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E. C. CHAPMAN

3,259,975

TUBE MANUFACTURE

Filed Dec. 19, 1963

FIG. 1

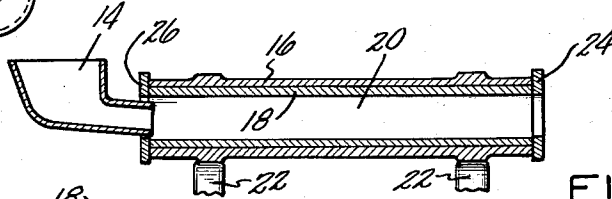
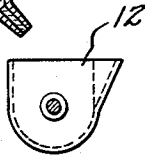
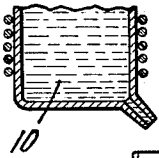


FIG. 2

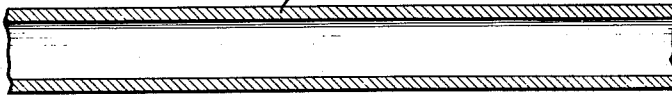


FIG. 3



FIG. 4

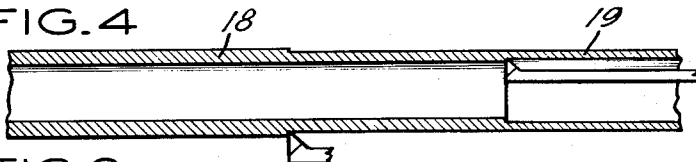


FIG. 5



FIG. 6

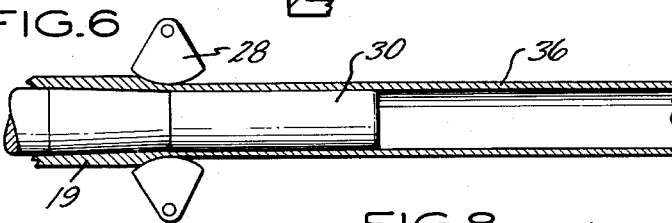


FIG. 7

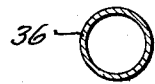


FIG. 8

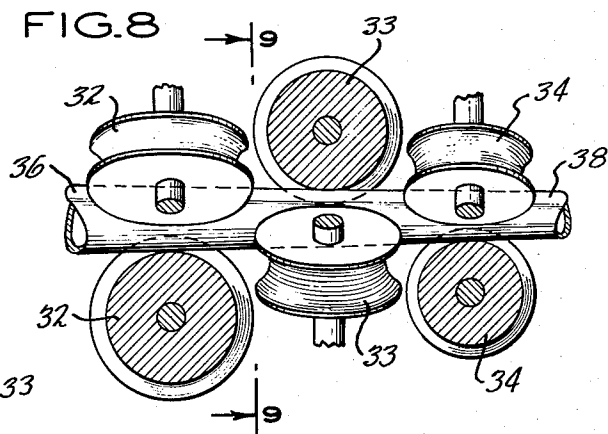
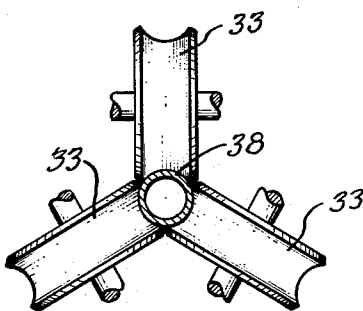


FIG. 9



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3,259,975

## TUBE MANUFACTURE

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15 Claims. (Cl. 29—528)

This invention relates to tube manufacture and particularly to an economical method of making high quality tubes such as boiler tubes especially those used in high pressure boilers.

An object of this invention is a method of making tubes with a minimum of plant investment and a minimum of forging steps.

A further object is an improved method by which a muff of improved forging quality and of sufficient size, including length, to render a stretch reducing step economically practical may be formed by centrifugal casting.

A further object is the combination of related steps of centrifugal casting a tubular member to obtain a pre-selected size and quality, cold rolling to reduce wall thickness and tube diameter and obtain additional length and then stretching reducing to reduce the diameter and further reduce wall thickness to produce the finished tube.

A further object is an improved method of producing, economically, a hot finished tube having more uniformly accurate dimensions of diameter and wall thicknesses.

A further object is to provide a method for producing hot finished seamless tubes of alloys difficult or impossible to hot work in the cast condition (as an ingot).

Other objects and advantages will be apparent from the following specification and the attached drawings in which:

FIG. 1 is a schematic showing of the centrifugal casting step;

FIG. 2 is a sectional view and FIG. 3 is one end view of the cast muff;

FIG. 4 is a sectional schematic view showing the smoothing operation;

FIG. 5 is an end view of the smoothed muff;

FIG. 6 is a sectional schematic view showing the rolling step reducing the wall thickness and diameter;

FIG. 7 is an end view of the tube with the reduced wall thickness;

FIG. 8 is a diagrammatic view showing the tube being stretched in the tube stretching mill; and

FIG. 9 is a diagrammatic end view of the tube in the stretching mill.

In the manufacture of tubing one of the problems is the production of tubing with a minimum of plant or machine investment and with a minimum of different steps or handling procedures, so as to produce tubing in a practical and economic manner.

Another problem is to economically provide a muff of a proper selected size and of a quality which will consistently satisfactorily respond to forging operation to provide a sound finished tube.

Another problem, particularly in the high alloy materials, such as the non-pierceable stainless and hot short steels, is to economically provide a sound hollow ingot of a size suitable for forging economically into tubes suitable for use as boiler tubes.

Boiler tubes, including the superheater tubes which

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may be as small as  $\frac{3}{4}$  inch in diameter and as large as 4 inches in diameter, are generally of carbon steel and heavy duty ferrous alloys which may be subjected to high temperature combustion gases of up to say 2800° F. and an internal pressure of say 3500 pounds per square inch or more and an internal temperature of 300° to 1200° F. Such a tube is preferably seamless particularly for operation at the higher temperatures and of as long a length as can be made practically, such as 60 feet or more so as to provide tubes with a minimum number of welds in furnace walls that may be say 125 feet high. To manufacture such tubes of a ferrous alloy containing ingredients such as 1.0 to 20% chromium, .5 to 5.0% molybdenum and .1 to 1% carbon, or 15 to 30% chromium and 7 to 35% nickel or type 347 or 316 AISI steel or non-ferrous alloys such as nickel or cobalt base alloys and consistently get good tubes presents difficulties which are overcome by the interrelated steps of applicant's process.

To manufacture a muff suitable for forming tubes in the  $\frac{3}{4}$  to 4 inch diameter range from the usual solid cast ingots requires a large plant investment including melting, casting, rolling and piercing equipment to form the muff, particularly in the case of non-pierceable materials where the perforation must be drilled or otherwise made in solid stock, and in order to get a muff suitable for producing a tube of such diameter and 50 feet or more long would require several forging operations.

It should be realized that in any tube making process there are limitations which determine the size—large or small—which can be economically performed by that process, for instance in making muffs from solid billets of non-pierceable material there are limitations on the length of billet that may be drilled which will vary directly with the size of the drilled hole; in piercing there is a limit on the length that can be pierced; in tube reducing there are limitations in the reduction of diameters in a single pass; in stretch reducing there is a limitation in reduction of wall thickness in a single pass and in centrifugal castings there are limitations as to the length that may be cast and the minimum inside diameter.

Applicant has invented a process of making tubes which utilizes the advantages of certain steps to overcome the limitation of others to provide a simple economical method of tube manufacture. It is this unique combination of steps that results in the production of high quality heavy wall small diameter tubes in an economic manner.

Applicant has found that muffs suitable for subsequently forging into small tubes say of 4 inches and less diameter with a minimum of forging steps can be economically produced by a centrifugal casting step in which thick walled tubes of say  $\frac{3}{4}$  to 2 inch wall thickness and in lengths of 8 to 12 feet, when the rotating mold is fed from one end and of 16 to 20 feet, when the rotating mold is fed from both ends, may be economically formed of the required diameters and quality. It should be noted that the dimensions herein given are by way of explanation and illustration only and are not to be considered strictly as limitations. In order to successfully and economically manufacture tubes from a centrifugal casting by subsequent forging operations, either hot or cold, or both, it is essential that the centrifugally cast muff be of a quality, size, and material which will con-

sistently provide uniform and sound tubes. The steel to form the cast muff is melted preferably under controlled atmospheric conditions such as in an argon atmosphere, in any suitable furnace, such as an induction furnace 10, to a desired pouring temperature which should be in a narrow range around 2800°, or slightly above, in order to provide proper distribution in the mold before congealing sets in. The composition of the melt is carefully controlled by the addition of suitable ingredients at the proper time to insure that the material reaching the mold will have the desired composition.

While, for simplicity in showing, the molten metal has been shown as passing from the furnace 10 to a ladle 12 from which it may be poured into the spout 14 feeding the rotating centrifugal mold 16 in which the muff 18 is cast, it should be understood that the entire path of the molten metal from the furnace 10 to and including the interior 20 of the rotating mold may be encased in or surrounded by an inert atmosphere such as argon or a reducing atmosphere such as hydrogen in order to avoid any contamination or impurities which could result in slag, dross or other impurities forming in the inner surface of the cast muff or contamination by moisture, oxygen and nitrogen from the air.

In casting the muff a predetermined amount of metal, determined by the dimensions of the muff to be cast, is poured at a preselected and carefully controlled rate through the nozzle 14 into the rapidly rotating muff 16 which may be rotated by any suitable means, such as rollers 22, driven from any suitable source not shown. The mold 16, which may be of metal, is lined, preferably with a porous ceramic material which will provide as smooth an outside surface to the cast muff as is possible in order to limit the extent of subsequent machining if such is found necessary or desirable, and will also act as an insulator to prevent rapid chilling of the outer surface of the molten metal as it flows into the mold. This lining material may be applied either by spraying or spinning onto a preferably preheated mold and is at least partially removed from the mold with the muff at the time of the extraction of the muff. Suitable end pieces 24 and 26 are applied to the preferably cylindrical mold and may have a central opening therein substantially equal to the inside diameter of the cast muff. As the molten metal must be applied to the interior of the muff at a preselected rate to avoid chilling and laps or cold shuts the diameter of the aperture through the end piece 26 must be at least large enough to accommodate a spout which will deliver the molten metal at the predetermined selected rate. While this acts as a limitation on the minimum inside diameter of the muff that may be successfully cast and while the necessity of obtaining a centrifugal force sufficient to force the molten metal outwards to obtain a sound casting under increased pressure may also act as a limitation on the minimum diameter that may be cast, it has been found that by using applicant's combination of steps these limitations do not impose a handicap. It should be noted that the pouring rate is critical, limited on the one hand by the necessity of pouring fast enough so as to avoid chilling and other defects caused by too rapid cooling and limited on the other hand by the danger of washing away the necessary lining material. For a cast muff about 8 feet long 5 inches in diameter and 1 inch wall, in order to obtain a sound casting, the pouring should be completed in about 30 seconds. The mold may then be rapidly quenched and the solidifying and shrinking of the muff from its high temperature permits ready removal by pushing or pulling it through the mold. For further details of the casting procedure reference may be made to application Serial No. 149,621, now Patent No. 3,164,871, filed by Paul F. Haughton for "Centrifugal Casting Apparatus and the Method of Making the Same," filed November 2, 1961 and application Serial No. 156,225, filed by Paul F. Haughton and James H. Espy for "End Core Design for Use as a Clo-

sure on Centrifugal Casting Molds," filed December 1, 1961, now Patent No. 3,197,827.

The muff 18 thus cast is of a malleable metal which, depending on its composition, can be subsequently forged, either hot or cold, and because of the centrifugal casting technique provides a muff of a dense homogeneous structure particularly free of flaws or defects that would adversely affect subsequent working or tubes produced by such working. Hot short material, such as type 347 or 316 steels give difficulty when worked hot directly from the casting, but by using applicant's process can be subsequently satisfactorily hot worked. Because of the higher temperatures associated with piercing, satisfactory muffs of this type of material free of defects cannot be produced by piercing billets no can satisfactory blooms or billets be made by hot rolling. Certain other high alloy materials cannot be successfully pierced.

Conventional steel mill methods for making tubes include casting an ingot with its normal segregation of impurities toward the center and often shrinkage cavities at the core of these ingots. The ingots are subsequently heated and hot rolled into billets with the poorest metal falling at the center of the solid round billets. It is well known that the concentration of impurities is highest in the center of such a billet. Impurities are highest in the last metal to solidify and since ingots solidify from the outside inward the most impure metal necessarily falls at the center with the increased concentration toward the top. Therefore, when billets are pierced with the conventional piercer this working is done through the poorest metal in the ingot. The inside surface of the resulting hollow, therefore, is the poorest metal in the hollow and this is the metal that is exposed to contents of the boiler which corrode or to acid which is used in acid washing the boiler. Therefore, with the conventional mill method of making tubes we have the poorest metal in the most vital location since it is never removed by boring or other machine operations. With a centrifugal casting, however, impurities are rapidly thrown to the inside and the distance the impurities have to travel to escape is a very small fraction of this distance in the ingot and there are no shrinkage cavities. After pouring any minor degree of contamination is readily removed by boring. Therefore, the centrifugally cast hollow from the standpoint of uniformity and soundness of metal throughout is far superior to a hollow produced by conventional mill procedures.

Furthermore, cast ingots with their heavier mass cool much slower than centrifugal castings allowing not only segregation of impurities but also segregation of alloying elements on which the good properties of the finished tube depends. This segregation is much greater in an ingot than in a centrifugal casting. Therefore, it is impossible to hold the final chemical analysis at the optimum balance of alloys with ingots and tubes made from ingots will vary in analysis to a greater extent than tubes made from centrifugal castings. ASTM and other specifications, therefore, provide wide ranges of the specified elements within which tubes deficient in serviceable properties can be produced. Such tubes meet the specifications but deteriorate in service. Furthermore, it is less costly since the investment of heavy machinery required for rolling the ingots and billets is eliminated. Likewise, the piercer is eliminated. Several heating operations for hot working and the necessary furnaces are also eliminated. Applicant's process therefore eliminates a number of costly operations of the conventional steel mill methods for making tubes. Applicant's process further permits the production of such tubes economically at a relatively small production rate per year. Since a number of operations are eliminated, the labor costs are less. With less investment and labor cost, tubes can be produced economically with less tonnage. It is applicable to almost any ferrous and non-ferrous metal and probably has greater flexibility in this regard than other processes. Many materials cannot be pierced and centrifugal castings can be made of such ma-

terials. Many materials are difficult to hot work in the ingot form and cold working as a first operation after the casting is the proper and sometimes the only method of reduction. This is a very important advantage of this process. For instance, some high alloy steels and non-ferrous metals can be worked more easily when cold than when hot. Well-known materials that have these characteristics are high nickel alloys, copper and copper alloys and many of the austenitic stainless steels. Some such materials give such difficulty in hot working in the cast condition that the introduction of a cold working operation prior to any hot working makes possible the production of tubes where heretofore this has not been possible. Certainly in many cases it is possible to achieve the desired quality where this is not possible where the operations are hot as applied to the ingot in the as-cast condition.

The minor surface defects produced by possible irregularities in the mold ceramic lining on the exterior of the muff and the dross or other impurities that may appear on the interior surface of the muff 18 may be removed by subsequent mechanical operations such as turning i.e. removing metal by a cutting tool 26, or grinding to provide smooth exterior and interior surfaces and a muff 19 having walls of good concentricity and of uniform dimensions throughout the length and circumference of the muff. This muff 19 has an outside diameter which may be several times that of the desired finished tube and a wall thickness which may be several times that of the desired finished tube.

In order to efficiently transform this muff into a long tube of reduced dimensions applicant has found that after subjecting the muff 19 to a heat treatment to refine the grain structure for some materials and/or to remove cold working strains after the cold working i.e. the machining operation, the tube can most efficiently be reduced in wall thickness by subjecting it to a cold working rolling operation in a device 28 known as a tube reducing or a rocking machine by which the wall thickness can be reduced up to 70 or 80% in a single pass by squeezing the tube between rolls or rockers 28 and over a mandrel 30. This operation will materially lengthen the tube, reduce the outside and inside diameter and wall thickness. For some materials the heat treating operation is not required prior to reducing.

By this tube reducing operation the wall thickness may be brought down to approximately the wall thickness desired in the finished tube evenly and accurately, the concentricity improved and the diameter reduced to provide a semi-finished product 36 with a diameter several times that of the finished tube but with a concentricity providing a uniform wall thickness throughout the length and circumference of the tube, substantially that desired of the finished tube. This cold working followed by heating will further compact and improve the grain structure of the already dense casting and provide a product which can be transformed into the desired finished tube in one further forging step.

The uniformity of quality of the centrifugal casting and the avoidance of the non-metallic inclusions or shrinkage cavities of the ingot are essential if the tube reducing operation is to be successful. As this tube reducing operation is carried out cold, i.e., the metal is plastically deformed without heating and therefore the casting in order to withstand this severe operation must have no macroscopic defect, i.e., defects of a size that will result in fracture of the casting during reduction. Castings are produced by the centrifugal casting process of such a quality that after the tube reducing operation they can be successfully hot stretched reduced without developing flaws. This means that the material as a result of grain refinement is not hot short and that the cold reducing operation has not introduced flaws which would cause failure in the subsequent hot operation. Both of these operations test the material severely. If the material is

successful in passing both of these operations it is certain to be a good material since it has been tested both hot and cold.

Where mills start with ingots containing their normal defects, roll these into billets and pierce these billets, a high percentage of the hollows so produced contain defects of the types mentioned above plus additional defects that are often generated in the piercing operation. Defects are often generated or aggravated in the subsequent mill operations after piercing if an attempt is made to reduce the wall thickness of the pierced hollow in order to make it suitable for stretch reducing. It is well known that seamless tubes cannot be consistently successfully produced on a stretch mill from hollows produced by conventional processes because the defects that are present in such hollows will cause failure of the tube as it is being reduced in the stretch mill.

It is well known that by either the piercing operation or extrusion, eccentricity results which often exceeds the limits permitted for stretch reducing or which are unacceptable for the finished tube. In order to make certain that the wall thickness of tubes made from pierced or extruded billets does not fall below the minimum required at any point in the tube the tubes are furnished with excessive wall thicknesses in order to allow for the variation in wall thickness inherent in processes using a piercing or extrusion step. Tubes made from centrifugal castings, on the other hand, tube reduced and stretch reduced can be much more closely controlled as regards tolerances and the hot finished tube can even meet so-called finished tolerances that normally only result from tubes finished on either the tube reducer or by cold drawing. This effects an additional reduction in cost. The reason why the dimensions of the tube produced by applicant's process can be more accurately controlled are several. The start is made with a very concentric hollow since all centrifugal castings are more concentric than can be produced consistently by the piercing or the extruding operation. The castings are machined inside and out and the machining can be done to close tolerance. The tube reducing operation itself removes up to 50% of any eccentricity remaining in the machined hollow. For boiler service it is very important that the tolerances be held close since the flow of water and steam depends on the pressure drop through the circuits and the pressure drop is dependent on the inside cross sectional area of the tube. Closer tolerances are required for many other types of service. Tubes with very close tolerances are in demand for many uses and are not obtainable by prior commercial processes.

This next forging step should be a stretch reducing step in which the semi-finished tube 36 from the tube reducing machine is heated and then hot stretched and rolled to reduce the tube diameter from that of a semi-finished product 36 without materially changing the wall thickness to produce the finished tube 38 having substantially concentric inner and outer walls and of the desired outside and inside dimensions and length. The heating of the cold worked tube 36 serves the double purpose of refining the grain and relieving the stress in the cold worked tube as well as rendering that tube sufficiently ductile to be stretch reduced in the stretch mill.

The stretch reducing mill consists of a series of roll stands 32, 33, 34, the number depending on the degree of reduction required and may be 24 or more. Each set of rolls reduces the diameter of the tube but at the same time through individual speed control of each individual set of rolls, by well-known means not shown, the wall thickness likewise can be reduced by putting tension on the tube. Before the stretch principle was developed, the rolls were not individually driven and the so-called hot reducing mill merely reduced diameter with some increase in wall thickness. Generally, in the production of boiler tubes and others, a reduction in wall thickness is desired since this makes possible thinner

walls in the finished tube. By utilizing stretch a tube with a thicker wall and a greater weight can be used in entering the stretch mill and the greater weight means that a longer tube can be provided with the consequent lower cost.

The stretch mill has the great advantage of having the capacity to take a relatively large diameter hollow and reduce it in one pass down to a practically unlimited small diameter. For instance, hollows in the order of 7 inches in diameter may be reduced down to the order of  $\frac{1}{2}$  inch in diameter in one pass through the stretch mill. Since it is easier to make large diameter centrifugal casting than small diameter, and since the weight goes up directly with the diameter, it becomes obvious that a stretch mill is uniquely suited for the process of producing tubes from centrifugal casting. From the standpoint of cost it is desirable to enter the stretch mill with as large a diameter and the heaviest weight possible. The heaviest weight possible calls for the longest length, the largest diameter and the heaviest wall. The cost of the finished tube per unit length is reduced proportionately with increase in weight of the starting hollow.

The stretch reducing mill has a limitation on the maximum wall reduction it can make whereas in general there is no limitation on the diameter reduction it can make. The maximum reduction in wall thickness is in the order of 35%. The stretch mill has no limitation on the length it can receive and the length limitation in the present process is imposed by the maximum length of centrifugal casting that can be produced with the desired diameter and wall thickness.

In the stretch reducing mill process there is a certain amount of discard on each end of the tube produced due to the fact that the wall thickness does not reduce sufficiently on the ends since stretching cannot develop until the tube enters the second set of rolls. Likewise, stretching is not completed at the finishing end since the stretch will not be achieved after the tube has passed the next to last set of rolls. Therefore, it is advantageous to make a tube of sufficient length so that the discard is a small percentage of the tube length. The amount of discard depends on the spacing of the rolls and these rolls are placed as close together as is practicable. With the longer tubes produced in the stretch mill which tubes may be 150 to 500 feet long there is a great saving in cutting losses which are less on an average when a number of lengths can be cut from one tube than if only single or possibly double lengths were made.

It is desirable in order to produce as long a tube as possible to have the centrifugal casting of maximum weight and of maximum wall thickness. Since the stretch mill has a limitation for wall reduction and the centrifugal casting has a limitation for length of casting it is desirable to have a step between the casting and the stretch mill will reduce the wall thickness and lengthen the tube as much as possible. The tube reducer or cold rolling step can make a material reduction in the wall thickness and some reduction in the diameter of the casting. With the reduced diameter and the reduced wall thickness a cross sectional area reduction of more than 70% is possible, for many materials since the tube reducing operation which takes a machined hollow and both reduces its diameter and wall thickness and at the same time increases its length can make cross sectional area reduction of over 70%, say 80% for many materials. This means that the entering length is multiplied by 5. If the reduction is 66% the length will be multiplied by 3. With a casting length of 20 feet, after reduction the tube reduced hollow would be from 60 to 100 feet long. This tube after passing through the stretch reducing mill would have a final length of from 150 to 500 feet or longer depending on the proportions of the tube being reduced and the proportions of the finished tube. With tubes of this length the discard would be but a small percentage of the total length of the tube produced.

It should be noted that in applicant's process the centrifugal casting is first cold worked and then hot worked. It is not feasible to cold work an ingot into a form suitable for making tubes. Because of the poor hot working properties of many materials, a cast tubular shell provides an ideal form from which to start. Materials that cannot be hot worked or are hot worked with great difficulty in the cast form can be hot worked in the wrought form. Hence, after the centrifugal casting has been reduced in the tube reducer by cold working followed by heating it is then in a form metallurgically as regards grain size and structure that permits the hot operation in the stretch mill. Many of these materials bring very high market prices because of the difficulty in reducing the original ingot down to a finished tube. For example, a nickel-chrome alloy in considerable use today may sell for \$2.00 a pound in a size  $1\frac{1}{2}$  inches O.D. and .200 wall thickness but in the finished size in which it is used of about  $\frac{3}{8}$  inch O.D. to  $\frac{1}{4}$  inch O.D. and .04 to .10 wall thickness it sells for \$6.00 a pound. This great increase in price is due to the number of cold draw passes interstage anneals and pickling operations required which are obviated by applicant's process.

There are also materials that should be furnished in the hot worked condition because of their metallurgical properties. When tubes are finished hot they are finished from a very high temperature and certain chemical elements are, therefore, retained in solution in the material providing extra strength. Since cold finishing as a final operation is the usual way to make tubes to close tolerances and this operation destroys the high temperature strength of the material, very high heat treatment temperatures are required to restore this strength to some degree. These high heat treating temperatures have many drawbacks such as the difficulty in providing suitable heat treating equipment, oxidation of the material during treatment, and undesirable metallurgical characteristics such as very coarse grain size. Hence with these materials the final operation should be done hot since the hot working temperatures are high enough to provide the strength required. Furthermore the final heat treating cost is reduced or totally eliminated. Applicant's process is unique in providing the requirements of close tolerances with a final hot working step.

This method, it should be noted, is particularly efficient in the use of material, which in the case of high alloys may be quite expensive. It has been found that by careful control of the casting process particularly smooth castings both inside and out may be obtained requiring only approximately  $\frac{1}{8}$  inch cut or machining on the outside and inside surfaces to provide a substantially flaw free cast muff 19. While there may be some irregularities in the end surfaces of the muff these are not important as on each end they will appear in the portion that must subsequently be discarded. It should further be noted that the portion which must be discarded is but a minor percentage of the finished tube being perhaps 4 feet out of 300.

The major cost elements of plant equipment to perform this process are the furnace and the rotating mold, the turning or grinding mechanism for machining the cast muff, the rocking or rolling machine and the stretch mill. It is thus seen that when compared with any method for making high alloy steel tubes from a solid ingot, including producing the ingot in the first place, that applicant's method can produce a better tube more economically. This is particularly true in producing long tubes of 150 feet or more of high alloy steel or stainless steel and of the small diameters of less than 4 inches and of the comparatively thick walls required for boiler tubes.

Attempts have been made to form tubes directly from individual centrifugal castings but have been disappointing either from the economical or quality standpoint. The failures appear to have been due largely to the inability to make castings that would stand up under the

subsequent forging operations or to properly correlate the forging and casting steps so as to economically produce a tube. If the casting is of such a size or the forging operations of such nature that two or more wall thickness reductions in addition to the diameter reduction are necessary or the tube to be drawn is so short that a substantial portion becomes waste the method loses its economic appeal. In order to produce a casting of a quality which can be satisfactorily forged the several casting steps must be carefully controlled including the casting size in relation to the finished product.

There is a novel and unique cooperation between the several steps of this process which renders each step particularly adapted for cooperation with the others. For instance in the casting step muffs can readily be cast of a length, diameter concentricity and wall thickness particularly suited for conversion into tubes by the following forging steps and this size can readily be selected so that only two forging steps are required to complete the tube to the desired finished size. By controlling the amount of metal poured into the rotating mold a wall thickness can be obtained that is well within the capacity of the tube reducing machine to produce an accurately concentric tube of substantially the finished wall thickness in but one pass and selecting the proper size of rotating mold a diameter can be obtained that is well within the capabilities of the stretch mill to reduce to the finished tubing size still maintaining the accurate concentricity in one pass through the stretch mill and the mold length can be adjusted so as to provide a cast muff which will be long enough to provide a finished tube of a length great enough to provide small cutting losses. The net yield from metal melted to finished tube is greater, thus effecting an overall reduction in cost. Cropping of the ingot and trimming of billets is eliminated.

It is to be understood that the invention is not limited to the specific embodiments and details herein illustrated and described but may be used in other ways without departure from its spirit and that various changes can be made which would come within the scope of the invention which is limited only by the appended claims.

I claim:

1. In the manufacture of seamless tubes, the steps of centrifugally casting a muff having a preselected length, diameter and wall thickness, reducing said muff size in a single cold tube-reducing operation, mainly reducing the wall thickness of and lengthening the casting, then reducing the diameter of the elongated cold reduced tube to the desired finished diameter and wall thickness and further lengthening the tube in a single hot rolling and stretching operation to provide a finished tube from a casting in only two metal flowing steps.

2. In the manufacture of seamless tubes as claimed in claim 1, casting the muff of a metal which is hot short in the as cast state at hot forging temperatures.

3. In the manufacture of seamless tubes to a preselected finished wall thickness and a preselected finished diameter, the steps of centrifugally casting a muff having a length to diameter ratio of over twelve and a wall thickness of over twice the finished wall thickness and an inside diameter of over twice the finished tube diameter, reducing the wall thickness in a single cold rolling step, and reducing the diameter and further reducing the wall thickness in a single hot stretching step to provide a finished tube from a casting in only two metal flowing steps.

4. In the manufacture of tubes as claimed in claim 3 the step of smoothing the surface and improving the concentricity of the cast muff before the cold rolling step.

5. In the manufacture of seamless tubes the steps of centrifugally casting a muff, smoothing the inside and outside surfaces of said muff, heating said muff, to relieve stresses induced by the smoothing operation, cold reducing said muff with the metal in the as cast state to mainly reduce the wall thickness to provide a tube having a wall thickness of nearly finished size and a diameter substan-

tially greater than finish size, hot rolling and stretching said tube to mainly reduce the diameter of the cold worked tube and provide a tube of a desired finished diameter and wall thickness.

6. In the manufacture of seamless tubes as claimed in claim 5, casting the muff of a metal which is hot short in the as cast state at hot forging temperatures.

7. In the manufacture of seamless metal tubing, the steps of melting metal, pouring said molten metal at substantially 2800° F. and substantially 15 pounds per second into a refractory lined cylindrical rotating mold, molding the metal in cylindrical shape by centrifugal force while cooling to form a substantially concentric muff having a larger inside diameter and a greater wall thickness than the desired finished tube, cold working said muff over a mandrel to reduce the wall thickness and further improve the concentricity of the tube, heating said cold worked tube and while heated stretch reducing said tube to reduce the diameter and further reduce the wall thickness to finished size to provide a tube of finished diameter and wall thickness.

8. In the manufacture of seamless metal tubing as claimed in claim 7, wherein the muff is of a metal which is hot short in the as cast state at hot forging temperatures.

9. In the manufacture of tubing as claimed in claim 7 the steps of smoothing the cylindrical surfaces of said cast muff to remove surface irregularities, and improve the concentricity of the muff, and treating said smoothed muff to remove smoothing cold work stresses, before the cold working step.

10. In the production of seamless tubes in the range of  $\frac{3}{8}$  to 4 inches in diameter with wall thickness of .04 to .5 inch by producing a major reduction of the wall thickness of a tubular blank in one step and producing a major reduction of the diameter of the tubular blank in another step, the steps of forming a blank by centrifugal casting a tubular blank, cold reducing said cast blank, mainly by reducing the wall thickness, in one pass to nearly finished tube size and then hot reducing said cold reduced blank, mainly by a diameter reduction, in one pass to finished tube diameter and wall thickness.

11. The method of making seamless tubes from a tubulous casting comprising first subjecting the casting to a cold forging operation to improve the concentricity of the tube, and the grain structure and reduce the wall thickness and increase the casting length, then subjecting the cold forged tube to a hot stretching operation to reduce the tube diameter and wall thickness and further increase the tube length.

12. The method of making seamless tubes as claimed in claim 11 in which the tubulous casting is a casting of a metal which is hot short in the as cast state at hot forging temperatures.

13. The method of making a hot finished seamless tube to substantially cold finish tolerances comprising centrifugally casting a substantially flawless, substantially concentric muff of malleable material, larger in diameter and wall thickness than the finished tube, cold reducing the diameter and wall thickness of said muff and improving the concentricity, and then hot stretching said cold worked muff without materially altering the concentricity to produce an elongated hot finished tube of substantially cold finish tolerances.

14. The method of making a seamless metal tube comprising pouring a predetermined quantity of substantially uncontaminated molten metal into a rotating cylindrical mold to form a substantially concentric cylindrical muff of predetermined limited dimensions and weight and substantially flawless material, cold reducing said muff over a mandrel in a single pass through a cold swaging tube reducing machine to reduce the cross sectional area over 60%, mainly by wall thickness reduction, improve the concentricity and materially lengthen said muff, heating said cold reduced muff and further reducing the cross sectional area over 60%, mainly by diameter reduction

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and lengthening said tube in a single pass through a hot stretch reducing mill to provide a substantially concentric elongated seamless tube.

**15.** The method of making a tube as claimed in claim **14** including machining said muff to improve the concentricity, smooth the surfaces and remove any contamination, before the cold working step.

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