March 17, 1970 C. W. FINKL ET AL 3,501,290

METHOD OF TREATING MOLTEN METAL WITH ARC HEAT AND VACUUM

Filed Aug. 29, 1966 2 Sheets-Sheet 1

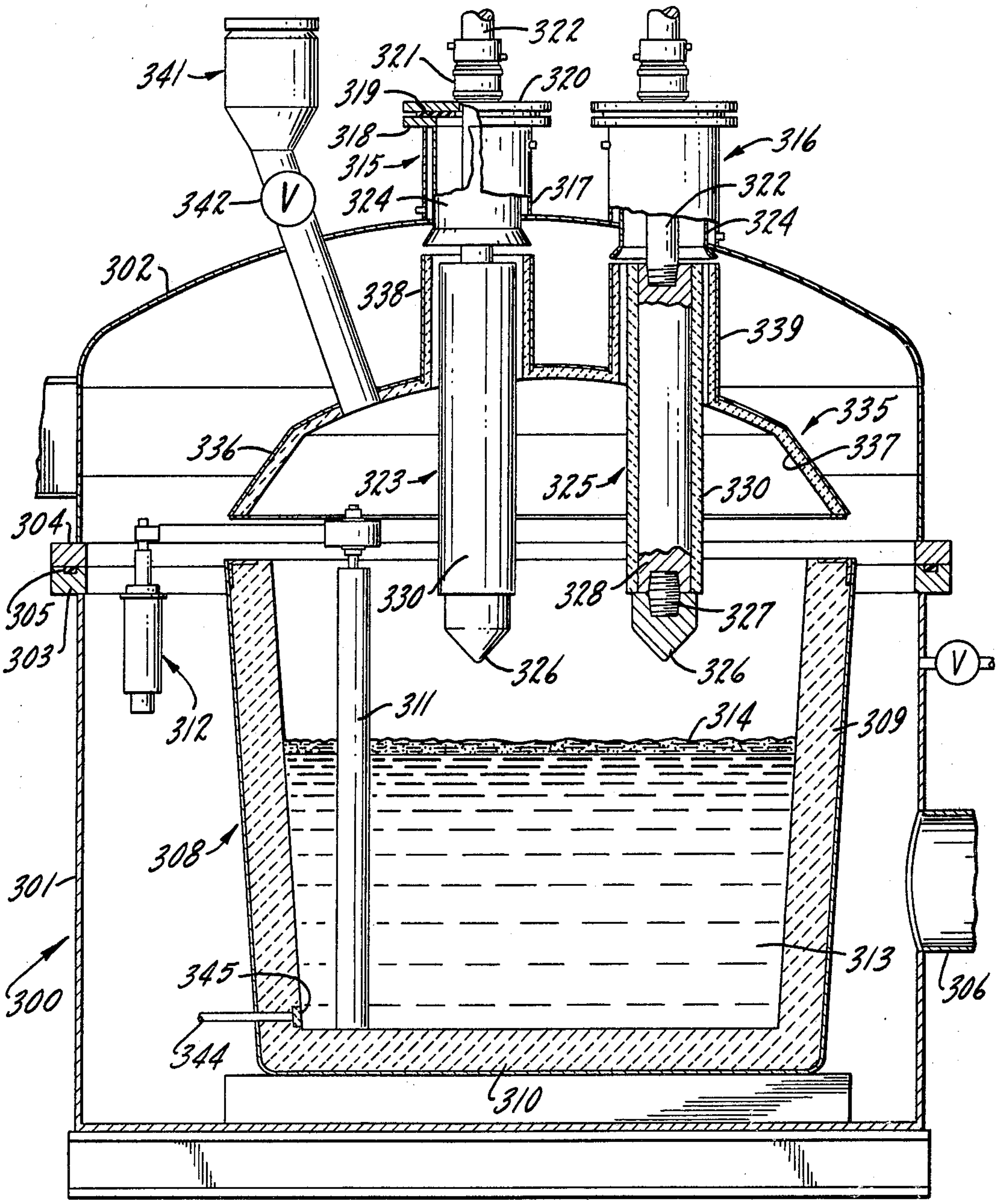

Fig. 1.

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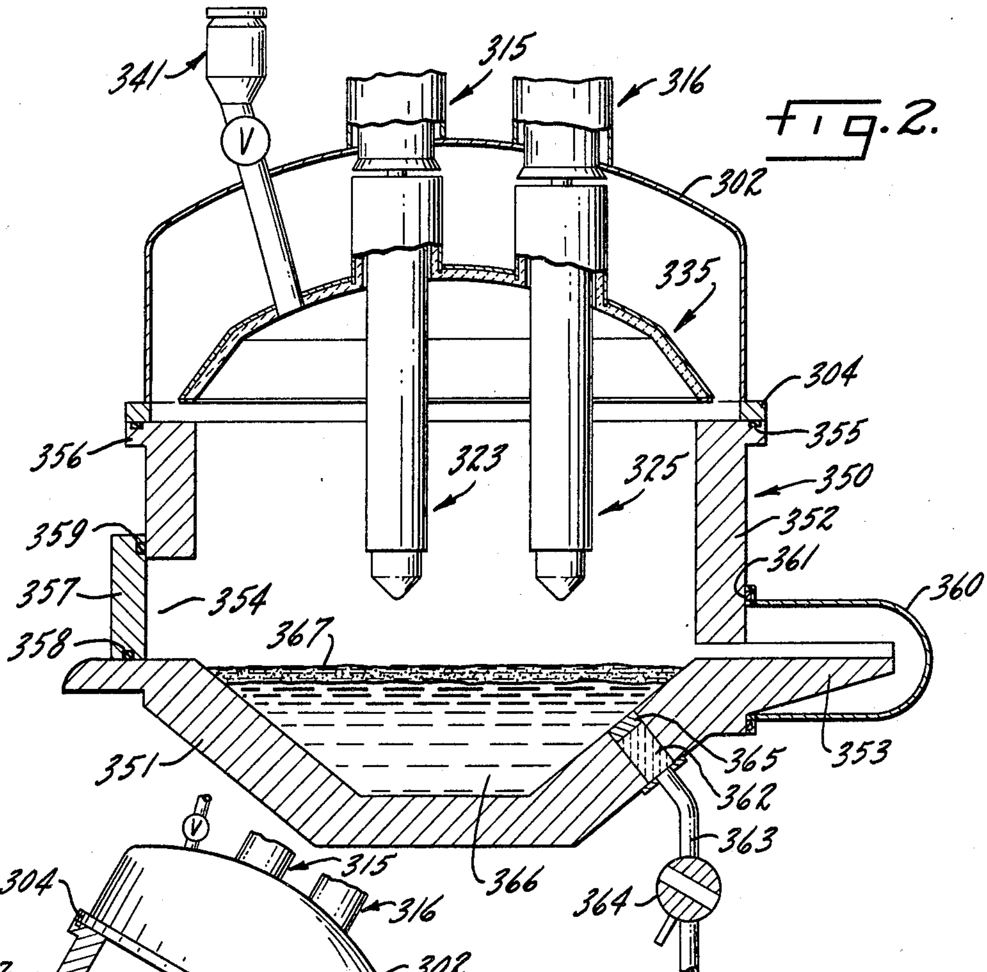

Fig. 2.

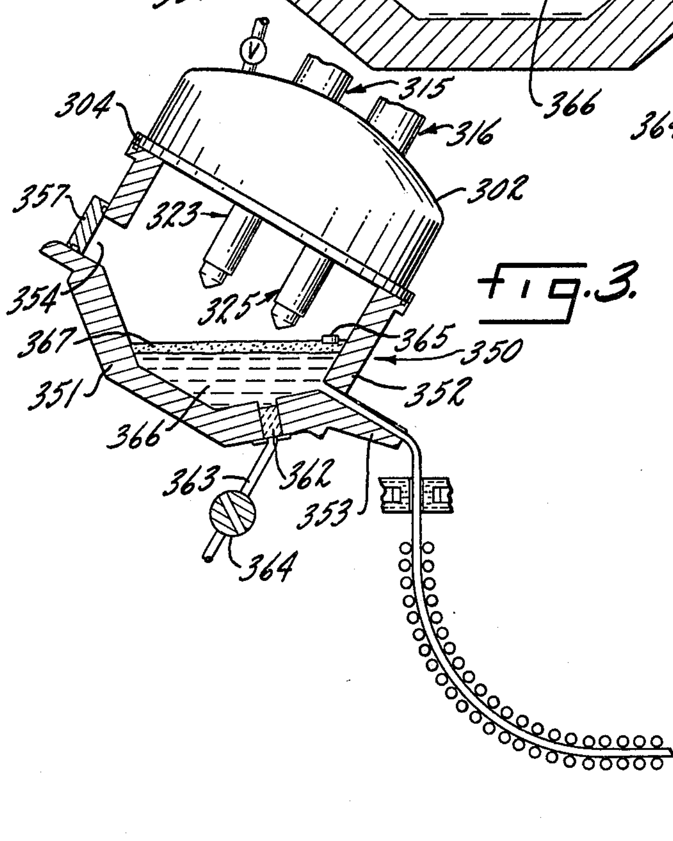

Fig. 3.

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METHOD OF TREATING MOLTEN METAL WITH ARC HEAT AND VACUUM

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Int. Cl. C21c 7/10, 5/52

U.S. Cl. 75—12 5 Claims

ABSTRACT OF THE DISCLOSURE

A method of treating molten metal in which heat is added to a charge by an AC heating arc struck between non-consumable electrode means and the metal charge, the temperature of the metal is regulated to the proper range by the heating arc, and the metal is simultaneously subjected to a degassing vacuum during at least a portion of the time the time the arc is operated. After treatment the metal may be poured.

This application is a continuation in part application of copending application Ser. No. 462,559, filed June 9, 1965.

This invention relates to methods and apparatus used in the production of steel. Specifically, it relates to a convenient and efficient mode of controlling, to some extent at least, the temperature of the steel at some stage or stages in the production process.

Sand casting and ingot casting comprise one field of application of the invention. In order to obtain sound centers and proper surface characteristics of sand castings and ingots teeming temperatures should be held within plus or minus 10° F. This degree of control can now be obtained by superheating in the furnace in order to compensate for temperature loss which will occur due to treatment performed between tap and teem, such as vacuum degassing. Furnace superheating requires additional time, increases furnace costs due to the resultant higher than normal rate of erosion of the furnace refractories, and, in the event the metal is tapped too cold, the vacuum degassing or other treatment must be shortened.

Another application of the invention is in the basic oxygen process of producing steel which has come into widespread use. In this process molten iron from a blast furnace or other melting source is transferred to an oxygen converter where it is blown with oxygen to lower the carbon and other oxidizable elements, and at least partially refine the steel. The throughput, which is extremely high when contrasted to prior methods of single vessel steel making, is almost continuous and is therefore ideally adapted to a continuous casting process. When the oxygen converter is incorporated into a continuous casting process the basic equipment for producing continuously cast sections from raw material consists of only three pieces of equipment, namely, the blast furnace or other primary melting source, the oxygen converter, and a continuous casting machine.

While the above described system has many inherent capabilities which are not readily achievable in other commercially used processes it does have certain drawbacks. For example, the material charged into the oxygen converter may include scrap within a rather wide range of percentage of the charge. Usage of large quantities of scrap may be economically desirable, as where the price of scrap is low in comparison with the price of blast furnace iron or if sufficient iron is unavailable. However when a large percentage of the charge is scrap the molten

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metal produced may be too cool for use in a continuous casting process because the continuous casting machines now in commercial use have a relatively small range of permissible temperature variation for providing sound cast strands. If, therefore, the entering temperature of the steel at the continuous casting machine is too cold, as when delays occur or an unusually high percentage of scrap is utilized in the converter, or too hot, stringers or other undesirable defects may be present in the cast strand. It is in this situation that this invention finds particular application, because the temperature of the steel can be lowered or raised within limits just prior to entering the continuous casting machine by treatment according to the present invention.

Accordingly, a primary object of this invention is to provide a method for sand casting, ingot casting, or continuous machine casting in which the temperature of the metal may be closely controlled and maintained to within a few degrees of the optimum desired temperature. In other words, the present invention contemplates the use of an auxiliary apparatus as a polishing unit for the primary purpose of regulating the temperature of the molten metal for the purpose of raising, lowering or maintaining the temperature of the molten metal being processed so as to maintain the temperature at an optimum desired level. It may of course be used in conjunction with other processes, such as vacuum degassing with or without auxiliary agitation such as gas purging.

Another object is to provide a method for treating steel including a treatment station at which refining and addition procedures may be most conveniently carried out, such as the addition of aluminum additives for deep drawing steels in the continuous casting process. Thus, a dwell period is provided in the steel making process which makes time available for running analysis of the steel, and adding required charge materials.

The field of application of the invention is not limited to a continuous casting process, sand casting or ingot casting. In fact it is applicable to any steel making process in which temperature control of the metal is required.

For example, up to now the vacuum degassing of large open hearth heats on the order of 200 tons has not become widespread due to difficulties in superheating the steel the slight amount needed to enable vacuum degassing to be most effectively carried out. The temperature of the steel can be raised the desired amount if the charge is kept in the open hearth or other melting unit long enough, but the additional furnace fuel, the refractory erosion, and the time involved may increase the overall cost of the steel making process to a point where the economic advantage of vacuum treatment is largely nullified. By employment of the method and apparatus of this invention, the molten metal can be tapped at a normal or slightly increased tapping temperature and thereafter further heated without difficulty by means of a more economical and efficient alternating curent arc.

Accordingly, another object of the invention is to provide a method for the vacum degassing of large and small heats of molten metal economically and efficiently including heats as small as ten tons and below which up to now have been considered virtually impossible to degas.

The method of this invention is also usable in conjunction with other types of steel making equipment to thereby achieve better utilization thereof. It may for example be used in conjunction with a degassing operation carried out in a vacuum tank to facilitate refining. Thus, desulphurization in a vacuum tank by the addition of lime, limestone and even silicon is made feasible because of the increased heat of the metal and slag. In the past the addition of lime has not always been completely effective when added at a time when slag covered metal was exposed to a vacuum because of the relative coolness of the slag.

It will also be possible to save furnace time and reduce the overall cost of the steel making process while maintaining the quality of the steel with the present invention. Thus, the electric arc furnace, which has heretofore performed the function of refining in addition to melting can be used solely for melting and the refining and charge material addition functions may be transferred to the ladle or other supplemental handling receptacles.

In perhaps its broadest aspect the inventive concept might best be described as the absorption of heat from an AC arc under vacuum by a metal charge contained in a receptacle having a metal contacting surface of low electric current conductivity. By the term "metal contacting surface of low electric current conductivity" or equivalent expressions is meant materials which are today generally considered to be nonconductors of electricity, such as silica, alumina, zirconia, and magnesium bricks of the type widely employed in the steel industry as linings for molten metal holding receptacles. As a rule the aforesaid materials are generally characterized in that they also have comparatively low heat conductivity characteristics. Unless the context indicates otherwise, the foregoing meaning is intended to be expressed by the above term in this specification and the appended claims.

An application of this concept is the employment of an AC arc derived from either a single of multi-electrode source, preferably a three-electrode three-phase sixty cycle source, in an electric furnace into which a metal charge has been placed. After treatment the metal may be poured into other receptacles, such as a ladle, for further treatment and processing. Preferably however the treated metal is cast directly into a mold from the receptacle in which the metal has been treated. Either an ingot, sand, close tolerance ceramic or continuous casting mold may be employed.

If apparatus design and space considerations permit, the metal might be bottom poured directly from a furnace which has been modified to accommodate the nonregulated, nonconsumable AC vacuum electrodes of this invention. In this later event the pouring stream may be shrouded in inert gas. The term "nonregulated" when used in this specification and the claims in reference to position control of the AC arc source denotes the absence of automatic control means associated with the arc source, such as the conventional voltage controlled electrode positioners so widely employed today. The term does not exclude rough manual adjustment made between the AC arc source and the treatment receptacle which may, under some circumstances, be desirable, such as when the boil, and therefore the level, of the molten metal bath drops substantially over a relatively long period of time, usually measured in minutes, due to removal of the oxygen and other deleterious gases contained in the steel and the consequent decrease in intensity of the CO boil, or killing of the bath by the addition of active deoxidizers.

Accordingly another object of the invention is to provide a method for treating metals in a receptacle having a metal contacting surface composed of a material having low electric current conductivity, such as a ceramic refractory, by use of a non-regulated AC arc.

Another object is to provide method as described in the preceding paragraph in which the AC arc is maintained under a vacuum sufficiently low to effectively degas the charge in a molten condition for at least a portion of the time the charge is in the receptacle.

Yet a further object is to provide a method as described in the immediately preceding paragraphs in which the charge is in solid condition at the commencement of the process and an AC arc is initially maintained under substantially atmospheric conditions until a portion or all of the charge is in a molten condition at which time vacuum conditions are established above the metal and about an AC arc which requires no arc voltage regulation.

Finally, this invention relates to a method for confining the glow effect of an alternating current arc of the type described in our aforesaid copending application below the rim of the metal holding receptacle, and therefore within the available freeboard area.

Other objects and inventions will become apparent from a reading of the following detailed description of the invention.

The invention is illustrated more or less diagrammatically in the accompanying drawings wherein:

FIGURE 1 is a sectional view, with parts broken away for clarity and others indicated diagrammatically, through a vacuum tank within which is located in a molten metal holding receptacle,

FIGURE 2 is a sectional diagrammatic view of another embodiment of the invention; and

FIGURE 3 is a view illustrating incorporation of the invention into a continuous casting process.

Referring first to FIGURE 1, a vacuum tan is indicated generally at **300**, said tank including a lower stationary portion **301** and an upper removable cover or dome **302**. It will be understood that the cover, and the mechanism associated therewith and carried thereby, may be lifted and swung out of registry with the lower section **301**, by any suitable life and swing mechanism, a detailed description of which is not essential to an understanding of the invention. The lower and upper portions of the vacuum tank **300** terminates in flanges **303** and **304**, respectively, between which a vacuum tight seal **305** is located. A connection to a source of vacuum is indicated at **306**. Any suitable means for creating a vacuum within tank **300** may be employed. It may for example be desirable to employ a multi-stage steam ejector system. If the internal volume of the vacuum tank lies within the range of approximately 1200 to 1900 cubic feet, and it is contemplated that heats of 35 to 40 tons are to be treated, a three or four stage steam ejector capable of reducing the vacuum to two mm. Hg absolute or less in from five to ten minutes will be quite suitable.

A molten metal receptacle, here a ladle, is indicated generally at **308**, said receptacle consisting of an upwardly and slightly outwardly extending refractory lined side wall **309**, and a refractory lined bottom **310**. In this instance, a bottom pour ladle has been shown, the discharge opening of which is controlled by a conventional stopper **311**, which is raised and lowered by any conventional control mechanism indicated at **312**, the heat **313** in this instance carrying a thin layer of slag **314** on its surface.

A plurality of vacuum tight housing structures are indicated generally at **315** and **316**. Preferably three such structures placed 120° apart about a common circle are utilized. Each housing includes an outer wall **317** which terminates at its upper end in a flange **318**. An isolator ring **319** is tightly clamped between flange **318** and aperture plate **320**. A flexible coupling **321** makes vacuum tight engagement with the upper end **322** of a carbon or graphite electrode structure which is indicated generally at **323**. A cooling chamber is formed between a sleeve **324** and outer wall **317**, sleeve **324** being welded at its upper and lower portions to flange **318** and dome **302** respectively.

Each of the electrode structures **323**, **325** consists essentially of a graphite tip **326**, which is connected by any suitable means **327** to shank portion **328** which in turn is connected by any suitable means to the lower end of current conductor **322**. Shank portion **328** is of a smaller outside diameter than the upper end portion of tip **326**. A refractory sleeve **330** surrounds shank portion **328** and rests upon the ledge formed by the overhang of tip **326**. Any suitable means may be employed for raising and lowering the electrodes.

A heat shield is indicated generally at **335**. The heat shield includes a metallic shell **336** and a refractory lining

337. Projections **338** and **339** accommodate the electrode means **323**. The heat shield is secured to and carried by dome **302** by any suitable means, a detailed description of which is not necessary to an understanding of the invention.

A vacuum tight charge material container is indicated generally at **341** and a control valve therefor at **342**. One or a plurality of such charge material addition containers may be employed, heat shield **335** being suitably apertured to provide access to the interior of receptacle **308**.

Another embodiment of the invention is illustrated in FIGURES 2 and 3.

In this embodiment a conventional electric arc furnace is indicated generally at **350**. The furnace includes a hearth section which consists of the forehearth **351** and a generally vertically upwardly extending section **352**. A conventional tapping spout is indicated at **353** and a charging opening at **354**. The conventional furnace roof and associated electrode assembly has been replaced by the hood assembly of FIGURE 1. A sealing member **335** forms an airtight seal between flange **304** of the hood assembly and the upper flange **356** of the vertical section **352** of the furnace. The charging door **357** which closes charging opening **354** is sealed about its periphery as at **358** and **359**. A tapping spout closure member **360** is sealingly connected to the front face of the furnace as at **361** so that the interior of the furnace is vacuum tight. The interior will be connected by any suitable source of vacuum, now shown for purposes of clarity.

A porous refractory gas emission plug is indicated at **362**, the rear face of the plug being in communication with a source of gas **363**, access to which is controlled by valve **364**. A protective mud plug is indicated at **365** for a purpose which will appear hereinafter. In the illustrated condition, a molten metal charge **366** is contained in the forehearth, the charge including a layer of slag **367**.

The use and operation of the invention is as follows:

For purposes of convenience the FIGURE 1 embodiment of the invention will be described as applied to an oxygen converter-continuous casting process.

Molten metal from a blast furnace, cupola or other suitable primary melting unit is charged into an oxygen converter along with a desired proportion of scrap.

After treatment in the converter the molten metal is tapped into treatment receptacle **308**. The temperature of the molten metal at this time may be too high or too low for further processing depending on many factors, one of which is the amount of scrap charged into the converter. If a high percentage of scrap is utilized in the converter the temperature of the molten metal at the time it is tapped into the receptacle **308** may be too low, and this condition will be assumed.

After tapping into the ladle **308** it is transferred to vacuum tank **300** and placed therein as shown in FIGURE 1. As soon as dome **302** is connected vacuum system **306** is activated and the pressure within tank **300** reduced to the desired level. Any suitable pressure may be utilized but for commercial operations a pressure on the order of two mm. Hg absolute or less will usually minimize the time the molten metal is treated prior to pouring from receptacle **308** in the type of system illustrated in FIGURE 1.

An important benefit flowing from the use of this invention is that a higher absolute vacuum may be employed to obtain very low final gas values.

Vacuum values on the order of one or two mm. Hg are perhaps the most widely used today, particularly in connection with steels to be used in heavy forgings. Indeed, one leading steel producer has advocated the use of vacuum levels on the order of 100 microns or below to achieve optimum results.

Now, is is well known that vacuum levels of such low magnitude are not theoretically necessary to obtain the desired results. Consider for example the acceptable hydrogen level for the production of substantially flake free foregoing steel. If the upper tolerable limit for such steel is 2.2 p.p.m., which is a limit currently in use, it is known from Sievert's Law that this level may be obtained with a vacuum of around 9 mm. Hg if the steel can be held in a molten condition for a long enough period of time. See for example the article "Production-scale Steel Degassing in Vacuum," Tix, Proceedings of the Electric Furnace Steel Conference, 1955, pp. 70–81 and the theoretical discussion therein of the importance of partial pressures above the melt on final gas contents of the solid product. The lower levels of 1 to 2 mm. Hg, or below, are currently considered essential however because such low levels increase the rate of evolution of hydrogen from the molten metal to the vacuum environment, and allow the process to be successfully concluded within the rather limited time now available for treatment. In effect, the lower the vacuum, the greater the driving force tending to cause evolution of the included deleterious gases and the shorter the time the metal need be exposed to the vacuum, and therefore the smaller will be the temperature drop of the steel. Indeed, it might be considered that current secondary vacuum degassing processes are limited by the temperature drop limitation of the steel which may be defined as the time between tapping from the melting unit until the metal is too cold to teem. Even the use of induction coils are too little or no avail in increasing the permissable temperature drop limitation since the primary effect of such coils is to agitate the metal. They do not appear to add any appreciable amount of heat.

Since the temperature drop of the steel may be arrested, or even increased if desired, with this invention the steel may be held for long periods of time at vacuum levels higher than those currently used, but still low enough to lower the final gas content to the desired level.

A higher absolute vacuum level enables a fewer number of ejector stages to be used, thus lowering the initial and operating expense of the vacuum system. It may for example make possible the use of only the condensing stages in a multi-stage steam ejector system which has advantages those skilled in the art can readily appreciate.

Thus, for example, in a four stage steam ejector system serving a vacuum tank of approximately 1200 cubic feet in which the lowest vacuum stage is non-condensing and the remaining stages are condensing, it is possible to efficiently degas the molten metal using only the three condensing stages. Experience has shown that initially the vacuum level will be around 5–6 mm. Hg which will eventually decrease to around 2 mm. Hg as the end point is reached. Both levels will be quite sufficient to reach or closely approach an equilibrium between the hydrogen in the steel and in the atmosphere within the extended treatment time made possible by this invention. The end product will be a steel having a final hydrogen content within the above-mentioned upper limit.

While the molten metal and its accompanying thin slag layer **314** are subjected to the vacuum, an alternating current arc is established between electrode means **323**, **325** and others, if present, and the molten metal, all as set forth in detail in our aforesaid copending application.

Because of the encasement of the shank portion **328** of each electrode in a refractory sleeve **330** the arc will be maintained between the tip **326** of the non-consumable electrode and the molten metal **312**. The tendency for the arc to wander from the electrode to the receptacle, heat shield **335** or other metallic portions of the system is thereby eliminated. Furthermore, the provision of a pointed tip on the electrodes further helps to confine the arc and reduce the glow effect.

By suitable design of the system components and appropriate manipulation thereof during treatment the temperature of the molten metal **313** may be closely regulated. In one application of the invention to a heat of approximately 37 tons of electric furnace low alloy steel a current of 12,000 amps was measured at a kilowatt input of 2600. At this level a very good arc was maintained, the transformer voltage being read at 147 and the arc voltage at approximately 110. It will be understood however that tthe above figures are given by way of example only, for the system is operable over a wide range of voltage and current flow. Values of up to 17,000 amps with a 4500 kw. input have been measured, and even higher values are contemplated.

It has been observed that as the described current flows there is a tendency for a glow effect to be established but the refractory sleeves **330** are very effective in confining the AC arc to the molten bath and reducing the glow effect.

It has also been discovered that the establishment and maintenance of the alternating current arc is independent of the arc length within wide limits. Listed below are the results of a commercial heat of steel in which the length of the arc was changed during the heat to determine the effect of a variable length or arc on the intensity and stability of the arc.

Arc length, in.	Arc volts	Amps
6	80	8,000
11	77	8,000
16	83	8,000

The arc length is the distance between tip **326** and the nominal level of the steel. Under vacuum condition a violent boil occurs and the arc length varies from instant to instant even when the position of the electrode is fixed with respect to the receptacle **308.** As is readily apparent from the above table the heat input remains substantially constant over a wide range of arc length variation. This is surprising in that it was thought that variations in the arc length would have a disruptive effect on the stability and intensity of the arc.

If the molten metal had been tapped into receptacle **308** from an open hearth furnace at the normal tapping temperatures, the AC arc may be maintained long enough to raise the temperature to a level suitable for further processing, such as continuous casting. When used in this fashion this unit performs the additional function of a heating unit.

While receptacle **308** is in vacuum tank **300** other process steps may be carried out. Charge material, including alloy additions, may be admitted to the melt from hopper **341** by manipulation of valve **342** at any desired time in the cycle. As explained in further detail in Patent No. 3,145,096 it may be desirable to hold off certain additions, such as aluminum and silicon, until late in the cycle.

Furthermore refining operations can be carried out within tank **300.** For example lime, which is a potent desulphurizing agent, may be added from a charge material addition hopper and the heat thereby desulphurized in tank **300** rather than in the primary melting unit. Since the temperature of the slag can be increased over its entering temperature by virtue of the heat from the AC arcs the slag layer **314** will present little hindrance to desulphurizing by the addition of lime. It will be understood of course that no slag or a partial slag may be present depending on the particular requirements of the steel undergoing treatment.

If desired the degassing action can be promoted by the use of additional metal agitating means. Induction stirring coils for example may be employed to create a doughnut-shaped boil, or a mechanical mixing action can be provided by rocking the container or utilizing a paddle-type stirrer. Preferably agitation is induced by the admission of a purging agent, such as helium, argon or desiccated air through conduit **344** and purging plug **345** from a suitable source, not shown. If desired reactive gases may be used for hydrogen and oxygen reduction, or even for alloying purposes. The upward passage of the finely divided gaseous bubbles creates a circulatory effect which causes molten metal from regions remote from the surface to be brought to the surface where the virgin metal is exposed to the vacuum. Purging near the rod has additional benefit of clearing slag from the region of the stopper rod thereby reducing the corrosive effect of the slag on the stopper rod refractories.

After treatment at the vacuum station shown in FIGURE 1 the ladle **308** is transported to a pouring station where it is preferably teemed into a continuous casting machine. Alternately, the molten metal may be teemed into ingot, sand or ceramic molds, either in air or under an inert gas shroud.

In the embodiment of FIGURES 2 and 3 the invention is illustrated in connection with an electric arc furnace. In this instance a conventional electric arc furnace has been modified to the extent that the conventional furnace roof with the usual electrodes has been replaced by the vacuum arc cover described in detail in connection with the embodiment of FIGURE 1.

A charge is admitted to forehearth **351** through opening **354**, or through the top of the furnace. The charge might be admitted to the forehearth in molten condition, or a combination of molten and solid materials might be employed, but preferably the conventional solid scrap charge is used.

After charging, the material is melted down. Firstly, conventional AC arcs may be employed with arc voltage regulation as in a conventional arc melting furnace, at atmospheric pressure, to bring the charge to a molten condition, after which the conventional electrode regulation may be removed and the arcs may be operated in vacuum as described in this application. Alternately, the solid charge may be melted by the application of the AC arc from the illustrated electrodes, under vacuum.

At least as soon as the charge **366** is molten a vacuum is drawn in the furnace and the remaining treatment is carried out in a manner similar to that described in connection with the FIGURE 1 embodiment. Prior treatment may of course be carried out partially or entirely in a vacuum. If desired, further agitation may be imparted to the charge **366**, particularly after addition of alloys from hopper **341**, by mechanically agitating the charge by any suitable means. In this instance a purging arrangement has been shown. By manipulation of valve **364** a gas which is inert with respect to the charge undergoing treatment, such as argon, helium, carbon monoxide or desiccated air is bubbled upwardly through the charge to thereby set up a circulation which brings metal remote from the surface of the charge to the surface, and creates a circulation which ensures good mixing of the alloying materials. Purging also increases the interface action between the slag and the bath. It will be understood that the pressure of the gas behind protective plug **365** will blow the plug out of its indicated recess, the plug then floating to the surface where it may later be removed with slag **367**.

If the charge is to be lip poured, as it will be in connection with the illustrated structure of FIGURES 2 and 3, the interior of the furnace is brought up to atmospheric pressure, preferably by the admission of a non-explosive agent such as nitrogen, and closure member **360** is removed. If desired, the upward bubbling of a purging gas through plug **362** may be continued to push the slag **367** against the rear wall of the surface and the furnace tipped to a point at which the metal is drained from the furnace beneath the layer of slag. If the furnace is bottom poured into a continuous casting machine the arc can be used to make up radiation losses during casting. It may even be desirable to maintain a constant teeming rate by regulation of the vacuum to provide a substantially constant ferrostatic head as more fully described in copending application S.N. 462,559.

In FIGURE 3 the furnace is shown in conjunction with a continuous casting machine, the treated charge **366** being poured directly into the upper end of the casting machine.

If desired, the furnace may be modified to the extent that it may be bottom poured. In this event it may be expedient to shroud the treated stream of metal with an inert gas by a technique now well-known in the art, an example of which is illustrated in Patent 3,236,636.

In either embodiment a gas may be bled into the chamber to further reduce the glow effect, the amount of gas being insufficient to affect the vacuum degassing.

It will be understood that the immediately above described process has been based on the treatment of a ferrous alloy. Although it is contemplated that this will be the primary field of application the principles of the invention will be applicable to the treatment of non-ferrous metals such as nickel, copper and chromium and alloys thereof, such as Inconel and Monel, all of which may be generally described as having melting points of about 2000° C. or below. The invention is not applicable to metals such as carbon, tungsten, molybdenum, rhenium, columbium and tantulum, all of which have melting points of 3500° C. and above, since those metals require special treatment. Furthermore, the material from which the forehearth **351** is formed is a non-metallic refractory such as silica or alumina brick which is available from many sources in the industry today. Other types of brick such as zirconia and magnesia may be employed although such other types are of course considerably more expensive than the first mentioned types. All types of refractory have in common however the fact that they have very low electrical current conductivity characteristics. In the illustrated process the metal contracting receptacle is intended to merely function as a receptacle, and not as a carrier of electric current.

Although the invention has been described mainly in terms of a process in which the metal is at least partially molten before exposure to vacuum, it is contemplated that the process will be applicable to metal which is in a solid state prior to exposure to vacuum. This latter procedure, which may be termed primary or solid-to-liquid state degassing, would be exemplified by a conventional electric furnace modified as in FIGURES 2 and 3 into which solid scrap is charged. The former procedure, which may be termed secondary or liquid state degassing, would be exemplified by the ladle degassing system of FIGURE 1 wherein metal, which has been brought to a molten condition without the use of a non-consumable AC electrode operating in vacuum, is the starting material. In all instances, use of non-consumable AC electrode means is contemplated during the subjection of the metal charge to vacuum.

Although a description of several embodiments of the invention have been herein disclosed it will be apparent to those skilled in the art that various changes, modifications and divisions may be made to the disclosures without departing from the scope and principles of the invention. Accordingly, it is intended that the scope of the invention be limited not by the foregoing exemplary descriptions, but solely by the hereinafter appended claims.

What is claimed is:

1. In a method of treating metal, the steps of
charging metal into a treatment receptacle,
subjecting the metal in the treatment receptacle to an AC heating arc maintained directly between non-consumable electrode means and the metal,
regulating the temperature of the metal in the treatment receptacle to a range suitable for casting by simultaneously subjecting the molten metal in the treatment receptacle to a vacuum sufficiently low to degas the molten metal during at least a portion of the time the molten metal is subjected to the AC heating arc,
positively confining the AC heating arc to the surface of the molten metal during the time in which the arc is operated, and
thereafter pouring the molten metal from the treatment receptacle.

2. The method of claim **1** further including the step of
treating the molten metal by means of an oxygen converter, an open hearth furnace, a Bessemer converter, an electric arc furnace, or a blast furnace prior to placement in the treatment receptacle.

3. The method of claim **1** further including the step of regulating the alloy content of the charge during subjection of the vacuum.

4. The method of claim **1** further characterized in that the metal is continuously cast.

5. The method of claim **1** further including the steps of
forming the metal in a blast furnace, and
thereafter decarbonizing the molten metal thus formed prior to placement in the treatment vessel.

References Cited

UNITED STATES PATENTS

2,848,317	8/1958	Coupette	75—49
3,215,423	11/1965	Taylor	75—49 X
3,341,321	9/1967	Morrison et al.	75—49 X

FOREIGN PATENTS

946,881	1964	Great Britain.
602,449	7/1960	Canada.
871,659	6/1961	Great Britain.

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U.S. Cl. X.R.

75—10, 49; 266—34