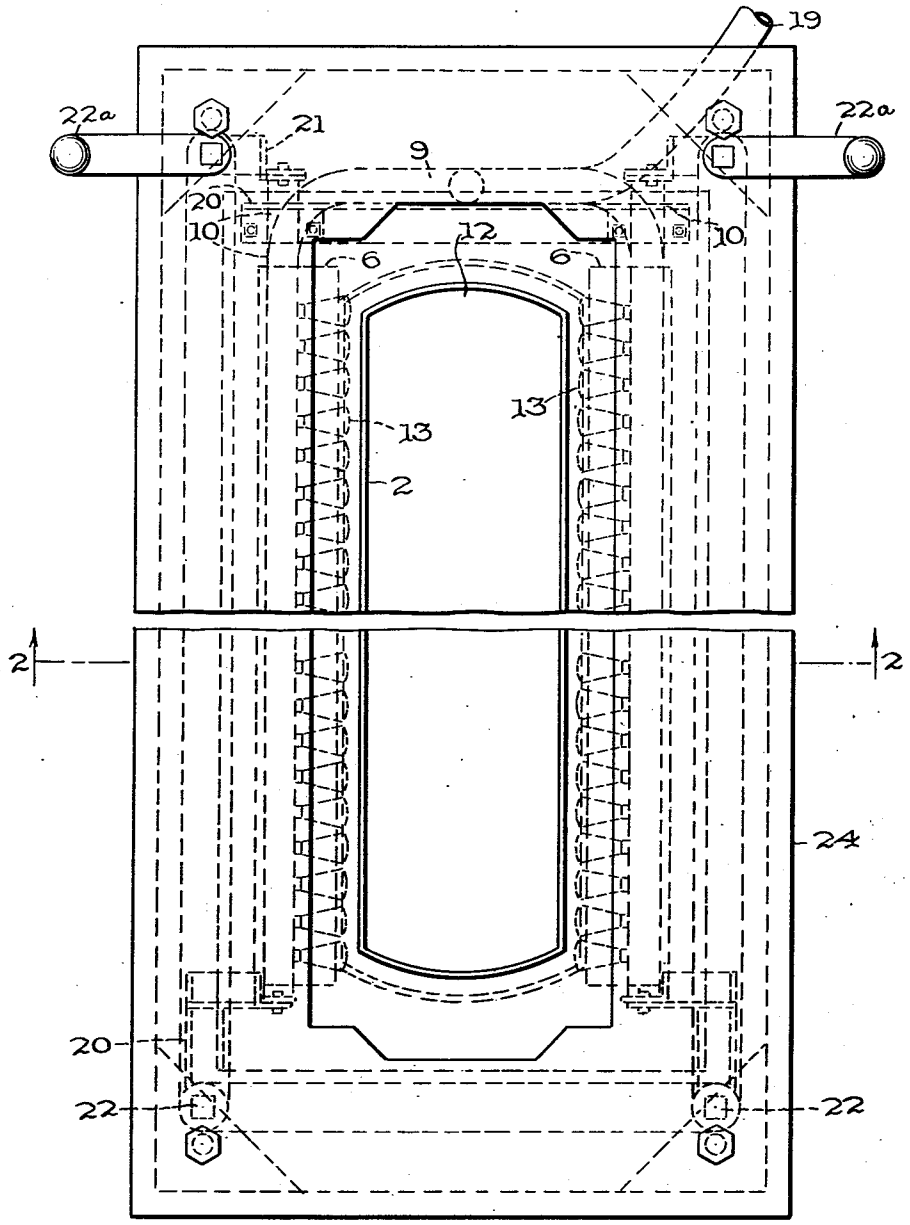
July 16, 1957 P. P. ZEIGLER 2,799,068

METHOD OF CASTING METALS

Filed Sept. 3, 1953 4 Sheets-Sheet 1

FIG. 1.



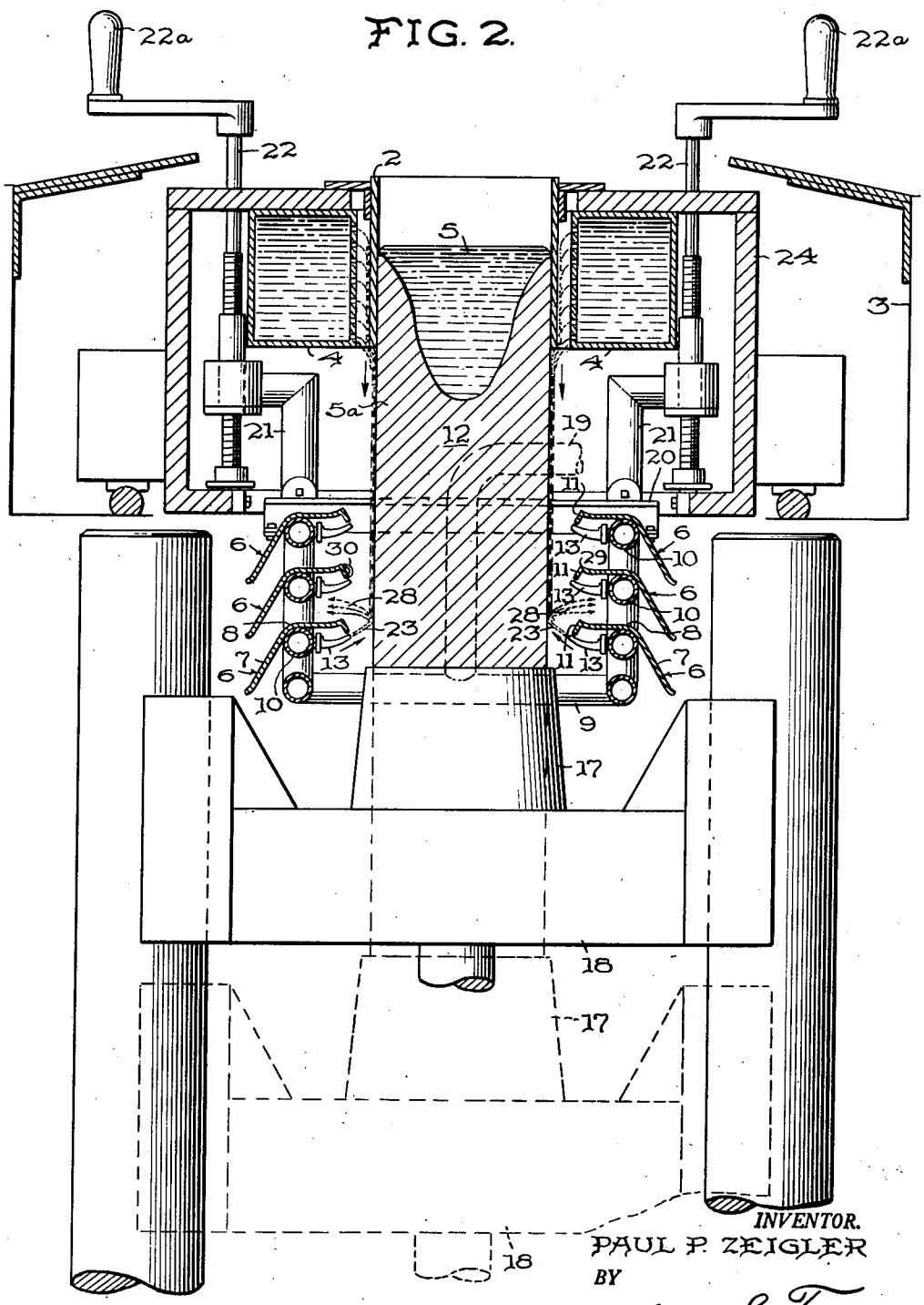
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METHOD OF CASTING METALS

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FIG. 2.



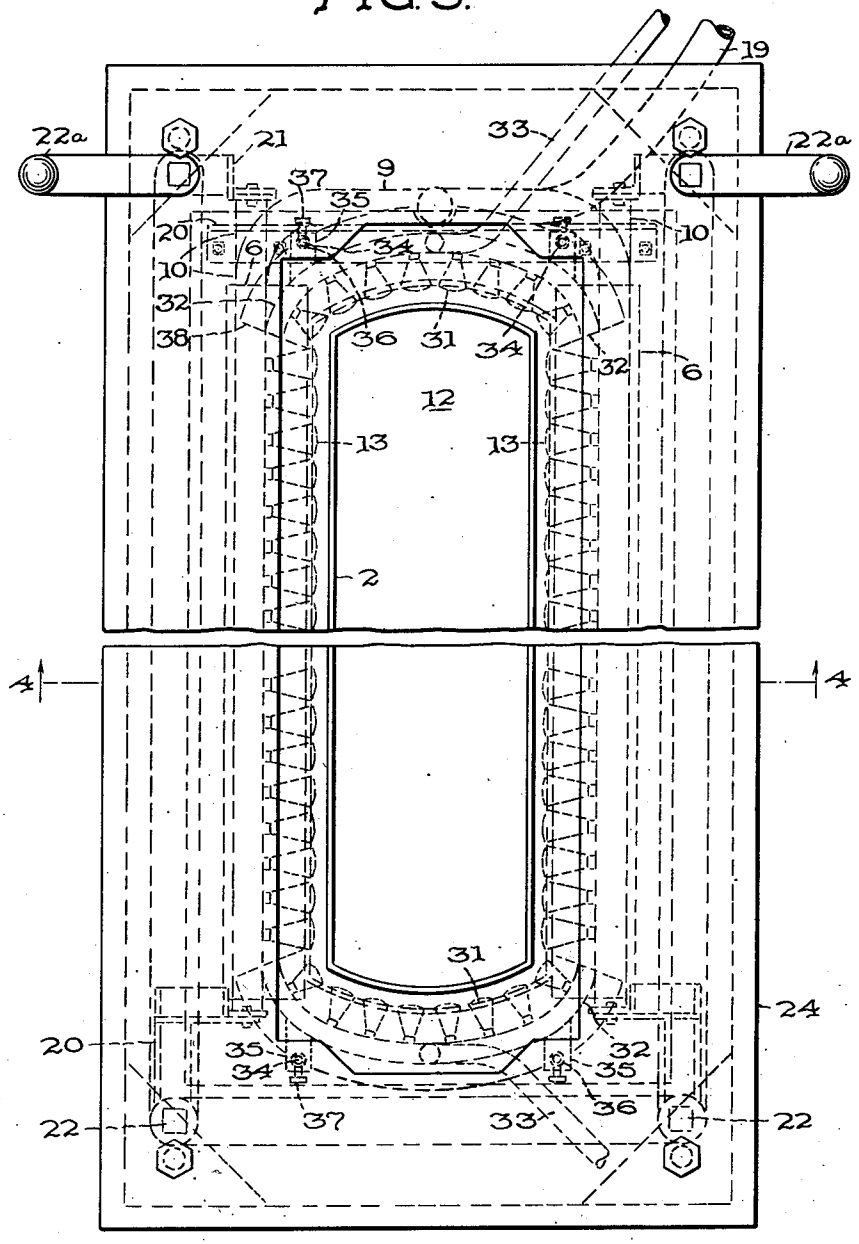
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METHOD OF CASTING METALS

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FIG. 3.



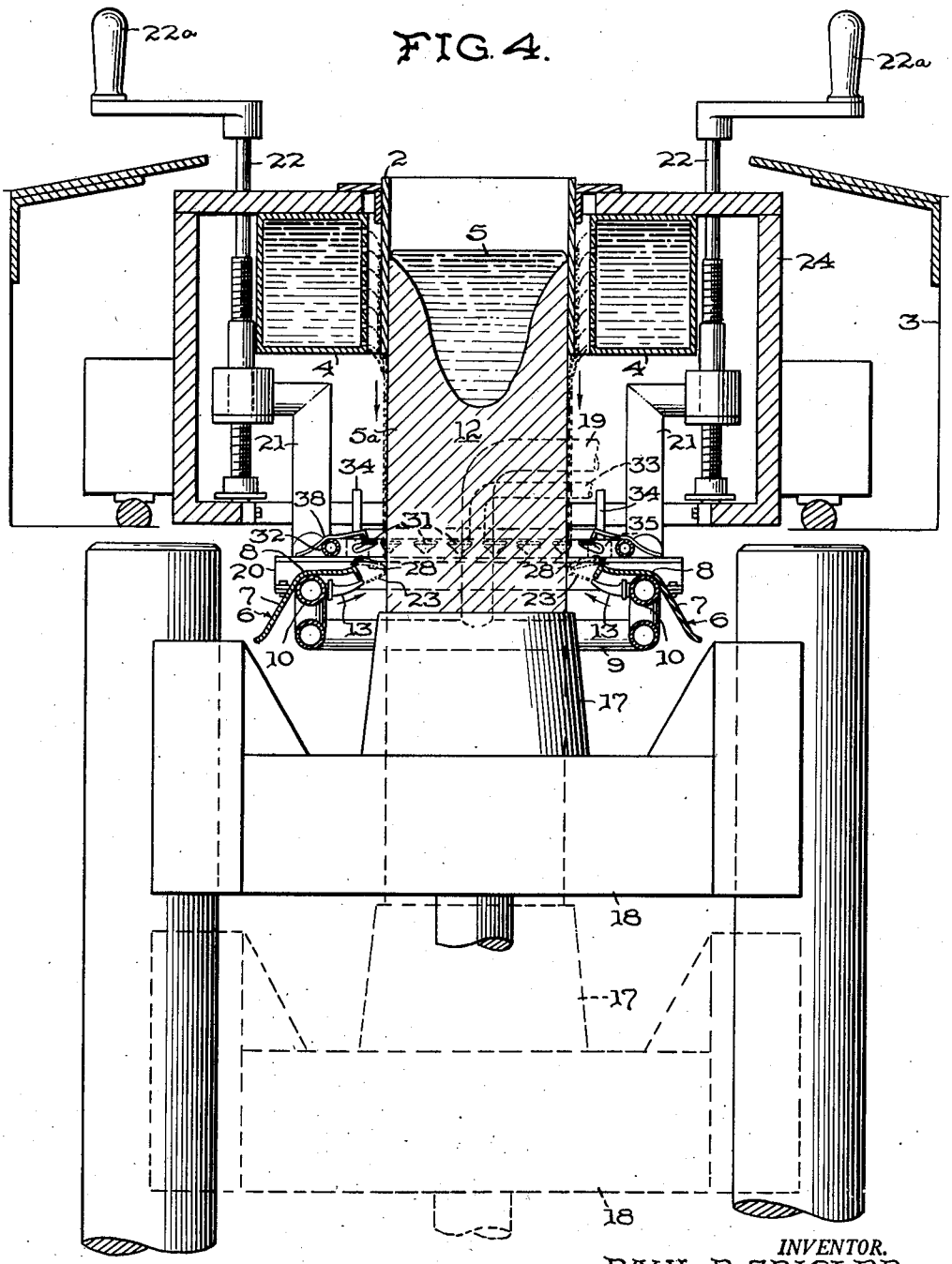
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METHOD OF CASTING METALS

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FIG. 4.



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2,799,068

METHOD OF CASTING METALS

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Application September 3, 1953, Serial No. 378,365

10 Claims. (Cl. 22—200.1)

This invention relates to the casting of metals. It more particularly relates to a method for controlling the cooling of continuously cast ingots having a rectangular or substantially rectangular cross-sectional configuration.

This application is a continuation-in-part of my copending application Serial Number 158,289, filed April 26, 1950, now abandoned.

In the continuous casting of various metals, including aluminum and aluminum alloys, molten metal is fed into one end of an open-ended mold shell and is partially cooled therein to at least form an outer shell of solidified metal. The casting is continuously withdrawn by any suitable means from the opposite end while at the same time a supply of coolant, usually water, is applied continuously to the mold and/or to the solid casting as it emerges from the mold. The term "continuous" casting referred to herein is intended to include casting procedures which may be of a strictly continuous nature (in which the casting is cut to length without interruption of the casting procedure) or where the casting is of a semicontinuous nature; i. e., a casting of desired length may be cast, the flow of metal stopped, the casting removed and the procedure commenced anew. In the casting of aluminum and aluminum alloys, one method commonly used is that disclosed in the Ennor Patent No. 2,301,027.

In the Ennor patent the cooling is accomplished by means of a water spray directed around the periphery of the mold shell by means of spray pipes or a spray box. Water jets impinge upon the outer surface of the mold and the embryo ingot as it emerges below the mold. The amount of water applied or the amount of cooling accomplished is uniform about the periphery of the mold and casting. Although Ennor utilizes spray means for cooling the mold shell, other well known means may be used such as a cooling jacket surrounding the mold shell. In such case, the cooling fluid may not ultimately flow down onto the ingot surface and add to the cooling fluid applied directly to the ingot and it may be necessary to increase the volume of cooling fluid applied directly to the ingot in order to provide the desired rate of heat abstraction from the metal.

In all of these prior cooling methods the water which is applied to the mold and/or the casting is allowed to run down the full length of the surfaces of the ingot below the mold. While the application of coolant directly to the embryo ingot immediately upon emergence from the mold shell has served to promote rapid freezing and to improve metallurgical quality considerably, it has been found in the casting of certain high strength aluminum alloy ingots of substantially rectangular cross-section that the uninterrupted flow of coolant down the ingot surfaces leads to excessive internal stresses resulting in the occurrence of defects such as center cracks which render the ingots unsuitable for working or machining and thus result in considerable economic loss to the industry. Additionally, rectangular ingots, wherein the thickness is small relative to the length and width, are particularly

susceptible to the defects of corner and/or edge cracking. Ingots of such shape or configuration are commonly referred to as sheet ingots. These defects are caused by excessive cooling of the lower sections of the ingot or billet giving rise to undesirably high temperature gradients between the inner and outer portions of the ingot or billet. That is to say, if the large volume of cooling water required for rapid cooling of the mold to form the shell of the ingot and/or of the part of the embryo ingot just below the mold is allowed to run down too great a distance below the bottom of the mold excessive heat abstraction takes place and the aforementioned defects will develop. This distance will vary with the type of alloy and with the size of the ingot or billet being cast, as well as other factors involved in any conventional casting operation. The term "edges," as used herein, is defined as the relatively narrow longitudinally extending surfaces of the ingot as distinguished from the relatively wide ingot faces. The term "corner," as used herein, is defined as the point or place which joins an ingot edge to an ingot face.

The excessive cooling of the ingot can be effectively prevented by means of this invention, wherein there is a controlling of the coolant flowing down over the lower portion of the ingot and a restriction of its length of travel down the surfaces of the ingot at predetermined levels. More particularly, it has been found that the occurrence of center cracking can be eliminated or substantially eliminated by removing all or substantially all of the coolant from the ingot surfaces at a predetermined level below the bottom of the mold shell. Not only is the incidence of center cracks substantially reduced or eliminated but at the same time desirable control may be had over metallurgical characteristics such as grain size, shrinkage porosity and size and dispersion of alloy constituents. Although the removal of the coolant from the ingot surfaces at a predetermined level below the mold shell eliminates or substantially eliminates the occurrence of center cracking while allowing desired control over other metallurgical characteristics, it was found that in some instances the defects of corner and/or edge cracking persisted to an undesirable extent. By means of this invention it has been found that the occurrence of corner and/or edge cracking can also be eliminated or substantially eliminated by removing all or substantially all of the coolant flowing down the corner and/or edge portions of the ingot at a predetermined level or levels closer to the bottom of the mold shell than the level of removal of coolant from the faces of the ingot. The distances from the bottom of the mold shell where the coolant is removed from the various ingot surfaces is determined by factors such as chemical composition of the ingot, size of ingot, rate of ingot withdrawal from the mold shell, etc.

Various means may be used for removing the cooling fluid but it has been found preferable to make use of an air jet wiper located at the proper distances from the bottom of the mold and which discharges air streams against the downwardly flowing coolant to deflect the coolant off of the ingot surfaces.

Although the method of the instant invention has been found particularly adapted for use in the continuous casting of aluminum alloys, its use is not restricted thereto and it can be successfully employed in any continuous casting process for metals such as that for steel, where the danger of center, edge, and corner cracking and other serious defects caused by excessive cooling of the ingot or billet exists.

Accordingly, it is an object of this invention to provide an improved method of continuously casting ingots of substantially rectangular cross-section wherein the ingot is long and wide as compared with its thickness.

Another object of this invention is to provide an improved method for eliminating or substantially eliminating various defects caused by excessive cooling in the continuous casting of substantially rectangular ingots and billets, i. e., sheet ingots or the like.

A more specific object of this invention is to provide an improved method for the continuous casting of sheet ingots, particularly of high strength aluminum alloys, wherein corner and/or edge cracking, as well as center cracking, are eliminated or substantially eliminated by control of the rate of heat abstraction from the ingot surfaces.

A further object of this invention is to provide a novel means for preventing excessive cooling of ingots, billets and the like during continuous casting thereof.

Further objects and advantages of the invention will be apparent from the following detailed description taken in conjunction with the drawings, wherein:

Figure 1 is a broken plan view of one form of apparatus for performing the invention and shows the general arrangement of a continuous casting mold for sheet ingots and the air wipers used therewith;

Figure 2 is a vertical, sectional view taken along line 2—2 of Figure 1, the position assumed by the ingot as it is lowered from the mold being shown in dotted lines;

Figure 3 is a broken plan view of a modification of the apparatus of Figures 1 and 2 for performing the invention and shows the general arrangement of a continuous casting mold for sheet ingots and a modified arrangement for the air wipers shown in Figures 1 and 2, and

Figure 4 is a vertical, sectional view taken along line 4—4 of Figure 3, the position assumed by the ingot as it is lowered from the mold being shown in dotted lines.

With further reference to the drawings and particularly Figure 2, there is shown one form of apparatus for practicing the invention which comprises a mold shell **2** suitably mounted over a casting pit **3** by any of the conventional means. Within the mold shell **2** and extending therebelow is an embryo ingot **12** comprising a pool of molten metal **5** and solidified casting **5***a*, the pool **5** extending downwardly and forming a liquid crater or core within the ingot. The molten metal is continuously poured into the mold by any of the means commonly used. The solidified portion of the ingot rests upon a block **17** which block in turn is mounted upon a vertically adjustable platen **18**.

Means are provided for cooling the mold shell **2** and also for directly cooling the embryo ingot **12** as it emerges from the shell. These means may suitably consist of the spray boxes **4** containing the cooling water. These boxes encircle the ingot. From these spray boxes water is directed against the outer surfaces of the mold shell **2** and the surfaces of the embryo ingot emerging therefrom. Affixed to each of these spray boxes is a header tank (not shown) connected to the spray box by suitable means for regulating the amount of water head in the boxes.

Located at predetermined distances below the bottom of the mold shell **2** is a plurality of air jet nozzles **13**, which project from segments of the air header pipe **9**. The air header pipe **9** is comprised of a lower U-shaped portion, to each leg of which there is connected by suitable means and in gas flow relation therewith a plurality of pipe segments **10** of substantially the same length as and mounted parallel with each lower leg. It is to these segments **10** that nozzles **13** are connected. These nozzles are mounted in battery formation and several tiers of nozzles are provided at each face of the ingot. The nozzles are mounted in such a manner as to direct air streams **23** against the surfaces of the ingot emerging from the mold shell and to remove the water flowing down the ingot surfaces. These nozzles can be made active or inactive, as required.

In the practice of the instant invention, the end nozzles of the first and/or second tier are made active, thereby allowing the coolant to flow down the ingot faces until it is removed by the active nozzles spaced from the ends of the second and/or third or last tier, as the case may be. It will thus be seen that by proper selection of active nozzles the line of coolant removal for the corners and edges of the ingot occurs at a level or distance closer to the mold shell than the line of coolant removal for the faces of the ingot. By removing the coolant from the corners and edges of the ingot, which are normally subject to a greater rate of heat abstraction, at a level closer to the mold shell than the level of removal of coolant from the ingot faces, the serious defects of corner and/or edge cracking, as well as center cracking, are eliminated or substantially eliminated. Although Figure 2 shows three tiers of nozzles on each side of the ingot, it is to be understood that two tiers can be used satisfactorily. The provision of more than two tiers of nozzle is desirable, however, in that it permits greater adjustability of the levels of coolant removal for the faces, edges and corners of the ingot.

The air wipers are generally positioned such that the air streams are directed toward the ingot surfaces at an angle of from 20° to 50° with respect to a horizontal plane normal to the ingot face. The wipers are spaced back from the ingot surface to allow ample clearance between the nozzles and the ingot surface. In most instances a spacing of from ⅜ to 1½ inches has been found to give a satisfactory deflection clearance about the nozzles, thereby avoiding the dropping of water back into the nozzles which would interfere with the otherwise smooth action of the wiper. The air pressure is maintained at a figure suitable for producing substantially clean lines of coolant removal. To avoid the effect of line pressure variations, a pressure regulator may be used on the inlet side of a control valve (not shown) so that the outlet pressure will remain constant for a given predetermined setting of the valve.

The term air jet, as employed herein is intended to apply to any gas, including nitrogen, the noble gases as well as any other gaseous media. Obviously, air is the most economic gas for such use and is not hazardous in the continuous casting of aluminum and the majority of other metals.

Although other means may be used for ensuring complete removal of the water initially removed by the nozzles, it is contemplated that there be associated with each battery of nozzles a horizontally mounted deflector baffle **6**. These baffles are successively bent along their lengths so as to form an inclined drain surface **7**, a curved portion **8** fitting about the upper outer periphery of the aforementioned pipe segments **10** of air header pipe **9**, and finally end in a downwardly turned flange **11** located above the tips of the nozzles **13**. The water **28** removed from the faces of the ingot is deflected against the baffles **6**, whence it finally flows down over the drain surface **7** thereof, and into a suitable drain (not shown).

The air header pipe **9** is connected to a suitable source of compressed air supply such as by means of pipe **19**. Associated with this pipe but not shown is an air pressure gauge and a control valve provided with a setting indicator for regulating the pressure of the air being emitted from the nozzles **13**.

Each end of the air header pipe **9** may be mounted upon a bracket **20** and L-shaped arms **21** may be connected directly to the air header pipe **9** as indicated in Figures 1 and 2 or to this bracket. These arms are threadedly mounted upon shafts **22** suitably mounted on the frame **24**, said frame also serving to mount the mold shell **2**. When shafts **22** are turned by the cranks **22***a* they will thereby cause brackets **20** and air header pipe **9** to move upwardly or downwardly so that air header pipes **9** and jet nozzles **13** may be drawn up or down with respect to the mold shell **2** and be placed at a greater or smaller distance from the mold shell, which distance will in turn be governed by such factors as the chemical composition of the alloy being cast, the size of the ingot

or billet being cast, rate of withdrawal of the casting from the mold shell as well as other factors involved in any continuous casting operation. Also, by this means this distance can be adjusted during casting if necessary.

The nozzles **13** are of a design which will deliver a uniform stream of air and can be of a standard type. These are preferably mounted closely together as shown in Figure 1 to give satisfactory coverage for the ingot surfaces.

In Figure 2 there is also shown a longitudinal, curved metal guard **30** on one of the baffle flanges which may be welded to each baffle flange **11** to protect the nozzles **13** during the removal of the ingot and to prevent molten metal splash from the ingot from clogging them.

In the operation of the instant device it has been found desirable to flange the baffles **6** downwardly above the air nozzles to form a sharp or almost normal junction between air stream **23** and baffle flange **11** to avoid the creation of a partial vacuum at the point of alignment of the nozzles and baffles, which would tend to pull deflected water **28** back into the air stream **23**. On the other hand, the proper curvature of the right angle bends **29** on the top or base of the flanges **11** causes a desirable partial vacuum at a proper point at the bend **29** which is in the deflected stream of combined air and water which passes over it during operation. The partial vacuum pulls the deflected stream downward and over the drain baffle and helps prevent bounce and interference with the smooth water flow on the ingot above the point of water removal.

Although the general arrangement of apparatus described hereinabove in conjunction with Figures 1 and 2 is satisfactory in performing the method of the instant invention, it has been found preferable to utilize the modified arrangement as shown in Figures 3 and 4 wherein a single tier of nozzles is provided around the entire periphery of the ingot and wherein the nozzles along the edge and corner surfaces of the ingot are positioned at a level closer to the mold shell than in the case of the nozzles along the ingot faces. The structure in Figures 3 and 4 is substantially the same as that disclosed in Figures 1 and 2, with the exception that the number of tiers of nozzles along the ingot faces has been reduced to one and a battery of nozzles has been added at each ingot edge, and the reference numerals indicate like parts in each figure.

As can be seen from Figures 3 and 4, a single row of nozzles **13** has been provided for each ingot face. At the edges and corners of the ingot is provided a separate row or battery of nozzles **31**. These nozzles **31** are mounted on a suitable arcuate pipe member **32** which, in turn, is connected to a suitable source of compressed air supply such as by means of pipe **33**. As in the case of pipe **19**, pipe **33** has associated therewith an air pressure gauge and a control valve provided with a setting indicator for regulating the pressure of the air being emitted from the nozzles **31**.

Pipe member **32** is preferably adjustably mounted on bracket **20**. Projecting upwardly from bracket **20** are rod members **34**. Pipe member **32** is provided with block members **35**. Each block **35** has a vertical aperture **36** therein in alignment with a rod **34** and adapted to receive the rod in sliding engagement. Blocks **35** are also provided with a threaded horizontal aperture opening into the vertical aperture. Within the horizontal aperture is provided a set screw **37** for rigidly securing pipe member **32** to rods **34**. It will be seen that by this means set screws **37** may be loosened, pipe member **32** and mounted nozzles **31** moved vertically upward or downward to adjust the position thereof, as desired, relative to nozzles **13** and fixed in this position by tightening set screws **37** upon guide rods **34**. It will be understood that nozzles **31** could suitably be mounted independently of bracket **20**.

Associated with nozzles **31** for ensuring complete removal of water initially removed by the nozzles from the edges and/or corners of the ingot is a horizontally mounted deflector baffle **38** which is of substantially the same configuration as baffle **6**. Baffle **38** is provided with suitable cut-out portions about blocks **35** and pipes **19** and **33**.

It is to be understood with respect to the nozzle arrangements shown in Figures 1 to 4 that, if desired, provision can be made for regulating the air under pressure emitted from each active nozzle so that the amount of coolant removed from the ingot by any one nozzle would be controlled.

As an example of the instant invention, a sheet ingot 13" x 38" of the well-known aluminum alloy 75S was cast. This particular alloy ingot is particularly susceptible to cracking defects when cast by continuous direct-chill processes as heretofore known wherein the coolant was allowed to flow uninterruptedly down the ingot surfaces. The chemical composition of the metal cast was 1.60% copper, 0.12% silicon, 2.60% magnesium, 0.20% iron, 5.75% zinc, 0.20% chromium, 0.10% manganese, 0.05% titanium, balance aluminum. The ingot length was approximately 105 inches. The pouring temperature of the molten metal was about 1275° F. Water was used as the coolant fluid with a flow rate of about 180 gallons per minute and at a temperature of about 54° F. The coolant was removed from the ingot faces at a level about 12 inches below the mold shell while the coolant was removed from both the edges and corners of the ingot at a level about 10 inches below the mold shell. The rate of ingot withdrawal was 2.75 inches per minute. The forward ends of the air nozzles were spaced back from the ingot surfaces about ¾ inch and the air pressure at the nozzles maintained at about 7 p. s. i. The air streams emitted from the nozzles were directed upwardly against the ingot surfaces at an angle of about 25° with respect to a horizontal plane normal to the ingot surface. This ingot was cast free of edge, corner and center cracks.

It will thus be seen that by practice of the instant invention it is now possible to continuously cast rectangular or substantially rectangular ingots, i. e., sheet ingots or the like, which are free or substantially free of edge and corner cracking as well as center cracking caused by excessive cooling of the lower portions of the ingot by proper control of the removal of the coolant from the ingot surfaces. While the invention is particularly suited for the casting of high strength aluminum alloys, it can be advantageously applied to the casting of other metal where similar problems exist.

It will be obvious that various modifications and alterations may be made in this invention without departing from the spirit and scope thereof and it is not to be taken as limited except by the appended claims herein.

What is claimed is:

1. In the continuous casting of metal ingots of substantially rectangular cross-section wherein molten metal is supplied to an open mold shell, is partially cooled therein to at least form an outer shell of solidified metal, and a liquid coolant is applied to the ingot emerging from said mold shell, the improvement which comprises effectively removing substantially all of the coolant from the ingot surfaces at different levels spaced below the mold shell, the coolant at the corners of the ingot being removed at a level closer to said mold shell than the level at which the coolant is removed from the ingot faces and applying no significant amount of coolant to the ingot surfaces below said levels of coolant removal.

2. In the continuous casting of metal ingots of substantially rectangular cross-section wherein molten metal is applied to a mold shell, is partially cooled therein to at least form an outer shell of solidified metal, and a liquid coolant is applied to the ingot emerging from said mold shell, the improvement which comprises effectively removing substantially all of the coolant from the ingot around the periphery thereof at different levels spaced

below the mold shell, the level of coolant removal at the corners and edges of said ingot being closer to the mold shell than the level of coolant removal at the ingot faces, and applying no significant amount of coolant to the ingot surfaces below said levels of coolant removal.

3. A method according to claim 2 wherein gas streams are directed upwardly against the ingot surfaces to thereby remove the coolant therefrom.

4. In the continuous casting of metal ingots of substantially rectangular cross-section wherein molten metal is supplied to an open mold shell, is partially cooled therein to at least form an outer shell of solidified metal, and a fluid coolant is applied to the ingot emerging from said mold shell, the improvement which comprises effectively removing substantially all of said coolant from the ingot surfaces at different levels spaced below said mold shell, the coolant on the edges of said ingot being removed on a level closer to the bottom of the mold shell than the level at which the coolant is removed from the faces of the ingot, and applying no significant amount of coolant to the ingot surfaces below the levels of coolant removal.

5. In the continuous casting of light metal sheet ingots wherein molten metal is supplied to an open mold shell, is partially cooled therein to at least form an outer shell of solidified metal, and a liquid coolant is applied to the ingot emerging from said mold shell, the improvement which comprises effectively removing substantially all of the coolant from the ingot surfaces at different levels spaced below the mold shell and wherein at least that portion of the coolant on the corners of said ingot is removed at a level closer to the bottom of said mold shell than the level of removal of coolant from the ingot faces, and applying no significant amount of coolant to the ingot surfaces below the levels of coolant removal.

6. A method according to claim 5 wherein the metal is predominantly composed of aluminum.

7. A method according to claim 5 wherein gas streams

are directed upwardly against the ingot surfaces to thereby remove the coolant therefrom.

8. A method according to claim 5 wherein the coolant on the ingot edges is removed at a level closer to the bottom of the mold than the level of removal of coolant from the ingot faces.

9. In the continuous casting of sheet ingots wherein molten metal is supplied to an open mold shell, is partially cooled therein to at least form an outer shell of solidified metal and a liquid coolant is applied to the ingot emerging from said mold shell, the improvement which comprises effectively removing the coolant from the ingot surfaces at levels spaced from the mold shell and below which substantial center cracking would occur, the coolant on at least the corners of said ingot being removed at a level closer to the bottom of the mold shell than the level of coolant removal from the ingot faces to substantially reduce corner cracking, and applying no significant amount of coolant to the ingot surfaces below the levels of coolant removal.

10. A method according to claim 9 wherein the coolant on the ingot edges is removed at a level closer to the bottom of the mold shell than the level of coolant removal from the ingot faces to substantially reduce edge cracking.

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