

[54] **THROTTLE-REVERSER CONTROL SYSTEM FOR WATER JET PROPELLED SEACRAFT**

[75] Inventor: **Francis C. Ashleman**, Seattle, Wash.

[73] Assignee: **The Boeing Company**, Seattle, Wash.

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[51] Int. Cl.² **F02K 1/20**; B63H 11/10

[58] Field of Search 60/221, 222, 230; 114/66.5 H, 151; 115/11, 12 R, 14; 239/265.19; 244/230; 318/588

[56] **References Cited**

UNITED STATES PATENTS

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Primary Examiner—Trygve M. Blix
Assistant Examiner—Stephen G. Kunin
Attorney, Agent, or Firm—Brown, Murray, Flick & Peckman

[57] **ABSTRACT**

A control system for water jet ship propulsion apparatus of the type having reverser bucket apparatus which is selectively and controllably movable into the path of a driving jet to reverse the thrust of the jet. The invention is characterized in the use of plural potentiometers connected to a single control throttle, one of the potentiometers acting to control the driving engine for the propulsion apparatus and the other acting to control the position of the reverser bucket apparatus. Both potentiometers employ shorted sections such that the driving engine will run at idle speed on either side of a neutral setting while the reverser bucket apparatus is moved from a fully-retracted to a fully extended position for reverse thrust. Once the reverser bucket apparatus reaches one of its two extreme positions, engine speed can be increased with increased thrust. In the engine idle region, reverser bucket modulation of the jet stream can be effected to give forward and reverse boat speed control at the engine idle setting.

6 Claims, 6 Drawing Figures

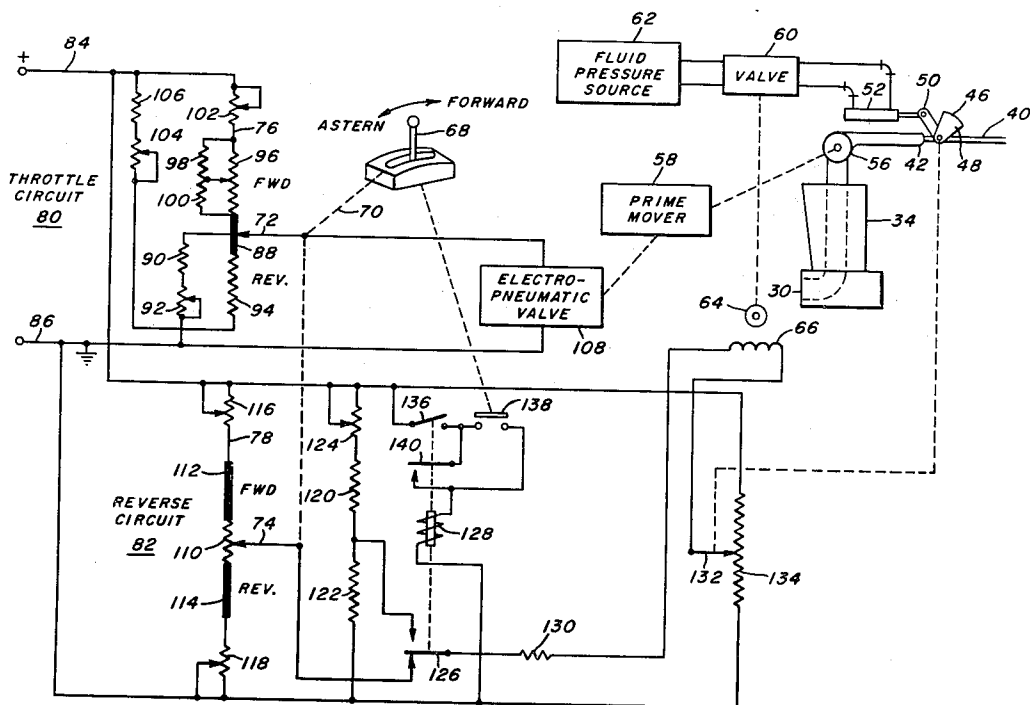


FIG. 1.

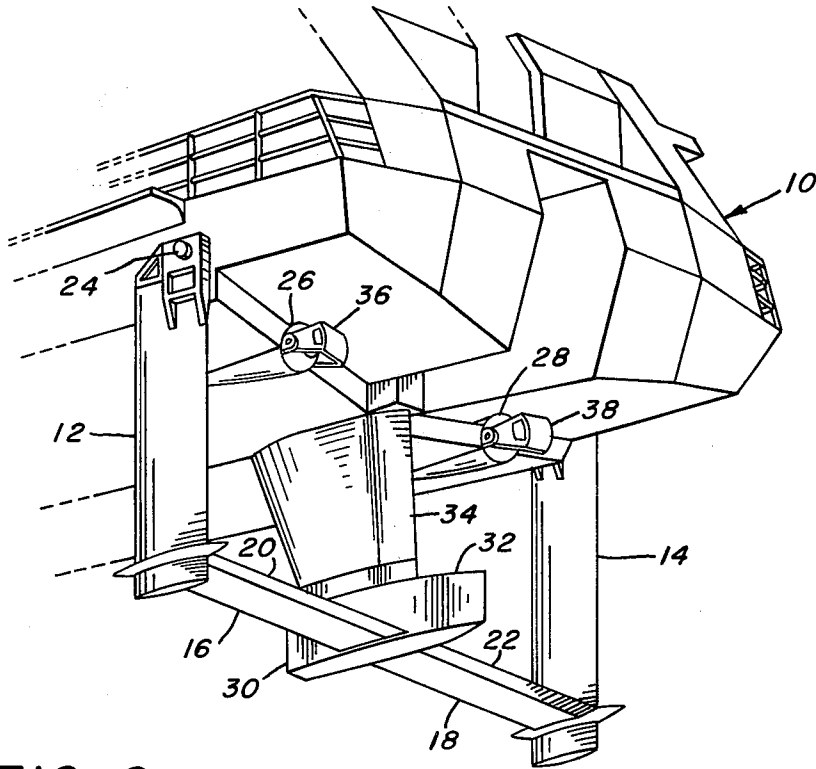


FIG. 2.

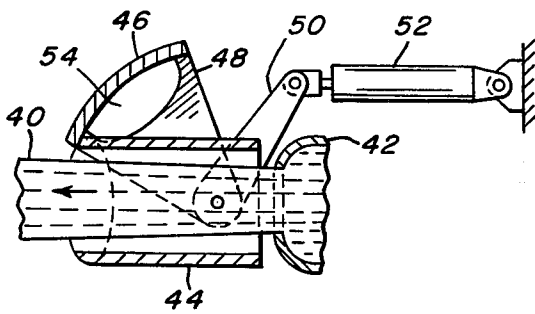


FIG. 3.

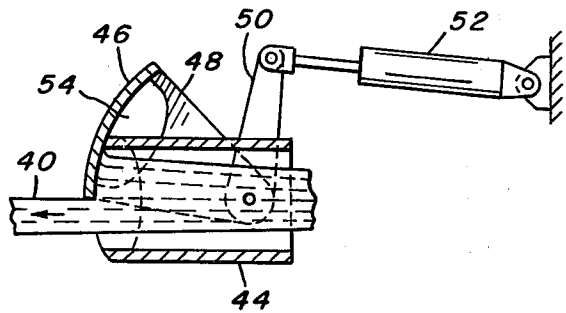


FIG. 4.

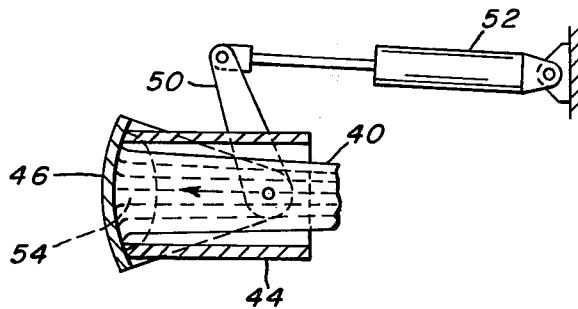
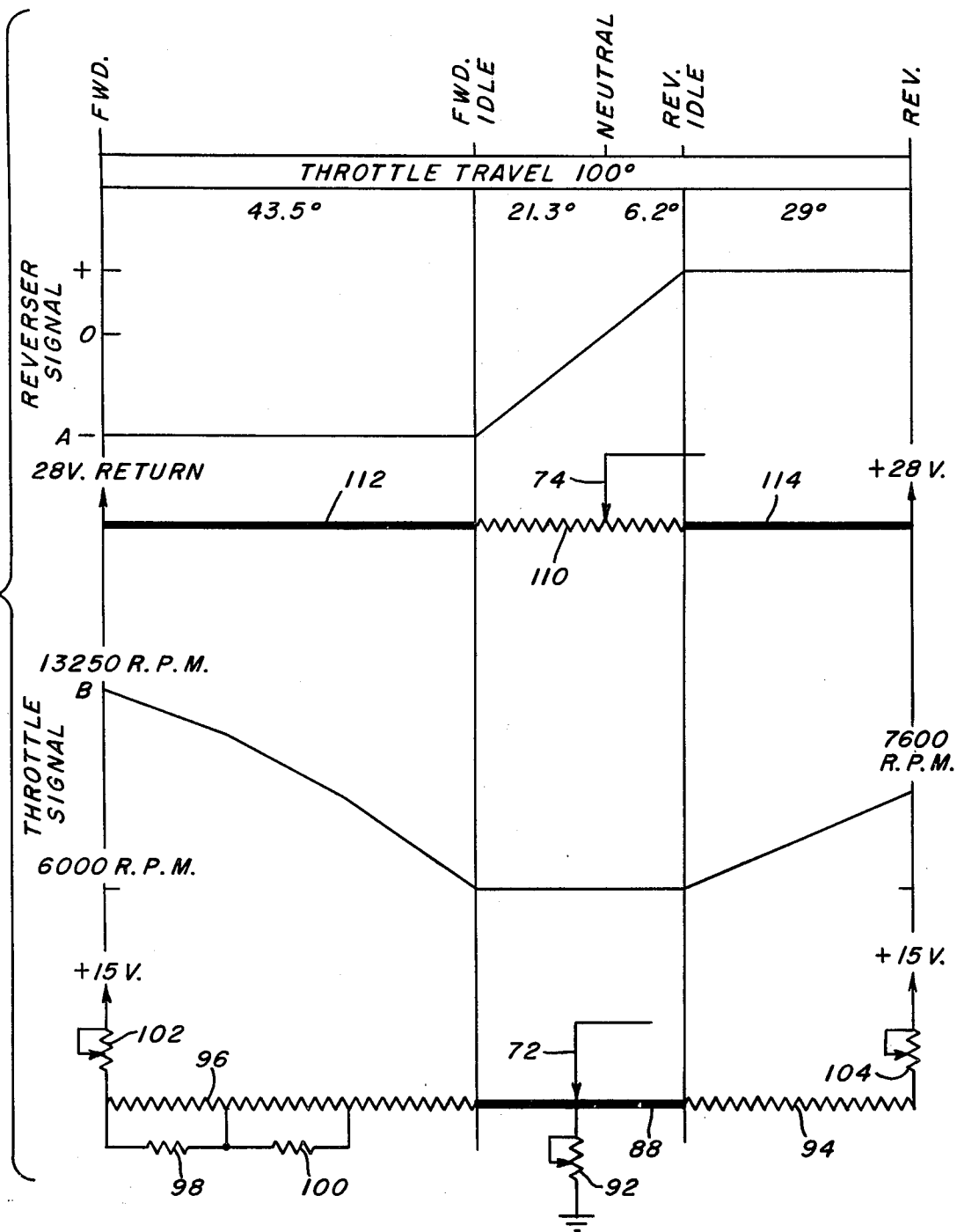


FIG. 6.



THROTTLE-REVERSER CONTROL SYSTEM FOR WATER JET PROPELLED SEACRAFT

BACKGROUND OF THE INVENTION

The present invention is particularly adapted for use in a water jet propulsion system for seacraft, particularly hydrofoil ships. In a propulsion system of this type, water is scooped up from a body of water traversed by the ship, energy is added to the water by means of a pumping element driven by an engine, the water is discharged in the form of a driving jet to propel the ship, and reverser bucket means is provided to selectively and controllably move into the path of travel of the driving jet to reverse the thrust of the ship. The jet is normally discharged above the water line so as to reduce back pressure.

In a propulsion system of this type, it is necessary to provide a throttle control which, among other things, has a neutral setting which positions the reverser bucket in the jet stream to give a zero net thrust. Additionally, an engine idle region should be provided which will allow bucket modulation of the jet stream to give forward and reverse boat speed control at the engine idle setting, this being normally for docking and the like purposes. However, it is also desirable to provide a neutral hold feature which will allow throttle advance without bucket deployment for the purpose of engine testing and start-up procedures. A control of the type described above can be implemented with solid-state electronic systems; however these are complex and excessively costly.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided control means for the driving engine and reverser bucket means of a water jet ship propulsion system which, instead of using expensive solid-state electronic controls, utilizes special potentiometers with shorted sections, along with a minimum of circuit components to achieve the requirements set out above.

Specifically, there is provided first means including an electrically operated valve means for controlling the speed of an engine driving a pumping element of the water jet system, together with second means including electrically operated valve means for controlling movement of the reverser bucket means into the path of travel of the driving jet. The system includes a throttle having neutral, forward and reverse positions together with first and second potentiometers having wiper elements operatively connected to the throttle. The first potentiometer is provided with a shorted central section on either side of the neutral position of the wiper and is connected to the first means for controlling the speed of the engine whereby the engine will idle at the neutral position and at regions on either side of neutral. The wiper element of the second potentiometer is provided with shorted sections on either side of a central, resistive section whereby, as the throttle moves through the regions on either side of neutral where the engine is idling, the reverser bucket means will move from a fully retracted position for forward thrust to a fully extended position for reverse thrust. Under the circumstances, movement of the reverser bucket with the engine idling modulates the jet stream to give forward and reverse boat speed control at the engine idle setting.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings which form a part of this specification, and in which:

FIG. 1 is a perspective aft view of the stern portion of a hydrofoil craft incorporating a water jet propulsion system and with which the control system of the present invention may be used;

FIGS. 2, 3 and 4 are side views showing the manner in which the reverser bucket means of the propulsion system may be moved from a fully-retracted position to a fully-extended position wherein the entirety of a jet stream is deflected backwardly;

FIG. 5 is a schematic circuit diagram of the control system of the invention; and

FIG. 6 schematically illustrates the operation of the invention.

With reference now to the drawings, and particularly to FIG. 1, there is shown the aft portion of a hydrofoil 10 having downwardly-depending struts 12 and 14 interconnected at their lower ends by means of foils 16 and 18. The foils have control surfaces 20 and 22, respectively, at their trailing edges. At the bow of the craft, not shown, is a third downwardly depending strut which acts as a rudder and which carries at its lower end a foil. A more complete description of the hydrofoil craft itself can be had, for example, by reference to U.S. Pat. No. 3,745,969, issued July 17, 1973. The struts 12 and 14 and the foils carried thereby can be rotated upwardly into a retracted position about a pivot point 24.

The present invention is concerned with the propulsion means for the hydrofoil craft. Propulsion is obtained by means of jet streams of water passing out of nozzles 26 and 28 on either side of the craft. Water is scooped from the sea through an opening 30 at the forward end of a foil section 32 and is then directed upwardly through a center column 34 to port and starboard pumps, not shown, driven by port and starboard prime movers such as jet engines. From the pumps, the water is then discharged through the nozzles 26 and 28 which propel the craft forwardly. In order to obtain reverse motion of the craft, reverser bucket devices 36 and 38 are provided for each of the nozzles 26 and 28. For forward motion of the craft, the bucket assemblies 36 and 38 are rotated into positions where they do not intersect the issuing jet stream. However, by rotating the bucket assemblies 36 and 38 into the jet stream, the jet is deflected backwardly to thereby obtain reverse thrust.

The operation of the reverser bucket assemblies is perhaps best shown in FIGS. 2, 3 and 4. The water jet, indicated by the reference numeral 40, issues from a nozzle 42 and passes through a cylindrical member 44 which can be tilted upwardly or downwardly to deflect the jet stream. However, the manner in which this is accomplished will not be described herein. The reverser bucket means itself comprises a dished or curved member 46 pivotally connected to a support member, not shown, by means of side arms 48 which are, in turn, connected through a linkage 50 to the piston of a pneumatic or hydraulic cylinder 52. Provided in one side of the dished portion 46 is an opening 54, the arrangement being such that as the dished portion 46 is moved downwardly by pressurization of cylinder 52, more and more of the dished portion 46 will intersect the jet stream as shown in FIGS. 3 and 4. As it does intersect

the jet stream, the water is propelled to the side and backwardly out through the opening 54, thereby creating a reverse thrust for the craft.

The propulsion control system of the invention is shown in FIG. 5 wherein elements corresponding to those of FIGS. 1-4 are identified by like reference numerals. As was explained above, water is scooped through opening 30 (also identified in FIG. 1) and then passes upwardly through the center column 34 to a pump 56 driven by a prime mover 58, such as a jet engine. From the pump 56, the water is driven through the nozzle 42, thereby creating the jet stream 40 which can be intersected by the dish-shaped reverser member 46 to deflect the stream backwardly. Member 46, in turn, is carried on side members 48 connected through the linkage 50 to the piston rod of cylinder 52. It will be understood, of course, that in an actual installation there are two jets and accompanying propulsion means, only one being shown in FIG. 5.

Opposite ends of the cylinder 52, in turn, are connected through valve 60 to a source 62 of fluid under pressure. The valve 60 is adapted to connect the source of fluid under pressure to either end of the cylinder 52 such that rotation of the dished member 46 can be in either direction, depending upon the position of the valve. The valve 60, in turn, is controlled by means of an electrical actuator 64 provided with a control winding 66. The actuator 64 is such that when the voltage at the opposite ends of the winding 66 is the same, then the actuator 64 will stop. However, when the voltage becomes unbalanced, the actuator will turn in one direction or the other to move the valve 60 until the voltages are again equal.

Manual control for the craft is by way of a throttle 68 which may be moved in one direction for forward movement of the craft and in the reverse direction for astern movement. The throttle 68 is connected through a mechanical linkage 70 to the wiper elements 72 and 74 of potentiometers 76 and 78, respectively. The potentiometer 76 is included in the throttle circuit 80; while the potentiometer 78 is part of a reverser circuit 82.

Both ends of the potentiometer 76 are connected to the positive terminal 84 of a source of direct current voltage, not shown; while opposite ends of the potentiometer 78 are connected to the opposite terminals 84 and 86 of the same source of direct current potential. The potentiometer 76 includes a central shorted section 88 whose center point is connected through a resistor 90 and an idle trimming pot 92 to the terminal 86. On one side of the shorted section 88 of potentiometer 76 is a reverse resistive section 94; and on the other side of the shorted section 88 is a forward resistive section 96, this being shorted by means of resistors 98 and 100 for a purpose which will be hereinafter described. The upper end of the forward resistive section 96 is connected through a forward trim pot 102 to the terminal 84; while the lower end of the reverse resistive section 94 is connected through a reverse trim pot 104 and resistor 106 to the same terminal 84.

With the wiper element 72 in the shorted sector or idle position shown, the resistance of the potentiometer and resistances 90 and 92 make a voltage divider. As a result, with the throttle 68 in its shorted sector or idle position, current will flow from the wiper element 72 to an electropneumatic valve 108 back to the terminal 86 to establish an idle speed for the prime mover 58 which can be set by resistor 92. Furthermore, as the throttle is

moved in either the astern or forward direction from its dead center or null position, its idle speed will persist for a period by virtue of the shorted section 88. However, as the wiper element 72 moves beyond the shorted section 88 in either direction, the voltage across the electropneumatic valve 108 will be increased to increase the speed of the prime mover 58 and, hence, the thrust imparted by the water jet 40.

Since the wiper element 74 on potentiometer 78 is also connected to the mechanical linkage 70, the two wiper elements 72 and 74 will move in unison. However, when the wiper element 74 is at the central or idle region, it contacts a resistive section 110 which is bounded on either side by shorted sections 112 and 114. The sections 112 and 114 are connected through trimming pots 116, 118, respectively, to the positive and negative terminals 84 and 86 of the direct current voltage source.

In shunt with the potentiometer 78 is a second voltage divider comprising equal resistors 120 and 122 in series with a trimming pot 124. The midpoint between resistors 120 and 122 is adapted to be connected through contacts 126 of relay 128 and resistor 130 to one side of the control winding 66 for the servo device 64. Ordinarily, however, the relay 128 will be deenergized such that the movable tap 74 of potentiometer 78 is connected through resistor 130 to the winding 66. The other side of the winding 66 is connected to a moveable tap 132 on potentiometer 134 connected between the positive and negative terminals 84 and 86. It can be seen, therefore, that as the tap moves back and forth on the resistive section 110, the servo device 84 will move the valve 60 while the tap 132, mechanically connected to the linkage 50, moves in a like amount until the bridge circuit is again balanced and the servo device 64 stops.

The system includes a neutral hold feature comprising a manually-operable switch 136 and a switch 138 connected to the throttle 68 and which is closed when the throttle is in its neutral position. Assuming that switches 136 and 138 are closed, relay 128 will become energized and will remain energized until manual switch 136 is opened by virtue of holding contacts 140. At the same time, energization of relay 128 acts to connect the midpoint of resistors 120 and 122 to the control winding 66 such that the position of the servo 64 is maintained at the neutral setting by the position of the tap on pot 124.

The operation of the invention can perhaps best be understood by reference to FIG. 6 which shows the throttle travel limits and the relation of the two throttle-coupled potentiometers and their signal output requirements as a function of throttle lever position. Waveform A in FIG. 6 illustrates the signal appearing on the tap 74 of the reverser potentiometer 78; whereas waveform B represents the signal on the tap 72 of potentiometer 76. The taps 74 and 72 are shown in their neutral positions in FIG. 6.

As tap 72 moves to the right or left of its central or neutral position, and assuming that it still contacts the shorted section 88, the output signal from the tap shown by waveform B remains constant with the prime mover rotating the pump 56 at a speed of 6,000 revolutions per minute. However, as the tap 72 moves beyond the shorted section 88 in either the reverse or forward direction, the resistive section 96 or 94 is contacted whereby the output signal (waveform B) increases. In the case of reverse thrust, the output signal increases to

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the point where the engine or prime mover 58 rotates at a speed of 7,600 revolutions per minute; whereas in the forward direction, it advances until the prime mover rotates at a speed of 13,250 revolutions per minute. The shunts 98 and 100 are utilized to linearize the throttle relationship as the tap 72 moves along the resistive section 96.

At the same time that tap 72 is moving back and forth, the tap 74 is also moving as explained above. However, in contrast to the throttle signal, the reverser signal increases from a negative value on the forward side of neutral to a positive value. In this process, the reverser bucket means is moved from a fully retracted position such as that shown in FIG. 2 to a fully extended position such as that shown in FIG. 4 wherein the jet stream is fully deflected for reverse thrust. In-between the fully-retracted and fully-extended positions, the engine is idling at a speed of 6,000 revolutions per minute; while the position of the bucket can be adjusted to give forward and reverse boat speed control. When switch 136 is closed and the throttle 68 is at its neutral position, relay 128 will be energized whereby the position of the reverser bucket will be fixed as determined by the pot 124. Under these circumstances, the throttle can be advanced in either the forward or reverse direction without altering the position of the reverser bucket which allows for engine testing and start-up.

Although the invention has been shown in connection with a certain specific embodiment, it will be readily apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention.

I claim as my invention:

1. In a ship propulsion system of the type in which water is scooped from a body of water traversed by the ship, energy is added to the water by means of a pumping element driven by an engine, the water is discharged in the form of a driving jet to propel the ship, and reverser bucket means is provided to selectively and controllably move into the path of travel of the driving jet to reverse the thrust of the ship; the improvement in control means for side driving engine and reverser bucket means comprising:

first means including electrically operated valve means for controlling the speed of said engine and the amount of energy added to the water by said pumping element;

second means including electrically operated valve means for controlling movement of said reverser bucket means into the path of travel of said driving jet;

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a throttle having neutral, forward and reverse positions;

first potentiometer means having a wiper element operatively connected to said throttle and having a shorted central section on either side of the neutral position of said wiper and connected to the first means for controlling the speed of said engine whereby the engine will idle at the neutral position and in regions on either side of neutral; and

second potentiometer means having a wiper element operatively connected to said throttle for controlling the position of said reverser bucket means and having shorted sections on either side of a central resistive section whereby, as said throttle moves through said regions on either side of neutral, the reverser bucket means will move from a fully retracted position for forward thrust to a fully extended position for reverse thrust.

2. The improvement of claim 1 including a source of direct current potential connected to said first and second potentiometer means, means connecting said first means for controlling between the wiper element on said first potentiometer means and one terminal of said direct current voltage source, and means connecting said second means for controlling between the wiper element on said second potentiometer means and a point on a voltage divider connected between the opposite terminals of said direct current voltage source.

3. The improvement of claim 2 wherein opposite ends of said first potentiometer means are connected to one terminal of said source of direct current potential and the midpoint of said central shorted section of the first potentiometer means is connected to the other terminal of the direct current potential source, the opposite ends of the second potentiometer means being connected to the respective opposite terminals of said direct current potential source.

4. The improvement of claim 3 including resistors in shunt with resistive regions on one side of the shorted central section of the first potentiometer means to linearize the response of said throttle.

5. The improvement of claim 1 wherein said first and second potentiometer means are of essentially the same length and said wiper elements of the respective potentiometer means are connected to said throttle to move in unison.

6. The improvement of claim 2 including a voltage divider connected in shunt with said second potentiometer means, and means for selectively disconnecting said wiper element on the second potentiometer means from said second means for controlling and for connecting a point on said second potentiometer means to said second means for controlling, whereby the position of said reverser bucket means will be fixed.

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