US 20090320542A1

(19) **United States**

(12) **Patent Application Publication**

Kephart

(10) **Pub. No.: US 2009/0320542 A1**

(43) **Pub. Date: Dec. 31, 2009**

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

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(21) Appl. No.: **12/380,580**

(22) Filed: **Feb. 26, 2009**

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/321,370, filed on Jan. 16, 2009.

(60) Provisional application No. 61/011,677, filed on Jan. 18, 2008.

Publication Classification

(51) **Int. Cl.**
B21C 37/12 (2006.01)

(52) **U.S. Cl.** **72/49**

(57) **ABSTRACT**

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

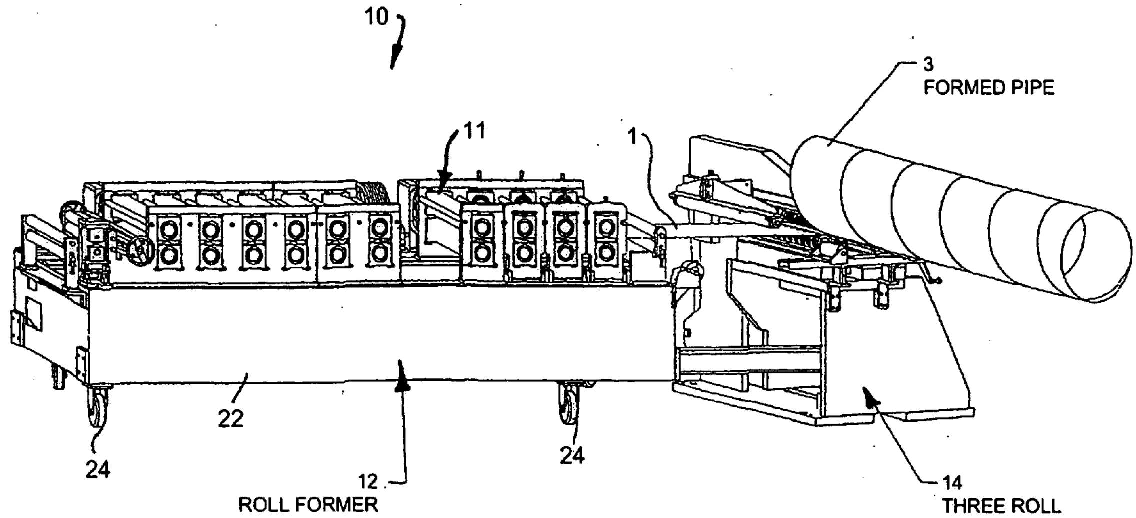
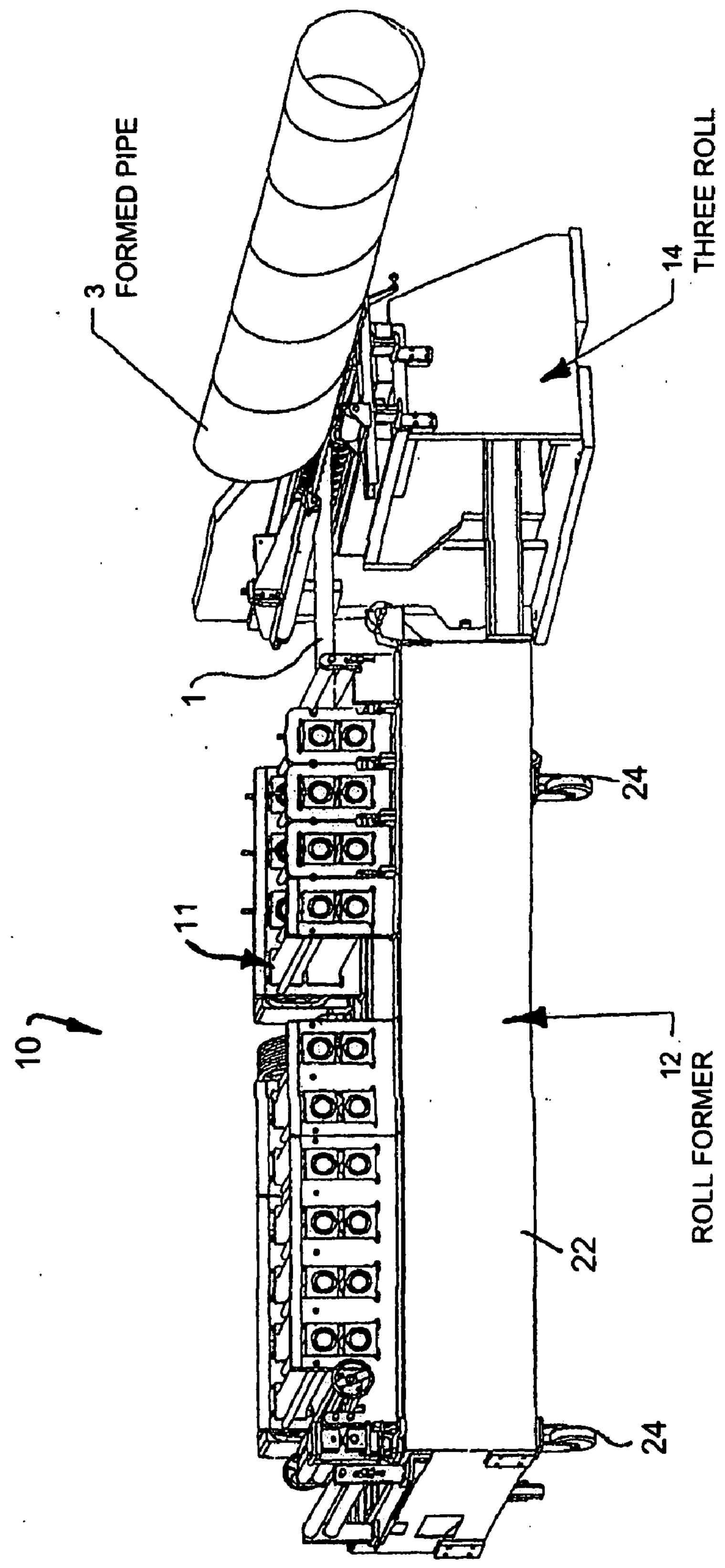


FIG. 1



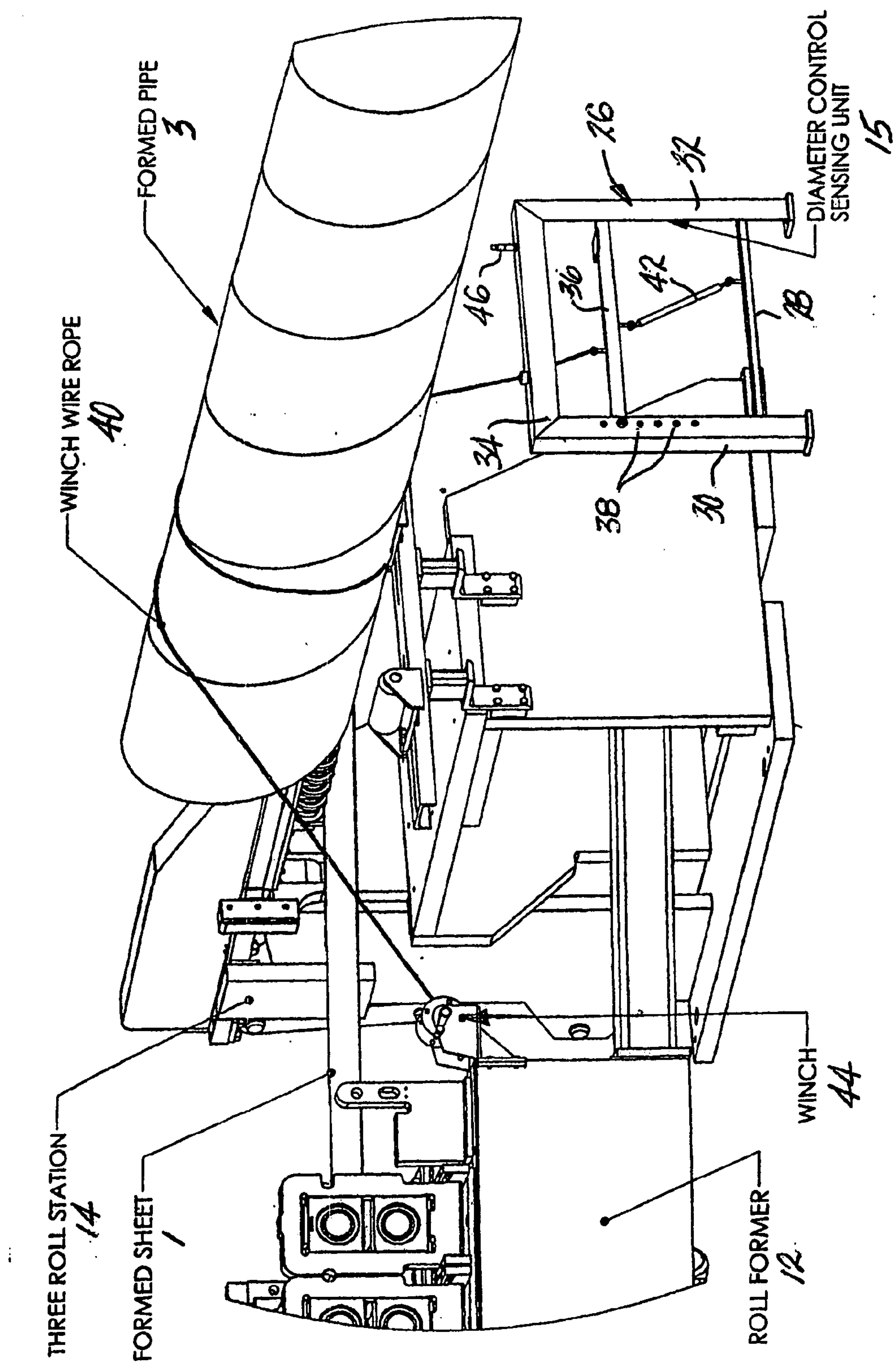

THREE ROLL STATION
14
FORMED SHEET
1
ROLL FORMER
12
WINCH
44
WINCH WIRE ROPE
40
FORMED PIPE
3
DIAMETER CONTROL
SENSING UNIT
15
26
32
46
36
42
18
34
38
30

FIG. 2

FIG. 3

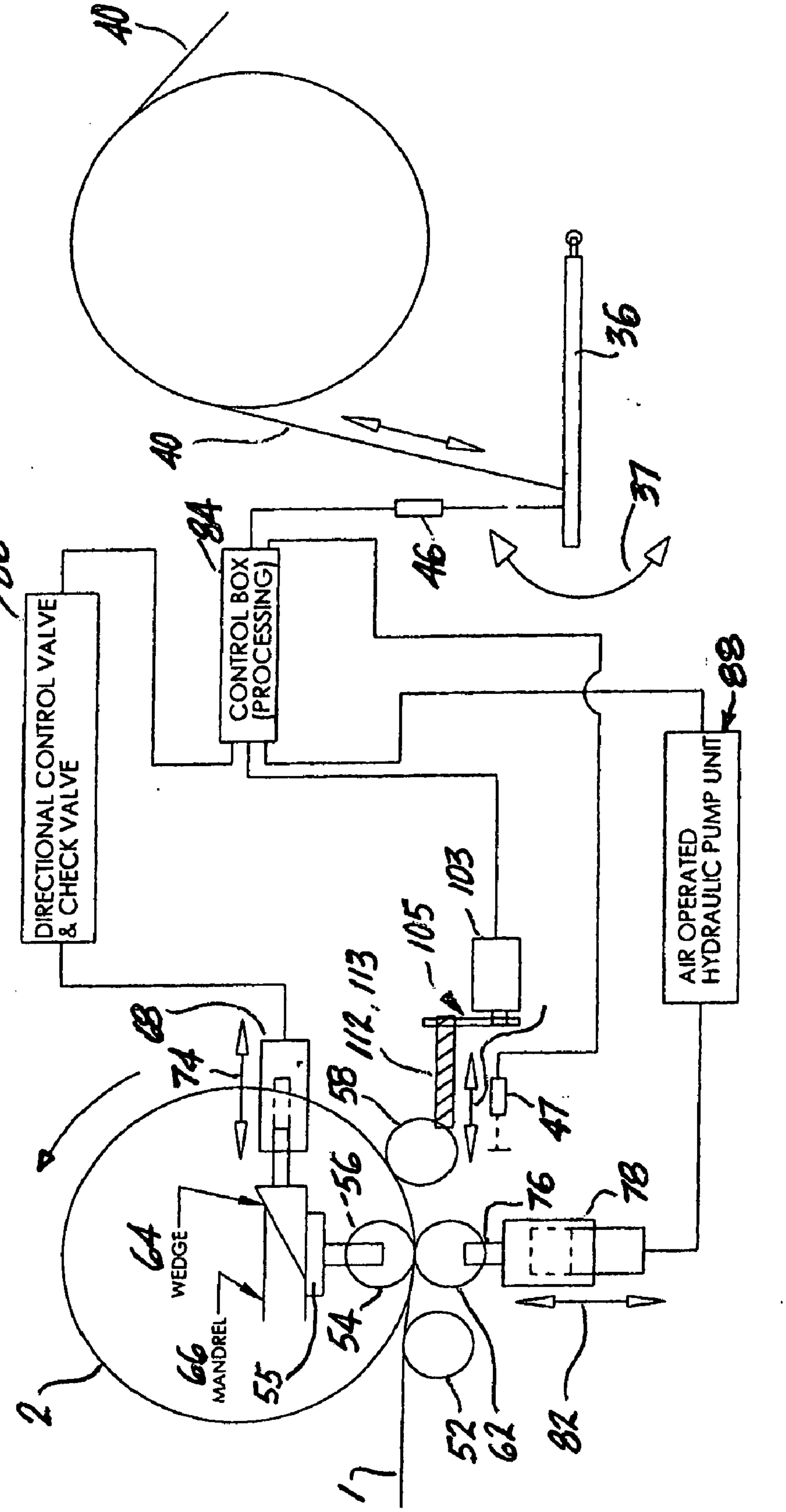

DIRECTIONAL CONTROL VALVE & CHECK VALVE
CONTROL BOX (PROCESSING)
AIR OPERATED HYDRAULIC PUMP UNIT
WEDGE
MANDREL
86
84
88
40
36
37
46
47
103
105
112, 113
58
68
74
64
66
56
55
54
76
78
2
1
52
62
82

FIG. 4

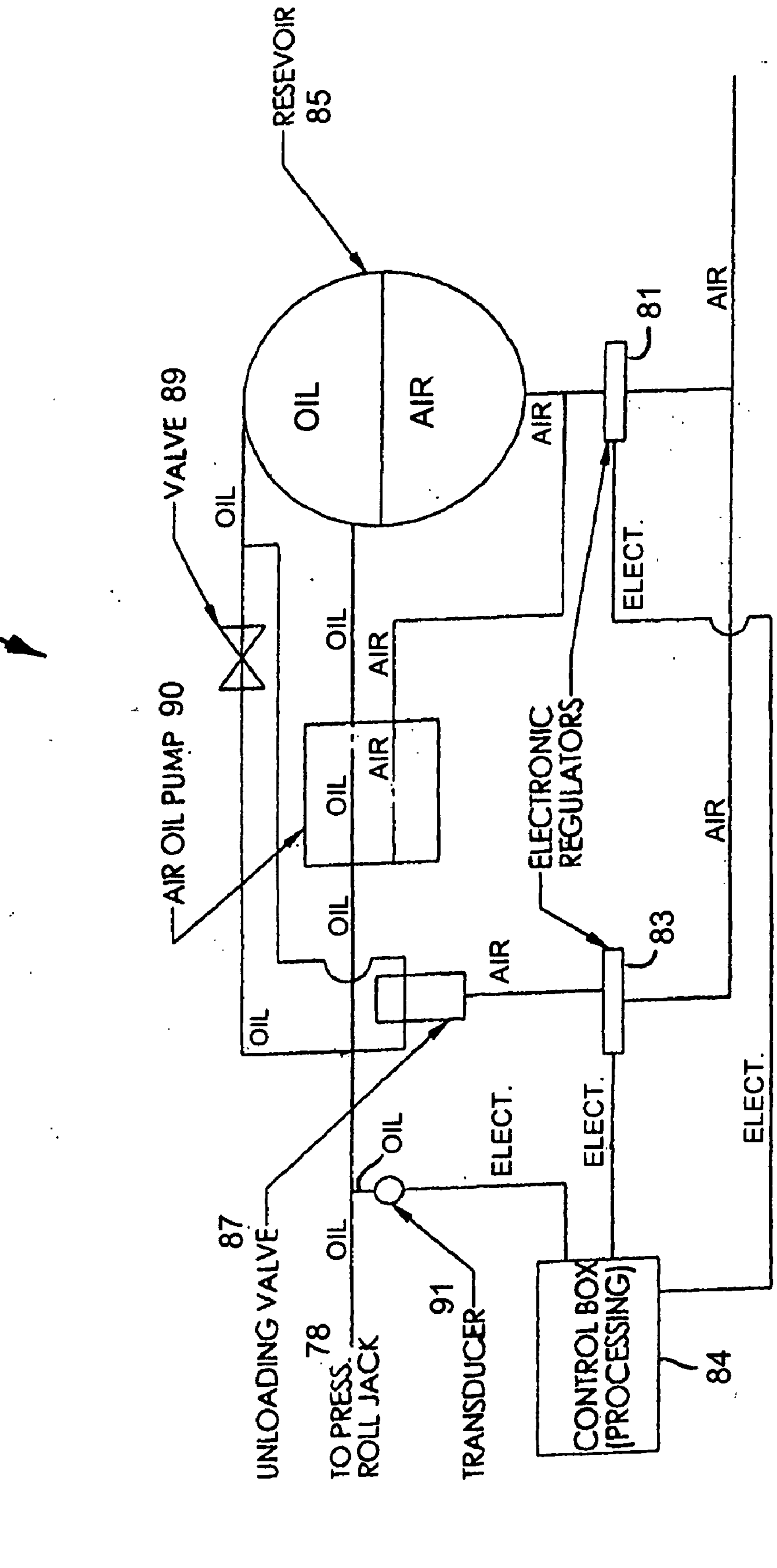
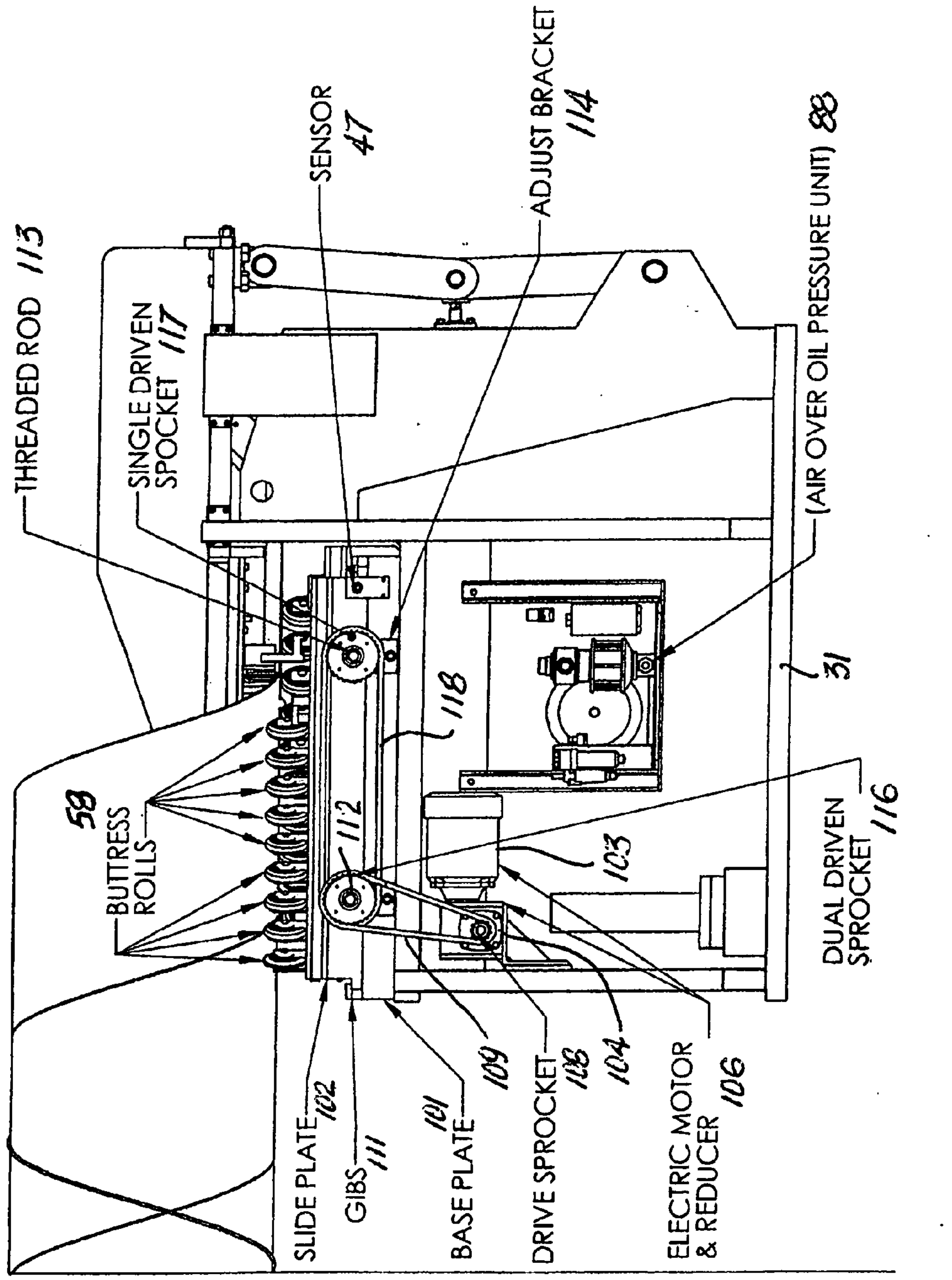

88
RESEVOIR 85
OIL
AIR
VALVE 89
AIR OIL PUMP 90
ELECTRONIC REGULATORS
81
83
UNLOADING VALVE 87
TO PRESS. ROLL JACK 78
TRANSDUCER 91
CONTROL BOX (PROCESSING)
84
ELECT.

FIG. 5


100
THREADED ROD 113
SINGLE DRIVEN SPOCKET 117
SENSOR 47
ADJUST BRACKET 114
(AIR OVER OIL PRESSURE UNIT) 88
BUTTRESS ROLLS 58
118
112
31
103
DUAL DRIVEN SPROCKET 116
SLIDE PLATE 102
GIBS 111
BASE PLATE 101
109
DRIVE SPROCKET 108
104
ELECTRIC MOTOR & REDUCER 106

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±¼ (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 e 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 the 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 correct± 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.

* * * * *