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(54) IMPROVEMENTS IN FLOATING, DEEP-DIGGING LADDER-TYPE DREDGES

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

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 fifty feet have long been dredged successfully by hydraulic ladder dredges, but beyond a depth of about sixty 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 one hundred and fifty 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 eighty 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 fifty to eighty feet would not be adequate or efficient at depths of one hundred feet and greater. When the dredges were made according to prior-art designs, every additional foot added costs and ineffi-

ciencies. 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 been 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 sixty feet below the surface of the ocean in exposed waters which might be fairly close to shore.

According to the invention, there is provided a floating deep-digging dredge having a hull, an articulated dredge ladder pivotally supported by the hull and comprising a plurality of sections pivoted together for relative swinging movement in a vertical plane only, a suction pump in the hull connected to a pipeline having an intake connected to or disposed adjacent to excavating means on the lower end of the ladder, a suspension of adjustable length for each swingable section of the ladder, and adjustment means for adjusting the lengths of the suspensions, in which dredge: the pipeline comprises a rigid pipeline section fixedly secured to each ladder

section and a flexible connection joining the pipeline sections at each pivot connection of the ladder sections; each suspension includes a block-and-tackle suspension supported by

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Embodiments of the present invention make deep digging—down to five hundred 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 dredges embodying the invention are provided in a plurality of sections, two or three usually being sufficient for water depths of sixty to two hundred fifty 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 embodiments of 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 mean, 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 embodying 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. Thus, preferred embodiments of the invention include 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 addition to these features—the employment of articulated dredges to get greater depth and the swell-compensating mechanism to enable operation in offshore waters—a number of other significant preferred features are provided. As noted below, these features materially improve the performance and the

economics of the dredges embodying 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.

A preferred feature of 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 being with the pipe in a vertical or nearly vertical position.

Many of the features herein described are applicable to relatively shallow dredging as well as to deep dredging.

In order that the invention may be readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 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.

Figure 2 is a view similar to Figure 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.

Figure 3 is a view similar to Figure 2 of the dredge of Figure 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.

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

Figure 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 centre 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.

Figure 6 is a motion diagram of an off-

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shore dredge like those of Figures 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.

Figure 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.

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

Figure 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.

Figure 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 devices for excavating and recovering subaqueous materials.

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

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

Figure 13 is an enlarged fragmentary view of the connection of the suspension to the lower most ladder section.

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

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

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

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

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

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

The dredge 50 of Figure 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 minimising 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 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 dredge 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 purposes 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 Figure 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.

Figures 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.

Figures 2, 3 and 4 show an offshore dredge 150 generally similar to the dredge 50 to Figure 1, but having some important differences. The hull 151 supports an articulated ladder having two swingeable sections 153 and 154, pivoted to each other at a pivot 156, while the after ladder 153 is pivoted to the hull within a hull ladder well opening on pivots 155 supported by the ladder well hull sides.

The principal differences which distinguish the dredge 150 of the Figures 2, 3 and 4 structure from that of Figure 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 twenty feet or even more. It is apparent that if no attempt is made to compensate for the swell, 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 Figure 2 embodiment, 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 Figures 2 and 3.

Figures 2 and 3 illustrate the broad effect of the compensating mechanism, which is shown in more detail in Figures 15 to 21. Figure 3 shows the dredge 150 as it is at a swell crest, and Figure 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 Figure 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 centre line shown in Figure 2.

Figure 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 compensation 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 Figure 4) quarter lines 174 and 175 are taken up, along with a stern line 173 payout 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.

Figures 3 and 4 show a sheave tube 172 or "Christmas tree" which preferably replaces the spud 74 of Figure 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 respec-

tive 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 centre 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 utilising the principles of this invention for swell compensation.

Figure 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 Figures 2 and 3 for the respective suspension systems 162 and 163. The engine room 185 of Figure 4 contains the main pump and drive, main engines and auxiliary machinery.

Figure 5 shows a very deep digging dredge 200 for sea or inland waters with four articulated ladder sections 203, 204, 205 and 206, with their respective independent 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 Figures 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 compensating action can be taken at a pivot connection 210 or for swells of greater magnitude at a pivot connection 209. A broken ladder centre line 231 shows the compensating action being taken at the pivot connection 210.

Broken ladder centre line 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 centre 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 Figure 21, the sounding device 187, which may be of well-known type acts through a cable 188, e.g. in cooperation 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 height 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 setting of a pitch potentiometer 435, in accordance with the angle which the true horizontal makes with the nominally horizontal centre 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 Figure 18. The swell-and-pitch correction module 491 operates in cooperation with a Y-coordinate command 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 illustrated in Figure 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 command 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 Figures 2 and 3, the Y-coordinate command module 492 provides two signals 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 Figure 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 command 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 Figure 2 position to the Figure 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 potentiometer 434 to the swell-and-pitch correction module 491 (Figure 18) to provide correction signals 466 and 465 respectively for the Y' 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 (Figure 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 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 huffline 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 (Figure 21), that measures the variable angle B between the horizontal centre 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 (Figure 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 Figure 18.

The voltage-to-current converter 439 and all the other voltage-to-current converters spoken of in this specification, may be standard items. For instance, they may each be of a Foxboro 66GT or 66GC series voltage-to-current converter made by The Foxboro Company, of Foxboro, Massachusetts, United States of America. These converters accept a 1 to 5 volt DC input and convert it to a proportional 10 to 50 milliamper 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 one-to-five 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 a standard item, it need not be further described.

Similarly, the summing amplifier 457 and all the other summing amplifiers used here may be a Foxboro 66CT or 66CC series electronic "Consotrol" summing amplifier. These summing amplifiers are able to receive up to four 10 to 50 milliamper DC input signals and to provide a 10 to 50 milliamper 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, 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 standard items, such as the Foxboro 66BT and 66BC series electronic "consotrol" current repeaters. These repeaters receive a 10 to 50 milliamper DC input signal and produce an electrically isolated 10 to 50 milliamper DC output. They have a low input resistance of about 100 ohms and can feed an external load up to 660 ohms. Such units are often used to extend the total load fed by computer devices the 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 a standard 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 feed 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 standard 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 a standard item, 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 milliamperes 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 no external common connections between the input circuits. The constant current source 451 used for this multiplier may be a standard item such as a Foxboro 66ET and 66BC series electronic "Conso-

5 trol" current source, which provides an output that is adjustable from 10 to 50 milli-
amperes. Each may include a transistorised
10 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
15 also includes two signal characterizers 459 and 460 (like the signal characterizers 461 and 462). It also includes a summing ampli-
fier 455 and two current multipliers 453
20 and 454. The current repeater 448 of the Y-coordinate command module 492 is connected to the signal characterizer, 459 and 460 of
the swell-and-pitch correction module 491. The current multiplier 452 and the voltage
25 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
30 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
35 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 cor-
rection signal 466 is proportional to the
product of those two inputs.

The current repeater 449 of the Y-co-
40 ordinate 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
45 to the signal characterizer 461, which there-
upon 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
50 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.

55 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 Figure
60 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
65 471 is fed directly to a motor operated setter

476 of the control module 498 (Figure 20).
This, like the other motor operated setters to
be described, may also be a standard item,
such as, the M-line, model C, motor oper-
ated setter made by Leeds & Northrup Com-
pany, of Philadelphia, Pennsylvania, United
States of America. This motor-operated setter
476 tracks the signal 471 and positions three
retransmitting slide wires which are set-point
70 potentiometers 501, 502 and 503 for res-
pective 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/
80 auto-manual stations to be described, may
also be a standard 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
85 483 compare the set point potentiometers 501,
502, and 503 with the outputs 508, 509 and
510 of the position feed-back summing ampli-
fiers 443, 444 and 445 (see Figure 20), and
the unbalance between the respective signals
90 become respective error signals 515, 516 and
517 that are proportional in magnitude and
polarity to the unbalance.

The outputs 515, 516 and 517 are fed
95 directly to the respective position adjusters
488, 489 and 490 (Figure 20). This, like
the other position adjusters to be described,
may also be a standard item, such as the
Leeds and Northrup Company's P.A.T. control
100 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
105 instance) from the set point units 481, 482
and 483 and, through an amplifier, energize
either a "raise relay" or a "lower relay", de-
pending upon the polarity, magnitude, dura-
tion and rate of change of the error signal.
They are used in closed loop control systems
110 as the heart of the unit. They are complex
units but are well known and are com-
pletely described in published material. The
signal 471 is used here as the set point, and
the position feedbacks are set mechanically
115 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
120 and 445 (like the converter 439). The out-
puts 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,
125 516 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 177 130

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 (Figure 19), like the motor-operated setter 476. The motor operated setter 472, tracks the signal 467 and positions a retransmitting slide wire set point potentiometers 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 module 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 magnitude 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 Figures 15, 17 and 19, each of the two ladder suspensions shown in Figure 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, Figure 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 unaffected by the pitch and/or swell on the hull. Each system may comprise an air filter-regulator 422 and 433, which may be the model 015-025 made by C. A. Norgren Company, of Littleton, Colorado, United States of America; 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; the 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 (Figure 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 drives 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 491. The output from the current repeater 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 module 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 is 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 multiplier 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 amplifier 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 signals 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 module 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.

Figure 7 shows some important details of a dredge like those of Figures 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 connection 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. Figure 8 shows the clevised upper end 205 of ladder section 154 connected to the lower end of section 153 by the shaft 156.

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

Figure 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 Figure 1, 161 of Figures 2 and 3, and 215 of Figure 5, while not shown in Figure 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.

Figures 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 supported 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 Figure 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 superstructure as related to the ladder; this is especially important with sea dredges.

Figure 5 illustrates the progressive advantages of this invention at increasing dredging 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 sided 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 embodying this invention compared to a conventional integral one-piece ladder of equivalent length that the required supporting hull, superstructure, 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 step-

ping 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 favourable economics not possible by prior art designs.

Attention is drawn to our co-pending Patent Application No. 57849/73 (Serial No. 1,359,829) which describes and claims a floating deep digging dredge having a well compensating mechanism such as is employed in some of the above-described embodiments of dredges according to the present invention.

WHAT WE CLAIM IS:—

1. A floating deep-digging dredge having a hull, an articulated dredge ladder pivotally supported by the hull and comprising a plurality of sections pivoted together for relative swinging movement in a vertical plane only, a suction pump in the hull connected to a pipeline having an intake connected to or disposed adjacent to excavating means on the lower end of the ladder, a suspension of adjustable length for each swingable section of the ladder, and adjustment means for adjusting the lengths of the suspensions, in which dredge: the pipeline comprises a rigid pipeline section fixedly secured to each ladder section and a flexible connection joining the pipeline sections at each pivot connection of the ladder sections; each suspension includes a block-and-tackle suspension supported by superstructure on the hull and connected to the lower end of the respective ladder section; and the adjustment means includes winch means for a cable of each block-and-tackle suspension.

2. A dredge according to claim 1, including means for maintaining an upper portion of the ladder in a position approaching vertical while utilising a lower portion of the ladder to obtain a desired digging angle of the excavating means, thereby substantially reducing hydraulic pipe friction of the dredged material being transported to the surface, thus reducing pipe wear.

3. A dredge according to claim 2, including means for maintaining all but the lowermost ladder section in a substantially vertical position while utilising the lowermost ladder section to obtain the desired digging angle of the excavating means.

4. A dredge according to claim 1, wherein the ladder includes an upper swingable ladder section having a main pivot adjacent to its upper end supported by the hull and a lower swingable ladder section pivoted to the section above it and having the excavating means at its lowest extremity.

5. A dredge according to claim 4, wherein the upper swingable ladder section is pivoted about a point within a hull ladder well opening on pivots supported by the ladder well hull sides.

6. A dredge according to claim 4, wherein there are two swingable ladder sections pivoted to each other, the upper ladder section being pivoted at its upper end to the hull, whereby the lower section may be positioned at various angles above and below the centre line continuation of the upper ladder section.

7. A dredge according to claim 4, wherein there are at least three swingable sections successively pivoted to each other and with the upper end of the upper section being pivoted to the hull, whereby any swingable ladder section may be positioned above or below the centre line continuation of each section adjacent to it.

8. A dredge according to any one of the preceding claims, wherein the lower end of at least the lowermost ladder section is suspended by two sets of block-and-tackle suspensions lying in the same plane but inclined to each other set at acute angles symmetrical about the centre line of the dredge and of the ladder.

9. A dredge according to any one of the preceding claims, including booster pump means for the pipeline contained in and supported by one of the ladder sections.

10. A dredge according to claim 9, wherein the booster pump means comprises a plurality of booster pumps in series.

11. A dredge according to claim 9, wherein the booster pump means includes a booster pump supported adjacent to the lower end of the uppermost swingable ladder section, within or near the suspension therefor, thereby reducing the bending movement induced by the weight of the booster pump.

12. A dredge according to any one of the preceding claims, wherein the lowermost swingable ladder section supports a cutter head drive means adjacent to its lower end adjacent to the suspension therefor, thereby reducing the bending movement induced by the weight of the cutter head drive means.

13. A dredge according to any one of the preceding claims, including sounding means for determining instantaneously the height of the hull above the bottom of the water on which the hull is floating, depth signal generating means actuated by the sounding means, angle sensing means for determining instantaneously the angle which the true horizontal makes with the nominally horizontal centre line of the hull, angle signal generating means actuated by the angle sensing means, and control means receiving the depth signal and the angle signal and controlling the length of the suspension of at least the lowermost ladder section and accommodating it to swells

ping ahead after the ladder is raised, as is the case with conventional one piece ladder dredges.

5 (8) With the lighter weight suspended ladder and multiple suspensions faster ladder hoisting speeds are attainable than by prior art construction.

10 (9) Cumulatively the features of the invention provide a high degree of dredging efficiency, flexibility, and favourable economics not possible by prior art designs.

15 Attention is drawn to our co-pending Patent Application No. 57849/73 (Serial No. 1,359,829) which describes and claims a floating deep digging dredge having a well compensating mechanism such as is employed in some of the above-described embodiments of dredges according to the present invention.

WHAT WE CLAIM IS:—

20 1. A floating deep-digging dredge having a hull, an articulated dredge ladder pivotally supported by the hull and comprising a plurality of sections pivoted together for relative swinging movement in a vertical plane only,
25 a suction pump in the hull connected to a pipeline having an intake connected to or disposed adjacent to excavating means on the lower end of the ladder, a suspension of adjustable length for each swingable section of the ladder, and adjustment means for adjusting the lengths of the suspensions, in which dredge: the pipeline comprises a rigid pipeline section fixedly secured to each ladder section and a flexible connection joining the
30 pipeline sections at each pivot connection of the ladder sections; each suspension includes a block-and-tackle suspension supported by superstructure on the hull and connected to the lower end of the respective ladder section; and the adjustment means includes winch means for a cable of each block-and-tackle suspension.

2. A dredge according to claim 1, including means for maintaining an upper portion of the ladder in a position approaching vertical while utilising a lower portion of the ladder to obtain a desired digging angle of the excavating means, thereby substantially reducing hydraulic pipe friction of the dredged material being transported to the surface, thus reducing pipe wear.

3. A dredge according to claim 2, including means for maintaining all but the lowermost ladder section in a substantially vertical position while utilising the lowermost ladder section to obtain the desired digging angle of the excavating means.

4. A dredge according to claim 1, wherein the ladder includes an upper swingable ladder section having a main pivot adjacent to its upper end supported by the hull and a lower swingable ladder section pivoted to the section above it and having the excavating means at its lowest extremity.

5. A dredge according to claim 4, wherein the upper swingable ladder section is pivoted about a point within a hull ladder well opening on pivots supported by the ladder well hull sides.

6. A dredge according to claim 4, wherein there are two swingable ladder sections pivoted to each other, the upper ladder section being pivoted at its upper end to the hull, whereby the lower section may be positioned at various angles above and below the centre line continuation of the upper ladder section.

7. A dredge according to claim 4, wherein there are at least three swingable sections successively pivoted to each other and with the upper end of the upper section being pivoted to the hull, whereby any swingable ladder section may be positioned above or below the centre line continuation of each section adjacent to it.

8. A dredge according to any one of the preceding claims, wherein the lower end of at least the lowermost ladder section is suspended by two sets of block-and-tackle suspensions lying in the same plane but inclined to each other set at acute angles symmetrical about the centre line of the dredge and of the ladder.

9. A dredge according to any one of the preceding claims, including booster pump means for the pipeline contained in and supported by one of the ladder sections.

10. A dredge according to claim 9, wherein the booster pump means comprises a plurality of booster pumps in series.

11. A dredge according to claim 9, wherein the booster pump means includes a booster pump supported adjacent to the lower end of the uppermost swingable ladder section, within or near the suspension therefor, thereby reducing the bending movement induced by the weight of the booster pump.

12. A dredge according to any one of the preceding claims, wherein the lowermost swingable ladder section supports a cutter head drive means adjacent to its lower end adjacent to the suspension therefor, thereby reducing the bending movement induced by the weight of the cutter head drive means.

13. A dredge according to any one of the preceding claims, including sounding means for determining instantaneously the height of the hull above the bottom of the water on which the hull is floating, depth signal generating means actuated by the sounding means, angle sensing means for determining instantaneously the angle which the true horizontal makes with the nominally horizontal centre line of the hull, angle signal generating means actuated by the angle sensing means, and control means receiving the depth signal and the angle signal and controlling the length of the suspension of at least the lowermost ladder section and accommodating it to swells



in the water level on which the hull floats.

5 14. A dredge according to claim 13, including a stern line and two quarter lines, each for extending from a sea bottom anchor to the dredge, three winches for varying the lengths of the stern line and the quarter lines, and means actuated by the control means for controlling the instantaneous lengths of said stern line and quarter lines during swells.

10 15. A dredge according to claim 14, wherein the depth signal generating means comprises first command means actuated by the sounding means, the angle signal generating means comprises second command means
15 actuated by the angle sensing means and the winch means comprises a separate luffline winch for each suspension, such dredge including third command means for setting a nominal position of the stern line and quarter
20 line winches, and additional command means for setting a nominal position for each luffline winch, the control means being connected to all of said command means and transmitting the settings of the third and additional com-

mand means to their winches by a series of outputs, the control means having means for superimposing on the outputs the effects of the first and second command means, so that the nominal positions of the winches are kept changing to actual positions varying from the nominal positions by amounts such as are needed to keep the position of the excavating means substantially constant.

16. Floating deep-digging dredges substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

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