

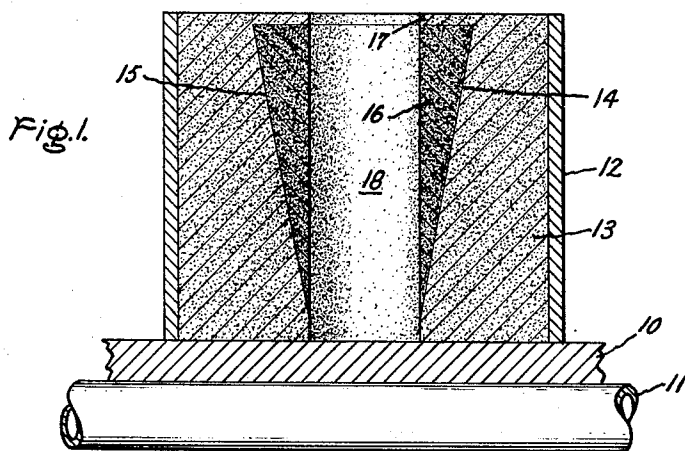
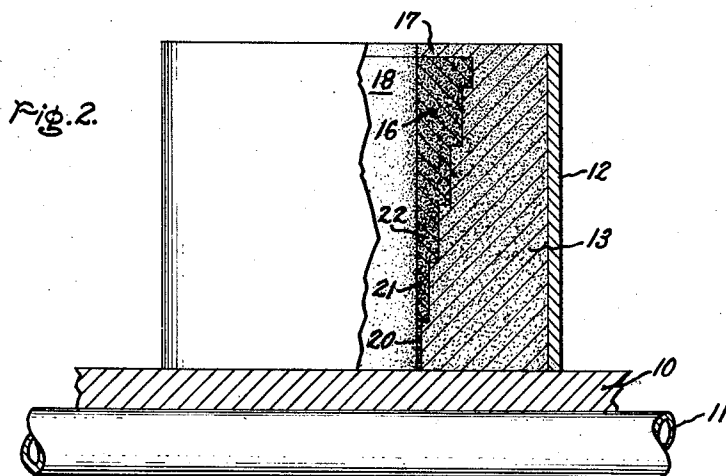
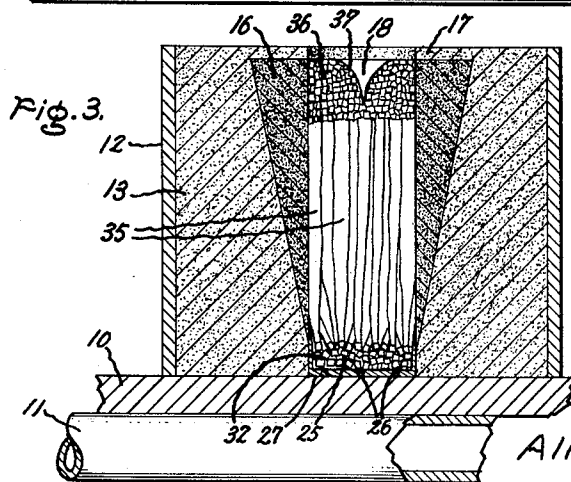
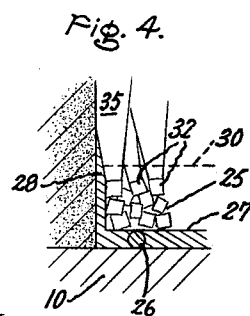
Sept. 6, 1960

A. J. KIESLER

2,951,272

METHOD AND APPARATUS FOR PRODUCING GRAIN-ORIENTED INGOTS

Filed Sept. 22, 1958



Inventor:
Allan J. Kiesler,
by Paul A. Frank
His Attorney.

1

2,951,272

METHOD AND APPARATUS FOR PRODUCING
GRAIN-ORIENTED INGOTSAllan J. Kiesler, Schenectady, N.Y., assignor to General
Electric Company, a corporation of New York

Filed Sept. 22, 1958, Ser. No. 762,658

6 Claims. (Cl. 22—126)

This invention relates to the preparation of ingots comprising castings consisting primarily of a plurality of elongated columnar as-cast grains whose longitudinal axes are substantially parallel, and, more particularly, to a method and apparatus for producing such ingots utilizing sand molds, and which provides for the automatic control of critical temperature gradients in the mold during solidification of the cast metal to insure the formation of the columnar as-cast grain structure in the ingots.

This application is a continuation-in-part of applicant's co-pending application, Serial No. 610,905, filed September 20, 1956, assigned to the same assignee as the present application, and now abandoned.

It has been found desirable to produce ingots of certain iron-base alloys consisting essentially of elongated columnar, as-cast grains, the longitudinal axes of the grains being substantially parallel. This has been accomplished, for example, by casting the molten alloy into a mold consisting of a tubular member of a refractory material such as fused alumina, which has been pre-heated to a temperature of about 1400° C. and which is provided with a water-cooled, substantially planar copper bottom which is maintained at about room temperature during the casting and solidification of the molten metal. In this manner, the superheat and the latent heat of the molten material is substantially all extracted through the cooled mold bottom, the rate of heat transfer through the sidewalls of the mold being minimized by the sensible heat of the mold walls and the insulating characteristics of the refractory material thereof. The ingots so produced are largely composed of elongated columnar as-cast grains which extend with their longitudinal axes substantially parallel to the direction of the flow of the heat during its extraction, or, in other words, the mean or average direction of the longitudinal axes of these columnar grains is substantially perpendicular to the cooled copper bottom of the mold.

It has been found that ingots such as these, composed of magnetically soft materials such as silicon-iron, containing up to about 5 percent silicon may be processed by appropriate rolling and heat treatment to form a grain-oriented sheet or strip-like material having useful magnetic properties. Similar iron-base alloys consisting of up to about 8 percent aluminum, balance substantially all iron, or up to about 5 percent molybdenum, balance substantially all iron, may also be used. For preferred compositions which are particularly useful, reference is made to applicant's copending application, Serial No. 610,909, filed September 20, 1956, and assigned to the same assignee as the present application. It has additionally been found that the crystallographic orientation among the several elongated columnar as-cast grains of such ingots may be improved by casting the molten metal upon a seed slab supported by or constituting the cooled bottom of such ingot molds. The seed slab is composed of a material which may have substantially the identical composition as the molten metal, or may be composed of a different composition that is characterized by hav-

2

ing a crystal lattice parameter compatible to that of the cast metal and has its crystal lattice so oriented with respect to the direction of solidification of the ingot that upon casting, the heat from the molten metal causes the exposed surface of the seed slab to be melted and as heat is extracted through the seed slab, the molten metal in contact with the seed slab solidifies into an ingot, the crystal lattice or lattices of which assume the orientation of the crystal lattice of the seed slab.

Accordingly, it is a principal object of my invention to provide an apparatus for casting grain-oriented, columnar ingots which does not require the application of external heat before or during the casting and solidification of the ingot.

A further object of my invention is the provision of an apparatus for casting such ingots which does not require precise control and timing of external cooling means.

A yet further object of my invention is the provision of a method for casting grain-oriented columnar ingots by pouring molten metal upon a seed slab whereby the rate of heat extraction through the seed slab is controlled by the initial mode of solidification of the molten metal. Other and specifically different objects and advantages of my invention will become apparent from the following detailed description of certain specific examples of my invention particularly with reference to the accompanying drawings, in which:

Fig. 1 is a semi-schematic cross-sectional elevational view with parts broken away, of an embodiment of my invention;

Fig. 2 is a similar semi-schematic cross-sectional view with parts broken away, of another embodiment of my invention;

Fig. 3 is a semi-schematic elevational view of the apparatus of Fig. 1 after an ingot has been cast upon a seed slab therein and solidified, and illustrating a further feature of my invention; and,

Fig. 4 is an enlarged view in greater detail of a portion of Fig. 3.

Briefly stated, in accordance with one embodiment of my invention, I provide a casting apparatus consisting of a cooled, substantially planar, heat exchange member upon which is supported a tubular mold which may be constructed of ordinary foundry molding sand, or similar pulverulent molding materials, the inner faces forming the mold cavity of which are lined with a material which is capable of discharging large amounts of heat when exposed to contact with molten metal by means of an exothermic reaction which does not contaminate the molten metal to any substantial degree, and a seed slab upon which the molten metal is to be cast, supported in closely spaced relationship to the heat exchange or mold bottom.

More particularly, and with reference to the figures of the drawing, the apparatus of my invention includes a substantially planar base plate 10 constructed of a material having a high thermal conductivity, preferably copper. Means for cooling plate 10 are provided and schematically illustrated in Fig. 1 by one of a plurality of tubular conduits 11 in a heat exchange relationship with plate 10 and through which a coolant such as cold water may be circulated.

Supported upon plate 10 is a hollow, tubular flask member 12 which may have any convenient configuration in a cross-section perpendicular to the plane of the paper, such as, for example, circular, rectangular, square, or the like. A pulverulent molding material, preferably ordinary foundry molding sand 13 is rammed into flask 12 in a conventional manner about a pattern having a cross-sectional area which is greater at one end than at the other end, so that when it is removed a tapered

cavity remains in the sand. As shown in Fig. 1, this tapered cavity is defined by the straight lines 14 and 15. A second pattern is then placed in the cavity in the rammed foundry sand. This second pattern has substantially the dimensions and configuration of the desired ingot. One end of the second pattern has substantially the same cross-sectional area and configuration of the small end of the first pattern and closely fits the corresponding end of the cavity. The opposite end is usually geometrically similar in cross-section to the first end but at least slightly larger in area to provide sufficient "draught" for removal after the mold is complete. The tapered space between the walls of the tapered cavity in the rammed foundry sand and the substantially straight sides of the second pattern are rammed with a mold lining material 16 which is capable of giving off large quantities of heat by an exothermic reaction when contacted by molten metal. The tapered cavity may also be filled with a prerammed core. When the rammed exothermic material substantially fills the tapered space, an additional quantity of foundry sand may be rammed in place to form a cap-like structure over the exothermic material as shown at 17. The second pattern may then be removed, leaving a tubular mold cavity 18 substantially as shown.

As a more specific example, a mold was prepared as shown in Fig. 1 in which the mold cavity 18 was rectangular in cross section and measured about 6" x 11" x 11". In this respect the cavity 18 was about 6" thick and 11" high measured in the plane of the paper and 11" wide measured in a plane perpendicular to the plane of the paper. The thickness of the exothermic lining at the top was about 2" and tapered to 0 at substantially the bottom of the mold cavity. The particular exothermic material used consisted essentially of a pulverulent mixture of about 50 to 60 percent "grog," or crushed fired clay, about 20 to 25 percent powdered aluminum, about 10 percent powdered iron oxide and about 5 percent powdered sodium nitrate. It will be appreciated that numerous exothermic materials which react in a similar manner may be substituted if desired for this particular material. This particular material depends upon a well-known "thermite" reaction between the aluminum and iron oxide constituents for the production of the desired heat. The grog and nitrate constituents act to slow the reaction in order to prolong the evolution of heat, to aid in ramming the material into a coherent form and to prevent the products of the reaction from unduly contaminating the ingot during solidification. By tapering the exothermic lining material as shown, provision is made for applying greater amounts of heat therefrom to the cast metal in the top of the mold to permit solidification to occur from the bottom to the top and thereby increase the amount of ingot metal which solidifies into columnar grains.

If desired, the exothermic lining material may be formed in cross sectional configuration specifically different from that illustrated in Fig. 1. For example, if desired, the lining may be formed in the stepped configuration shown in Fig. 2 which comprises a plurality of zones of exothermic material extending from the bottom to the top of the mold cavity, each successive zone above the lowest zone 20 being thicker than its immediately lower preceding zone. See for example, that zone 21 is thicker in cross section than zone 20 and is in turn thinner in cross section than the adjacent zone 22. It will be apparent, however, that the zones of lining material in this embodiment by and large form a tapered body with the thickest layers thereof adjacent the top of the mold cavity and the thinnest layers adjacent the bottom of the cavity.

In practice it has been found that when molten-iron base alloys are cast into the mold cavity 18 of the apparatus illustrated in Figs. 1 and 2, directly upon the mold bottom plate 10 which is maintained at about room

temperature during pouring and solidification of the mold metal, that solidification begins at the cooled surface of the bottom 10. As the level of the molten metal rises in the mold, the exothermic lining material begins to react to produce large quantities of heat, a large portion of which is transferred to the molten metal to retard its loss of heat laterally into the sand portion of the mold. A large portion of the superheat and latent heat of the molten metal is thereby extracted through the mold bottom and solidification of the metal in the mold progressively occurs from the bottom to substantially the top of the ingot thus formed. Substantially all of the metal in the ingot with the exception of the very top "pipe" section of the ingot is composed of elongated columnar grains with their longitudinal axes substantially parallel and extending in a direction substantially parallel to the direction of heat extraction, i.e., from the top to the bottom of the mold cavity. It will be therefore seen that by employing the apparatus of my invention as illustrated in Figs. 1 and 2 that preheating of the mold is avoided, the use of expensive, fragile refractory molds is avoided, the foundry sand comprising the bulk of the mold may be separated from the reacted exothermic lining material which tends to be bonded together in relatively large pieces and re-used. Furthermore, the molds may be made up in large numbers in advance of the casting operation and may be stored for a considerable time if desired, rendering the casting apparatus of my invention highly adaptable to mass production techniques.

The embodiment of my invention shown in Figs. 3 and 4 is illustrative of a molding apparatus as shown in Fig. 1 adapted to be used with a seed slab. The reference numerals applied to Fig. 1 are applied to similar structure in Figs. 3 and 4.

Prior to my invention considerable effort had to be expended in properly timing the pouring of molten metal upon a seed slab to insure a sufficient degree of melt back from the seed slab in the production of grain oriented ingots. According to one aspect of my invention, I provide a thermal insulation of the seed slab from the heat extraction member during the initial stage of the casting operation which automatically ceases to so insulate within a very short interval of time after the start of the pouring operation. During the short time the insulation is effective, however, sufficient melt back of the seed slab will occur so that the seed slab is effective during subsequent solidification to control grain orientation of the ingot cast thereupon. This is accomplished in the following manner.

The mold apparatus is assembled as shown in Figs. 1 and 3 and cooling water is circulated through conduit 10. A seed slab 25 is placed in the bottom of the mold cavity 18 supported in closely spaced relationship to the upper surface of plate 10 by means of a plurality of spacing elements 26. These spacing elements may be made from any suitable material but should occupy only a relatively small volume of the insulating space between the bottom 27 of the seed slab 25 and plate 10 and should not restrict the flow of molten metal into this space. I have found that two or three short lengths of drill rod or the like are quite effective as spacing members. The lateral dimensions of the seed slab are such that a small marginal space 28 is provided between the periphery of the slab and the sidewalls of the mold so that a metered flow of molten metal may be introduced through said space 28 and thereby fill the insulating space.

In operation, the spacing elements 26 are placed in the bottom of the mold cavity 18, seed slab 25 is preferably preheated and placed upon spacing elements 26 and molten metal is poured into said mold cavity. Before the molten metal is poured, the ability of the heat extraction plate 10 to cool the seed slab is restricted to the relatively small amount of heat which can flow

5

through the small volume of spacers 26 and be transmitted by radiation across the insulating air gap. Molten metal poured into the mold first strikes the upper surface of the insulated seed slab shown by dashed line 30 and substantially immediately raises the surface temperature thereof to the melting point effecting melt back to approximately the point shown by the solid line rectangles 32 schematically representing individual grains of the seed slab in Figs. 3 and 4. Some of the molten metal passes through the marginal space 28 into the air gap or insulating space between the seed slab 25 and plate 10 and between and around the spacing elements 26. Heat is extracted from the molten metal occupying this space by plate 10 and is caused to freeze therein in a very short interval of time. This solidified metal forms an excellent conductor of heat and large quantities of heat may then be extracted from the seed slab 25 by plate 10. This causes solidification of the liquid metal nearest the seed slab and the formation of elongated columnar grains 35 of which grow upwardly in the mold from the seed slab 25 as shown until the rate at which heat is extracted from the remaining molten metal through the solidified portion of the metal by means of plate 10 is substantially balanced by the heat lost through the top and sides of the mold by radiation, conduction and convection. It will be appreciated that the exothermic mold lining 16 is effective to prevent heat losses through the sides of the mold cavity as previously described. At this point, the remainder of the molten metal solidifies as a zone of equiaxed grains as shown at 36 and a conventional pipe 37 is formed. In practice the pipe and equiaxed portion, as well as the seed portion, may be cropped as scrap.

From the foregoing, it may be seen that I have provided a thermal insulation for the seed slab during the critical first part of the pouring operation and means for automatically destroying or rendering ineffective the insulation to provide good heat transfer between the heat exchanger and the seed slab when the need for the insulation no longer exists, thereby permitting the casting operation to be accomplished without the necessity of varying or otherwise manually controlling the temperature of the heat extraction member 10.

It will be apparent to those skilled in the molding art that the spacer elements 26 may have any desired configuration and may be made from a wide variety of materials. Further, they may be separate from the seed slab or be integral with or attached to the face or the faces of the seed slab. Many other variations of my invention will readily occur to molding practitioners and the specific embodiments of my invention described in the specification and illustrated in the drawing are to be regarded as exemplary only and I intend the scope of my invention to be limited only by the appended claims.

As indicated above, the method of this invention is applicable to a variety of binary alloys of magnetically soft character. Similarly it is applicable to ternary alloys of the same general type. Thus this new method may be used to obtain the aforesaid results and advantages where a silicon-aluminum-iron alloy is concerned. Such alloys will contain amounts of aluminum and silicon in the general ranges stated above and consequently they will contain less than 8% aluminum and less than 5% silicon according to the amount of silicon or aluminum, respectively, which has been substituted in the general binary formulas. Ternary alloys of molybdenum, however, are not generally contemplated for use in the present method because of the tendency for molybdenum to produce clustering effects with other alloying elements and thereby impair or destroy alloy magnetic properties. Those skilled in the art will understand that this effect will vary in accordance with the molybdenum content of such an alloy and that ternary or quaternary alloys containing molybdenum in such amounts as to be inconsequential in this detrimental respect are contemplated

6

for use in accordance with this invention and included within the scope of the appended claims. On the other hand those alloys which are magnetically weak because of this undesirable characteristic of molybdenum are not so contemplated or included within these claims.

Generally described the ternary alloys useful in this invention will contain less than 5% silicon, less than 8% aluminum and will contain a minimum of 92% iron.

What I claim as new and desire to secure by Letters

10 Patent of the United States is:

1. An apparatus for casting grain-oriented ingots comprising a body of rammed pulverulent molding material having a vertically disposed opening extending therethrough, a substantially tubular lining disposed within said opening and supported by said rammed molding material to define a substantially tubular vertically disposed mold cavity, said tubular lining having its greatest thickness adjacent the top of the mold cavity and being composed of a pulverulent material capable of undergoing an exothermic chemical reaction when exposed to contact with molten iron-base alloys, a horizontally disposed substantially planar heat exchanger supporting said body of rammed molding material which comprises a bottom closure for said vertically disposed mold cavity, 25 a grain-oriented seed slab, and means for supporting said seed slab in spaced relationship to the upper surface of said heat exchanger and to a side wall of said tubular vertically disposed mold cavity whereby a thermally insulating air space is provided between said seed slab and said heat exchanger and at least one passageway is provided between the side walls of said mold cavity and said seed slab to afford communication for the passage of molten metal from said mold cavity above said seed slab into said insulating air gap between said seed slab 30 and said heat exchanger.

2. An apparatus as defined in claim 1 in which said vertically disposed opening through said body of rammed pulverulent molding material is defined by at least one surface consisting of substantially straight line elements inclined at an acute angle to the vertical direction and intersecting the mold cavity at about the upper surface of said heat exchanger.

3. An apparatus as defined in claim 1 in which said vertically disposed opening through said body of rammed pulverulent molding material is defined by at least one surface consisting of a plurality of alternatively arranged vertical and horizontal straight line elements whereby said vertically disposed opening has its greatest width adjacent the top of said opening and its smallest width adjacent the upper surface of said heat exchanger.

4. A method for casting grain-oriented ingots consisting essentially of iron containing up to about 5 percent silicon, comprising the steps of supporting a grain-oriented metal seed slab corresponding in composition to that of the ingot in spaced relationship to a heat exchanger, casting molten metal upon the surface of the seed slab remote from the heat exchanger, causing the seed slab to become molten, conducting a portion of the molten metal into the space between the seed slab and the heat exchanger to substantially fill the space, extracting the superheat and latent heat from the metal filling the space to thereby form a band of high heat conductivity between the seed slab and the heat exchanger and extracting heat from the remainder of the molten metal through the seed slab by means of the heat exchanger.

5. A method for casting grain-oriented ingots consisting essentially of iron containing up to about 8 percent aluminum, comprising the steps of supporting a grain-oriented metal seed slab corresponding in composition to that of the ingot in spaced relationship to a heat exchanger, casting molten metal upon the surface of the seed slab remote from the heat exchanger, causing the seed slab to become molten, conducting a portion of 75 the molten metal into the space between the seed slab

7

and the heat exchanger to substantially fill the space, extracting the superheat and latent heat from the metal filling the space to thereby form a band of high heat conductivity between the seed slab and the heat exchanger and extracting heat from the remainder of the molten metal through the seed slab by means of the heat exchanger.

6. A method for casting grain-oriented ingots consisting essentially of silicon, aluminum and iron in which the silicon content is less than 5 percent, the aluminum content is less than 8 percent and the iron content is at least 92 percent, comprising the steps of supporting a grain-oriented metal seed slab corresponding in composition to that of the ingot in spaced relationship to a heat exchanger, casting molten metal upon the surface of the seed slab remote from the heat exchanger, causing the seed slab to become molten, conducting a portion of

8

the molten metal into the space between the seed slab and the heat exchanger to substantially fill the space, extracting the superheat and latent heat from the metal filling the space to thereby form a band of high heat conductivity between the seed slab and the heat exchanger and extracting heat from the remainder of the molten metal through the seed slab by means of the heat exchanger.

References Cited in the file of this patent

UNITED STATES PATENTS

1,923,000	Bailey	Aug. 15, 1933
2,281,718	Scully et al.	May 5, 1942
2,594,998	Rocco	Apr. 29, 1952

FOREIGN PATENTS

525,078	Belgium	Dec. 15, 1953
---------	---------	---------------