Effect of Ingot size on Required Heat Input for at least 80% Sound Metal Recovery.
Recovery of sound ingot metal as affected by extraction of heat from steel and mold walls.

Fig. 3.

Temperature difference, °C, between mid-length and bottom of mold wall 15 minutes after teeming.

Fig. 4.

Mold wall thickness of mid-length, inches.

Length of horizontal Columnar Grains at mid-length Cross section of Ingot - Inches.
INGOT MOLDS PROVIDED WITH A HOT-TOP

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Application January 12, 1952, Serial No. 266,134

2 Claims. (Cl. 22—139)

This invention relates to ingot molds and to processes for the casting of molten metal therein to produce ingots having a high proportion of recoverable sound metal.

In teeming molten metal into ingot molds, it is desirable that as great a proportion as possible of the resultant ingot be a metallurgically sound product. Recoverable sound metal comprises that portion from the bottom of the ingot up to the highest cross-section level free from flaws. Unsoundness in an ingot may comprise pipe, cavities that may be either macroscopic or microscopic, or loose intergranular structure present within the interior of the ingot. Furthermore, a large portion of the metal teemed into the mold tends to concentrate toward the central axis of the ingot as well as rising upward. Excessive amounts of the impurities along the axis are not desirable. Due to these and other flaws, it is a necessity in the metals industry to crop the upper end of cast ingots since flaws and unsound structure are concentrated within the upper portions thereof.

Ordinarily, about 10% of a carbon steel ingot is cropped, leaving a recovery of less than 90% of substantially sound metal. However, many metals have a higher volume of contraction during solidification than does carbon steel or a low alloy steel. As the coefficient of volume contraction increases, the problem of producing ingots with a high proportion of recoverable sound metal increases manifold.

The refractory alloys mentioned in the article entitled "Precipitation-hardened alloys for gas-turbine service" on page 583 of the August 1947 issue of Transactions of the A.S.M.E. and the numerous alloys discussed in the article entitled "Gas-turbine alloys, 10 years later" on pages 503 to 511 of the October 1950 issue of "Metal Progress" have been found to be very difficult to cast into ingots having a high percentage of recoverable sound ingot. A 70% recovery of ingots of these alloys is considered quite good. A desideratum in the metallurgical art is to secure a consistently high recovery of over 70% of each heat cast as sound ingot of these refractory metals, and preferably a recovery of 80% or more.

These refractory alloys containing large amounts of alloying elements usually have a relatively high volume contraction on solidification, and the problems encountered in producing ingots therefrom with a reasonably high recovery of sound metal of the order of 70% or higher have taxed the skill and ability of those working in the art. Particularly in casting relatively large ingots, it has not been feasible to secure consistently a high percentage of recovery of sound ingots.

The object of this invention is to provide a mold suitable for casting high alloy content ingots wherein the extraction of heat from the bottom of the teemed ingot is so correlated to the extraction of heat from the sides of the mold that horizontal columnar grains do not extend to the axis of the mold whereby a high proportion of recoverable sound metal is consistently secured.

A further object of the invention is to provide a mold for casting a sound ingot wherein there is correlated the extraction of the heat from the metal teemed into the mold so that the metal solidifies without building horizontal columnar grains extending more than 90% of the distance from the ingot wall to the axis of the ingot and a supply molten metal is maintained at the top of the ingot to fill any cavities developing by solidification contraction along the axis of the ingot.

A still further object of the invention is to provide an ingot mold in which heat is applied at the top of the ingot by an arc developed between two arcing members so that, after teeming, the molten metal at the top of the mold remains fluid until the main body of the ingot has solidified into a sound ingot and is free from contamination.

Another object of the invention is to provide a process for casting ingots whereby heat is extracted from the bottom and sides of the ingot mold in a predetermined ratio so that the ingot solidifies progressively from the bottom to the top without developing horizontal columnar grains exceeding 90% of the distance from the mold walls to the axis of the ingot and molten metal is present at the top of the ingot until all the metal to a height equal to approximately 80% of the length of the ingot has solidified.

Other objects of the invention will, in part, be obvious and will in part appear hereinafter. For a better understanding of the nature and object of the invention, reference should be had to the following detailed description and drawing, in which:

Figure 1 is a vertical section of a mold contracted in accordance with the present invention;

Fig. 2 is a graph plotting the amount of heat to be applied to the top of a teemed ingot in proportion to the amount of metal teemed to recover at least 80% sound metal;

Fig. 3 is a chart plotting the recovery of sound ingot metal against the temperature difference between the mid-length and bottom of a metal mold wall 15 minutes after teeming, using steels of various materials; and

Fig. 4 is a graph plotting the length of the horizontal columnar grains at the mid-length portion of the cross-section of an ingot for various mold wall thicknesses at the mid-length portion of the mold.

In accordance with our invention we have produced an ingot mold in which molten metals having high coefficients of volume contraction in passing from the liquid to the solid state, may be cast in accordance with a selected procedure, and will result in ingots having an exceptionally high percentage of recoverable sound metal. In the ingot mold of this invention, we have been able to correlate the extraction of heat throughout the entire length of the teemed ingot so that solidification progresses from the bottom of the ingot upward without permitting horizontal columnar grains of ingot metal to be built up from the sides of the mold walls to more than 90% of the distance to the axis.

By such a solidification schedule, a large unrestricted axial space is maintained in the teemed ingot into which molten metal is supplied from a pool of molten metal in the ingot head, thereby avoiding excessive piping, microscopic or macroscopic shrinkage cavities, or loose intergranular structure. By a high recovery of ingot, we mean approximately 70% or more of the ingot from the bottom up is metallurgically sound.

Briefly, the ingot mold of this invention comprises:

1. A metal mold made of selected metal and of a size and construction to withdraw heat at a predetermined rate from a teemed ingot;

2. A tubular metal shell comprising the mold properly seated on the stoo1, the shell having a wall thickness within prescribed limits;

3. A ceramic hot top fitting on top of the tubular mold;
4. A layer of thermal insulation about the tubular mold and ceramic hot top; and

5. A heater member, closing the open end of the hot top, for maintaining teemed metal in the hot top molten for a predetermined length of time, so that it will fill any axial cavity that develops as the metal solidifies.

Materials for the tubular mold are: For casting steel, a layer of thermal insulation about the tubular mold and ceramic hot top; and a heater member, closing the open end of the hot top, for maintaining teemed metal in the hot top molten for a predetermined length of time, so that it will fill any axial cavity that develops as the metal solidifies.

Upon the upper surface 20 of the stool, there is placed a tubular metal mold 22 with its major axis 24 being vertically disposed. The base end 26 of the metal mold is in contact with and closely fits the face 20 of the metal stool. The tubular metal mold 22 may be of any suitable shape. We have employed circular cylindrical molds, rectangular molds, slightly barred cylinders, and fluted molds. Successful results were had with tapered tubular molds of circular cross-section that were smaller at the bottom than the top, as well as with molds that were of uniform cross-sectional area. If molds of variable cross-section are used as specified, the direction of the taper is preferably with the big end up. The metal mold may be made of any suitable metal capable of standing up under the molten metal, for example, steel, cast iron and various alloys. Since the requirements for thermal conductivity are not as critical for the mold wall as for the stool, stainless steel may be employed for this purpose.

In practicing the invention, we have used metal molds having a considerable variation in the ratio of the minimum transverse dimension at the largest cross-section to the length or vertical height of the metal mold. Examples of ratios that have been used are from 0.3 to 0.5. In one instance, a mold with an extreme ratio of 0.27 was made use of.

We have discovered, as will be pointed out in detail hereinafter, that the mold wall thickness plays an extremely important part in determining the extent of build-up of horizontal columnar crystals in the walls of the mold towards the axis. It is critically important to prevent these crystals from reaching the axis of the mold, and, in fact, a substantial axial area should be free from any horizontal columnar crystals if sound ingots are to be produced. The solidification of metal in the axial core of the mold must be controlled so that it progresses generally upward. To accomplish this, we have found it to be critical that the mold wall thickness of the metal mold, above the lowermost 20% of its height, be such that there is no substantial portion at any point exceeds a thickness equal to 45% of the shortest distance from the interior surface of the mold at that point to the vertical axis 24 of the tubular mold.

The wall thickness of the tubular metal molds need not be uniform. We have employed many varieties of shapes and proportions for the mold wall thickness. Substantial sized ingots have been cast in the tubular metal molds of a thickness of 0.04 inch, and 1200 pound ingots have been cast in molds whose walls were 0.25 inch thick.

At the upper end 28 of the tubular mold 22, there is placed an open-ended ceramic hot top 30 having an interior surface 32 generally in continuation of the interior surface of the tubular metal mold. Disposed about the exterior of the metal mold 22 and the ceramic hot top 30 is a layer of heat insulating material 38 retained in place by a shell 40. The heat insulating material 35 may be sand, magnesite oxide, finely divided ceramic materials and the like, such materials being capable of withstanding temperatures that may be present when metal is cast in the mold. A layer of sand at least 2 inches thick about
the mold and hot top has given good results in practice. The ceramic refractory member 30, insulating material 38 and shell 40 terminate in an upper surface 34.

Placed upon the upper surface 34 is a heater member 41 closing the opening in the hot top 30. The heater member 41 comprises a shell 42 of a suitable heat resisting metal containing a refractory ceramic cap 44. The ceramic cap 44 has an opening 46 through which metal may be teemed into the mold and after teeming, a slug of graphite, ceramic or other refractory is placed therein to prevent loss of heat through the opening. Through the sides of the member 41 are placed hollow, electrically insulating, refractory members 50, for instance, of sillimanite, which extend through lateral projections 52 at opposite sides thereof. Passing through the hollow refractory members 50 are two carbon rods 54 and 56 and an arc 58 is drawn therebetween. The ceramic cap 44 has a downwardly facing cavity 60 essentially axially aligned with the axis 24. The cavity is preferably a paraboloid of revolution having its axis along the axis 24. However, it may comprise a rounded surface departing slightly from a parabolic cross-section. The arc 58 is preferably generated, by suitable positioning of the carbon rods 54 and 56, so that its center is also on the axis 24. Radiant energy from the arc is radiated both directly and by reflection from the walls of the cavity 60 to the upper surface 62 of metal 64 that has been teemed into the ingot and maintains most of the portion thereof in the hot top 30 melted. A sight hole 66 may be present in the ceramic cap 44 for observation.

There must be maintained a correlation between the heat-absorbing capacity of the metal mold 12, the thickness of the tubular metal mold 22, and the amount of insulating material 38 applied thereon so that there is present within 15 minutes after teeming a temperature difference of at least 200° C. between the bottom 26 of the tubular metal mold and the midpoint of the metal mold, that is, halfway between the surfaces 26 and 28. The maintenance of this temperature difference is one of the critical factors required to produce a high percentage of recoverable sound ingot, particularly of alloys characterized by a high volume contraction during solidification.

In Fig. 2, there is plotted a curve A of the total heat input required from the heater member 41 for various weights of ingots cast in the mold to insure at least 80% sound metal recovery. The curve A is the result of numerous tests in which ingots as small as 25 and 50 pounds and as large as 2400 pounds were employed in determining the amount of heat required to be applied to insure the high percentage of sound metal recovery. The equation corresponding to the curve is the heat input in B. t. u. equals 70,000 plus 120 times the ingot weight in pounds. It will be understood that if a 70% recovery of sound metal would be acceptable, the heat input may be slightly lower than as indicated in Fig. 2. The total heat input comprises both the amount required to preheat the hot top and ceramic cap to a temperature of above 1000° C., and the amount applied after teeming. We have found that from 20 to 30 kilowatt hours (1 kilowatt hour equals 3413 B. t. u.) will preheat the ceramic hot top and refractory cap of a 1200 pound ingot mold to about 1400-1450° C. For preheating other sized molds to the same temperature, the heat input will increase or decrease from this value as the square root of the ratio of the ingot weight to 1200 pounds. Thus, for a 9600 pound ingot, the preheating will require from 55 to 85 kilowatt hours.

In unusually long ingots are cast, that is, the ratio of transverse dimension to length is less than 0.3, a slight increase of heat input is recommended. Thus for an ingot of a 0.27 ratio we find approximately 10,000 B. t. u. more should be applied than for a 0.8 ratio.

Since there is a consumption of the electrode carbons oxidation, this oxidation introduces substantial amounts of heat to the mold, and it should be taken into account. We have found that in 1½ hours of arcing, approximately 60,000 B. t. u. are contributed by the combustion of 1½ inch diameter carbon electrodes, i. e., at a rate of 40,000 B. t. u. per hour of arcing.

The heat input to the ingot may be supplied in part entirely by other means than with an arc developed between the two carbon electrodes. Gas burners, fuel oil burners and resistance elements may be substituted therefor. In particular the hot top may be preheated with a gas burner.

In certain instances we have applied heat generating compositions on top of the teemed metal in the ingot mold, and thereby supplied a part of the required heat. These heat generating compositions comprise combustibles such as aluminum or magnesium powder and oxidizing agents, etc. The trade designates them as "liquidizers." It will be appreciated that the required purity of the cast ingot metal and the relative reactivity of some of its components may cause a preference for one heating means over another after teeming. We have found that the arcing structure shown in Fig. 1 of the drawing is suitable for use in casting ingots of compositions that are extremely sensitive to the atmospheres present. However, the casting of conventional types of steel may be carried out in the presence of a gas-heating device with complete success.

Referring to Fig. 3 of the drawing, the points plotted illustrate the recovery of sound metal based on the temperature difference between the middlelength and bottom of the mold wall 15 minutes after teeming. In this figure the points plotted represent the results of various indicated materials, namely, magnesium oxide, stainless steel, cast iron and copper. It will be noted that the magnesium oxide and stainless steel steels did not produce satisfactory ingots because of the inadequate thermal conductivity and in case of cast iron and copper steels were satisfactory. The stainless steel steel was used in producing an extremely small ingot weighing 25 pounds. If the ingots were 50 pounds or larger, the temperature difference using a stainless steel steel would have been considerably less than in the case of the 25 pound ingot, that is, such difference would be less than 200° C.

Using the ingot mold construction of this invention, the schedule of solidification of the teemed metal should be so conducted that the horizontal columnar grains that build up from the tubular shell 22 will end a substantial distance from the axis 24. Under these preferred conditions a substantial volume of molten metal will be present along the axis during most of the solidification time. We have found that if the columnar grains reach the axis, then gases escaping from the solidifying melt will be entrapped. Furthermore, shrinkage cavities, either macroscopic or microscopic, may develop along the major portion of the axis of the ingot as a result of such excessive horizontal grain growth. Furthermore, if the axial portion is obstructed by such horizontal columnar grain melt, molten metal cannot flow from the hot top down along the axis to fill any spaces that may develop due to volume contraction as metal solidifies.

The thickness of the mold wall is a highly important factor in determining the length of the horizontal columnar grains. From studies of a great number of ingots cast in molds of various shapes and sizes, we have obtained the information plotted as curve B in Fig. 4 of the drawing. It will be noted from curve B that the length of the columnar grains is roughly twice that of the mold wall thickness. We have further determined that, to secure sound ingots, the mold wall thickness should be at least 45% of the distance from the internal surface of the mold at any point to the axis opposite that point. Inasmuch as the bottom 20% of the height of the mold is not in-
volved to any extent in the columnar grain growth, the wall thickness of this portion is immaterial, and the lower 20% of the mold may exceed this limit, but the upper 80% of the tubular mold must be so proportioned that no substantial portion of the mold wall exceeds this maximum thickness. In practice, we prefer to maintain the mold wall thickness considerably below this 45% upper limit, since our experience is that better ingot structures are obtained with much thinner mold walls.

The wall thickness of the metal mold should not be subject to abrupt changes in thickness. A uniform tapering of the mold walls with the thickest part at the bottom is preferred if the mold wall is of a non-uniform thickness.

The following procedure has given good results in casting an ingot in the mold as shown in Fig. 1 of the drawing. Initially, the heater member 41 is placed on the hot top of the empty mold 10, and an electric arc is produced between the carbon rods 54 and 56 in order to preheat the ceramic cap 44 and the ceramic hot top 30. For highly refractory alloys, the preheated temperature of the hot top and the cap 44 adjacent the cavity 60 should be at least 1000°C, and preferably at the melting point of the metal being cast. We have heated the mold to temperatures from 1400°C to 1500°C and higher with excellent results when casting refractory metals.

When the mold has been so preheated, the molten metal being otherwise ready for teeming, the plug 48 is withdrawn from the opening 46 and the carbon rods 54 and 56 are separated, the flow of electrical current, of course, having been interrupted. The molten metal is then teemed into the mold to fill the tubular shell 22 and most of the ceramic hot top 30.

The plug 48 is then replaced and the carbon rods 54 and 56 are brought into arcing position and electrical current is applied to cause an arc to be drawn therebetween. A high heat input is required during the first 30 minutes after teeming of the metal. In casting 1200 pound ingots, we have secured good results when at least 50 B. t. u. per pound of metal was applied during the first half hour; that is, at a rate of at least 25 kilowatts for the first half hour, 25000 B. t. u. from combustion of the carbon electrodes. As examples, we have successfully used the following heating schedules in casting 1200 pound ingots: applying 25 kilowatts for the first hour and 20 kilowatts for the second hour, the average sound billet metal recovery for 10 ingots was 93.8%; when 20 kilowatts are applied for one hour and 20 kilowatts for the second hour, 10 ingots with an average metal recovery of 82.2% were secured; 13 ingots with an average recovery of 83.6% sound billet were secured with 35 kilowatts being applied for one hour and 20 kilowatts for a second hour; 88.7% of sound billet was secured for a number of ingots in which current was applied to the heater at the rate of 35 kilowatts for one-quarter hour, 20 kilowatts for another quarter of an hour and 10 kilowatts for one hour; and, more than 20 ingots having an average metal recovery of 85.3% were secured when the electrical current to the arc was supplied at the rate of 35 kilowatts for one-quarter hour, 20 kilowatts for three-quarters of an hour and finally 10 kilowatts for one hour. A number of ingots having a recovery of 90% of sound metal were produced when the electric arc functioned to provide 35 kilowatts for one-half hour, 25 kilowatts for one-half hour and 15 kilowatts for one hour. In each instance the oxidation of the carbon electrodes supplied 40,000 B. t. u. per hour of arcing. In all these preceding pours, the metal was teemed at temperatures of from 1450°C to 1550°C, the ceramic hot top was preheated to about 1400°C prior to teeming, and the metal ingot thickness was with approximately three inches of sand insulation placed about the mold and ceramic hot top.

The alloy cast in these tests was the highly refractory alloy disclosed in Patent 2,519,406: If the ceramic hot top has been preheated so that it is below the melting temperature of the molten metal being cast in the mold, a higher heat input during the first half hour than the 50 B. t. u. per pound of metal being teemed will be required to maintain a substantial pool of highly fluid metal in the hot top.

In using the mold of this invention in the manner prescribed, the teemed metal progressively solidifies rapidly from the bottom of the mold upwardly and at a slower rate from the side walls of the metal mold toward the axis. In approximately one hour, the major proportion of the metal within the tubular metal mold is solidified except for a substantial column along the axis. Within two hours, practically all of the metal in the metal mold will be solidified and only a small pool of molten metal within the hot top remains fluid. At this time, the electric current to the carbon rods 54 and 56 may be interrupted and the metal permitted to solidify entirely.

As examples of ingots cast with the mold constructed in accordance with this invention are the following:

**Example I**

A sheet steel mold one-quarter inch thick and of a tapered rectangular cross-section having a dimension of 14 inches by 14 inches at the top and 13 inches by the bottom and of a length of 18 inches was placed on a copper stool 25 inches by 25 inches, the full 22 inches thickness with water cooling channels being present therein. A fire clay hot top 7 inches in length was placed on top of the metal mold. A four-inch thickness of sand insulation was placed around the entire mold and on the hot top. The hot top was preheated to a temperature of 1400°C, and after teeming, heat was applied at the rate of 25 kilowatts for one-quarter hour, 20 kilowatts for three-quarters of an hour and 10 kilowatts for one hour, providing a total of 334 kilowatt hours. The combustion of the electrode carbons introduced 60,000 B. t. u. Within 15 minutes after teeming, the midlength of the metal mold was at a temperature 480°C higher than the bottom of the mold. The amount of sound metal recovered from the ingot was 94%. The horizontal columnar grains extended less than 2 inches from the mold walls.

**Example II**

An alloy comprising 22% cobalt, 18% chromium, 42% nickel, 0.7% manganese, 0.7% silicon, 2.1% titanium, 0.3% aluminum and 0.02% carbon about a 50% recovery of sound, usable metal when teemed into conventional molds which yield over 90% recovery of carbon steel ingots. A 1200 pound heat of this alloy at 1550°C was cast in a tapered 3/4 inch thick sheet steel mold having internal dimensions of 14 inches by 14 inches at the top and 13 inches by 13 inches at the bottom and 18 inches long and placed on a water cooled copper stool 25 inches by 25 inches by 6 inches and provided with a graphite plug. A fire clay hot top 7 inches long was used. From 4% inches to 5% inches of sand was applied about the mold and hot top. A total of 225,000 B. t. u. was applied to the mold top, heat being applied at the rate of 30 kilowatts during the first half hour after teeming. In 15 minutes after teeming, the midpoint of the metal mold was 480°C hotter than the bottom of the metal mold. Over 85% of sound ingot metal was recovered. The horizontal columnar grains were 3/16 inches in length.

**Example III**

A tapered sheet steel mold of a uniform wall thickness of 1/2 inch, with a square internal area of 16.5 by 16.5 inches and mold comprises 24 inches at the bottom and 24 inches long was placed on a cast iron stool 25 inches by 25 inches and of a thickness of 6 inches. A ceramic hot top approximately 6 inches high was placed at the upper end of the sheet metal mold, and 4 inches of
sand were placed around the entire metal mold and hot top. The hot top was preheated to a temperature of approximately 1400° C. by an electrical arc as shown in Fig. 1 before the metal was formed. Within 15 minutes after teeming into the mold 2400 pounds of molten metal at a temperature of 1500° C., the composition being similar to that set forth in Patent 2,519,406, the temperature at the midpoint of the mold was 215° C. higher than the temperature at the bottom of the mold at the point of contact with the cast iron stock. A total input of 335,000 B. t. u. was applied including preheating by applying 40 kilowatt hours, and heating after teeming at the rate of 35 kilowatts during the first half hour, for another half hour at a rate of 20 kilowatts and 10 kilowatts for the next hour and 70,000 B. t. u. were introduced by the combustion of carbon electrodes.

The percent of sound metal recovered from the ingot after solidification is 73%. A section through the ingot showed the horizontal columnar grains were relatively small. This example shows the critical nature of the heating requirement. To secure 80% ingot recovery, the curve of Figure 2 requires 358,000 B. t. u. to be applied. However, a 73% recovery is still quite acceptable.

Example IV

A 305 pound ingot of the copper alloy disclosed in Patent 2,053,709 was cast in a mold made of ¾ inch thick sheet steel, the mold being 20 inches long. The sheet steel mold had a uniform cross-section of 7¾ inches by 7¼ inches. A fire clay hot top 4 inches long was placed on the mold. The mold rested on a cast iron stool 12 inches by 12 inches by 5 inches thick. The sheet steel mold and hot top were insulated with slightly more than 2 inches of sand. A total of 110,000 B. t. u. by application of resistance heating elements, the mold top being preheated to 1700° C., to the mold to keep the copper alloy molten in the hot top, heat for the first half hour after teeming being applied at the rate of 10 kilowatts. In 15 minutes after teeming, a temperature difference of over 200° C. was present between the bottom of the mold and the midpoint of the mold. An ingot comprising 100% of sound copper alloy was obtained.

The mold of the present invention may be employed for the casting of ingots of numerous metals and alloys; thus carbon steel, low alloy steel, nickel, high nickel alloys, stainless steel, and highly refractory alloys of all types are examples of metals that may be cast therein with a high recovery of sound ingot.

It shall be understood that the detailed description and drawing are exemplary and not in limitation of the molds or the process disclosed herein.

We claim as our invention:

1. A mold for casting ingots comprising, in combination, a vertically-disposed, tubular open-ended metal mold having a height greater than its transverse dimensions and having a wall thickness of at least ½ inch, and at no point above the lowermost 20% having a substantial portion of the wall of a thickness exceeding 45% of the shortest distance from the interior surface of the mold at that point to the vertical axis of the mold, a metal stool closely fitting and closing the base opening of the mold, the stool being of a metal having a thermal conductivity of at least 0.075 calorie per square centimeter per centimeter per degree centigrade per second, the metal stool cooperating with the metal mold to withdraw heat from a ferrous metal ingot cast therein at a rate such that within 15 minutes after teeming there is a difference of at least 200° C. between the base portion and the midsection of the tubular mold, an open-ended refractory ceramic hot top placed on top of the tubular metal mold and in axial alignment therewith, the hot top being at least 20% of the length of the metal mold, a substantial thickness of thermally insulating material applied about the entire exterior of the hot top and the tubular metal mold to reduce the flow of heat from them, the thermally insulating material being equivalent to a layer of sand of a thickness of at least two inches, and a heater member disposed over the upper end of the hot top, the heater member comprising a refractory ceramic cap completely closing the end of the hot top with a downwardly facing cavity and a heating device comprising two electrical conductors disposed to produce an arc therebetween so disposed in the cavity that heat from the arc is reflected by the walls of the cavity downwardly into the end of the hot top.

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