

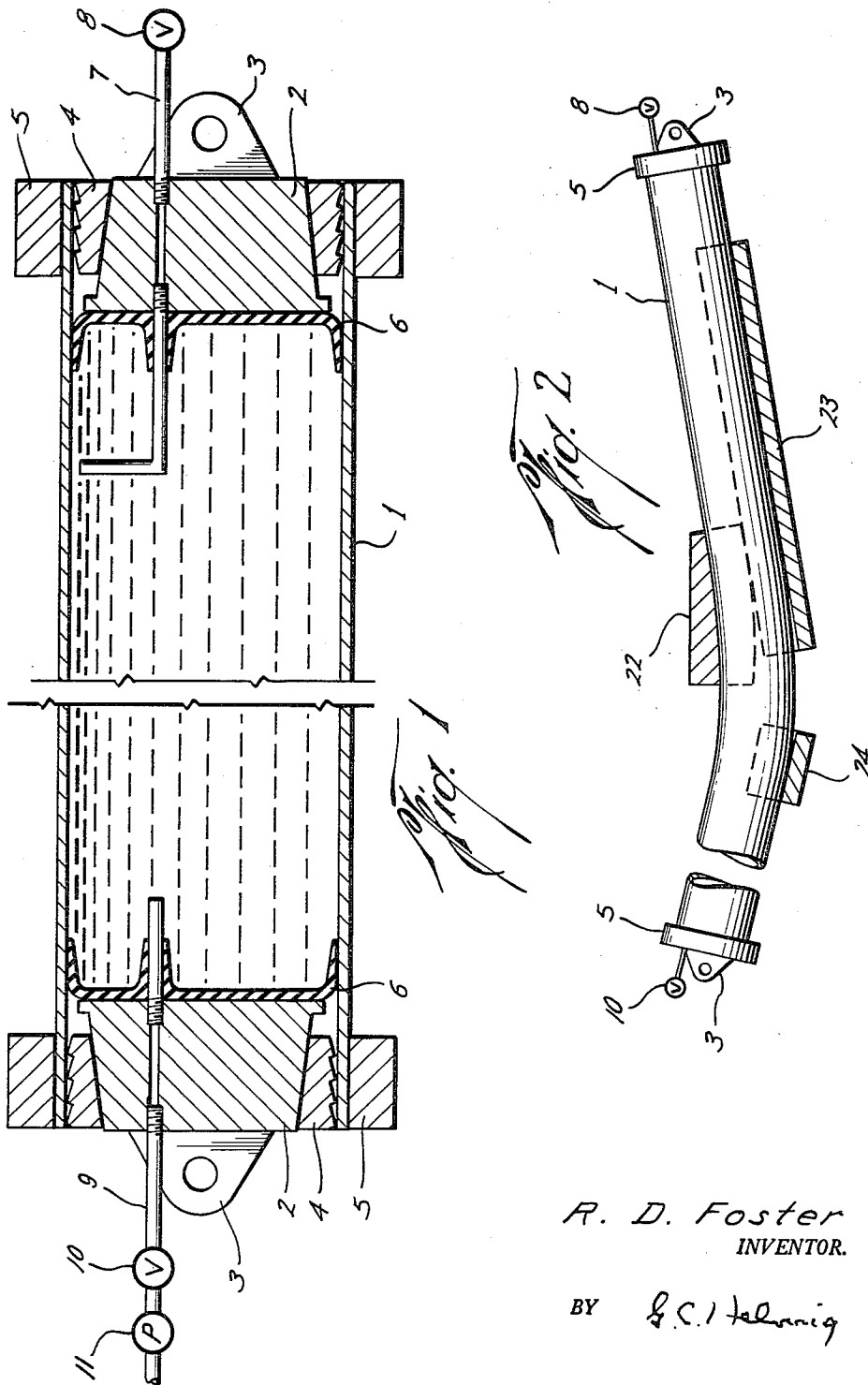
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BENDING PIPE

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BENDING PIPE

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1 Claim. (Cl. 153—39)

This invention relates to cold bending of tubular goods such as large diameter thin walled steel conduits used in cross-country pipe lines.

Oil and gas transmission lines comprise separate joints or sections of pipe up to about forty feet in length in end to end welded together succession and often containing either or both horizontal and vertical bends to follow right of way direction and earth contour. In hilly country, as many as eighty percent of the pipe sections may need to be bent and the common practice is to bend the pipe sections before welding and usually on site or in yards close to the place of installation and by portable bending machines such as illustrated in Ballard Patent 2,708,471.

In using such machines, desired longitudinal curvature is effected by operating separately on successive length increments of pipe and in each bending step the pipe wall on the inside of the curve bears on a longitudinally curved and stationarily supported die while a movable stiff back of greater length than the die engages a diametrically opposite wall portion at the outside of the curve and forcibly pushes laterally on the pipe for a gradually formed bend with the outermost wall portion undergoing stretching elongation while the wall metal on the innermost side is crowded or upset. Dependent on wall thickness and steel hardness, there is a critical point in the extent of permissible upsetting and wall thickness increase which can take place before wrinkles or hills and valleys appear on the compressed wall. Interior wrinkles in a flow line increase frictional resistance to fluid travel and absorb transmission force and also interfere with free passage of pigs. More and more pipe line specifications require smooth interiors to decrease flow force loss and enable fewer and more widely spaced apart pumping stations for lesser construction and operating expense. Additionally, the restrictions on wrinkling formation limit shortness of curve radius to which a pipe joint may be bent.

Limitations on bending curvature and surface irregularities are becoming more serious because larger diameter pipe lines for greater flow capacity at higher pressures are being laid and in the interest of low material and handling costs, weight is kept down with adequate strength by using relatively thinner walls of stronger steel. Such pipe greatly aggravates wrinkle formation and restricts the degree of curvature which can be formed without irregular displacement of the metal as it is upset. I have discovered that the problem of bending such pipe to sharper curvature without inside wrinkling can be met by performance of the bending operation while the pipe is held under pretensioned stress. In the bending on a pipe wall surface under longitudinal pretension stress, wrinkles from upsetting of the inner wall cannot occur until after pretension has gone through zero and the compressive yield point is exceeded. Whether upsetting occurs at all depends on the extent of initial tension and in a given bending operation, inside wall upsetting can be controlled from zero to any amount nearly equal to the outside tensile stretch and predetermined by the degree of pretension placed on the pipe wall. If the difference in outer wall stress during a bending operation and the original yield is less than double the longitudinal tensile stress in the metal at the start of the bending operation,

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then there will be no objectional inside upsetting. It follows that a decrease in longitudinal pretension stress will allow an earlier upsetting of the inside wall of a bend and that an increase in longitudinal pretension stress will delay inside wall upsetting. The degree of bending with permissible upsetting is limited only by the amount of stretching the outer wall will stand without metallurgical damage.

To accomplish useful and satisfactory cold bending, it is an object of the present invention to provide for easily and quickly imposing a longitudinal force on a pipe between its opposite ends to place it under tension stress throughout its length and for maintaining the pipe in longitudinal pretension while performing the bending operation until the re-formed metal has a permanent set.

A further object is to provide for detachably mounting force transmitting and sealing headers to opposite ends of a pipe for confining pressure liquid, introduced through header carried valved connections, to fill the pipe and act on the opposite end headers for imposing longitudinal tension stress on the pipe wall and for maintaining the pipe wall in pretensioned condition while it is operated upon in a bending machine and forcibly formed to desired length curvature.

Other objects and advantages of the invention will become apparent in the course of the following specification having reference to the accompanying drawing wherein FIG. 1 is a longitudinal sectional view of a pipe section with its opposite ends secured and sealed to header assemblies and FIG. 2 shows a partially bent pipe fitted to the operating components of a bending machine.

Referring to FIG. 1, there is shown a length of pipe 1 having both ends closed by suitable caps which preferably are easily applied header assemblies fitted within the pipe. Each header comprises a plug 2 having an outwardly tapered peripheral surface and a forwardly projecting handling lug 3. A circular succession of expansible slip segments are sleeved on the plug 2 and are wedged radially outwardly against the interior pipe wall surface upon relative outward plug travel for detachably anchoring the header in the pipe end and for transferring internal fluid pressure force into the pipe wall between its ends. An annular band 5 closely fitted exteriorly on the pipe end in radial alignment with the slips 4, may be employed to buck and protect the pipe wall against excessive expansion force incident to slip wedging action. An inward flat face on the tapered plug 2 is overlaid by and desirably has secured by bonding or otherwise to it a packer cup 6 of rubber or the like, whose annular flexible lip makes expansive sealing contact with the interior pipe surface.

At the end header toward the right of the drawing, an air vent pipe 7 extends from the pipe interior through both the packing cup 6 and the plug 2 and contains a readily accessible hand valve 8 for opening and closing the passage through the pipe 7. Similarly, the opposite header assembly has extended through it a pipe 9 providing an inlet to the sealed pipe interior and having a control valve 10 for detachably coupling to the outlet side of a motor driven pump 11 to supply water or other liquid under pressure.

After the header assemblies are fitted within and anchored to the opposite pipe ends, liquid under pressure from the pump 11 is delivered through the open valve 10 to the interior of the end sealed pipe. With the vent valve 8 open, all previously enclosed air will be displaced from the pipe interior, whereupon the vent valve 10 is closed. Continued delivery of pressure fluid from the pump 11 will raise the pipe internal pressure to a magnitude that pressure action on the opposed headers will place tension stress in the pipe wall between the spaced apart headers. Upon attainment of a predetermined lon-

gitudinal tension in the pipe wall, closure of the inlet valve 10 will entrap and hold the pressure liquid between the headers and such tensioned condition of the pipe wall will be maintained by the pressure force transmitted through the pipe coupled headers.

With entrapped liquid pressure maintaining the pipe wall under longitudinal tension, the pipe is operated upon in the regular fashion by a conventional bending machine, whose principal operating elements are shown in FIG. 2 as including a curved upper die 22, a movable stiff back 23 and a hinged holding shoe 24. In the customary practice, a pipe length increment will be progressively engaged with and bent on the die 22 by lateral force applied through powered movement of the shiftable stiff back 23. The pipe wall portion bearing on the die 22 will be on the inner side of the formed bend, which is to say that the arc of curvature is of shorter radius at the inside wall than at the outermost wall portion engaged by the stiff back 23. With the pipe wall pretensioned at the start of bending, the tendency for the inside wall portion to be crowded will first result in a decrease in tension stress in the inner wall and an initial stage of bending can occur before pretensioning is completely relieved. This delays the start of upsetting and the action of the entrapped pressure liquid continues in opposition as a tension force to the build-up of opposing compression force, so that crowding of the metal is scaled down and permits a greater amount of curvature to be effected without wrinkling than if pretensioning stress were absent. Inasmuch as liquid pressure acts in all directions, the confined liquid body to some extent may act similarly to an internal bucking fixture in radially opposing internal surface roughness as upsetting progresses. Following completion of the successive bending operations as required to finalize pipe curvature, internal pressure is relieved by opening one or both valves 10 and 12 and the headers are removed for re-use.

For a fuller explanation of the foregoing and for exemplary purposes, a bending operation on a length of forty feet of thirty-six inch diameter steel pipe of three-eighths inch wall thickness will be discussed. As previously indicated, during each bending performance the pipe wall radially outwardly of a neutral axis which may be assumed to coincide with the pipe longitudinal center line, is stretched or elongated and the inside wall is placed under longitudinal compression, which upsets the metal and shortens arcuate length. The wall in the transverse plane of the neutral axis undergoes no change. For this pipe the yield point will be in the neighborhood of fifty-two thousand pounds per square inch. Compression force somewhat greater than the plate yield point can be reached before wrinkling occurs, but usually the yield point is the limit specified. To keep safely below that limit and avoid crowding the wall to formation of wrinkles, the practice heretofore has been to restrict bending curvature within one-half of one degree per twelve inches of pipe length. This means that the outside wall will be elongated to approximately twelve and one-eighth inches and the inside wall will shorten to approximately eleven and seven-eighths inches. Inasmuch as no bending is performed on either end portion of the pipe, the maximum permissible over-all curvature in a joint thirty feet long heretofore has been between ten and twelve degrees as a limit for retaining a smooth interior surface.

That previous limit of permissible curvature can now be doubled or tripled by the herein disclosed improved practice of holding the pipe under tension while it is being bent so that compressive stress is decreased by the amount of pretensioning stress. As an example of the

utilization of the new proposal, the spaced apart ends of a header closed pipe are pulled farther apart hydraulically by a force of eight hundred thousand pounds to place the wall metal under stretch stress of fifteen thousand pounds per square inch. Internally sealed water pressure then maintains the pipe wall under longitudinal stress and in the bending operation, additional tension will be placed on the pipe wall outermost of the curve and a compressive action will occur in the innermost wall, first relieving pretension stress and then stressing the metal in compression, with the compressive force being diminished by the amount of pretensioning stress. Bending can proceed safely beyond the range permissible on non-pretensioned pipe and by comparison a bending which would place sixty thousand pounds per square inch tension on the outside wall and a prohibitive sixty thousand pounds per square inch compression on the inside of a non-pretensioned pipe, would in the case of a pretensioned pipe place a tension stress of sixty thousand pounds per square inch plus fifteen thousand pounds per square inch, or a total tension stress of seventy-five thousand pounds per square inch, on the outside wall and a compression stress of sixty thousand pounds per square inch less the pretensioned stress of fifteen thousand pounds per square inch, for a total compression of forty-five thousand pounds per square inch, on the inside wall which is well below the yield stress of fifty-two thousand pounds per square inch. Accordingly, the metal is not upset to the extent at which wrinkles are formed on the inside of a pipe. In all stages of bending operation, the total of compressive force on the inner wall of a pretensioned pipe will be lessened by the amount of pretensioning stress as against what it would be in the absence of pretensioning. As a result, the degree of curvature can be carried much further in the cold bending of pipe without running into objectionable interior surface irregularities.

What is claimed is:

The method of bending relatively large diameter steel pipe by stretching the wall outermost from the pipe axis and upsetting the wall innermost from said axis, comprising sealing both ends of the pipe, pumping liquid under pressure into the pipe to fill the same and impose tensile stress on the order of several thousand pounds in the pipe wall longitudinally thereof between the sealed ends and then clamping the outermost wall and the innermost wall between powered bending dies and increasing power application to effect further die closing movement and the imposition of lateral bending force on the liquid filled and longitudinally tensioned pipe which responds to the bending force with a gradual relief in tensile stress on the innermost wall through zero followed by an upsetting of the metal in the innermost wall under a compressive stress below that which would cause wrinkling by an amount approximately equal to the tensile stress initially imposed on the wall and finally opening the bending dies and removing the liquid and the end seals upon completion of the bending operation.

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