APPARATUS FOR THE CONTINUOUS PRODUCTION OF CAST BILLETs

Filed Feb. 19, 1962

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APPRARATUS FOR THE CONTINUOUS PRODUCTION OF CAST BILLET

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Filed Feb. 19, 1962, Ser. No. 174,629
8 Claims. (Cl. 22—57.2)

This invention relates to an apparatus for the continuous production of cast billets or ingots. More particularly, the invention provides a novel apparatus for continuously casting a plurality of ingots or billets in a regular sequence.

Conventional direct chill casting is accomplished in a ring mold assembly resembling in appearance a hollow cylindrical member open at both ends. A block or plug is inserted within the cylindrical cavity, of the ring mold, to seal the bottom, and molten metal is introduced at the upper open end of the ring mold. The lower portion of the hollow cylindrical cavity is cooled to a temperature to cause solidification of the molten metal. As the mold fills with metal the bottom block is lowered out of the cylindrical cavity, solid cast metal is withdrawn in the form of a continuous body. The cast billet is lowered at the desired casting speed and the metal flow coincides with the billet and in this manner a continuous cast billet can be produced of any desired length.

Standard casting machines of the type referred to operate on a batch basis. Thus, after a billet of predetermined length has been cast, the machine is shut down and the billet removed. After removal of the billet and cleaning of the entire machine the entire operation must be repeated each time to produce another cast billet. These conventional type casting facilities are capable of only limited production capacity. Because of time consuming starting, stopping and unloading stages in the standard operation actual metal casting periods are limited to approximately 50 to 75% of the total time required for the casting operation. A major portion of the time spent by casting station operators involves cleaning up equipment after each casting and getting the equipment ready for the next or subsequent cast. Moreover, because of the nature of the operations it is impossible to spend time during casting to prepare for subsequent castings. Many of the operations between casts have to be manual because of the arrangement of equipment and necessity of taking casting stations apart to recover the product from the station. Oftentimes defects occur at the ends of the casting as a result of the abrupt starting and stopping of the ingot casting. This scrap loss may be as high as 15 to 20% but could be reduced in an operation with improved starting and stopping techniques.

The present invention involves an apparatus which can produce and discharge individual cast billets or ingots of a practical uniform length with a minimum of scrap loss, continuously and at a regular cycle for indefinite periods.

The apparatus comprises a plurality of individual casting units arranged in a circular pattern like a carousel and operated in a manner similar to a bottle-filling machine. Each casting operation is started from a fixed position or active casting station, as the carousel rotates the bottom block of the casting unit is lowered in a helical pattern while molten metal is poured into the top of the ring mold to produce a continuous billet. Upon completion of the casting cycle each individual cast billet is removed at an unloading or inactive station and conveyed onto suitable off-loading equipment. The resetting and drying of the bottom block and the lubrication and replacement of the mold of each casting unit is performed during one portion of the total cycle at certain inactive stations. The starting and stopping of metal flow to each of the casting units may be automatically performed, thereby enabling the operator of the apparatus to merely supervise operation and to recondition and replace component parts of the casting units, as required.

The invention is illustrated in the accompanying drawings wherein:

FIG. 1 is an elevational view of a continuous casting apparatus of the invention.

FIG. 2 is an elevational view across one of the casting stations.

FIGS. 3, 4 and 5 are illustrations of the siphon-trap assembly and its components.

FIG. 6 is a partial plan view illustrating the various automatic operations which occur around the rotating drum, and

FIG. 7 is a component travel curve describing the vertical travel of the various components for each position or station during rotation.

The continuous casting machine, according to the invention, and as seen in FIG. 1, comprises a rotating drum 10, a central supporting section 20, and a casting and heat metal transfer assembly 30. Rotating drum 10, supported with platform 12 by stationary center post 14 and revolves on a top bearing wheel assembly 16.

Central supporting section 20 extends vertically above platform 12 and at the center thereof. A variable speed drive 21 and a torque arm 22 are connected to central supporting section 20 and provide the power to rotate the drum 10 and platform 12 together with central supporting section 20. Extending from central supporting section 20 are a plurality of siphon support arms 24 which are preferably pivoted mounted and support optional tubular vacuum connecting means 26 which, if desired, may be a part of the siphon assembly 28. In addition to tubular vacuum connecting means 26, siphon assembly 28 includes bifurcated or divergent tubular vacuum members 27 and 27' which means are hereinafter referred to as the siphon. The siphon assembly including the bifurcated siphon arms 27 and 27' and tubular vacuum connecting means 26 are mounted from a vacuum header tube 23 which is in turn connected by suitable piping means to a vacuum producing compressor or fan means, not shown.

Casting and molten metal transfer assembly 30 is shown and described in FIG. 2. As can be seen the bifurcated tubular arms 27 and 27' which comprise the siphon arm 27 of the siphon assembly 28. The outer arm 27' of the siphon is disposed in a fixed molten metal supply trough 32 which is of a circular configuration and concentric with rotating drum 10. The feed trough 32 is comprised of an outer shell 31 and an inner lining 33 of suitable refractory material. The inner arm 27 of the bifurcated siphon means extends into the ring mold assembly 40. Ring mold assembly 40 comprises the mold itself 42, a hot top 44 and a spray box or cooling assembly 46. The function of a hot top is to minimize the radiant cooling of the siphon and reduce cold folding on the billet surface. The bottom block 48 serves as the bottom portion of the ring mold during the start of casting. Thus, molten metal is transferred from the fixed trough 32 through the bifurcated tubular arms 27 and 27' of the siphon assembly 28 into the mold cavity formed by the ring mold 32 and bottom block 48. Siphon traps 60 and 69 which will be further described are disposed beneath the open ends of siphon conduit arms 27 and 27'. During pouring molten metal enters trap 60 and overflows the trap to fill up the cavity. The siphon cup 60 also acts as a ballast or distributor to reduce the tendency for shrinkage in the billet core and increase the casting rate for any particular size casting. A coolant which may be any suitable cooling fluid, e.g., water, is supplied from the spray box 46 onto the outer surface of the mold 42, and
molten metal within the lower portion of the cavity solidifies. After the metal of the bottom portion of the cavity has solidified, bottom block 48 is lowered to allow the solidified cast body to descend. In this manner a continuous core or elongated metal ingot or billet can be cast to any desired length as will be hereinafter described.

The casting operation is performed while the rotating drum with the casting and molten metal transfer assembly revolves about its central axis. The two arms 27 and 27' of the siphon assembly 28 are disposed beneath the surface of molten metal in both the fixed trough 32 and the continuous mold assembly 40, while the drum rotates. Thus, during casting the mold assembly moves both vertically and in a circular path and results in an over-all spiral descending path of travel without interruption of the molten metal transfer.

The bottom block 48 is connected by block connecting arm 49 to a bottom block guide unit 50. The bottom block guide unit 50 comprises a pivot pin 51, to allow freedom of vertical movement of connecting arm 49 and bottom block 48, and wheels 54 mounted and aligned between angle tracks 56 to maintain vertical alignment of the bottom block assembly while the cast billet 47 is lowered with bottom block 48 from the position 48'. Angled tracks 56 extend vertically over the length of the rotating drum to permit vertical aligned movement of the mold assembly. This can be seen in FIGS. 2 and 6. The angle arm 64 of the siphon assembly is connected to a roller 58 which is arranged so as to roll freely along a fixed helical bottom block cam rail 61. In the view shown the mold assembly is schematically depicted in the "bottom" position wherein the roller 58 is in contacting engagement with tangential bottom block raising roller 62. Raising roller 62 is connected by arms 64 at the ends thereof to a hydraulic lifting device, not shown, which, upon engagement by roller 58 and after removal of the cast billet and cessation of metal pouring is activated to raise the guide block assembly to its uppermost position. Angle arm 64 is provided to limit the maximum vertical movement of the guide block assembly as it is raised into starting position.

As shown in FIG. 4, the siphon valve mechanism, i.e., siphon trap assembly, of the casting apparatus enables the casts to be started or stopped precisely with a minimum disturbance of the molten metal. The level within each of the plurality of mold assemblies can also be maintained by maintaining a uniform level in the distribution molten metal supply trough. The aforementioned valving device, i.e., siphon trap assembly, consists of arms 29 and 29' with cups or traps 60 and 60' which fit over the open end of siphon 27 and 27' to prevent air from entering the raised conduit when the siphon is removed from the molten metal.

As can be seen in FIGS. 3, 4 and 5 the siphon assembly comprises bifurcated conduit 27 and 27'. The bifurcated conduit is preferably connected by tubular connecting means 26 to a vacuum header means 23. The siphon trap assembly comprises cups 60 and 60' which are connected to arms 29 and handle means 25 having curved end portions adapted to envelop bifurcated conduit means 27 and 27' at the connecting portion thereof. The entire siphon and trap assembly is best seen in FIG. 5 wherein the unit is shown assembled.

The siphon equipment used to transfer metal from the circular supply trough, filled and maintained with a constant level of molten metal, comprises conduit members 27 and 27'. The casting rate of individual billets determines the amount of flow through the conduit 27 and 27' from the higher supply level to lower discharge or mold level.

The difference in level is in turn determined by the required flow rate and the resistance to flow caused by the length and shape of the siphon conduit. In general, the level difference is slight, i.e., about 1/2" or 1/4" since the flows involved are small and the siphon conduit tubes must be of a practical size to permit fabrication and cleaning. Beneath each end of the conduit siphon tube 27 and 27' is disposed the cup portions 60 and 60' of the siphon trap assembly. The siphon trap assembly permits a precise and instantaneous shutoff by lifting the assembly from the liquid metal. The traps or cups 60 and 61 on the end of the conduit maintain the continuous flow of metal ready for instantaneous flow at the next start. The traps also eliminate the added flow of metal at the end of a cast which would come from draining the siphon spout. In addition, the traps enable rapid operation by avoiding the additional time otherwise required at the start of a cast for the siphon or spout to refill. This lifting and lowering action to stop and start metal flow constitutes an effective valving (off and on) technique without resorting to sealing off of the conduit by plugging. Thus, the siphon trap assembly permits a precise finish or "cut-off" to the completed cast and a precise start-up for the new cast. The interruption of flow must, of course, be accomplished well within the time it takes for the trapped metal to freeze in the siphon. This precise interruption of flow accomplished by means of the cup portions 60 and 60' of the siphon trap assembly as stated above provides an effective "valving" action to the flow of the metal without the necessity of plugs, seats or gaskets.

The siphon itself is "primed" originally by manipulating the closed conduit first to a horizontal plane and then inclining one end while the conduit at the other end is submerged in molten metal. This action expels the air from within the tube so that if the submerged end is placed in the cups of the siphon trap assembly and the siphon and cups are withdrawn from the metal during operation, the primed and trapped siphon may be ready for service.

An alternate method of priming the siphon is to use a vacuum force established by means of a third leg of the conduit of the siphon conduits, i.e., a tubular connection member 26. In this case, the third conduit 25 may be extended from the siphon conduit 27, 27' at the connecting portion thereof and connected to a suitable vacuum creating means through header 23. This vacuum can also be used to remove dissolved gases that are liberated within the tube, as well as providing an initial prime to the siphon conduit. The amount of vacuum necessary is very small, on the order of 8" to 11" of water. The vacuum force can be effectively generated by a mechanical inspirator or an exhaust fan. If a vacuum source is used, a suitable valving means close to the leg of the siphon should be provided to trap the partial vacuum above the metal. This will prevent the metal from surging in the traps and top leg of the conduit when the siphon assembly is raised from the trough and mold at the end of a cast and lowered into the mold at the start of the new cast. In addition, it may be desirable to heat the vacuum leg above the conduit to prevent freezing of the molten metal.

The trap assembly shown in FIG. 4 is designed so that the conduit can be assembled into the cups without exposing the open ends thereof and releasing the siphon. When the assembly is raised from the bath by the handle, the siphon remains trapped ready for use to equalize the level between the distribution trough and the ring mold. As the siphon with trap assembly is lowered into the distribution trough and the ring mold, the flow starts to equalize the levels. Uniform uninterrupted operation is accomplished by synchronizing the continuous lowering of the cast billet with the vacuum addition. Turbulence during metal casting is at a minimum as the conduit is purged to normal spout control since there is no energy from a hydrostatic head to be dissipated with a flow control mechanism at the orifice.

Upon completion of the cast, flow of the molten metal must be stopped. The siphon and trap assembly is then raised out of the mold and trough, and the traps at each end of the conduit prevent air from entering the conduit and releasing or breaking the siphon force (vacuum) which holds the metal in the conduit. The as-
assembly is transferred to a casting station in which the casting operation is about to be started. If the metal to be cast contains dissolved gas which may be released in the conduit it is necessary to use the vacuum means for the evacuation of the castings to the casting stations. This evacuation operation cannot be applied while the siphon is out of the metal inasmuch as the molten metal level over the conduit ends is relatively small and the metal reserved in the traps would be exhausted. To accomplish the evacuation, it is necessary to use the vacuum tube described above, a fixed valve to permit vacuum interruption when the siphons are transferred from a station wherein a cast has been completed to another station wherein the casting operation is beginning. Upon completion of a casting cycle the entire mold with its attached hot top can be changed while the casting station is inactive.

As described above, the bottom block for each casting station is secured to a bottom block guide unit. The guide unit is vertically aligned with the mold and guided by angle tracks and V wheels or other devices during its vertical travel. The bottom block is lowered by a radial roller which follows a fixed helical bottom block cam rail which may be separate or attached to the casting pit walls or structure. The bottom block may be raised to the proper elevation by a tangential elevator roller where it is redeposited upon the helical cam rail to permit the start of a subsequent casting operation. The cast billet is removed from the casting station by tipping bottom block assembly outward and downward to an unloading cradle. At the end of the lowering operation the billet is broken loose from the mold down locks and the bottom block. The bottom block is then righted as it is elevated by the tangential roller. The assembly is raised to a position that will permit access to the bottom block for blowing with air to clear off water left from the cooling operation. The bottom block is raised into contact with the mold, and the mold and bottom block reset together into their normal elevational position with respect to the spray box. As described above, the vertical movement of the block assembly from the bottom of the spiral cam position to the raised position for initiating a subsequent casting operation can be accomplished by a simple hydraulic lifting mechanism. However, any suitable mechanism may be employed, such as for example, cams suitably cut and fixed at required stations or chain mechanisms.

The variable speed drive unit which powers and controls the speed of the rotating drum may also power the bottom block elevating mechanism, the unloading cradle, and the siphon equipment. These components can be set with timing gears to permit all components to work in unison and automatically.

The continuous casting apparatus as described above preferably provides 16 active casting units and 4 inactive casting stations all of which are in continuous operation. Referring to FIG. 6 it is seen that rotating drum 10 rotates in a generally clockwise direction. As a casting station approaches the unloading area from the siphon equipment is removed out of the mold and trough and installed in a casting station about to be started. In the diagram of FIG. 6 casting station No. 6 is entering the unloading stage, the siphon is removed and the down travel halted.

The complete ingot is permitted to solidify and the casting station assumes the position designated as No. 7. The casting station, as illustrated in FIG. 2, is positioned at the unloading pit area where the mold assembly will be tilted and the cast billet broken loose from its mold down locks in the bottom block. The bottom block, now free of the billet, is turned into an upright position and elevated by a tangential roller mechanism described in FIG. 2. As the bottom block is raised it assumes a position designated as casting station No. 8. Next an air nozzle is directed onto the bottom block to remove water which may have remained. After drying, the bottom block is reset into engagement with the mold. As the casting station is further rotated and assumes a position designated as zero, the molten metal transferring and casting operation again begins. As can be seen only four of the stations—6, 7, 8 and 9—are inactive and the remaining stations are in various active stages of molten metal filling.

The vertical and rotational travel of the mold during casting cycle operation can be best seen in FIG. 7. As can be seen in the component travel curve as the stations approach from the left of the diagram the bottom block of the casting station is lowered at a uniform rate along the spiral descending rail until it approaches casting position No. 6 corresponding to position 6 in FIG. 6. The siphon is removed and the downward travel is halted. Between stations 6 and 7 the cast billet is allowed to totally solidify. As it approaches station 7 the mold is tipped and the billet unloaded therefrom. The bottom block is raised between positions 7 and 8 and the bottom block and continuous mold are reset and blown off before station 9 so that when the mold reaches position No. 9 it is ready to begin a new cast. Upon the beginning of casting bottom block begins to descend and to repeat the cycle.

Since the majority of steps during the casting operation are mechanized and in a continuous sequence, the resulting cast billets have a uniformity heretofore unattainable. Precise starting and stopping conditions available in the described continuous casting operations allow the reduction of scrap losses while the increased capacity and productivity enable a reduction in the length of the mold now conventionally required to allow the operator sufficient time to make full adjustments for the start of the casting operation. Moreover, the time between stops and starts occurs at regular intervals and at the same place for each individual casting station. This regularity permits one operator and an assistant to accomplish the work now done by twice as many people.

The circular arrangement and automation of the continuous casting apparatus allows 80 to 85% of the casting stations to operate continuously. This is a considerable saving when compared to conventional semicontinuous or batch-type operations. Furthermore, in avoiding the necessity of disassembling the casting station to remove the product, the over-all efficiency of operation is vastly increased. Thus, the continuous casting apparatus will produce a billet of uniform quality and minimum scrap loss while providing a method of starting and stopping metal flow with a minimum of turbulence and corresponding contamination of the molten metal.

It is apparent that various changes and modifications may be made without departing from the invention, and the scope of the invention is to be limited only by the appended claims, wherein what is claimed is:

1. A casting apparatus for the continuous casting of elongated bodies comprising a plurality of casting and molten metal transfer stations moveable about a central axis, said casting and molten metal transfer stations being equipped with ring mold assemblies having vertically moveable bottom portions, siphon means associated with each of a major portion of said ring mold assemblies, said siphon means being operable to transfer molten metal from a molten metal supply source at a uniform predetermined rate to a corresponding number of said ring mold assemblies during movement of said casting and molten metal transfer stations, means to lower said bottom portions of said ring mold assemblies at a predetermined rate, said rate of molten metal transfer to said ring mold assemblies coinciding with the rate of descent of said bottom portions, means to halt the molten metal flow through said siphon means upon completion of a casting cycle, and means to restore said bottom portions of said ring mold assemblies upon completion of a casting cycle and removal of the cast elongated bodies to the vertical ele-
3,174,297 rational position occupied at the start of molten metal transfer to said ring mold assemblies.

2. A continuous casting apparatus comprising a circular casting assembly, said casting assembly including a cylindrical revolving drum portion and a stationary concentric wall portion, means to rotate said revolving drum portion, a cylindrical molten metal supply trough affixed to said stationary concentric wall portion and extending around the periphery along the major portion thereof, a plurality of casting and molten metal transfer stations including a number of active stations affixed to said revolving drum, each of said active casting and molten metal transfer stations being equipped with a ring mold assembly and siphon means having bifurcated conduit portions adapted to extend simultaneously into said molten metal supply trough and said ring mold, said ring mold assembly including an open end ring mold and a vertically movable bottom portion, means to guide said vertically movable bottom portion along a substantially uniform descending path of travel from an uppermost to a lowermost position during rotation of said revolving drum portion, means to raise said vertically movable bottom block portion from said lowermost to said uppermost position, means to maintain the bottom block portion in vertical alignment with said ring mold during vertical travel.

3. A casting apparatus for the continuous casting of elongated bodies comprising a plurality of casting and molten metal transfer stations movable about a central axis, each of said casting and molten metal transfer stations being equipped with a ring mold assembly having a vertically movable bottom portion, a plurality of siphon means to transfer molten metal from a molten metal supply source at a uniform predetermined rate to a corresponding number but less than the total of said ring mold assemblies during movement of said casting and molten metal transfer stations, means to lower at a predetermined rate said bottom block portions of said ring mold assemblies into which molten metal is being transferred by said siphon means, said rate of molten metal transfer to said ring mold assemblies coinciding with the rate of descent of said bottom block portions, means to halt the molten metal flow through said siphon means upon completion of a casting cycle, and means to restore said bottom portion of said ring mold assembly upon completion of said casting cycle and removal of the cast elongated body to the vertical elevation position occupied at the start of molten metal transfer to said ring mold assembly.

4. A casting apparatus for continuous production of elongated bodies comprising a circular casting assembly including a cylindrical revolving drum portion and a stationary concentric wall portion, means to rotate said revolving drum portion, a cylindrical molten metal supply trough affixed to said stationary concentric wall portion and extending around the periphery along the major portion thereof, a plurality of active casting and molten metal transfer stations comprising (1) a ring mold assembly, and (2) a siphon means, said ring mold assembly comprising (a) an open end ring mold, (b) a vertically movable bottom block portion, means to lower said vertically movable bottom block portion at a substantially uniform descending path of travel from an uppermost to a lowermost position, said siphon means comprising bifurcated conduit portions adapted to extend simultaneously into said molten metal supply trough and said ring mold assembly, said bifurcated conduit portions effect the transfer of molten metal from said supply trough to said ring mold assembly during rotation of said revolving drum assembly, a siphon trap assembly associated with each of said siphon means, said siphon trap assembly comprising cup portions adaptable to close the ends of said bifurcated conduit portions to halt the flow of molten metal from said molten metal supply trough to said ring mold assembly upon completion of a casting cycle, and means to restore said bottom block portions of said ring mold assemblies to the uppermost vertical elevational position occupied at the start of molten metal transfer to said ring mold assemblies upon completion of a casting cycle and removal of the cast elongated body to said casting station.

5. A casting apparatus for the continuous casting of elongated bodies in a regular casting cycle, comprising

(A) revolvable support means,

(B) a plurality of casting and molten metal transfer stations affixed to said revolvable support means, (1) each of said casting and molten metal transfer stations operable to produce at least one cast elongated body upon each complete revolution of said revolvable support means,

(C) a plurality of siphon means having bifurcated conduit portions, (1) each of said siphon means being operable to transfer molten metal from a supply source to one of said casting and molten metal transfer stations during rotation of said revolvable support means,

(D) a siphon trap assembly associated with each of said siphon means, (1) said siphon trap assembly comprising cup portions adaptable to

(a) close the ends of said bifurcated conduit portions to halt the transfer of molten metal to that casting station to which said siphon means has been transferring molten metal upon completion of that station's casting cycle and

(b) reopen said bifurcated conduit portions to resume transfer of molten metal to a casting station which has completed a casting cycle and from which a cast elongated body has been removed.

6. A casting apparatus according to claim 5 wherein said casting and molten metal transfer stations include ring mold assemblies, said ring mold assemblies comprise an open end ring mold and vertically movable bottom block portions, and said casting apparatus being provided with means to lower said bottom block portions of said ring mold assemblies at a predetermined rate from an uppermost to a lowermost position and means to restore said bottom block portions upon completion of a casting cycle and removal of the cast elongated body to the uppermost position occupied at the start of molten metal transfer to said casting station.

7. A casting apparatus according to claim 6 including means to maintain said bottom block portion in vertical alignment with said ring mold during vertical movement.

8. A casting apparatus according to claim 5 wherein said revolvable support means comprises a circular revolving drum and said molten metal supply source comprises a molten metal supply trough affixed to a stationary wall portion concentrically disposed adjacent to said revolving drum and extending around a major portion of the periphery of said revolving drum.

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