(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 151 838
A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 84300740.2

(22) Date of filing: 07.02.84

(51) Int. Cl.[4]: C 21 D 9/08

(43) Date of publication of application:
21.08.85 Bulletin 85/34

(84) Designated Contracting States:
AT BE DE FR GB IT NL SE

(71) Applicant: Ball, Daniel Graham
Lothos Lodge Beechers Drive The Avenue
Farnham Common SL2 3JV Buckinghamshire(GB)

(72) Inventor: Ball, Daniel Graham
Lothos Lodge Beechers Drive The Avenue
Farnham Common SL2 3JV Buckinghamshire(GB)

(74) Representative: Rowe, Eric Nielsen et al,
Edward Evans & Co. Chancery House 53-64 Chancery Lane
London WC2A 1SD(GB)

(54) Heat treating hardenable carbon steel pipe.

(57) An annular zone of a carbon steel pipe (10) is heated to an austenizing temperature by an induction heater (14) as the pipe (10) is moved through the heater (14) followed by quenching of the heated zone with a spray (22) of an even conical sheet of quenching fluid travelling at a preselected angle to the surface of the pipe (10) such that after striking the pipe surface the fluid remains in contact therewith resulting in rapid controlled quenching of a well defined area of the pipe (10).

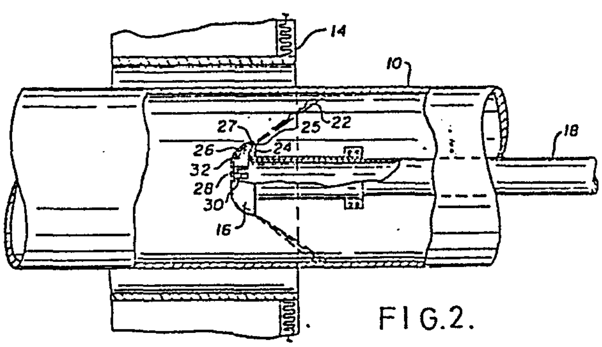

FIG.2.

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Heat Treating Hardenable Carbon Steel Pipe

The present invention relates to a process and apparatus for hardening steel pipe by heating and then quenching.

The usual method of heat treating eutectoid steel is to first convert the ferrite phase to austenite by heating the steel to temperatures of the order of 1000°C. The steel is then cooled sufficiently rapidly for the austenite phase to convert to martensite rather than to ferrite and carbide. Cooling times of more than the order of one second can result in significant formation of the softer ferrite-carbide phase. Achieving controlled quenching within such a time constraint for large objects such as long pipes has proven to be difficult. Methods such as immersing the heated pipe into a water bath are subject to splashing of cooling fluid onto the upper areas of the pipe or rapid steam formation contacting the upper portions of the pipe both of which result in localized ferrite-carbide formation and resultant nonuniform hardening of the pipe.

Another problem with conventional methods is that they generally necessitate heating long sections of pipe and thus encounter difficulties in transporting the pipe, in deformation due to sag in the heated area and cooling during transport to the quenching bath.

It is desirable to cool the heated pipe close to the heat source in order to avoid cooling through radiation, heat conduction along the pipe and local heat transfer to rollers in other parts contacting the pipe in its travel from the heater to the quenching spray. Such heat loss not only represents a lower efficiency of operation but exposes the pipe to development of nonuniformity of hardness due to the aforesaid localized cooling. Cooling the pipe close to the heater also reduces the length of heated pipe and thus avoids problems associated with sag.

However, cooling the interior surface of long sections of pipe sufficiently rapidly and within a well defined area close to the area being heated poses many problems. One method disclosed in U.S. Patent No. 4,110,092 issued to Kunioka on August 24, 1978 and directed only to cooling pipe as opposed to quenching it uses an annular cooling nozzle having a plurality of equispaced nozzle openings whose spray direction is at a dip angle of between 30° and 70° and at a transversal angle of between 30° and 90° with respect to the radial direction of the nozzle. The method disclosed in Kunioka although suitable for cooling pipe is not suitable for quench hardening pipe as the helical flow up one side of the pipe would not be the same as that down the other. In addition, the areas of intersection of water on the pipe surface from adjacent nozzle openings would create turbulence.

According to the invention there is provided a process for heat treating hardenable carbon steel pipe which includes heating an annular zone of said pipe to an austenizing temperature which zone moves at a preselected speed in a direction along the pipe toward an end thereof. The heated pipe is quenched proximate the annular zone with a spray of an even conical sheet of cooling fluid travelling at a preselected angle to the surface of the pipe such that after striking the pipe surface, fluid remains in contact therewith. By simultaneously quenching the heated pipe near the annular zone of pipe heated the amount of heated pipe intermediate the heater and the quenching spray is minimized and any significant amount of sag of the pipe is avoided. By utilizing an even conical spray directed at an angle to the surface as stated above, a sharp well defined quench area is achieved and any tendency toward turbulence, backflow or splashing of the fluid toward the heater is avoided. Thus, an extremely hard uniform martensitic structure on the surface quenched is produced.

Preferably the preselected angle is less than 40° to the surface of the pipe.

By maintaining the pipe open at both ends and ensuring that all liquid in the quenching spray after striking the pipe remains in contact therewith and moves in the direction of movement of the pipe, air is educted by the spray and caused to flow along the direction of the longitudinal component of the spray velocity. Such an airflow assists in the prevention of splash or spray upstream and the prevention of any vapour barrier from being established adjacent the surface of the pipe which would otherwise reduce the cooling rate of the pipe.

Advantageously, the cooling fluid is water and the temperature of the water in the spray is maintained at a level less than 80°C.

By moving an end of the pipe adjacent to which induction heating and quenching is commenced in a circular arc of a selected radius away from the induction heating zone and associated quenching area, a quench hardened bend is produced. In establishing such a bend an annular zone of a width lying in the range of 2.5 to 5 cm (1 to 2 inches) is produced by utilizing a narrow induction coil.

In another aspect of the invention there is provided apparatus for heat treating hardenable carbon steel which includes an annular induction heater for enclosing and heating an annular zone of the pipe and a quench head for emitting an even spray of a conical sheet of cooling fluid onto an interior surface of the pipe. The spray impacts on the pipe near the annular zone at an angle to the surface of the pipe such that the cooling fluid remains in contact with the pipe surface thereafter, minimizing the establishment of a vapour barrier on the pipe surface and maximizing the cooling effect of the cooling fluid. Also included are means for supporting and moving the pipe through the heater and over the quench head. Preferably the quench head has an adjustable annular orifice for directing cooling fluid onto the pipe surface at an angle less than 40°. By providing an adjustable orifice, adjustment of the angle of impact of the conical sheet of spray is possible in order to optimize the flow of cooling fluid along the pipe surface after impact.

Advantageously, the quench head includes an adjustable lance for support and adjustment of the position of the quench head relative to the induction heater so that the spray impinges on the heated pipe adjacent the annular zone of pipe being heated. A bending machine may also be provided for bending an end of the pipe as it passes over the quench head and through the induction heater.

In the accompanying drawings:

Figure 1 is an elevation view of the apparatus for heat treating hardenable carbon steel;

Figure 2 is a sectional view of a portion of the apparatus showing a portion of the induction heater, the quench head and a section of pipe undergoing treatment;

Figure 3 is a plan view of apparatus for induction bending and simultaneously hardening the bend of a pipe according to the invention; and

Figure 4 is a sectional view of a portion of the apparatus of Figure 3 showing the quench head, induction heating coil and a portion of the pipe undergoing bending.

Figures 1 and 2 show apparatus for heat treating a straight elongated pipe 10 supported on a plurality of rollers 12 in a position in which it is enclosed by an induction heater 14 and passes over a quench head 16 axially aligned with the pipe axis. The quench head 16 is supported by an elongated lance 18 which also provides cooled water to the quench head 60. The lance 18 is supported at one end by an adjustable lance support tower mechanism 20 which positions the quench head at a selected position along the longitudinal axis of the pipe.

Figure 2 illustrates the relationship between the quench head 16, the pipe 10 and the induction heater 14. The quench head consists of a front cup shaped plate 26 supported from an extension 28 of the lance 18 and an opposed back plate 24 also supported by the lance 18. The peripheries 25 and 27 of the back plate 24 and the front plate 26, respectively, define an annular orifice which directs water under pressure within a chamber 32 in an even conical sheet spray 22 toward the interior surface of the pipe 10 at an angle thereto of less than 40°. Water reaches chamber 32 by a plurality of apertures 30 in pipe extension 28. Adjustment of the angle of spray is achieved by adjusting the size of the annular orifice.

The process of hardening pipe involves delivering a section of pipe 10 to be hardened onto rollers 12 at one end of the feeding and quenching apparatus. The pipe is then advanced longitudinally into the induction heater 14 which heats a small annular zone of the pipe as it is moved through the heater 14 and over the quench head 16. For a given size of pipe diameter an initial adjustment is made of the quench head annular orifice by moving the pipe over the quench head and adjusting the orifice so that the angle of spray results in the water in the spray maintaining contact with the interior surface of the pipe after impact. The position of the quench head 16 is also adjusted for a given diameter of pipe 10 so that it impacts on the interior of the pipe surface a short distance past the induction heater 14. After the pipe has been moved through the induction heater and quenched it is positioned over lance 18 and must therefore be reversed back to its initial position, taken off the rollers 12, a new section of pipe delivered to the rollers 12, and the process repeated.

The width of the zone heated is in the range of 15 to 20 cm (6 to 8 inches) which is less than the width of the induction heater.

Shown in Figures 3 and 4 is an apparatus for producing a quench hardened bend in a section of pipe. The apparatus consists of the quench head 34 supported on a lance 36 in a manner similar to the apparatus illustrated in Figures 1 and 2. However, in Figure 3 the quench head 34 is reversed from its position as shown in Figures 1 and 2. In addition, the induction heating coil 38 is narrower lying in the range of 2.5 to 5 cm (1 to 2 inches). An adjustable rotatable bending arm 32 clamps an end of the pipe and is movable from a position adjacent the induction heater 38 in a circular path away from the latter. A ram 31 compresses the pipe against the bending arm 32. Illustrated in Figure 4 is the quench head 34 and associted lance 36 in combination with the inductor coil 38 and a section of pipe 30. The quench head is identical to that shown in Figures 1 and 2 except that the annular orifice is directed forwardly of the lance 36 through the induction coil 38 and onto the pipe surface a short distance beyond the induction coil 38.

The process of producing a quench hardened bend according to the apparatus shown in Figures 3 and 4 is initiated by positioning the pipe 30 so that it projects through the induction coil a short distance and is clamped by the bending arm 32. The pipe is moved forward against the force of the bending arm 32 by ram 31. The bending arm 32 rotates and the induction heater heats a small annular zone of the pipe thereby providing the flexibility for the pipe to be bent. A small heated zone is desirable in such a case in order to produce an accurate, well-defined bend. The spray 40 is adjusted in angle of direction in a way similar to that shown in

Figures 1 and 2 in order that the water after impact on the pipe surface flows evenly along the surface to maximize cooling and minimize any tendency toward splash back in the upstream direction. In a way similar to the process for hardening straight sections of pipe, air is educted from the upstream end of the pipe by the spray causing an airflow in a direction of the longitudinal component of velocity of the spray. The latter airflow assists in preventing back flow or the development of a vapour barrier along the pipe surface.

Although water has been mentioned as the cooling fluid, other fluids such as air or a mixture of water and air would be suitable.

By quenching only the interior surface of the pipe the interior surface is hardened while the exterior surface is tough and ductile.

Alternatively, both the interior and exterior surfaces of the pipe could be quenched and the exterior surface subsequently tempered at temperatures up to approximately 700°C.

A single machine, which provides an alternative reduced capital equipment option, may comprise one set of mechanical pipe handling equipment, rams, and drive control systems, one lance for internal quenching, various quench heads as required, two alternative induction heating ring systems (one for bending the other for straight pipe hardening since the latter can be processed faster), and one electrical/water and other service supply system. This single combined machine can manufacture hardened straight pipe and hardened bends by having the body of the bending machine tracked out of line and beyond the bending arm and into line with the larger induction coil, that is the coil used for straight pipe. There are speed controls, enabling straight hardened pipe to be manufactured many times faster than the bends. The machine is thus a combination of the embodiments of Figures 1 and 3. The direction of straight hardening over the quench lance may be reversed, i.e. the pipe travels off the lance rather than on to it as it is being hardened.

Other variations include means to rotate the pipe while heating and quenching are taking place; means to allow rotation of the quench head while heating and quenching straight or, especially, bent pipe and means to rotate the pipe and the quench head in opposite directions during heating and quenching.

Relative rotation between the pipe and the quench head provides a margin of safety for ensuring that the pipe is quenched uniformly. This is critical if irregular bending of the pipe is to be avoided.

Typically, in straight hardening, the heater draws 1000W and quenching is effected by a flow of 37.9 litres per second (500 gallons per minute) of cooling water.

Claims

1. A process for heat treating hardenable carbon steel pipe (10 or 30) to provide differential hardening of the pipe (10 or 30), the hardness decreasing radially outwardly and the ductility increasing radially outwardly, characterised by:

(a) heating an annular zone of said pipe (10 or 30) to an austenizing temperature which zone moves at a preselected speed in the direction along said pipe (10 or 30) toward an end thereof; and

(b) simultaneously quenching said heated pipe (10 or 30) proximate said annular zone thereof with a spray (22 or 40) of an even conical sheet of cooling fluid travelling at a pre-selected angle to a surface of the pipe (10 or 30) such that after striking the pipe surface fluid remains in contact therewith.

2. A process, as defined by Claim 1, wherein said preselected angle is less than 40° to the surface of said pipe (10 or 30).

3. A process, as defined by Claim 2, wherein said conical cooling fluid spray (22 or 40) impacts on said pipe (10 or 30) sufficiently close to said zone such that the pipe (10 or 30) immediately prior to being sprayed is in an austenitic phase.

4. A process, as defined by Claim 3, wherein said pipe (10 or 30) is open at both ends to permit air to be educted by the cooling fluid spray (22 or 40) and to cause an airflow along the direction of the longitudinal component of spray velocity.

5. A process, as defined by any preceding claim, wherein only the interior surface of the pipe (10 or 30) is quenched.

6. A process, as defined by Claim 5, wherein the interior surface of pipe (10 or 30) is quenched and the depth of resulting hardening controlled.

7. A process, as defined by any one of Claims 1 to 4, wherein both the interior and exterior surfaces of the pipe (10 or 30) are heated and quenched to form martensite after which the exterior surface only is tempered by heating.

8. A process, as defined by any one of Claims 1 to 7, wherein both ends of the pipe (10) remain in coaxial alignment and the width of the annular zone heated is in the range 15 to 20 cm (6 to 8 inches).

9. A process, as defined by any preceding claim, wherein both ends of the pipe (10) remain in coaxial alignment and there is relative rotation between the pipe (10) and the spray (22).

10. A process, as defined by any of Claim 1 to 7, including moving an end of said pipe (30) adjacent to which induction heating and simultaneous quenching is commenced in a circular arc of a selected radius away from an induction heating zone and an associated quenching area by a ram (31) which compresses the pipe (30) against a bending arm (32) whereby a quench hardened bend is produced.

11. A process, as defined by Claim 10, wherein the width of the annular zone heated is in the range of 2.5 to 5 cm (1 to 2 inches).

12. Apparatus for heating treating hardenable carbon steel pipe (10 or 30) to provide differential hardening of the pipe (10 or 30), the hardness decreasing radially outwardly and the ductility increasing radially outwardly, characterised by:

(a) an annular induction heater (14 or 38) for enclosing and heating an annular zone of said pipe (10 or 30);

(b) a quench head (16 or 34) for simultaneously emitting an even spray (22 or 40) of a conical sheet of cooling fluid onto an interior surface of said pipe (10 or 30) proximate said annular zone at an angle to the surface of the pipe (10 or 30) such that the cooling fluid remains in contact with said interior surface after impact thereby minimizing the establishment of a vapour barrier on said interior surface; and

(c) means (12 or 31) for supporting and moving said pipe (10 or 30) through said induction heater (14 or 38) and over said quench head (16 or 34).

13. Apparatus, as defined by Claim 12, wherein said quench head (16 or 34) has an adjustable annular orifice for directing fluid onto the pipe surface at angles less than 40° thereto.

14. Apparatus, as defined by Claim 13, wherein said quench head (16 or 34) is adapted to emit water.

15. Apparatus, as defined by Claim 14, wherein said quench head (16 or 34) includes an adjustable lance (18 or 36) for supporting said quench head (16 or 34) and adjusting its position relative to said induction heater (14 or 38) so that the spray (22) impinges on the heated pipe (10 or 30) adjacent the annular zone of pipe (10 or 30) being heated.

16. Apparatus, according to any one of Claim 12 to 15, for heat treating pipe (10) wherein both ends of the pipe (10) remain in co-axial alignment, in which means are provided for effecting relative rotation between the pipe (10) and the quench head (16).

17. Apparatus, as defined by any one of Claim 12 to 15, further including a bending machine (32) for bending an end of said pipe (30) as said pipe (30) passes over said quench head (34) and through said induction heater (38) for simultaneously heating a zone of said pipe proximate said induction heater (38) and quenching the interior surface of said pipe (30) to form a martensitic phase.

18. Apparatus for heat treating hardenable carbon steel pipe (10 or 30) to provide differential hardening of the pipe (10 or 30), the hardness decreasing radially outwardly and the ductility increasing radially outwardly, characterised by:

(a) first and second annular induction heaters (14 and 38) respectively provided for enclosing and heating annular zones of first and second pipes (10 and 30);

(b) a quench head for simultaneously emitting an even spray (22 or 40) of a conical sheet of cooling fluid onto interior surfaces of said pipes (10 or 30) proximate said annular zones at an angle to the surfaces of the pipes such that the cooling fluid remains in contact with said interior surfaces after impact thereby minimising the establishment of a vapour barrier on said interior surfaces;

(c) laterally movable means (12 and 31) for supporting and moving the first and second pipes (10 and 30) respectively through said first and second annular induction heaters (14 and 38) and over said quench head; and

(d) a bending machine (32) for bending an end of a second pipe (30) as said second pipe (30) passes over said quench head and through the second induction heater (38) for simultaneously heating a zone of said second pipe (30) proximate said induction heater (38) and quenching the interior surface of said second pipe (30) to form a martensitic phase.

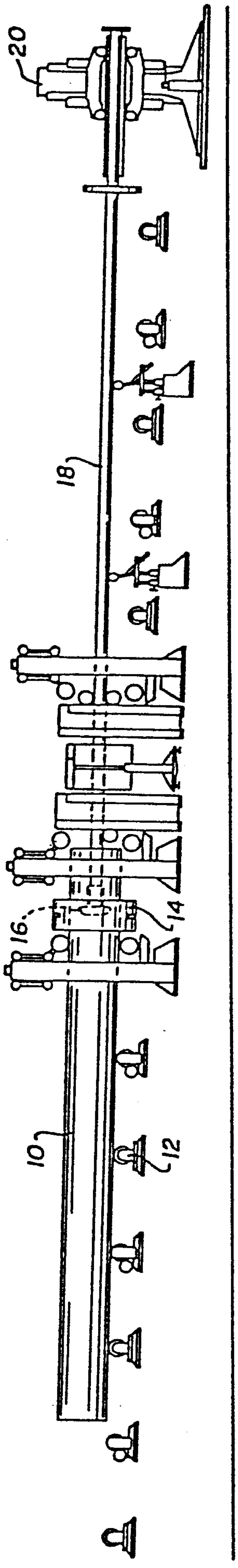

FIG.1.

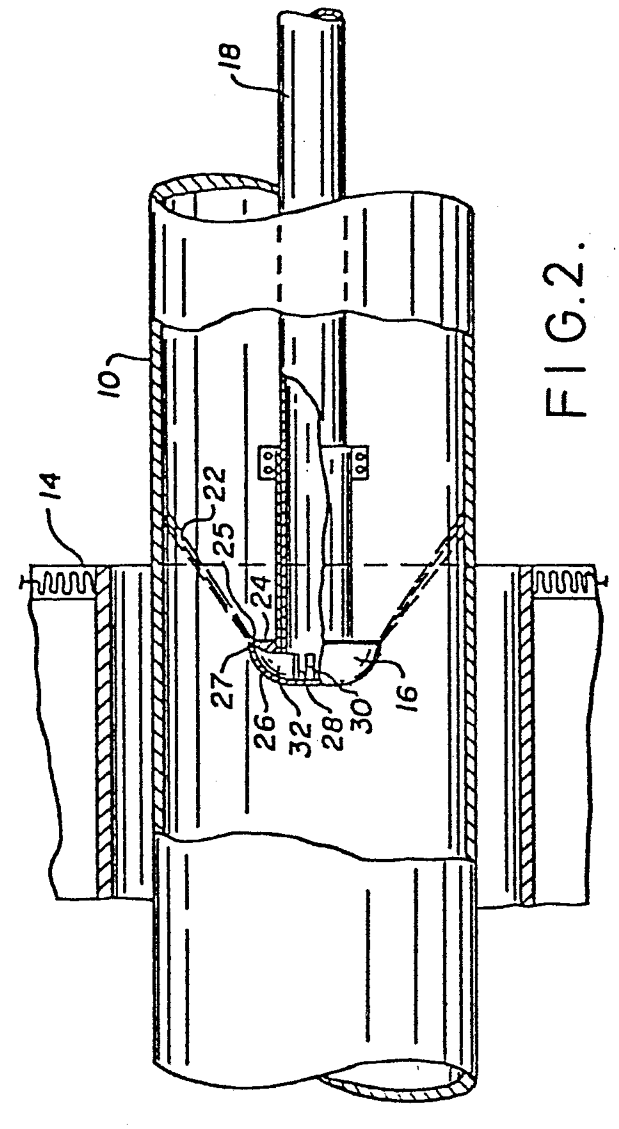

FIG.2.

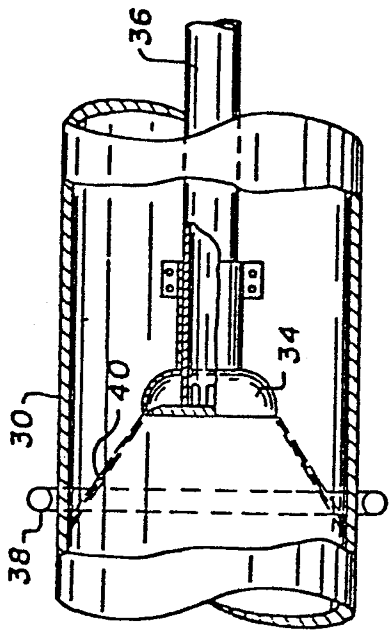

FIG.4.

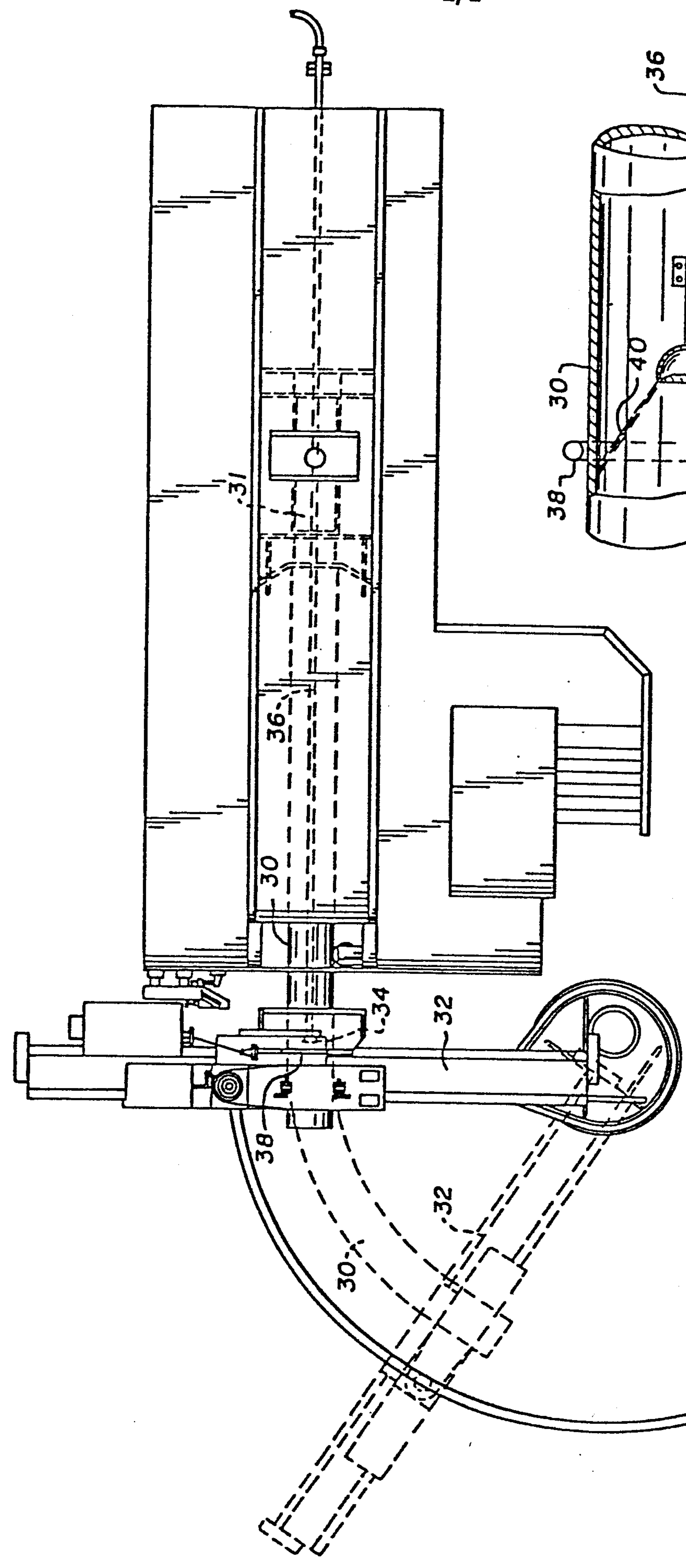

FIG.3.

European Patent Office

EUROPEAN SEARCH REPORT

0151838

Application number

EP 84 30 0740

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	DE-C- 752 084 (OHIO CRANKSHAFT) * Page 3 * ---	1	C 21 D 9/08
Y	GB-A-1 347 445 (LUDWIG-OFAG-INDUGAS) * Figure 1 * ---	1	
A	US-A-3 973 999 (M. NAKAYAMA et al.) ---		
A	US-A-4 123 301 (T.A. POPE et al.) ---		
A	US-A-4 165 246 (F. REINKE et al.) ---		TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
A	GB-A-1 385 243 (MANNESMANN) ---		C 21 D 9/08
A	DE-C- 945 930 (GEWERKSCHAFT REUSS) ---		
A,D	US-A-4 110 092 (K. KUNIOKA et al.) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	09-10-1984	SUTOR W

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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