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[54] **PROCESS FOR PREPARING KILLED LOW CARBON STEEL AND CONTINUOUSLY CASTING THE SAME, AND THE SOLIDIFIED STEEL SHAPES THUS PRODUCED**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 7,231, Jan. 30, 1970, abandoned.

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[51] **Int. Cl.** **C21c 7/10,** B22d 27/20

[58] **Field of Search**... 75/49, 51, 57, 59, 53; 164/64

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[57] **ABSTRACT**

A heat of low carbon steel is killed by making an initial metallic aluminum addition to the ladle to produce partially deoxidized steel, followed by vacuum degassing and thereafter making a further metallic aluminum addition to complete the deoxidation. The heat of vacuum degassed killed steel contains 0.005–0.15% of carbon, 0.20–0.75% of manganese, residual silicon in an amount less than 0.020%, aluminum in an amount of at least 0.02% and less than 0.03%, less than 125 parts per million of oxygen and the remainder iron and incidental impurities, and it may be cast continuously. The solidified steel shapes thus produced may be in the form of slabs, and the slabs may be rolled to produce flat rolled products which are especially useful in the production of tinplate and galvanized steel.

13 Claims, No Drawings

PROCESS FOR PREPARING KILLED LOW CARBON STEEL AND CONTINUOUSLY CASTING THE SAME, AND THE SOLIDIFIED STEEL SHAPES THUS PRODUCED

RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 7,231 filed on behalf of Robert S. Miltenberger on Jan. 30, 1970 for A Process For Preparing Killed Low Carbon Steel and Continuously Casting The Same, And The Solidified Steel Shapes Thus Produced. Application Ser. No. 7,231 is now abandoned.

BACKGROUND OF THE INVENTION

This invention broadly relates to a novel process for killing heats of low carbon steel. The invention also relates to novel process for killing low carbon steel and thereafter continuously casting the same to produce semi-finished steel shapes. In one of its more specific variants, the invention further relates to the preparation of flat rolled products from the semifinished steel shapes produced by the process of the invention.

One recent important innovation in steel making is the casting of molten steel continuously into semifinished shapes such as blooms, slabs and billets. The successful continuous casting of shapes equivalent in section to conventional semifinished shapes eliminates the ingot and primary mill stages of conventional prior art rolled steel production, and thus offers important economic advantages.

While the continuous casting of steel seems to be simple in principle, many difficulties are encountered in actual practice. This is due in part to the high melting point, high specific heat, and low thermal conductivity of steel, and the necessity for close control of variables such as the temperature and oxygen content of the molten steel. The heat of steel must be killed sufficiently to prevent pinholes or blow holes from forming in the surface of the solidified steel shapes as they are cast. Any tendency for the molten steel to effervesce excessively and thereby form pinholes or blow holes in the thin solidified skin that is formed initially around the molten steel interior of a shape is especially undesirable. This is true from the standpoint of weakening the skin and increasing the chance of escape of molten steel therefrom, as well as from the standpoint of surface imperfections. The initial temperature of the molten steel as it is fed to the mold is also of importance as the solidification rate must be predictable and fast enough to form a skin of sufficient thickness and strength to support the casting. It is therefore apparent that a successful continuous casting operation depends to a large extent upon providing properly deoxidized molten steel which is at a uniform casting temperature.

The heat of steel to be deoxidized and continuously cast may be prepared by a number of prior art steel making practices, but the basic oxygen process results in substantially lower costs and is often preferred. In accordance with one prior art basic oxygen process, the furnace is charged with scrap, molten ferrous metal from a blast furnace, and other charge materials necessary to produce a low carbon steel upon blowing with oxygen. In instances where the heat is to be cast into conventional ingots, the final temperature need not be higher than about 2,900°F., and it is possible to stop the oxygen blow after the manganese, silicon, phosphorus and sulfur have been reduced to desirable levels and

sufficient carbon is present to impart strength to the steel after vacuum degassing. In instances where the heat is to be cast continuously into semifinished shapes, the final temperature should be about 2,940°–3,000°F., and thus if the heat is overcharged with scrap, it is necessary to continue the oxygen blow for a longer period of time to assure that the higher temperature is obtained. This lowers the carbon content of the steel and raises the oxygen content. It is necessary to deoxidize the heat of steel before continuous casting and in theory deoxidation may be effected by making aluminum and/or silicon additions. However, in such instances the steel contains undesirably high aluminum, silicon, aluminum oxide and/or silicate contents for the manufacture of tinplate, tinfree steel, galvanized steel and other uses where a high degree of softness and ductility and low nonmetallic inclusions are of importance.

When producing finished steel having the foregoing properties, usually the heat of steel is largely deoxidized by vacuum degassing, i.e., by subjecting the heat to a sharply reduced pressure, and preferably to a vacuum approaching 1–2 millimeters of mercury or less. Several suitable prior art processes are known, such as the Dortmund-Horder (D-H) process and the Ruhrstahl-Heraeus (R-H) process. In these processes, the molten steel is subjected to a vacuum in an evacuated vessel for a sufficient period of time to evolve the gasses and for the gasses to be removed by a vacuum connection. The reaction of carbon with oxygen to produce carbon monoxide which is evolved is highly endothermic, and thus the initial temperature of the melt is lowered substantially in instances where it is desired to reduce the oxygen content to below 125 parts per million. The carbon content is also reduced markedly, and often insufficient carbon remains in the steel to provide adequate strength for certain end uses such as container stocks. When the initial oxygen content of the heat is high, the steel reacts violently upon being subjected to the vacuum existing in the vacuum chamber of the degassing apparatus and a long degassing period is necessary to reduce the oxygen content to a level acceptable for continuous casting. This results in markedly higher costs for deoxidation of the steel on a per ton basis as the degassing apparatus is expensive to operate over an extended degassing period and the life of the refractory lining is reduced very sharply.

In view of the foregoing, the preparation of light gauge strip or sheet for the manufacture of tinplate, galvanized steel and similar uses which require a high degree of softness, ductility, and a low content of nonmetallic inclusions presents a series of problems which have not been adequately solved by the prior art. This is especially true in instances where it is desired to combine a plurality of recent innovations which are capable of reducing costs such as a basic oxygen steel making process with vacuum degassing and continuous casting.

It is an object of the present invention to provide a novel process for deoxidizing heats of low carbon steel to produce killed steel which is suitable for casting continuously.

It is a further object to provide a novel process for casting steel continuously which utilizes heats of killed low carbon steel prepared by the process of the invention.

It is a further object to provide a novel process for deoxidizing heats of low carbon steel by means of controlled aluminum additions before and after vacuum degassing, and thereafter casting the killed steel continuously to produce semifinished shapes.

It is a further object to prepare flat rolled products suitable for the manufacture of tinplate, tin free steel and galvanized steel from the semifinished steel shapes produced by the process of the invention.

Still other objects and advantages of the invention will be apparent from the following detailed description and the examples.

DETAILED DESCRIPTION OF THE INVENTION INCLUDING PREFERRED VARIANTS THEREOF

In accordance with one important variant of the present invention, a heat of killed low carbon steel containing 0.005–0.15% of carbon, 0.20–0.75% of manganese, residual silicon in an amount less than 0.02%, aluminum in an amount of at least 0.02% and less than 0.03%, less than 125 parts per million of oxygen, and the remainder iron and incidental impurities is prepared and is introduced into a mold for continuously casting steel, and is cast therein to produce a solidified steel shape continuously. The phosphorus content of the steel should be less than 0.04%, the sulfur content should be less than 0.05%, and the nitrogen content should be less than 0.03%. Preferably the nitrogen content is about 0.012–0.02% in instances where high physical strength is important, and steel for the manufacture of tinplate preferably should contain substantially less than 0.020% of silicon.

When producing steel for the manufacture of many galvanized products, it is often preferred that the steel contain about 0.005–0.05% of carbon, about 0.20–0.50% of manganese, residual silicon in an amount less than 0.020%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.005% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 125 parts per million of oxygen and for better results, less than 100 parts per million of oxygen, and the remainder iron and incidental impurities. It is often preferred that steel for the manufacture of many tinplate products contain about 0.04–0.07% of carbon, about 0.30–0.60% of manganese, residual silicon in an amount between about 0.008% and less than 0.020%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.02% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 125 parts per million of oxygen and for better results less than 100 parts per million of oxygen, and the remainder iron and incidental impurities.

A heat of steel for use in the present invention may be prepared by any suitable prior art steel making practice, and it may be produced in, for example, an open hearth furnace, an electric furnace, or a basic oxygen furnace. It is preferred to use molten steel produced by a basic oxygen process.

The prior art basic oxygen process for producing low carbon steel is satisfactory without modification. When practicing the present invention, the low carbon steels produced by the basic oxygen process contain not more than about 0.20% of carbon and preferably 0.03–0.20% of carbon. The manganese content is less than 0.3% and is usually about 0.08–0.20%, the silicon content is less than 0.02% and is usually below 0.01%, the phosphorus content is less than 0.04% and is usually below 0.02%, the sulfur content is less than 0.05% and is usually below 0.03%, and the remainder is iron and incidental impurities. Trace amounts of tramp elements such as copper, tin, lead, zinc and the like may be present but the concentrations are very low. The oxygen content is below 1000 parts per million and is often about 200–800 parts per million, and the nitrogen content is less than 0.01%, usually is less than 0.008%, and is often about 0.003–0.005%. The temperature of the melt is usually about 2,850°–3,000°F. and is preferably about 2,910°–2,990°F. for continuous casting.

Basic oxygen steel making processes and apparatus, vacuum degassing processes and apparatus, and continuous casting processes and apparatus for use in preparing heats of steel, and then vacuum degassing and continuously casting the same are disclosed in numerous patents and literature references, including the "Making, Shaping and Treating of Steel," 8th Edition, edited by Harold E. McGannon (1964), the disclosures of which are incorporated herein by reference. Pages 453–456, 552–556 and 664–666 of the text "The Making, Shaping and Treating of Steel" are especially pertinent.

It is not possible to produce a heat of steel having the desired composition for continuous casting as tapped. Accordingly, a heat of steel produced by a prior art steel making process is adjusted in composition to produce a killed steel as defined herein which has a sufficiently low oxygen content to be suitable for continuous casting without formation of pinholes or blowholes. This may be conveniently accomplished by charging the steel making furnace with ingredients and employing operating procedures and practices which will result in approximately the desired carbon, phosphorus, and sulfur contents in the steel as tapped from the furnace, or which will result in the desired contents thereof after the addition agents are added. The aluminum content in the steel as tapped is lower than in the final killed steel, and the oxygen content is markedly higher. It is necessary to make an initial aluminum addition to the heat of unkilled steel in an amount to arrive at the desired oxygen level for vacuum degassing, and to make a further aluminum addition after vacuum degassing in an amount to result in the desired final oxygen content in the completely deoxidized steel. A manganese addition also should be made as it is not practical to charge enough manganese to a basic oxygen furnace to result in the desired manganese content in the steel as tapped. A nitrogen addition may be made in instances where higher physicals are desired.

The first aluminum addition and the manganese addition, and the nitrogen addition when made, may be made in the ladle at the time of tapping the heat. The second aluminum addition preferably, but not necessarily, is made to the vacuum degassing apparatus following degassing. The first aluminum addition is preferably made in the form of metallic aluminum such as pig aluminum or aluminum shot, and the second aluminum addition is preferably made in the form of metallic aluminum shot. Manganese may be added in the form of electrolytic manganese, high or medium carbon ferromanganese or other suitable alloys of manganese. A ferromanganese addition is usually made prior to degassing and in an amount to increase the as tapped manganese content to the desired final specification. The nitrogen addition usually is made in the form of calcium cyanamide, but other nitrogen addition agents may be used. In instances where it is desired to adjust the carbon content of the steel, this may be done by selecting a high carbon manganese addition agent, or by making a carbon addition to the ladle in accordance with prior art practices.

The aluminum addition which is made prior to degassing should be sufficient to control wildness in the vacuum degassing chamber and thereby reduce the rate of erosion and increase the useful life thereof. The initial aluminum addition is made in an amount to partially deoxidize the steel and to result in an oxygen content of less than 800 parts per million and preferably less than 600 parts per million, and for better results less than 500 parts per million. This usually requires an aluminum addition of about 0.1–1 pound per ton and within this range, less aluminum is required as the carbon content of the unkilled steel as tapped increases. As a general rule, tap carbon contents up to about 0.06% require an aluminum addition of about 0.6–1.0 pound per ton, a carbon content of about 0.07–0.10% requires an aluminum addition of about 0.4–0.6 pound per ton, and a carbon content of about 0.11–0.20% requires an aluminum addition of about 0.2–0.3 pound per ton.

The partially deoxidized steel is preferably vacuum degassed under nonoxidizing conditions and while agitating the heat to thereby assure a uniform and predictable composition. This may be conveniently accomplished by using Dortmund-Horder (D-H) or Ruhrstahl-Heraeus (R-H) vacuum degassing apparatus and by operating the same under prior art conditions. The R-H vacuum degassing apparatus is preferred, and argon is the preferred inert gas for use therewith.

The partially deoxidized steel should be vacuum degassed over a period of about 5–30 minutes, and preferably for about 8–20 minutes in most instances. In many instances, the oxygen content is lowered to less than 300 parts per million, and the vacuum degassing step is terminated thereafter when the temperature of the molten steel reaches the optimum level for continuous casting and/or when the oxygen content has reached the desired level. It is preferred in some instances that the degassing step be continued until the oxygen content is below 200 parts per million, and for best results, below 100 parts per million.

The final aluminum addition following the vacuum degassing step is made in an amount to complete the deoxidation and to reduce the oxygen content to less than 125 parts per million, and preferably to less than 100 parts per million. The aluminum content of the completely deoxidized steel is less than 0.03 percent. For better results, the final aluminum addition should be made under nonoxidizing conditions and with agitation so as to assure a uniform and predictable recovery. This may be conveniently accomplished in the vacuum degassing apparatus, and aluminum shot is the most convenient form of aluminum. The final aluminum addition should be made in an amount to provide a total of less than 3 pounds per ton, and preferably less than 2 pounds per ton, of aluminum in the first and final additions. As a general rule, less aluminum need be added to steels having higher carbon contents. For instance, the final aluminum addition may be from about 1 pound to less than 2 pounds per ton for steels initially containing up to 0.06% of carbon, from about 0.7 to 1 pound per ton for steels containing 0.07–0.10% of carbon, and about 0.4–0.7 pound per ton for steels containing 0.11–0.20% of carbon.

The vacuum degassing apparatus may be operated for approximately 1–5 minutes, and for better results around 3 minutes, following the final aluminum addition for the purpose of stirring the completely deoxidized heat of steel and assuring a uniform composition and temperature. The final oxygen content is usually between 50 and 125 parts per million, and in many instances is between about 50 and 100 parts per million. The temperature of the completely deoxidized steel is sufficiently high for continuous casting, and the exothermic reaction of the added aluminum and the relatively short degassing period which is necessary aid in this respect. Practicing the present invention assures a uniform composition and temperature throughout the heat, and a sufficiently high temperature for continuously casting the heat, all of which are necessary for a successful continuous casting operation.

Heats of killed low carbon steel prepared as described above contain residual silicon in an amount less than 0.020% and have a very low metallic inclusion content, and the heats are especially suitable for continuous casting. The molten steel may be fed periodically into the tundish of a prior art continuous caster, and is then introduced into the open end of a prior art continuous casting mold by means of a tundish nozzle. The continuous casting mold is water cooled, and solidification of the steel is initiated therein following prior art practices. A body of molten steel is present in the top of the mold, and a steel casting with a solidified skin surrounding a liquid steel core is withdrawn from the bottom of the mold. Solidification of the molten interior of the casting is accomplished by means of water sprays located beneath the mold. The solidified steel casting, which may be in the form of a slab, may be cut into desired lengths, cooled, surface conditioned, reheated to a hot working temperature, and thereafter worked by a prior art process such as by hot and/or cold rolling to produce flat rolled steel products including strip and plate. The hot rolled strip may be further reduced in thickness by cold rolling, or it may be given other prior art treatments to arrive at a final product.

The composition of the steel employed in practicing the present invention is based upon the results of spectrographic analysis of samples. The total amounts of the various elements in the steel are determined, and the steel compositions described herein are based thereon.

The foregoing detailed description and the following specific examples are for purposes of illustration, and modifications may be made therein without departing from the invention.

EXAMPLE I

A heat of low carbon steel is prepared by a basic oxygen process following prior art steel making practices and is tapped into a ladle. The steel has a tap temperature of 2,980°F. and the slag covered ladle contains 300 tons of molten steel. The steel contains 0.07% of carbon, 0.20% of manganese, less than 0.01% of silicon, less than 0.01% of phosphorus, less than 0.025% of sulfur, less than 0.004% of nitrogen, 500 parts per million of oxygen, and the remainder iron and trace amounts of incidental impurities.

The ladle additions are 150 pounds of pig aluminum, and 2400 pounds of ferromanganese containing 78% of manganese, 6.5% of carbon and the remainder iron and incidental impurities. The resulting incompletely deoxidized steel contains 0.09% of carbon, 0.45% of manganese, about 0.01% of aluminum, approximately 350 parts per million of oxygen, and the remaining constituents in the steel do not change appreciably. The steel temperature in the ladle is 2,940°F.

The incompletely deoxidized steel is subjected to a vacuum treatment in Ruhrstahl-Heraeus (R-H) vacuum degassing apparatus. The R-H apparatus is operated in accordance with prior art practice using argon as the inert gas for injection into one of the two legs which are submerged in the molten steel. Partially deoxidized molten steel is withdrawn from the ladle and is introduced into the vacuum vessel where it is subjected to a subatmospheric pressure of approximately 1–2 mm. of mercury absolute, and the molten steel then flows down the other leg and is returned to the ladle.

After vacuum treatment for approximately 15 minutes, aluminun shot in an amount of 200 pounds is added to the molten steel in the vacuum vessel and the vacuum treatment is continued for an additional 3 minutes.

The final temperature of the completely deoxidized molten steel is 2,910°F., the carbon content is 0.06%, the aluminum content is less than 0.025%, the oxygen content is less than 100 parts per million, and the remaining constituents do not change appreciably. The R-H apparatus agitates the molten steel in the ladle and provides a convenient method of making the final aluminum addition under nonoxidizing conditions. As a result, it is possible to closely control the final chemistry and temperature, and the melt is homogeneous.

The heat of killed steel is poured periodically from the ladle into the slag covered tundish of a continuous caster. The molten steel is withdrawn from the tundish through the tundish nozzle and is introduced into the upper end of an open-ended water cooled continuous casting mold for casting slabs at a rate to maintain the desired level of molten metal. The mold is reciprocated vertically and a casting in the form of a slab having a solidified outer shell and a molten interior is withdrawn continuously from the bottom of the mold. The casting is sprayed with water as it descends beneath the mold until it is completely solidified, and the casting is cut into predetermined lengths. The slabs thus produced are allowed to cool, inspected for surface imperfections, scarfed, reheated to a hot rolling temperature, hot rolled into steel strip having a thickness of approximately 0.1 inch, and then cold rolled to approximately 90% reduction following conventional practices. The strip is especially useful for the manufacture of tinplate.

EXAMPLE II

A heat of low carbon steel is prepared by a basic oxygen process following prior art steel making practices and is tapped into a ladle. The steel has a tap temperature of 2,970°F. and the basic oxygen furnace contains 300 tons of molten steel. The steel contains 0.03% of carbon, 0.15% of manganese, less than 0.01% of silicon, less than 0.01% of phosphorus, less than 0.025% of sulfur, less than 0.004% of nitrogen, 700 parts per million of oxygen, and the remainder iron and trace amounts of incidental impurities.

The ladle additions during tapping the basic oxygen furnace are 200 pounds of pig aluminum, and 2,200 pounds of ferromanganese containing 78% of manganese, 6.5% of carbon and the remainder iron and incidental impurities. The resulting incompletely deoxidized steel contains 0.05% of carbon, 0,35% of manganese, about 0.01% of aluminum, approximately 400 parts per million of oxygen, and the remaining constituents in the steel do not change appreciably. The steel temperature in the ladle is 2,940°F.

The incompletely deoxidized steel is subjected to a vacuum treatment in Ruhrstahl-Heraeus (R-H) vacuum degassing apparatus. The R-H apparatus is operated in accordance with prior art practice using argon as the inert gas for injection into one of the two legs which are submerged in the molten steel. Partially deoxidized molten steel is withdrawn from the ladle and is introduced into the vacuum vessel where it is subjected to a subatmospheric pressure of approximately 1–2 mm. of mercury absolute, and the molten steel then flows down the other leg and is returned to the ladle.

After vacuum treatment for approximately 18 minutes, aluminum shot in an amount of 275 pounds is added to the molten steel in the vacuum vessel and the vacuum treatment is continued for an additional 3 minutes.

The final temperature of the completely deoxidized molten steel is 2,910°F., the carbon content is 0.01%, the aluminum content is less than 0.025%, the oxygen content is less than 100 parts per million, and the remaining constituents do not change appreciably. The R-H apparatus agitates the molten steel in the ladle and provides a convenient method of making the final aluminum addition under nonoxidizing conditions. As a result, it is possible to closely control the final chemistry and temperature, and the melt is homogeneous.

The heat of killed steel is poured periodically from the ladle into the slag covered tundish of a continuous caster. The molten steel is withdrawn from the tundish through the tundish nozzle and is introduced into the upper end of an open-ended water cooled continuous casting mold for casting slabs at a rate to maintain the desired level of molten metal. The mold is reciprocated vertically and a casting in the form of a slab having a solidified outer shell and a molten interior is withdrawn continuously from the bottom of the mold. The casting is sprayed with water as it descends beneath the mold until it is completely solidified, and the casting is cut into predetermined lengths. The slabs thus produced are allowed to cool, inspected for surface imperfections, scarfed, reheated to a hot rolling temperature, hot rolled into steel strip having a thickness of approximately 0.1 inch, and then cold rolled to approximately 60% reduction following conventional practices. The strip is especially useful for the manufacture of galvanized steel.

When preparing flat rolled steel products for use in preparing galvanized steel, it is often preferred to prepare a heat of steel by a basic oxygen process containing initially about 0.03–0.06% of carbon and 400–1,000 parts per million of oxygen. The initial aluminum addition is made in an amount to produce partially deoxidized molten steel containing 300–800 parts per million of oxygen. A ferromanganese addition is also made in the ladle in an amount to bring the manganese content up to the desired level. The partially deoxidized steel is vacuum degassed until the oxygen content is 150–550 parts per million. Aluminum is added to the vacuum degassed steel in an amount to produce molten killed steel containing 0.005–0.05% of carbon, 0.20–0.50% of manganese, residual silicon in an amount less than 0.02%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.005% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 125 parts per million of oxygen, and the remainder iron and incidental impurities. Thereafter the molten killed steel is continuously cast into slabs and the slabs are hot and cold rolled to produce a flat rolled steel product suitable for use in preparing galvanized steel.

When preparing blackplate for use in preparing tinplate, it is often preferred to prepare a heat of steel by a basic oxygen process containing initially about 0.04–0.07% of carbon and 250–600 parts per million of oxygen. The initial aluminum addition is made in an amount to produce partially deoxidized molten steel containing 150–500 parts per million of oxygen. A ferromanganese addition is also made in the ladle in an amount to bring the manganese content up to the desired level. The partially deoxidized steel is vacuum degassed until the oxygen content is 100–350 parts per million. Aluminum is added to the vacuum degassed steel in an amount to produce molten killed steel containing about 0.04–0.07% of carbon, about 0.30–0.60% of manganese, residual siicon in an amount less than 0.02%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.02% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 125 parts per million of oxygen, and the remainder iron and incidental impurities. Thereafter the molten killed steel is continuously cast into slabs and the slabs are hot rolled and cold rolled to produce blackplate suitable for use in preparing tinplate.

I claim:

1. A process for casting steel continuously consisting essentially of the steps of preparing a heat of unkilled low carbon steel, adding a deoxidizing agent consisting essentially of metallic aluminum to the unkilled steel in an amount of 0.1–1 pound per ton to partially deoxidize the steel, the partially deoxidized steel containing less than 800 parts per million of oxygen, vacuum degassing the partially deoxidized steel to lower the oxygen content to less than 600 parts per million, adding a deoxidizing agent consisting essentially of metallic aluminum to the degassed steel in an amount to complete the deoxidation and to produce molten killed steel having an oxygen content of less than 125 parts per million, the deoxidizing agent consisting essentially of metallic aluminum and the aluminum being added in a total amount of less than 3 pounts per ton of steel, the molten killed steel consisting essentially of 0.005–0.15% of carbon, 0.20–0.75% of manganese, residual silicon in an amount less than 0.020%, aluminum in an amount of at least 0.02% and less than 0.03%, less than 125 parts per million of oxygen, and the remainder iron and incidental impurities, introducing the molten killed steel into a mold for continuously casting steel, and casting the molten killed steel in said mold to produce a solidified steel shape continuously.

2. The process of claim **1** wherein the molten killed steel in said mold is cast continuously into a solidified steel slab, and the slab is rolled to produce a flat rolled steel product.

3. The process of claim **1** wherein said molten killed steel contains less than 0.04% of phosphorus, less than 0.05% of sulfur, less than 125 parts per million of oxygen and less than 0.03% of nitrogen.

4. The process of claim **1** wherein said molten killed steel consists essentially of 0.005–0.05% of carbon, 0.20–0.50% of manganese, residual silicon in an amount less than 0.02%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.005% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 100 parts per million of oxygen, and the remainder iron and incidental impurities.

5. The process of claim **1** wherein said molten killed steel consists essentially of about 0.04–0.07% of carbon, about 0.30–0.60% of manganese, residual silicon in an amount less than 0.02%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.02% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 100 parts per million of oxygen, and the remainder iron and incidental impurities.

6. The process of claim **1** wherein said heat of unkilled low carbon steel is tapped into a ladle, said aluminum addition to partially deoxidize the steel is made in the ladle, said partially deoxidized molten steel is withdrawn from the ladle and is introduced into the vacuum vessel of a vacuum degassing apparatus and is vacuum degassed therein, and said aluminum addition to complete the deoxidation is made to the degassed steel in the vacuum vessel.

7. The process of claim **1** wherein said heat of unkilled low carbon steel is prepared by a basic oxygen steelmaking process, and the said heat of low carbon unkilled steel contains initially not more than 0.20% of carbon, less than 0.3% of manganese, less than 0.02% of silicon, less than 0.04% of phosphorus, less than 0.05% of sulfur, less than 0.01% of nitrogen, less than 1000 parts per million of oxygen, and the remainder iron and incidental impurities.

8. The process of claim **7** wherein the said heat of unkilled low carbon steel prepared by the basic oxygen process contains initially about 0.03–0.20% of carbon, about 0.08–0.20% of manganese, less than 0.01% of silicon, less than 0.02% of phosphorus, less than 0.03% of sulfur, less than 0.008% of nitrogen, about 200–800 parts per million of oxygen, and the remainder iron and incidental impurities.

9. The process of claim **7** wherein said heat of steel is tapped into a ladle, said aluminum addition to partially deoxidize the steel is made in the ladle, said partially deoxidized steel contains about 150–600 parts per million of oxygen, said partially deoxidized steel is introduced into the vacuum vessel of a vacuum degassing apparatus and is degassed therein to lower the oxygen content to about 100–300 parts per million, and said aluminum addition to complete the deoxidation is made to the degassed steel in the vacuum vessel in an amount to produce molten killed steel having an oxygen content of less than 125 parts per million.

10. The process of claim **7** wherein the said heat of unkilled low carbon steel contains initially about 0.03–0.06% of carbon and 400–1,000 parts per million of oxygen, said partially deoxidized molten steel contains 300–800 parts per million of oxygen, said vacuum degassed steel contains 150–550 parts per million of oxygen, and said molten killed steel consists essentially of 0.005–0 05% of carbon, 0.20–0.50% of manganese, residual silicon in an amount less than 0.02%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.005% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 100 parts per million of oxygen, and the remainder iron and incidental impurities.

11. The process of claim **10** wherein the molten steel in said mold is cast continuously into a solidified steel slab, and the slab is hot and cold rolled to produce a flat rolled steel product suitable for use in preparing galvanized steel.

12. The process of claim **7** wherein the said heat of unkilled low carbon steel contains initially about 0.04–0.07% of carbon and 250–600 parts per million of oxygen, said partially deoxidized molten steel contains 150–500 parts per million of oxygen, said vacuum degassed steel contains 100–350 parts per million of oxygen, and said molten killed steel consists essentially of about 0.04–0.07% of carbon, about 0.30–0.60% of manganese, residual silicon in an amount less than 0.002%, aluminum in an amount of at least 0.02% and less than 0.03%, about 0.003–0.02% of nitrogen, about 0.005–0.02% of phosphorus, about 0.01–0.035% of sulfur, less than 100 parts per million of oxygen, and the remainder iron and incidental impurities.

13. The process of claim **12** wherein the molten steel in said mold is cast continuously into a solidified steel slab, and the slab is hot and cold rolled to produce blackplate suitable for use in preparing tinplate.

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