Nov. 13, 1951 O. SMALLEY 2,574,764

PROCESS FOR THE INCORPORATION OF ADDITIVES INTO MOLTEN METAL

Filed Oct. 6, 1949 3 Sheets-Sheet 1

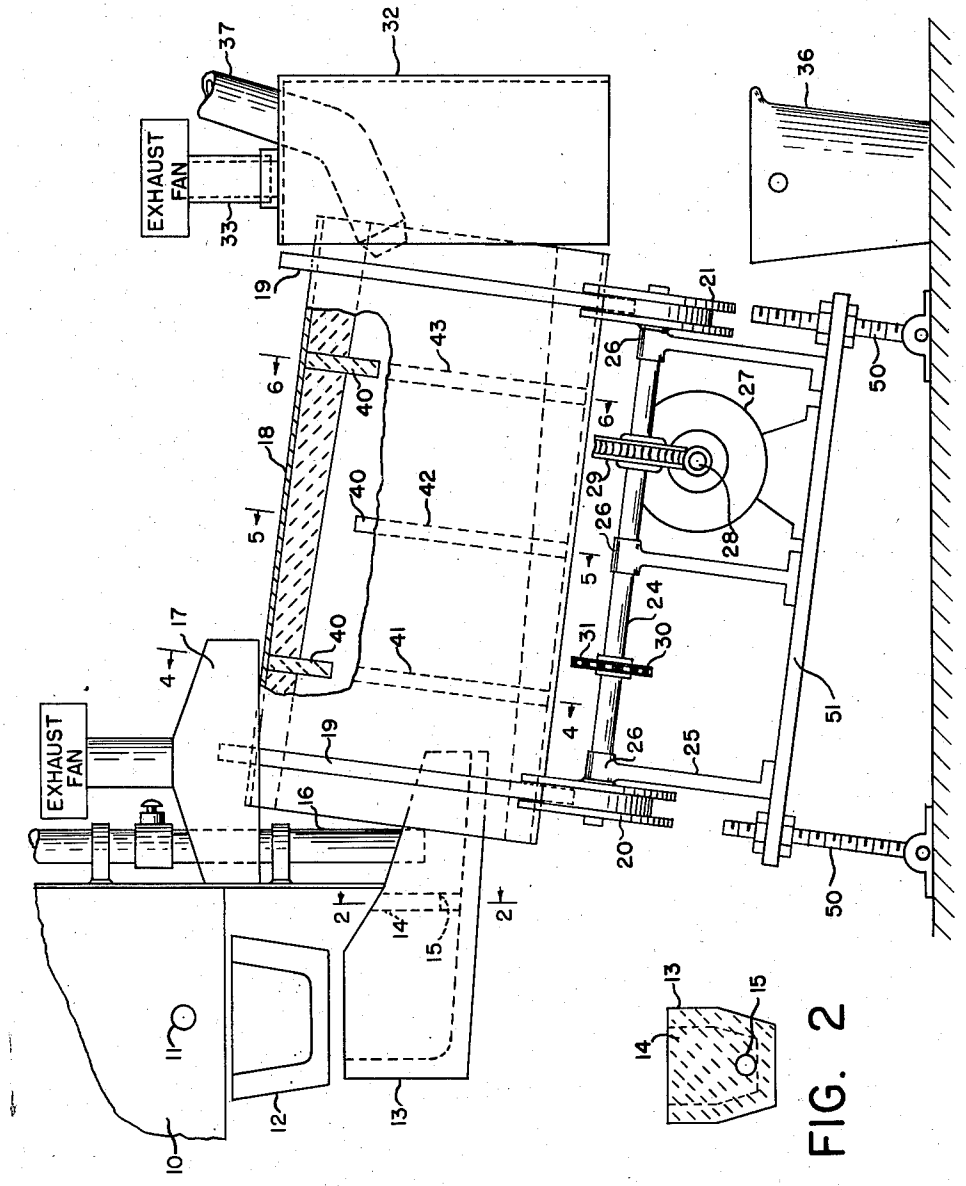



FIG. 1



FIG. 2

INVENTOR.
OLIVER SMALLEY

BY
Woodling and Kroost
attys

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PROCESS FOR THE INCORPORATION OF ADDITIVES INTO MOLTEN METAL

Filed Oct. 6, 1949 3 Sheets-Sheet 2

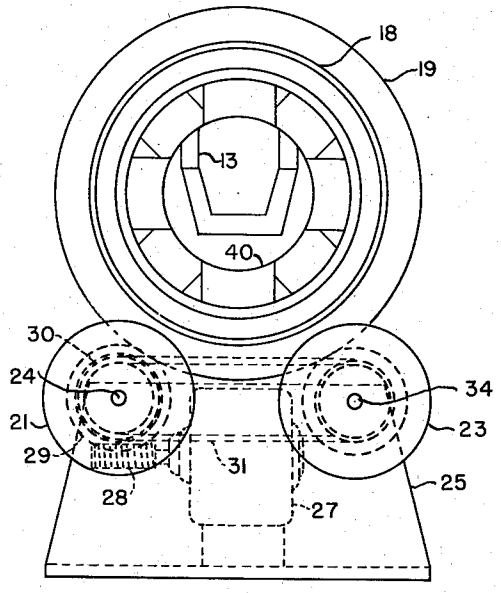



FIG. 3

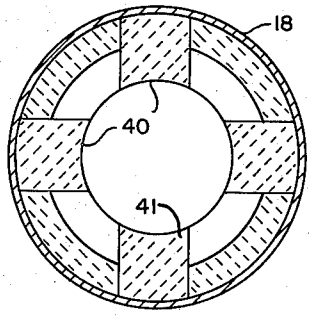



FIG. 4

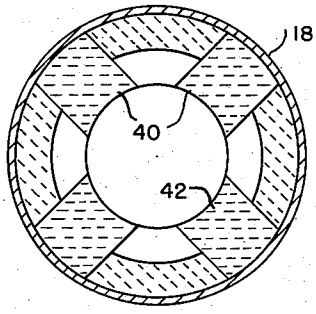



FIG. 5

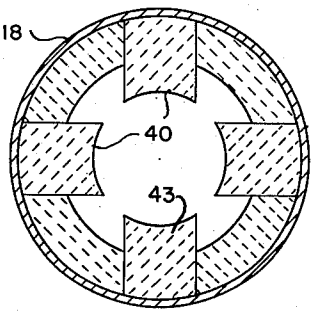



FIG. 6

*INVENTOR.*
OLIVER SMALLEY

*BY*
Woodling and Kroost
attys

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PROCESS FOR THE INCORPORATION OF ADDITIVES INTO MOLTEN METAL

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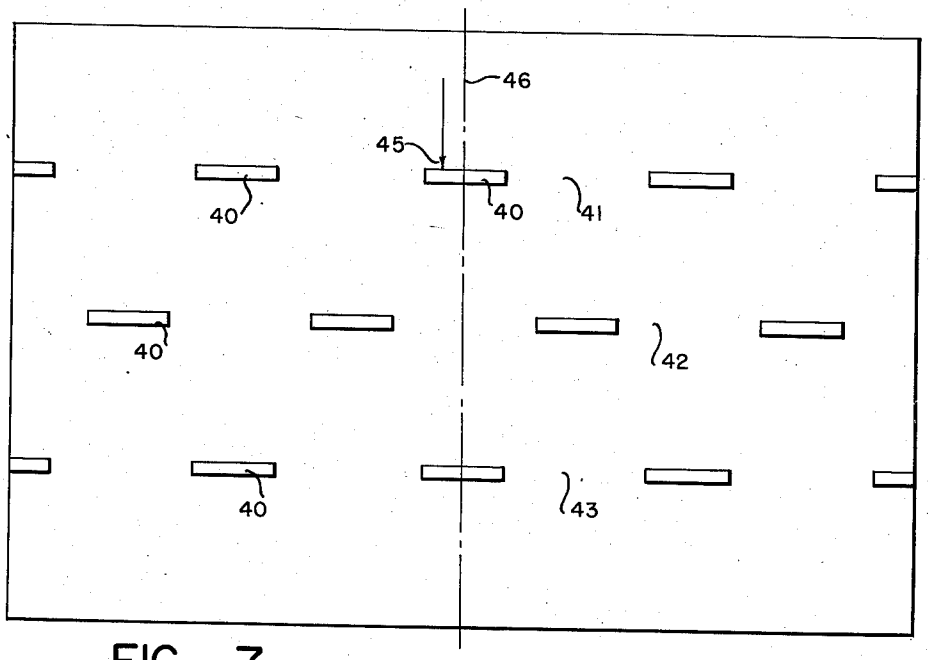



FIG. 7

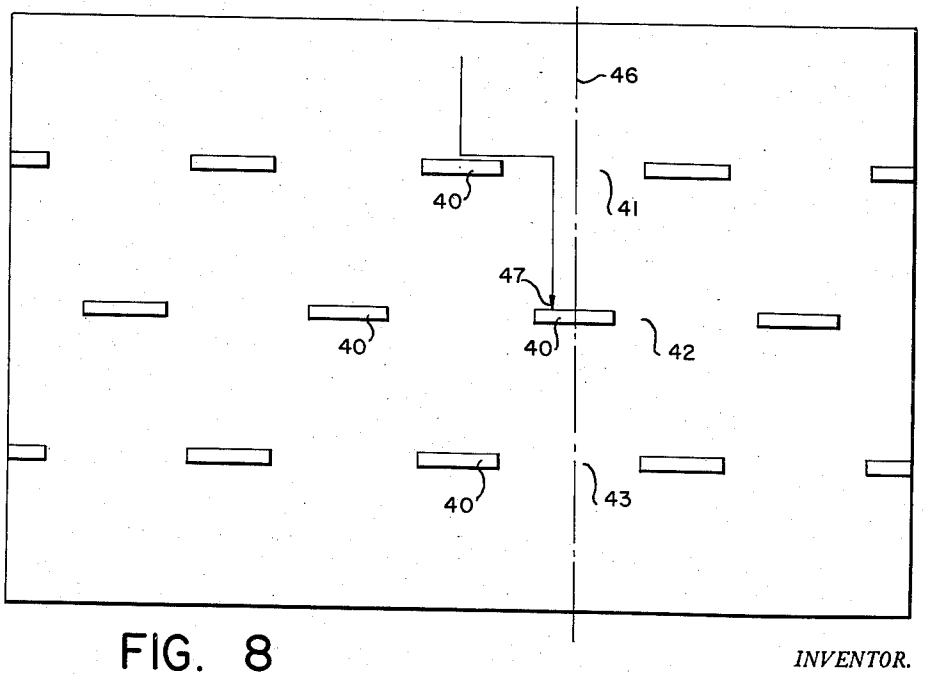



FIG. 8

INVENTOR.
OLIVER SMALLEY

BY Woodling and Kroost
attys

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# UNITED STATES PATENT OFFICE

2,574,764

## PROCESS FOR THE INCORPORATION OF ADDITIVES INTO MOLTEN METAL

Oliver Smalley, Larchmont, N. Y., assignor to Meehanite Metal Corporation, a corporation of Tennessee

Application October 6, 1949, Serial No. 119,857

2 Claims. (Cl. 75—61)

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This invention relates generally to the production of nodular cast iron, but relates specifically to improved methods and apparatus for the introduction of highly volatile and refractory additives to molten metal of all types and for all purposes.

At the outset, it is to be understood that there are various mechanical means known which are used to stir pots or ladles of molten metal for various purposes, including the mixing of alloying agents, and that apparatus is available for mixing additives into molten metal by taking advantage of natural laws. The latter devices include production of a vortex over an escape opening and dropping powdered alloying metal at the vortex, and another method comprises pouring molten metal and the alloying metal into a reduced-area passageway leading to the bottom of a ladle. By the last method the alloying metal is carried to the bottom of a pool of molten metal and is distributed as it tends to rise.

In the production of nodular cast iron, and in other metallurgical processes, highly volatile and refractory additives are useful to produce improved properties in castings. However, the commercial production of metals alloyed with such agents has been seriously hampered, because the amounts of the volatile and refractory additives must be comparatively large in commercial operations. When such large additions are attempted by the methods, and with the equipment, known and used heretofore, serious loss of alloy, incomplete incorporation, and heavy fumes are encountered. On a laboratory scale, of course, experiments can be readily carried on to learn what additives would be desirable, and no real problems arise because of the very small amount of volatile and explosive additive used. When full-scale production is attempted, however, quite serious problems are encountered.

Specifically, it is common practice to add volatile materials directly to a ladle of iron for the purpose of purification of the cast iron, with subsequent improvement of graphite structure in physical properties. The addition of volatile materials such as magnesium or alloys of magnesium, is accompanied by intense burning and the evolution of gaseous products under pressure. Because these materials ignite at the temperature of molten cast iron, the instantaneous addition of a quantity of magnesium or similar volatile and inflammable material to the ladle of metal may be dangerous. It is not uncommon for the addition to be accompanied by an explosion and by the evolution of a tremendous quantity of heat.

Furthermore, since the materials are volatile

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their addition to the surface of a ladle of metal does not allow intimate contact with the whole body of metal, and therefore it is practically impossible to completely control the effect of the addition. For example, a laboratory experiment may determine that a particular given percentage of magnesium or magnesium alloy is beneficial for improving the properties of a cast iron. The amount necessary for addition to a ladle filled with such cast iron can be calculated and an additional amount added to make up the usual losses to be expected, and that calculated amount of the additive is then thrown into a ladle. If the operator is fortunate enough to get the additive below the surface of the iron before it completely volatilizes and burns, nevertheless he may not be able to distribute the additive evenly throughout the metal by simply stirring the entire ladle. Further, although alloying additive practice may frequently be theoretically discussed, a practical point often overlooked is that the ladle of molten iron is rapidly cooling as long as it is in the ladle, and therefore the time available for adding the alloying additive is extremely limited if the casting to be made is poured before the cast iron becomes too cold for maximum desirable properties.

Therefore, an object of this invention is to provide an improved method of incorporating volatile and refractory agents into molten metal.

Another object of this invention is to provide a commercial method and apparatus for mechanically controlling the feeding of meta-carbide stabilizing agents with or without the addition of graphitizing agents to a stream of molten iron coordinated with the flow rate of the iron, without loss of temperature, in order that the iron will be sufficiently hot and castings may be poured from the molten metal after the metal has been treated.

Another object of this invention is to provide a stream of molten metal flowing at a constant rate, and intermittently interrupting the stream with a series of moving baffles, to cause turbulence and mixing of the stream.

And another object of this invention is to produce a stream of molten cast iron and add volatile and refractory alloying agents at a rate relative to the rate of flow of the cast iron, thereby reducing the mass of alloying additive entering the molten iron at a given time to a minimum, and yet fully incorporating the alloy into the iron before the iron can cool below good casting temperature.

Another object of this invention is to provide apparatus for producing a stream of molten metal flowing at a regulated rate, with means

to add alloying agents at a selected point in the stream, and mechanical tumbling stirring means immediately downstream therefrom, to cascade and interrupt the metal stream and secure complete control over the incorporation of the alloy into the molten metal without appreciable loss of temperature.

A further object of this invention is to provide an improved tumbler stirring mechanism for mixing cast iron with alloying agents and other additives as they flow from a furnace.

Still another object of this invention is to provide an improved tumbler for use in metallurgical mixing, wherein the tumbler may either rotate continuously or oscillate about its longitudinal axis, and move a plurality of baffle vanes across the path of the metal flow.

Other objects and a fuller understanding of this invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a side elevation of a short-length model of the improved apparatus embodying the features of this invention;

Figure 2 is a section taken along line 2—2 of Figure 1;

Figure 3 is an end view, with the exhaust hood removed, of the apparatus of Figure 1, looking from the discharge end toward the entrance end;

Figure 4 is a section taken along line 4—4 of Figure 1;

Figure 5 is a section taken along line 5—5 of Figure 1;

Figure 6 is a section taken along line 6—6 of Figure 1;

Figure 7 is a developed view illustrating the tumbler split open at the top of Figure 4 and drawn as a flat member with a reference line indicating the bottom of the tumbler in the particular rotary position to illustrate the relative positions of the baffle vanes; and

Figure 8 is the same view as Figure 7, but having the reference line moved laterally to illustrate the effect of rotational movement upon the position of the baffle vanes with respect to the flow of metal through the tumbler.

The mechanical apparatus illustrated in the drawings has been developed to carry out the principles of this invention. The apparatus may be called an incorporator, and is either mobile for use with a plurality of separate cupola furnaces, or may be stationarily mounted with respect to one particular cupola.

The illustrated incorporator comprises generally a cylindrical barrel tumbler 18 having circular tracks 19 circumferentially therearound at each end.

The tumbler 18 is preferably more than twice as long as the diameter, and may be increased to any length according to the nature of the material to be added, considering such characteristics as refractoriness and the characteristics and temperature of the molten metal to be treated. In some cases the length of the cylinder may be twenty times the diameter according to the effect to be produced. The diameter of the tumbler 18 is governed by the quantity of molten metal to be treated and the speed of rotation or oscillation of the tumbler. It is preferred that the diameter should not be any larger than is necessary to produce effective cascading and mixing. The tumbler 18 is supported and rotated about its longitudinal axis by a combined drive and support. The drive and support includes legs 25 supporting a



longitudinal drive shaft 24. Bearings 26 rotatably support the shaft 24 on the legs 25. A second shaft 34 is supported parallel to shaft 24 in the same manner. However, shaft 24 in the illustrated embodiment is the primary drive shaft, and is driven directly by a motor 27 through a worm 28 and worm gear 29, whereas shaft 34 is the secondary drive shaft and is driven from shaft 24 by a sprocket 30 and a chain 31. A sprocket, similar to sprocket 30, is adapted to drive secondary shaft 34 from chain 31.

Each of the shafts 24 and 34 are equipped on the ends thereof with flanged rollers. In the drawings, only rollers 20, 21, and 23 can be seen, the fourth roller being behind roller 20 in Figure 1, and behind roller 23 in Figure 3. The rollers form a four-point support for the tumbler 18, with tracks 19 running in the flanges of the rollers. Therefore, the rollers not only support the tumbler 18, but rotatably drive the tumbler. The speed of the motor 27 may be varied to control the rotational speed of the tumber 18, or if desired, a transmission may be used.

Furthermore, it has been found that the incorporation may be effectively accomplished by oscillating the tumbler 18 through 180 degrees of oscillation rather than by producing a continuous rotation. Therefore, a suitable mechanism may be incorporated to drive the shafts 24 and 34 with oscillating motion rather than continuous drive motion.

The speed of rotation of the tumbler 18 should be such as to overcome gravity up to substantially 180 degrees of rotation. That is, the speed should preferably be such that the molten stream will be carried up the side of the internal surface of the tumbler 18, but the speed must not be such as to completely overcome gravity and cause the molten metal to cling to the internal wall through a complete revolution. A speed control device is used so that the speed of rotation can be adjusted according to the quantity of metal to be treated, the angle of slope of the tumbler, and the design and arrangement of any baffles which may be used. Speed is not critical, but it must be sufficiently slow that it will not throw the molten stream against the internal walls with sufficient centrifugal force to cause the molten metal to adhere on the internal wall. It must be sufficiently slow to permit slipping of the metal with a raining or cascading action. It should, however, be such as to overcome the force of gravity up to as much as 180 degrees, in order to produce effective mixing. Gravity acts with a constant magnitude and in a vertical direction. The length of the cylinder and its angle of spinning and its diameter are factors in determining the speed to produce proper stirring.

A portion of a metallurgical furnace, such as a cupola, is indicated by the reference character 10 in Figure 1 of the drawings. The cupola 10 is provided with a tap hole 11 of conventional design. For convenience of illustration, the tumbler 18 is shown at an angle to the direction of tap hole 11, and two trough members 12 and 13 are provided to deliver the flow of molten metal from cupola 10 to the tumbler 18.

The trough 12 is of conventional design and is used merely to direct the flow of metal. The trough 13, however, is provided with a wall 14 to dam the metal, and the wall has an orifice 15 therethrough of predetermined size. It is to be understood that one such trough can be used alone, rather than the two as illustrated. Those skilled in furnace operation are familiar with the

fact that gas pressure within the furnace, and the depth of the molten metal collected, will vary the rate of metal flow from the cupola 10, and therefore the metal is collected behind the wall 14 and allowed to flow at a fairly constant rate through the orifice 15. The rate will not be absolutely constant, of course, because the liquid height behind wall 14 will vary, but the variation is not appreciable as compared to the direct feed from the cupola, and is satisfactory for the purposes of this invention.

One phase of this invention is the incorporation of additives into a flowing stream of metal at a rate which is related to the rate of metal flow past a given point where the additives are injected. The orifice 15 provides a substantially constant flow at any selected rate, and can be varied in size by partially plugging the orifice. Therefore, the amount of metal passing through the orifice at any moment can readily be determined and controlled. Knowing the rate of metal flow, the additive material, whether it be alloying agent or flux, can be added to the controlled stream at a slow, even rate. In the drawings, the feed pipe 16 of a suitable feeding device is provided to measure and direct the additive material to the stream in trough 13; thus, each increment of flowing metal is supplied with correct amount of additive. A hood 17 is provided over the trough 13 to remove any gases and fumes which may be produced at the instant of contact of the additive with the molten metal.

The tumbler 18, as illustrated, is open at both ends, and from the illustration it will be seen that the trough 13 extends into the forward open end of the tumbler. The molten metal and the incompletely incorporated additive are directed into the tumbler 18 immediately after the additive is injected.

I have discovered that excellent incorporation of additive material into a molten stream of metal can be accomplished by taking advantage of the surface friction of the inside of the tumbler with the molten metal. Therefore, by rotating the tumbler at a sufficient rate of speed, the bottom portion of the stream is actually pulled out from under the body of the metal stream and gently cascaded into the top of the stream, thereby producing a rapid and effective, although gentle, form of mixing to produce complete incorporation of the additive material into the molten metal. In some metals, and with some types of additive materials, however, I have found that more vigorous stirring for a longer period of time is decidedly beneficial, and therefore have provided a further feature of my invention in that baffle vanes 40 are used.

Therefore, my invention comprises a longitudinal tumbler barrel adapted to rotate at a sufficient rate to mix the stream of molten metal with the additive material as it flows through the tumbler, and also includes the provision of laterally extending baffle vanes 40 in the tumbler to interrupt the longitudinal flow of metal momentarily and cause a more violent churning action.

As previously stated, the length of the tumbler should be at least twice as long as the diameter and in some instances may be as much as 20 times the diameter according to the effect to be produced. In the drawings, the minimum length tumbler has been illustrated, and in this minimum length tumbler three longitudinally spaced rows of baffles 40 are illustrated. These rows are numbered 41, 42 and 43. The baffles may be formed by embedding refractory blocks



in a refractory lining, as illustrated, or by molding a solid baked refractory unit which may be inserted into a shell. In Figures 7 and 8 the tumbler 18 has been drawn as a flat sheet substantially as if the tumbler had been split longitudinally along the top and laid open flat upon the sheet. The lateral dimension in Figures 7 and 8 is the circumference of the tumbler illustrated in Figure 1, and the longitudinal length is the normal minimum length with respect to the circumference chosen for illustration. The length of the tumbler illustrated in Figure 1 is slightly more than twice the diameter, and the Figures 7 and 8 are drawn to the same scale as the Figure 1. It is clearly to be understood that the tumbler illustrated in the drawings is substantially a minimum length tumbler, but that the maximum length is determined only by the need of a particular type of metal and additive material.

In the Figures 7 and 8 it can be seen that the baffle vanes 40 in each of the rows 41, 42 and 43 are laterally staggered in order to avoid any open path directly through the tumbler. Therefore, when violent agitation and stirring is necessary the baffles 40 will act momentarily as dams, causing a sudden stopping of the metal flow and therefore producing an additional stirring by the momentum force within the stream itself. In Figure 7 an arrow 45 is drawn directly beside a reference line 46. The reference line 46 is provided for convenience of illustrating the fact that the Figure 8 represents a rotational shift of the tumbler with respect to the position illustrated in Figure 7. It will be seen that the reference line 46 has been laterally shifted in the Figure 8. The arrow 45 indicates that metal flowing along the bottom of the tumbler 18 will impinge upon the baffle vane 40 and be momentarily stopped in its flow. However, the tumbler 18 is continuously rotating, and therefore the baffle vane 40 which has stopped the flow of metal in the instant illustrated in the Figure 7, is now moved laterally in Figure 8, and the stream of metal then flows down the side wall of the tumbler attempting to gain the lowermost position in the tumbler, and is therefore freed from interference in its longitudinal flow and will follow a path substantially as illustrated by the arrow line 47 in Figure 8.

By using the baffle vanes 40 to interrupt the flow of metal, the molten stream is subject for a longer period of time to the rolling action of the tumbler, and furthermore the baffle vanes 40 will be cut through the molten stream and will also tend to splash and mix the molten stream. It is to be understood that the primary mixing is caused by the "kneading" action produced by the friction of the tumbler lining with the metal stream, pulling the bottom portion of the metal stream out and splashing it back into the top of the stream, and that the baffle vanes are added in the event that a more prolonged and violent stirring action is required due to the circumstances of a particular metal or additive material which cannot be incorporated by gentle stirring.

It has been found that in normal operation upon a wide variety of molten metals, the speed of revolution of the tumbler without baffles is most desirable at less than 10 revolutions per second, but that less than 5 revolutions per second are preferable when the baffle vanes 40 are employed. The exterior shell of the tumbler 18 is preferably a cylinder, and the interior lining

may then be built to any desired form and may be cylindrical, conical, polygonal, or cruciform, or it may be a modification or a combination of these. In the illustrated embodiment the interior lining has been built up into a conical form with the large end placed toward the stream of metal as it leaves the furnace, and the entire tumbler is set at an angle such that the resulting internal surface will be about ten degrees slope away from the furnace. Any suitable method may be used to adjust the angle at which the longitudinal axis of the tumbler is disposed with reference to the horizontal, and for this purpose a base member 51 is illustrated as being adjustably supported upon adjustment screw legs 50. As a general rule, the angle of the interior lining upon which the molten metal flows through the tumbler should vary between two degrees and fifteen degrees, whether produced by building up the interior lining or by tilting of the entire apparatus.

Although the baffle vanes 40 have been illustrated in longitudinally spaced rows with the baffles staggered with respect to the next adjacent row and thereby produce a maze, it has been found that when baffles are employed, they may also be placed at various angles one with another, or they may be continuous to certain lengths or any form that will assure breaking up and cascading metal and additive material with maximum effect when the cylinder is either under a rotational or oscillating movement.

At the exit end of the tumbler 18 is a hood 32 and an exhaust stack 33 to carry off fumes and dust from the additive step. Also, in order to preheat the tumbler 18 and to add heat to the stream of molten metal, a gas jet 37 is directed into the exit end of the tumbler 18.

The illustrated preferred embodiment of the apparatus may be used to carry out the new process developed for incorporating volatile and explosive additives, and high melting point additives, to molten metal with a minimum of loss and danger, coupled with the maximum incorporation of additives into the molten metal. These accomplishments can be obtained because the amount of additive supplied to the molten metal in a given period of time is reduced to an extremely low value, and therefore the explosive and volatile nature of the additive is reduced to a useful minimum. In other words, the molten metal is conducted in a stream which is deep enough to permit thorough agitation for mixing the additive into the molten metal, but the amount of molten metal and volatile additive coming into contact at one instantaneous period of time is considerably less than by the method of adding the entire amount of alloy to a ladle containing a full body of the molten metal.

By adjusting the rate of flow of the metal from the cupola furnace and through the tumbler 18, and by simultaneously adjusting the rate of addition of the alloying agents, and also simultaneously controlling the speed of rotation of tumbler 18, it has been found that the addition can be made conveniently with complete success and very little loss of the additive material.

As an example, it has been found that the rate of flow of the molten metal from the cupola furnace may be between 300 pounds per minute and 4000 pounds per minute, but it is preferable to keep the flow rate between 500 and 1500 pounds per minute. Also, the rate of flow of the alloying additive may be varied between 1 pound and 120 pounds per minute, but it is preferably kept between 5 and 45 pounds per minute, depending upon the severity of action of the additive material when applied to the molten metal.

Many metallurgical compositions have been developed for the production of nodular and other types of iron, as well as producing various types of alloys, and cleansing various types of alloys. These processes and products are well known and need no extensive elaboration to explain the value of the invention disclosed herein, but probably the most outstanding example of explosive alloying material is the addition of certain basic earth metals or alloys, such as magnesium and lithium, to molten cast iron for the purpose of producing nodular cast iron. These materials, of course, will ignite at the temperature of molten iron, and will tend to float on the top of the molten iron and thus prevent their incorporation with the mass. Furthermore, even if a quantity of the volatile additives were plunged below the surface of a ladle of molten iron, the high volatile nature of the material at the temperature of the molten iron will prevent thorough mixing and distribution of the metal or alloy without considerable stirring to circulate the molten iron throughout the ladle. In theory, it appears entirely possible to stir the ladle of molten iron for a suitable period of time to incorporate such materials thoroughly, but attempts to carry out such a procedure on a commercial scale have produced variable results, because after the ladle of metal has been stirred to assure the thorough distribution of the additive, it has always been found that the ladle of metal has cooled to such an extent as to endanger the production of controlled properties and sound castings. Therefore, it is of no value to assure complete alloy distribution only to find that the resulting product is uncertain in its end result. The process and apparatus of this invention provide a complete incorporation of the volatile explosive metals and alloys and at the same time assure the delivery of the properly alloyed molten metal at a temperature which will permit successful casting.

On the other hand, many alloy materials, although not highly volatile or explosive, are of extremely high melting point. Others resist even distribution throughout the body of the molten metal without thorough mixing. Ferromolybdenum and ferrochromium are two examples of high melting point alloys, whereas sodium carbonate, ferrosilicon-magnesium (Mg–8–20%) alloys, and graphite are examples of additives which must be thoroughly stirred into the molten body to effect proper contact. The addition of small amounts of these materials to the moving stream followed immediately by thorough agitation will assure complete incorporation of the additive into the molten body.

Although this invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. The process of introducing additive materials into molten metal without appreciable heat loss comprising, flowing the molten metal in a stream, introducing the additive material to the stream, continuously rolling the stream laterally in one direction with respect to the direction of flow thereof to fold the stream upon itself, and simultaneously intermittently interrupting the

stream at points downstream from the place where the addition is made.

2. The process of introducing additive materials into molten metal comprising, flowing the molten metal in a stream, introducing the additive material to the stream, thereafter simultaneously separating portions of the stream by partial interruption of the flow, and blending the separated portions downstream by continuously rolling the stream laterally in one direction with respect to the direction of flow thereof to fold the stream upon itself.

OLIVER SMALLEY.

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