Aug. 17, 1965 AB FLOWERS 3,201,287

HEAT TREATING METHOD

Original Filed July 7, 1959 4 Sheets-Sheet 1

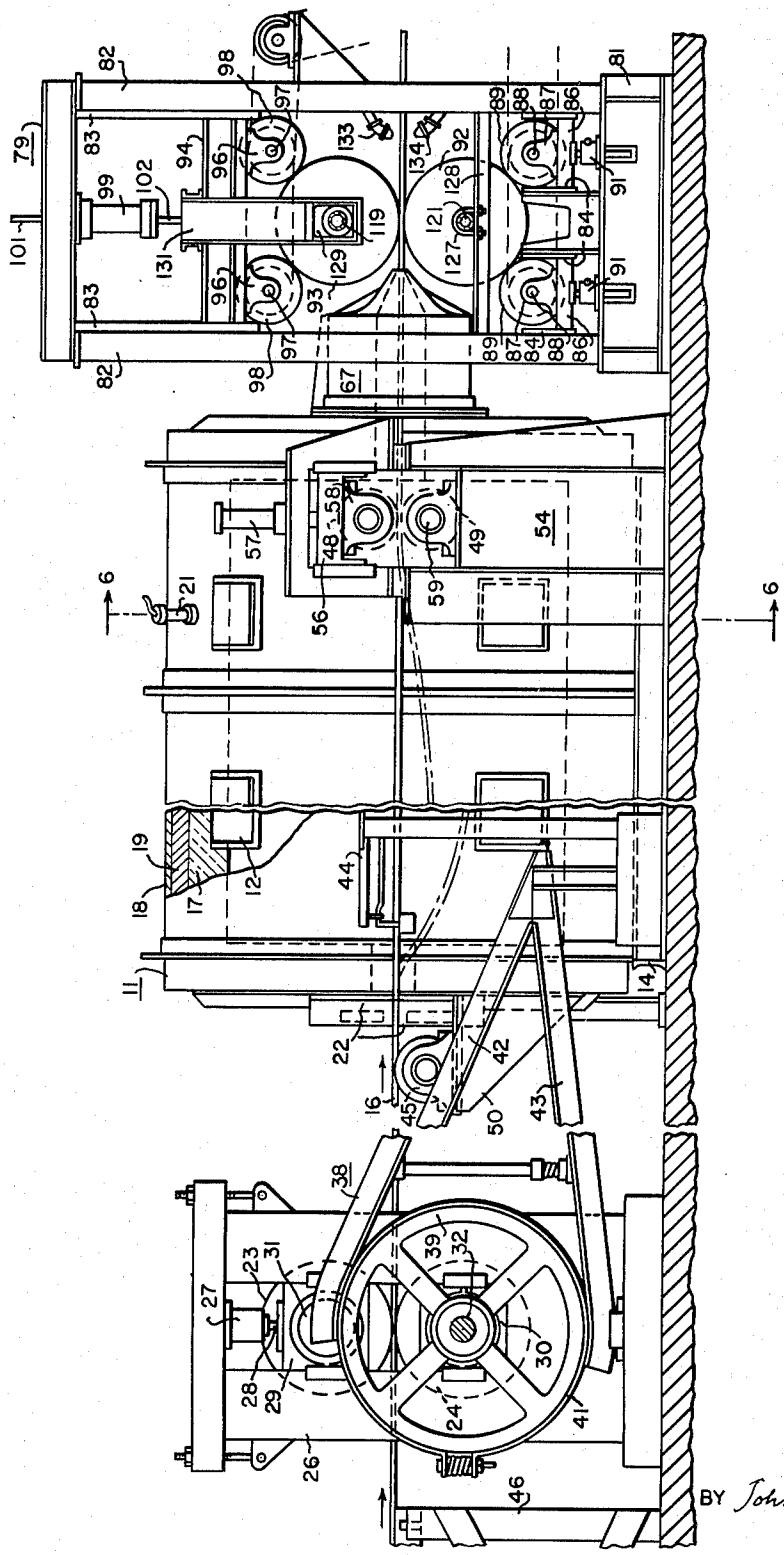


Fig. 1

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HEAT TREATING METHOD

Original Filed July 7, 1959 4 Sheets-Sheet 2

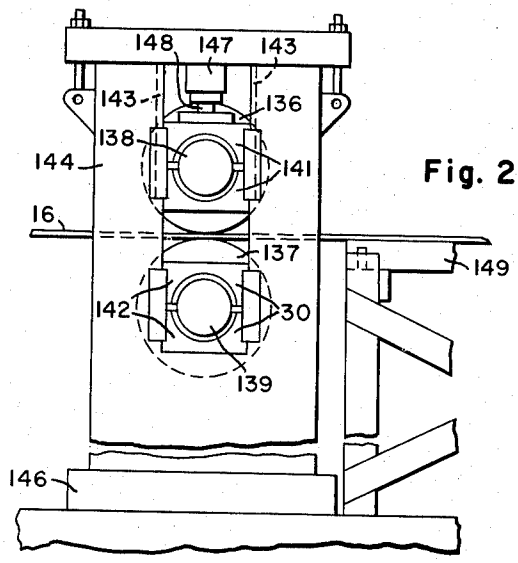


Fig. 2

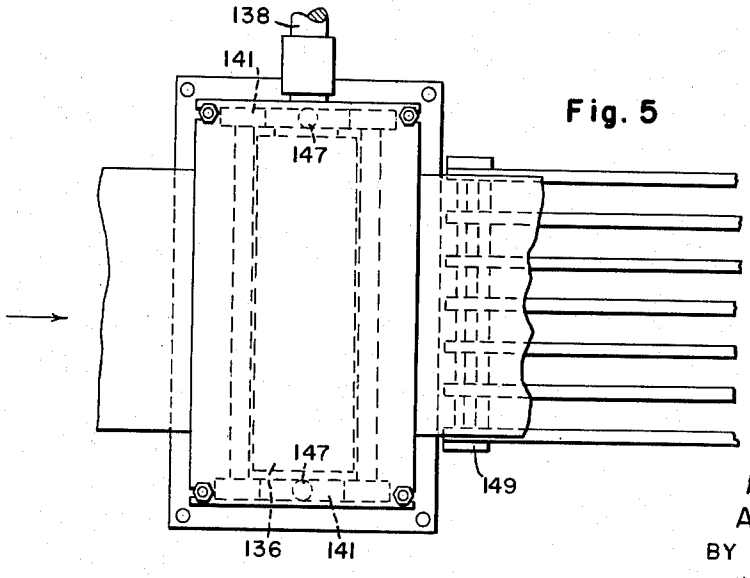


Fig. 5

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HEAT TREATING METHOD

Original Filed July 7, 1959 4 Sheets-Sheet 3

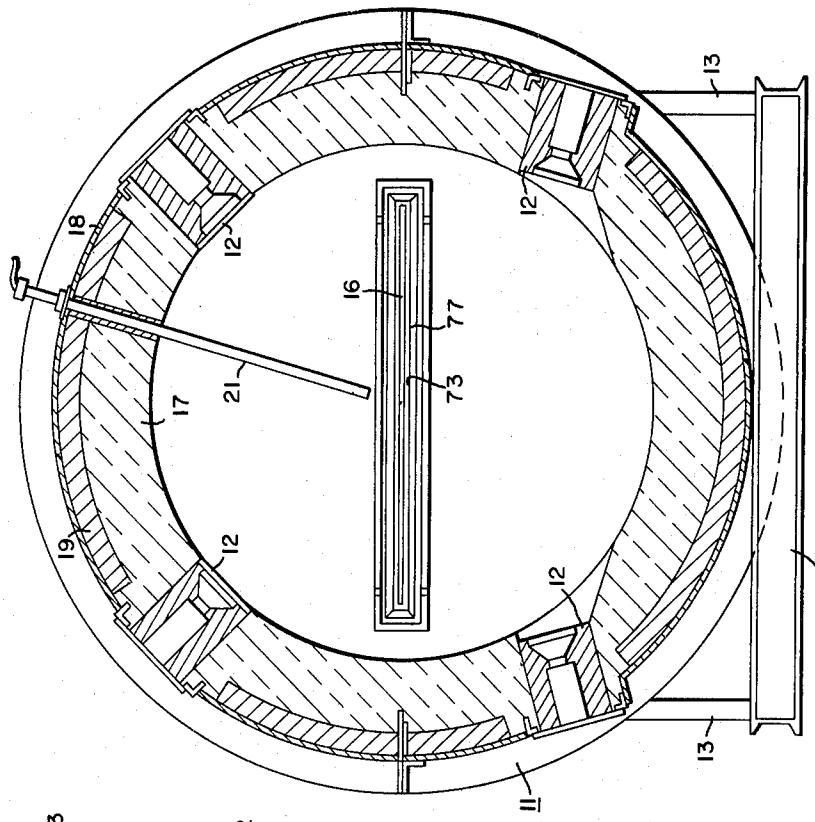


Fig. 6

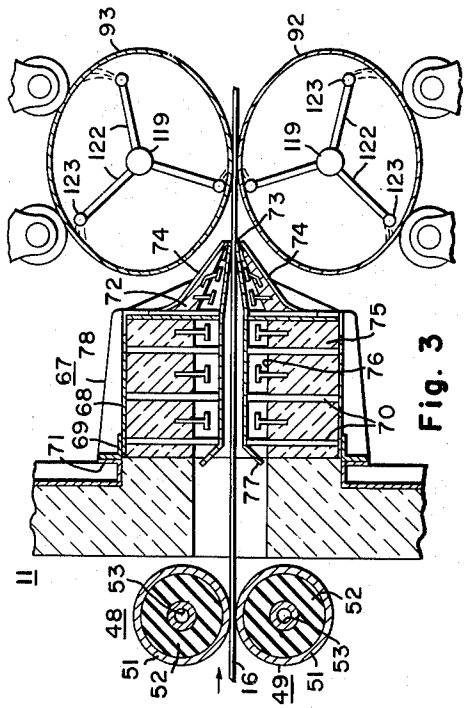


Fig. 3

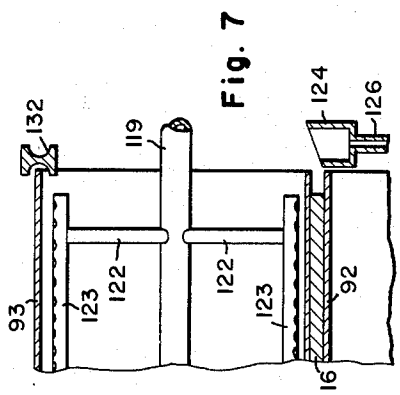


Fig. 7

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Aug. 17, 1965 AB FLOWERS 3,201,287

HEAT TREATING METHOD

Original Filed July 7, 1959 4 Sheets-Sheet 4

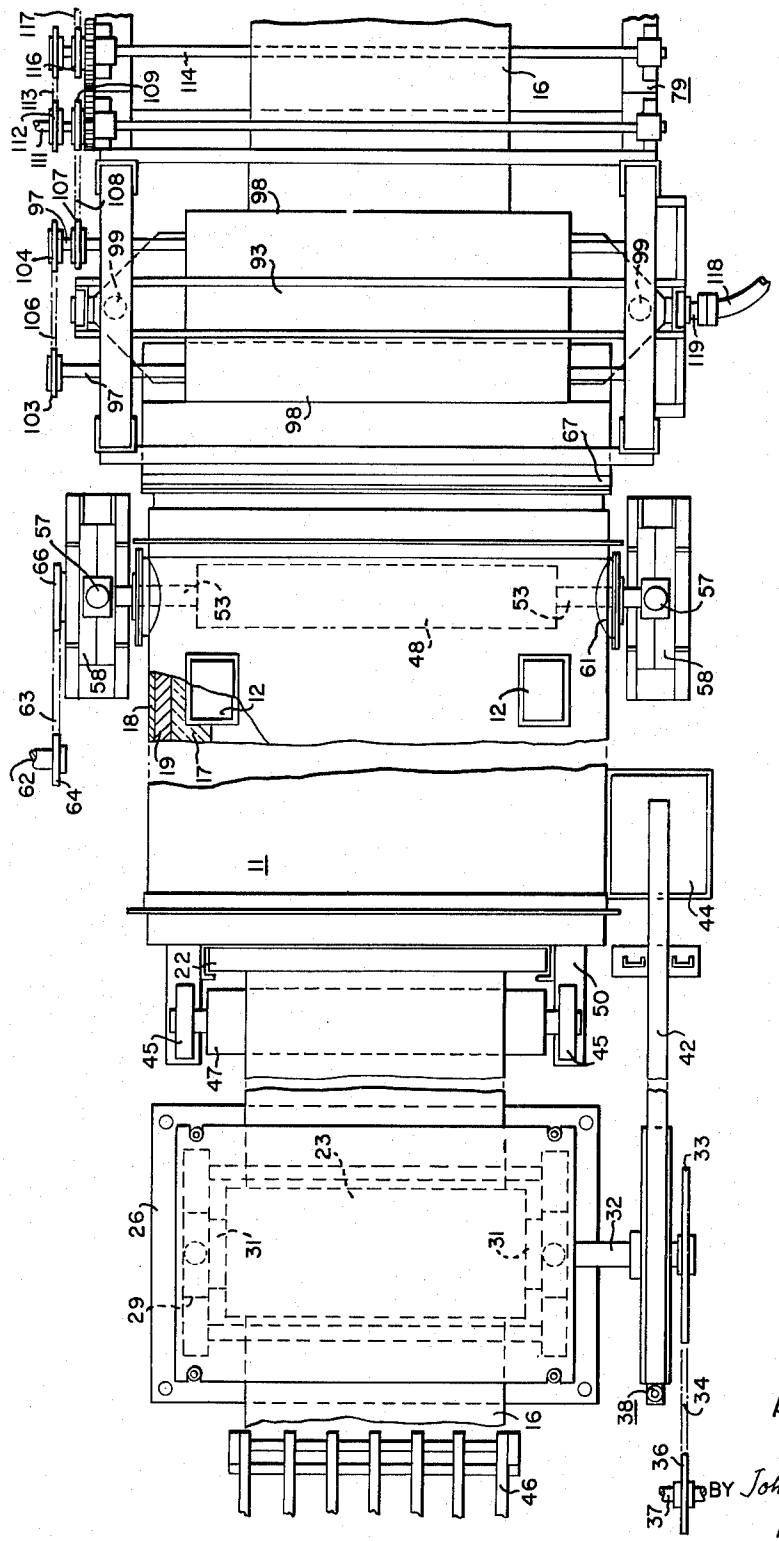


Fig.4

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United States Patent Office 3,201,287
Patented Aug. 17, 1965

3,201,287

HEAT TREATING METHOD

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Original application July 7, 1959, Ser. No. 825,470, now Patent No. 3,109,044, dated Oct. 29, 1963. Divided and this application June 10, 1960, Ser. No. 35,867
5 Claims. (Cl. 148—11.5)

This application is a divisional application of my copending application, Serial No. 825,470, filed July 7, 1959, now Patent No. 3,109,044, granted October 29, 1963.

This invention relates to a process for heat treating high strength materials such as titanium or zirconium and, more particularly, to a heat treat process in which the workpiece or sheet is held under tension during a quenching operation to prevent warping.

In the continuous heat treating of steel sheets, for example, quenching is often done by merely passing the sheet under a water spray by means of a roller conveyor. The temperature gradient set up in a quenching operation of this type results in relatively high thermal and transformation stresses which cause the sheet to become warped or twisted so that it becomes necessary to again flatten the product by stretching or tempering. Although these straightening procedures are satisfactory for steel sheets, they are entirely inapplicable to sheets of high strength materials such as titanium and zirconium, which must be processed to thicknesses of 0.010 to 0.187 inch at a desired flatness of 1% or less. The strength of these materials must be improved by aging rather than by tempering and, since the yield strength of a titanium alloy may be in the range of 100,000 to 250,000 p.s.i., no practical stretching apparatus is available for straightening warped sheets of this material.

Previously to this invention, several attempts were made to flatten sheets of high strength material to a flatness of 1%. One of these methods involved solution quenching sheets in a press; however, it was found that excessive warpage occurred with this procedure and a flatness of 1% could not be attained. Another method involved solution quenching under tension from a vertical drop bottom furnace. It was found that with this method flatness ranged from 0.8% to 8.0% so that it is entirely inapplicable to the production of sheets having a uniform flatness of 1% or less. Still another method of quenching was to encase the high strength sheet in a welded steel envelope which was passed through the quenching medium, the idea being that the steel envelope would maintain the flatness of the high strength sheet. Although the quenched properties on sheets processed in this manner have been satisfactory, 1% flatness has not been consistently achieved.

It is also known to cool heated metal sheet material by passing the same over a series of spaced offset rolls. However, this method possesses the distinct disadvantage of extracting heat preferentially from one surface of the sheet. The consequent difference in the rate of cooling of the two sides of the sheet accentuates warpage and sheets produced by this method commonly cannot be held within the narrow warpage limits allowable for most present day uses of sheets of such high strength materials.

In the use of a series of multiple rolls to cool sheet material, it has been a common practice to lower the temperature of the heated sheet in successive stages by passing the sheet over successive rolls maintained at successively lower temperatures. Such a procedure is unsatisfactory in the processing of many high strength materials such as titanium and titanium alloys. In the case of titanium, for example, it is highly desirable, indeed

necessary, to remove the heat by a substantially instantaneous quenching procedure. Thus, titanium exists in several crystalline forms, at elevated heat treating temperatures the common form being beta titanium, whereas at room temperature the common form is alpha titanium. In order to obtain the best high strength qualities in the finished product, it is desirable to obtain, insofar as possible, the beta structure. This is possible with a very rapid quench, but upon slow cooling, a larger proportion of the alpha crystalline form is obtained thereby decreasing the ability of the metal to strengthen upon subsequent elevated temperature aging. Moreover, a slow cooling of titanium from elevated temperatures results in a coarse crystalline structure with little ability to harden, whereas a rapid cooling or quenching of the metal gives a finer structure with good ability to harden.

In view of the deficiencies of the prior art, it is a primary object of this invention to provide a method for continuously quenching sheets of high strength material under tension while maintaining a flatness of 1% or less.

More specifically, an object of the invention resides in the provision of a method for cooling sheets of high strength material by passing the same through a pair of cooled rolls whereby the heat in the sheet material is transferred to the rolls by conduction.

A still further object of the invention is to provide a heat treating procedure for producing a uniform, continuous and substantially instantaneous quench.

In accordance with the invention, hereinafter described in detail, there is provided a method of temperature treating elongated sheets of high strength metal, such as titanium, while preventing warping of the metal, which comprises heating the metal sheet to an elevated temperature, maintaining the sheet at the elevated temperature until just prior to quenching of the sheet to a lower temperature, quenching the sheet by extracting heat energy uniformly and simultaneously from both sides thereof, compressing the sheet during the quenching step and applying to the sheet, during both the heating and quenching steps, a longitudinally directed tensile force of a magnitude sufficient to prevent warping of the sheet. In the performance of the method of the invention, sheets of titanium or other high strength material are first passed through a pair of entry rolls. Thereafter, the sheet is heated to a temperature in the range of 1200° F. to 1700° F. in a heat treating furnace. The sheet is then passed through a pair of furnace flattening rolls and a roll pass defined between a pair of hollow quench rolls having their axes mutually parallel and substantially vertically aligned with respect to each other. Each of these hollow quench rolls is provided with a pair of back-up drive rolls and with connections for introducing a cooling fluid to the interior of the quench roll. The cooling fluid maintains the temperature of the hollow quench rolls at or about room temperature such that, when the metal sheet or strip passes through the roll pass defined therebetween, the heat rapidly flows from both surfaces of the strip to the quench rolls and thence to the cooling fluid by conduction. Thereafter, the sheet may pass through a quench spray and a pair of exit tension rolls to complete the operation. Tension may be maintained on the strip during the quenching operation by the entry and exit rolls, the flattening rolls and the hollow cooling or quench rolls to maintain the sheet flat during the quenching operation and prevent any buckling or warping. Skid tables may be provided for accommodating the sheet prior to and after its travel through the heat treating apparatus.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying

drawings which form a part of this specification and in which:

FIG. 1 is a side elevational view, partly in cross-section, of a portion of a heating and quenching apparatus suitable for carrying out the process of the present invention;

FIG. 2 is a side elevational view of a portion of the exit tension rolls and exit skid table;

FIG. 3 is an enlarged cross-sectional side elevation of the exit end of the heating furnace and a portion of the quenching apparatus;

FIG. 4 is a top plan view of the apparatus illustrated in FIG. 1;

FIG. 5 is a top plan view of the apparatus illustrated in FIG. 2;

FIG. 6 is a cross-sectional view of the heating furnace taken along line 6—6 of FIG. 1, and

FIG. 7 is a cross-sectional elevation of a portion of the quench rolls and associated cooling means.

Referring now to the drawings wherein the same reference numerals are used to identify similar parts, and more particularly to FIG. 1, there is provided a furnace designated generally by the numeral **11** which may be of any suitable type, such as of the electrical resistance or induction type, or of the metal bath heating type but is preferably of the radiant gas-fired type, the latter being preferred because of its rapid and uniform heating qualities. In the apparatus shown herein the furnace is of the gas-fired type and is provided with a plurality of primary heating elements in the form of burners **12**.

As shown in FIG. 6, the furnace is preferably of a circular cross-section and may be supported on legs **13** which are secured to a base **14** which, as illustrated in FIG. 6, may suitably be formed of steel I-beams. Burners **12** are spaced at approximately 90° angles from each other and are fixed within the furnace walls at predetermined angles with respect to a strip or sheet workpiece **16** to give maximum and uniform heating of the strip as it passes through the furnace. The furnace may have interior walls **17** of any suitable insulating material such as firebrick or the like and may have an exterior housing or wall **18** formed of sheet steel. Intermediate walls **19** of any suitable insulating material, such as plasticizable, hardening insulator, may also be provided.

The furnace may conveniently be constructed to any desired length to accommodate the strip therein for the required heating time. The heating time may, alternatively, in some instances, be varied as a function of the rate of travel of the strip through the furnace. The temperature of the strip may be determined continuously by means of a thermocouple **21** inserted through the furnace walls and spaced a short distance from the strip **16**.

The furnace **11** is provided with adjustable entry doors **22** which are normally adjusted to provide a slot-like entrance into the furnace just large enough to allow entry of the strip. This arrangement conserves heat in the furnace and also reduces the entrance of air into the furnace. If desired or necessary in the processing of any particular high strength material, subject to substantial oxidation at the working furnace temperatures, suitable sealing means may be provided at the entry door and also at the exit end of the furnace to substantially eliminate the entry of air into the furnace. In such instances, it may also be desirable to provide an inert gaseous atmosphere such as argon, nitrogen or the like within the furnace. Such inert gases are normally maintained at a pressure slightly higher than atmospheric in order to further insure the exclusion of air from the furnace.

Positioned adjacent the furnace and in longitudinal alignment therewith are a pair of entry rolls **23** and **24** (FIGS. 1 and 4). These may be mounted in a frame **26** and the upper roll **23** may be vertically movable with respect to the lower roll **24** by means of a pair of pneumatic cylinders **27** provided with piston rods **28** having the extremities thereof secured by suitable means to upper bearing blocks **29** in which the ends of shaft **31** of

the roll **23** is journaled. The lower entry roll **24** having a shaft **32**, journaled in lower bearing blocks **30**, is driven through the shaft **32**, by means of a suitable prime mover (not shown), through a first sprocket wheel **33** (FIG. 4) attached to the shaft **32**, sprocket chain **34** passing over the sprocket wheel **33** and a second sprocket wheel **36** mounted on a drive shaft **37** driven by the prime mover.

For the purpose of applying tension to the strip as it passes between the entry rolls **23** and **24**, there is provided a Prony brake designated generally by the numeral **38** and comprising a brake wheel **39** of any suitable material such as wood, having a metallic brake band **41** passing about the periphery thereof, and brake arms **42** and **43** secured to and bearing against a scale **44**. By this means, any desired degree of tension, within the capabilities of the apparatus, may be applied to the strip.

As illustrated in FIGS. 1 and 4, an entry skid table **46** is provided adjacent the entry rolls for supporting the strip prior to its entry between the entry rolls. A guide roller **47** having a shaft thereof journaled in bearings **45** and mounted upon a bracket **50** secured to the furnace **11**, is provided near the entry doors of the furnace in order to more accurately align the advancing strip **16** with the door slot and to support the underside of the strip prior to its entry into the furnace.

Located within the furnace and adjacent the exit end thereof are a pair of furnace flattening rolls designated generally by the numerals **48** and **49**. These rolls, having exterior metallic sheaths **51** and insulating bodies **52** are provided with hollow shafts **53** through which water or other cooling fluid may be circulated during the operation of the furnace. The lower flattening roll **49** may be mounted, as illustrated, on a stand **54** and the upper roll **48** may be mounted on a yoke **56** supported upon the stand **54** and adapted for vertical adjustment with respect to the lower roll **49** whereby pressure may be exerted upon the strip **16** passing therebetween. Movement of the upper roll **48** and associated yoke **56** may be effected, for example, by means of a pair of pneumatic cylinders **57**. As shown in FIG. 4, the ends of the shafts **53** of the rolls **48** and **49** may be journaled, respectively in bearings **58** and **59** externally of the furnace. The shafts **53** pass through metallic housings **61** secured to and projecting from either side of the furnace **11**. Each of the furnace flattening rolls **48** and **49** is driven by a prime mover (not shown) through a drive shaft **62** (FIG. 4) and a sprocket chain **63** extending around a first sprocket wheel **64** on the drive shaft **62** and a second sprocket wheel **66** on each of the respective shafts **53** of the flattening rolls. It is desirable to provide means to move the upper flattening roll **48** a slight distance horizontally with respect to the lower flattening roll **49** and parallel to the longitudinal axis of the furnace, i.e., the direction of travel of the workpiece. In this manner, if excessive warping of the strip occurs during heating, the slight offsetting of the axial center lines of the flattening rolls lends to the compressive force exerted by the rolls upon the strip a horizontal component and causes the strip to travel through an offset path thereby acting to remove the warping and further flatten the strip as it passes between the flattening rolls.

The exit end of the furnace is provided with an extension designated generally by the numeral **67** and comprising a metal housing **68** secured as by a first flange **69** (FIG. 7) to a second flange **71** of the furnace housing (FIGS. 1 and 3). The extension is provided with an elongated nozzle-like extremity **72** defining a slot-like aperture **73** for exit of the strip. Preferably, the upper and lower external surfaces of the extension are of an arcuate or beveled shape as shown at **74** in order that the extension may extend radially inwardly of and between a pair of quench rolls to be hereinafter described. Internally, the furnace extension **67** is provided with walls **75** of a suitable insulating material defining an elongated cavity or bore **76** of generally rectangular cross section. Centrally mounted as by means of supports **70** within the

cavity 76 is a hollow sleeve 77 for passage therethrough of the strip. Embedded within the insulation of the extension above and below the sleeve 77 are a plurality of secondary heating elements 78, for example, of the electrical resistance type, for maintaining, primarily by radiant heat transfer, but also by convective and, to a lesser extent, by gas conductive heat transfer, the elevated temperature of the strip up to the point of exit from the furnace.

The quenching apparatus, as illustrated in FIGS. 1, 3, 4, and 7, comprises a frame denoted generally by the numeral 79 mounted upon a base 81. If desired the base 81 may be slidably mounted upon a sub-base (not shown) for adjustment of the frame 79 and associated mechanisms longitudinally with respect to the exit end of the furnace. The frame 79 comprises opposed pairs of upright members 82 (FIG. 1), to each pair of which is secured an upper pair of slideways 83 and two lower pairs of slideways 84. Slidably mounted in the latter are a pair of support members 86 upon which are mounted a pair of lower bearing blocks 87. The support members 86 are provided with keys (not shown) for engaging grooves (not shown) in the slideways. The lower bearing blocks have journaled therein the extremities of shafts 88 of a pair of lower backup drive rolls 89 adjustable vertically, in the lower slideways 84, by suitable means, such as by a pair of worm gear jacks 91 secured, at the upper extremities thereof, to the bearing block support members 86. Freely and rotatably supported upon the lower backup rolls 89 is a hollow, cylindrical quench roll 92 of relatively large diameter, e.g., 24 inches, and constructed of thin-walled, high-strength sheet material, such as a titanium alloy, so as to be resiliently deformable to a generally elliptical shape under an applied compressive force. For example, titanium alloy sheet having a thickness of 0.040 inch has been found suitable for this purpose.

Freely and rotatably supported upon the lower quench roll 92, similar thereto in construction, and defining therewith a roll pass for passage therebetween of the strip 16, is an upper quench roll 93. Slidably mounted in the upper slideways 83 are the extremities of a pair of cross members 94 to each of which is secured a pair of upper bearing blocks 96 having journaled therein the extremities of shafts 97 of a pair of upper backup or drive rolls 98. The latter are vertically extendable and retractable, in the upper slideways 83, by suitable means, as by a pair of pneumatic cylinders 99 supplied with air through line 101 and having associated piston rods 102 secured, at the lower extremities thereof, to the cross members 94. In this manner, and by cooperative adjustment of the lower backup rolls 89, a compressive force may be applied to the quench rolls 92 and 93 whereby the same may be firmly pressed against the strip 16 as it passes therebetween, thereby assuring a good, heat-conductive engagement between the strip and the quench rolls. As illustrated in FIG. 3, the quench rolls may be compressed to such an extent that they assume generally elliptical shapes, thereby increasing the heat transfer area of contact with the strip 16 and thereby assuring adequate and rapid cooling or quenching of the heated strip. Similiarly positioned backup rolls 89 and 98 are mutually vertically aligned and are preferably positioned such that the plane extending through the longitudinal centerlines of the backup rolls and the undeformed quench rolls lies at an angle of about 45° to the horizontal line of travel of the strip 16.

Both pairs of backup rolls are preferably power-driven by suitable means. For example, as illustrated in FIGS. 1 and 4, the shafts of the backup rolls may be provided, adjacent the extremities thereof, with a pair of first sprocket wheels, as at 103 and 104 (FIG. 4) the shafts being power-connected through first sprocket chain 106. One of each of the pairs of shafts 88 and 97 is driven through a second sprocket wheel 107 and a second chain 108 by a third sprocket 109 on a transmission shaft 111 which may, with advantage, be driven through a fourth sprocket 112 and a fourth chain 113 by a drive shaft 114, powered by a prime mover (not shown) through a fifth sprocket 116 and a fifth chain 117.

Cooling of the quench rolls is obtained by continuously spraying a cooling fluid, such as water, onto the interior surface of the quench rolls. This may be achieved, for example, by providing cooling fluid supply lines as illustrated at 118 (FIG. 4) connected to upper and lower hollow header pipes 119 and 121 respectively (FIG. 7) extending along the longitudinal axis of each quench roll and having a number of similar hollow feeder pipes 122 extending radially therefrom. The feeder pipes 122 are connected, at their outer extremities to perforated spray pipes 123 adjacent and slightly spaced from the interior walls of the quench rolls and extending substantially the length thereof. As shown in FIG. 7, it is preferred, in order to obtain maximum cooling effect, that one of the perforated spray pipes 123 in each of the quench rolls be located immediately adjacent the area of contact with the strip 16 and, further, that the sprays of coolant from these perforated pipes 123 be directed at an angle to and substantially in the direction of the line of travel of the strip. The resultant, rapidly moving film of coolant greatly enhances the heat transfer capacity at the contact area of quench rolls. The coolant-supply piping within the quench rolls is of such dimensions and is so arranged as to avoid contact with the interiors of the quench rolls at the maximum extent of deformation. Cooling fluid, introduced into the interiors of the quench rolls, flows, by gravity, down the walls of the quench rolls and collects in the lowermost portions thereof from which it flows from both open ends of the quench rolls. The cooling fluid may be removed by any suitable means such as, for example, troughs 124, located at both ends of each quench roll and provided with drain lines 126 (FIG. 7). The arrangement illustrated and described herein provides means having a high heat capacity for substantially instantaneously extracting the excess heat energy content of the strip uniformly and simultaneously from both sides thereof thereby assuring maximum metallurgical properties obtainable by a rapid quenching operation while at the same time supporting the quenching portion of the strip to prevent warping due to the rapid withdrawal of the heat energy content.

For purposes of convenience in removing cooling fluid, it is preferred to make the lower quench roll of slightly less length than the upper quench roll (FIG. 7). The maximum width of strip is, moreover, preferably slightly less than the length of the perforated spray pipes 123 in order to assure uniform cooling of the strip completely to the edges thereof.

The header pipe 121 supplying the lower quench roll 92 may be secured against movement by suitable means, as by a first yoke 127 (FIG. 1) passing thereabout and attached to a cross piece 128 of the frame 79. In the case of the header pipe 119 supplying the upper quench roll, the same may be secured in position by suitable means, as by a second yoke 129 mounted upon a depending support 131 secured to the frame 79.

Lateral movement of the quench rolls 92 and 93 may be prevented by any suitable means, for example, by the provision of grooved rollers 132 (FIG. 7) mounted on the frame 79 and bearing against the edges of the quench rolls at the ends thereof.

If desired, or necessary, in the processing of a particular strip material, additional cooling of the strip may be achieved by spraying a cooling fluid, such as water, upon the upper and under surfaces of the strip after it leaves the quench rolls. This may be accomplished by introducing the cooling fluid through suitable spray nozzles such as 133 and 134 illustrated in FIG. 1.

Downwardly of the strip pass, i.e., to the right of the quench rolls as illustrated in FIGS. 1 and 4, there is lo-

cated a pair of exit tensioning rolls 136 and 137 (FIGS. 2 and 5). The exit rolls 136 and 137 are provided with shafts 138 and 139, respectively, having the extremities thereof journaled, respectively, in pairs of upper bearing members 141 and in pairs of lower bearing members 142. The upper bearing members 141 are preferably mounted, for vertical movement, in guideways 143 in a framework 144 which is mounted on a base 146. Vertical movement of the upper exit tensioning roll assembly is obtained by means of a pair of pneumatic cylinders 147 having piston rods 148 secured at their lower extremities and through suitable means to the upper bearing members. The lower bearing members 142 are mounted upon the framework 144 and, if desired, may also be provided for vertical adjustment by any suitable means. By this means, and by cooperative adjustment of the Prony brake 38, varying degrees of tension may be applied to the strip as desired. The exit rolls 136 and 137 are power driven, through their respective shafts 138 and 139, by a suitable prime mover (not shown). As illustrated in FIGS. 2 and 5, there is provided an exit skid table 149 for support of the strip as it leaves the exit tension rolls.

In operation, the furnace 11 is preheated to the operating temperature. Leader strips (not shown) are welded to the ends of a length of sheet or strip 16 to be heat treated and quenched. The entry rolls 23 and 24, the furnace flattening rolls 48 and 49, the quench rolls 92 and 93, and the exit tensioning rolls 136 and 137 are separated to permit the leader strip to be passed between the roll passes defined by the respective pairs of rolls. Thereafter, the various rolls are adjusted to make contact with the strip or leader, each pair of rolls being adjusted to give the desired pressure upon the strip. Thereafter, the prime movers operating the entry rolls, furnace flattening rolls, quench backup drive rolls and exit rolls are actuated to start the strip moving through the furnace where it is heated, for example in the case of certain titanium alloys, to a temperature between 1200 and 1750° F. and maintained at such temperature for a period sufficient to obtain the desired effects upon the strip. The apparatus illustrated is capable, in several ways, of removing from the strip any substantial variation from uniform flatness. For example, in the cases of very slight variation, the portion of the strip within the furnace and between the entry doors and the furnace flattening rolls may be allowed to form, under its own weight, a catenary loop as illustrated by the dot-dash lines in FIG. 1. The tension placed upon the strip by the weight of this loop tends to straighten the strip. The action of the furnace flattening rolls, by application of vertical pressure to the strip as it passes therebetween, also tends to remove any variation from flatness of the strip. Greater warping may often be overcome by offsetting the furnace rolls with respect to each other whereby, as aforementioned, greater degrees of warping may be overcome. If there is considerable warping of the strip within the furnace and a consequent variation from uniform flatness which is not overcome by the aforesaid procedures, then additional tension may be applied to the strip between the entry rolls 23 and 24 and the exit tensioning rolls 136 and 137. Thus, any desired tensile force may be applied by application of a braking force by means of the Prony brake arrangement to the entry rolls. Such tensile force may be applied longitudinally of the strip as it passes through the furnace and quenching apparatus tends to remove or prevent warping of the strip. As the strip leaves the furnace flattening rolls, the elevated temperature of the strip is maintained in the furnace extension 67 by means of the heating elements 78. The nozzle-like configuration of the furnace extension and its position between the quench rolls 92 and 93 assures the maintenance of the elevated temperature of the strip substantially until the strip contacts the quench rolls whereupon the strip is substantially instantaneously quenched to room temperature thereby assuring optimum metallurgical qualities of the strip. If required, further cooling or liquid treatment may be effected by spraying a cooling or a liquid treating medium upon the strip through the nozzles 133 and 134. After passage of the strip through the quench rolls, it passes through the exit tensioning rolls 136 and 137 and thence onto the skid table 149 from which point any suitable disposition may be made of the strip as by coiling, cutting into predetermined lengths, subjection to further mechanical operations or chemical processes, etc.

Thus, it may be seen that by use of the processes herein described, it is possible to obtain, through the use of controlled heating, cooling and tensioning means and methods a substantially uniformly flat sheet having desirable metallurgical properties. In the event that it is desirable to form in the strip as it leaves the furnace higher temperature transformation products, it is possible, of course, to do so by introducing a cooling liquid into the quench rolls at a temperature higher than room temperature.

It can thus be seen that the present invention affords a means for heating and quenching high strength materials while at the same time maintaining these materials in a flat and unwarped condition. Although the process of the invention has been shown as carried out by a certain specific embodiment, it will be readily apparent to those skilled in the art that the process of the invention may be carried out by means of apparatus other than that herein described without departing from the spirit and scope of the invention.

I claim as my invention:

1. A method of producing strip having a variation from flatness not exceeding about 1% and comprising a high strength metal selected from the group consisting of titanium and alloys thereof comprising continuously moving said strip, heating said strip to a temperature of between about 1200° F. and about 1750° F. in a heating zone, applying tension to said strip longitudinally thereof while in said heating zone, applying opposed compressive forces to both sides of a transverse portion of the strip extending from edge to edge thereof while said strip is in said heating zone, quenching said strip to substantially room temperature by passing said strip through a cooling zone wherein both sides of said strip are contacted with a solid heat transfer medium having a heat capacity sufficiently great so as to substantially instantaneously extract from said strip the excess heat content thereof, maintaining the elevated temperature of the strip substantially unchanged until entry of the strip into the cooling zone, and applying a compressive force to both sides of said strip throughout the cooling zone.

2. A method of producing thin sheets of metal of the type having a yield strength in excess of about 100,000 pounds per square inch and having a variation from flatness less than about 1% which comprises continuously moving said sheets, heating the moving sheets to an elevated temperature conducive to the warping of the sheets upon quenching thereof to a lower temperature, exerting a longitudinally applied tensile force to said sheets during heating thereof, exerting a substantially vertically applied compressive force to a transversely extending segment extending from edge to edge of said sheets during heating thereof, substantially instantaneously performing a quenching operation upon said sheets by extracting excess heat content simultaneously from both sides thereof, exerting a substantially vertically applied compressive force to said sheets during the entire quenching operation, and maintaining said sheets at said elevated temperature substantially until performance of the quenching operation.

3. A method of preventing warping of high strength metallic sheet material of reduced thickness during heat treatment at an elevated temperature such as to give rise to a tendency to warping of the material upon subsequent quenching thereof, which comprises continuously moving said material, exerting upon said material a tensile force applied longitudinally thereof, heating said material to

said elevated temperature while under the influence of said tensile force, compressing transverse segment of said material extending from edge to edge thereof during heating thereof, substantially instantaneously reducing the temperature of said material by simultaneously extracting heat energy from both sides thereof, and compressing said material during the temperature reduction operation.

4. A method of preventing warping of elongated sheets of high strength metal during heat treatment thereof comprising heating a sheet to an elevated heat treating temperature, maintaining the elevated temperature of said sheet substantially until quenching to a substantially lower temperature conducive to warping of the sheet, quenching by extracting heat energy uniformly and simultaneously from both sides of said sheet, compressing said sheet during quenching thereof, and applying to said sheet during heating and quenching thereof a longitudinally directed tensile force of a magnitude sufficient to prevent warping of the sheet.

5. A method of producing heat treated, substantially warp-free, high strength sheet material comprising heating the material to an elevated heat treating temperature conducive to material warping upon quenching from said elevated temperature to a substantially lower temperature, quenching the heated material to said lower temperature, and, simultaneously with the quenching step, applying both compressive and tensile stress to that portion of the material undergoing quenching.

References Cited by the Examiner

UNITED STATES PATENTS

1,857,670	5/32	Steckel	80—60
2,441,500	5/48	Miess	266—3
2,445,866	7/48	Wilson et al.	266—3
2,642,764	6/53	Porth	80—60
2,783,788	3/57	Ungerer	148—131
2,836,527	5/58	Kessler et al.	148—131 X
3,005,737	10/61	Blair	266—3

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