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CENTRIFUGAL CASTING OF METAL

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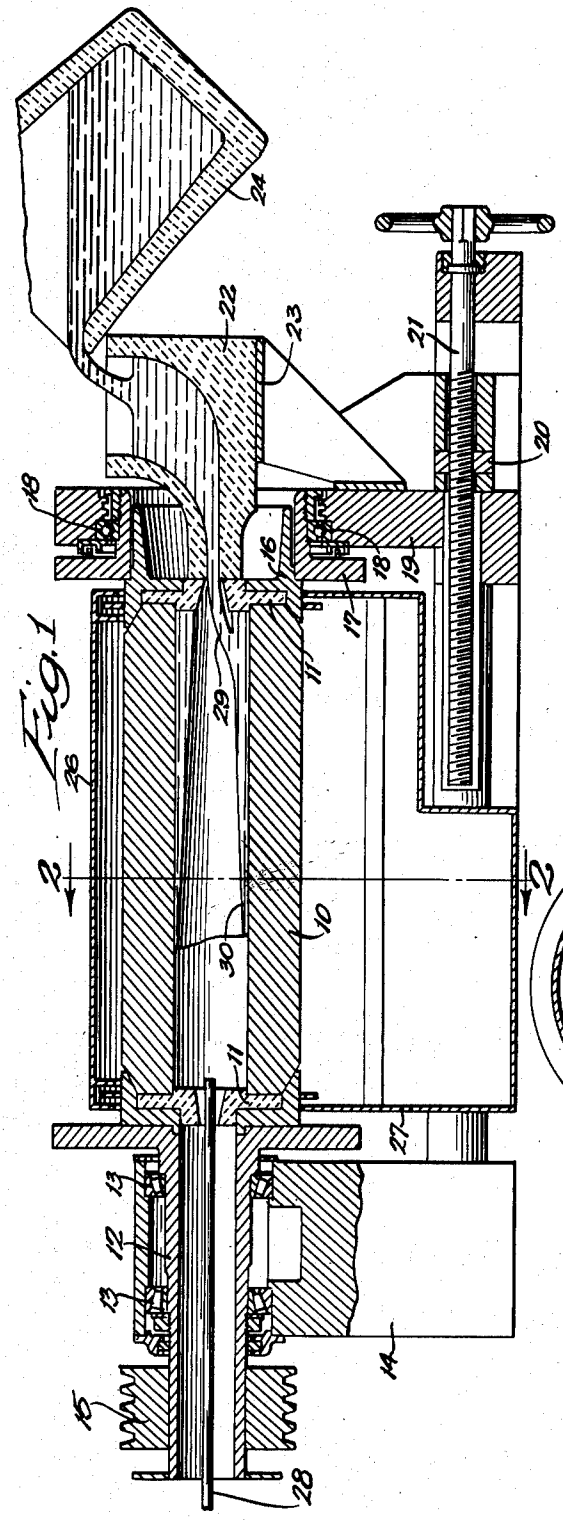


Fig. 1

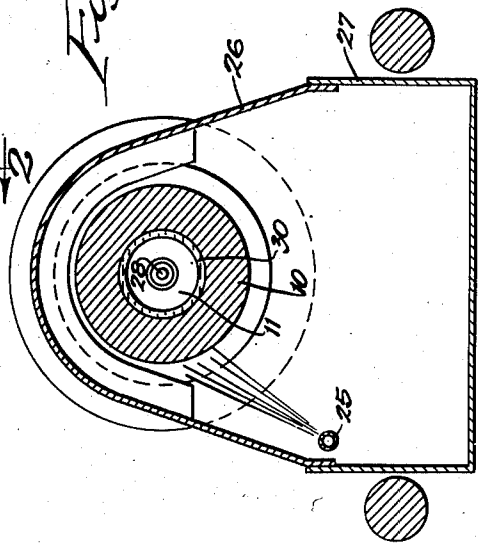


Fig. 2

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CENTRIFUGAL CASTING OF METAL

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5 Claims. (Cl. 22—200.5)

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This invention relates to the centrifugal casting of metal and more particularly to method and means for producing centrifugal castings by both vertical and horizontal rotation, etc.

This application constitutes a continuation-in-part of my co-pending application, Serial No. 248,696, filed September 28, 1951, now abandoned.

The centrifugal casting of metal by the use of rotatably-mounted molds has long presented an extremely serious problem centering in the porous character of the inner surfaces of the casting. The castings have minute and even microscopic voids in the wall section adjacent the inner surface, and this porosity not only results in the loss of metal which must be machined away, but it decreases the usefulness of the castings in those fields where the metal is required to retain gases, corrosives, and other liquids under pressure or vacuum.

The above described porosity in the centrifugal castings has up to the present time been accepted in industrial practice as a necessary defect in this type of product. In the specifications of some manufacturers of centrifugal castings of high alloy steel, it is common practice to make a finish allowance of $\frac{3}{16}$'' of metal on a wall $\frac{3}{8}$'' thick, to insure complete removal of porous material on the inner surface. Since high alloy steel is used extensively in the production of centrifugal castings, it is obvious that the loss of the porous portion of the casting and of the labor required to remove this portion of the casting, represents a heavy burden upon the manufacturer and purchaser.

The machine widely used in the industry for the production of centrifugal castings consists of two main components, a metal case mounted for rotation, and a rotating mechanism. Quite generally, it has been the custom of the industry to line the metal case with a molding sand similar to that used in the foundry industry for the production of static castings. The molding sand is a poor heat conductor, and for that reason is inefficient in transferring heat away from the molten metal during cooling and particularly during its solidification. In such a casting operation, the casting solidifies from the inner surface as well as from the outer surface and there is a heavy concentration of porosity toward the inner wall surface of the casting.

When a permanent mold, such as a metal mold is used, the castings similarly have to a shallower depth a porous wall portion near their inner wall surface. Thus, whether a sand-lined mold be used or a permanent mold be employed, objectionable porosity within the wall section results, and the value of the casting is greatly reduced.

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An object of the present invention is to provide a method and means for producing centrifugal castings which are sound and free of porosity. A further object is to provide a method for producing centrifugal castings in which the wall section of the casting adjacent the inner surface is sound and free of porosity. A still further object is to provide a method for the production of centrifugal castings wherein sound castings are formed rapidly and with a minimum of expense and with no appreciable increase in cost, such castings being substantially free of porosity and effective for retaining gases, corrosive fluids, etc. under high pressure or vacuum. A further object is to provide a process for producing centrifugal castings in which a gas is employed to apply carbon to the molten metal in the casting operation as it solidifies for forming a casting of a high degree of soundness and uniformity and thereby, for some uses, eliminating the necessity of machining the casting about its inner diameter. Yet another object is to produce a carburized surface to a predetermined desired depth on the inner diameter of a centrifugal casting by controlling the amount of carbon applied. Other objects and advantages will appear as the specification proceeds.

The invention of the present application may be carried out in a variety of different forms of mold apparatus. A sand-lined mold may be used, or a permanent, etc., mold may be employed. For the purpose of illustration, the invention will be described in connection with a permanent mold and apparatus for supporting and rotating the same as set forth in the accompanying drawing, in which—

Figure 1 is a longitudinal sectional view of mold apparatus which may be employed in the carrying out of my invention; and Fig. 2, a transverse sectional view, the section being taken as indicated at line 2—2 of Fig. 1, the completed casting, however, being shown in the view.

In the illustrative form of apparatus set out in Figs. 1 and 2, 10 designates a metal mold or any other suitable type of mold provided with apertured end closures 11 which may be formed of molding sand or any other suitable material. The closure and mold 10 are supported at one end upon a rotatably-mounted member 12, supported by bearings 13 upon the base 14. The tubular member 12 serves as a drive member and is equipped with a pulley 15 adapted to receive belts from a motor-driven pulley. It will be under-

stood that any suitable means for rotating the drive member 12 may be employed. The members 10 and 11 at the other end are supported upon a tubular member 16, which in turn is supported by the ring member 17 carried by the bearings 18. The support 19 for the bearings is movably mounted and is actuated by a nut 20 mounted upon the handle-equipped screw 21. Since the latter is a well-known construction, a detailed description is believed unnecessary.

A pouring cup 22, which may be formed of molding sand or of metal or any other suitable material, is placed upon a support bracket 23, as shown more clearly in Fig. 1, and molten metal is poured from the vessel 24 of refractory material into the pouring cup, as illustrated.

In order to cool the mold, should such cooling be desired, I provide a spray header 25 having perforations therein for discharging water upwardly against the mold 10 and I provide also a casing 26 for returning water to the sump 27 therebelow. The spray header 25 may be connected by a pump to the sump 27 for utilizing the water returned to the sump after the spray operation.

In the practice of my invention, I introduce a pipe or conduit 28 into the mold at one end thereof for the purpose of introducing a gas bearing carbon which will be deposited upon the inner surface of the casting. The pipe 28 will lead from a gas cylinder or gas manifold (not shown), which is maintained under pressure and causes the gas to flow through the mold and is equipped with a control valve (not shown). For example, the pipe 28 may lead from a gas main containing city gas or from a cylinder containing butane, hydrogen, argon, or any desired type of gas which will form carbon or to which a finely-ground carbon material may be added for deposit upon the inner surface of the casting.

It has heretofore been believed that the use of carbonaceous material must be limited to non-ferrous application, due to the detrimental effect of carbon on steel castings. I have discovered that not only may carbon be applied to the inner surface of castings and the carbon pick-up thereof effectively controlled to avoid undesirable effects upon the casting, but that the carbon itself gives a highly beneficial effect in eliminating the objectionable porosity heretofore encountered and in producing castings having sound and uniform inner surfaces.

A pipe 28 may lead from a gas main containing a combustible gas which, when introduced into the interior of the mold, will deposit a coating of carbon upon the interior surface of the coating as it is formed and it solidifies. Alternatively, the pipe 28 may lead from a hopper containing lamp black, graphite, or any other form of carbonaceous material and a compressed gas may be employed for carrying the carbon within the bore of the casting for deposit therein.

When a hydrocarbon gas such as ordinary city gas, butane, methane, and the like, is passed through the mold and preferably through the bore of a hollow molten casting, a solidification of the metal along the inner surface of the casting is brought about, with substantially no porosity therein. The deposit of finely-divided carbon material into the bore of the casting during solidification results in a casting having an inner sound portion with no evidence of porosity.

Why the above steps result in the production of a sound casting, I am unable to explain. It is possible that the carbon deposit along the inner bore of the casting at the time when solidification begins is effective in protecting the inner metal surfaces from oxygen by forming carbon dioxide or carbon oxide. Further, the carbon may have some effect in lowering the melting temperature and producing a better flow of the metal during the stage of solidification. By employing a gas for the deposit of the carbon, I find that an effective control of carbon pick-up is provided and that it is practicable to treat steel centrifugal castings through the application thus of controlled quantities of the carbon during the stage in which the casting is being formed.

Under prior practice, after the metal is poured and the hollow molten body is produced through centrifugal action, it is possible that as the metal tends to solidify from its outer and inner surfaces, the metal solidifying from the inner surface tends to shrink away from its support while at the same time being urged outwardly by centrifugal force. The unequal rate of shrinkage and the effect of the centrifugal force may cause relative movement of metal portions along the inner surface, and the presence of oxygen in contact with such metal portions may produce oxidation and prevent such oxidized portions from later merging with the interior body of molten metal, thus producing a porous inner wall surface.

Under such prior practice, as the metal at the outside surface contacting the mold begins to solidify and such solidification progresses inwardly toward the wall section of the inner surface, there is a simultaneous removal of heat, but at a lower rate, from the inner surface. Thus, as a result, a shallow depth of metal may solidify from the inner surface. Since there is a contraction of metal during solidification, this shallow depth of solidifying metal may tend to shrink away from its support and fracture to keep contact with that support. This process of solidification, shrinkage, and fracturing on the inner surface of the casting may repeat itself continually until solidification is complete. If oxygen is present, and uninhibited, oxidation of the metal may occur during this movement of the metal about the inner surface of the casting. The oxide-coated metal thus formed, when fractured and moving into the molten backing metal, is not capable of being absorbed by the molten metal and thus welded thereto.

The foregoing is a possible explanation of the action which might produce the varying degrees of inner surface unsoundness and roughness in castings produced by the prior methods, and it may also explain why the deposition of carbon along the inner surfaces of the molten tubular body prevents oxidation at the critical moment when solidification along the inner surface is being completed.

In the solidification stage when shrinkage and fracturing occur along the inner surface of the hollow body, it is my belief that the presence of the carbon allows the clean, solid metal which is being fractured to be forced into the underlying liquid metal by centrifugal force, so that it continues to be a uniform part of the wall. Oxidation of the metal which is being fractured is prevented and the clean metal emerges uniformly with the underlying liquid metal body.

In the application of the carbon in order to provide an effective control which will avoid excessive pick-up of the carbon by the metal, I prefer to employ a gas which is effective as a carrier for the carbon in comminuted or finely-divided form or a gas which will form carbon for

deposit upon the casting. The carrier gas or finely-divided carbon may be an inert gas such as argon, nitrogen, helium, or a gas such as hydrogen, or even air. Even though the carrier gas contains oxygen, it is believed that the presence of the carbon protects the metal from the oxygen by forming CO_2 or CO. Excellent results have been obtained by introducing a hydrocarbon gas into the mold, thus forming carbon and depositing the same upon the inner surface of the casting. For example, methane, butane, propane, acetylene, etc., are found to be very effective, and combinations of gases such as are found in the usual city gas, give excellent results. City gas, which ordinarily comprises water gas enriched with hydrocarbon gas or gases, when passed through the bore of the casting during or near the solidification stage, produces a casting free of porosity.

Referring to the drawing, the gas is introduced through pipe 28 to bring about a deposit of carbon upon the inner surface of the molten metal as solidification begins. In Fig. 2, the solidified casting is indicated by the numeral 30. The casting shown in Fig. 2 is a hollow casting in the shape of a cylindrical tube. It will be understood, however, that the casting may be of any shape that can be made if rotated about a center of gravity. For example, a cream separator bowl, which is elliptical in shape and has one end closed or solid, may be formed on a vertical axis machine. Tubular and non-tubular castings having various irregular shapes in cross-section, as, for example, castings such as screws for conveyors, housings with bosses, and other castings having a variety of odd shapes, may be formed.

The finished casting is not only free of porosity which may be observed visually, but also of "micro-porosity." The term "micro-porosity" is used to indicate porosity which is scattered throughout the body of the casting and which is too small in physical size to be detected without the aid of high magnification or special sensitive indicators such as dyes and dye developers. In checking castings to determine porosity, it is common to taper machine a length of the casting and then apply dye over the machined portion of the casting. After removing the dye from the surface, a white coating known as a "developer" is applied, and if there are holes or pores within the casting, the dye therein passes into the white developer coating and thus indicates the porosity of the casting.

As described above, the employment of gas for depositing carbon upon the interior of the metal casting during the forming or solidification of the casting gives a sharp decrease in the depth of the zone of unsound or porous metal on the inner surface of the casting and in most cases an elimination of such inner porosity altogether.

The following may be set out as specific examples of the process.

Example I

A steel mold such as is shown in the drawings was used and preliminarily washed to provide a uniform coating of refractory material of about .030 inch on the inner surface of the mold. The wash was applied at a temperature of 110° F. by spraying into the mold as it was rotated. The mold was then preheated to a temperature of about 550° F. to eliminate moisture, etc. The mold was then placed in the machine, with dry sand end closures in place, and rotated at a speed of 1300 R. P. M. A conduit carrying city gas was inserted into the mold at the end opposite the pouring cup. The gas was of the type regularly supplied by the Portland Gas & Coke Company, consisting mainly of water gas enriched to a calorific content of approximately 700 B. t. u.'s per cubic foot by the addition of hydrocarbon gases. Prior to inserting the conduit into the mold, the gas issuing therefrom was ignited; and the excess gas issuing from the ends of the mold was also ignited.

Molten metal taken from an electric arc, basic lined furnace was then poured into the pouring cup. Generally, this metal was a steel alloy containing about 18% chromium, 8% nickel, and a small amount of molybdenum. The metal was poured at a temperature of 2920° F. through a ⅝'' pouring cup aperture. The time required for pouring was about 11 seconds. The flow of gas through the bore of the casting was continued for a period of time until it was safe to assume that the casting was solidified. The flow of gas was then stopped, and an examination of the interior of the casting through the end holes showed that the casting had solidified. The machine was then shut down, the temperature of the mold being about 700° F.; and the mold containing the casting was removed. The casting was then pulled from the mold and allowed to cool. The casting was 3¾ inch outside diameter, 2½ inch inside diameter, $24\frac{5}{16}$ inches long, and weighed 40 pounds.

The outer surface of the casting was uniformly smooth and free of pinholes. The casting was machined to provide a long taper and then subjected to dye check or dye penetrant inspection. No porosity or pitting could be detected.

The inner surface of the casting was dark gray in color, of uniform appearance, with a maximum roughness not exceeding .010 inch. No porosity or other defects appeared after examination which included dye checking, etc.

Example II

The process, for the forming of a 12¼'' O. D. tube, was carried out in accordance with the description given in Example I, except that the gas was not introduced until 3½ minutes after pouring was completed. An excellent casting having a sound inner surface (as well as outer surface) was produced. No porosity or other defects were discovered following the dye checking or dye penetrant inspection.

Example III

On a production run, I made some sand mold centrifugal castings, 6'' O. D. x ⅞'' wall section x 6 ft. long, of a titanium-stabilized alloy containing 25% chromium and 12% nickel. I also made some 3½'' O. D. x ¾'' wall section x 6 ft. long castings in the same alloy. It was decided to duplicate these castings, using conventional techniques but with the use of gas as described in Example I, to determine if the benefits could be duplicated in castings made in sand molds. Specimen rings were machined, faced, and polished from one casting of each size, both from those made without gas and those with gas.

By visual inspection, all four castings had excellent, smooth, uniform outer surfaces. The castings made without the addition of gas showed $\frac{3}{32}$'' gross I. D. porosity on the 3½'' diameter casting, and ⅛'' gross I. D. porosity on the 6'' diameter castings. The castings treated with gas showed no I. D. porosity whatever, by unaided visual inspection.

Dye check inspection of the 6" specimen cast without gas showed porosity to a depth of $\frac{5}{32}$" on the inside diameter, and of the 3½" diameter specimen to a depth of ⅛". Dye check inspection of the specimens treated with gas showed no porosity whatever on the I. D. All four specimens showed roughness on the outside surface to the extent of approximately .010".

Example IV

I duplicated Example I, with the exception that butane gas was substituted for city gas.

The resultant casting was indistinguishable from that produced in Example I, on visual inspection. A thick coating of lamp black was found to have been deposited in the bore of the casting, and subsequent machine work on the casting showed the metal adjacent to the bore to be considerably harder than that on the outside of the casting. This casting was taper machined and dye check inspected, the same as previous castings. It was found to be equivalent in every respect to that produced in Example I.

Example V

A casting 8⅞" O. D. x 3" wall section x 24" long was poured in an alloy containing 18% chromium and 8% nickel. The casting weighed 388 pounds. It was cast in a metal (cast iron) mold, and water cooling was required to control the temperature of this mold during the process of pouring. Butane gas was used during the entire operation.

The resultant casting, when machined and inspected, was found to have O. D. porosity to the extent of .050" and I. D. porosity of .150", and it was substantially free of the micro-porosity which is common to castings of this size and shape produced by centrifugal casting methods.

Example VI

A sand-lined mold was preliminarily coated on the interior with a silica flour wash and the mold heated in excess of 400° F. to remove moisture. Propane was ignited and introduced into the mold and the excess gas issuing from the ends of the mold was also ignited. Molten steel was poured through a pouring cup aperture in about 11 seconds. The flow of gas through the bore of the casting was continued until the casting was solidified and the flow of gas was then stopped, the machine was shut down, and the mold containing the casting was removed. The casting was then pulled from the mold and allowed to cool. It was found that the outer surface of the casting was free of pinholes and smooth, while the interior of the casting was uniform and apparently free of porosity. The casting was machined at one end to provide a long taper and subjected to dye check inspection. The dye check inspection showed no pitting or porosity at any point through the casting.

Example VII

Processes corresponding to that set out in Example I, were carried through on high alloy steels, consisting roughly of 10 to 30% chromium, 0 to 90% nickel, and the balance iron (the carbon content being from 0.01% to 1%, and the silicon content being from 0.1 to 3%). The process was similarly applied to such high alloy steels containing from 0.1 to 3% of columbium, containing sometimes 0.1 to 3% titanium, and containing from 0 to 4.0% copper. In some tests, the high alloy steel contained boron in from 0 to 5%. and sometimes tungsten in from 0 to 5%. Other alloys contain molybdenum from 0 to 2.5%, or selenium from 0 to 1%, or tellurium from 0 to 1%, or vanadium from 0 to 3%.

Since such high alloy steels are expensive, and are employed in parts which demand perfection, the foregoing tests were made to determine the efficacy of the combustible gas in preventing the development of porosity during the casting operation. The results with all of these products were comparable in all respects to that set out in Example I.

Example VIII

The process was carried on substantially as described in Example I for the forming of a casting 3¾" in outside diameter, 2½" inside diameter, and approximately $24\frac{5}{16}$" long. After the metal was poured, I introduced finely-divided diatomaceous earth with hydrogen gas into the interior of the casting so as to deposit a coating of the earth on the interior of the casting. City gas was introduced immediately after the deposition of the diatomaceous earth so that the diatomaceous earth coating served as a barrier between the metal surface and the soot which was deposited from the partial combustion of the gas. The inner surface of the metal casting was found to be uniformly free of porosity. Even when city gas was omitted, it was found that the diatomaceous earth coating very substantially improved the interior surface of the metal casting.

The above tests were repeated to deposit diatomaceous earth in a coating of different thicknesses up to a maximum of ⅛". Similar tests were made in which city gas was introduced after the deposition of the coating of diatomaceous earth and in which the diatomaceous earth served as a barrier between the metal surface and the soot which was deposited from the partial combustion of the gas.

Example IX

The process was carried on substantially as described in Example I except that carbon was added to the interior of the casting by a different procedure. 15% of carbon by weight was mixed with comminuted zirconite flour and the resulting mixed solid was carried into the interior of the rotating mold by means of hydrogen. The result was a casting with a sound, porous-free inner surface and with the desired controlled depth of carburization. In this process, it was found that any inert gas could be effectively employed for carrying the mixture of flour and carbon into the interior of the casting for depositing a carbon layer on the inner surface of the casting to a predetermined desired depth.

It will be understood that at times it is desired to produce a carburized surface on the inner diameter of a tube through the controlled use of carbon. Heretofore the application of carbon to such surfaces has been found to be detrimental due to the fact that there was no control of the amount of effective carburization. Through the process described above, in which the amount of carbon is controlled, it is possible to produce a carburized surface to a predetermined desired depth.

In the various different embodiments, the process permits considerable variation, particularly with respect to the time of introduction of the gas and the period through which the gas is introduced. By introducing the carbon-forming or bearing gas at a time after the metal has been poured, I find that there is less carbon pick-up, while at the same time a casting having a sound

inner surface is produced. The relative time of introduction of the gas and the period of such introduction will be brief and well after the pouring of the metal, while for other products the same should be introduced at a different time and for a longer period. Where in the forming of steel castings it is desired to sharply limit the carbon pick-up, I have found that excellent results are obtained by introducing the gas just before solidification of the metal becomes complete.

Through the use of the foregoing process, I am able to produce a steel casting having a carburized inner surface where a completely carburized surface is desirable. On the other hand, where a carburized surface in a steel casting is not desirable, I am able to employ carbon to reduce porosity while at the same time keeping the amount of the carbon pick-up within a controlled limit. I am able to control the carbon pick-up to the degree desired through the employment of a gas which forms carbon, or a gas containing carbonaceous solids, or by the use of a permeable barrier, or by the timing of the addition of the gas relative to the forming or solidification of the casting.

While, in the foregoing specification, I have set forth a description of the process in considerable detail for the purpose of illustrating the invention, it will be understood that such details may be varied widely by those skilled in the art without departing from the spirit of my invention.

I claim:

1. In a centrifugal casting process for forming a casting in a mold, in which process molten metal is poured into a mold mounted for rotation and the mold rotated about an axis to form the casting, the steps of pouring molten metal into the mold as the same is rotated to form a hollow molten body, and, after pouring the metal and before the metal has cooled to room temperature, coating the interior of the hollow casting with carbon by directing upon said interior a stream of gas bearing carbon particles.

2. The process of claim 1, in which the gas is inert under the conditions prevailing within the hollow casting.

3. The process of claim 1, in which the gas is a hydrocarbon gas which forms carbon particles as it undergoes combustion and decomposition.

4. In a centrifugal casting process for forming a casting in a mold, in which process molten metal is poured into a mold mounted for rotation and the mold rotated about an axis to form a hollow casting, the steps of pouring molten metal into the mold as the same is rotated to form a hollow molten casting, and, after pouring the metal and before the metal has cooled to room temperature, coating the interior of the hollow casting with carbon by directing upon said interior a gas containing carbon particles, and continuing the application of carbon to the interior of said hollow casting as it solidifies.

5. In a centrifugal casting process for forming a hollow casting in a mold mounted for rotation and in which the mold is rotated about an axis to form the casting, the steps of pouring molten metal into the mold as the same is rotated to form a hollow molten body, and, after the casting is formed and just before solidification of the casting becomes complete, coating the interior of the casting with carbon by directing upon said interior a stream of gas bearing carbon particles.

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