

[54] **METHOD AND APPARATUS FOR BENDING PIPE**

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[58] Field of Search **72/128, 369**

[56] **References Cited**

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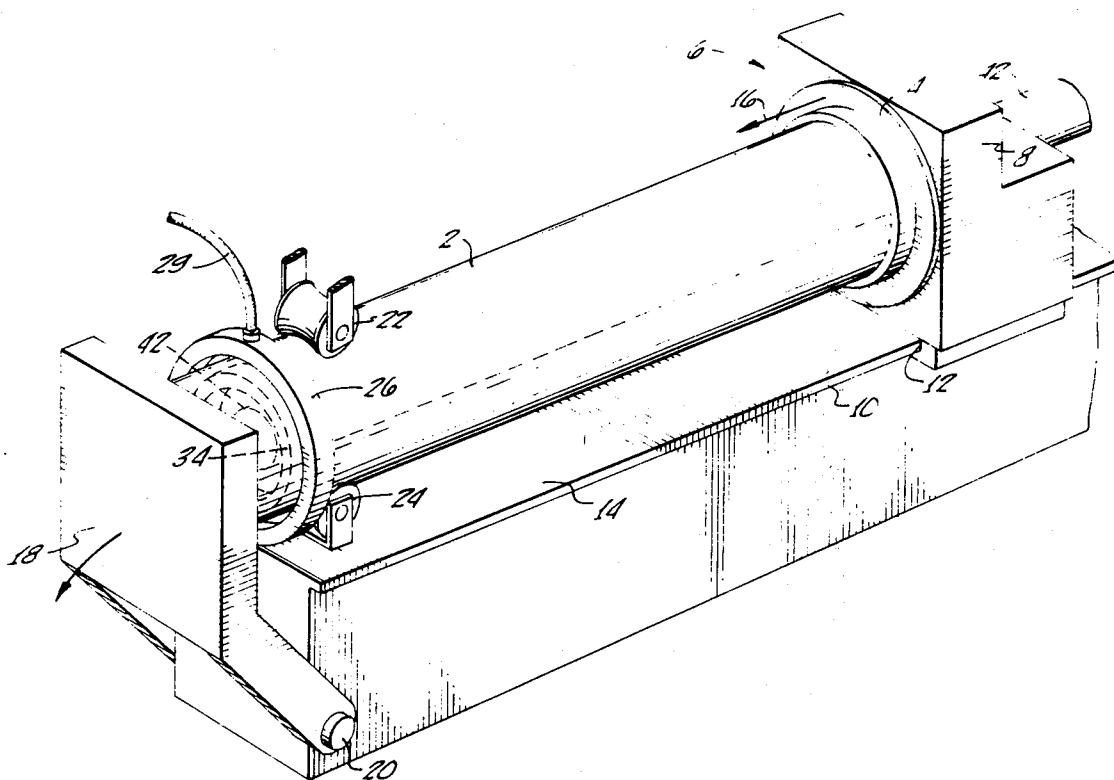
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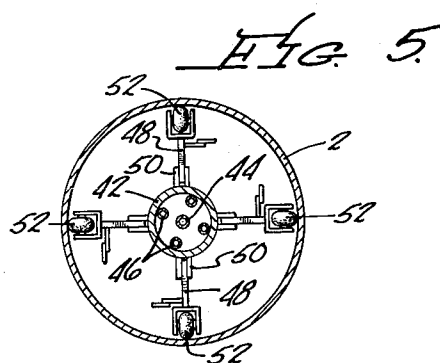
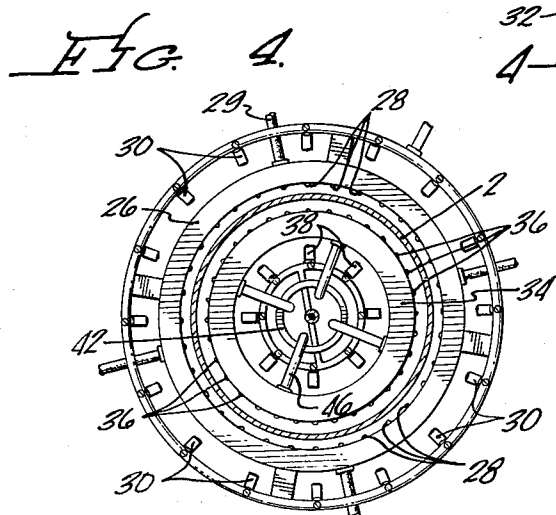
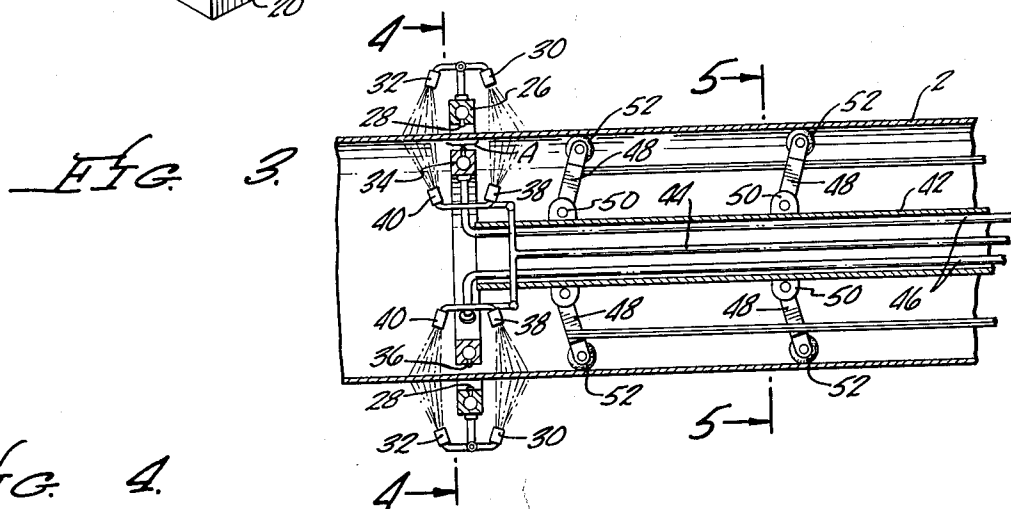
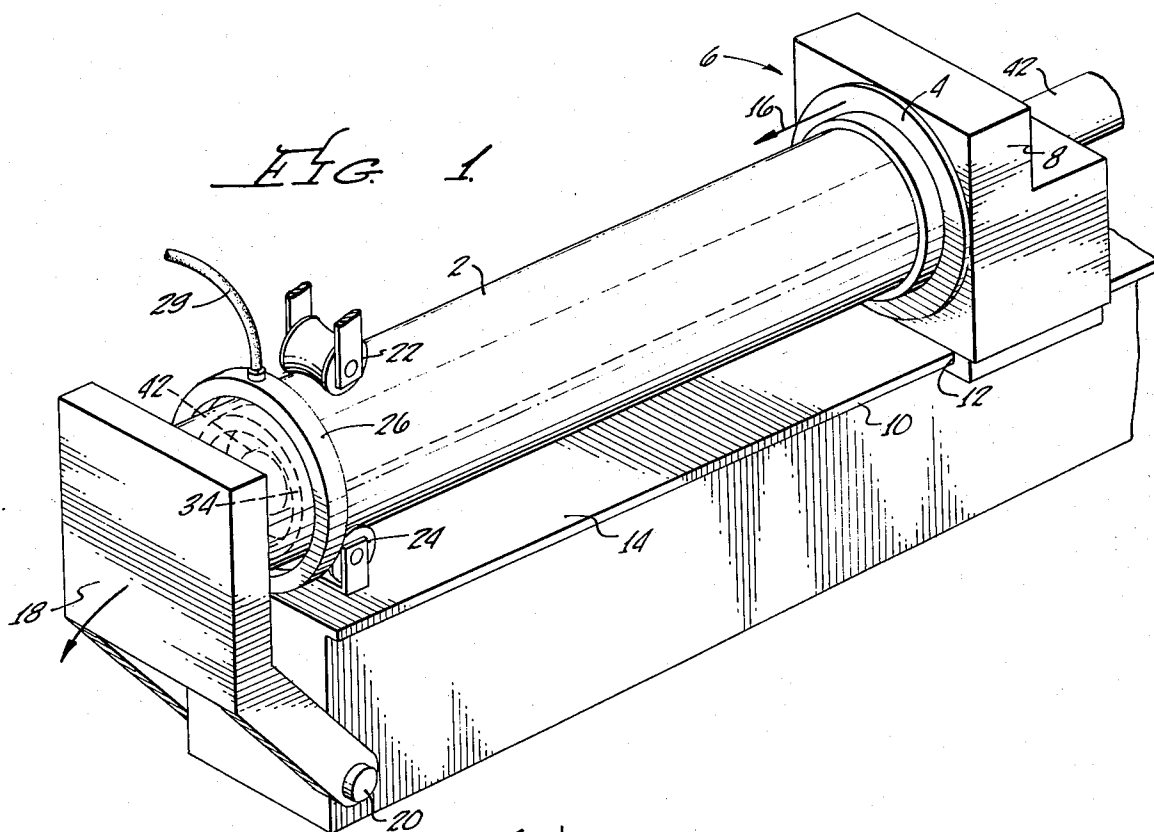
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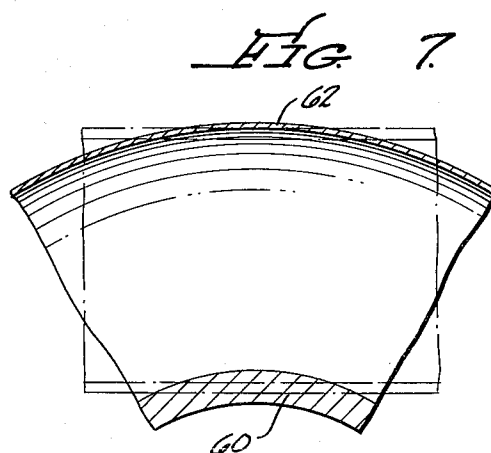
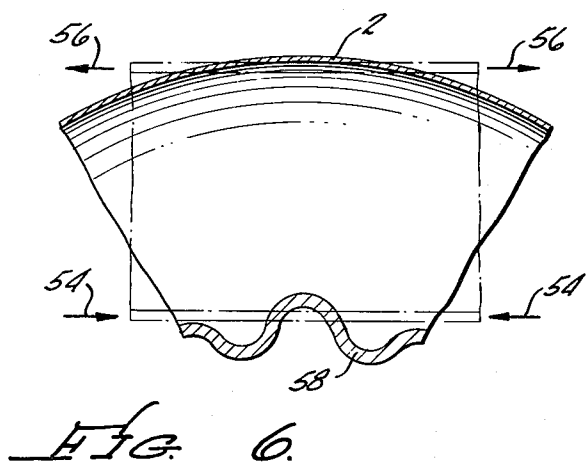
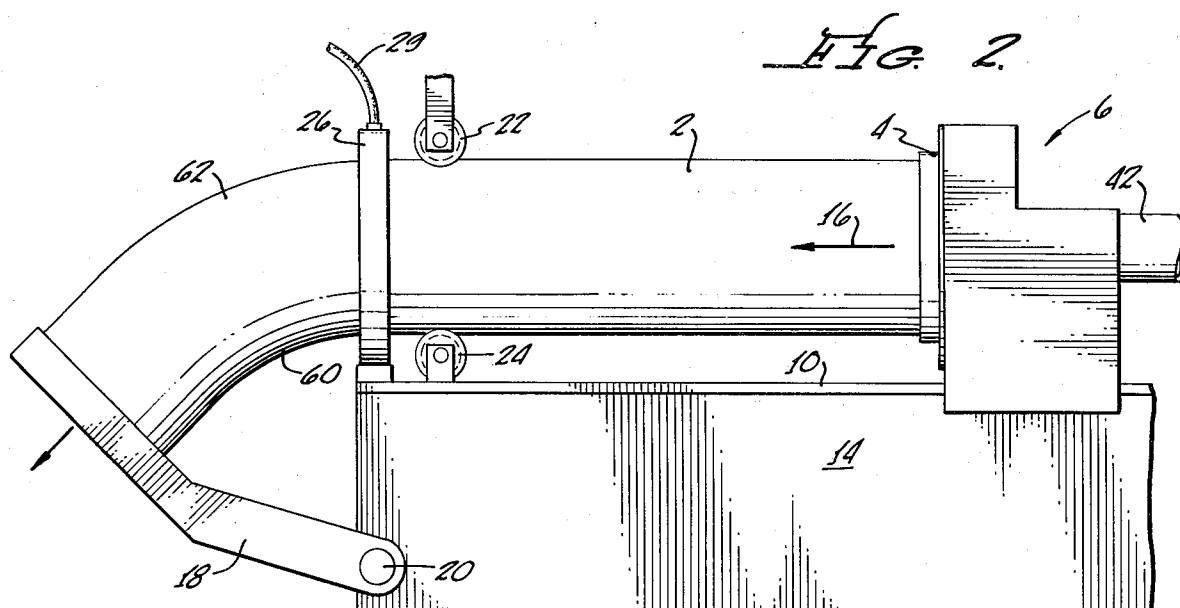
ABSTRACT

Large diameter thin-walled pipe is bent by a ram pushing the pipe forward axially and a bending arm forcing the forward end of the pipe to follow a curved path. A pair of gas burners mounted inside and outside the pipe in a plane passing through the center of the bend heat the pipe in a narrow bending zone to a temperature substantially reducing the yield strength of the metal.

13 Claims, 7 Drawing Figures







METHOD AND APPARATUS FOR BENDING PIPE

SUMMARY OF THE INVENTION

This invention relates to the forming of bends in large diameter pipe having relatively thin walls. This application is related to my copending application for "Method and Apparatus for Bending Pipe," Ser. No. 456,787, filed Apr. 1, 1974.

Forming bends in thin-walled tubing or pipes has been a very difficult procedure because the walls tend to buckle or wrinkle on the inside of the bend when subjected to the substantial stress required for bending. This tendency is stronger, the thinner the wall thickness in relation to the diameter of the pipe. Prior art commercial techniques often supported the pipe internally or externally to resist buckling. That requires tooling which is extremely costly for large diameter pipe. In addition, the problem of extracting the finished part from the tooling seriously limits the complexity of the bends that can be formed.

It is known that pipe can be bent by pushing it along its axis from one end while guiding the leading end about a radius. However, such a technique is completely unsatisfactory for thin-walled pipe because the compressive stress on the inside of the bend exceeds the column strength of the pipe wall, and buckling results. Patent No. 785,083, issued to Brinkman describes such a procedure using a wide heat zone to reduce bending forces.

In order to overcome buckling, a narrow heat zone must be employed as described by Hirayama et al. in U.S. Pat. No. 3,368,377. The narrowness of the heated zone is of paramount importance as it is a result of this narrowness that the pipe is prevented from wrinkling or buckling. The principle involved is that a column compressed at either end will thicken rather than buckle if the thickness of the column is more than about one half of its length. The metal at the inside of the bend in the hot zone may be regarded as a short column under compression. Since bending occurs only in the heated zone, in this analogy the length of the column corresponds to the width of the heat zone and the thickness of the column corresponds to the wall thickness.

The width of zone which may be permitted without buckling is dependent on the wall thickness of the pipe and to a lesser degree on the diameter of the pipe. For a pipe of exceptionally thin wall in relation to its diameter, the heated zone should be as narrow as twice the wall thickness. For somewhat thicker walls, or smaller diameters, the zone may widen somewhat. In the case of thick-walled pipes and solid bars the tendency towards buckling is so limited that little attention need be paid to the width of the heat zone. In these cases heat is used merely to reduce the bending forces. In general, the zone should be as hot as possible without microstructural deterioration of the metal.

Heating by induction, as described by Hirayama, has several disadvantages. The induction power sources and induction coils are expensive, and the point-to-point heat input into the metal is very sensitive to the local air gap between the coil and pipe which varies around the periphery of the pipe, tending to cause uneven temperature. By contrast, the heat input of gas flame is insensitive to this factor. In addition, induction coils present a shock hazard to the user and construction of an induction coil for uniform heat around the entire periphery without a gap, presents difficulties.

This invention is a method and apparatus for bending pipe using gas burners, but which by virtue of a narrow heat zone is operable for large diameter thin-walled pipe, even for relatively small radius bends. One of the difficulties that has been found with a single gas burner is that surface overheating may occur under the flame. The excess temperature damages the surface metal and provides an unsatisfactory product. Applicant has discovered that the overheating is a result of the intense heat necessary to provide a narrow heat zone between the adjacent water cooled regions. This overheating is inherent in the prior art processes in order to sufficiently heat the pipe in a narrow zone to permit bending, without buckling.

It is an inherent characteristic of gas heating, that heat is imparted to the metal via the surface only. In order to obtain a through temperature of 1,800°F. and overcome the heat losses into the adjacent, water quenched metal and radiation from the inner surface, a single burner on the outside, (per the prior art) may cause surface melting and erosion. This problem is overcome by utilizing the second burner ring inside the pipe thereby effectively doubling the surface available for heat input while reducing heat losses.

This invention overcomes the overheating problem of the prior art by applying heat with two generally concentric sets of gas burners; one outside the pipe and one inside the pipe. Both sets of burners are located at the bending zone. The two sets of burners cooperate to raise the temperature of the metal in the bending zone throughout its thickness sufficiently to permit bending without buckling while avoiding any local overheating and scoring.

The two sets of burners may each have quenchers associated with them to confine the high temperature to a narrow bending zone. The interior set of burners is guided in the pipe by rollers to assure its proper position in the pipe.

This combination has been found to overcome the problems encountered in the prior art and to result in a very satisfactory method and apparatus for bending large diameter thin-walled steel pipe.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an apparatus constructed in accordance with this invention;

FIG. 2 is a side elevation of the apparatus of FIG. 1 showing a pipe in the process of being bent;

FIG. 3 is a partial longitudinal section through the pipe and burners of the apparatus;

FIG. 4 is a section taken generally along lines 4—4 of FIG. 3;

FIG. 5 is a section taken generally along lines 5—5 of FIG. 4;

FIG. 6 is a schematic section illustrating the forces buckling a pipe in prior art processes; and

FIG. 7 is a schematic section illustrating the dimensional effect of bending a pipe in accordance with this invention.

SPECIFICATION

Referring to FIGS. 1 and 2, a pipe 2 in which a bend is to be formed is shown in position on the apparatus of this invention. By way of example, a typical pipe would be of 304 stainless steel of an overall diameter of about 16 inches and having a wall thickness of about three-eighths inch. The trailing end of the pipe is re-

ceived in a collar 4 which is mounted on a ram 6. The ram includes a slide 8 mounted by suitable guides such as the illustrated flange 10 and groove 12 for sliding movement along a base 14. Suitable power means such as a hydraulic or pneumatic cylinder (not shown) is attached to the slide 8 for pushing the pipe 2 axially in the direction of the arrow 16.

A bending arm 18 is removably but rigidly connected to the forward end of the pipe 2 so that the forward end of the pipe and the bending arm move as a unit. The bending arm is pivotally mounted on the base 14, for example by a shaft 20, for pivotal movement about the desired center of curvature of the bend.

Roller type guides 22, 24 may bear on the pipe from above and below and on either side to guide the pipe in its movement forward.

A burner ring 26 is mounted so as to be disposed around the pipe in a plane perpendicular to the longitudinal axis of the pipe and passing through the axis of bending 20. The burner ring preferably is a gas burner having a plurality of jets 28 connected to gas supply lines 29 and disposed around the circumference of the pipe 2 so as to heat the pipe to a temperature at which its yield strength is substantially reduced. For 304 stainless steel, for example, this preferably is a temperature in the range of about 1,600°F. to 2,000°F., and preferably about 1,800°F. In many instances lower or higher temperatures can be used satisfactorily, but at temperatures below 1,000°F. the decrease in yield strength of 304 stainless, for example, would not be sufficient to overcome buckling for most thin-wall applications, and metallurgical deterioration begins at temperatures in excess of 2,200°F. The actual temperature range which can be used will be determined empirically for the particular pipe and bend.

A pair of quench rings 30, 32 are also disposed around the pipe 2 in the same plane as the burner ring 26. Each quench ring includes a set of jets; those of the first ring 30 being directed slightly forward of the burner ring and those of the second ring 32 being directed slightly rearward of the burner ring. The quench ring jets are connected to a source of coolant such as air, or preferably water, or a combination of the two, to cool the pipe 2 forward and rearward of the burner 26 and restrict the heated zone to a narrow band A.

A second burner ring 34 is disposed interior of the pipe in the same plane as the exterior burner ring 26. Like the exterior burner ring, it comprises a series of closely spaced gas burner jets 36 disposed around its entire circumference for heating the interior surface of the pipe in the same zone A as the exterior burner heats the exterior surface. Quench rings 38, 40, generally similar to the exterior quench rings 30, 32, may also be mounted in association with the internal burner ring 34 for the same purpose as the external quench rings 30, 32, and to lower the temperature of exhaust gases traveling down the inside of the pipe.

The internal burner 34 and quench rings 38, 40 in the exemplary embodiment are mounted on a longitudinally extending support pipe 42 which extends out the rear end of the pipe 2 through the slide 8 and which houses a water pipe 44 for supplying water and air to the internal quench rings and gas lines 46 for supplying gas to the internal burner ring 34. A series of circumferentially and longitudinally spaced arms 48 are attached to the support pipe 42 by brackets 50. A roller 52 at the outer end of each of the arms 48 is in contact

with the interior surface of the pipe 2 so as to center the support arm 42 and the internal burner ring 34 and quench rings 38, 40 in the pipe 2.

In operation, the ram 6 is urged forward by its power source to move the pipe 2 longitudinally of its axis in the direction of the arrow 16. Since the forward end of the pipe can move forward only arcuately with the bending arm 18, the path of the forward end of the pipe necessarily is through an arc having its center of curvature at the axis 20 of the bending arm. Accordingly, a torque or bending moment is applied to the pipe 2 tending to bend the pipe about the axis 20.

Referring now to FIG. 6, which is a schematic longitudinal section through a portion of a representative pipe 2, it will be evident that the bending moment applied to the pipe applies compressive forces 54 to the inside portion of the bend and tensile forces 56 to the outside portion of the bend. The compressive forces tend to shorten the pipe on the inside portion of the bend and the tensile forces tend to lengthen the pipe on the outside portion of the bend from its initial shape as shown in the dashed lines.

If the thickness of the pipe wall is relatively small in relation to the diameter of the pipe as is the case with the pipes for which this invention finds its primary application, the compressive forces 54 generated on the inside of the bend in order to cause bending at normal temperatures tend to form buckles or wrinkles 58 in the metal. This tendency is stronger the thinner the wall thickness in relation to the diameter of the pipe, and makes impractical the bending of pipe. It is for that reason that the narrow heat zone is used.

The burners 26, 34 are designed to generate sufficient heat to raise the temperature of the pipe 2 in the narrow heated zone A to above a preselected temperature at which the yield strength is substantially reduced, e.g. 1,800°F. With the reduced yield strength, the required bending moment, and therefore the resulting compressive stress is less.

A constant preselected pressure is kept on the ram 6 which is sufficient to cause bending stresses in the pipe 2 equal to the yield strength of the metal at the preselected temperature. Since longitudinal movement of the pipe can occur only as the pipe bends, the pipe does not move until the temperature in the heated zone A reaches the preselected temperature. At that time the compression and tension in the heated zone A equals or exceeds the yield strength of the metal and the metal begins to bend, thereby permitting the pipe 2 to advance under pressure of the ram 6. As the pipe advances, new cold metal is brought into the heated zone and the bending process continues when the new portion is heated to the appropriate temperature. The temperature of the heated zone is not controlled directly, but is controlled by the ram pressure setting. The temperature increases until the metal yields, under the applied force of the ram 6. As the pipe 2 bends, it passes slowly through the burners 26, 34 and hot metal is displaced by cold metal. The speed with which the new metal is heated to the forming temperature, which controls the rate of advance of the pipe 2, is dependent on the amount of excess heat available. Thus, the apparatus is self-regulating in that no movement will occur until the desired temperature is achieved since no bending will occur until the metal's yield strength is reached.

The bend resulting from this invention is typified by FIG. 7 which shows the pipe thickened at the inside of the bend 60, and thinned at the outside of the bend 62 relative to its original shape as shown in dashed lines.

What is claimed is:

1. A device for bending pipe comprising:

a first burner means through which the pipe is passed to heat a narrow band of the exterior of the pipe to a temperature substantially reducing its yield point; second burner means around which the tube is passed to heat a narrow band of the interior of the tube to a temperature substantially reducing its yield point, said interior heated band and said exterior heated band being substantially opposite each other;

means for feeding the pipe past said burners; and means for applying a bending moment to the heated portion of the pipe.

2. A device in accordance with claim 1 wherein said first and second burner means are located generally in a common plane perpendicular to the pipe axis.

3. A device in accordance with claim 2 and further comprising means associated with at least one of said burner means for cooling the pipe forward and rearward of said burner means to confine the heated area to a narrow band.

4. A device in accordance with claim 3 wherein said band extends axially along the pipe about twice to four times the thickness of the pipe wall.

5. A device in accordance with claim 3 wherein said cooling means comprises means exterior of the pipe for applying coolant to the exterior surface of said pipe.

6. A device in accordance with claim 3 wherein said

cooling means comprises means both exterior and interior of the pipe for applying coolant to both the exterior and interior surfaces of said pipe.

7. A device in accordance with claim 2 and further comprising means coacting with the interior wall of said pipe and said second burner means to locate said second burner radially relative to said pipe wall.

8. A device in accordance with claim 7 wherein said second burner means and said first burner means are located on respective arcs centered on the axis of the pipe.

9. A device in accordance with claim 7 wherein said coacting means is a plurality of rollers mounted on said burner and engaging the interior wall of said pipe.

10. A device in accordance with claim 1 wherein the feeding means is a ram pushing the rear end of the pipe.

11. A device in accordance with claim 1 wherein the bending means is affixed to the forward end of the pipe and pivots about the center of bend being made.

12. A method of bending a thin-walled pipe of large diameter comprising the steps of:

heating the pipe both internally and externally with gas burners in a narrow band to a temperature substantially reducing its yield point;

applying a bending moment to the pipe portion in the narrow band; and

progressively moving the narrow band along the pipe as the portion in the band bends.

13. A method in accordance with claim 12 further comprising the step of confining the width of the band having a substantially reduced yield point to approximately two to four times the wall thickness of the pipe.

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