

[54] **DEVICE FOR MAKING MOLTEN METAL FOR CASTING**

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[30] **Foreign Application Priority Data**

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[51] Int. Cl.C21b 11/00

[58] Field of Search ..75/61; 266/34 L, 34 LM, 34 A, 266/33 R

[56] **References Cited**

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[57] **ABSTRACT**

Apparatus for melting metal for casting, comprises a vessel and a framework mounting the vessel on a base. A continuously cooled vertical injector above the vessel mixes separately delivered fuel gas and oxygen-rich gas at the lower end of the injector and burns the fuel-gas-oxygen mixture so as to direct the flame into the vessel. A fluid blower disposed adjacent the injector produces a fluid curtain between the flame of the fuel-gas-oxygen mixture and the inner surface of the vessel so as to surround the frame. Drive means translates the framework together with the vessel along a closed path so as to cause the material in the vessel to rotate therein about an axis which is offset from the central axis of the vessel.

15 Claims, 7 Drawing Figures

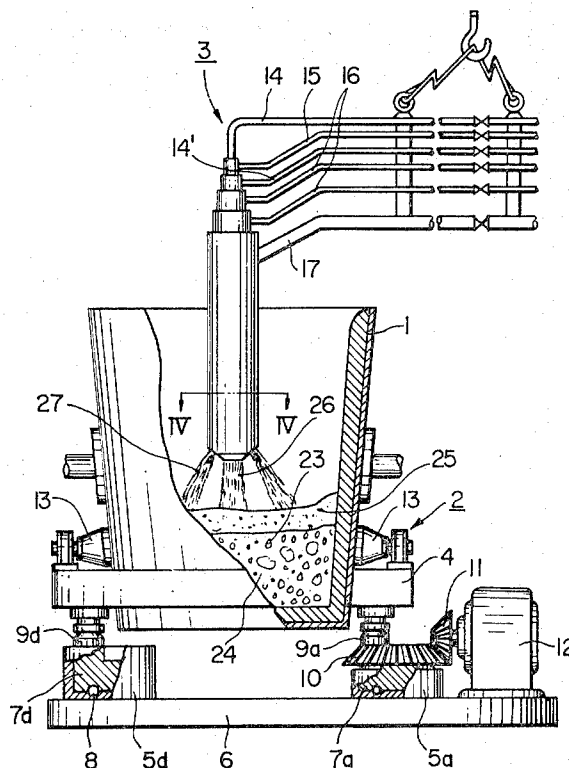


Fig. 1

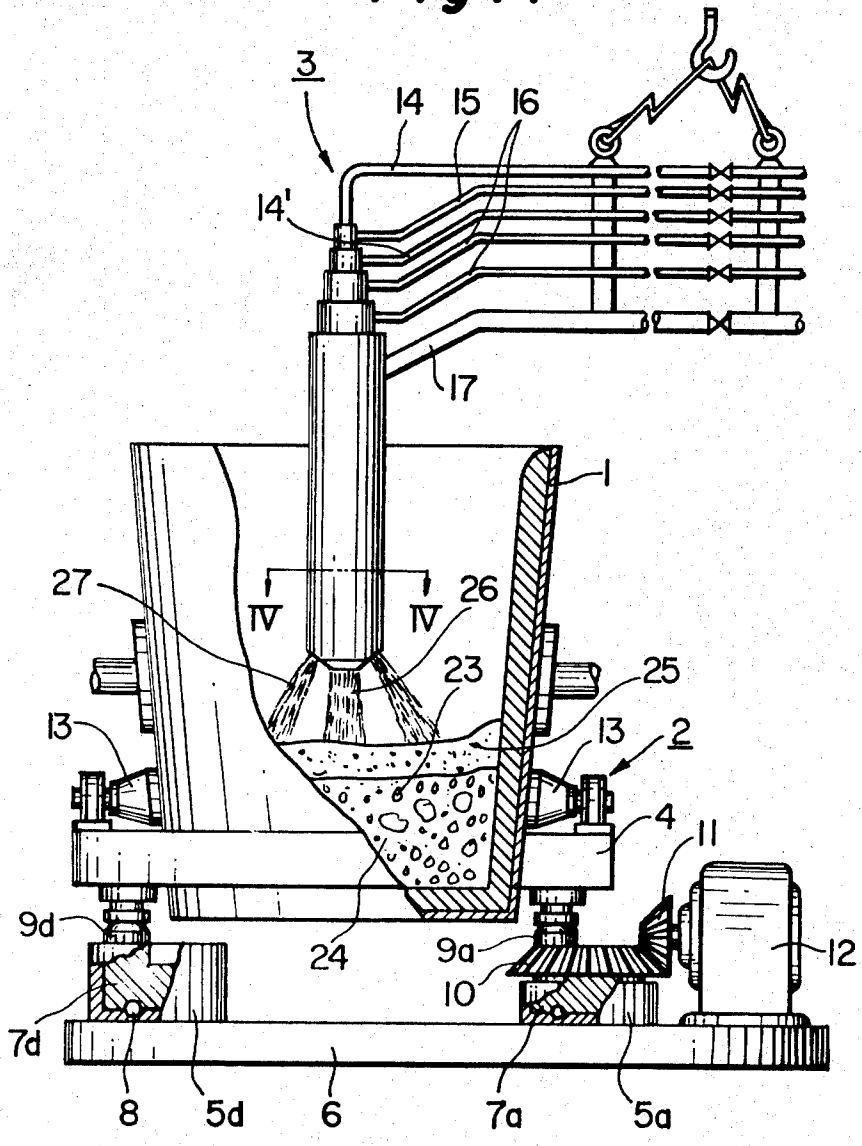


Fig. 2

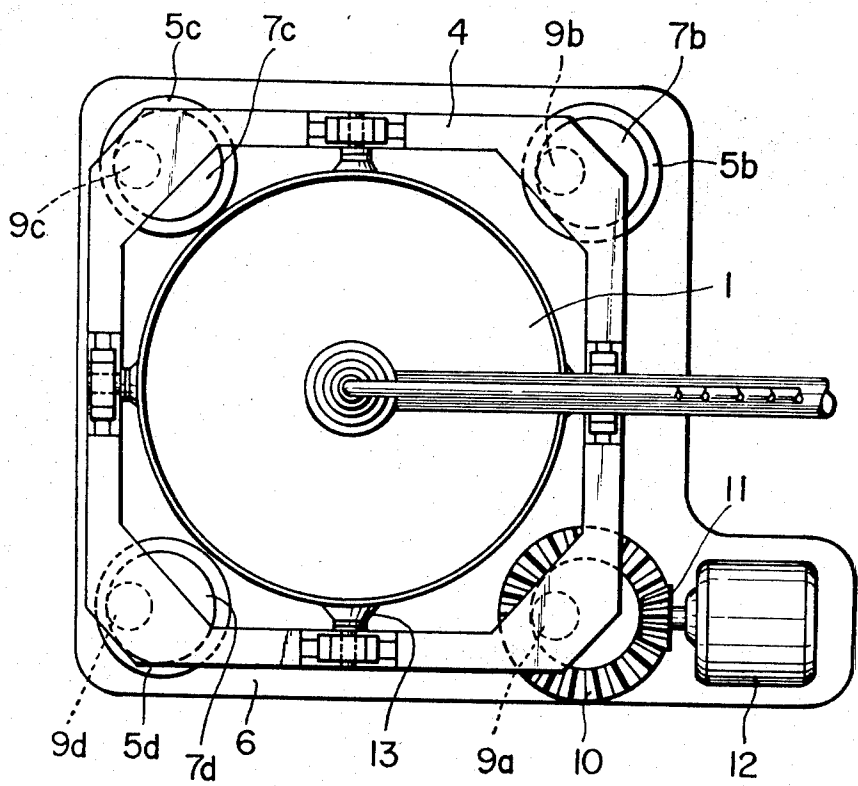


Fig. 3

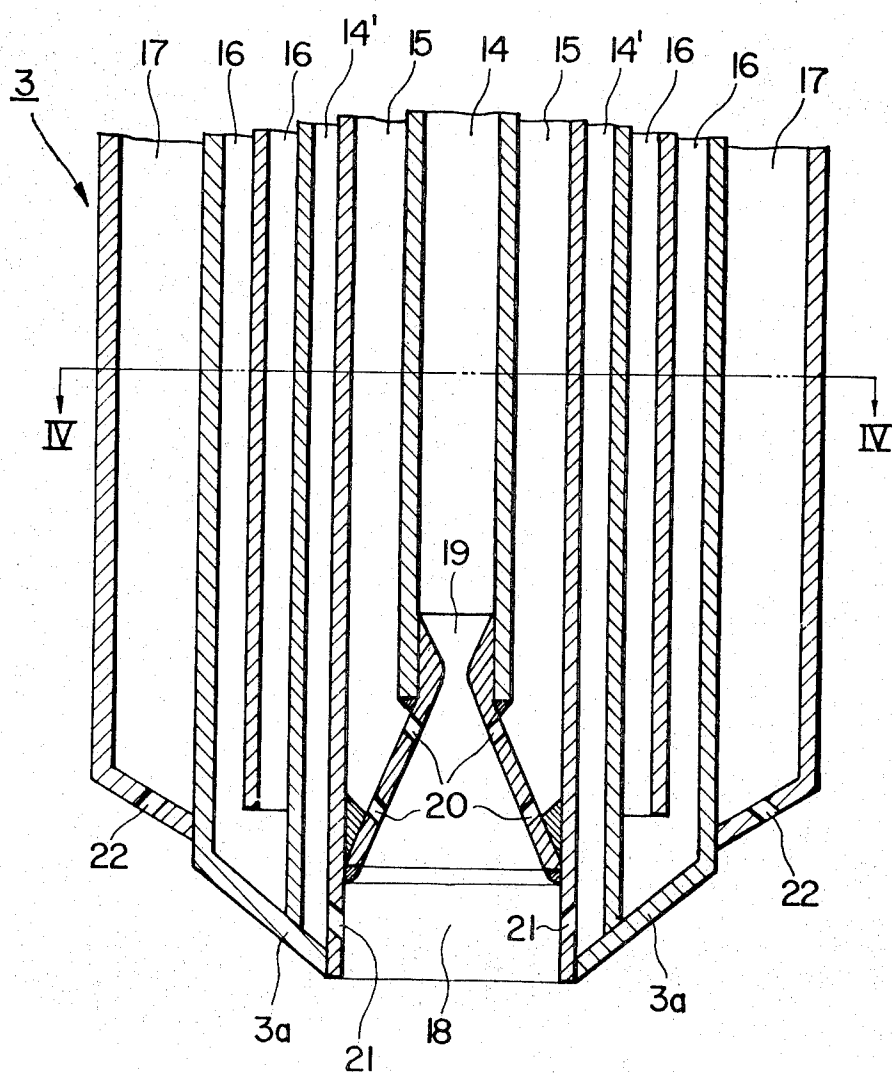


Fig. 4

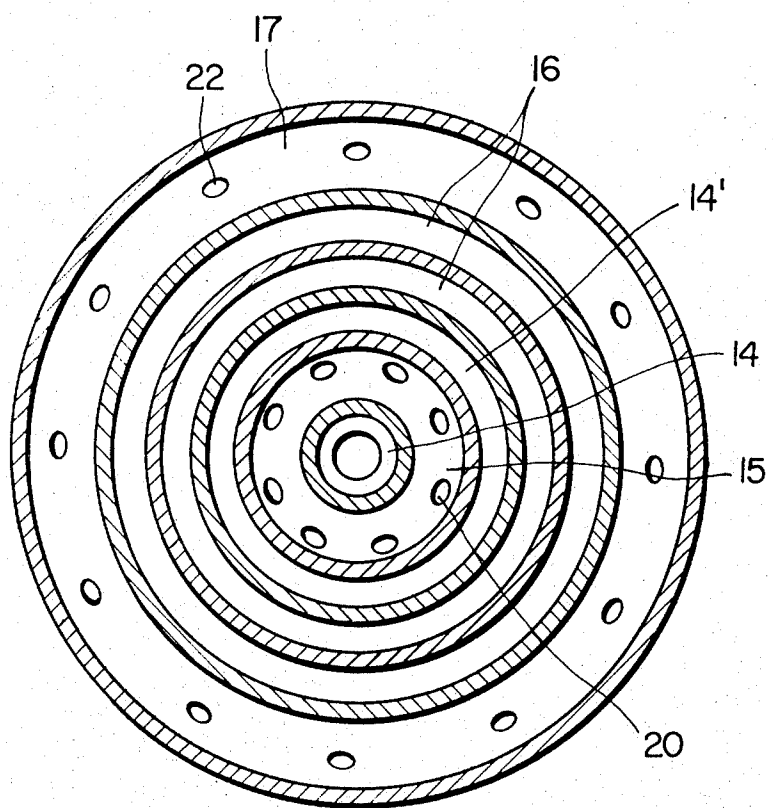


Fig. 5

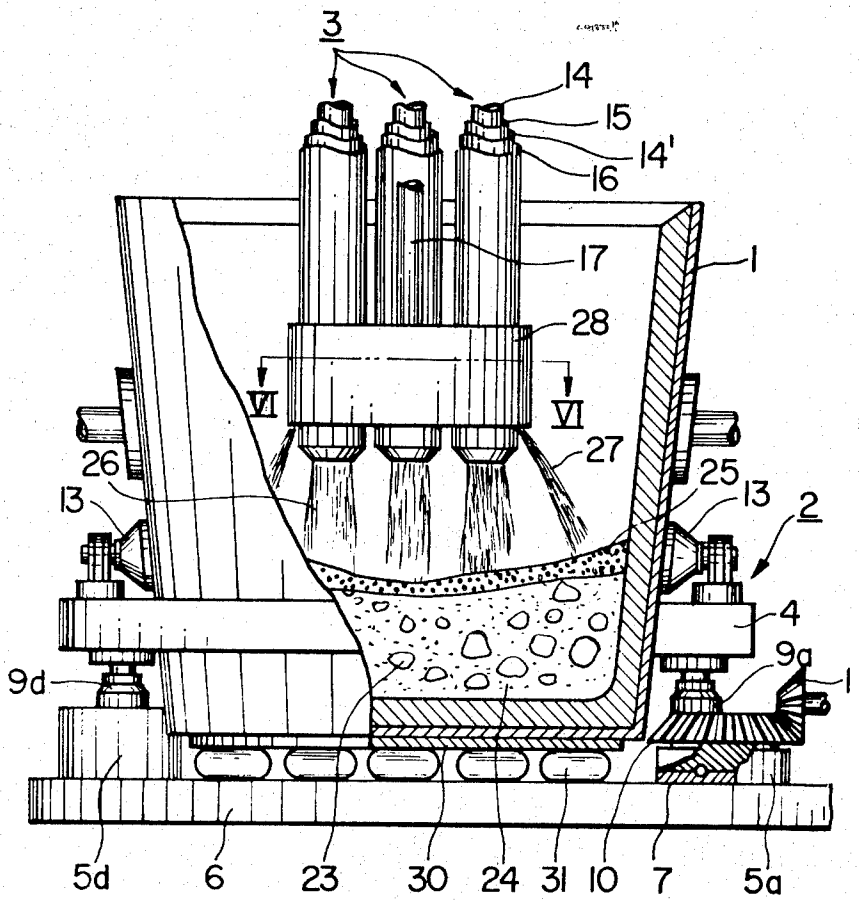


Fig. 6

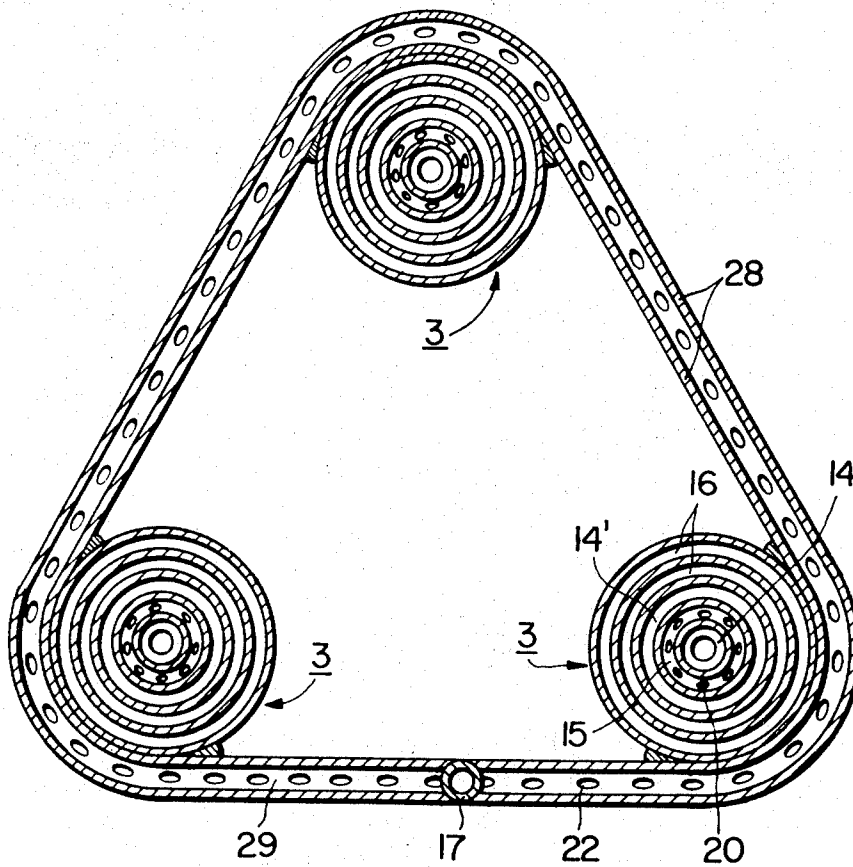
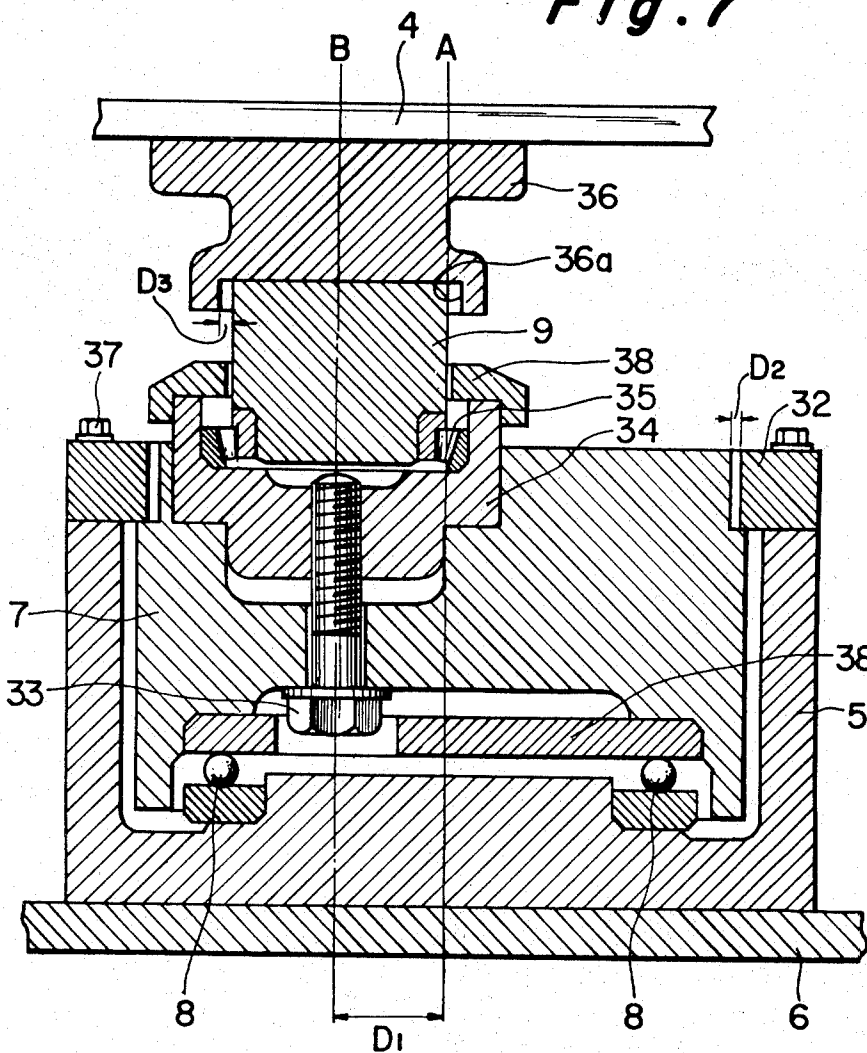


Fig. 7



DEVICE FOR MAKING MOLTEN METAL FOR CASTING

This application is a division of copending application Ser. No. 17,151, filed Mar. 6, 1970 and now U.S. Pat. No. 3,653,877.

This invention relates to apparatus for practicing a method of making molten metal for casting, directly from cold starting material, and a device therefor. More particularly, the present invention relates to apparatus for practicing a method of making molten metal for casting, directly from cold starting material, comprising these steps of placing cold starting material in a vessel, covering the cold starting material with a flux layer, heating the flux layer by blowing one or more flames of fuel-gas-oxygen mixture into the vessel as separately delivered fuel-gas and oxygen are mixed, intermingling the heated flux and the cold starting material by rotating them in the vessel about an axis which is offset from the central axis of the vessel by translating the vessel along a closed path, adding a composition-control agent in the molten metal being agitated by the translation, and producing a fluid curtain around the flames so as to inhibit the direct heating of the inner wall of the vessel by the flames.

According to a conventional method of making molten metal for molding, cold starting materials, such as cold pig iron, scrap iron, and various chipped irons, are melted in a cupola, and then one or more additives, such as ferrosilicon and ferro-manganese, are added into the molten metal in the cupola through its tuyere in order to adjust the composition of molten metal so as to produce a desired composition. The molten metal thus made in the cupola by the conventional method has various drawbacks: namely, that the contents of indispensable ingredients of cast metal, e.g., silicon and manganese, are low; that the maximum amount of carbon to be added in the molten metal is limited, e.g., to about 3.5 percent in the case of iron; that a large amount of gaseous elements, e.g., oxygen, hydrogen, nitrogen, etc., are dissolved in the metal; that the sulfur content, which is critical to the properties of cast metal, cannot be reduced. Accordingly, molten metal for refined cast articles, such as molten iron for spheroidal graphite cast iron, which should be free from sulfur and oxygen, is further treated by transferring the molten metal from the cupola to an electric furnace for refinement, e.g., desulfurization, carburization, deoxidation, etc. In order to avoid the transfer from the cupola to the electric furnace, it has been also practiced to melt solid metal in an electric furnace to begin with, so that the melting and the refinement of the metal can be made continuously in the same electric furnace.

In any of the aforesaid conventional methods, the preparation of molten metal for refined cast metal articles requires the use of an electric furnace. The electric furnace for the refining should be of closed type, in order to prevent the oxidation of the molten metal. Accordingly, the equipment for making the molten metal for refined cast articles are usually costly. In other words, an apparatus for making refined molten metal becomes economically feasible only when a large amount of such refined molten metal is necessary, but the use of the apparatus cannot be economically justified for producing a small amount of the refined molten metal.

In order to make both the ordinary grade molten metal and the refined molten metal on a small scale, it has been a practice to melt cold starting material in a cupola and to refine the composition of the molten metal in a ladle to which the molten metal is scooped. According to a known refining method, one or more composition-control agents are added into the molten metal in the ladle. At the same time, the molten metal is agitated by eccentrically rotating it at a high speed in the ladle, to accelerate the reaction of the agents with the molten metal. With such combination of a cupola and a ladle, molten metals with different degree of refinement can comparatively easily be made on a small scale for a wide range of refinement. The eccentric rotation of the molten metal results in its quick reactions with the added agents and an improvement of its venting quality. The combination of a cupola and a ladle, however, has the following drawbacks.

1. In transferring the molten metal from the cupola into the ladle, the molten metal is cooled, even if the ladle is preheated. When the molten metal in the ladle is cooled to a temperature below a certain value, the composition refinement cannot be carried out effectively. To demonstrate the effects of the temperature of the molten metal on its refinement, the inventor has made a series of tests. Refining agents, or composition-controlling agents, which consisted of 2.5 percent of coke powder, 1.0 percent of ferrosilicon, 0.3 percent of calcium-silicon, and 1.5 percent of calcium carbide, were added into five samples of molten iron, which were previously transferred into different ladles from a cupola. The molten metals were treated by eccentric rotation at different temperatures. Measurement was made on the degree of desulfurization, and the yields of carbon and silicon, on the samples thus treated. The results are shown in Table 1.

TABLE 1

Sample No.	Temperature for treating molten metal (°C)	Yield of carbon (%)	Yield of silicon (%)	Degree of desulfurization (%)
1	1,450	66	98	87
2	1,440	58	96	82
3	1,430	52	92	76
4	1,420	44	89	69
5	1,410	38	85	61

As shown in Table 1, the inventor has confirmed that the success of the composition control of molten iron in a ladle largely depends on the treating temperature thereof, more particularly the temperatures of the molten iron in the ladle during the treatment. Furthermore, the inventor made a test by measuring the temperature change in a process of scooping molten metal from a cupola into a preheated ladle for eccentric rotation. It was found that a temperature drop of 100° C. or more was inevitable in the scooping. In short, with a cupola, it is usually difficult to raise the temperature of molten metal to 1,500° C. or higher, and the molten metal temperature is dropped by 50° to 100° C. in transferring it into a preheated ladle. The eccentric rotation of the ladle and the addition of the composition-control

agents also cause heat loss from the molten metal in the ladle, resulting in a temperature drop of 50° to 80° C. in such refining process.

2. In the known method of making molten metal casting, the refining is carried out only in a ladle, while using a cupola only for melting. Accordingly, gaseous materials contained in the molten metal in the cupola, e.g., oxygen, hydrogen, nitrogen, are dispersed in vain and cannot be used effectively for the refining purpose. For instance, the aforesaid gaseous materials have desulfurizing power, but such power cannot be used in a useful manner.

3. The known method comprises two steps, a cupola step and a ladle step, using two different equipments. Accordingly, the method is complicated and time-consuming.

As pointed out in the foregoing, different methods of making molten metal for casting have been used depending on the kind and the amount of the metal to be cast, but none of the conventional methods can get rid of the aforesaid shortcomings.

In order to obviate such shortcomings of the known methods, the inventor has made a series of studies on a method and a device for selectively making different kinds of molten metals for casting, by a simple process, regardless of the amount of the molten metal required. As a result, the inventor has succeeded in providing an improved method and a device for making different kinds of molten metals, yet retaining all the advantages of conventional methods.

The inventor noticed the following points.

- a. Neutral flames of gaseous mixture of hydrocarbon-oxygen system, which are commonly used in gas-welding, can heat the metal being welded to 3,000° C or higher, while the existence of welding flux materials (e.g., borax, sodium, silicate, etc.) substantially prevents oxidation of useful elements in the metal being welded, such as carbon, silicon, and manganese, during the welding. If such flames can be applied to the making of molten metal for casting, the temperature of the molten metal can be raised to a level considerably higher than that obtainable by a cupola.
- b. If both the melting step of the starting cold material and the refining step of the molten metal for casting can continuously be done in a common container, the aforesaid temperature drop of the molten metal during its transfer, from a cupola to a ladle, can be eliminated, together with the tedious preheating of the ladle.
- c. In controlling the composition of the molten metal for casting, if the molten metal is heated while eccentrically rotating the molten metal in a container, e.g., a ladle, the molten metal can be thoroughly mixed with composition-control agents without causing any temperature drop of the molten metal. Thus, composition control, especially desulfurization, can quickly be effected.

In order to take advantage of the last mentioned points, the inventor had to solve the following difficulties.

- i. There is no readily available refractory lining material, which withstands a high temperature of 3,000° C. or higher, generated by flames of the

gaseous mixture of hydrocarbon-oxygen system. It is also difficult to melt cold starting material without causing oxidation thereof.

- ii. Conventional welding burners for hydrocarbon-oxygen mixture are not suitable for burning a large amount of gaseous fuel mixture.

After years of studies, the inventor has devised the following countermeasures to the above difficulties.

A. By preheating flux material to a white-hot temperature and by thoroughly mixing cold starting material with the white-hot flux material, the cold starting material can be melted substantially instantly without causing any noticeable oxidation of the starting material.

B. In the case of making molten iron for casting, by burning a gaseous fuel mixture, e.g., that of hydrocarbon-oxygen system, while completely surrounding the flame of the gaseous fuel mixture with a water curtain, the following special effects can be achieved.

- a. The starting material can be heated by the flame of the gaseous fuel mixture to 3,000° C. or higher, without exposing the inner surface of a container of the starting material to such high temperature.
- b. The existence of a water curtain results in generation of (CO+H₂) gas, which tends to accelerate chemical reduction in the container.
- c. The hydrogen thus generated permeates in the molten iron, so that the viscosity and the density of the gaseous materials dissolved in the molten iron are reduced. Accordingly, the venting quality and permeability of the molten metal for casting are improved.

C. In the case of making molten nonferrous metal for casting, by completely surrounding one or more flames of fuel-gas-oxygen mixture, e.g., heavy-oil-oxygen mixture, with an air curtain, the inner surface of a vessel, containing such molten nonferrous metal, can be protected from the high temperature of such flames.

D. By separately delivering fuel gas and oxygen-rich gas into the space surrounded by the water curtain, and by mixing the fuel gas and the oxygen-rich gas therein, it becomes possible to eliminate the danger of backfire, or reverse flow of the fuel-gas oxygen mixture, which may lead to a large explosion. Thus, a large amount of gaseous fuel mixture can effectively be burnt.

An object of the present invention is to provide apparatus for practicing a method for making molten metal for casting, which essentially comprises four different processes; namely a first process of placing starting cold material in a refining vessel and then placing a flux layer on the cold starting material; a second process of heating the flux layer to white-hot condition by directing one or more flames of fuel-gas-oxygen mixture thereto from above the flux layer; a third process of melting said cold starting material by continuing said injection of the flames of the fuel-gas-oxygen mixture from above the vessel, while eccentrically rotating and agitating said cold starting material and said white-hot flux in the vessel by translating said vessel along a closed locus; and a fourth process of continuing said injection of the flames, forming a water curtain so as to surround the flames, and adding com-

position-control agents into the molten metal, whereby a molten metal for casting with a desired composition is produced.

Another object of the present invention is to provide a device for making molten metal for casting, comprising a base; a vessel receiving cold starting material and flux material therein; a framework integrally holding said vessel while being movable supported by said base; a continuously cooled vertical injector means being disposed directly above said vessel and mixing separately delivered fuel-gas and oxygen-rich-gas at the lower end of the injector means, which injector means burns the fuel-gas-oxygen mixture as being formed so as to direct a flame of the mixture into the vessel; a fluid blower being disposed in the proximity of said injector means and producing a fluid curtain between the flame of the fuel-gas-oxygen mixture and the inner surface of the vessel, so as to surround the flame; a driving means; and a transmission means being operatively connected to the driving means and adapted to translate the framework together with the vessel along a closed path, so as to cause the starting material and flux in the vessel to rotate therein about an axis which is offset from the central axis of the vessel.

It is another object of the present invention to provide a device of the last mentioned type for making molten metal for casting, which device further includes a means for alternately translating a vessel containing the metal being melted along a closed path in opposite directions, and a braking means to quickly bring the vessel to rest at the end of the translation of the vessel in either direction for readying the vessel for quick reversal of the translating direction.

For a better understanding of the invention, reference is made to the accompanying drawings, in which:

FIG. 1 is an elevation, with a part in section, of a device for making molten metal for casting, according to the present invention;

FIG. 2 is a plan view of the device of FIG. 1;

FIG. 3 is a partial sectional view of an injector usable in the device of FIG. 1;

FIG. 4 is a sectional view, taken along the line IV—IV of FIG. 3;

FIG. 5 is a view similar to FIG. 1, illustrating a different embodiment of the present invention;

FIG. 6 is a sectional view, taken along the line VI—VI of FIG. 5; and

FIG. 7 is a vertical sectional view of a supporting cylinder of a framework in an embodiment of the present invention, which support cylinder is suitable for alternately translating the framework along a closed path in opposite directions.

Like parts are designated by like numerals and symbols throughout the drawings.

Referring to FIGS. 1 to 4, a device for making molten metal for casting, embodying the present invention, generally comprises a vessel 1 for melting cold starting material and controlling the composition of the molten metal by adding a composition-control agent, an agitator 2 for translating the vessel 1 along a closed path so as to cause the molten metal in the vessel to swirl eccentrically therein, and an injector 3 for injecting fuel-gas-oxygen mixture toward the starting cold metal in the vessel 1 and for injecting a water curtain surrounding the injected flame of the fuel-gas-oxygen mixture.

The vessel 1 can be a ladle of conventional construction. The lining of the vessel is not directly exposed to the high temperature of the flame of the fuel-gas-oxygen mixture, as will be described hereinafter. Accordingly, the inner surface of the vessel 1 can be lined with comparatively inexpensive refractory material, such as chamotte.

The agitator 2 includes a substantially rectangular framework 4 which integrally supports the vessel 1 by means of clamps 13. In the illustrated embodiment, the four corners of the framework 4 are movably supported by a suitable means on a stationary base 6 in such manner that the framework 4 can be translated along a closed circular path. More particularly, four support cylinders 5a to 5d (to be collectively referred to as 5) are secured to the base 6, and each of the support cylinders 5a to 5d holds a rotary member 7a, 7b, 7c, or 7d (to be collectively referred to as 7), respectively, which is rotatably fitted in the support cylinder. In order to facilitate the rotation of the rotary member 7 in the cylinder 5, bearing balls 8 are inserted between the bottom surface of the rotary member 7 and the inner bottom surface of the cylinder 5. Each rotary member 7 is provided with an eccentric shaft 9a, 9b, 9c, or 9d (to be collectively referred to as 9), which extends upwards from the top of the rotary member 7. The four support cylinders 5 are so disposed on the base 6 that the four eccentric shafts 9, each being carried by one of the support cylinders 5, can be connected to the four corners of the framework 4, as can best be seen from FIG. 2.

To drive the translation of the framework 4, one of the rotary members, e.g., 7a, is driven by a motor 12 through a suitable transmission, for instance the combination of a bevel gear 10 secured to that rotary member 7a and a bevel gear 11 secured to the output shaft of the motor 12. When the rotary member 7a is driven by the motor 12, the rotary member 7a rotates in the support cylinder 5a about the axis of the member 7a, so that the eccentric shaft 9a secured to the rotary member 7a is rotated about the axis of the rotary member 7a. In other words, the eccentric shaft 9a rotates eccentrically, with respect to its own axis. In response to the rotation of the eccentric shaft 9a, the rectangular framework 4 translates along a circular path, because the remaining rotary members 7b, 7c, and 7d follow the rotation of the rotary member 7a while eccentrically turning the eccentric shafts 9b, 9c, and 9d along the identical paths with that of the eccentric shaft 7a at different locations.

As a result of it, the vessel 1 carried by the framework 4 makes a circular translation together with the framework 4.

For simplicity's sake, the agitator 2 is illustrated as a means for translating the vessel 1 along a circular path, but the path of the translation is not limited to such a circle. For instance, by using suitable cam means instead of the eccentric shafts 9 of FIG. 1, the vessel 1 can be translated along a closed path of desired configuration, such as an elliptic path.

Similarly, the number of the support cylinders 5 and the rotary members 7 is not limited to four, respectively, as illustrated in FIGS. 1 and 2. In fact, the vessel 1 can be movably supported by one support cylinder 5, or by any suitable number of support cylinders 5, by slightly modifying the structure of the framework 4 or the bottom of the vessel 1, in a manner known to those skilled in the art.

In order to effect thorough stirring of the vessel 1, it is desirable to translate the vessel 1 alternately in opposite directions, by a suitable means, such as a reversible motor, which may replace the motor 12 of FIG. 1. When the direction of the translation of the vessel 1 is periodically changed, a braking means must be used to bring the vessel quickly to rest. Due to the heavy weight of the vessel and the materials loaded therein, a considerably long period of time elapses before the vessel comes to rest after the driving means, e.g., the motor 12, is de-energized. Thus, the overall efficiency of the melting device is reduced.

According to a feature of the present invention, there is provided a means for quickly braking the movement of the vessel 1 at the time of the direction reversal of its translation. FIG. 7 illustrates the construction of supporting means which causes a vessel 1 to quickly stop after the de-energization of a prime mover. In the figure, the supporting means comprises a supporting cylinder 5 firmly secured to the base 6 of a metal-melting device. A rotary member 7 rotatably fits in the cylinder 5 in a concentric manner. Ball bearings 8 are inserted between the lower surface of a contact plate 38 disposed at the bottom of the rotary member 7 and the upper surface of the bottom wall of the support cylinder 5, so as to ensure the smooth rotation of the member 7 relative to the support cylinder 5. A cylindrical lower boss 34 is secured to the rotary member 7 by a bolt 33, for receiving an eccentric shaft 9 therein. The axis B—B of the eccentric shaft 9 is offset from the axis A—A of the support cylinder 5, as shown in FIG. 7, by a given distance D_1 . Roller bearings 35 are inserted between the eccentric shaft 9 and the lower boss 34, for allowing smooth rotation of the eccentric shaft 9 relative to the lower boss 34. In other words, the eccentric shaft 9 of this embodiment not only rotates about the axis A—A of the support cylinder 5 in an eccentric manner, but also spins about its own axis B—B. A cover 39 is provided at the top of the lower boss 34 to protect the roller bearings 35 from dust particles. An upper boss 36 is secured to the lower surface of a framework 4 at such locations that the lower ends of the upper boss 36 operatively engages the upper end of the eccentric shaft 9. As a result, the eccentric rotation of the shaft 9 causes the framework 4 to translate along a circular path, as described hereinbefore, referring to FIGS. 1 and 2.

To provide for the improvement of the braking power, the supporting means of FIG. 7 includes a gap D_2 between the outer peripheral surface of the top portion of the rotary member 7 and the inner peripheral surface of a top ring 32, which is secured to the top of the support cylinder 5 by means of bolts 37. Another gap D_3 is provided between the outer peripheral surface of the eccentric cylinder 9 and the inner peripheral surface 36a of a vertically extending flange portion of the upper boss 36.

When four supporting means, as shown in FIG. 7, are used in the agitator 2 of FIGS. 1 and 2, the translation of the framework 4 and accordingly the vessel 1 can be effected by connecting one of such supporting means to the reversible motor 12 (not shown in FIG. 7) through a gear train. With the supporting means of FIG. 7, when the motor is de-energized, the framework 4 carrying the vessel 1 quickly comes to rest, as compared with the supporting means of FIGS. 1 and 2. The

two kinds of gaps D_2 and D_3 of FIG. 7 act to absorb or facilitate the absorption of the kinetic energy of the rotating framework 4 and the vessel 1, because the presence of the gaps D_2 and D_3 causes the framework 4 to make irregular movement due to the playing in the movement by the eccentric shaft 9 and the rotary member 5. Without such gaps D_2 and D_3 , the vessel continues its smooth movement for some time by inertia. The different supporting means of FIG. 7 may tend to move in different directions, so as to increase the friction between adjacent moving parts and the braking effects of such means. As the time from the de-energization of the prime mover, e.g., the reversible motor, of the melting device to the rest of the vessel decreases, the overall efficiency of the stirring operation of the contents of the vessel is improved, because the direction of the translation of the vessel can be changed more frequently in a given period of time.

Referring to FIGS. 3 and 4, the injector 3 comprises concentrically disposed cylindrical passages; namely, a central fuel passage 14 for delivering fuel, such as acetylene, oxygen passage 15 for delivering oxygen-rich gas, such as oxygen gas or air, a second fuel passage 14' for delivering the same fuel as the central passage, cooling water passages 16 for circulating cooling water by feeding cold cooling water through one of the passages 16 while returning the warmed water through the other one of the passages 16, and a surrounding water passage 17 for delivering water for producing water curtain. A mixing chamber 18 is formed at the lower end of the injector 3, which directly communicates with the central hydrocarbon passage 14 for through a throttle 19 for gasifying the fuel. The very lower ends of the oxygen passage 15 and the second fuel passage 14' are closed, and openings 20 and 21 are bored in the proximity of the lower ends of those passages, respectively, so as to inject the oxygen-rich gas and gasified fuel into the mixing chamber 18.

In other words, the oxygen passage 15 and the fuel passages 14, 14' are so disposed that the fuel and the oxygen are delivered separately through the injector 3, until they are injected into the common mixing chamber 18. With such separate delivery of the fuel and oxygen, the danger of back fire and ensuing explosion can completely be eliminated, which have been rather frequently encountered within conventional acetylene gas burners.

Water curtain nozzles 22 are provided at the lower end of the surrounding water passage 17, so as to direct a water curtain 27 in a direction obliquely away from the axis of the injector 3, while surrounding a flame 26 of the fuel-gas-oxygen mixture thus mixed at the mixing chamber 18. By the use of the water curtain 27, the inner wall of the vessel 1 is protected from being directly heated by the flame 26 of the fuel mixture.

An end plate 3a of the injector 3 is exposed to the flame 26 of the fuel-gas-oxygen mixture, but it can be made of common metallic material, because it is cooled by water flowing through the cooling water passages 16.

In operation, cold starting material 23, such as cold pig iron and scrap iron, is placed in the vessel 1. It is preferable to use granular material 23, although bulky blocks of the cold starting material can be also melted by the illustrated device of the invention. In the case of

the bulky blocks of starting material 23, in order to improve its mobility, finely chipped metal 24 is added in the vessel 1 for surrounding the bulky blocks 23. It is also possible, and preferable, to form the cold starting material 23 with the chipped metal 24 alone. The bulky blocks and the chipped metal will be referred to as cold starting materials 23, 24, because they are mixed together in the course of melting by translating the vessel 1 along a circular path.

The cold starting material 23 and the chipped metal 24 in the vessel 1 are covered with a layer of coke powder 25, and the coke powder is then heated to white-hot condition by the flame 26 of the fuel-gas-oxygen mixture from the injector 3. The white-hot coke powder thus heated acts as a heating medium in the course of melting the starting materials 23, 24. At the same time, the coke powder layer 25 prevents oxidation of the starting material 23, 24. Accordingly, in the process of heating the coke layer 25, no water curtain is necessary to surround the flame 26.

After coke layer 25 is made white-hot, the driving motor 12 is actuated to drive the framework 4 along a circular path, together with the vessel 1, as described in the foregoing. The inventor has found through experiments that in response to such translation of the vessel 1, the cold starting materials 23, 24 and the white-hot coke layer 25 begin to rotate about an axis, which is offset from the central axis of the vessel 1, whereby the white-hot coke is thoroughly mixed with the starting materials 23, 24. The heat carried by the white-hot coke 25 is transferred to the starting materials 23, 24 to heat the latter. The starting materials 23, 24 are further heated by the flame 26 of the fuel-gas-oxygen mixture. The cold starting materials 23, 24 are thus melted, to produce molten metal.

The fuel-gas to be used in the melting process is, for instance, acetylene, propane, or other similar combustible hydrocarbon gas. With the flame 26 made by burning such fuel-gas, the temperature of the starting materials 23, 24 is substantially instantly increased without allowing oxidation of the material.

There is a known process of melting metal by blowing oxygen to the metal. The oxygen, however, consumes certain ingredients of the metal being melted, such as manganese, carbon, silicon, etc., and the oxidizing temperature of such ingredients is used for melting the metal. In casting iron or other metals, the aforesaid ingredients are necessary to achieve satisfactory properties of the cast articles. Accordingly, the oxygen gas blowing process cannot be used for preparing molten metal for casting.

The inventor has noticed the fact that acetylene-oxygen neutral flame is used in gas welding for achieving a temperature of 3,000° C. or higher, and he has found that other fuel-gas-oxygen flames can be used for melting cold starting material for the purpose of making molten metal for casting. For making molten iron, for casting, hydrocarbon, e.g., acetylene, is found to be preferable. In the case of gas welding of metal, flux materials, such as borax and sodium silicate, are used in order to separate oxides of the metal being welded as slags and to prevent ingredients in the metal, such as carbon, silicon, and manganese, from being oxidized. The coke layer 25 in the vessel 1, as illustrated in FIG. 1, fulfills similar functions to those of flux materials in

gas welding. In other words, the white-hot coke powder 25 acts not only as the heat carrying medium, but also as a medium for preventing the metal being melted from oxidation and for preventing oxidation of various elements added to the metal being melted.

After the starting materials 23, 24 are melted, valves (not shown) of the water curtain nozzles 22 of the surrounding water passage 17 are opened, so as to produce a water curtain 27 surrounding the flame 26. With the water curtain 27, the inner surface of the vessel 1 is protected from the flame 26. Furthermore, hydrogen gas H_2 is generated at the boundary between the flame 26 and the water curtain 27, by thermal cracking of water in contact with the flame 26.

The hydrogen gas H_2 favorably behaves in various ways. Since hydrogen has a large diffusion coefficient, it diffuses into the molten metal and accelerates chemical reduction in the molten metal together with carbon monoxide (CO) gas dissolved in the molten metal. The large heat conductivity of hydrogen, which is seven to 10 times that of carbon monoxide gas, improves heat conduction to the molten metal. It should be noted that the existence of hydrogen gas in the molten metal reduces the viscosity and density of gases dissolved in the molten metal, so that its venting quality is improved. Thus, the danger of producing defective cast articles is completely eliminated.

The presence of hydrogen gas in the vessel 1 also enables direct preparation of molten metal for casting from powdered ore, e.g., magnetite sand, sintered ore, iron ore, or pelleted ore, because hydrogen reduces the ore to separate the desired metal.

A suitable composition-control agent is added into the metal thus melted, for adjusting its composition, depending on the desired kind of the cast good, such as common cast iron, or high grade cast iron. Typical agents for common cast iron or gray pig iron are, for instance, coke breeze, ferrosilicon, calcium silicon, etc.

Upon completion of the composition-adjustment, the molten metal becomes ready for casting.

It is one of the important features of the invention that both the melting of a metal and the adjusting of its composition for readying it to casting are carried out continuously in one vessel without transferring the molten metal to any other container.

The present invention has been described by mostly referring to an example of melting iron, but the invention is not restricted to iron, but it can be used for melting other metals, such as for preparing molten metal of non-ferrous alloy for casting.

Only one injector 3 is shown in the embodiment of FIGS. 1 to 4, but the number of the injectors is not restricted to one. In fact, a plurality of such injectors can be used for melting a comparatively large quantity of the cold starting material.

FIGS. 5 and 6 illustrate another embodiment of the invention, which includes three injectors 3 disposed at vertices of an equilateral triangle, in symmetry with each other relative to the axis of a vessel 1. Referring to FIG. 6, the three injectors 3 are secured to walls 28 of a belt-like triangular water tank 29 at the inside of three vertices thereof, respectively. A surrounding water passage 17 is connected to the top of the water tank 29, while a plurality of water curtain nozzles 22 are bored on the bottom wall of the water tank 29. Accordingly,

three flames 26 of fuel-gas-oxygen mixture from the three injectors 3 are enclosed by a triangular water curtain 27 from the water tank 29.

In the embodiment of FIGS. 5 and 6, it is not necessary to use the surrounding water passage in each injector 3. The single surrounding water passage 17 connected to the water tank 29, as shown in FIG. 5, will be sufficient.

While a large amount of cold starting materials 23, 24 is placed in the vessel 1, the agitator 2, especially the framework 4 thereof, is exposed to a very heavy load. The support cylinders 5 are subjected to a heavy thrust load. In order to diversify the heavy thrust load, a plurality of pneumatic bearing balls 31 are disposed between the base 6 and a heat-insulating plate 30, which is secured to the bottom of the vessel 1.

Each of the pneumatic bearing balls 31 is made of about 5 mm thick rubber shell. In a preferred embodiment, the ball consists of three rubber layers; namely, an outer rubber layer with high resistances to aging, bending, and fatigue; an intermediate layer which withstands a high internal pressure of the ball; and an inner layer with high airtightness.

The pneumatic bearing ball 31, for instance, can withstand an internal pressure of about 20 Kg/cm², or can bear a load of 10 tons or more per ball.

The translation of the vessel 1, by means of the agitator 2, eliminates uneven distribution of the load, because the translation aims at even distribution of the cold starting material and the homogeneous mixture of the molten metal with the composition-control agent. In short, the mechanical load on the framework 4 and the support cylinder 5 are well diversified, so that smooth translation of the vessel 1 can be ensured.

The invention will now be described in further detail, referring to Examples.

EXAMPLE 1

Cold starting material consisting of 100 Kg of chipped iron and 400 Kg of scrap steel was placed in a vessel 1, as shown in FIG. 1. Table 2 shows the compositions of the chipped iron and the scrap steel. The cold starting material was covered by a coke layer by spraying 45 Kg of coke with composition, as shown in Table 3, on the surface of the starting metal.

TABLE 2

Starting material	Composition (%)				
	Carbon	Silicon	Manganese	Phosphorus	Sulfur
Chipped iron	3.2	1.8	0.6	0.3	0.1
Scrap steel	0.2	0.2	0.5	—	—

TABLE 3

Ingredients of coke	Fixed carbon	Ash content	Volatile matter	Sulfur content
Percentage	87.75	10.63	0.94	0.58

A fuel-gas-oxygen mixture was prepared by using acetylene as the hydrocarbon, in which the partial pres-

sure of oxygen was about 3 Kg/cm², while the partial pressure of acetylene was about 0.4 Kg/cm². The coke layer was heated to white-hot by burning the gaseous mixture. A driving motor 12 was then actuated to agitate the vessel 1, while maintaining the burning flame 26 of the gaseous mixture, so that the starting metal and the coke layer rotated in an eccentric manner relative to the axis of the vessel.

It was confirmed by observation that as the coke got mixed with the cold starting material, the material began to melt. The temperature of the flame 26 was raised by increasing the partial pressure of acetylene to about 1 Kg/cm². At the same time a valve on a surrounding water passage 17 was opened to form a water curtain 27. The rate of water supply to the water curtain 27 was so controlled that water vapor of 1,000° C. or higher was generated in the proximity of the molten metal thus prepared. The average temperature of the molten metal in the vessel 1 increased to about 1,000° C. in about 5 minutes after forming the water curtain 27.

Then, 2.5 Wt. percent of coke, based on the total weight of the starting metal, 1.05 Wt. percent of ferrosilicon, and 0.35 Wt. percent of calcium silicon were added into the molten iron, while continuing the agitation of the vessel 1. Tables 3, 4, and 5 show the composition of the coke, ferrosilicon, and calcium silicon thus added, respectively.

TABLE 4

Ingredients of ferrosilicon	Silicon	Carbon	Phosphorus	Sulfur
Percentage	75 ~ 78	less than 0.3	less than 0.05	less than 0.05

TABLE 5

Ingredients of calcium silicon	Calcium	Silicon	Carbon
Percentage	30 ~ 35	55 ~ 65	less than 1.00

When the temperature of the molten metal in the vessel 1 reached about 1,500° C., valves for all the passages of the injector 3 are closed, to cease the formation of the flame 26 and the water curtain 27. The agitation of the vessel 1 lasted for three minutes after the ceasing of the flame, and then the agitator 2 was stopped.

After removing the slag layer floating on the molten iron, gray pig iron was produced by casting the molten iron. Table 6 shows the composition of the gray pig iron thus produced. As can be seen from the table, the gray pig iron had excellent mechanical strength.

TABLE 6

60	Ingredients of gray pig iron	Car Sil-bonicon	Man-ganese	Phos-ph-orus	Su-fur	Tensile Strength (Kg/mm ²)	Hardness (HB)	
65	Percent- tage	3.75	1.56	0.48	0.089	0.091	22.2	190

In this Example, the amount of oxygen used was about 1,400 liters, and that of acetylene was about 400 liters, which amounts were about 20 percent less than the corresponding amounts required in conventional methods.

Thus, the method of the present invention reduces the fuel cost of preparation of molten metal for casting.

EXAMPLE 2

Cold starting material consisting of 500 Kg of magnetite sand was placed in a vessel 1, as shown in FIG. 1, and the surface of the magnetite sand was covered by spreading thereon 50 Kg of coke and 10 Kg of lime or calcium oxide. Table 7 shows the composition of the magnetite sand used in this Example.

TABLE 7

Ingredients of magnetite sand	Percentage
Total iron	50.91
FeO	30.06
Fe ₂ O ₃	38.63
SiO ₂	8.18
TiO ₂	13.41
Al ₂ O ₃	2.45
MgO	3.01
CaO	0.87
MnO	0.69
P	0.15
S	0.12
V	0.21

An acetylene-oxygen mixture, in which the partial pressure of oxygen was about 3 Kg/cm² and that of acetylene was about 0.4 Kg/cm², was burned to produce a flame 26 for heating the coke to white-hot temperature. The white-hot coke was then mixed with the magnetite sand by agitating the vessel 1 while maintaining the flame 26, in the same manner as Example 1. Thus, the magnetite sand was melted.

Then the temperature of the flame 26 was raised by controlling the partial pressure of oxygen at about 5 Kg/cm² and the partial pressure of acetylene at about 1 Kg/cm². At the same time, a water curtain 27 was formed in such manner that the temperature of steam at the surface of the molten iron was 1,000° C. or higher. The molten iron started to boil in about 8 minutes after the formation of the water curtain 27. Then, the flame 26 and the water curtain 27 were ceased for about 2 minutes, while holding the vessel 1 stationary. After removing the slag layer floating on the molten iron, a steel sample was made by casting the molten iron. Table 8 shows the composition of the steel sample thus produced.

TABLE 8

Ingredients of cast steel	Carbon	Silicon	Manganese	Phosphorus	Sulfur
Percentage	0.03	—	—	0.05	0.01

Thus, it has been confirmed that molten steel can be made continuously and directly from magnetite sand, by taking advantage of the presence of the water curtain. Furthermore, it has been demonstrated that by

controlling the carbon content, molten metal for casting can directly be obtained from granular ore, or in this case molten iron from magnetite sand. The amounts of oxygen and acetylene used in this Example were about 2,000 liters and about 600 liters, respectively.

EXAMPLE 3

A nonferrous cold starting material, consisting of copper, bronze, tin, and zinc at ratios as shown in Table 9 was placed in a vessel 1, as depicted in FIG. 1. Neutral flux consisting of 5 Kg of borax and 5 Kg of scrap glass were spread on the surface of the nonferrous metal, so as to cover the latter.

TABLE 9

Ingredients of nonferrous starting material	Bronze blocks	Copper Wire scrap	Tin blocks	Zinc blocks	Total
Weight (Kg)	400	88	10	2	500

A fuel-gas-oxygen mixture, consisting of heavy oil and air, in which the oxygen content was enriched by 20 percent to an oxygen partial pressure of about 2 Kg/cm², was injected into the vessel 1 through an injector 3, to generate a flame 26 for melting the neutral flux. Table 10 shows various properties of the heavy oil used.

TABLE 10

Properties of heavy oil used in Ex. 3

Item	Value
Specific gravity	0.94
Flash point	111°C
Borné degree	16-24
Carbon residue	5.7%
Moisture content	0.4%
Composition	Carbon 85.28%
	Hydrogen 11.34%
Composition	Sulfur 1.61%
	O ₂ + N ₂ 1.67%

By agitating the vessel 1, the flux and the cold starting material were mixed, and the starting material began to melt. Then, the partial pressure of the air in the fuel-gas-oxygen mixture was raised to about 3 Kg/cm², while enhancing the partial pressure of the heavy oil therein. At the same time, an air curtain 27a was formed about the flame 26. The temperature of the molten metal increased to about 1,150° C. in 20 minutes after the formation of the air curtain 27a. Then, the flame 26 and the air curtain 27 were ceased, and 2.5 Kg. of lime stone was added into the molten metal. The molten metal in the vessel 1 was forced to move in the vessel 1 about an axis which is offset from the central axis of the vessel 1. The forced agitation lasted for about 5 minutes, to effect thorough degassing. Thus, a molten metal ready for casting was achieved, and a sound bronze sample was cast by pouring the molten metal. Table 11 shows the composition of the bronze sample thus prepared.

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TABLE 11

Item	Melting method	
	Known reduction-melting method	Method of the invention
Composition	Copper	86.90
	Tin	10.08
	Zinc	1.18
	Lead	—
Tensile strength (Kg/mm ²)	Iron	—
	—	—
Elongation (%)	27	34
Specific gravity	22	46
Porosity (%)	8.274	8.843
	6.98	0.64

In order to demonstrate the features of the method according to the present invention, the same cold non-ferrous starting material was melted by a known reduction-melting method, in which the starting metal was placed in a rotary crucible, which was then heated in a reducing atmosphere by means of a heavy oil burner. Various properties of a sample made by casting the molten metal thus produced are also shown in Table 11.

It is apparent from Table 11 that the composition of the cast metal was so improved by the present invention that the mechanical strength of the metal melted by the method of the invention is greater than that melted by the known reduction-melting method.

Furthermore, the time necessary for melting the metal was considerably saved, as compared with that of the known reduction-melting method, which requires about one hour. With the method of the invention, oxygen gas or oxygen-enriched air could be used in the fuel-gas-oxygen flame 26 without causing any adverse effect on the inner lining of the vessel 1.

Some of the salient features of the present invention can be summarized as follows:

1. With the present invention, the cold starting material is melted in a vessel, while simultaneously controlling the composition thereof, in a very quick and simple manner. As a result, a high thermal efficiency can be achieved.
2. In the present invention, the melting of the cold starting material is carried out by using an intermediate coke layer spread on the surface of the metal. Accordingly, the metal is substantially instantly melted without causing the metal to be oxidized. Furthermore, the composition of the metal can be controlled by using a suitable agent, while rotating the molten metal in the vessel about an axis which is offset from the central axis of the vessel, and while enclosing the molten metal with a water or air curtain. Thus, various gaseous elements generated in the course of melting, such as oxygen, hydrogen, and nitrogen, can be utilized for the control of the metal composition. For instance, desulfurizing agents can be used very effectively in the method of the invention, because their desulfurizing power can be supplemented with the action of gaseous substances generated in the process of melting the metal, so as to produce a sound low-sulfur molten iron for making spheroidal graphite cast iron.
3. It is an important feature of the invention that the control of the composition of the molten metal for casting can be carried out very quickly, because

the molten metal can be heated to a high temperature by the combustion of fuel-gas-oxygen mixture. Thus, the effects of carburization and desulfurization can be improved.

4. With the present invention, large particles or blocks of the cold starting material and coke can be used, because such particles or blocks are forced to rotate in a vessel about an axis which is offset from the central axis of the vessel. If a cupola is used for melting the metal, the grain size of the starting material must be limited within a certain range.
5. The use of an air or water curtain surrounding the flame of fuel-gas-oxygen mixture protects the refractory lining of the vessel from direct heating by the flame. Accordingly, the lining can be made with commonly used refractory material, such as chamotte.
6. If a water curtain is used, hydrogen gas (H₂) is generated at the contact of the water curtain with the flame of the gaseous mixture. The hydrogen gas thus generated accelerates the reducing reaction of the molten metal and reduces the viscosity of gases dissolved in the molten metal, so that the heat transfer through the molten metal can be improved.
7. In the device of the invention, fuel-gas is delivered to the point of ejection through a separate passage from that of oxygen or air, so that the desired fuel-gas-oxygen mixture is formed only at a position where the mixture is burnt, which position can be enclosed by the water or air curtain. Thus, the danger of back fire is completely eliminated. With such arrangement, a large amount of the gaseous mixture can be burnt effectively while ensuring the complete exclusion of the risk of explosion of the gaseous mixture.
8. The direction of the translation of the melting vessel can quickly be reversed simply by using a reversible motor, whereby the stirring effects of the contents of the vessel can greatly be improved.

Having described my invention, I claim:

1. Apparatus for melting metal for casting, comprising a base; a vessel receiving cold starting material and flux material therein; a framework fixedly holding said vessel while being movably supported by said base; a continuously cooled vertical injector means disposed directly above said vessel and mixing separately delivered fuel-gas and oxygen-rich-gas at the lower end of the injector means, which injector means burns the fuel-gas-oxygen mixture so formed and directs a flame of the mixture into the vessel; a fluid blower disposed adjacent said injector means and producing a fluid curtain between the flame of the fuel-gas-oxygen mixture and the inner surface of the vessel, so as to surround the flame; a driving means; and a transmission means operatively connected to the driving means and adapted to translate the framework together with the vessel along a closed path, so as to cause the starting material and flux in the vessel to rotate therein about an axis which is offset from the central axis of the vessel.
2. Apparatus as claimed in claim 1, said continuously cooled vertical injector means comprising concentric cylindrical tubes including a central tube having a

throttle at the lower end thereof; a second tube surrounding the central tube; a third tube surrounding the second tube; a fourth tube surrounding the third tube and having a first compartment adjacent the third tube for carrying cold water for cooling the central, second, and third tubes, and a second compartment communicating with said first compartment for returning the cooling water after cooling the tubes enclosed by the fourth tube; a fifth tube forming said fluid blower; and a combustion chamber disposed immediately below the lower opening of said throttle of said central tube and communicating with said second and third tubes through holes bored at the lower ends thereof, said fourth tube being extended downward so as to surround the combustion chamber while forming a continuously cooled bottom surface of the injector means.

3. Apparatus as claimed in claim 2, said first and third tubes carrying the fuel-gas, said second tube carrying the oxygen-rich gas.

4. Apparatus as claimed in claim 2, said first and third tubes carrying the oxygen-rich-gas, said second tube carrying the fuel-gas.

5. Apparatus as claimed in claim 2, said first and second tubes carrying the fuel-gas, said third tube carrying the oxygen-rich-gas.

6. Apparatus as claimed in claim 1, said continuously cooled vertical injector means comprising a plurality of vertical injector elements; said fluid blower comprising a loop-shaped belt-like fluid tank which holds said vertical injector elements so as to enclose all the injector elements within the loop of the tank, said vertical injector elements being disposed in symmetry with each other with respect to the central axis of the vessel; each of the projector elements including a central tube having a throttle at the lower end thereof, a second tube surrounding the central tube, a third tube surrounding the second tube, a fourth tube surrounding the third tube and having a first compartment adjacent the third tube for carrying water for cooling the central, second, and third tubes, and a second compartment communicating with said first compartment for returning the cooling water after cooling the tubes enclosed by the fourth tube, and a combustion chamber disposed immediately below the lower opening of said throttle of the central tube and communicating with said second and third tubes through holes bored at the lower ends thereof, said fourth tube being extended downward so as to surround the combustion chamber while forming a continuously cooled bottom surface of the injector.

7. Apparatus as claimed in claim 6, said first and third tubes of each injector element carrying the fuel-gas, said second tube thereof carrying the oxygen-rich gas.

8. Apparatus as claimed in claim 6, said first and third tubes of each injector element carrying the oxygen-rich gas, the second tube thereof carrying the fuel-gas.

9. Apparatus as claimed in claim 6, said first and second tubes of each injector element carrying the fuel-gas, said third tube thereof carrying the oxygen-rich-gas.

10. Apparatus as claimed in claim 1, said transmission comprising a supporting means including support cylinders secured to the base, a rotary member rotatably carried by said support cylinders, an eccentric shaft connected to said rotary member and secured to said framework, said rotary member being rotated by said driving means, whereby in response to the rotation of the rotary member the vessel is translated together with the framework.

11. Apparatus as claimed in claim 1, said transmission comprising a plurality of supporting means, including support cylinders secured to the base, a plurality of rotary members each being rotatably fitted in one of said support cylinders, respectively, eccentric shafts each connected to each of the rotary shafts while being secured to said framework, selected one of said rotary members being rotated by said driving means, whereby in response to the rotation of the selected rotary member the vessel is translated together with the framework.

12. Apparatus as claimed in claim 10, there being a gap between the base and the rotary cylinder, and a gap between the rotary member and the framework.

13. Apparatus as claimed in claim 11, there being gaps between each of the bases and each of the rotary cylinders, and gaps between each of the rotary members and the framework.

14. Apparatus as claimed in claim 1, the inner surface of said vessel being lined with chamotte.

15. Apparatus as claimed in claim 1, and a heat-insulating plate secured to the bottom of the vessel and a plurality of pneumatic bearing chambers inserted between the heat-insulating plate at the bottom of the vessel and the base, whereby a large portion of the weight of materials in the vessel is borne by the pneumatic bearing chambers in a movable manner.

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