Nov. 5, 1963 T. W. AVERA ETAL 3,109,477

MANDREL FOR PIPE BENDING MACHINES

Filed Sept. 25, 1962 3 Sheets-Sheet 1

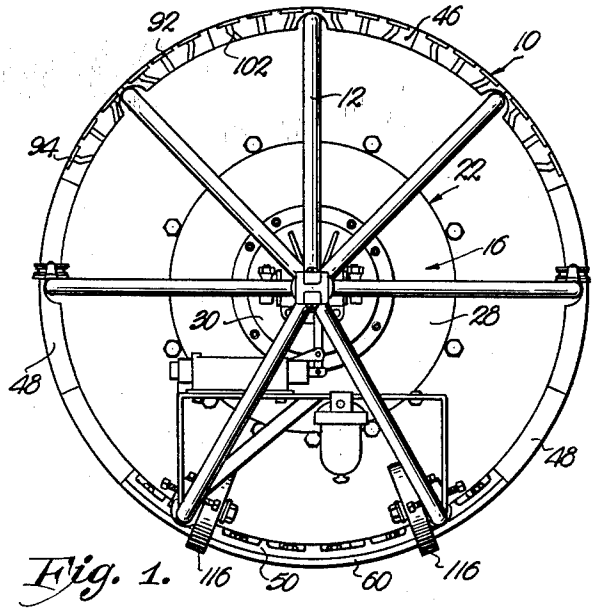


Fig. 1.

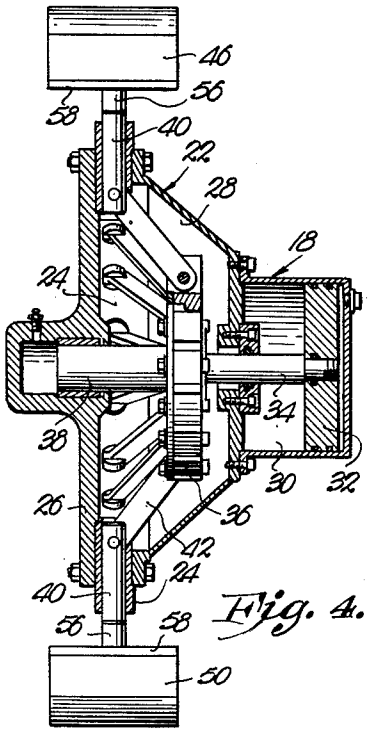


Fig. 4.

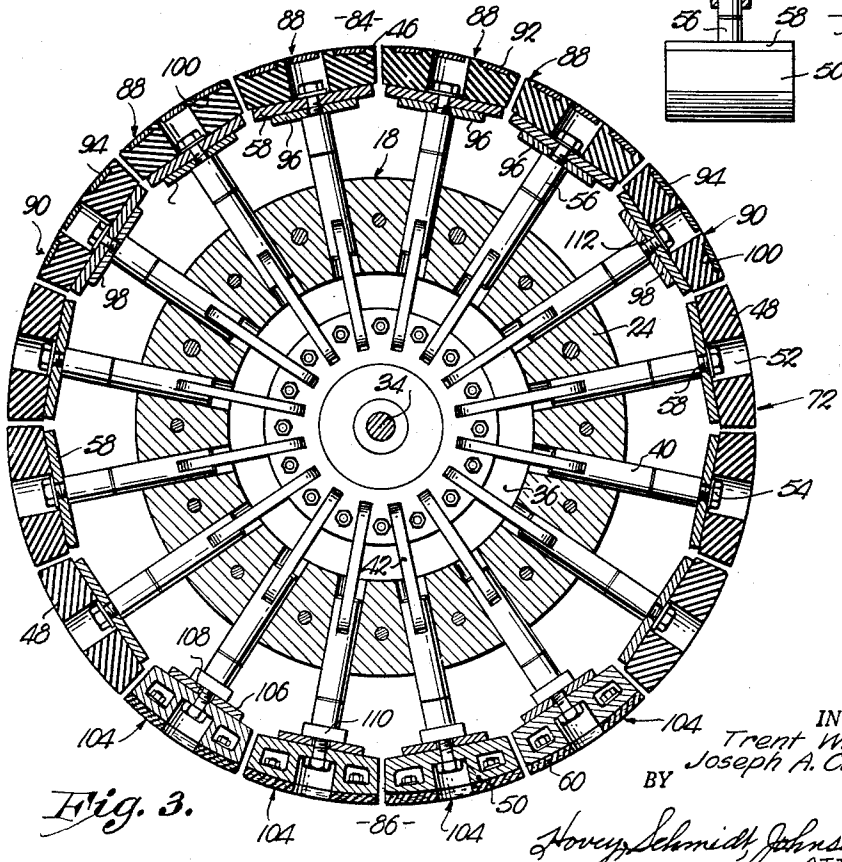


Fig. 3.

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MANDREL FOR PIPE BENDING MACHINES

Filed Sept. 25, 1962 3 Sheets-Sheet 2

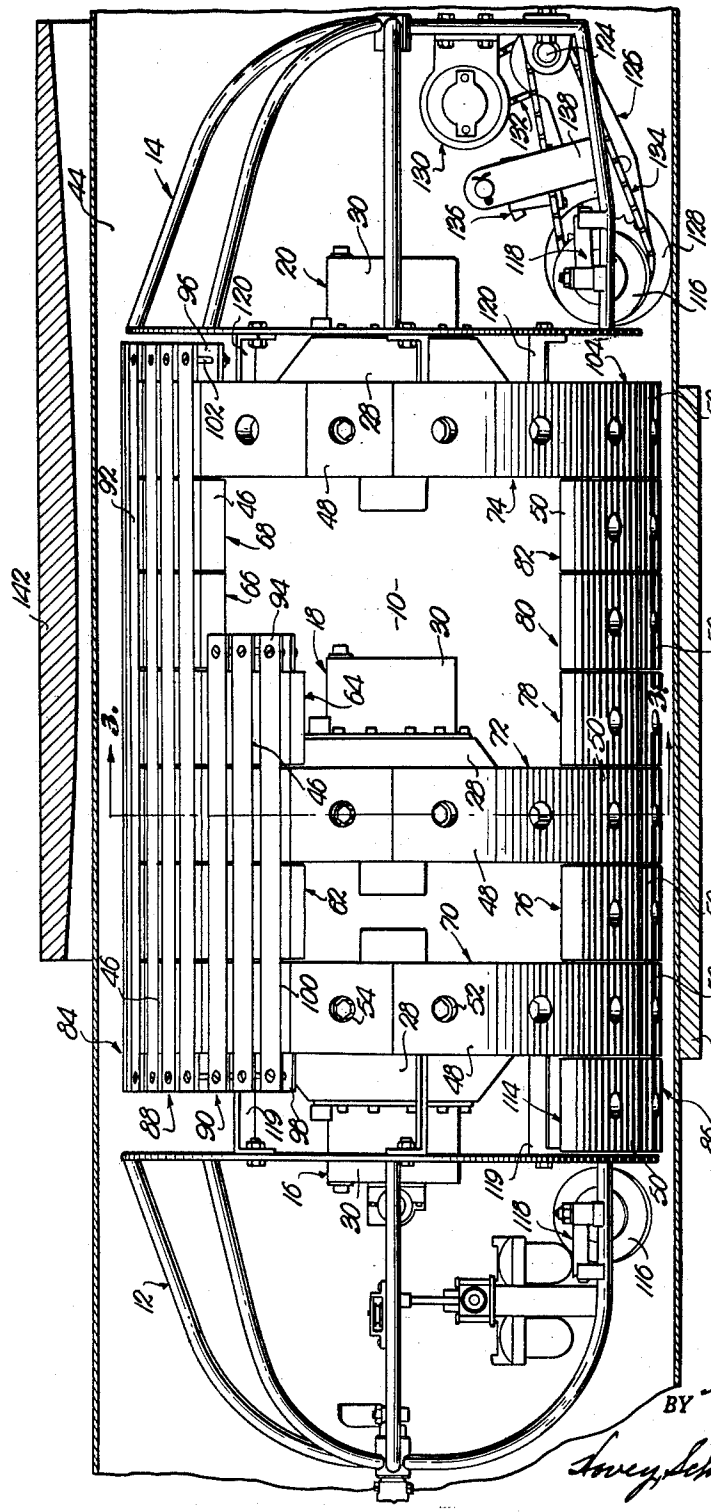


Fig. 2.

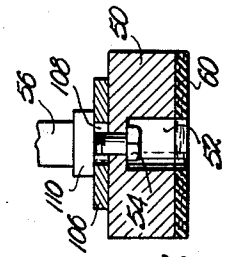


Fig. 7.

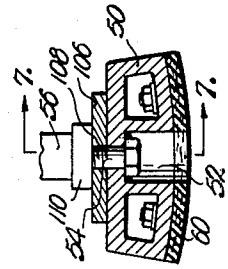


Fig. 6.

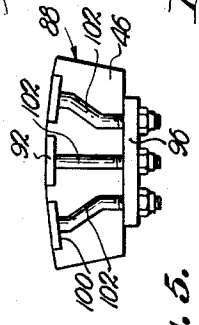


Fig. 5.

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MANDREL FOR PIPE BENDING MACHINES

Filed Sept. 25, 1962 3 Sheets-Sheet 3

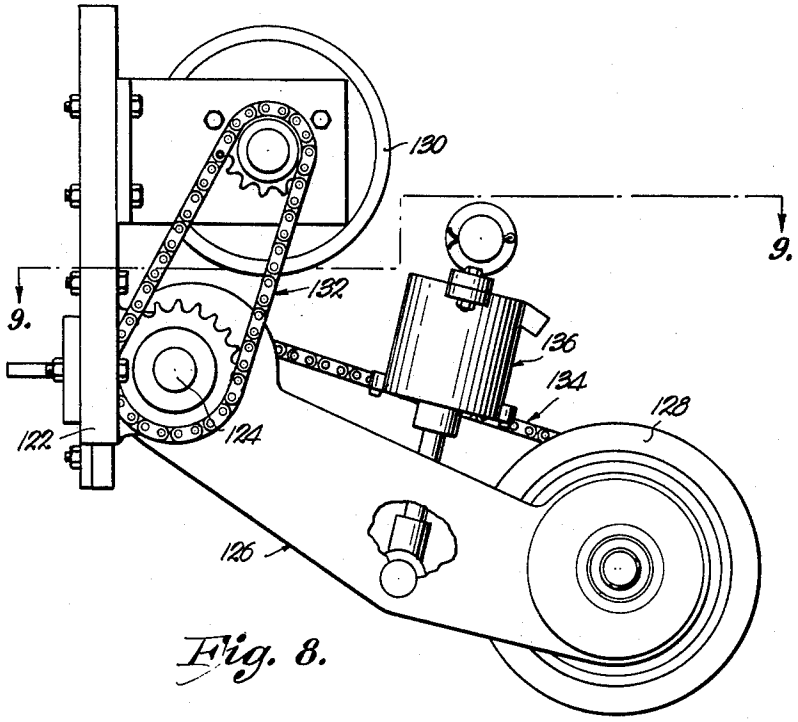


Fig. 8.

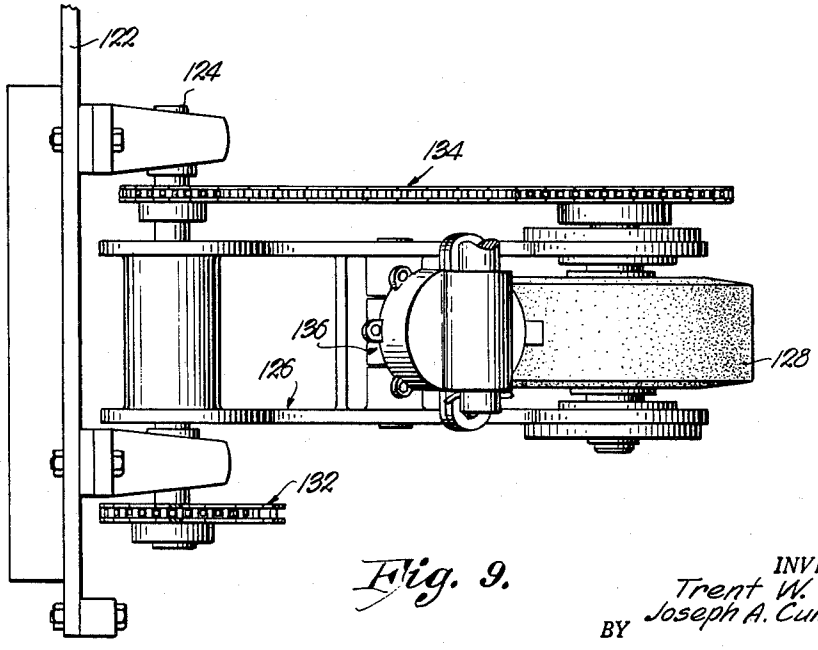


Fig. 9.

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3,109,477

MANDREL FOR PIPE BENDING MACHINES

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Filed Sept. 25, 1962, Ser. No. 226,093
16 Claims. (Cl. 153—63)

This invention relates to the art of bending pipe and more particularly to pipe bending apparatus in the nature of a mandrel adapted for expansion inside a pipe to be bent in tight engagement with the inner surface of the pipe for the purpose of supporting the latter for bending and adapted to flex with the pipe during the bending operation so as to maintain it smooth and cylindrical at the zone of bend.

It is the primary object of the present invention to provide a mandrel which may be quickly expanded against the pipe and held tightly therewithin during the bending operation and thereupon rapidly contracted so that the pipe may be advanced for successive bending operations without loss of time, to the end that the complete bending operation may be completed without slow-down interference because of the use of the mandrel in conjunction with the pipe bending machine.

The most important object of the instant invention is to provide an expansible mandrel that is fully effective in its function of maintaining the pipe smooth and cylindrical at the zone of bend throughout a wide range of differing types of pipe insofar as diameter is concerned and including pipes whose walls differ in thickness, as well as tensile strength and hardness of the material that makes up the wall of the pipe.

Another important object of the present invention is the provision of a collapsible pipe bending mandrel that is provided with parts which properly engage the pipe wherever it has any tendency whatsoever to buckle, wrinkle, collapse, or otherwise deform improperly as a consequence of the bending operation so that the inner surface of the pipe throughout the zone of bend remains or becomes smooth and uninterrupted as well as uniformly cylindrical throughout the length of the bend.

Still another important object of the instant invention is the provision of a mandrel in the nature of an elongated flexible body that is substantially cylindrical throughout its length or otherwise has the same cross sectional shape of the pipe to be bent and made in a manner to yield or bend properly with the pipe as the latter is being bent, while at the same time maintaining its tight grip against the pipe throughout the length of the body, with the result that the necessary attenuation takes place in the pipe along the large radius of the bend and the essential compression takes place in the pipe throughout the smaller radius of the bend while the pipe-engaging parts of the mandrel remain in tight contact therewith.

A further oject of the present invention is to provide a mandrel whose pipe-engaging parts bear against the pipe in a manner to avoid any possible bulging of the pipe at various locations within the bend so that bumps, depressions and other undesirable deformities are completely avoided.

An extremely important aim of our instant invention is to provide apparatus for facilitating the bending of pipe that operates in a manner to assure supporting engagement of the mandrel parts with the pipe quickly and easily and in complete absence of interference, slow-down or ineffective clamping as might otherwise be experienced if a frictional, sliding interengagement between the mandrel and the pipe were necessary during the expansion and contracting operation.

Yet another aim of our instant invention is to provide

a mandrel wherein the forces exerted against the pipe are properly distributed, not only longitudinally, but circumferentially of the mandrel.

It is contemplated that the instant invention shall have the important aim of providing a pipe bending mandrel which combines a powerful and truly radial action of expansion with not only the over-all flexible characteristics of the mandrel, but the resilient nature of the pipe-engaging parts, all for the purpose of attaining the necessary and desired results above enumerated.

In the drawings:

FIGURE 1 is an end elevational view of a mandrel for pipe bending machines made according to our present invention;

FIG. 2 is a side elevational view of the mandrel showing the same in a contracted position within a fragment of a pipe, the latter of which is in turn illustrated schematically within certain parts of a pipe bending machine;

FIG. 3 is an enlarged cross-sectional view taken on line 3—3 of FIG. 2, illustrating only the mandrel, but in an expanded condition;

FIG. 4 is a cross-sectional view fragmentarily illustrating one of the expansion units or assemblies, the section being within a plane through and parallel to the longitudinal axis of the mandrel;

FIG. 5 is an enlarged, detailed end-elevational view of one of the beams of the uppermost pipe support of the mandrel;

FIG. 6 is an enlarged, detailed, cross-sectional view through one of the pipe-engaging parts of one of the beams of the lower pipe support of the mandrel;

FIG. 7 is a cross-sectional view taken on line 7—7 of FIG. 6;

FIG. 8 is an enlarged elevational view of the drive entirely removed from the remaining structure of the mandrel showing that side of the drive opposite to that seen in FIG. 2; and

FIG. 9 is essentially a top view of the drive partially in section and taken along irregular line 9—9 in FIG. 8.

As best seen in FIG. 2 of the drawings, our expansible pipe bending mandrel which embodies the concepts of the instant invention is in the nature of an elongated flexible body broadly designated by the numeral **10** and provided with spider-like framework **12** and **14** at its ends. Body **10** includes a plurality of longitudinally spaced expansion units or assemblies **16**, **18** and **20** which may be of identical construction; therefore, reference may be had to FIGS. 3 and 4 of the drawings for an understanding of the details of the unit **18**.

A housing **22** has a ring **24** closed on opposite faces thereof by a plate **26** and a hollow cone **28**, the latter of which has a cylinder **30** attached thereto.

A piston **32** within the cylinder **30** has its stem **34** attached to a disc **36**, the latter of which is in turn provided with a guide **38** reciprocably carried by the plate **26**.

The ring **24** carries a plurality of radially reciprocable rams or plungers **40** that are actuated by links **42** which pivotally interconnect the plungers **40** with the disc **36**. It is to be understood at this juncture that the details of construction of the fluid-actuated plungers **40** as just above described may be varied within the spirit of the instant invention since the construction thereof, as depicted in FIGS. 3 and 4 of the drawings, is for illustrative purposes only, showing but one manner of power actuation for the plungers **40**. Within these concepts, therefore, it is manifest also that means other than the pneumatic or hydraulic actuated piston **32** may be provided to supply the power to force the plungers **40** in a radial direction outwardly from the axes of the units **16**, **18** and

20 that is coincident with the reciprocable path of travel of the piston 32, the stem 34, the disc 36 and the guide 38.

Each of the plungers 40 of each of the units 16, 18 and 20, regardless of the number of plungers 40 chosen for each unit, and regardless of the number of expansion units that are utilized in the mandrel, may be provided with a shoe in the nature of a pad or a block, positioned to firmly engage the inner surface of pipe 44 when the mandrel is expanded in the manner illustrated by FIG. 3 of the drawings. Such expansion takes place upon movement of the pistons 32 to the inner ends of the cylinders 30, placing the links 42 in substantial alignment with the plungers 40. The plungers 40 are then in substantial surrounding alignment with the disc 36 and are effectively locked against inward movement so that there is no need to rely substantially on fluid pressure as the means for preventing inward radial movement on the part of the plungers 40 as the result of the pressures which they must withstand during bending of the pipe 44.

All of the shoes of the mandrel which engage the pipe 44 as aforementioned may be resilient if desired but, as illustrated, there are three types of shoes 46, 48 and 50, the shoes 46 and 48 all being resilient. The shoes 50 may be solid, made, for example, from a suitable metallic, hard rubber or plastic material. The rubber or other substance chosen for the shoes 46 and 48 should be selected in light of the great pressures to be applied thereto and if resilient material is also selected for the shoes 50, it is contemplated that such rubber or other material be appreciably harder and much less resilient than the material chosen for the shoes 46 and 48. In other words, by way of example, shoes may be identical if so desired.

All of the shoes 46, 48 and 50 are provided with a single central opening 52 which receives the head of a cap screw 54 extending into the outermost end of the corresponding plunger 40 through spacers 56. Each of the shoes 46 and 48 has a metallic pusher plate 58 bonded to its innermost face and interposed between the corresponding head of bolt 54 and spacer 56. On the other hand, it is desirable, when the shoes 50 are made from metallic material, that their outer faces be provided with a facing 60 bolted or otherwise attached thereto, and made from belting or suitable material capable of protecting the inner surface of pipe 44 or protective coatings that are oftentimes provided on the inner face of pipes 44. It may be, however, that facings 60 can be eliminated, depending on the nature of the material chosen for blocks 50.

It is seen, therefore, that each of the assemblies 16, 18 and 20 is provided with a continuous annular row of shoes or pads concentric to their axes (which is coincident with the longitudinal axis of the body 10), such shoes being in side-by-side relationship and spaced only slightly when expanded, as shown in FIG. 3 of the drawings.

In addition, the body 10 is provided with a number of arcuate rows 62, 64, 66 and 68 of shoes 46, also concentric with the longitudinal axis of the body 10 and disposed at the top of the latter. The row 62 is interposed between the annular rows 70 and 72, whereas the rows 64, 66 and 68 are in side-by-side relationship between the two annular rows 72 and 74.

Similarly, a row 76 of shoes 50 is interposed between rows 70 and 72 and a number of rows 76, 78, 80 and 82 of shoes 50 are disposed in side-by-side relationship between the rows 72 and 74. The rows 76, 78, 80 and 82 are likewise concentric with the longitudinal axis of body 10 at the bottom of the latter.

It should be explained at this juncture that each of the annular rows 70, 72 and 74 is made up of an arcuate row or segment of shoes 46 in longitudinal alignment with proximal shoes 46 of the rows 62, 64, 66 and 68. In much the same manner, each of the rows 70, 72 and 74 includes an arcuate row or segment of shoes 50 disposed in longitudinal alignment with proximal shoes 50 of rows 76, 78, 80 and 82. This means, then, that the segmental

arcuate rows 62, 64, 66, 68, 76, 78, 80 and 82 do not have any shoes corresponding to the shoes 48 that are found in the annular rows 70, 72 and 74. The shoes 48 are located in the rows 70, 72 and 74 between their uppermost shoes 46 and their lowermost shoes 50, the disposition of shoes 48 being such as to move laterally in opposite directions against the pipe, as distinguished from a general up-and-down movement on the part of shoes 46 and 50 at the top and bottom of the pipe 44.

The arrangement is such as to present an uppermost pipe support assembly broadly designated by the numeral 84 and a lowermost pipe support assembly broadly designated by the numeral 86. The upper support 84 includes a plurality of elongated, flexible beams 88 and 90 of substantially identical nature, except only that the beams 88 extend the full length of body 10, whereas the beams 90 are somewhat shorter. Each of the beams 88 and 90 includes a longitudinal series or straight row of shoes 46 in end-to-end relationship clamped together as a unit.

It is to be understood at this juncture that each of such straight rows could comprise a single length of resilient material rather than be subdivided into individual shoes as shown. A plurality of elongated, longitudinally extending, flexible strips, preferably of metallic material 92, are provided for each beam 88 and in the same manner each beam 90 has a number of similar strips 94. Each beam 88 is also provided with support structure in the nature of a strip 96 throughout its length and a similar strip 98 is provided for each of the beams 90. Grooves 100 extending longitudinally of the body 10 are provided in the outermost faces of each of the shoes 46 for receiving the strips 92 and, as seen in FIG. 3, the strips 94 are similarly recessed within the outer faces of the shoes 46 of the beams 90.

The strips 96 and 98 are in the nature of bars substantially wider and somewhat heavier than the strips 92 and 94 and extend along the inner faces of the shoes 46 of corresponding beams 88 and 90. The clamping means for connecting the shoes 46 of the beams 88 and 90 together as individual units is in the nature of a bolt for each strip 92 and 94, respectively, such bolts 102 passing through bars 96 and 98 as best seen in FIGS. 2 and 5, located at each end respectively of each beam 88 and 90. It is now clear that, inasmuch as the shoes 46 are clamped together between strips 92 and 96 and between strips 94 and 98 in straight rows extending longitudinally of the body 10, the shoes 46 of segmental rows 62, 64, 66 and 68 move in unison with the shoes 46 of annular rows 70, 72 and 74 as the units 16, 18 and 20 are in turn expanded and contracted in unison.

If desired, still another beam three blocks long might be provided beneath each of the four block beams 90.

The shoes 50 that make up the longitudinally extending beams 104 of the lower support 86 are interconnected by longitudinally extending strips or bars 106 that bear against the inner faces of the shoes 50, it being noted in FIG. 7 that the bars 106 are provided with elongated slots 108 that extend longitudinally of the body 10 for clearing the bolts 54, and each of the spacers 56 that are proximal to such enlarged openings 108 has an external flange or enlargement 110 that bears against the bars 106 in covering relationship to the slots 108. It is also desirable, as noted in FIG. 3, that each of the bars 96 and 98 be provided with a clearance opening 112 for bolts 54 that is slightly enlarged to present at least a slight looseness of the corresponding bolts 54 within the openings 112.

Because of the bars 106 for each of the beams 104, all of the shoes 50 of the arcuate or segmental rows 76, 78, 80 and 82 move in unison with the shoes 50 of the annular rows 70, 72 and 74 in much the same manner as above described with respect to the beams 88 and 90 of the upper support 84.

It has been found desirable to make the beams 104 longer than the beams 88; hence, still another arcuate row

of shoes 50 is provided on the bars 106 adjacent the row 70, such additional row being designated by the numeral 114 and disposed to place the row 70 between the rows 76 and 114.

The shoes 48 may be identical with the shoes 46, except only that they are not interconnected by flexible strips and accordingly are devoid of the grooves 100. They present, therefore, secondary pipe-engaging means and cooperate with the two primary supports 84 and 86 in producing the desired results obtained through use of the mandrel of the instant invention.

While the strips 92 and 96 clamp together all of the shoes 46 of the rows 70, 62, 72, 64, 66, 68 and 74, the strips 94 and 98 of the beams 90 connect together only the shoes 46 of the rows 70, 62, 72 and 64. On the other hand, each strip 106 of each beam 104 interconnects all of the shoes 50 of the rows 114, 70, 76, 72, 78, 80, 82 and 74.

It is now evident from FIGS. 2 and 3 that when the body 10 is fully expanded the inner face of pipe 44 is engaged by all of the shoes 46, 48 and 50, as well as by all of the strips 92 and 94, the engagement by the shoes 50 being through their facings 60. The engagement is continuous longitudinally of the body 10 at the supports 84 and 86 and is continuous circumferentially at the rows 70, 72 and 74, inasmuch as the sets of shoes 46, 48 and 50 of each of these annular rows present continuous pipe-engaging bands for the mandrel body 10. It is also believed readily apparent that the shoes between the outer strips and the inner bars serve as spacers for maintaining the outer pipe-engaging strips properly spaced from the support bars therefor.

It is to be explained at this juncture that the arrangements above described may be varied considerably within the concepts of the instant invention to suit the desires of the manufacturer and the needs of particular pipe bending operations. The supports 84 and 86 extending longitudinally of the body 10 and generally continuous throughout its length have been provided in such manner because of the fact that the greatest amount of adequate support for the pipe 44 is needed at the small and large radii of the bend.

On the other hand, there is a lesser need for supporting the pipe 44 between the upper and lower supports 84 and 86, making it possible to attain good results without need for continuing either the support 84 or the support 86 throughout the circumference of the body 10, thereby reducing the cost of manufacture and the over-all weight of the mandrel, as well as simplifying its construction. It is also contemplated that the number of rows of continuous shoes, as well as the number of units 16, 18 and 20 and the spacing therebetween may be varied considerably from that illustrated in the drawings and above explained, depending upon various pipe bending requirements.

Framework 12 is attached to the unit 16 by brackets 119 and similar brackets 120 mount the framework 14 on the unit 20. The primary support for the body 10 in the pipe 44 when body 10 is contracted, as illustrated in FIG. 2, is through a pair of inclined wheels 116 on each of the frameworks 12 and 14, respectively, each wheel 116 being provided with suitable toe-in and toe-out, as well as height adjustment means 118 for preventing the mandrel from rolling over in the pipe 44.

Fore and aft movement of the mandrel is provided by the drive, illustrated in FIGS. 2, 8 and 9. A plate 122 on the framework 14 carries a jackshaft 124 which in turn swingably supports an extension 126 having a friction roller 128 adjacent its lowermost end.

A prime mover such as a fluid motor 130 carried by plate 122 is operably connected with the shaft 124 by chain and sprocket wheel means 132 and another chain and sprocket wheel means 134 operably interconnects shaft 124 and roller means 128.

Power means which may take the form of a fluid piston and cylinder assembly 136 pivotally interconnects extension 126 with an upstanding arm 138 on framework 14.

The roller 128 rests loosely on the bottom of the pipe 44 during pipe bending operations while the body 10 is expanded, but when relative movement between the mandrel and the pipe 44 is to take place the assembly 136 is actuated to compress roller 128 tightly against the pipe 44, without lifting the mandrel off the guide wheels 116, to provide a friction or traction drive. Thereupon roller 128 is rotated by actuation of the prime mover 130. The pipe 44 is advanced from left to right, viewing FIG. 2, after each bending operation; therefore, roller 128 is caused to rotate in a direction to maintain the mandrel in substantially the position shown in FIG. 2 with respect to the pipe bending machine during the advancement of the pipe 44.

Pipe bending machines are conventionally provided with a transversely arcuate support 140 for the pipe 44 together with a transversely concave but longitudinally convex bending shoe 142 in diametrically opposed relationship to the support 140. Therefore, as successive bends are made in the pipe 44 it is normally advanced several inches after each bending operation, whereas the mandrel itself is maintained in the same relationship to the support 140 and the shoe 142 by operation of the driving mechanism.

The mandrel is controlled from a remote point exteriorly of the pipe 44, the controls extending into the pipe 44 for operable connection with fluid control valving mounted on framework 12. The valve that controls the downward motion of the drive roller 128 may be the same valve that controls the expansion and contraction of the mandrel. When the mandrel is contracted, the assembly 136 may be actuated by the same fluid that retracts the three expanding mechanisms of the mandrel. When the mandrel is expanded, fluid in the cylinder of assembly 136 may be exhausted to atmosphere through the valve. The fluid control valving for operating the prime mover 130 should also be adapted for actuation exteriorly of the pipe 44 remote from the mandrel.

It is now apparent that when the body 10 is expanded so that all parts of its periphery are tightly engaged with the pipe 44, the latter is firmly and adequately supported for bending and, since the various pipe-engaging parts are strategically located, rather sharp bends may be easily and quickly formed without any collapsing or other deformations taking place at any point within the zone of the bend. More particularly, as bending takes place, all of the flexible shoes 46 and 48 yield with the bend and at the same time all of the strips 92, 94, 96, 98 and 106 flex longitudinally to accommodate not only the small radius of the bend adjacent the shoe 142 but the larger radius along the support 140.

Manifestly, the bending operation necessitates tensioning of the material from which the pipe 44 is made at the shoe 142, but no buckling or wrinkling occurs because of the support that is provided by the beams 88 and 90 of the support 84. These supports, made as illustrated and above described, eliminate all corrugations that would otherwise form at the shoe 142 and the beams 88 and 90 perform such function in a manner to also prevent formation of dents, bumps, depressions and other undesirable deformities.

By the same token, the support 86 permits the necessary attenuation of the material forming the pipe 44 at the larger radius of the bend and does so in a manner to avoid formation of irregularities of any nature whatsoever in the pipe 44.

All such results take place while the mandrel effectively forms pipe 44 into a cylindrical shape or holds it cylindrical while bending takes place. Such result occurs by the cooperative action of the shoes 48, since the continuous annular bands 70, 72 and 74 prevent the pipe 44

from taking on an elliptical or other undesirable cross-sectional configuration.

As the large radius of the bend is formed along a support **140** the flexible bars **106** are permitted to bend therewith while the shoes **50** maintain their tight grip with the pipe **44** because of the loose fit incorporated in the support **86** by the slots **108**. Similar results are obtained during flexing of the strips **92**, **94**, **96** and **98** to accommodate for the smaller radius of the bend because of the loose fit provided at the openings **112**.

It is to be understood, however, that the entire body **10** remains in full and firm contact with the interior of the pipe **44** during the bending operation while the two radii of the bend are formed, since it is not possible for any of the plungers **40** to retract once the discs **36** become substantially aligned with the plunger, as above explained. It is for this reason that the body **10** maintains the same cross-sectional configuration as the pipe **44** throughout the length of the body **10** and throughout each bending operation. It is therefore impossible for the bending operation to cause the pipe **44** to take on any cross-sectional configuration other than cylindrical, and it is also not possible for any irregularity such as wrinkling and depression to be formed in the pipe **44**.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. An elongated, longitudinally flexible and resilient, transversely expansible mandrel adapted for insertion into a pipe to be bent for supporting the pipe against distortion adjacent the zone of bending thereof, said mandrel comprising:

a first, elongated, longitudinally flexible and resilient assembly for supportingly engaging a longitudinal area of the pipe adjacent said zone during bending of the pipe;

a second, elongated assembly disposed in spaced, opposed, generally aligned, parallel relationship to said first assembly and provided with elongated support structure extending longitudinally of the second assembly;

elongated, resiliently flexible, pipe-engaging strip means disposed outwardly of the support structure in generally parallel, spaced relationship therefrom;

resilient spacer means disposed between said strip means and the support structure along the longitudinal length thereof;

a pair of expansion units spaced apart longitudinally of the assemblies and each operably coupled to said one assembly and to the support structure of the other assembly at longitudinally spaced, directly opposed points thereon; and

means connecting the strip means and spacer means with said support structure, whereby upon movement of said assemblies relatively away from each other by said units, said one assembly and the strip means are shifted into firm, substantially conforming, supporting engagement with opposed, longitudinally extending areas of the pipe at said zone thereof.

2. An elongated, longitudinally flexible and resilient, transversely expansible mandrel adapted for insertion into a pipe to be bent for supporting the pipe against distortion adjacent the zone of bending thereof, said mandrel comprising:

a first, elongated, longitudinally flexible and resilient assembly for supportingly engaging a longitudinal area of the pipe adjacent said zone during bending of the pipe;

a second, elongated assembly disposed in spaced, opposed, generally aligned, parallel relationship to said first assembly and provided with elongated, longitudinally flexible and resilient support structure extending longitudinally of the second assembly;

elongated, resiliently flexible, pipe-engaging strip means disposed outwardly of the support structure in generally parallel, spaced relationship therefrom;

spacer means disposed between said strip means and the support structure along the longitudinal length thereof;

a pair of expansion units spaced apart longitudinally of the assemblies and each operably coupled to said one assembly and to the support structure of the other assembly at longitudinally spaced, directly opposed points thereon; and

means connecting the strip means and spacer means with said support structure, whereby upon movement of said assemblies relatively away from each other by said units, said one assembly and the strip means are shifted into firm, substantially conforming, supporting engagement with opposed, longitudinally extending areas of the pipe at said zone thereof.

3. An elongated, longitudinally flexible, transversely expansible mandrel adapted for insertion into a pipe to be bent for supporting the pipe against distortion adjacent the zone of bending thereof, said mandrel comprising:

a pair of generally circular, normally substantially axially aligned, spaced, independent expansion units each having a series of radially movable, circumferentially projecting members thereon;

upper and lower elongated, spaced, opposed, aligned, generally parallel, pipe-engaging assemblies each having a plurality of parallel, elongated, longitudinally resiliently flexible beams carried by members of the units in aligned relationship longitudinally of the assemblies, movable radially with respective members and serving to interconnect the units with the members thereof normally lying in imaginary, generally parallel, spaced circles, said assemblies having outer faces of transverse configuration substantially conforming to the transverse inner surface configuration of the pipe and adapted to support opposed upper and lower areas of the pipe at said zone during bending of the pipe, said beams of the upper assembly each having at least one elongated, resiliently flexible, pipe-engaging strip thereon and each beam supporting its strip for flexing separately from the flexing of a respective beam; and

operating means coupled to said members of the units for simultaneously shifting all of the members along the radial paths of travel thereof whereby the beams of said assemblies may be radially shifted to move the strips and the beams of said lower assembly into firm, conforming engagement with said opposed upper and lower areas of the pipe.

4. A mandrel as set forth in claim 3 wherein said operating means includes pneumatically operable components permitting rapid shifting of the members toward respective extremities of the radial paths of travel thereof.

5. In a pipe bending mandrel having an elongated body adapted for insertion into a pipe to be bent, said body comprising:

a pair of diametrically opposed pipe supports, each having at least one beam provided with a row of separate pipe-engaging shoes and a continuous, longitudinally extending, elongated element;

a pair of longitudinally spaced expansion assemblies disposed between the supports for moving the latter radially outwardly in diametrically opposite directions;

means connecting the elements with the assemblies for outward movement of the elements by the assemblies; and

means coupling each row with its corresponding element for normally holding the shoes in a straight line extending longitudinally of the body and for outward movement of each row of shoes as a unit by its element, said elements being flexible for longi-

tudinal deformation of the beams in response to the bending of the pipe into arcs conforming to the curvatures of the bend in the pipe while the shoes are held against the pipe by said assemblies.

6. In a pipe bending mandrel having an elongated body adapted for insertion into a pipe to be bent, said body comprising:

a pair of diametrically opposed, pipe-engaging supports, one of the supports having a plurality of side-by-side, parallel beams, each beam being provided with a continuous, longitudinally extending, elongated bar, a plurality of continuous, longitudinally extending, elongated, parallel strips spaced radially outwardly from the bar, and a row of separate shoes between the strips and the bar;

a pair of longitudinally spaced expansion assemblies disposed between the supports and each provided with a plurality of radially reciprocable rams;

means connecting each bar with one ram of each assembly respectively for outward radial movement of the bars by the rams; and

means connecting the strips with corresponding bars for clamping the shoes in place and normally holding the same in straight lines extending longitudinally of the body and for outward movement of each row as a unit by its bar, said bars, said strips and the other of said supports all being flexible for longitudinal deformation of the beams and the other support in response to the bending of the pipe into arcs conforming to the curvatures of the bend in the pipe while the supports are held against the pipe by said assemblies.

7. A collapsible mandrel adapted for expansion inside a pipe to support the latter for bending and for flexing with the pipe during bending, said mandrel comprising:

a pair of spaced expansion units, each having an annular row of shoes, and each having mechanism for moving its shoes radially outwardly against the inner face of the pipe;

structure interconnecting the units; and

flexible means for preventing wrinkling of the pipe during bending, said means spanning the distance between the units and being disposed for movement against the pipe by the mechanisms as the shoes are moved outwardly.

8. A collapsible mandrel adapted for expansion inside a pipe to support the latter for bending and for flexing with the pipe during bending, said mandrel comprising:

a flexible body of uniform diameter throughout its length, said body including a plurality of annular rows of shoes;

a series of strips of resilient material extending longitudinally of the body, said strips connecting the shoes of each row with the shoes of adjacent rows; and

means for exerting radial thrust on the shoes for forcing the shoes and the strips against the pipe.

9. A collapsible mandrel adapted for expansion inside a pipe to support the latter for bending and for flexing with the pipe during bending, said mandrel comprising:

an elongated, flexible body of uniform diameter throughout its length, said body including a plurality of side-by-side, longitudinally extending, flexible beams, each of said beams having a longitudinally row of adjacent pipe-engaging blocks and a resilient, pipe-engaging strip extending longitudinally of the body, together with means attaching the strip to the blocks, at least certain of the blocks of each beam having means coupled therewith for reciprocating the beams radially of the body, said blocks being disposed to engage a substantial area of said pipe longitudinally thereof to provide support for the area during bending of the the pipe at said area.

10. For use in bending pipe, a mandrel for maintaining the pipe smooth and cylindrical at the zone of bend, while flexing with the latter therewithin during bending, said mandrel including:

an elongated body having an upper and a lower longitudinal, transversely arcuate, series of side-by-side assemblies, each of said assemblies being provided with an arcuate row of pipe-engaging blocks normally concentric to the longitudinal axis of the body, said blocks being disposed to engage a substantial portion of the upper and lower areas of the pipe;

flexible pipe-engaging elements extending longitudinally of the body and connected to said assemblies; and

a pair of units supporting the blocks for radial movement of the latter and said elements into and out of engagement with the pipe, said units being spaced longitudinally of the body whereby the body flexes between the units during bending of the pipe.

11. For use in bending pipe, a mandrel for maintaining the pipe smooth and cylindrical at the zone of bend, while flexing with the latter therewithin during bending, said mandrel including:

an elongated, generally cylindrical body having a succession of side-by-side, transversely arcuate, circumferentially extending rows of resilient, pipe-engaging blocks throughout its length in substantially concentric relationship to the longitudinal axis of the body;

means connected with each block of a spaced pair of said rows for shifting the same radially into tightly clamped engagement with the pipe, said blocks being disposed to engage a substantial area of the pipe; and

flexible pipe-engaging means connecting the remaining rows with said pair of rows for movement therewith into and out of engagement with the pipe, whereby said remaining rows yield to the bending of the pipe in response to deforming of said flexible means as said pair of rows remain clamped tightly to the pipe.

12. For use in bending pipe, a mandrel for maintaining the pipe smooth and cylindrical at the zone of bend, while flexing with the latter therewithin during bending, said mandrel including:

an elongated body having an arcuate series of longitudinally extending, flexible, pipe-engaging strips, together with spaced annular rows of pipe-engaging blocks, with said series and said rows in substantially concentric relationship to the longitudinal axis of the body;

means connecting each strip with one block of each row; and

means for each row respectively and circumscribed thereby for moving the blocks and strips radially outwardly into engagement with the pipe.

13. For use in bending pipe, a mandrel for maintaining the pipe smooth and cylindrical at the zone of bend, while flexing with the latter therewithin during bending, said mandrel including:

an elongated body having an arcuate series of longitudinally extending, flexible pipe-engaging strips, together with spaced annular rows of pipe-engaging blocks, with said series and said rows in substantially concentric relationship to the longitudinal axis of the body;

means connecting each strip with one block of each row;

means for each row respectively and circumscribed thereby for moving the blocks and strips radially outwardly into engagement with the pipe; and

means disposed in diametrically opposed relationship to said series and connecting said rows for limiting the extent of movement of the latter toward and away from each other.

14. A mandrel adapted for insertion into a pipe to be bent and comprising:

a substantially cylindrical body having a pair of longitudinally extending, diametrically opposed, transversely arcuate pipe supports, each having a number of rows of side-by-side, pipe-engaging blocks, one

support having a plurality of flexible pipe-engaging strips mounted on the blocks thereof; and

structure between the supports for moving the same radially outwardly in opposite directions until the blocks and strips engage the pipe.

15. In pipe-bending apparatus for insertion into a pipe which is to be bent, an expansible mandrel having the same cross-sectional shape as the pipe to be bent and including:

a pair of spaced expansion units each having a series of spaced rams reciprocable simultaneously toward and away from the pipe and each having a row of pipe-engaging pads surrounding the same with each pad secured to the outermost end of a corresponding ram for reciprocation therewith, presenting a continuous band when the unit is contracted, with the pads disposed in side-by-side relationship; and

flexible means bridging the units and connected therewith for engagement with the pipe when the units are expanded.

16. In apparatus of the kind described:

an elongated mandrel having the same cross-sectional area of a pipe into which the same is to be inserted during bending of the latter, said mandrel including:

a plurality of side-by-side, arcuate rows of pads having outermost pipe-engaging faces,

said rows being concentric with the longitudinal axis of the mandrel and extending throughout the length of the latter,

certain of said rows being continuous and annular in surrounding relationship to said axis,

the remaining rows being interposed between the continuous rows,

certain of the pads being resilient and disposed to present a number of straight, longitudinal, side-by-side series of end-to-end pads at the top of the mandrel,

certain of the pads being disposed to present a number of straight, longitudinal, side-by-side series of end-to-end pads at the bottom of the mandrel,

each of said series of pads having a flexible bar extending longitudinally of the mandrel along the inner faces of the pads thereof,

each pad of each series at the bottom of the mandrel being connected with the corresponding bar,

each of said series of pads at the top of the mandrel having a number of flexible strips extending longitudinally of the mandrel along said outermost faces thereof,

means clamping the pads of each of said series at the top of the mandrel between their strips and their bars,

each pad of each continuous row having a radially reciprocable device for moving the same radially outwardly to force all the pads and all the strips against the pipe.

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