not only because there is no firing step but also because the process of firing always involves a certain wastage of product as a result, for example, of shrinking, cracking and distortion to an unacceptable extent.

The material of which a green dried but unfired nozzle is made should have a very low rate of wear, as otherwise the original accurate dimensions will be lost as the teeming continues. We have found that a number of materials are suitable for this purpose, these including alumino-silicate compositions containing 60% or more alumina, fused or sintered magnesia (commonly termed "dead-burnt magnesite"), chrome-magnesite, magnesite-chrome, fused stabilised zirconia (ZrO_2), zircon (zirconium silicate), silicon carbide and graphitised compositions based on clay containing more than 25% alumina. Of these compositions we prefer dead-burnt magnesite because it shows little or no wear by the liquid steel and because it is relatively cheap. The magnesite used should be of high quality and should contain at least 85% MgO with a chemical analysis within the following range:

	Percent
MgO	85.0–98.0
SiO_2	0.5–3.0
Al_2O_3	0.2–2.0
Fe_2O_3	0.2–7.0
CaO	0.5–3.0

Particularly suitable magnesite contains 91.5% MgO, 6.5% Fe_2O_3, 1.4% CaO, 0.9% SiO_2 and 0.5% Al_2O_3. These preferred magnesite nozzles may be given a coating of carbonaceous clay to assist in preventing skulling.

The production of unfired magnesite brick such as is used for nozzles according to this invention is well known in the art. High-grade magnesite is crushed and screened and then mixed with a small proportion of an acid bonding material, for example hydrochloric acid, sulphuric acid or sulphite lye. The mixed material is then shaped under pressure and dried, for instance at 150° C. to form a coherent self-supporting product, and it is in this form that the nozzles are preferably used in the present invention.

The stoppers may also be used in the unfired state, but it is preferable that they should be fired in the usual way. It is found that an unfired stopper tends to break if it is lowered violently onto the nozzle. The stopper is preferably made of a fired carbonaceous alumino-silicate clay which wears uniformly at a low rate, since then the profile of the stopper is essentially maintained despite wear, the stopper merely penetrating deeper into the nozzle as wear takes place.

One assembly of the nozzle and stopper according to the invention will now be described with reference to the accompanying drawings, in which:

FIGURE 1 shows the assembly; and

FIGURE 2 diagrammatically illustrates mechanism for lifting the stopper.

In the assembly shown in FIGURE 1 the nozzle is shown at **1** and consists of green dried but unfired refractory. It has a bore **2** which has a short frusto-conical part **3** with an included angle of 60°, this part **3** merging into a frusto-conical part **4** with an included angle of 47.5°, the part **4** in turn merging into another frust-conical part **5** constituting the main length of the bore.

The stopper is shown at **6** and has an upper frusto-conical part **7** and a lower frusto-conical part **8**, the included angle of which is 60°.

In the closed position the part **8** makes contact with the part **3**. When the stopper is raised, as shown in FIGURE 1, an annular space **9** is left between the parts **8** and **3**, and the width of this annular space determines the amount of metal that can flow through the nozzle under any given ferrostatic head.

It will be seen that immediately below the area of contact both the stopper and nozzle are frusto-conical but the included angle of the part **4** of the bore, namely 47.5°, is less than that (60°) of the part of the stopper below the area of contact.

Above the part **3** the bore of the nozzle flares outwardly over a curve as shown at **10**. Thus in the closed position there is practically no small space above the area of contact in which metal might tend to freeze. Instead of making the area of contact close to but not at the top of the bore of the nozzle, it may be right at the top, the surface of the nozzle at its upper end flaring outwardly at right angles to the axis, as shown in dotted lines at **11**.

The frusto-conical part **8** of the stopper extends over the greater part, but not all, of the length of the stopper that enters the bore of the nozzle. This part **8** of the surface of the stopper merges into a concave surface **12** which terminates in a nose **13** that is circular in cross-section. This feature is found to be of considerable advantage in reducing turbulence. Such turbulence is found to be caused if the bottom part of the stopper is truly conical, whereas by shaping it as shown the stream of liquid metal leaving it has a hollow core and passes onwards down the bore **2** of the nozzle substantially without turbulence.

It is common practice to connect a stopper to a mechanism by which it can be lifted. Such a mechanism is diagrammatically shown in FIGURE 2, where the ladle is shown at **14**. The top of the stopper has a threaded recess **15** shown in FIGURE 1 for the reception of a lifting rod **16** which can be raised through a horizontal bar **17** and a vertical rod **18**, the rod **18** passing through guides **19** and **20**. A lever **21** is pivotally mounted at **22** in a bracket **23** fixed to the guide **20**, and is forked to engage a cross pin **24** which extends across the lower end of the shaft **18**. By rocking the lever **21** the rod can be lifted to lift the stopper. All this is conventional. Now in the invention is is highly desirable that the movement of the stopper should be restricted so that its nose **13** cannot come out of the bore of the nozzle. This result is easily achieved by providing means for so limiting the movement of mechanism that the stopper can never be lifted completely out of the bore. As shown, the rocking movement of the lever **21** is limited by the guide **20**, which it strikes at the top of its rocking stroke.

Control of the rate of teeming is desirable for all teeming processes, and assemblies according to the invention may be used for conventional teeming in air, or vacuum degassing processes, in which control is most important. The rate of teeming may be required to be changed constantly or stepwise, and it is simple to calibrate the positions of the stopper in relation to the nozzle in terms of rate of flow of liquid metal. One advantage of the accurate control of rate of teeming is that if the steel tapping temperature should depart from standard, small variations can be compensated for by alterations in the rate of teeming. Another advantage is that the number of different nozzles which must be kept in stock in order to be able to teem at different rates is reduced, since one size of nozzle can be used for any of several rates by appropriate setting of the nozzle.

While a present preferred embodiment of the invention has been illustrated and described it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied within the scope of the following claims.

What is claimed is:

1. A nozzle and stopper assembly for use in the teeming of liquid steel or other molten metal from a bottom-pour ladle in which the stopper penetrates deeply into the nozzle and the stopper and the bore of the nozzle are both at least partially frusto-conical and both have their frusto-conical surfaces tapering downwardly, the frusto-conical portion of the nozzle including a surface having a lesser included conical angle of taper than a corresponding portion of the stopper, so that the stopper, when lifted from

the nozzle, defines an annular space which increases in cross-sectional area as the stopper is raised to accurately control the flow of metal without turbulence, the stopper and the bore of the nozzle being shaped with small portions having the same included conical angles of taper to make contact with one another only over a small area of the stopper and the bore of the nozzle, the frusto-conical surface of the stopper merging into concave surface and terminating with a projecting nose which is circular in section to reduce turbulence, the bore of the nozzle being shaped such that the stopper does not increase in cross sectional area at any point below the area of contact in the closed position of the stopper and the bore of the nozzle does not increase in cross sectional area at any point below the termination of the frusto-conical surface, and an outwardly flaring surface of the nozzle immediately above the area of contact so as to avoid metal being trapped between the nozzle and stopper when the stopper is moved into the closed position during teeming.

2. An assembly as in claim **1** in which the nozzle is made of a refractory material and the green dried but unfired state.

3. An assembly as in claim **2** wherein the nozzle is made of dead burnt magnesite containing at least 85% magnesium oxide.

4. An assembly as in claim **2** wherein the stopper is made of a fired refractory material.

5. An assembly as in claim **1** further comprising mechanism for lifting the stopper including means for so limiting the movement of the mechanism that the stopper can never be completely lifted out of the bore of the nozzle.

References Cited

UNITED STATES PATENTS

2,051,509	8/1936	Wile	251—333 X
2,822,789	2/1958	Philps et al.	251—333 X
2,927,737	3/1960	Zeuch et al.	251—333 X
3,192,582	7/1965	Cope et al.	222—566 X

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U.S. Cl. X.R.

222—566; 251—333