Jan. 24, 1956 F. H. COUPLAND, JR., ET AL 2,731,690

METHOD FOR THE MANUFACTURE OF CENTRIFUGALLY CAST TUBULAR METAL ARTICLES

Filed July 29, 1954 4 Sheets-Sheet 1

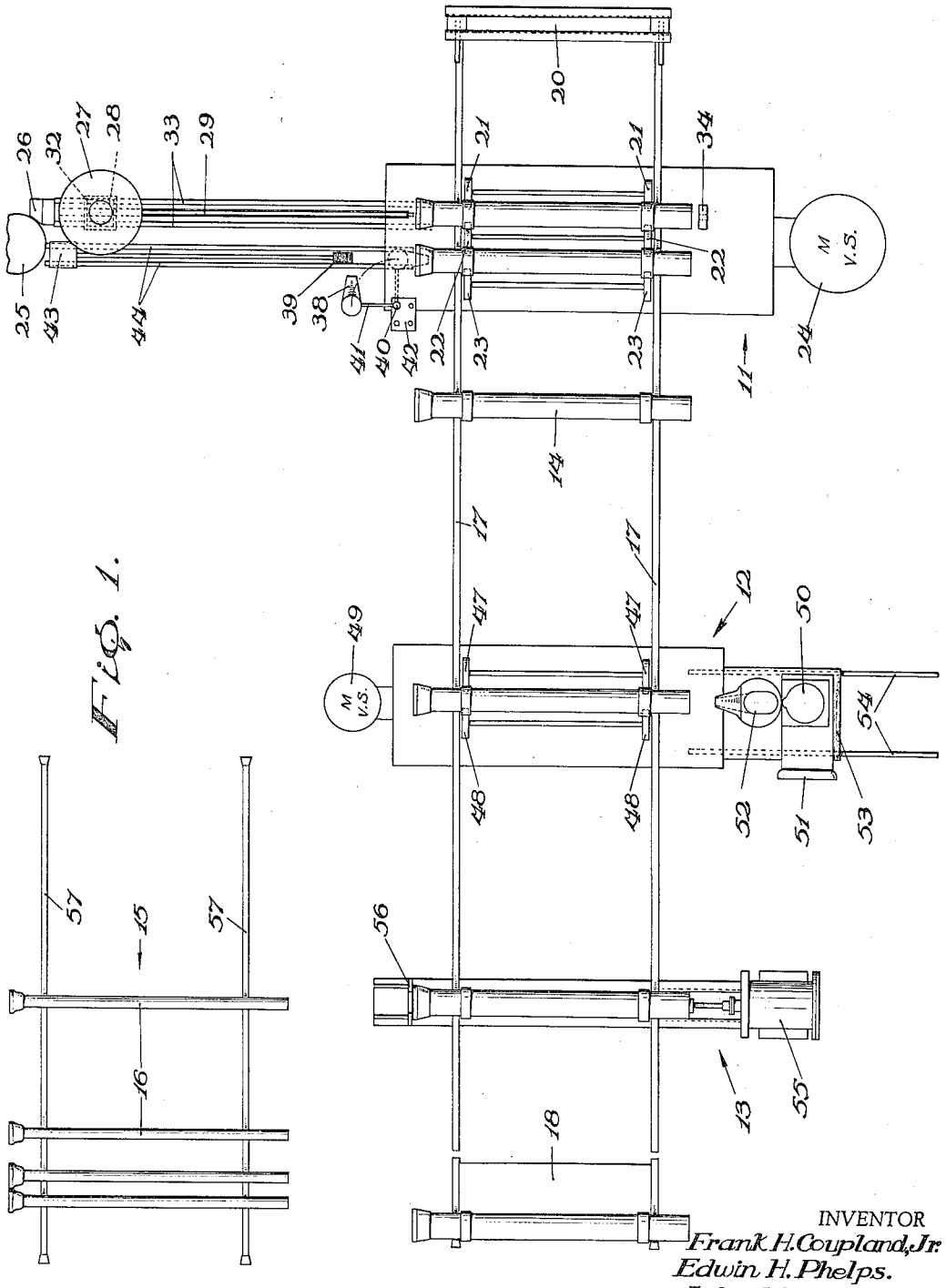


Fig. 1.

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Filed July 29, 1954 4 Sheets-Sheet 2

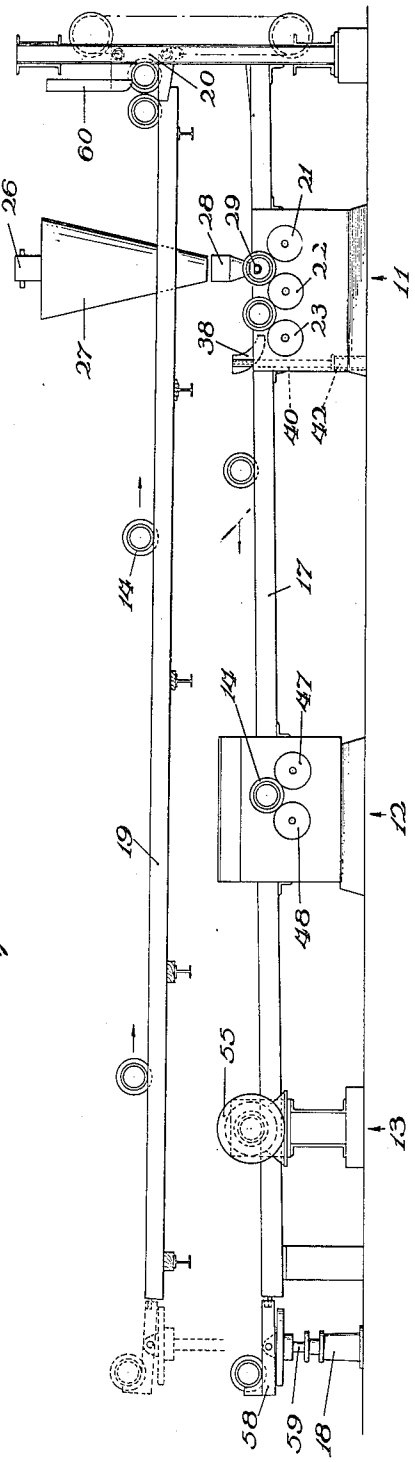


Fig. 2.

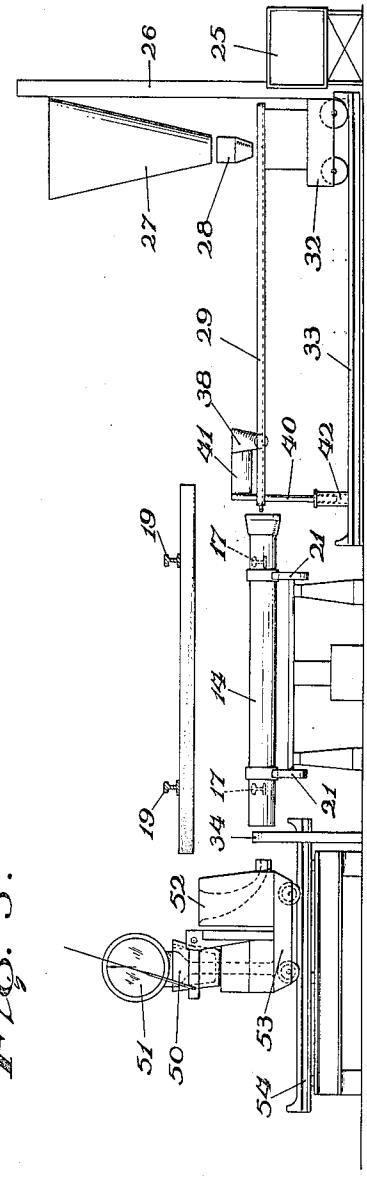


Fig. 3.

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Filed July 29, 1954 4 Sheets-Sheet 3

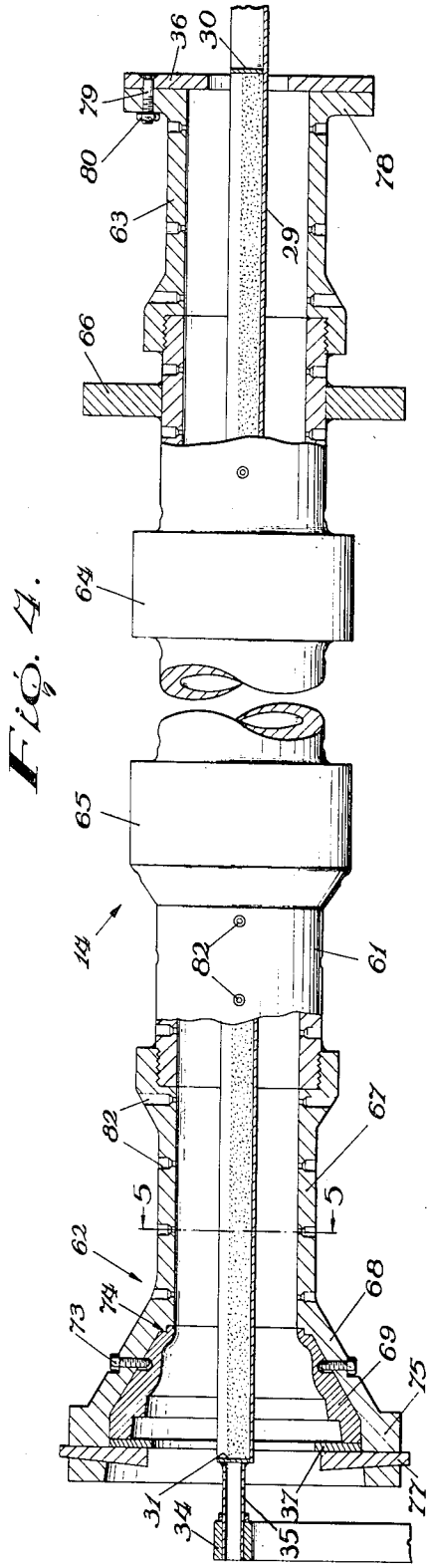


Fig. 4.

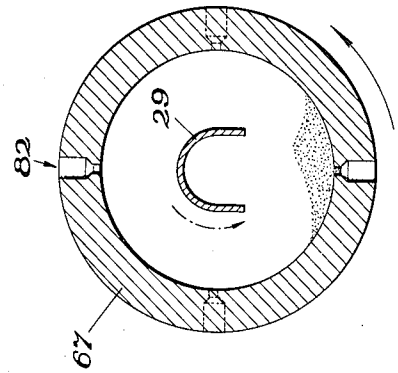


Fig. 6.

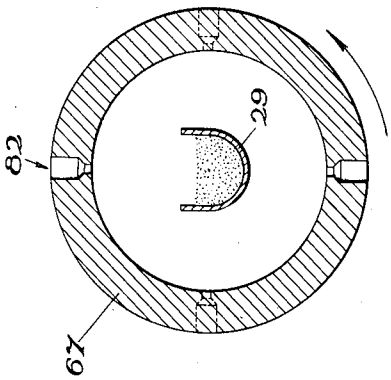


Fig. 5.

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Filed July 29, 1954 4 Sheets-Sheet 4

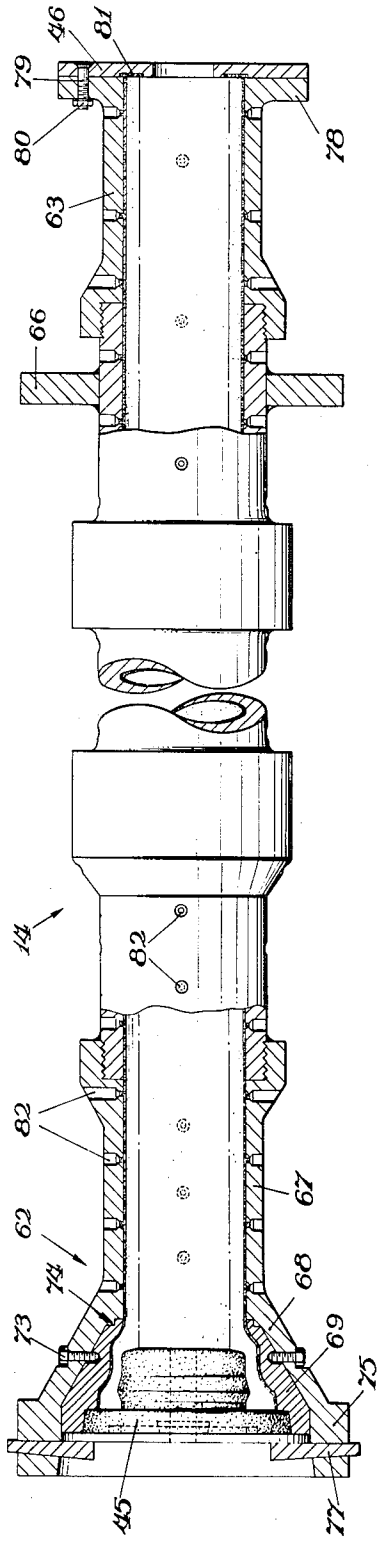


Fig. 7.

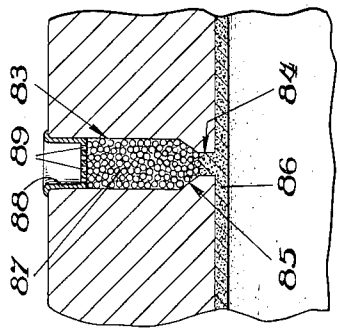


Fig. 10.

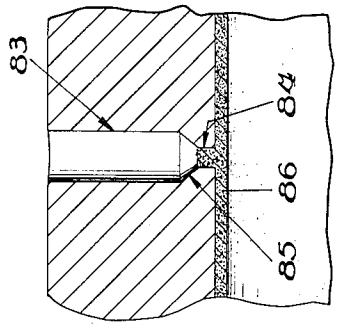


Fig. 9.

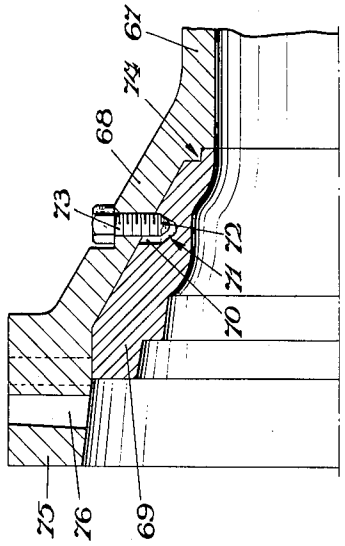


Fig. 8.

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2,731,690

METHOD FOR THE MANUFACTURE OF CENTRIFUGALLY CAST TUBULAR METAL ARTICLES

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Application July 29, 1954, Serial No. 446,488

18 Claims. (Cl. 22—200.5)

This invention relates to the manufacture of centrifugally cast tubular metal articles, and is particularly concerned with an improved method for centrifugally casting iron and steel pipe, tubing and similar hollow bodies of generally cylindrical form.

Inasmuch as the invention is especially well adapted to the production of cast iron pipe, the following disclosure will be directed primarily to this particular application of the inventive concept. By so doing, however, it is not intended to limit the scope of the invention to the centrifugal casting of cast iron pipe, because it will be obvious that it has equal utility in the manufacture of other types of hollow metal castings.

Heretofore, there have been in general use in the industry only two different methods of centrifugally casting cast iron pipe; the Sandspun method employing a sand mold formed by ramming green sand around a pattern inside a vented metal flask, and the de Lavaud process in which an unvented metal mold is used.

In the Sandspun procedure, the sand mold must be made relatively thick, two inches being a representative thickness, in order to facilitate ramming and also prevent the molten metal from being forced out through the vent holes which are provided in the metal flask to permit ready escape of the water vapor and other gases formed during the casting operation. The use of sand molds requires an extensive amount of mechanical equipment for storing, supplying and reconditioning the sand, ramming the sand into the flasks, maintaining the flasks and patterns in properly centered positions, and cutting out the sand before stripping the cast pipes from the molds. Considerable labor is also expended in performing the various manual operations necessary in ramming and stripping the molds. These disadvantages of the sand mold process are offset to a substantial extent by the fact that the resulting castings have the desirable characteristics of a typical sand cast gray iron structure and do not require annealing.

In the de Lavaud method, the metal mold is normally equipped with a jacket through which water is circulated to reduce the mold temperature produced by the rapid transfer of heat from the molten iron, and is also usually provided with a relatively thin inner coating or facing of suitable composition, such as dry powdered ferro-silicon or a water suspension of such refractory materials as silica flour and bentonite. In most cases, however, such mold coatings are ineffective protection against heat checking, and do not retard the freezing rate sufficiently to prevent chilling of the iron. A subsequent annealing treatment is therefore necessary to reduce the hardness and brittleness of the as-cast product of the de Lavaud method. In metal mold casting, it is normally impossible to vent the mold due to the surrounding water jacket and because the liquid iron would flow out through the vent holes, or plug them up, during the casting operation. Consequently, it is one of the limitations of the de Lavaud process that the mold facing used may not contain gas-forming materials, because the only available

path for escape of the gases is through the freezing metal with the resultant danger of forming blowholes and leaks in the casting. The difficulty of providing an adequate protective coating on a non-vented metal mold without causing trouble due to gas formation in the coating also accounts for the excessively high maintenance and replacement costs which are incurred in the use of metal molds. Compared with the sand mold process, the principal advantages of the metal mold procedure reside in the relatively higher rate of production per casting machine which results from the rapid rate of solidification of the poured metal, and the fact that it is not necessary to form a new mold for each casting.

The process of the present invention successfully combines the advantages and eliminates the disadvantages of the previously known rotary sand mold and metal mold procedures by providing a novel method of forming and using sand lined, vented metal molds to produce high quality unchilled castings rapidly and efficiently, at low cost and with substantially less capital investment than is required for other centrifugal installations.

The new method is characterized by the use of a vented metal mold having a smooth, uniformly hard, bonded refractory lining of self-sustaining character which is rapidly and accurately formed by a carefully controlled centrifugal procedure, and which, while of substantially less thickness than the sand molds of the prior art, is effective both to avoid unduly rapid freezing of the casting metal and to protect the metal mold against overheating and wear. The mold lining is composed of a mixture of silica sand or other granular refractory and a dry thermosetting resin which, when heated to a predetermined temperature by the extraction of heat from the mold wall, forms a homogeneous, strongly bonded refractory capable of adhering tenaciously to the inner surface of said wall. Once the sand-resin mixture has fused and set, it constitutes a smooth, dense coating on the interior of the mold which will readily withstand the washing action of the molten metal during casting, but, after the casting has frozen, will disintegrate as a result of burning of the resin under the heat of the solidified metal so as to permit rapid, easy stripping of the casting from the mold. Lined molds of this character may be prepared in quantity with the use of relatively little sand, and, being non-hygroscopic, may be held in storage for indefinite periods of time before being used for casting.

The casting step of the method of the present invention is generally similar to that of the prior Sandspun process, but is characterized by a substantially shorter casting time than that previously obtainable, due to the fact that the resin bonded lining of the mold is very much thinner than the ordinary sand mold and therefore freezes the casting much more quickly. As compared with the de Lavaud casting operation, the present method has the advantage that the gases created in the mold lining may readily escape outwardly through the vents of the mold and are not forced inwardly through the molten metal, the vents being covered by a strong but permeable lining which permits passage therethrough of the gases but effectively prevents the molten metal from flowing into the vents.

Gray iron castings produced by the new process are characterized by a distinctive improved structure in comparison with gray iron castings produced by other centrifugal methods. Ordinary sand mold centrifugal processes produce a relatively coarser grained gray iron with large graphite flakes which, when machined to a fine finish, may show a somewhat rough pitted surface appearance. The usual metal mold centrifugal processes produce a chilled outer surface which can be softened by annealing, but the resultant annealed structure contains free ferrite and is consequently undesirable for many applications. By

the process of the present invention, using a resin-sand mold lining of controlled thickness, there is obtained in the as-cast state an unchilled fine grained pearlitic iron with flake graphite in random distribution, a structure which has been found to be the most desirable for many applications, particularly those where resistance to wear is essential.

It will be apparent from the foregoing general description that the principal object of this invention is to provide an improved process for making centrifugally cast metal pipe and similar articles in sand lined metal molds, which process produces clean, smooth castings having generally the same properties as those obtainable by the Sandspun method, but does so more quickly, at lower cost and with substantially less equipment and labor than the prior procedure. Other objects, including the provision of a new method of centrifugally lining a vented metal mold with a thin coating of a resin bonded refractory, will appear more fully upon consideration of the detailed description of the invention which follows. In this connection, it is to be expressly understood that the specific mold lining and pipe casting procedures hereinafter described and the particular apparatus shown in the accompanying drawings are illustrative only and are not to be construed as representing the full scope of the invention defined in the appended claims.

In the drawings, wherein like reference characters indicate like parts throughout the several views:

Figs. 1 and 2 are diagrammatic plan and front elevation views, respectively, of an installation for producing centrifugally cast cast iron pipe in accordance with the present invention, certain of the elements having been omitted in the interest of simplicity;

Fig. 3 is a diagrammatic end elevation of the mold lining apparatus of the system of Figs. 1 and 2, also showing the pouring ladle and associated equipment at the casting station;

Fig. 4 is a side view, partially in section, of one embodiment of mold adapted to carry out the invention, this view also showing the trough by which the sand-resin mixture may be introduced into the metal mold in the position occupied thereby just before the mixture is dumped into the rotating mold;

Fig. 5 is an enlarged cross section of the metal mold and trough taken substantially on line 5—5 in Fig. 4;

Fig. 6 is a cross section similar to Fig. 5, but showing the trough in inverted position;

Fig. 7 is a partially sectioned side view similar to Fig. 4 showing the sand lined mold as it exists just prior to pouring of the molten metal;

Fig. 8 is an enlarged half axial section of the bell end of the metal mold of Fig. 4 showing the removable metal insert for shaping the outer surface of the bell of the pipe and the means by which said insert is detachably fixed in place;

Fig. 9 is an axial sectional view, on an enlarged scale, of the form of vent embodied in the metal mold of Figs. 4 and 7; and

Fig. 10 is a view similar to Fig. 9 showing a modified form of vent.

The method of making a cast iron pipe provided by the present invention comprises a series of coordinated steps performed at successive stations of a production line system adapted for continuous, closed cycle operation.

In practice, the beginning of the cycle may be taken to be the centrifugal casting step wherein a charge of molten iron is poured into a rotating mold comprising a vented metal mold having a resin bonded sand lining and rotation of the mold is continued until the cast metal solidifies or freezes into the form provided by the mold. During the casting, the mold is supported in a substantially horizontal position on, and is rotated by, the motor driven rollers of an ordinary centrifugal casting machine, and the molten iron is delivered into the mold from a tiltable ladle by a relatively short pouring trough of conventional construction. In making extra long or extra heavy pipe, it may be desirable to use a longer trough extending a substantial distance into the mold and to withdraw the trough as the metal is poured to facilitate longitudinal distribution of the charge.

If desired or necessitated by the size and weight of the mold, the mold may be rotated at a uniform speed throughout the casting operation, which speed must be sufficient to form the casting on the mold wall centrifugally as the metal is introduced. This is known as high speed casting and involves a relatively high speed of rotation such as to create centrifugal forces at the inner surface of the mold on the order of 60 to 75 times the force of gravity. For example, in making a 20" pipe by the high speed casting procedure, it is desirable to rotate the mold at from 450 to 500 R. P. M.

If is preferable, however, to introduce the molten iron into the mold while the latter is rotating at a speed below that at which the metal is caused to cover the mold wall by centrifugal force, so that the metal may first distribute itself longitudinally in the form of a trough or slab on the bottom of the slowly spinning mold. Then, as soon as all or the major portion of the charge is in the mold, the rotation is accelerated to a speed at which the metal will distribute itself circumferentially and form the pipe under centrifugal action. This procedure is called low speed casting, and is particularly desirable because any loose particles of the mold lining or impurities in the molten metal, together with the slag, will float on top of the slab lying along the bottom of the mold and will not be trapped against the mold lining or within the wall of the casting.

In utilizing the low speed casting technique in the method of the present invention, to which it is particularly adaptable because the molds provided by the invention are substantially lighter than the sand molds used in the Sandspun process for making pipe of the same diameter, the mold is spun at a relatively low speed of from 20 to 80 R. P. M. while approximately 75% of the molten iron charge is being poured into the mold, and is then very rapidly accelerated, within a period of from 5 to 10 seconds, to a relatively high speed on the order of ten or more times the low speed. For example, in casting a 6" pipe, the mold may be rotated at approximately 50 R. P. M. for about 12 seconds after pouring of the metal begins, during which time 75% of the metal in the ladle is delivered into the mold. The speed is then increased in about 6 seconds to approximately 850 R. P. M., equivalent to a centrifugal force of about 60 times the force of gravity, and the high speed rotation is continued until the casting solidifies, which takes only about one minute. In the case of a 20" pipe, the mold may be rotated at approximately 20 R. P. M. for the first 20 seconds of the casting operation, accelerated during the next 10 seconds to a speed of approximately 400 R. P. M., equivalent to a centrifugal force of about 45 times the force of gravity, and then spun at the latter speed for from four to four and one-half minutes while the casting freezes. Due to the fact that the resin bonded sand linings of the molds of the present invention are very much thinner than the sand molds of the prior art, the length of time required for the casting step is substantially less than in the Sandspun process, the saving in time being between two and ten minutes per cast, depending upon the size and thickness of the casting, with a consequent increase in production rate.

Since the temperature of the molten iron is in the neighborhood of 2400° to 2500° F. when it is poured and comes into contact with the mold lining, the heat of the metal quickly burns out the resin in the lining, thus destroying the bond between the granules of sand and the adhesion of the sand to the metal wall of the mold. The result is that, by the time the mold has been transferred from the casting station to the stripping station, the lin-

ing is devoid of strength and the pipe is ready to be stripped without any further operation on the lining.

At the stripping station, the casting is removed from the mold, carrying with it most of the lining in the form of a frangible carbonized crust, and is delivered to a cooling station where the encrusted remains of the lining are removed and the pipe is cleaned with wire brushes or in any other suitable manner. If desired, the burned sand of the old lining may be screened to remove lumps and fines, and then returned to the sand preparation station for reuse. It is desirable to strip the pipe from the mold as quickly as possible after the casting step has been completed in order to prevent excessive heating of the metal mold by the cast metal because, upon completion of the stripping operation, the empty mold is returned to the lining station where it is prepared for the next cast, at which time it is essential that the temperature of the mold wall be within a predetermined range such that the heat therefrom will be sufficient to fuse the new lining into a strongly bonded mass, but not so high as to char any of the resin in the lining. Accordingly, it is preferable to strip the mold within a minute or two after the casting has frozen, and to so time the return of the empty mold to the lining station that normal atmospheric cooling during the return will reduce the outside mold wall temperature to within the range from 300° to 600° F., and preferably to between 350° and 400° F., the permissible limits of said temperature being dependent upon the kind and amount of resin binder used in the lining. If necessary, artificial cooling may be resorted to in order to reduce the mold temperature to within the desired range between the stripping and lining stations.

If, for any reason, the metal mold is cold when ready to be lined, or its temperature is below the desired minimum, it may be heated in any suitable manner, as by gas torches or in a heating chamber. In normal operation of the method, however, each mold is lined while the metal wall still retains sufficient heat from the previous casting step to exert the desired melting and polymerizing effect on the resin of the lining mixture.

At the lining station, the metal mold is provided with a relatively smooth, hard, self-sustaining coating adherent to the mold wall composed essentially of a mixture of silica sand, or other granular refractory, and a thermosetting resin, the two ingredients being thoroughly mixed together in proportions of from 95.0 to 98.5% by weight of sand and from 1.5 to 5.0% by weight of resin. While various types of resin binders may be used, a two-stage phenol formaldehyde resin containing approximately 10% of hexamethylenetetramine has been found quite satisfactory and is preferred because it melts and polymerizes when heated to any temperature between 300° and 600° F., a range within which the temperature of the metal mold may be readily maintained during repeated casting cycles.

The term "two-stage phenol formaldehyde resin" refers to a resin which is produced by first reacting to a controlled degree phenol and a limited amount of formaldehyde, and then incorporating additional formaldehyde in the resin in the form of hexamethylenetetramine which decomposes on heating to formaldehyde and ammonia. The characteristics of such a resin are its dry powder form, insolubility in water, fusibility above 300° F., and capability after melting of polymerizing to an infusible phase with strong bonding properties. Among the commercially available resins of this type suitable for use in the method of the present invention are Thor 278, manufactured by the Borden Chemical Company, and R–136, manufactured by the Barrett Company. This particular type of resin has the further advantage that it undergoes a distinctive color change as it polymerizes which provides a visual indication of when the lining has set. A phenol furfural resin containing hexamethylenetetramine has also been used, but is not as satisfactory as the phenol formaldehyde type in that it does not exhibit the color change above mentioned.

The sand used for the lining should be a good quality, washed silica sand which has been thoroughly dried and then screened to eliminate all foreign matter and provide a sand of the grain size and distribution necessary to produce the desired smooth mold finish. Sand having an AFS grain fineness of from 40 to 150 is preferred for the making of cast iron pipe, a typical sand having an AFS grain fineness of 100 with 70% on screens 70 through 200. When casting steel, coarser sand may be used in order to facilitate escape of the greater amount of gas which is generated with the higher casting temperatures of steel. It has also been found that, within the permissible range of grain sizes, the coarser the sand, the rougher the surface of the lining, but the more uniform its thickness. Relatively fine sand, on the other hand, provides a smoother lining, but is apt to result in a wavy surface with a consequent non-uniform thickness.

In preparing the lining mixture, carefully weighed quantities of the dry, screened sand and the bonding resin in dry powder form are charged into a suitable mixer or muller in the proportions above indicated and thoroughly mixed together, after which the mixture is transferred to a storage bin from which measured quantities are dispensed as the molds are lined. When lining molds for the production of pipe up to about 6" or 8" in diameter, the preferred proportions of the lining mixture are 97.0% sand and 3.0% resin; for the larger sizes of pipe, it is preferable to use 97.5% sand and 2.5% resin. In lieu of a mechanical mixture of dry sand and powdered resin, it is also possible to form the lining of sand which has been coated with liquid resin and then dried, in which event the resin content may be as low as 0.5% of the weight of the coated sand.

The metal molds used in producing pipe in accordance with the present invention are generally similar in construction to the mold flasks heretofore used in the Sandspun process, although differing from the latter in certain important details which will be pointed out hereinafter in connection with the description of the apparatus shown in the accompanying drawings. In general, however, each metal mold consists of a substantially cylindrical tube of cast iron or steel having a wall thickness preferably at least three times the thickness of the casting to be produced, the outer surface of the mold being provided with spinning bands or tires for rotating the mold on the motor driven rollers of the lining and casting machines. One end of the mold may be equipped with a bell shape for casting pipes complete with bells or flanges, the other end being adapted to receive a stop-off plate or core to prevent the molten metal from running out during casting. The inside surface of the mold which forms the outside contour of the casting may have any shape which will allow the solidified casting to be withdrawn from one end of the mold, or a split mold may be used for producing other contours. The metal mold is preferably vented in order to permit the escape of the gases generated in the lining during casting, particularly when making steel pipe or relatively long pipe of other metals, although vents may not be essential if the mold is relatively short.

In forming the mold lining, the empty metal mold, still hot from the preceding casting or having been otherwise heated to the desired temperature, and with either one or two annular lining stop-off plates attached to its ends, is placed on the rollers of a suitable spinning mechanism, similar to the conventional centrifugal casting machine, and is rotated while a measured quantity of the loose, dry sand-resin mixture is introduced into the interior of the mold and distributed uniformly along the axis thereof. If desired, the inside surface of the metal mold may be blacked or coated with carbon with an acetylene flame prior to the lining operation. When this is done, there is less tendency for the sand of the lining to adhere to the

mold wall when the casting is stripped from the mold, and whatever sand may remain in the mold after stripping can be readily brushed, blown or poured therefrom.

Although the sand-resin mixture may be delivered into the mold in various ways, as by spraying it with air through a nozzle which is passed through the mold or by means of an auger conveyor similar to that used for the cement lining of pipes, the preferred method is to place the required volume or weight of mixture to produce a given thickness of lining in a trough of substantially the same length as the mold, evenly distributing the mixture over the full length of the trough, insert the trough in the rotating mold, and then quickly invert the trough so as to allow the lining mixture to drop out on the lower portion of the inside surface of the mold wall. Immediately after dumping the mixture, the trough is quickly withdrawn from the mold so as to prevent it from absorbing heat which might adversely affect the next lining charge.

After the lining mixture has been delivered into the mold, rotation of the latter is continued to uniformly distribute the loose granules of the mixture circumferentially over the inner surface of the mold, and until substantially all of the thermosetting resin has polymerized under the effect of heat extracted from the mold and has bonded the sand particles together to form a relatively smooth, hard refractory lining adherent to the mold wall. When the preferred phenol formaldehyde resin is used, curing or setting of the lining is clearly indicated by its change in color from near-white to lemon-yellow or light tan. Should the lining be darker than the desired color, it would indicate that the temperature of the metal mold is above the proper range and that some of the resin in the lining is apt to char and thereby weaken the lining if the mold is permitted to stand for any substantial length of time before being used for casting.

It has been discovered by experimentation that the proper spinning speed of the mold during the lining operation is best determined by the centrifugal force created at the inner surface of the mold wall and by expressing said force in terms of the force of gravity, in accordance with the formula

$$Kg=\frac{N^2D}{70,500}$$

where kg represents a centrifugal force equal to K times the force of gravity, N is the speed of rotation of the mold in revolutions per minute and D is the inside diameter of the metal mold in inches. It has also been discovered that, in lining molds of different sizes, different speeds and techniques of mold rotation may be employed in order to obtain the desired results.

For example, in lining molds for the production of pipe having diameters in the neighborhood of 6", good results have been obtained by using a two-speed technique; i. e., first, while the lining mixture is being delivered into the mold and until the particles thereof begin to adhere to the mold wall, maintaining a relatively low spinning speed such as to create a centrifugal force not greater than 0.5 times the force of gravity, and preferably on the order of 0.1 times the force of gravity, so that the particles of the mixture are not held to the mold wall by centrifugal force, but are allowed to roll along the bottom of the inner surface of said wall, and then, after the particles begin to adhere to the mold wall, accelerating to a speed sufficient to produce a force not less than 5.0 times the force of gravity, and preferably 8.0 times the force of gravity or higher. Specifically, with a metal mold having an inside diameter of 7", the lining mixture may be introduced while the mold is spinning at about 35 R. P. M., giving a value of 0.12 g according to the above formula, and after partial adherence is established, the spinning speed may be accelerated to about 300 R. P. M., which is equivalent to 9.0 g.

The advantages of forming the mold lining while thus controlling the speed of rotation of the mold are several. For example, if the lining mixture is introduced while the mold is rotating more rapidly than permitted by the above limitations, the lining will tend to be rippled and uneven, while if the rotation is too slow in the second stage when the resin is setting, the coating may lack density and be relatively soft. By proceeding in the manner described, a smooth, hard, dense coating of any desired thickness, within the limits hereinafter stated, can be produced.

Another advantage of this particular lining technique is that it permits the use of a vented metal mold in spite of the fact that the lining is centrifugally formed. If a vented mold is spun too rapidly when the lining mixture is first introduced, the particles thereof may be forced out through the vent holes, resulting in an uneven and non-uniform lining, with a very thin or non-existent coating over each vent hole. By employing the two-speed rotational procedure, small quantities of the lining mixture are permitted to enter and harden in the innermost portions of the vent holes during the initial low speed rotation and thereby effectively seal them against expulsion of sand or resin at the subsequent higher spinning speed. The lining so produced is, however, quite permeable to gas, particularly as the resin burns out during the casting operation, so that the vent holes adequately serve their intended purpose. For example, it has been found that open vents having ⅛" diameter openings into the interior of the metal mold, spaced from 3" to 8" apart, can be effectively closed and sealed with a permeable refractory coating by the present method.

When the method of the present invention is applied to the casting of pipe of relatively small diameter, such as 2" pipe, the above-described lining procedure may be modified by rotating the mold at a uniform, relatively low speed throughout the lining operation. For example, satisfactory results have been obtained in the lining of molds for casting 2" pipe by rotating the molds continuously during the lining operation at a speed of approximately 50 R. P. M., equivalent to a centrifugal force of about 0.1 times the force of gravity. This procedure provides a lining of uniform thickness and adequate density, but somewhat less smooth than that resulting from the two-speed technique. The desired smoothness may be obtained, however, by the application to the lining of a facing of relatively fine sand, ground coke and resin in the manner hereinafter described.

In lining molds of relatively large diameter, such as those used in the production of 12" pipe and larger, it is preferable to apply the lining in two separate layers of approximately equal thickness, forming the first layer while rotating the mold at a relatively high speed such as to create a centrifugal force of approximately 50 times the force of gravity or greater, and then forming the second layer at an even higher speed which may be equivalent to a centrifugal force of about 130 times the force of gravity or more. The following tabulation indicates the mold rotational speeds at which the two lining layers may be formed in molds for pipe of the sizes indicated:

Pipe Diameter	Mold Speed in Revolutions Per Minute	
	First Lining Layer	Second Lining Layer
12"	525	790
14"	500	775
16"	450	750
18"	400	700
20"	375	675

In this two-stage lining procedure, each layer of the lining is formed separately by placing in the lining trough approximately half of the total amount of lining mixture required to produce the desired thickness of lining, evenly distributing the mixture over the full length of the

trough, inserting the trough in the rapidly rotating mold, and then inverting the trough so as to deliver the lining mixture onto the lower portion of the inside surface of the mold wall. The second lining layer may be applied as soon as the first layer has cured or set, either by rotating the mold at the higher speed in the same spinning machine, or after transfer of the mold to an adjacent machine. In view of the relatively high rotational speeds employed, the vent holes in the mold wall should be provided with core box vents of the character hereinafter described and illustrated in Fig. 10 in order to prevent the escape of lining mixture through the vent holes and consequent defects in the lining adjacent said holes.

The two-stage, high-speed lining procedure produces an extremely smooth, hard lining of high density and uniform thickness which, due to the fact that the first lining layer is formed at a lower speed than the second, facilitates stripping of the casting from the mold because the lining adheres more tightly to the casting than to the mold wall.

While the thickness of the mold lining may be varied somewhat to produce pipes of different diameters in the same metal mold, it has been found preferable in practice to carefully control the lining thickness for best repetitive production. The factors governing the thickness of the mold lining have already been indicated in functional terms in the general description of the invention. Although diameter, metal casting temperature, and other considerations may affect the required lining thickness to some extent, the principal factor determining the optimum value of said thickness is the thickness of the metal casting to be produced. For example, it has been determined experimentally that for castings having a wall thickness from ¼" to ½", a mold lining thickness of from 0.12" to 0.18" meets the requirements most effectively. For thicker castings, thicker linings are desirable. As a useful method of determining the optimum lining thickness for a casting of a given thickness, the following empirical formula has been developed:

$$T=0.25\sqrt{t}$$

where T represents the lining thickness and t is the thickness of the casting. Typical values obtained from this formula are as follows:

Casting Thickness (t)	Lining Thickness (T)
Inches	*Inches*
0.125	0.088
0.25	0.125
0.50	0.177
1.00	0.250
2.00	0.354

In commercial production, satisfactory results can be obtained by approximating the optimum values derived from the above formula and using the same lining thickness for castings of several different wall thicknesses within a limited range. For example, in casting pipe having diameters of from 12" to 20", wherein the wall thicknesses may vary from about 0.40" to about 0.65", it has been found that a uniform lining thickness of 0.18" will effectively produce the improved results which are characteristic of the method of the present invention. When, as in the foregoing example, the lining is formed in two layers, it will be understood that the lining thickness specified is the combined thickness of both layers, and that the thickness of each layer may be varied as desired as long as the second layer is at least as thick as the maximum irregularity in the surface of the first layer. In practice, the desired lining thickness may be readily assured by first establishing either the weight or the volume of lining material required to produce that thickness and then using carefully weighed or volumetrically measured quantities of said material for each lining; in the case of a two-layer lining, the simplest procedure is to use half of the computed weight or volume of lining material for each layer.

After the mold has been lined in the manner above described and the lining stop-off plates have been removed, the lining may be provided with a wet facing or blacking in order to close the spaces between the sand grains and give a smoother finish to the casting. When the metal to be cast is cast iron, the facing may consist of a water suspension of ground coke and clay; when casting steel, a slurry of silica flour and bentonite is preferred. The facing may be applied in any suitable manner, as by pouring, spraying or brushing it onto the inner surface of the mold lining. For example, with the apparatus illustrated in Figs. 1, 2 and 3, the facing procedure involves pouring the facing into the mold through a funnel while the mold is rotated at a relatively slow speed, withdrawing the funnel and then passing a brush through the mold while the latter is rotated at a substantially higher speed so as to uniformly distribute the facing over the lining surface. The facing operation may conveniently be performed at the lining station using the same mold spinning mechanism as that employed for the lining step. The facing dries relatively quickly after it has been applied, due to the heat of the mold wall, and burns out when the molten metal is poured during the subsequent casting step.

When the lining is formed by the one-step, uniform speed procedure described above with reference to the casting of small diameter pipe, it is preferable to face or black the lining with a dry mixture of relatively fine sand, ground coke and thermosetting resin so as to provide the lining with a smoother, stronger surface than would result from the application of a wet facing of coke and clay, or silica flour and bentonite. A suitable dry facing mixture may contain from 33 to 50% by weight of silica sand having an AFS grain fineness of 150 and from 50 to 67% by weight of ground coke, plus an amount of resin binder equal to from 8 to 12% of the total weight of the sand and coke. The resin is preferably of the same kind as that used in the lining mixture. The dry facing mixture may be blown into the lined mold by means of a suitable nozzle which is moved along the axis of the mold while the latter is rotated at a relatively slow speed by the same mold spinning mechanism as that employed for the lining step. The heat of the mold wall and lining quickly fuses the resin of the facing mixture and firmly bonds the sand and coke constituents thereof to the inner surface of the lining.

In lining large diameter molds with the two-stage, high-speed technique, it has been found that the separate facing or blacking operation may be omitted and a more satisfactory casting surface obtained by simply including in the lining mixture used for the second lining layer small amounts of graphite and iron oxide. For example, when the mixture used for the first layer of the lining has the preferred portions of 97.5% sand and 2.5% resin, the second layer may consist of 94.75% sand, 2.5% resin, 2.25% graphite and 0.5% iron oxide. The graphite, like the coke of the separately applied facing mixtures, prevents the molten metal from wetting the sand and thus avoids sand penetration into the outer surface of the casting, while the iron oxide strengthens the lining by reducing its brittleness and increasing its high temperature deformation characteristic, thereby making the lining more resistant to penetration by the molten metal. If desired, the graphite may be used without the addition of iron oxide if the lining is otherwise sufficiently strong to resist penetration during the casting operation.

Upon completion of the lining and facing operations, the bell end of the mold is fitted with an oil sand socket core of conventional type, also faced with blacking, while the opposite end receives a stop-off plate preferably provided with an annular groove facing the space to be occupied by the spigot end of the cast pipe, which groove is filled with a faced, resin bonded sand mixture of the same

composition as the mold lining adapted to prevent chilling of the end of the casting. The mold is now ready to repeat the cycle beginning with the casting step previously described, and may therefore be transferred directly to the casting station. On the other hand, since the lining has no affinity for water, the lined mold of the present invention can be prepared far in advance of casting and kept for an indefinite period of time before use, if so desired.

Turning now to the drawings, Figs. 1, 2 and 3 show in diagrammatic form one arrangement of mechanism which may be used for the production of cast iron pipe in accordance with the present invention. As shown, the installation comprises a mold lining and facing station **11**, a casting station **12** and a stripping station **13** arranged in production line fashion and interconnected by means for transporting the molds **14** from one of said stations to another in a closed cycle, together with a fourth station **15** to which the stripped pipes **16** are delivered for cooling, cleaning and storage.

The mold lining and facing, casting and stripping stations are connected by a set of parallel rails **17** which slope downwardly at a slight angle from right to left as viewed in Figs. 1 and 2 so that the molds may be transferred from the lining and facing station **11** to the casting station **12**, and from the latter to the stripping station **13** by simply rolling them along the rails under the influence of gravity. The rails **17** also extend beyond the stripping station **13** to an elevator **18** adapted to raise the empty metal molds after the cast pipes have been stripped therefrom and deliver them to a second set of rails **19** (omitted in Fig. 1 in the interest of clarity) which are positioned directly above the rails **17** of the lower run and slope in the opposite direction so as to roll the molds to the right in Figs. 1 and 2 and return them to the lining and facing station **11** with the aid of a lowering device or drop **20**. When the drop **20** moves downwardly from its upper position shown in Fig. 2, the mold carried thereby is deposited on the right-hand ends of the rails **17** which extend outwardly beyond the lining and facing station **11** and on which the mold may roll to said station.

The mold lining and facing station **11** includes three sets of mold rotating rollers **21**, **22** and **23** which are commonly drivable by a manually controlled, variable speed motor **24** through a suitable belt or gear transmission. The rollers **21**, **22** and **23** are so arranged that one mold may rest on and be rotated by rollers **21** and **22**, while another mold may be simultaneously supported and rotated at the same speeds as the first one by rollers **22** and **23**. Any suitable means (not shown) may be provided for delivering the molds to and ejecting them from the roller supported positions indicated in Figs. 1 and 2.

Axially aligned with the metal mold **14** resting on rollers **21** and **22** is the apparatus for preparing and delivering into the rotating mold the sand-resin mixture for forming the mold lining. As shown, this apparatus includes a muller **25** in which the desired proportions of sand and resin are thoroughly mixed in the predescribed manner, and an elevator **26** which carries the mixture upwardly from the muller **25** and delivers it into a storage bin **27**. From the storage bin, charges of the sand-resin mixture may be withdrawn into a measuring hopper **28** which is so designed as to hold the desired amount of mixture necessary to produce a lining of given thickness. Beneath the hopper **28** and substantially coaxial with the mold on rollers **21** and **22** is a movable lining trough **29** which, as indicated in Figs. 4, 5 and 6, may be substantially U-shaped in cross section and provided with vertical division plates **30** and **31** defining the ends of the portion of the trough into which the measured quantity of mixture is delivered from the hopper. Any suitable means, such as a strike or a leveling vibrator, may be used for evenly distributing the sand-resin mixture throughout the length of the trough.

The trough **29** is so mounted that it can be moved quickly into and out of the mold **14** as the latter is rotated on rollers **21** and **22**, for which purpose the trough may be slidably supported in suitable fixed guides or, as shown in Figs. 1 and 3, mounted on a movable carriage **32** running on rails **33**. If desired, a trunnion **34** may be provided at the end of the lining machine opposite the carriage **32** for receiving a cylindrical extension **35** on the end of the trough **29** (see Fig. 4) so as to ensure that the trough is properly supported and centered axially with respect to the mold. The mounting of the trough, whether it be in fixed guides or on the carriage **32**, is such that, after the trough has been inserted in the spinning mold, it may be quickly inverted as indicated in Fig. 6 to dump the sand-resin mixture onto the bottom portion of the mold wall and then rotated back to its original position and rapidly withdrawn from the mold.

As the metal mold approaches the lining station on the rails **17**, or after it has been placed on the rollers **21** and **22** but before their rotation is begun, an annular lining stop-off plate **36** (see Fig. 4) is detachably fitted to the spigot end of the mold for preventing loss of the lining mixture and forming a square edge at the end of the lining. If desired, a similar stop-off plate **37** may be fitted at the bell end of the mold, although this is not normally necessary.

Assuming that the lining is to be formed by the single-stage, two-speed procedure, the mold is placed on rollers **21** and **22** and the motor **24** is started and so regulated as to rotate the mold at a relatively low speed, equivalent to a centrifugal force of less than 0.5 times the force of gravity. After the proper quantity of sand-resin mixture has been delivered from the measuring hopper **28** to the lining trough **29** and has been evenly distributed along the length thereof, the trough is quickly moved into the rotating mold, inverted to dump the mixture onto the bottom of the latter, and immediately withdrawn. As soon as the sand grains begin to stick to the mold wall due to melting of the resin, the operator adjusts the control circuit of motor **24** to accelerate the mold rotation to a speed such that the centrifugal force at the inner surface of the mold wall increases to more than 5.0 times the force of gravity. High speed rotation is then continued until the change in color of the lining indicates that the resin has polymerized and the lining has cured or set, whereupon the motor **24** is stopped, the lining stop-off plates **36** and **37** are removed, and the lined mold is transferred from rollers **21** and **22** to rollers **22** and **23** for the facing step. It will be obvious that rollers **21** and **22** may also be used to rotate the mold while forming the lining by either the one-step, uniform speed procedure, or the two-stage, high-speed technique, by appropriate adjustments of the control circuit of motor **24**.

Although various means may be employed for applying the desired carbon facing to the lining, the mechanism illustrated consists of a blacking funnel **38** and a brush **39**. As shown, the funnel **38** is detachably fixed to a post **40** by a mounting plate **41**, the post **40** being pivotally supported for movement about a vertical axis in a base **42** so that the funnel may be swung to and from a position in which the outlet thereof extends into the bell end of the mold, as indicated in broken lines in Fig. 1. The brush **39**, which has a handle coaxial with and at least as long as the mold, is mounted on a carriage **43**, the latter being movable on rails **44** so that the brush may be readily passed through the rotating mold from one end to the other. While the lined mold on rollers **22** and **23** is being rotated at low speed, simultaneously with the next mold in line which is then undergoing the first portion of the two-speed lining operation previously described, the funnel **38** is moved to the broken line position of Fig. 1 and the facing slurry is introduced into the mold by pouring it through the funnel. As soon as all of the facing is in the mold, the funnel **38** is withdrawn and, as the rotation of the mold is accelerated concurrently with the latter portion of the lining operation on the next mold, the brush **39** is moved into the mold and so manipulated as to dis-

tribute the facing uniformly over the inner surface of the lining. Alternatively, the handle of the brush 39 may be hollow and serve as a conduit for introducing the facing suspension into the mold through or just ahead of the brush.

When the mold is rotated by rollers 21 and 22 at a uniform speed throughout the lining operation, it is apparent that rollers 22 and 23 will likewise provide a uniform rotational speed during the facing step. Although the roller arrangement illustrated is not adapted to carry out simultaneously both stages of the two-stage, high-speed lining procedure when different speeds are used in the two stages, it can be employed for simultaneously lining two molds by such a procedure with both molds undergoing the two stages in succession without transfer from one set of rolls to the other.

After the mold has been lined and faced at station 11, it is rolled along the rails 17 to the casting station 12 and provided with a bell socket core 45 and a spigot stop-off plate 46 of the character hereinafter described and illustrated in Fig. 7. The completed mold is then ready for casting. If, however, it is not needed for casting immediately, it may be left on the rails as long as desired without fear of deterioration because of the non-hygroscopic, self-sustaining character of the lining. In this connection, the length of rails 17 between stations 11 and 12 is preferably sufficient to accommodate all of the molds normally used in the system so that, whenever casting operations are suspended, all molds may be lined while still hot from their last casts and left ready for use when casting is resumed.

The apparatus at casting station 12 is substantially the same as that heretofore used in centrifugal casting according to the Sandspun method, and comprises two sets of mold rotating rollers 47 and 48 driven by a variable speed motor 49, a tiltable pouring ladle 50, a scale 51 for weighing the molten charge in the ladle and a relatively short pouring spout or trough 52 adapted to deliver the molten metal into the spigot end of the rotating mold. The ladle 50, scale 51 and spout 52 (all of which have been omitted from Fig. 2 in the interest of clarity) are mounted on a wheeled carriage 53 which is movable on rails 54 toward and away from the pouring position. The motor 49 may be automatically controlled in known manner by the mechanism which tilts the pouring ladle 50 so as to rotate the mold at a relatively low speed while the major portion of the molten iron charge is being poured and then rapidly accelerate it to a relatively high speed sufficient to cast the poured metal centrifugally. Although the casting apparatus shown in Fig. 1 is adapted to pour the metal into the mold through the spigot end thereof, it will be understood that, in casting some sizes or types of pipe, it may be preferable to introduce the metal from the bell end of the mold, or even from both ends simultaneously.

After the casting operation has been completed, the mold with its contained solidified casting is ejected from the casting station 12 and rolled along the rails 17 to the stripping station 13. During this portion of the cycle, the bell socket core 45 and spigot stop-off plate 46 are removed from the ends of the mold and the heat of the cast metal completely burns out the resin binder of the mold lining, leaving the lining devoid of strength, so that the solidified pipe may be either pushed or pulled from the mold with relatively little effort. For the latter purpose, the stripping station may be provided with a hydraulic ram 55 adapted to engage the spigot end of the cast pipe and push it out of the mold while axial movement of the mold itself is prevented by abutment of the bell end thereof against a suitable stop frame 56 having a central opening through which the pipe passes. When the bell end of the pipe has been forced out of the mold a sufficient distance, it may be grabbed by a pipe puller mechanism (not shown) and dragged out of the mold onto a set of rails 57 at station 15 where the pipe is permitted to cool and may be cleaned both externally and internally with wire brushes, or in any other suitable manner. After cooling and cleaning, the pipes 16 may be left on the rails 57, or transferred to any other convenient storage point, pending shipment.

After the finished pipe has been stripped from the mold, the empty metal mold is rolled from the stripping station 15 along the rails 17 to the elevator 18. As indicated in Fig. 2, the elevator 18 is provided with a mold supporting platform 58 tiltably mounted at the upper end of a hydraulic piston 59, the rails 17 and 19 of the lower and upper runs, respectively, being provided with suitable stop members which cause the platform 58 to tilt into the same planes as said rails so as to either receive or discharge the molds by gravity. When the elevator 18 is raised to its upper position, the empty mold carried on the platform 58 rolls therefrom onto the rails 19 of the upper run and along the latter to the opposite end of the system where it is lowered by the drop 20 and returned to the lining and facing station 11 on rails 17. The mold lowering device or drop 20 may be of any suitable construction, but is preferably pneumatically controlled for descent and counterweighted to return it to raised position, and provided with a pair of vertically extending stop bars 60 adapted to engage and prevent the next mold in line from rolling off the ends of rails 19 while the mold in the drop is being lowered.

As the hot, empty metal mold returns along the rails 19 of the upper run, any sand that may remain therein from the lining of the previous cast may be blown out by compressed air or otherwise removed, and the temperature of the mold is permitted to drop to within the range desired for the next lining operation. As previously indicated, artificial cooling means may be incorporated in the return run in the event that the length thereof is insufficient to produce the desired cooling under atmospheric conditions. Also, if necessary, a mold heating station may be added between the drop 20 and the lining and facing station 11.

The metal molds employed in practicing the new method embody certain features of novelty in comparison with those previously known which are claimed in copending application Serial No. 348,952, filed April 15, 1953. One form of such mold is shown in Figs. 4–9 of the accompanying drawings, which figures also illustrate the mold lining operation and the characteristics of the mold as it exists when ready for the casting step.

Referring first to Fig. 4, which shows the metal mold before the resin bonded sand lining has been formed, it will be seen that the mold is made up of three main parts, an elongated body or center section 61 of substantially cylindrical form (the greater portion of which has been broken away in Fig. 4), a bell end section 62 which is threaded onto and welded to one end of the body 61, and a spigot end section 63 similarly threaded and welded to the opposite end of the body.

The body section 61, which is preferably formed of cast iron with a wall thickness at least three times the thickness of the pipe to be cast therein, has an inside surface of uniform diameter, but on its outside is provided with two enlarged cylindrical portions 64 and 65, one adjacent each end of the body, adapted to serve as spinning bands or tires for cooperation with the motor driven rollers of the lining and facing station 11 and casting station 12 previously described. The body section 61 also has welded to its exterior, adjacent spinning band 64, an enlarged guide flange 66 which cooperates with a guide rail (not shown in Figs. 1–3) in known manner to properly position the mold in an axial direction with respect to the rollers of the rotating mechanisms at stations 11 and 12. If desired, one of the spinning bands may be grooved to receive the rollers of the rotating mechanisms and so located as to cooperate with the guide rail, in which event the guide flange 66 may be omitted.

The bell end sectoin 62 of the mold, which is preferably made of cast steel, has an inner cylindrical portion

67 which forms a prolongation of the body section 61 and an outer hopper portion 68 of outwardly flared, substantially frusto-conical form adapted to house a removable insert 69 for shaping the outer surface of the bell or flange end of the pipe to be cast in the mold. The insert 69 of the present invention is of relatively permanent character, being made of metal, either cast iron or steel, and is detachably held in place within the hopper 68 by means which insure accurate centering of the insert with respect to the rest of the mold and tight engagement between the inner end thereof and the abutting end of the inner cylindrical portion 67 of the bell end section 62.

As shown best in Fig. 8, the outer peripheral surface of the metal insert 69 conforms to the inner surface of the hopper portion 68 of the metal mold and has formed therein a plurality of radially extending recesses 70 equally spaced circumferentially of the insert, the outer portions of which recesses are cylindrical while the inner or bottom portions thereof are substantially conical, as indicated at 71. Each of recesses 70 is adapted to receive the similarly conical inner end 72 of a radially extending cap screw 73 which is threaded through the wall of the hopper 68. Inasmuch as the cylindrical and conical portions of each recess 70 are of greater diameter and depth, respectively, than the body and conical end of the cooperating screw 73, and the conical portion of the recess and the conical end of the screw are of the same angularity, it will be apparent that, as the screws are threaded inwardly and their conical ends 72 engage the conical bottoms 71 of the recesses, a wedging action will be exerted on the insert 69 which tends to force the latter axially inwardly and tightly clamp the outer periphery and inner end of the insert against the adjacent surfaces of the hopper 68 and inner cylindrical portion 67 of the mold end section 62. Accurate centering of the insert 69 with respect to the rest of the mold is additionally insured by shouldering or rabbeting the inner end of the insert and the abutting end of cylindrical portion 67 of bell end section 62, as indicated at 74.

The inner circumferential surface of insert 69 may have any desired shape, depending upon the form which it is desired to impart to the corresponding end of the cast pipe, but is such that, when the insert is in place, said surface forms a smooth continuation of the inner cylindrical surface of portion 67 of bell end section 62 which in turn constitutes a prolongation of mold body section 61. In practice, each insert 69 is interchangeable with a number of others having different inside contours. Since the mold lining method of the present invention results in a smooth, dense refractory lining over the entire interior surface of the mold, including the insert 69, the joint between the inner end of the latter and the mold body is effectively covered by the lining and leaves no mark on the outside surface of the casting.

The outer end of hopper portion 68 of the mold is provided with a substantially cylindrical rim 75 wherein are formed a plurality of circumferentially spaced, radially extending holes 76 adapted to receive wedge-shaped keys 77 which are driven into said holes from the inside of the rim so that, when the mold is rotated, centrifugal force tends to force the keys even tighter into the holes. The keys 77 engage and hold in place against the outer end of insert 69 either the annular lining stop-off plate 37 shown in Fig. 4 when the latter is used during the lining operation, or the bell socket core 45 shown in Fig. 7 which is used during the casting step.

Although the use of interchangeable, permanent metallic inserts 69 results in certain obvious advantages, it will be apparent that ordinary sand insert cores might be used instead, if desired, in which case the cap screws 73 could be eliminated and the sand cores held in place by the wedge keys 77.

The spigot end section 63 of the metal mold is also preferably made of cast steel and consists of a substantially cylindrical prolongation of center section 61 having at its outer end a radially extending flange 78 forming a convenient means for detachable connection to the mold of the lining stop-off plate 36 of Fig. 4 and the casting stop-off plate 46 shown in Fig. 7. In each case, the stop-off plate is provided with a plurality of axially extending stud bolts 79 adapted to pass through holes in the flange 78 and receive nuts 80 which secure the plate to said flange. While the inner surface of lining stop-off plate 36 is smooth so as to form a square edge at the end of the mold lining, the corresponding surface of casting stop-off plate 46 is provided with an annular groove 81 which faces the spigot end of the pipe to be cast in the mold (indicated in broken lines in Fig. 7) and is filled with a quantity of resin bonded sand of the same composition as the mold lining which serves to prevent chilling of the end of the casting. It is also preferable to face the bonded refractory filling of groove 81 with the same blacking as that applied to the mold lining.

Instead of dividing the metal mold into three sections as shown, it is obvious that the cylindrical portions 61, 63 and 67 may be made in one piece with a separately formed hopper portion 68 threaded and welded thereto, or, alternatively, that the entire mold may be machined from a single casting.

In pursuance of the advantages resulting from the use of vented molds, an improved form of vent has been devised which is particularly effective with the mold lining procedure of the present invention. As indicated in Figs. 4–7, the metal mold is provided with a relatively large number of uniquely constructed vents, indicated generally at 82, constituting openings through the mold wall for escape of the gases formed during casting. The vents 82 are distributed more or less uniformly over the entire length of the mold, with the exception of the hopper portion 68 and the spinning band portions 64 and 65. The number and positioning of the vents should be such as to permit ready escape therethrough of substantially all of the gas generated during the casting operation, and will depend upon a number of factors such as the thickness of the lining, the percentage of resin binder therein, the grain size of the lining sand, the character and thickness of the facing on the lining, and the temperature of the metal being cast. As an example, it has been found that, in a mold for casting a 6″ cast iron pipe 20 feet long, four axially extending rows of vents located 90° apart with a spacing of approximately 3.7″ between adjacent vents in the same row, the vents in adjacent rows being staggered, will be adequate under all normal conditions of lining thickness, amount of resin binder, etc.

As shown best in the enlarged view of Fig. 9, each vent 82 consists of a radially extending hole drilled through the mold wall having an outer portion 83 of uniform diameter which extends inwardly from the outer surface of the mold almost to the inner surface thereof, and a relatively short inner portion 84 of substantially smaller diameter which opens into the interior of the mold, the shoulder 85 connecting the outer and inner portions of the hole preferably being inclined as shown, rather than square. While the length of the outer portion 83 will vary with the thickness of the mold wall, it is desirable to limit both the length and the diameter of the inner portion 84 to approximately ⅛″, and to make the diameter of the outer portion 83 approximately three times that of the inner portion.

When a metal mold having vents of this character is lined according to either the single stage, two-speed technique or the one-step, uniform speed procedure of the present invention, the inner portions 84 of the vent holes become filled with the sand-resin lining mixture during the slow rotation of the mold immediately following dumping of the lining trough. Since the relatively small amount of sand-resin mixture in each of said inner vent portions is surrounded by the heated metal of the mold wall, thus providing a relatively high ratio of heating surface to volume of the mixture, the resin in each of these quanti-

ties melts and polymerizes very quickly and rapidly fuses the sand grains together in a rigid, gas permeable mass, and also cements said mass to the surrounding wall of the inner portion 84 of the vent hole, before the lining indicated at 86 in Fig. 9 is formed. After this preliminary closure of the vent holes, the mold lining 86 forms in uniform manner over the entire interior of the mold and provides an additional coating over the inner ends of the vents of the same thickness and density as the rest of the lining.

In some cases, particularly when relatively fine sand or a relatively small percentage of resin is used in the lining, or when the lining is formed by the two-stage, high-speed method, it is desirable to take special steps to prevent the possibility of escape of the sand-resin lining mixture through the vent holes during the lining operation. To this end, as shown in Fig. 10, the outer portion 83 of each vent may be packed with a quantity of unbonded, relatively coarse granular refractory 87, such as sand of a size that will not pass through a 1/8" mesh screen. In order to hold the packing in place, a cup-shaped metal core box vent 88, having a plurality of perforations 89 in the bottom thereof, may be fixed in the outer end of the vent hole, as by peening. With this arrangement, the gases generated in the lining during casting can freely escape through the porous refractory mass 87 and the perforations 89 of the core box vent 88, while the refractory packing and core box vent effectively prevent the lining mixture from being thrown out through the vent hole under centrifugal force. It will be understood that, in this modification, the packing 87 and core box vent 88 are relatively permanent parts of the mold, it being unnecessary to renew the packing for each cast, but only at such times as it is desired to thoroughly clean the vents.

There is thus provided by the present invention a new and improved method for centrifugally casting hollow metal articles of cast iron, steel or non-ferrous metals which is particularly well adapted to the production of pipe, especially pipes having belled or flanged ends. The method lends itself well to rapid and efficient production of castings with a minimum of equipment and manual labor, and produces high quality, clean castings to close tolerances and of any reasonable shape and size.

While the castings made in accordance with the present procedure have all of the advantageous characteristics of those made in conventional sand molds, including an unchilled, close grain structure free from inclusions, the improved method of centrifugally lining metal molds with a relatively thin, resin bonded refractory coating avoids such disadvantages of the prior Sandspun procedure as the necessity for manually ramming a relatively thick green sand lining around a pattern with the aid of expensive machinery, the use of a large amount of sand and sand handling equipment, and the need for expensive cutting mechanism or other means for removing the sand lining from between the flask and the casting before the latter can be stripped from the mold. The faster freezing of the cast metal with the relatively thinner mold lining provided by the present invention, as well as the fact that the relatively lighter weight of the molds enables quicker acceleration of their rotation during the casting step, result in an increased production rate in comparison with the sand mold process of the prior art. The new procedure likewise embodies most of the advantages of the old de Lavaud method employing metal molds, but without such disadvantages thereof as the excessive wear and cracking of the molds due to contact with the molten metal, and the necessity for annealing the chilled castings produced by said method.

Although certain examples have been given of the procedural steps of the method and one specific embodiment of apparatus for performing the method has been described and illustrated in the accompanying drawings, it will be obvious that the invention is not limited to these illustrative examples or to the particular apparatus shown, but that various changes, which will now suggest themselves to those skilled in the art, may be made in both the method and the apparatus without departing from the inventive concept. Reference is therefore to be had to the appended claims for a definition of the limits of the invention.

This application is a continuation-in-part of abandoned application Serial No. 212,468, filed February 23, 1951.

What is claimed is:

1. A method of making hollow metal castings of generally cylindrical form in rotatable vented molds comprising the steps of providing a rotatable hollow metal mold having vents in the wall thereof and having said wall heated to a temperature within the range from 300° to 600° F., forming a refractory lining of predetermined thickness in said metal mold by delivering into the interior thereof a measured quantity of loose, dry granular refractory-thermosetting resin material calculated to provide a lining of the desired thickness, uniformly distributing said material longitudinally of the mold and fusing said material into a strongly bonded lining adherent to the mold wall by the use of heat extracted from said wall while rotating said mold about a substantially horizontal axis to uniformly distribute the material circumferentially over the inner surface of the mold, introducing a charge of molten metal into the lined mold while rotating the latter about a substantially horizontal axis, continuing said rotation until the metal has solidified, utilizing the heat of said metal to burn out the resin in the mold lining and thereby destroy the bond between the refractory granules and the adhesion of said granules to the wall of the mold while the gases produced in said lining by the heat of said metal escape outwardly through the vents in the mold wall, stripping the solidified metal casting from the mold, and relining the mold while the wall thereof retains sufficient heat from the casting to fuse the refractory-resin material of the new lining.

2. A method of making cast iron pipe in rotatable vented molds comprising the steps of providing a rotatable hollow metal mold having vents in the wall thereof and having said wall heated to a temperature within the range from 300° to 600° F., forming a refractory lining of predetermined thickness in said mold by delivering into the interior thereof a measured quantity of loose, dry silica sand calculated to provide a lining of the desired thickness and having mixed therewith a small proportion of thermosetting resin, uniformly distributing the sand-resin mixture longitudinally of the mold and fusing said mixture into a strongly bonded lining adherent to the mold wall by the use of heat extracted from said wall while rotating said mold about a substantially horizontal axis to uniformly distribute the mixture circumferentially over the inner surface of the mold, applying a carbon facing to the lining of said mold, pouring a charge of molten iron into the lined mold while rotating the latter about a substantially horizontal axis, continuing said rotation until the iron has solidified, utilizing the heat of said iron to burn out the resin in the mold lining and thereby destroy the bond between the sand granules and the adhesion of said granules to the wall of the mold while the gases produced in said lining by the heat of said metal escape outwardly through the vents in the mold wall, stripping the solidified iron casting from the mold, and relining the mold while the wall thereof retains sufficient heat from the casting to fuse the sand-resin mixture of the new lining.

3. A method of centrifugally casting tubular metal articles of the type wherein a charge of molten metal is introduced into a refractory lined metal mold while the mold is rotating about a substantially horizontal axis, characterized by the steps of providing a rotatable hollow metal mold having vents in the wall thereof, and lining said mold with a material composed of a granular refractory and a thermosetting resin while rotating said mold to uniformly distribute the lining material circumferentially over the inner surface of the mold and maintaining its

temperature within the range from 300° to 600° F. so that the heat of the mold fuses the refractory-resin material into a strongly bonded coating adherent to the inner surface of said mold.

4. The method defined in claim 3 wherein the lining material consists essentially of from 95.0 to 99.5% by weight of silica sand and from 0.5 to 5.0% by weight of a fusible phenolic resin.

5. The method defined in claim 3 wherein the lining material consists essentially of from 95.0 to 98.5% by weight of dry silica sand and from 1.5 to 5.0% by weight of a powdered thermosetting resin.

6. The method defined in claim 3 wherein the lining material consists essentially of silica sand having a coating of thermosetting resin, the resin content of the sand coating being from 0.5 to 5.0% of the weight of the coated sand.

7. A method of centrifugally casting tubular metal articles of the type wherein a charge of molten metal is introduced into a refractory lined metal mold while the mold is rotating about a substantially horizontal axis, characterized by the steps of providing a rotatable hollow metal mold having vents in the wall thereof, heating said mold to a temperature within the range from 300° to 600° F., distributing uniformly along the axis of said mold a measured quantity of a loose, dry lining material consisting essentially of silica sand and a thermosetting resin, rotating said mold about its axis to uniformly distribute the particles of said material circumferentially over the inner surface of said mold, and continuing the rotation of said mold until said particles have been fused together to form a hard refractory lining adherent to the mold wall under the effect of the heat of said wall on the thermosetting resin.

8. The method defined in claim 7 wherein the resin content of the lining material is from 0.5 to 5.0% of the total weight of said material.

9. The method defined in claim 7 including the additional step of applying a carbon-containing facing to the inner surface of the resin bonded sand lining of said mold.

10. A method of centrifugally casting hollow metal bodies of the type wherein a charge of molten metal is introduced into a refractory lined metal mold while the mold is rotating about a substantially horizontal axis, characterized by the steps of delivering into the interior of a hollow metal mold having vents in the wall thereof a measured quantity of loose, dry refractory-thermosetting resin material calculated to provide a lining of predetermined thickness, distributing said material uniformly along the axis of said mold while rotating said mold at a relatively low speed, insufficient to hold the particles of said material to the mold wall by centrifugal force, and while maintaining the temperature of said mold wall within the range from 300° to 600° F., continuing the low-speed rotation of said mold until the particles begin to adhere to the mold wall due to the effect of the heat of said wall on the thermosetting resin, and then rotating said mold at a substantially higher speed, sufficient to hold the remaining loose particles of said material to the mold wall by centrifugal force, until substantially all of the resin has polymerized and bonded the particles together to form a relatively smooth, hard lining adherent to the mold wall.

11. The method defined in claim 10 wherein the relatively low speed of rotation of the mold is such that the centrifugal force created at the inner surface of said mold is not more than about 0.5 times the force of gravity, and the substantially higher speed is such that the centrifugal force created at the inner surface of said mold is not less than about 5.0 times the force of gravity.

12. A method of centrifugally casting hollow metal bodies of the type wherein a charge of molten metal is introduced into a refractory lined metal mold while the mold is rotating about a substantially horizontal axis, characterized by the steps of heating a hollow metal mold having vents in the wall thereof to a temperature within the range from 300° to 600° F., rotating the heated mold about a substantially horizontal axis at a relatively low speed such that the centrifugal force created at the inner surface of said mold is not more than about 0.5 times the force of gravity, delivering into said rotating mold a measured quantity of loose, dry granular refractory-thermosetting resin material calculated to provide a lining of predetermined thickness, distributing said refractory-resin material uniformly along the axis of said mold, continuing the low-speed rotation of said mold to uniformly distribute the refractory granules circumferentially over the inner surface of the mold and until said granules have been fused together to form a hard refractory lining adherent to the mold wall under the effect of the heat of said wall on the thermosetting resin, and then applying a carbon-containing facing to the inner surface of said mold lining while rotating the mold at substantially the same speed as that at which it was rotated during the lining operation.

13. The method defined in claim 12 wherein the carbon-containing facing consists essentially of a dry mixture of relatively fine sand, ground coke and a thermosetting resin.

14. The method defined in claim 12 wherein the carbon-containing facing is applied to the mold lining by blowing into the lined mold a dry mixture of from 33 to 50% by weight of relatively fine silica sand and from 50 to 67% by weight of ground coke, plus an amount of thermosetting resin equal to from 8 to 12% of the total weight of the sand and coke.

15. A method of centrifugally casting hollow metal bodies of the type wherein a charge of molten metal is introduced into a refractory lined metal mold while the mold is rotating about a substantially horizontal axis, characterized by the steps of delivering into the interior of a hollow metal mold having vents in the wall thereof a measured quantity of loose, dry refractory-thermosetting resin material calculated to provide a lining layer of predetermined thickness, distributing said material uniformly along the axis of said mold while rotating said mold at a relatively high speed, sufficient to hold the particles of said material to the mold wall by centrifugal force, and while maintaining the temperature of said mold wall within the range from 300° to 600° F., continuing the high-speed rotation of said mold until said particles have been fused together to form a hard refractory lining layer adherent to the mold wall under the effect of the heat of said wall on the thermosetting resin, then delivering into the interior of the partially lined mold a second measured quantity of loose, dry refractory-thermosetting resin material containing a small proportion of graphite while rotating said mold at a speed higher than the speed employed during formation of the first lining layer, and continuing said rotation until the particles of said second quantity of lining material have been fused together to form a second hard refractory lining layer adherent to said first layer.

16. The method defined in claim 15 wherein the refractory-resin material used for forming the first lining layer contains from 0.5 to 5.0% by weight of a fusible phenolic resin, and the mixture used for forming the second lining layer contains from 0.5 to 5.0% by weight of a fusible phenolic resin and a substantially equivalent amount of graphite.

17. The method defined in claim 15 wherein the refractory-resin material used for forming the second lining layer also contains a small amount of iron oxide.

18. The method defined in claim 15 wherein the speeds at which the mold is rotated during formation of said first and second lining layers are such that the centrifugal

forces created at the inner surface of said mold are not less than about 50 times the force of gravity.

References Cited in the file of this patent

UNITED STATES PATENTS

359,483	Whitley	Mar. 15, 1887
1,620,830	Moore et al.	Mar. 15, 1927
2,239,530	Langenohl et al.	Apr. 22, 1941
2,245,747	Barr	June 17, 1941
2,289,681	Projahn et al.	July 14, 1942
2,294,935	Ritchie	Sept. 8, 1942
2,344,020	Boucher	Mar. 14, 1944
2,399,606	Schuh et al.	Apr. 30, 1946
2,449,136	Pattison	Sept. 14, 1948
2,450,755	Higgens	Oct. 5, 1948

2,518,055	Olsen et al.	Aug. 8, 1950
2,559,161	Johnston	July 3, 1951
2,598,554	Johnston	May 27, 1952
2,623,809	Myers	Dec. 30, 1952
2,631,342	Romine	Mar. 17, 1953
2,645,558	Burchartz	July 14, 1953
2,663,921	Cito	Dec. 29, 1953
2,689,990	Samuels	Sept. 28, 1954

OTHER REFERENCES

Modern Metals October 1950, pages 22–24.

Fiat Final Report No. 1168, The "C" Process of Making Molds and Cores for Foundry Use. Published May 30, 1947, by Office of Technical Services, Dept. of Commerce, Washington, D. C., 10 pages.