

PATENT SPECIFICATION

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(54) DEEP-DIGGING FLOATING DREDGE

(71) We, CAMERON EDWARD MCKAY AND GEORGE PATON BARKER, respectively, a citizen of the United States of America, of 1632 Coronado Waw, Burlingame, California 94010, United States of America, and a British subject of "Belmar", 85 Sauchenbush Road, Kirkcaldy, Fife, Scotland; do hereby declare this invention, to be described in the following statement:—

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

While dredges have been used for many years in gold mining and other similar mining operations, they have heretofore been confined to relatively shallow depths and to relatively quiet waters. Depths up to about sixty to eighty feet have long been dredged successfully, but beyond a depth of about ninety 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 dredges have been operated as deeply as about one hundred and twenty-five feet below water level, they have not been operated much below that depth for several reasons. For one thing, the manufacturing cost for dredges of prior-art designs capable of digging below about one hundred and twenty-five feet below water level was in itself so high as to make the venture uneconomical. Very heavy high-strength ladder girders had to be provided if the large-magnitude live and dead forces were to be withstood. Structures that were efficient for depths of seventy-five to one hundred feet would not be adequate or efficient at depths of one hundred and twenty-five 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 rose, the digging buckets would be lifted from engagement with the sand, soil or rock, and so a large proportion of the time the buckets would come up empty or with only a small proportion of their capacity filled; the alternative to this would have damaged the buckets, the ladder, and related structural and mechanical components by having the buckets 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 well known that in many instances really valuable minerals lay more than a hundred feet below the surface of the ocean in exposed waters which might be fairly close to shore.

According to the present invention, there is provided a floating deep-digging dredge having a hull and a dredge ladder which is provided with excavating means operative at a lower end of the ladder and which is connected to suspension means of adjustable length supported by superstructure on the hull, in which dredge: the ladder has a plurality of ladder sections including a swingable ladder section pivotally supported at its upper end by the superstructure for relative swinging movement in a vertical plane only; the excavating means comprises an endless digging bucket line supported by the ladder and extending on both top and bottom sides of the ladder; such bucket line passing around an upper driving tumbler and a lower tumbler; and the suspension means comprises a block-and-tackle suspension connected to the lower end of the swingable ladder section to support such swingable section, winch means for a cable of the block-and-tackle suspension being provided for adjusting the length of the suspension.

Embodiments of the present invention provide an articulated ladder structure and other significant structural features in a combination which make deep digging — down to
5 two 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
10 made unnecessary for using articulated structures; thus, ladders embodying this invention are provided in a plurality of sections, two or three usually being sufficient, depending upon the total depth needed. By combining
15 these plural sections with adequate rigging lines and manoeuvring 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
20 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
25 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
30 greater depths be attained, as indicated earlier, but in offshore dredges compensation can be made so that the digging engagement of the dredge buckets, well below the surface, is substantially unaffected by swell and wave
35 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 of this invention can operate efficiently even
40 with relatively high swells and even where the minerals lie well below the surface of the sea. An embodiment of the invention provides a compensating mechanism which is sensitive to swells and waves and which acts
45 to change the angle of the dredge ladder and its approach sufficiently to keep the digging buckets in engagement with the material being dredged.

In order that the invention may be readily
50 understood, embodiments thereof will now be described in more detail, 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
55 ladder in two sections.

Figure 2 is a view similar to Figure 1 of a modified form of dredge for use in relatively quiet waters in which the ladder is made in three articulated sections.

Figure 3 is a view similar to Figure 2 of an offshore dredge embodying the principles
65 of the invention, made in three articulated

sections, with an additional fixed ladder section at the top, above the uppermost of the three movable ladder sections. In this view the four ladder sections are all aligned in a straight line.

Figure 4 is a view of the dredge of Figure 3 in a position where the two lower sections are inclined downwardly relative to the upper two sections, in order to compensate for a swell.

Figure 5 is a view similar to Figure 3 of an offshore dredge having two movable sections with a fixed ladder section thereabove. The view shows the movable ladder portions in two different positions, the lower position being shown in solid lines and the upper one in broken lines.

Figure 6 is a diagrammatic view illustrating four different positions of the dredge ladder of Figure 5, all with the two movable ladder sections kept in a straight line.

Figure 7 is a view similar to Figure 5, with the dredge of Figure 5 shown with the lower movable ladder section inclined downwardly from the upper movable ladder section to compensate for a swell. An upper position of the lower movable ladder section is shown in broken lines.

Figure 8 is a diagrammatic view illustrating four different positions where the angle between the two ladder sections remains as in Figure 7.

Figure 9 is a block diagram of control apparatus for obtaining compensation for swell through the ladder suspensions and headline in the dredge of Figures 3 and 4.

Figure 10 is a diagrammatic view in elevation of the input system for the compensation apparatus of Figure 9.

Figure 11 is a diagrammatic view in elevation of the ladder-suspension control apparatus of Figure 9.

Figure 12 is a diagrammatic view in elevation of a headline compensating apparatus used in the control of Figure 9.

Figures 13A, 13B and 13C constitute an electrical circuit diagram for the device of Figures 9 to 12.

Figure 14 is a view in side elevation of a modified form of dredge having two movable ladder sections and a secondary fixed-position ladder to which the upper of the two movable sections transfers the bucket load.

Figure 15 is an enlarged view of the fixed ladder ramp and the upper portion of the articulated pivoted ladder sections, broken twice in the middle and at each end of the frame, also showing the upper tumbler and its drive machinery, the upper pivoted connection of the swingable ladder, and the intermediate pivoted connection for the articulated ladder sections.

Figure 16 is a similar view of the same

parts as shown in Figure 15 in side elevation.

5 Figure 17 is a view similar to Figure 15 of the lower portion of the articulated ladder, broken in the middle of the framework, also showing an optional form of combined ladder end and an optional form of bucket idler located at the pivotal connection of the articulated ladder sections.

10 Figure 18 is a view similar to Figure 17, showing the same parts as shown in Figure 17 in side elevation.

15 Figure 19 is a view in section taken along the line 19—19 in Figure 16, showing the independent structural supports for both the fixed upper ladder ramp and the upper pivoted connection of the swingable ladder.

20 Figure 20 is an enlarged fragmentary view in side elevation of the upper part of a fixed ramp ladder generally like that of Figure 15, but with a modification incorporating, in addition to the main discharge chute, a series of save-all grizzly bars and a save-all collection chute.

25 Figure 21 is a fragmentary top plan view of a dredge having a skew suspension for its lowermost articulated ladder section.

Figure 22 is a view of the dredge of Figure 21 in side elevation.

30 Figure 23 is a detailed fragmentary view of the connection of the suspension to the lowermost ladder section.

Figure 24 is a fragmentary view in side elevation enlarged with respect to Figure 22.

35 Figure 25 is a view similar to Figure 5 of a dredge having a fixed upper ramp and a single swingable ladder section.

40 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 a superstructure 52. The hull 51 and the superstructure 52 support 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, which may also provide the axis of rotation of an upper tumbler 56. The lower ladder section 54 is attached to the lower end of the upper ladder section 53 by a pivot member 57, and it carries a lower tumbler 58 at its lower end. A single continuous bucket line 60 goes around the two ladder sections 53 and 54, passing from a turnover at the upper tumbler 56 down to the digging position at the lower tumbler 58. On their upper run the buckets 61 ride across supporting planar ladder surfaces 62 and 63, and on the lower run their slack may be taken up somewhat by one or more intermediate idlers. As shown in the drawing, there is an underrun bucket idler 64 on the hull 51 and an underrun bucket idler 65 supported from the upper ladder section 53. These idlers 64

and 65 help to limit slack and tension in the bucket line, among other things.

65 The underrun bucket idler 65 can be located within or very close to the suspension points of the adjacent ladder section 53, thereby minimising the bending moment in that ladder section 53, which is induced by the weight of the underrun buckets 61 carried by the idler 65. This structure is not possible in conventional one-piece ladders, where the bucket idlers must be located approximately midway between the upper and lower ends of the one-piece ladder, thereby inducing the maximum bending moment. The idler 65, when located as shown in Figure 1, contributes further to enabling reduction in the required section-size and weight of all of the swingable ladder sections. Conventional endless track-type idlers may be used in lieu of the wheel-type idlers 65 shown, with the same location advantages.

80 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 66 and an after ladder suspension system 67, each of which comprises a block-and-tackle assembly and a plurality of cables 68 secured to its respective ladder. A headline 70 at the forward end of the hull 51 passes over a pulley 71 down to a headline winch 72, and each of the ladder hoists includes a cable 73 or 74 passing from an upper pulley of the suspension system 66 or 67 to a winch 75 or 76, located at appropriate locations on the hull 51. The forward ladder suspension system 66 is, of course, the longer, since the forward ladder section 54 goes down deeper.

105 At the upper end of the after ladder section 53, adjacent the upper tumbler 55, there is a revolving screen 77 which receives the material dumped from the buckets 61 through an open end 78 and which slopes down over a tail sluice 80. The oversized dredged barren material goes through the screen 77 and into the tail sluice 80, with the valuable mineral-containing fraction going through the screen perforations and out to the side in a part not shown in Figure 1 but well known in dredges. At the tail sluice 80, the dredged mineral-barren material washes back in a well-known manner, the tailings going out the end of the tail sluice 80 and gradually building up there. Other conventional apparatus for handling the dredged material for mineral recovery or for other purposes may be employed, many such being well known in the dredging art.

120 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 81 is provided on the hull 51 to receive the

pivot assembly 57 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-piece 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 82 and 83 in Figure 1 show, respectively, (1) how the two ladder sections 53 and 54 can be dropped lower and in line and (2) how the ladder section 54 can be used at a different angle in line with the upper ladder section 53. In the solid line position, the lower ladder section 54 is dropped below the centreline continuation of the upper ladder 53.

Figure 2 shows a similar dredge 100 with a hull 101 and having a three-section ladder assembly with an upper ladder section 102, an intermediate ladder section 103 and a lower ladder section 104. The dredge 100 is capable of being used at depths even greater than those of which the Figure 1 device is capable. It is feasible to go beyond Figure 2 and have more than three movable articulated ladder sections. Once again, the general principle is the same. The upper ladder section 102, while movable, does not necessarily have to move during times when both the intermediate ladder section 103 and the lower ladder section 104 swing, and the lower ladder section 104 can be swung relative to the intermediate ladder section 103, the broken lines 105, 106, and 107, illustrating some of the ladder positions.

Each ladder section 102, 103, and 104 has its suspension 112, 113, or 114, like the suspensions 66 and 67. The bucket line 110 is like the bucket line 60, but longer. There are two well-side slots 115 and 116 to accommodate the two pivot members 117 and 118. Each suspension 112, 113, 114 has its winch 122, 123, and 124. The headline 120, the rotating screen 121, and tail sluice 125 are like the corresponding parts in Figure 1, and the upper tumbler 126 may rotate about the same axis as that for the pivot for the upper ladder section 102. Operation is basically the same as for the dredge 50.

Figures 3 to 13 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 3 and 4 show an offshore dredge 130 generally similar to the dredge 100 of Figure 2, but having some important differences. The hull 131 and superstructure 132 support an articulated ladder having three swingable sections 133, 134 and 135, pivoted to each other at pivots 136 and 137, while the after ladder section 133 is pivoted to the superstructure by a pivot 138.

In addition, however, this dredge 130 provides a fixed ladder section or ramp 140 above the after ladder 133. The bucket line 141 continues up the ramp 140 and around an upper tumbler 142 at the top thereof. This ramp or fixed ladder section 140 is never moved and enables the attainment of a higher upper level without having to increase the section thicknesses and weight of the upper most movable ladder section 133. As a result, of course, greater depths can be obtained with substantially the same movable ladder sections as in Figure 2, since the fixed ladder section 140 takes up a substantial portion of the total ladder length involved.

The broken line 155 shows how the three ladder sections 133, 134 and 135 may be kept in line while being swung relative to the fixed ladder section 140. During this swinging, the position of the upper portion of the bucket line 141 is not changed, and it still is able to dump its load into a rotating screen 156 (or other receiving apparatus) with the relationship between the bucket line 141 and the screen 156 (or other receiving apparatus) remaining unchanged. The under-run bucket line 141 goes down to a lower tumbler 143, via idlers 144 and 145. The idler 145 has the advantage, previously noted as to the idler 65 of Figure 1, of minimising the bending moment of the ladder section 133, by being located within or close to its suspension point. Suspensions 146, 147 and 148 are operated by respective winches 150, 151 and 152 to raise and lower each ladder section 133, 134 and 135, either all together, or separately.

The other principal differences which distinguish the Figure 3 structure from that of Figure 2 are those that enable the dredge of Figure 3 to be used in offshore or ocean waters where there are swells, so that 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 swelling, the dredge buckets will either come up empty most of the time 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 lower

tumbler 143 is kept in a fixed position for any selected digging depth, in relation to the dredging face and the dredged sea bottom 153 irrespective of the water surface conditions in terms of waves and swells. The lower tumbler 143 remains at its fixed x, y position (or the x', y' position shown in broken lines) for any selected digging depth, while the ladder 133, 134, 135 traverses the lower tumbler 143 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 154 suspended by a cable 157 and (2) an angle indicator 158, which are shown in Figure 3 and, in more detail, in Figure 10.

Figures 3 and 4 illustrate the broad effect of the compensating mechanism, which is shown in more detail in Figures 9—13. Figure 4 shows the dredge 130 as it is at a swell crest, and Figure 3 shows the same dredge 130 in the swell trough. During the trough time the dredge hull 131 is closer to the bottom 153 than during the crest time; therefore during the crest the two lower ladder sections 134 and 135 are dropped to gain additional depth, as shown in Figure 4, the upper section 133 here remaining unchanged. However, only the lower ladder section 135 may be dropped for swells of lesser magnitude. As the water level drops again to the trough, the ladder is straightened out and may return to the common centre line as shown in Figure 3.

Figures 5—8 help to clarify the general aspect of this compensating action while also illustrating an alternative dredge 170 having a hull 171, superstructure 172, a fixed upper ramp or ladder 173 and two swingable ladder sections 174 and 175 with their suspensions 176 and 177 and articulated joint or pivot 178 and an upper pivot 179 for the section 174.

The use of the fixed upper ramp 140 (Figure 3), 173 (Figure 5), or 323 (Figure 25) enables either (1) a shorter length of suspended ladder 133, 134, 135 (Figure 3) or 174, 175 (Figure 5), or 324 (Figure 25), with the ensuing advantages of having less suspended ladder weight, less required capacity in the ladder suspension and hoisting systems and a reduction in the structural requirements of certain elements of the superstructure, or (2) increasing the digging depth of existing conventional dredges by installing a fixed upper ladder ramp 140 or 173 or 323 and then utilising an original suspended ladder 324 with its upper pivot connection relocated at a lower position, whether or not additional pivoted ladder sections 174 or 134 and 135 are added thereto.

Figure 5 shows, in broken lines, an upper nearly horizontal stowed position of the ladder sections 174 and 175. In solid lines it shows a lower digging position, also with the ladder

sections 174 and 175 in a straight line. Figure 6 shows, in diagrammatic form only, four positions A, B, C and D of the ladder combination 174, 175, always kept in a straight line, for trough conditions. These four positions correspond to different stages of digging when the dredge makes its "bite" at different levels along a digging face.

Figures 7 and 8 correspond to swell crest conditions of the dredge 170, with the lower ladder section 175 inclined downwardly about its pivot 178, by slacking its suspension 177. Positions A, B, C, and D in Figure 8 are the same as the same positions in Figure 6, with the ladder section 175 inclined relative to ladder section 174 to make up for the rise in level of the hull 171. The idea, thus, is to compensate for the difference in vertical distance of the hull 171 above the bottom 153 by so dropping the lower ladder section 175 relative to the ladder section 174 that the lower tumbler 180 remains in exactly the same position as the water rises and falls.

As shown in Figure 10, the sounding device 154 of well-known type acts through a cable 157, e.g., in cooperation with pulleys 149 and a weight 159, to provide a mechanical signal indicating the change in the vertical position of the dredge hull 131 up and down as crest and trough conditions occur. This may be interpreted as the height of the hull 131 above the bottom 153 or may be taken from any predetermined point of reference. The mechanical signal from the sounding device 154 is used mechanically to vary the resistance setting of a swell potentiometer 401. Similarly, the angle indicator 158 is set at or adjacent the pivot member 138 (Figures 3 and 4) and acts mechanically to vary the resistance setting of a pitch potentiometer 402, in accordance with the angle which the true horizontal makes with the nominally horizontal centre line of the hull 131. The potentiometers 401 and 402 transmit electrical signals as voltages to a swell-and-pitch correction module 403, as shown in Figures 9 and 13A. The swell-and-pitch correction module 403 operates in cooperation with a Y-coordinate command module 404 having a command potentiometer 405 and an X-coordinate command module 406 having a command potentiometer 407. The modules 403, 404, and 406 are described below and are illustrated in Figure 13A.

The lower tumbler 143 is initially positioned into a preselected x, y (or x', y') position by the Y-coordinate command module 404 and the X-coordinate module 406; these command modules 404 and 406 may be commanded by a winchman manually through the potentiometers 405 and 407. For a dredge 130 like that of Figures 3 and 4, the Y-coordinate command module 404 provides three signals Y1, Y2, and Y3, one to set each of the three ladder suspensions 148, 130

147 and 146, respectively, to move its ladder section 135, 134 and 133 to the proper elevation. In a dredge like that of Figures 5—8, there are only two ladder suspensions 176 and 177.

In both types of dredge there is only one signal from the X-coordinate command module 406 because that signal controls only the headline 184.

As the dredge hull 131 begins to rise vertically on an incoming swell from the Figure 3 position to the Figure 4 position, the conventional automatic sounding device 154 indicates the depth of water between the dredged bottom datum 153 and the dredge hull 131. This depth is transmitted by the cable 157 and the swell potentiometer 401 to the swell-and-pitch correction module 403 (Figure 9) to provide correction signals 435, 436 and 437 respectively for the Y1, Y2 and X coordinates. A forward ladder suspension control module 470 and an intermediate ladder suspension control module 500 receive respective corrected signals 441 and 442 and issue a command signal causing respective hydraulic-system solenoid valves 160 and 161 to open (see Figure 11) so that respective pistons 162 and 163 in hydraulic cylinders 162a and 163a move to the left, and respective sheaves 164, 165 move from position "D" towards position "C", thus paying out lufflines 168 and 167 to the forward and intermediate ladder suspensions 148 and 147 respectively by an amount such that the lower tumbler 143 remains at its desired digging elevation, the y coordinate. Meanwhile, a headline control module 450 (Figure 9) receives a corrected signal 440 and issues a command signal for a hydraulic-system solenoid valve 181 to open (see Figure 12), moving a piston 182 in a cylinder 182a to the right, and a sheave 183 moves from position "E" toward position "F", thus taking up on a headline 184, so that the lower tumbler 143 remains at its x digging coordinate. Thus, the x, y position of the lower tumbler 143 remains the same.

On a falling swell the sounding device 154, the transmitting swell potentiometer 401, and swell-and-pitch correction module 403 provide signals for reverse action of the compensating system, that is, the lufflines 168 and 167 are taken up and the headline 184 is paid out the required amount.

The forward and intermediate ladder suspension control modules 470 and 500 and the headline control module 450 issue commands for the compensation cylinders 162a and 163a and 182a to adjust for the variable swells.

When the vertical rise and fall of the dredge hull 131 under swell condition causes the pistons 182, 162 and 163 to approach the end of their travel in or out, limit switches 185, 186, 185a, 186a, or 185b, 186b, completing the "raise" or "lower" circuit to their

respective motors 187, 187a, 187b to pay out or take up lines 184, 168 or 167, as the case may be, over the travel capacity of the hydraulic cylinders 182a, 162a and 163a, until the control signal is removed. In the case of single headline 184, the practical travel capacity of the system is adequate for a headline travel for a related vertical motion of the dredge hull 131.

The swell signal is corrected by a suitable angle measuring device 158 (Figure 10), that measures the variable angle β between the horizontal centre line of the hull 131 and true horizontal, which, in itself, compensates for fore-and-aft hull trim under sea conditions, further insuring the desired positioning of the lower tumbler 143 at all times. This angle is transmitted to the swell-and-pitch control module 403 by the potentiometer position indication 402.

Of the command modules 403, 404 and 406 (Figures 9 and 13A) the X-coordinate command module 406 is the simplest, comprising basically a voltage-to-current converter 408 and a summing amplifier 409, as shown in Figure 13A.

The voltage-to-current converter 408 and all the other voltage-to-current converters spoken of in this specification, may be standard items. For instance, they may each be 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 milliamperes DC output. A constant current source forming part of this converter energises a remote slide wire, such as the command potentiometer 407. 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 408. Other values, of course, can be provided. The converter 408 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 409 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 milliamperes DC input signals and to provide a 10 to 50 milliamperes DC output signal that is proportional to their sum. The summing amplifier may be a solid-state unit with a two-stage magnetic amplifier connected to a suitable supply voltage. As will become apparent, 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 404 includes a voltage-to-current converter 410

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like the converter 408, which takes its input from the command potentiometer 405 and which supplies, in this instance, three current repeaters 411, 412, and 413. These current repeaters, like the others used elsewhere in the circuitry 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 to transmitters. They may be of solid-state construction throughout with a magnetic transistor amplifier. Each of them is connected to a suitable supply voltage.

The Y-coordinate command module 404 also includes two summing amplifiers 414, and 415, both connected to the current repeater 412. These summing amplifiers 414 and 415 may be standard units identical to the summing amplifier 409 already described. Each of these summing amplifiers 414 and 415 feeds its signal to a signal characterizer 416 or 417, while the current repeater 413 feeds its signal directly to a signal characterizer 418 to produce the Y3 output 443. Each of these signal characterizers 416, 417, and 418, 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 components.

The swell-and-pitch correction module 403 has two inputs, as already noted, one from the swell command potentiometer 401 operated by the sounding device 154, which feeds into a voltage-to-current converter 420, and the other from the pitch command potentiometer module 402 operated by the angle generator 158, which feeds its output to another voltage-to-current converter 421.

The voltage-to-current converter 421 feeds its current output to a current multiplier 422, which is supplied by a constant current source 423 and to another current multiplier 424, fed by a constant current source 425, to achieve two different multiplied outputs. These current multipliers may also be standard 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 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 sources 423, 425 used for these multipliers may each be a standard 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.

Thus, the current multipliers 422 and 424 are used to supply two independent products originating from the same signal. They may be supplying substantially the same product or they may be supplying a different product, depending on the setting of the current sources 423 and 425.

The swell-and-pitch correction module 403 also includes three signal characterizers 426, 427 and 428 (like the signal characterizers 416, 417, 418). It also includes a pair of summing amplifiers 430 and 431 and three current multipliers 432, 433 and 434. The current repeater 411 of the Y-coordinate command module 404 is connected to the signal characterizers 426 and 427 of the swell-and-pitch correction module 403. The current multiplier 422 and the voltage to current converter 420 are connected to the summing amplifier 430, and the voltage-to-current converter 420 is also connected to the summing amplifier 431, to which is also connected the output from the current multiplier 424. The output from the summing amplifier 430 is connected to the current multipliers 432 and 433. The signal characterizer 426 is also connected to the current multiplier 432, so that the output (or correction signal) 435 from the current multiplier 432 is proportional to the product of the multiplication of the outputs of the signal characterizer 426 and the summing amplifier 430. The summing amplifier 431 and the signal characterizer 427 are connected to a current multiplier 434, whose output or correction signal 436 is proportional to the product of those two inputs.

The current repeater 412 of the Y-coordinate command module 404 is connected to the summing amplifiers 414 and 415, and the current multiplier 434 feeds its output or correction signal 437 to the summing amplifier 415. The output from the summing amplifier 415 goes to the signal characterizer 417, which thereupon produces the Y2 output 442.

The current repeater 412 also feeds its signal to a signal characterizer 428 which feeds its output to the current multiplier 433, and the output from the current multiplier 433 is fed to the summing amplifier 409, which is otherwise fed directly by the voltage-to-cur-

rent converter 408 of the X-command module 406. This produces the signal output 440 of the X-command module 406.

5 The output 435 of current multiplier 432 is fed to the summing amplifier 414, as is the signal from the current repeater 412, and the sum of these is then fed to the signal characterizer 416 to produce the Y1 output 441.

10 What has been described so far, then results in a single output 440 from the X-command module and three outputs 441, 442 and 443 from the Y-coordinate command module, and this concludes the description of Figure 13A.

15 The output 440 from the X-coordinate command module is fed to the X-coordinate or headline control module 450. The output 440 is fed directly to a motor operated setter 451 of the control module 450 (Figure 13B). This, like the other motor operated setters to be described, may be a standard item, such as, the M-line, model C, motor operated setter made by the Leeds & Northrup Company, of Philadelphia, Pennsylvania, United States of America. This motor operated setter 25 451 tracks the signal 440 and positions a retransmitting slide wire which is a set point potentiometer 452 for a set point/auto-manual station 453, the set point potentiometer 452 being fed directly to the set point/auto-manual station 453. This, like the other set point/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 station 35 453 compares the set point potentiometer 452 with the output 454 of a position feed-back summing amplifier 455 (see Figure 13C), and the unbalance between these two signals becomes an error signal 456 that is proportional in magnitude and polarity to the unbalance.

40 The output 456 is fed directly to a position adjuster 460 (Figure 13C). 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 known as the M-line Module C control unit. These are used for electric drive units to provide precise control of process variables. They receive an error signal or input (e.g., the error signal 456 in this instance) from the set point unit 453 and, through an amplifier, energizes either a "raise relay" or a 55 "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 440 is used here as the set point, and the position feedbacks are set mechanically through position-feedback potentiometers 461 and 462.

65 The position-feedback potentiometer 461

feeds its signal to a voltage-to-current converter 463 (like the converter 408), and the position feedback potentiometer 462 feeds its signal to a voltage-to-current converter 464 of the same type. The outputs from the converters 463 and 464 are fed to the summing amplifier 455, which feeds its output 454 into the set point/auto-manual station 453 that provides the error signal 456 to the position adjuster 460. The position adjuster 460 75 has two output cables 465 and 466, the cable 465 feeding raise-lower control power to the solenoid valve 160 and a pump 188 for the compensating system hydraulic cylinder 162a, and the cable 466 feeding raise-lower control power to the motor 187 for the headline winch 189.

The output 441 from the Y-coordinate command module 404 is fed to a control module 470. The output 441 is fed directly to a motor-operated setter 471 (Figure 13A), like the motor-operated setter 451. The motor operated setter 471, tracks the signal 441 and positions a retransmitting slide wire set point potentiometer 472 feeding directly to a set point/auto-manual station 473. The set point/auto-manual station 473 compares the set point potentiometer 472, with the output 474 of a voltage-to-current converter 475, and the unbalance between these two signals becomes an error signal 476 that is proportional in magnitude and polarity to the unbalance. The output or error signal 476 is fed directly to a position adjuster 480. The control module 470 also has a position-feedback potentiometer 481 sending a signal to the voltage-to-current converter 475 which provides the base signal for the position adjuster 480, from which outputs 482 and 483 are fed to the solenoid valve 160 and pump 188a forward ladder hoist motor 187 for the winch 152.

The Y-coordinate command module 404 sends its second or Y2 signal 442 to control module 500. The output 442 is fed directly to a motor operated setter 501, which tracks the signal 442 and positions a retransmitting slide wire set point potentiometer 502, which is fed directly to a set point/auto-manual station 503. The set point/auto-manual station 503 compares the set point potentiometer 502, with the output 504 of a position feedback summing amplifier 505, and the unbalance between these two signals becomes an error signal 506 that is proportional in magnitude and polarity to the unbalance. The output or error signal 506 is fed directly to a position adjuster 510 like those previously described. The signal 442 is used as the set point signal, and the unit's position feedback is controlled by two feedback potentiometers 511 and 512, respectively feeding voltage-to-current converters 513 and 514, the outputs of which are added by the summing amplifier 505. The outputs 515 and 516 130

from the position adjuster 510 is then used to control the solenoid valve 161 and hydraulic pump 188b and the intermediate ladder hoist motor 187b for the winch 151.

5 The third output signal from the Y-coordinate command module 404 is the signal 443, which is fed to control module 520. Here again, the output 443 is fed directly to a motor operated setter 521 which tracks the
10 signal 443, and positions a retransmitting slide wire set point potentiometer 522. The set point potentiometer 552, is fed directly to a set point/auto-manual station 523 which compares the set point potentiometer 522,
15 with the output 524 of a voltage-to-current converter 525, and the unbalance between these two signals becomes the error signal 526 that is proportional in magnitude and polarity to the unbalance and is fed directly
20 to a position adjuster 530. The position feedback is set by a feedback potentiometer 531 feeding its signal to the voltage-to-current converter 525. A single output 532 from the position adjuster 530 is connected to the after
25 ladder hoist motor 190 for the winch 150.

As shown in Figures 9 and 11, each of the three ladder suspensions shown in Figure 11 receives feedback from its command potentiometers, each of which is related to
30 the position of the devices controlled thereby. Thus, the control module 470 for the forward ladder 135 receives feedback from its position-indicating potentiometer 481 that is located adjacent a pulley 191 for the suspension line 148. The intermediate control
35 module 500 for the ladder 134 receives feedback from the potentiometer 511 that indicates the position of the travelling sheave 165 and from the potentiometer 512 that indicates the position of the winch drum 151. The control module 520 for the after ladder
40 133 receives feedback from its potentiometer 531 that indicates the position of the winch drum 150.

45 Similarly, as shown in Figure 9 and 12, the command module 450 for the headline 184 receives feedback from the command potentiometer 461 indicating the position of the travelling sheave 183 and from the
50 potentiometer 462 indicating the position of the winch drum 189.

In operation, the command signal for the Y-coordinate command module 404, provided by the potentiometer 405, which is calibrated
55 in feet, is adjusted by the dredge winchman. The slidewire energisation signal built into the voltage-to-current converter 410 provides the energisation for the potentiometer 405; and the output signal of the voltage-to-current
60 converter 410 drives the three current repeaters 411, 412 and 413. The output from the current repeater 411 drives the two signal characterizers 426 and 427 in the swell-and-pitch correction module 403. The output
65 from the current repeater 412 drives the two

summing amplifiers 414 and 415; and the signal characterizer 428 in the swell-and-pitch correction module 403. The output of the current repeater 413 drives the signal characterizer 418, whose output signal 443 is the
70 Y3 output 443 used to drive the after ladder suspension control module 520.

The two summing amplifiers 414 and 415 provide the sum of Y plus Y1' and Y2'. Their output drives the signal characterizers
75 416 and 417 which respectively provide the Y1 and Y2 output signals 441 and 442 that drive the forward and intermediate ladder suspension control modules 470 and 500 respectively.
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The X-coordinate command module 406 input signal is fed to the voltage-to-current converter 408 and from there to the summing
85 amplifier 409, whose other input signal comes from the swell-and-pitch correction module 403, and the output 440 therefrom drives the headline control module 450.

The swell-and-pitch correction module 403 receives four signals; first and second are from the respective current repeaters 411 and
90 412 of the Y-coordinate command module 404; third, the pitch from the potentiometer 402 that is positioned by the angle indicator 158; and fourth, the swell from the potentiometer 401 which is positioned by the sounding device 154. The pitch signal is proportional to the tangent of angle β , and is sent to the two multiplier amplifiers 422 and
95 424. The second input of each of the multiplier amplifiers 422 and 424 is the constant signal provided respectively, by the two current sources 423 and 425 which represent one leg of a triangle. The outputs of the two multiplier amplifiers 422 and 424 are equal
100 to the Y1' and Y2' pitch component, and these two components are inputs to their respective summing amplifiers 430 and 431.

The swell signal from the voltage-to-current converter 420 is proportional to the vertical distance that the bottom of the dredge
110 hull 131 lies above the trough of the swell, and this signal is the other input to the two summing amplifiers 430 and 431. The output of the summing amplifiers 430 and 431 are the values of the swell pitch components Y1' and Y2'. The swell pitch components, outputs of the summing amplifiers 430 and 431 are corrected according to the depth the dredge
115 is digging by the multiplier amplifiers 432 and 434, whose second inputs are from the signal characterizers 426 and 427 which are driven by a "Y" coordinate signal. The outputs 435 and 436 of the multiplier amplifiers 432 and 434 are then equal to the required
120 Y1' and Y2' coordinate corrections, which are inputs to the Y-coordinate command module 404.

The X' coordinate is computed by the Y1' output from the summing amplifier 430 as one input to multiplier amplifier 433, and
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the second input is the output from the signal characterizer 428, which is driven by a "Y" coordinate signal. The output 437 of X' coordinate multiplier amplifier 433 is the correction input to the X-coordinate command module 406.

The swell and pitch signal may be adjusted and calibrated so that the final output signals 440, 441, 442, and 443 are all positive.

The set point of the position adjuster 480 is adjusted by the input signal 441 from the Y-coordinate command module 404. This set point signal 441 is balanced against the actual feedback signal 474 from the potentiometer 481 and the voltage to current converter 475, which represent the actual Y-coordinate of the lower tumbler 143. The resultant error signal 476, proportional to the deviation and direction of the lower tumbler 143 from the set point, is transmitted to the position adjuster 480. The output of the position adjuster 480 is contact closure of one of the relays 484 and 485. The relay 484 is energised when the value is greater than the set point; the relay 485 is energised when the value is less than the set point. Positioning of the lower tumbler 143 is accomplished by closing either the "raise" relay 485 or the "lower" relay 484 to energise the compensating hydraulic system valve 160 and the ladder hoist motor 187a if the hydraulic cylinder reaches maximum travel to the position called for by the control unit 470. At this "balanced" position, neither relay 484 nor 485 is closed. The position controller 480 has auto, manual "raise" and manual "lower" pushbuttons; deviation and position meters; and adjustable proportion reset and rate actions.

The intermediate ladder suspension and the headline control modules 500 and 450 are similar to the forward ladder suspension control module 470 except for the feedback position signals, which come from the travelling sheave 165 and the hoist drum 151. The hydraulic cylinder feedback potentiometer 511 feeds the voltage-to-current converter 513; and the winch drum potentiometer 512 feeds the voltage-to-current converter 514, and these output signals from the converters 513 and 514 are added in their respective summing amplifier 505. The output of the summing amplifier 505 is the position feedback signal 504 to the respective set point/auto-manual station 503. Similarly, the position of the sheave 183 is noted by the potentiometer 461, and the position of the winch drum 189 is noted by the potentiometer 462, and their signals are summed and reported to the set point/auto-manual station 453.

The after ladder suspension control module 520 is simpler than the forward ladder suspension control module 470. The control "raise" or "lower" signal energises the ladder

hoist motor 190 only, and the position feedback signal is from the potentiometer 531 for the winch drum 150.

For raising the ladder above water for maintenance and repairs to the lower tumbler 143, bucket idlers, or idlers, bucket line, etc., or for other reasons, manual control of the ladder hoists and headline winch is employed, with the automatic compensating systems cut out.

The sea dredge of Figures 5—8, employing two lower articulated ladder sections 174 and 175 have suspension systems with analogous compensating arrangements. For this particular example of a deep digging sea dredge, swells up to about twenty feet can be compensated for.

Figure 14 shows a dredge 250 having a hull 251, a superstructure 252, two articulated ladder sections 253 and 254, and a fixed ladder section 255. In this instance, the fixed ladder section 255 is not arranged to support the same bucket line as the ladder sections 253 and 254; instead the dredged material is transferred from a lower bucket line 256 that did the digging to an upper bucket line 257 on the upper fixed ladder section 255. The lower bucket line 256 thus drops its load, as it rounds its upper tumbler 258, into the lower bucket line 257 which is coming up from its lower tumbler 259. The load is then carried over the upper tumbler 260 of the upper bucket line 257 and spilled into a rotating screen 261, or other suitable treatment or receiving device.

The combination in Figure 14 of two independent tandem bucket line systems 256 and 257 employing a fixed ladder section 255 for the upper bucket line 257 has the following additional advantages:

(1) the upper tumbler 258 for the digging bucket line 256 and its drive are at a lower elevation, thus materially shortening the length of the digging bucket line 256;

(2) the upper or second-stage ladder section 255 is not subjected to a long bucket line dead load nor to digging loads, therefore it can be of relatively light construction throughout;

(3) the dredge 250 can have a lower vertical centre of gravity, since the upper tumbler 258 for the digging bucket line 256 and its drive machinery can be located at a substantially lower height than for a conventional single bucket line system;

(4) further contributing to a lower centre of gravity and favourable economics is the lighter superstructure 252 required for carrying the relatively light dead and live loads of the second-stage elevating system 255.

Figures 15 to 20 show some important details of a dredge like those of Figures 5 and 7 in having a fixed upper ramp section

173 of the ladder, with a ladder section 174 pivoted below it and articulated to a lower ladder section 175. An upper tumbler 270 is secured to a shaft 271, on which is mounted a pair of pinion gears 272, 273 that are driven by pinion gears 274, 275 to drive the upper tumbler and thereby the bucket line 280, which is not shown in Figures 15—19. The fixed ramp 173 supports a plurality of rollers 276, as do the articulated ladder sections 174 and 175 over which the bucket line 280 moves. The upper end of the ramp 173 includes a frame section 277 that diverges out beyond the bucket line 280 and is secured to both the superstructure 278 and the hull of the floating dredge. The pivot shaft 179 supported by the superstructure 278 and independent of the fixed ramp 173 supports the clevised upper end 281 of the upper section 174 of the articulated portion of the ladder; similarly, the lower end of the upper section 174 supports the shaft 178 on which the clevised upper end 282 of the lower section 175 of the articulated ladder is pivotally supported. The shafts 178 and 179 may, as an option, carry flanged guide rollers 283 and 284, and there is a lower tumbler 285 at the lower end of the ladder portion 175.

Figure 18 also shows an alternate form of lower ladder end 279 wherein the top surface 289 of the ladder end 279 is cambered, while the bottom surface 292 is straight. This feature provides (1) for several additional feet of digging depth, as compared with a conventionally shaped ladder end in a ladder of the same overall length, and (2) for additional clearance between the bottom surface 292 of the ladder end 279 and the under-run buckets aft of the lower tumbler 285, — a desirable feature when digging on a hard bottom where the under-run buckets tend to rub on the bottom surface of the ladder end near the lower tumbler, thereby causing wear and damage to both the buckets and the underside of the ladder end.

Figure 20 shows one important effect of the use of the fixed ramp 173. This is its assurance that the bucket line 280 engages and leaves the upper tumbler 270 at the same angle — tangent at all times to the pitch circle of the upper tumbler 270. The same view shows another advantage that can be used: the bucket line 280, in conjunction with a deck bucket idler 286 is able to maintain a constant minimum clearance distance between the discharging bucket lips 287 and the receiving chute lip 288 for all the vertical positions of the digging ladder, thus reducing to a minimum the spillage and loss of the dredged material. Further, a plurality of generally vertical inclined grizzly bars 290 may be used in conjunction with a save-all chute 291 to recover additional dredged material not received by the chute 288. Further for reasons that dredge designers will

appreciate, the receiving chute 288 location is facilitated by the introduction of a fixed ramp 173, in that the height of both the upper tumbler and receiving chute can be raised, by the introduction of a fixed ramp without increasing the swingable ladder length, to improve the efficiency of the gravity flow system of the treatment plant and/or to place the plant tailings further astern of the dredge via the tail sluices shown as 80 and 125 respectively in Figures 1 and 2.

The articulated ladder with the fixed-ramp upper ladder section 173 may be used for either inland waters or sea dredges, thus enabling the bucket line 280 to lead at all times tangent to the pitch circle of the upper tumbler 270, which is coaxial with the upper tumbler shaft 271. This very desirable feature has not been heretofore satisfactorily attainable, especially in the case of sea dredges. Moreover, none of the digging forces that act on the lower tumbler 285 pass beyond the upper end pivot connection 179 of the suspended swingable ladder section 174; thus pivot connection is structurally independent of the fixed ramp upper ladder section 173, so that the upper tumbler 220 and the drive machinery are positively protected from all digging forces. In conjunction with the deck bucket idler 286, a constant minimum clearance distance is maintained between the discharging bucket lips 287 and the receiving chute lip 288 for all vertical positions of the diffing ladder 174, 175, thereby reducing spillage and loss of dredged material to the minimum, and even this is salvaged by the grizzly bars 290 and save-all chute 291.

Another significant feature of the foregoing arrangement is that the swingable ladder can be lowered to a greater angle of inclination. Thus, additional digging depth can be had with a given length of swingable ladder; this has not been possible with the conventional dredges hitherto available.

Figure 25 shows a dredge 320 having a hull 321 and superstructure 322 supporting a fixed upper ladder ramp 323 and a single swingable ladder section 324, carrying a bucket line 325. There is an upper tumbler 326 at the top of the ramp 323 and a lower tumbler 327 at the lower end of the swingable ladder section 324. A suspension system 328 enables the raising and the lowering of the ladder section 324. The structure has some of the advantages just described, in comparison with conventional dredges, though it lacks many of the advantages of the system of Figure 5. This dredge may be used for either inland waters or in the sea, but cannot be provided with the swell compensation system previously described, due to not having a multiple-section swingable ladder.

Figures 21 to 24 show a modified form of ladder suspension system having improved lateral stability. Instead of the suspension

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lines being parallel they are inclined to each other, though 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 coplanar but converge together from their upper pulley blocks 307, 308 to a structure 310 supporting lower pulleys 311 and 312. The structure 310 is secured to the ladder section 301 by suspension rods 313 and 314. As shown in Figure 21, the angle at which the lines 305 and 306 converge widens as the lines are shortened and the structure 310 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.

Attention is drawn to our co-pending Patent Application No. 57849/73 (Serial No. 1359829) which describes and claims a floating deep-digging dredge having a swell 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 and a dredge ladder which is provided with excavating means operative at a lower end of the ladder and which is connected to suspension means of adjustable length supported by superstructure on the hull, in which dredge: the ladder has a plurality of ladder sections including a swingable ladder section pivotally supported at its upper end by the superstructure for relative swinging movement in a vertical plane only; the excavating means comprises an endless digging bucket line supported by the ladder and extending on both top and bottom sides of the ladder, such bucket line passing around an upper driving tumbler and a lower tumbler; and the suspension means comprises a block-and-tackle suspension connected to the lower end of the swingable ladder section to support such swingable section, which means for a cable of the block-and-tackle suspension being provided for adjusting the length of the suspension.

2. A dredge according to claim 1, wherein the ladder includes a plurality of swingable sections pivoted together.

3. A dredge according to claim 2, includ-

ing an upper swingable ladder section having a main pivot adjacent its upper end supported by the superstructure on the hull, and a lower swingable ladder section pivoted to the section above it and having the lower tumbler for the digging bucket line at its lower extremity, the suspension means comprising a plurality of block-and-tackle suspensions each connected to the lower end of a respective swingable ladder section.

4. A dredge according to claim 3, wherein the upper tumbler for the digging bucket line is supported on a shaft that is supported by the superstructure and the upper swingable ladder section is pivoted on the shaft, so that its pivot is coaxial with the axis of the upper tumbler.

5. A dredge according to claim 3, wherein the upper tumbler for the digging bucket line is supported by the superstructure and the upper swingable ladder section is pivoted about a point below the upper tumbler on a pivot supported by the superstructure.

6. A dredge according to claim 3, wherein the ladder has a fixed uppermost section supported by the superstructure, the superstructure also supporting the upper tumbler for the digging bucket line, and the upper swingable ladder section is pivoted on the superstructure below and independent from the fixed uppermost section for swinging movement relative to the fixed section.

7. A dredge according to claim 3, wherein the lower swingable ladder section has a clevised upper end with clevis arms supporting a shaft, a lower end of the ladder section above the lower swingable section lying between the clevis arms and being pivotally mounted on the shaft.

8. A dredge according to claim 7, including a bucket line guide roller supported on the shaft at the clevised end of the lower swingable ladder section, the digging bucket line meeting and leaving the guide roller tangent thereto.

9. A dredge according to any one of claims 3 to 8, wherein the lower swingable ladder section has its lower end provided with a straight lower surface and a cambered upper surface.

10. A dredge according to any one of claims 3 to 9, wherein the lower end of the swingable lower ladder section is suspended by two sets of block-and-tackle suspensions lying in the same plane but inclined to each other at acute angles symmetrical about the centre line of the dredge and of the ladder.

11. A dredge according to claim 1, including: a fixed uppermost ladder portion supported by the superstructure on the hull; a swingable ladder portion comprising at least one swingable section and being pivoted at its upper end to the superstructure by a pivot which is supported independently of the fixed ladder portion and is offset from its axis, the

lines being parallel they are inclined to each other, though 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 coplanar but converge together from their upper pulley blocks 307, 308 to a structure 310 supporting lower pulleys 311 and 312. The structure 310 is secured to the ladder section 301 by suspension rods 313 and 314. As shown in Figure 21, the angle at which the lines 305 and 306 converge widens as the lines are shortened and the structure 310 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.

Attention is drawn to our co-pending Patent Application No. 57849/73 (Serial No. 1359829) which describes and claims a floating deep-digging dredge having a swell 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 and a dredge ladder which is provided with excavating means operative at a lower end of the ladder and which is connected to suspension means of adjustable length supported by superstructure on the hull, in which dredge: the ladder has a plurality of ladder sections including a swingable ladder section pivotally supported at its upper end by the superstructure for relative swinging movement in a vertical plane only; the excavating means comprises an endless digging bucket line supported by the ladder and extending on both top and bottom sides of the ladder, such bucket line passing around an upper driving tumbler and a lower tumbler; and the suspension means comprises a block-and-tackle suspension connected to the lower end of the swingable ladder section to support such swingable section, winch means for a cable of the block-and-tackle suspension being provided for adjusting the length of the suspension.

2. A dredge according to claim 1, wherein the ladder includes a plurality of swingable sections pivoted together.

3. A dredge according to claim 2, includ-

ing an upper swingable ladder section having a main pivot adjacent its upper end supported by the superstructure on the hull, and a lower swingable ladder section pivoted to the section above it and having the lower tumbler for the digging bucket line at its lower extremity, the suspension means comprising a plurality of block-and-tackle suspensions each connected to the lower end of a respective swingable ladder section.

4. A dredge according to claim 3, wherein the upper tumbler for the digging bucket line is supported on a shaft that is supported by the superstructure and the upper swingable ladder section is pivoted on the shaft, so that its pivot is coaxial with the axis of the upper tumbler.

5. A dredge according to claim 3, wherein the upper tumbler for the digging bucket line is supported by the superstructure and the upper swingable ladder section is pivoted about a point below the upper tumbler on a pivot supported by the superstructure.

6. A dredge according to claim 3, wherein the ladder has a fixed uppermost section supported by the superstructure, the superstructure also supporting the upper tumbler for the digging bucket line, and the upper swingable ladder section is pivoted on the superstructure below and independent from the fixed uppermost section for swinging movement relative to the fixed section.

7. A dredge according to claim 3, wherein the lower swingable ladder section has a clevised upper end with clevis arms supporting a shaft, a lower end of the ladder section above the lower swingable section lying between the clevis arms and being pivotally mounted on the shaft.

8. A dredge according to claim 7, including a bucket line guide roller supported on the shaft at the clevised end of the lower swingable ladder section, the digging bucket line meeting and leaving the guide roller tangent thereto.

9. A dredge according to any one of claims 3 to 8, wherein the lower swingable ladder section has its lower end provided with a straight lower surface and a cambered upper surface.

10. A dredge according to any one of claims 3 to 9, wherein the lower end of the swingable lower ladder section is suspended by two sets of block-and-tackle suspensions lying in the same plane but inclined to each other at acute angles symmetrical about the centre line of the dredge and of the ladder.

11. A dredge according to claim 1, including: a fixed uppermost ladder portion supported by the superstructure on the hull; a swingable ladder portion comprising at least one swingable section and being pivoted at its upper end to the superstructure by a pivot which is supported independently of the fixed ladder portion and is offset from its axis, the



- upper tumbler for the digging bucket line being supported by the superstructure coaxial with the pivot of the swingable ladder portion and the lower tumbler being carried at the lower end of the swingable ladder portion; a continuous transfer and delivery bucket line supported by the fixed ladder portion, to which the digging bucket line transfers its load as it passes over the upper tumbler; and means for receiving the load from the transfer and delivery bucket line as it passes over the top of the fixed ladder section, at a constant angle.
12. A dredge according to claim 11, wherein the means for receiving includes inclined grizzly bars and a secondary receiving chute.
13. A dredge according to claim 11 or 12, wherein the swingable ladder portion includes an upper swingable ladder section pivoted at its upper end to the superstructure on the hull and a lower swingable ladder section pivoted to the section above it and having the lower tumbler for the digging bucket line at its lower extremity, the suspension means comprising a plurality of block-and-tackle suspensions each connected to the lower end of a respective swingable ladder section.
14. A dredge according to any one of claims 3 to 10 and 13, wherein there are two swingable ladder sections pivoted to each other, the upper ladder section being pivoted at its upper end to the superstructure.
15. A dredge according to any one of claims 3 to 10 and 13, wherein there are at least three swingable ladder sections successively pivoted to each other as well as being pivoted to the superstructure at the upper end of the upper section thereof.
16. A dredge according to any one of claims 2 to 10 and 13 to 15, including means for controlling the suspension lengths of the ladder and accommodating it to swells in the water level on which the hull floats to keep the position of the digging bucket line relative to the dredging face substantially constant.
17. A dredge according to any one of claims 3 to 10 and 13 to 15, 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, control means receiving the depth signal and the angle signal means and controlling the suspension length of at least the lower swingable ladder section and accommodating it to swells in the water level on which the hull floats.
18. A dredge according to claim 17, including a headline extending from shore or sea bottom to the dredge, a headline winch for varying the length of the headline, and a control circuit actuated by the control means for controlling the instantaneous length of the headline during swells.
19. A dredge according to claim 17, wherein the depth signal generating means comprises a first command potentiometer actuated by the sounding means, the angle signal generating means comprises a second command potentiometer actuated by the angle sensing means, the winch means comprising a separate luffline winch for each of the suspensions, a headline extending from shore or sea bottom to the dredge, a headline winch for varying the length of the headline, a third command potentiometer for setting a nominal position of the headline winch, additional command potentiometers, one for setting a nominal position for each of the luffline winches, control means connected to all of the command potentiometers and transmitting the settings of the third and additional command potentiometers 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 potentiometers, so that the nominal positions of the headline winch and the luffline winches are kept changing to actual positions varying from the nominal positions by amounts such as are needed to keep the position of the digging bucket line substantially constant.
20. A dredge according to claim 19, wherein some of the lufflines have associated with them respective hydraulic cylinders and pistons, the pistons being connected to a translatable sheave, the control means also determining both a nominal position and actual positions for the piston, as determined by the superposition of the command signals.
21. A dredge according to claim 20, having a feedback potentiometer for each winch and each hydraulic piston to provide a base signal at the nominal position thereof, the control means correcting said base signal by an error signal obtained from the first and second command potentiometers.
22. A dredge according to claim 1, including: a fixed uppermost ladder section supported by the superstructure on the hull; a single swingable ladder section pivotally supported by the superstructure adjacent the



- lower end of the fixed section and in alignment therewith, the upper tumbler for the digging bucket line being supported by the superstructure at the top of the fixed ladder section and the lower tumbler for the digging bucket line being carried at the lower extremity of the swingable ladder section.
- 5 23. Dredges substantially as hereinbefore described with reference to, and as illustrated
- 10 in, the accompanying drawings.

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