June 3, 1969 J. E. FOLDESSY 3,447,591

APPARATUS FOR BENDING A CASTING HAVING A LIQUID CORE

Original Filed March 6, 1964 Sheet 1 of 10

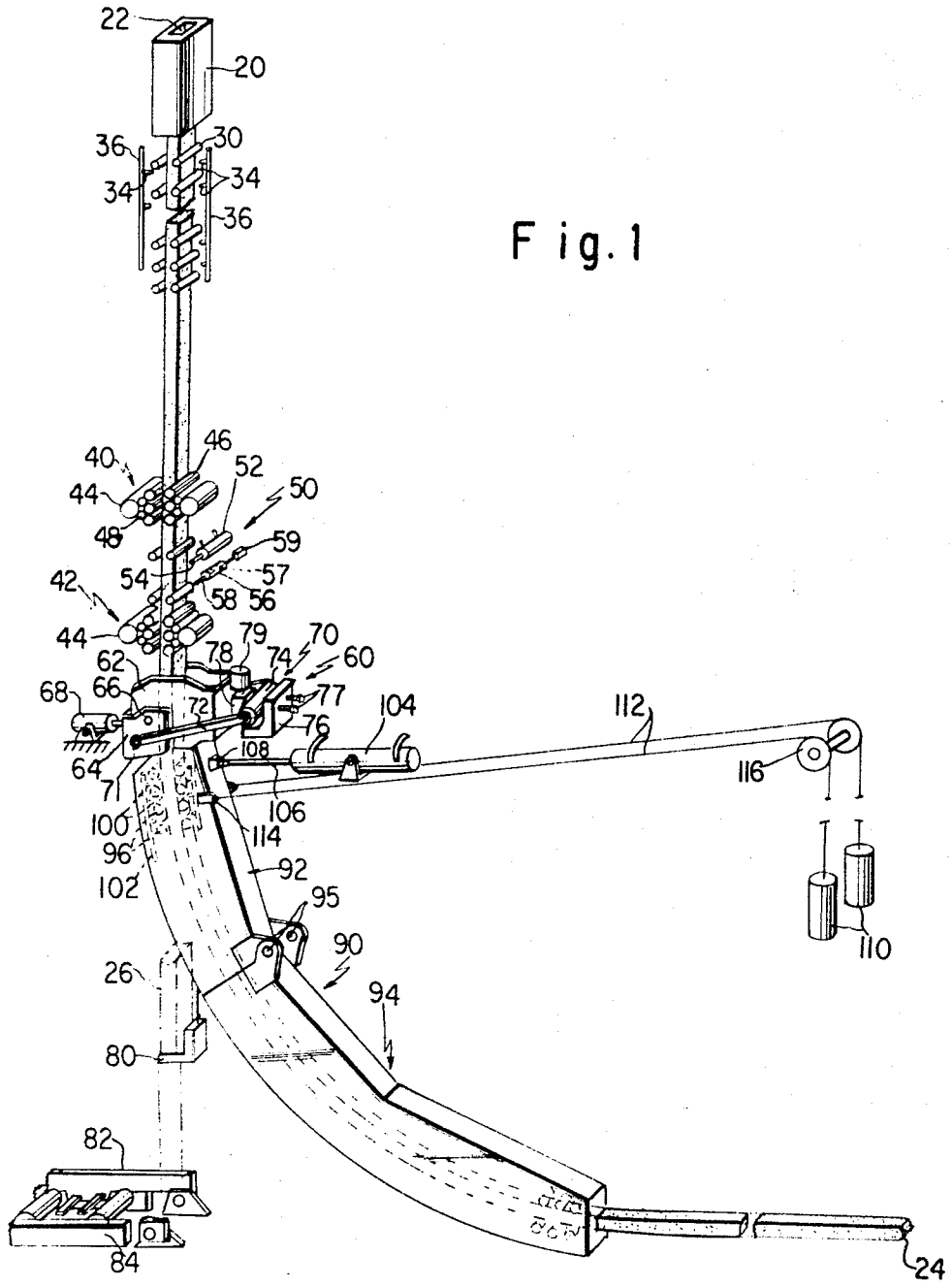


Fig. 1

INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

June 3, 1969 J. E. FOLDESSY 3,447,591

APPARATUS FOR BENDING A CASTING HAVING A LIQUID CORE

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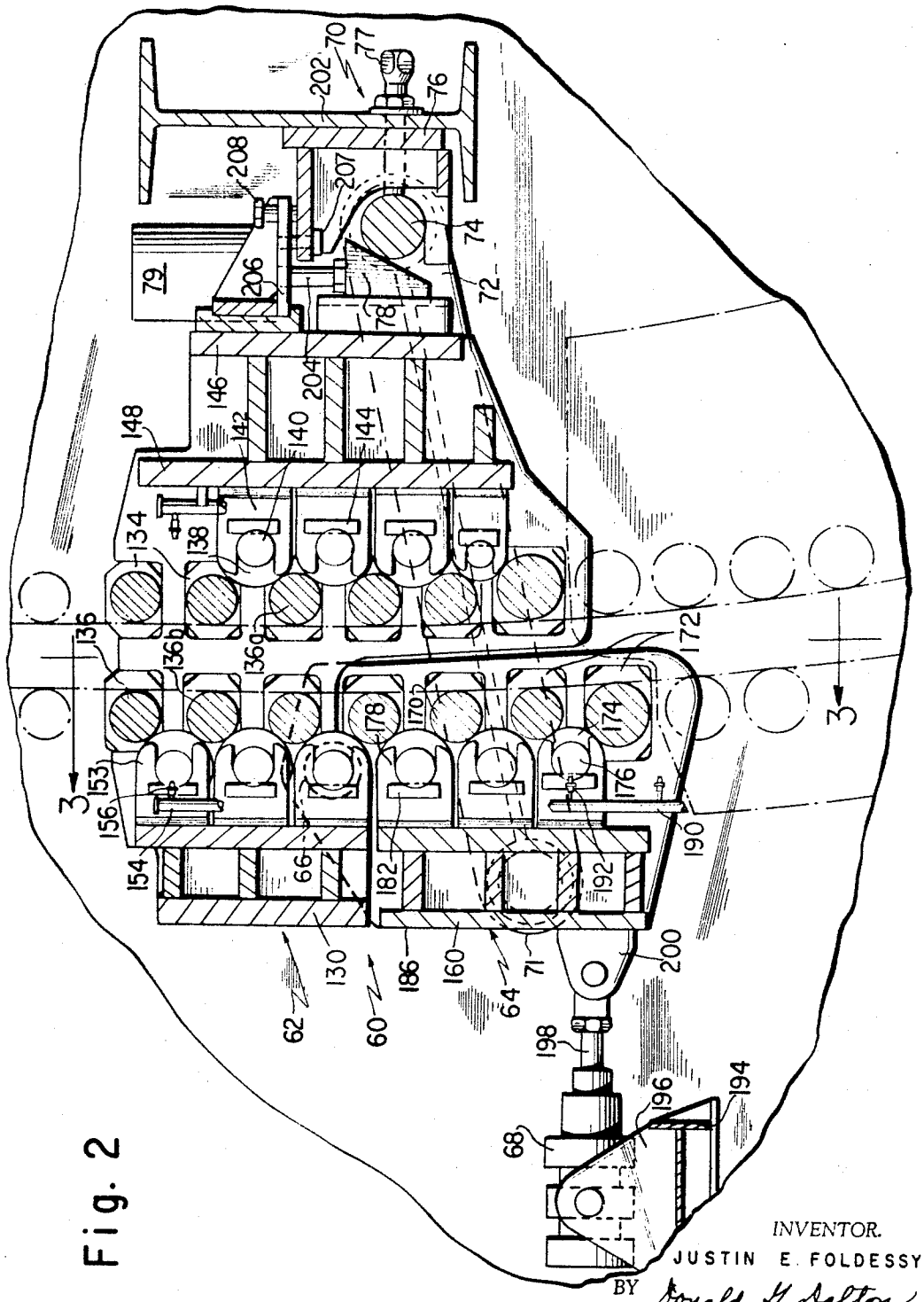


Fig. 2

INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

June 3, 1969 J. E. FOLDESSY 3,447,591

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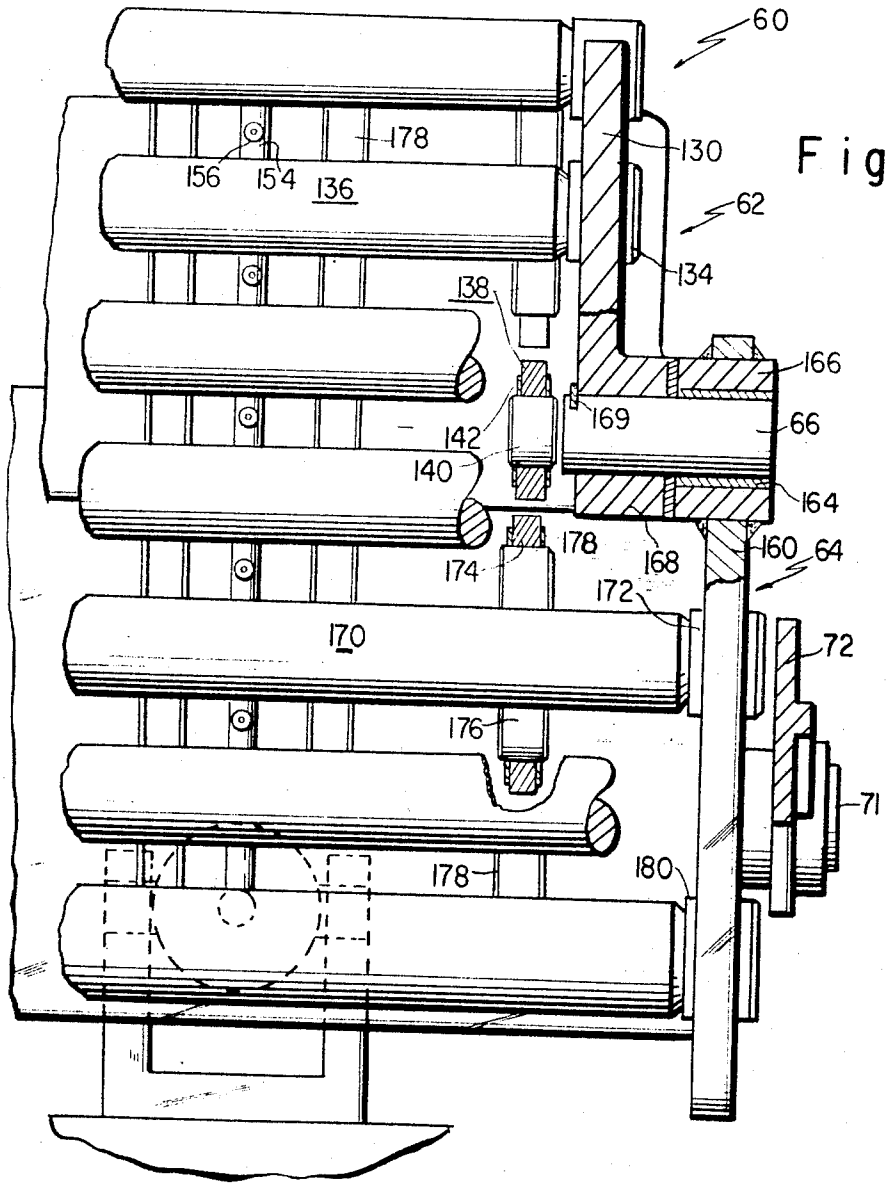


Fig. 3

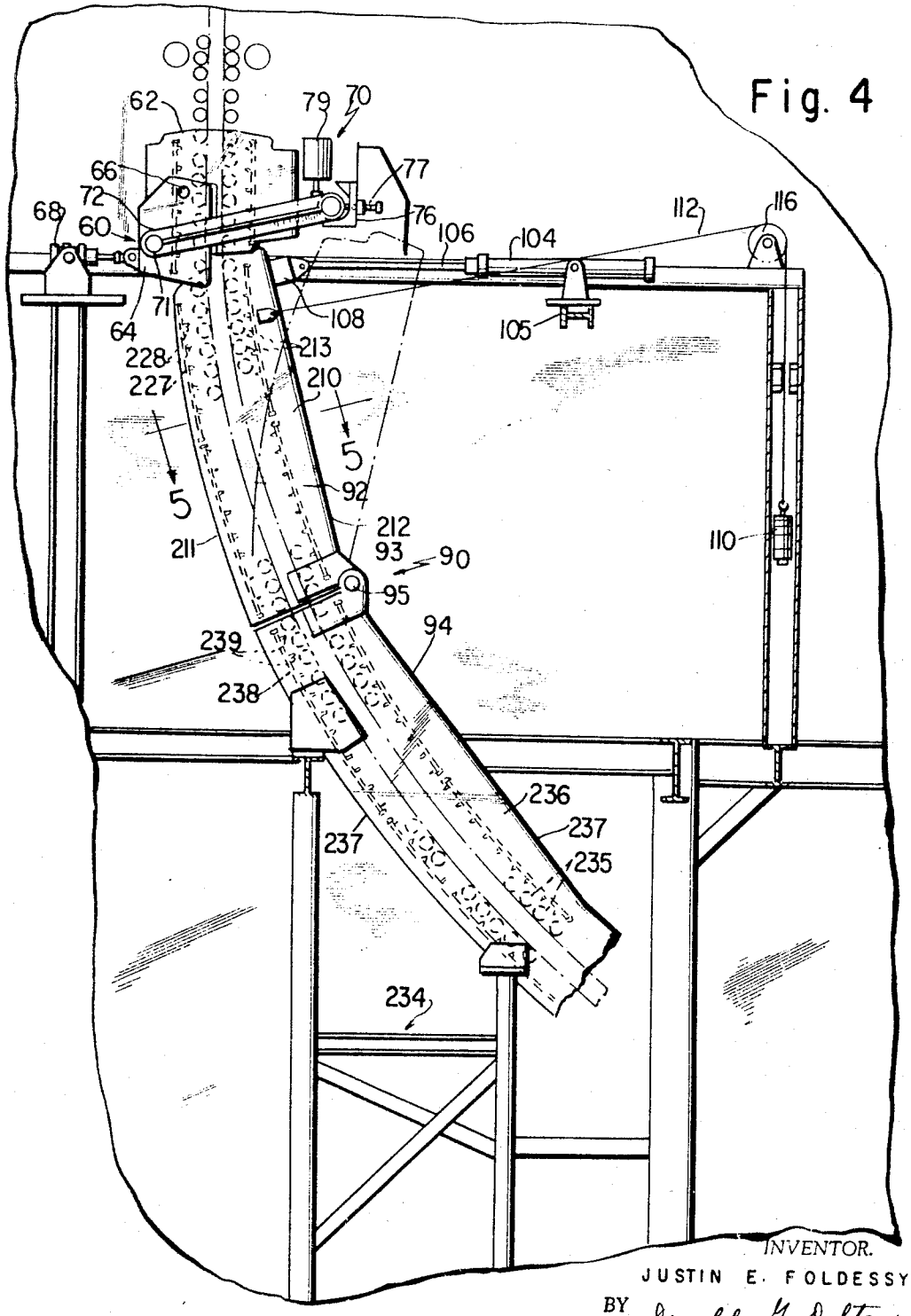
INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

June 3, 1969 J. E. FOLDESSY 3,447,591

APPARATUS FOR BENDING A CASTING HAVING A LIQUID CORE

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Fig. 4



INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

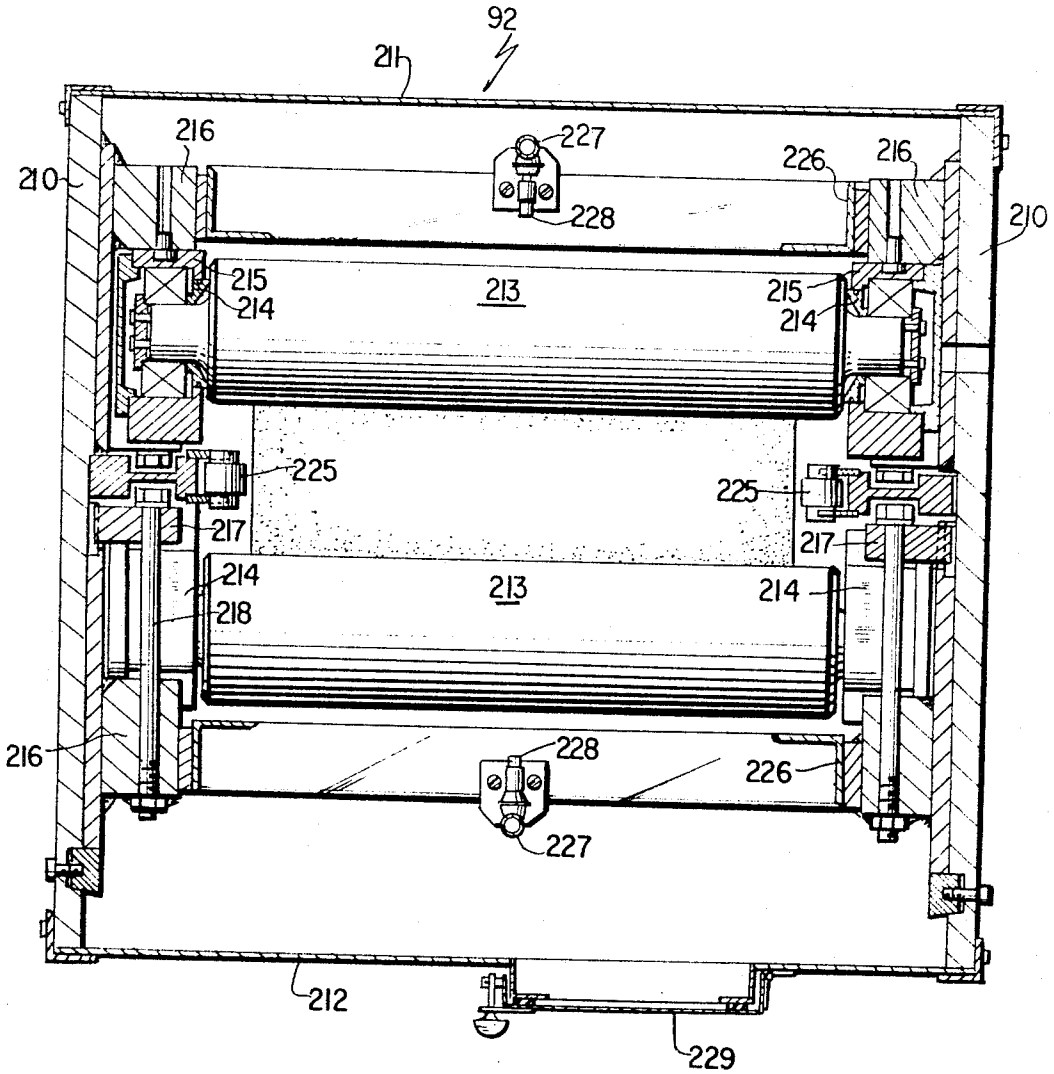


Fig. 5

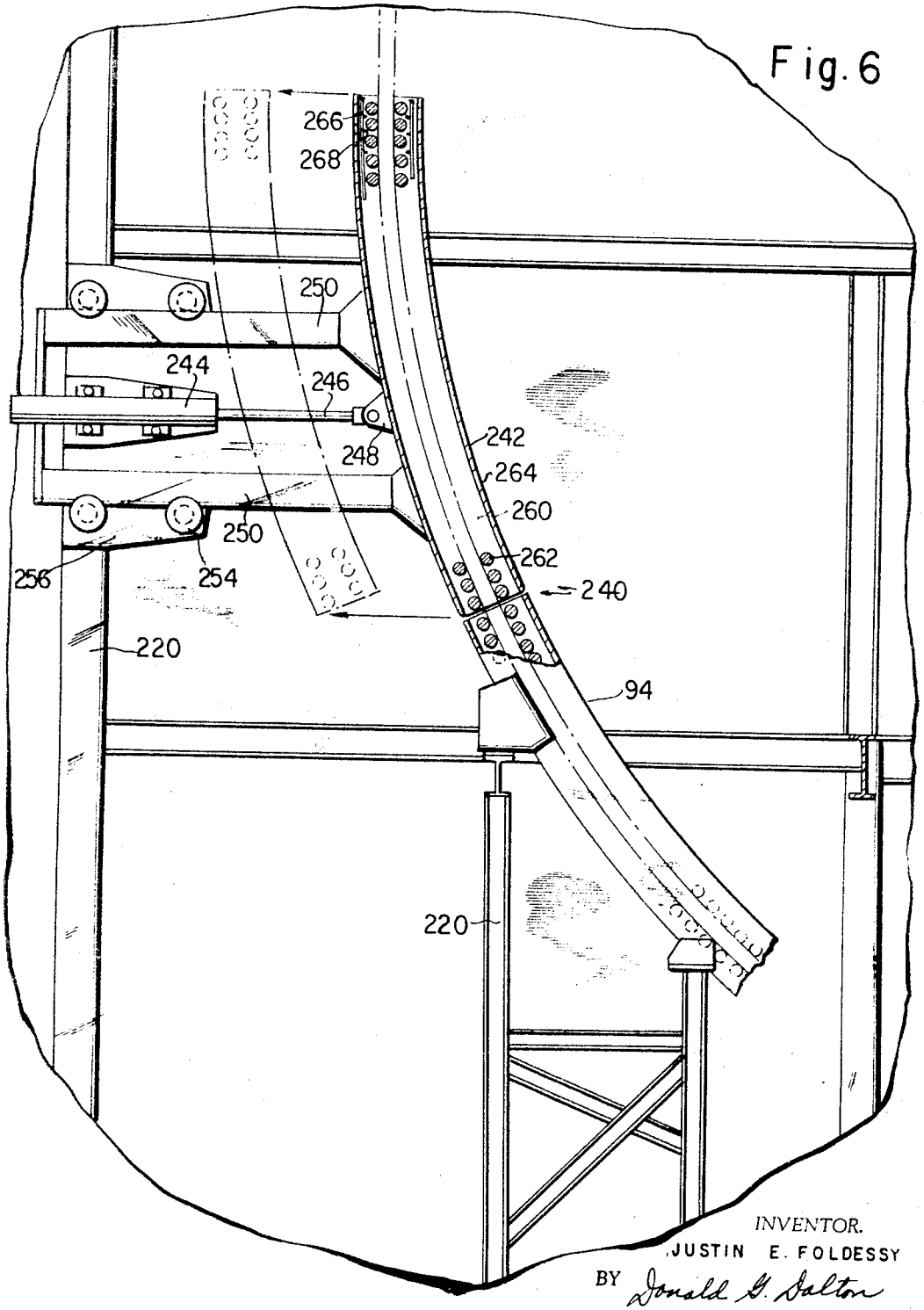
INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

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Fig. 6



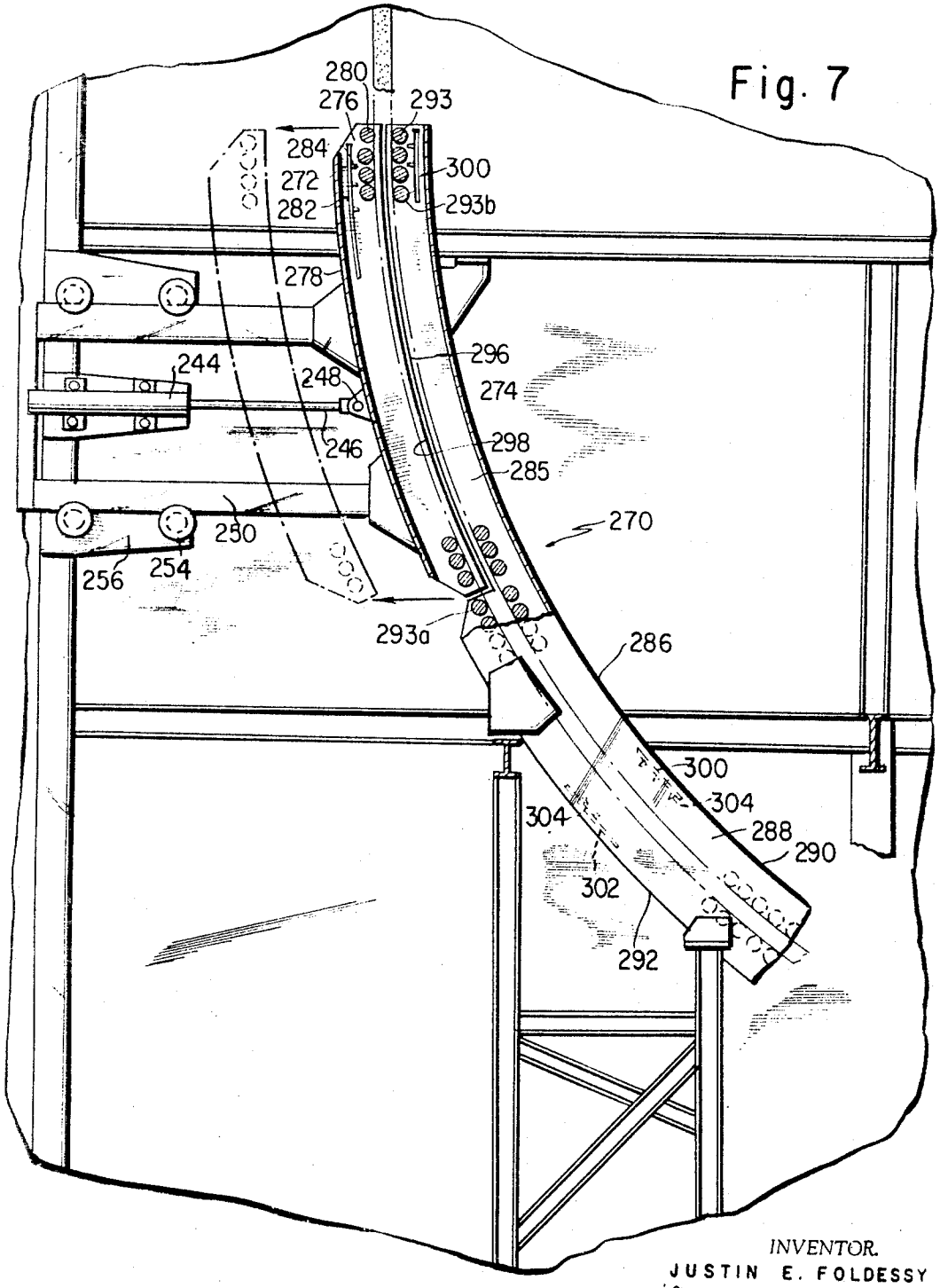
INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

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Fig. 7

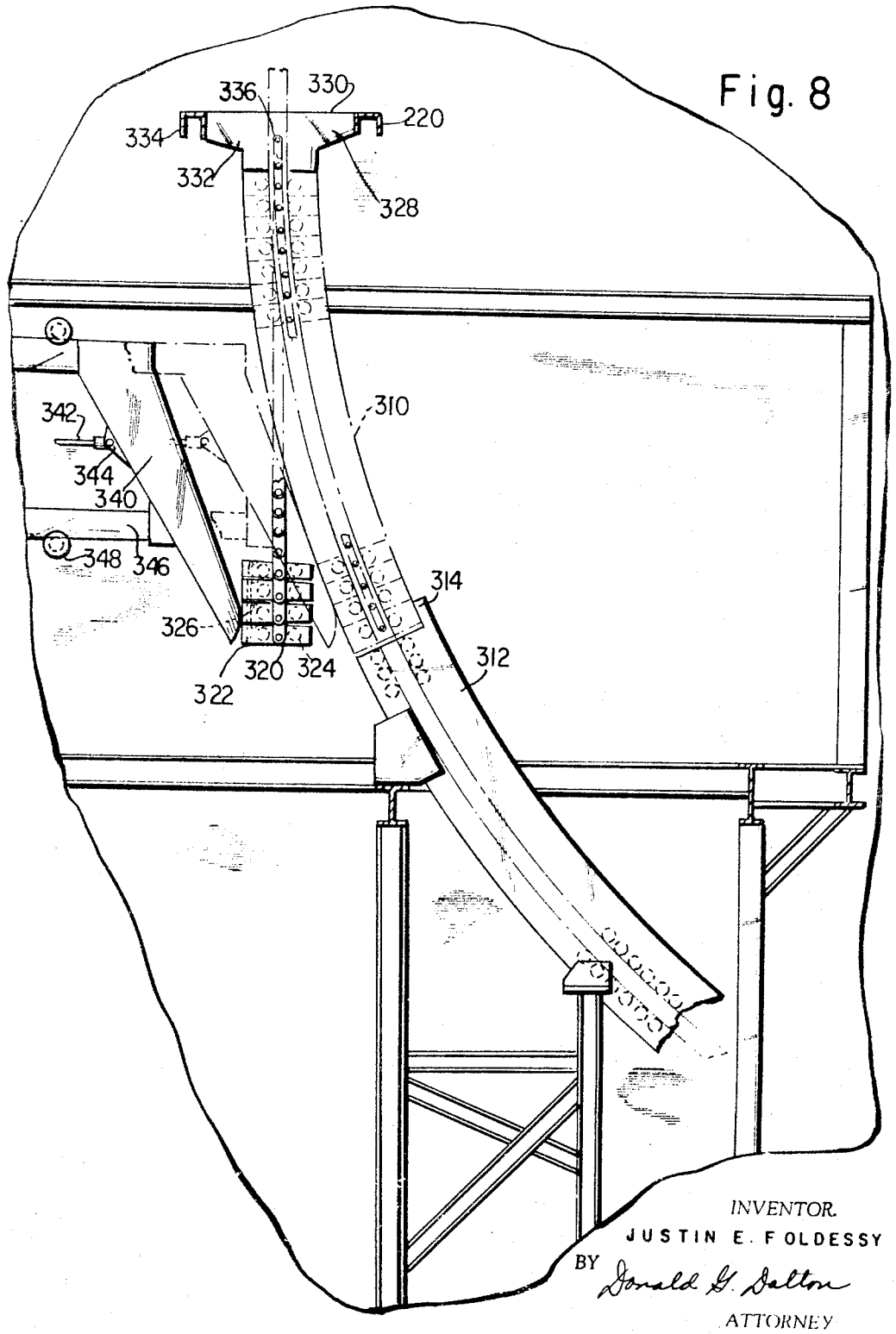


INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

APPARATUS FOR BENDING A CASTING HAVING A LIQUID CORE

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Fig. 8



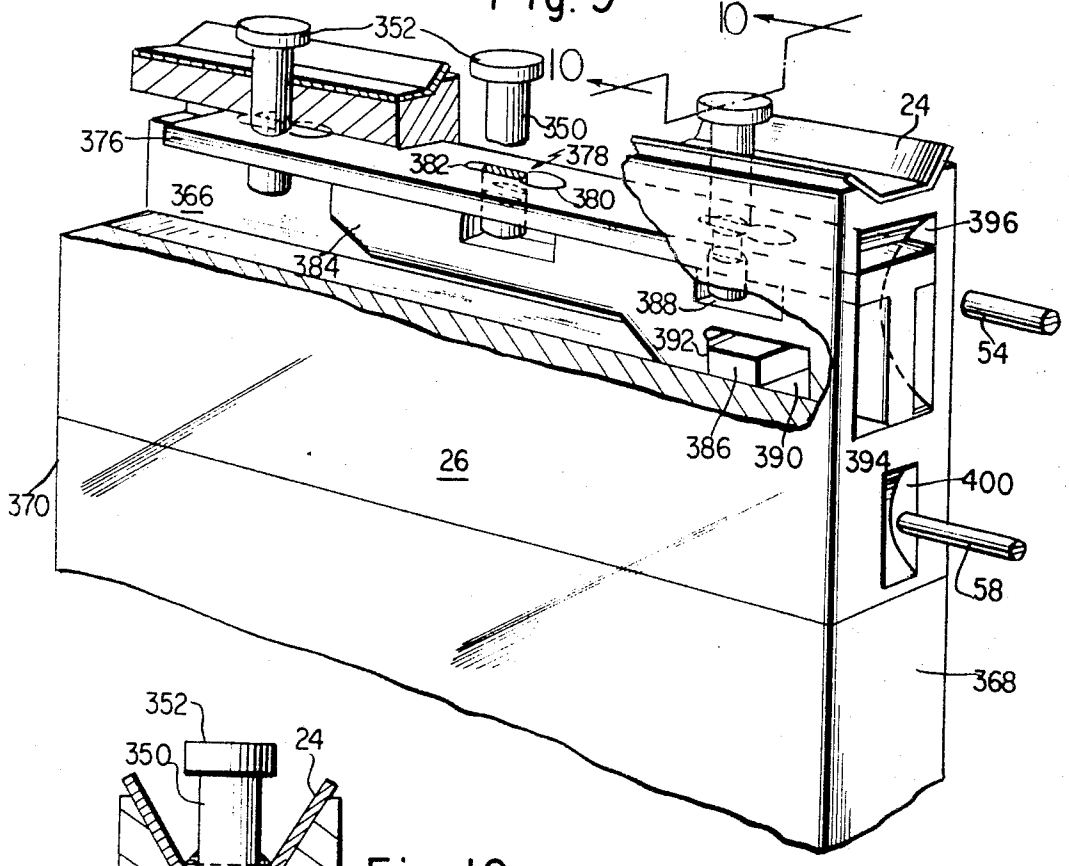
INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

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Fig. 9



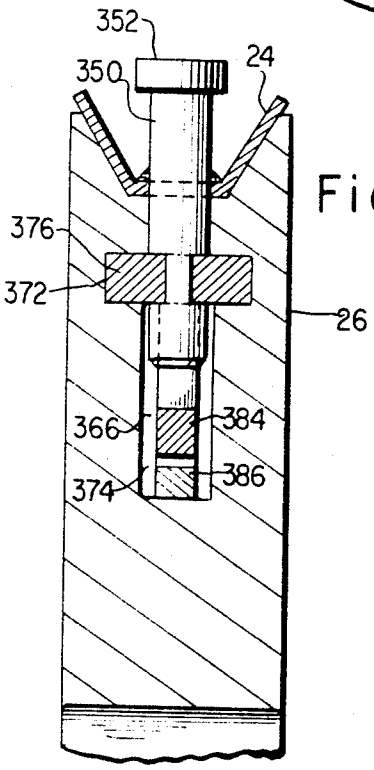


Fig. 10

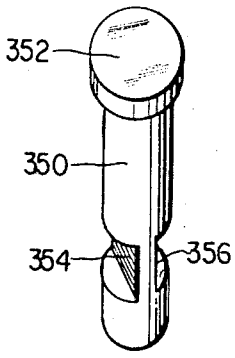


Fig. 11

INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

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Original Filed March 6, 1964 Sheet 10 of 10

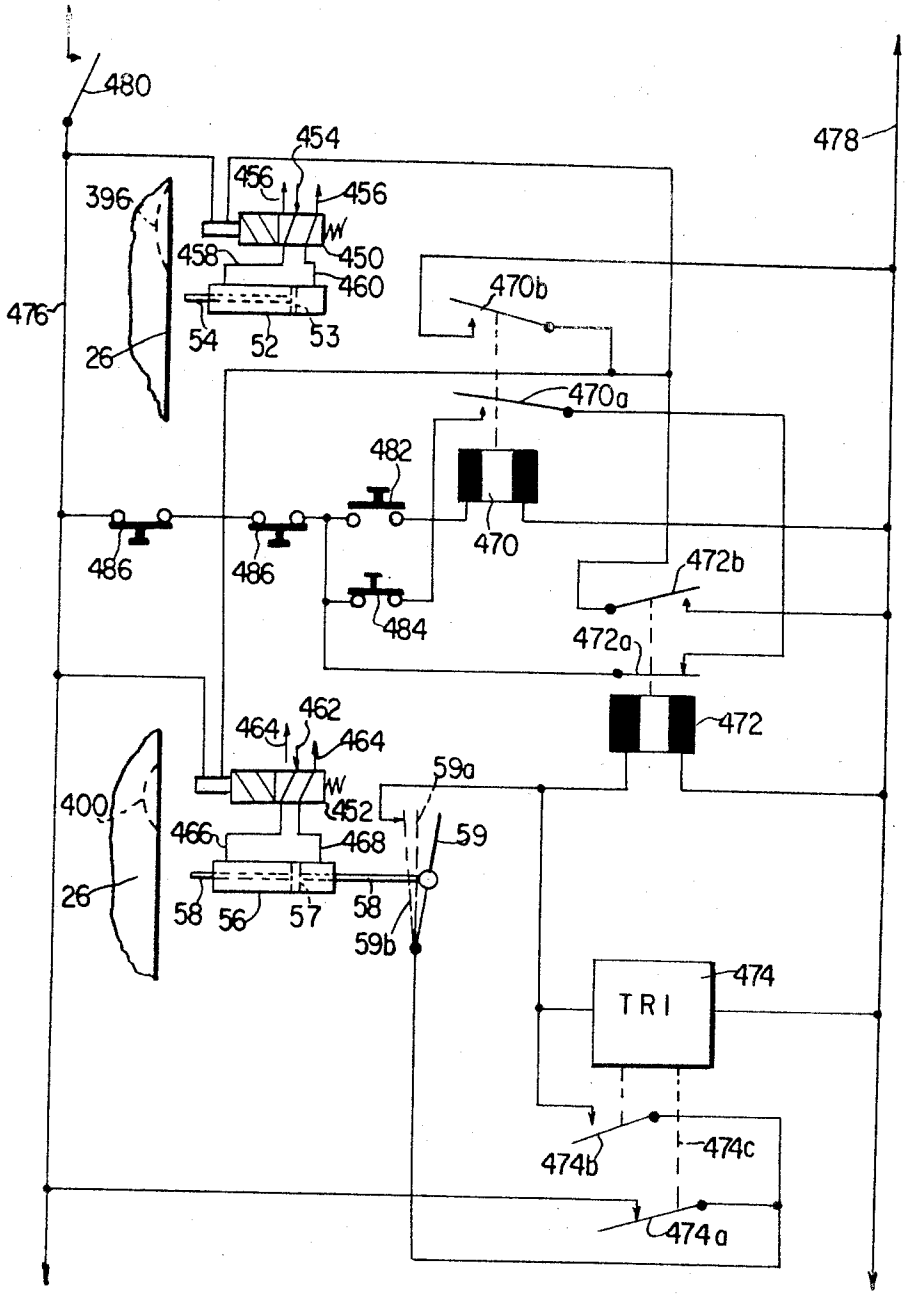


Fig. 12

INVENTOR.
JUSTIN E. FOLDESSY
BY Donald G. Dalton
ATTORNEY

United States Patent Office

3,447,591

Patented June 3, 1969

3,447,591

APPARATUS FOR BENDING A CASTING HAVING A LIQUID CORE

Justin E. Foldessy, Ogden Dunes, Ind., assignor to United States Steel Corporation, a corporation of Delaware

Original application Mar. 6, 1964, Ser. No. 349,944, now Patent No. 3,338,297, dated Aug. 29, 1967. Divided and this application Feb. 10, 1967, Ser. No. 615,196

Int. Cl. B22d *11/12, 27/04*

U.S. Cl. 164—282 2 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for moving a continuopsly formed casting in a continuous metal casting apparatus. A plurality of pinch rollers are arranged in two pairs below the cooling mold and above a guide mechanism for guiding the casting from a vertical path to a lateral path. The idler rolls of the pinch rollers engaging the casting are driven by through backup rolls. Also, the top pinch rolls are driven at a higher speed than the lower pinch rolls to force the casting against the starter bar immediately prior to separation.

Cross reference to related application

This application is a division of my copending application Ser. No. 349,944, filed Mar. 6, 1964, now Patent No. 3,338,297, issued Aug. 29, 1969.

Background of the invention

This invention relates to a method and apparatus for continuous casting, especially to a novel method for bending and guiding a continuously formed casting in a curved path before the core of molten metal is solidified and to apparatus therefor.

It is customary in the continuous casting of metals to provide an apparatus comprising a vertical tubular mold open at the upper end for receiving molten metal and open at the lower end for the discharge of a metal casting, cooling means comprising a plurality of water sprays located below the mold for directing cooling water against the casting as it descends vertically, guide means comprising a plurality of guide rolls, located between the water sprays, for guiding the casting vertically as it moves downwardly through the cooling zone, and motor driven pinch rolls located below the guide rolls for controlling the rate of descent of the casting. The cooling means are mounted on a suitable immovable frame. The guide rolls and pinch rolls are mounted for rotation in suitable mountings, which are also mounted on an immovable frame.

As the casting emerges from the discharge opening of the mold, it has a solidified metal skin around its periphery but has a liquid core of substantial volume. This liquid core is gradually solidified as the casting descends through the cooling zone. By the time the casting reaches the bottom of the cooling zone and passes through the pinch rolls in the usual apparatus, the liquid core is nearly solidified.

It is necessary to close the lower discharge end of the mold initially when molten metal is being poured into the mold. This is usually done by the insertion of a starter bar into the bottom of the mold. The starter bar is an elongated metal bar, usually rigid, which has a cross-sectional shape approximately the same as that of the mold with a slightly smaller cross-sectional area in order to permit ready insertion of the bar upwardly through the guide rolls and into the bottom of the mold. The starter bar, in addition to closing the discharge end of the mold while molten metal is being poured, also supports the

metal column or casting as it descends through the guide rolls and pinch rolls.

After the starter bar has passed through the pinch rolls, it is severed from the casting. This is conventionally done by means of one or more cutting torches located a short distance below the pinch rolls. These torches cut the casting a short distance above the top of the starter bar. The starter bar, with a short length of casting attached to the top thereof, is lowered vertically, supported by a suitable platform, basket, or the like. At the bottom of its vertical travel, the starter bar is lowered to a horizontal position and transported horizontally away, by power driven rollers for example. The short length of casting attached to the starter bar must be removed before the starter bar can be used again.

The casting (excluding the short length which remains attached to the starter bar) after its severance from the starter bar is generally handled in either one of two different ways. According to one mode of operation, the casting is cut into lengths by means of the above mentioned cutting torches. Each cut length of casting is then lowered vertically and laid down to the horizontal position and transported away in the same manner as the starter bar. According to a second mode of operation, the casting after severance from the starter bar is deflected from its vertical path by a horizontally reciprocable roll known as a pusher roll, and guided in a curved path as it is bent from its initial vertical direction to a horizontal direction by means of a stationary guide frame having a plurality of guide rolls beneath the casting for supporting it. When the casting reaches a horizontal direction, it is straightened out by conventional means, such as straightening rolls. The casting after straightening may be reheated if necessary and rolled, or otherwise treated in any desired manner.

Both of the two above modes of operation and the apparatus associated therewith contemplate that the casting will be completely or at least nearly solidified by the time it passes through the pinch rolls. It is essential that the casting be completely solidified before it is cut with a cutting torch in order to detach the starter bars; otherwise the liquid metal in the core of the casting would flow out when the casting is cut.

The present methods and apparatus for continuous casting of metals and particularly of iron and steel, have the disadvantage that a tower of considerable height is required in order to provide a vertical cooling zone of adequate height for solidifying the casting completely. To minimize the unwieldy height of the cooling zone, it is desirable to cool the casting partially during its vertical descent, to solidify only part of the molten metal core, and thereafter completing solidification while the casting is being bent from the vertical to a horizontal direction.

A further disadvantage of present continuous casting apparatus is that a short length of casting remains attached to the starter bar after cutting and must be separated before the starter bar can be used again.

Summary of the invention

In order to bend a casting and to disconnect the same from the starter bar without the necessity of cutting the casing with cutting torches I have invented, a novel type of starter bar which can be completely disconnected from the casting without severance or any part of the casting remaining attached to the starter bar is essenial. Presently known rigid starter bars cannot be used with this invention because these have to be severed from the casting.

It is an object of this invention to provide a continuous casting apparatus which includes a casting guide frame especially designed for guiding a casting having a core of molten metal in a curved path.

Another object of this invention is to provide novel casting guide frame structures which are especially suited for guiding a casting having a molten metal core in a curved path.

Brief description of the drawings

This invention will now be described with reference to the accompanying drawings in which:

FIG. 1 is an isometric and schematic view of the apparatus of this invention;

FIG. 2 is a side sectional view of the apparatus for bending the casting;

FIG. 3 is a view taken along the line 3—3 of FIG. 2;

FIG. 4 is a side elevation showing a curved guide frame according to one embodiment of the invention;

FIG. 5 is a cross section taken along the line 5—5 of FIG. 4;

FIG. 6 is a side elevation of a curved guide frame according to a second embodiment of this invention;

FIG. 7 is a side elevation of a third embodiment of this invention;

FIG. 8 is a side elevation of a curved guide frame according to a fourth embodiment of this invention;

FIG. 9 is an isomeric view, with parts cut away and parts shown in section, of a starter bar which is useful in the apparatus of this invention;

FIG. 10 is taken along the line 10—10 of FIG. 9;

FIG. 11 is a detail perspective view of a pin for anchoring the casting to the chill plate; and

FIG. 12 is an electrical circuit diagram of an actuation system for automatically disconnecting the starter bar from the chill plate and casting when the starter bar reaches a predetermined elevation.

Description of the preferred embodiment

Referring now to FIG. 1, **20** is a generally vertically extending tubular mold having a passage **22** extending therethrough. This passage **22** includes an upper opening for the introduction of molten metal to form a casting and a lower discharge opening through which said casting may descend continuously as it is formed. The mold may be of any cross-sectional shape desired, but for purposes of illustration a rectangular mold is shown.

It is necessary to close the lower discharge passage of mold **20** prior to the pouring of molten metal therein. A chill plate **24** which is initially releasably secured to a starter bar **26** as shown in FIG. 9 constitutes a member for initially closing the mold and for forming a surface against which the molten metal of the casting solidifies after it is poured into the mold. An exemplary embodiment of this chill plate and starter bar will be described later with reference to FIGS. 9 to 11 inclusive. The chill plate **24** and the starter bar **26** releasably secured thereto are initially inserted into the lower end of the mold so as to close the lower discharge opening. Molten metal is then poured into the upper opening of passage **22** until the metal reaches a predetermined depth within mold **20**. The outer surface of molten metal abutting tubular mold **20**, and the lower surface of molten metal abutting chill plate **24**, solidify while still in the mold and before descent of the starter bar begins. Means which will be described in detail with reference to FIGS. 9 to 11 provide a firm interlocking grip between chill plate **24** and the solidified lower end of the metal casting. After the depth of molten metal in the mold has reached a predetermined level near the top, the starter bar, chill plate, and casting attached thereto are lowered.

A plurality of guide rolls **30** are located directly below a discharge passage of the mold for guiding the starter bar and the casting in a vertical path as they descend. Such guide rolls are well known in continuous casting apparatus.

Also located below mold **20** is a cooling means comprising a plurality of spray nozzles **34** which are supplied with water through headers **36**. The spray nozzles **34** are

directed against the opposite faces of the castings, and are positioned to direct their streams of water between successive guide rolls **30**. The structure of water spray nozzles and headers for continuous casting apparatus is known in the art, and any of the known structures may be used here.

The spray nozzles **34** and guide rolls **30** together constitute a vertical cooling section in which at least a part of the molten metal in the core of the casting is solidified. An important difference between this vertical cooling section and vertical cooling section of a conventional continuous casting apparatus is that the length of the cooling section in this apparatus will be less than that necessary for complete solidification of the casting under conventional casting conditions.

A pair of pinch roll assemblies **40** and **42** are located at predetermined elevations below guide rolls **30** and spray nozzles **34**. Each of the pinch roll assemblies comprises a pair of large driven rolls **44** and a plurality of smaller idler rolls **46** which are arranged to bear against the opposite faces of the casting and to exert a force against the casting so as to control the rate of its descent. In addition to the idler rolls **46**, additional rolls **48** may be located between the driven rolls **44** and the rolls **46** which bear against the faces of the casting.

An actuation system **50** is located between upper pinch roll assembly **40** and the lower pinch roll assembly **42** for releasing starter bar **26** from chill plate **24** when the starter bar reaches the predetermined elevation at which the actuating means **50** is located. Suitable actuating means are fully described in the copending applications of Justin E. Foldessy and Francis Gallucci, Ser. No. 333,383, filed Dec. 26, 1963, now Patent No. 3,266,104 issued Aug. 16, 1966, and Justin E. Foldessy and Andrew L. Poulos, Ser. No. 333,449, filed Dec. 26, 1963, now Patent No. 3,274,-653, issued Sept. 27, 1966. The operation of this actuating means will be described in further detail with particular reference to FIG. 12.

The bending means, indicated generally at **60**, is located below the lower pinch roll stand **42**. The purpose of this bending means is to bend the casting and deflect it from its vertically downward path in a laterally extending direction. The amount of deflection imparted by bending means **60** is small but is suffiicent to facilitate the guiding of the casting in a curved path as it continues to descend. This bending means **60** includes a stationary roll assembly **62**, and a movable roll assembly **64** which is movable through a small arc about a pair of axially aligned non-rotating shafts **66** which are journaled in stationary roll assembly **62** so as to permit unimpeded vertical descent of the starter bar **26** in a first position and to initiate the deflection of the casting from its initial vertical direction to a direction which is genetrally vertical but with a small horizontal component when in its second position. Bending means **60** also includes a hydraulic cylinder **68** for moving the bending means between the two positions, and a locking means indicated generally at **70**, comprising a pair of pivot pins **71**, a pair of arms **72** pivotally secured at one end to pivot pins **71** and at the oppoiste end to a shaft **74**, which is held in place between a back-up plate **76** having set screws **77** therein, and vertically reciprocable wedge **78** which can be moved up and down by hydraulic cylinder **79**, so as to lock the movable frame member **64** in position.

The starter bar **26** continues its straight downward course after it is released from the chill plate **24** and casting attached thereto by the operation of actuation mechanism **50**. As indicated in the last paragraph, bending means **60** is in its first position as the starter bar descends. A vertically traveling receptacle **80** receives starter bar **26** during its vertical descent below the bending mechanism **60** and lowers the starter bar to a predetermined level. When the traveling receptacle **80** reaches the bottom of its travel, the starter bar **26** is received by a tilter frame **82** which lowers it to the horizontal position, and

it is then conveyed away on horizontal conveyor **84**, for reuse if necessary. The traveling receptacle **80**, tilter frame **82**, and horizontal conveyor **84** are all known in the art, and further details will not be given here.

The apparatus of this invention includes a novel casting guide means **90** which guides the casting in a curved path from the generally vertical direction in which the casting is traveling as it emerges from bending means **60**. The casting guide means **90** is preferably located immediately below bending means **60** so that the casting its continuously supported and guided as it descends from the bending means to the casting guide means. This guide means **90** includes an upper movable section **92** and a lower fixed section **94**. The upper movable section **92** is pivotable about pivot pins **95** which are located at thte bottom of this section. Each of the sections **92** and **94** of guide means **90** includes a plurality of rolls **96**, the axes of which are arranged along two curved lines defining therebetween a curved path for the casting, and a plurality of spray nozzles **100** which are supplied with water through headers **102**. As the casting is guided in a curved path in its descent through guide means **90**, it is further cooled by water issuing through the spray nozzles **100** and is completely solidified.

The upper movable section **92** is movable between a retracted position shown in dot and dash lines in FIG. 4, in which the starter bar **26** may be brought vetrically downwardly without interference from the guide section, and a normal operating position which is shown in solid lines in FIG. 4, in which the upper guide section is adapted to receive and guide the casting as it descends below the bending means **60**. The upper guide section **92** in its second position provides a curved path for the casting from bending means **60** to the fixed guide section **94**. Movement of the upper section **92** is accomplished by means of hydraulic cylinder **104** having a piston rod **106** which is attached to the movable section **92** by means of an attaching bracket **108**. Counterweights **110** facilitate movement of the movable section **92** from normal to retracted position so as to lessen the amount of force which has to be exerted by hydraulic cylinder **104**. In addition the counterweights will minimize the shock in positioning table from the retracted to the normal position. The counterweights are attached to cables **112** which are attached at their opposite ends to casting guide frame section **92** by means of attaching brackets **114**. Cables **112** pass over pulleys **116**.

The casting is traveling in a curved path as it emerges from the lower or discharge end of fixed section **94** of guide means **90**. It may then be processed further as desired.

Various embodiments of the curved guide section **90** may be made within the scope of this invention. Four such embodiments will be described in detail with particular reference to FIGS. 4 and 5, 6, 7, and 8, respectively.

Referring now to FIGS. 2 and 3, the stationary roll assembly **62** in bending means **60** includes a box type fixed frame **130** having bearings **134** which receive guide rolls **136** which bear against the two opposed faces of the casting as it descends. Guide rolls **136** are arranged in a pair of rows **136***a* and **136***b* which bear against the two opposite faces of the casting. The upper rolls in row **136***a* are aligned so that the lines along which each of these rolls contact the casting lie in a vertical plane. The rolls in the lower portion of row **136***a* are aligned so that the lines of contact between these rolls and the casting define a curved surface having a large radius of curvature with the center to the right as seen in FIG. 4. The opposed row **136***b* of rolls, which is to the left as seen in FIG. 4, consists of several rolls aligned to form a vertical plane. The guide rolls **136** are supported against outward bending by a plurality of back-up rolls **138**, which are journaled on stub shafts **140**. Shafts **140** are supported by bifurcated brackets **142** and held in place by keys **144**. The fixed box type frame **130** supports guide rolls **136***a* and **136***b* as well as back-up rolls **138**. The guide roll bearings **134** are mounted directly on the frame **130**. The stationary roll assembly **62** is also provided with a pair of water headers **154** having a plurality of spray nozzles **156** projecting therefrom. The water spray nozzles **156** are arranged so as to project their streams of water between adjacent rolls **136**.

The structure of the movable roll assembly **64** is generally similar to that of stationary roll assembly **62**. Movable roll assembly **64** includes a movable frame **160** and the assembly **64** is pivoted about a pair of axially aligned non-rotating shafts **66**. Shafts **66** are placed in bushing **164**, which in turn is placed in bearings **166**, integrally connected to frame **160**. These shafts **66** also extend through sleeves **168** in the fixed frame **130** and locked in position by keys **169**.

Movable roll assembly **64** has a plurality of guide rolls **170** which are journaled in bearings **172** secured in side walls of frame **160**. The lines of contact between rolls **170** and the casting form a curved surface having a large radius of curvature. When movable roll assembly **64** is in its first position, these rolls are in such a position that they do not interfere with the vertical downward travel of starter bar **26**. When movable roll assembly **64** is in its second position, these rolls initiate the bending of the casting from its vertical downward path to a curved path. A plurality of back-up rolls **174** journaled on stub shafts **176** support the guide rolls **170** at spaced intervals to prevent bending. Shafts **176** are supported by bifurcated brackets **178** and held in place by keys **182**. Movable roll assembly **64** has a water header **190** having a plurality of spray nozzles **192** projecting therefrom to direct cooling water against the casting. These spray nozzles are arranged to project their streams of water between adjacent rolls **170**.

Movable roll assembly **64** is rotated through a small arc about the axles **66** by means of hydraulic cylinder **68**. The hydraulic cylinder is mounted on a fixed platform **194** by means of pivot ears **196**. Hydraulic cylinder **68** has a piston (not shown) and a piston rod **198** which projects externally therefrom and is fixedly attached to frame **186** of movable roll assembly **64** by means of pivot ears **200**. When movable roll assembly **64** has been moved to the selected position, it is secured in place by means of locking structure **70**. The back-up plate **76** is bolted to beam **202**, which is part of the stationary supporting structure. Screws **77** limit the position of shaft **74**. The travel of wedge **78** is controlled by the position of the piston in cylinder **79**. This cylinder has a piston rod **204** which limits the movement of wedge **78**. Cylinder **79** is fixedly mounted on bracket **206**. Adjusting screws **207** and **208** are provided for initially aligning fixed roll assembly **62**. The movable roll assembly may be locked in either retracted position for permitting vertical descent of a starter bar or casting, or normal position for initiating the deflection of the casting into a curved path as it descends by appropriate movement of wedge **78** and shaft **74**.

Referring now to FIGS. 4 and 5, a casting guide means **90** includes a movable upper guide frame **92** and a lower fixed guide frame member **94** as already explained. The movable guide frame member **92** is a four-sided enclosed structure having a pair of side walls **210** and a pair of end walls **211** and **212**. The lower end wall **211**, which lies beneath the curved path of the casting, is a relatively thin curved wall of steel plate, and parallel to the curved path of the casting. Upper end wall **212**, which lies above the curved path of the casting, is also a relatively thin steel plate wall. The guide section **92** has a plurality of guide rolls **213** which guide the casting in a curved path. The axes of guide rolls **213** lie along a pair of curved lines which define the curved path of the casting therebetween. Guide rolls **213** are journaled in bearings **214**, which are eccentrically mounted in chocks **215**. Chocks **215** are held in housings **216**. Centering rolls **225** can be

provided if desired. Separator beams **226** are secured to housings **216** for alignment of the guide frame **92**. A pair of water headers **227** are fixedly mounted on beams **226**. These water headers supply a plurality of spray nozzles, **228**, which are arranged to direct streams of cooling water against the casting and between successive guide rolls **213**. An inspection door **229** in side wall **212** may be provided.

Pivotal movement of frame **92** about pivot pin **95** is provided by hydraulic cylinder **104**, which has a piston rod **106** attached to a mounting bracket **108** which is in turn attached to frame **92**. Cylinder **104** is mounted on a suitable fixed structural framework member such as I-beam **105**.

Movable frame member **92** is movable between a retracted position, shown in the dotted lines of FIG. 4, which permits unimpeded vertical descent of starter bar **26**, and a normal operating position, shown in the solid lines of FIG. 4, wherein the upper end of this frame member **92** is positioned directly below the lower end of bending means **60** so as to provide a continuous curved path for the casting as it descends. Bending of the casting is initiated by the bending means **60**. When the casting emerges from the bending means **60** and enters guide frame member **92** it conforms to the curved path of guide rolls **213**.

Fixed guide frame member **94** is supported by a fixed structural framework **234**. This fixed guide frame member **94** is virtually identical to the movable guide frame member **92**, and hence a cross-sectional view and a detailed description of this frame member are omitted. Fixed frame member **94** is an enclosed four-sided structure having a plurality of guide rolls **235**, a first pair of sides **236** perpendicular to the axes of the guide rolls, and a second pair of sides **237** intersecting sides **236** and lying generally parallel to the guide rolls. The axes of guide rolls **235** as shown in FIG. 4 lie along a pair of curved lines which define therebetween a path for the casting as it descends. The lines of contact between the guide rolls **235** and the descending casting form a pair of generally curved surfaces which define a curved path for the casting. The casting as it emerges from the bottom of guide frame **94** is traveling in an oblique direction having a substantial horizontal component. Guide frame **94** is also provided with a pair of water headers **238** having a plurality of spray nozzles **239** for directing cooling water against the casting to complete solidification before it emerges from the lower end of fixed guide frame **94**. The streams of water emerging from nozzles **239** are directed between successive guide rolls **235**.

Referring now to FIG. 6, there is shown a second embodiment of the guide frame according to this invention. This embodiment, designated generally as **240**, includes a movable guide frame member **242** and a fixed guide frame member **94**. The fixed guide frame member **94** in this embodiment is similar to that shown in the embodiment of FIG. 4.

Movable guide frame member **242** is reciprocable between a retracted position, shown in dotted lines, and a normal position, shown in solid lines in FIG. 6. Reciprocating movement is provided by a hydraulic cylinder **244** having a piston rod **246** extended therefrom and connected to a mounting bracket **248**, secured to the side walls of frame member **242**. A pair of tracks **250** secured to framework **242** ride on flanged wheels **254** which are journaled in mounting brackets **256** which are secured to the fixed structure framework **220**.

The structure of guide frame **242** is generally similar to that of guide frame **92** illustrated in FIG. 4, the only essential difference being the manner of movement. Guide frame **242** is an enclosed four-sided structure having a pair of side walls **260** in which a plurality of guide rolls **262** are journaled. Guide rolls **262** are arranged in a pair of curved rows, their axes lying along a pair of curved lines defining a path for the casting therebetween. The lines of intersection between the guide rolls **262** and the path of the casting as it descends define a pair of curved surfaces. The other two side walls **264** intersect side walls **260** and are generally parallel to guide rolls **262**. A pair of water headers **266** having a plurality of spray nozzles **268** are provided for directing cooling water against the casting.

When the movable guide frame memebr **242** is in the retracted position shown in dotted lines, the starter bar **26** is free to descend vertically without interfering with this guide frame member. When the guide frame member is moved to the normal position, shown in solid lines in FIG. 6, it receives the casting as it emerges from bending means **60** while it is traveling substantially vertically, and guides the casting in a curved path. The movable frame member **242** in its normal position, and the fixed frame member **94** cooperate to provide a single continuous curved path for the casting.

Guide frame **270** according to the third embodiment of the invention, shown in FIG. 7, comprises a movable rigid frame **272** and a fixed rigid frame **274**. The frame **270** of this embodiment is similar to frame **240** as shown in FIG. 6, except that a portion of the frame structure which is included in movable frame memebr **242** in FIG. 6 is a part of fixed frame **274** in this embodiment. The movable rigid frame **272** is an open three-sided structure having a pair of opposed side walls **276**, a curved back wall **278** which is generally parallel to the path of the casting, and a plurality of guide rolls **280**. The axes of guide rolls **280** are arranged along a single curved line, and these guide rolls are adapted to bear against a single face of the casting during its descent. Frame **272** is provided with a water header **282** and a plurality of spray nozzles **284** projecting there from. These spray nozzles direct water between adjacent guide rolls **280** and against one face of the casting. Guide frame **272** is reciporcable between the retracted position, shown in dotted lines, which permit unimpeded vertical descent of the starter bar, and the normal position, shown in solid lines, in which guide frame **272** cooperates with guide frame **274** to provide a curved path for the casting as it descends. The structure for accomplishing reciprocatory movement of guide frame **272** is similar to that for moving guide frame **242** in FIG. 6 and consists of a hydraulic cylinder **244** having piston rod **246** attached to mounting bracket **248** of frame **272**. A pair of tracks **250** secured to frame **272** ride on flanged wheels **254** which are mounted on brackets **256** for guiding the movement of curved guide frame **272**.

Guide frame **274** consists of an upper portion **285** and a lower portion **286**. Frame portion **286** is a four-sided structure having a pair of opposed side walls **288** and a pair of curved side walls **290** and **292** which are generally parallel to the path of the casting, and axes of guide rolls **280**. Side **290** extends the entire height of fixed upper portion **285**. Side **292** extends only below the lower portion **286** of frame member **274** and its upper end terminates at the lower end of movable frame member **272**. Only the lower portion **286** is an enclosed four-sided structure. The upper portion **285** is a three-sided structure which is complementary in shape with movable frame member **272**. Frame member **274** has guide rolls **293** arranged in two curved rows **293***a* and **293***b* for guiding the opposite faces of the casting. Row **293***a* lies entirely in the lower portion of the frame and is a continuation of row **280** in movable frame member **272** when that frame member is in operating position. Row **293***b* extends the entire length of frame **274**. Frame **274** has a water header **300** which lies parallel and close to side wall **290**, and a second water header **302** which lies parallel and close to side wall **292**. Each of these headers has a plurality of nozzles **304** projecting laterally therefrom and adapted to spray cooling water against the casting.

Referring now to FIG. 8, there is illustrated a fourth embodiment of the present invention. In this embodiment there is a movable guide frame section **310** and a fixed guide frame section **312** therebelow. Fixed guide frame

section 312 is structurally similar to guide frame section 94 in the embodiments of FIGS. 4 and 5 except for the presence of an outwardly extending guide flange 314 near the top thereof for guiding the movable section 310 as will be hereinafter explained.

Movable guide section 310 comprises a chain 320 arranged at each side having a plurality of links therein. Pivotally attached to each link is a guide section 322 having one pair of rolls 324 journaled in said guide section and adapted to bear against the opposite faces of the casting. Each of the guide sections 322 also includes water spray nozzles 326 adjacent one end thereof, arranged to direct streams of water against the casting without striking guide rolls 324. In other words, each of these streams of cooling water is directed between the guide roll 324 in the guide section supporting said nozzle and the corresponding guide roll in the adjacent guide section. Each of the guide sections 322 extends transversely of chain 320 on either side thereof.

The top of guide section 310 has a supporting structure 328 for supporting chain 320. This supporting structure 328 is a suitably designed structure having a top surface 330 and a pair of side walls 332 extending downwardly therethrough. This structure 328 is fixedly secured to a fixed rigid supporting structure denoted herein by a pair of channel sections 334. A pin 336 or number of pins extending through each side wall 332 supports chain 320. When no lateral force is applied to frame member 310, it hangs freely in a vertical position, and in this position permits unimpeded descent of the starter bar. The frame member 310 can be moved by a suitable supporting member or pusher 340 to normal position, in which the frame assumes a curved shape and in which the lower end of frame 310 is in alignment with fixed frame 312 and is held in proper alignment by guide flange 314. The surface contour of pusher member 340 is made to suit the desired curve of frame 310 in its normal operating position. The actuating means for pusher 340 is similar to the actuating means for the embodiments shown in FIGS. 6 and 7, and consists of a hydraulic cylinder (not shown), a piston rod 342 attached to the bracket 344 which is fixed to pusher 340, and a pair of tracks 346 which are an integral part of pusher 340 and each co-act with flanged guide wheels 348, which are mounted for rotation in fixed structures.

Because the casting in normal operation according to this invention has a liquid core after it passes through the lower pinch roll stand 42, it is not possible to severe this casting with the usual cutting torch as it descends vertically below the pinch rolls. According to the conventional practice, the casting is severed a short distance above the top of the starter bar, and then the starter bar with this short length of casting is lowered vertically. The remainder of the casting may be cut into lengths and lowered vertically or may be deflected into a curved path according to means presently known in the art. Operation according to this invention requires separation of the casting from the starter bar without cutting the casting, so that the starter bar may descend vertically while the casting is bent by bending means 60 and deflected and guided in a curved path by the guide frame 90 of this invention.

The starter bars used in the present invention may comprise an elongated metal body having a metallic chill plate releasably secured to the top thereof. One such starter bar is illustrated in FIGS. 9 to 11. This starter bar is described in greater detail and claimed in the copending application of Justin E. Foldessy and Francis Gallucci, Ser. No. 333,383, filed Dec. 26, 1963, now Patent No. 3,266,104, issued Aug. 16, 1966, and entitled "Continuous Casting Apparatus Having a Quickly Disconnectable Starter Bar."

Referring now to FIGS. 9 to 11, starter bar 26, which is adapted to be inserted into the lower end of tubular open-ended continuous casting mold 20 as indicated in FIG. 1, is an elongated metal body having a metallic chill plate 24 releasably secured to the upper end thereof.

This metallic chill plate is approximately ¼" to ½" thick. It protects the starter bar 26 from direct contact with molten metal poured into the mold. Chill plate 24 has a plurality of cylindrical pins 350 welded thereto. Pins 350 have heads 352 above the chill plate for gripping the casting in an interlocking grip, and also have necked portions 354 below the chill plate. The starter bar 26 has a T-shaped transverse passage 366 extending therethrough from one edge wall 368 to the opposite edge wall 370 and holes in the upper end to receive pins 350. A rectangular slide plate 376 is slidable in channel 366. Slide plate 376 has a plurality of slots 378 which engage necked portions 354 of pins 350 so as to secure chill plate 24 to bar 26 when the slide plate 376 is in the position shown and to release bar 26 from chill plate 24 and the attached casting when the slide plate 376 is moved to the left. The slots 378 have circular portions 380 which are slightly larger in diameter than pins 350, and oblong portions 382 are narrower than the diameter of pins 350 but slightly wider than the necked portions 354. A flange 384 attached to slide plate 376, and a limit stop 386, limit the extent of sliding movement of slide plate 376. Piston rod 54 strikes slide plate 376 when this slide plate reaches the elevation at which this piston rod is located. This causes sliding movement of slide plate 376 to the left to release the starter bar 26 from chill plate 24. The starter bar may then be lowered at a speed greater than that at which chill plate 24 and the attached casting descends. Starter bar 26 also may have an indentation 400 in at least one edge for receiving piston rod 58 and thereby setting actuating means 50 into operation.

An atlernative starter bar which is useful in this invention is that described and claimed in the copending application of Justin E. Foldessy and Andrew L. Poulos, Ser. No. 333,449, filed Dec. 26, 1963, now Patent No. 3,274,653, issued Sept. 27, 1966, entitled "Quickly Disconnectable Starter Bar."

Disconnection of starter bar 26 from plate 24 in the attached casting is accomplished by a striker arm 54 striking slide plate 376 in starter bar 26 when the slide plate reaches the predetermined elevation at which striker arm 54 and cylinder 52 are located. This cylinder is fixedly mounted between the upper and lower pinch roll stands 40 and 42 as has been indicated. Striker arm 54 is normally retracted away from starter bar 26 as shown in FIG. 1. To release starter bar 26 from chill plate 24, piston 53 and striker arm 54 are moved toward the path of the starter bar and casting. When the striker arm 54 reaches the limit of its travel in this direction, it strikes slide plate 376 moving it to the left and releasing starter bar 26 from chill plate 24. Striker arm 54 is then retracted. Striker arm 54 can be operated in any desired manner. In a preferred embodiment, which will now be described, arm 54 is operated automatically when starter bar 26 reaches a predetermined elevation.

FIG. 12 schematically illustrates a preferred electromechanical automatic actuation system 50 whose function is to release starter bar 26 from plate 24. All components are shown in the de-energized position.

Air cylinders 52 and 56 are conrolled by solenoid operated air valves 450 and 452 respectively. Solenoid valve 450 has a connection 454 for the supply of air under pressure, a pair of exhaust connections 456, and connections 458 and 460 leading to either end of cylinder 52. Solenoid operated valve 452 is of identical construction having an air supply passage 462, a pair of air exhaust passages 464, and a pair of connections 466 and 468 leading to the respective ends of cylinder 56.

Operation of solenoid operated valves 450 and 452 is controlled by the state of the contacts associated with control relays 470 and 472 and timing relay 474. Current for the electrical system is supplied from a power source (not shown) through electrical lines 476 and 478.

Switch 480 is located in line 476. When this switch 480 is closed, the actuation system 50 is supplied with power and is in condition to be operated.

Operation of system 50 is initiated by pushing one of the two parallel push buttons 482 and 484, both of which are normally open, to closed position. When one of the push buttons is closed, relay 470 is energized, thereby closing the normally open contacts 470*a* and 470*b*. The closing of contact 470*b* energizes the solenoid controlled air valve 452 so as to supply air pressure from supply line 462 to cylinder 56 through line 468 so as to extend the sensing arm 58 forward sufficiently to contact and ride on the edge of the starter bar 26. It should be noted that when the sensing arm 58 is thus extended forward, the limit switch 59 is moved to the dotted line position 59*a*, in which position it is still open. Closing of switch 59 requires a further forward extension of the sensing arm 58.

Contact 470*a* closes to provide a holding action so that when the push button 482 or 484 is released, the relay 470 will remain energized by current flowing between the lines 476 and 478 through the normally closed contact 472*a*, the now closed holding contact 470*a*, and the relay coil 470. The two buttons 486 which are in this path of current flow are kept normally closed and are simply included for safety purposes to permit manually stopping the operation of this actuation system 50 at two different locations. Accordingly, the manual release of buttons 482 and 484 will, because of the action of this holding contact 470*a*, leave the sensing arm 58 projected in a forward direction to ride on the starter bar 26.

As the starter bar 26 descends, the sensing arm 58 will ride into the indentation 400, thereby causing the sensing arm 58 to project further forward (to the left in FIG. 12) so as to close the limit switch 59 (shown by the dotted line position 59*b*). As a consequence, relay 472 is energized through the now closed limit switch 59 and the normally closed contact 474*a*, which is controlled by timing relay 474 as will be hereinafter explained.

When relay 472 is energized, normally open contact 472*b* is moved to the closed position, which in turn energizes solenoid operated air valve 450. This causes air under pressure from supply line 450 to be introduced into air cylinder 52 via connection 460, which moves the piston 53 in cylinder 52 and forces the striker arm 54 forward (to the left in FIG. 9) with sufficient force so that the arm 54 will strike the slide plate 376, causing the slide plate 376 to move it to the left as seen in FIG. 9 sufficiently to disengage the starter bar 26 from chill plate 24 and the lower end of the casting. The sensing arm 58 and striker arm 54 are spaced from one another the same distance apart as are the indentation 400 and the slide plate 376, so that the entrance of the sensing arm 58 into the indentation 400 results in the actuation of the striker arm 54 at just the appropriate time to cause the arm 54 to hit the slide plate 376.

The closing of the limit switch 59 also energizes the timing relay 474, the coil of which is arranged in parallel with the coil of the relay 472. Energizing of the timing relay 474 closes the normally open contact 474*b*, which contacts 474*b* then operates as a holding contact for both the relay 472 and the timing relay 474 so that when the sensing arm 58 rides out of the indentation 400, due to the downward motion of the starter bar 26, the limit switch 59 may open without de-energizing the relay 472 and timing relay 474. The contact 474*a* is a normally closed contact which is associated with the timing relay 474 but whose state is not affected by the state of the timing relay 474.

When the timing relay 474 has been energized, it starts on a predetermined timing cycle, at the end of which the timing relay 474 mechanically opens the contacts 474*a* through mechanical linkage 474*c*, thereby de-energizing the relay 472 and the timing relay 474.

While the timing relay 474 is running through its preset time cycle, it as well as relay 472 remain energized. Normally open contacts 472*b* are closed by the energizing of the relay 472 and remain closed during the timing cycle. Therefore, solenoid operated air valve 450 remains energized and striker arm 54 remains in is forward position (to the left in FIG. 12) while timing relay 474 is running through its preset timing cycle. The duration of this timing cycle is normally not over about two seconds.

Once the timing relay 474 has run its cycle, it mechanically opens contact 474*a* so as to de-energize both timing relay 474 and control relay 472. De-energizing of relay 472 causes contact 472*b* to revert to its normally open position and thus de-energize the solenoid actuated air valve 450. De-energizing of the solenoid actuated air valve 450 causes the air cylinder 52 to switch and retract the striker arm 54 to its normally retracted position free of the starter bar 26 and the casting.

Energizing of relay 472 as a consequence of the sensing arm 58 entering the indentation 400 also acts to open the normally closed contacts 472*a*, thereby de-energizing the relay 470. This de-enegizing of the relay 470 opens normally open contacts 470*b* thereby de-energizing the solenoid actuated air valve 452 and causing the air cylinder 56 to switch and consequently retract the sensing arm 58. Thus the sensing arm 58 is retracted and moved out of the way of the starter bar 26 and the casting immediately after it has entered the indentation 400 and this retraction of the sensing arm 58 is achieved automatically.

After the timing relay 474 has gone through its timing cycle and caused the normally closed contact 474*a* to open, the timing relay 474 is de-energized and resets itself resulting in the normally open contact 474*b* opening and the normally closed contact 474*a* reclosing. In this fashion actuation system 50 returns to its initial state, that being the state illustrated in FIG. 12. It should be noted that in this initial state all of the relays 470, 472 and 474 are de-energized so that the contacts shown are in their normal position. It should also be noted that in this initial state the solenoid actuated air valves 450 and 452 are de-energized and place air pressure in the cylinders 52 and 56 in such a fashion as to cause the sensing arm 58 and striker arm 54 to be in their retracted positions (to the right in FIG. 12.)

It should be understood that FIG. 12 is a somewhat simplified schematic drawing of automatic actuation system 50. Additional safety buttons, fuses, meters and the like may be employed to provide information and monitoring of the operation of this automatic actuation system.

Other automatic actuation systems besides the one illustrated can be used. If desired, the sensing mechanism including cylinder 56 and sensing arm 58 can be omitted and the admission of fluid under pressure to cylinder 52 can be under the control of an operator.

Operation according to this invention will now be described with particular reference to FIG. 1. Prior to the start of a casting, the upper end of starter bar and chill plate attached are inserted into the lower end of an open-ended tubular continuous casting mold 20. Molten metal is then poured into the mold until it reaches a predetermined elevation near the top thereof. When this predetermined elevation is reached, the starter bar and the casting attached thereto are slowly brought downward at a uniform rate under the control of pinch roll assemblies 40 and 42. The outer surface of the casting, and the lower end of the casting which abuts the chill plate, solidify while the casting is still in the mold and before movement of the starter bar downwardly is commenced.

After the height of metal in the mold has reached a predetermined level, the starter bar and the casting are brought slowly downward until the starter bar reaches the predetermined elevation at which it is disconnected from the casting by actuation system 50. The upper pinch rolls 40 may be accelerated to rotate at a slightly greater speed than the lower pinch rolls 42 at this time, so as

to maintain a slight compression on the casting and the starter bar. A slight compression on the starter bar facilitates disconnection of the starter bar from the chill plate and casting.

The starter bar, being of substantial length and inflexible, must be brought straight downwardly by suitable means such as traveling receptacle **80**. The starter bar is then brought rapidly downward, while the casting and the chill plate continue to descend at the slow rate still under the control of pinch rolls **40** and **42**. From the time the starter bar is inserted into the bottom of the mold prior to pouring, until the starter bar has been disconnected and lowered below the path of the retractable section **92**, the retractable section is in the retracted position as shown in dotted line position in FIG. 4. This permits unimpeded vertical descent of the starter bar.

After the starter bar has been taken out of the way, the casting continues to descend through the lower pinch roll stand **42** and bending means **60**. In contrast to presently known continuous casting operations in which the casting is completely solidified before it is bent, the casting in the present invention has a core of molten metal, as it enters bending means **60** in the normal mode of operation. The casting is deflected slightly from its vertical line of travel while in bending means **60**. Before the casting emerges from the lower end of bending means **60**, the retractable section **92** is retracted from its dotted line position to its normal operating or solid line position as shown in FIG. 4 so as to receive the casting as it emerges from the lower end of bending means **60**.

The casting continues to descend successively through the upper and lower sections **92** and **94** of curved guide frame **90**, being guided by the guide rolls therein as it descends. The casting still has a liquid core as it enters guide frame **90** and it is cooled by water sprays **100** so as to solidify this liquid core before the casting emerges from the lower end of the fixed section **94** of guide frame **90**. The casting may be further processed as desired.

An important advantage of the present invention is that it is possible to cast metal continuously in an apparatus having less height than the usual continuous casting apparatus. Presently it is considered necessary to solidify the casting completely while it is still traveling in the vertical cooling section directly below the mold and before reaching the pinch rolls. Now it is found that such procedure is not necessary. Instead, partial solidification in the cooling zone directly below the mold is sufficient, and solidification can be completed in a second cooling zone in which the casting is guided in a curved rather than a vertical path. This makes it possible to operate with a vertical cooling zone of considerably less height than was heretofore thought possible.

While this invention has been described with reference to specific embodiments thereof, it is understood that the scope shall be measured only by the scopee of the appended claims.

I claim:

1. In continuous metal casting apparatus comprising a generally vertically extending mold having an upper opening for the introduction of molten metal to form a casting and a lower discharge passage through which said casting may descend continuously as it is formed, the improvement comprising a plurality of pinch rolls arranged in a pair of vertical rows and adapted to engage a pair of opposite faces of said casting for controlling the speed of descent thereof, back-up roll means including a plurality of back-up rolls engaging and supporting said pinch rolls, and motor means for driving said back-up rolls and thereby driving said pinch rolls in frictional engagement with said back-up rolls to control the speed of said casting.

2. The apparatus of claim **1** wherein said pinch rolls are further arranged in an upper assembly and a lower assembly, the pinch rolls of one of said assemblies being rotatable at a different speed from the pinch rolls of the other of said assemblies.

References Cited

FOREIGN PATENTS

731,659	6/1955	Great Britain.
840,676	7/1960	Great Britain.
932,196	7/1963	Great Britain.

J. SPENCER OVERHOLSER, *Primary Examiner.*

R. SPENCER ANNEAR, *Assistant Examiner.*

U.S. Cl. X.R.

226—181

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,447,591 June 3, 1969

Justin E. Foldessy

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 13, "continuopsly" should read -- continuously --; line 26, "1969" should read -- 1967 --. Column 2, line 61, "casing" should read -- casting --. Column 3, line 23, "isomeric" should read -- isometric --. Column 4, line 53, "genetrally" should read -- generally --. Column 5, line 10, "its" should read -- is --; line 15, "thte" should read -- the --; line 27, "vetrically" should read -- vertically --. Column 8, lines 7 and 23, "memebr", each occurrence, should read -- member --; line 35, "reciporcable" should read -- reciprocable --. Column 9, line 48, "severe" should read -- sever --. Column 11, line 42, "450" should read -- 454 --; line 60, "contacts" should read -- contact --. Column 14, line 10, "scopee" should read -- scope --.

Signed and sealed this 21st day of April 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents