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[54] AUTOMATIC SUBMARINE TRENCHER

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[52] **U.S. Cl.** **61/72.4,** 37/94, 37/102
[51] **Int. Cl.** **E02f 5/08,** E02f 16/1, E02f 1/00
[58] **Field of Search** 37/94, 102, 85, 90; 61/72.4, 61/72.1, 72.3

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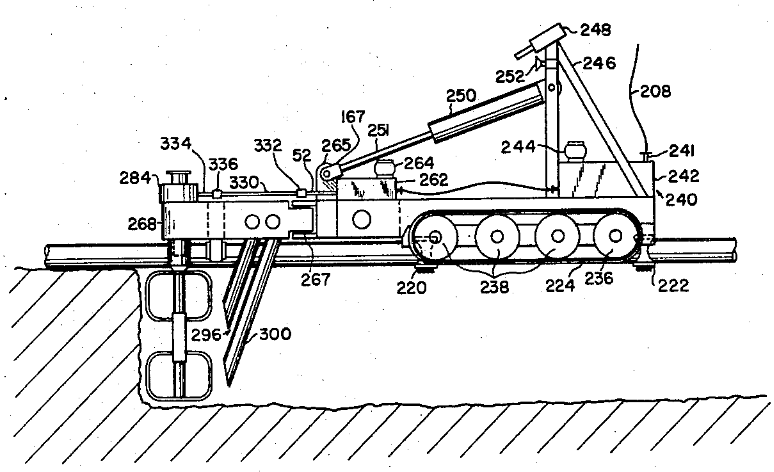
[57] **ABSTRACT**

An automatic trencher is provided for entrenching a pipeline in the bed of a body of water. The trencher is adapted to ride over the pipeline and includes one or more trenching tools which cut away the formation of the bed to form a single trench therein for receiving and burying the pipeline. Power and control signals are supplied by a flexible cable coupling the trencher with an accompanying overhead marine vessel. This power is used to move the trenching tools, to advance the trencher along the path of the pipeline as the trench is being formed, and to energize surveillance apparatus. Depending on the type of soil, tools of various configurations can readily be interchanged while the trencher is submerged. Piston-type hydraulic pump-motor combinations rotate the tools and propel the trencher along the desired path. Means responsive to the fluid pressure in the pumps automatically maintain the power output at the tools substantially constant within a wide range of load variations, thereby greatly increasing both the efficiency of the tools and the speed of the trenching operation.

21 Claims, 13 Drawing Figures



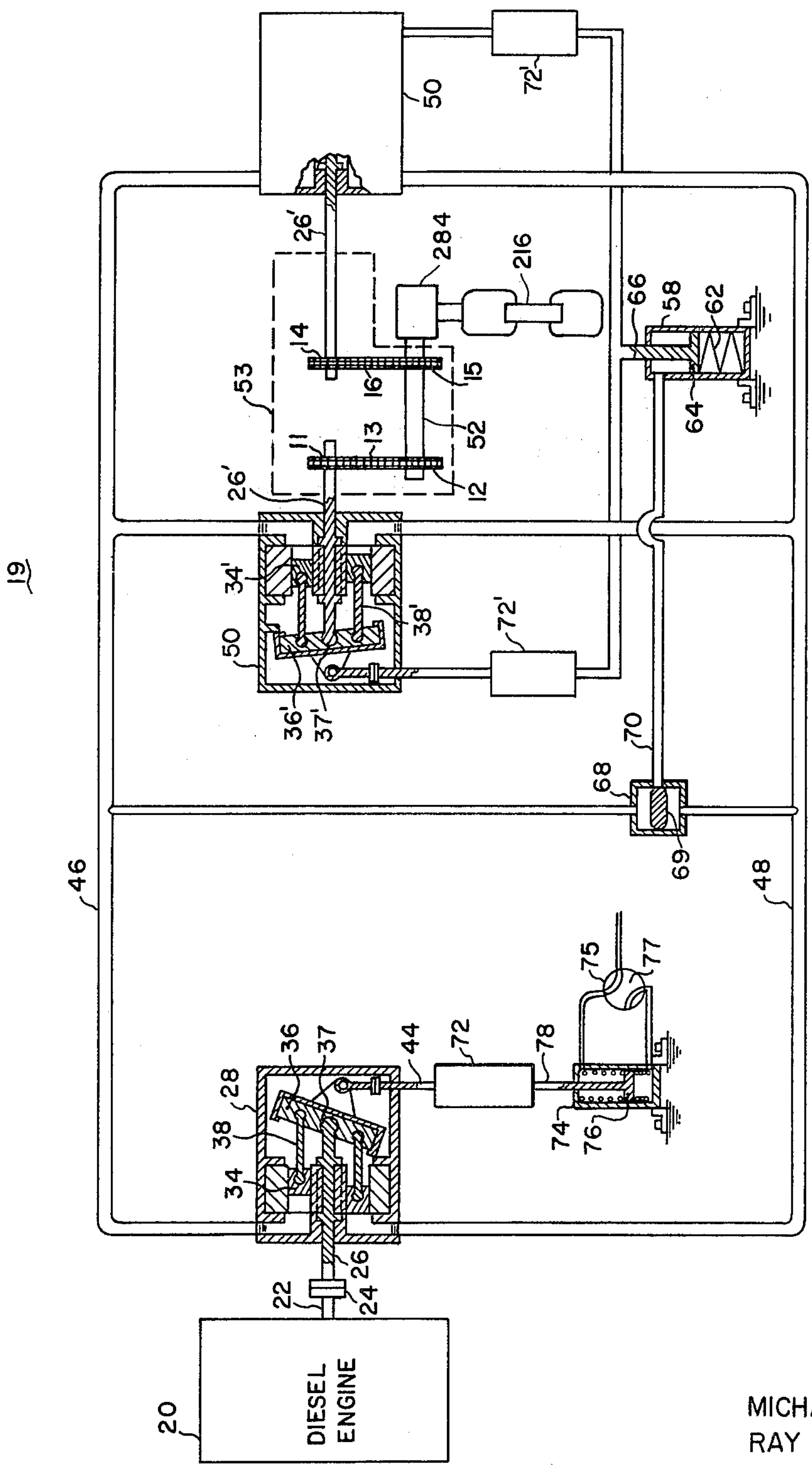


FIG. 1

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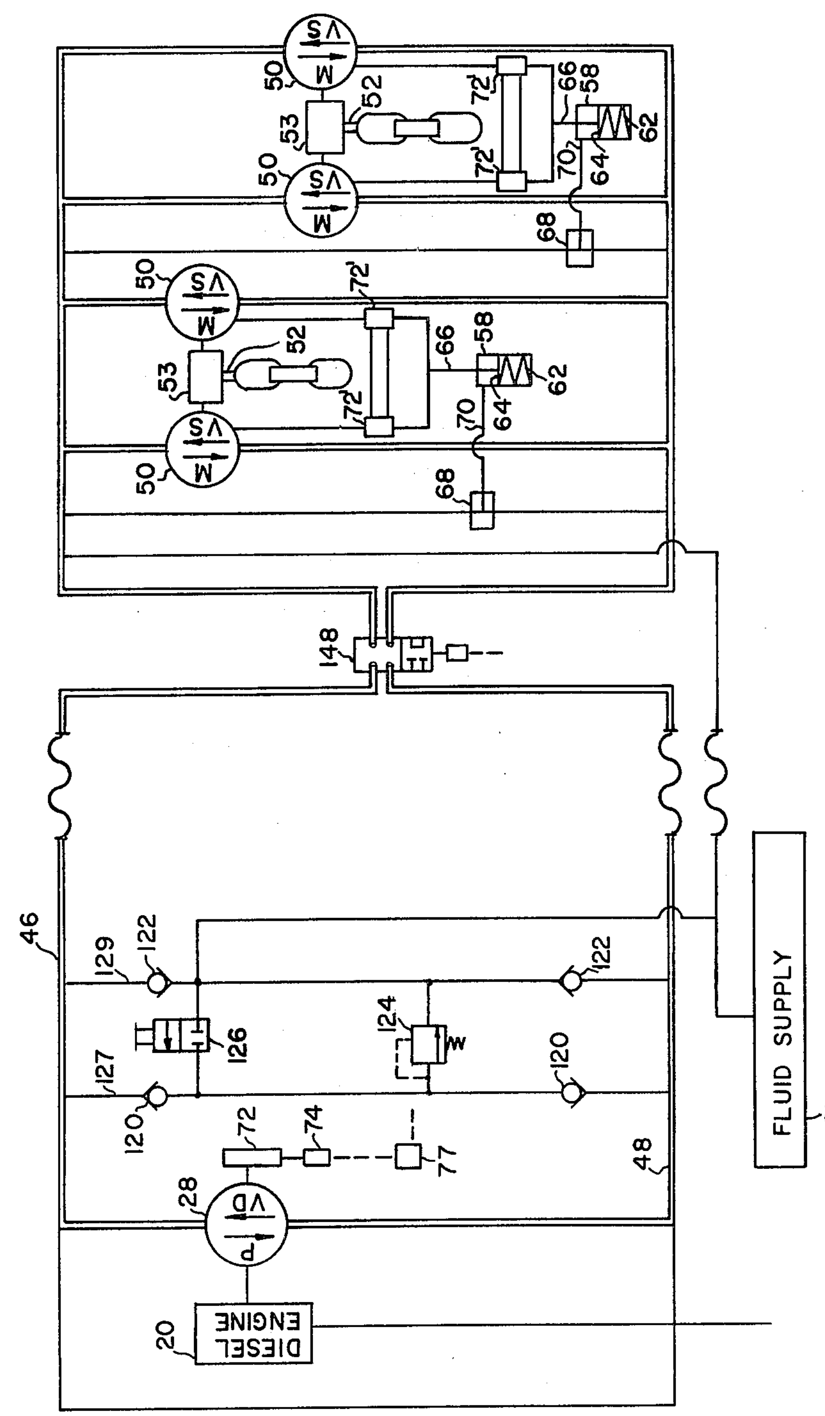

FIG. 2

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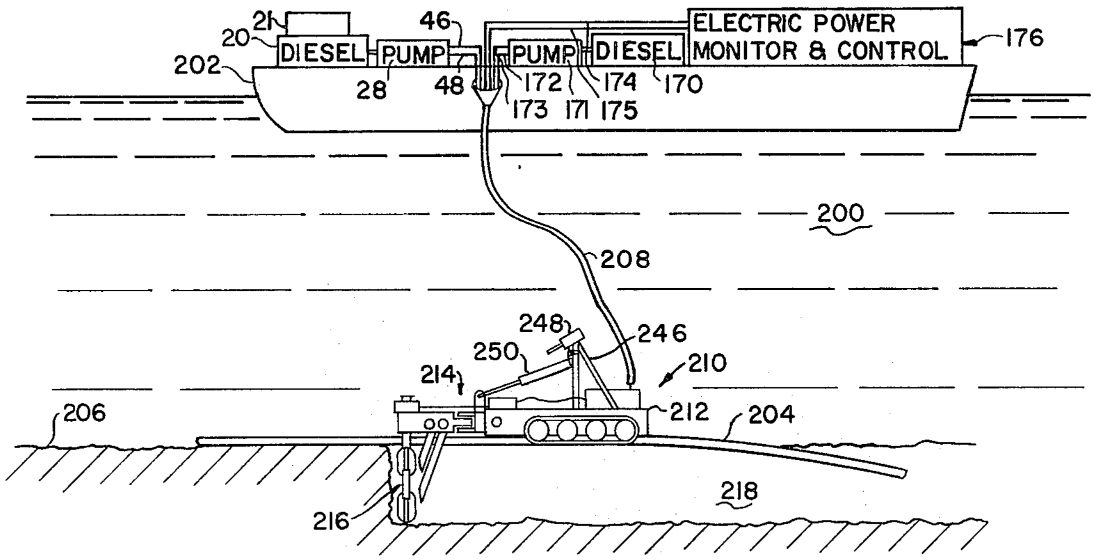

FIG. 3

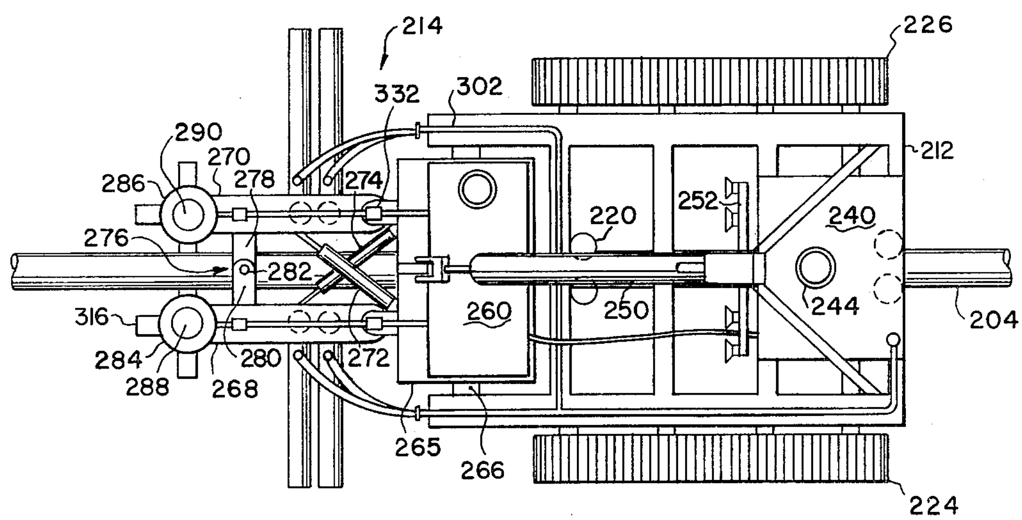

FIG. 4

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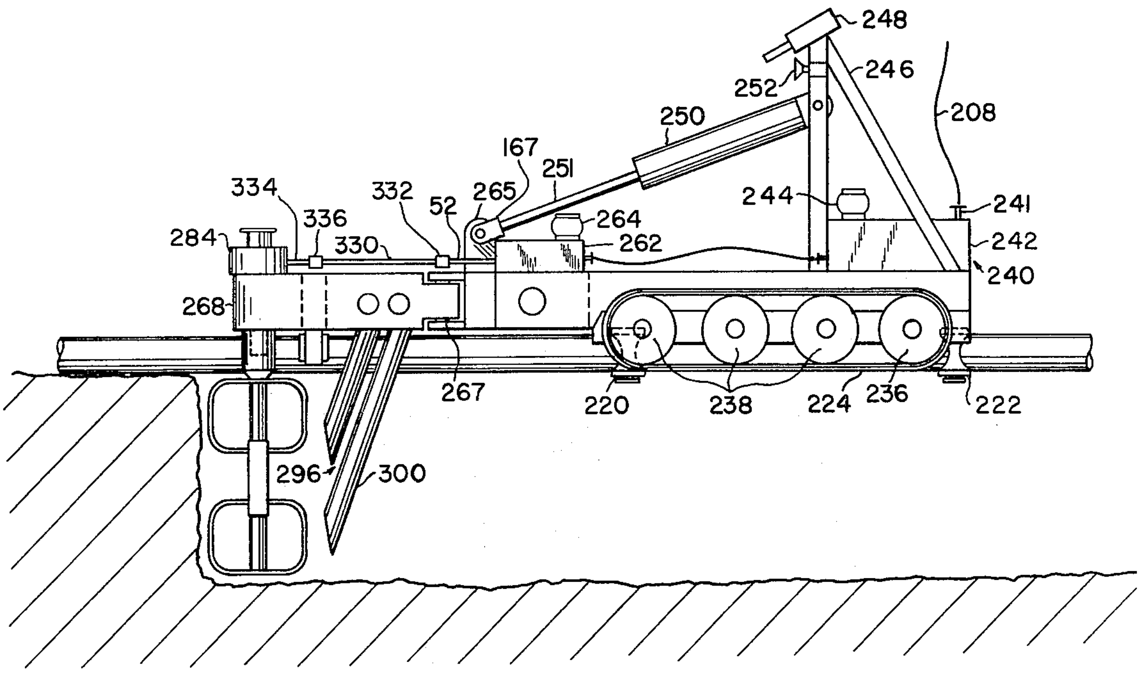

FIG. 5

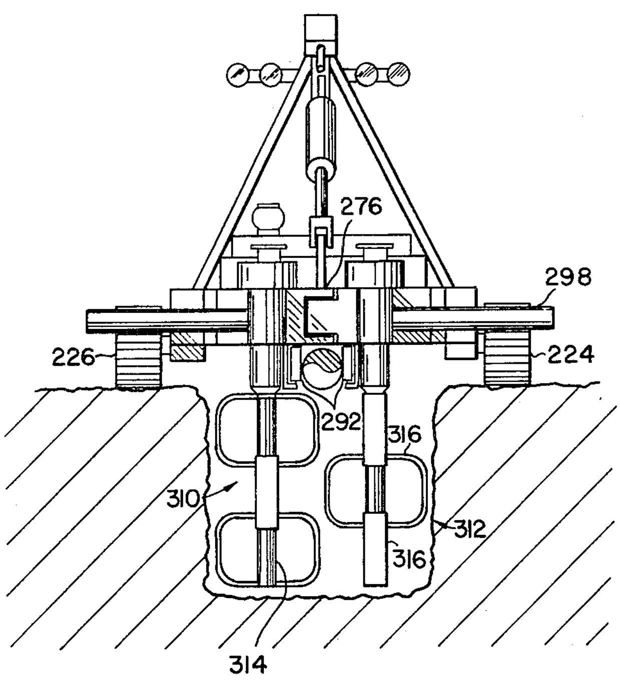

FIG. 6

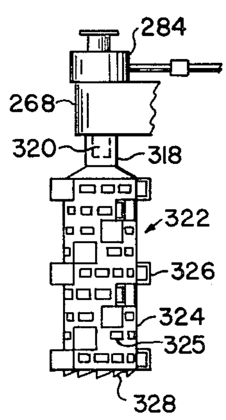

FIG. 8

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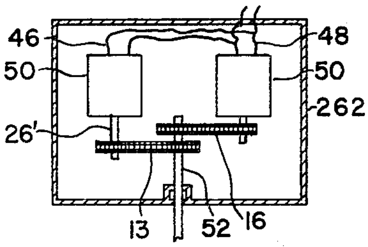

FIG. 9

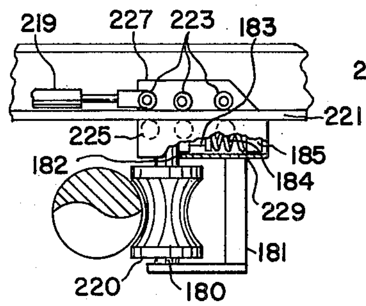

FIG. 11

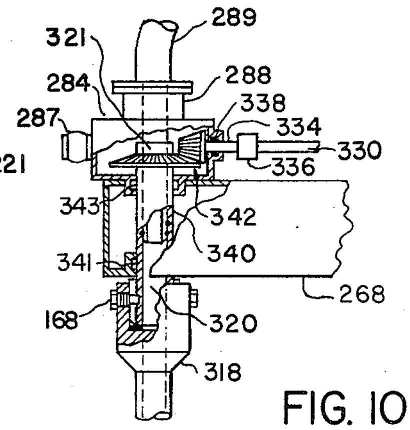

FIG. 10

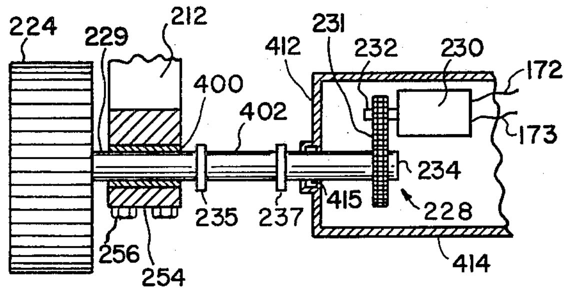

FIG. 7

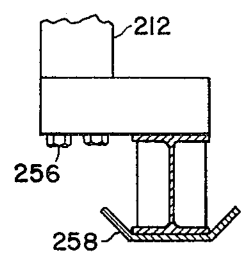

FIG. 13

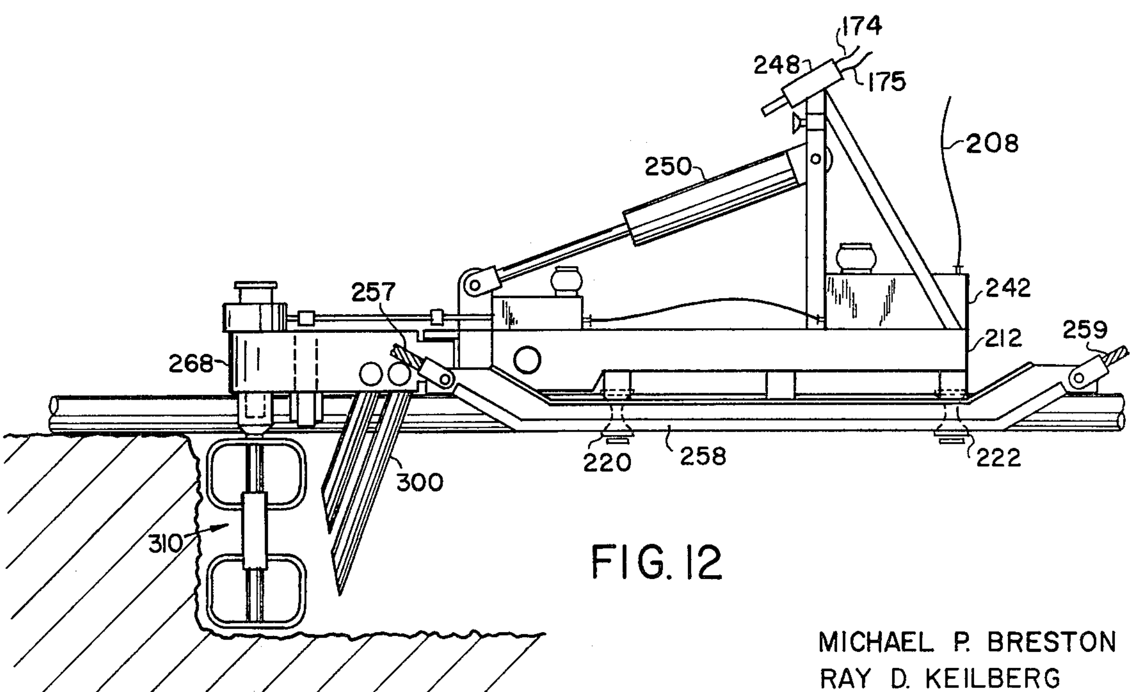

FIG. 12

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AUTOMATIC SUBMARINE TRENCHER

BACKGROUND OF THE INVENTION

Prior art trenchers for entrenching pipelines are known to have serious drawbacks. Some trenchers, for example, are self-propelled on hydraulically operated wheels which ride on the coating of the pipeline. In practice it is difficult to avoid damaging the coating and creating cracks therein through which sea water can reach the metal pipe and corrode its wall. To repair a damaged section of an underwater pipeline is extremely expensive. Also, since the trencher must work in hard as well as soft soils, the loads on the cutters vary over a considerable range. The prime movers of known trenchers are accordingly provided with complex control mechanisms which often require the shifting of gears, clutches, control knobs, throttles, etc. To prevent the cutters from stalling, the prime movers (diesel engines on the floating vessel) are adjusted to deliver to the cutters considerably more energy than is actually required by them. Among the consequences of the above are: greater fuel consumption, and faster wear of the blades on the cutters. The replacement of the cutters (or their blades) is very time-consuming and expensive. These and other drawbacks prevent prior art trenchers from carrying out the entrenching of a pipeline at fast rates of speed even in moderately soft soils.

SUMMARY OF THE INVENTION

It is therefore a general object of the invention to provide a trencher, for entrenching a pipeline under the bed of a body of water, intended to obviate known problems, including the type previously described.

It is a particular object of the invention to provide such trenchers wherein the cutters are easily interchangeable to allow the depth and width of the trench to be readily varied. It is another object of the invention to provide a submerged trencher wherein a substantially constant horsepower is developed by the trenching tools as the trenching operation progresses. It is a further object of the invention to provide an apparatus for entrenching pipe wherein the trenching tools are subjected to a minimum of wear and tear, thereby making it possible for the trenching operation to progress at a faster rate and for a longer period of time.

It is yet another object of the invention to provide a trencher wherein the trenching tools are rotated by piston-type hydraulic motors.

It is a further object of the invention to provide a trencher which rides over the pipe as it cuts the trench in such a manner as to: minimize loading the pipe, prevent damaging its outer coating, and receive continuous propulsion power from an indication of the position of the trencher relative to the pipe.

An apparatus for digging trenches on the bed of a body of water, according to a preferred embodiment of the invention, utilizes a floating marine vessel movable forwardly along a longitudinal path relative to the pipeline. The trencher includes a frame supported by ground-engaging means adapted for rolling or sliding motion on the surface of the bed of the body of water. The rolling motion is obtained from submerged propulsion means. Rotatable cutters, adapted for cutting a single trench in the bed, are connected to the frame by coupling means selectively adjustable in both horizontal and vertical directions.

In order to guide the ground-engaging means relative to the pipeline, sensor means coupled to pipe-engaging means provide propulsion control signals which are used to selectively control the speed and torque of the hydraulic motors driving the ground-engaging means.

In the preferred embodiment, the ground-engaging means include self-propelled rolling tracks which can be easily disconnected from the frame and replaced with sliding skids. The trencher is then towed on the bed by a floating vessel to cause a trench to be cut therein.

Further apparatus aspects of the invention reside in the provision of vertical guide rollers connected with the ground-engaging means for gently guiding the ground-engaging means along the path of the pipeline.

Important apparatus aspects of the invention reside in the provision: of a prime mover which can be allowed to run at a constant speed thereby efficiently utilizing its full output power capabilities, of piston-type motors for rotating the cutting tools, and of pressure transducers effective to continuously and automatically control the angular velocity and the torque of the cutting tools.

Other aspects reside in the provision of removable tracks which can be replaced with interchangeable skids to allow the trencher to become towed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 diagrammatically illustrate a preferred hydraulic network used to rotate the cutting means;

FIG. 3 is a side view of the pipe entrenching system in accordance with a preferred embodiment;

FIG. 4 is a top view of the system shown in FIG. 3;

FIG. 5 is a side view of the system shown in FIG. 3;

FIG. 6 is a front view of the system shown in FIG. 3;

FIG. 7 is a detail view of a portion of the track propulsion means;

FIG. 8 illustrates another embodiment of a cutter means;

FIG. 9 is a detail view of a portion of power means applied to the cutter means;

FIG. 10 illustrates the manner of detachably coupling and securing a cutting means;

FIG. 11 is a side view, partly in section, illustrating the manner of displacing a guide roller relative to the pipeline;

FIG. 12 is a side view of an entrenching system sliding on skids; and

FIG. 13 is a partial view of a skid shown in FIG. 12.

DETAILED DESCRIPTION OF THE HYDRAULIC POWER SUPPLY FOR THE CUTTER ELEMENTS

In FIGS. 1, 2 there is shown a hydraulic power supply 19 with automatic power output control means. Power supply 19 includes a diesel engine 20 having a shaft 22 coupled by a coupling device 24 to the shaft 26 of a suitable hydraulic pump 28. Various types of hydraulic pumps are commercially available. An axial-piston type pump is preferred for the load requirements of the cutter elements. An axial-piston type pump includes an odd number of pistons 34 spaced circumferentially. A base plate 36 is connected to the pistons 34 by connecting rods 38. The base plate 36 is flexibly coupled to shaft 26 by a universal joint 37. Rotation of shaft 26 causes pistons 34, base plate 36 and rods 38 to rotate together as an assembly about the axis of shaft 26. Linear movement of a control rod 44 causes the base plate 36 to tilt relative to the axis of shaft 26. When the base plate 36 tilts, the connecting rods 38 change the strokes of pistons 34.

In operation of pump 28, when base plate 36 is in a plane perpendicular to the axis of shaft 26, the stroke of pistons 34 is zero with no fluid circulating through the pump. By tilting the base plate, a pumping action is created. Fluid (typically oil) is drawn into the pistons'cylinders during one half revolution, and forced out ahead of the pistons during the other half revolution. The greater the tilt angle of the base plate, the greater the stroke of the pistons and hence, the greater the volume pumped by the pump. The direction of fluid flow through the pump can be reversed almost instantaneously by tilting the inclinable base plate 36 in the opposite direction relative to the axis of shaft 26.

Pump 28 feeds two main hydraulic lines 46, 48 across which are connected a number of identical motors 50, each shaft of each motor is mechanically coupled to a rotating element 52. Since the speed of rotation of element 52 is usually considerably less than the operating speed of motors 50, a conventional planetary reduction gear 53 is interposed to provide an appropriate drive ratio therebetween.

It will be appreciated that the internal construction of motors 50 and of pump 28 are exactly identical.

Direction of rotation of motors **50** is controlled by the direction of fluid flow through the motors and, hence, by the position of the base plate **36** relative to the axis of shaft **26** in pump **28**. Since the base plate is always tilted at least a minimum angle, any fluid flow through a motor **50** will impart rotation to its shaft **26**. To better bring out the similarity in design between the pump **28** and motors **50**, their internal parts are assigned the same reference characters, with the reference characters in the motors followed with a prime. Since the base plate **36'** is always tilted at least a minimum angle, any fluid flow through a motor **50** will impart rotation to its shaft **26'**. The angular velocity of shaft **26'** can be continuously varied by changing the tilt angle between a minimum and a maximum angle, and vice versa. When the tilt of base plate **36'** is at a minimum, the pistons' stroke is the shortest; less fluid volume is needed to rotate the inside motor assembly, and the motor has its maximum speed and minimum torque. Thus the smaller the minimum angle of tilt is, the greater the maximum speed will be. On the other hand, when the tilt is at its maximum angle, the pistons' stroke is longest; more fluid is needed to rotate shaft **26'**; and the motor has it s maximum torque and minimum speed.

Motors **50** are made to automatically and continuously develop, for a given input power, a substantially constant output horsepower while handling the load on element **52**. The input power applied to a motor **50** by pump **28** is directly related to the fluid's velocity and pressure. The torque requirements of the load on element **52** govern the pressure in motor **50** and, hence, in supply lines **46, 48**. The fluid's pressure in line **46, 48** is continuously monitored by a pressure transducer **58** which includes a calibrated spring **62**, a piston **64** having a rod **66**. Since the pressure can be higher in either of lines **46** and **48**, there is provided between the lines a shuttle valve **68** which supplies to a line **70** either the pressure of line **46** or of line **48** whichever is greater.

The primary actuator for pump **28** is a low pressure, air-operated cylinder **74** whose piston **76** is coupled by a rod **78** to a hydraulic force amplifier **72** which is coupled to rod **44**. When piston **76** becomes displaced, base plate **36** is caused to tilt and thereafter amplifier **72** keeps the control rod **44** in place until another command from the throttle of pump **28** causes air pressure to be admitted into air cylinder **74** thereby raising or lowering piston **76** therein. Thus the force amplifier **72** transmits the displacement of rod **78** to the control rod **44**, in response to an air command signal which is greatly amplified by the amplifier **72** to develop the considerable force required to tilt the base plate **36**.

The base plate control system of each motor **50** also includes a hydraulic amplifier **72'** functioning in the manner above-described. In the case of the motors, however, each pair of amplifiers **72'** is actuated by the output force from the pressure transducer **58**. The spring **62** is such that only pressures above a minimum pressure level can push piston **64** down against the spring's force. The minimum tilt of base plate **36'** in motor **50** provides a sufficient torque on shaft **26'** to handle light loads on element **52**.

As previously mentioned, an increase in load torque causes a corresponding increase in the main line fluid pressure. When the line pressure exceeds the minimum pressure level on, say, line **46**, the vane **69** in shuttle valve **68** will move down allowing the line **46** pressure to exert a force, through line **70**, on piston **64** and move it down. A downward displacement of piston **64** causes the base plate **36'** to tilt.

When base plate **36'** tilts in response to an increase in line pressure, the speed of shaft **26'** decreases and its torque increases so that the horsepower developed by motor **50** remains substantially constant. The magnitude of this power is determined by the volume of fluid pumped through the motor by pump **28**. When the load torque is at its expected maximum level, the line pressure reaches its maximum value causing the base plate **36'** to assume its maximum tilt angle. The speed velocity of shaft **26'** is then at a minimum and its torque at a maximum.

A series of check valves is connected across the two main circuit lines **46, 48** at a point near pump **28**: two check-valves **120** and two check-valves **122**. A pressure relief valve **124** is mounted between the junctions of the check-valves to allow pressure above a set minimum to pass from the intake line to the exhaust line around the pump **28**. Thus if excess pressure should accidentally build up in either of the main circuit lines **46, 48**, it will enter one of the intake check-valves **120**, pass through the pressure relief valve **124**, and exit through the opposite exhaust check-valve **122**. An air-operated cross-over valve **126** is provided between the intake and exhaust check-valve lines **127** and **129**, respectively. Valve **126** becomes automatically actuated, whenever pump **28** is in its neutral (non-pumping) position, to allow cross-over between the main circuit lines **46, 48**. The main hydraulic input is into the exhaust check-valve line **129**. From there the super-charged pressure passes through that valve **122** which is connected to the line (**46** or **48**) having the lower pressure.

When the element **52** is rotating, circulation through the main lines **46, 48** is counter clockwise. An air-operated valve **148** can shut off fluid circulation to the motors in order to make available the prime mover **20** and pump **28** to operate other auxilliary machines. The air cylinder **74** is actuated through a throttle valve **75** having a valve spool **77**. When spool **77** is in its neutral position, pump **28** delivers no fluid to the motors **50**. The flow of fluid through pump **28** depends on the position of throttle valve **75** relative to its neutral position.

In operation of the power supply **19**, the prime mover engine **20** may be set to run at a constant speed (corresponding to maximum torque) thereby conserving fuel. Air cylinder **74** is then operated to cause pump **28** to deliver a desired output volume into the main hydraulic lines **46, 48**. When the line pressure is less than the minimum pressure level, the base plates **36** and in motors **50** will be at their minimum tilt positions and the motors will have a sufficient torque capability to handle average loads. For greater loads the pressure on line **48** rises above the minimum pressure level thereby compressing spring **62**. The down movement of piston **64** causes the base plate **36'** to tilt by an angle corresponding to the displacement of piston **64**. This results in a decrease in the speed of element **52** and in a corresponding increase of its torque. Thus, a load change will cause through transducer **58** an instantaneous decrease in speed and increase in torque, or vice versa. The design factors are such that the output horsepower of each motor **50** remains substantially constant over the expected load range.

It will therefore be appreciated that the operator by merely controlling the position of valve spool **77** in air valve **75** can set the base plate **36** in pump **28** in neutral position (no pumping) or on either side of the axis of shaft **26** (pumping in either clockwise or counterclockwise direction). The actuation of air cylinder **74** through valve **77** is the main throttle control which needs to be manipulated by the operator. Consequently, the gear ratio between the speed of pump **28** and the speed of motors **50**, is automatically selected by the load on element **52**.

GENERAL DESCRIPTION OF THE TRENCHING SYSTEM

Referring to FIGS. **3–11**, there is shown a preferred embodiment of a trenching system, generally designated as **200**, which utilized a vessel **202** movable in the general longitudinal direction of a pipeline **204** desired to be buried in the sea bed **206**. Vessel **202** is coupled through an umbilical cable **208**, to a trencher machine, generally designated as **210**. The umbilical cable **208** has an outer flexible jacket within which are housed flexible lines supplying fluid power, electric power, and control signals to and from the trencher **210**. The trencher **210** is built on a frame **212**, which can be towed or self-propelled. A trenching apparatus **214** is carried by and is movable relative to frame **212**. The trencher **210** rides above the pipeline **204** and with the use of rotatable cutter elements or tools **216** excavates a trench **218** in the formation of the sea bed **206**. Front and rear guide rollers **220, 222** are vertically disposed on frame 212 and gently guide the frame along the pipeline 204. Frame 212 is of the open frame design and supports a receiving-and-transmitting unit 240 housed in an enclosure 242 which is pressure compensated by a pressure compensator 244. Compensator 244 makes the pressure inside enclosure 242 substantially equal to the surrounding outside water pressure. Unit 240 receives the umbilical cable 208 through a flanged port 241. Extending above frame 212 is a tripod 246 which supports a rotatably mounted television monitor camera 248, a pivotally mounted hydraulic cylinder 250, and a plurality of high-intensity light beams 252.

The Propulsion System

Frame 212 is propelled on tracks 224 and 226. Each track is independently driven by a power unit 228 (FIG. 7) having a hydraulic motor 230. The shaft 232 of motor 230 is coupled to a drive shaft 234 via a chain 231 riding on sprockets. Shaft 234 is coupled to a drive shaft 229 through an intermediate shaft 402 which, in turn, is coupled to shafts 229, 234 through detachable coupling devices 235, 237, respectively. The free end of shaft 229 is fixedly secured to a drive sprocket 236 which provides the necessary propulsion to track 224 or track 226. A plurality of idler sprockets 238 are also provided; the exact number and the spacing of the idler sprockets will vary with the length of the track 224. The power unit 228 is housed in a pressure-compensated enclosure 414 and shaft 234 extends outwardly therefrom through a dynamic seal 415 in the side wall 412. Drive shaft 229 is supported by a detachable bracket 254 which is secured to frame 212 by bolts 256. Shaft 229 is journaled in a sleeve bearing 400 extending through bracket 254. Enclosure 414 is disposed immediately below the receiving unit 240. It will be appreciated that through the side wall (not shown), opposite to the side wall 412, extends another shaft 234 to similarly power track 226. Since the construction is symmetrical, the description is limited whenever possible to the components used in one half of the trencher 210.

Under certain operating conditions, it may be desirable to tow frame 212. In that event, track 224 can be easily disconnected by removing the detachable bracket 254, disconnecting coupling devices 235 and 237, and substituting for bracket 254 a skid sub-assembly 258. Sub-assembly 258 is secured to frame 212 by the same bolts 256. Each skid 258 is towed by a towing cable 257 or 259 depending on the direction of travel.

The Trenching Apparatus

The trenching apparatus 214 includes a power drive unit 260 housed in an enclosure 262 which is pressure compensated by a compensator 264. Enclosure 262 is supported by and fixedly attached to a frame 265 secured to a horizontal pivot shaft 266 journaled for rotation on frame 212. Pivotally supported on a pair of vertical pivots 267 are arms 268, 270. Rod 251 of hydraulic cylinder 250 is pivotally connected by a clevis 167 to frame 265. Two hydraulic cylinders 272, 274 are pivotally connected between frame 265 and arms 270, 268, respectively. When the rods of cylinders 272, 274 are extended (by remote control operation through the umbilical cable 208), arms 268, 270 rotate away from a vertical plane extending through the longitudinal axis of the pipeline 206. Conversely, when these rods are caused to move inside cylinders 262, 274 the arms 268, 270 move toward the pipeline. When arms 268, 270 are fully rotated inwardly they are detachably coupled together by a locking mechanism 276 having male and female connector parts 278, 280 joined together by a removable pin 282 or by a remotely operated lock (not shown).

Mounted near the ends of arms 268, 270 are gear boxes 284, 286, respectively (FIGS. 4, 10). Each gear box is completely enclosed and pressure compensated by a compensator 287. Connected to the top walls of gear boxes 284, 286 are flanged connectors 288, 290, respectively. To each connector is coupled a water hose 289. Rotatably supported on the frames of arms 268, 270 are diametrically opposed rollers 292 whose function is to protect the coating of the pipeline. The rollers are conveniently made of a resilient material such as urethane. Each of arms 268, 270 is provided with one or more jet assist suction tubes, generally designated as 296. Each suction tube 296 includes a horizontal tube portion 298 and a vertically slanted tube portion 300. Each jet assist tube 296 receives high pressure water through a line 302 extending from the unit 240.

As can be best seen from FIG. 11, each roller 220 or 222 rides on a rail 221 via upper and lower rollers 223, 225 rotatably mounted on a bracket 227 having a pressure-compensated enclosure 229. Roller 220 is rotatably mounted on a shaft 180 one end of which is fixedly secured to a lower bracket 181 and its other end extends through a port 182 which has a diameter slightly greater than the outer diameter of shaft 180. A piston 183 is operatively coupled to a spring 184 which exerts a force on a load cell 185. Load cell 185 may include one or more strain gauges which are connected to the floating vessel 202 through the umbilical cable 208. A remotely operated hydraulic cylinder 219 is pivotally connected to the frame of bracket 227 for moving roller 220 or 222 away from or toward the pipeline.

The cutters can assume various configurations depending on the cutting action, the nature of the soil being excavated, are the desired geometrical configuration of the trench. As can be best seen in FIGS. 5, 6, particular type cutters 310, 312 have a hollow vertical shaft 314 from which extend a plurality of substantially C-shaped blades 316. Each diametrically opposite pair of blades 316 can be made into a unitary construction fixedly or detachably secured to shaft 314. The detachable coupling of the blades to shaft 314 is preferred in order to allow for the easy replacement of worn out blades. The top end of each shaft 314 forms an enlarged head 318 (FIG. 10) which serves as a female connector for receiving the lower end 320 of a stub-shaft 340. A bolt 168 secures head 318 to shaft 340. Shaft 340 extends through two dynamic seals 341, 343 in the frame of arm 268.

Inside gear box 284 is a beveled gear arrangement 342 which serves to couple the top end 321 of the vertical shaft 340 to a horizontal drive shaft 334. Shaft 334 is journaled in a dynamic seal 338.

With particular reference to FIGS. 1, 5, 9, and 10 shaft 334 is coupled to an intermediate drive shaft 330 through a universal joint 336, and shaft 330 is coupled to the shaft 52 (FIG. 1) through a universal joint 332.

The piston-type hydraulic motors 50 have their shafts 26′ coupled to shaft 52 through the planetary reduction gear mechanism 53, which can conveniently include two chains 13, 16 riding on two pairs of sprockets 11, 12 and 14, 15, respectively.

In FIG. 8 is shown a different configuration of a cutter tool, generally designated as 322. Tool 322 is formed from a tubular member 324 to the outer cylindrical periphery of which are secured (fixedly or detachably) a plurality of blades 326 preferably in the form of scoops. Other blade configurations, such as the C-shaped blades 316, can also be employed. The bottom end of tube 324 is provided with a plurality of vertically extending teeth 328 to facilitate the penetration of cutting tool 322 into the formation of the sea bed. The connecting mechanism for detachably securing the cutter 322 to the drive shaft 340 is identical to that shown and described in connection with the coupling of tool 310 to the drive shaft 340.

With certain cutters it may be desired to jet water through the hollow shaft 314 or the tube 324 by forcing water through the hose 289 connected to the flanged connector 288 (FIG. 10). The high-water pressure will exit through the bottom opening of shaft 314 or through ports 325 in the outer wall of tube 324.

On the marine vessel 202 is provided the diesel engine 20 for driving the hydraulic pump 28. Another prime mover or diesel engine 170 drives a hydraulic pump 171 which feeds hydraulic fluid through lines 172, 173 to the track-propulsion motors 230. Other hydraulic and air lines (not shown) extend from a fluid supply source 21 through the umbilical cable 208 for actuating the remotely operated hydraulic and air devices such as 250, 272, 274, and 219, etc., previously described.

Electric power is applied to the television camera 248, the high-intensity light beams 252, and to other electrically operated instrumentalities used on or in connection with the trencher 210. The power and signals are fed through cables 174, 175 from an electric power monitor-and-control system, generally designated as 176.

DESCRIPTION OF THE OPERATION OF THE TRENCHER SYSTEM

Prior to lowering the trencher 210 above the pipeline 204, cylinders 272, 274 are extended to their maximum length thereby moving arms 268, 270 away from each other. Arms 268, 270 rotate on pivots 267. Cylinder 250 is then contracted to cause the rotation of frame 265 in a clockwise direction as viewed in FIG. 5. Cylinders 219 are then extended to allow for a maximum separation between the oppositely disposed guide rollers 220, 222.

A suitable crane (not shown) on the deck of vessel 202 is used to lower the trencher machine 210 above pipeline 204. Divers will be used to assist during the lowering of machine 210. When the use of divers is not feasible or desirable, other conventional control and guidance means can be employed. After frame 212 is disposed above pipeline 204, there may be a need to center the machine relative to the vertical plane extending from the longitudinal axis of the pipeline. The centering is accomplished by rotating tracks 224 and/or 226 independently and/or simultaneously. With the tracks resting well on the sea bed 206, their positions relative to the pipeline are monitored by observing the signals received from the load cells 185. A signal is received from a load cell 185 when its corresponding guide roller 220 engages the wall of pipe 204. The force exerted by the pipe on roller 220 or 222 is transmitted to the load cell 185 by the piston 183 and spring 184. As the centering of the frame 212 progresses, the operator gradually contracts cylinders 219 until all four guide rollers gently engage the pipe 204.

Thereafter motors 50 are energized to cause the rotation, in opposite directions, of cutters 310, 312. As cutters 310, 312 cut away portions of the soil formation, cylinder 250 is gradually extended until the cutters assume both the desired angle relative to the vertical, and the desired penetration into the trench. Cylinders 272, 274 are then contracted to cause arms 268, 270 to move towards each other until the locking mechanism 276 can be locked with pin 282. Pin 282 can be inserted by a diver or it can be remotely operated.

During the lowering of the cutters 310, 312 into the sea bed formation, the tracks 224, 226 are simultaneously propelled forward to provide an opening for the jet assist suction tubes 296. High pressure water from lines 302 is ejected through the horizontally extending tubes 298 so that a relatively low pressure (pumping action) is created in each of the vertically extending tubular portions 300. Tubes 300 suck up the debris of the cutting operation and eject them through the tubular portions 298 which extend past tracks 224, 226 to prevent the accumulation of debris in the path of travel of the tracks.

The speed with which the trencher 210 progresses depends on how fast the cutters 216 will cut away from formation of bed 206. Since the density of the soil varies from location to location, different loads will be imposed on the cutters. The speed and torque of the piston-type hydraulic motors 50 will be automatically varied by the pressure sensing devices 58 (as previously described in connection with the hydraulic circuit of FIGS. 1, 2) to maintain the output power at the cutters 216 substantially constant. Since the speed and torque of the cutters are automatically varied, depending on the density of the soil encountered, it will be appreciated that minimum wear-and-tear is imposed on the blades 316, and, hence, the blades will require less frequent replacement thereby allowing longer uninterrupted trenching operations.

After the trencher 210 is properly centered about the pipeline with the selectively adjustable coupling devices secured and locked in their proper positions, the track propulsion system will be operated, in a manner as to maintain the ground-engaging means (tracks or skids) along their desired course of travel, by selectively and independently controlling the speed and torque developed by the propulsion motors 230. Should the ground-engaging means not follow the desired course, the side guide rollers 220 or 222 will produce signals from their load cells 185, which signals will be transmitted through the umbilical cable 208 to the monitor-and-control station 176 on the deck of vessel 202. These signal are used to properly control the propulsion system. The control can be manual or automatic as will be apparent to those skilled in the art.

SUMMARY OF THE ADVANTAGES

The apparatus of the present invention provides considerable advantages in carrying out pipe entrenching operations on the bed of a body of water.

Particular advantages are provided by the sensing means coupled to the side guide rollers which gently roll on the coating of the pipe to determine the desired path of travel for the ground-engaging means. The sensing means provide a continuous remote indication for persons on the vessel of the actual position of the pipeline on the sea bed relative to the frame.

A very significant advantage is provided by the piston-type motors which automatically vary the speed of the cutting tools to maintain the proper torque for the type of soil being excavated.

Another significant advantage lies in the provision of readily interchangeable cutting means for various types of soil and for various geometrical configurations of the trench.

Although the invention has been described with reference to preferred embodiments, it will be apparent to those skilled in the art that additions, deletions, modifications, substitutions and other changes, not specifically described or illustrated in connection with the preferred embodiments, may be made which fall within the scope of the appended claims.

What we claim is:

1. In a trenching system for cutting a trench in the bed of a body of water and including: a frame, ground-engaging means coupled to said frame and adapted to move on said bed, at least one axially extending support arm, movable coupling means coupling said arm to said frame for selectively moving said support arm relative to said frame, and at least one rotatable cutter means extending downwardly from said support arm, the improvement comprising:

hydraulic power means including a prime mover,

a hydraulic pump,

at least one hydraulic motor,

a hydraulic circuit operatively coupling said pump to said motor to energize said motor with hydraulic fluid,

means coupling the output shaft of said motor to said cutter means to rotate said cutter means when said motor is energized, and

control means responsive to the pressure in the hydraulic circuit for automatically adjusting the power output of said motor.

2. The system of claim 1 wherein said motor is a piston-type motor having a speed control element,

said control means is coupled to said speed control element to automatically vary the speed of said shaft in accordance with the variation in the amplitude of said pressure, and

a floating marine vessel housing at least said prime mover and said hydraulic pump, said pump being coupled to said frame by a flexible umbilical cable.

3. The system of claim 4 wherein said ground-engaging means include:

a pair of self-propelled tracks, and

at least one hydraulic motor coupled to each track for moving said tracks, independently or simultaneously, on said bed toward or away from the direction of the trench being cut.

4. The system of claim **3** wherein said frame moves over a pipeline and further including:

roller means rotatably supported on said frame and adapted to rollingly engage said pipeline at horizontally spaced locations for guiding said frame on said pipeline.

5. The system of claim **4** and further including:

sensor means coupled to said roller means for monitoring the position of said frame relative to said pipeline, and

monitoring means adapted to be positioned on said vessel and connected to said sensor means, said monitoring means being responsive to the signals produced by said sensor means for providing an indication of the position of said frame relative to said pipeline.

6. The system of claim **5** wherein said ground-engaging means include self-propelled track means remotely operated from said vessel in dependence on said monitored signals received from said sensor means.

7. The system of claim **6** wherein said cutter means extend downwardly at a predetermined depth below said ground-engaging means whereby forward motion of said frame causes said cutter means to cut a trench in said bed.

8. The system of claim **7** and further including:

at least another axially extending support arm,

movable coupling means coupling said arm to said frame for selectively moving said support arm relative to said frame,

means movably interconnecting said arms for selective movement of said arms away from and toward each other, and

at least another rotatable cutter means extending downwardly from said another support arm.

9. The system of claim **8** wherein said frame extends rearwardly of said cutting means and is adapted for motion along said pipeline, and

pivot means carried on said frame for imparting pivotal motion to said arms about a generally horizontal axis.

10. The system of claim **1** wherein said ground-engaging means is a skid adapted for sliding movement on the surface of said bed.

11. The system of claim **1** wherein said cutter means comprises a tubular member having outwardly extending, generally C-shaped blades thereon.

12. The system of claim **13** wherein said blades are in the form of scoops.

13. The system of claim **4** wherein said roller means are movably supported on said frame, and

means for selectively positioning said roller means on said frame relative to said pipeline.

14. The system of claim **11** wherein said cutter means are detachably secured to their respective arms.

15. The system of claim **14** wherein said tubular member is hollow and further including:

high-pressure water means connected to said tubular member to facilitate the trenching operation.

16. A trenching system for cutting a trench in the bed of a body of water including:

a frame for moving over a pipeline,

roller means rotatably supported on said frame and adapted to rollingly engage said pipeline at horizontally spaced locations for guiding said frame on said pipeline;

ground-engaging means coupled to said frame and adapted to move on said bed;

at least one axially extending support arm,

movable coupling means coupling said arm to said frame for selectively moving said support arm relative to said frame;

at least one rotatable cutter means extending downwardly from said support arm;

said ground-engaging means including:

a pair of self-propelled tracks,

at least one hydraulic motor coupled to said tracks for moving said tracks on said bed toward or away from the direction of the trench being cut,

a floating marine vessel coupled to said frame by a flexible umbilical cable,

said vessel housing at least a prime mover and a hydraulic pump for energizing said hydraulic motor;

sensor means coupled to said roller means for monitoring the position of said frame relative to said pipeline,

monitoring means adapted to be positioned on said vessel and connected to said sensor means, said monitoring means being responsive to the signals produced by said sensor means for providing an indication of the position of said frame relative to said pipeline; and

said track means being remotely operated from said vessel in dependence on said monitored signals received from said sensor means.

17. The system of claim **16** and further including:

at least another axially extending support arm,

movable coupling means coupling said another arm to said frame for selectively moving said another arm relative to said frame,

means movably interconnecting said arms for selective movement of said arms away from and toward each other, and

at least another rotatable cutter means extending downwardly from said another arm.

18. The system of claim **17** wherein each cutter means comprises a tubular member from the outer periphery of which outwardly extend generally C-shaped blades.

19. The system of claim **17** wherein said roller means are movably supported on said frame, and

movable means coupled to said frame for selectively positioning said roller means on said frame relative to said pipeline.

20. The system of claim **19** wherein each of said cutter means is detachably secured to its corresponding arm.

21. The system of claim **20** wherein said tracks are detachably coupled to said frame.

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