May 24, 1927. J. W. MOON 1,629,724

PROCESS OF MANUFACTURING METAL TUBING

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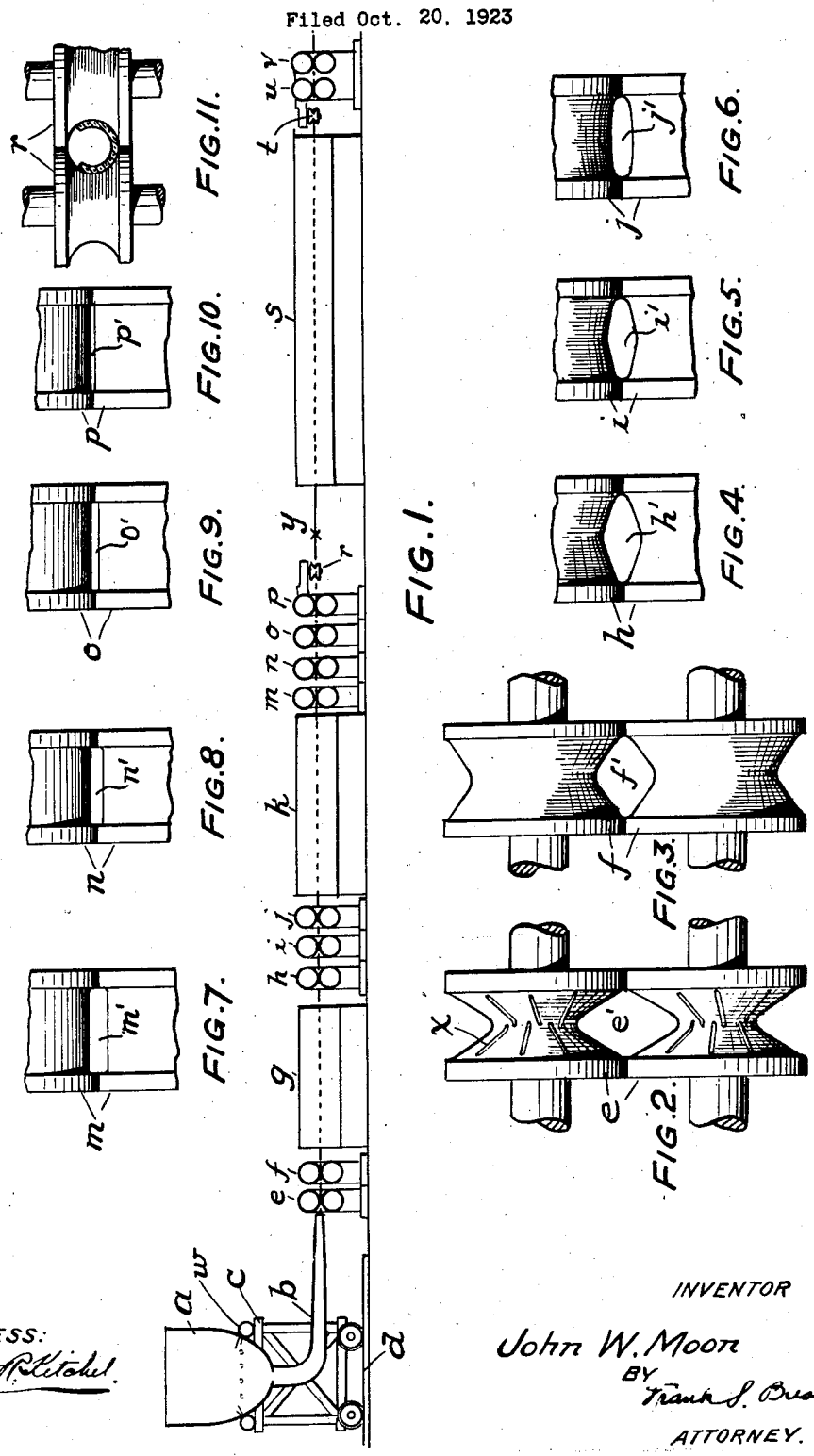

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UNITED STATES PATENT OFFICE.

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PROCESS OF MANUFACTURING METAL TUBING.

Application filed October 20, 1923. Serial No. 669,683.

In a patent issued to me December 4, 1923, No. 1,476,632, I set forth a process of making metal tubing wherein a strip of skelp of indefinite length is continuously advanced through a long enveloping heating medium to heat it throughout its entire cross-section to a high temperature and as the strip continues to advance and as it emerges from the furnace bending the skelp into tubular form and welding its edges together to form a tube. The edges may be raised to a welding heat in the furnace, or by means of an air blast after emergence from the furnace.

In a patent issued to me December 4, 1923, No. 1,476,537, I set forth an apparatus, in principle the same as that disclosed in the first mentioned patent, but somewhat improved in detail, for carrying out said process.

The patented process and apparatus are operating successfully on a commercial scale.

It is desirable, in the practice of this process, to use skelp of the greatest practicable length. One of the difficulties involved in producing skelp of great length is that the temperature of the metal continuously falls during the rolling process. While, therefore, all the rolls operate on the more advanced part of the metal of the billet under proper temperature conditions, the metal toward the rear end of the billet cools materially before it is acted upon by the rolls and particularly before it reaches the finishing rolls, so that the rear end of the skelp cannot be rolled at a proper temperature. One of the objects of the invention is to so modify the skelp rolling process that all the rolls will operate on the metal while the latter is at a suitable temperature, regardless of the length of the skelp. This object I may accomplish in either of two processes, both involving the same principle so far as temperature control is concerned, one of which, however, permits the production of the skelp from a billet or ingot, as heretofore, and the other of which involves the production of the skelp direct from fluid metal. The latter mode of maintaining proper temperature conditions is an integral part of my process for making tubing direct from fluid metal, of which I will proceed to give a general description.

In the practice of the process set forth in my said patents, it is found that the smaller the diameter of the tubing, the greater the economy in its production as contrasted with preceding methods of tube manufacture. If my patented process can be so improved as to still further reduce the cost—on the basis of linear feed of finished tubing—the field of economical use of my patented process may be extended to include the manufacture of tubing of relatively large diameter.

The manufacture of metal tubing by known processes, including my patented process as well as other processes, involves, prior to the actual tube-forming process, the casting and soaking of billets, their reheating, the rolling of the skelp, the cooling of the same, the transportation of the skelp to the tube mill, and their reheating before conversion into tubes. These processes involve a considerable waste, as well as expenditure, of heat, repeated re-handling, much labor, and transportation, all of which are items of serious expense which enter into the cost of the finished product. My object is to so simplify and modify these processes that they can be consolidated with my patented process and with it constitute one integral continuous process by which metal tubing of any diameter may be produced direct from the fluid metal and more economically than by any known process.

A description of my process will be better understood if accompanied by drawings of the complete chain of mechanism that I preferably employ to carry out my process.

Fig. 1 is a side elevation of the complete tube-forming plant.

Figs. 2 and 3 are face views of the first and second pairs of rolls respectively.

Figs. 4 to 10 inclusive represent the shapes of subsequent roll passes.

Fig. 11 is a face view of the rolls for bending the skelp into partly tubular form.

My process is not, however, dependent on any specific mechanical instrumentalities. Nor is there anything novel in the particular construction of the plant elements shown. Indeed, Fig. 1 is essentially diagrammatic; the structural details of each of the elements shown being known, or capable of being readily worked out by those skilled in the art.

a is a ladle for receiving molten metal from the furnace; *b* a mold for receiving

molten metal from the ladle; *c* a car body, on a track *d*, by which the ladle and mold may be supported, and transferred from the furnace to the rolls; *e* and *f* are preliminary reducing rolls; *g* a heat equalizing furnace; *h*, *i* and *j* a set of intermediate shaping rolls; *k* a reheating furnace; *m*, *n*, *o* and *p* a set of rolls adapted to roll the skelp to finished form; *r*, a pair of skelp-bending rolls; *s* a skelp-reheating furnace; *t* pipe forming and welding rolls; *u* and *v* pipe sizing rolls.

Molten metal is tapped from the furnace into ladle *a*, which is then, together with the mold *b*, transferred to bring the latter into proper juxtaposition to the first pair of reducing rolls *e*. It is necessary to maintain the metal in the ladle molten and to this end I have provided tuyères *w*, thru which air is blown into the metal. While this operation tends to decarburize the metal, it will be understood that the carbon content of skelp may vary within reasonable limits and is desirably quite low. The metal, as it is tapped from the furnace, may be, therefore, of such relatively high carbon content that some decarburization in the ladle may not be objectionable; but if it is desired to maintain the carbon content of the skelp uniform, this can be effected by introducing into the ladle, from time to time, enough carbon to supply the deficiency created by oxidation. Any other means of maintaining molten the metal in the ladle may be adopted.

The mold *b* should be of such diameter and length that the metal, or at least the skin thereof to a considerable depth, will solidify before it reaches the exit end of the mold. Preferably, the mold should curve downward and forward from its mouth and should taper in diameter from entrance to exit. The pressure of metal entering the mold tends to force the metal out of the exit end of the mold; but it is desirable, if not necessary, that the reducing rolls *e* and *f* should have a powerful drawing action on the metal. To this end the metal-engaging faces of one or both pairs of rolls *e* and *f* should be provided with lateral grooves *x* into which the metal will be forced and by means of which the rolls will secure a positive grip on the metal. The preferred shape of the reducing roll passes is shown in Figs. 2 and 3 by the reference letters *e'* and *f'*. The reduced strip, as it emerges from the grooved rolls, will have formed on its outer surface lateral ribs complementary to the grooves *x* of the roll faces. In passing from rolls *e* to rolls *f*, the strip of metal should be given a quarter turn, the greater the diameter of the strip being vertical as it passes through rolls *e* and horizontal as it passes through rolls *f*.

It will be understood that the particular construction and arrangement of reducing rolls described is not required and forms no essential part of the present invention, being merely illustrative of a desirable embodiment of the invention.

The molded metal, as it leaves the mold, is by no means of a uniform temperature throughout. The difference in temperature between the surface and the core may amount to several hundred degrees. The central core may approximate the melting point of the steel. Of course, the difference in temperature between the surface and core of the metal, as it emerges from the mold, as well as the absolute temperatures of surface and core, will depend upon the length and shape of the mold. While a high internal temperature, as well as a substantial difference in temperature between the surface and core of the metal, would preclude successful rolling to its ultimate cross-section, no serious objection exists to this condition as long as the cross-section of the metal is relatively thick. In order to equalize the temperature throughout, I provide, following the preliminary reducing rolls *e* and *f*, a furnace *g* in the nature of a soaking furnace. The temperature of this furnace may be maintained at the average temperature of the strip passing through it. Hence, while the strip travels through furnace *g*, the part of the strip relatively near the surface absorbs heat both from the furnace itself and from the interior of the strip, so that when the strip emerges from the furnace, it is of approximately the same average temperature as when it entered but with such temperature evenly distributed throughout its mass. It must be understood that the speed of travel of the strip, as it emerges from the mold *b* and passes through the rolls *e* and *f* and the furnace *g*, is, by reason of its relatively great cross-section, very slow, so that the furnace *g* need not be of great length.

A uniform temperature condition in the strip may be effected not only by a furnace temperature approximating the average temperature of the strip as it enters the furnace *g*, but also by a higher temperature or even a lower temperature. In the first case, the interior of the strip will tend to retain its heat or part with it slowly, while the exterior part of the strip will be brought up rapidly more or less closely to the temperature of the interior. In the second case, the absorption of heat from the interior will be rapid and substantial, while the exterior will be elevated in temperature slowly and to a more or less limited degree. It will be understood, therefore, that the temperature of the furnace *g* may vary within considerable limits and still be effective to equalize the temperature, inside and outside, of the moving strip.

Nor is it necessary that the furnace *g* should be located precisely as described. It may be located between rolls *e* and *f*, or

even between the mold and the first pair of rods *e*, although this is not desirable; or it may be found practicable to locate at a more advanced position in the chain of rolls; or in certain cases it may be found possible to eliminate it, and rely upon the re-heating furnace *k* to act also as a heat equalizing furnace.

As the still relatively thick and slowly moving strip leaves the heat equalizing furnace *g*, it enters the first pair *h* of shaping rolls and passes through these rolls and shaping rolls *i* and *j* successively, *h'*, *i'* and *j'* are suggestive shapes for the shaping roll passes.

As the strip emerges from the pair of rolls *j*, its shape, in cross-section, begins to approximate the shape of the finished skelp, although it is still considerably thicker than at the conclusion of the rolling operation. By this time, the metal has parted with considerable heat, and in order to facilitate subsequent rolling, the strip is caused to travel through a reheating furnace *k*, which should be at such temperature that the temperature of the strip, as it emerges therefrom, will be substantially elevated. The furnace *k* will ordinarily be considerably longer than the furnace *g*, because the strip, by reason of its reduced cross-section, will be traveling through furnace *k* more rapidly than through furnace *g*. It will be understood, however, that the length of the furnace will depend upon the temperature of the furnace as well as the degree to which it is desired to heat the strip. A short highly heated furnace will as effectively raise the temperature as a long and cooler furnace. A furnace of the latter type is, however, much preferable, because it will effect a more even heating of the strip outside and inside.

The finishing rolls *m*, *n*, *o* and *p* reduce the strip to the final cross-section which it is desired that the skelp should have. *m'*, *n'*, *o'* and *p'* represent the passes of these rolls. In other words, that part of the strip which at any given time is emerging from the final finishing roll is finished skelp.

The reheating of the strip between the reducing and shaping rolls and the finishing rolls is of importance, and is a step in the process that is applicable to skelp rolled from an ordinary ingot as well as skelp rolled direct from the molten metal. In the former case, it solves the problem of producing a skelp that is unlimited in length except by the practicable limit of size of the ingot from which it is rolled. If the skelp is rolled from an ordinary ingot, the temperature of the furnace *k* may be gradually raised as the rolling operation proceeds, because as the continuous elongation of the ingot proceeds the temperature of the metal which, at any given time, is passing through and beyond the preliminary rolls, gradually drops. By gradually increasing the temperature of furnace *k*, all points along the length of the continuous strip, as such points feed to the finishing rolls, may be at approximately the same temperature.

In rolling skelp from the fluid metal, if the metal as it feeds into the mold, is maintained at a constant temperature, the reduced temperature of the metal which, at any given time, is passing through and beyond the preliminary rolls, will be substantially constant, and therefore the furnace *k* may be maintained at a substantially constant higher temperature. In rolling skelp from the fluid metal, the reheating furnace *k* need not be positioned at the precise point shown and described. It may be nearer the beginning of the chain of rolls, or perhaps nearer the end of the chain.

It will be understood that no precise number of pairs of rolls is required for the successful execution of the process. It will also be understood that the terms "reducing rolls", "shaping rolls" and "finishing rolls" are arbitrary, there being no real difference in function of the various pairs of sets of rolls; each pair of rolls operating to reduce the cross-section of the strip and to shape it in a form more or less approximating its final shape dependent upon its distance from the end of the chain, while the "finishing" operation is a matter of degree and might be strictly applied to only the last pair of rolls *p* and then only so far as it finishes the skelp as such.

It is preferred to pass the skelp, after it leaves the rolls *p*, through a pair of rolls *r*, which bends it into a U-form, or a form approximating a tube with spaced edges. When the skelp is bent into this shape, it acquires a stiffness and rigidity that it is desirable to have in passing through the furnace *s*.

From this point on, the process is the same as that described in my prior patents. That is, the furnace *s*, which is relatively long and narrow, is maintained at a temperature high enough to heat every part of the length of the skelp, as it travels therethrough, to a heat more or less approximating that required for welding. It is perhaps preferable that the skelp should be heated to such degree that it will leave the furnace *s* at about the cinder stage and then raise the temperature of the edges, just before it reaches the bending and welding rolls *t*, by directing blasts of air against the skelp or the edges thereof, which also cleans the edges to be welded. But the air blast may be omitted, and the skelp, or the edges thereof, heated to a welding heat just before leaving the furnace.

The bending and welding rolls *t*, and also the bending rolls *r* at the rear of the furnace, are mounted to turn on vertical axes,

while the sizing and drawing rolls u and v are positively driven and are mounted to turn on horizontal axes. The rolls r may be omitted, and the flat skelp passed through the final heater, as rolls t are capable of functioning as a tube-forming roll; or practically the entire tube-forming operation, except the welding of the edges, may be effected by the rolls r. In enumerating, in the claims, the final heating and tube-forming steps, I do not mean to be limited to any particular sequence of these two operations, unless the bending operation is distinctly specified as being performed in part before heating and in part after heating.

An open space is provided between the skelp bending rolls r and the mouth of the furnace. In starting the mill, a section of finished tubing should be inserted in the furnace s and passed through the rolls t, u and v, which should be stationary. The rear end of this tube section should project back of the furnace nearly as far as the rolls r. This section of finished tubing should be so positioned before the advanced end of skelp emerges from the bending rolls r. As soon as the advanced end of the skelp reaches the rear end of the tube section, the approximating ends of skelp and tube should be secured together by spot welding, as at y. During this operation, all the rolls should be temporarily stopped; or if the skelp forming rolls are maintained in operation, rotation of the drawing rolls u and v should be started and the welding effected during the passage of the abutting ends of skelp and pipe over the open space between the rolls r and the rear of furnace s. Once this welding operation is completed, the operation of the mill is practically entirely automatic.

Having now fully described my invention, what I claim and desire to protect by Letters Patent is:

1. The process of manufacturing metal tubing which comprises flowing fluid metal in a traveling stream and during its travel molding it to shape and as it increases in length causing it to solidify at a point in advance of the rear of the traveling stream, rolling the ingot strip, as it continues to travel, to reduce and shape the same into the form of skelp, and as the skelp continues to travel subjecting it to heat, bending it into tubular form, raising the temperature of at least its edges to a welding heat and uniting the edges to form a closed tube.

2. The process of manufacturing metal tubing which comprises flowing fluid metal in a traveling stream and during its travel molding it to shape and as it increases in length causing it to solidify at a point in advance of the rear of the traveling stream, subjecting the strip, as it continues to advance, to rolling operations to reduce and shape the strip to the form of skelp, and to a heat equalizing operation tending to distribute the heat uniformly through the strip, and as the skelp continues to advance subjecting it to heat, bending it into tubular form, raising the temperature of at least its edges to a welding heat and uniting the edges to form a closed tube.

3. The process of manufacturing metal tubing which comprises flowing fluid metal in a traveling stream and during its travel molding it to shape and as it increases in length causing it to solidify at a point in advance of the rear of the traveling stream, subjecting the strip, as it continues to advance, to a number of rolling operations to reduce and shape the strip to the form of skelp, heating the strip, after it is partially rolled to shape, to elevate its temperature preparatory to the subsequent rolling operations, and as the skelp continues to advance again reheating it and raising the temperature of at least its edges to a welding heat and bending it into tubular form and uniting the edges to form a closed tube.

4. The process of manufacturing metal tubing which comprises flowing fluid metal in a traveling stream and during its travel molding it to shape and as it increases in length causing it to solidify at a point in advance of the rear of the traveling stream, subjecting the strip, as it continues to advance, to a number of rolling operations to reduce and shape the strip to the form of skelp, subjecting the strip, after it is partially rolled to shape, to a heat equalizing operation tending to distribute the heat uniformly through the strip, and as the skelp, after it is rolled, continues to advance, again reheating it and raising the temperature of at least its edges to a welding heat and bending it into tubular form and uniting the edges together to form a closed tube.

5. The process of manufacturing metal tubing which comprises flowing fluid metal in a traveling stream and during its travel molding it to shape and as it increases in length causing it to solidify at a point in advance of the rear of the traveling stream, subjecting the strip, as it continues to advance, to rolling operations to reduce and shape the strip to the form of skelp, to a heat equalizing operation tending to distribute the heat uniformly through the strip and to heating adapted to substantially raise the temperature of the strip, the second heating following the first heating and being applied after the skelp is partially rolled to shape but before the rolling is finished, and as the skelp continues to advance again reheating it and raising the temperature of its edges to a welding heat and bending it into tubular form and uniting the edges together to form a closed tube.

6. The process of manufacturing metal

tubing which comprises flowing fluid metal in a traveling stream and during its travel molding it to shape and as it increases in length causing it to solidify at a point in advance of the rear of the traveling stream, rolling the ingot strip, as it continues to travel, to reduce its cross-section, then subjecting the thus partially rolled ingot strip, as it continues to travel, to a heat equalizing operation tending to distribute the heat of the metal uniformly through the strip, rolling the thus heated skelp, as it continues to travel to still further reduce its cross-section and shape it, then subjecting the strip, as it continues to travel, to heating adapted to substantially raise the temperature of the strip, then rolling the strip, as it continues to travel, to form the finished skelp, and as the strip continues to advance again reheating it and raising the temperature of at least its edges to a welding heat and bending it into tubular form and uniting the edges to form a closed tube.

7. The process of manufacturing metal tubing which comprises flowing fluid metal in a traveling stream and during its travel molding it to shape and as it increases in length causing it to solidify at a point in advance of the rear of the traveling stream, rolling the ingot strip, as it continues to travel, to reduce and shape the same into the form of flat skelp, bending the skelp, as it continues to advance, into a partly tubular form with spaced apart edges, and as the skelp continues to advance, heating it so as to raise the temperature of at least its edges to a welding heat, completing the bending of the tube and uniting the approximating edges to form a closed tube.

8. The method of manufacturing by a continuous process metal tubing from a strip of relatively great cross-section whose surface and core are heated to substantially different temperatures, which comprises subjecting the strip to a plurality of series of rolling operations adapted to greatly elongate it and reduce its cross-section and shape it to the form of skelp of a thickness substantially corresponding to that of the finished tubing; then subjecting the skelp to a final operation adapted to bend it into a tubular form, heat it throughout and raise the temperature of at least its edges to a welding heat and unite the edges to form a closed tube; and in the course of its travel subjecting it to a plurality of temperature regulating operations alternating with the specified section-reducing operations, one of said temperature regulating operations comprising subjecting the strip to a temperature between the temperatures of the core and surface, thereby promoting an exchange of heat between core and surface tending to equalize the temperature throughout the strip, and another of said temperature regulating operations comprising subjecting the strip to heat adapted to restore heat lost in transit to prepare it for subsequent section-reducing operations.

In testimony of which invention, I have hereunto set my hand, at Philadelphia, on this 13th day of October, 1923.

JOHN W. MOON.