

[54] **APPARATUS FOR PRECISION BENDING OF PLASTIC PIPE**

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[51] Int. Cl. **B29c 17/00**

[58] Field of Search **425/384, 174, 392, 425/162, 395, 343, 342; 72/388; 264/89, 94, 339, 295; 65/292, 296**

[56] **References Cited**

UNITED STATES PATENTS

1,877,629	9/1932	Replogle	264/94
3,671,161	6/1972	Kostur et al.	425/388
3,352,960	10/1967	McLaughlin	264/339
3,362,860	2/1971	Rottner et al.	425/384
2,433,055	12/1947	Linden et al.	263/5 R

3,184,796 5/1965 Southcott et al. 425/384

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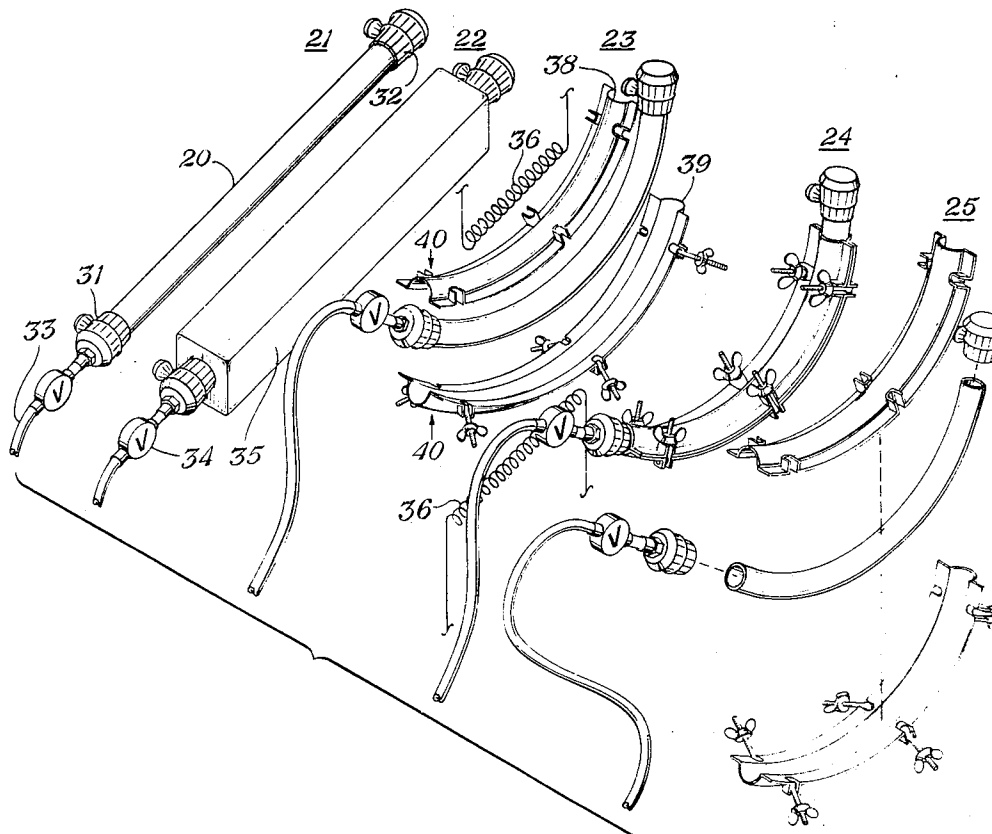
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[57] **ABSTRACT**

The specification discloses a process and system for bending plastic pipe to form a desired elbow. In one embodiment there is imposed a super atmospheric pressure within the interior of a segment of the pipe by applying a fluid pressure to the interior of the pipe. The segment of the pipe is heated to its softening temperature and then bent to a predetermined degree of bend while maintaining the fluid pressure on the interior wall to form an elbow with a minimum of distortion of the side walls. Bending is carried out in conformance with a jig. With the formed elbow in the jig, it is cooled while maintaining the fluid pressure on the interior walls. The fluid pressure then is removed and the elbow is released from the jig.

10 Claims, 15 Drawing Figures



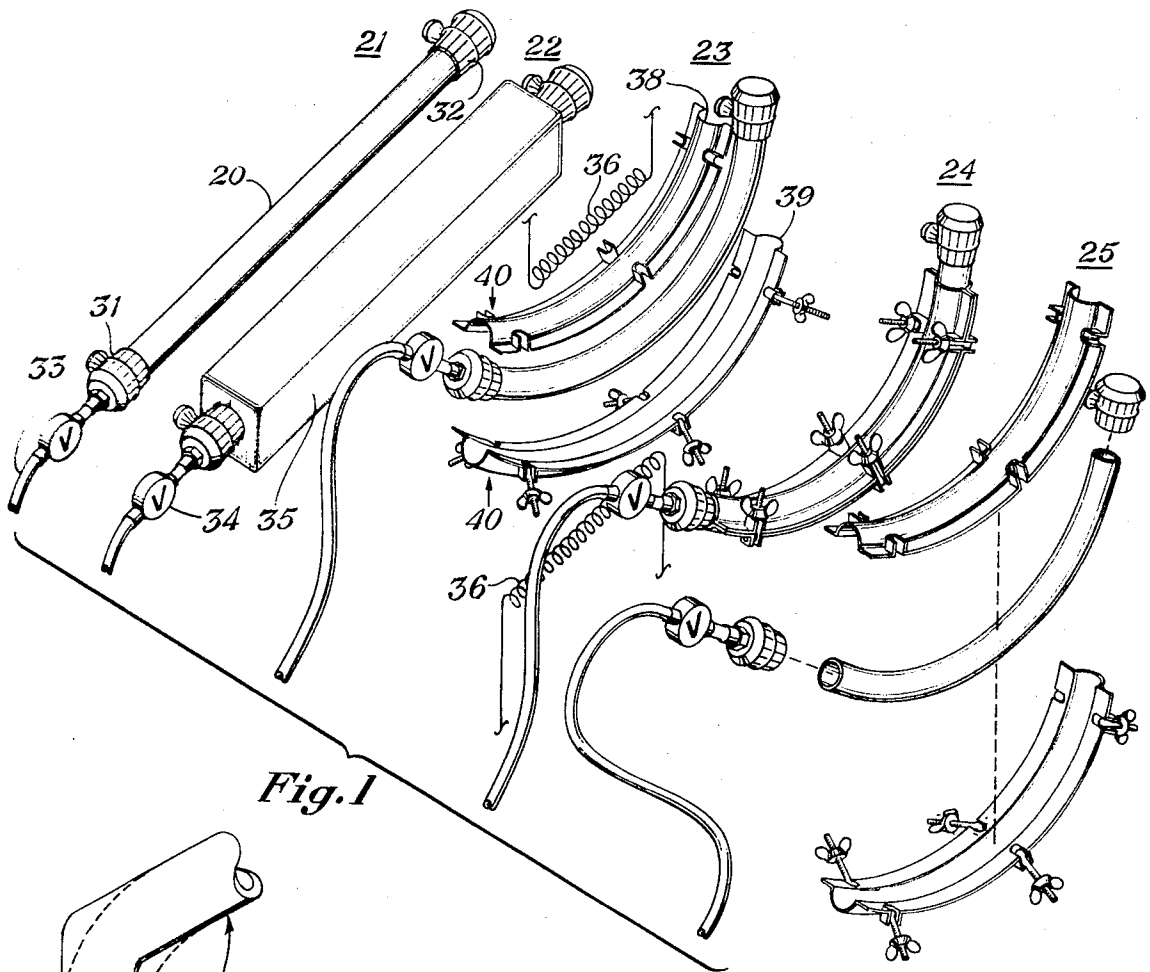


Fig. 1

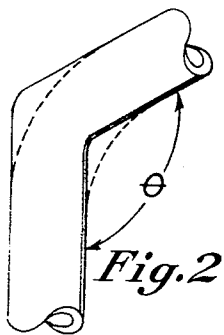


Fig. 2

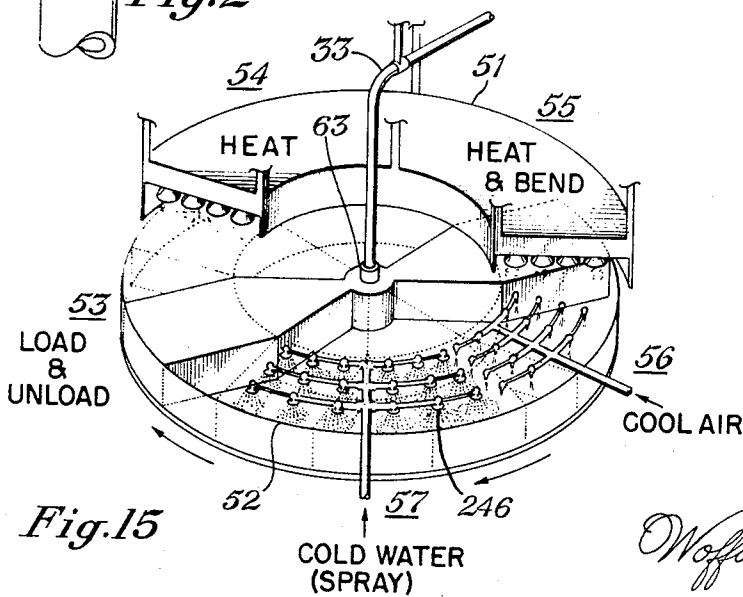


Fig. 15

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Fig. 5

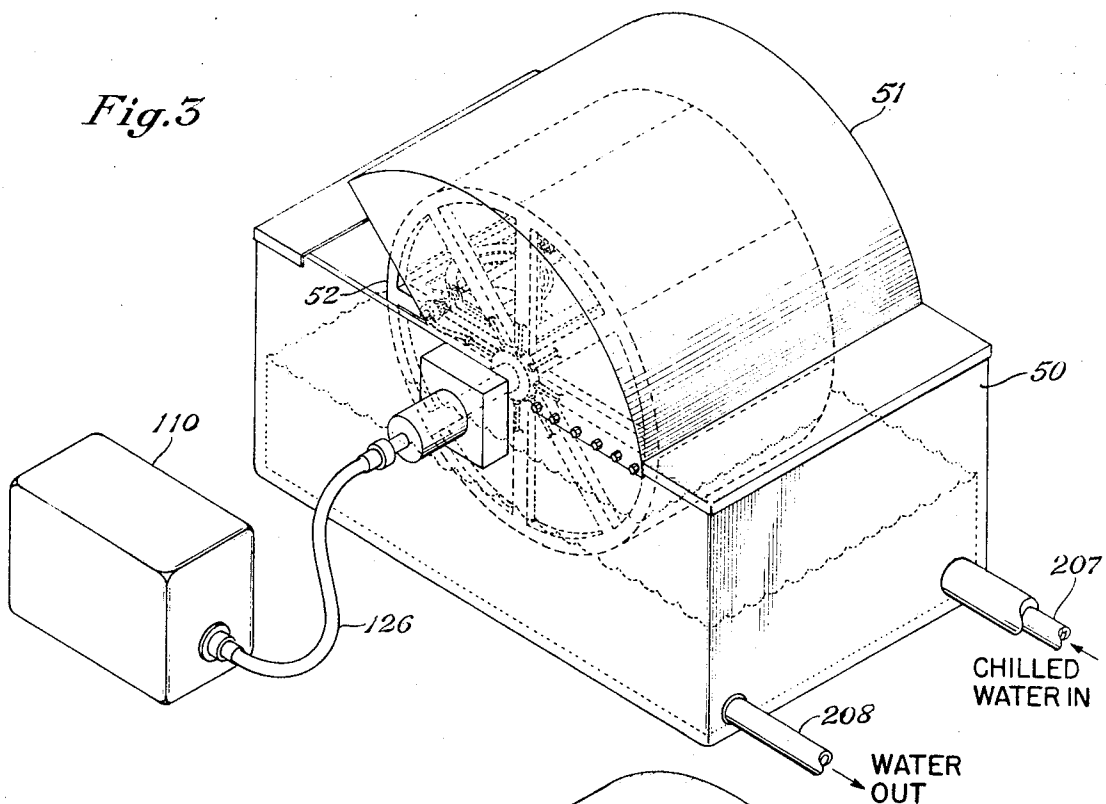
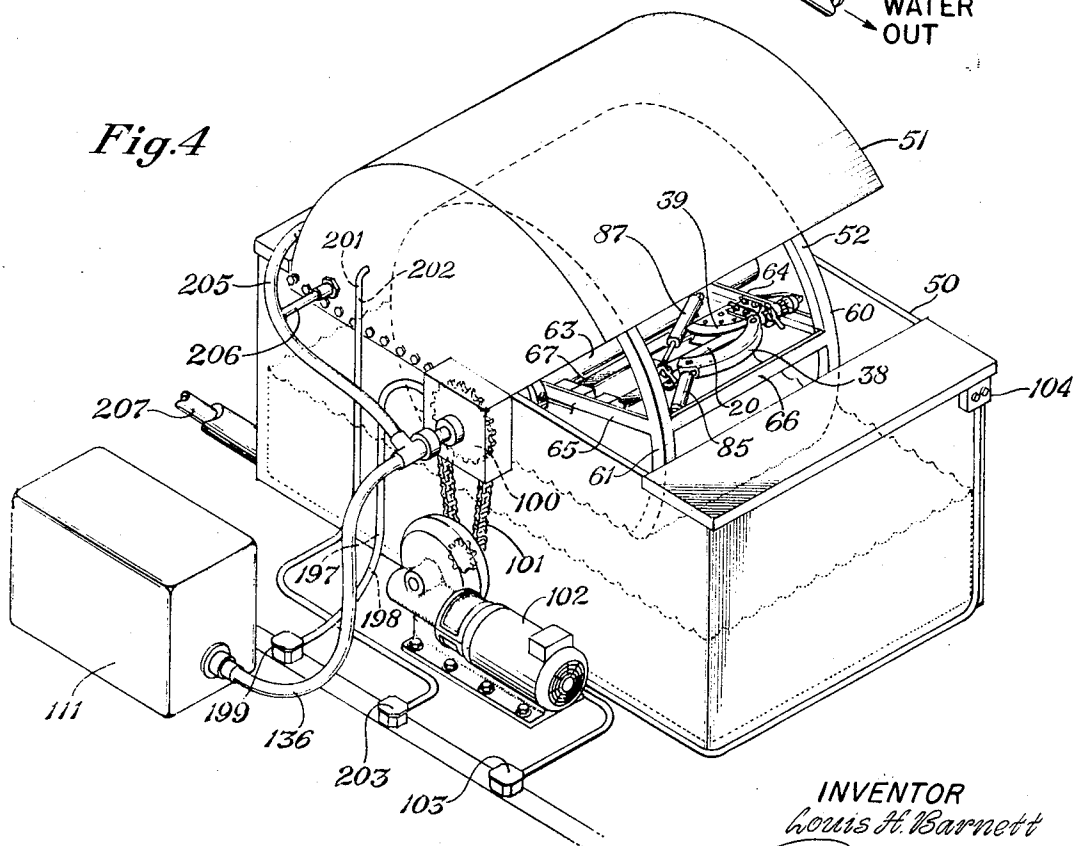


Fig. 4



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Fig.6

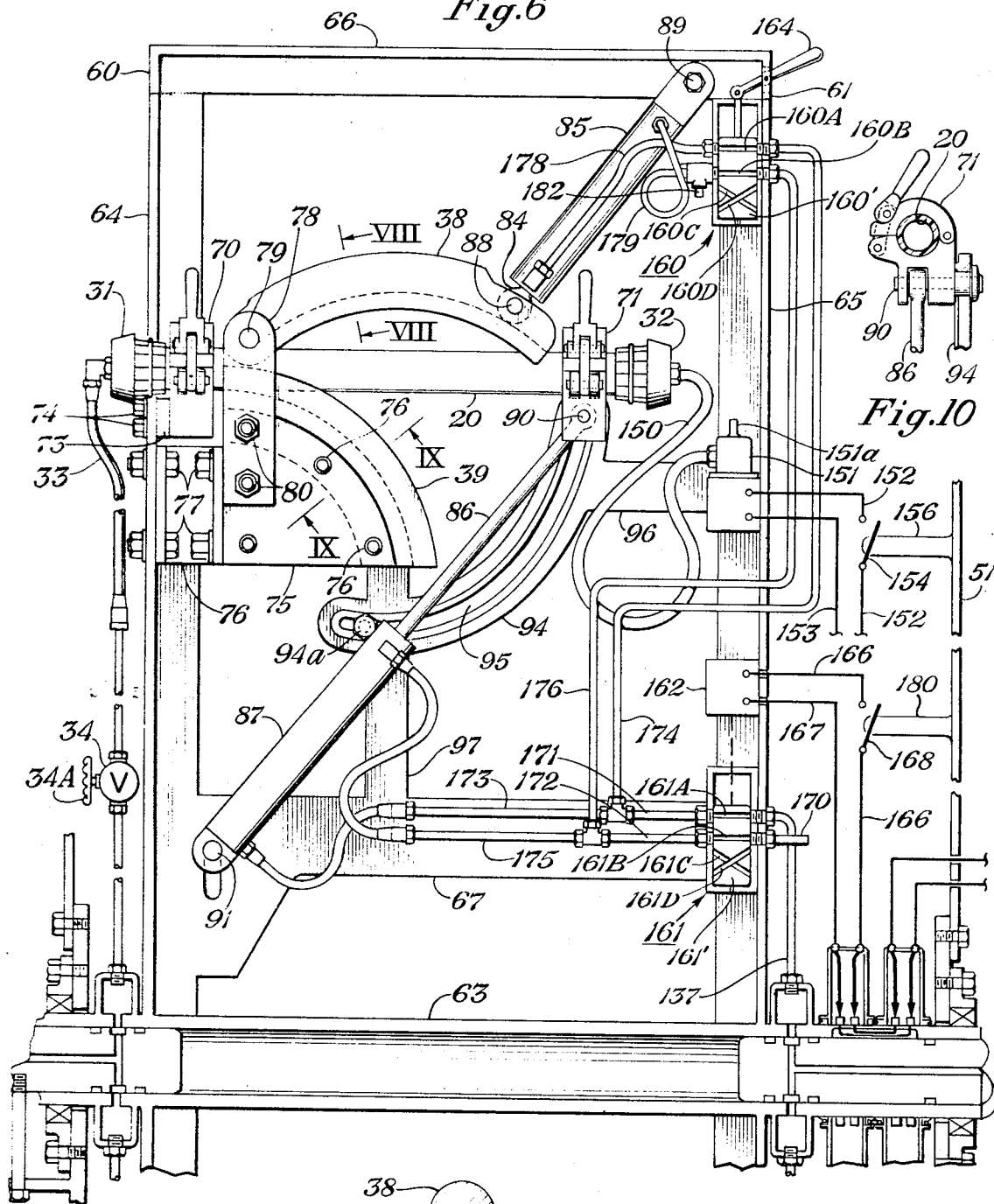


Fig.10

Fig. 8

Fig. 7

Fig.9

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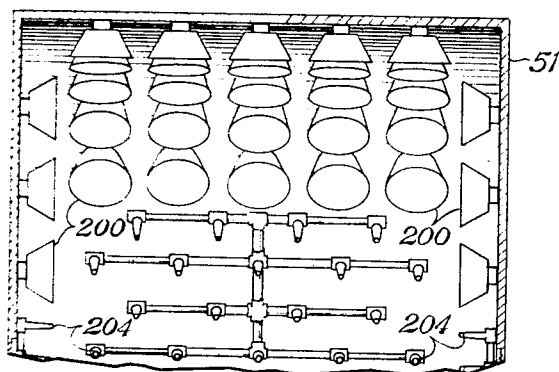


Fig. 13

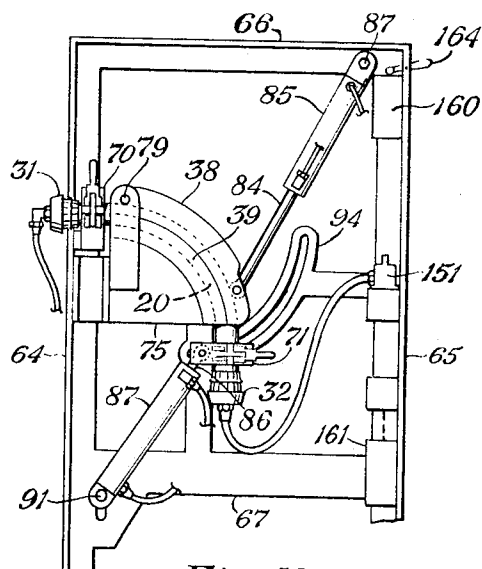


Fig. 12

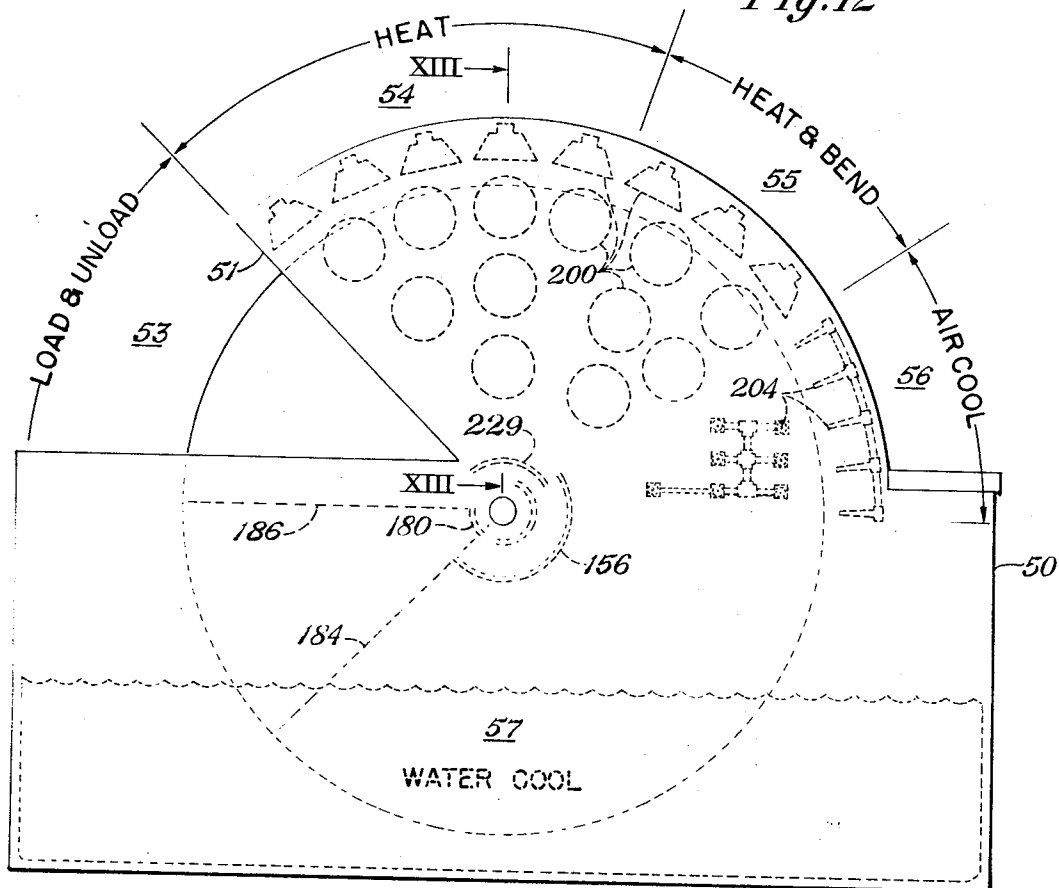
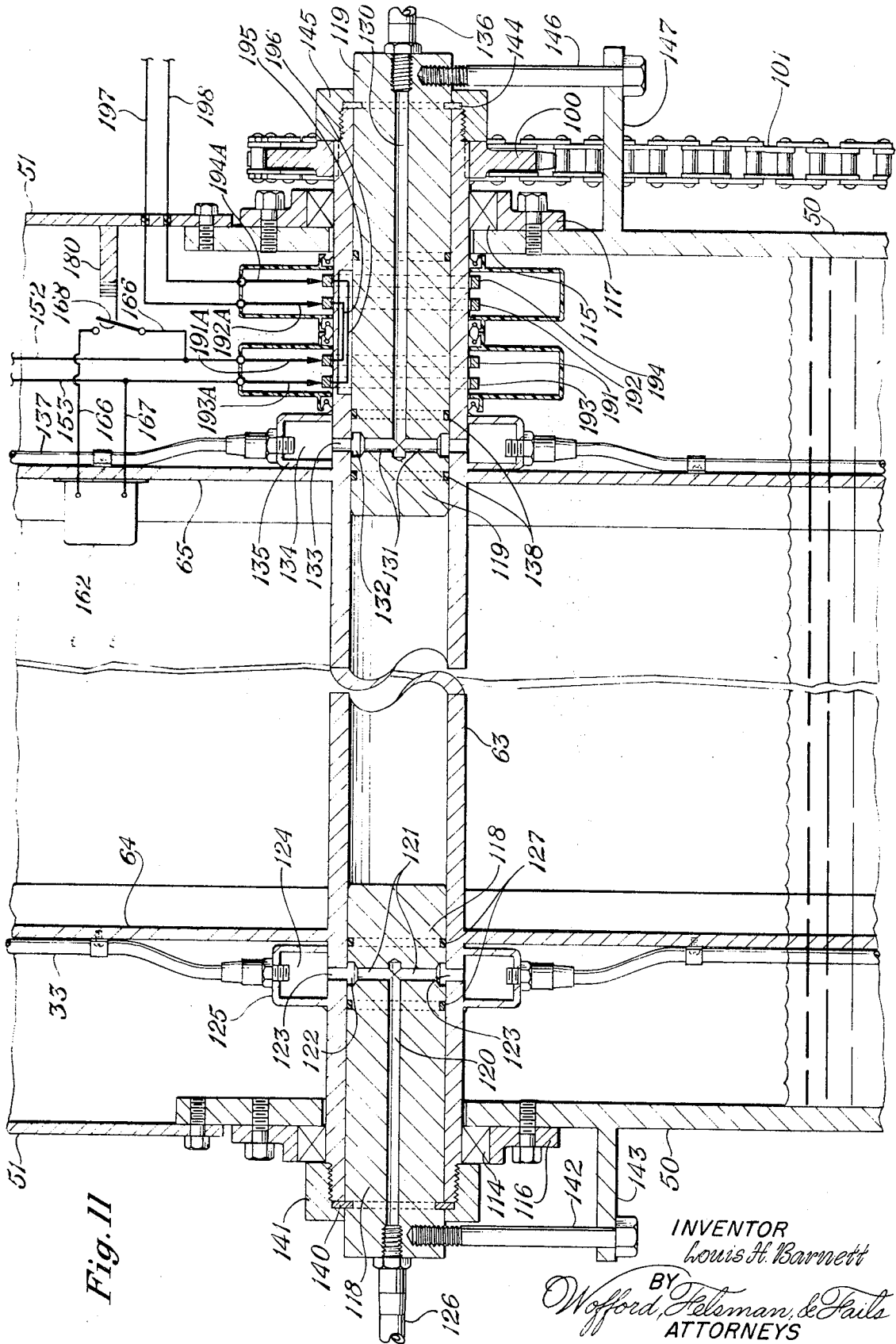
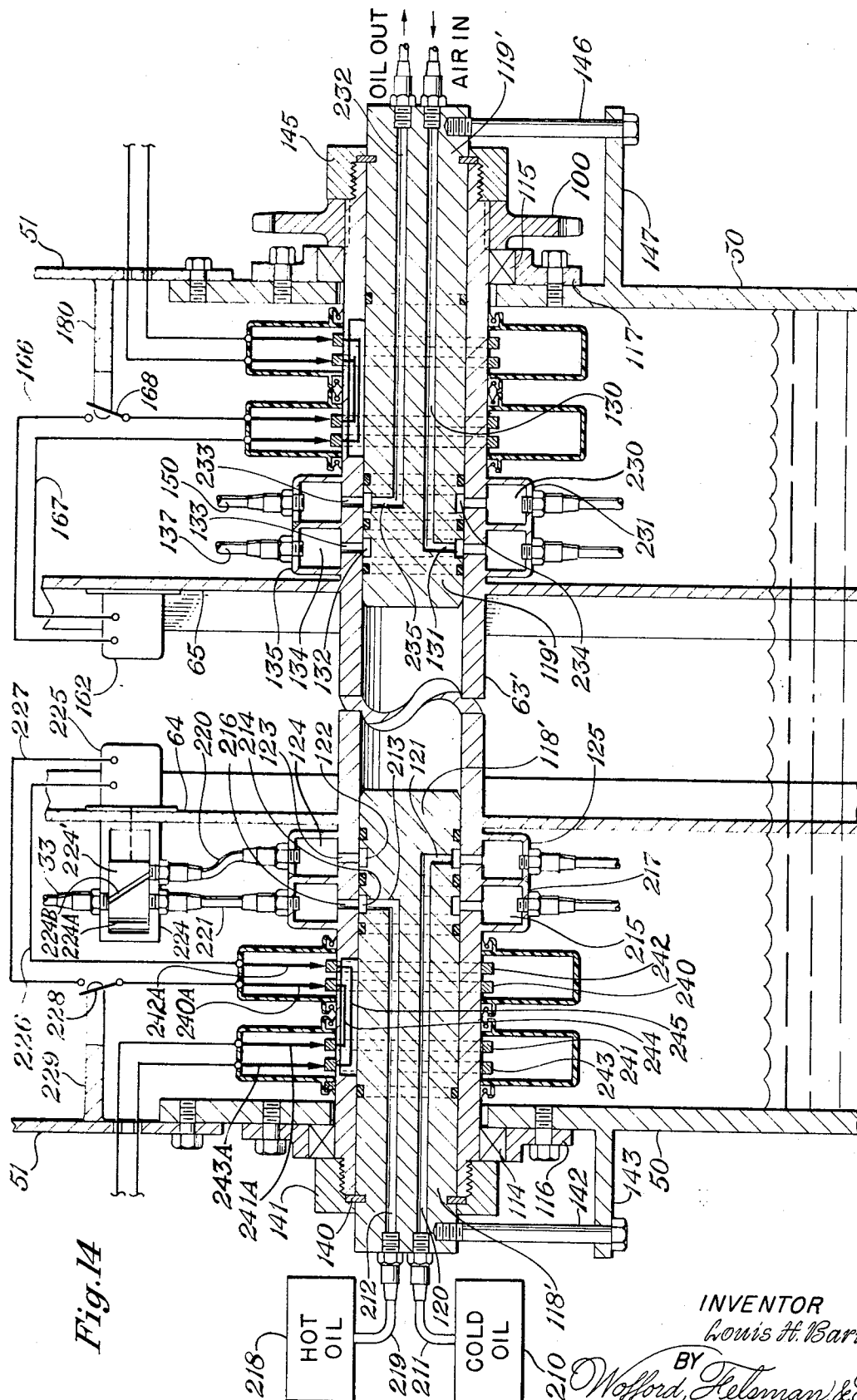


Fig. 5

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APPARATUS FOR PRECISION BENDING OF PLASTIC PIPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the bending of pipe and more specifically to the bending of plastic pipe to form a predetermined elbow with a minimum distortion of the side walls.

2. Description of the Prior Art

Plastic pipe formed from thermoplastic materials have been used increasingly for many applications; for example, for electrical conduits and for fluid flow conduits in many fields. Needed for this purpose are elbow segments bent to various angles for turning corners. Hertofores, the elbows have been formed by manually heating and bending the conduit sections to form each elbow. This has required skilled labor and has resulted in poor quality control with a high rate of rejection. Hence, the elbows formed in this manner have been expensive; and, moreover, the elbows produced have disadvantages in that the side walls and cross-section frequently are distorted in the region of the bend. One example will serve to illustrate an objection to such distortion. When such conduits are used for extended periods for flowing certain liquids, material from the liquids builds up or becomes deposited on the interior wall surfaces thereby restricting the flow. Hence, it becomes necessary to flow balls known as "pigs" through the conduit for cleaning purposes. If the elbows of the conduits have side walls which are distorted, the pigs will become stuck or lodged in the elbows thus prohibiting the use of pigs for cleanout purposes.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a technique and system for bending plastic pipe or conduits into the form of a desired elbow with a minimum of distortion of the side walls. In carrying out the process, there is established a pressure differential across the walls of a segment of a conduit to be bent, the higher pressure being on the interior. The segment of conduit is heated to its softening temperature along a length sufficient for an arc of a desired degree of bend. While maintaining the pressure differential across the walls, the segment of conduit is bent, while at its softening temperature, to a precisely determined degree or bend in conformance with at least an interior jig means to form a precision elbow with a minimum of distortion of the side walls. The formed elbow is cooled while maintaining the pressure differential. The pressure then is equalized and the elbow is released from engagement with the jig.

The system for bending the plastic conduit to form the desired elbow comprises a differential pressure inducing means for establishing a pressure differential across the walls of a segment of conduit with the higher pressure being on the interior thereof. The differential pressure inducing means is operable to maintain the differential pressure while the segment of conduit is being subjected to a heating means, a bending means, and a cooling means. In the embodiment disclosed, the conduit is loaded in a jig assembly and rotated to a heating location, a heating and bending location, and a cooling location to carry out the desired operations.

In one aspect, the pressure differential is established by imposing a super atmospheric pressure within the

interior of the segment of conduit. In one embodiment, this pressure is obtained by applying gas under pressure to the interior of the segment of conduit. While under this pressure, the conduit is moved to a heating location and then to a heating and bending location, each location having heating means for applying heat to the outer walls of the conduit. The formed elbow then is moved to a cooling location which comprises gas and liquid cooling means. Liquid cooling may be obtained with a bath or spray of cooled liquid. The cooled elbow then is moved to a loading and unloading location where the pressure is removed and the elbow removed from the jig.

In a further aspect, the pressure is applied to the interior walls of the conduit by flowing a liquid through the conduit. Initially, a liquid hot enough to soften the plastic to its softening temperature is passed through the conduit. In this state, and while the hot liquid is flowing through the conduit, the conduit segment is bent to form the desired elbow. Following bending, a cool liquid is passed through the conduit to cool and harden the plastic while maintained in the desired elbow configuration. Following cooling, the liquid flow is terminated and the formed elbow is removed from the system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates in simplified form, the process of one embodiment of the present invention;

FIG. 2 illustrates two types of bends which may be formed in plastic pipe;

FIG. 3 is a partial side and rear view of the system of one embodiment of the present invention;

FIG. 4 is a partial side and front view of the system of FIG. 3;

FIG. 5 is a cross-sectional side view of the system of FIGS. 3 and 4;

FIG. 6 is a detailed illustration of one section of the rotating wheel of the system of FIGS. 3 and 4;

FIG. 7 illustrates a side view of one of the clamps employed in the section of FIG. 6;

FIGS. 8 and 9 are cross-sectional views of the jigs of FIG. 6 taken through the lines 8—8 and 9—9 thereof;

FIG. 10 illustrates an end view of the movable clamp and arcuate guide of FIG. 6;

FIG. 11 is an enlarged cross-sectional view of the axle of the system of FIGS. 3, 4, and 6;

FIG. 12 is a partial view of the section of FIG. 6 showing the bending jigs closed about a bent plastic conduit;

FIG. 13 is a cross-sectional view of FIG. 5 taken through the lines 13—13 thereof and illustrating more clearly the heating lamps and air nozzles employed in the system;

FIG. 14 illustrates a modification of the system of FIG. 11 for flowing hot and cold oil through the plastic conduits; and

FIG. 15 illustrates a further modification for rotating the plastic conduits about a vertical axis to the heating, bending and cooling locations situated in a horizontal plane.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

Referring now to FIGS. 1 and 2, there will be described briefly the process of the invention for bending a segment of a pipe or conduit 20 to a desired elbow.

By elbow is meant a configuration formed by a conduit bent to various angles illustrated by θ in FIG. 2. The angle of bend θ may be for example 45°, 90°, 120°, etc. In addition, the bends may be smooth or sharp, illustrated in dotted and solid lines respectively in FIG. 2. The conduit 20 is formed of any thermoplastic material which may be softened by heat then hardened by cooling. The thermoplastic material is, of course, sufficiently rigid to serve in the application of, or use, as a pipe or conduit. The material, for example, may be poly vinyl chloride; polystyrene; acrylonitrile butadiene styrene copolymer; or the poly olefinics such as polyethylene, polypropylene; or other homopolymers and copolymers identified as thermoplastic in nature.

In carrying out the process, the conduit 20 is moved to a plurality of locations or stations, illustrated in FIG. 1 as a loading location 21, a heating location 22, a heating and bending location 23, a cooling location 24, and an unloading location 25. At the loading location 21, both ends of the conduit 20 are capped by caps illustrated at 31 and 32. The conduit 20 may have its ends threaded and the caps threaded onto the ends or the caps may be clamped onto the ends of the conduit.

At the heating, bending and cooling locations, a differential pressure is established across the walls of the conduit, the higher pressure being on the interior thereof. This is done to minimize or eliminate distortion of the side walls of the conduit as it is heated, bent and cooled. Conduit 33 extending through the cap 31 is employed for establishing the increased pressure on the interior walls of the conduit 20. The pressure may be established by maintaining the exterior of the conduit 20 in a vacuum or a partial vacuum and exposing the interior to atmospheric pressure by way of conduit 33. In the preferred embodiment, however, the exterior of the conduit 20 is maintained at atmospheric pressure and a fluid pressure is applied to the interior of the conduit 20 by way of conduit 33. The remaining description will be directed to this preferred embodiment.

In one embodiment the increased pressure to the interior of the conduit 20 is established by applying a gas under pressure to the conduit 20 by way of conduit 33. The pressure is relatively low but high enough to prevent the walls from becoming distorted as the conduit is heated, bent and cooled. The differential pressure is proportioned to such factors as wall thickness, degree of softness of the wall, and the completeness of the jig, or mold, surrounding the softened conduit. For example, only a few ounces per square inch may be adequate with thin walled conduit and only an interior jig, whereas several pounds per square inch gauge (psig) differential pressure may be advisable with an enclosing mold or with thick walled conduit. The pressure may be controlled by any suitable means, as by a regulator 34 on the line directly or on a main source to which the conduit 33 is connected. Having established the increased pressure on the interior of the conduit 20, it is moved to the heating location 22 where it is heated to its softening temperature by a heater illustrated at 35.

After the conduit 20 has been heated to its softening temperature it is moved to the heating and bending location 23 where the pressure is maintained on the interior of the conduit; heat is maintained by heating elements illustrated at 36; and the conduit is gradually bent into the desired elbow by means of a jig assembly which comprises interior jig, or die, 38 and an exterior

jig, or die, 39. Both of these jigs have concave half-sections which conform to the diameter of the conduit 20. Bending may be accomplished by moving the jig halves 38 and 39 gradually together as indicated by the opposing arrows 40. In the preferred embodiment, the jig 39 is maintained stationary while the jig 38 is moved toward the jig 39, in abutting relationship therewith. The gas pressure on the interior of the conduit 20 pushes outward on the conduit walls to maintain the walls in conformance with the concave surfaces of the jig.

After jig 38 has been moved adjacent jig 39 and the conduit 20 bent to the desired shape determined by the jigs 38 and 39, the jig assembly and the conduit 20, in its desired elbow shape, is moved to the cooling location 24. At this location the formed elbow may be cooled in a number of ways such as applying cool air to the exterior of the assembly and then by applying the formed elbow to a bath or spray of cool water. During cooling, the increased pressure is maintained on the interior walls of the conduit 20. Following cooling, the formed elbow and jig assembly is moved to the unloading location 25 where the jig assembly is disassembled and the caps removed from the ends of the conduit. Following disassembly, the formed elbow is moved into supply for storage or shipment. The cycle is repeated to bend another conduit.

In the preferred embodiment, a system is provided for moving a plurality of conduits through the various locations or stations whereby a plurality of the conduits may be operated on at the various locations simultaneously to increase production.

Referring now to FIGS. 3-5, the system, in one embodiment, for bending the plastic pipe or conduit to the desired elbow comprises a tank 50 having a hood 51 coupled thereto and supporting a wheel 52 which is rotated about a horizontal axis. The wheel 52 comprises a plurality of sections, for example, 8 sections for holding a plurality of conduits to be subjected to the steps described hereinbefore, as they are moved or rotated to the plurality of operating locations or stations. In the system of FIG. 5, these locations comprise a loading and unloading location 53, a heating location 54, a heating and bending location 55, and a cooling location comprising an air cooling location 56 and a water cooling location 57.

The supporting wheel 52 comprises two rims 60 and 61 (FIGS. 4 and 6) which are coupled to an axle 63 by way of a plurality of spokes, two of which are illustrated at 64 and 65. The rims 60 and 61 also are coupled together by way of a plurality of cross bars, two of which are illustrated at 66 and 67. Each pair of spokes and associated cross bars comprises a section for supporting a conduit 20 as it is moved through the various heating, heating and bending, and cooling locations. One such section is illustrated in FIG. 6.

At each section there is located two clamps 70 and 71 and the jigs 38 and 39 for holding and bending a conduit 20. As seen in FIG. 7, clamp 70 is of the conventional type having a member 70A which is hinged for movement relative to member 70B for opening and closing the clamp. These members have concave surfaces 70C and 70D which together conform to the outer circumference of the conduit 20. A handle 70E is provided for clamping the members. Clamp 71 is illustrated in FIG. 10.

As seen in FIGS. 8 and 9, jigs 38 and 39 also have smooth concave surfaces 38A and 39A, respectively, which conform to the outer circumference of the conduit 20.

Clamp 70 is fixedly carried by the section and clamp 71 is moveably carried by the section. Also the interior jig 39 is fixedly carried by the section. The term "interior jig" is employed herein to mean the jig about which the conduit will be bent. The "interior jig" has its receiving surface defining a convex bend, for effecting the inside arc of an elbow. Clamp 70 is secured to the spoke 64 by way of plate 73 and bolts 74. Jig 39 is secured to spoke 64 by way of support 75, an eyebeam 76 and bolts 77. Jig 38 is pivotally coupled to jig 39 by way of supports 78 (only one of which is shown in FIG. 6), and pivot member 79 which extends through supports 78 and jig 38. Supports 78 are coupled to the support 75 by way of bolts 80. Jig 38, thus, may be moved away from and toward jig 39 to define an enclosing mold for the elbow bent to the desired shape.

A piston rod 84 and cylinder 85 are provided for moving the jig 38 while a piston rod 86 and cylinder 87 are provided for moving the clamp 71. Piston rod 84 is pivotally coupled to jig 38 by way of pivot member 88 while the cylinder 85 is pivotally coupled to cross bar 66 by way of pivot member 89. Piston rod 86 is pivotally coupled to the lower portion of the clamp 71 by way of pivot member 90 while the cylinder 87 is pivotally coupled to the lower cross bar 67 by way of pivot member 91.

Also provided is an arcuate guide 94 having a center slot 95 which guides the extending portion of pivot member 90 as shown more clearly in FIG. 10. Guide 94 is secured to spoke 65 and lower cross bar 67 by way of members 96 and 97, respectively. Thus, clamp 71 may be moved along an arcuate path to bend the conduit 20 into the desired shape about jig 39 and within its concave surface 39A.

At the loading location jig 38 and clamp 71 are in the positions illustrated in FIG. 6. Loading is carried out by opening the clamps 70 and 71 and inserting the conduit 20 between the open jigs 38 and 39. The clamps then are closed and the caps 31 and 32 are applied to the ends of the conduit 20. The wheel 52 is then moved to the various locations mentioned before for carrying out the bending operation.

As shown in FIG. 4 a drive system comprising a sprocket wheel 100, secured to the axle 63, a driving member such as a chain 101 and a motor and gear system 102 driven by a power source 103 is provided for rotating the wheel 52. The axle 63 is supported by bearing means secured to the wall of the tank 50. A start-stop control 104 is provided for controlling the rotation of the wheel 52. For example, at the loading and unloading location the control 104 may be actuated to stop rotation of the wheel 52 whereby a conduit 20 may be loaded in the clamps and jig arrangement. After it is loaded then the control 104 may be actuated to start rotation of the wheel 52. In FIG. 4 rotation is in the counter-clockwise direction.

When a conduit 20 is being loaded, valve control 34A (see FIG. 6) is closed to stop the flow of air through conduit 33. After the caps 31 and 32 have been placed on the ends of the conduit 20, the valve control 34A may be opened to pressurize the interior of the conduit.

A universal coupling means rotatably connected to sources of air pressure is provided for applying air continuously to each conduit 20 and to each pair of cylinders 85 and 87 during each cycle of wheel 52. The term "universal coupling means" is employed herein in the sense of a rotating joint that allows sealing interconnection between the respective elements regardless of the angle through which the apparatus is rotated. The universal coupling is referred to hereinafter as "rotating joint". In FIG. 6, it maintains the source of air pressure connected to each conduit and to each pair of cylinders 85 and 87 throughout the rotation of the wheel 52. The rotating joints are illustrated in and the elements thereof are specifically described with respect to FIGS. 6, 11 and 14, hereinafter. In addition, a switching system is employed to control the flow of air through each conduit 20 and the application of air to the cylinders 85 and 87 during each cycle of the wheel 52 to carry out the desired bending operation.

Referring to FIGS. 3 and 4, a low pressure source or compressor 110 is provided for applying low pressure air to the interior of the conduit 20. A higher pressure source or compressor 111 is provided for applying high pressure air to the cylinders 85 and 87. Air is applied from the compressor 110 to the conduits 20 and from the compressor 111 to the cylinders 85 and 87 by way of rotating joints, or universal couplings, formed in opposite ends of the axle 63. These rotating joints are illustrated in FIG. 11. As can be seen in FIG. 11, the axle 63 extends through the side walls of the tank 50 and is supported for rotation by bearings 114 and 115 which are supported by members 116 and 117, respectively. These members are secured to the side wall structure of the tank 50. Stationary cores 118 and 119 extend partially into opposite ends of the axle 63. Core 118 has an axial aperture 120 formed therein which connects with a plurality of radial apertures 121 which in turn extend to a circumferential slot 122. Extending through the axle 63 are a plurality of apertures 123 forming passageways from the slot 122 to an annulus 124 formed by annular member 125 which is secured to the exterior of axle 63 for rotation therewith. The conduit 33 as well as the corresponding conduits for the other sections are coupled to the member 125 in communication with the annulus 124. Air conduit 126 (see FIG. 3 also) extends from air compressor 110 to the axial aperture 120 formed in the core 118. Thus, as the axle 63 and, hence, as the wheel 52 rotates, air is supplied to the plastic conduits 20 by way of conduit 126 axial aperture 120, radial apertures 121, circumferential slot 122, apertures 123, annulus 124 and conduits 33. O-rings 127 prevent the leakage of air between core 118 and the axle 63.

The rotating joint formed in the other end of the axle 63 is similar and comprises stationary core 119 having an axial aperture 130 which connects with a plurality of radial apertures 131 which in turn extend to a circumferential slot 132. Extending through the axle 63 are a plurality of apertures 133 which form a passageway between the slot 132 and an annulus 134 formed by annular member 135. This member is secured to the axle 63 for rotation therewith. Conduit 136 (see FIG. 4 also) extends from the air compressor 111 to the axial aperture 130 while conduits 137 are coupled to member 135 in communication with the annulus 134. Thus, air is supplied from the air compressor 111 to the conduits 137 by way of conduit 136, axial aperture 130, ra-

dial apertures 131, circumferential slot 132, apertures 133, and annulus 134. O-rings 138 prevent leakage of air between axle 63 and core 119. Conduits 137 are in communication with the cylinders 85 and 87 of each section of the wheel 52 as will be described subsequently.

A retaining ring 140 prevents the core 118 from sliding axially with respect to the axle 63. This ring is supported in a circumferential slot formed in the core 118 and between the end of the axle 63 and an end cap 141 threaded to the end of the axle 63. Core 118 is prevented from rotating by a bolt 142 threaded into the core and extending through a support member 143 secured to the wall structure of the tank 50.

Similarly, retaining ring 144 prevents the core 119 from sliding axially with respect to axle 63. This ring is supported in a circumferential slot formed in the core 119 and between the end of the axle 63 and an end cap 145 threaded to the end of the axle 63. Core 119 is prevented from rotating by a bolt 146 threaded into the core and extending through a support member 147 secured to the other side wall structure of the tank 50. Sprocket wheel 100 is secured to the axle 63 by means such as conventional key and lock slot (not shown).

During each cycle of operation, air is fed to conduits 33 continuously through the rotating joint formed through core 118 and annulus 124. During loading and unloading, valve controls 34A are closed to stop the flow of gas to the conduits 20 to be loaded or unloaded. After loading, valve controls 34A are opened and during the heating, bending, and cooling cycle, air is continuously applied to the conduits 20 by way of open conduits 33.

At each section, a flexible conduit 150 extends from the end cap 32 and leads to a solenoid controlled or actuated valve 151 having a vent 151A. (see FIG. 6) This valve is closed when the conduit 20 passes through the heating location 54 and the heating and bending location 55. Thus, air is prevented from flowing through the conduit 20 when it passes through these two locations. The valve 151, however, is opened when the conduit 20 passes through the air cooling location 56 and through the water cooling location 57. Thus, as the conduit 20 passes through these locations, air will flow through the conduit 20 for cooling purposes. The inside diameter of conduit 150 and the opening through valve 151, however, are small and the pressure drop within the conduit 20 will not be significant as it passes through locations 56 and 57. Thus, through these locations the air pressure within conduits 20 will be sufficient to minimize distortion of the walls of the conduits 20.

Electrical energy is supplied to each solenoid actuated valve 151 by way of electrical leads 152 and 153 and switch 154. Switch 154 is a spring biased switch and normally is in the open position illustrated in FIG. 6. Thus, in this position electrical energy is not applied to the valve 151. This valve is a spring biased valve which is normally biased to the closed condition when not actuated. When switch 154 is closed, however, electrical current is applied to the valve 151 to open the valve to allow the flow of gas through the valve by way of conduit 150 and vent 151A. A circular shaped member or cam 156 (also illustrated in FIG. 5) is secured to the side wall structure of the hood 51 and of the tank 50 for closing the switch 154 as each section passes through the cooling locations 56 and 57. Thus, as a section passes through these two locations, the

switch 154 will be closed by the cam 156 to open the valve 151. As the section moves through other locations, the switch 154 will be open whereby valve 151 will be closed. Each section of the wheel 52 has a similar solenoid controlled valve 151 and switch arrangement 154 which is controlled by the cam 156 as each section passes through the locations 56 and 57.

Instead of a solenoid controlled valve 151 there may be employed a normally closed spring biased valve having a protruding control member which is actuated directly by cam 156 to open the valve as each section passes through locations 56 and 57.

Each jig 38 and clamp 71 are operated in the following manner during each cycle of the wheel 52. At the load and unload location 53 the jig 38 is in the open position shown in FIG. 6. In addition, clamp 71 is in the position also shown in FIG. 6. After loading the jig 38 and the clamp 71 remain in these positions as each section passes through the heating location 54. As the section passes through the heating and bending location 55, however, clamp 71 is pulled toward cylinder 87 by the piston rod 86 to bend the conduit 20 within and around jig 39 to the desired elbow configuration. The jig 38 follows the bending movement of the clamp 71, to aid in the final forming operation. An adjustable stop 94A is secured to the guide 94 in accordance with the degree of bend to be effected and limits the position to which the clamp 71 may be moved. Jig 38 terminates its bending movement when its lower edge abuts against the top edge of the jig 39 as illustrated in FIG. 12. The fully closed position of the jig 38 is reached prior to the passage of each section from the heating and bending location 55. The wheel 52 is driven slowly during its cycle whereby it may take 5 minutes for each section to pass through location 54 and a similar amount of time for the section to pass through each of locations 55, 56 and 57. If desired, the operator may temporarily stop rotation of the wheel 52 for a desired time period as each section enters the heating location 54 to ensure proper heating and softening of the conduit. This may be done automatically rather than manually. The jig 38 remains in its closed position as the section passes through the cooling locations 56 and 57. As the section exits from the cooling location 57 and approaches the loading and unloading location 53, the operator may temporarily stop movement of the wheel 52 by actuation of the start-stop control 104. The operator then may manually control the application of air to cylinder 85 to move the jig 38 to its open position. After the jig 38 has been moved to its full open position the bent conduit 20 in the form of a precisely formed elbow is unloaded. The cylinder 87 then is controlled to move the clamp 71 back to the position shown in FIG. 6 whereby a new conduit 20 may be loaded into the section for bending.

The system for controlling the flow of air to each pair of cylinders 85 and 87 comprises a pair of valves 160 and 161 respectively. Valve 160 is a manually controlled valve while valve 161 is controlled by a spring biased solenoid 162. Valves 160 and 161 have movable members, 160' and 161'. Each of these members have four passageways 160A-160D and 161A-161D respectively extending therethrough. Member 160' may be moved by handle 164 to position either passageways 160A and 160B or 160C and 160D for fluid flow through the valve. Member 161' is moved by solenoid 162. Solenoid 162 has electrical energy applied thereto

by way of electrical leads 166 and 167 and switch 168. Switch 168 is spring biased to the open position whereby solenoid 162 is in a nonactuated condition. In this condition solenoid 162 maintains member 161' normally in the position shown whereby air flows through the valve 161 by way of passageways 161A and 161B. When switch 168 is closed, solenoid 162 is actuated to move the member 161' to an opposite position whereby air flows through valve 161 by way of passageways 161C and 161B.

Coupled to each valve 161 is a conduit 137, vent 170, and conduits 171 and 172. Conduit 171 is coupled to conduits 173 and 174 which extend to cylinder 87 and valve 160. Conduit 172 is coupled to conduits 175 and 176 which also extend to cylinder 87 and valve 160. Conduits 173 and 175 are coupled to cylinder 87 on opposite sides of the piston that is located therein and coupled to piston rod 86. Conduits 178 and 179 extend from valve 160 to cylinder 85 on opposite sides of the piston therein which is coupled to the piston rod 84.

When the valves 161 and 160 are in the position shown, air from conduit 137 flows by way of passageway 161A to move the piston rods 86 and 84 in the position shown in FIG. 6. In this respect air flows to cylinder 87 by way of conduits 171 and 173 and to cylinder 85 by way of conduits 171, 174 passageway 160A and conduit 178. The other sides of the pistons are vented through passageway 161B and vent 170 by way of conduits 175 and 172 and by way of conduit 179, passageway 160B and conduits 176 and 172.

As indicated previously, piston rods 84 and 86 and hence, jig 38 and clamp 71 are in the positions shown in FIG. 6 after loading at location 53 and at the heating location 54. As the section enters the heating and bending location 55, piston rod 86 begins to move to pull the clamp 71 and hence, the conduit 20 towards jig 39 to carry out the desired bending operation. A short time later, piston rod 84 begins to move the jig 38 to its closed position to aid in the bending and forming operation. Movement of piston rods 84 and 86 to carry out bending and forming is initiated by closing switch 168 when the section moves into the heating and bending location 55. This actuates solenoid 162 to move member 161' to allow fluid flow through valve 161 by way of passageways 161C and 161D.

A circular shaped member, or cam, 180 is secured to the side wall of the hood 51 and the side wall of the tank 50 to close the switch 168, when the section enters the heating and bending location. As seen in FIG. 5, member 180 also extends through the cooling locations 56 and 57 and around to the horizontal level of the axle 63. Thus, switch 168 is closed as the section passes through the heating and bending location 55 and through the cooling locations 56 and 57. Thus, the piston rods 84 and 86 are moved to their bending and forming positions at locations 55 and are maintained in these positions through the locations 56 and 57. It will be understood that each section of the wheel 52 will have a similar system as shown in FIG. 6, whereby cam 180 will control each switch 168 in a similar manner.

As indicated previously, piston rod 84 starts moving to its forming position after piston rod 86 begins its initial movement. Piston rod 84 then follows movement of the conduit 20 whereby jig 38 is moved to its forming and closed position. Delayed movement of piston rod 84 is accomplished by the provision of a small bleed 182 coupled to valve 160 in the conduit 179. With this

arrangement less volume of fluid is applied to the piston of the piston rod 84 whereby it will move, when it moves jig 38 to its forming and closed position, at a slower rate than piston rod 86 effecting the bending.

When each section leaves the location 57; for example, at the position shown in dotted form at 184 in FIG. 5, rotation of the wheel 52 may be stopped by the operator. The operator then may unload the bent conduit by moving handle 164 of valve 160 to move passageways 160C and 160D of valve 160 between conduits 174 and 178 and between conduits 176 and 179 respectively. In this position, the piston rod 84 will be moved in an opposite direction to move the jig 38 to its open position, whereby clamps 70 and 71 may be opened and the caps 31 and 32 removed to unload the precisely formed elbow. After unloading, handle 164 may be moved to position passageways 160A and 160B for fluid flow through the valve 160, whereby the jig 38 may be moved back to its closed position. Rotation of the wheel 52 is again started by the operator. When the section moves beyond the curved switch control cam 180 to the position; for example, beyond that illustrated in dotted form at 186 is FIG. 5, switch 168 will open. Rotation of the wheel 52 again may be stopped by the operator and the piston rods 84 and 86 allowed to move back to the position shown in FIG. 6, whereby a new conduit 20 may be loaded and the cycle repeated.

Instead of the valve 161 being controlled by solenoid 162, the valve 161 employed may be spring biased and have a protruding control member which is actuated directly by cam 180 to control movement of member 161.

As illustrated in FIG. 11, two pairs of slip rings 191, 192 and 193, 194 and associated brushes 191A-194A are employed to apply electrical energy to the electrical leads 152, 153 and 166, 167. Leads 153 and 167 both are coupled to brush 193A while leads 152 and 166 are coupled to brush 191A. Slip ring 191 is coupled to slip ring 192 by way of conductor 195 while slip ring 193 is coupled to slip ring 194 by way of conductor 196. Extending from slip rings 192 and 194 are brushes 192A and 194A. Coupled to these brushes are electrical leads 197 and 198 which extend to an electrical power supply 199 as illustrated in FIG. 4.

Referring to FIGS. 5 and 13, heat is applied to locations 54 and 55 by heating elements comprising a plurality of heat lamps 200 which may be secured to the top of the hood 51, as well as to its side wall structure. The hood 51 is suitably insulated, as with fiberglass. Electrical energy is supplied to these lamps by way of conductors 201 and 202 which extend to an electrical power supply 203 as illustrated in FIG. 4.

Cooling air is applied to the location 56 by way of a plurality of nozzles illustrated at 204 in FIGS. 5 and 13. These nozzles are coupled to the compressor 111 by way of conduits 205 and 206 as illustrated in FIG. 4. Chilled water may be circulated through the lower section of the tank 50 for cooling purposes by way of an inlet and an outlet illustrated at 207 and 208 in FIG. 3.

It is to be understood that the elements and components are constructed of material sufficient to withstand the hot and cool temperatures provided by the heating lamps 200 and the chilled water applied to the lower portion of the tank 50. For example, the conduits 33, 150, 173, 174, 175, 176, 178 and 179 may be made of fluorocarbons; such as, teflon to withstand the heat

but remain flexible enough to allow the various members to move sufficiently to carry out the bending operations as described previously. If desired, metallic tubing with universal couplings may be employed to obtain the requisite flexibility of interconnection.

Although heat lamps are shown as the heating means, this invention may employ any other heating means such as electrical heating elements or circulating hot fluids.

Referring to FIG. 14, there will be described another embodiment for carrying out the heating and cooling operations. In this embodiment each conduit 20 is heated to its softening temperature by passing hot oil through the conduit as each section of the wheel 52 is moved through the heating location 54 and the heating and bending location 55. Cold oil then is passed through the bent conduit as each section passes through the cooling location. The hot and cold oil, thus, not only acts to soften and cool the conduits 20, but acts to provide an increased pressure or super atmospheric pressure within the conduits as they are heated, bent and cooled, thereby minimizing distortion of the wall of the conduits during these operations. As will become apparent from the descriptive matter hereinafter, a very similar universal coupling, or rotating joint, is employed for circulating the hot and cold oil as were employed in the embodiments of FIGS. 6 and 11 described hereinbefore.

In this embodiment there may be eliminated the heat lamps 200 as well as the cooling air nozzles 204 and the cooling water which was circulated through the bottom of the tank 50 as described previously.

The sequence of operation of the piston rods 84 and 86 and, hence, the jig 38 and clamp 71 is the same as that described with reference to FIG. 6. The cores 118 and 119, however, have been modified to provide inlet passageways for hot oil and cold oil and an outlet passageway for oil flowing through each plastic conduit 20. Aperture 120 is offset from the axis of the core 118' and cold oil is applied through the aperture 120 for flow to the annulus 124. The source of cold oil, illustrated at 210, is coupled to the aperture 120 by way of conduit 211.

Also extending into the core 118' is another aperture 212 which connects to a radially extending aperture 213. This aperture extends to a circumferential slot 214 which in communication with an annulus 215 by way of a plurality of apertures 216 extending through axle 63. Annulus 215 is formed by annular member 217 coupled to the outer wall of the axle 63 for rotation therewith. Hot oil is applied to the annulus 216 by way of apertures 212 and 213, circumferential slot 214 and aperture 216. A hot oil source is illustrated at 218 and is coupled to aperture 212 by way of conduit 219. Coupled to the annular members 125 and 217 and in communication with the two annulus 124 and 215 are two conduits 220 and 221 which extend to a valve 224. This valve is secured to spoke 64 and has a moveable element 224' through which two passageways 224A and 224B extend. The position of element 224' is controlled by a solenoid 225 which normally is spring biased to locate the element 224' in the position shown whereby cold oil may pass through conduit 220 to conduit 33. When solenoid 225 is actuated, it moves the element 224' to position passageway 224A between conduits 221 and 33 whereby hot oil will flow to conduit 33.

Electrical energy is applied to solenoid 225 by way of electrical leads 226 and 227 and switch 228. Switch 228 normally is spring biased to the open position shown. Thus, in this position cold oil is applied to conduit 33. A curve shaped member, or cam, 229 secured to the side wall structure of the hood 51 closes the switch 228 as it is moved passed the member 229. Member 229 is illustrated in more detail in dotted form in FIG. 5. It is secured to the side wall structure of the hood 51 opposite to that which member 180 is secured. As can be seen in FIG. 5, member 229 extends through both locations 54 and 55. Thus, as each section of the wheel 52 passes through these locations the switch 228 of each section will be closed to actuate its associated solenoid 225 whereby hot oil is passed into conduit 33 and, hence, into each plastic conduit 20. When each section of the wheel 52 leaves the location 55 and passes into the cooling locations previously defined by reference characters 56 and 57, the switch 228 will open whereby cold oil will pass into the conduit 33 and, hence, into the plastic conduit 20 for cooling purposes. If desired, the valve 224 may be spring biased and provided with a protrusion means to encounter the cam 229 and move the valve member 224' directly.

Flow of oil through the conduit 20 is obtained by coupling the conduit 150 (see FIGS. 6 and 14) to an annulus 230 formed by annular member 231 coupled to the other end of the axle 63 for rotation therewith. Annulus 230 leads to an outlet aperture 232 formed in the core 119'. The outlet aperture 232 is connected via conduit with an oil reservoir (not shown). Communication with the outlet aperture 232 is provided by apertures 233 formed through the axle 63; a circumferential slot 234 formed in the core 119'; and a radial aperture 235. In this embodiment, conduit 150 is coupled directly to the annular member 231 and the valve 151 (see FIG. 6) is not employed. Thus, at all times during the cycle, hot oil or cold oil flows through the plastic conduits 20. If desired, the oil out of aperture 232 may be routed back to the respective hot and cold oil sources, with a routing conduit valve similar to those of the entering oil.

In the embodiment of FIG. 14, the core 118' preferably is formed of a material which is a poor conductor of heat to minimize heat exchange between the hot and cold oil. Alternatively, the apertures in the core 118' may be lined with thermally insulated material.

Two pairs of slip rings 240, 241 and 242, 243 and associated brushes 240A-243A are employed to apply electrical energy to the leads 226 and 227. In this respect, lead 227 is coupled to brush 242A while switch 228 is coupled to brush 240A. Slip rings 240 and 241 are coupled together by way of lead 244 while slip rings 242 and 243 are coupled together by way of lead 245. Brushes 241A and 243A are coupled to a source of electrical energy (not shown).

When unloading the elbow or loading the section of conduit, manually operated valves, such as 34A, FIG. 6, are employed to control the oil flow. Oil from the unloaded elbow is collected in a suitable sump.

Referring now to FIG. 15 there will be described a further embodiment wherein the wheel 52 is modified to rotate about a vertical axis to pass the sections containing the conduits 20 to be bent through the various locations or stations which are in a horizontal plane rather than a vertical plane. Each of the sections of the wheel 52 is similar to that illustrated in FIG. 6 except

that the sections will be rotated in a horizontal plane. The locations through which the conduits 20 are to be passed are similar to those illustrated in FIG. 5 and comprise a loading and unloading location 53, a heating location 54, a heating and bending location 55, an air cooling location 56, and a water cooling location 57. In the embodiment of FIG. 15 the hood 51 surrounds the locations 54 and 55. Advantageously, the bending apparatus, similar to that illustrated in FIG. 6, may be disposed in a horizontal plane, if desired. Cooling air is passed over the bent conduits 20 at location 56 while cool water is sprayed over the bent conduits at location 57 by way of water nozzles 246. Air is passed into the conduits 20 through a rotating joint formed at the top of the axle 63. Air to control the pistons 85 and 87 is passed through a rotating joint located at the bottom of the axle 63. The system thus operates in a manner similar to that described with respect to FIG. 6 except for the cooling location 57 wherein cool water is sprayed over the bent conduits 20.

Although not shown, it will be understood that the electrical system employed will be properly insulated in all of the embodiments to prevent shock to the operators. Moreover, the electrical components are close to the axle 63 of the wheel 60 and away from the water bath of FIG. 5 or the water spray of FIG. 15.

It is to be understood that plastic conduits of different size and cross sectional configuration may be bent by employing clamps 70 and 71 as well as jigs 38 and 39 of different size and configuration. In addition, different degrees of bend and different types of bend (i.e., sharp or smooth) may be obtained by employing the desired types of jigs 38 and 39. The system is constructed whereby clamps 70 and 71 and jigs 38 and 39 may be readily removed and substituted. Also, the adjustable stop 94A may be readily positioned for holding the clamp 71 at a position that is equivalent to the precisely desired degree of bend in the elbow.

In addition to the above, it may be desirable to bend conduits, such as conduit bundles, having a plurality of longitudinally extending passageways. In order to bend conduits of this nature, the caps 31 and 32 will be modified to allow all of the apertures or passageways in the conduit to be pressurized to super atmospheric pressure.

If desired, each of the caps 31 and 32 may comprise a plurality of individually fitting caps so that the pressure in the respective passageways may be adjusted to effect the desired precision elbow. For example, in a two passageway conduit, the interior passageway may be provided a super atmospheric pressure P_1 that is greater than a super atmospheric pressure P_2 in the exterior passageway.

In accordance with the foregoing description, it can be seen that this invention provides method and apparatus for affecting automatic production of precisely formed elbows having a high degree of quality control. As indicated hereinbefore the quality control includes not only obtaining the desired degree of bend, but also obtaining the desired shape, without wrinkling of the elbow along the inside bend where such wrinkling is intolerable. Thus, the invention accomplishes its purpose and alleviates the disadvantages of the prior art.

Although the invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made only by way of exam-

ple and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention.

What is claimed is:

1. Apparatus for precision bending of plastic conduit comprising:

a. a rotatable means for moving a segment of conduit through a plurality of locations for carrying out a variety of cooperating functions, said rotatable means having a plurality of sections, the plurality being at least as great as the number of locations; each section including:

i. pressurizing means for establishing a super atmospheric pressure within a segment of conduit, said pressurizing means being connected with a pressurized source of fluid having a pressure regulating means and including cap means for emplacement at each end of said segment of conduit for controlling flow of fluid at each end of said segment of conduit; said pressurizing means being operable to maintain the super atmospheric pressure throughout said plurality of locations as said rotatable means is rotated there-through;

ii. clamping means for clamping each end of said segment of conduit, said clamping means having a fixed portion that is fixedly carried by said section, and a movable portion that is movable along a predetermined arcuate path so as to effect a desired degree of bend and desired shape of said segment of conduit;

iii. jig means having an interior wall of a desired finish for effecting an elbow having a desired finished surface, and comprising at least an interior jig means having a desired degree of bend disposed intermediate said fixed portion and said movable portion of said clamp means;

iv. automatic bending means connected with said movable portion of said clamping means for bending said segment of conduit responsive to an actuation means, said bending means having holding means for holding a desired degree of bend once attained; and

v. stop means for limiting the degree of bending that is automatically effected by said bending means;

b. loading and unloading location for emplacing said segment of conduit within said clamping means in a section and connecting said pressurizing means and for releasing said pressurizing means and taking a formed elbow from said clamping means; said loading and unloading location in combination with each said section including:

i. means for releasing the pressure from within said conduit and disconnecting said pressurizing means therefrom;

ii. means for releasing, respectively, said holding means, said bending means, and said clamping means for taking a formed elbow therefrom; and

iii. means for reconnecting said pressurizing means with a subsequent conduit and establishing pressure therewithin;

c. heating location including heating means and temperature controlling means disposed peripherally downstream of said loading and unloading location

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for heating said segment of conduit intermediate its ends to its softening temperature;

d. heating and bending location disposed peripherally downstream of said heating location for bending the segment of conduit at its softening temperature to form a precision elbow; said heating and bending location including:

i. a heating means for maintaining said segment of conduit at its softening temperature; and

ii. actuation means for automatically actuating said bending means to bend the softened segment of conduit into conformance with said jig means and said stop means and into a precise degree of bend and shape; and

e. at least one cooling location having means for subjecting said precision elbow to a cooling fluid to cool it below its softening temperature and into an inflexible state before it reaches said loading and unloading locations.

2. The apparatus of claim 1 wherein said cooling location comprises a gaseous cooling location and a chilled liquid cooling location.

3. The apparatus of claim 2 wherein said gaseous cooling location includes a second actuation means for permitting flow of gas through the interior of said conduit at super atmospheric pressure; and includes means for circulating cooling gas on the exterior of said precision elbow.

4. The apparatus of claim 2 wherein said chilled liquid cooling location includes a chilled liquid bath.

5. The apparatus of claim 2 wherein said chilled liquid cooling location includes a chilled liquid spray.

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6. The apparatus of claim 1 wherein said pressurizing means is connected with said source of fluid via a universal coupling means so as to be rotatably connected therewith throughout said plurality of locations.

7. The apparatus of claim 1 wherein said section of said rotatable means contains an exterior jig means and a fitting means for fitting said exterior jig means about said segment of softened conduit and in conforming relationship with said interior jig means to form an enclosing mold against which said super atmospheric pressure can conformingly press the walls of said softened precision elbow for more nearly exact definition of said precision elbow.

8. The apparatus of claim 1 wherein said rotatable means is rotatable about a horizontal axis to rotate said plurality of sections in a vertical plane through said loading and unloading location, said heating location, said heating and bending location, and said cooling location.

9. The apparatus of claim 1 wherein said rotatable means is rotatable about a vertical axis to rotate said plurality of sections in a horizontal plane through said loading and unloading location, said heating location, said heating and bending location, and said cooling location.

10. The apparatus of claim 1 comprising means for removably supporting said jig means whereby said jig means may be readily interchanged with different jig means to allow conduits of different sizes to be bent and at different degrees of bend.

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