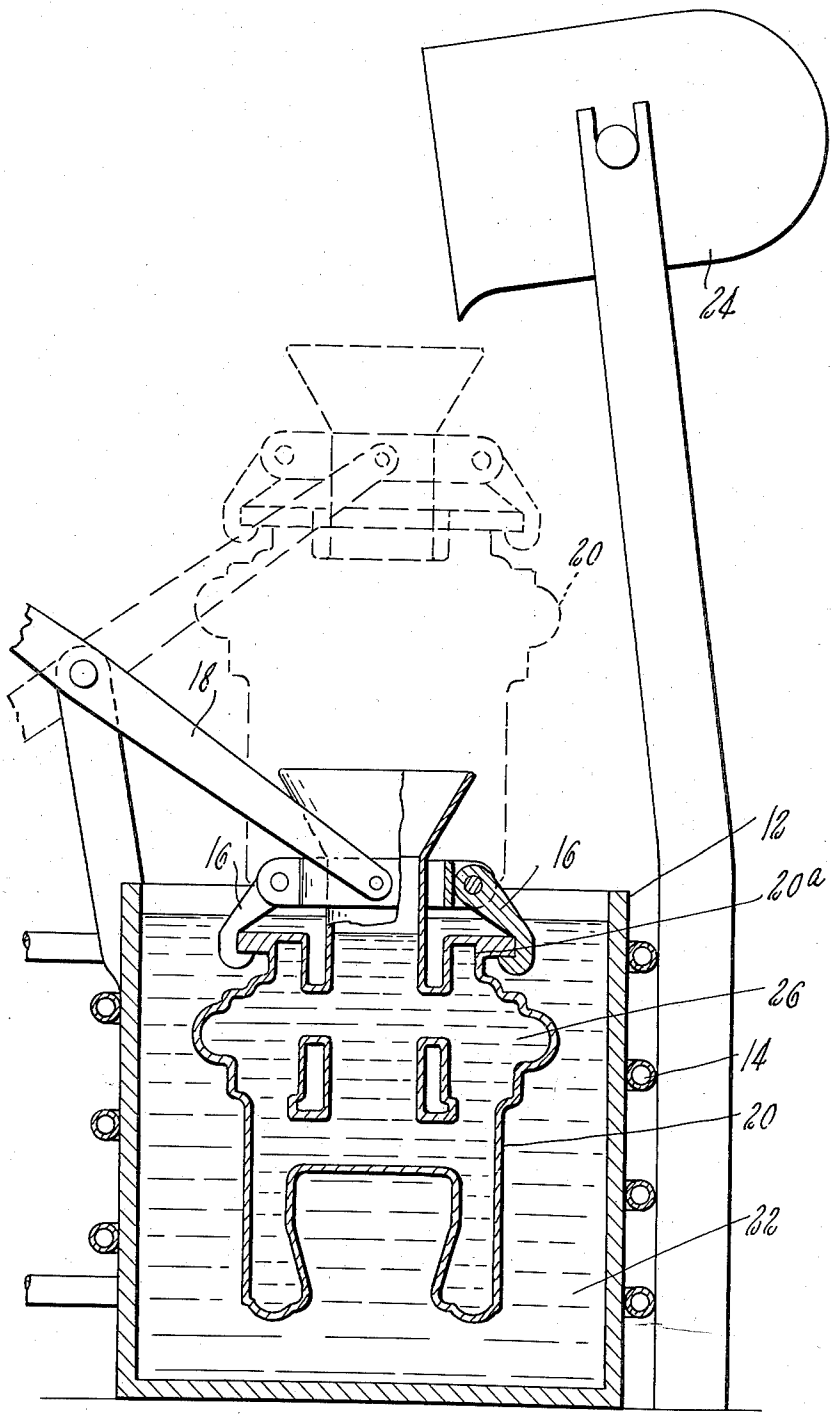
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METHOD OF CASTING REFRACTORY SHELLS

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METHOD OF CASTING REFRACTORY SHELLS

Richard T. Carter, % Hitchener Manufacturing Co., Milford, N.H.

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This invention relates to casting procedures and more specifically to protecting the surface of shell castings from the damaging effects of the atmosphere during the early stages of cooling, to controlling the rate of solidification of a shell casting, and to supporting the shell during casting or cooling.

For many years, the precision casting procedure, commonly referred to as the "Lost Wax Process" consisted of making an expendable pattern of the object to be cast, placing the pattern in a heat resistant container and filling the same with a refractory slurry which later sets into a solid mass around the pattern. The expendable pattern was later removed by solvents or heat and the mold so formed, was pre-heated to a suitable temperature to receive the molten metal. This mold, due to its low permeability, provided considerable protection to the cast surface from attack by oxygen and other elements of the atmosphere while the casting was solidifying. Also, because of the substantial mass of refractory material, the mold dissipated the heat of the cast metal slowly causing a relatively slow solidification rate. Hence, a casting produced from this type of mold generally had a relatively coarse grain size, detrimental in many instances. Also, lack of high permeability of this solid mold caused difficulty in filling intricate mold cavities because the trapped air and gases evolved from the melt could not readily escape.

More recently the art has progressed to a point where a lightweight mold is fabricated by surrounding the expendable pattern with a thin shell of refractory. Material usually built up in several layers, provides a thin-walled, low mass, highly gas permeable ceramic shell, which for a considerable range of castings, may be cast without additional support, thus saving considerably on mold weight, material cost, and process time. Such a shell is fully described, for example, in Patent Nos. 2,806,269, 2,806,270 of September 17, 1957. It is a particular feature of the shells therein described that thin, gas-permeable walls are produced permitting superior filling characteristics as well as more rapid cooling due to the much decreased mass of insulating refractory material. This produces a casting having a somewhat smaller grain size, which is frequently advantageous. However, a casting poured in an unsupported shell of the above nature presents cast surfaces in very close proximity to the surrounding atmosphere and lends itself readily to atmospheric attack, particularly in castings having heavy sections. Also, there is the problem of refractory impurities reacting with the cast surface in the presence of oxygen which may cause surface imperfections in the casting. The severity of the attack with different metals depends on the casting temperature and the mass of metal, but when present is generally characterized as oxidation pitting. Such pitting and like surface inperfections which occurs in shell casting has presented a very serious problem particularly in the casting of the more common low carbon steels. For

example, pits up to a depth of .020 inch may occur on castings which would be free from such defects if cast by the more widely known solid investment mold technique. Also, in ferrous casting, loss of carbon at the surface (decarburization) frequently occurs in previously known methods of casting, due to the carbon in the steel combining with the oxygen in the atmosphere, leaving the outer skin of the casting in the form of ferrite which is substantially free of carbon. The degree of decarburization is a function of the cooling rate and the availability of oxygen at the cast surface. Because the properties of iron base alloys vary considerably with the carbon content, this carbon must generally be replaced by a further operation known as carburizing, which involves forcing carbon back into the cast surface at temperatures above 1500° F., adding to the expense of the casting operation.

As for the cooling of a casting, the rate at which an unsupported shell casting will solidify and cool will depend mainly on the shell thickness, the rate of movement of air past the shell surface, and the prevailing temperature. Although the casting in a shell type of mold will generally solidify faster than the same shape cast within a solid refractory mold, giving somewhat smaller grain sizes, there is nevertheless, considerable demand for investment casting having much finer grain sizes, calling for solidification at much higher rates yet free of oxidation pitting and decarburization.

It is a main object of this invention to satisfy these requirements, by providing a novel process wherein the cast metal in a thin-walled, highly gas permeable refractory shell is protected from contact with the atmosphere during the early stages of cooling of the metal.

Another important object of the invention is to provide a process whereby the rate of solidification of a casting in a shell or other mold may be greatly accelerated and accurately controlled.

It is a particular feature of the invention to obtain an increased and controlled rate of casting solidification and to protect the cast surface from atmospheric attack in one simple operation.

It is another feature of the invention to provide a process for producing unpitted small grain-sized, ferrous castings in highly gas-permeable, self-supporting molds especially of the type of said Patent Nos. 2,806,269, 2,806,270.

The invention consists of immersing or partly immersing a monolithic refractory shell, preferably highly gas permeable and having relatively thin walls, in a liquid coolant while the metal contained in the shell is in yet a molten state, the liquid coolant acting as a barrier to atmospheric oxygen in addition to acting as a coolant. The immersion may take place simultaneously with pouring the metal into the shell or immediately following pouring. The liquid coolant preferably consists of a molten metal having a lower melting point than that of the cast metal, but glass, oil, salt, water or the like may also be used, depending on the rate of heat transfer required and the temperature at which the heat transfer is required to take place. The liquid used as a coolant acts essentially to conduct heat away from the mold and establish a controlled cooling rate; to further this object the cooling medium is preferably maintained at a predetermined temperature.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description of preferred embodiments thereof, taken in connection with the accompanying drawing showing a diagrammatic partially sectional view of means which may be used to carry out the invention.

Referring now to the drawing, the process of the in-

vention may be carried out by means of suitable apparatus including a vat **12** surrounded by induction heating coils **14**. Support means including a mold clamp **16** and a lever **18** pivotally mounted on the vat for raising and lowering the clamp are adapted to receive a shell mold **20** and to support and position it in the vat away from the vat walls. The vat is adapted to receive a body of liquid such as molten aluminum **22** which surround a substantial portion of the shell mold **20** and acts as a liquid coolant and oxidation barrier according to the invention. A tiltable melting pot **24** for the ferrous metal of the casting **26** is provided in a pouring position with respect to the mold **20** in raised position as shown in dotted lines in the drawing. The mold herein shown as a specific example is of the monolithic multi-layer refractory shell type and is intended to produce four identical objects by gating from a central sprue, the objects being cast in vertical position with an upwardly extending blind mold cavity **20***a* above the upper gate.

Basically, the casting operation consists in forming a monolithic refractory shell mold **20** by means of the "Lost Wax" process as described in said patents, positioning the mold **20** in clamp **16** in raised position, pouring the steel into the mold **20** to form the casting **26** and immersing the poured mold, with its metal still fluid, in the body of liquid **22** and there maintaining it until it solidifies, the liquid being kept at a temperature of say 1500° F. (well below the melting point of the steel of of the casting of upwards of 2000° F.). The pouring and immersion may as desired, take place either successively or simultaneously, or the immersion may even precede the pouring if desired. Also, immersion may be only partial under some circumstances, all as hereinafter explained. Metals have excellent rates of heat transfer, have liquid states over the complete range desired, have exceedingly high boiling points, and high specific heats. For these reasons metals are the most desirable media for effectively achieving the objects of this invention. For casting metals melting above 2000° F., such as ferrous metals and alloys, aluminum provides an excellent medium for most purposes. It provides the highest rate of thermal conductivity and also has a high specific heat. The high specific heat is of value in that more units of heat are required to change its temperature, and therefore the bath temperature may be more easily controlled. A bath temperature of about 1500° F. is found to be very effective in providing a very fine cast grain structure. Immersion of the shell mold until the molten metal therein solidifies and preferably for some interval of time thereafter is important in the practice of the invention. For instance, up to two minutes is required to cool the casting so as to avoid oxidation attack on some steels. The minimum time needed, however, must be found by experiment as it will depend on the thickness of the shell and the weight of the casting as well as upon the characteristics of the metal being cast. For casting non-ferrous metals a choice of liquid coolant may be made from metals in the lower melting point range such as lead, tin, zinc and their alloys. The thermal conductivity of various metals is not appreciably different in this temperature range, and the variation of solidification rates using the different metals available will be nearly proportional to the temperature of the metal used. The best medium to use in a particular case, then, will depend on the cooling conditions sought, and possibly on the cost of the available metallic coolants.

Water, water solutions of salts, etc. have relatively low rates of heat transfer, but will promote more rapid solidification rates than a shell cooled in air and are therefore sometimes preferred. Water, however, will not afford oxidation protection for ferrous alloys owing to the unavoidable generation of steam. However its cooling rate obtained is high due to its latent heat of conversion of water to steam. Oils of various types, including synthetic oils, like water and water solutions are useful with metals in the lower melting range below 2000° F. Agitation may be desirable, however. Glass also has a relatively low thermal conductivity and only remains in the liquid state at a relatively high temperature, say above 1800° F.

As has been stated above, the characteristics of relatively thin-walled, low mass, highly gas permeable refractory shell molds are especially improved by the practice of the present invention. This is not to say, however, that the coolant aspects thereof are not useful with more impermeable refractory molds, particularly in the case of such molds having relatively good heat conduction characteristics, as is likely to be the case with thin-walled shell or other molds. The practice of the present invention, then, is especially useful in conjunction with ferrous casting with thin-walled, highly gas permeable refractory shell molds wherein oxidation pitting or the like has been a problem because of the permeability of the shell to atmospheric oxygen during cooling of the casting. In the present invention, uniquely, shell thickness need not be increased or shell permeability otherwise decreased in order to insure freedom from pitting and the like. Rather, an extraordinarily thin shell may be utilized as is most desirable from the standpoint of extremely rapid cooling and solidification of the cast metal to give small grain size as well as to provide a highly gas permeable shell permitting the free escape through the shell of trapped air and gases evolved from the melt. This is especially important in monolithic shells having blind mold cavities, as at **20***a*, characteristic of molds constructed by the "Lost Wax" process. Of course, the shell utilized with the present invention must be self-supporting in the sense that it can be moved into the liquid coolant, but because of the support provided by the coolant, particularly with a molten metal coolant and simultaneous pouring and immersion, shell thickness may be reduced by about half that heretofore found necessary. For example, in shells constructed according to said patents a shell having as few as three shell layers is satisfactory, whereas a six layer shell heretofore has been considered a minimum for unsupported pouring of a casting of about 5 to 10 pounds weight.

Another advantage of the invention lies in the fact that it may be used to preferentially solidify a certain section of the casting by immersing the shell partially to a predetermined depth, so that only selected portions of a casting are surrounded by a bath having very high heat transfer properties. In this manner, certain gates in the mold may be omitted, and the main gating and feeding system may be reduced in volume. Also, one or more layers of different liquid coolants may be used to achieve preferential cooling in different parts of the mold. For example, the combination of glass and aluminum may be used to achieve a desirable cooling gradient.

Variations in the procedures disclosed herein are contemplated as falling within the scope of the invention as defined by the following claims.

I claim:

1. A method of casting of ferrous objects, comprising filling a gas permeable refractory shell mold with molten ferrous metal and while said metal is molten immersing a substantial portion of said filled mold in a bath of molten aluminum below the melting point of the poured ferrous metal.

2. A method of casting of ferrous objects, comprising filling a gas permeable refractory shell mold with molten ferrous metal and while said metal is molten immersing a substantial portion of said filled mold in a bath of molten metal below the melting point of the poured ferrous metal.

3. A method of casting as claimed in claim 2 further comprising simultaneously lowering said mold into a liquid coolant at substantially the same rate as the rising of the poured metal in the mold, whereby the outward forces upon the shell caused by the poured

metal are substantially countered by the inward forces caused by said coolant.

4. A method of producing a casting having a uniform carbon content from steel without utilizing a carburizing step comprising pouring molten carbon steel into a gas permeable, refractory shell mold and substantially immersing said mold during at least the first stages of cooling into a highly heated bath comprised of molten metal maintained at non-boiling, non-oxygen producing conditions substantially below the solidifying temperature of the molten carbon steel.

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