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JUNE 1, 1943.	CENTRIFUGAL CASTINGS	453,655
BY A. P. C.	Filed Aug. 5, 1942	3 Sheets-Sheet 1

Fig. 1

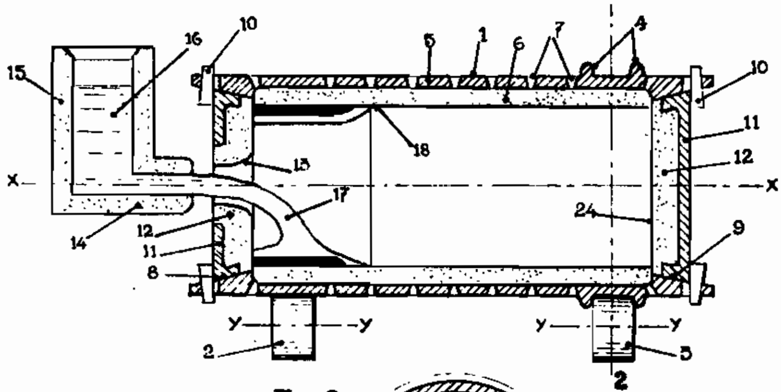
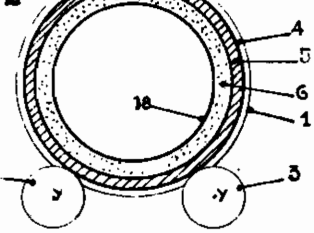


Fig 2



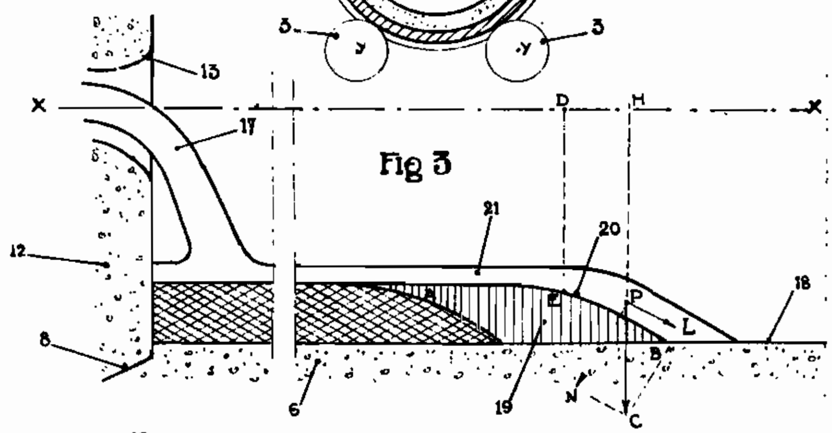


Fig 4

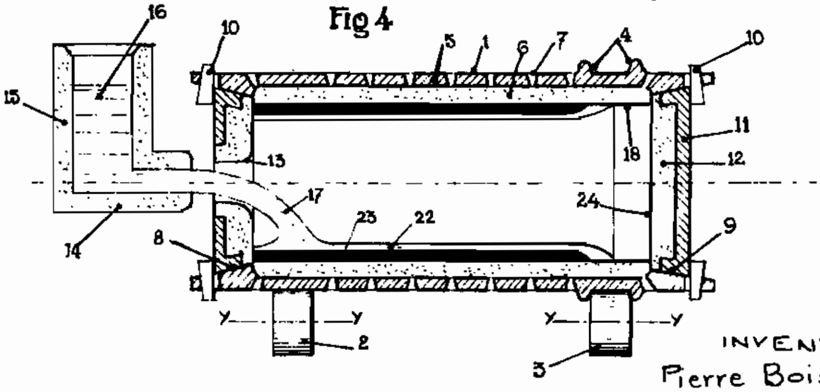


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Fig 10

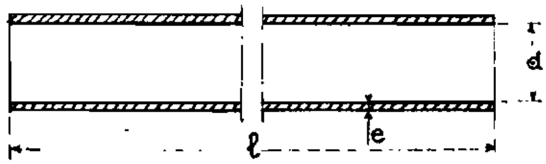

Fig.5

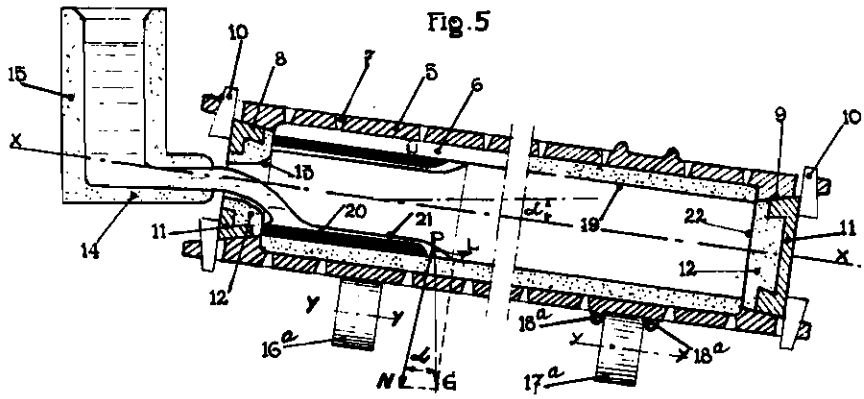

Fig.11

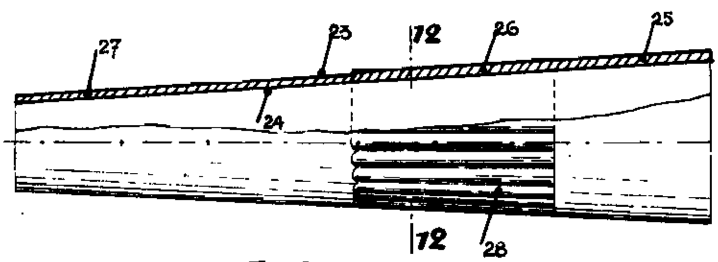

Fig.12

Fig.6

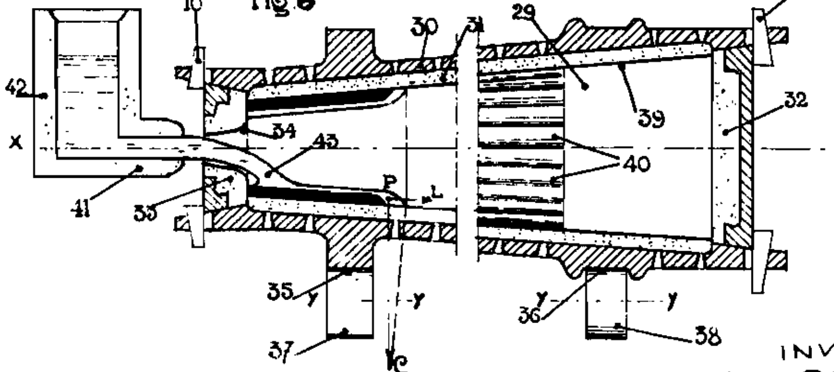

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Fig. 7

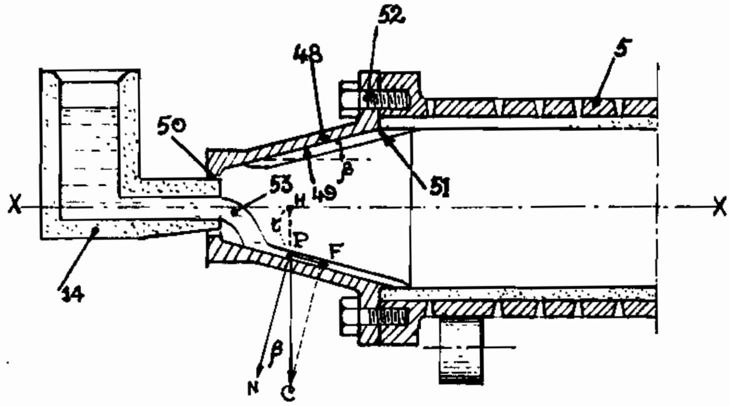


Fig. 8

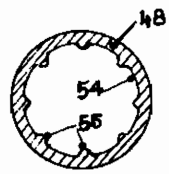
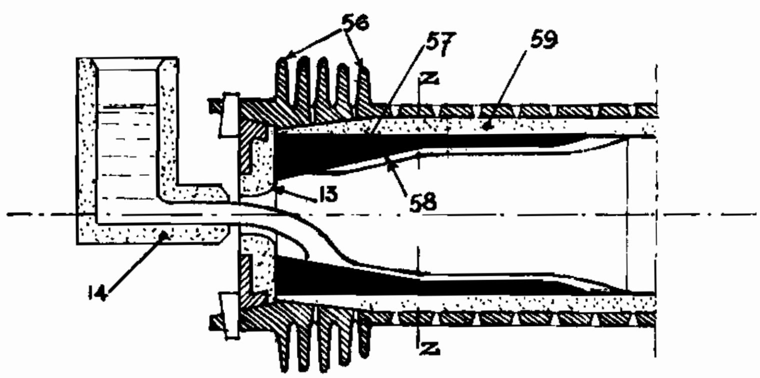


Fig. 9



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ALIEN PROPERTY CUSTODIAN

CENTRIFUGAL CASTINGS

Pierre Boissou, Pamiers, Ariege, France; vested in the Alien Property Custodian

Application filed August 5, 1942

The present invention relates to the casting by centrifugation into rotary moulds, of hollow members such as tubes or pipes.

The long and thin tubes used up to the present are generally obtained by distorting solid ingots, in the cold state, or more often in the hot state. Very numerous processes are known for effecting said distortions. All said processes have serious inconveniences: they are complicated, necessitate powerful plants, comprise successive steps requiring a considerable amount of labour and involving a very high consumption of energy. Moreover, they sometimes necessitate successfully reheating the metal several times, and the products thus obtained do not escape all the difficulties of manufacture and all the imperfections of execution inherent to rolling. In particular, the presence of solder can limit the conditions of use of certain welded tubes.

Finally, all these tubes can only be obtained in well defined shades of metal. For instance, in the case of steel, certain shades of steel may happen to be set aside, whatever may be the advantages they might offer, either because they are industrially unsuitable for rolling, or because they cannot be welded, or because they have an important shrinkage and that they are apt to present shrinkage holes, or for any other similar reason.

One the other hand, it is known that the casting of similar members, of very great length and reduced cross-section or of small thickness, has encountered very great difficulties as regards numerous materials and several metals. In particular, the casting by centrifugation of long and thin tubular members has only been solved up to now for certain metals or alloys relatively easy to melt and having great fluidity.

It has not been possible for instance to use centrifugal casting methods consisting in successively injecting the molten metal at each point of the rotating mould by means of a casting conduit moving longitudinally within said mould, for metals or alloys which are difficult to melt: in fact, the important and unavoidable cooling of said metals along the casting conduit would necessitate, in order that they should reach the mould at a sufficient temperature, a too important superheating which would involve difficulties in the melting, transport, oxidation or the like, of said metals.

On the other hand, the processes consisting in massively casting these same metals into a rotating mould are also inapplicable: in fact, the rapid solidification of said metals would not leave them the time to become distributed, along the mould, in the form of a uniform layer, especially if long and thin members are to be produced.

The present invention has for object a new centrifugal casting method allowing to obtain pipes or other long and thin tubular members, which can be applied to all metals, alloys or other fusible materials, even to those which are difficult to raise to a temperature much higher than their melting temperature, and which owing to their low fluidity reserve, do not lend themselves, industrially, to casting by the known methods.

Another object of the invention is to provide rotating devices for carrying out the process according to the invention and allowing the manufacture of cast articles of substantially tubular shape in very varied metals and in particular in steel.

The other objects of the invention will become apparent from the following description.

The method according to the present invention consists in progressively casting the molten metal at one end of the rotating mould, by injecting it into said mould through one of its end walls, in choosing and controlling the speed of injection and the speed of rotation of the mould in function of the temperature and of the physical characteristics of the metal, of those of the mould as well as the dimensions of the member to be manufactured, so as to determine the rapid solidification of the successive portions of said metal by contact with the walls of the mould, the entire period of casting being thus much longer than the time necessary for the solidification of each of the portions of said metal.

In the casting method according to the invention, the consecutive cooling, solidification and localization of the metal therefore begin from the inlet end of the mould (side where the casting is effected) and then proceed towards the opposite end, the molten metal injected at every instant proceeding, without appreciably cooling, at the internal surface of the metal previously injected, already solidified, but still very hot, until it reaches the free part of the mould and by contact with which it cools and solidifies in its turn.

The surface separating the molten metal and the solidified metal thus moves towards the end of the mould, without distorting, and assuming at every instant a flared shape which promotes the advance of the molten metal, as will be set forth hereinafter.

According to other features of the invention and for facilitating the advance of the molten metal within the mould, after its injection into the later, forces are exerted thereon having a longitudinal component directed towards the end of the mould, or, when it is injected into the mould, an initial impulse is imparted thereto directed in the same direction, or both the above mentioned forces and impulse are exerted thereon.

According to another feature of the invention, use is made of a mould closed at its end and comprising at its inlet end an orifice of reduced dimension, allowing solely the injection of the metal and the evacuation of the gases contained in the mould or dissolved in the metal, so as to prevent the entrance of ambient air, the internal cooling of the member and the formation, in the midst of the latter, of a solidification surface proceeding from the interior towards the exterior.

Such a rotating mould, metallic or not, comprises means for exerting on the molten metal to be cast after its injection into the mould, forces the longitudinal resultant of which is directed towards the end of the mould opposite the casting end, or for imparting thereto, when it is injected, an impulse directed in the same direction.

Said means can be constituted for instance, by a mould having a diverging profile or by a mould having an axis inclined relatively to the horizontal, or again by a distributor comprising a container for molten metal and a calibrated nozzle under pressure opening in alignment with the orifice of the mould, or also by a rotating divergent distributor placed in front of the mould, or finally by the combination of several of the above mentioned means.

Other features and advantages of the present invention will be set forth in the following description.

In the accompanying drawings given by way of example only:

Fig. 1 is a longitudinal section of a centrifugal casting device according to the invention, illustrated at the beginning of the casting;

Fig. 2 is a cross-section of said device, made according to line 2—2 of Fig. 1.

Fig. 3 is a diagrammatic view, on an enlarged scale, in longitudinal section of the same device, showing the flared shape of the surface separating the molten metal and the solidified metal, as well as the propelling action exerted by said surface, by its rotation, on the molten metal.

Fig. 4 is a view in longitudinal section, at the end of the casting, of the device illustrated in Figs. 1 and 2.

Fig. 5 is a view in longitudinal section of a modification comprising the use of an inclined cylindrical mould.

Fig. 6 shows a longitudinal section of another embodiment of the invention comprising the use of a truncated mould exerting an increased propelling action on the molten metal.

Fig. 7 is a partial diagrammatic view, in longitudinal section, of a modification of the casting device comprising the use of a divergent distributing injector intended to increase the initial speed of the metal or other molten material when it is injected in the mould, this plant being illustrated at the beginning of the casting.

Fig. 8 is a cross sectional view of a different form of distributor.

Fig. 9 is a longitudinal section of another modification of the casting device in which the member to be cast itself constitutes a divergent distributor.

Fig. 10 is a longitudinal section of a cylindrical pipe.

Figs. 11 and 12 illustrate by way of examples, a tubular article capable of being manufactured according to the invention.

According to the examples illustrated in Figs. 1 to 4, the plant for centrifugal casting according to the invention comprises a rotating mould 1 (Fig. 1) movable about a horizontal axis X—X. The mould is supported and rotatably driven by rollers 2 and 3 rotating about axes Y—Y, and capable of being rotatably driven in their turn by a driving device, not shown. The mould 1 is held stationary longitudinally by external flanges 4 which take a bearing laterally on the rollers 3.

The body of the mould is constituted by a metal frame 5 provided with a refractory lining 6 made of moulding sand compressed and stoved; holes 7 are formed through the frame 5 to allow the evacuation of the gases produced in the refractory lining at the time of casting.

The frame 5 is terminated at its ends by truncated bearings 8 and 9 on which are secured, by means of keys 10, the end walls of the mould; said end walls are themselves constituted by a metallic cup 11 which supports a refractory lining 12; one of the end walls is provided with a central orifice 13 for the injection of the molten metal.

This injection orifice opens in alignment with a nozzle 14 arranged at the bottom of a casting pot 15, said nozzle and its casting pot being constituted by a pisé or any other refractory material.

The casting, according to the method of the invention, is effected in the following manner: the mould 1 is set in rotation and the molten metal 16 is rapidly poured into the casting pot; the metal escapes through the nozzle 14 in the form of a jet 17 with a speed which is dependent on the height of metal above said nozzle; at the same time, the casting pot 15 continues to be fed so as to maintain constant the level of the metal and, consequently, the flow from the nozzle.

The metal enters the mould 1 and comes into contact with the internal wall 18 of the latter in the very vicinity of the inlet end of the mould. It is drawn along in the rotary movement of the mould and it is applied by centrifugal force against the internal surface 18.

The layer of metal 19 (Fig. 3) being for a moment the most forward in the mould 1 and encountering no obstacle to its flow at the front, continually tends under the action of centrifugal force, to spread out on a certain length AB and take the shape of a ring, the inner radius DE of which increases from the rear A towards the front B, thus constituting a tubular element the free inner surface 20 of which is flared towards the front. As said advanced molten layer of decreasing thickness becomes localized by the very contact of the cold or relatively cold mould, it solidifies and rapidly comes to rest in this position thus affording for the following molten layer 21 a solid truncated casing.

Each particle P of the layer 21 is thus subjected to a centrifugal force PC at right angles to the axis X—X. If the mass of the particle P is designated by m, its distance PH to the axis X—X by r and the angular speed of rotation of the mould by ω, the value of the centrifugal force is given by the known formula:

$$PC=m\omega^2\cdot r$$

This force can be decomposed into its two components: PN at right angles to the solidification surface of the ring and which applies the metal against said surface, and PL parallel to the meridian to said surface. The latter causes the metal to move towards the free part of the mould where it solidifies in its turn in the same conditions and in the same shape as the metal of the preceding layer, as it is intended in its turn to play the same useful transitory part for the benefit of the following layer.

The phenomenon thus finds very advantageously in itself the means of sustaining its own evolution according to a stable and lasting regime, as the molten layers which thus propagate forwardly constantly leave place behind them for the molten metal which continually penetrates into the mould during the casting operation.

Said metal thus proceeds (Fig. 4) in the form of a liquid cylinder **22** within the solid cylinder **23** formed by the metal already set. This solid cylinder is still very hot and, by contact therewith, the portions of molten metal successively injected practically maintain their temperature, they remain fluid, thus flowing through a metal tube the length of which progressively increases, and successively come into contact with the free internal and cold wall **18** of the mould against which they solidify in their turn.

Consequently, the placing in position of the metal proceeds step by step practically indefinitely. This phenomenon ceases only when the casting is stopped or when the advancing metal encounters the end wall **24** of the mould. The injection of the metal must have ceased at this precise moment as the casting is then normally terminated. It then suffices to remove the cast member from its mould.

According to an important feature of the method of the invention, the layer of metal solidified at each point rapidly reaches a thickness approximating the final desired thickness; the circulation of the molten metal within the metal cylinder already solidified prevents the latter from cooling and its thickness from increasing appreciably during all the casting period. The solidification therefore takes place as a whole, according to a longitudinal process.

On the contrary, in the known processes, said solidification takes place, in particular after the molten metal has been distributed on the entire length or on an important part of the length of the mould: the thickness of the solidified metal increases simultaneously at each point and the solidification thus takes place, as a whole, according to a radial process.

The final thickness of the tubes cast according to the method of the present invention depends on numerous factors and, in the first place, on the cooling action of the mould.

It may be noted that, all things being moreover equal, the layer of solidified metal is so much the thinner:

as the mould has a smaller thermal conductivity,
as it is hotter,
as it is thinner,
as it has a lower specific heat and
as, consequently, it heats up more rapidly.

For instance, the thickness of the solidified metal is greater in an entirely metallic mould than in a mould lined with refractory material.

On the other hand, the features and physical state of the cast metal also intervene in the solidification process, the solidified layer being so much the thinner,

as the metal has a higher specific heat,
as it is hotter and of a more fluid nature.

Finally, the thickness of the solidified metal depends, to a certain extent, on the duration of the casting, conditioned in its turn to the outflow of the nozzle; a more rapid casting limits the quantity of heat yielded to the mould by the metal, and consequently, the thickness of the solidified layer.

In any case, an important feature of the invention resides in the combined use of a mould having definite thermal characteristics and for instance uniform throughout its length, and a calibrated nozzle, or other device distributing the molten metal at a constant flow, in order to maintain constant, throughout the length of the mould, the thermal conditions of the solidification and to thus obtain members of uniform thickness.

When the mould is very long, the temperature of the molten metal may slightly diminish from the inlet end to the end of the mould and the conditions of solidification be slightly modified thereby. But, in this case, it remains possible to maintain the thickness of the members uniform throughout their length by varying the flow during casting or by varying the thermal characteristics of the mould, for instance, its thickness at various distances from its inlet end.

More generally, the invention allows of obtaining at every point the desired thickness of metal by simultaneously controlling the flow of metal at every instant of the casting and the thermal characteristics at every point of the mould.

Owing to the new manner in which the molten metal is distributed in the mould without its temperature and its fluidity diminishing appreciably, and to the possibility of acting on the various above mentioned factors, the invention allows said metal to be injected at a very great distance from the casting orifice and to thus obtain thin and long tubular members even with metals which it is very difficult and expensive to raise to a temperature higher than the melting temperature, which therefore have only a small temperature margin and the fluidity of which diminishes very rapidly as soon as their temperature lowers approximately to melting temperature.

According to the particular example of Fig. 10, the steel tube, cast by centrifugation according to the invention, is a long and thin tube for pipelines. Its outer surface and its inner surface can be cylindrical and concentric or conical and can comprise bosses, flutes, grooves, etc., as well as the members for assembling them and fitting them together.

The length l of said tubes can reach for instance 6 or 8 meters or even more. Their internal diameter d can vary for instance from a few centimeters, 2 cm. for instance, to several decimeters, and even if need be exceed one meter.

The thickness e of the walls of said tubes, which varies in function of the diameter, of the pressure of the fluid it is intended to transport and of various other factors, can lower to 4 or 5 and even to 2 millimeters or reach, for instance 15 to 20 millimeters for tubes of medium or of large diameter subjected to an important internal pressure or external stresses. For steel tubes the length of which exceeds one meter, it is possible to obtain, owing to the means of the invention, a wall thickness lower than 1% and even than 0.5% of the length, which is impossible with known casting processes.

Fig. 5 shows the same tube in course of manufacture by centrifugal casting in a rotating mould movable about an axis X—X inclined relatively to the horizontal. The mould is constituted by a metallic frame 5 internally provided with a refractory lining 6 made of moulding sand compressed and stoved, holes 7 being formed through the frame 5 for allowing the evacuation of the gases produced in the refractory lining at the time of casting. The frame 5 is terminated at its ends by truncated bearings 8 and 9 on which are secured, by means of keys 10, two end walls constituted by a metallic cup 11 which supports a refractory lining 12; the highest end wall has a central orifice 13 for the injection of the molten metal. This injection orifice opens in alignment with a nozzle 14 arranged at the bottom of a casting pot 15; said nozzle and its casting pot are constituted by a pisé or any other refractory material.

The mould is supported and rotatably driven by rollers 16*a* and 17*a* rotating about axes Y—Y, and rotatably driven in their turn by a driving device, not shown. The mould 1 is held stationary longitudinally by outer flanges 18*a* which take a bearing laterally on the rollers 17*a*.

In this modification the axis X—X of the mould is inclined relatively to the horizontal to the extent of an angle α. It results therefrom that the action PG of gravity, which is exerted on every particle P of the molten metal contained in the mould 1 and which is applied by centrifugal force against its internal wall 19, can be decomposed into two components, one,

$$PN = PG.\ \mathrm{Cos}\ \alpha$$

at right angles to the axis X—X and the other,

$$PL = PG.\ \mathrm{Sin}\ \alpha$$

parallel to said axis and directed towards the lower part 21 of the mould. Each particle of molten metal is thus drawn along towards the lower part of the mould until, when it comes into contact with the free wall 19 of the mould, it cools, solidifies and comes to rest in its turn.

According to a modification illustrated in Figs. 11 to 12, the tubular member 23 made of steel cast by centrifugation is intended to serve as an electric line support. Its inner surface 24 has the shape of a truncated cone. Its outer surface comprises three parts: a truncated part 25 located on the side of larger diameter and intended to be embedded in the ground, a central part 26 also of general truncated shape, and intended to be placed at men's height, and an end part 27, also truncated, longer than the preceding parts and constituting the top part of the post.

The central part 26 can be provided with external flutes 28 the cross section of which diminishes towards the small diameter of the post.

Fig. 6 illustrates the same tube during manufacture by centrifugal casting in a rotating mould 29. Said mould is similar to that above described: it is essentially composed of a metallic frame 30, an inner refractory lining 31 and two end walls 32 and 33 secured by keys 10. The end wall 33 placed on the side of small diameter of the mould is perforated by a central orifice 34 for the injection of the molten steel. The frame 30 rests, by its rolling tracks 35 and 36 on rollers 37 and 38 through the medium of which it can be rotatably driven about the horizontal axis X—X, by means of a driving device, not shown. The refractory lining 31 has an inner surface 39 complementary to the outer surface of tubular post 23; it can comprise flutes 40 intended to form the flutes 20 of the tubular post 23.

The injection orifice 34 opens in alignment with the nozzle 41 arranged at the base of the casting pot 42.

Owing to this method of construction of the moulds, each particle P of molten metal contained in a mould and rotatably drawn along is subjected to a centrifugal force PC which has a longitudinal component PL directed towards the bottom of the mould. This component is exerted on the molten metal throughout the length of the mould: it compensates the friction which would have the effect of progressively braking the flow of the metal and allows the latter to maintain its speed of advance on an increased distance. Owing to this arrangement much longer members can thus be obtained.

Calculation shows and experience confirms that a very small conicity suffices for exerting on the metal a very powerful action.

This action can be for instance calculated, in the case of a rotating mould having an average radius of 0.15 meter, a speed of rotation of 1.500 revolutions per minute and a very small conicity such that each of its generatrices forms an angle of $\frac{1}{1000}$ with the axis of rotation.

In this case a longitudinal acceleration component: PC=3,7 m/sec/sec, is obtained which is very important and which imparts great facility to the molten metal to proceed within the mould: this advance takes place in the same conditions as if the metal flowed freely; under the action of gravity, on a fixed inclined plane having a slope of

$$3{,}7 : 9{,}81 = 0{,}377$$

corresponding to an angle of inclination of 22 degrees.

It must be added that this very small conicity is easily obtained, for instance, in the case of sand moulds by giving the corresponding slightly conical shape to the metallic pattern used when clamping the mould. This clearance moreover allows the easy disengagement of said pattern after the preparation of said sand moulds; it has furthermore the advantage of facilitating the longitudinal shrinkage of the cast members and it renders their removal from the mould particularly easy after solidification.

Owing to the use of an inclined or truncated mould as above described, it is possible, for instance, to extend the length of the members obtained to 6 to 10 meters and even more, in the case of tubes having an internal diameter of several centimeters or of a few centimeters and a wall thickness of 2 to 15 millimeters.

It may be advantageous, for tubes of this length, to increase the initial speed of the metal at its inlet into the useful part of the mould.

This result is obtained for instance, according to the invention, by securing at the end of the mould 5 (Fig. 7) a rotating distributor 48, having an inner surface 49 of truncated shape widening from the orifice 50 admitting the metal up to its junction 51 with the mould 5. Said distributor is rendered rigid with the mould by screws 52 and it also rotates about the axis X—X.

The operation of said distributor is as follows: The molten metal 53 injected into the distributor through the orifice 50 comes into contact with the inner surface 49 of the distributor by which it is rotatably driven. Each particle P of the metal is thus subjected to a centrifugal force PC at right angles to the axis X—X.

If the mass of the particle P is designated by m, its distance PH to the axis X—X by r, and the angular speed of rotation of the distributor 48 by ω, the value of the centrifugal force PC is given by the known formula:

$$PC=m.\omega^2.r$$

By designating by β the angle formed by each generatrix of the truncated distributor 48 with the axis X—X, and by decomposing the force PC into its two components: PN at right angles to the wall of the distributor and PF directed according to a generatrix of said wall, it will be seen that the distributor according to the invention has the effect of exerting on each part of the metal a force one of the components of which:

$$PN=m.\omega^2.r.\text{Cos}\ \beta$$

is perpendicular to the wall 48 of the distributor and applies the metal against said wall, and the second component of which:

$$PF=m.\omega^2.r.\text{Sin}\ \beta$$

parallel to the generatrix of the truncated cone passing through P has for result to promote the movement of the metal towards the mould.

This latter force, which is proportional to the second power of the speed of rotation, increases as the radius r, that is to say very gradually, in proportion as the metal moves from the inlet of the distributor towards the mould and without causing any perturbation in its flow.

Owing to the invention, a very high longitudinal speed can thus be imparted to the metal at the moment it enters the mould, which allows it, before it loses its temperature and fluidity, to cover a longer distance within said mould: the possibility of producing members of increased length results therefrom.

The drawing along of the molten metal and the operation of the distributor can be improved by giving to the latter a rough internal surface. According to the embodiment illustrated in Fig. 8, this result is obtained by providing the inner surface 54 of the distributor 48 with longitudinal ribs 55 which become impressed in the molten metal and accelerate its centrifugal rotation.

The divergent rotating distributor can, according to the invention, be devised in various manners. Fig. 9 illustrates an embodiment in which the rotating mould is externally provided on the side of the casting orifice 13 with a series of cooling ribs 56. On the other hand, the thickness of the refractory lining 59 is greatly reduced straight below said ribs, so that, in this part of the mould, the cooling of the latter and consequently, that of the molten metal are considerably increased.

Said device operates as follows: At the beginning of the casting an important amount of metal 57 solidifies at the inlet to the mould and the inner surface 58 of said solidified portion assumes a truncated shape which acts as a divergent distributor on the molten metal subsequently injected into the mould.

If the presence of this reinforced portion is not desired in the cast member, it suffices to section it after removal from the mould, according to the plane Z—Z for obtaining a tubular element having the desired internal cylindrical shape.

It is very important to emphasize the simplicity of the new method for manufacturing said members: it allows, in fact, of directly obtaining finished members starting from molten metal and by avoiding any other metallurgical or shaping operation. A considerable reduction of the expenses of the plant, labour, fuel, and exploitation as well as an appreciable diminution of the metal losses result therefrom, relatively to the other processes.

Moreover, the invention has the great advantage of being indistinctly applicable to all metals or other fusible bodies, and in particular to those which do not lend themselves to other shaping processes.

By eliminating the use of a long casting conduit penetrating into the mould, the invention can be moreover applied to be utilisation of very small moulds and thus allows of manufacturing members of a smaller diameter than the other known centrifugal casting methods.

The method according to the invention has finally the great advantage, relatively to the other known methods, of producing members soundly constituted. Thus in the casting of metals in general, the formation of shrinkage holes in the thickness of the members is only avoided provided that the solidification of their walls takes place and proceeds according to a single working face; shrinkage holes are unavoidably produced each time the molten metal solidifies and shrinks in a closed space limited by two or more solidification faces which advance to meet each other. In the manufacture of long and thin tubular members and in particular of thin tubes, a solidification face is compulsorily formed at the outer surface of the member, owing to the cooling action of the mould. It is therefore essential to prevent the formation of another solidification face starting from the inner surface of the members. This result is obtained owing to the casting method and to the shape of the mould according to the invention.

In fact, the metal already stationary in the mould is protected from any cooling action from within the mould, by the layer of hotter molten metal which flows and is constantly renewed within the member. On the other hand, the outer cold air is prevented from entering the mould by closing the latter at both its ends by two end walls, one only of the end walls being perforated with an orifice as reduced as possible for the injection of the molten metal.

According to the embodiments illustrated in Figs. 1, 4, 5, 6 and 9, the orifice 13 or 34 for the injection of the molten metal opens opposite the nozzle 14 or 41 through which spurts the molten metal 17 or 43. Said orifice can also be enlarged to allow the introduction of the nozzle 14 into the mould or into the distributor 48 as shown in Fig. 7, this latter arrangement having the advantage of avoiding any projection of molten metal outside the mould. In both cases, the annular clearance existing between the orifice 13 on the one hand, and, on the other hand, the jet of molten metal 17 or the outside of the nozzle 14, must be reduced to the minimum.

At the beginning of casting, the air contained in the mould suddenly expanding very rapidly escapes outside. It is moreover known that molten metals contain a considerable quantity of dissolved gases or gases in the combined state. Said gases spontaneously evolve upon cooling and centrifugation appreciably accelerates the elimination of the gases from said metals in the molten or pasty state. The hot gases which, after the air escapes from a centrifugal mould such as above described, are for the greater part combustible gases; they ignite and burn at the outlet of the hole of the casting cup; it has been found that the flame persists for a relatively long time after the solidification of the metal is terminated, which allows of affirming that the external atmosphere does not at all penetrate into the tube or other member in course of solidification.

It results therefrom that the inner wall of said tube is sheltered from any cooling action exerted by the ambient air; it can only cool by contact with the external concentric layers which, in their turn, cool by contact with the centrifugal mould or chill. In other words, the calories of the metal flow radially in a single direction, that according to which centrifugal force acts, and the metal solidifies according to a single face at right angles to said direction. It results therefrom that no portion of the molten metal solidifies in a closed space limited by two or more solidification faces advancing to meet each other. Owing to this very advantageous feature of the invention, it has been proved that the tubes cast by centrifugation in accordance with the method and/or by means of the devices above described, have walls rigorously free from shrinkage holes.

The present invention therefore allows not only of obtaining by simple casting, that is to say in very advantageous economical conditions, thin and long tubular members, but also of avoiding the various defects which are frequent in the members obtained by other methods. Thus, the unevennesses in wall thickness are avoided by the centrifugal casting, and the longitudinal unevennesses by the method of distributing the metal along the mould.

Furthermore, the solid or gaseous inclusions are also driven out by the extremely intense action of centrifugal force, and the shrinkage holes eliminated by the particular cooling method directed exclusively from the exterior towards the interior of the member. Finally, the members obtained are perfectly isotropic at every point.

The long and thin tubes and other tubular members made of cast metal obtained according to the invention present numerous other advantages relatively to similar members obtained up to now by known ingot casting, forging, punching, rolling, drawing or other processes.

Furthermore, they can be constituted by any steel or other metal or alloy whatever, without it being necessary that the latter should satisfy the conditions of malleability, rolling, weldability, limited shrinkage, etc. This feature considerably extends the possibilities of the art and allows of using, for instance, new varieties of steel or other ferrous alloys which, up to the present, have not been practically used notwithstanding their particular advantages, either because they are industrially unsuitable for rolling, or because they are difficultly weldable, or because they have an important shrinkage, or for any other reason.

For instance, the invention is applicable to tubes for pipe-lines embedded in the ground, made of steel having 13% of chromium. As this steel is only slightly oxidizable, the tubes can be given a smaller thickness solely conditioned by the mechanical stresses to which said tubes are subjected owing to the internal pressure of the fluid conveyed or to external overstreses.

The regularity of these members is as remarkable as the quality of the metal constituting their walls; in fact, the unevennesses in wall thickness are avoided by centrifugal casting and the longitudinal unevennesses by the method of distributing the metal along the mould.

Finally, the members according to the invention are perfectly isotropic at all their points: they do not have the fibrous structure of members obtained by rolling: this feature is particularly advantageous for members subjected to corrosion, in particular, for the tubes of underground pipe-lines, as a fibrous structure promotes, as is known, the corrosion of the metal.

In addition to the embodiments illustrated in Figs. 10 and 11, the members manufactured can be cylindrical on a portion of their length and conical on another portion, or more generally can have an outer shape which flares towards the larger end of the mould. They can be externally provided with projections which are not flared provided that the inner surface of the member does not appreciably depart from the shape of the cylinder or truncated cone, and provided the mould is destroyed for allowing the removal of the member after each casting operation.

The cross section of the members can be circular or on the contrary have any external polygonal or like shape, or can be provided with flutes or grooves. The shape of said cross section can moreover vary along the mould.

The pipe-line tubes made of centrifugal steel can also have a widened end serving to constitute a socket joint: said widened end being provided only outside the member, the inside of the latter remaining cylindrical at the time of casting to be subsequently subjected to a suitable shaping or, again, the interior of the socket joint being also formed at the time of casting by means of a fitting core secured at one end of the mould, as known per se.

Finally, the length, thickness and internal diameter of the tubes and other tubular members can vary within wide limits; the values above indicated being given by way of example and not in a limiting sense. Said members can be used such as they issue from the mould or, on the contrary, can be subjected to any subsequent transformation.

Of course the invention is not limited to the embodiments illustrated and described which have been chosen only by way of example.

It can thus be applied not only to steel, but also to any metal, alloy or other fusible material capable of passing from a molten or pasty state to a solid state, whether this change of condition takes place upon cooling, as described, or for any other physical, chemical or like reason.

The mould can be destroyed at each operation, or on the contrary can be permanent, for instance, entirely metallic. It can have any other shape, for instance a cylindrical shape on a portion of its length and truncated on another portion, or the shape of a paraboloid of revolution.

The surface of the mould can be provided with counter-tapper parts which do not affect the general shape of the mould, provided said parts are destroyed or taken to pieces after each casting for allowing the removal of the members.

The cross section of the mould can be circular as illustrated, or on the contrary, it can have any fluted polygonal or like shape: the shape of the cross section can moreover vary along the mould. For instance, in the casting of pipes, one end of the mould can be widened for forming the socket joint of the member.

Use can also be made of a mould inclined towards the casting orifice, but sufficiently flared for the longitudinal component of centrifugal force to be greater than the longitudinal component, directed in reverse direction, of gravity. Conversely, use can also be made of a mould flared towards the casting orifice but sufficiently inclined in the reverse direction for the longitudinal component of gravity to be greater than that of centrifugal force.

The orifice for the injection of the metal can be arranged exactly at the center of the end wall of the mould or, in particular, in the case of a mould of large diameter, it can be out of center and placed for instance in the vicinity of the lower generatrix of the mould; in this case, a fixed cheek member can be used for obturating as completely as possible, the end of the mould and thus prevent, according to the invention, the entrance of the cold ambient air into said mould.

The divergent rotating distributor made of metal or of refractory material, can be secured in position and rotatably driven independently of the mould, at a speed equal to or different from that of the latter. The profile of said distributor can be truncated as shown, or can have any other general divergent shape, such as that of a sector of a paraboloid of revolution. Its surface can be smooth, rough, striated or grooved.

On the other hand, not only can a constant impulse be imparted to the metal or constant forces exerted thereon during the entire casting period, but said impulse and/or said forces can be varied during the operation, for instance at the end of the casting, either by modifying the speed of rotation or the inclination of the mould, or by changing the level of the molten metal in the casting pot.

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