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(54) **TUBE MAKING MACHINE WITH DIAMETER CONTROL AND METHOD**

Related U.S. Application Data

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(57) **ABSTRACT**

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A spiral pipe forming system and method which include automatic diameter or dimension sensing and correction.

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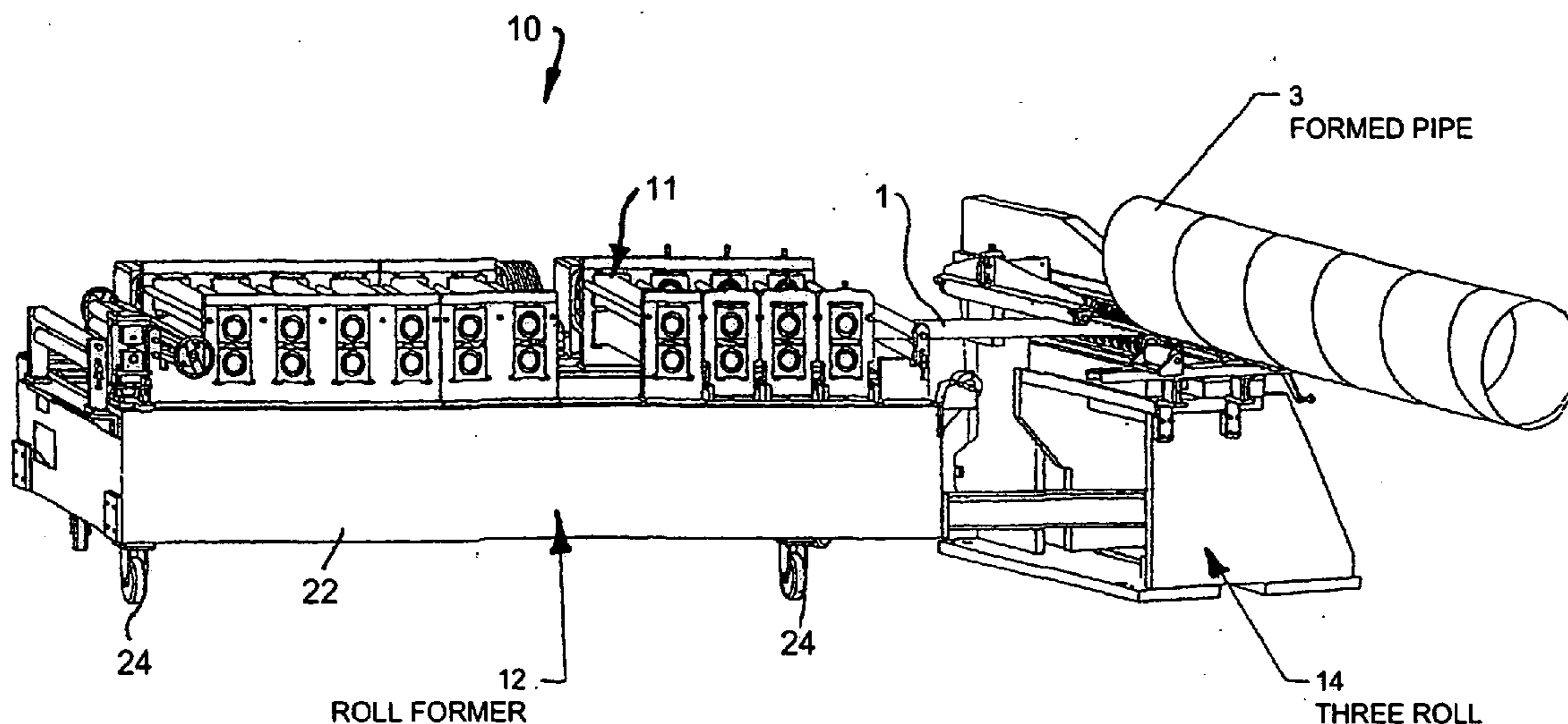
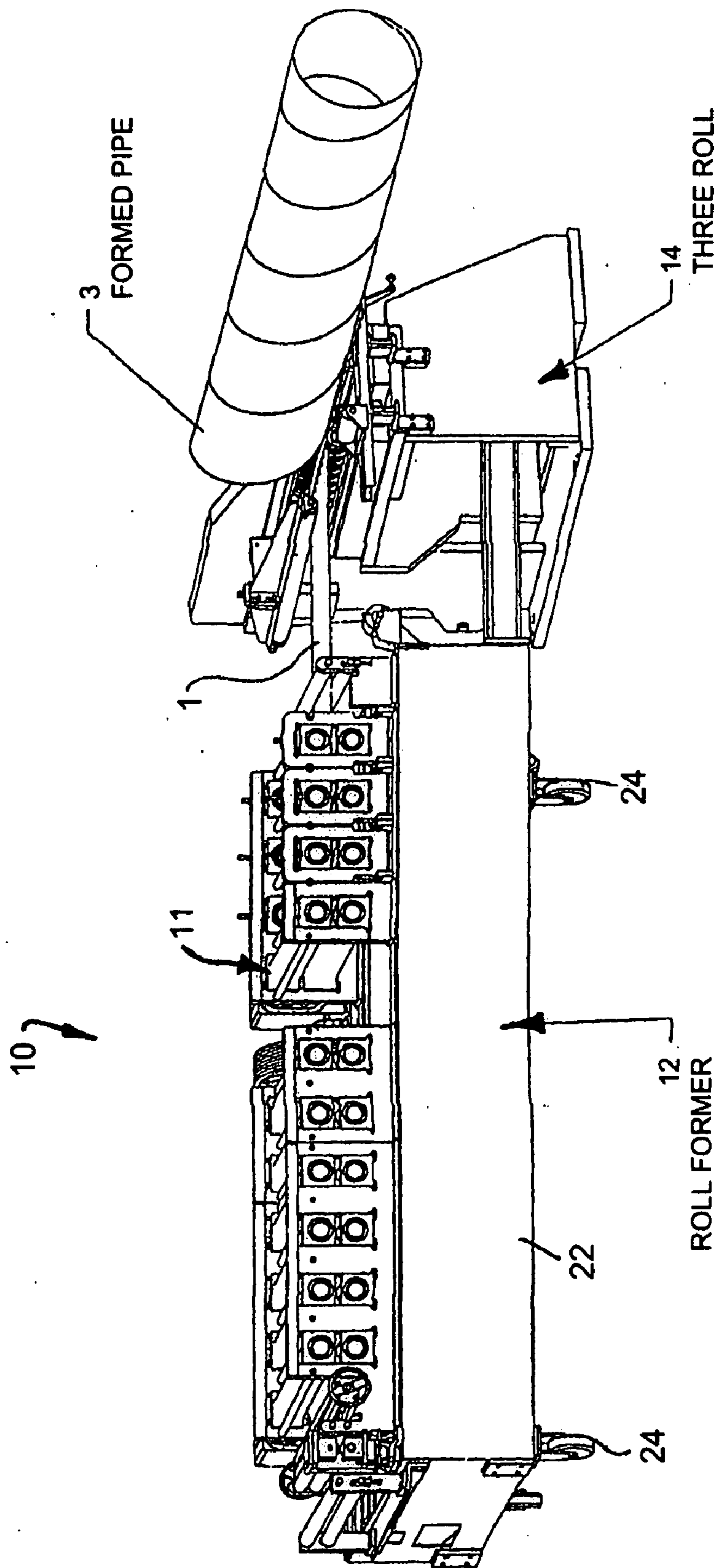


FIG. 1



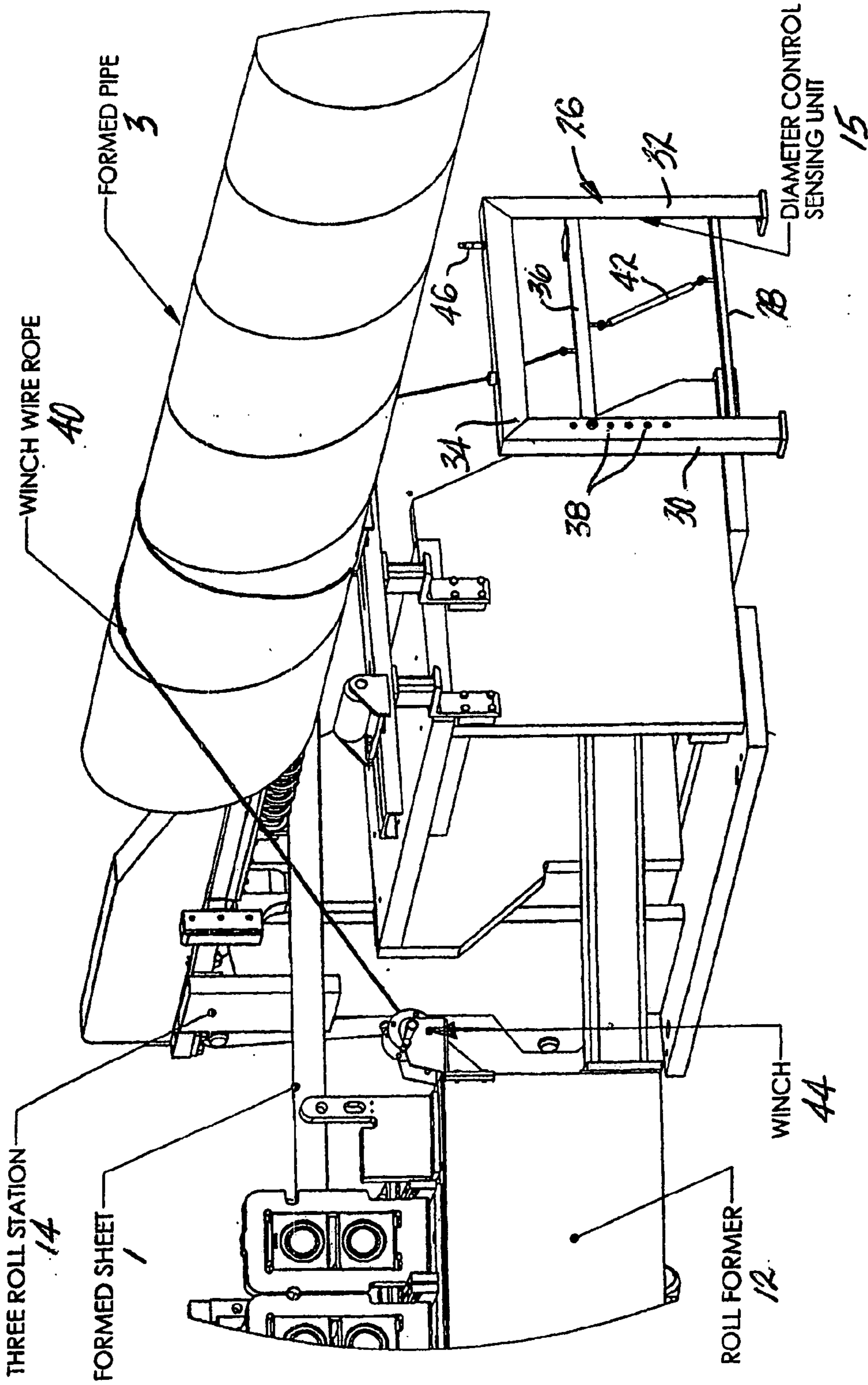


FIG. 2

FIG. 3

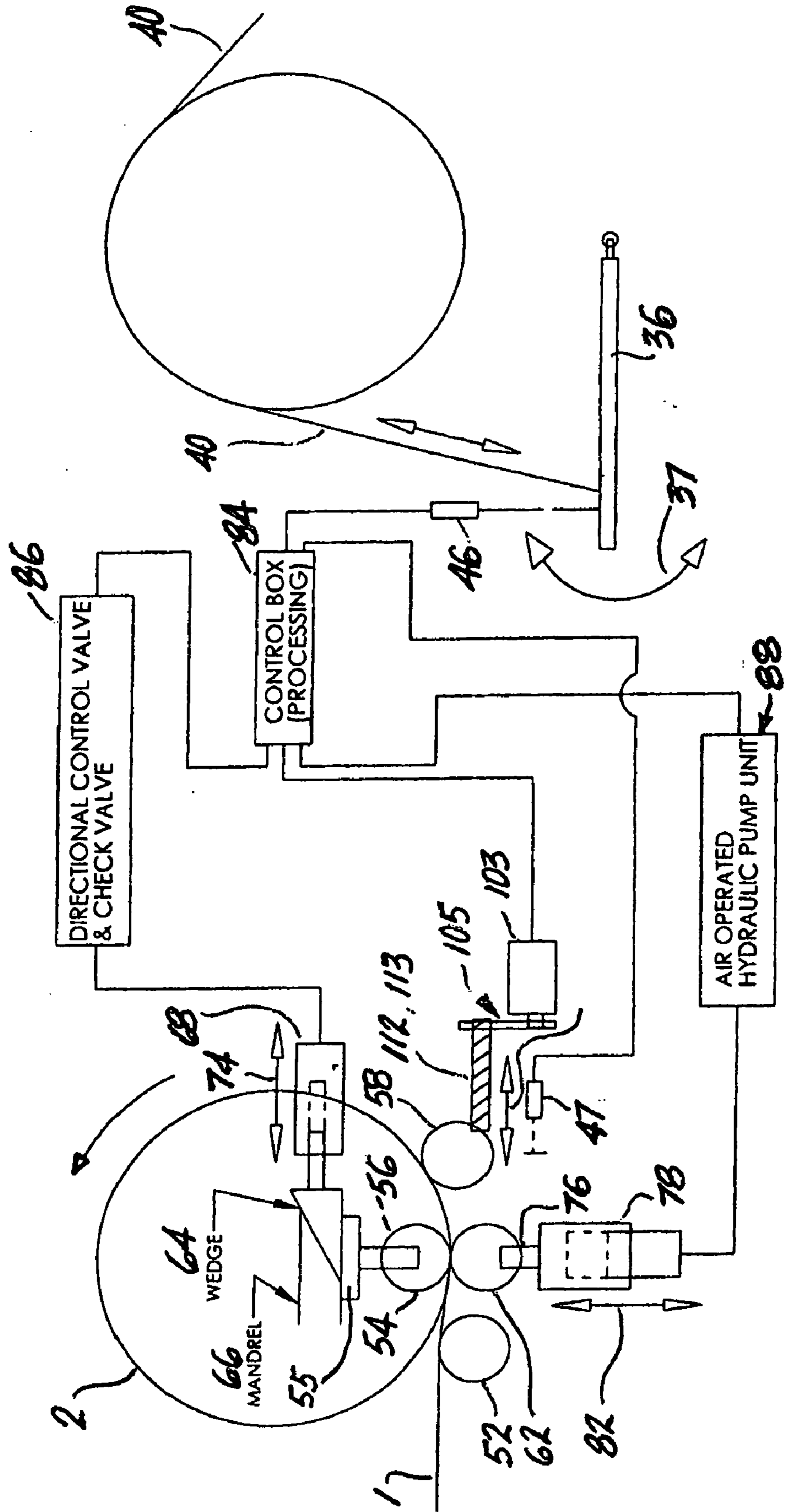
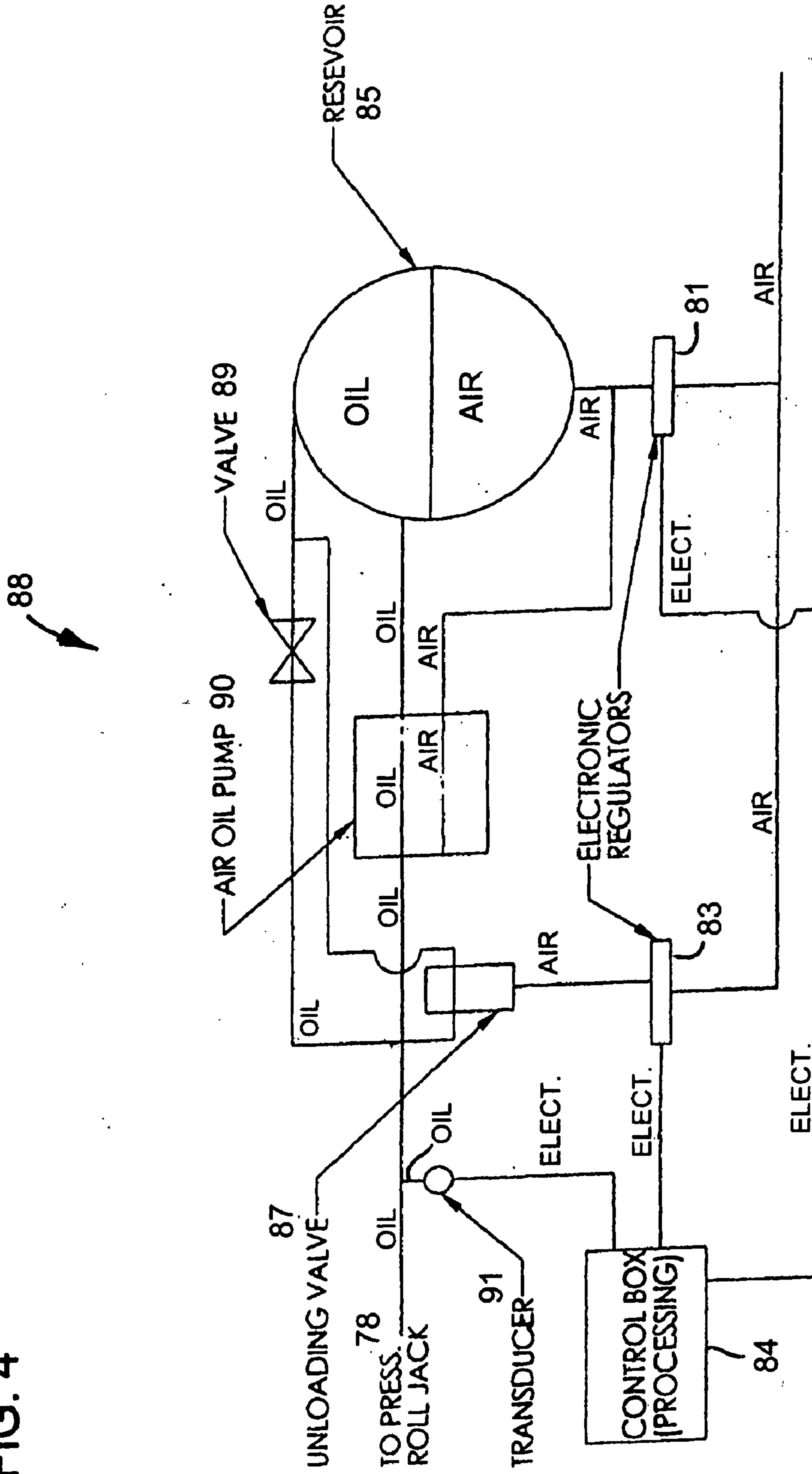


FIG. 4



TUBE MAKING MACHINE WITH DIAMETER CONTROL AND METHOD

[0001] This application is a continuation-in-part of U.S. application Ser. No. 12/321,370, titled "Tube Making Machine with Diameter Control and Method," filed Jan. 16, 2009, inventor William J. Kephart, which parent application claims the benefit of U.S. provisional application No. 61/011677, titled "Tube Making Machine with Diameter Control and Method," filed Jan. 18, 2008, inventor William J. Kephart. Both prior applications are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] A. Field of the Invention

[0003] The present invention relates to machines and methods for making spiral pipe from strips of sheet metal and, in particular, to machines and methods for accurately monitoring and controlling the diameter of such pipe. As used here, "pipe," "tube" and "conduit" are used interchangeably.

[0004] B. Description of the Related Art

[0005] Commonly assigned U.S. Pat. No. 3,940,962 describes a three-roll conduit forming mill and diameter control of Pacific Roller Die Company, Inc. The '962 patent is incorporated by reference in its entirety. As described in the '962 patent, the adjacent spiral edges of a strip which forms a spiral conduit are joined by interlocked edge flanges which are pinched or crimped tightly together by upper and lower lock-up rolls. The radial positioning of this pair of rolls relative to the conduit axis controls the diameter of the conduit. Thus, when the rolls are simultaneously raised, i.e., moved radially inward relative to the axis of the conduit, the diameter of the conduit increases. When the rolls are simultaneously lowered, i.e., moved radially outward relative to the conduit axis, the diameter of the conduit decreases. The position of the lock-up rolls is changed by control screws which are manually turned using wrenches. The '962 patent indicates the diameter changes effected by such movement are minor and occur gradually. For instance, in a machine for making 1 to 36 inch conduit, such adjustments may be used to effect diameter changes of approximately $\pm 1/4$ (one-fourth) inch.

[0006] The '962 patent also discloses the feasibility of making the adjustment automatic, by including means for monitoring the diameter, such as a belt or loop detector, which, when it senses a given diameter deviation would activate a servomechanism which in turn lowered or raised the lock rolls to correct the deviation.

SUMMARY OF THE INVENTION

[0007] In one aspect, the present invention is embodied in apparatus for forming a spiral pipe, comprising: lead, mandrel and buttress rolls for forming a spirally wound sheet, the apparatus further including inner and outer pressure rolls engaging and crimping together adjacent edges of the spirally wound sheet; a sensing system for monitoring changes in the diameter of the spirally wound sheet as it is formed and responsively generating signals containing information regarding changes in diameter; and a system responsive to the signals for moving the buttress rolls toward or away from the mandrel rolls and the pressure rolls to thereby correct the changes in diameter.

[0008] In another aspect, the present invention is embodied in apparatus for forming a spiral pipe, comprising: lead, mandrel and buttress rolls for forming a spirally wound sheet, the apparatus further including inner and outer pressure rolls engaging and crimping together adjacent edges of the spirally wound sheet; a sensing system for monitoring changes in the diameter of the spirally wound sheet as it is formed and responsively generating signals containing information regarding changes in diameter; a system responsive to the signals indicating relatively small changes in pipe diameter for moving the inner and outer pressure rolls in unison radially inward or outward relative to the axis of the pipe, to correct the relatively small changes in diameter; and a system responsive to the signals indicating relatively large changes in pipe diameter for moving the buttress rolls toward or away from the mandrel rolls and the pressure rolls, to correct the relatively large changes in diameter.

[0009] In yet another aspect, the present invention is embodied in a method of forming a spiral pipe with diameter control, comprising: using lead, mandrel and buttress rolls, forming a spirally wound sheet having adjacent edges; using interior and exterior pressure rolls, crimping adjacent edges of the sheet together; monitoring the diameter of the spirally wound sheet for changes therein; responsive to changes in the diameter, generating signals including information regarding changes in diameter; and automatically applying diameter correction selected from (1) moving the inner and outer pressure rolls in unison radially inward or outward relative to the axis of the spirally wound sheet, to move the adjacent edges of the spirally wound sheet and thereby correct relatively small changes in diameter; and (2) moving the buttress rolls toward or away from the mandrel rolls and the pressure rolls, to thereby correct relatively large changes in diameter.

BRIEF DESCRIPTION OF THE DRAWING

[0010] FIG. 1 is a perspective view of a three roll pipe-forming mill.

[0011] FIG. 2 is an enlarged partial view of the mill of FIG. 1, depicting an automatic diameter sensing system.

[0012] FIG. 3 is a schematic of an air-operated hydraulic pump unit.

[0013] FIG. 4 is a schematic depiction of a control system for the exterior pressure jack and roll.

[0014] FIG. 5 is a partial view of the three-roll pipe forming mill of the type shown in FIG. 1, depicting a buttress roll control system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0015] According to an embodiment of the present invention, a three roll apparatus for forming lock seam spiral pipe of controlled pipe size or diameter, e.g., constant diameter, includes lead, mandrel and buttress rolls and seam-forming rolls comprising a wedge-operated interior pressure roll and jack-operated exterior pressure roll. The diameter of the spiral pipe and deviations in the diameter are monitored as the pipe is formed, then responsive to deviations greater than a predetermined value or values, different sequences of steps are automatically applied to correct relatively large and relatively small deviations and, thus, collectively provide for automatic correction of a relatively wide range of deviations. Relatively large deviations are corrected by translating the buttress rolls. Relatively small deviations are corrected using

the seaming dies (pressure rolls), the wedge position and an associated control system. The control system pressurizes the exterior pressure roll jack such that a set pressure can be maintained. As a result, the exterior and interior pressure rolls can be adjusted up or down by the automatic diameter control while maintaining full pressure, i.e. without losing full pressure and causing the lock seam to be unsatisfactory; and wedge adjustments can be made during production of the pipe without dumping all pressure and temporarily shutting down the mill, as is the case with prior systems.

[0016] Responsive to relatively small deviations of 0-10% and typically 0-5%, the system automatically moves the pressure rolls up/down, thereby moving the lock seam radially inward/outward, and increasing/decreasing the diameter of the pipe. Responsive to relatively large deviations of 2-25% and typically 2-15%, the system automatically moves the buttress rolls generally horizontally toward/away from the mandrel and pressure rolls, thereby decreasing/increasing the diameter of the pipe. Thus, the system automatically corrects for a relatively wide range of diameter deviations. The adjustments are incremental so as not to over adjust and cause the system to oscillate while correcting the diameter. The small and large corrections can be applied alone or sequentially.

[0017] FIG. 1 depicts a three-roll pipe forming mill 10 by Pacific Roller Die Company, Inc which embodies the above system and method. The system includes a roll former system 12 for feeding a metal strip 1 to a three roll system 14, which forms the strip into a helical pipe 3. Diameter sensing and control system 16, FIGS. 2 and 3, monitor the diameter of the formed pipe 3 and responsively control the diameter of the pipe as it is formed, as indicated by reference numeral 2.

[0018] As is well known and as described more fully in the commonly assigned, incorporated patent, U.S. Pat. No. 3,940,962, the roll former 12 comprises a carriage 22 which is supported by casters 24 so that the oblique angle formed between the roll former and the three roll system can be varied, to thereby vary the diameter of the pipe or tube. The carriage 22 is an elongated frame which mounts an array 11 of corrugating rolls, arranged in a plurality of stands of matched pairs of upper and lower rolls. The rolls are horizontally aligned so that a strip 1 which is input to the roll former 12 passes through the upper and lower rolls of each stand and is deformed thereby into a corrugated profile, then exits the roll former and enters the three roll system 14. Commonly assigned U.S. Pat. No. 6,339,945 describes a tube-forming system which uses computer control of the helix angle between the tube infeed system and the tube forming system, to control and vary tube diameter and form linearly tapered, curved and constant diameter profiles. U.S. Pat. No. 6,339,945 is hereby incorporated by reference.

[0019] The operation of the three roll system 14 is also well known and thus is described in conjunction with the construction and operation of the diameter (or dimension) sensing and control unit 16 and diameter or dimension sensor or monitor 15 of system 16. Referring to FIG. 2, the diameter sensing mechanism 15 includes a support 26 comprising a horizontal base member 28, legs 30 and 32 and a horizontal top member 34. The legs 30 and 32 are bolted to the floor or other base. A pivot arm 36 is pivotally mounted at one of a plurality of mounting holes 38 spaced along the lengthwise dimension of leg 30. A tension spring 42 is pivotally mounted at one end to the pivot arm 36 and is pivotally mounted at the other end to bottom leg 28. A wire (or rope or cable, etc.) 40 is mounted at one end to winch 44, is wrapped one full loop around formed

pipe 3, and is attached at the opposite end to the pivot arm 36. Winch 44 and tension spring 42 bias or pull the pivot arm 36 in opposite directions, such that the winch can be used to orient the pivot arm in a desired orientation and the tension spring tends to maintain the pivot arm in the selected orientation. A sensor 46 such as an ultrasonic sensor is mounted on top member 34 and is focused or directed onto the pivot arm 36 and provides an output signal containing information regarding the distance between the sensor and the pivot arm. During operation of the three roll system 14, changes in the diameter of the pipe 3 effect movement of the cable 40 and the pivot arm 36, causing variations in the output signal which are representative of the changes in the diameter, radius, perimeter or other dimension which is being monitored.

[0020] The diameter or dimension control system 16 for the pipe forming mill 10 is depicted in FIG. 2 and, in particular, in FIG. 3. The three-roll forming arrangement 14 of Pacific Roller Die Company includes lead rolls 52, which engage the lower surface of sheet 1 entering the three roll system 14, mandrel rolls 56 and interior pressure roll 54 on the upper side of the sheet, i.e., the interior of the forming pipe 2, and buttress rolls 58 which shape the sheet helically into the pipe 2. Exterior pressure roll 62 engages the exterior surface of the pipe 2 opposite the interior pressure roll 54 and the two rolls cooperatively crimp the mating adjacent edges of the spirally formed sheet together and join the pipe along the adjacent sheet edges in a seam, or more precisely in the case of joined hook-shaped edges, in a lock seam.

[0021] The internal pressure roll 54 and the external pressure roll 62 are mounted to positioning devices which cooperatively move the internal pressure roll and the external pressure roll radially inward and outward together relative to the axis of the pipe for effecting the crimping action.

[0022] The positioning device for the internal pressure roll 54 comprises a wedge 64 and mandrel 66 arrangement and a hydraulic cylinder 68. As shown in FIG. 3, the interior pressure roll 54 is rotatably mounted to the vertical member or upright of a generally T-shaped support member 55, the upper horizontal (cross) member of which is slidably mounted on vertical rods (not shown) extending generally downward from the mandrel 66. During operation, the hydraulic cylinder 68 moves the shaft thereof bidirectionally, in opposite directions shown by arrow 74, and the mandrel 66 cams the wedge 64 along the angled lower surface of the mandrel and causes the wedge to move radially up or down. The camming action of the mandrel moves the wedge, the member 55 and the interior pressure roll 54 roll radially down against the pressure exerted by the exterior pressure roll 62, see below (or allows the pressure roll 54 to be moved radially up by the pressure exerted by the exterior pressure roll).

[0023] The external pressure roll 62 is mounted to shaft or piston 76 of hydraulic jack 78. Operation of the pump unit 90 causes the jack piston 76 to vary the pressure on the exterior pressure roll 62. The pressurized exterior pressure roll 62 maintains pressure against the interior pressure roll 54. (In the absence of the interior pressure roll 54, this pressure would move the exterior pressure roll 62 radially inward (up) or outward (down), as indicated by the arrow 82.) Thus, when the wedge 64 is extended to the left in FIG. 3, the camming action between the wedge and the mandrel 66 moves the wedge and the interior pressure roll 54 radially down against the pressure exerted by the exterior roll 62, so that the exterior pressure roll moves with and, the position thereof is defined by, the interior pressure roll. Conversely, when the wedge 64

is retracted to the right in FIG. 3, the wedge is cammed upward by the mandrel 66 and the pressure exerted by the exterior pressure roll 62 forces the interior pressure roll 54 to move radially upward along with the exterior pressure roll to a position defined by the wedge and the interior pressure roll.

[0024] The crimped tube edges or seam follow(s) the position defined by the interior pressure roll 54 during up and down movement thereof. That is, the synchronized radially inward and outward movement of the interior pressure roll and the exterior pressure roll 62 (with the interior pressure roll defining the position of the tube seam and the exterior pressure roll following the interior pressure roll) shifts the position of the pipe seam radially inward and outward in controlled fashion relative to the pipe axis.

[0025] Referring further to FIG. 3, the output side of sensor 46 is connected to control box 84, which can be a separate device or part of the programmable logic device or computer for controlling the system 10, and which typically is connected to an operator console (not shown). The control box is connected to a directional control valve and check valve arrangement 86 and to an air operated hydraulic pump unit 88. The directional control valve and check valve 86 is connected to the hydraulic cylinder 68 for providing electronic control of the hydraulic fluid which operates the hydraulic cylinder so that the piston thereof is translated bidirectionally, as discussed above, for camming the wedge 64 along mandrel 66 and moving the internal pressure roll 54 (and the exterior pressure roll 62) radially in and out. The air-operated hydraulic pump unit or system 88 is connected to the external pressure roll jack 78 for providing electronic signal controlled, air-operated hydraulic flow to that jack, for moving the piston 76 thereof bidirectionally, as discussed above, and thereby moving the external pressure roll 62 radially in and out.

[0026] Referring further to FIG. 3 and in particular to FIG. 4, there is shown a presently preferred embodiment of the air-operated hydraulic pump unit or system 88 for controlling the operation of the air-operated hydraulic pump 90 and the exterior pressure roll jack 78 and thereby the exterior pressure roll 62. The control system incorporates the aforementioned components and interconnected components including reservoir 85, electronic regulators 81 and 83, unloading valve 87, valve 89 and transducer 91, for pressurizing the exterior pressure roll jack such that a set pressure can be maintained.

[0027] Referring further to FIGS. 3 and 4, in the depicted system 88, factory air power is connected to both electronic pressure regulators 81 and 83. Electronic regulator 81 is in the air supply line to the air/oil pump 90 (1:100 ratio) and is also connected to the reservoir 85. When activated, the air powers the pump 90 and builds up pressure in the pressure roll jack 78. Electronic regulator 83 is connected to the pressure unloading valve 87 for the oil pressure to be released back to the reservoir.

[0028] In operation of system 88, the desired lock-forming pressure is defined at the operator console associated with control box 84 and the supply regulator 81 allows enough air pressure to accumulate at the air/oil pump 90 to reach the pressure set point. Once under full production mode, the control system 84 continuously monitors the seaming pressure through the pressure transducer 89, which is connected between the pressure roll jack 78 and the control box 84. When a pressure deviation of a predetermined value is sensed by the transducer 91, a signal is sent to control system 84 and the control system 84 responsively pulses a signal to one of the two electronic pressure regulators 81/83 to adjust the

actual seaming pressure up or down to match the set pressure previously entered at the main console. When the actual/sensed pressure is lower than the set point pressure, the control box 84 pulses a signal to the air supply regulator 81 to increase the pressure to the set point. For actual/sensed pressure that is higher than the pressure set point, the control box 84 pulses a signal to the unloading regulator 83 to decrease the pressure to the set point. As alluded to above, this system and method of operation corrects deviations and allows the set pressure to be maintained (e.g. within plus or minus 10%). As a result, (1) the pressure rolls 62 and 54 can be adjusted up or down by the automatic diameter control while maintaining full pressure, i.e. without losing full pressure and causing the lock seam to be unsatisfactory; and (2) wedge adjustments can be made during production without dumping all pressure and temporarily shutting down the mill, as is the case with prior systems.

[0029] When the size of the pipe 3 changes, pivoting of the pivot arm 36 in one direction (for example, counterclockwise; see arrow 37, FIG. 3) is associated with decreases in pipe size, whereas pivoting of the pivot arm in the opposite direction (clockwise) is associated with increases in pipe size. When the sensor 46 and the diameter monitoring and control system 16 detect (typically small) deviations from the desired pipe diameter, the output from the sensor 46 causes control box 84 to operate the internal and external pressure roll positioning devices in unison, and simultaneously move the internal pressure roll 54 and the external pressure roll 62 inward or outward relative to the pipe axis and thereby respectively increase or decrease the diameter of the pipe.

[0030] Referring to FIG. 5, there is shown a partial, elevation view of the three roll 14 which depicts a system 100 for mounting and adjusting the position of the buttress rolls 58. The buttress rolls 58 are mounted on a slide plate 102 which in turn is mounted to base plate 101 and translated bidirectionally along the base plate by a motor 103-driven sprocket drive system 105, FIG. 3, controlled by the control box 84.

[0031] In the illustrated embodiment electric motor 103 and reducer 104 unit 106 is mounted to the base 31 of the three roll 14. Drive sprocket gear 108 coming off the reducer 104 mounts and drives a chain loop 109, which is linked to and drives the buttress roll mounting subsystem. This subsystem comprises the base plate 101, the sliding plate 102, which is mounted on top of the base plate and guided in/out horizontally along gibs 111 (also known as guides, retainers, tracks, etc.). Two threaded rods 112, 113 are rotatably journaled to threaded holes in the sliding plate or in adjustment brackets 114 mounted to the sliding plate 102 so that reversible rotation of the two rods in unison bidirectionally moves/translates the sliding plate and the buttress rolls 58.

[0032] Matched sprocket gears 116, 117 are mounted on the rods 112, 113 and are connected by a chain loop 118 so that rotation of one of the rods rotates the other rod equally and pushes or pulls the sliding plate 102 and buttress rolls 58. As alluded to, the chain loop 109 coming off the drive sprocket 108 associated with the electric motor and reducer unit 106 connects the motor 103 to one of the driven sprockets 116, 117, illustratively, sprocket 116. The electric motor 103 is connected to and its operation is controlled by the control box 84. Ultrasonic sensor 47 is mounted on the base plate 101, connected to the control box 84 and aimed at the sliding plate 102 to generate signals that are transmitted to the control box 84, indicating (monitoring) the position of the buttress rolls 58.

[0033] When the sensor 46 and the diameter monitoring and control system 16 detect (typically large) deviations from the desired tube diameter, the operation of the electric motor 103 is controlled by control box 84 to automatically move the buttress rolls 58 toward/away from the mandrel and pressure rolls a predetermined distance for decreasing/increasing the diameter of the pipe as required. Prior to the automatic diameter-correction of the buttress rolls 58 (and optionally, during the correction process), the sensor 47 sends signals to the control box 84 containing information regarding the position of the buttress rolls so that the control box or other system computer can determine whether there is sufficient travel available to the buttress rolls to accomplish the desired correction. If the system determines there is insufficient travel available, it shuts down the mill to permit the necessary repositioning.

[0034] The present invention has been described in terms of preferred and other embodiments. The invention, however, is not limited to the embodiments described and depicted. Adaptation to other embodiments will be readily done by those of usual skill in the art, limited only by the claims appended hereto.

What is claimed is:

1. Apparatus for forming a spiral pipe, comprising lead, mandrel and buttress rolls for forming a spirally wound sheet, the apparatus further including inner and outer pressure rolls engaging and crimping together adjacent edges of the spirally wound sheet; a sensing system for monitoring changes in the diameter of the spirally wound sheet as it is formed and responsively generating signals containing information regarding changes in diameter; and a system responsive to the signals, for moving the buttress rolls toward or away from the mandrel rolls and the pressure rolls to thereby correct the changes in diameter.

2. Apparatus for forming a spiral pipe, comprising lead, mandrel and buttress rolls for forming a spirally wound sheet, the apparatus further including inner and outer pressure rolls engaging and crimping together adjacent edges of the spirally wound sheet; a sensing system for monitoring changes in the diameter of the spirally wound sheet as it is formed and responsively generating signals containing information regarding changes in diameter; a system responsive to the signals indicating relatively small changes in pipe diameter, for moving the inner and outer pressure rolls in unison radially inward or outward relative to the axis of the pipe, to correct the relatively small changes in diameter; and a system responsive to the signals indicating relatively large changes in pipe diameter, for moving the buttress rolls toward or away from the mandrel rolls and the pressure rolls, to correct the relatively large changes in diameter.

3. A method of forming a spiral pipe with diameter control, comprising: using lead, mandrel and buttress rolls, forming a spirally wound sheet having adjacent edges; using interior and exterior pressure rolls, crimping adjacent edges of the sheet together; monitoring the diameter of the spirally wound sheet for changes therein; responsive to changes in the diameter, generating signals containing information regarding the changes in diameter; and automatically applying diameter correction selected from (1) moving the inner and outer pressure rolls in unison radially inward or outward relative to the axis of the spirally wound sheet, to move the adjacent edges of the spirally wound sheet together, to thereby correct relatively small changes in diameter; and (2) moving the buttress rolls toward or away from the mandrel rolls and the pressure rolls, to thereby correct relatively large changes in diameter.

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