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SEARCH ROOM

May 5, 1970 FUKUICHI KUKIHARA 3,509,949

EXCAVATION OF TRENCHES FOR BURIED WALLS

Filed Aug. 28, 1967 5 Sheets-Sheet 1

FIG. 1

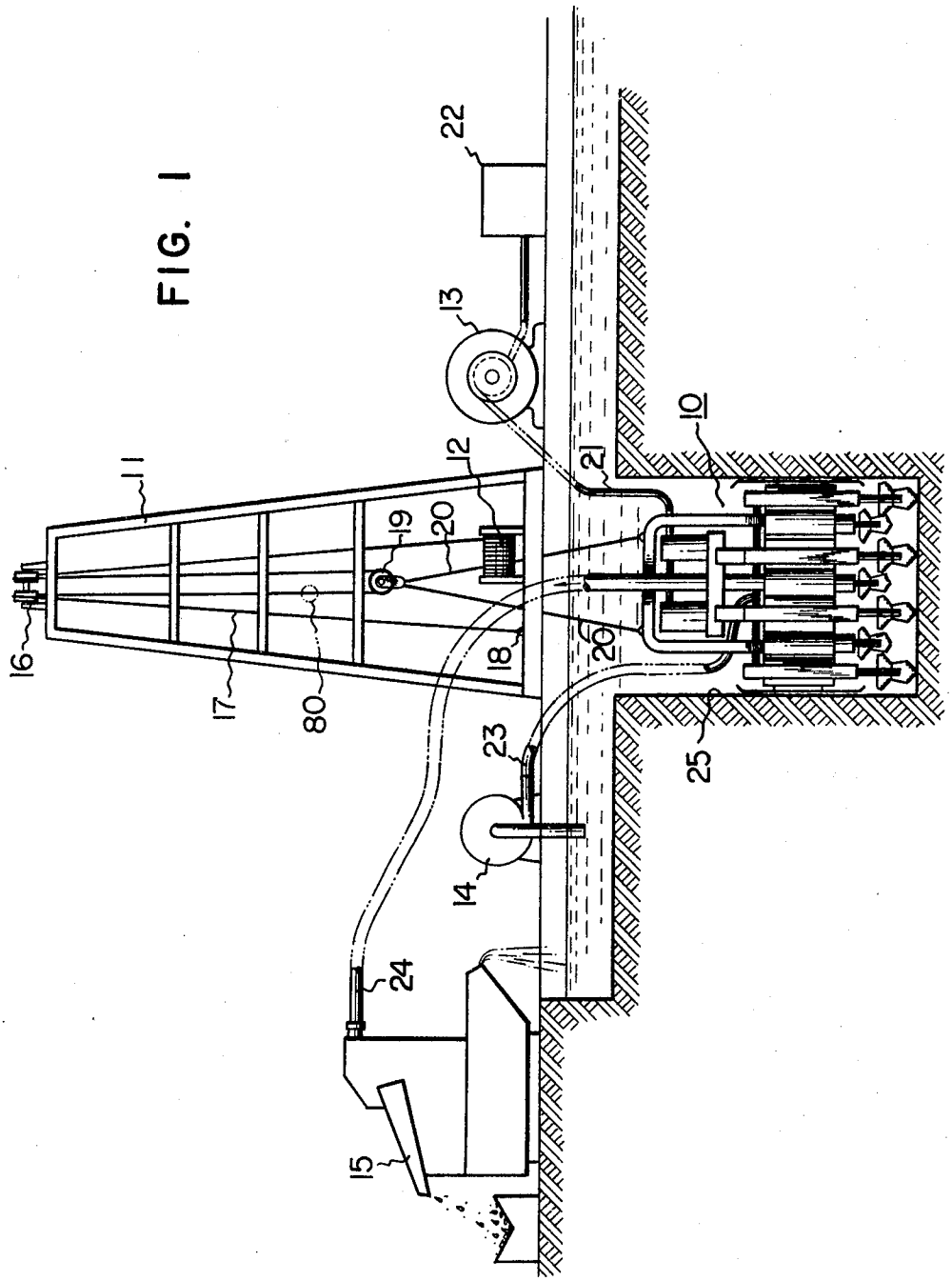
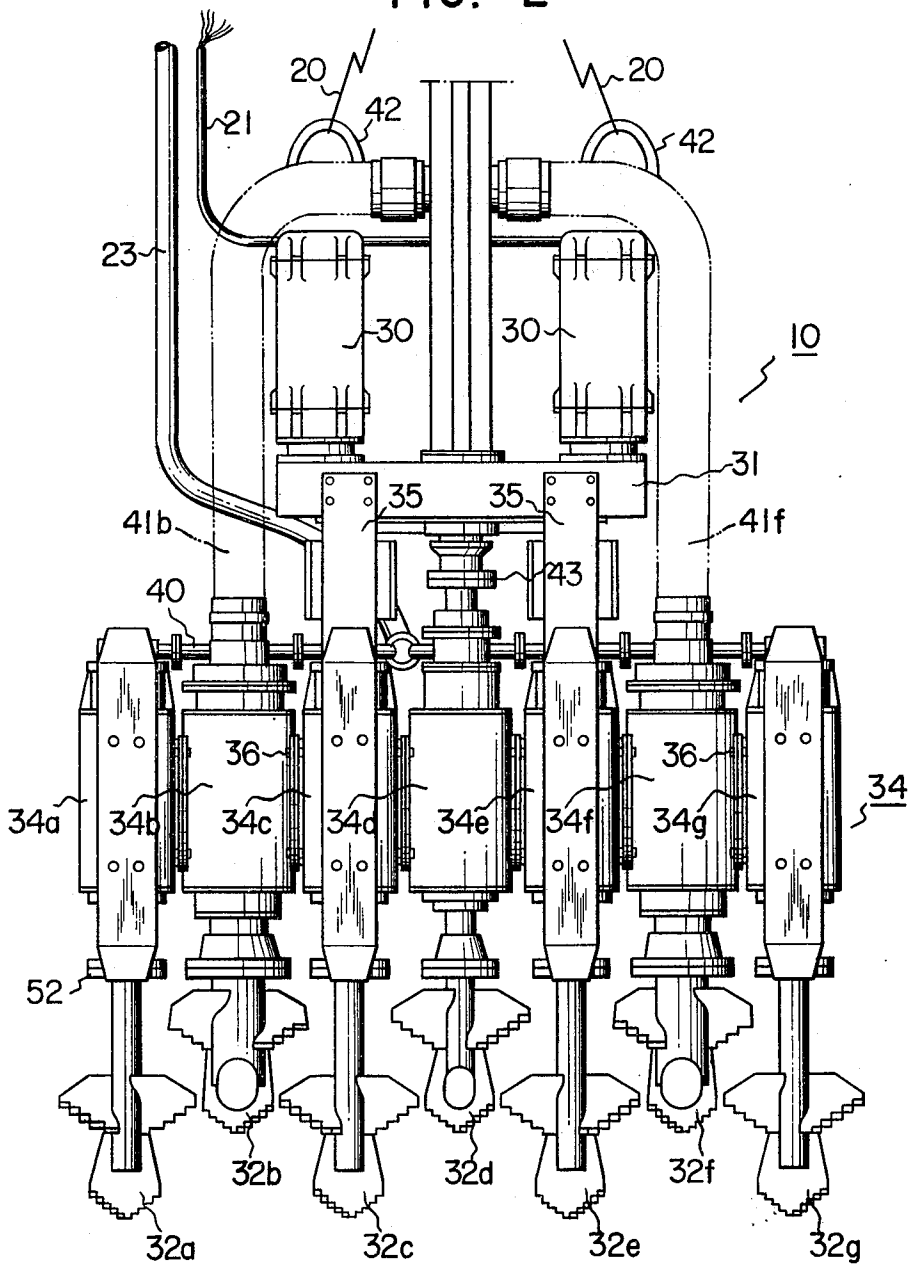


FIG. 2


20
20
21
42
42
23
30
30
10
31
35
35
41b
41f
43
40
36
36
34
34a
34b
34c
34d
34e
34f
34g
52
32b
32d
32f
32a
32c
32e
32g

May 5, 1970 FUKUICHI KUKIHARA 3,509,949

EXCAVATION OF TRENCHES FOR BURIED WALLS

Filed Aug. 28, 1967 5 Sheets-Sheet 3

FIG. 3

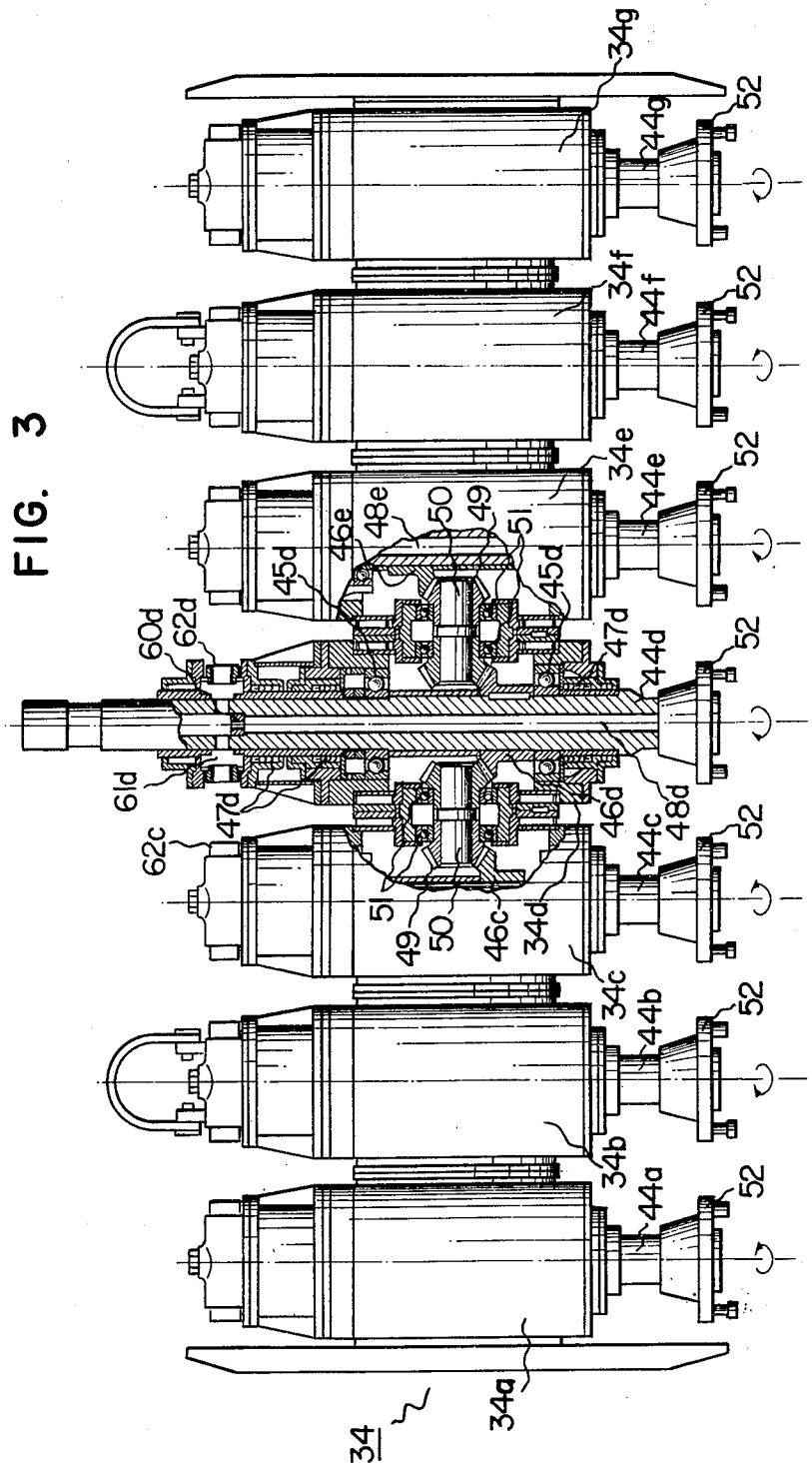
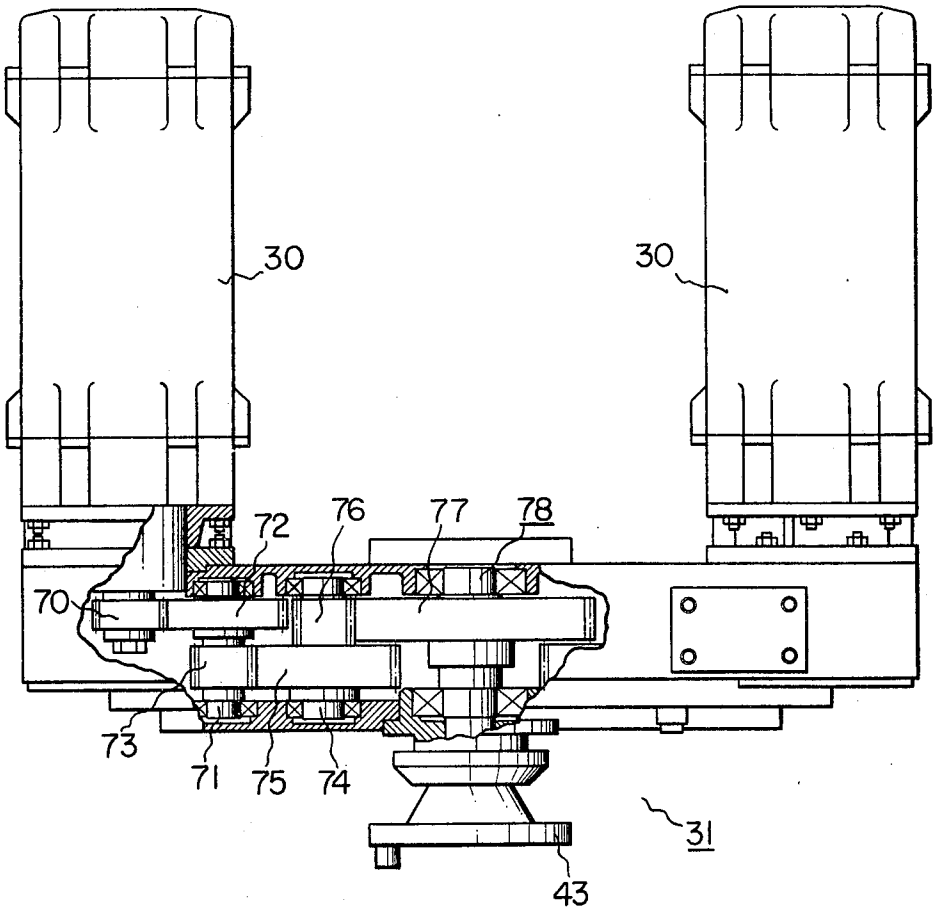


FIG. 4



May 5, 1970 FUKUICHI KUKIHARA 3,509,949

EXCAVATION OF TRENCHES FOR BURIED WALLS

Filed Aug. 28, 1967 5 Sheets-Sheet 5

FIG. 5

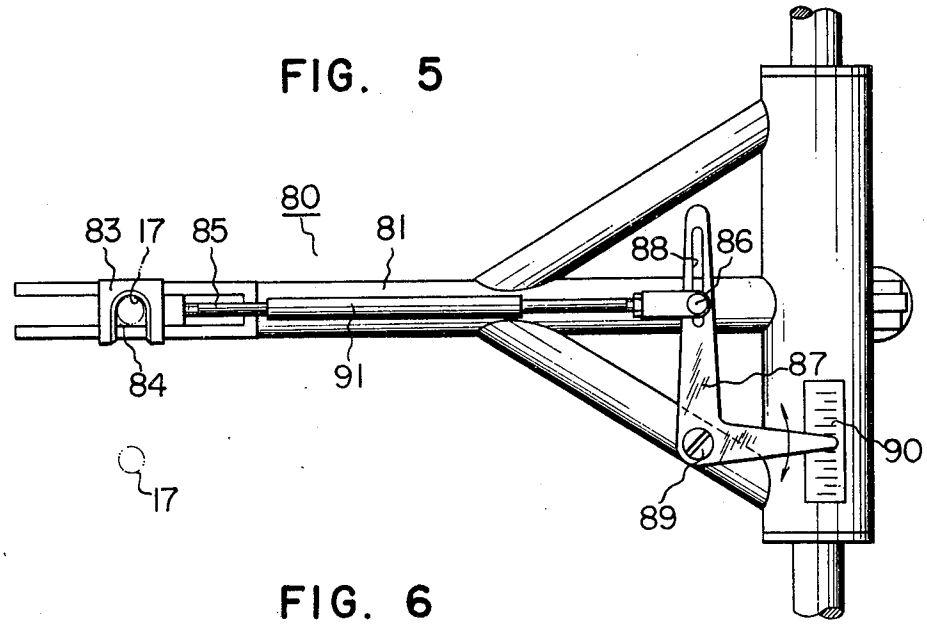
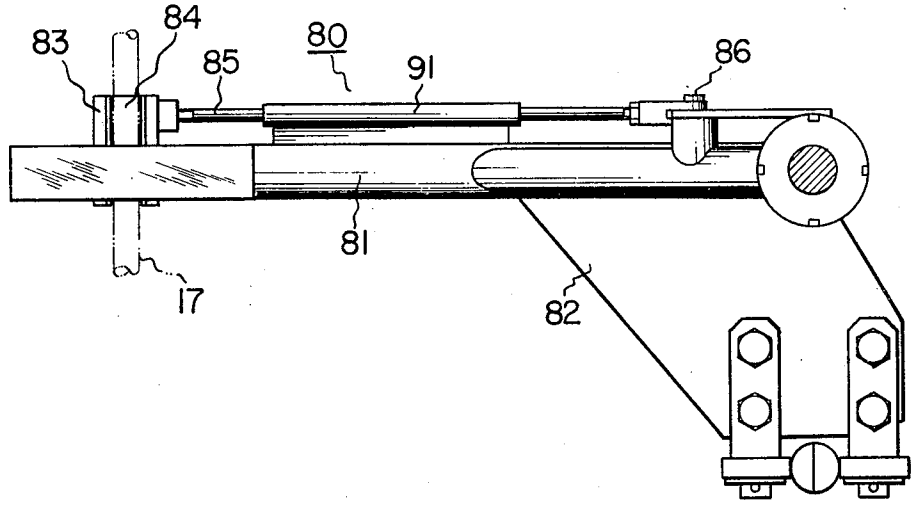


FIG. 6



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3,509,949

EXCAVATION OF TRENCHES FOR BURIED WALLS

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Int. Cl. E02f 3/88
U.S. Cl. 175—40 1 Claim

ABSTRACT OF THE DISCLOSURE

An excavator having a row of several drill bits provided with partly overlapping drilling paths, and in which some bits rotate counter to the others, is freely suspended and lowered as it excavates a trench, with water being forcibly ejected through some of the bits to form mud and thereby facilitate drilling, and the resulting mud being drawn through the other bits for removal.

BACKGROUND OF THE INVENTION

This invention relates generally to techniques in forming long narrow excavations in soil and more particularly to a new technique for excavating continuously long narrow excavations (hereinafter referred to as trenches) for placement therein of buried walls such as earth retaining walls, sheathings, and water barrier walls.

For forming trenches in soil for retaining soil or water, it is known in the art to first drill a series of vertical cylindrical holes at constantly spaced intervals and thereafter demolish and remove the walls between these holes to produce a continuous trench.

By this prior method, however, it is extremely difficult, if not impossible, to form trenches of the desired direction, shape, and dimensions in a rapid and efficient manner.

Another method proposed heretofore is to use a row of drill bits at the lower ends of long drill rods driven by driving mechanisms at the ground level. This method, however, imposes excessive stresses on the entire device particularly when trenches without askewness are to be excavated.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method of and equipment for efficiently forming trenches of the desired directions, shapes, and dimensions in the ground.

Another object of the invention is to prevent the application of abnormal or excessive forces on the equipment parts supporting an excavating machine by suspending the excavating machine assembly in a free state by means of a suspension wire and a wire-rope tackle instead of rigidly supporting the assembly by means of drill rods.

Still another object of the invention is to provide an excavating machine in which its prime mover is mounted directly thereon thereby overcoming the necessity of providing mechanical power transmitting means between the ground level and the excavating machine.

A further object of the invention is to provide an excavating machine having a plurality of drill bits and means for causing some of the drill bits to rotate in a direction opposite to that of the other drill bits thereby preventing undesirable askew turning of the excavating machine by virtue of which the trench would otherwise assume a warped or twisted shape.

A still further object of the invention is to cause a forced circulation of water between the bottom of the trench and the ground level thereby facilitating the excavation operation.

An additional object is to provide a twist detecting device for detecting undesirable twist or askewness in the position of the excavating machine during the excavating operation.

Other objects and advantageous features of the invention will become apparent as the disclosure proceeds.

According to the present invention, briefly summarized, there is provided an excavator for excavating trenches for walls comprising, essentially, an excavator body, a plurality of drill bits rotatably supported in a row at the bottom of the excavator body, adjacent drill bits having partly overlapping drilling paths, and a controllable prime mover mounted on the excavator body for driving the drill bits through a gear mechanism whereby approximately one-half of the bits rotate in a direction opposite to that of the remainder of the bits.

There is further provided in addition to the above described excavator, a hoisting device for controllably positioning the excavator and supporting the excavator in a suspended state during the excavating operation, a control system for controlling the prime mover, a water supply device for supplying water through some of the drill bits to form mud to facilitate drilling, and a mud removal device for removing the mud thus formed through the remainder of the bits.

The nature, principle, details, and utility of the invention will be more clearly apparent from the following detailed description with respect to a preferred embodiment of the invention when read in conjunction with the accompanying drawings, in which like parts are designated by like reference numerals.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a diagrammatic elevational view, partly in vertical section, showing the general organization of one example of excavation equipment according to the invention;

FIG. 2 is an elevational view showing the general organization of an example of an excavating machine or excavator according to the invention for use in the equipment shown in FIG. 1;

FIG. 3 is an elevational view, in vertical section, showing the bit driving shafts and the state of their intercoupling by gears in the main gear casing of the excavating machine;

FIG. 4 is an elevational view, partly in section and with parts cut away, showing the gear train within the reduction gear casing of the prime mover of the excavating machine; and

FIGS. 5 and 6 are respectively a plan view, with a part in section, and an elevational view showing a device for detecting skewness of the excavating machine structure.

Referring to FIG. 1, the excavation equipment illustrated therein is made up essentially of an excavating machine **10** (hereinafter referred to as the excavator **10**), a derrick or frame tower **11** for hoisting the excavator **10**, a winch **12** for controllably moving the excavator **10** vertically, a cable reel **13** for taking up slack in the power supply cable of the excavator **10**, a pump **14** for supplying water to the excavator **10**, and a mud treatment machine **15** installed at ground level for drawing mud upwardly through the excavator **10** and separating the solid sediments from water.

A pair of head sheaves **16** is rotatably supported at the top of the tower **11**, and one end of a wire rope **17** passed over the sheaves **16** is anchored to a point **18** at the base of the tower **11** through a cylinder device (not shown) for indicating the tension in the wire rope. From the point **18**, the wire rope is passed over and around one of the head

sheaves 16, under and around the sheave of a running block 19, and over and around the other sheave 16 and is then directed to and wound around the drum of the winch 12 mounted on the base of the tower 11.

The excavator 10 is suspended from the running block 19 by a suspension wire 20. Thus, by winding and unwinding the winch 12, the excavator 10 can be raised and lowered, with the vertical stroke of the drills of the excavator 10 being one half of the length of the wire rope 17 either wound or unwound.

The motive power source of the excavator 10, for example, two electric motors, are controllably supplied with power from a control device 22 through a water-tight cable 21 wound around a cable reel 13 provided at the ground level for taking up slack in the cable 21.

Water pumped by the pump 14 is delivered through a flexible hose 23 into the excavator 10. Mud is drawn up through the excavator 10 and through a hose 24 to the mud treatment apparatus 15. This drawing up of the mud is accomplished by the so-called air lift method whereby the mud is lifted by air transmitted from the ground level or by a method depending upon a suction pump installed at ground level, that is, a forced circulation method involving the washing of the bits by supplied water and the mud removal by the drawing up of the mud. The interior of a trench 25 being excavated by the excavator 10 is filled with muddy water.

The details of the excavator 10 are shown in FIG. 2. The excavator is provided with two prime movers 30, which are, for example, vertical electric motors of a water-submersible construction mounted on a reduction gear casing 31 housing a reduction gear mechanism described hereinafter. Below the casing 31, there is provided a main gear casing 34 for housing the vertical drive shafts of drill bits 32_a, 32_b, 32_c, 32_d, 32_e, 32_f, and 32_g and a gear mechanism for the intercoupling of the bit drive shafts as described hereinafter.

This main gear casing is made of several casing sections 34_a, 34_b, 34_c, 34_d, 34_e, 34_f, and 34_g secured together integrally in a row and is connected integrally with the above mentioned reduction gear casing 31 by connecting plates 35. Each of the casing sections 34_a through 34_g houses a vertical bit drive shaft and is rigidly fixed to the adjacent casing section or sections by bolts and nuts 36.

Throughout the following description, reference numerals with subscripts *a* through *g* respectively designate similar parts disposed in or associated with these casing sections 34_a through 34_g although some of these numerals and their respective parts may be omitted in the drawings for the sake of simplification of the drawings.

Referring to FIG. 3, the bit drive shafts housed within the main gear casing 34 for driving the bits 32_a through 32_g and designated by reference numeral 44 with corresponding subscripts *a* through *g* are rotatably supported by respective pairs of upper and lower bearings. For example, the central shaft 44_d is supported by a pair of bearings 45_d. A bevel gear is fixed to each bit shaft between its two bearings. For example, a bevel gear 46_d is fixed by means such as a key to the central shaft 44_d.

Furthermore, each bit drive shaft is provided around its upper and lower end parts with sealing or packing devices for preventing mud and water from infiltrating into the corresponding casing section. For example, the central shaft 44_d is provided with packing devices 47_d. In addition, each bit drive shaft has a hollow passageway formed therethrough in its axial direction for passage therethrough of a fluid such as water or mud. For example, the central shaft 44_d has a passageway 48_d.

In the spaces between adjacent bit driving shafts, there are respectively disposed cross shafts 50 with their axes perpendicular to the axes of the bit drive shafts. Each of the cross shafts 50 are rotatably supported at its middle part by a bearing 51 suitably supported in turn by a structural part of the main gear casing 34. Bevel gears 49 are fixed to the ends of each cross shaft 50 and are in mesh with the bevel gears 46 fixed respectively to the two neighboring bit drive shafts 44. For example, the bevel gears 49 on the ends of the cross shaft 50 between the bit drive shafts 44_c and 44_d are respectively in mesh with the bevel gears 46_c and 46_d fixed respectively to shafts 44_c and 44_d.

Thus, when the central bit drive shaft 44_d rotates, all of the bit drive shafts 44_a through 44_g also rotate. It is to be observed, however, that the bevel gears 46 fixed to the central bit drive shaft 44_d and the bit drive shafts to the left thereof, as viewed in FIG. 3, face upwardly and engage with the lower sides of their respective gears 49 fixed to the cross shafts 50. The bevel gears 46 fixed to the bit drive shafts 44 to the right of the central shaft 44_d face downwardly and engage with the upper sides of their respective gears 49.

By reason of these particular relationships between the bevel gears, if the central shaft 44_d rotates in the direction of the arrow as indicated in FIG. 2 (i.e., clockwise as viewed from above), the other bit drive shafts will rotate in the directions indicated by their respective arrows. That is, the shafts 44_b, 44_e, and 44_g will rotate in a clockwise direction, and shafts 44_a, 44_c, and 44_f in a counterclockwise direction, as viewed from above.

The bit drive shafts are provided at their lower ends with respective shaft coupling flanges 52 to which respective drill bits 32 are fixedly coupled. Each of the drill bits has a shape suitable for ordinary drilling action and, in addition, an internal passageway therethrough for the passage of water or mud. The shanks of the drill bits 32_a, 32_c, 32_e, and 32_g are longer than those of drill bits 32_b, 32_d, and 32_f, so that the bit cutting parts of the first mentioned bits project further downwardly than those of the second mentioned. When each drill bit is coupled to its bit drive shaft, the hollow passageways thereof are in mutual communication.

As shown in FIG. 2, a distribution pipe 40, consisting of a combination of several pipe sections, is provided horizontally at the upper part of the main gear casing 34. The distribution pipe 40 is connected to the flexible hose 23 for supplying water and, at the same time, communicates with the passageways 48_a, 48_c, 48_e, and 48_g of the bit drive shafts 44_a, 44_c, 44_e, and 44_g within the casing sections 34_a, 34_c, 34_e, and 34_g, respectively.

The passageways 48 within the bit drive shafts 44 are provided at their upper ends with respective constriction sleeves 60 screwed into the shafts 44. Chambers 61 are respectively formed at the upper ends of the casing sections 34 housing the bit drive shafts 44 and are respectively provided at their walls with suitable pipe fittings 62 for the detachable connection thereto of the above mentioned sections of the distribution pipe 40. The pipe fittings 62 which are not in use are closed by screw plugs.

Thus, the water supplied by the flexible water supply hose 23 is passed through the distribution pipe 40, the chambers 61, constriction sleeves 60, the passageways 48 within the bit drive shafts 44_a, 44_c, 44_e, and 44_g and through their respective drill bits 32. The water is thereby ejected into the holes being drilled by the drill bits 32_a, 32_c, 32_e, and 32_g.

As shown in FIG. 2, the mud discharge pipes 41_b and 41_f are connected to the upper ends of the casing sections 34_b and 34_f and thus communicate with the passageways 48_b and 48_f within the bit drive shafts 44_b and 44_f. The upper ends of the mud discharge pipes 41 are connected to the inlet end of the discharge hose 24 shown in FIG. 1. Thus, the passageways through the drill bits 32_b and 32_f and their respective bit drive shafts 44_b and 44_f are in communication with the mud treatment machine 15. The passageway within the central bit drive shaft 44_d can also be connected to the hose 24 although this connection is not shown.

Shackle fittings 42 are provided on the mud discharge pipes 41_b and 41_f for fastening the ends of the suspension wire 20.

The central bit drive shaft 44_d is driven by the power produced by the two motors **30** through reduction gears within the reduction gear casing **31** of the organiaztion shown in FIG. 4. A pinion **70** fixed to the output shaft of each motor **30** is in meshing engagement with a gear **72** fixed to a first intermediate shaft **71**, and a pinion **73** also fixed to the intermediate shaft **71** is in mesh with a gear **75** fixed to a second intermediate shaft **74**. A pinion **76** also fixed to the second intermediate shaft **74** is in mesh with a gear **77** fixed to a central output shaft **78**. The lower end of the output shaft **78** is provided with a coupling flange **43** for coupling with the upper end of the central bit drive shaft 44_d.

The excavation equipment above described operates in the following manner:

First, the frame tower **11** is placed at the position a trench is to be excavated. The excavator **10** is suspended by the suspension wire **20** from the running block **19** and set in the excavating position by the winch **12**. Then, by operating the control device **22**, the motors **30** of the excavator **10** are started.

The rotational power of the motors **30** is transmitted through the gear train **70**, **72**, **73**, **75**, **76**, and **77** within the reduction gear casing **31**, the shaft **78**, and the coupling **43** to the central bit drive shaft 44_d within the main gear casing **34**. The power is then transmitted from the shaft 44_d through the gear train defined by bevel gears **46** and **49** and cross shafts **50** to all of the other bit drive shafts **44** and, therefore, to all drill bits **32**, so that the drill bits **32** rotate in the respective directions as described hereinbefore.

By this rotation of the drill bits **32** and by the weight of the excavator **10** imparted downwardly on the bits, the soil is excavated, and a narrow long hole of a length corresponding to the length of the row of drill bits **32** is formed in the ground.

During this excavation, water is supplied to the excavator **10** from the pump **14** through the water supply hose **23**. The water passes the distribution pipe **40**, through the passageways **48** within the bit drive shafts 44_a, 44_c, 44_e, and 44_g, and the corresponding drill bits **32** and is ejected against the soil being drilled. The soil thus becomes muddy, thereby facilitating the drilling action of the drills bits.

On one hand, the drill bits 32_b, 32_d, and 32_f, having short shanks and disposed in a row at a position higher than the row of the other drill bits, drill the unexcavated soil parts remaining between the bits of the lower row as they advance behind the lower row. During this operation, the excavated soil in the form of mud is drawn up through the passageways in the bits **32** of the upper row and in their respective drive shafts **44**, through the mud discharge pipes **41**, and the mud discharge hose **24** by the action of a suction pump or an air lift and is thus transferred to the mud treatment apparatus **15**, in which the solid soil is separated from the water.

As described hereinbefore, the direction of rotation of the drill bits 32_b and 32_d of the upper row are the same, while that of the drill bit 32_f is in the opposite direction. Except for the combination of the bits 32_d and 32_e, adjacent bits rotate in mutually opposite directions. During the excavation, this relationship between the bit rotational directions not only affords stabilization of the bit drilling action but also prevents progressive twisting in the form of the trench as the excavation depth increases. This desirable excavating action is further improved by suspending the excavator **10** by the suspension wire **20**.

As the excavation with the bits progresses, the excavator **10** is gradually lowered by unwinding the wire rope **17** on the winch **12** to lower the running block **19**. The depth of excavation by the excavator can be readily determined by observing the vertical position of the running block **19**.

While twisting of the trench being excavated can be substantially completely prevented by the above described relationship between the bit rotational directions and the suspension of the excavator **10** with the suspension wire **20**, it is still possible for some twist to occur in certain cases. When a twist occurs in such cases, it is necessary to stop the excavation operation immediately and to effect appropriate adjustments. Such twists in the trench can be readily detected by a device in accordance with the invention, one example of which is illustrated in FIGS. 5 and 6.

The twist detecting device, generally designated **80**, includes a support structure defined essentially by cantilever arm **81** and a mounting bracket **82** for mounting the arm **81** to a suitable structural part of the frame tower **11**. A rope follower **83** for encompassing and engaging the wire rope **17** is mounted on the outer end of the arm **81** in a manner permitting it to slide freely longitudinally of the arm **81**. The rope follower **83** has a vertical through hole **84** through which passes one of the two lines or falls of the wire rope **17** between the head sheaves **16** and the running block **19**.

The rope follower **83** is fixed on its side facing the root end of the arm **81** to the outer end of a slidable connecting rod **85** slidably supported and guided by a guide member **91** in a direction parallel to the arm **81**. The inner end of the connecting rod **85** is provided with a clevis with a pin **86** slidably engaged with a slot **88** in one arm of an angle lever **87** of bell-crank shape rotatably supported by a pivot **89**. The other arm of the lever **87** is free and functions as pointer for indicating readings on a calibrated scale **90**.

The twist detecting device **80** is mounted on the frame tower **11** to project horizontally such as indicated by the dash line in FIG. 1, in a direction perpendicular to a plane passing through the two parallel lines or falls of the wire rope **17** stretched between the head sheaves **16** and the running block **19**.

If a twist occurs in the trench being excavated, the excavator **10** will assume a certain angle of askewness relative to the originally desired angular position. This askew angle will then be transmitted through the suspension wire **20** and running block **19** to cause a twist or warp in the plane passing through the two falls of the wire rope **17**.

Consequently, the wall of the wire rope passed through the rope follower **83** of the detecting device **80** will undergo a displacement with a component in the longitudinal direction of the arm **81**, whereby the rope follower **83** will undergo a displacement in the longitudinal direction of the arm **81**. This displacement will be transmitted through the connecting rod **85** and clevis pin **86** to rotate the angle lever **87**, so that the indicator arm of the lever **87** will be displaced along the scale **90** to indicate the direction and magnitude of displacement. From this reading, the direction and magnitude of askewness of the excavator **10** can be determined.

The above described excavation procedure is continued until a trench of the required depth and length determined by the length of the row of drill bits has been formed, whereupon one cycle of excavation has been completed. The excavator **10** is then hoisted clear of the ground, and the frame tower **11** shifted in parallelism in the direction of the trench centerline to a position for excavating a succeeding trench contiguous to and in alignment with the first trench. The cycle of excavation is then repeated. Thereafter, successive cycles of excavation are effected in the same manner to excavate a continuous, long trench.

In certain cases, successive trenches may be formed in an alternately staggered pattern, with each trench having a centerline offset relative to those of the immediately adjacent trenches. The magnitude of this offset may be of the order of the lateral width of the trench.

As described above, the present invention provides excavation equipment including a novel excavator whereby trenches for underground walls of the desired directions, shapes, and dimensions can be efficiently formed.

What we claim is:

1. Apparatus for excavating trenches for buried walls comprising, in combination: an excavator having an excavator body, water-submersible motive power means installed on the excavator body, and a plurality of drill bits driven by the motive power means and rotatably supported by the excavator body at the bottom part thereof in one plane adjacent drill bits having partly overlapping drilling paths, approximately one-half of the plurality of drill bits rotating in one rotational direction opposite to that of the remainder of the drill bits, approximately three quarters of the drill bits being provided therethrough with central passageways for water, and the remainder of the drill bits being provided with like passageways for mud; positioning means for lowering and raising the excavator in a suspended state, comprising a hoist structure movably installed on the ground surface, a wire-rope tackle mounted on the hoist structure and including a runniny block, a controllable power driven winch for operating the wire-rope tackle, and a suspension wire device connected at its upper part to said running block and its lower end to the excavator body, and a displacement detecting device mounted on said hoist structure and engaged with said wire-rope tackle for detecting displacement therein due to twist displacement in the suspension wire caused by askewness in the angular position of the excavator body about the vertical axis thereby to detect twist in the shape of the trench being excavated; power supply and control means comprising a control station at the ground level, a waterproof cable connected between the control station and the motive power means of the excavator for controllably supplying power thereto; water supply means comprising a pump and a hose connecting the pump to said passageways for water through some of the drill bits; and mud removal means comprising a mud discharge hose communicating at its inlet end to all of said passageways for mud through some of the drill bits, and a mud treatment apparatus connected to the outlet end of the mud discharge hose and operating to draw mud through the discharge hose from the region immediately below the excavator body, to separate the mud thus drawn into solid sediments and water, and to return the water thus separated to fill the trench being excavated, with a part of said water being pumped for water supply by the water supply means.

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C. D. CROWDER, Assistant Examiner

U.S. Cl. X.R.

37—65, 80; 175—91, 96, 206