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[54] **UNDERWATER PIPELINE AND CABLE TRENCHING APPARATUS**

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[52] **U.S. Cl.** **61/72.4,** 37/61, 37/65

[51] **Int. Cl.** **E02f 5/08,** E02f 16/1

[58] **Field of Search**.....................61/72.4, 72.1, 72.3, 61/63, 64, 65, 61

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[57] **ABSTRACT**

An underwater trenching apparatus includes a bottom-riding frame assembly provided with a rotary cutter member carried thereby. A plurality of vertical and horizontal rollers support and guide a pipeline above and adjacent to the cutting elements of the cutter member during advancement to the apparatus. Movable means are included to permit displacement of at least one of said rollers to allow lateral insertion or removal of the pipeline from within the confines of the plurality of rollers after the frame assembly is disposed upon the ocean floor in a straddling manner over the pipeline.

14 Claims, 7 Drawing Figures

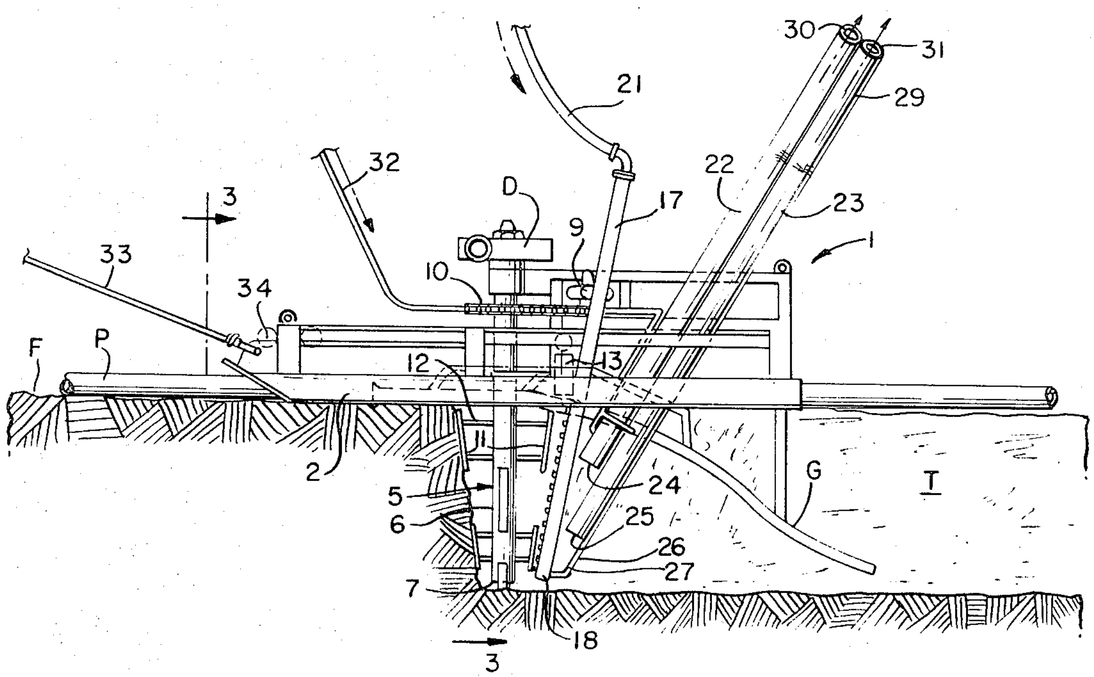

FIG. 1.

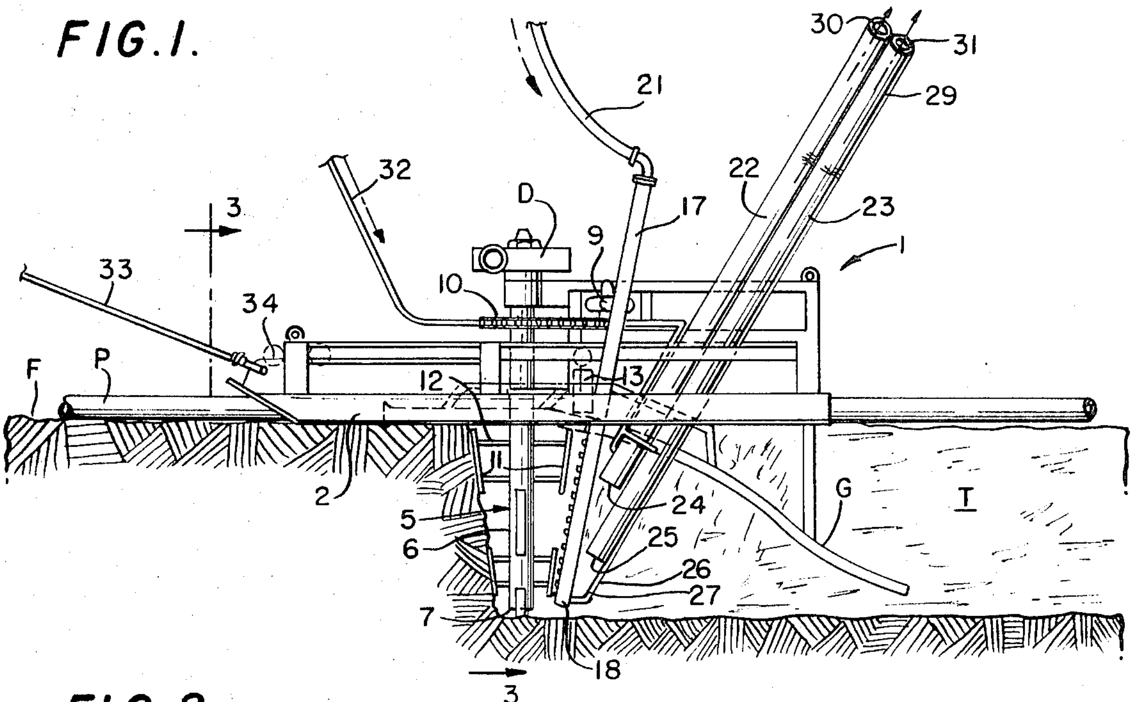

FIG. 2.

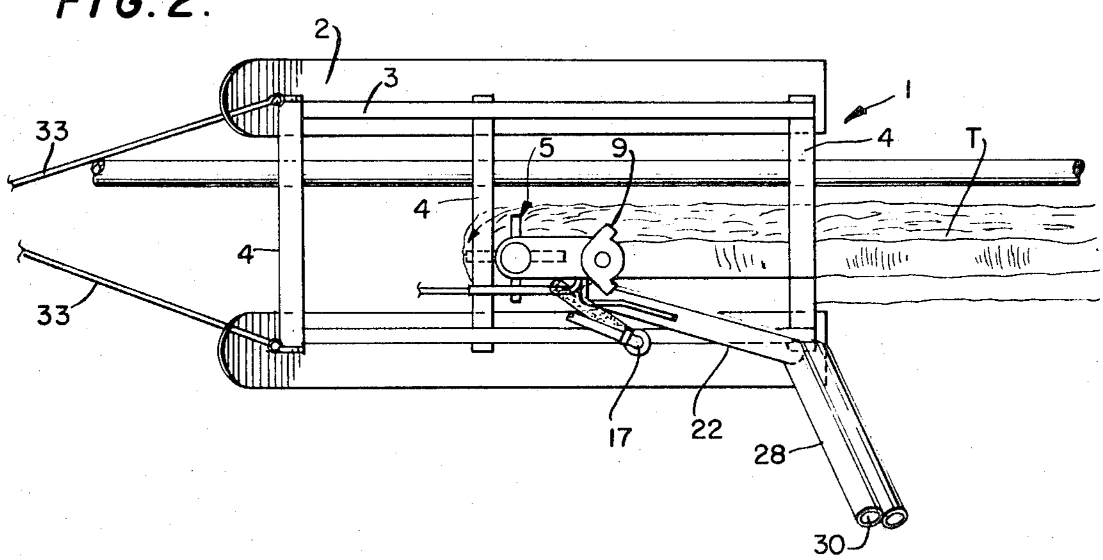

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FIG. 3.

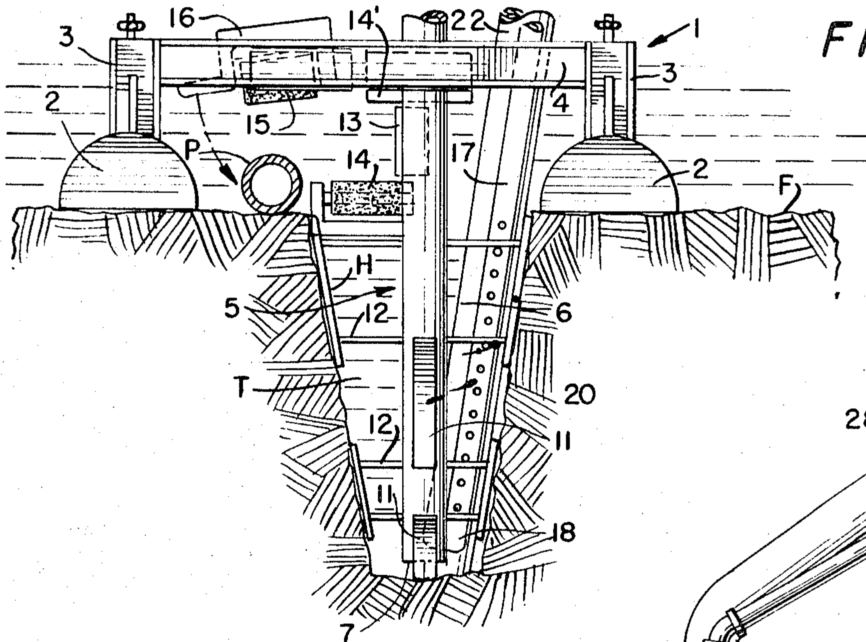
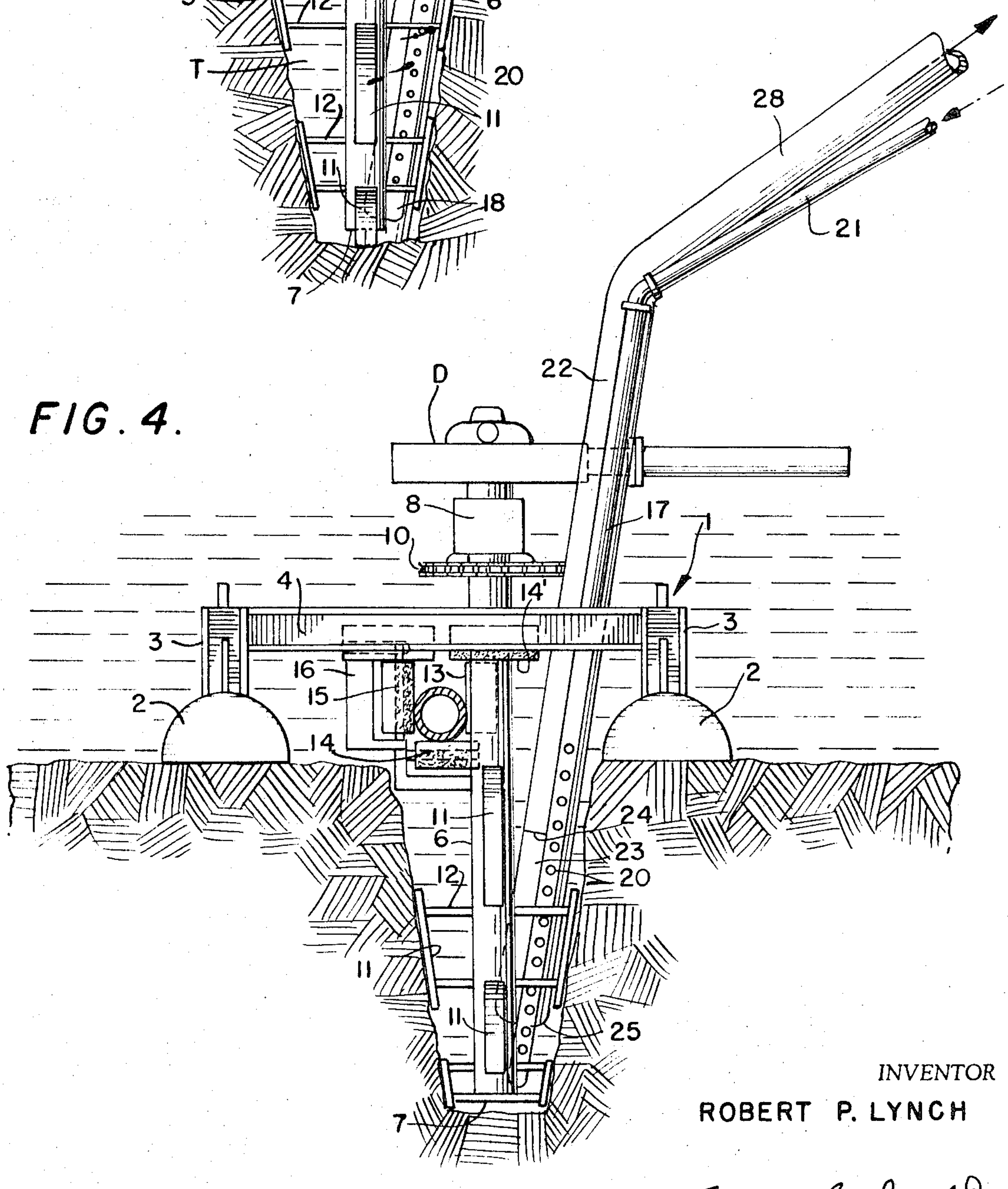


FIG. 4.



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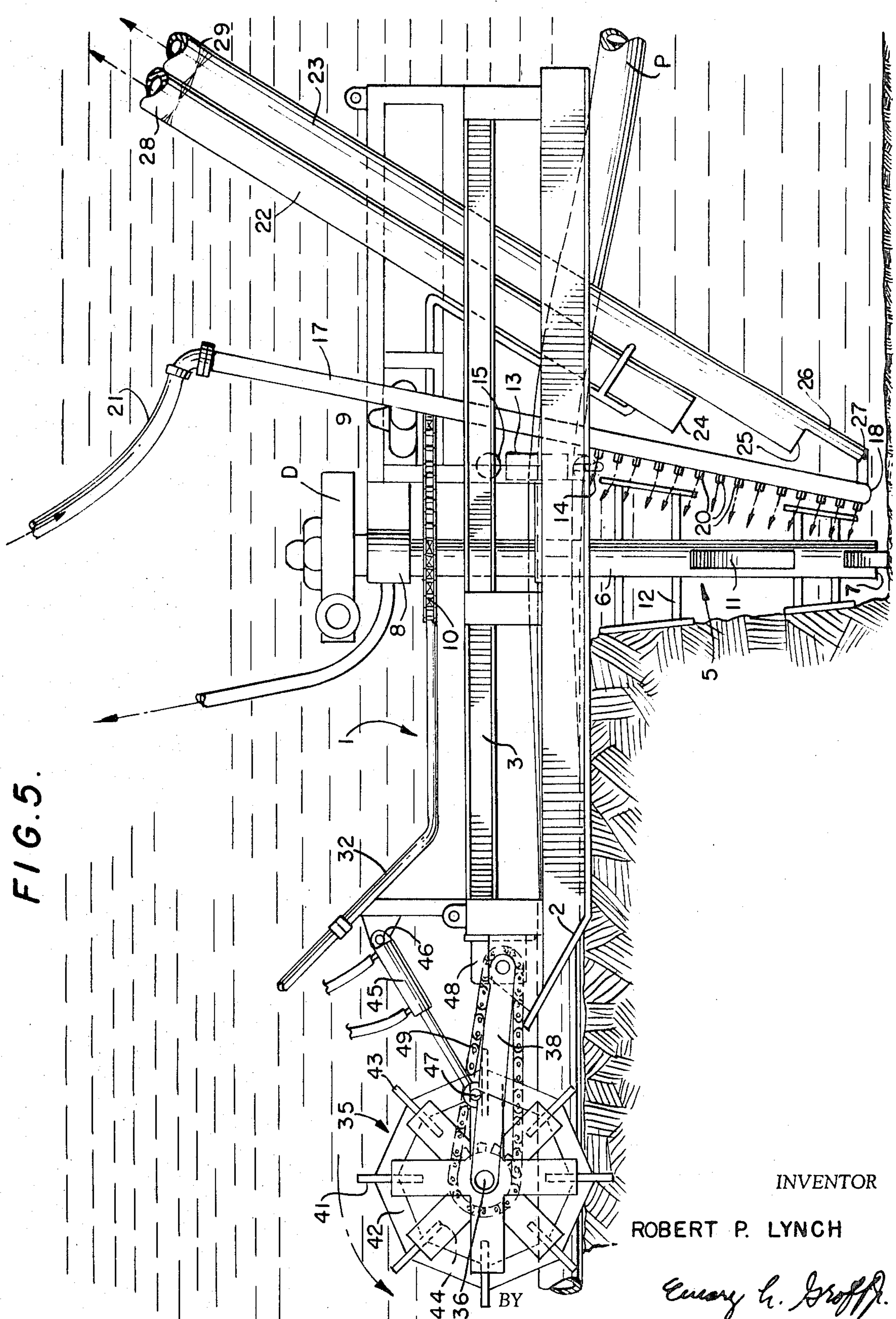

FIG. 5.

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FIG. 6.

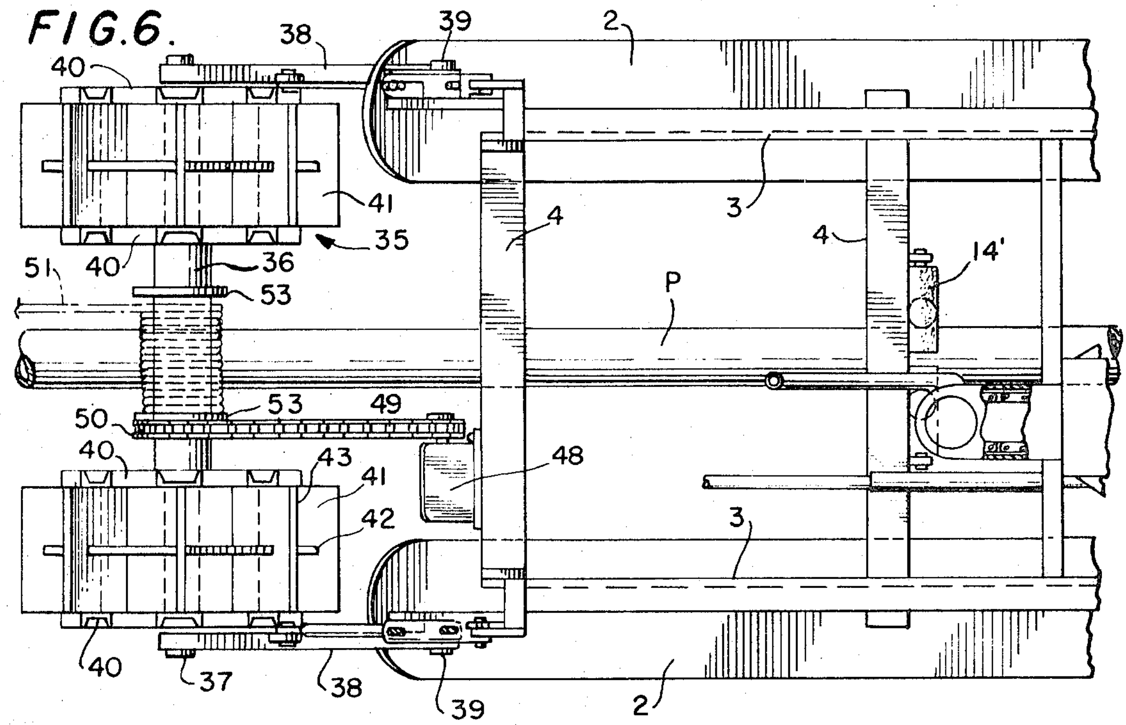
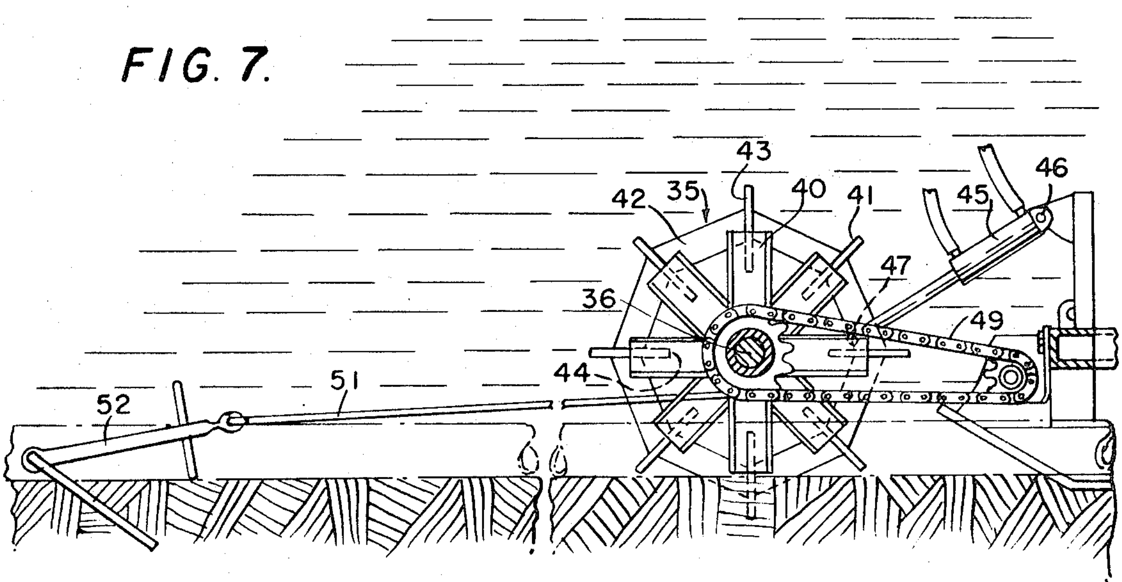


FIG. 7.



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UNDERWATER PIPELINE AND CABLE TRENCHING APPARATUS

This invention relates generally to pipeline and cable machines, and more particularly, to an apparatus for the placement of underwater pipelines and cables in trenches.

Steel pipelines as utilized to transport oil or gas from offshore locations to an onshore processing and distribution station are usually buried in the ocean floor to prevent damage from bottom currents, anchors, fishing gear, and other potential hazards. The most common technique utilized for burying offshore pipelines involves the use of an apparatus such as a surface jet barge in combination with a submersible jet sled. The barge serves as a floating base and contains extensive apparatus including high pressure water pumping machines and suction dredge pumps, all of which lead by means of often cumbersome lines to the jet sled, which comprises a frame adapted to straddle a pipeline previously deposited upon the ocean floor.

Many types of jet sleds are well known in the art, yet all of these utilize a basic principle wherein high pressure water generated upon the barge is transmitted to a plurality of nozzles on the sled so arranged as to excavate a trench immediately below the pipeline. The disrupted soil often is subsequently removed by means of a plurality of suction pipes behind the jet nozzles which pipes communicate with the barge-mounted dredge pumps.

Many disadvantages are inherent in the above-described system, none the least of which is the inefficiency of an arrangement wherein both the water jet and suction forces are generated on the surface of the water and must be transmitted through significant distances to the sled device located on the ocean floor. It will be appreciated that a strong surface current and/or rough seas impose potential dangers to the connecting lines between the barge and sled. Additionally, a problem often arises in the means commonly used to advance the jet sled along the pipeline. This is usually effected by means of a cable system between the barge and sled and wherein the barge pulls itself by means of an anchor winch, which operation is extremely hazardous and difficult to control at any time when the surface of the water is not perfectly calm.

Although one manner of advancing the trenching apparatus of the present invention may include a surface-controlled tow cable, improved means are provided to more efficiently create the trench, comprising a rotary cutter assembly together with a water jet pipe and air lift pipes to break up and carry away the soil cuttings as they develop.

As a modification to the present invention, an arrangement is provided including self-propelling means in the form of traction wheels and which may be further combined with an anchored cable so that the entire advancement of the apparatus is achieved by self-contained underwater means.

Likewise, there may be associated with the cutter tube a suction dredge pump to assist in removing the dislodged soil and directing it laterally of the moving apparatus. The one or more water jet pipes are preferably located immediately adjacent the cutter tube in order to remove all displaced soil adhering to the revolving cutter bars and to maintain this dislodged material in a suspension so that adjacently disposed air lift pipes may carry away the thus-formed suspension from the area of the trench.

Unique means are included comprising a plurality of rubber-covered rollers which are strategically located on the sled assembly and manipulated after placement of the apparatus adjacent a previously laid pipeline in order to actually lock the pipeline with the machine. Subsequent movement of the apparatus then assures perfect guidance of the pipeline along a line juxtaposed the revolving cutter tube and safely above its cutter bars.

Accordingly, one of the primary objects of the present invention is to provide an improved underwater pipeline and cable trenching apparatus including a bottom-riding sled assembly having a single rotating cutter tube associated with a plurality of rollers adapted to be positioned to guide a previously deposited pipeline along a path above and immediately adjacent the cutter tube as the apparatus is advanced along the ocean floor.

Another object of the present invention is to provide an underwater trenching apparatus readily adaptable to handle either previously deposited pipeline and cable or to simultaneously receive a cable from a surface craft while the apparatus is being propelled to entrench the cable.

A further object of the present invention is to provide an underwater trenching apparatus including a self-contained traction wheel assembly adjustably mounted and including a plurality of radial drive plates adapted to be driven into the ocean floor to propel the apparatus.

Still another object of the present invention is to provide an underwater trenching apparatus having a pair of slider pads for supporting the apparatus upon the ocean floor and including self-contained propelling means comprising a rotary traction wheel assembly, the operation of which also causes reeling in of an anchored cable.

Another object of the present invention is to provide an underwater trenching apparatus including a rotary cutter assembly having a water jet pipe juxtaposed the cutting elements of the cutter assembly and provided with an adjacent air lift pipe to carry away soil cuttings.

With these and other objects in view which will more readily appear as the nature of the invention is better understood, the invention consists in the novel construction, combination, and arrangement of parts hereinafter more fully described, illustrated and claimed.

A preferred and practical embodiment of the invention appears in the accompanying drawings, in which:

FIG. 1 is a side elevation of the underwater trenching apparatus of the present invention.

FIG. 2 is a top plan view of the apparatus shown in FIG. 1.

FIG. 3 is a front elevational view of the apparatus shown in FIGS. 1 and 2.

FIG. 4 is an enlarged front end elevation of the apparatus shown in FIG. 3 and illustrates the pipeline after it has been locked into the operating position by means of the pivotal rollers.

FIG. 5 is a side elevation of a modification of the present invention.

FIG. 6 is a fragmentary top plan view of the apparatus of FIG. 5.

FIG. 7 is a fragmentary side elevation of the structure shown in FIG. 5 and illustrates a further modification including an anchored cable.

Similar reference characters designate corresponding parts throughout the several figures of the drawings.

Referring now to the drawings, more particularly FIGS. 1–4, the present invention will be seen to comprise an underwater trenching apparatus including a sled assembly generally designated **1** and having a pair of parallel and laterally spaced-apart slider pads **2-2** which form the foot portions or supporting means of the spaced apart side frames **3—3** which are joined together by a plurality of cross frame members **4**. Suitably attached to the intermediate portion of the sled assembly **1** is a vertically disposed cutter assembly generally designated **5** and which includes a torque tube **6** having its greater portion extending downwardly beneath its supporting cross frame member **4**. The torque tube **6** is of hollow construction and when combined with a suction dredge pump D at its upper end to assist in carrying away the cuttings, it will be understood that the bottom **7** of the tube will be open. The cutter assembly **5** is rotated preferably by means of a hydraulic motor **9**, likewise suitably attached to the sled assembly **1** and which rotates the cutter assembly by means of a drive chain **10** or other means connecting the two elements. Suitable mounting means, including the upper bearing **8**, support the cutter assembly **5** upon the sled frame. The principal means for removing the cuttings will be described hereinafter and the alternate use of the dredge pump D will be understood to facilitate operation in very shallow water.

Mounted upon the periphery of the tube **6** are a plurality of cutter bars **11** which are disposed in a standoff manner with respect to the tube **6** by means of the plurality of cutter bar brackets **12**. As will be seen most clearly in FIGS. 3 and 4, the cutter bars are mounted in diametrically opposed relationship and each succeeding pair of cutter bars is offset 90° from one another in order to provide a staggered cutter assembly which has been found to be most desirable in reducing any concentrated strain during operation of the cutter assembly. Additionally, experience has shown that a freer cutting action is achieved with this arrangement as there is less likelihood of a build-up of dislodged material upon the cutter elements, particularly when operating within heavy soils. A further point to be noted is the angular disposition of the various cutter bars **11** vhich are arranged in a manner to define an inverted frusto-conical configuration. The cutter bars **11** may be formed with any configuration determined to be most suitable for use in the particular environment at hand. For example, the leading edge of each bar may be beveled and/or serrated or optional rock-cutting teeth may be attached to the bars. Also, the standoff brackets **12** may include beveled leading edges to assist in cutting dislodged clay into chunks small enough to be drawn into air lift pipes disposed adjacent the cutter assembly.

From a review of FIGS. 3 and 4, it will be noted that a plurality of rubber-covered rollers are provided immediately to the rear of the cutter assembly **5**. A first lateral guide roller **13** is disposed with its axle vertically aligned and slightly laterally offset with respect to the torque tube **6**, as shown in FIG. 4, for reasons which will become apparent hereinafter. A bottom support roller **14** is fixedly located in a horizontal plane slightly above the level of the ocean floor and extends laterally in a direction away from the cutter assembly **5**, while a third roller **15** is mounted within a roller bracket **16** which is pivotally attached to the sled frame to provide for the alternate movement between the positions as shown in FIGS. 3 and 4.

FIG. 3 illustrates the appearance of the present apparatus after it has been lowered from the surface craft into position with the slider pads **2—2** straddling the pipeline P and after the hydraulic motor **9** and the dredge pump D have been actuated in order to allow the cutter assembly **5** to dig itself into the position shown in this figure of the drawings. At this point, the piepline P is then shifted slightly laterally to position it upon the bottom support roller **14** and against the inner guide roller **13**, whereupon the pivotally attached outer guide roller **15** is moved from the position of FIG. 3 to the position of FIG. 4 and thence locked into this position so that the two lateral guide rollers **13** and **15** firmly engage the periphery of the piepline as it rests upon the bottom support roller **14**. In view of the fixed mounting of the first lateral guide roller **13** with its periphery well spaced away from the longitudinal axis passing through the torque tube **6**, it will be appreciated that the surface of the pipeline P will be maintained clear of the rotating torque tube **6** during propulsion of the trenching apparatus, while the fixedly disposed bottom support roller **14** will insure that the rotating cutter bars **11** located below the level of this roller **14** do not come in contact with the yet to be entrenched pipeline.

Mounted upon the frame assembly **1** at a point to the rear of the cutter assembly **5** is a vertically disposed water jet pipe **17**, the lower portion **18** of which is positioned at a level slightly above the lowest point of the bottom cutter bars **11**. As will be seen in FIGS. 1 and 4 of the drawings, the jet pipe **17** is angled outwardly at an inclination substantially indentical to the inclination of the cutter bars **11** and is also inclined rearwardly from the bottom **18** thereof to its upper portion. A plurality of discharge nozzles **20** are provided along the forward periphery of the pipe **17** from the bottom **18** to a point above the top of the uppermost cutter bar **11**. Extending downwardly from the attendant servicing barge is a water line **21** which is adapted to supply water at high pressure to the jet pipe **17** during operation of the cutter assembly **5** for the purpose of breaking up cuttings as dislodged by the rotating cutter assembly and also dislodging cuttings tending to accumulate on the cutter bars and their brackets **12** so that a substantially homogeneous dispersion of relatively small cuttings and water is achieved.

Suitably attached to the frame assembly at a point immediately behind the jet pipe **17** are a pair of air lift pipes designated **22** and **23**, each of which includes an inclined main section having a bottom inlet **24** and **25**, respectively. As shown in FIG. 1, the inlet **24** of the pipe **22** is disposed at an elevation substantially higher than the inlet **25** of the pipe **23**, which latter inlet is located adjacent the bottom of the cutter assembly. The longer air lift pipe **23** is provided with a baffle plate **26** along its rearmost portion from which forwardly extends a bottom plate **27**. With this structure it will be appreciated that, upon the introduction of pressurized air into the main body of each of the air lift pipes, a significant suction will be generated in the areas of the inlets **24** and **25** and the dispersion of the dislodged cuttings will be drawn up into the two air lift pipes and directed through the outwardly-angled extensions 28 and 29 to be ejected from the outlets 30 and 31, which outlets are located at points disposed a suitable distance to one side of the trench T. A suitable air supply line 32 extending from the surface barge leads to the lower portion of each of the air lift pipes to provide the lifting force and resultant suction in the areas of the inlets 24 and 25.

From the foregoing description it will be seen that, upon the activation of the various described components, the cutter assembly 5 will be rotated so that the angularly disposed cutter bars 11 thereof will dislodge material from the floor to create the illustrated trench T, while the high pressure water being discharged from the plurality of nozzles 20 on the jet pipe 17 insures a homogeneous dispersion of these cuttings which are subsequently drawn into the air lift pipe inlets 24 and 25 and discharged to one side of the trench from the lift pipe outlets 30 and 31. The foregoing action is a continuous operation during the advancement of the trenching apparatus along the ocean floor F. This advancement of the apparatus may be accomplished by numerous means, the simplest of which may comprise the use of a tow cable 33 extending from a surface barge to the tow brackets 34 located at the forward portion of the apparatus. Constant tension winch means, as is well known in the art, may be included on the surface craft to enable operation of the apparatus at a fairly constant rate of speed in spite of the fluctuations in the progress of the towing craft on the surface of the water. Under certain conditions, however, it will be appreciated that the tow cable manner of advancing the apparatus along the floor F is unsuitable. Such would be the case during operations at maximum depths or during high seas. Also, the tow cable arrangement may be impractical when operating in a particularly hard soil. During these referenced instances, the present apparatus may be satisfactorily operated when employing the modifications shown in the embodiment of FIG. 5 or the further embodiment of FIGS. 6 and 7, it being understood that the basic trenching apparatus as described to this point is the same as used in these further modifications, since these embodiments offer alternate means for advancing the frame assembly along the ocean floor.

In the arrangements shown in FIGS. 5–7, a dual traction wheel assembly, generally designated 35, is adjustably mounted forward of the front of the trenching apparatus. The traction wheel assembly is mounted for rotation upon a transversely extending axle 36 suitably journalled at its ends within bearings 37 carried by the forward portion of traction wheel frame arms 38. The rear portion of each of the two frame arms 38 is attached to the forward portion of the apparatus frame assembly at the pivot points 39. Each segment of the traction wheel comprises a plurality of lateral support members 40 radially extending from the axle 36 and including, between their outermost ends, a radially extending drive plate 41. As will be seen most clearly in FIG. 6, each drive plate 41 is sandwiched between a pair of oppositely disposed support members 40 and each pair of adjacent drive plates is reinforced by means of a longitudinal plate 42 suitably attached, such as by welding, to the medial portion of each drive plate intermediate its outer edge 43 and inner edge 44. Adjustment of the traction wheel assembly 35 is achieved by means of a fluid cylinder 45 having a fixed pivot point 46 connected to the cross frame member 4 and a movable forward pivot point 47 connected to the frame arm 38. A suitable fluid cylinder 45 mounted as above described is preferably provided for each frame arm 38 so that, upon simultaneous actuation of the two cylinders 45, the traction wheel assembly is raised or lowered about the pivot points 39 to either clear the drive plates 41 from the ocean floor F or to urge these plates into engagement with the surface of the floor.

Suitable means in the form of a hydraulic motor 48 are included on the frame assembly for rotating the traction wheel assembly in the direction shown by the arrow in FIG. 5. Drive transmission means such as the chain 49 extends from the hydraulic motor 48 to a driven gear 50 fixedly attached to the traction wheel axle 36 so that, upon actuation of the motor 48, the traction wheels will be rotated. When it is desired to advance the trenching apparatus along the ocean floor and the cutter assembly 5 is actuated, the hydraulic motor 48 is activated and subsequently the fluid cylinders 45 are regulated in order to lower the pivotally attached traction wheel assembly so that its drive plates 41 will be urged into the surface of the ocean floor in order to pull the trenching apparatus forwardly. The disposition of the plate inner edges 44 at points radially spaced a significant distance from the axle 36 provides a self-clearing feature for the traction wheels as it will be appreciated that soil accumulating between each pair of adjacent plates 41 will be constantly pushed inwardly until clearing the inner edges 44.

The additional modification included in FIGS. 6 and 7 provides for an anchor cable 51 to deliver further traction when utilizing the traction wheel assembly 35. On certain occasions, the mere rotation of the traction wheel assembly will be insufficient to satisfactorily advance the trenching apparatus, either because the soil is extremely hard or, on the other hand, the surface of the ocean floor may be so sandy that insufficient traction is provided by engagement of the drive plates with the floor surface. By utilizing the anchor cable 51, dual traction means are in effect provided. One end of the cable 51 is attached to an anchor 52 which is driven into the ocean floor well in advance of the apparatus. The opposite free end of the cable 51 is suitably attached to the traction wheel axle 36 which includes a pair of side plates 53 defining a winch drum therebetween. In this manner operation of the hydraulic motor 48 concurrently rotates the traction wheel assembly while winding up the cable 51 to assist in pulling the trenching apparatus forwardly.

As discussed to this point, the trenching apparatus will be seen to relate to the burying of a pipeline, either one that has been previously laid on the ocean floor or which is simultaneously played from a lay barge pipe ramp as the apparatus is advanced along the floor. It will be understood that the same apparatus may be employed to bury a cable, which likewise may be either prelaid on the bottom or, simultaneously reeled from the surface as the apparatus is advanced for the entrenching operation. FIG. 1 of the drawings includes a cable guide G which is removably attached to the frame assembly and extends from a point adjacent to and above the cutter bars 11 to a point located below and rearward of the cutter assembly. By this arrangement, the cable is positively guided or directed to the bottom of the trench T and by adjustment of the jet pipe 17 and air lift pipes 22–23, simultaneous backfilling of the trench can be accomplished. Quite obviously, the cable guide G may be constructed of a plurality of removable half-sections to permit the attachment or removal of the apparatus to an intermediate section of prelaid or partially entrenched cable.

A complete assembly of guide rollers **13–15** is shown in the drawings adjacent the cutter assembly and intermediate cross frame member **4**. Included in this group of rollers is the fixedly-mounted horizontally disposed roller **14'** located above the bottom roller **14** and having its lower periphery in a plane below the bottom of the cross frame members **4**. The upper fixed roller serves to preclude engagement between the pipeline and sled frame in instances wherein the pipeline may become more buoyant than the sled. Although only one assembly of the various pipeline guide rollers are shown in the drawings, it will be understood that additional similar assemblies of rollers are preferably provided adjacent both the fore and aft cross frame members **4** in order to assure lateral stability of the advancing apparatus.

I claim:

1. An underwater pipeline and cable trenching apparatus comprising, a frame assembly including a pair of spaced apart side frames each having support means for slidably engaging the ocean floor, a substantially vertically disposed cutter assembly mounted upon said frame assembly between said side frames, said cutter assembly provided with a central torque tube journalled for rotary movement and extending downwardly below said frame assembly, a plurality of cutter bars mounted upon said tube in a standoff manner, motor means on said frame assembly for driving said cutter assembly, pipeline guiding and supporting means disposed between said side frames and adjacent said cutter assembly, said pipeline guiding and supporting means including a fixed horizontally disposed bottom support member having an upper surface in a plane no lower than the bottom of said side frame support means, a fixed vertically disposed inner support member adjacent said bottom support member, a vertically disposed outer support member adjacent said bottom support member and laterally spaced from said inner support member, said outer support member mounted for adjustable movement towards and away from said inner support member, a water jet pipe carried by said frame assembly and disposed adjacent said cutter assembly and advancing means connected to said frame assembly for propelling the apparatus when a pipeline is disposed within the confines of said bottom, inner and outer support members and said cutter tube is rotating and said jet pipe is operating.

2. An underwater apparatus according to claim **1** wherein, said side frame support means comprises a longitudinally extending pad.

3. An underwater apparatus according to claim **1** including, pairs of said cutter bars mounted upon said tube in diametrically opposed relationship, and successive pairs of said bars are angularly offset with respect to one another.

4. An underwater apparatus according to claim **1** including, laterally extending brackets connecting said cutter bars to said torque tube and said cutter bars describe an inverted frusto-conical configuration.

5. An underwater apparatus according to clam **1** wherein, said cutter torque tube is hollow and includes a bottom opening and a top-mounted suction dredge pump.

6. An underwater apparatus according to claim **1** wherein, the leading edges of said cutter bars are beveled.

7. An underwater apparatus according to claim **1** wherein, said bottom, inner and outer support members comprise rollers.

8. An underwater apparatus according to claim **1** wherein, said outer support member comprises a roller pivotally attached at its upper end to said frame assembly.

9. An underwater apparatus according to claim **1** including, an air lift pipe carried by said frame assembly and disposed adjacent said cutter assembly and water jet pipe.

10. An underwater apparatus according to claim **1** wherein, said advancing means comprises a tow cable attached to the forward portion of said frame assembly.

11. An underwater apparatus according to claim **1** wherein, said advancing means comprises a traction wheel assembly adjustably mounted adjacent the forward portion of said frame assembly.

12. An underwater apparatus according to claim **11** wherein, said traction wheel assembly includes, a pair of frame arms pivotally attached to said frame assembly, a transverse axle supported between the free ends of said frame arms, spaced apart lateral support means radially extending from said axle, a plurality of radially projecting drive plates mounted between said spaced apart support means, and motor means connected to said axle for rotating same to propell said apparatus as said drive plates dig into the ocean floor.

13. An underwater apparatus according to claim **12** including, fluid cylinder means connecting said traction wheel assembly to said frame assembly for pivotal adjustment therebetween.

14. An underwater apparatus according to claim **12** wherein, said axle includes a cable winch drum thereon.

* * * * *