United States Patent

Kocks

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[54] **PROCESS FOR CASTING METAL WITH VERTICAL POURING AND HORIZONTAL COOLING**

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[51] **Int. Cl.** **B22d 13/00**
[58] **Field of Search**......164/136, 116, 337, 114–118, 164/107, 298, 127, 98; 249/137

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[57] **ABSTRACT**

A method and apparatus are provided for casting metals wherein the molten metal is cast into the top of an upright ingot mold whose axis is in a generally vertical position, the mold is capped, and then rotated so that its axis is on the horizontal position and cooling the metal in the mold while holding it with its axis in said horizontal position.

9 Claims, 6 Drawing Figures

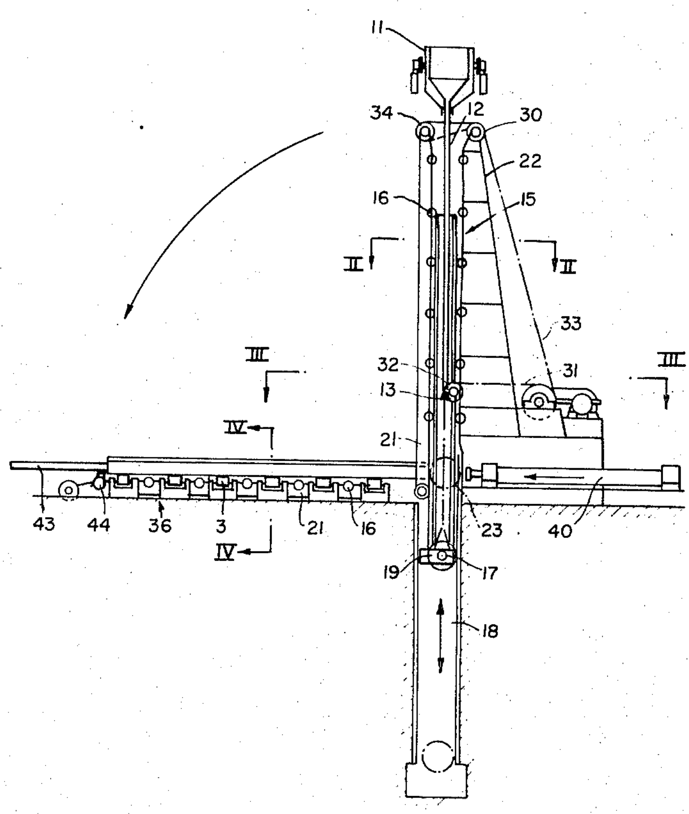

Fig. 1

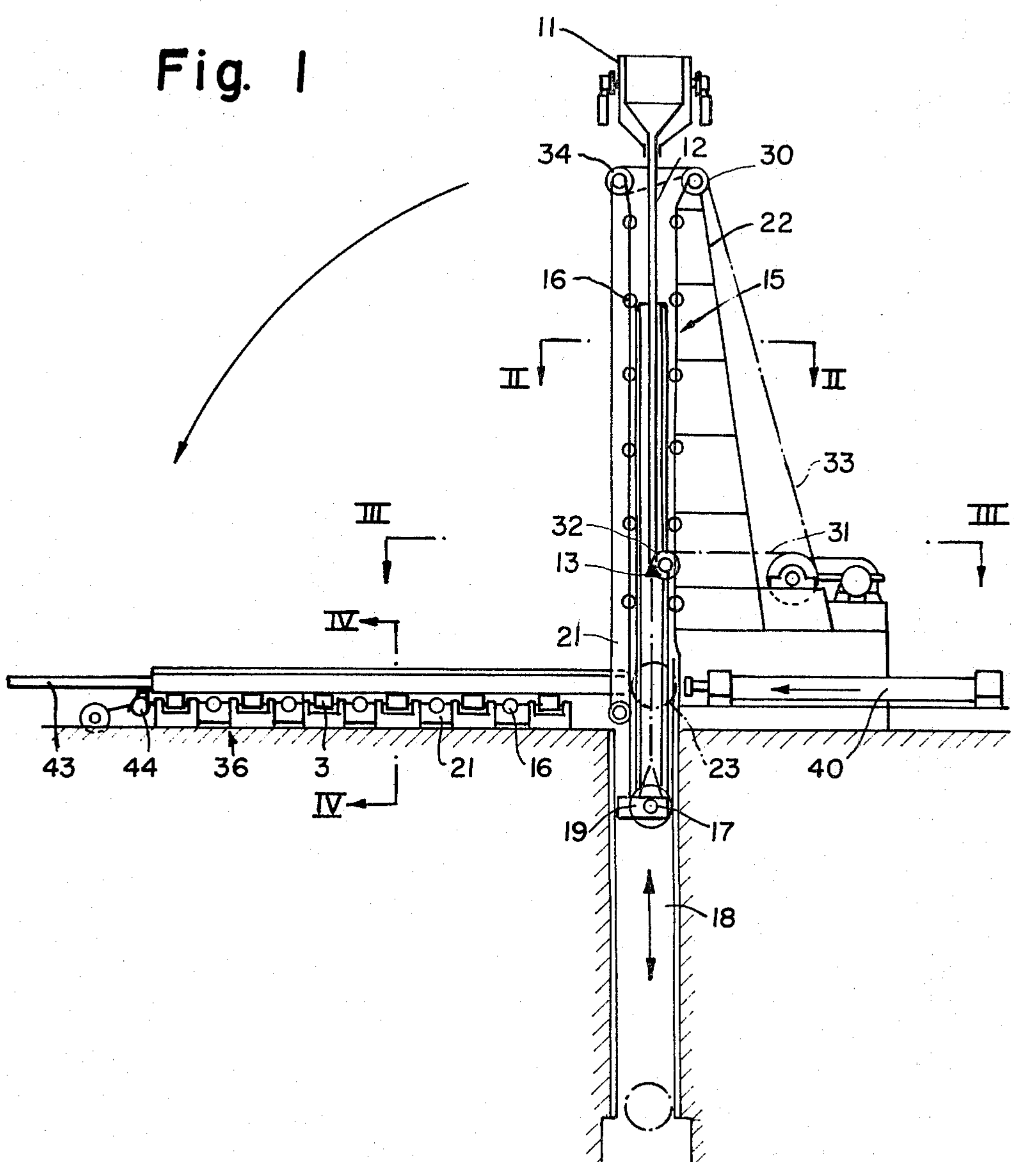

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Fig. 2

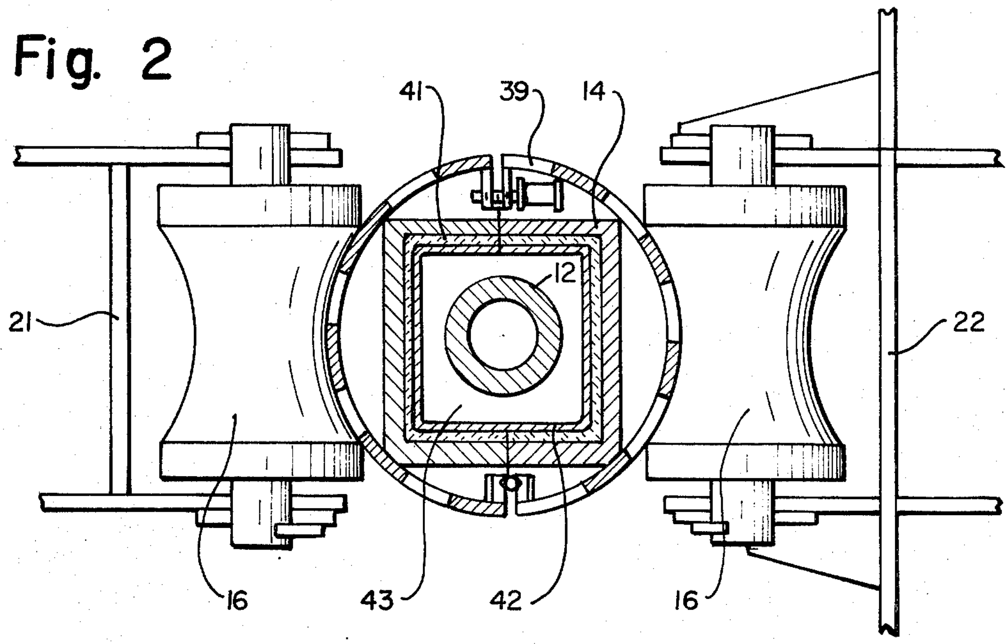

Fig. 3

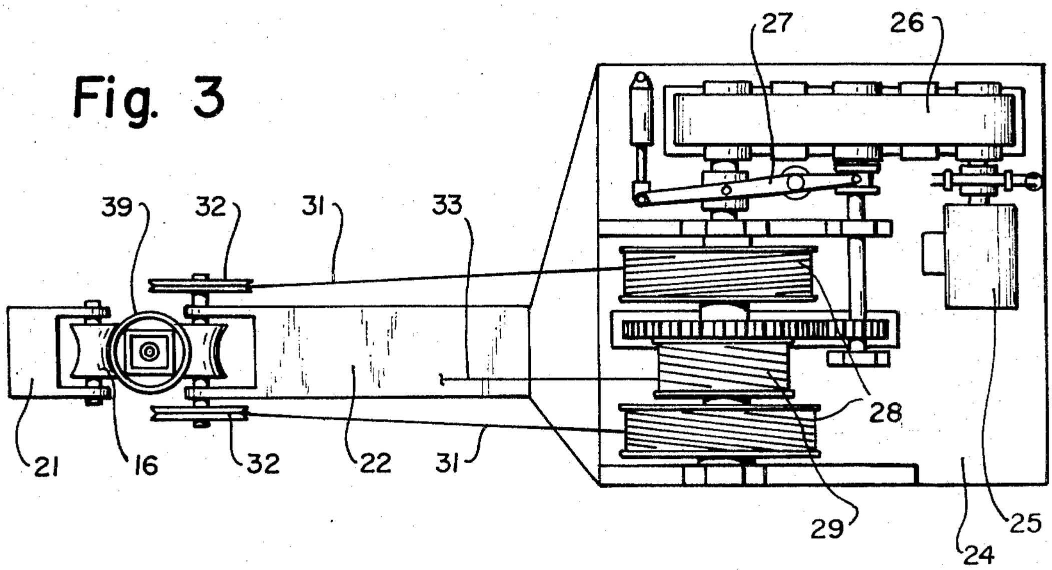

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Fig.5.

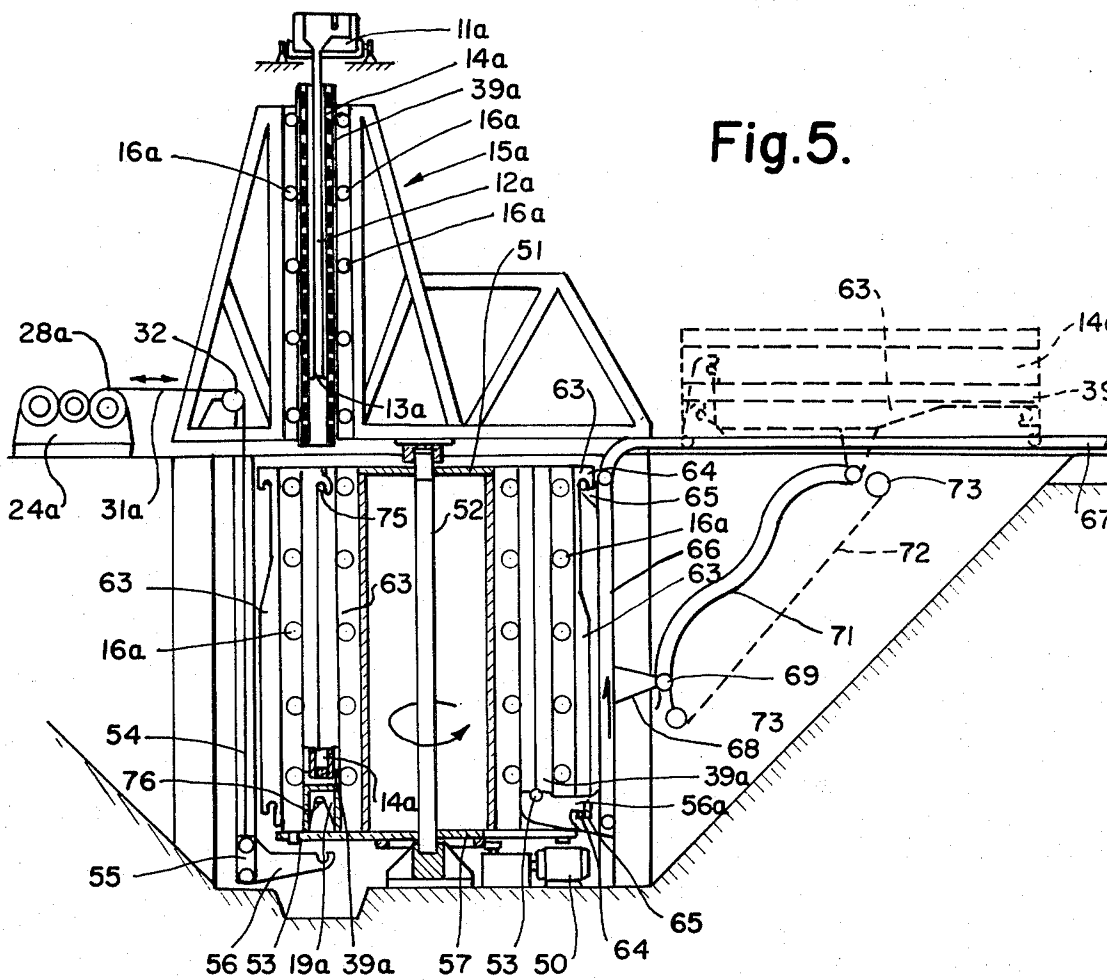
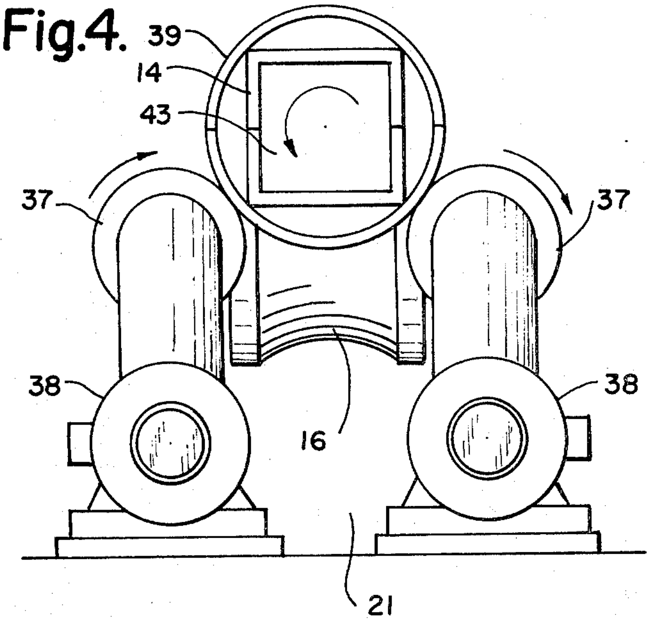


Fig.4.



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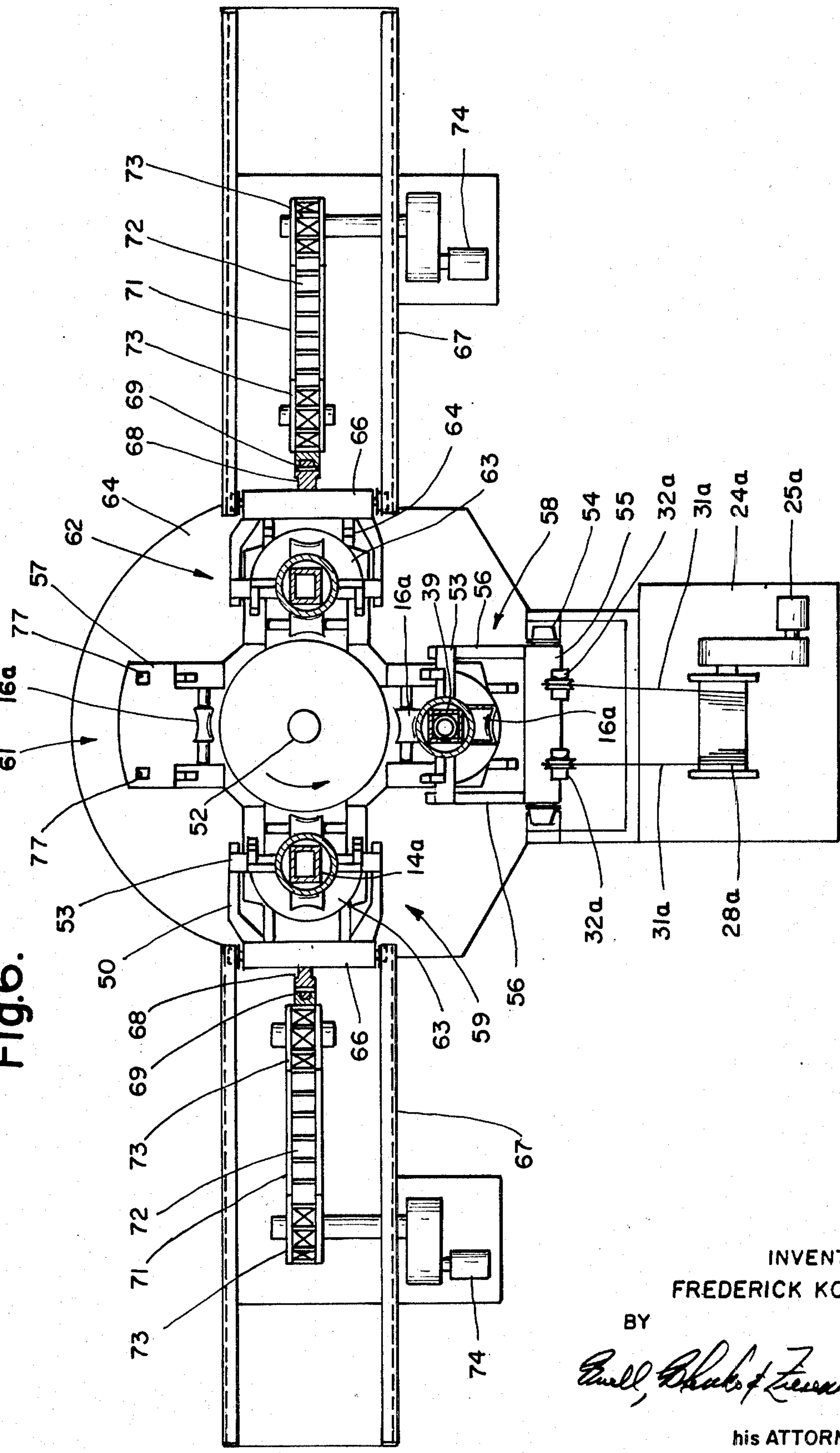

Fig.6.

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PROCESS FOR CASTING METAL WITH VERTICAL POURING AND HORIZONTAL COOLING

This invention relates to methods for casting metals and particularly to a process for casting metals where the liquid metal is cast into an open ingot mold out of a furnace or a ladle.

Liquid metal cast into open top ingot molds is generally known as "top poured". The ingots produced by this method are recognized to have a series of inherent disadvantages such as low casting speed, high porosity and segregations. There are a number of methods known to inhibit porosity and segregations and to improve surface of ingot. Known methods are, however, costly for casting of high volume steel and are therefore not generally accepted and used.

Furthermore it is known to continuously cast steel into relatively small billets. This usually is done by means of a casting tower with a water-cooled copper mold which cools the metal with more or less penetration of the outer zone until a solidified casting is obtained. Support and stripper rolls are used for transporting the billet, so that the center of the billet is also solidified. Billets are then cut to length and are further processed in rolling mills.

Conventional continuous casting machines have a relatively small capacity to absorb liquid metal and require relatively high investment cost. The billet surface quality is often unsatisfactory. Another serious quality deficiency in ordinary continuous casting practices is the forming of cracks, hairline cracks, piping due to high cooling rate applied to outer zone versus the relatively long remaining liquid center. The ratio of strand length to strand cross section is too great so that the solidifying and shrinking inner zone is not supplied with sufficient material from the outer zones.

The danger of similar effects also exist for top pouring of ingots but only to a minor extent because of the generally low ratio of ingot height to cross section where sufficient liquid material can be supplied from the head of ingots. When applying short ingot molds and the top pouring method a certain casting speed cannot be exceeded since the ingot wall promoting quick solidification cannot withstand the ferrostatic pressure originating from the ingot center. Longitudinal cracks occur in which air penetrates oxidizing the surface which in subsequent rolling prevents cracks from welding together. The tendency of producing such cracks increases with increased ingot heights in order to obtain the more favorable crosssections for rolling as derived through continuous casting.

The objective of this invention lies in preventing the above stated disadvantages and in developing a casting method for absorbing high volume of liquid metal and producing homogenous ingots or billets free of surface defects and piping. The solution to this objective consists of a process including the steps of capping the ingot-mold immediately on filling and swinging the same immediately into a horizontal position. A capping of the ingot can be achieved by spraying water on top of the ingot or by closing the top with a suitable cover. This cap could be equipped with a mandrel submerging in the liquid metal which would freeze-in the ingot top because of high heat transmission capability.

A pivoting of the closed ingot mold into a horizontal axis provides the advantage that even at great heights

of ingot mold, when pivoted into the horizontal, a reduction of ferrostatic pressure is achieved thus preventing forming of cracks. Therefore, this method lends itself to produce ingots with a height to diameter ratio of at least 20:1 and preferably in excess of 40:1. This practice is especially advantageous for pouring the metal at high speed, for instance ten times conventional speed in the ingot mold. The rapid filling of the ingot-mold reduces the time differential between initiation of skin formation between beginning and end of pouring, achieving a uniform formation of solidification of outer zone. In order to keep the relative light outer zone as thin as possible and to avoid stresses between solidified skin and liquid inner zone, the ingot mold can be rotated about its longitudinal axis, vibrated or put in a pendulum type motion. An unprecedented uniform cooling can thus be achieved, resulting in a very homogenous ingot, free of porosity. The porosity would then occur in the ring zone between the solidified skin and the ingot mold.

Solidification velocity initiated from the outer skin can be influenced to a great extend by insulating materials. This can be achieved by lining the mold with fireproof materials on inside and outside of mold or by inserting a cartridge consisting of paper or synthetics.

Special advantages are gained by applying a so-called cartridge method, utilizing a thin-walled steel cartridge liner inserted in the ingot-mold prior to casting. The steel cartridge fuses itself with the liquid metal providing an excellent surface for the ingot, eliminating oxidized cracks and splashed metal deposits since the oxygen is barred from entering the ingot surface welded with liquid metal.

The cartridge can consist of the same material as the liquid metal. A plated type ingot can be obtained when the steel cartridge is made of a different material than the ingot. Sudden filling of the ingot makes it possible to cast ingots at an advantageous ratio of length to cross section. Therefore the described invention permits a process combining the favorable economy of continuous casting and the higher quality of conventional ingot practice. Using the top-pour method with sufficient insulation and rotation of ingot, a uniform temperature distribution over the ingot length and cross section is achieved so that ingot can be processed at any desired temperature without reheating and rolled without the usually occurring scale loss. At rolling temperature and due to shrinkage between the ingot and the ingot mold, a circular gap occurs, facilitating extraction of ingot from mold by means of a pushing or a pulling device. Metals with low shrinkage characteristics can also be cast utilizing a longitudinal split ingot mold, which also facilitates extraction of ingot from mold. For the production of hollow ingots, this invention can also be used by filling only the amount of metal required for a hollow cast ingot, swinging the ingot mold into the horizontal (referred to herein also as the longitudinal axis) and rotating the same, utilizing centrifugal force to form a hollow ingot. The casting process can also be executed with the ingot mold already rotating in vertical position where a parabolic cavity would be formed which after swinging into the horizontal would convert itself to a cylindrical hollow billet until the casting is solidified. It is also possible to work with a stationary ingot mold during casting and start rotation only after tilting the mold into the horizontal.

The apparatus consists of an ingot mold for receiving metal from a melting furnace, converter or ladle with preferably a preceeding tundish. The mold is mounted so that it can pivot from the vertical to the horizontal axis and if desired a rotation can be induced. The tundish can be made for instance of Hamatite in order to resist high casting speeds and to avoid leakage of metal as common with refractory lined units. The tundish will also preferably incorporate a casting pipe submerged into the ingot mold with a splash shield. With this method splashing of liquid metal onto the ingot mold inner surface can be avoided for instance maintaining a constant distance between end of pouring pipe to liquid metal surface by moving the casting pipe or lowering the ingot mold or lifting the tundish. The cross section of pouring pipe opening should be considerably larger than the entry opening into the pipe in order to protect pouring pipe lining against erosion through liquid metal stream. Advantages of this invention are especially pronounced by a device consisting of a stationary tundish and ingot-mold guide with opposed guide rollers, a lift table which can rotate around its horizontal axis and a horizontal roller drive with discharge pusher arranged at an opposite location.

The ingot-mold guide can consist of a two-piece frame where one part of the frame can be rotated and is connected to a winch. The winch consists of two independently driven lifting and pivoting drums so that the ingot with lifting table can be lifted independent from the swivelling of the frame part. In order to bring the ingot immediately after tilting into the horizontal position and into a rotation, the movable part of the ingot guide is arranged in a horizontal between the rolls of the roller drive. More than one ingot mold could also be arranged in a driven frame with vertical axis of rotation and with at least one ingot lift so that during casting at least one ingot mold can be pivoted into the horizontal and at least one empty ingot mold can be inserted into frame. The extraction of the filled ingot mold from the rotating frame and inserting of the empty ingot mold is provided by means of ingot cars which are equipped with individual drive and can lift the ingots by means of ingot carriers or place the same into the rotating frame.

In the foregoing general description I have set out certain objects, purposes and advantages of my invention. Other objects, purposes and advantages of this invention will be apparent from a consideration of the following description and the accompanying drawings in which:

FIG. 1 is a side elevation of a casting device according to this invention, partially in section,

FIG. 2 is a section according to line II—II of FIG. 1,

FIG. 3 is a section according to line III—III of FIG. 1,

FIG. 4 is a section according to line IV—IV of FIG. 1,

FIG. 5 is a side elevation of a casting device according to this invention, partly in section, with a rotating frame for a multitude of ingots, and

FIG. 6 is a plan view of a casting device according to FIG. 5.

In the drawing there is illustrated a casting device which consists of a stationary or movable tundish **11** with a pouring pipe **12** proportional to ingot length, the exit of which is equipped with splash shield **13** to protect wall of ingot mold **14** against metal splashing. The tundish **11** is arranged above an ingot guide **15** with opposed guide rollers **16** arranged around a horizontal axis **17** where the vertical shaft **18** contains lift table **19**. The ingot guide **15** consists of a two-piece frame **21, 22** where the frame parts **21** can be pivoted from the horizontal into the vertical axis around center **23**. The vertical movement of lift table **19** and the swivelling of frame part **21** is achieved by means of a combined winch **24** with motor **25** acting over gear **26** and coupling **27**, cable drum **28** for vertical movement of the lifting table and independently drives drum **29** for pivoting of the frame part **21**. Cables **31** are operated over sheaves **32** of lift table **19** whereas pivoting cable **33** operates over sheaves **30** and **34**. By unwinding both cables **31**, frame part **21** moves in the direction of arrow **35** moving ingot **14** into the horizontal position at the time when lift table **19** has arrived at the elevation of the horizontal roller drive **36**.

The roller drive **36** consists of two parallel rows of rollers **37** each individually driven by a motor **38**. In the horizontal position, guide rollers **16** are arranged between two drive rollers **37** so that the ingot **14** and the supporting frame **39** are resting on rollers **37** and can be rotated if desired. The ingot mold **14** is supported by a frame **39** which can be eliminated in case of a cylindrical ingot mold geometry. The ingot mold **14** is equipped with insulating refractory **41** and a steel cover **42** in order to reduce cooling speed and to obtain faultless ingot surface.

At the beginning of casting the free end of casting pipe **12** is located barely above lift table **19** and ingot mold **14** respectively. The supporting frame **39** is in its uppermost or top position. During casting, the left table **19** and support frame **39** with the ingot mold **14** are lowered by unwinding lift cables **31** at a speed corresponding to the discharge velocity of metal out of ladle **11** or the cast pipe **12** in order to maintain a constant distance between splash cover **13** and liquid bath surface of ingot mold **14**. During the downward movement, supporting frame **39** is guided between rollers **16**.

As soon as the ingot mold is filled, the ingot head is covered, for instance by water spray to solidify the metal or insertion of a plug, and the ladle with casting pipe **13** is removed from guide frame **15**. By operating winch **24**, lift table **19**, supporting frame **39** and ingot mold **14** travel to the top position and are pivoted with cable **32** into the horizontal with frame part **21**. The pivot motion ends as soon as support frame **39** rests on rollers **37**. Thereafter the drive motors **38** are energized and support frame **39** with ingot mold **14** are rotated. As soon as ingot **43** has cooled sufficiently, discharge pusher **40** is energized by moving ingot **43** from ingot mold **14**, during which time the supporting frame **39** is held by a stop **44**. The ingot **43** can thereafter be moved to a rolling mill as soon as the desired rolling temperature is reached.

The device illustrated in FIG. **5** correlates basically to the casting device according to FIG. 1 to 4. For this reason, corresponding parts are designated by same numbers with the suffix *a*. The basic difference is that ingot mold guide **15*a*** is arranged above turning device

51 driven by motor 50 with vertical axis 52. Additionally, cables 31*a* are connected with an ingot lift consisting of car 55 guided on tracks 54 with horizontal carrier arms 56 connecting to trunion 53 during lifting and lowering of ingot supporting frame 39*a*. The ingot carriers 63, as well as ingot guide 15*a* and rotating frame 51 incorporate guide rollers 16*a* which can be moved up or down between which the supporting frame by means of ingot lift.

Turning frame 51 consists of four ingot holders 57, which can move by ¼ revolution from casting station 58 to discharge station 59, the empty station 61 and ingot station 62. In cast station 58, filling of the ingot mold is accomplished according to above description during which time (at discharge station 59), ingot carrier 63 with supporting frame 39*a* and ingot mold 14*a* are removed from turning rotating frame and supplied to a roller drive (not shown). A new ingot carrier 63 with supporting frame and empty ingot mold is inserted in rotating frame 51 at ingot station 62. The ingot carriers 63 are equipped with downwards directed attachments 64 in which hooks 65 of ingot car 66 engage at discharge and ingot station 59 and 62. The ingot car 66 is equipped with carrier arm 56*a* for support frame 39*a* and guided in track 67. Nose 68 is equipped with a roller 69, guided in a bar 71 and connected to an endless chain 72. The chain 72 operates over sprocket 73 of which only one is driven by motor 74. As soon as filling of the ingot mold is completed, the turning frame is rotated ¼ revolution so that the filled ingot mold is moved from cast station 58 into discharge station 59. The hooks 65 engage, after energizing of motors 74 (part of ingot car 66), into lifting attachments 64 of ingot carrier 63 and the carrier arms 56*a* under trunions 53. With continued motion of chain 72, ingot car 66 with ingot carrier 63 moves into shown casting position as illustrated in FIG. 5, shown at discharge position (indicated by dotted lines). The supporting frame and ingot will then be discharged from ingot carrier. Simultaneously, ingot carrier 63 with empty ingot mold is inserted in ingot station 62 and lowered onto the corresponding ingot holder 57, where over lever 75 engaging hook 76 the ingot carrier 63 completes interlocking of rotating frame 51 and bolts 76 in hole 77 of frame 57.

The rotating frame could accommodate, due to high metal capacity, a number of cast discharge and ingot stations. Thereby between two cast stations always one discharge and ingot station could be located. With such means a great number of ingot molds can be filled in a small space and large amounts of liquid metal can be cast.

While I have illustrated and described certain presently preferred practices and embodiments of my invention in the foregoing specification, it will be understood that this invention may be otherwise embodied within the scope of the following claims.

I claim:

1. A process for casting metals comprising the steps of:
   a. casting molten metal into the top of an upright ingot mold whose axis is in a generally vertical position;
   b. capping said ingot mold immediately upon completion of said casting whereby egress of molten metal is prevented;
   c. pivoting said ingot mold immediately upon capping so that its axis is in the horizontal position; and
   d. cooling the metal in the mold in the horizontal position.

2. A process according to claim 1 wherein the metal is cast at high velocity into an ingot mold having a height to diameter ratio in excess of 20:1.

3. A process according to claim 1 wherein the ingot mold is slowly rotated around its axis after pivoting into the horizontal position.

4. A process according to claim 1 wherein the cooling rate is reduced by insulating materials forming the walls of the ingot mold.

5. A process according to claim 1 wherein the ingot mold is lined with a steel cartridge prior to casting.

6. A process according to claim 1 wherein the pouring stream height during casting is maintained at an approximate constant level.

7. A process according to claim 1 wherein the ingot mold is filled only to a height equivalent to the volume of metal corresponding to a desired hollow ingot and then rotated around the horizontal axis.

8. A process according to claim 7 wherein the ingot mold is rotated during casting and solidification.

9. A process according to claim 7 wherein the ingot mold is stationary during casting and is only rotated after beginning of pivoting motion from vertical to horizontal.

* * * * *