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Barker et al.

[11] **3,739,503**

[45] **June 19, 1973**

[54] **HYDRAULIC DREDGE HAVING ARTICULATED LADDER AND SWELL COMPENSATOR**

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[21] Appl. No.: **62,962**

[52] **U.S. Cl.** **37/67**, 37/72, 254/172

[51] **Int. Cl.** **E02f 3/88**

[58] **Field of Search** 37/61–67, 58, 72; 299/9; 254/172

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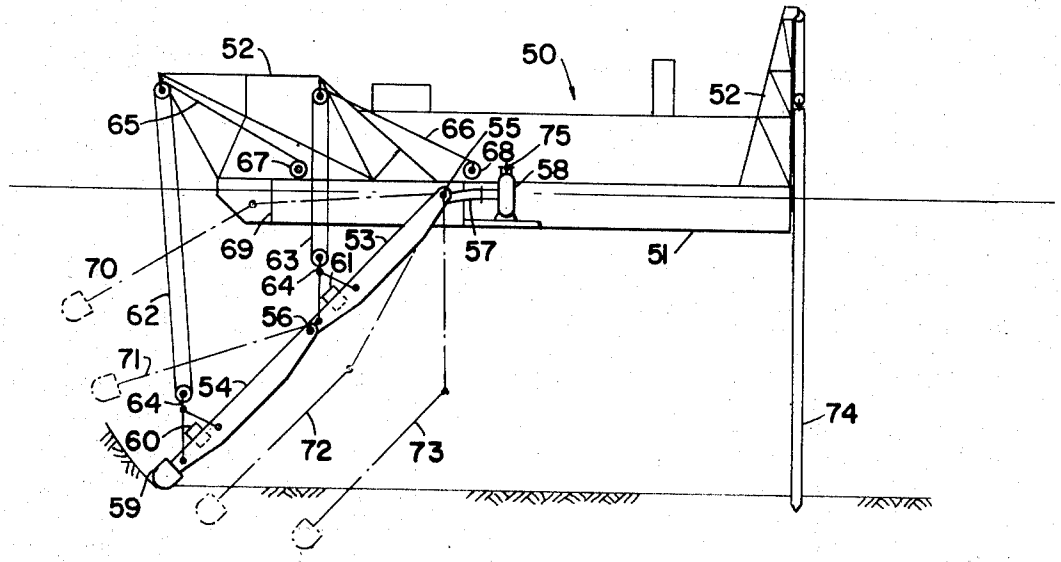
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[57] **ABSTRACT**

A deep-digging floating hydraulic dredge having an articulated ladder with two or more sections pivoted together for relative swinging movement in a vertical plane only with a cutter head or other digging device and pump pipeline supported by the ladder. For seagoing use the dredge may have sounding means for determining instantaneously the height of the hull above the bottom of the water on which the hull is floating, angle sensing means for determining instantaneously the fore-and-aft angle to the horizontal of the dredge hull, and control means receiving an input depth signal and an input angle signal controlling the suspension length of the articulated ladder sections and accommodating it to swells in the water level on which the hull floats.

7 Claims, 21 Drawing Figures



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SHEET 1 OF 9

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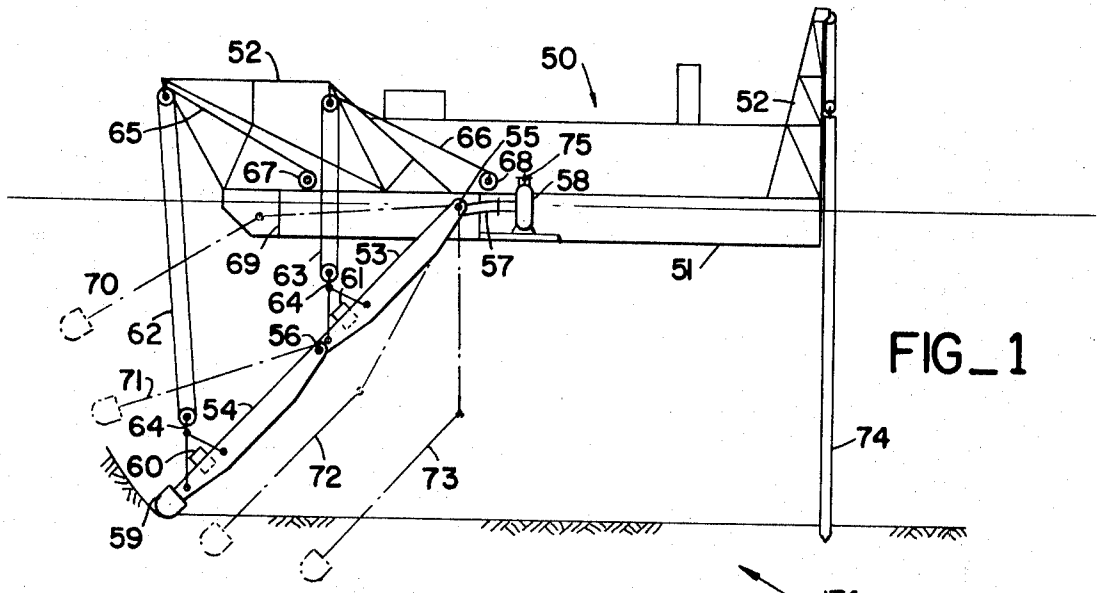


FIG_1

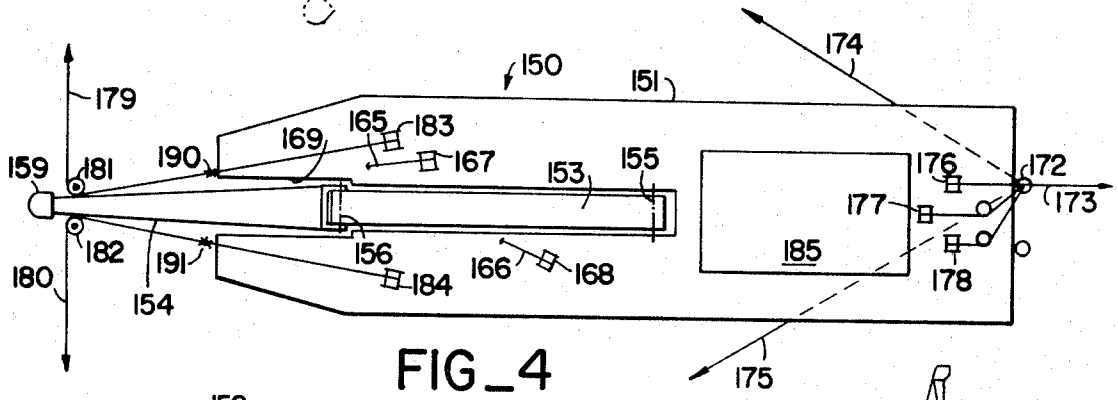


FIG_4

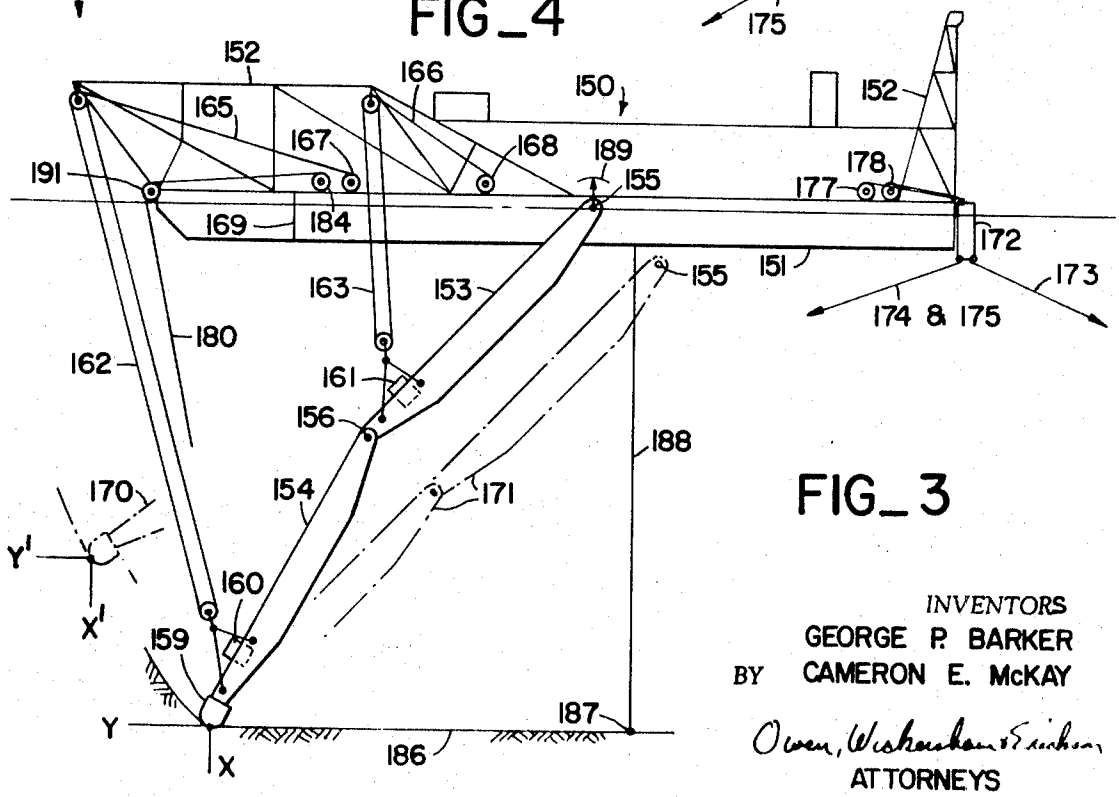
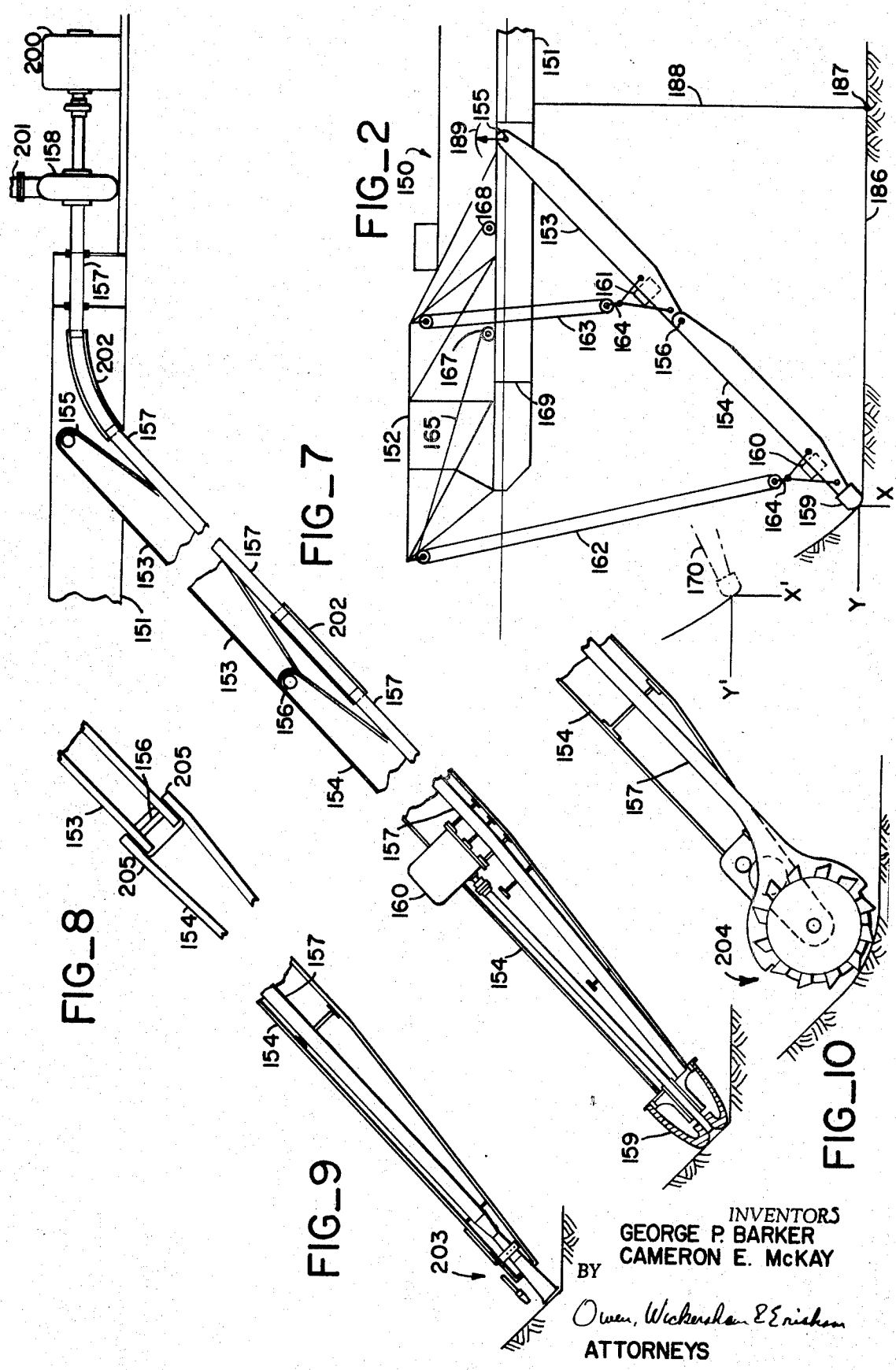


FIG_3

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FIG_2
FIG_7
FIG_8
FIG_9
FIG_10
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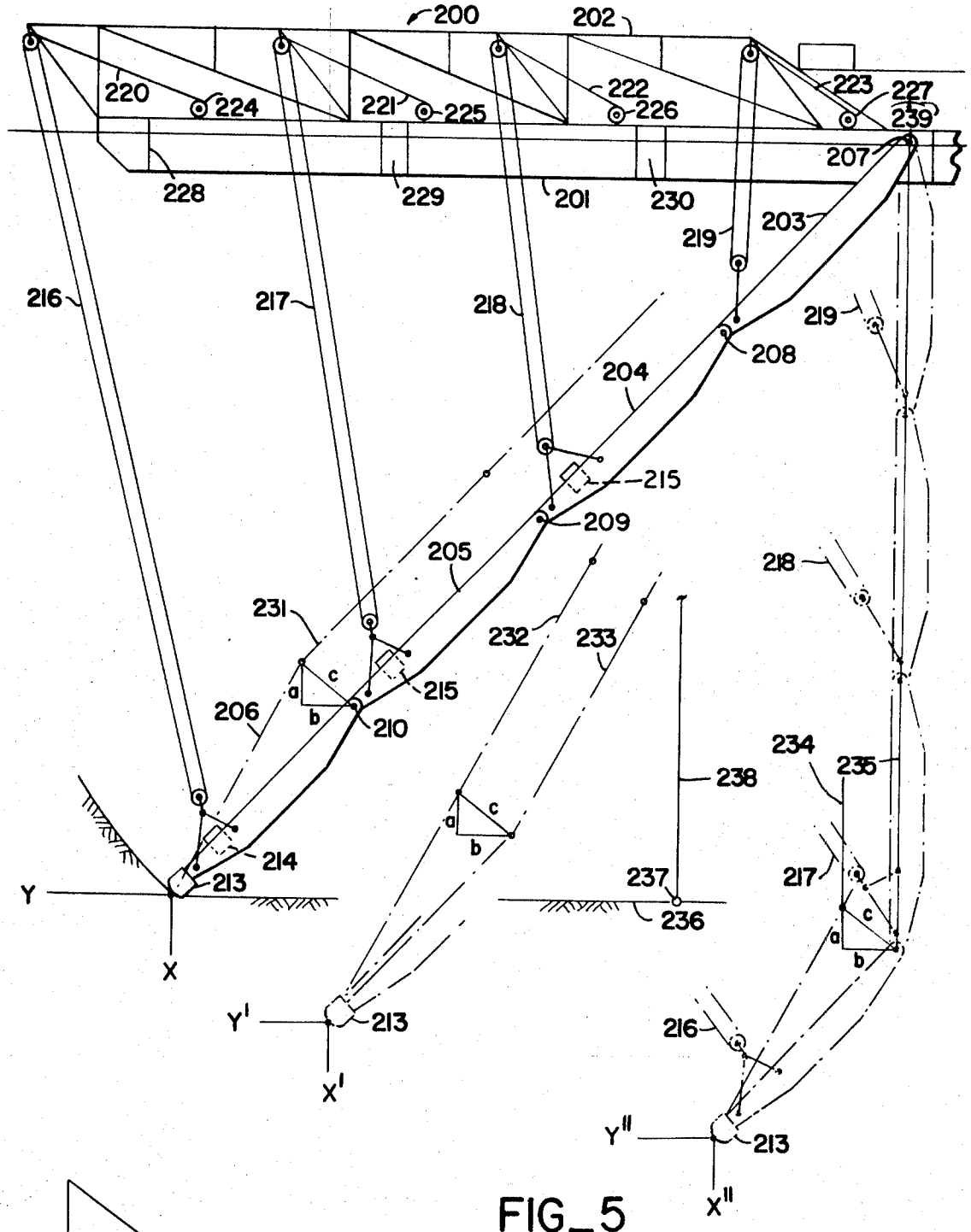


FIG_5

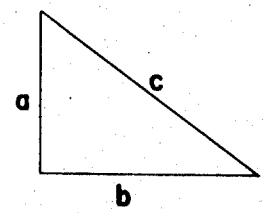


FIG_6

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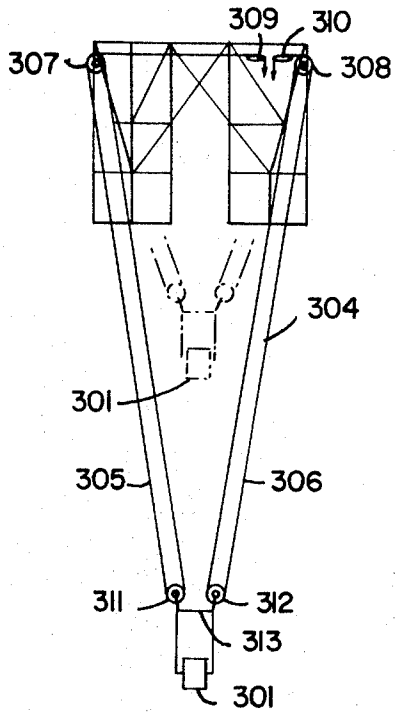


FIG_11

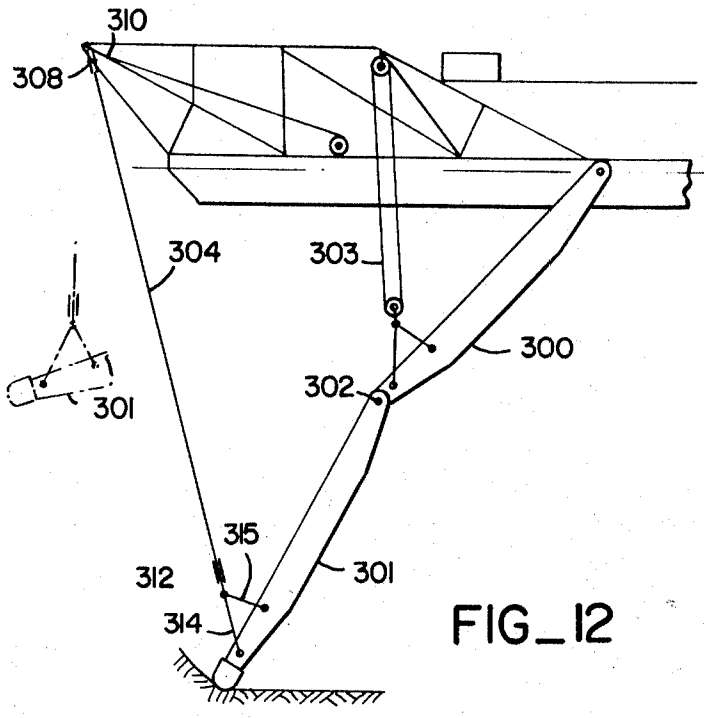


FIG_12

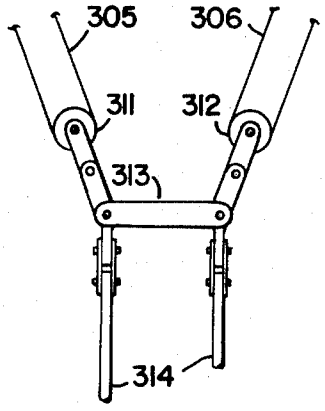


FIG_13

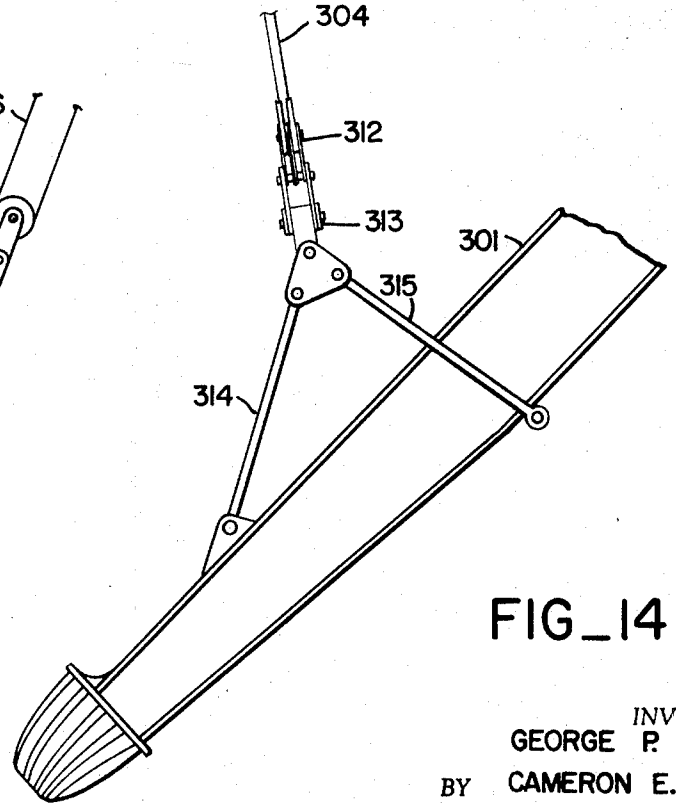


FIG_14

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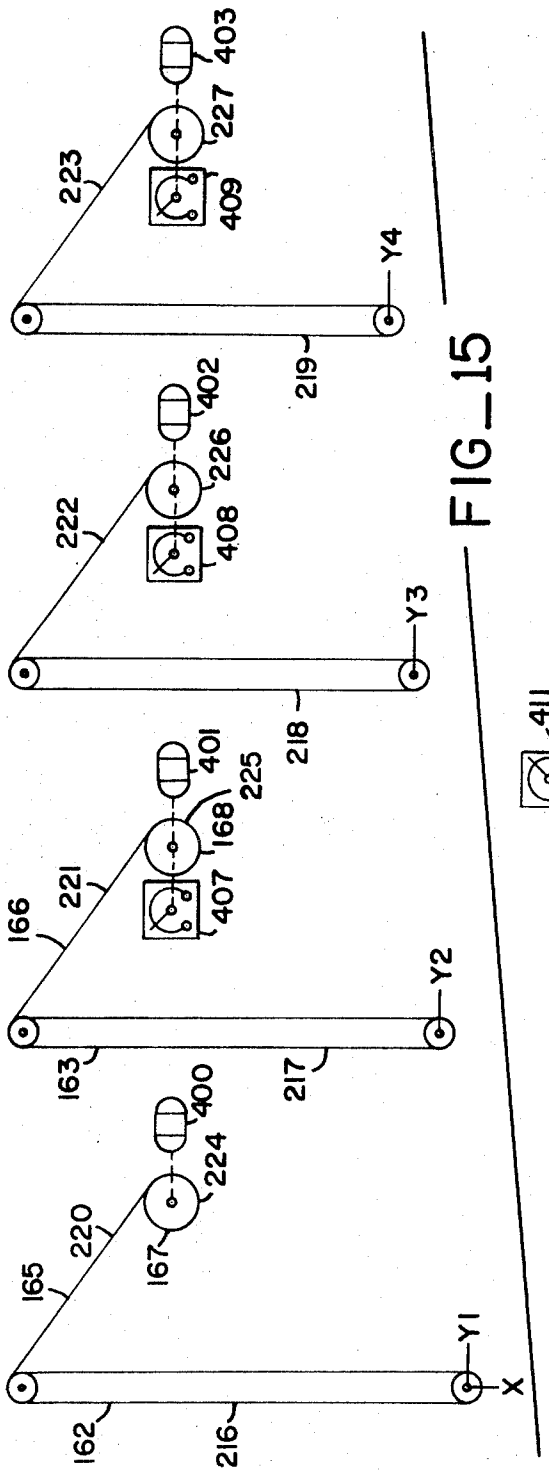


FIG_15

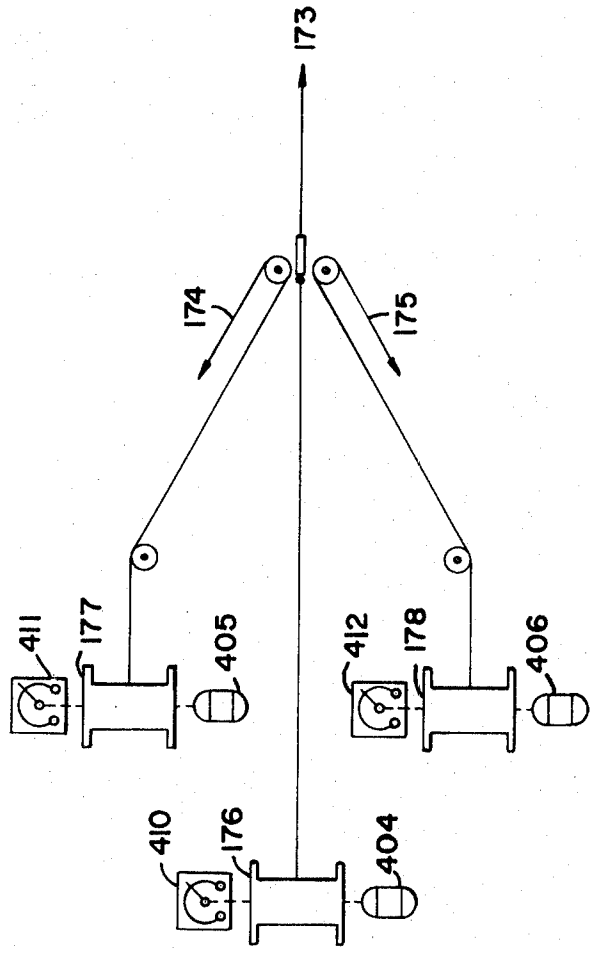


FIG_16

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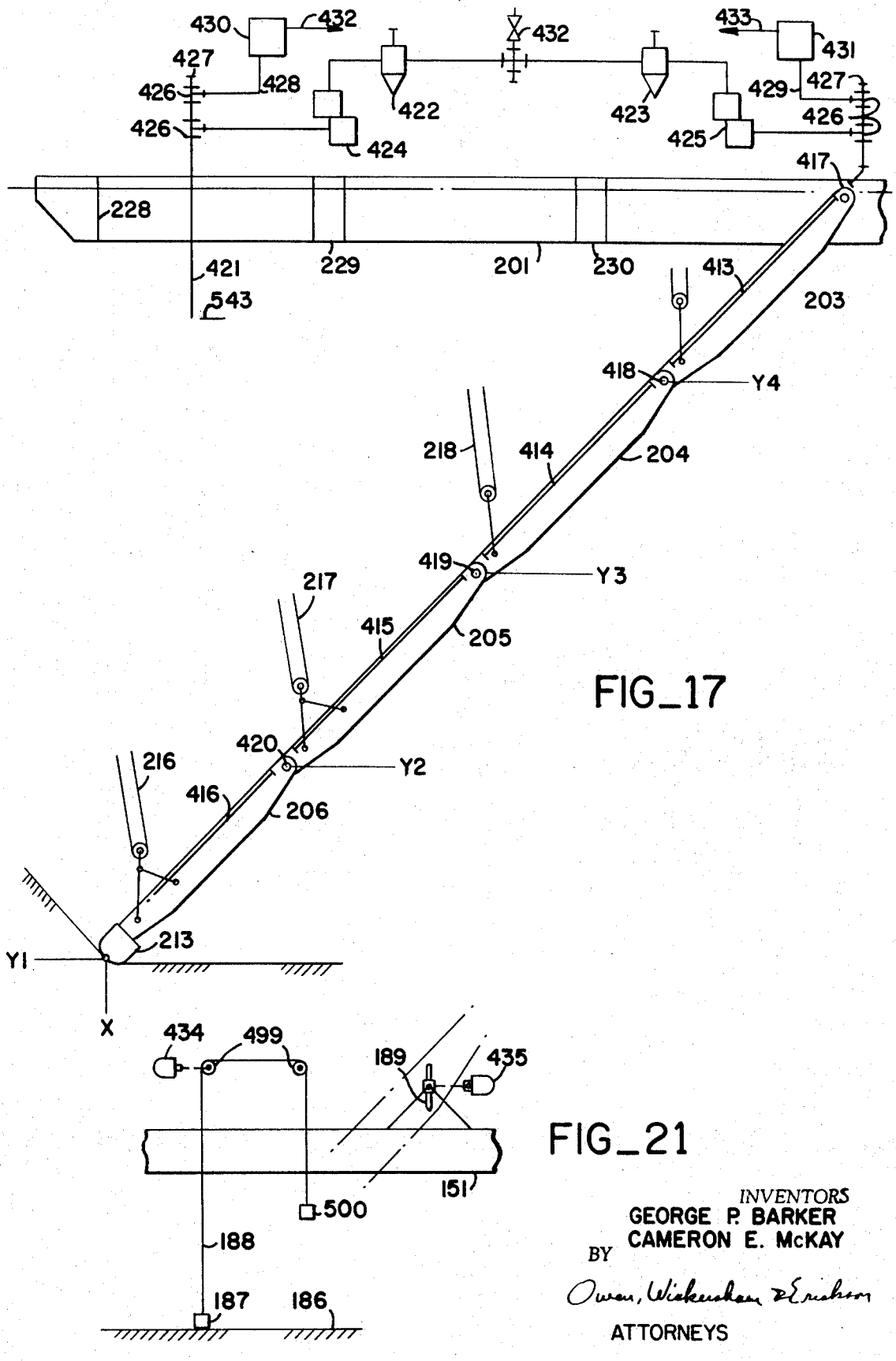


FIG_17

FIG_21

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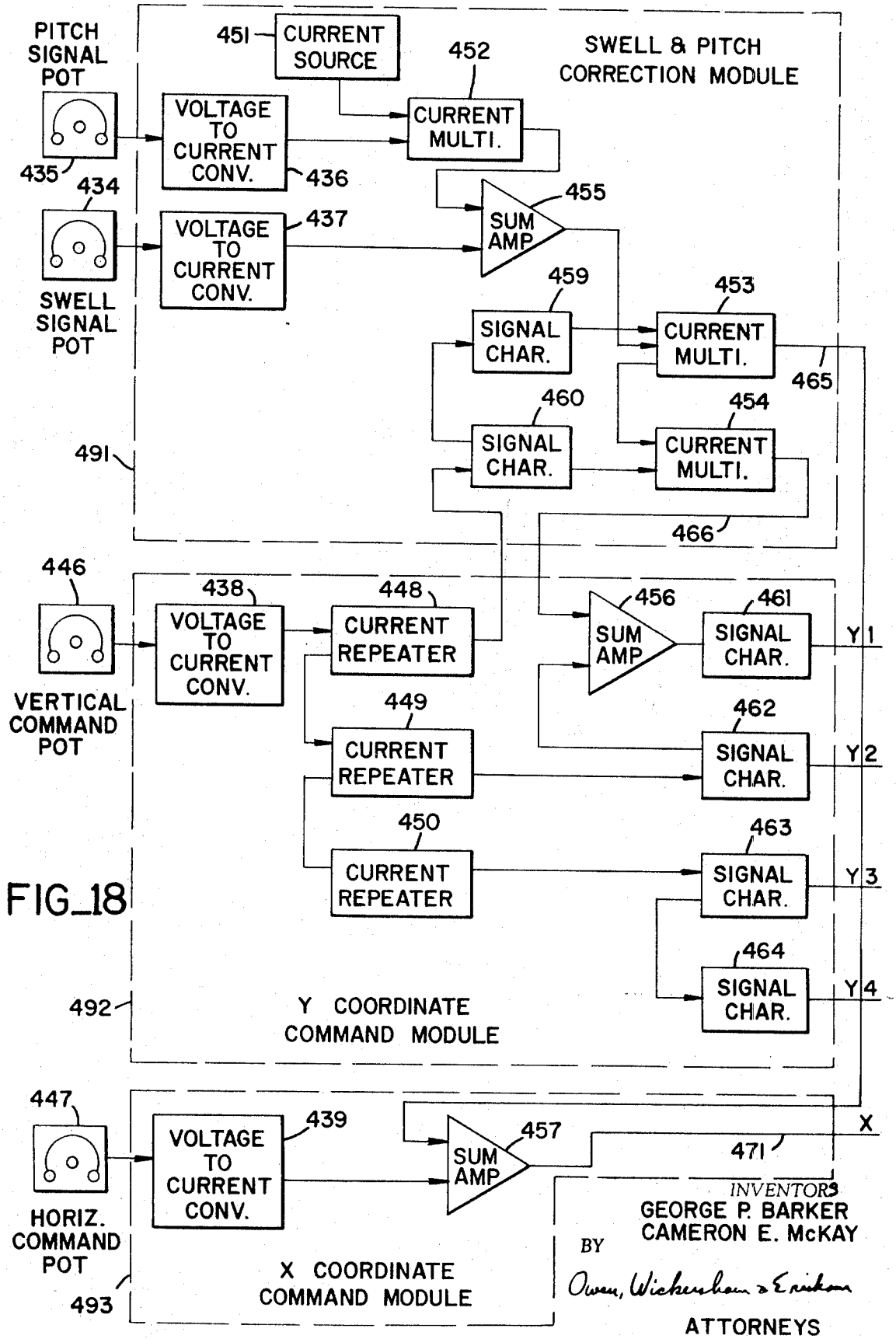


FIG_18

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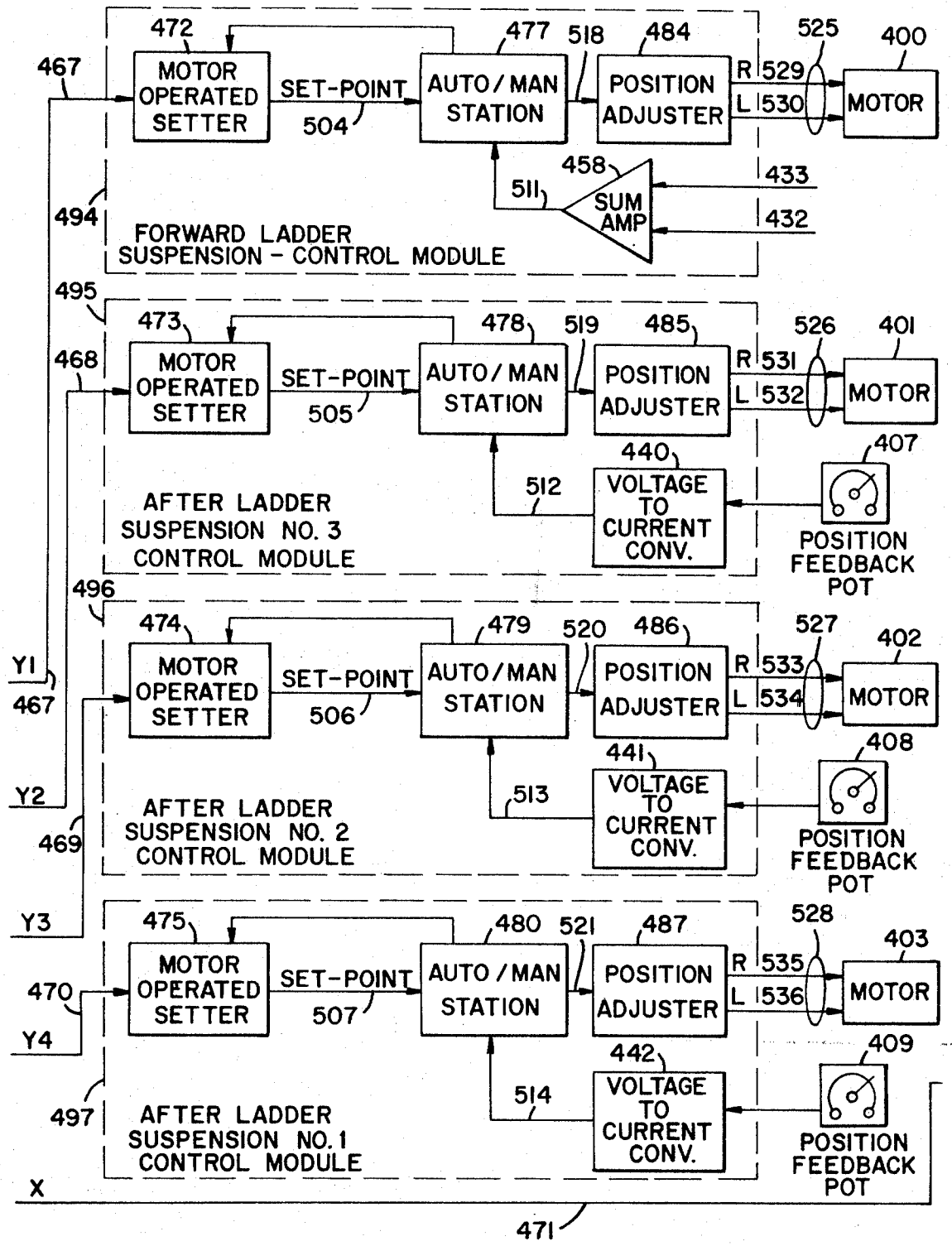


FIG_19

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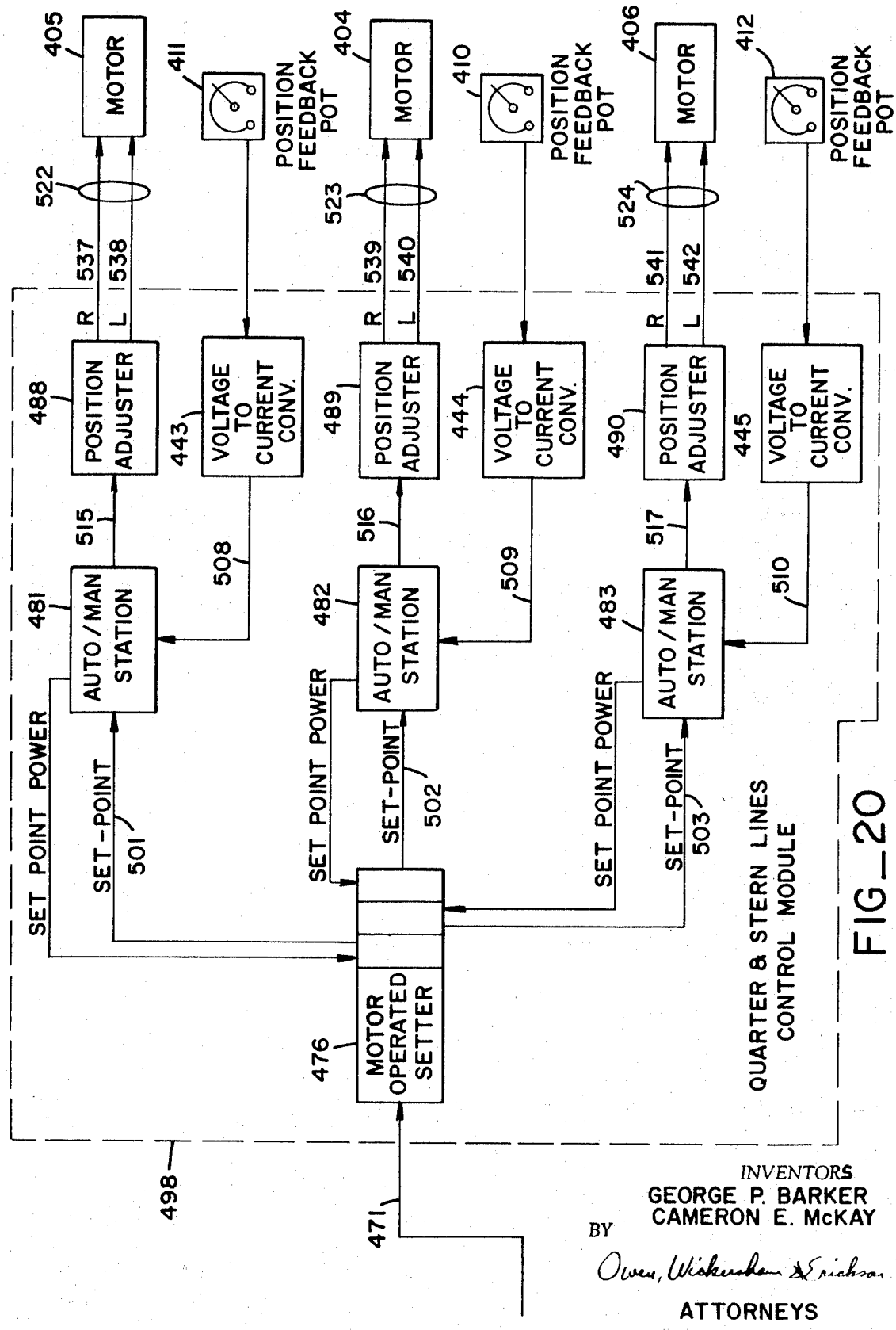


FIG_20

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HYDRAULIC DREDGE HAVING ARTICULATED LADDER AND SWELL COMPENSATOR

This invention relates to improvements in floating deep-digging ladder-type dredges.

BACKGROUND OF THE INVENTION

While hydraulic ladder dredges have been used for many years in excavating subaqueous materials for marine construction work and, to some extent for mining minerals, they have heretofore been confined to relatively shallow depths and to relatively quiet waters. Depths up to about 50 feet have long been dredged successfully by hydraulic ladder dredges, but beyond a depth of about 60 feet below water level, the unit cost of dredging has increased sharply, and such deep-water dredging has become much less economical. As one goes still deeper the costs increase disproportionately.

Thus, although a few hydraulic ladder dredges have been operated as deeply as about 150 feet below water level on limited construction projects, they have not been operated much below that depth for several reasons. For one thing, the manufacturing cost for hydraulic ladder dredges of prior-art designs capable of digging below about 80 feet below water level was in itself so high as to make such dredging very costly. Very heavy high-strength ladder girders had to be provided if the large-magnitude live and dead load forces were to be withstood. Structures that were efficient for depths of 50 to 80 feet would not be adequate or efficient at depths of 100 feet and greater. When the dredges were made according to prior-art designs, every additional foot added costs and inefficiencies. Similarly, operating costs of such prior-art structures were also intolerable.

Dredges have encountered problems other than those of depth alone. For example, in operations where the water is not a quiet pond, particularly with offshore dredges operating in the ocean, swells and waves cannot be avoided. The result has been that dredges could operate offshore only during times when the water was very quiet, and they had to remain idle much of the time. Even then, each time a swell or wave would rise, the cutter head or other digging device would be lifted from engagement with the sand, soil or rock, and so a large proportion of the time very little material would be dug by the cutter head or recovered by the mouth of the suction pipe at the lower ladder end. The alternative to this would have damaged the cutter head, the ladder, and related structural and mechanical components by having the lower ladder end and the cutter repeatedly strike the material being dug with great force as each wave or swell subsided. These same conditions restricted the offshore operations to relatively shallow protected waters, even though it was often desirable to economically excavate subaqueous materials or minerals that lay more than 60 feet below the surface of the ocean in exposed waters which might be fairly close to shore.

SUMMARY OF THE INVENTION

The present invention provides a novel articulated ladder structure and other significant structural features in a combination which make deep digging — down to 500 feet and more below water level — quite practical and economical. The large cross-sectional ladder girder thicknesses and the excessive weights that would be required by prior-art structures are avoided and made unnecessary by using articulated structures; thus, the ladders of this invention are provided in a plurality of sections, two or three usually being sufficient for water depths of 60 to 250 feet, and depending upon the total depth needed. By combining these plural sections with adequate rigging lines and maneuvering lines, the depth can be extended at costs that are far less than what one familiar with prior-art structures would have expected. The invention becomes quite significant in locations where it is known that there are extensive deposits of precious metals, gems, commercial minerals, sand, or gravel, or any other subaqueous deposits of commercial value, at depths too great to be accessible at economic costs to the prior-art dredges. The invention is also applicable to dredges utilized for marine construction in excavating both offshore and inland waters.

In the present invention, not only can greater depths be attained, as indicated earlier, but in offshore dredges compensation can be made so that the digging engagement of the dredge cutter head, well below the surface, is substantially unaffected by swell and wave conditions. This does not means, of course, that dredging should be carried on when the seas become rough, but in other than rough or stormy conditions, an ocean-going dredge of this invention can operate efficiently even with relatively high swells and even where the minerals or other materials lie well below the surface of the sea. The invention provides a compensating mechanism which is sensitive to swells and waves and which acts to change the angle of the dredge ladder and its approach sufficiently to keep the digging end in engagement with the material being dredged.

In connection with these major features of the invention — the employment of articulated dredges to get greater depth and the swell-compensating mechanism to enable operation in offshore waters — the invention includes a number of other significant features. As noted below, these features materially improve the performance and the economics of the dredges of this invention and give improved performance with lower overall costs.

The invention enables economic increase of the digging depth range of existing dredges with conventional one-piece rigid ladders, by introducing an articulated ladder section between the ladder pivot connection or trunnion on the hull and the upper end of the existing ladder along with the nominal extension of the forward hull and superstructure and the addition of a forward suspension with a second ladder hoist.

The invention also presents an important advantage in many situations of reducing the wear and friction in the pipes through which the slurry is brought to the surface, by most or much of the length through which the slurry is taken to be with the pipe in a vertical or nearly vertical position.

Many of the invention's features are applicable to relatively shallow dredging as well as to deep dredging.

Insofar as the invention relates to offshore dredging, it applies not only to hydraulic dredges, but to any kind of floating ladder dredge; insofar as it relates to deep dredging other than offshore dredging, that is, where the dredge operates in a pond or river where the water level changes very slowly, the invention is particularly directed to hydraulic ladder type dredges.

Other objects and advantages of the invention will appear from the following description of some preferred forms thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a simplified view in side elevation of a deep-water dredge, for use in relatively quiet waters, embodying the principles of the invention and having an articulated ladder in two sections. The two ladder sections are shown aligned in a straight line, while broken lines show several different positions of these ladder sections.

FIG. 2 is a view similar to FIG. 1 of an offshore dredge embodying the principles of the invention, made in two articulated sections. In this view the two ladder sections are aligned in a straight line. Broken lines show a higher digging position of the cutter head and the lower ladder end.

FIG. 3 is a view similar to FIG. 2 of the dredge of FIG. 2 in a position where the lower section is inclined downwardly relative to the upper section, in order to compensate for a swell. Broken lines show the relative positions of the ladder sections at the trough of the swell.

FIG. 4 is a plan view of the dredge of FIG. 3, showing the dredge-positioning and swinging lines.

FIG. 5 is a simplified view in side elevation of a modified form of a deep digging dredge also embodying the principles of this invention, made in four articulated ladder sections. The four ladder sections are aligned in a straight line, with broken center lines showing the relative positions of the ladder sections under swell conditions. Other positions of the ladder sections, at greater digging depths, under swell conditions are also shown by broken lines.

FIG. 6 is a motion diagram of an offshore dredge like those of FIGS. 2 to 5 compensated for swell conditions. This motion diagram shows the vertical and horizontal compensating components and the resultant required to provide for swell.

FIG. 7 is an enlarged view in side elevation and in section of an articulated ladder section, broken twice in the middle, also showing the cutter head with drive, the pump suction pipe with flexible connections, and the main pump with drive located in the dredge hull.

FIG. 8 is a fragmentary plan view of a portion of the ladder of FIG. 7 at the articulated pivot connection.

FIG. 9 is a view in side elevation, partly in section of a modified form of lower ladder section end, showing the optional use, in lieu of a cutter head, of a hydraulic venturi-jet system for digging and recovering subaqueous materials.

FIG. 10 is a view in side elevation and in section of another modified form of lower ladder section end showing the optional use of a bucket wheel device for excavating and recovering subaqueous materials.

FIG. 11 is a view in front elevation of a dredge skew suspension system for the lowermost articulated ladder section.

FIG. 12 is a view in side elevation of the suspension system of FIG. 11.

FIG. 13 is an enlarged fragmentary view of the connection of the suspension to the lowermost ladder section.

FIG. 14 is a fragmentary enlarged view in side elevation of the lower part of the system of FIG. 12.

FIG. 15 is a diagrammatic view in elevation of the ladder-suspension control apparatus for swell compensation of the dredge of FIG. 5.

FIG. 16 is a diagrammatic view of the winching system for the dredge of FIG. 5.

FIG. 17 is a diagrammatic view in side elevation of the ladder and compensating apparatus used in the control of the system of FIG. 5.

FIGS. 18, 19, and 20 comprise an electrical circuit diagram for the device of FIG. 5.

FIG. 21 is a diagrammatic view in elevation of the input system for the compensation apparatus of FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The dredge 50 of FIG. 1, which is designed for deep dredging in relatively quiet waters, such as a pond, a sheltered bay, or a river where the water level changes rather slowly, has a hull 51 with superstructure 52. The hull 51 supports the uppermost of two articulated ladder sections 53 and 54 by means of a pivot axis member 55 at the top of the upper ladder section 53. The lower ladder section 54 is attached to the lower end of the upper ladder section 53 by a pivot member 56, and it carries a cutter head 59 at its lower end. A single continuous hydraulic pump line 57 is carried by the two ladder sections 53 and 54, running from the cutter head 59 to the suction side of a main pump 58 located in the dredge hull 51. A cutter drive 60 and a booster pump 61 are contained in the ladder sections 54 and 53 respectively. A spud 74 positions the dredge 50 to swing in a horizontal plane in the process of excavating subaqueous materials.

The cutter head drive 60 and the booster pump 61 can be located within or very close to the suspension points of their respective ladder sections 54 and 53, wherein they are contained, thereby minimizing the bending moment in those ladder sections 54 and 53, which is induced by the weight of the cutter head drive 60 and the booster pump 61. This structure is not possible in conventional one-piece ladders, where the booster pump and the drive must be located approximately midway between the upper and lower ends of the one-piece ladder, thereby inducing the maximum bending moment. The location of the pump 61 and drive 60 according to the present invention, contributes further to enabling reduction in the required section-size and weight of their respective swingable ladder sections.

Each of the articulated ladder sections 53, 54 is adapted to swing pivotally relative to the hull 51 and to its adjacent ladder section. The support and relative swinging may be accomplished by means of a forward ladder suspension 62 and an after ladder suspension system 63, each of which comprises a block-and-tackle assembly and a plurality of cables secured at 64 to its ladder. Each of the ladder hoists includes a cable 65 or 66 passing from an upper pulley of the suspension system 62 or 63 to a winch 67 or 68, located at appropriate locations on the hull 51. The forward ladder suspension system 62 is, of course, the longer, since the forward ladder 54 goes down deeper.

A discharge side 75 of the main pump 58 may deliver dredged material to processing equipment aboard the dredge 50, or via a floating pipeline to sites onshore or offshore. other conventional apparatus for handling the dredge material for mineral recovery or for other pur-

poses may be employed, many such being well known in the dredging art.

In order to enable the ladders **53** and **54** to move up and down from below the hull to above it and back, a suitable well-side slot **69** is provided on the hull **51** to receive the pivot assembly **56** between the ladder sections **53** and **54.**

By making the ladder articulated, neither of the ladder sections **53** and **54** has itself to withstand all of the burden; so each ladder section **53** and **54** can be substantially smaller in cross-section and in weight than a one-piece ladder properly designed to do the job. A single ladder capable of dredging down to the depths contemplated in this invention would have to be very heavy and very thick, and it therefore would be quite difficult to raise and lower, as well as being expensive to construct. But by having the ladder in more than one section with an articulated joint between sections and with two suspension assemblies, a much more efficient operation is obtained, enabling far greater depth without correspondingly larger structures.

Broken lines **70, 71, 72** and **73** in FIG. **1** show, respectively, how the lower ladder section **54** can be dropped below or raised above the centerline continuation of the upper ladder section **53,** thus allowing for positioning the cutter head **59** at the most efficient vertical plane digging angle throughout the digging depth range. The broken line **73** shows the upper ladder section **53** in a vertical or near vertical position, which offers an important advantage; for it materially reduces pipe friction and wear in that section of the main pump suction line **57** contained in the upper ladder section **53.** This feature is particularly important in the case of deeper digging dredges, where pipe friction and wear, in the suction line **57** to the main pump **58,** progressively increases with the required longer suction line.

FIGS. **2** to **6** relate to offshore dredging, where the problems brought on by waves and swells are met. In addition there are some other structural differences which are applicable to quiet-water dredges.

FIGS. **2, 3,** and **4** show an offshore dreged **150** generally similar to the dredge **50** of FIG. **1,** but having some important differences. The hull **151** supports an articulated ladder having two swingable sections **153** and **154,** pivoted to each other at a pivot **156,** while the after ladder **153** is pivoted to the hull by a pivot **155.**

The other principal differences which distinguish the dredge **150** of the FIGS. **2, 3,** and **4** structure from that of FIG. **1** are those that enable the dredge **150** to be used in offshore or ocean waters where there are swells, where the difference between the crests and troughs may be up to 20 feet or even more. It is apparent that if no attempt is made to compensate for the swelling, the cutter head will either not be in continuous engagement with the subaqueous material or will crash into the solid bottom some of the time. In the present invention, the dredging face is kept substantially constant, to maintain uniform and continuous digging production and to eliminate cyclical impact forces to the lower ladder end where the digging mechanism is located. The cutter head **159** is kept in a fixed position for any selected digging depth, in relation to the dredging face, and the dredged sea bottom **186** irrespective of the water surface conditions in terms of waves and swells. The cutter head **159** remains at its fixed x, y position (or the x', y' position shown in broken lines) for any selected digging depth, while the ladder **153, 154** traverses the cutter head **159** laterally from port to starboard or starboard to port in the process of excavating the subaqueous material. The compensating mechanism includes (1) a sounding device **187** suspended by a cable **188** and (2) an angle indicator **189,** which are shown in FIGS. **2** and **3.**

FIGS. **2** and **3** illustrate the broad effect of the compensating mechanism, which is shown in more detail in FIGS. **15** to **21.** FIG. **3** shows the dredge **150** as it is at a swell crest, and FIG. **2** shows the same dredge **150** in the swell trough. During the trough time the dredge hull **151** is closer to the bottom **186** than during the crest time; therefore during the crest the lower ladder section **154** is dropped to gain additional depth, as shown in FIG. **3,** the upper section **153** here remaining unchanged. As the water level drops again to the trough, the ladder is straightened out and may return to the common center line shown in FIG. **2.**

FIG. **6,** a motion diagram, helps to clarify the general aspect of this compensating action by illustrating the vertical movement "a" of the dredge under swell conditions and the compensating resultant "c" required to maintain the cutter head **159** at its fixed x, y position (or x', y') position for any selected digging depth. This compensating resultant "c" is attained in either direction to compensate for the rise and fall of the hull **151** of dredge **150.** When the hull **151** rises to a swell crest a line **165** pays out to the suspension system **162,** enabling the cutter head **159** to remain at the y vertical position, and simultaneously (see FIG. **4**) quarter lines **174** and **175** are taken up, along with a stern line **173** paying out for the cutter head **159** to remain at the x horizontal position. The reverse action takes place when the dredge hull **151** falls to a swell trough. This resultant movement of the dredge **150** and upper ladder section **153** with respect to the lower ladder section **154** are taken at the ladder pivot connection **156** and are not transmitted to the cutter head **159,** which remains at the selected x, y or x', y' position.

FIGS. **3** and **4** show a sheave tube **172** or "Christmas tree" which preferably replaces the spud **74** of FIG. **1** when digging at greater depths or under swell conditions. The sheave tube **172** contains depression and direction sheaves to lead the stern line **173** and quarter lines **174** and **175** from their respective winches **176, 177** and **178** to anchors on the sea bottom. Bow swing lines **179** and **180** from winches **183** and **184** via sheaves **190, 181,** and **191, 182** to sea bottom anchors swing the cutter head **159** with ladder and dredge bow in horizontal arcs about the vertical center line of the sheave tube **172** to traverse the cutter head **159** from port to starboard and starboard to port in the process of dredging. Other arrangements of positioning and traversing lines well known to the dredging art may be employed utilizing the principles of this invention for swell compensation.

FIG. **4** shows ladder sections **153** and **154** in plan view, with a ladder well slot **169** to provide clearance for the pivot structure **156** when the ladder is raised above the bottom of the hull **151.** Ladder hoist winches **167** and **168** are also shown as in FIGS. **2** and **3** for the respective suspension systems **162** and **163.** The engine room **185** of FIG. **4** contains the main pump and drive, main engines and auxiliary machinery.

FIG. **5** shows a very deep digging dredge **200** for sea or inland waters with four articulatd ladder sections **203, 204, 205** and **206,** with their respective indepen-

dent suspension systems **219, 218, 217** and **216,** having corresponding ladder hoist winches **227, 226, 225** and **224.** This dredge is similar in most respects to dredge **150** of FIGS. **2, 3** and **4,** and for sea dredging can be equipped with a swell compensating system also similar to that of dredge **150.** With more than two articulated ladder sections the swell compenating action can be taken at a pivot connection **210** or for swells of greater magnitude at a pivot connection **209.** A broken ladder center line **231** shows the compensating action being taken at the pivot connection **210.**

Broken ladder center lines **232** and **233** show the ladder position at a greater digging depth than illustrated by the solid lines. In this case the compensating action is also taken at the pivot connection **210.**

Broken ladder center lines **234** and **235** show the ladder positions at maximum digging depth, with swell compensating being taken at the pivot connection **210.**

As shown in FIG. **21,** the sounding device **187,** which may be of well-known type acts through a cable **188,** e.g., in cooperating with pulleys **499** and a weight **500,** to provide a mechanical signal indicating the change in the vertical position of the dredge hull **151** up and down as crest and trough conditions occur. This may be interpreted as the heigth of the hull **151** above the bottom **186** or may be taken from any predetermined point of reference. The mechanical signal from the sounding device **187** is used mechanically to vary the resistance setting of a swell potentiometer **434.**

Similarly, the angle indicator **189** is set at or adjacent the pivot member **155** and acts mechanically to vary the resistance settting of a pitch potentiometer **435,** in accordance with the angle which the true horizontal makes with the nominally horizontal center line of the hull **151.** The potentiometers **434** and **435** transmit electrical signals as voltages to a swell-and-pitch correction module **491,** as shown in FIG. **18.** The swell-and-pitch correction module **491** operates in cooperation with a Y-coordinate common module **492** having a command potentiometer **446** and an X-coordinate command module **493** having a command potentiometer **447.** The modules **491, 492,** and **493** are described below and are illustrated in FIG. **18.**

The cutter head **159** is initially positioned into a preselected x, y (or x', y') position by the Y-coordinate command module **492** and the X-coordinate common module **493;** these command modules **492** and **493** are commanded by a winchman manually through the potentiometers **446** and **447.** For a dredge **150** like that of FIGS. **2** and **3,** the Y-coordinate command module **492** provides two signas Y1 and Y2, one to set each of the two ladder suspensions **162** and **163,** respectively, to move its ladder sections **154** and **153** to the proper elevation. In a dredge like that of FIG. **5,** there are four such signals because there are four ladder suspensions **216, 217, 218** and **219.** In both types of dredge there is only one signal from the X-coordinate commond module **493,** because that signal controls only a quarter and stern line control module **498.**

As the dredge hull **150** begins to rise vertically on an incoming swell from the FIG. **2** position to the FIG. **3** position, the conventional automatic sounding device indicates the depth of water between the dredged bottom datum **186** and the dredge hull **151.** This depth is transmitted by the cable **188** and a swell potentiomter **434** to the swell-and-pitch correction module **491** (FIG. **18**) to provide correction signals **466** and **465** respectively for the Y1 and X′ coordinates. A forward ladder suspension control module **494** receives a corrected signal **467** which causes a command signal to be issued that energizes a forward ladder hoist winch motor **400** to run in the lower direction, thus paying out a luffline **165** to the forward ladder suspension **162** by an amount such that the cutter head **159** remains at its desired digging elevation, the y coordinate. Meanwhile, a quarter and stern line control module **498** (FIG. **20**) receives a corrected signal **471** and issues command signals for quarter lines winch motors **405** and **406** to take up on the quarter lines **174** and **175** and a stern line winch motor **404** to pay out stern line **173** so that the cutter head **159** remains at its x digging coordinate. Thus, the x, y position of the cutter head **159** remains the same.

On a falling swell the sounding device **187,** the transmitting swell potentiometer **434,** and swell-and-pitch correction module **491** provide signals for reverse action of the compensating system, that is, the luffline **162** is taken up and the quarter lines **174** and **175** are paid out and the stern line **173** takes up the required amount.

The swell signal is corrected by a suitable angle measuring device **189** (FIG. **21**), that measures the variable angle B between the horizontal center line of the hull **151** and true horizontal, which, in itself, compensates for fore-and-aft hull trim under sea conditions, further insuring the desired positioning of the cutter head **159** at all times. This angle is transmitted to the swell-and-pitch control module **491** by the potentiometer position indication **435.**

Of the command modules **491, 492** and **493** (FIG. **18**) the X-coordinate command module **493** is the simplest, comprising basically a voltage-to-current converter **439** and a summing amplifier **457,** as shown in FIG. **18.**

The voltage-to-current converter **439** and all the other voltage-to-current converters spoken of in this specification, may be off-the-shelf items. For instance, they may each be a Foxboro **66**GT or **66**GC series voltage-to-current converter. These converters accept a 1 to 5 volt DC input and convert it to a proportional 10 to 50 milliampere DC output. A constant current source forming part of this converter excites a remote slide wire, such as the command potentiometer **447.** A thousand-ohm slide wire with travel adjusted to approximately **155** to **825** ohms may provide the 1-to-5 volt DC signal, which is fed to the input of the converter **439.** Other values, of course, can be provided. The converter **439** may contain a magnetic and transistor amplifier and be connected to a supply voltage. Since it is an off-the-shelf item, it need not be further described.

Similarly, the summing amplifier **457** and all the other summing amplifiers used here may be a Foxboro **66**CT or 66CC series electronic "Consotrol" summing amplifier. These summing amplifiers are able to receive up to four 10 to 50 milliampere DC input signals and to provide a 10 to 50 milliampere DC output signal that is proportional to them. The summing amplifier may be a solid-state unit with a two-stage magnetic amplifier connected to a suitable supply voltage. As will be seen in this invention, some of the summing amplifiers are used with only two input signals, while others are used with more input signals.

The Y-coordinate command module **492** includes a voltage-to-current converter **438** like the converter **439**, which takes its input from the command potentiometer **446** and which supplies, in this instance, two current repeaters **448** and **449**. These current repeaters, like the others used in this invention may also be off-the-shelf items, such as the Foxboro **66BT** and **66BC** series electronic "Consotrol" current repeaters. These repeaters receive a 10 to 50 milliampere DC input signal and produce an electrically isolated 10 to 50 milliampere DC output. They have a low input resistance of about 100 ohms and can feed an external load up to 600 ohms. Such units are often used to extend the total load fed by computer devices to transmitters. They may be of solid-state construction throughout with a magnetic transistor amplifier, and, of course, they have many uses other than in this invention. Each of them is connected to a suitable supply voltage.

The Y-coordinate command module **492** also includes one summing amplifier **456**, which is connected to the current repeater **449**. This summing amplifier **456** may be off-the-shelf unit identical to the summing amplifier **457** already described. The summing amplifier **456** feeds its signal to a signal characterizer **461**. Also the current repeater **449** feeds its signal directly to a signal characterizer **462** to produce the Y2 output **468**. Each of these signal characterizers **461** and **462**, like others to be mentioned later, may be off-the-shelf items. For example, the Foxboro 66N series signal characterizer, is a completely solid-state instrument that provides up to eight slope adjustments and up to eight break point adjustments for the generation of both linear and nonlinear functions. It includes a buffer amplifier, a shaping circuit, and an operational amplifier, which can be connected in various ways with other minor ingredients.

The swell-and-pitch correction module **491** has two inputs, as already noted, one from the swell command potentiometer **434** operated by the sounding device **187**, which feeds into a voltage-to-current converter **437**, and the other from the pitch command potentiometer module **435** operated by the angle generator **189**, which feeds its output to another voltage-to-current converter **436**.

The voltage-to-current converter **436** feeds its current output to a current multiplier **452**, which is supplied by a constant current source **451**. This current multiplier may also be off-the-shelf items, such as the Foxboro 66DT and 66DC series electronic "Consotrol" multiplier dividers. These are solid-state analog computing instruments which receive up to three DC input signals at 10 to 50 milliamperes and put out a 10 to 50 milliampers DC output signal which is proportional to the computed value. There is no electrical isolation between the input, so that only one of the input circuits can be grounded and there should be not external common connections between the input circuits. The constant current source **451** used for this multiplier may be an off-the-shelf item such as a Foxboro 66ET and 66EC series electronic "Consotrol" current source, which provides an output that is adjustable from 10 to 50 milliamperes. Each may include a transistorized amplifier and other features. Here they are used only for reliable current sources of a standard current to give a fixed multiplier.

The swell-and-pitch correction module **491** also includes two signal characterizers **459** and **460** (like the signal characterizers **461** and **462**). It also includes a summing amplifier **455** and two current multipliers **453** and **454**. The current repeater **448** of the Y-coordinate command moduel **492** is connected to the signal characterized, **459** and **460** of the swell-and-pitch correction module **491**. The current multiplier **452** and the voltage to current converter **437** are connected to the summing amplifier **455**. The output from the summing amplifier **455** is connected to the current multipliers **453** and **454**. The signal characterizer **459** is also connected to the current multiplier **453**, so that the output (or correction signal) **465** from the current multiplier **453** is proportional to the product of the multiplication of the outputs of the signal characterizer **459** and the summing amplifier **455**. The summing amplifier **455** and the signal characterizer **460** are connected to a current multiplier **454**, whose output or correction signal **466** is proportional to the product of those two inputs.

The current repeater **449** of the Y-coordinate command module **492** is connected to the summing amplifier **456**, and the current multiplier **454** feeds its output or correction signal **466** to the summing amplifier **456**. The output from the summing amplifier **456** goes to the signal characterizer **461**, which thereupon produces the Y1 output **467**.

The current repeater **448** feeds its signal to a signal characterizer **459**, which feeds its output to the current multiplier **453**, and the output from the current multiplier **453** is fed to the summing amplifier **457**, which is otherwise fed directly by the voltage-to-current converter **439** of the X-command module **493**. This produces the signal output **471** of the X-command module **493**.

What has been described so far, then, results in a single output **471** from the X-command module and two outputs **467** and **468** from the Y-coordinate command module, and this concludes the description of FIG. **18**, for a dredge with two articulated ladder sections.

The output **471** from the X-coordinate command module is fed to the quarter and stern line control module **498**. The output **471** is fed directly to a motor operated setter **476** of the control module **498** (FIG. **20**). This, like the other motor operated setters to be described, may also be an off-the-shelf items, such as, the Leeds and Northrup Company's M-line, model C, motor operated setter. This motor-operated setter **476** tracks the signal **471** and positions three retransmitting slide wires which are set-point potentiometers **501, 502** and **503** for respective set-point/auto-manual stations **481, 482** and **483**. The set-point potentiometers **501, 502** and **503** are fed directly to their respective set-point/auto-manual stations **481, 482** and **483**. This, like the other set point/auto-manual stations to be described, may also be an off-the-shelf item such as the Leeds and Northrup Company's M-line, model, C, P.A.T., set point/auto-manual station. The set point-/auto-manual stations **481, 482** and **483** compare the set point potentiometers **501, 502**, and **503** with the outputs **508, 509** and **510** of the position feed-back summing amplifiers **443, 444** and **445** (see FIG. **20**), and the unbalance between the respective signals become respective error signals **515, 516** and **417** that are proportional in magnitude and polarity to the unbalance.

The outputs **515, 516** and **517** are fed directly to the respective position adjusters **488, 489** and **490**

(FIG.20). This, like the other position adjusters to be described, may also be an off-the-shelf item, such as the Leeds and Northrup Company's P.A.T. control known as the M-line Module C control unit. These are used for electric drive units to provide precise control of process variable. They receive an error signal or input (e.g., the error signals **515, 516** and **517** in this instance) from the set point units **481, 482** and **483** and, through an amplifier, energize either a "raise relay" or a "lower relay," depending upon the polarity, magnitude, duration and rate of change of the error signal. They are used in closed loop control systems as the heart of the unit. They are complex units but are well known and are completely described in published material. The signal **471** is used here as the set point, and the position feedbacks are set mechanically through position-feedback potentiometers **410, 411** and **412.**

The position-feedback potentiometers **410, 411** and **412** feed their respective signals to the voltage-to-current converters **444, 443** and **445** (like the converter **439**). The outputs **508, 509** and **510** from the respective converters **443, 444** and **445** are fed into the set point/auto-manual stations **481, 482,** and **483** that provide the error signals **515, 516** and **517** to the position adjusters **488, 489** and **490,** The position adjusters **488** and **490** have output cables **522** and **524** each feeding raise-lower control power to the motors **405** and **406** for the quarter line winches **177** and **178.** The position adjuster **489** has output cable **523** which feeds raise-lower control power to the motor **404** for the stern line winch. The quarter line position adjusters **488** and **490** are reverse acting in respect to the stern line position adjuster **489.** That is, when the stern line position adjuster **489** signals to pay out the stern line, the quarter line position adjusters **488** and **490** will signal for the quarter lines to be taken up. It is obvious that the two quarter lines should be changed the same distance and somewhat less than the stern line.

The output **467** from the Y-coordinate command module **492** is fed to a control module **494.** The output **467** is fed directly to a motor-operated setter **472** (FIG. **19**), like the motor-operated setter **476.** The motor operated setter **472,** tracks the signal **467** and positions a retransmitting slide wire set point potentiometer **504** feeding directly to a set point/auto-manual station **477.** The set point/auto-manual station **477** compares the set point potentiometer **504,** with the output **511** of a summing amplifier **458,** and the unbalance between these two signals becomes an error signal **518** that is proportional in magnitude and polarity to the unbalance. The output or error signal **518** is fed directly to a position adjuster **484.** The control module **494** also has two position-feedback pressure transmitters **430** and **431** sending signals to a summing amplifier **458** which provides the base signal for the position adjuster **484** from which a raise-lower control output **525** is fed to the forward ladder hoist motor **400** for the winch **167.**

The Y-coordinate command module **492** sends its second or Y2 signal **468** to a control moduel **495.** The output **468** is fed directly to a motor operated setter **473,** which tracks the signal **468** and positions a retransmitting slide wire set point potentiometer **505,** which is fed directly to a set point/auto-manual station **478.** The set point/auto-manual station **478** compares the set point potentiometer **505,** with the output **512** of a position feedback voltage-to-current converter **440,** and the unbalance between these two signals becomes an error signal **519** that is proportional in magntidue and polarity to the unbalance. The output or error signal **519** is fed directly to a position adjuster **485** like those previously described. The signal **468** is used as the set point signal, and the unit's position feedback is controlled by a feedback potentiometer **407,** feeding voltage-to-current converter **440.** The output **526** from the position adjuster **485** is then used to control the after ladder hoist motor **401** for the winch **168.**

As shown in FIGS. **15, 17** and **19,** each of the two ladder suspensions shown in FIG. **15** receives a feedback signal that is related to the position of the devices controlled thereby. Thus, the control module **494** for the forward ladder **154** receives feedback from its pressure transmitters **430** and **431** that indicate the depth, the Y-coordinate, of the cutter head. The control module **495** for the after ladder **153** receives feedback from its potentiometer **407** that indicates the position of the winch drum **168.**

The cutter head Y1 coordinate position may be determined by a continuous air purge system, FIG. **17,** that provides a continuous signal which is proportional to the vertical distance between the cutter head and the air purge reference **543.** The system is a standard liquid level continuous purge type (bubble tube) which consists of two purge systems so arranged that difference in pressure between the two systems will represent the depth of the cutter head **159** and that this pressure is uneffected by the pitch and/or swell on the hull. Each system may comprise an air filter-regulator **422** and **423,** which may be C.A. Norgren Company model 015–025; a flow controller **424** and **425** which may be a Brooks Instruments model 8800; and bubble tubes which may comprise pipes **413, 414, 415, 416** and **421;** pipe tees **426,** pipe plug **427,** flexible sections of armoured hose **417, 418, 419** and **420;** and electronic pressure transmitters **430** and **431** which may be Foxboro model 611 GM electronic "Consotrol" pressure transmitters; and valves **432.** The air filter regulators **422** and **423** supply clean air to the flow controllers **424** and **425.** The flow controllers **424** and **425** are set to provide a constant flow of air out the bubble tubes. The pressure at the top of the bubble tubes is transmitted **428** and **429** to the pressure transmitters **430** and **431.** This pressure represents the actual static head that the bubble tube is below the water. The pressure transmitters **430** and **431** have force-balance measuring elements and an electronic transmitter which has an output signal **432** or **433** of 10 – **50** ma D.C. The output signals **432** and **433** are inputs (FIG. **19**) to the summing amplifier **458** in the control module **494.** The output of this summing amplifier **511** is the difference between the two bubble tube pressures, and is the actual distance the cutter head **159** is below the air purge reference **543.**

In operation, the command signal for the Y-coordinate command module **492,** provided by the potentiometer **446,** which is calibrated in feet, is adjusted by the dredge winchman. The slide wire excitation signal built into the voltage-to-current converter **438** provides the excitation for the potentiometer **446,** and the output signal of the voltage-to-current converter **438** drive the two current repeaters **448** and **449.** The output from the current repeater **448** drives the two signal characterizers **459** and **460** in the swell-and-pitch correction module **419.** The output from the current re-

peater 449 drives the summing amplifier 456 and the signal characterizer 462, whose output signal 468 is the Y2 output 468 used to drive the after ladder suspension control moduel 495.

The summing amplifier 456 provides the sum of Y plus Y1'. This output drives the signal characterizer 461, which provides the Y1 output signal 467 that drives the forward ladder suspension control modules 494.

The X-coordinate command module 493 input signal is fed to the voltage-to-current converter 439 and from there to the summing amplifier 457, whose other input signal comes from the swell-and-pitch correction module 491, and the output 471 therefrom drives the quarter and stern line control module 498.

The swell-and-pitch correction module 491 receives three signals; the first is from the current repeater 448 of the Y-coordinate command module 492; the second, the pitch from the potentiometer 435 that its positioned by the angle indicator 189; and the third, the swell from the potentiometer 434 which is positioned by the sounding device 187. The pitch signal is proportional to the tangent of angle B, and is sent to a multiplifer amplifier 452. The second input to the multiplier amplifier 452 is the constant signal provided by the current source 451, which represents one leg of a triangle. The outputs of the multiplier amplifier 452 is equal to the Y1' pitch component, which is an input to the summing amplifier 455.

The swell signal from the voltage-to-current converter 437 is proportional to the vertical distance that the bottom of the dredge hull 151 lies above the trough of the swell, and this signal is the other input to the summing amplifier 455. The output of the summing amplifier 455 is the value of the swell pitch component Y1'. The swell pitch component output of the summing amplifier 455 is corrected according to the depth the dredge is digging by the multiplier amplifier 454, whose second input is from the signal characterizer 460 which is driven by a Y-coordinate signal. The output 466 of the multiplier amplifiers 454 is then equal to the required Y1' coordinate correction, which is input to the Y-coordinate command module 492.

The X'-coordinate is computed by the Y1' output from the summing amplifier 455 as one input to the multiplier amplifier 453, and the second input is the output from the signal characterizer 459, which is driven by a Y-coordinate signal. The output 465 of X' coordinate multiplier amplifier 453 is the correction input to the X-coordinate command module 493.

The swell-and-pitch signal may be adjusted and calibrated so that the final output signsl 467, 468 and 471 are all positive.

The set point of the position adjuster 484 is adjusted by the input signal 467 from the Y-coordinate command module 492. The set point signal 504 is balanced against the actual feedback signal 511 from the pressure transmitters 431 and 432 and the summing amplifier 458, which represent the actual Y-coordinate of the cutter head 159. The resultant error signal 518, proportional to the deviation and direction of the lower tumbler 159 from the set point, is transmitted to the position adjuster 484. The output of the position adjuster 484 is a contact closure of one of the relays 529 and 530. The relay 529 is energized when the value is greater than the set point; the relay 530 is energized when the value is less than the set point. Positioning of the cutter head 159 is accomplished by closing either the "raise" relay 529 or the "lower" relay 530 to energize the ladder hoist motor 400. At this "balanced" position, neither relay 529 nor 530 is closed. The position controller 484 has auto, manual "raise" and manual "lower" pushbuttons; deviation and position meters; and adjustable proportion reset and rate actions.

The after ladder suspension control module 495 is similar to the forward ladder suspension control module 494 except for the feedback position signals, which come from the hoist drum 168. The winch drum potentiometer 407 feeds the voltage-to-current converter 440 and the output signals from the converter 440 is the position-feedback signal 512 to the set point/auto-manual station 478.

The quarter and stern line control module 498 is similar to the after ladder suspension control moduel 495 except that the command signal 471 is made to provide three set point signals 501, 502 and 503. The position-feedback potentiometers 411, 410, and 412 feed the voltage-to-current converters 443, 444 and 445. The output of the voltage-to-current converters 443, 444 and 445 is the feedback signal 508, 509 and 510 to the respective set point/auto-manual stations 481, 482, and 483.

The articulation of two forward ladder sections, in place of one forward ladder section for compensation of the pitch-and-swell, may simply be added to the control. The swell-and-pitch correction module 491 would have to have added one current source, one summing amplifier, two current multipliers and one signal characterizer. This will then provide a Y2' correction signal to the Y-coordinate command module 492. The Y-coordinate command module 492 would have added one current repeater and one summing amplifier.

For raising the ladder above water for maintenance and repairs to the cutter head 159, cutter drive, booster pump, pivot, etc., or for other reasons, manual control of the ladder hoists, quarter line and stern line winches may be employed, with the automatic compensating systems cut out.

FIG. 7 shows some important details of a dredge like those of FIGS. 2, 3, and 4 in having the upper ladder section 153 connected to the dredge hull 151 at the pivot 155, with the lower ladder section 154 pivoted below it and articulated at the pivot 156. The cutter head 159 with its drive 160 is contained within and supported by the lower end of the ladder section 154. The suction pipe 157 runs from the back of the cutter head 159, through and supported by the ladder sections, 154 and 153, through the double bulk-heads of the hull 151 to the suction side of the main pump 158. The main pump and drive 200 is contained within the hull of the dredge. Flexible hose connections 202 are located in the suction pipe 157 near the ladder pivot connections 155 and 156 to allow articulated motion of the ladder sections at these pivot points. The upper end of the ladder is secured to the hull 151 within the ladder well at the pivot connection 155. The lower end of the upper ladder section 153 supports the shaft 156 on which the clevised upper end 205 of the lower section of the articulated ladder is pivotally supported. FIG. 8 shows the clevised upper end 205 of ladder section 154 connected to the lower end of section 153 by the shaft 156.

FIG. 9 shows an alternate form of lower end digging device 203, namely, a conventional venturi-jet pump located just above the suction entrance to the pipe 157.

Also shown are external high pressure water agitating nozzles to facilitate the picking up of the subaqueous material by the suction pipe **157.**

FIG. **10** also shows another alternate form of lower end digging device **204,** namely a conventional type of bucket wheel with drive for digging the subaqueous material for pick up and transport by suction pipe **157.**

The booster pump **61** of FIG. **1, 161** of FIGS. **2** and **3,** and **215** of FIG. **5,** while not shown in FIG. **7** can be of a conventional centrifugal or venturi-jet type. When dredging at depths of about eighty feet or more below water surface, some type of booster pump is required in the suction line to the main pump onboard the dredge to compensate for the increase in pipe friction at these greater depths. When dredging at greater depths two or more booster pumps in series may be utilized.

FIGS. **11** to **14** show a modified form of ladder suspension system having improved lateral stability. Instead of the suspension lines being parallel they are inclined to each other, through co-planar. Thus, two ladder sections **300** and **301,** articulated together at **302,** are supporeted by suspension system **303** and **304,** respectively. The suspension system **304,** includes two block-and-tackle lines **305** and **306** that are co-planar but converge together from their upper pulley blocks **307, 308,** to a structure **313** supporting lower pulleys **311** and **312.** The structure **313** is secured to the ladder **301** by suspension rods **314** and **315.** As shown in FIG. **11,** the angle at which the lines **305** and **306** converge widens as the lines are shortened and the structure **313** and the ladder section **301** are raised. At all times lateral suspension stability is improved, as compared with structures having parallel suspension lines.

This structure substantially eliminates all lateral bending moments in the dredge ladder, such as are imposed by the lateral digging forces as the dredge swings laterally or traverses from port to starboard or from starboard to port, in the process of excavating the subaqueous material. It also materially improves the structural integrity of the dredge hull and supersturcture as related to the ladder; this is especially important with sea dredges.

FIG. **5** illustrates the progressive advantages of this invention at increasing dreding depths. Some examples are:

1. Infinite vertical plane positions and related angles between the plurality of articulated ladder sections providing at all depths optimum dredging production.
2. When digging at depth the uppermost ladder sections may be positioned vertically or near vertically, thus substantially reducing hydraulic pipe friction and pipe wear in transporting the dredged material to the surface.
3. All of the uppermost ladder sections may be interchangeable, to offer obvious economics and advantages.
4. The ladder sections may be of open sides truss design thereby reducing the effect of sea current forces on the sides of the ladder structure.
5. Some or all of the ladder sections may be constructed of light weight metals or alloy steels thus further reducing the overall weight of the suspended ladder.
6. The combined weight of the articulated ladder sections is so much less for a dredge of this invention compared to a conventional integral one-piece ladder of equivalent length that the required supporting hull, supersturcture, ladder suspension and ladder hoist machinery may be of substantially less size and weight, making deep dredging quite feasible and economical at far greater depths than possible by prior-art designs.
7. In deep dredging cuts (banks) this invention provides for the dredge proper to be moved (stepped) ahead while the ladder digging end is still positioned and digging at the bottom of the last cut. Consequently no lost production time is entailed in stepping ahead after the ladder is raised, as is the case with conventional one piece ladder dredges.
8. With the lighter weight suspended ladder and multiple suspensions faster ladder hoisting speeds are attainable than by prior art construction.
9. Cumulatively the features of the invention provide a high degree of dredging efficiency, flexibility, and favorable economics not possible by prior art designs

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

We claim:

1. A floating deep-digging ladder dredge, including in combination,

a hull,

a main pump within said hull,

superstructure supported on said hull,

an articulated ladder comprising a plurality of sections pivoted together for relative swinging movement in a vertical plan only and including

an upper swingable ladder section having a main pivot adjacent its upper end supported by said hull, and

a lower swingable ladder section pivoted to the section above it and having excavating means at its lower extremity,

a pipeline supported by said ladder passing from said excavating means through said ladder to said main pump,

a plurality of block-and-tackle suspensions supported by said superstructure, each suspension being connected to the lower end of a swingable ladder section for support thereof and having a cable,

winch means for said cable supported by said hull,

sounding means for determining instantaneously the height of the hull above the bottom of the water on which the hull is floating,

depth signal means actuated by said sounding means,

angle sensing means for determining, instantaneously, the angle which the true horizontal makes with the nominally horizontal centerline of said dredge hull,

angle signal means actuated by said angle sensing means,

control means receiving said depth signal and said angle signal means and controlling the suspension length of at least said lower ladder section and accommodating it to swells in the water level on which the hull floats.

2. The dredge of claim **1,** having

a stern line and two quarter lines, each extending from a sea bottom anchor to said dredge,
three winches for varying the lengths of said stern line and said quarter line, and
a control circuit actuated by said control means for controlling the instantaneous lengths of said stern line and quarter lines during swells.

3. A floating deep-digging ladder dredge, including in combination,
a hull,
a main pump within said hull,
superstructure supported on said hull,
an articulated ladder comprising a plurality of sections pivoted together for relative swining movement in a vertical plane only and including
an upper swingable ladder section having a main pivot adjacent its upper end supported by said hull, and
a lower swingable ladder section pivoted to the section above it and having excavating means at its lower extremity,
a pipeline supported by said ladder passing from said excavating means through said ladder to said main pump,
a plurality of block-and-tackle suspensions supported by said superstructure, each suspension being connected to the lower end of a swingable ladder section for support thereof and having a cable,
winch means for said cable supported by said hull,
sounding means for indicating instantaneously the height of the hull above the bottom of the water on which the hull is floating,
first command means actuated by said sounding means,
angle sensing means for indicating instantaneously the angle which the true horizontal makes with the nominally horizontal centerline of said hull,
second command means actuated by said angle sensing means,
said winch means comprising a separate luffline winch for each said suspension,
a stern line and two quarter lines each extending from a respective sea bottom anchor to said dredge,
a stern line winch and two quarter line winches, for varying the lengths of said stern line and quarter lines,
third command means for setting a nominal position of said stern line and quarter line winches,
additional command means, one for setting a nominal position for each said luffline winch, and
control means connected to all of said command means and transmitting the settings of said third and additional command means to their said winches by a series of outputs, said control means having means for superimposing on said outputs the effects of said first and second command means,
so that the nominal positions of said winches are kept changing to actual positions varying from said nominal positions by amounts such as are needed to keep the position of said excavating means substantially constant.

4. A floating deep-digging dredge having a hull and a superstructure with a ladder pivotally supported by said hull and a main pump within said hull connected by a pipeline to excavating means on the lower end of the ladder, characterized by
the ladder comprising a plurality of articulated sections of substantially equal length pivoted together for relative swining movement in a vertical plane only,
a plurality of block-and-tackle suspensions supported by said superstructure, each suspension being connected to the lower end of a swingable ladder section for support thereof and having a cable with winch means for said cable supported by said hull,
said pipeline comprising a plurality of pipe sections, one supported by each ladder section and connected by a flexible connection at each ladder articulation,
sounding means for determining instantaneously the height of the hull above the bottom of the water on which the hull is floating,
depth signal means actuated by said sounding means,
angle sensing means for determining, instantaneously, the angle which the true horizontal makes with the nominally horizontal centerline of said dredge hull,
angle signal means actuated by said angle sensing means,
control means receiving said depth signal and said angle signal means and controlling the suspension length of at least said lower ladder section and accommodating it to swells in the water level on which the hull floats.

5. The dredge of claim 4 having
a stern line and two quarter lines extending from respective sea bottom anchors to said dredge,
a stern line winch and two quarter line winches for varying the length of said stern line and quarter lines, and
means actuated by said control means for controlling the instantaneous length of said stern line and quarter lines during swells.

6. A floating deep-digging dredge having a hull and a superstructure with a ladder pivotally supported for relative swinging movement in a vertical plane only, by said hull and excavating means on the lower end of the ladder, characterized by
block-and-tackle suspension means for the ladder supported by said superstructure and connected to the lower end of at least one swingable ladder section for support thereof and having a cable,
winch means for said cable supported by said hull,
sounding means for determining instantaneously the height of the hull above the bottom of the water on which the hull is floating,
depth signal means actuated by said sounding means,
angle sensing means for determining, instantaneously, the angle which the true horizontal makes with the nominally horizontal centerline of said hull,
angle signal means actuated by said angle sensing means,
control means receiving said depth signal and said angle signal means and controlling the suspension lengths of said ladder and accommodating it to swells in the water level on which the hull floats,
a stern line and two quarter lines extending from respective sea bottom anchors to said dredge,

a stern line winch and two quarter line winches for varying the length of said stern line and quarter lines, and

means actuated by said control means for controlling the instantaneous length of said stern line and quarter lines during swells.

7. The dredge of claim **6,** wherein

said depth signal means comprises first command means actuated by said sounding means,

said angle signal means comprises second command means actuated by said angle sensing means,

said winch means comprising a separate luffline winch for each said suspension,

a stern line and two quarter lines each extending from a respective sea bottom anchor to said dredge,

a stern line winch and two quarter line winches, for varying the lengths of said stern line and quarter lines,

third command means for setting a nominal position of said stern line and quarter line winches,

additional command means, one for setting a nominal position for each said luffline winch,

control means connected to all of said command means and transmitting the settings of said third and additional command means to their said winches by a series of outputs, said control means having means for superimposing on said outputs the effects of said first and second command means,

so that the nominal positions of said winches are kept changing to actual positions varying from said nominal positions by amounts such as are needed to keep the position of said excavating means substantially constant.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,739,503 Dated June 19, 1973

Inventor(s) George P. Barker and Cameron E. McKay

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Heading [76] Inventors, the address of the second inventor, Cameron E. McKay, should read --1900 Pineridge Drive, Reno, Nevada 89502--. Col. 4, line 66, "other" should read --Other--. Col. 5, line 41, "dreged" should read --dredge--. Col. 7, line 21, "cooperating" should read --cooperation--; lines 39 and 46, "common module" should read --command module--; line 51, "signas" should read --signals--. Col. 9, line 13, "600 ohms" should read --660 ohms--; line 57, "not" should read --no--. Col. 10, line 4, "moduel" should read --module--; lines 4-5, "characterized" should read --characterizer--; line 57, delete the comma after "model"; line 64, "417" should read --517--. Col. 12, line 68, "module 419" should read --module 491--. Col. 13, line 4, "moduel" should read --module; line 19, "its" should read --is--; lines 23-24, "multiplifer" should read --multiplier--; line 52, "signsl" should read --signals--. Col. 14, line 17,"moduel" should read --module--. Col. 15, line 21, "through" should read --though--; line 41, "supersturcture" should read --superstructure--; line 59, "open sides" should read --open sided--. Col. 16, line 3, "supersturcture" should read --superstructure--; line 21, place a period after "signs". Col. 17, line 14 (line 7 of claim 3), "swining" should read --swinging--. Col. 18, line 5 (line 8 of claim 4), "swining" should read --swinging--.

Signed and sealed this 18th day of December 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents

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