

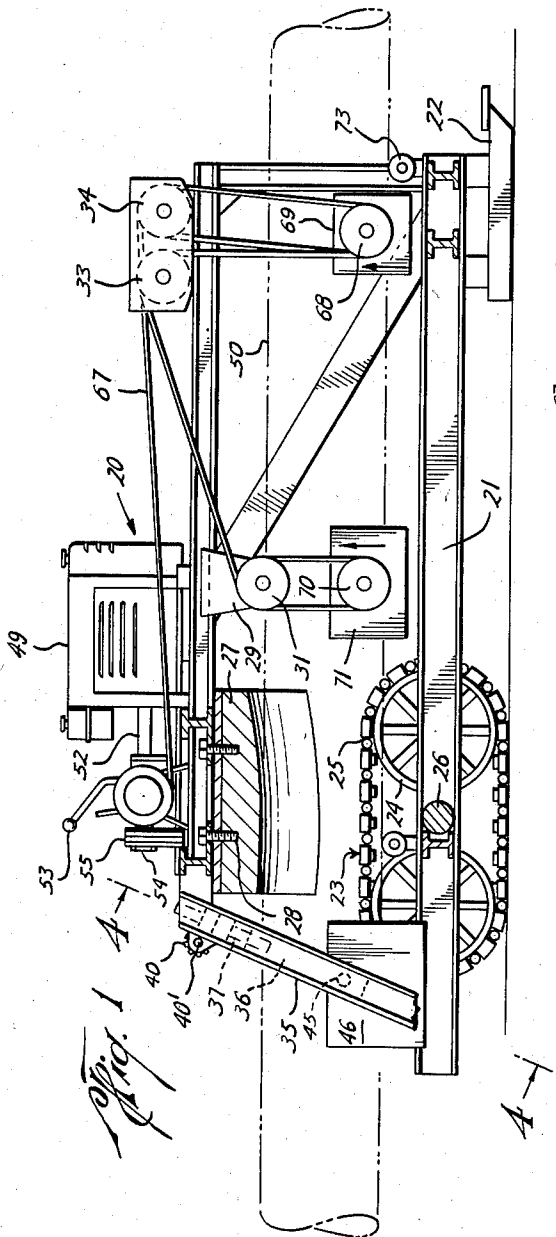
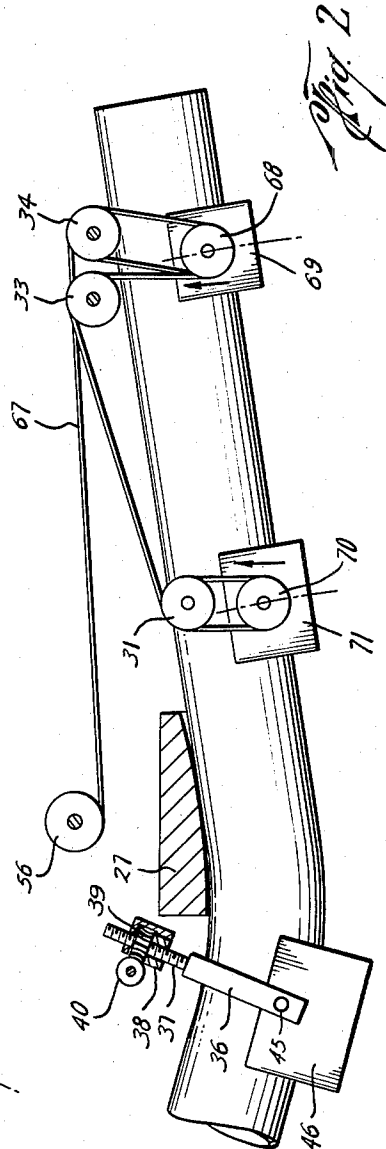
Feb. 7, 1961

S. L. BALLARD
PIPE BENDING MACHINE

2,970,633

Filed Feb. 21, 1956

4 Sheets-Sheet 1



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INVENTOR.

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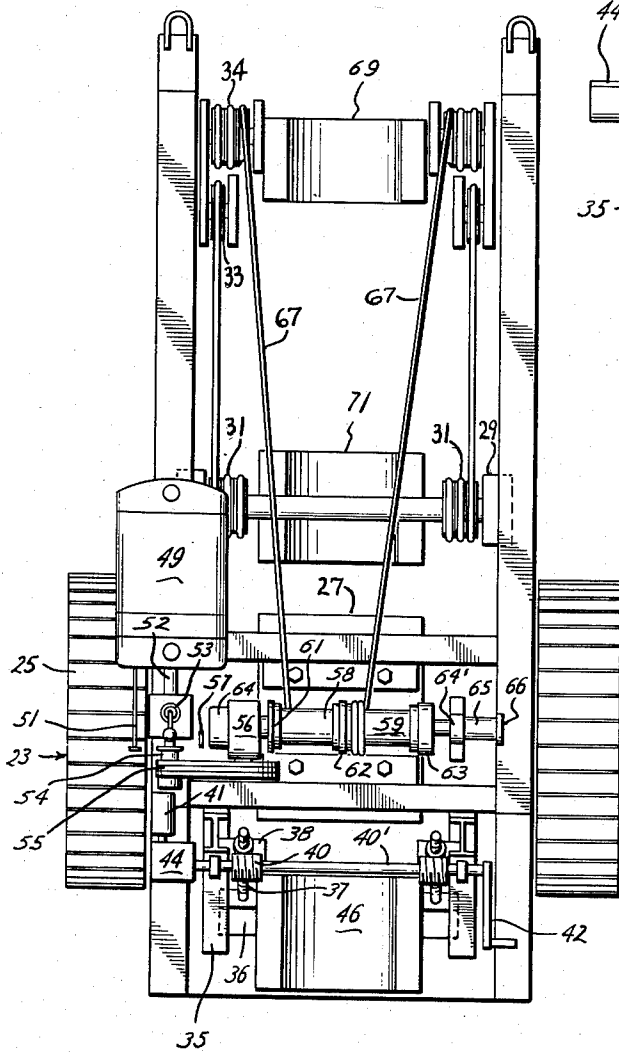
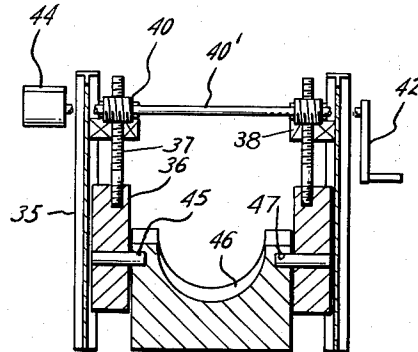
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Fig. 3

Fig. 4



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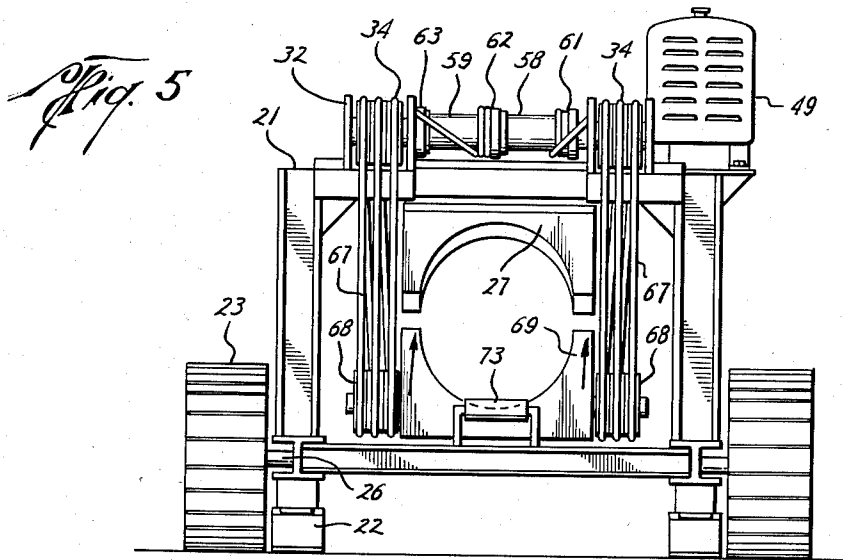
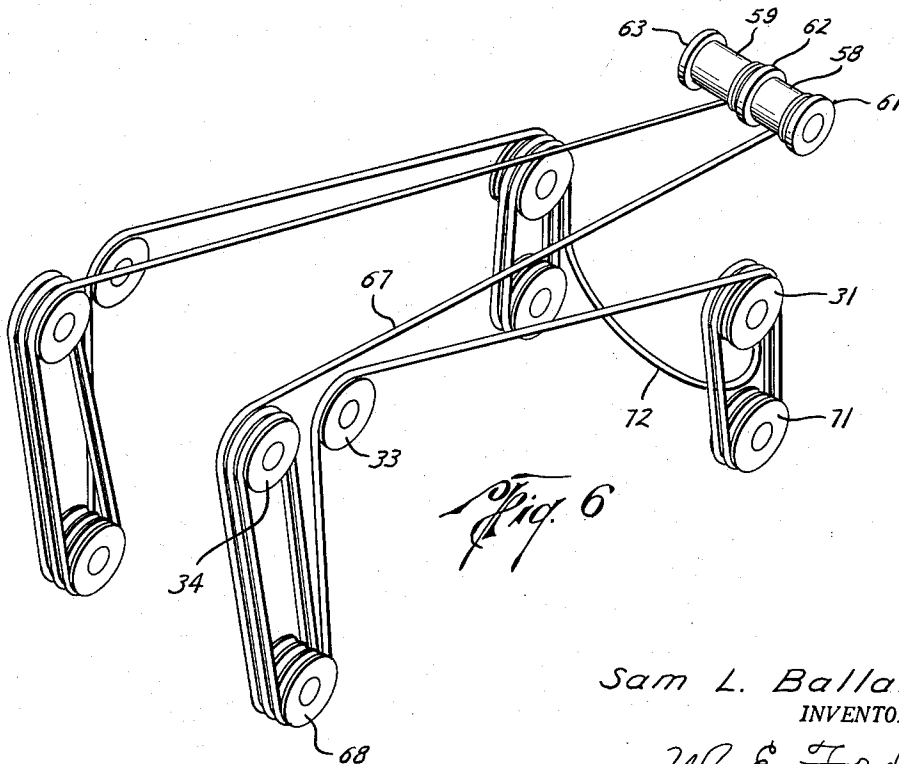
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4 Sheets-Sheet 3



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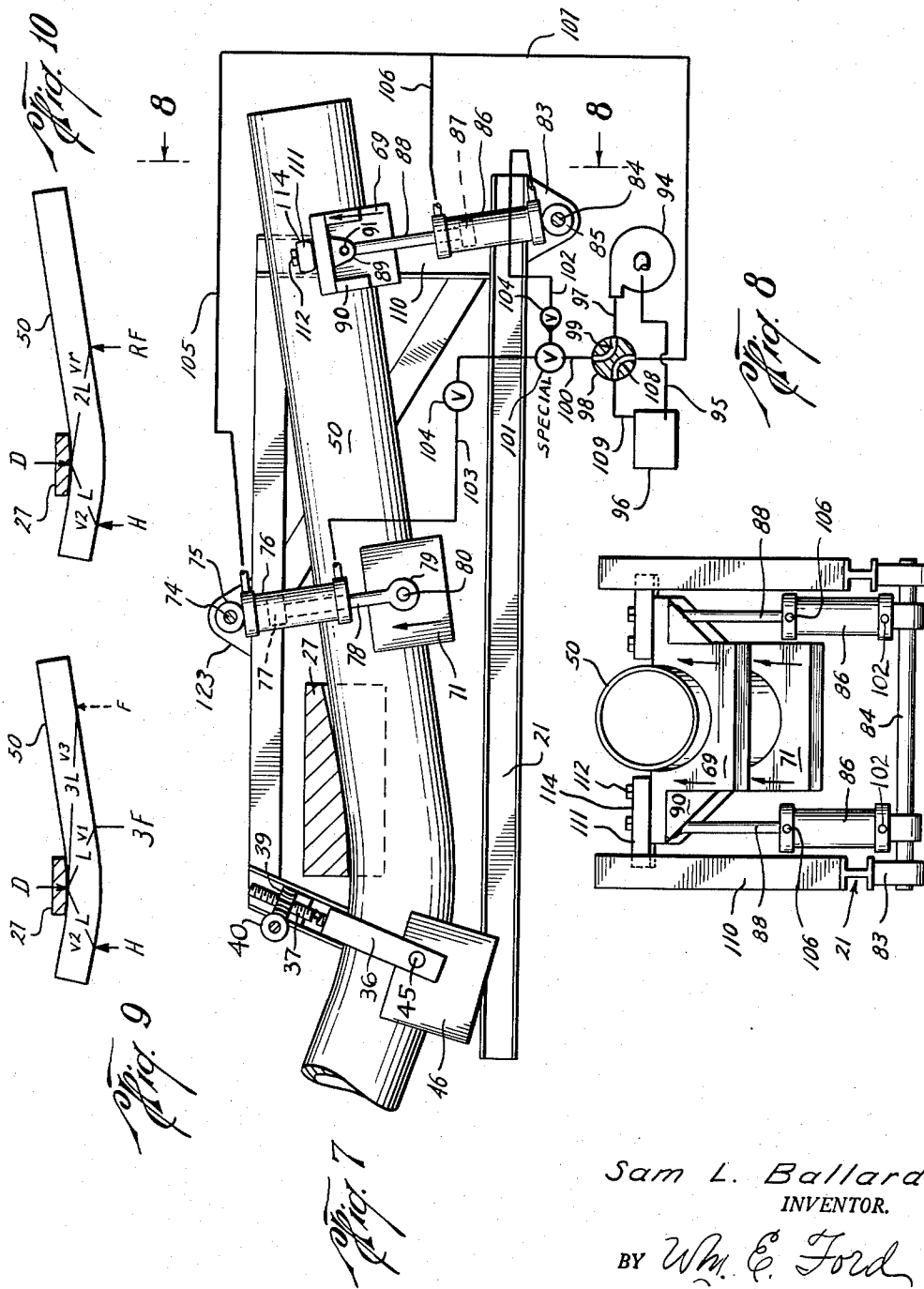
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2,970,633

PIPE BENDING MACHINE

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Filed Feb. 21, 1956, Ser. No. 566,946

6 Claims. (Cl. 153—32)

This invention relates to pipe bending machines and particularly to the class adapted to cold bend pipe of large diameters, such as pipe employed in pipe lines for the transmission of gas over long distances. Heretofore pipe bending machines which have carried out cold bending have relied upon an element termed a strongback or stiffback such as disclosed in Patent Nos. 2,589,651 and 2,708,471 to Sam L. Ballard and such as disclosed in patent application Serial Number 32,911 filed June 14, 1948, by John L. Coody, now Patent No. 2,740,452, and patent application Serial Number 152,237 filed March 27, 1950, by John L. Coody, now Patent No. 2,740,453. Whether operable by cables or by hydraulic rams these machines included a substantially straight bending shoe curved transversely to receive one side of the pipe to be bent and disposed with one end coextensive with or closely proximate the curved bending die on the opposite side of the pipe therefrom. From the end of the curved die opposite the holding shoe the stiffback, strongback, or bending shoe element extended at considerable length in direction opposite the holding shoe and on the outer end thereof a leverage force was applied. Also proximate or coextensive with the end of the bending die opposite the holding shoe a bending force was applied, so that the bending force urges the pipe into the bending die and the leverage force working through substantially the whole length of the bending shoe element to obtain a large bending moment worked with a substantially greater moment than the bending moment to bend the pipe in the direction of the bending die.

This was an obvious result since if the force applied at the point of leverage were approximately equal to the bending force, then the leverage force acting through the extended length of the strongback would far exceed in moment the moment resulting from the bending force acting through the short distance to the ever moving point of bending.

Under such conditions when unskilled operators operate the bending machine or when for other reasons the machine may be operated too quickly, the excess of moment applied at the point of leverage would exert too great a strain on the pipe on the inside of the bend so that the pipe would tend to bend or wrinkle with the result of rejections by the trade and consequent waste of pipe, time and labor.

In order to remedy this condition it was ascertained by practice observations that a bending force might be applied at some location at a distance on one side of the center of the bending die substantially or proximately equal to the distance from such center to the holding shoe on the opposite side thereof. Under such conditions, although the moment of bending which equals the force multiplied by the distance to the point of bending, will constantly change and decrease during bending as the point of bending moves successively along the bending die from the holding shoe end thereof to the opposite end thereof, nevertheless, by locating the application of the bending force at such a location there would never be

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such application of dynamic bending moment as opposed by static holding moment as to depart in great degree from the equilibrium of bending condition under which the pipe is subjected to such excess strain during bending as to cause buckling or wrinkling of the pipe, even when bent at substantially short radii.

It was further observed that in application, as the pipe was brought towards the end of the bend, the momentum of bending would continue as the bending moment diminished as the point of bending moved toward the end of the bending die opposite the holding shoe, and in cases as when thin wall pipe was being bent, successful bending could be accomplished without the abetting excess moment of the leverage force acting at some substantial spaced distance outwardly of the bending force and applied through a substantially long lever arm distance.

In furtherance of these observations and when operations were conducted on pipe of certain strength characteristics and wall thickness in proportion to the diameter thereof, it became apparent that bending might be accomplished without fear of wrinkling or buckling the pipe through the excess leverage moment if the leverage moment were reduced to the status of a booster moment which booster moment in the case of thin wall pipe might not exceed the bending moment, and which booster moment in the case of thick wall pipe might not substantially exceed such bending moment.

Also, through extended observations, a bending condition was visualized whereby a resultant location for a combination of bending and leverage forces might be determined, as by a formula involving the mathematical theory of limits, and such location would be at some spaced distance outwardly of the bending force point of application hereinabove described and at some substantially spaced distance inwardly from the hereinabove described point of location of the leverage force.

In fine, by a studied location of the point of application of the bending force, or of a resultant force combining the bending force and leverage force, the elongated, substantially straight, and substantially rigid bending shoe element termed the strongback or stiffback in prior art machines now in operation could be entirely eliminated and replaced by a single, short, straight, bending shoe operable at the hereinabove described resultant location, or by two substantially straight, short bending shoes located at the hereinabove described locations of bending force and leverage force. In this manner the load requirements of the means for bending the pipe could be appreciably lowered to the extent that there is no longer needed that part of such load requirement heretofore required to move that substantial length and weight of the strongback or stiffback which was inoperative in any point of time except as a connector between the part thereof through which the leverage force was applied and the part thereof through which the bending force was applied.

This substantial and radical departure may be carried out by substantially altering current bending machines by reducing the number of sheaves and loops in the respective pulleys and cable comprising the motive means through which the leverage force operates, whereas the number of pulley sheaves and cable loops comprising the motive means through which the bending force operates is some substantial multiple of the aforesaid leverage force sheaves and loops. Optionally two separate winches can comprise the motive means, one to operate the leverage force cable through pulleys with few sheaves therein, and the other to operate a bending force cable through pulleys having a greater number of sheaves therein with attendant greater number of cable loops.

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In hydraulic machines this flexibility can be obtained by providing a small diameter ram or piston to comprise the motive means through which the leverage force is applied and a large diameter ram or piston to comprise the motive means through which the bending force is applied. Optionally, separate hydraulic systems may be provided also to comprise the motive means, one to operate the leverage force with lesser force application, and one to operate the bending force with greater force application. Or still another motive means arrangement which may be provided is that of a common fluid system operating through a conventional "sequence" valve, or through a conventional Vickers apparatus which distributes fluid power disproportionately with the greater power being delivered to the point of bending force application and the lesser power being delivered to the point of leverage force application.

Also in practice it has been experienced that the holding shoes heretofore employed which were rockably mounted on an eccentric or which changed position for bending by means of a wedging action required extremely heavy beams and reinforcing structures to enable them to withstand the excessive bending moments to which they were subjected. Also such holding shoes transferred the load placed upon them against a structure which took the thrust at a point 90° from the sides of the shoe substantially in a longitudinal plane including the pipe axis, and thus the holding shoes tended in service to spread apart sidewardly so that the pipe could spread therein in oval contour. Also hazard existed in the wedges of certain types of machines slipping out during bending or in other types of machines the eccentric would not hold position. As a remedy a holding shoe which was pivotally suspended from light beams or tracks to the side thereof would take thrust sidewardly and thereby would not spread out of round, could be safe from hazard in operation, and the support therefor could be designed for easy adjustment as bending progressed.

In consequence of the conditions prevailing in the trade and the problems challenging solution the various objects of this invention can be set forth as hereinabove.

It is a primary object of this invention to provide a pipe bending machine which eliminates the employment of the substantially straight, elongated, rigid bending shoe element employed in the cold bending of pipe, especially pipe of large diameters employed in pipe lines, but also in smaller diameters of pipe, such element heretofore having been termed the strongback or stiffback, and having been employed to receive thereagainst a bending force applied on the opposite side of the bending die from the bending shoe and adjacent or coextensive with the end of the bending die opposite the holding shoe, and a second force termed a leverage force applied at a spaced distance outwardly of the point of application of the bending force.

It is another object of this invention to provide a pipe bending machine of this class which through elimination of the strongback requires less motive power in operation, to the extent that the motive power is no longer needed which has heretofore been required to move the heavy weight of strongback connecting the part to which the bending force is applied and the part to which the leverage force is applied.

It is a further object of this invention to provide a pipe bending machine of this class in which the tendency to wrinkle or buckle the pipe on the inside of the bend is eliminated by reducing in substantial degree the leverage moment heretofore employed.

It is also another object of this invention to provide a pipe bending machine of this class in which the leverage moment and bending moment heretofore separately employed may now be employed as a resultant moment with point of force application spaced intermediate the above described points of application of the leverage force and

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bending force, thereby eliminating one shoe employed in the embodiments hereinabove described, and thus eliminating shoe weight.

It is also still a further object of this invention to provide a pipe bending machine of this class in which the holding shoe may be suspended sidewardly by light support means, thereby eliminating machine weight and keeping the pipe in round cross-section, and facilitating holding shoe operation.

It is still another object of this invention to provide an improved method of pipe bending insuring against wrinkling or buckling the pipe.

It is also still a further object of this invention to provide a pipe bending machine of this class in which the holding shoe is pivotally mounted to pivot during the bending operation.

Other and further objects will be apparent when the specification is considered in connection with the drawings in which:

Fig. 1 is a sectional elevation of a cable operated, vertical pipe bending machine disclosing one embodiment of the invention;

Fig. 2 is a longitudinal sectional view, partially diagrammatic, best showing the operative elements of the embodiment of Fig. 1;

Fig. 3 is a plan view of the machine shown in Fig. 1;

Fig. 4 is a transverse sectional elevation taken along line 4-4 of Fig. 1;

Fig. 5 is an end view of the embodiment of the invention shown in Fig. 1 taken at the end thereof opposite the end through which the view of Fig. 4 is taken;

Fig. 6 is a perspective view, partially diagrammatic, showing the cable reeving of the embodiment of Fig. 1;

Fig. 7 is a sectional view, partially diagrammatic, showing a hydraulically operable machine;

Fig. 8 is an end view of the machine shown in Fig. 7;

Fig. 9 is a moment diagram illustrating the employment of the leverage force in booster status; and

Fig. 10 is a moment diagram illustrating the employment of a force which is the resultant of the leverage force and the bending force shown separately in Fig. 9.

Referring in detail to the drawings, a pipe bending machine is shown in Fig. 1 which embodies the invention in one aspect. The machine 20 has a frame 21 which has a skid 22 to support its forward end and rearwardly it is supported by a traction assembly 23 including on each side longitudinally spaced apart wheels 24 about which there is installed an endless traction or caterpillar chain 25. The wheels 24 have their axles journaled in the ends of a conventional connection bar, not shown, and an axle 26 extending transversely across the frame, has the connection bars on each side pivotally mounted on its ends centrally of the connection bars.

A die 27, curved transversely to receive the semi-peripheral surface or half of the pipe to be bent and curved longitudinally to receive the bend of the pipe, is removably mounted by machine screws 28 on the frame 21 with the bend receiving surface facing downwardly. On each side of the frame 21 a bracket 29 supports an axle on which is mounted a pulley 31 and on each side the frame also carries support plates 32 in which are journaled the axles of pulleys 33, 34.

On the rear of the machine the stanchion member which on each side connects the upper and lower part of the frame 21 is an I-beam or H-beam 35 with flanges extending transversely of the frame and web extending lengthwise of the frame. A block or bar 36 of rectangular cross-section fits between the flanges on the inner side of each beam 35 and such bar 36 has a rod 37 connected rigidly thereto or formed therewith, the upper end of the rod being threadably received through a transversely extending frame bracket 38. Above the bracket 38 a worm pinion 39 is held positioned and threadably receives the rod 37 therethrough and meshes with a worm 40 on a shaft 40' journaled in brackets 43 on the frame

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21. Said shaft 40' is driven by a reversible motor 41 through a gear-box 44, both mounted on the frame 21. The rotation of the worm 40 thereby rotates the pinion 39 and the rod 37 is consequently moved up and down as the bar or block 36 tracks in the beam 35. Optionally the motor 41 may be disconnected by a conventional clutch, not shown, and the worm shaft rotated by a hand crank 42.

Each block 36 has an axle 45 extending inwardly therefrom and a holding shoe 46 has a bore hole 47 on each side to receive an axle 45 therein, whereby the holding shoe is pivotally mounted on and suspended by the axles 45. The holding shoe 46 is short and straight in length and is curved transversely to receive the semi-peripheral surface of the pipe to be bent.

A means of power or motive means such as an internal combustion engine 49 is mounted on top of the frame 21 and its clutch handle 51 extends rearwardly therefrom. The motive means also includes an engine shaft 52 which extends rearwardly to a gear shift 53 and from the gear shift a pulley 54 is rotated to drive a belt 55 which extends over and drives a similar pulley, not shown which is mounted to drive a winch 56 with shaft journaled at 64, 64' and controlled by a hand clutch 57 and a conventional foot brake, not shown. The winch 56 has two drum sections 58 and 59 defined by flanges 61, 62 and 63. Outwardly of the journal 64' the winch shaft has a smaller diameter drum 65 thereon having an outer flange 66, and this drum receives cable for moving pipe into the machine for successive bending operations, as will be hereinbelow described.

From each cable drum 58, 59 a cable 67 is payed out and extends over that pulley 34 on its side of the machine and downwardly under a pulley 68 also comprising part of the motive means and which is mounted on a side of a leverage shoe 69. Such leverage shoe is curved transversely to receive the semi-peripheral surface of the pipe to be bent and is straight longitudinally and comparatively very short in length. The cable 67, as an included part of the motive means, is reeved through the sheaves of the pulleys 34, 68 and from the final fall it extends upwardly over the pulley 33 and from thence over the pulley 31 and downwardly around a pulley 70 which is mounted on a corresponding side of a bending shoe 71. Such bending shoe 71 is curved transversely to receive the semi-peripheral surface of the pipe to be bent and is straight longitudinally and is approximately the length of the holding shoe 46.

The cable 67 is reeved through the sheaves of the pulleys 31, 70 and from the inward sheave on each side it extends across the machine as shown at 72 in Fig. 6 and is thus continuous from its point of connection to the drum 59 on one side to its point of connection to the drum 58 on the other side.

In operation a pipe 50 to be bent is handled into the forward end of the machine and over a guide roller 73 mounted on the frame for that purpose and the pipe rests in and is supported by the leverage shoe 69, bending shoe 71, and holding shoe 46, as shown in Fig. 1.

The engine 49 is then started and the gear shift 53 operated and the winch 56 is rotated to take up the cable 67 with the consequence that a bending force is applied to the bending shoe 71 to draw it upwardly and force the pipe into the bending die 27. As shown in the drawings, with the same or greater number of falls reeved through the sheaves of the pulleys 34, 68 than the falls reeved through the sheaves of the pulleys 31, 70, the force applied at the point of leverage is greater than the force applied at the bending shoe, and the moment of leverage force is consequently much greater than the moment applied at the bending shoe, since the leverage force acts through the extended distance from the leverage shoe to the point of bending on the bending die 27, whereas the bending force is applied through the substantially

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shorter distance from the bending shoe to the point of bending on the bending die.

The machine as shown in Figs. 1-6 may be used where the pipe to be bent is of substantial wall thickness and strength in which case the leverage force may act as the major force moving the pipe while the bending shoe acts to support and move the pipe upwardly into bending position. With such pipe the excess moment of leverage will not be so great as to cause the pipe to bend or wrinkle, and the sideward pull exerted by the cables will not cause the die and bending shoe to spread sidewardly as readily as with other types of machines and therefore at least during the early life of these elements the pipe will hold round rather than oval cross-section in bending. On the other hand a balance of moments within limits is preserved between the bending shoe moment and the opposing holding shoe moment so that fineness of control is maintained upon the pipe in the zone of bending.

In this type of machine there is eliminated the stiffback or strongback now employed in certain conventional vertical and horizontal pipe bending machines, and in machines operated by cables or by hydraulic pistons or rams, and the excess weight going into this element is eliminated. Also when the points of application of bending force and of leverage force were joined together, as in the strongback or stiffback, there result in usage the bending of the strongback so that it departed from a longitudinally straight element and assumed a curvature in the same direction as the curvature of the bending die with the consequence that often the pipe bent thereby would bend or wrinkle unduly so that these expensive elements had to be recalled from service and discarded.

The result was inherent in such types of machines, since the strongback rolled about the pipe as it was bent, so that as bending progressed and the contact point of bending moved away from the holding shoe end of the machine and toward the leverage end, a greater and greater length of the strongback was out of contact with the pipe and served no present function but had to be supported as idle weight until again used in making a subsequent bend. On the other hand, the elimination of the strong back and the substitution of two separate shoes therefor, each of short length and light weight, and with such short shoes being readily reinforceable to prevent warping or bending longitudinally, results in a much more efficient machine and one requiring less motive power in the engine 49, and less winch capacity. As a consequence a much lighter and easier maneuverable machine can be provided.

In the machine as shown in Figs. 1-6 variation in the ratio of leverage moment to bending shoe moment can be obtained by the reeving of the cable 67 through the respective pulleys 34, 68 and 31, 70. Thus a bending moment can be obtained equal to or greater than the leverage moment by employing a number of falls in the reeving of the pulleys 31, 70 that bears a ratio to the number of falls in the reeving of the pulleys 34, 68 equal to or greater than the ratio of distance from the point of leverage force application to the point of bending contact in the bending die 27 to the distance from the point of bending force application to the pipe in the bending shoe to the point of pipe bending contact in the bending die 27. Under these conditions thin walled pipe may be bent without danger of wrinkling or buckling due to the application of the leverage force moment.

Also, a machine of still greater flexibility may be obtained by supplying two separately motivated winches and a cable reeving as shown in Fig. 11 of Patent No. 2,708,471 for Pipe Bending Machine issued May 17, 1955, to Sam L. Ballard. In such case the timing of the application of bending shoe force and leverage force can be controlled so that the winch operating the cable extending through the pulleys 31, 70 may first be actuated to urge the pipe into the bending die and later the winch

operating the cable extending through the pulleys, 34, 68 may be actuated to apply the leverage moment to bending after the pipe is in bending position in the die. Thus a greater flexibility in bending may be obtained so that advantage may be taken of the timeliness of bringing the support of the two forces into play at the proper instant as needed in the bending process, and in this regard no specific limitation is placed on this sequence and as to which force may first be applied, as the sequence may necessitate variation dependent upon the characteristics and dimensions of the pipe being bent.

As successive bends are made in the pipe the pipe is moved from front to rear in the machine and the holding shoe 46 must assume greater initial angularity as it takes position at the beginning of each new bend. Each time this angularity is increased the block 36 must be moved upwardly and this is accomplished by actuation of the motor 41, or by the hand crank 42 when the motor is declutched.

In Figs. 7-8 another embodiment of the invention is disclosed in which a frame 21 supports thereon a bending die 27, a holding shoe 46, with supporting and moving elements corresponding with those hereinabove described for the embodiment of Figs. 1-6, and with frame structure in general corresponding with the frame, structure hereinabove described. However variation is made in the motive means or force supplying elements actuating the bending shoe 71 and the leverage shoe 69 in that each are actuated by hydraulic motive means. To this end a bracket 123 on the frame supports a pivot pin 74, and a journal 75 connected to a cylinder 76 receives the pivot pin 74 therein so that the cylinder may pivot thereabout.

A piston 77 operates in the cylinder 76 and the rod 78 of the piston 77 sealably extends through the cylinder head and terminates in a journal 79 which receives therein a bearing pin or axle 80 extending from one side of the bending shoe 71. A similar piston-cylinder construction is correspondingly mounted on the opposite side of the bending shoe 71 by corresponding mounting elements. Also a bracket 83 on the end of the frame 21 supports a pivot pin 84, and a journal 85 connected to a cylinder 86 receives the pivot pin 84 therein. A piston 87 operates in the cylinder 86 and has a rod 88 which extends sealably through the cylinder head and terminates in a cross-pin 91. A bracket 90 is affixed to a side of the leverage shoe 69 and has a journal 89 thereon to receive the cross-pin 91 therein and thus the piston rod 88 is pivotally connected to the bracket 90 to pivot in a vertical plane parallel to a vertical plane through the longitudinal axis of the pipe to be bent. A guide bar 111 is affixed to the bracket 90 by machine screws or bolts 112 and this guide bar extends outwardly and guidably bears between the flanges of an upright H-beam or I-beam 110 on the frame 21, the sides 114 of the guide bar being rounded and the guide bar being lesser in degrees of width than the distance between the flanges of the upright 110 for reason apparent when the operation of the machine described herein below may be considered.

In this construction the bending shoe 71 and the leverage shoe 69 as well as the holding shoe 46 have force transmitted thereto sidewardly rather than at the arcuate part thereof spaced 90° from the side surfaces. In this manner the strain placed on the shoes does not tend to spread them sidewardly so that they present a round surface to the pipe for a much longer period than when the force may be applied 90° from such points of application as in conventional hydraulic pipe bending machines now in the field. This reaction of bending forces to the side of the pipe rather than at an apex spaced 90° therefrom is illustrated by arrows in Figs. 1, 2, 5, 7, and 8.

The view of Fig. 7 may be considered as a plan view as well as an elevation because in either position the elements of the machine thus shown now operate to bend

pipe. When employed as a horizontal pipe bending machine these elements can achieve a much better result than with the present horizontal hydraulic pipe bending machines employing the strongback or stiffback to effectuate bending since in such machines, as the force is now applied 90° from the sides of the strongback, this element has to be supported on the bed of the machine and slides thereon with friction.

A pressure fluid system, shown diagrammatically, is provided to operate the pistons 77 and 87 and such system includes a pump 94 which takes suction by way of a suction line 95 from a reservoir 96 and delivers pressure fluid through a discharge line 97 to a four-way valve 98 and through the passage 99 in the valve to a supply header 100. The supply header 100 extends to a special valve 101 from which one line or conduit 102 extends to one end of the cylinder 86 and another line or conduit 103 extends from the valve 101 to one end of the cylinder 76. From the other ends of the cylinders 76 and 86 conduits 105 and 106 respectively lead to a header 107 which extends to the valve 98 to connect with the passage 108 therein which in turn connects with a return line or conduit 109 to the reservoir 96.

In operation the valve 98 is turned to the position shown in Fig. 8 and the pump is started to draw fluid from the reservoir 96 and discharge it through the valve 98 to the valve 101. Such valve 101 may be a valve which needles or reduces the pressure of the fluid delivered so that the fluid at greater pressure may be delivered through one of the conduits 102, 103 than through the other of such conduits in cases where the conduits 102, 103 may be of different diameters. Optionally such valve 101 may proportion the volume of fluid delivered to the conduits 102, 103 when the conduits may be of different diameters. As another feature the valve 101 may vary the time at which fluid may be admitted to the conduits 102, 103 so that fluid may be admitted to one of the conduits earlier, later, or partially coincident with the admission of fluid to the other conduit.

In supplementation of the operation of the valve 101 each conduit 102, 103 may have a choke or similar fitting 104 therein. In such case as when the valve 101 does not needle the fluid this function may be carried out by the manual setting of the choke 104. Optionally the fitting 104 may serve as other functional devices when the valve 101 is not provided to carry out together all of the functions hereinabove described as within its capability.

The fluid admitted into the cylinder 76 by way of the conduit 103 urges the piston toward the pivot pin 74 and thereby urges the bending shoe 71 against the pipe received therein to urge the pipe into the bending die 27. As this occurs the fluid on the opposite side of the piston 77 is urged out of the cylinder 76 and by way of the conduit 105, the header 107, the valve 98, and the return conduit 109 it is delivered back to the reservoir 96.

In a corresponding manner fluid from the valve 101 is delivered to the conduit 102 and into the cylinder 86 to move the piston 87 toward the pipe and therewith the rod 88 which forces the leverage shoe against the pipe and motion continues to apply the leverage force as such enters to move the end of the pipe against the static opposition of the bending shoe 27.

At the end of the bending the four-way valve 98 may be turned some distance as 45° to place the passages 99 and 108 out of communication with the conduits 97, 100 and 107, 109, and thereby the shoes 71 and 69 may be fluid locked at the end of bending. To return to initial position the four-way valve 98 is turned to place the passage 108 in position to place the conduits 97, 107 in communication and the passage 99 in position to place the conduits 100, 109 in communication whereby the pump delivers fluid to the cylinders through the header 107 and fluid returns from the cylinders through the conduits 102, 103, and the valve 101, to the header 100,

and through the valve 98 by way of the return conduit 109 to the reservoir 96.

With the construction hereinabove described the proportion of bending force to leverage force may be varied in a number of ways as by varying the volume of fluid delivered, the rate of fluid delivery and pressure, and the time of delivery into each of the cylinders 76 and 86. Also at outset the delivery capacity and/or force may be varied as, for instance providing much larger diameter piston 77 in proportion to the diameter of the piston 87. Thus there is provided a machine comparable to the machine embodied in Figs. 1-6 in which the various means of controlling a hydraulic system compare with the various means described hereinabove for controlling bending with a cable operated machine.

The operation of both machines is illustrated graphically in Figs. 9 and 10. In Fig. 9 a pipe 50 is shown being bent against a die 27, a large force $3F$ being applied at the bending shoe to act over a varying distance L^v1 so that the moment of bending is equal to $3FL^v1$. A much smaller force F is shown as being applied at the point of leverage to act through a varying distance $3L^v3$ much greater than the distance L^v1 so that the moment of bending is equal to $3FL^v3$. As bending progresses the distance L^v2 increases toward the forward end of the machine. Correspondingly the distance L^v1 decreases as the point of bending die contact moves forwardly. At the same time the distance $3L^v3$ decreases as the point of bending die contact moves forwardly. It can thus be seen that studied application to the employment of forces and to the relative distances through which such forces may act can result in machines operable without strongbacks which may be employed in accordance with the methods hereinabove described and in utilization of the structures hereinabove described, and in utilization of modifications thereof within the broad scope and spirit of this invention, to successfully cold bend pipe of various tensile strength, diameters, and wall thicknesses, with less rejects from wrinkling or buckling or from out-of-roundness than heretofore encountered in the trade.

In accordance with the concepts hereinabove set forth a machine conceived after the diagram of Fig. 10 is included in this invention which may operate to carry out both the function of the bending shoe and of the leverage shoe by employment of a single shoe of no greater length than say the bending shoe hereinabove described as such bore relation to the length of the bending die, and such shoe could be located at some point intermediate the locations described herein for such two shoes. Such shoe, thus located, could have a force RF applied thereto to act over a distance $2L^v1$ and the holding shoe would oppose the opposite end of the pipe with a static moment HL^v2 . In such case the distance L^v2 would increase forwardly as bending die contact moved forwardly. On the other hand the distance $2L^v1$ will decrease as bending die contact moves forward in bending. Machines constructed after this principle may be cable operated by a single winch and a single pair of pulleys cable connected on each side between frame and resultant bending shoe. Also in hydraulic operated machines the principles hereinabove set forth may be employed by a single cylinder-piston arrangement employing the generally described fluid system, such cylinder-piston being located intermediate the positions of these elements as described in the embodiment disclosed in Figs. 7-8.

In accomplishing bending in all of the fashions hereinabove described it is pointed out that the bending shoes, leverage shoes, or resultant shoes hereinabove described all maintain contact with the pipe without substantial slippage and are moved by the movement of the rams or pistons or of the cables while in substantial firm grasp against the pipe against longitudinal slippage movement, and the same is true in the case of the holding shoe during bending.

This invention is not limited to the methods and structures hereinabove described but other methods and structures are included as well as such may fall within the broad spirit of the invention and within the broad scope of interpretation claimed and merited for the appended claims.

What is claimed is:

1. A pipe bending machine comprising a frame, a bending die on said frame curved transversely to receive one side of a pipe to be bent and curved longitudinally about an axis remote from said frame to receive a bent length of pipe, a holding shoe on said frame substantially shorter longitudinally than said bending die and substantially spaced from one end of said die and disposed on the opposite side of the pipe from said die and curved transversely to receive the said opposite side of the pipe, a bending shoe also disposed on the opposite side of the pipe from said bending die and substantially shorter longitudinally than said bending die and curved transversely to receive the said opposite side of the pipe and substantially spaced from the opposite end of the bending die a distance substantially equal to the spacing of the holding shoe from the bending die, a leverage shoe also disposed on the opposite side of the pipe from said die and curved transversely to receive the said opposite side of the pipe and spaced a substantially greater distance than said bending shoe on the opposite side of the bending shoe from the bending die, and motive means including means pivotally mounting said bending shoe, means swingably connecting said mounting means to said frame, means to swing said bending shoe pivotal mounting means and said bending shoe therewith in direction to contact the pipe to be bent and to apply a bending force to bend the pipe into the curvature of the bending die, said motive means also including means spaced from said bending shoe pivotally mounting said leverage shoe, means swingably connecting said leverage shoe pivotal mounting means to said frame to swing said leverage shoe independently of movement of said bending shoe pivotal mounting means to change the distance between the pivotal axes of both of said mounting means before bending begins and to move said leverage shoe in direction to contact the pipe to be bent so as to apply a leverage force to complete the bending of the pipe into the longitudinal curvature of the die.

2. A pipe bending machine as claimed in claim 1 in which said motive means is connected to each of the sides of said bending shoe and leverage shoe to apply forces at substantially diametrically opposite points in direction of bending.

3. A pipe bending machine as claimed in claim 1 which includes means on each side of said frame providing a pivotal connection with said holding shoe and movable with relation to said frame and operable to permit said holding shoe to be rocked in accordance with the movement of bent pipe thereinto to position the pipe for subsequent bending.

4. A pipe bending machine as claimed in claim 1 in which said means to swing said bending shoe pivotal mounting means and said bending shoe therewith in direction to contact the pipe to be bent applies a bending force of one value to bend the pipe into the curvature of the bending die, and in which said means to swing said leverage shoe pivotal mounting means independently of movement of said bending shoe pivotal mounting means moves said leverage shoe in direction to contact the pipe to be bent and applies a leverage force of a different value than said bending force to complete the bending of the pipe into the longitudinal curvature of the die.

5. A pipe bending machine comprising a frame, a bending die on said frame having a die recess curved transversely to receive one side of a pipe to be bent and curved longitudinally about an axis remote from said frame, a holding shoe on said frame substantially shorter

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longitudinally than said bending die and substantially spaced from one end of said die and disposed on the opposite side of the pipe from said die and curved transversely to receive the said opposite side of the pipe, a bending shoe also disposed on the opposite side of the pipe from said bending die and substantially shorter longitudinally than said bending die and curved transversely to receive the said opposite side of the pipe and substantially spaced from the opposite end of the bending die a distance substantially equal to the spacing of the holding shoe from the bending die, a leverage shoe also disposed on the opposite side of the pipe from said die and curved transversely to receive the said opposite side of the pipe and spaced a substantially greater distance than said bending shoe on the opposite side of the bending shoe from the bending die, and motive means including a winch on said frame, pulley means, and cable means extending from said winch, said pulley means including pulley means on said frame and pulley means on said bending shoe with said cable means being reeved therethrough to pivotally mount said bending shoe and to swing said bending shoe pulley and said bending shoe therewith in direction to contact the pipe to be bent and to apply a force to bend the pipe into said bending die recess, said pulley means also including pulley means on said frame and pulley means on said leverage shoe with said cable means being reeved therethrough to pivotally mount said leverage shoe and to swing said leverage shoe pulley and said leverage shoe therewith independently of movement of said bending shoe pulley to change the distance between the pulley axes of said mountings and to move said leverage shoe in direction to contact the pipe to be bent and to apply a leverage force to complete the bending of the pipe into the curvature of the die.

6. A pipe bending machine comprising a frame, a bending die on said frame having a die recess curved transversely to receive one side of a pipe to be bent and curved longitudinally about an axis remote from said frame, a holding shoe on said frame substantially shorter longitudinally than said bending die and substantially spaced from one end of said die and disposed on the opposite side of the pipe from said die and curved transversely to receive the said opposite side of the pipe, a bending shoe also disposed on the opposite side of the pipe from said bending die and substantially shorter longitudinally than said bending die and curved transversely to receive the said opposite side of the pipe and substantially spaced from the opposite end of the bending die a distance substantially equal to the spacing of the holding shoe from

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the bending die, a leverage shoe also disposed on the opposite side of the pipe from said die and curved transversely to receive the said opposite side of the pipe and spaced a substantially greater distance than said bending shoe on the opposite side of the bending shoe from the bending die, and motive means including a swingably mounted hydraulic ram with piston end and cylinder end, one end being pivotally mounted on said frame and the other end pivotally mounting said bending shoe, said hydraulic ram thus being adapted to swingably move said bending shoe pivotal mounting and to swing said bending shoe therewith to move said bending shoe in direction to contact the pipe to be bent and to apply a force to bend the pipe into said bending die recess, said motive means also including a second hydraulic ram swingably mounted independently of said bending shoe hydraulic ram, said second hydraulic ram having piston end and cylinder end, one end being pivotally mounted on said frame and the other end pivotally mounting said leverage shoe, said second hydraulic ram thus being adapted to swingably move said leverage shoe pivotal mounting to change the distance between the axes of said pivotal mountings and to swing said leverage shoe therewith and to move said leverage shoe independent of movement of said bending shoe and in direction to contact the pipe to be bent and to apply a leverage force to complete the bending of the pipe into the curvature of the die.

References Cited in the file of this patent

UNITED STATES PATENTS

462,538	Doyle	Nov. 3, 1891
1,284,516	Whitecotton	Nov. 12, 1918
1,662,131	Schonfield	Mar. 13, 1928
1,741,840	Harmon et al.	Dec. 31, 1929
1,816,218	Henry et al.	July 28, 1931
1,877,110	Wunderlich	Sept. 13, 1932
2,246,992	Dickinson	June 24, 1941
2,286,255	Brooks	June 16, 1942
2,346,371	Fink	Apr. 11, 1944
2,347,593	Cummings	Apr. 25, 1944
2,491,893	Duer	Dec. 20, 1949
2,525,403	DeWitt	Oct. 10, 1950
2,547,870	Kelso	Apr. 3, 1951
2,589,651	Ballard	Mar. 18, 1952
2,740,453	Coody	Apr. 3, 1956

FOREIGN PATENTS

2,538	Great Britain	of 1903
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