(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 511 825 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **92303815.2**

(51) Int. Cl.[5] : **B22D 11/10,** B22D 41/01

(22) Date of filing : **28.04.92**

(30) Priority : **01.05.91 GB 9109383**

(43) Date of publication of application :
04.11.92 Bulletin 92/45

(84) Designated Contracting States :
BE DE ES FR GB IT LU NL SE

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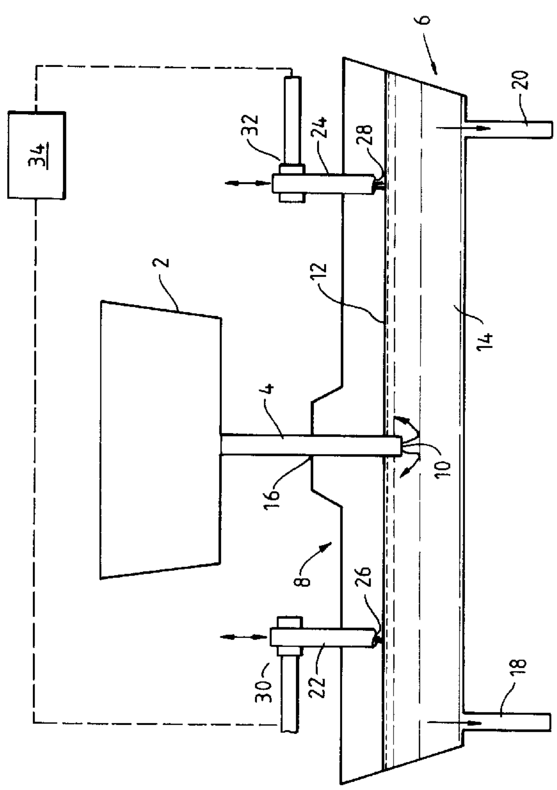
(54) **Heating method and apparatus.**

(57) Molten material, for example steel, is poured from a ladle 2 into a tundish 6. The molten material is heated in the tundish by means of electric arcs struck between graphite electrodes 22 and 24 and the surface 12 of the material in the tundish 6. The electric arcs are stabilised by means of a gas such as argon which is passed down axial passages in the electrodes 22 and 24. Each electrode 22 and 24 receives a direct current electricity supply from a power source 34.



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This invention relates to a method and apparatus for heating a molten material in a tundish.

Tundishes are widely used in systems for transferring molten steel from a furnace in which the steel is made or melted, for example, a basic oxygen or an electric arc furnace, to a continuous casting machine. In such systems, the molten metal is normally fed from the furnace to a ladle which typically has a capacity of from 50 to 400 tonnes. The metal is then poured from the ladle into a tundish typically having a smaller capacity, for example from 6 to 50 tonnes. The tundish is used continuously to feed molten metal to the casting machine. One consequence of this molten metal transfer procedure is that there is a substantial drop in temperature as the metal passes from the furnace to the casting machine. For example, molten steel may leave a melting furnace at a temperature of 1750°C and be received in the continuous casting machine at a temperature of 1530°C. Moreover, the temperature at which the molten metal is received by the casting machine tends to vary, thereby producing a variable microstructure in the resulting steel. For example, the grain size may be particularly affected. Indeed, if a fine grain size is required, then it will generally be necessary to maintain a controlled degree of superheating both in the ladle and the tundish. In general, it is desirable that the depth of the tundish should not be excessive, say no more than about 1.5 metres. Accordingly, the greater the capacity of the tundish, the larger is its surface area, and hence the greater is the rate of heat loss. The need to heat the steel in the tundish is therefore particularly marked for tundishes of large capacity.

It has accordingly been proposed to heat molten metal in a tundish by means of a thermal plasma. A thermal plasma is a gas of sufficient energy content that a significant fraction of the species present are ionised permitting the conduction of electrical energy. Thermal plasmas have been used commercially in, for example, smelting ores. Energy from a transferred arc non-consumable plasma torch is typically transferred directly to the ore being smelted. In a conventional metallurgical furnace used to perform such a process, the electrode of the plasma torch is typically mounted within a framework on top of the furnace and passes through a sleeve arrangement in the lid, allowing the length of the electrode on the underside to be varied according to the operating level of the material being heated in the furnace. A gas used to form the plasma is argon.

In practice, there is a need for ever larger continuous casting machines and hence a need to transfer molten steel at increasing rates to such casting machines. This in turn implies a need for tundishes of ever greater capacity and hence surface area since although it is possible to increase the rate of flow of molten steel in a tundish of given size and hence reduce its residence time therein to meet an increased demand for molten steel, an excessive flow velocity in the tundish has undesirable metallurgical consequences. With greater surface area of molten metal, heat tends to be lost at a greater rate, and hence there is a need for an improved heating means. Commercially available plasma torch tundish heating systems have, however, a limited heating capacity, and it is generally not possible to generate more than about 1 MW from such systems. Moreover, the number and size of plasma torches that can be employed are limited by the generally confined space above a tundish that is available for their installation and by the fact that they need to be supplied with a large electrical current, with gas to form the plasma, and with a stream of water or other coolant to prevent them from overheating. Thus, there is a practical limit on the size of the tundish and hence the size of the continuous casting machine that can be used to produce steel castings of a given quality.

Induction heating is a known alternative method to the use of a plasma torch to heat molten material in a tundish. Induction heating has, however, a number of disadvantages. The stirring action within the molten metal that such heating creates tends to enhance the rate of erosion of the refractory lining, and may have an adverse effect on the metallurgical properties of the steel since it can give rise to reduced cleanliness and an increased number of inclusions. Moreover, the requirement to have the induction heaters physically located in the tundish tends to make refining more diffuclt. In addition, the need to provide water cooling creates problems relating to the design of equipment in order to ensure that the water can never come into contact with the molten metal. Furthermore, the energy efficiency of induction heating tends to be less than that of plasma heating. Finally, as several tundishes are typically required to service one continuous casting machine, several induction heating connections are required, adding considerably to the capital cost.

It is an aim of the present invention to provide a method and apparatus which make it possible to reduce the limitations described above on the heating of molten material, particularly steel, in a tundish.

According to the present invention there is provided a method of heating a molten material in a tundish wherein said heating is provided by means of one or more gas-stabilised electric arcs, each extending to the surface of the molten material from the tip of a carbon electrode located thereabove wherein each electrode receives a direct current supply.

The invention also provides apparatus for transferring molten material comprising a tundish; at least one carbon electrode whose tip is located above the surface of the molten material, each said electrode being adapted to be supplied with an arc stabilising gas, and a DC power source associated with each electrode, whereby, in use, the molten material is able to be heated by means of at least one electric arc struck between the tip of each electrode and the surface of the molten material.

Preferably, a noble gas or mixture of noble gases is supplied through the or each carbon electrode so as to stabilise the arc associated therewith. For this purpose, the or each electrode is preferably provided with an axial gas passage. The passage typically has a diameter in the range of 6 to 10 mm. Smaller diameters are difficult to drill accurately, while larger diameters generally unnecessarily reduce the current conducting capacity of the electrode and reduce arc stability. Preferably argon or a mixture of argon and helium is employed as the arc stabilising gas. By stabilising the arc, it becomes possible to keep it coaxial with the electrode, thereby reducing any tendency for the arc to be displaced towards the wall of the tundish. Such displacement would tend to increase the rate at which refractory used to protect the inner wall of the tundish is eroded.

Preferably, a plurality of carbon electrodes are used to heat the molten material. At least one electrode is preferably a cathode and at least one other electrode is preferably an anode. Such an arrangement avoids the need to employ the kind of return electrode in physical contact with the molten material that is employed in single torch systems using a (non-consumable) plasma torch to heat the molten material.

The or each electrode is normally disposed vertically.

Preferably, during steady state operation of the method according to the invention, the axial distance between the tip of the or each electrode and the surface of the molten material is a chosen length in the range 10-1000mm. More preferably, such length is in the range of 100mm to 500mm. Typically, the or each carbon electrode has associated therewith means for adjusting said length. Accordingly, the precise arc length may be selected so as to provide an exact amount of heating to the molten material in the tundish. In addition, it enables a minimum separation between the electrode tip and the surface of the molten metal to be selected when first striking the arc. The electrode may then gradually be withdrawn until a chosen arc length is achieved.

The method and apparatus according to the invention may be used without the disadvantage of substantial transfer of matter from the electrode to the melt that is usually associated with consumable electrodes. Generally, the amount of carbon that is transferred from each electrode of a pair used to heat molten material is insignificant, e.g. less than 0.1% of the total weight of the molten material, particularly when the molten material is a low carbon steel. For example, the amount of carbon that is so added may be in the order of 80 grams per tonne when the heat input is 20 KWH per tonne of steel. We attribute this ability to keep down carbon transfer from the electrodes to the metal to an ability to maintain the tip of each electrode well away from the molten material during normal operation. This in turn is a function of the stability of the arc and the use of a DC power source. The latter helps to guard against intermittent extinguishment of an arc that tends to be a characteristic of the use of AC. If the arc is extinguished, it is generally desirable to lower the electrode until it is almost dipping into the melt before striking a fresh arc. We believe that when the tip of the electrode is particularly near the surface of the molten material, e.g. when striking an arc, the rate of transfer of carbon to the melt is much greater than during normal operation.

Although, in the method and apparatus according to the invention, the rate of erosion of the electrodes may be relatively low, from time-to-time adjustment of the position of each electrode will be desirable in order to maintain the arc voltage at a constant value or within chosen limits. Such adjustment can typically be made manually, although if desired, an automatic or semi-automatic system may be employed for this purpose.

Typically, the power source has a current control means, which enables a specific current to be set of a given arc length and hence arc voltage. Typically, the arc voltage is selected to be 120V when using a pure argon stabilising gas; higher arc voltages can be created for a given arc length by including helium in an argon stabilising gas. Preferably, the current density in each electrode is 30A/cm^2 of electrode cross-sectional area (in a plane perpendicular to the axis). Suitable stabilising gas flow rates are in the range of 25 to 100 litres per minute per 1000A.

The method and apparatus according to the invention make it possible to achieve all the normal advantages of using a plasma torch to heat the molten material. In particular, if the tundish is fed from a ladle, the ladle tapping temperature can be reduced (in comparison to what it would be if there were no heating) saving costs on power and electrodes and reducing the interval of time between consecutive batches. In addition, a required tundish temperature may be held throughout casting to improve the quality of the resulting casting, including the fineness and consistency of the grain size.

Moreover, by using at least two electrodes in the method according to the invention it is possible readily to achieve a heat input of more than 1.5 MW. This in turn facilitates the effective use of large tundishes and helps to ameliorate the difficulties described above with respect to use of non-consumable plasma torches.

Other advantages that arise are that carbon electrode systems require less bulky support systems and fewer services than non-consumable plasma torches. Accordingly, they are more readily usable when there is a relatively confined space between the ladle or other device feeding the tundish and the tundish itself. In addition, there is less constraint on power input since graphite electrodes are readily available in a large range of sizes and therefore power inputs. Since there is no need to provide water cooling for the electrodes, the energy efficiency of the system is increased. The absence of such water cooling also reduces the risk of water impinging upon the molten material in the tundish and thus causing a safety hazard. Moreover, since return electrodes that are required for plasma torches are not needed when a plurality of carbon electrodes are used, there are reduced tundish maintenance costs. Further, by appropriately selecting the number of electrodes used, it may be possible to reduce the size and cost of the necessary power source in comparison with a plasma torch system.

The method and apparatus according to the invention will now be described by way of example with reference to the accompanying drawing, which is a schematic drawing of a molten steel pouring system for use with a continuous caster.

The drawing is schematic and not to scale.

Referring to the drawing, there is shown a ladle 2 having a bottom spout 4 extending vertically downwards through the roof 8 of a tundish 6 and terminating in an outlet 10 below the surface 12 of a volume of molten steel 14 in the tundish 6. A vent passage 16 is defined between the outer surface of the spout 4 and the roof 8 of the tundish 6. The tundish 6 has outlets 18 and 20 for molten steel at its bottom.

In accordance with the invention, the tundish 6 has associated therewith two spaced-apart, graphite, electrodes 22 and 24. In use, the tips 26 and 28 of the electrodes 22 and 24 respectively are each positioned a chosen axial distance above the level of the surface 12. Although not shown in the drawing, the electrodes 22 and 24 are each provided with an axial passage for the flow of an arc stabilising gas therethrough. In addition, the electrodes 22 and 24 have associated therewith respective support mechanisms 30 and 32 which enable electrodes 22 and 24 to be held vertically. The support mechanisms 30 and 32 also enable the vertical positions of the electrodes 22 and 24 to be adjusted. In use, the electrodes 22 and 24 make an electrical circuit with the molten steel and a DC power source 34, one of the electrodes 22 and 24 being a cathode and the other an anode. The electrodes 22 and 24 are also provided with argon supply for their gas passages.

In operation, with the outlets 18 and 20 closed, molten steel is poured into the tundish 6 to a chosen level a little way above that of the outlet 10 of the spout 4 of the ladle 2. The electrodes 22 and 24 are then lowered to, say, 10mm above the surface. Argon is passed through the central passage of each electrode and a current applied thereto such that an arc is struck between the surface 12 of the molten steel 14 and the tips 26 and 28 of the respective electrodes 22 and 24. The electrodes 22 and 24 are then gradually raised to a chosen height, say 200mm, above the surface 12 of the molten metal 14 in order to give a chosen rate of heating the molten metal. The temperature of the molten steel is thus raised to a chosen value at which the amount of heat per unit time received by the molten steel from the electric arcs at least balances the amount of heat lost per unit time by the steel to its surrounds. The outlets 18 and 20 are then opened and the molten steel discharged into a continuous casting machine (not shown). The argon that emanates from the electrodes 22 and 24 displaces gas from the head space defined between the roof 8 of the tundish 6 and the surface 12 of the molten steel. Such gas passes out of the tundish 6 through the outlet 16. The fitting of the electrodes 22 and 24 is substantially air-tight. Accordingly, the amount of oxygen in the atmosphere above the surface of the molten metal in the vicinity of the electrodes 22 and 24 may be minimised, thus minimising wear of the electrodes 22 and 24.

The operating parameters for the above-described apparatus may be selected from the ranges described hereinabove.

The apparatus shown in the drawing may be used repeatedly to heat batches of molten steel from the ladle 2 and then discharge the heated molten steel into a continuous casting machine. Typically, a plurality of apparatuses according to the invention may be used simultaneously to feed a single continuous casting machine.

Claims

1. A method of heating a molten material in a tundish, wherein said heating is provided by means of one or more gas-stabilised electric arcs, each extending to the surface of the molten material from the tip of a carbon electrode located thereabove, wherein each electrode receives a direct current supply.

2. A method as claimed in claim 1, in which a plurality of carbon electrodes are employed, at least one electrode being a cathode, and at least one electrode an anode.

3. A method as claimed in claim 1 or claim 2, in which the arc-stabilising gas is a noble gas or a mixture of noble gases.

4. A method as claimed in any one of the preceding claims, in which after striking the or each arc, the or each electrode is maintained in a position such that the axial distance its tip and the surface of the molten material is maintained at a chosen length in the range of 10mm to 1000mm.

5. A method as claimed in claim 4, in which said length is in the range of 100 to 500 mm.

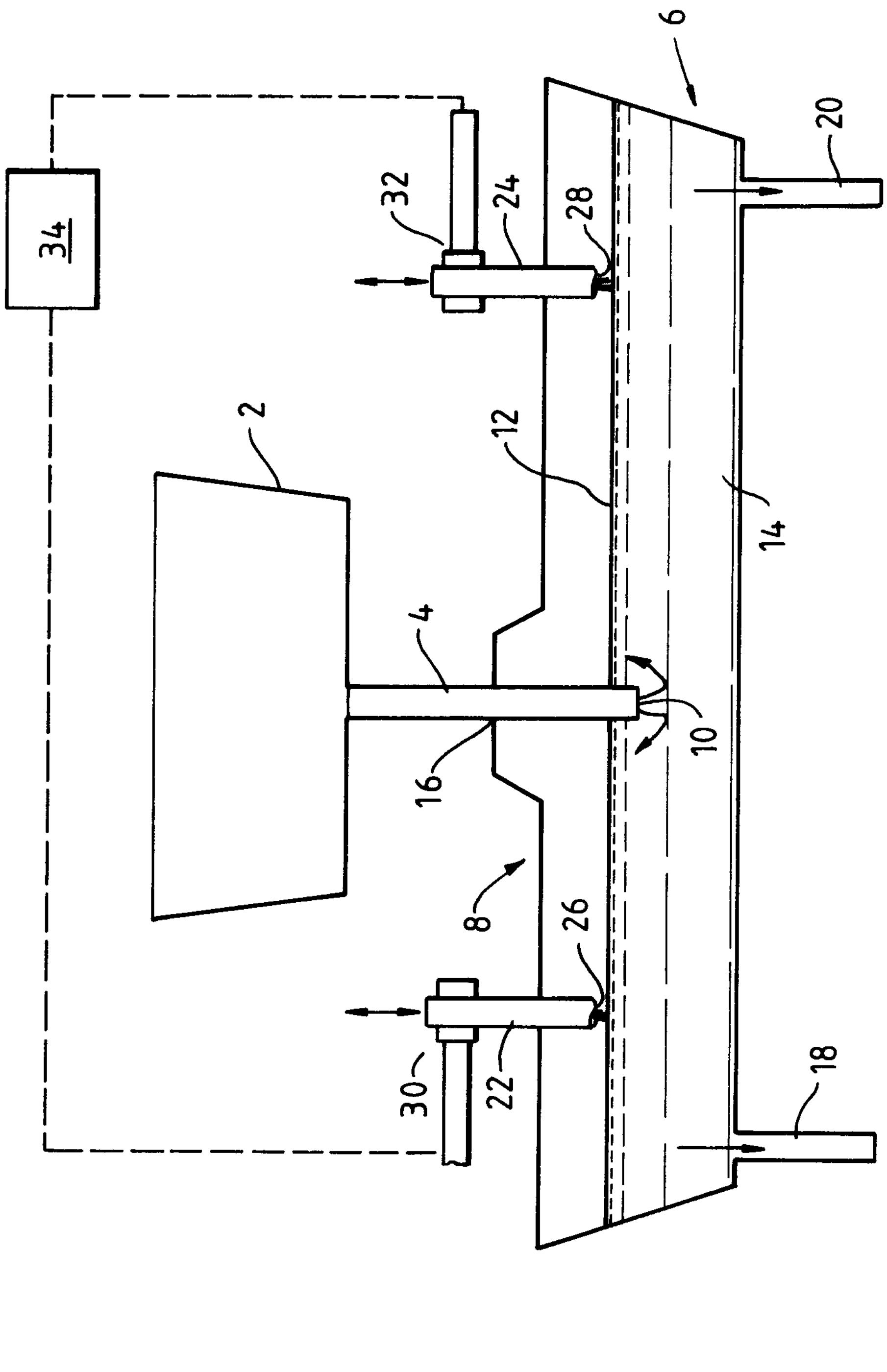
6. A method as claimed in any one of the preceding claims, in which the molten material is a steel.

7. Apparatus for transferring molten material comprising a tundish; at least one carbon electrode whose tip is located above the surface of the molten material, each said electrode being adapted to be supplied with an arc stabilising gas, and a DC power source associated with each electrode, whereby, in use, the molten material is able to be heated by means of at least one electric arc struck between the tip of each electrode and the surface of the molten material.

8. Apparatus as claimed in claim 7, wherein there is a plurality of said electrodes, at least one electrode being a cathode and at least one other electrode being an anode.

9. Apparatus as claimed in claim 7 or claim 8, in which the or each electrode has therethrough an axial passage for an arc stabilising gas or gas mixture.

10. Apparatus as claimed in any one of claims 7 to 9, in which the or each electrode has associated therewith means for adjusting the axial distance from its tip to the surface of the molten material.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EUROPEAN SEARCH REPORT

Application Number

EP 92303815.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB - A - 2 239 828 (DAVY MC KEE) * Abstract; fig. 1; claims 1,4 *	1,3,5, 7,10	B 22 D 11/10 B 22 D 41/01
A		2,8	
A	EP - A - 0 235 340 (NIPPON STEEL CORPORATION) * Abstract; description, columns 4-6 *	1,2,6, 7,8,10	
A	AT - B - 320 884 (ALLMÄNNA SVENSKA ELEKTRISKA AKTIEBOLAGET IN VÄSTERAS) * Description; fig. 1 *	1,2,6, 7,8,10	
A	US - A - 4 357 485 (LAMARQUE) * Abstract; fig. 1 *		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B 22 D 11/00
B 22 D 41/00
H 05 B 7/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	06-07-1992	SCHÖNWÄLDER

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