

May 31, 1966

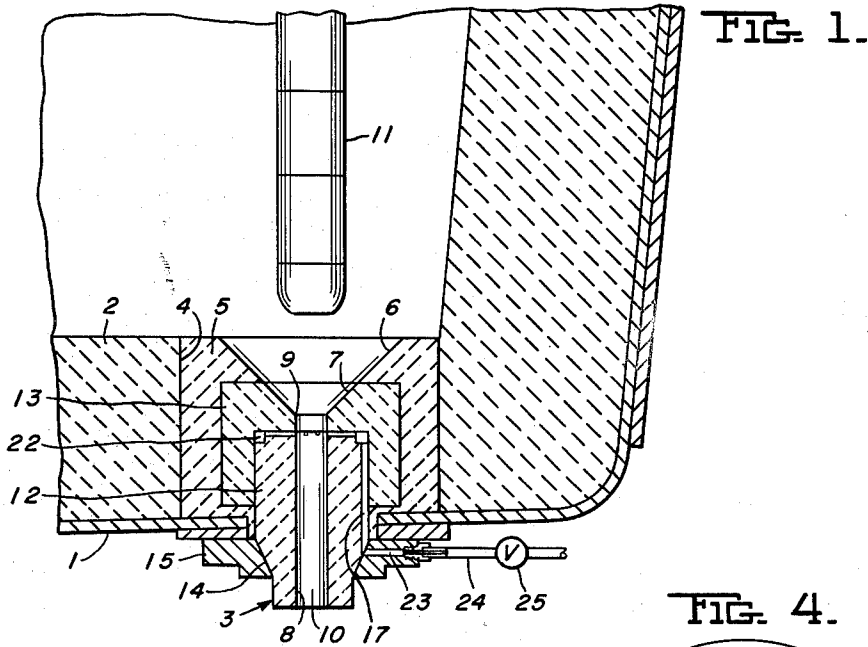
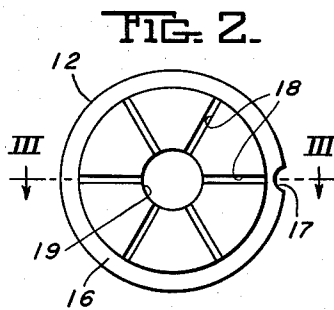
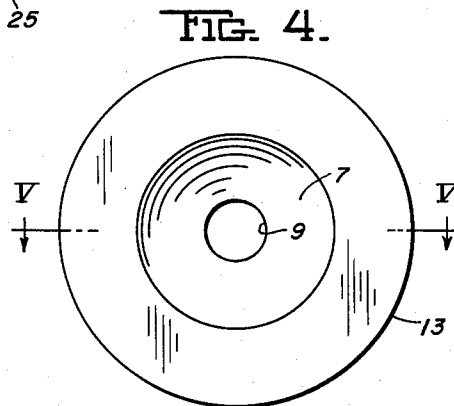
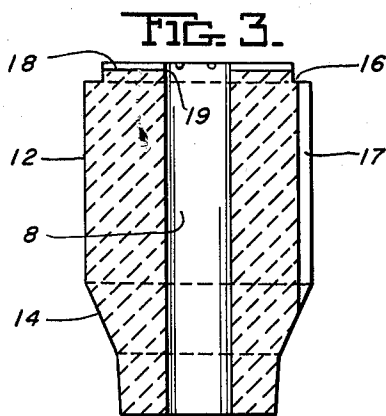
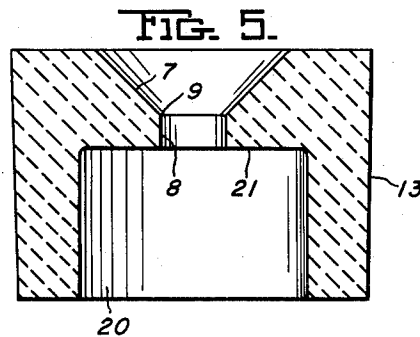
D. K. GRIFFITHS ETAL

3,253,307

METHOD AND APPARATUS FOR REGULATING MOLTEN METAL TEEMING RATES

Filed March 19, 1964

2 Sheets-Sheet 1



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FIG. 6.

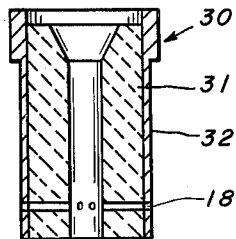


FIG. 7.

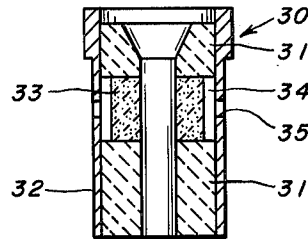
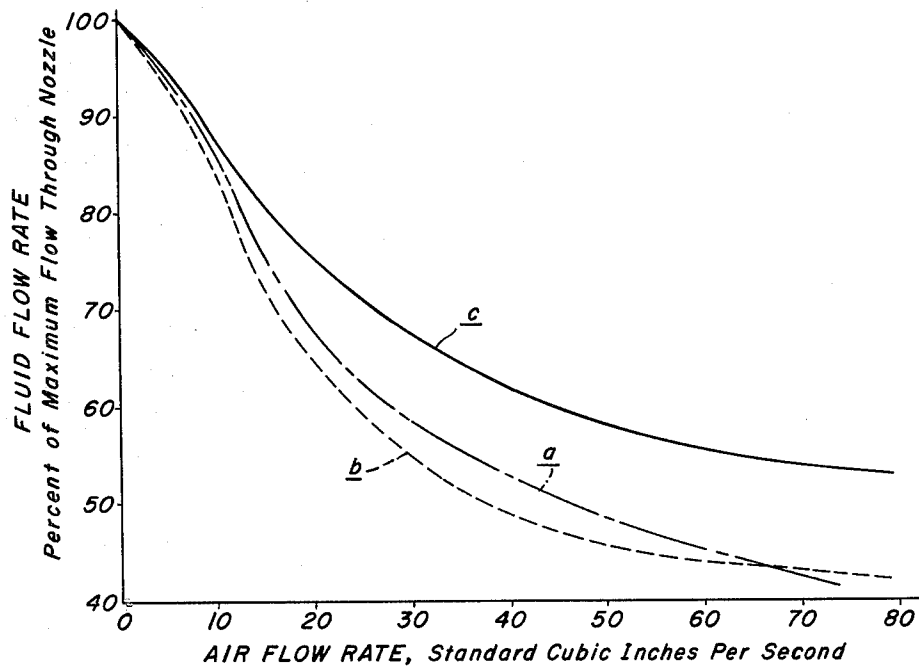


FIG. 8.



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METHOD AND APPARATUS FOR REGULATING
MOLTEN METAL TEEMING RATES

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This invention is directed to the problem of regulating the rate at which molten metal is discharged from a refractory-lined ladle or tundish and thus, for example, the rate at which it is delivered to continuous casting apparatus. As indicated, it relates to a method and apparatus for regulating the teeming rate at which molten metal is discharged through a nozzle orifice from a refractory-lined vessel.

The method and apparatus of this invention are especially adapted for continuous casting operations in which slabs, blooms or billets are cast directly from molten metal without the customary intermediate steps of casting ingots, soaking and rolling more commonly employed in their production. In such operations, molten metal is teemed into the top of special casting apparatus from the bottom of which the slabs or billets are withdrawn in the form of a solid steel shell with a liquid interior. Ideal casting conditions require that the molten metal be fed to the top of the apparatus at the same rate at which the solidified metal casting is removed from the bottom. While the use of a tundish between the ladle and casting apparatus has been proposed for obtaining a more uniform rate of delivery of the molten metal to the casting apparatus, there is nothing to restrict or regulate the discharge of metal from the tundish after its stopper rod has been opened. The tundish is thus subject to the same disadvantages that are encountered in teeming ladles, since it does not have any provision for retarding the delivery of molten metal to the casting apparatus when operating conditions call for a slower rate of metal feed.

An object of this invention accordingly is to regulate the rate at which molten metal is discharged from the teeming nozzle of a refractory-lined vessel, this being accomplished in a manner to be described by introducing compressed gas into the nozzle orifice to reduce the size of the stream of metal flowing therethrough and thus restrict or retard the rate at which the metal is discharged from the vessel. Although the use of pressurized gas for regulating or retarding the discharge of molten metal through a teeming nozzle has been proposed before, and forms the subject matter of copending application Serial No. 350,231, filed March 9, 1964 by James B. Wagstaff, now Patent No. 3,200,457, to which reference is made for a more detailed explanation of the principles involved, such regulation is effected by the method and apparatus of this invention without any mixing of the gas with the metal flowing through the nozzle. As will be apparent from the following description, this is accomplished by introducing the gas into the nozzle orifice through the sides of the nozzle and from an area or points distributed circumferentially about its inner surface and spaced below the upper end of the nozzle. In this manner the gas is applied uniformly around and against the outer surface of the stream of molten metal flowing through the nozzle orifice and operates to reduce the diameter of such stream and reduce the rate of metal discharge.

Other objects and advantages of the invention will become apparent from the following description and the accompanying drawings, in which:

FIGURE 1 is a vertical sectional view through a teeming nozzle constructed in accordance with the principles of this invention and illustrating its arrangement in a

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refractory-lined vessel, such as a ladle or tundish, for molten metal, the vessel being shown fragmentarily;

FIGURE 2 is a plan view of the lower part of the nozzle shown in FIGURE 1;

FIGURE 3 is a sectional view taken substantially along the line III—III of FIGURE 2;

FIGURE 4 is a plan view of the upper part of the nozzle shown in FIGURE 1;

FIGURE 5 is a sectional view taken substantially along the line V—V of FIGURE 4;

FIGURES 6 and 7 are vertical sectional views of modified nozzles used in laboratory studies of this invention; and

FIGURE 8 is a graph illustrating the manner in which the method and apparatus of this invention operate to regulate the flow of liquid through the nozzle orifice.

In the drawings, the numeral 1 designates the metal shell of a vessel for holding molten metal, such as a tundish or a ladle, which has a refractory lining 2 and a teeming nozzle 3 mounted in its bottom in a position concentrically with respect to aligned openings through the shell 1 and lining 2. An enlarged opening 4 in the refractory lining 2 has a rammed well 5 of refractory material about the nozzle 3. The well 5 has an upwardly facing conical recess 6 which forms a continuation of the surface of a conical well or depression 7 in the upper end of the nozzle 3. The nozzle 3 has a centrally located cylindrical bore 8 which intersects with the conical well 7 and defines a circle 9 at its point of intersection therewith. The conical well 7 and cylindrical bore 8 depending therefrom cooperate to provide a teeming orifice 10 through the nozzle 3. A stopper rod 11 has seating engagement at its lower end against the conical well 7 for stopping the flow of metal through the orifice 10. The structure thus far described is conventional.

In the preferred construction, as shown in FIGURES 1 through 5 of the drawings, the nozzle 3 is formed in two parts which include a lower part 12 and an upper part 13. The lower part 12 comprises a refractory cylindrical body in which the centrally arranged and axially extending bore 8 is formed and has a tapered outer surface 14 by which it is supported on a mounting plate 15 that is welded in position on the bottom of the ladle shell 1. The upper end of the body 12 has a groove 16 that extends circumferentially about its outer periphery and a groove 17 that extends axially along its outer side surface from the tapered surface 14 to its upper end where it intersects with the top groove 16. The upper end of the body 12 further has a plurality of radially extending grooves 18, preferably six in number, that extend from the peripheral groove 16 and open through the inner surface 19 of the cylindrical bore 8. The upper part 13 of the nozzle 3 has a cup-shape with the conical well 7 and a portion of the cylindrical bore 8 formed in one end thereof and an enlarged cylindrical opening 20 at its other end that provides for its being fitted telescopically over the upper end of the nozzle portion 12 as shown in FIGURE 1. When the nozzle part 13 is fitted on the lower nozzle part 12 in this manner, its end surface 21 cooperates with the groove 16 in the upper end of the nozzle 12 to form a manifold 22 extending circumferentially about the upper end of the nozzle part 12 through which gas is supplied to the radially extending passages 18. Gas is supplied to the manifold 22 through the side groove 17 which has its lower end connected with a passage 23 through the mounting plate 15. Gas under pressure is delivered to the passage 23 by a conduit 24 which is connected with a source (not shown) of gas under pressure. The gas admitted to the passage 23 is delivered through the side groove 17, manifold 22 and radially extending grooves 18 to the interior of the nozzle orifice 10 and its rate of flow is controlled by a throttle valve 25 in the conduit 24.

After the stopper rod 11 is elevated to its open position, the rate at which metal teems through the orifice 10 may be retarded by operating the throttle valve 25 to admit gas through the passages 17, 22 and 18 into the orifice 10. The gas delivered by the passages 18 into the orifice 10 is applied uniformly and circumferentially about the outer surface of the stream of metal flowing through the orifice 10 and operates to reduce the diameter of such stream. The reduction in diameter of the stream of teeming metal and corresponding decrease in rate of metal discharge is determined by the rate at which gas is admitted by the valve 25 to the orifice 10. In laboratory apparatus using water as a liquid, the gas jets from the passages 18 were observed to form a restriction in the nozzle similar to the diaphragm in a camera.

Generally stated, increases in the rate of gas flow through the passages 18 operate to decrease the teeming flow of metal through the orifice 10. For example, the teeming time of a laboratory-size heat of 500 pounds of molten metal through a one inch nozzle without any regulation was 30 seconds and was extended to 87 seconds by admitting gas to the nozzle orifice 10 at a constant rate of 6.6 standard cubic feet (s.c.f.) of gas per minute, which constitutes a gas flow rate of 38.2 s.c.f. of gas per ton of steel. Further increases in the gas flow rate were found to reduce the teeming rate and extend the teeming time for a longer period. The gas flow rate should of course be kept below that at which it produces irregularity or breakup of the streamline flow of the metal teeming through the nozzle 10 and thus spraying of the metal after it leaves the nozzle.

The flow of gas should be continuous during teeming, since molten metal flowing into the passages 18 can freeze and block such passages. A slow gas bleed is sufficient to prevent this and keep the passages 18 open for the admission of gas when control is necessary. For this purpose a conventional throttle valve adjusted to provide a slow gas bleed in its off position to the supply passages 17 and 22 may be used. As set forth in E. A. Nirmaier and James B. Wagstaff Patent No. 2,866,241, a gas bleed of this type into the orifice 10 through the passages 18 will also operate to provide a streamline flow of the metal in the orifice 10 by preventing negative pressures and turbulence due to cavitation of the metal stream flowing therethrough.

Any of a number of different gases depending on the grade of steel may be used for controlling the rate of metal flow. An inert gas such as argon is recommended for critical grades. Nitrogen is more economical but can not be used if it is detrimental to steel quality. Compressed air is not recommended in most cases, since oxidation would possibly overheat the steel and form non-metallic inclusions in the steel.

In the preferred construction described above, the gas passage openings 18 are located at the upper end of the nozzle orifice in a position below the lower end 9 of the well 7 roughly opposite the vena contracta of the stream of metal teeming downwardly from orifice 9 at the bottom of the well 7. In this respect laboratory investigations have shown that best results are obtained when the jets 18 are located below the upper end of the nozzle a distance not greater than twice the diameter of the orifice, but that good results are obtained with openings 18 at any location along the length of the orifice 10. Such investigations were made with nozzles 30 constructed, as shown in FIGURES 6 and 7, from molded refractory material 31 in a steel shell 32 and having axial length of 7 inches and an orifice 10 that had a diameter of $\frac{3}{4}$ inch. The nozzles 30 were mounted in the bottom of a plastic box containing the water discharged through the nozzles and gas was supplied to the passages 18 through tubes (not shown) that were connected with openings in the shell 32. From data obtained during these investigations, the graphs of FIGURE 8 were prepared. In this showing the curves *a* and *b* illustrate the results that

were obtained with the gas passage openings 18 adjacent the top of the orifice 10 as in FIGURE 1, and the curve *c* shows the results obtained with the passages 18 adjacent the bottom of the nozzle as shown in FIGURE 6. In the nozzles used in obtaining the data for curves *a* and *c*, the diameter of passages 18 was $\frac{1}{8}$ inch, while the passages 18 had a diameter of $\frac{1}{16}$ inch in the nozzle used for the preparation of curve *b*. These studies indicated that the size and shape of the passages 18 did not materially affect the results obtained. Comparison of the curves *a* and *c* shows that better control was provided by location of the jets 18 at the top of the nozzle corresponding to the location shown in FIGURE 1, and comparison of the curves *a* and *b* shows that the $\frac{1}{16}$ inch diameter jets 18 were slightly more effective than those of other sizes. The effect of passages 18 having a rectangular cross-section was also examined, but did not produce any advantage. Models in which the passages 18 extended generally tangential to the inner surface of the orifice 10 were examined, but tended to rotate the stream and cause it to break up or splatter, a condition which would be undesirable in teeming metal. All curves show that the reduction in discharge of liquid through the nozzle increased with increasing rates of gas flow.

In the nozzle shown in FIGURE 7, a porous plug 33 was used in place of the radial extending passages 18 for delivering gas to the orifice 10. The plug 33 was placed in the sleeve 32 between the upper and lower valve parts 31 and had an outer diameter less than the diameter of the sleeve 32 to provide a manifold 34 into which gas under pressure was fed through openings 35 in the sleeve 32 by gas supply tubes (not shown). Gas thus fed to the manifold 34 diffused through the plug 33 into the orifice 10. The use of a porous plug 33 in this manner resulted in a flow curve similar to those shown in FIGURE 8 and which occupied a position roughly between the curves *a* and *b*.

From the foregoing it will be apparent that the method and apparatus of this invention provide for regulating the flow of fluid through a vertically extending orifice. Attention is particularly directed to the fact that such regulation is effected solely by gas introduced under pressure into the nozzle orifice at a point spaced from the inner end of the nozzle, and that the rate of flow of the liquid can be varied by varying the rate at which the gas is introduced into the nozzle. The invention in these respects is, moreover, especially adapted for regulating the teeming discharge of molten metal through a ladle nozzle, attention being directed particularly to the fact that the introduction of gas into the nozzle uniformly about the circumference of its inner surface and at a point spaced from its inner end enables the regulation without any tendency of irregularly or breakup of the teeming stream of metal which would otherwise cause splashing of the metal as it is delivered to the molding apparatus.

While several embodiments of our invention have been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

We claim:

1. A method of regulating the discharge of liquid through a cylindrical nozzle orifice in the bottom of a container which comprises injecting gas under pressure into said orifice at a point below its upper end to restrict the rate at which the liquid will flow through said orifice.
2. The method defined in claim 1 characterized by said gas being injected into said orifice in a radial direction toward the center thereof.
3. The method defined in claim 2 characterized by said gas being projected uniformly and circumferentially against the stream of liquid flowing through said orifice and in such manner that it operates to reduce the diameter of said liquid stream.

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4. The method defined in claim 3 characterized by said gas being projected in the form of a plurality of jets respectively arranged at circumferentially spaced points about said nozzle.

5. A method of regulating the rate at which molten metal teems through a cylindrical nozzle orifice in the bottom of a refractory-lined ladle which comprises forcing gas under pressure into said nozzle at a point below its upper end, said gas being projected radially inwardly about the circumference of said nozzle against the stream of metal teeming through said nozzle in such manner that it operates to reduce the diameter of stream and thereby the rate of discharge of metal from said ladle.

6. The method defined in claim 5 characterized by projecting said gas into said nozzle in the form of a plurality of jets at circumferentially spaced intervals about said nozzle.

7. The method defined in claim 5 characterized by varying the rate at which said gas is forced into said ladle to vary the rate of metal discharge from said ladle.

8. Apparatus for regulating the discharge of molten metal through a teeming orifice in the bottom of a refractory-lined ladle comprising the combination with a refractory nozzle defining said orifice, of means providing a gas passage opening through the side of said nozzle for the delivery of gas into said orifice at a point below the upper end thereof, and means for controlling the rate at which metal flows through said discharge orifice comprising means for supplying gas under pressure to said gas passage means, and a throttle valve in said supply means for regulating the gas delivered into said orifice to thereby regulate the rate at which molten metal teems through said orifice.

9. Apparatus as defined in claim 8 characterized by said gas passage means comprising a plurality of radially extending passages arranged at circumferentially spaced intervals about said nozzle, each of said passages having a discharge orifice at the inner surface of said nozzle, the arrangement of said passages being such that the gas is applied circumferentially to the stream of metal flowing through said nozzle orifice and operates to reduce its diameter and to restrict its rate of flow.

10. Apparatus as defined in claim 9 characterized by said gas passage discharge orifices being arranged in a

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common plane and being located below the upper end of said teeming orifice a distance such that they are opposite the vena contracta of the stream of metal flowing through said teeming nozzle orifice.

11. Apparatus as defined in claim 8 characterized by said gas passage means comprising a porous refractory ring that forms a part of said nozzle and through which said gas diffuses into said teeming orifice.

12. Apparatus for regulating the discharge of molten metal through a teeming orifice in the bottom of a refractory-lined ladle comprising a refractory nozzle defining said orifice, said nozzle comprising a lower part of cylindrical shape with a central bore therein forming the lower end of said orifice, the upper end of said lower part having a circumferentially extending groove about its periphery and a plurality of grooves extending radially inwardly from said peripheral groove and opening into said bore, and a cup-shaped upper part fitted over said lower part and having a central bore forming the upper end of said orifice, said upper part cooperating with said lower part to render said peripheral groove effective as a manifold for supplying gas to each of said radial grooves for movement therethrough into said orifice, means for supplying gas under pressure to said manifold for delivery through said radial grooves into said orifice, the gas delivered through said radial grooves into said orifice operating to reduce the diameter of the stream of metal flowing there-through, and means for regulating the gas delivered to said manifold to regulate the rate at which molten metal teems through said orifice.

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