

United States Patent

[11] 3,633,656

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| [21] | Appl. No. | 13,259 |
| [22] | Filed | Feb. 20, 1970 |
| [45] | Patented | Jan. 11, 1972 |
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- [54] **APPARATUS FOR MAKING INGOTS**
10 Claims, 3 Drawing Figs.

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| [52] | U.S. Cl. | 164/348,
249/79, 164/126 |
| [51] | Int. Cl. | B22d 27/04 |
| [50] | Field of Search | 164/122,
126, 127, 128, 348; 249/79, 174 |

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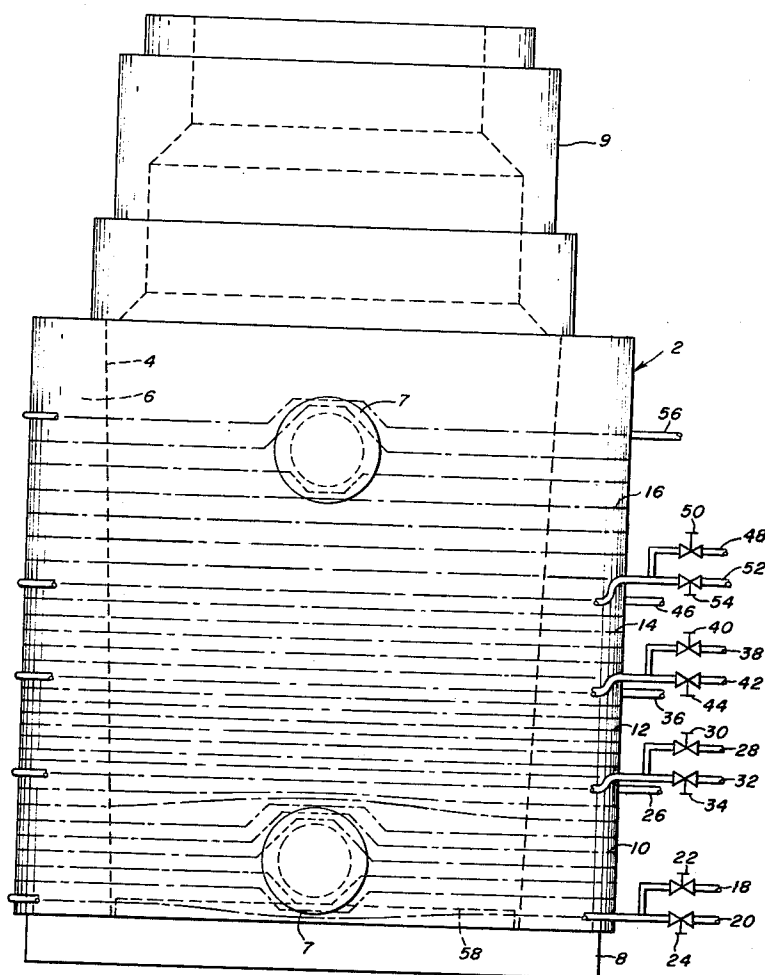
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ABSTRACT: A large generally cylindrical ingot mold is provided with four sections of tubing around its outer surface except for some distance from its top. A valve-controlled water feed and a valve-controlled steam feed are provided to each of the sections. The intermediate cooling sections have a greater cooling effect per square foot of mold surface than the top and bottom sections. After molten steel is poured into the mold, steam is fed into all four sections for several hours. Then at spaced time intervals steam is turned off and water turned on successively to the bottom section, the second section, the third section and finally to the top section. This condition exists for a time period longer than the period with steam on. Then at spaced time intervals water is turned off and steam turned on successively to the bottom section, the second section, the third section, and finally to the top section. The steam is turned off prior to stripping of the mold from the ingot.





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APPARATUS FOR MAKING INGOTS

This invention relates to apparatus for making ingots and more particularly to making large steel generally cylindrical ingots such as are used for forging rotors. Such ingots may weigh as much as 360 tons. This requires the use of molds having an inside diameter as great as 134 inches, an outside diameter of approximately 180 inches, and a height of approximately 13 feet. Prior to my invention it was difficult to make ingots without a substantial amount of axial porosity or pipe. In many instances the porosity was such that a relatively large percentage of the ingot had to be discarded and in some instances the entire ingot had to be discarded. Voids approximately as large as the size of a football sometimes occurred. To decrease the amount of axial porosity the mold is usually provided with a refractory lined hot top. Also exothermic material has been used as part of the hot top and as a covering over the top of the molten steel. An electric arc has also been used to provide heat to the top of a non-hot-topped ingot. While all of these methods reduce the extent of the pipe, they do not insure that the ingot will be satisfactory and in many the pipe is still too large so as to limit the usable amount of the ingot and in some instances the entire ingot may have to be discarded. Most of the methods discussed above also may introduce undesirable nonmetallic inclusions such as aluminates into the body of the ingot.

In some instances it has been proposed to use cooling means embedded in or surrounding a mold. However, to my knowledge this has not been done with molds of the large size referred to herein. The cooling characteristics and the problems involved in casting these large generally cylindrical ingots are much different than in casting the usual type of ingots in molds which have much smaller dimensions. Ashdown U.S. Pat. No. 1,251,951 dated Jan. 1, 1918 is illustrative of a mold having a cooling conduit cast therein. It appears that the pitch of the conduit is uniform for the usual height of mold which results in a uniform cooling effect per square foot of mold surface while I have found that this cooling effect must vary. This construction often results in cracking of the mold in use or during the casting operation which is a difficult and expensive procedure. Any problems present are intensified as the size of the mold and the wall thickness increases. British Pat. No. 698,303 dated Oct. 14, 1953, discloses a sand-type mold having cooling coils in the sand. This, too, is used for making small diameter ingots of the order of 20 inches. There is danger of leakage of molten steel to the tubes which can cause explosions. The heat transfer is also poor. In addition, the purpose of the cooling of this type of casting is different than cooling large ingots. Cortes U.S. Pat. No. 1,836,310 dated Dec. 15, 1931, is illustrative of ingot molds having cooling coils around the outside thereof. However, the varying cooling sections have the same cooling effect per sq. ft. of mold surface which as stated above is not satisfactory. If the coolant to any one section is turned off the construction is such that the tubes of that section will act as an insulator, thus causing poor cooling characteristics.

I have made studies which show that axial porosity is a result of undesirable cooling profiles from the bottom to the top of the ingot and that desirable cooling characteristics for large size generally cylindrical molds are different than for smaller cylindrical or rectangular molds. Large generally cylindrical molds as covered by my invention include molds having a cylindrical cross section or one approaching a cylindrical cross section such as six- or eight-sided molds. The invention has utility on sizes as small as 75 in. in diameter, but is most useful in making ingots of 95 in. in diameter and larger.

It is therefore an object of my invention to provide apparatus for making a large generally cylindrical ingot which greatly improves the solidification of an ingot, thus resulting in less axial porosity.

This and other objects will be made apparent after referring to the following specification and attached drawings, in which:

FIG. 1 is a schematic view of an ingot mold with my invention incorporated therein;

FIG. 2 is an enlarged vertical sectional view showing the arrangement of the cooling tubing in the lower cooling sections; and

FIG. 3 is a view, similar to FIG. 2, but showing the tubing arrangement in the top cooling section.

Referring more particularly to the drawings, reference numeral 2 indicates a standard big-end-up ingot mold. While the mold is shown as having smooth outer and inner surfaces, it will be understood that in most cases at least inner opening 4 of the mold will be corrugated. In one particular mold the outside diameter is 14 feet, 9½ inches and has a sidewall 6, 18 inches thick at the top tapering to 24 inches at the bottom. Trunnions 7 are provided, two diametrically opposed at the top and two diametrically opposed at the bottom. The mold 2 rests on a stool 8. The height of this particular mold is 12 feet, 11 inches. A hot top 9 rests on top of the mold 2. The parts so far described are conventional.

According to my invention, four sections of tubing 10, 12, 14 and 16 are wrapped around the mold. The tubing used is 1½ inches outside diameter steel boiler tubing and preferably has a covering of heat transfer cement 17 thereon as shown in FIGS. 2 and 3 in order to increase the heat transfer to the conduit. One particular type which has been successfully used is "Thermon T-63." The lower section 10 preferably starts 4 inches from the bottom of the mold 2 and has eight spirals with a 4-inch pitch. The second section 12 also has eight spirals with a 3-inch pitch. The third section 14 has six spirals with a pitch 4 inches and the top section 16 has seven spirals with a pitch 6 inches terminating 29 inches from the top of the mold. The sections of tubing are substantially continuous with only enough space between sections to provide for feeding and discharge connections. In FIG. 1, only the centerline of the tubes are shown in most part for the sake of clarity. It will be noted that the tubes are bent around the trunnions 7. The bottom section 10 is alternatively fed with steam through conduit 18 or with water through conduit 20. Valve 22 in conduit 18 controls the flow of steam and valve 24 in conduit 20 controls the flow of water. A discharge 26 of steam or water is located at the upper end of the section. In like manner steam is fed to section 12 through conduit 28 having a valve 30 therein or water is fed through conduit 32 having a valve 34 therein and discharged at 36 at the top end of the section. Steam is fed to section 14 through conduit 38 having a valve 40 therein and water is fed through conduit 42 having a valve 44 therein and discharged at 46 at the top end of the section. Steam is fed to section 16 through conduit 48 having a valve 50 therein and water is fed through conduit 52 having a valve 54 therein and discharged at 56 at the top end of the section. It will be seen that each of the bottom and top sections 10 and 16 cover approximately 25 percent of the mold height, that each of the intermediate sections 12 and 14 cover approximately 15 percent of the mold height, and that the top 20 percent of the mold height is free of cooling sections. While this arrangement is preferred it may be modified so that each of sections 10 and 16 cover between approximately 20 and 30 percent of the height, each of sections 12 and 14 cover between approximately 10 and 20 of the height, and with between approximately 20 and 25 percent of the top being bare. Because of the spacing or pitch of the spirals the cooling effect per sq. ft. of mold surface is greatest for section 12, next greatest for sections 10 and 14, and least for section 16. It is necessary that the average cooling effect for the combined intermediate sections 12 and 14 be greater than that of the top and bottom sections.

In casting, a steel plate or insert 58 is positioned on top of the cast iron stool 8. The molten steel is then poured in the usual manner. Almost immediately (and at least within about 20 min.) after completion of pouring or casting of the steel, steam is delivered to all four sections 10, 12, 14 and 16 by opening valves 22, 30, 40 and 50. Preferably the steam has a pressure of approximately 80 p.s.i. and travels at sonic velocity through the tubes. Approximately 6 hours after the pour, valve 22 is closed and the valve 24 opened to deliver

water to section 10. Six and one half hours from the end of the pour valve 30 is closed and valve 34 opened to introduce water into the second section 12. Seven hours after cast, valve 40 is closed and valve 44 opened to deliver water to section 14. Twelve hours after cast, valve 50 is closed and valve 54 opened to deliver water to section 16. The water volume per section is preferably about 30 gal. per min. and remains on all sections until 46 hours after cast at which time valve 24 is closed and valve 22 opened to deliver steam to section 10. Sixty-two hours after cast valve 34 is closed and valve 30 opened to deliver steam to section 12. Eighty hours after cast, valve 44 is closed and valve 40 opened to deliver steam to section 14. Ninety-six hours after cast, valve 54 is closed and valve 50 opened to deliver steam to section 16, and the hot top 9 is stripped. One hundred hours after cast all the valves are closed and the ingot is stripped from the mold. The pressure and velocity of the steam supplied after shutting off the water are less than that of the original steam and the pressure is preferably about 10 p.s.i. Under the above conditions the average heat transfer using the higher pressure steam is twice that when using the lower pressure steam and half that when using water. It will be seen that the water is first turned into the bottom section and then successively to the 12, 14 and 16 sections, but remains on longest to the top section and successively shorter to sections 14, 12 and 10. Also, the water is on much longer than the initial steam. The above procedure results in final solidification of molten steel occurring in the hot top near its junction with the ingot mold. It will be noted that the cooling surface to mold exterior surface ratio is 1.2 to 1 for sections 10 and 14, 1.6 to 1 for section 12 and 0.8 to 1 for section 16.

While I have described one specific embodiment of my invention, it will be understood that the number of sections or zones may vary and that the specific sizes and arrangement of pipe may also vary. While it is preferred to use both steam and water as coolants, either can be used alone. It is also possible to connect the sections together with only one control of flow rather than the four controls shown. In other words, the tubing would be continuous. However, this would require the use of higher pressures and result in poorer control. While four sections are shown, it is possible to operate with only three sections regardless of whether the tubing is continuous or the sections separate as shown. Regardless of which arrangement is used, it is necessary to have the cooling effect per sq. ft. of mold exterior surface in the lower section and in the top section less than the cooling effect of the intermediate section or sections. The reason for having the cooling effect of the bottom section less than the intermediate section is that a large amount of heat is lost through the stool. The reason for having the cooling effect of the top section less is that it is desirable to keep the metal in this section molten as long as possible. For the same reason the top section is terminated below the top of the mold.

Other embodiments and modifications may also be made within the scope of the attached claims.

I claim:

1. In combination with a large generally cylindrical metallic ingot mold having a minimum diameter of approximately 75 inches; a bottom cooling tubular section closely surrounding the outside periphery of said mold adjacent the bottom thereof, a top cooling tubular section closely surrounding the outside periphery of said mold starting a substantial distance from the top thereof with the portion of the mold above the top cooling section being free of cooling sections, at least one

intermediate cooling tubular section closely surrounding the outside periphery of said mold between the top and bottom sections, each of said cooling sections extending substantially completely around the outside of the mold and in heat transfer relationship with the mold surface, and means for introducing a fluid coolant to said sections, said intermediate cooling section being so arranged on said mold surface so as to have a greater cooling effect per square foot of mold surface than said top and bottom sections.

2. The combination of claim 1 in which each of said cooling sections are separate from the others, and said means for introducing a fluid coolant includes a separate feed and a separate control valve to each section.

3. The combination of claim 2 in which the coolant includes both water and steam, and in which said means for introducing a fluid coolant includes a separate water feed and a separate steam feed to each section, and a separate control valve for each feed.

4. The combination of claim 2 in which each tubular section comprises a tube wound helically around the mold, the average pitch of the cooling tubes in the top and bottom sections being greater than the average pitch of the tubes in the intermediate section in order to obtain the greater cooling effect in the intermediate section.

5. The combination of claim 1 in which there are two intermediate sections, the bottom section covering between 20 and 30 percent of the height of the mold, each of the intermediate section covering between 10 and 20 percent of the height of the mold, the top section covering between 20 and 30 percent of the height of the mold, and the top of the mold being bare of cooling sections for a distance between 20 and 25 percent of the height of the mold.

6. The combination of claim 5 in which each of said cooling sections are separate from the others, and said means for introducing a fluid coolant includes a separate feed and a separate control valve to each section.

7. The combination of claim 6 in which the coolant includes both water and steam, and in which said means for introducing a fluid coolant includes a separate water feed and a separate steam feed to each section, and a separate control valve for each feed.

8. The combination of claim 6 in which each tubular section comprises a tube wound helically around the mold, the average pitch of the cooling tubes in the top and bottom sections being greater than the average pitch of the tubes in the intermediate section in order to obtain the greater cooling effect in the intermediate section.

9. The combination of claim 1 in which each tubular section comprises a tube wound helically around the mold, the average pitch of the cooling tubes in the top and bottom sections being greater than the average pitch of the tubes in the intermediate section in order to obtain the greater cooling effect in the intermediate section; and said combination including a covering of heat transfer cement substantially surrounding said tubes, and a stool at the bottom of said mold, said stool being free of cooling sections.

10. The combination of claim 9 in which there are two intermediate sections, the bottom section covering between 20 and 30 percent of the height of the mold, each of the intermediate section covering between 10 and 20 percent of the height of the mold, the top section covering between 20 and 30 percent of the height of the mold, and the top of the mold being bare of cooling sections for a distance between 20 and 25 percent of the height of the mold.

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