

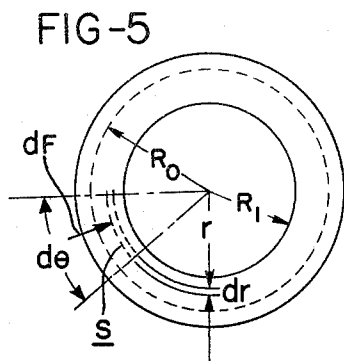
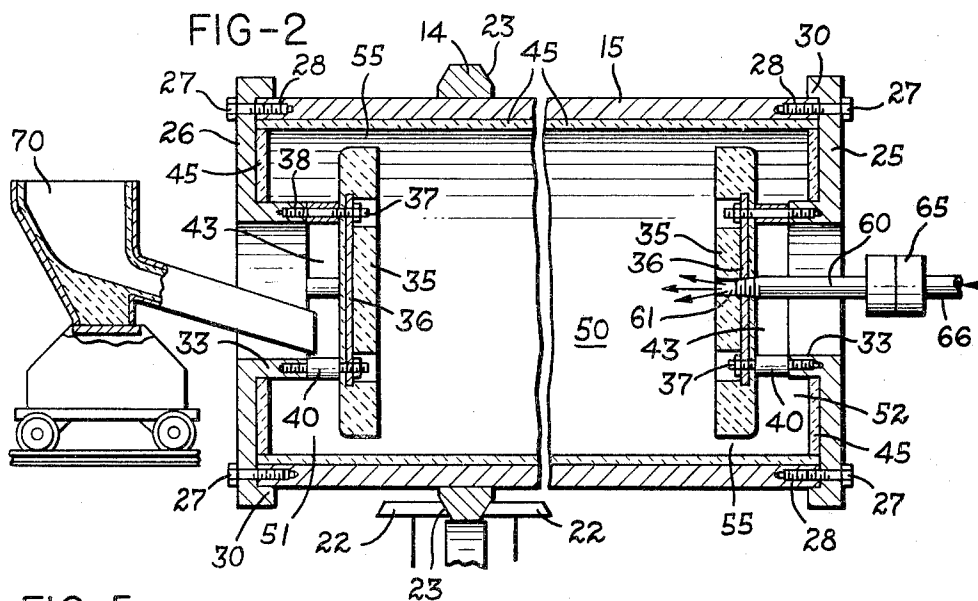
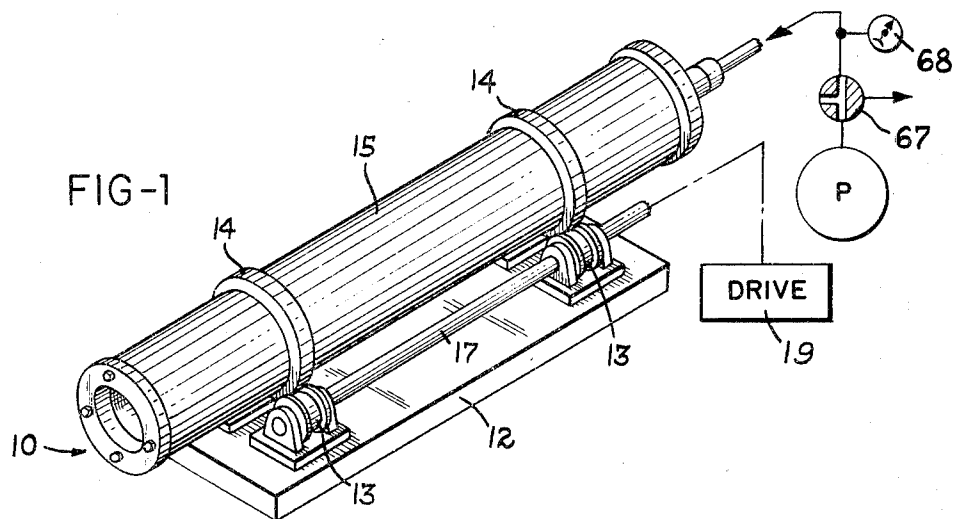
Aug. 2, 1966

W. E. ROJECKI
CENTRIFUGAL CASTING APPARATUS FOR CASTING
A FLANGED ROLL AND METHOD OF CASTING

3,263,285

Filed July 14, 1964

3 Sheets-Sheet 1



INVENTOR.

WALTER E. ROJECKI

BY

Marchal, Biebel, French & Bugg
ATTORNEYS

Aug. 2, 1966

W. E. ROJECKI
CENTRIFUGAL CASTING APPARATUS FOR CASTING
A FLANGED ROLL AND METHOD OF CASTING

3,263,285

Filed July 14, 1964

3 Sheets-Sheet 2

FIG-3 75

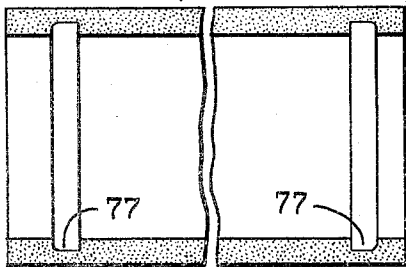


FIG-4 75

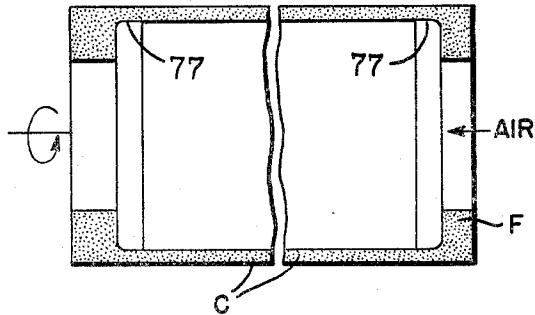
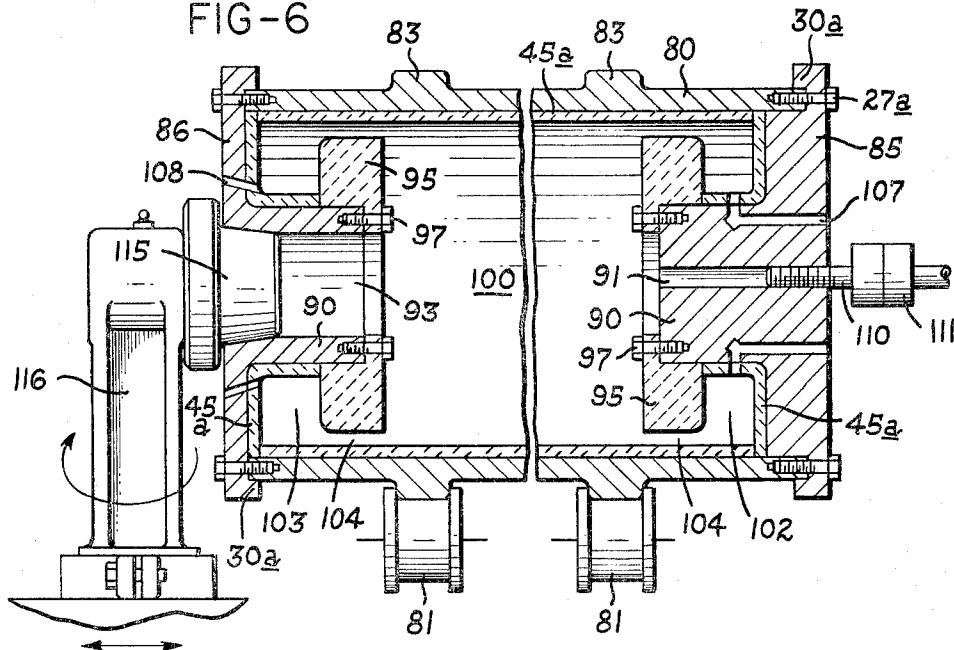


FIG-6



INVENTOR.

WALTER E. ROJECKI

BY

Marshall, Biebel, French & Bugg
ATTORNEYS

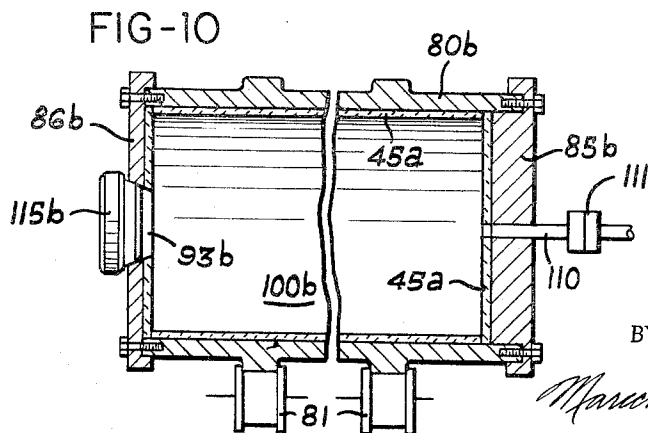
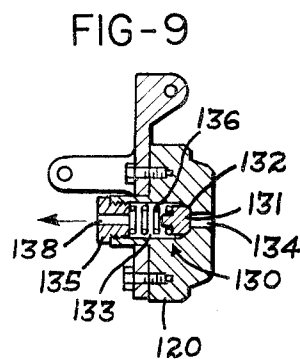
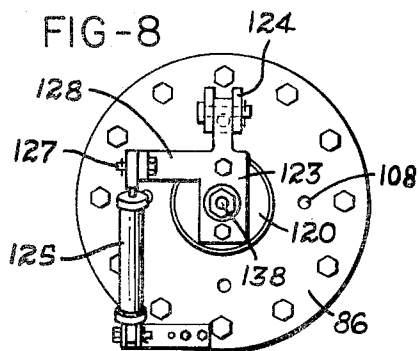
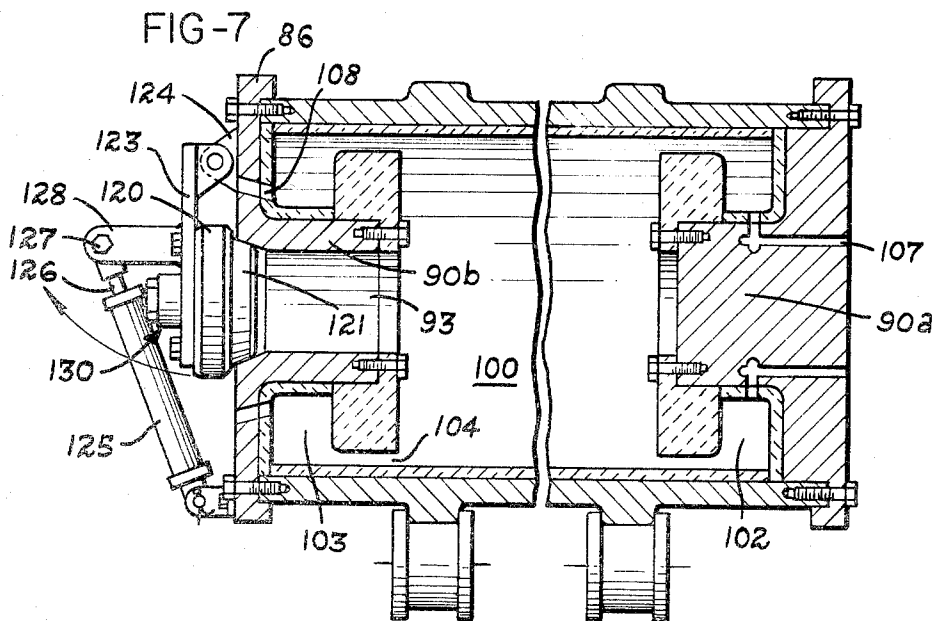
Aug. 2, 1966

W. E. ROJECKI
CENTRIFUGAL CASTING APPARATUS FOR CASTING
A FLANGED ROLL AND METHOD OF CASTING

3,263,285

Filed July 14, 1964

3 Sheets-Sheet 3



INVENTOR.

WALTER E. ROJECKI

BY

Marshall, Kibel, French & Bugg
ATTORNEYS

1

2

3,263,285

CENTRIFUGAL CASTING APPARATUS FOR CASTING A FLANGED ROLL AND METHOD OF CASTING

Walter E. Rojecki, Watertown, N.Y., assignor to The Black Clawson Company, Hamilton, Ohio, a corporation of Ohio

Filed July 14, 1964, Ser. No. 384,033

14 Claims. (Cl. 22—65)

This application is a continuation-in-part of my copending application Serial No. 198,256, filed May 28, 1962, now abandoned.

This invention relates to centrifugal casting.

The invention has special relation to the production of large tubular shells for uses such as in dryer drums, suction rolls and other similar tubular members of the type which are widely employed in the manufacture and/or handling of paper and other web materials and which require in use the strength characteristics developed by centrifugal casting. Shells of this type commonly require the application of end heads, particularly in cases such as dryer drums and suction rolls, which must be secured to the shells in pressure tight relation, and a convenient procedure for this purpose is to provide internal flanges within the shells to which the end heads can be bolted or otherwise secured.

It has been a common practice in producing shells of the general type outlined above to cast the shell centrifugally with essentially the desired uniform final thickness and then to weld separately fabricated flanges to the inner surfaces of the shell. This process involves substantial added expense both in the welding operation and also in the separate production of the individual flange members. In addition, some metals which are commonly used for shells produced by centrifugal casting cannot be welded successfully, such for example as bronze in the case of paper machine suction rolls, and it has been a common practice to cast the shells for such rolls substantially thicker than would otherwise be necessary in order to provide adequate wall thickness to receive the mounting bolts for the associated end heads. Theoretically it would also be possible to cast a shell of a thickness substantially greater than desired and then to machine portions of the interior sufficiently to produce the desired flanges, but this would be an expensive and time consuming operation.

This invention is also concerned with the production of centrifugal castings having an improved metallurgical grain structure providing a substantial reduction in centerline cavities and microshrinkage which occur during the solidification of the metal to thus produce an end product which is denser and more homogeneous. These features provide added strength and more uniform conductivity in the casting and thus improve the usefulness thereof, e.g., as a drier roll for use in a paper making machine.

It is an important object of the present invention to make possible the production of centrifugally cast tubular members having internal flanges which are integrally formed thereon in the same casting operation with the body of the shell, and it is therefore among the objects of the invention to provide apparatus for and a method of centrifugally casting tubular members having one or more integral flanges projecting radially inwardly thereof at selected locations.

Another object of the invention is to provide apparatus for and a method of centrifugally casting a tubular member having internal flanges on either end thereof, wherein the apparatus is relatively simple in design and capable of producing castings of uniform size and shape at low unit cost.

A further object of the invention is to provide a method and apparatus for producing a tubular member having one or more radially extending integral flanges spaced as desired on the internal surface of the tubular member without requiring a welding operation.

A further object of this invention is to provide a method and apparatus for centrifugally casting metal products which have a uniform and very dense metallurgical grain structure substantially free of voids and centerline cavities, and further to provide such a method and apparatus which creates a casting having compact grain structure throughout and having also an outer configuration which closely conforms to the shape of the mold even after the casting is completely cooled.

It is also an object of the invention to provide as new articles of manufacture, centrifugally cast tubular bodies, such as drums, shells and the like, having improved and compact grain structure, and further to provide tubular bodies of these types with one or more internal flanges which are integrally united with the bodies thereof.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings—

FIG. 1 is a perspective view showing one form of casting apparatus in accordance with the invention for performing the method of the invention;

FIG. 2 is a sectional view through the casting apparatus of FIG. 1 which further illustrates the method of the invention;

FIGS. 3 and 4 illustrate schematically the successive steps of the method of the invention in conjunction with the apparatus in FIGS. 1 and 2;

FIG. 5 is a schematic end view of the finished casting shown in FIG. 4;

FIG. 6 is a sectional view similar to FIG. 2 illustrating another embodiment of the invention;

FIG. 7 is a sectional view similar to FIGS. 2 and 6 of another embodiment of the invention;

FIG. 8 is a reduced end view of the left-hand end of the core case shown in FIG. 7;

FIG. 9 is an enlarged sectional view through the closure mechanism used in the embodiment of FIG. 7; and

FIG. 10 is a sectional view similar to FIG. 6 of another embodiment of the invention.

Referring to the drawings, which illustrate preferred embodiments of the invention, FIG. 1 shows a mold or casting apparatus 10 which is supported for rotation on the base 12 by drive rollers 13 engaging the drive bands 14 on the drum or core cast 15. Two of the rollers 13 are interconnected by the drive shaft 17 which has one end connected to the motor 19, shown schematically, for rotating the mold 10 in a conventional manner. As shown in FIG. 2, the mold may have the thrust rollers 22 mounted in engagement with the sides 23 of the drive bands 14 for preventing axial movement of the core case 15.

The core case 15 is tubular in shape and has heads or end plates 25 and 26 secured on the ends thereof by bolts 27 which extend through apertures in the outer peripheral portion of these plates and threadedly engage the tapped bores 28 in each end of the case 15. The axially extending flanges 30 may be provided around the outer circumference of the end plates 25 and 26 for overlying engagement with the ends of the case 15 to add structural rigidity to the mold, especially when it is rotated at high speed.

Each of the end plates 25 and 26 includes a boss 33 which projects inwardly of the interior of the core case 15 and serves as a mounting for the adjacent expendable partition member or baffle 35. These baffles 35 are formed of heat resistant material which preferably is of

a frangible nature facilitating breakage and removal from the interior of the finished casting. For example, each of the baffles 35 may be cast of ceramic material such as baked foundry core sand, a baked mixture of silica sand and calcined gypsum, or a baked mixture of silica sand and Portland cement. In addition, these baffles can be made of metal alloys, e.g., steel, depending on the temperature and the particular requirements of a specific casting operation. If the presence of the baffles in the finished casting is not undesirable, the baffle may be constructed of a metal which will be fused to the cast material during the casting operation and thus form an integral part of the finished product.

Each of the baffles 35 includes an internal reinforcing and mounting plate 36 which is entirely surrounded by the ceramic material and supports a plurality of spaced mounting bolts 37 which engage tapped bores 38 in the associated boss 33. The location of each of the baffles 35 may be established by the use of heat resistant tubular spacers 40 of appropriate length surrounding each of the bolts 37, and this arrangement also establishes openings 43 forming a direct connection to the atmosphere from the interior of the core case 15 for the escape of air which might otherwise be trapped within the mold when the molten metal is supplied thereto.

The entire inner surface of the core case 15 and the inner end faces of the end plates 25 and 26 are preferably covered with a liner 45 of suitable refractory material so that these parts can withstand and dissipate the heat from the molten metal which is poured into the core case 15. This liner 45 may be fabricated conventionally of molding sand for insertion within the core case, and the core case 15 may also be perforated in accordance with conventional practice to facilitate dissipation of heat from the interior thereof.

The baffles 35 divide the interior of the mold 10 into a central pressure chamber 50 and a pair of flange chambers 51 and 52 each of which extends between the outer surface of one of the baffles 35 and the inner surface of the adjacent end plate 25 or 26. These chambers are interconnected only by the annular passages 55 formed between the entire outer periphery of each of the baffles 35 and the inner surface of the liner 45 so that molten metal will readily flow between the chambers 50, 51 and 52. As already noted, the flange chambers 51 and 52 are vented to the atmosphere through the spaces 43 between the sleeves 40 on the mounting bolts 37.

Pressurized fluid, preferably air or other gas, is admitted to the chamber 50 through a pipe 60 which has one end secured to a through hole 61 in one of the baffles 35. The other end of pipe 60 is connected, as by the rotary coupling shown schematically at 65, to a supply pipe 66 leading from a source P of pressure fluid and provided with a suitable control valve 67 and pressure gauge 68.

In the method of the invention, the motor 19 is energized to rotate the mold 10 at a predetermined speed so that as the molten metal is poured through the openings 43 from the pouring basin 70, it is distributed over the entire inner surface of the liner 45 under the action of centrifugal force. The rate at which the mold 10 is rotated in order to achieve uniform distribution is determined by, inter alia, the inner diameter of the liner 45 and the mass of the molten metal, since these factors affect the amount of centrifugal force necessary to hold the molten metal on the inner surface of the liner 45. During the metal pouring step, the pipe 60 is connected to the atmosphere to prevent air pressure from building up in the chamber 50 and restricting the flow of metal and this is readily accomplished by using a valve 67 having one position in which it opens the pipe 60 to atmosphere. At this stage of the method, the molten metal will have assumed the configuration represented at 75 in FIG. 3, with the grooves 77 being formed by the peripheral edges of the baffles 35.

After the pouring is completed and while the mold 10 is being rotated, the chamber 50 is pressurized by actuating valve 67 to connect the source P to the pipe 60 and allowing a predetermined pressure to fill the chamber 50 so that a portion of the molten metal is forced from the chamber 50 through the annular passages 55 into the flange chambers 51 and 52 thus producing a rotating molten mass having the configuration shown in FIG. 4. Air will not be trapped in the flange chambers when the molten metal is forced therein since it readily passes to the atmosphere through the openings 43.

The amount of pressure in the chamber 50 during this step of the method is dependent upon the size of the mold and the various conditions present in each particular casting operation. Thus the size of the casting being made, the density of the metal being cast, and the amount of centrifugal force being exerted on the molten material are considerations which must be considered in determining pressure required. The pressure must be sufficient to force the molten metal through the annular passages 55 into the flange chambers 51 and 52 but less than that which would reduce the thickness of the metal in the pressure chamber 50 to less than the radial dimension of the passages 55 so that the pressurized fluid will not flow into the flange chambers. It should be apparent that this pressure in the chamber 50 does not increase the radial or exploding pressure on the walls of the core 15 above that of conventional centrifugal casting apparatus since the centrifugal force thereon is reduced by the amount of such pressure.

The flow between the chambers 50, 51 and 52 is actually induced by a pressure differential therebetween, and thus by subjecting the flange chambers 51 and 52 to a decreased pressure or vacuum, substantially the same effect can be obtained as pressurizing the chamber 50. This pressure differential could also be developed by a combination of pressure and vacuum, wherein the pressure in the chamber 50 is increased and the flange chambers 51 and 52 are subjected to a decreased atmospheric pressure or vacuum. When a vacuum is used, a hollow rotary cylindrical seal or the like would be filled into the openings in the end plates 33 to engage the inner diameter of these openings.

The amount of molten metal initially poured into the mold 10 is controlled to equal the volume of metal desired in the finished casting, and the radial dimension of the passages 55 between the outer periphery of the baffles 35 and the inner surface of the liner 45 determines the minimum thickness of the casting wall. If the pressure in the chamber 50 is excessive, the molten metal will be forced into the flange chambers 51 and 52 until the metal remaining in the pressure chamber 50 no longer has a thickness sufficient to block the passages 55, and the pressurized fluid in the chamber 50 will then escape into the flange chambers 51 and 52. Since such fluid flow causes unanticipated variables in the process, it is desirable to regulate the speed of rotation and pressure in the chamber 50 so that the wall thickness of the casting is always greater than the radial dimension of the passages 55.

The theoretical pressure required in the pressure chamber 50 to form a flange of a particular size in a particular casting apparatus can be determined as outlined below. Referring to FIGS. 4 and 5, the radial force dF acting on particular segments of the molten material can be calculated from the known fact that

$$dF = (dm)(a)$$

where dm is the mass of the segment, and a is its acceleration. Since the segment is being rotated, the normal acceleration a is equal to $(w^2)(r)$, where w is the rotational speed and r the radius of rotation of the segment s , so that

$$dF = (dm)(w^2)(r)$$

5

The mass dm equals $(p/g)dv$, where p is density, dv is the volume of the segment and g is gravity, so that

$$dF = \left(\frac{p}{g}\right)(dv)(w^2)(r)$$

The volume dv of the segment is the product of its theoretical dimensions, thus $dv = (r)(de)(dr)(L)$ where (de) is the angular width, dr the radial thickness, and L the axial length of the segment, thus

$$dF = \left(\frac{p}{g}\right)(r)(de)(dr)(L)(w^2)(r)$$

The pressure acting on the segment s equals force divided by area, or

$$dP = \frac{dF}{dA}$$

The area dA of the segment on which the pressure acts is $(dr)(de)(L)$ so that:

$$dP = \frac{dF}{(dr)(de)(L)}$$

or

$$= \left(\frac{p}{g}\right)(w^2)(r)(dr)$$

therefore

$$P = \frac{(P)(w^2)}{(g)(Ro)} \int_{Ri}^{Ro} r dr$$

Integrating between the radial dimensions of a flange having an inner radius Ri and an outer radius Ro , it is found that the pressure required in the chamber 50 to form a flange having these dimensions is

$$P = \frac{pw^2}{3g}(Ro^2 - Ri^2)$$

Thus the pressure in the chamber 50 is dependent on the variables of density, speed of rotation, and the internal and external radii of the flange. For castings having flanges of the same dimensions and formed at the same rotational speed, the pressure required in the mold to produce the flanges is directly proportional to the density of the material being cast. As an illustrative example, if the maximum centrifugal force at the outer radius Ro of the flanges is 75 G's (w^2Ro) or 75 times gravity, and if the flange has a radius Ro of 29 inches, a radius Ri of 27.5 inches, and is composed of material having a density of .263 lb./in.³, the pressure required in the chamber 50 is 28.9 p.s.i. There is some variation in the density of the metal as it cools, but it is comparatively slight and has been disregarded in the above illustrative calculations.

The above specific example is provided for purposes of illustration only and is in no way intended to limit the scope of the invention. The size of the castings made can vary over a wide range from quite small to very large, and likewise the centrifugal force can be much lower as theoretically only slightly above one gravity is required to hold the metal against the internal surface of the core case 15.

The mold 10 is rotated and the pressure maintained until the metal cools and solidifies, thus producing a tubular casting C having a uniform wall thickness throughout and integral internal flanges F on either end thereof, as shown schematically in FIG. 4. The grooves 77 will still be present but to a lesser degree than in FIG. 3, and they may be eliminated in the course of a conventional machining of the interior of the casting for cleaning purposes. It is also within the scope of this invention to provide cooling means for accelerating the solidification of the casting, for example, by running a coolant over the outside of the core case 15 or by providing cooling coils in the various components thereof.

To remove the finished casting C from the mold, the end plates 25 and 26 are disconnected from the core case

6

15 and the baffles 35 are removed from the casting C by any appropriate method, for example, by cutting them into smaller pieces or, in the case of ceramic material, by disintegration. Once these parts are removed, the end plates 25 and 26 can easily be separated from the casting C, and the latter removed from the core case 15. In certain instances where the presence of the baffles 35 is not objectionable in the finished casting, they may be left in place thus adding weight to the finished casting and eliminating the removal step from the process.

FIG. 6 illustrates another embodiment of the casting apparatus which is quite similar to the FIG. 2 embodiment except for the annular baffles and the manner in which they are mounted. This embodiment includes a core case 80 which is supported on and rotated by the drive rollers 81 which engage the drive bands 83 extending circumferentially around the outer surface of the case 80. The core case 80 is tubular in shape and has end plates 85 and 86 secured to each end thereof in a manner similar to that of the FIG. 2 embodiment, that is, by bolts 27a. The axially extending flanges 30a are also provided in this embodiment on the end plates 85 and 86 for overlying engagement with the core case 80.

Each of the end plates 85 and 86 includes an inwardly projecting boss 90 with the plate 85 having a relatively small passageway 91 therethrough, whereas the plate 86 has a relatively large opening 93 therein so that the pouring basin 70 or its equivalent may easily supply molten metal to the apparatus. Each of the bosses 90 has an annular baffle 95 secured thereto as by the bolts 97, and these baffles 95 are formed of heat resistant material of the type described hereinabove with reference to the baffles 35 in FIG. 2. The inner surfaces of the core case 80 and end plates 85 and 86 are covered with a liner 45a which is also similar to that shown in FIG. 2 for withstanding and dissipating the heat from the molten metal.

The baffles 95 divide the interior of the core case 80 into a central pressure chamber 100 and a pair of flange chambers 102 and 103 each of which extends between the outer surface of a baffle and the inner surface of the adjacent end plates 85 or 86. These chambers are interconnected solely by the annular passages 104 between the entire outer periphery of each baffle 95 and the inner surface of the liner 45a so that the molten metal will readily flow between the chambers 100, 102 and 103. The flange chambers 102 and 103 are vented to the atmosphere by the passages 107 and 108, respectively, so that when the metal is forced thereto, air will not be trapped therein to obstruct the casting operation.

The passageway 91 in the end plate 85 has connected thereto the pipe 110 which communicates through a rotary coupling 111 to a source of pressure, not shown, for pressurizing the central pressure chamber 100 in a manner similar to that described hereinabove. The opening 93 in the end plate 86 is closed, after the metal has been poured into the chamber 100, by means such as a tapered plug member 115 mounted on the support member 116 for rotation with the end plate 86 when it is in closing relation with the opening 93. The support member 116 is operable to insert and withdraw the plug member 115 in an axial direction from the opening 93 so that it will not interfere with the rotation of the core case 80, and once the support member 116 has withdrawn the plug member 115, it pivots to a position wherein it will not obstruct or interfere with the pouring of metal into the core case 80.

The operation of this embodiment is substantially identical to that of the FIG. 2 embodiment. Thus the core case 80 is first brought up to speed and the molten metal is poured through the opening 93. The centrifugal force caused by rotation of the case 80 causes the molten metal to be held against the liner 45a in a configuration similar to that of FIG. 3. The plug member is then placed in the opening 93 to seal the chamber 100, after which the source of pressure is connected to the chamber 100

through passage 91 causing a predetermined amount of the molten metal to flow into the flange chambers 102 and 103 so that the rotating molten metal assumes a configuration similar to that shown in FIG. 4, and this situation is maintained until the metal solidifies. To remove the finished casting, the end plates 85 and 86 are separated from the core case 80 and the baffles 95, and the casting removed from the case 80. If it is desired to remove the baffles, they may be disintegrated or removed in any of the ways described above. The amount of metal poured onto the core case 80 is determined in the same manner as described above in connection with the FIG. 2 embodiment.

Another embodiment of the invention is shown in FIG. 7 wherein the structure is quite similar to that described above in connection with FIG. 6. The primary differences are that the passageway 91 and the associated pressurizing equipment have been eliminated from the inwardly projecting boss 90a so that the central portion of this boss is substantially solid. In addition, the plug member 115 and its support 116 are not present, and in place thereof a disk-shaped plug 120 is provided having an inner portion 121 for engaging the annular seat 122 to seal the large diameter passageway 93 through the left-hand boss 90b, as shown in FIG. 7.

A typical apparatus for moving the plug 120 includes the arm 123 rigidly secured to the plug 120 and pivotally secured to the projection 124 on the end wall 86. An actuator 125 is secured to the wall 86 below and to one side of the plug 120 and has its rod 126 connected by the pivot pin 127 to the projection 128 on the arm 123 (FIG. 8). When the actuator is extended, the rod 126 moves the plug 120 through 180° to an inoperative position so that free access is gained to the passageway 93 for pouring the molten metal into the central chamber 100.

As shown in FIG. 9, a pressure relief valve 130 is provided in the plug 120 for relieving pressure within the chamber 100 when it exceeds a predetermined value, as will be explained. This valve includes a poppet 131 which seats against the shoulder 132 formed at the juncture of the passages 133 and 134 which have different diameters. The retainer 135 is threadedly secured within the larger passage 133, and the spring 136 is interposed between the retainer 135 and the poppet 131 to urge the latter against the shoulder 132 to seal the passage 134.

By turning the retainer 135, it can be moved with respect to the poppet 131, to vary the biasing effect of the spring 136 with proportional change in pressure required to unseat the poppet 131. An opening 138 is placed in the plug 135 so that the passage 133 is continually connected to the atmosphere. While a specific structure has been shown for sealing the passageway 93, it will become apparent that numerous other forms of structure will fulfill the purposes thereof.

In operation, the plug 120 is moved by the actuator 125 to its inoperative or retracted position so that molten metal may be poured directly into the chamber 100 in a manner similar to that described above in connection with FIG. 6. The centrifugal force caused by rotation of the case 80 forces the molten metal to be distributed uniformly over the inner surface of the liner 45a. The plug 120 is then moved by the actuator 125 to its operative position wherein it seals the passageway 93 so that the central chamber 100 is sealed from the atmosphere.

The hot gases generated by the molten metal within the chamber 100 quickly build up a high pressure within this chamber to create a pressure differential between the central and flange chambers 100 and 103. Each of the flange chambers 103 is vented to the atmosphere through the passageways 107 and 108, and any gas pressures which are created therein as a result of the molten metal are quickly exhausted to the atmosphere. The high pressure in the central chamber 100 causes the molten metal to flow to the passageways 104 and into the flange chambers 102 and 103 so that the rotating molten metal as-

sumes a configuration similar to that shown in FIG. 4, and this configuration is maintained until the metal solidifies to form a casting having integral internal flanges *f*. The rotation is then stopped, and the core case is disassembled to remove the finished casting, as described above.

The relief valve 130 in the plug 120 is adjusted so that when a pressure within the central chamber 100 is greater than that desired, the poppet 131 will crack open and vent a portion of the gases to the atmosphere, thus decreasing the pressure within the chamber 100 to maintain the desired pressure therein. As explained in connection with the FIG. 2 embodiment, the desired pressure is that which will force the molten metal into the flange chambers while maintaining sufficient metal in the central chamber 50 to block the annular passages 55. The bias of the plug 136 can be varied by loosening or tightening the retainer 135 to change the maximum pressure which can build up within the chamber 100.

Thus it is seen that the pressurization of the chamber 100 occurs without the application of exterior air pressure air pressure as required in the embodiments described above. This greatly simplifies the structure required since no rotating glands or air pumps are required. However, it is within the scope of this invention to combine this thermal process of generating pressure within the chamber 100 with the application of vacuum applied to the passages 107 and 108, or with the application of additional pressure from an exterior source to the chamber 100.

As indicated above, many different forms of structure can be used to perform the function of the plug as described above. For example, the plug 120 could be biased into sealing engagement with the seat 122 and the passage 93 after the metal is poured so that it would open to vent any pressure greater than that desired in the chamber 100. Suffice it to say that any structure which substantially performs the function of venting an excess pressure from the chamber 100 is within the scope of this invention.

Another important feature of the invention is the improved grain structure which is produced during the casting of the tubular member, and this grain structure can also be produced in centrifugally cast products which do not have internal flanges, as will be seen. The fluid pressure acts against the inner surface of the molten metal to pressurize this molten metal in an outward radial direction and thereby to compress or squeeze the newly formed grains together as they are transformed from a liquid to a semi-solid or plastic state and then to a solid state. This action tends to reduce the air pockets substantially, as well as centerline cracks or voids which tend to occur during the solidification of the metal.

In the conventional centrifugal casting processes wherein the interior of the core case is not pressurized as in this invention, the solidification of the mold starts at the mold wall since it is cold compared to the temperature of the molten metal. Thus grains or dendrites start growing inwardly from the mold wall, but soon a thin crust also forms on the inner surface of the molten mass and this solidification proceeds outwardly. At this point the grain growth is proceeding from both the inner and outer diameter with the centrifugal force tending to feed metal to the areas of solidification. However, as the liquid metal transforms to solid metal, there is a decrease in volume, e.g., 3% for steel, and as the last portion of the liquid transforms into a solid mass, cavities can begin to form at random between the inner and outer layers since there is no further molten metal to fill these cavities.

However, in this invention the added pressure within the central chamber also squeezes out gas pockets and causes the liquid metal to be forced into the cavities and pockets, as well as into the very small openings created between the grains due to their formation in a random and interlocking pattern. Stated otherwise, when the

voids or pockets (often called microshrinkage) are created during solidification of the metal, the fluid pressure causes molten metal to be forced into these pockets to fill the same and thus to create a homogeneous casting free of the usual voids and centerline cracks. In addition, it has been found that this additional pressure causes the casting to conform substantially to the inner configuration of the mold, since the pressure is applied throughout the solidification process.

In a conventional casting, the centrifugal force acting on the molten metal imparts some compacting force but these forces are not sufficient to fill all of the cavities completely, since the centrifugal force acting on the innermost layer of the casting is smaller. This occurs because centrifugal force is a function of diameter and mass, and the mass is less and the diameter is decreased at the innermost portion of the casting. By pressurizing the center of the rotating mass as it cools, the entire molten mass is compressed and the individual grains forced together during solidification. The pressurization causes the liquid or plastic metal to flow into cracks and crevices between the grains as they form, especially during the plastic state, thereby resulting in a substantially improved end product having fewer cavities or voids as a result of the elimination of centerline and microshrinkage.

The resulting product is more homogeneous and is denser and thus is better suited for use in pressure vessels because it is less likely to fail from fatigue. Moreover, the greater density of the material provides a higher degree of and more uniform heat conductivity thus facilitating use of the products of this invention as drier cylinders for the paper industry. The resulting product more accurately follows the contour of the mold walls as a result of the pressures applied during transfer from the molten to the solid state. The pressure holds the interfaces of the molten or plastic material being cast against that of the mold tightly together until the casting has solidified. This results in a more precise casting which closely conforms to the mold internal configuration.

The apparatus shown in FIG. 10 is used for producing a tubular casting with the above described compact grain structure but without the integral internal flanges. The core case 80b thus is substantially identical to that shown in FIG. 6 and the similar parts have been given the same reference characters. The end walls 85b and 86b are flat on the inside thereof and define the end of the central chamber 100b. The wall 85b has the pipe 110 connected to a source of pressure to the rotating gland 111, whereas the plug 115b seals the aperture 93b in the end wall 86b.

In operation, the plug 115b is removed and molten metal is then poured in the chamber 100b of the rotating core case. The metal assumes a uniform thickness over the inner side walls of the core case, and the plug 115b is replaced to seal the aperture 93b. The pressure is then connected to the chamber 100b in the manner described above in connection with FIG. 6, and this pressure is maintained until the metal solidifies to thus produce an improved centrifugal casting having all of the advantages of compact grain structure described above, but without the internal flanges on the casting.

While several embodiments of the apparatus have been shown and specifically described, it is within the scope of this invention to provide numerous other embodiments for carrying out the herein described inventive method for producing centrifugal castings having one or more integral internal flanges therein. The essential requirements for producing internal flanges are that a pressure chamber and at least one flange chamber be provided, and it should be apparent that numerous expedients may be utilized by one skilled in the art to mount the baffles used to separate these chambers. Similarly, the material used in constructing the baffles may vary widely depending upon the particular requirements of the specific casting operations to be carried out thereby.

The fluids used to pressurize the chambers 50 and 100 can vary, depending upon the particular casting requirement, without departing from the scope of the invention, and the use of air or an inert gas is preferred to prevent corrosion, since the handling thereof is relatively simple. Likewise, the material which is cast in the molds can be varied so long as it will change from the liquid state to solid state under conditions which can take place in the mold. Thus while the invention is particularly applicable to the casting of metals, and has been so described, other materials can be cast therein without departing from the scope of the invention.

The illustrated embodiments of the molds produce an integral internal flange on each end of a tubular member, but it is within the scope of the invention to place these internal flanges at any point on the inner surface of the tubular member by merely appropriately positioning the partition member or baffles in the molds. For example, if in the FIG. 2 embodiment these baffles 35 were placed in the central portion of the mold 10 with a space therebetween suitably vented to the atmosphere, an internal flange intermediate the ends of the tubular member could be formed. In a similar manner, the baffles 35 can be used to form flange chambers in the mold so that a plurality of flanges can be formed at various points on the inner surface of the tubular member.

The casting C which is produced by the above described process has a hollow cylindrical body with one or more integral internal flanges therein. The metallurgical grain structure of the casting is substantially identical and indistinguishable throughout including the juncture between the flange and the body. The slag and other light impurities collect on or near the innermost surfaces of the casting, that is, on the inner peripheral surface of the flange and on the inner surface of the body, from where they can be easily removed by machining, if desired.

Since no welding operation is required, the casting is not subjected to high local temperatures which often cause distortion, and it is produced at a much lower cost since the flange does not have to be produced separately. The inner surface of the hollow cylindrical body does not require machining prior to welding to remove the slag and other impurities from the area to be welded, as would be required to weld a flange as a separate component to a centrifugally cast body. Also metals and other materials which are not suitable for welding can be formed easily into a tubular body having internal flanges therein by the present process. When a flange having a relatively thick axial dimension is desired, an appreciably stronger juncture with the body is attained by this process since a flange of this type could not be welded along the entire surface of contact with the body.

While the method herein described, the forms of apparatus for carrying this method into effect, and the product or article produced by the aforesaid method and apparatus, constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to this precise method and form of apparatus, and that changes may be made in either without departing from the scope of the invention which is defined in the appended claims.

Cross reference is made to the copending application Serial No. 349,798, filed May 4, 1964, now abandoned, of Frank W. Fruitman, which application is assigned to the assignee of this invention.

What is claimed is:

1. Apparatus for centrifugally casting a tubular member having an internal flange therein, comprising a tubular mold mounted for rotation, partition means separating the interior of the mold into pressure and flange chambers, said partition means having an outer diameter smaller than the inner diameter of said mold to provide a passage interconnecting said chambers, means defining an opening in said mold through which a predetermined

volume of a molten material can be supplied to said chambers, drive means for rotating said mold at a speed sufficient to cause the molten material to be distributed evenly over said inner surface of said mold, and means for creating and maintaining a pressure differential between said chambers to cause a predetermined portion of the molten material to flow from said pressure chamber through said passage into said flange chamber so that the material in said flange chamber forms an integral internal flange on the tubular member when the material solidifies.

2. Apparatus for centrifugally casting a tubular member having an internal flange therein, comprising a tubular mold mounted for rotation, partition means mounted in said mold for separating the interior thereof into pressure and flange chambers, said partition means having an outer diameter smaller than the inner diameter of said mold to provide a passage between said chambers, means defining an opening in said mold through which a predetermined volume of a molten material can be supplied to said chambers, drive means for rotating said mold at a speed sufficient to cause the molten material to be uniformly distributed over the inner surface of said mold, means for creating and maintaining an increased pressure in said pressure chamber to cause a predetermined portion of the molten material to flow from said pressure chamber through said passage into said flange chamber until the material solidifies so that the material in said flange chamber forms an integral internal flange on the tubular member, and means for venting the air trapped in said flange chamber.

3. Apparatus for centrifugally casting a tubular member having an internal flange therein, comprising a hollow mold mounted for rotation and having closed ends, at least one of said ends having a partition mounted on and spaced from said one end to separate the interior of said mold into pressure and flange chambers, said partition having an outer diameter smaller than the inner diameter of said mold to provide a passage interconnecting said chambers, means for supplying a predetermined volume of a molten material to said chambers, drive means for rotating said mold at a predetermined speed sufficient to cause the molten material to be distributed evenly over said inner surface of said mold, and means for creating and maintaining a pressure differential between said chambers to cause a predetermined portion of the molten material to flow from said pressure chamber into said flange chamber thus forming an integral internal flange on a tubular member when the material solidifies.

4. Apparatus for centrifugally casting a tubular member having internal flanges therein, comprising a mold mounted for rotation about its axis and having closed ends, an extension projecting axially inwardly from each of said ends, partitions mounted on and projecting radially from each said extension and spaced from the associated end to form flange chambers between each of said partitions and the associated end and a pressure chamber between said partitions, said partitions having an outer diameter smaller than the inner diameter of said mold to provide a passage interconnecting adjacent said chambers, means for supplying a predetermined volume of a molten metal to said chambers, means for rotating said mold at a sufficient speed to cause the molten metal to be distributed over said inner surface of said mold and for simultaneously pressurizing said pressure chamber to cause a predetermined portion of the molten metal to flow from said pressure chamber through said passages into said flange chambers wherein the metal solidifies thus producing a tubular member having an internal flange on each end thereof.

5. A method of casting a tubular member having at least one internal flange, comprising the steps of placing a predetermined quantity of molten material into a mold having an interior chamber separated into pressure and flange-forming chambers connected by an annular passage adjacent the inner surface of said mold, rotating said mold

at a speed sufficient to cause said molten material to assume a uniform thickness over the inner surface of said mold, creating a pressure differential between said chambers to force a predetermined amount of said molten material from said pressure chamber through said passage into said flange-forming chamber, correlating said speed of rotation and said pressure differential so that the thickness of said material on said inner surface is at least equal to the radial dimension of said passage, and maintaining said pressure and rotation until said material solidifies so that the material adjacent said inner surface forms a tubular member and the material in said flange-forming chambers forms internal flanges on said tubular member.

6. A method of casting a tubular member having at least one internal flange, comprising the steps of pouring a predetermined quantity of molten material into a tubular mold having a partition therein separating the interior thereof into a pressure chamber and a flange-forming chamber connected only by an annular passage formed between the outer periphery of said partition and the inner surface of said mold, rotating said mold at a speed sufficient to cause said molten material to assume a uniform thickness over the inner surface of said mold, pressurizing said pressure chamber to force a predetermined amount of said molten material from said pressure chamber through said passage into said flange-forming chamber, correlating said speed of rotation and said pressure so that the thickness of said material on said inner mold surface is at least equal to the spacing between said partitions and said surface, and maintaining said pressure and rotation until said material solidifies so that the material adjacent said inner surface forms a tubular member and the material in said flange-forming chambers forms internal flanges on said tubular member.

7. A method of casting a tubular member having an internal flange on each end thereof, comprising the steps of pouring a predetermined quantity of molten material into a tubular mold having partitions therein separating the interior thereof into flange-forming chambers with a pressure chamber therebetween and annular passages between the outer periphery of said partitions and the inner surface of said mold for interconnecting said chambers, rotating said mold at a speed sufficient to cause said molten material to assume a uniform thickness over the inner surface of said mold, pressurizing said pressure chamber to force a predetermined amount of said molten material from said pressure chamber through said passage into said flange-forming chambers so that the thickness of the material which remains in said pressure chamber against the inner surface of the mold is at least as great as the radial dimension of each of said passages, and maintaining said pressure and rotation until said material solidifies so that the material adjacent said inner surface forms a tubular member and the material in said flange-forming chambers forms internal flanges on said tubular member.

8. A method of casting a tubular member having at least one internal flange, comprising the steps of pouring a predetermined quantity of molten material into a tubular mold having a partition therein separating the interior thereof into a pressure chamber and a flange-forming chamber connected only by an annular passage formed between the outer periphery of said partition and the inner surface of said mold, rotating said mold at a speed sufficient to cause said molten material to assume a uniform thickness over the inner surface of said mold, creating a pressure differential between said chambers to force a predetermined amount of said molten material from said pressure chamber through said passage into said flange-forming chamber, correlating said speed of rotation and said pressure so that the thickness of said material on said inner mold surface is at least equal to the spacing between said partitions and said surface, and maintaining said pressure and rotation until said material solidifies so that the material adjacent said inner surface forms a tubu-

13

lar member and the material in said flange-forming chamber forms internal flanges on said tubular member.

9. A method of casing a tubular member having at least one internal flange, comprising the steps of placing a predetermined quantity of molten metal into a mold having an interior chamber separated into pressure and a flange-forming chamber connected only by an annular passage adjacent the inner surface of said mold, rotating said mold at a speed sufficient to cause said molten metal to assume a uniform thickness over the inner surface of said mold, sealing said mold to allow the molten metal to heat the gases within said interior chamber to create a pressure differential between said chambers to force a predetermined amount of said molten metal from said pressure chamber through said passage into said flange-forming chamber, and correlating said speed of rotation and said pressure differential so that the thickness of said metal on said inner surface is at least equal to the radial dimension of said passage until said metal solidifies so that the metal adjacent said inner surface forms a tubular member and the metal in said flange-forming chamber forms internal flanges on said tubular means.

10. A method of casting a tubular member having at least one internal flange comprising, the steps of placing a predetermined quantity of liquid material into a mold having an interior chamber separated into pressure and a flange-forming chamber connected only by an annular passage adjacent the inner surface of said mold, rotating said mold at a speed sufficient to cause said liquid material to assume a uniform thickness over the inner surface of said mold, sealing said mold, applying heat to the gases within said interior chamber to raise the pressure thereof to create a pressure differential between said chambers to force a predetermined amount of said liquid material from said pressure chamber through said passage into said flange-forming chamber, and correlating said speed of rotation and said pressure differential so that the thickness of said material on said inner surface is at least equal to the radial dimension of said passage until said material freezes so that the material adjacent said inner surface forms a tubular member and the material in said flange-forming chamber forms internal flanges on said tubular means.

11. A method of casting a tubular member having at least one internal flange, comprising the steps of placing a predetermined quantity of molten metal into a mold having an interior chamber separated into a pressure and a flange-forming chamber connected only by an annular passage adjacent the inner surface of said mold, rotating said mold at a speed sufficient to cause said molten metal to assume a uniform thickness over the inner surface of said mold, sealing said mold to allow the molten metal to heat and expand the gases within said interior chamber to create a pressure differential between said chambers to force a predetermined amount of said molten metal from said pressure chamber through said passage into said flange-forming chamber, relieving the pressure within said interior chamber when it exceeds a predetermined amount required to maintain said pressure differential so that the thickness of said metal on said inner surface is at least equal to the radial dimension of said passage, and maintaining said pressure differential and rotation until said metal solidifies so that the metal adjacent said inner surface forms a tubular member and the metal in said flange-forming chamber forms an internal flange on said tubular member.

12. A method of casting a tubular member having at least one internal flange, comprising the steps of placing a predetermined quantity of molten metal into a mold having an interior chamber separated into a pressure and a flange-forming chamber connected only by an annular passage adjacent the inner surface of said mold, rotating said mold at a speed sufficient to cause said molten metal to assume a uniform thickness over the inner surface of

14

said mold, sealing said mold to allow the molten metal to heat the gases within said interior chamber to create a pressure differential between said chambers to force a predetermined amount of said molten metal from said pressure chamber through said passage into said flange-forming chamber, relieving the pressure in said pressure chamber to maintain said predetermined pressure therein, and correlating said speed of rotation and said predetermined pressure so that the thickness of said metal on said inner surface is at least equal to the radial dimension of said passage until said metal solidifies so that the metal adjacent said inner surface forms a tubular member and the metal in said flange-forming chamber forms an internal flange on said tubular member.

13. Apparatus for centrifugally casting a tubular metallic member having an internal flange therein comprising, a tubular mold mounted for rotation, partition means separating the interior of the mold into pressure and flange chambers, said partition means having an outer diameter smaller than the inner diameter of said mold to provide a passage interconnecting said chambers, means defining an opening in said mold through which a predetermined volume of a molten metal can be supplied to said chambers, drive means for rotating said mold at a speed sufficient to cause the molten metal to be evenly distributed over said inner surface of said mold, and means for closing said opening to allow the molten metal to pressurize said pressure chamber to a preset level to create and maintain a pressure differential between said chambers and cause a predetermined portion of the molten metal to flow from said pressure chamber through said passage into said flange chamber so that the metal in said flange chamber forms an integral internal flange on the tubular member when the metal solidifies.

14. Apparatus for centrifugally casting a tubular metallic member having an internal flange therein, comprising a tubular mold mounted for rotation, partition means separating the interior of the mold into pressure and flange chambers, said partition means having an outer diameter smaller than the inner diameter of said mold to provide a passage interconnecting said chambers, means defining an opening in said mold through which a predetermined volume of a molten metal can be supplied to said chambers, drive means for rotating said mold at a speed sufficient to cause the molten metal to be evenly distributed over said inner surface of said mold, means for closing said opening to allow the molten metal to heat the gases within said pressure chamber and build up a pressure therein, and pressure relief means for limiting the pressure build-up within said pressure to a predetermined amount to cause a preset portion of the molten metal to flow from said pressure chamber through said passage into said flange chamber so that the metal in said flange chamber forms an integral internal flange on the tubular member when the metal solidifies.

References Cited by the Examiner

UNITED STATES PATENTS

1,480,000	1/1924	McWane	22—65
1,500,707	7/1924	Janney	22—65
1,842,280	1/1932	Neuberth	138—177
1,954,892	4/1934	Russell et al.	138—177
2,745,152	5/1956	Johnson	22—65
2,770,857	11/1956	Boissou	22—65
2,874,412	2/1959	Flemming et al.	22—113.5

FOREIGN PATENTS

431,064	7/1926	Germany.
226,540	5/1925	Great Britain.

MARCUS U. LYONS, *Primary Examiner.*

LEWIS J. LENNY, *Examiner.*