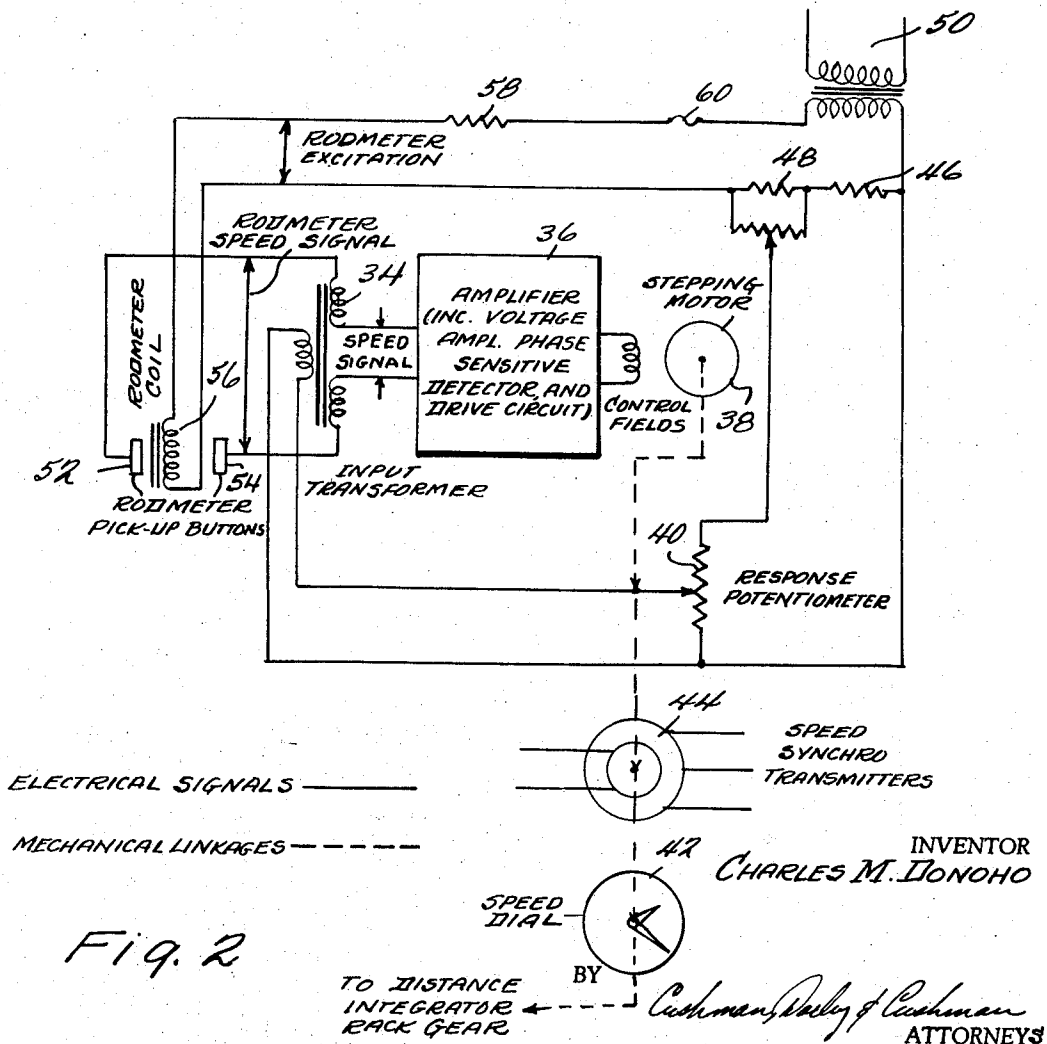
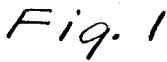


3,362,220

8 Sheets-Sheet 1



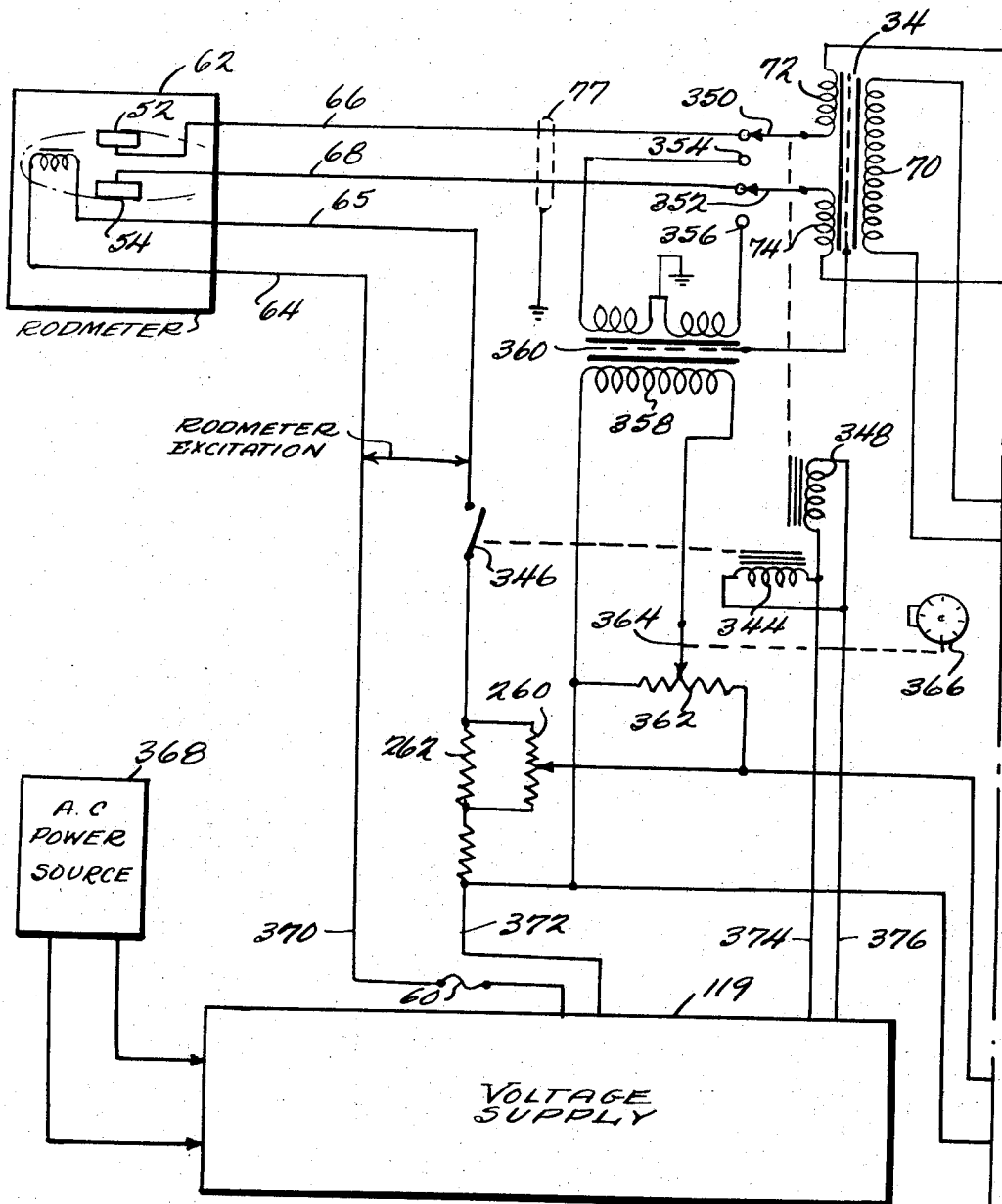
Jan. 9, 1968

C. M. DONOHO
ELECTROMAGNETIC LOG

3,362,220

Filed May 28, 1965

8 Sheets-Sheet 2



INVENTOR
CHARLES M. DONOHO

Fig. 3a

BY
Cushman, Kenney & Cushman
ATTORNEYS

Jan. 9, 1968

C. M. DONOHO
ELECTROMAGNETIC LOG

3,362,220

Filed May 28, 1965

8 Sheets-Sheet 3

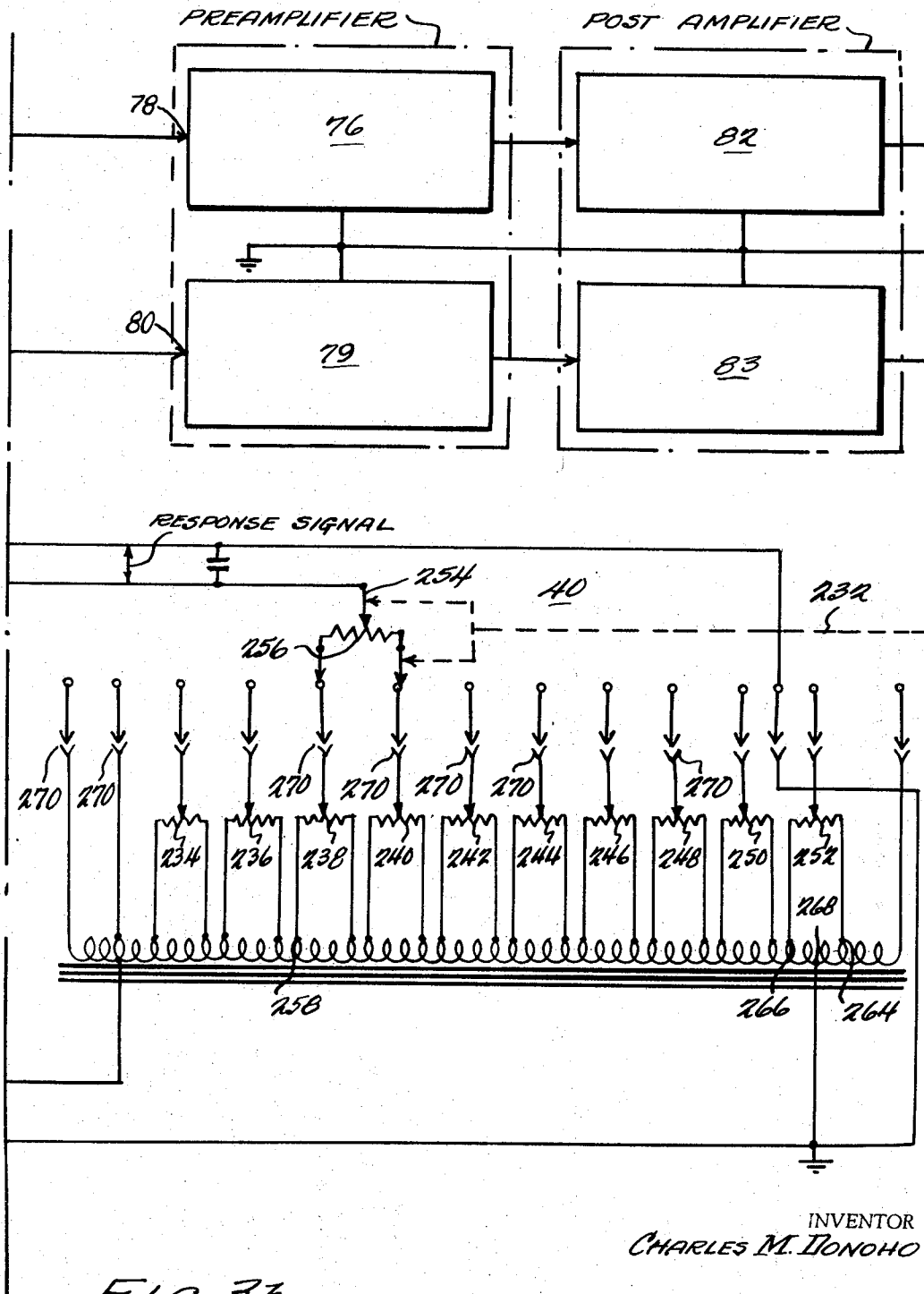


Fig. 3b

INVENTOR
CHARLES M. DONOHO

BY
Cushman, Darby & Cushman
ATTORNEYS

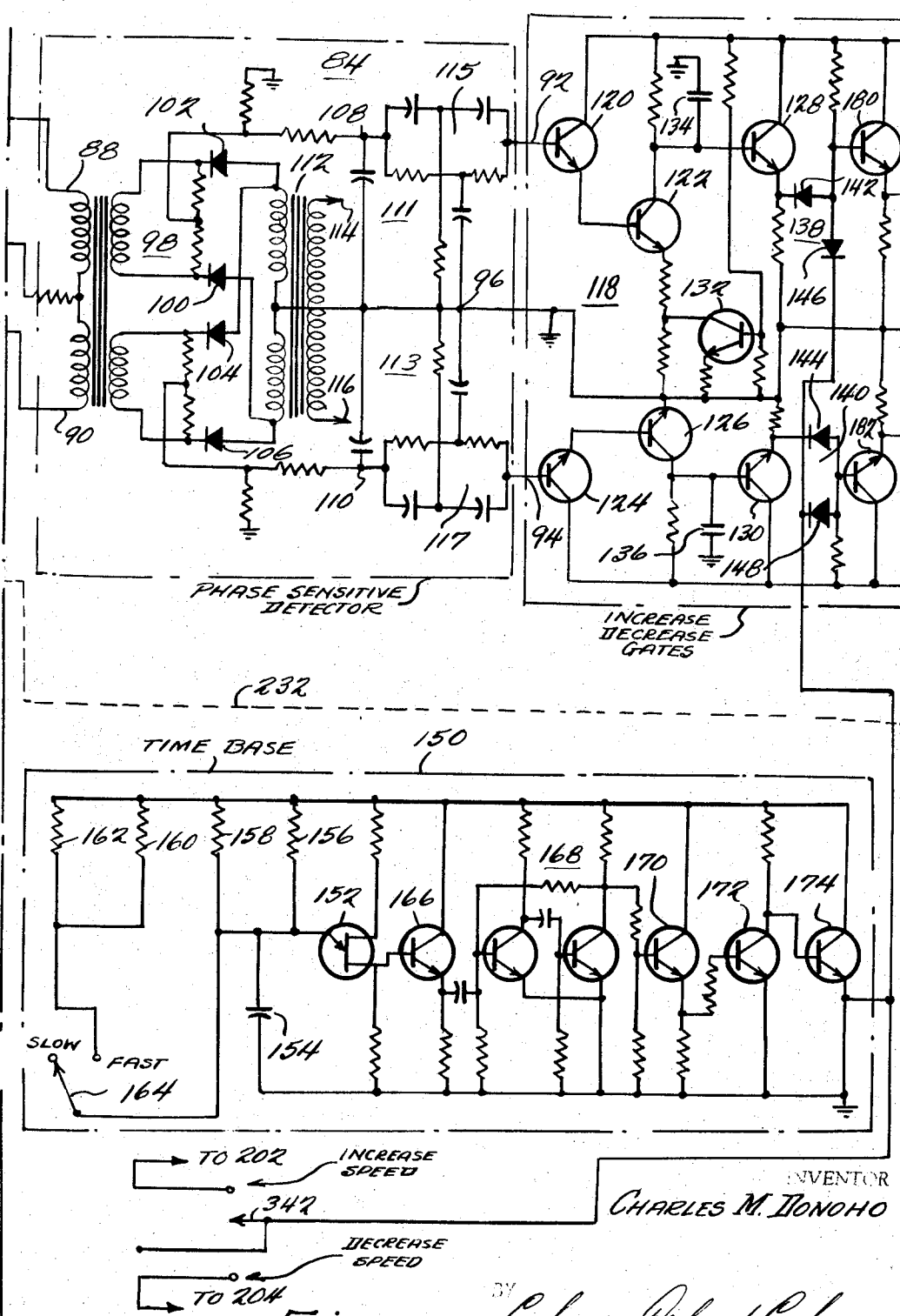
Jan. 9, 1968

C. M. DONOHO
ELECTROMAGNETIC LOG

3,362,220

Filed May 28, 1965

8 Sheets-Sheet 4



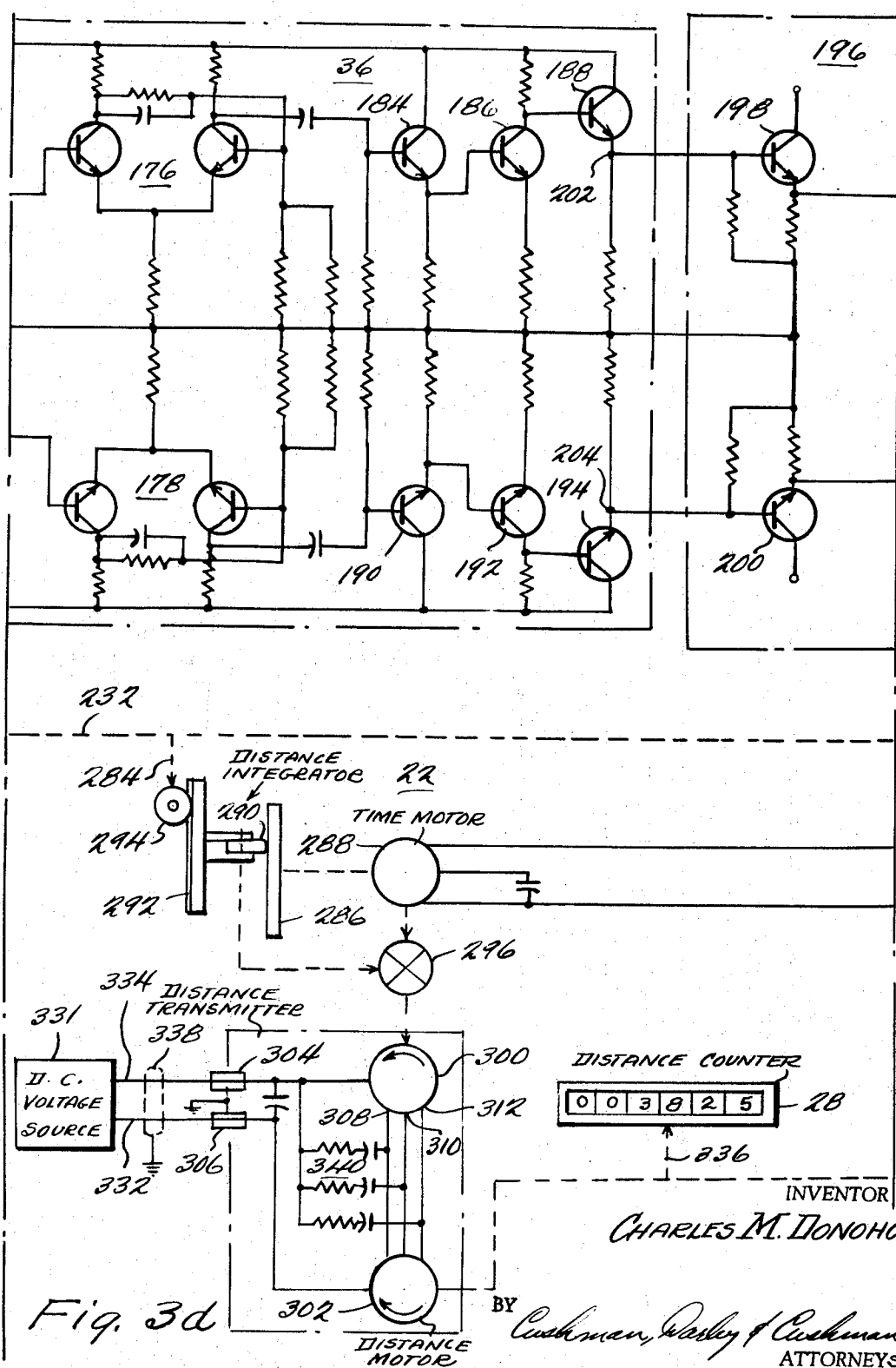
Jan. 9, 1968

C. M. DONOHO
ELECTROMAGNETIC LOG

3,362,220

Filed May 28, 1965

8 Sheets-Sheet 5



Jan. 9, 1968

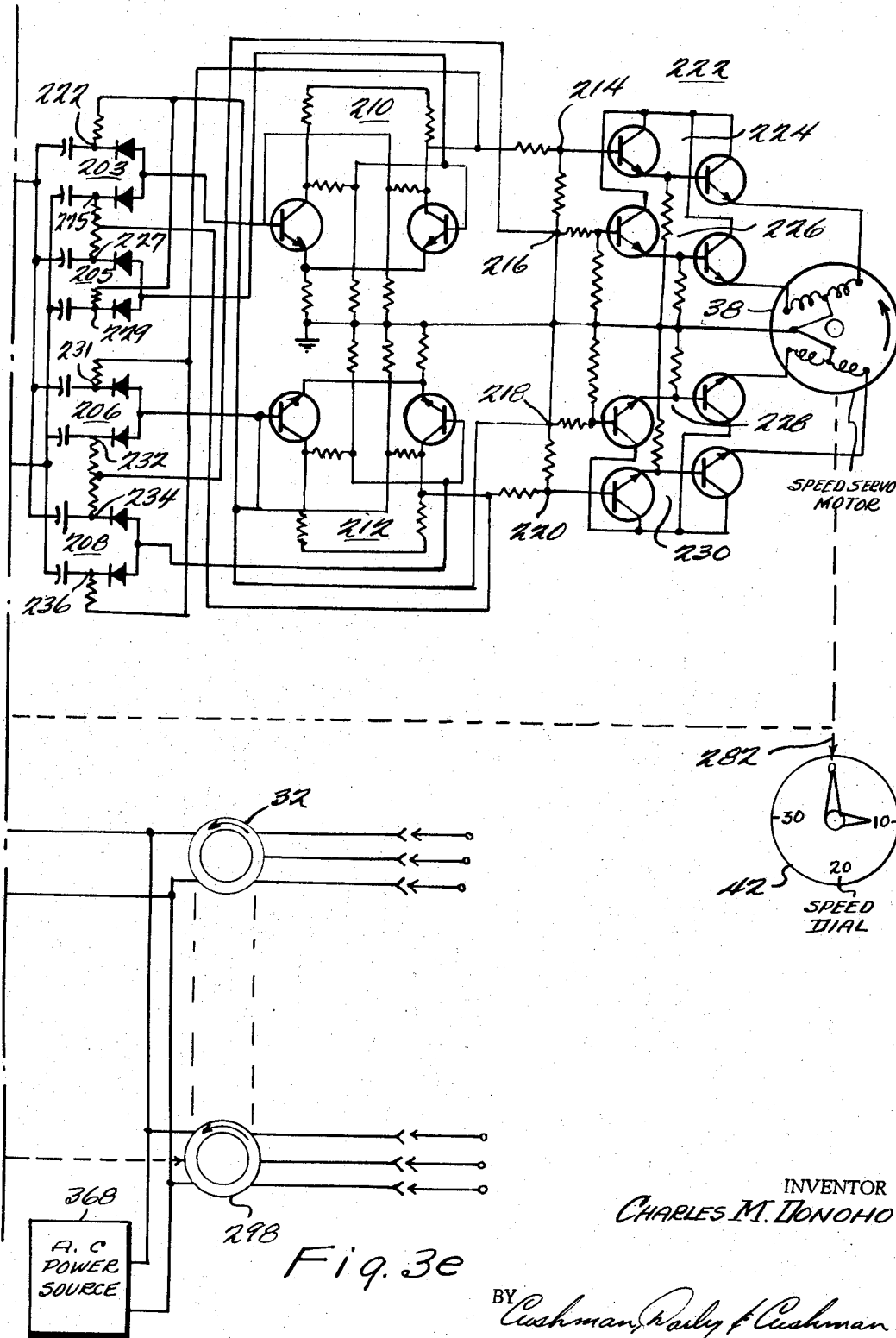
C. M. DONOHO

3,362,220

ELECTROMAGNETIC LOG

Filed May 28, 1965

8 Sheets-Sheet 6



Jan. 9, 1968

C. M. DONOHO
ELECTROMAGNETIC LOG

3,362,220

Filed May 28, 1965

8 Sheets-Sheet 7

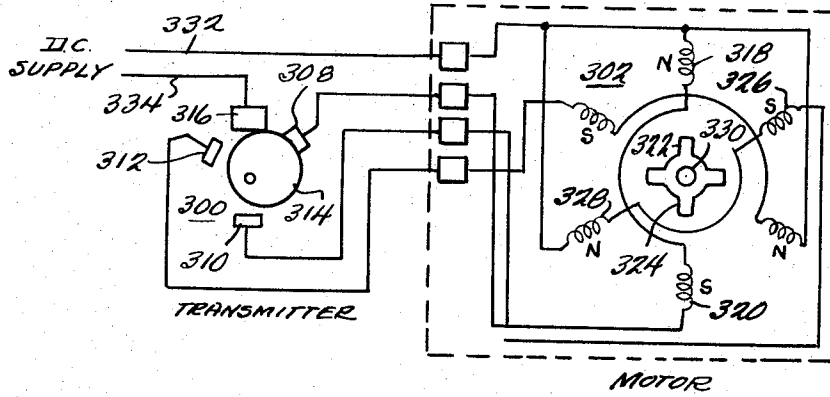


Fig. 6

<u>STEPPING SEQUENCE</u>				
LOGIC TERMINALS	214	216	218	220
1	C	O	C	O
2	O	C	C	O
3	O	C	O	C
4	C	O	O	C
5	C	O	C	O

Fig. 4

INVENTOR
CHARLES M. DONOHO

BY *Cushman, Dooling & Cushman*
ATTORNEYS

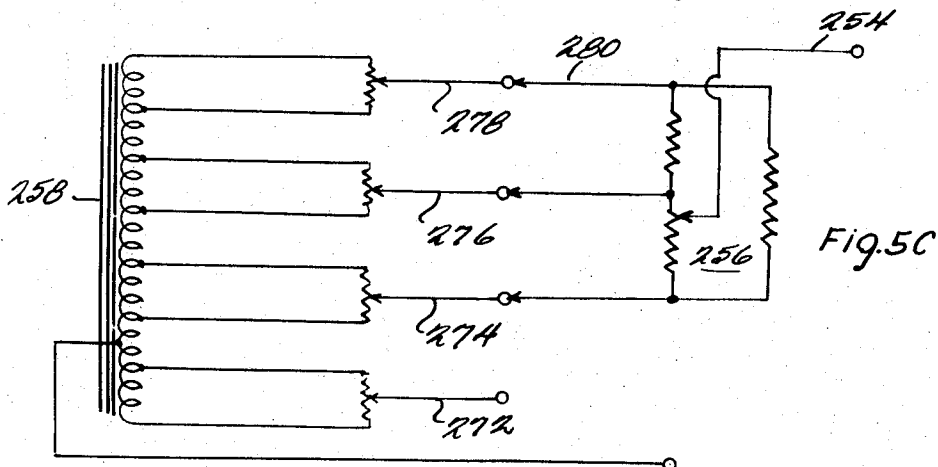
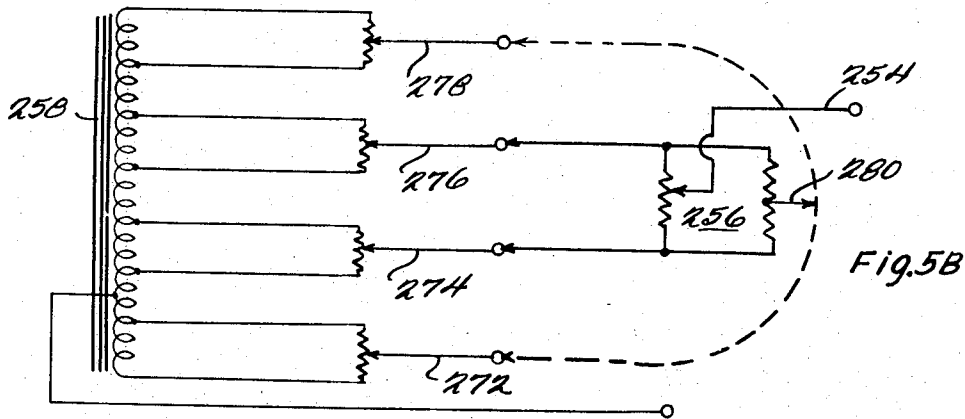
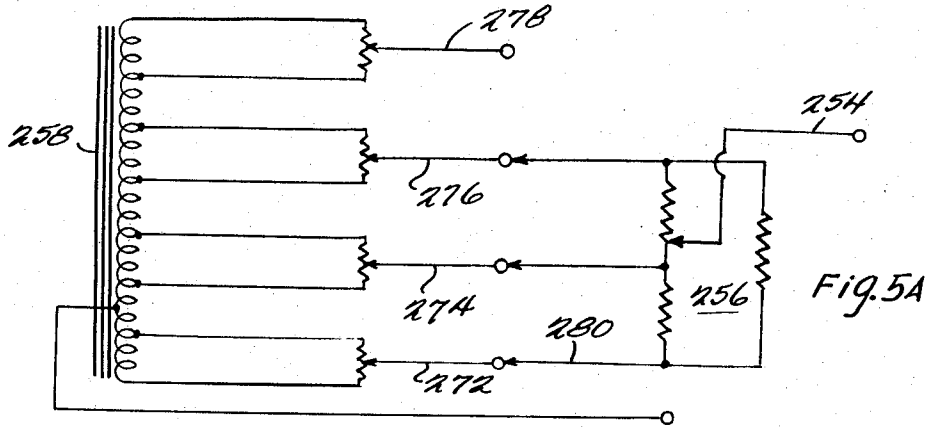
Jan. 9, 1968

C. M. DONOHO
ELECTROMAGNETIC LOG

3,362,220

Filed May 28, 1965

8 Sheets-Sheet 8



INVENTOR
CHARLES M. DONOHO

BY
Cushman, Pardy & Cushman
ATTORNEYS

United States Patent Office

3,362,220

Patented Jan. 9, 1968

1

3,362,220

ELECTROMAGNETIC LOG

Charles M. Donoho, Shadyside, Md., assignor to Chesapeake Instrument Corporation, Shadyside, Md.

Filed May 28, 1965, Ser. No. 459,716

15 Claims. (Cl. 73—181)

This invention relates in general to apparatus which measures the velocity of a ship by sensing the velocity of the water with respect to the hull, and the apparatus necessary for accomplishing the measurement of the velocity; and in particular, this invention relates to improved circuitry for more economically determining the velocity of a ship by operating on a sense signal derived from measuring the velocity of the water past the hull of the ship.

The invention also relates to apparatus for conveniently setting an estimated speed into the speed indicating apparatus whenever it is not possible or desirable to obtain the speed indications from measuring the velocity of the water with respect to the hull of the ship. This invention also relates to improved means for providing a test signal to the speed indicating apparatus for trouble-shooting purposes. Further, the invention relates to improved apparatus for indicating the distance traveled by the ship.

A prior art device for determining ship velocity, as described in the United States Patent to Soller et al., 3,114,260, granted on Dec. 17, 1963, employs continuously operating servo motors to control the devices which indicate the speed and distance traveled by the ship. Since continuously operating servo motors are employed, this necessitates a large amount of gearing between the servo motors and the devices driven therefrom because, in order for the servo motors to generate sufficient torque to drive these devices, the servo motors have to be operated at relatively high r.p.m.'s—for example, 400 r.p.m. Further, because the servo motors are of the continuously operating type, this means that the gearing between the servos and the control devices is continuously operating and therefore being subjected to constant wear. Further, the speed indicating devices are continuously moving about the null setting of the servo and therefore providing a distracting indication of the ship's velocity and also introducing undesirable noise level.

Another problem posed by the prior art arises because vacuum tubes are employed throughout the electronic portion of the speed determining mechanism. In order to eliminate the costs, heating requirements, weight, and reliability problems associated with vacuum tubes, the present invention has been completely transistorized. Normally, this changeover from vacuum tubes to transistors poses no particular problem. However, due to the fact that a very small signal is detected at the sensing buttons at the hull of the ship, and due to the fact that this signal must be amplified by a very large amount in order for it to be utilized by the speed determining mechanism, special problems have been introduced by transistorizing the speed determining apparatus which have been overcome in the present invention and which will be described in more detail hereinafter.

Further, there has been no provision in the prior art devices for conveniently providing operators at locations remote from the speed determining mechanism with the capability of inserting an estimated speed into the speed determining mechanism whenever it is deemed desirable to do so.

It is an object of this invention to provide apparatus for determining the speed of a ship in response to a signal generated from a sensor outside the hull of the ship, where said apparatus has no continuously operating servo motors, thereby reducing the amount of wear and decreasing the amount of maintenance of the apparatus.

2

It is another object of this invention to provide a completely transistorized ship speed determining apparatus which may be employed in conjunction with devices which measure the flow rate of water past the hull of a ship.

It is another object of this invention to provide improved means for remotely inserting an estimated speed into a ship speed indicating device whenever the normal means for providing a speed indication is disabled.

It is another object of this invention to provide means for conveniently providing a test signal to the speed determining apparatus whenever it is desired to do so.

It is another object of this invention to provide improved means for calibrating the speed determining apparatus.

It is another object of this invention to provide means for controlling speed and distance indicating devices by applying positive torque to these devices at all times with a minimum of gearing therebetween.

It is another object to provide a quietly operating speed determining apparatus.

It is another object of this invention to provide means for controlling speed and distance indicating devices where said means does not continuously operate, thereby eliminating an undesirable and distracting jitter into the speed indication setting.

A brief description of the invention for accomplishing the above-mentioned objects will now be given. The speed determining apparatus employs a sensing means (known as a rodmeter) which is located outside the hull of the ship and which measures the velocity of the water with respect to the hull of the ship and therefore provides an indication of the ship's velocity. Rodmeters are well known in the art and have been described in the above-mentioned patent and also in the patent to Snyder et al. 2,969,673, granted Jan. 31, 1961. Basically, these devices, in response to the flow of water by them, generate an electrical sense signal the magnitude of which is representative of the velocity of the water with respect to the ship, or conversely, the velocity of the ship with respect to the water. Once the electrical signal has been generated, it is fed to a voltage comparison device where it is compared with a reference or response signal. If there is a difference in magnitude between the reference signal and the sense signal, a servo-type device is driven which (1) changes the setting of a speed-indicating device to conform the speed indication with the magnitude of the sense signal and controls other devices which are responsive to the servo-type device and (2) changes the magnitude of the reference signal to eliminate the difference in magnitude between the sense signal and the reference signal.

In the present invention, the servo-type device employed is a stepping motor, which is capable of providing positive torque to the devices which it controls without the necessity of employing gearing means between the stepping motor and the devices controlled thereby. Electrical circuitry is also provided for supplying the proper arrangement of input pulses to the stepping motor to drive it in accordance with the requirements of the system. Means are also provided for providing a fast and slow response to the speed determining apparatus to changes in the ship's movement with respect to the water by varying the rate that the input pulses are applied to the stepping motor.

Also, improved means are provided for calibrating the device which delivers the response signal at discrete intervals of ship speed where each speed may be calibrated independently of any other speed. This device is known as an interpolating potentiometer and it consists of a series of commutator bars which correspond to the increments of speed of the ship. Calibrating potentiometers are connected to the commutator bars and these

enable the discrete and independent calibration of the means for developing the reference signal.

A stepping motor is also employed in the apparatus for determining the distance traveled by the ship. Generally, this stepping motor is responsive to a chopped DC voltage. The stepping motor in turn controls a synchro through positive action torque for controlling remotely located distance indicators. The stepping motor then controls the setting of a distance indicator.

Pushbutton controls are also employed to remotely insert a speed setting into the speed indicator in the absence of a speed indication from the rodmeter. This pushbutton provides a connection from the above-mentioned source of pulses to the stepping motor which controls the speed indicating device; and therefore, this device will change the setting of the speed indicator until the pushbutton is released.

Other objects and many of the attendant advantages of this invention will be readily appreciated when the same is considered in connection with the accompanying drawing in which like reference numerals designate like parts throughout the figures thereof and wherein;

FIGURE 1 shows an illustrative embodiment of the invention and environment in which it operates;

FIGURE 2 broadly shows an illustrative embodiment of the speed servo shown in FIGURE 1;

FIGURE 3 is a combination block and schematic diagram of an illustrative embodiment of the invention, where FIGURE 3 comprises FIGURES 3A, 3B, 3C, 3D and 3E, each of these figures being an extension to the right of the figure alphabetically preceding it;

FIGURE 4 is a table illustrating the various patterns of output pulses from the logic circuit illustrated in FIGURE 3;

FIGURES 5A, 5B and 5C illustrate the various positions of the interpolating potentiometer, shown in FIGURE 3, as it switches from one speed range to another; and

FIGURE 6 illustrates diagrammatically the stepping transmitter and stepping motor used in the distance servo as shown in FIGURE 3.

Reference should now be made to FIGURE 1 which shows generally the entire system for measuring the speed of a ship and the distance it has traveled. Mechanical connections are shown by dotted lines and electrical connections are shown by solid lines. The ship 10 has a rodmeter 12 inserted below its hull. The rodmeter is shown blown up at 14. The rodmeter generates an electrical signal the magnitude of which is proportional to the speed of the ship. This electrical signal is transferred to speed servo or speed determining apparatus 16. The mechanical connections from the speed servo 16 control a speed indicating device or dial 18, the short hand of which may go through a full revolution for each 40 knots of the ship and the long hand of which may go through a full revolution for each knot of the ship. The speed servo 16 also controls a distance indicating apparatus or means generally indicated at 20 which comprises an integrator 22, a time motor 24, a distance servo 26 and a counter (preferably miles counter) 28. The mechanical output from the distance servo 26 also controls one or more synchro transmitters 30 which, in turn, control distance indicating devices remote from the speed servo 16. The speed servo 16 also controls one or more speed indicating devices remote from the servo through synchro transmitters 32.

Reference should now be made to FIGURE 2 which is a combination block and schematic diagram of the speed servo 16 described with respect to FIGURE 1. Electrical connections are shown by solid lines and mechanical connections are shown by dotted lines. The speed servo 16 functions to translate the signal voltage from the rodmeter into a mechanical angular output which drives an indicating dial and synchro transmitters and the dis-

tance indicating device. The angular output is proportional to the ship's speed.

The important functional components of the speed servo, as shown in FIGURE 2, are:

- (1) The input (or mixing) transformer 34;
- (2) The amplifier 36 (including a voltage amplifier, phase sensitive detector and drive circuits);
- (3) The motor 38, which is preferably a stepping motor and is responsive to input pulses to achieve its stepping action; and
- (4) The response potentiometer 40.

The input transformer 34 receives two input signals—(1) the signal from the rodmeter or the sense signal and (2) the signal from the response potentiometer 40 or response or reference signal. The response signal is an electrical indication of the present position of the stepping motor output. It is initially produced by the voltage drop across the resistors 46 and 48 in the rodmeter coil supply 50. The magnitude of the response voltage is adjusted by the response potentiometer 40, whose wiper contact is driven through gearing by the stepping motor 38.

The amplifier 36 consists of a pre-amplifier, post-amplifier, phase sensitive detector, increase-decrease gates, logic circuitry and drive circuitry. These will be described in more detail hereinafter. Preferably, each of the above-mentioned amplifier components are on a separate printed circuit board assembly and are completely transistorized.

The output from the amplifier 36 drives stepping motor 38. The input signal from the rodmeter is developed across contacts 52 and 54, the sense signal appearing across these two terminals being an AC sense signal. The excitation coil 56 for the rodmeter is excited from an AC source generally indicated at 50. Limiting resistor 58 and fuse 60 are also provided. When the input signal from the rodmeter is not equal to the response signal in magnitude, the input transformer 34 will feed an error signal voltage corresponding to the difference in magnitude between these two input voltages into the first stage of the amplifier 36. This signal will drive the stepping motor 38, which in turn causes the response potentiometer 40 to be driven in a direction which changes the response voltage until it equals the rodmeter sense voltage. Because the motor is also geared to the speed indicating two-pointer dial 42, the synchro transmitters, and the distance indicating device, it drives each of these at the same time. The system is calibrated so when the response voltage matches a given rodmeter sense voltage, the value indicated by the dial, transmitted by the synchros and put into the distance indicating device, corresponds to the ship's actual speed in knots. So long as the equipment remains energized, this process continues as ship speed changes, always matching the ship's actual speed in accordance with the rodmeter sense signal.

Reference should now be made to FIGURE 3, which shows a combination block and schematic diagram of the entire system shown in FIGURE 2 but in more detail. Dotted lines indicate mechanical connections and solid lines indicate electrical connections.

The rodmeter is indicated generally at 62. Energization of the rodmeter excitation coil, as described in FIGURE 2, takes place through a cable comprising wires 64 and 65 and the sense signal delivered from the rodmeter is transferred over a cable comprising wires 66 and 68. The input transformer 34, as shown in FIGURE 2, functions as an error detector whose output is the difference between the rodmeter sense (or speed) signal input and the response voltage input. The primary winding 70 of the transformer is excited by the response voltage delivered from the response potentiometer generally indicated at 40, see FIGURE 3b. The two secondary windings 72 and 74 of the transformer 34 are connected in series with the pickup buttons on the rodmeter, as shown in FIGURE 2. The winding ratio between primary and sec-

ondary may be 35:1, and the scaling is a function of the ratio between response signal and the sense signal. The response voltage is connected in phase opposition to the sense voltage. Therefore, the response voltage and the speed voltage add algebraically within the transformer 34. The algebraic sum of these two voltages is the error signal voltage. When the magnitude of the response voltage is equal to the magnitude of the speed voltage, the resulting error signal is zero.

If the ship's speed should increase, the algebraic sum of the voltage would produce an error signal in phase with the speed or sense signal. If the ship's speed should decrease, the resulting error signal will be 180° out of phase with the speed or sense signal. An error signal in phase with the speed signal will drive the stepping motor 38 in the increasing speed direction, while an error signal 180° out of phase will drive the stepping motor in the decreasing direction.

The pre-amplifier 76 of FIGURE 3b is a conventional amplifier having high input impedance, low noise, a voltage gain of preferably about 300 and high common mode rejection. Normally, the error signal being amplified may be about six microvolts which means very small stray pickup levels can be tolerated. Shielded input leads 77 and an enclosure around the amplifier reduces pickup to acceptable levels. In addition, the high common mode rejection of the conventional amplifier also rejects any pickup which appears at the two input terminals 78 and 80 of FIGURE 3b with the same phase or instantaneous polarity. The output voltage from the rodmeter occurring on lines 66 and 68 is an AC signal such that the instantaneous polarity of this desired signal at terminals 78 and 80 is opposed, or out of phase, and is therefore amplified.

The post amplifier 82 is a double-ended voltage amplifier with a voltage gain of preferably about 25. The post amplifier amplifies the output signal from the pre-amplifier 76 and drives a phase sensitive detector 84, see FIGURE 3c. Each amplifying stage in both the pre-amplifier 76 and the post-amplifier 82 is followed by an emitter-follower stage.

Note that there are two outputs from the pre-amplifier and post-amplifier stages 76 and 82 and therefore both of the voltages appearing at 78 and 80 are amplified an equal amount.

The total gain from terminal 78 or 80 to terminal 88 or 90, respectively, is less than what was employed in prior art vacuum tube approaches to this problem. When utilizing vacuum tubes, there is no practical limit to the amount of gain that could be developed in the pre-amplifier and post-amplifier stages without saturating the vacuum tubes. However, by transistorizing the amplifier stages, the problem of saturating the transistors becomes acute since the maximum permissible voltage swing on the transistors before saturation is exceeded before the error signal occurring at terminals 78 and 80 is amplified to a sufficient level. To overcome this problem, the gain of the pre-amplifier and post-amplifier stages in combination is reduced to a point where saturation cannot occur and further amplification at a later stage in the amplifier 36 is introduced where it can introduce no saturation effects into the transistors.

The phase sensitive detector 84 of FIGURE 3c for the error signal occurring at terminals 78 and 80 converts the AC signal to a direct voltage. The direct output voltage from the phase detector 84 occurring at terminals 92 and 94 is proportional in amplitude to the size of the error signal and is negative or positive depending on the polarity of the error signal. For zero error the rodmeter sense signal is equal to the response signal from the response potentiometer 40 and therefore the output of the detector is balanced and the terminals 92 and 94 are at equal voltages with respect to ground terminal 96. For example, terminals 92 and 94 will be at 3.5 volts DC with respect to ground when the error signal at terminal 78 and 80

is zero. For an increasing error of about one knot (that is, an increase in the speed of the ship of one knot), the rodmeter sense signal being higher than the response signal, the voltage at terminal 92 will decrease to about 2.5 volts, for example, and terminal 94 will increase to about 4.5 volts or the difference between terminals 92 and 94 will be about 2.0 volts. Amplifier gain at this point is preferably two volts per knot. Since the rodmeter sensitivity is generally about 325 microvolts per knot, the total voltage gain is about 6150 from terminals 78 and 80 to terminals 92 and 94.

The phase-sensitive detector 84 comprises a balanced modulator 98 which includes two identical stages connected in parallel to handle the power required by the stepping motor 38. Each stage comprises a pair of diodes 100, 102 and 104, 106. These diodes are connected to deliver a full wave rectified voltage at terminals 108 and 110. Transformer 112 is preferably connected to deliver from terminals 114 and 116 a 60-cycle 50-volt signal from the supply voltage block 118. The voltage delivered from the transformer 112 forwardly biases the transistors 100, 102, 104, 106 when the signal applied across terminals 88 and 90 is in phase with the signal delivered from transformer 112. However, when the signal applied from terminals 88 and 90 is 90° out of phase, or in quadrature with, the desired error signal, the detector 84 will reject these signals because the signal delivered from terminals 114 and 116 will back-bias the diodes 100 through 106 when the undesired quadrature signal is present. These undesired signals are always present in varying amounts depending on each rodmeter and each installation and these signals consist of quadrature voltage, stray pick-up signals and harmonics.

Respectively connected to terminals 108 and 110 are a pair of RC 111 and 113 and parallel T 115 and 117 filters to remove ripple resulting from the detection or rectification process. These filters have been especially chosen to insure adequate filtering or smoothing of the rectified DC voltage (which implies a long time constant for the filters) while at the same time, these filters insure fast response of the step motor 38 to control the speed and the distance indicating devices when this is required (which implies a relatively short time constant). The choice of parallel T filters makes this compromise between fast and slow time constants most effective.

The output signals occurring at terminals 92 and 94 of the phase sensitive detector 84 are fed to an increase-decrease gating circuit generally indicated at reference numeral 118. As discussed earlier, for an increasing error signal, the signal for the voltage at terminal 92 decreases and the terminal 94 increases. This change is amplified in a differential DC amplifier which introduces the requisite gain into the error signals which could not be done in the pre-amplifier 76 and post-amplifier 82 stages because of the problem of transistor saturation, as described hereinbefore. The inputs to the increase-decrease circuit comprise Darlington connected transistors 120, 122, 124 and 126; all these transistors are suitably biased from the voltage supply 119. The Darlington connections are employed to insure proper impedance matching between the amplifiers 128 and 130 and the terminals 92 and 94, respectively. A constant current transistor 132 is employed to insure that the voltage levels at the inputs to amplifiers 128 and 130 are maintained at a substantially constant value when the voltage levels at terminals 92 and 94 remain substantially constant in spite of temperature variations, which can be quite significant on ship-board.

Condensers 134 and 136 are also provided to further smooth the DC error signals. Amplifiers 128 and 130, respectively, drive AND gates 138 and 140. The output of amplifier 128 is connected to diode 142 of AND gate 138 and the output of amplifier 130 is connected to the diode 144 of AND gate 140. Diodes 146 and 148 of

AND gates 136 and 140 are both connected to the output of time base 150.

The time base 150 of FIGURE 3c comprises preferably a relaxation oscillator. Unijunction transistor 152 in conjunction with timing capacitor 154 and resistors 156, 158, 160 and 162, comprise the basic relaxation oscillator. The oscillator is capable of being adjusted to run at slow and fast speeds by switch 164. The frequencies of the oscillator were chosen to make it possible to switch the response of the stepping motor 38 from 40 knots per minute to 8 knots per minute or vice-versa. In other words, slow speed is used when the ship's motion is other than forward speed, or water turbulence is causing the rod-meter signal to vary in an oscillating manner. The speed servo 16 is unable to follow any change over 8 knots per hour per minute when it is in "slow" operation. The "fast" operation has been introduced to insure that the speed indicators on the ship are responding in accordance with the ship's speed as they actually occur. There, of course, is a conflict in desiring the speed indicating devices to follow the ship's motion too quickly or too slowly. This problem is minimized by the provision of a slow and fast time base to actuate the stepping motor depending on the particular situation. In prior art devices, it is necessary to change the gearing ratios between the continually operating synchro motors and the speed and distance indicating devices in order to change the response time. This has now been replaced in the present invention by the simple switching of switch 164.

The above illustrates one reason why the stepping motor 38 of FIGURE 3e in the speed servo 16 is preferable—that is, it is simple to change speed electrically, and it does not require gearing changes. Also the step motor, for zero error, is locked electrically at whatever sense signal is being received from the rod-meter 62 and is motionless unless the speed or sense signal is varying by more than plus or minus .02 knot; for example, when this "dead zones" or "gate with" of ± 0.02 knot is exceeded, the step motor 38 may run at 33 or 165 steps per second depending on the setting of switch 164, in the direction necessary to reduce this error to zero.

The unijunction transistor 152 is followed by an emitter follower 166, "one-shot" switch circuit 168, another emitter follower 170, amplifier 172 and output emitter follower 174. The output from the unijunction transistor comprises spike-like signals which are shaped into rectangular pulses by single shot 168 which occur at a regular rate. The signal appearing from the output of the emitter follower 174 is a rectangular train of pulses preferably extending from -1 volt to $+13$ volts.

The output from the time base 150 is applied to the diodes 146 and 148 as described above. AND gates 138 and 140 may be termed increase and decrease gates, respectively, and the outputs from these gates are pulses of the same frequencies as the time base whose amplitudes are set by the output from detector 84. The Schmidt triggers 176 and 178 are respectively connected to the outputs of AND gates 138 and 140 through emitter followers 180 and 182. The triggering voltage at the base of transistors 180 and 182 necessary for triggering either Schmidt trigger 176 or 178 is $+6.5$ volts, for example. When the error signal is zero, the voltage at the outputs of AND gates 138 and 140 will both be $+6$ volts and therefore the Schmidt triggers will not be actuated. However, when there is an increasing error signal in excess of 0.2 knot, the voltage at the output of AND gate 138 will increase above 6.5 volts and will therefore actuate Schmidt trigger 176. As the voltage level of the pulses occurring at the output of AND gate 138 increases, the voltage level of the output pulses occurring at the output of AND gate 140 will decrease. Therefore, Schmidt trigger 178 will not be actuated. The .5 voltage margin corresponding to the difference between the 6.5 volts necessary to actuate the Schmidt triggers and the 6 volts corresponding to zero

error signal corresponds to an error in the speed or sense signal of about .02 knot. The output signals from the Schmidt triggers 176 and 178 are bi-directional pulses and are respectively shaped and amplified in the emitter follower 184, rectifier 186, and emitter follower 188, and the corresponding emitter follower 190, rectifier 192 and emitter follower 194. The rectifier 186 is normally off and therefore when negative spikes are applied at its base, it remains non-conductive. However, when positive pulses appear at the bases transistors 186 and 192, negative spikes respectively appear at the outputs thereof. All of these transistors within the increase and decrease gating circuitry are biased from the suitable supply within the supply voltage block 119.

Logic circuit 196 comprises two emitter followers 198 and 200 for receiving the negative spikes from the output terminals 202 and 204, respectively, of the increase-decrease gating circuitry 118. The output signals from the emitter followers 198 and 200 drive four AND gates 203, 205, 206 and 208. These AND gates are conditioned by output voltages from two flip flops 210 and 212. The logic circuit 196, see FIGURE 3e, comprising the AND gates 203 through 208 and the two Schmidt triggers 210 and 212, may be thought of as a four-state counter that counts up or down in response to pulses on its increase input terminal 202 or its decrease input terminal 204, respectively. The AND gates and the Schmidt triggers are biased from a suitable source of a voltage supply 119.

There are four output terminals 214, 216, 218 and 220 from the logic circuit 196. There are four conditions possible on the output terminals 214–220 corresponding to the four counts or steps. These are shown in FIGURE 4 where "C" stands for conducting and "O" stands for "off," where the output terminals 214–220 of the logic circuit are shown at the top of the figure. The interconnections between the outputs of the Schmidt triggers 210 and 212, which condition the AND gates 203–208 at terminals 222, 224, 226, 228, 230, 232, 234 and 236, result in the output signal configurations at terminals 214–220 in accordance with the input signals appearing at either terminals 202 or 204. For each pulse occurring at 202 or 204, the stepping motor 38 is advanced one step. Because of the construction of the stepping motor 38, the input pulses must be applied in a prescribed manner in order for the stepping motor to properly rotate. The pattern of pulses occurring at terminals 214–220, as shown in FIGURE 4, is the required pattern of sequence to appropriately step the stepping motor 38.

Referring to FIGURE 4, it can be seen that two terminals are always conducting and that two are always off. Further, only one terminal at a time can change condition and the sequence repeats itself after four steps. A step occurs each time a pulse is received from the increase-decrease gate circuitry 118. The sequence is 1, 2, 3, 4 for increasing pulses and 4, 3, 2, 1 for decreasing pulses and the motor 38 steps counterclockwise for increasing pulses and clockwise for decreasing pulses.

The drive circuit 222 comprises four double emitter followers capable of driving $\frac{1}{2}$ ampere through the windings of the motor 38. There are double emitter followers 224, 226, 228 and 230 respectively connected to terminals 214, 216, 218 and 220 for supplying the requisite current to the stepping motor 38. A suitable supply of voltage is provided for the drive circuit from the voltage supply 119.

The stepping motor 38 preferably has a permanent magnet rotor and four stator field windings. The rotor has 50 teeth which makes it a 100 pole motor capable of stepping 1.8° per step or 200 steps in one revolution in response to direct current inputs to its field windings from the drive circuit as described before. The motor 38 preferably can deliver about 25 ounce-inches of torque to a slip clutch which is set for about 20 ounce-inches. The motor 38 runs in the direction required to reduce the error signal to zero. In doing so, the motor 38 drives the speed synchro trans-

mitters 44, the two pointers on the speed indicator 42, the distance indicating device, and the response potentiometer 40.

The response potentiometer 40 is a combination interpolating potentiometer 256 and switching unit whose shaft 232 is driven through gearing by the stepping motor 38. The potentiometer wiper 254 is always positioned in accordance with the output of the stepping motor 38. Potentiometer 256 has an output voltage which after correction by the trimming potentiometers 234-252 is proportional to the ship's speed. Potentiometer 256 provides the feedback response signal which is added algebraically to the rod-meter sense signal to develop the error signal which input transformer 34 feeds to the amplifier 36. The trimming potentiometers 234-252 are connected across one knot segments, for example, of auto transformer 258 at intervals of 4 knots, for example. There are preferably 9 of these potentiometers to cover the range from 0 to 40 knots. Each of the trimming potentiometers 234-258 are preferably 5 ohms. These potentiometers and their attached graduated dials permit adjustment up to ± 0.5 knot at the 4-knot increments. Therefore, the output of potentiometer 256 is a series of straight line segments which are so adjustable that a variety of curves can be approximated. This is desirable because there are changing flow characteristics of water with respect to the hull at different speeds and because eddies and other distortions of flow patterns are caused by the hull shape and, further, the rod-meter's sense signal is not exactly linear—that is, a given increment in speed does not cause an exactly proportional increment in signal voltage in all parts of the rod-meter's operating range.

Therefore, the above-mentioned non-linearities are compensated by the response potentiometer 40 by introducing analogous non-linearities into the response voltage. This is done by the trimming potentiometers 234-252, described above which are part of the calibration assembly.

A zero adjustment potentiometer 252 is provided because the amplifier 26 is unable to reject completely all stray signals. The unrejected portion of these signals appears as a fixed speed signal at zero speed. This zero speed signal, due to the fact that perfect rod-meters cannot be manufactured or because of stray pickup, may appear as a plus or minus speed error signal. Zero adjustment potentiometer 252 provides a signal which opposes the fixed speed signal so that the log will read zero at zero speed. It does this in the following way: Resistor 252 is connected to taps 264 and 266 of auto transformer 258. Tap 268 is at ground or zero volts and the transformer 258 is energized to provide voltages at taps 264 and 266 that represent -1 and $+1$ knot, respectively. The arm of potentiometer 252 can therefore be varied plus or minus one knot above 0. Therefore, the response voltage which is the voltage between the wiper 254 of potentiometer 256 and ground can be adjusted to a value which cancels the zero speed or sense signal.

A full-scale adjustment potentiometer 260 is also provided and is connected across resistor 262. It functions as a variable voltage divider to provide a voltage to auto transformer 258 representing full-scale of 40 knots which can be varied plus or minus four knots. By adjusting the voltage developed across auto transformer 258, it adjusts the average slope of the entire response voltage curve. This determines the volts per knot ratio of the response circuit as a whole.

The interpolating potentiometer 256 as shown in FIGURE 4 is driven through mechanical linkage to 232 from the stepping motor 38. The response potentiometer 40 consists of a series of commutator bars which correspond to the taps of trimming potentiometers 234-252. The taps are located at 4-knot increments, for example.

Potentiometer 256 comprises a 360° torroidal resistance element, precisely tapped at three 120° intervals. Connection between the commutator bars and the cali-

bration potentiometer is made through a multiconnector cable and plug 270 which is part of the response potentiometer 40.

Rotating the shaft 232 of the interpolating potentiometer switches the taps of the interpolating resistance element one at a time along the commutator and simultaneously controls the potentiometer output wiper 254. There are approximately three interpolations per shaft turn of the interpolating potentiometer. This interpolating potentiometer 256 is a commercially available item normally used for function generation purposes. However, its combination with the auto transformer 258 and the trimming potentiometers 234-252 in the present invention to obtain response potentiometer 40, is felt to be new. A brief description of how the potentiometer switches the taps of the interpolating resistance element one at a time will now be given with respect to FIGURE 5.

FIGURE 5A shows the electrical relation of the interpolator commutator bars 272-278, interpolating resistance element of potentiometer 256 and output wiper 254. The output wiper has just passed commutator bar 274 (4-knot tap), traveling in a clockwise direction, and is interpolating between bars 274 and 276. Resistance element tap 280 is just about to disengage from commutator bar 272.

In FIGURE 5B, as the output wiper 254 moves in a clockwise direction, the output voltage changes linearly from the voltage on commutator bar 274 to that on commutator bar 276 (4 to 8 knots). Resistance element tap 280 has disengaged from the commutator bar 272 and is switching to commutator bar 278.

In FIGURE 5C the output wiper 254 is approaching commutator bar 276. Resistance element tap 280 has completed switching and is in contact with commutator bar 278. Continued clockwise rotation of the output wiper 254 will result in smooth interpolation past commutator bar 276 (8 knots).

This potentiometer interpolates from 0 to 40 knots in four-knot increments as described above. It has high resolution and linearity, low phase shift, low output impedance, and high input impedance. In FIGURE 3, potentiometer 256 is interpolating between 24 and 28 knots.

Ship speed as transmitted by the stepping motor 38 is indicated on a dial on the face of the speed indicating device 42. The dial is a clock-type indicator with the short hand making one complete revolution for a change in speed of 40 knots, and the long hand making one complete revolution for a change in speed on one knot. The above values of speed are given for illustrative purposes and there is no intention to restrict the invention thereto. The hands are driven through gearing 282 by the stepping motor 38. Speed is also transmitted on one or more synchros 32 which can be driven at various speeds.

Distance integrator 22 uses the stepping motor output through mechanical linkage 284 to develop a continuous shaft rotation proportional to distance traveled. The integrator 22 is basically a roller- and disc-type integrator consisting of:

- (1) A smooth disc 286 rotated at a constant speed by a synchronous time motor 288;
- (2) A wheel or roller 290 driven by friction contact with the surface of the disc 286;
- (3) A non-rotating rack gear 292 which can position the wheel 290 at any required distance, within limits, from the center of the disc 286;
- (4) A spur gear 294, driven by the stepping motor 38, which engages the rack gear 292 and translates it longitudinally when it rotates; and
- (5) A mechanical differential 296 which receives two inputs—one from the wheel 290 and the other from the disc 286 or from the time motor 288—where the output from the mechanical differential 296 is proportional to the difference between them.

The rate of rotation of the wheel 290 depends on (1) the rotational rate of the disc 286, which is constant, and (2) the distance of the wheel 290 from the center of the disc 286, which is regulated by the position of the rack 292. The rack 292, when translated by the rotation of the gear 294, moves the wheel 290 towards the center of the disc 286 as the speed goes down, or towards the periphery of the disc 286 as the speed increases. The number of rotations made by the wheel 290 is thus proportional to the distance the ship travels through the water. If the output of the wheel 290 goes directly through gearing through the distance indicator or miles counter 28, then at zero speed input the wheel would, in order to give zero miles output, have to be positioned at the center of the disc 286. Since the time motor 288 operates continuously so long as the equipment is energized, whether the ship is moving or not, prolonged rubbing contact at a single point on the disc 286 and the wheel 290 when the ship's speed is zero, would cause excessive wear. To avoid this, the zero position of the wheel is at a radius of 0.25 inch from the center of the disc 286. Thus, the wheel 290 is always in rolling contact with the disc 286 and it rotates even when the ship's speed is zero. At zero knots, the wheel rotates at 300 r.p.m. preferably.

The function of the differential 296 is to cancel out this continuous wheel rotation at zero speed. Rotation of wheel 290 drives one end gear of the differential 296. The time motor 288 drives the other end gear of the differential 296. When the ship's speed is zero (wheel 290 at minimum distance from the center of the disc 286), the inputs to the two end gears of the differential 296 are equal and opposite in direction. Thus, the spider develops a zero output. As the ship's speed exceeds zero, the difference in the inputs to the differential 296 becomes greater, and the spider rotates at a rate proportional to speed. Maximum difference between end gear speeds, and hence maximum speed output, occurs when the wheel 290 is positioned by the stepping motor 38 at maximum difference (for example, one inch) from the disc 286 center. At maximum speed (for example, 40 knots), the wheel may rotate at 1200 r.p.m. Since the minimum distance from the center of the disc 286 permitted for the wheel 290 corresponds to zero speed output from the stepping motor 38, the equipment can register only positive (forward) increments of distance.

The integrator output is a continuous rotation at a rate proportional to ship's speed or distance traveled. This output is used to drive miles counter 28 and one or more synchro transmitters 298, which transmit a corresponding synchro signal to remote receivers for indicating distance traveled. However, any appreciable direct load on the integrator output is likely to cause slippage, wear and inaccuracy. Therefore, instead of driving the counter 28 and synchro 298 directly, the integrator output controls a distance servo 26 which in turn drives these units. This servo may be thought of as a torque amplifier.

The main components of the distance servo 26 are:

- (1) The step transmitter 300;
- (2) The step or distance motor 302; and
- (3) The radio interference filters 304 and 306.

The step transmitter 300 is a switching device driven by the output of the distance integrator which energizes coils and the distance stepping motor 302, in a definite sequence which causes the stepping motor 302 to rotate in direction and amount proportional to the transmitter rotation. The manner for rotating the step transmitter 300 will now be described with reference to FIGURE 6. The three contacts 308, 310 and 312 are spaced 120° apart around the stepping transmitter 300 and are adjusted to make contact during rotation of the eccentric 312 driven by the shaft of the step transmitter 300, which in turn is driven by the differential 296. There is a 60° overlap

in the closing of adjacent contacts. The common contact 316 remains closed at all times to the eccentric 314 to complete the circuit. The switching sequence for the direction shown is 316-308, 316-308-310, 316-310, 316-310-312, 316-312, 316-312-308 and back to 316-308 in one revolution.

Each of the step contacts 308-312 is connected to a pair of diametrically opposite coils in the 6-pole stepping motor 302. When the coils 318 and 320 are energized by contact 308, the pair of armature poles 322 and 324 nearest these coils will align with them. Contact 310 closes 60° before contact 308 opens, sending current through coils 326 and 328. This makes contacts 308 and 310 opposite in polarity and causes the armature to rotate 15° in a counterclockwise direction to align itself as closely as possible with coils 318 and 326. Next, contact 308 opens and the armature 330 rotates another 15° to bring the pair of armature poles then nearest coils 326 and 328 in line with them. A similar rotation takes place when contact 312 is closed and contact 310 opens 60° later. Thus, a 60° rotation of the stepping transmitter 300 causes the stepping motor 302 to rotate 15°, giving a 4-1 ratio between the transmitter and receiver.

The above description of the relation between the stepping transmitter 300 and the stepping motor 302 is for illustrative purposes only and, further, the use of specific numbers is for illustrative purposes only, and any variation on the number of poles in the stepping motor or number of contacts in the stepping transmitter is within the scope of the invention.

The stepping motor 38 employed in the speed servo 36 is similar in construction and operation to the stepping or distance motor 302 and, therefore, the above illustrative description for the stepping motor 302 also applies to the stepping motor 38. Of course, the source of pulses for the stepping motor 38 is different from that of the source of pulses for the stepping motor 302. For the stepping motor 302, the source of pulses is the stepping transmitter 300, which is essentially a chopper of DC voltage which is applied from terminals 332 and 334, whereas the source of pulses for the stepping motor 38 is the time base 150 which has been described before.

The stepping or distance motor 302 may drive the distance output synchro 298 at 300 turns per nautical mile. The stepping motor 302 also drives the distance counter through linkage 336. The distance counter 28 may be a 6-place commercial-type unit that registers to 0.01 nautical miles. Maximum indication may be 9,999.99 nautical miles. A reset knob permits turning the counter back to zero if necessary. The counter receives the continuous rotational speed signal from the distance servo 26, and records cumulatively the number of turns (corresponding to distance traveled) it has traveled since it was last at zero.

Since the stepping transmitter 300 is a switching device, it generates a radio frequency noise which must be kept below certain levels so that other equipment aboard ship may not be affected. This is accomplished by shielding and filtering. The distance servo 26 is enclosed in a metal box and the supply leads are shielded at 338 and are brought into the metal box through radio frequency interference filters 304 and 306. In addition, RC filtering 340 is connected directly across the step transmitter 300.

Thus, there has now been described a distance indicating mechanism or means which does not use continuously operating servo motors and therefore limits the need for excessive gearing to insure that the proper torque is being delivered to the devices controlled by the distance servo 26. The advantages which are gained through the use of stepping motor 302 over continuously operating motors is the same as that pointed out for stepping motor 38 and, therefore, the advantages of stepping motors in a system for measuring ship's speed has been extended to the distance-indicating portion of the system.

A dummy log circuit is also included in the system to permit the speed-indicating device 42 to be set at any speed either at the locale of the indicating device 42 or else at a location remote from the locale of speed-indicating device 42. Switch 342 is employed to increase or decrease the speed setting on speed indicating device 42. As has been discussed before, the simple operation of a switch to insert locally or remotely an estimated speed into the speed-indicating device is a desirable feature whenever the normal means for obtaining the speed becomes disabled. This particular feature is available in prior art ship speed determining systems; however, generally an extra black box, in addition to the circuitry employed for determining the speed by normal means, is necessary. However, in the present invention, the circuitry of the speed-determining apparatus, which is normally used for determining speed from the rod-meter, can also be employed to provide a dummy log or estimated speed.

Switch 342 is a center off, spring return, two-position switch which is used to connect the output from the time base 150 to the increase input terminal 202 of the logic circuit 196 or to the decrease input terminal 204. As a result, the stepping motor 38 is driven so as to increase or decrease the speed setting.

Remote control units (not shown) may also be used to permit setting of the speed-indicating device 42 to any desired speed. The switches at the remote control locations would be connected in parallel with switch 342 and would be of the same type as switch 342. Also, indicator lights are provided at the remote locations to indicate to the operator that the speed-determining apparatus or log has been switched to dummy log operation. By watching the speed indicator at its remote location, he can set speed by means of his "increase-decrease switch" until the speed-indicating device is at the desired speed setting.

Testing of the speed-determining apparatus is also included in the system and may be accomplished in the following manner. A switch (not shown) is closed in the voltage supply 119 which energizes the coil of relay 344 thereby transferring the contact 346 and deenergizing the excitation of the rod-meter through wires 64 and 65. The coil of relay 348 is also energized thereby transferring the contacts 350 and 352 to terminals 354 and 356, respectively. A simulated sense voltage is now applied across the primary winding 358 of transformer 360. The amount of voltage across the primary winding 358 is determined by the setting of potentiometer 362. The wiper 364 of potentiometer 362 is controlled by the setting on the test input dial 366.

For example, if the test input now is set for 34 knots (as shown), the voltage developed across primary winding 358 will correspond to a 34-knot sense signal. This signal is applied across the secondary windings 72 and 74 of input transformer 34 through contacts 350 and 352, respectively. Therefore, the loop is now set up in the speed servo 36 which simulates the loop established when signals are received from the rod-meter and, therefore, a simple and convenient method for testing the equipment is provided.

The voltage supply 119 is driven from an AC power source 368. Within the voltage supply are the necessary circuits (1) for developing a DC voltage across wires 332 and 334 for driving the step transmitter 300; (2) for developing the excitation or test voltage across wires 370 and 372 (as the case may be); and (3) for developing the energization voltage across wires 374 and 376 which is used for energizing relays 344 and 348.

Switch 172 may be employed to give a speed determination and indication by merely operating the switch and thereby reversing the polarity of the response signal applied to winding 50.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that the scope of the invention is limited only by the appended claims.

What is claimed is:

1. Apparatus for measuring the speed of a ship, said apparatus being of the type which employs a sensor to generate an alternating current sense signal in response to the flow of water by the hull of the ship where the sense voltage is employed to control the device for indicating said ship speed, said apparatus comprising:

(a) means for discretely stepping said speed indicating device to a plurality of discrete positions, said stepping means including a stepping motor and said speed indicating device being responsive to the angular positions of the shaft of said stepping motor, each angular position being indicative of a speed of said ship;

(b) means for generating an alternating current response signal indicative of the speed of said ship from said means for discretely stepping the speed indicating device;

(c) means responsive to said sense signal and said response signal for generating a drive signal having a predetermined frequency for driving said stepping means when said sense signal and said response signal are different from one another in magnitude; and

(d) means for selectively setting the frequency of said drive signal at one of a plurality of discrete values.

2. Apparatus as in claim 1 where said stepping means steps said speed indicator in the forward or backward direction depending on whether said ship speed is increasing or decreasing respectively.

3. Apparatus for measuring the speed of a ship, said apparatus being of the type which employs a sensor to generate an alternating current sense signal in response to the flow of water by the hull of the ship where the sense signal is employed to control a device for indicating said ship speed, said apparatus comprising:

(a) means for discretely stepping said speed indicating device through a plurality of positions, said stepping means including a stepping motor and said speed indicating device being responsive to the angular positions of the shaft of said stepping motor, each angular position being indicative of a discrete speed of said ship;

(b) means for generating an alternating current response signal indicative of the speed of said ship from said means for discretely stepping the speed indicating device;

(c) means responsive to the difference in magnitude of said sense signal and said response signal for generating an error signal when said difference exists;

(d) means for generating a drive signal for said stepping including variable frequency oscillator means; and

(e) gating means responsive to said error signal for gating said drive signals to said stepping means.

4. Apparatus as in claim 3 including differential amplifier means for amplifying said error signals and reducing the undesirable effects of in-phase interference signals occurring at the differential inputs of said differential amplifier means.

5. A device as in claim 4 including phase sensitive detector means for converting the amplified error signal output from said amplifier means to a DC voltage and for eliminating undesirable signals which appear in quadrature with the desired error signal.

6. Apparatus for measuring the speed of a ship, said apparatus being of the type which employs a sensor to generate a sense signal in response to the flow of water by the hull of the ship where the sense signal is employed to control a device for indicating said ship speed, said apparatus comprising:

(a) means for discretely stepping said speed indicating device through a plurality of positions, said stepping means including a stepping motor and said speed

indicating device being responsive to the angular positions of the shaft of said stepping motor, each angular position being indicative of a discrete speed of said ship;

- (b) means for generating a response signal indicative of the speed of said ship from said means for discretely stepping the speed indication device;
- (c) means responsive to the difference in magnitude of said sense signal and said response signal for generating an error signal when said difference exists;
- (d) means for generating a drive signal for said stepping including oscillator means;
- (e) gating means responsive to said error signal for gating said drive signals to said stepping means; and
- (f) a plurality of input terminals associated with said stepping motor for respectively receiving a plurality of input signals which rotate the rotor of said motor in one direction or the other depending on whether the ship speed is increasing or decreasing and where said apparatus includes a logic circuit for generating said plurality of input signals, said logic circuit having first input terminal for receiving said drive signals when the ship speed is increasing and a second input terminal for receiving the drive signals when the ship speed is decreasing.

7. Apparatus as in claim 6 where said means for generating an error signal includes means for generating a first error signal having a first polarity and second error signal having a polarity opposite to said first polarity and said gating means includes first and second gating means respectively responsive to said first and second error signals for respectively gating said drive signal to said first and second input terminals of said logic circuit.

8. Apparatus, as in claim 6, including remote control means for setting the said speed indicating device from a location remote from the said apparatus, said remote control means including means for switching the output of said oscillator means to either of the first and second inputs to the said logic circuit input terminals.

9. Apparatus for measuring the speed of a ship, said apparatus being of the type which employs a sensor to generate a sense signal in response to the flow of water by the hull of the ship where the sense voltage is employed to control the device for indicating said ship speed, said apparatus comprising:

- (a) means for discretely stepping said speed indicating device to a plurality of discrete positions, each being indicative of a speed of said ship;
- (b) means for generating a response signal indicative of the speed of said ship from said means for discretely stepping the speed indicating device, said means for generating a response signal including an autotransformer connected to a voltage source, said transformer having a plurality of trimming potentiometers connected at discrete intervals along said auto-transformer for calibrating said response signal generator, and an interpolating potentiometer connected between any two of said trimming potentiometers for interpolating and deriving the said response signal from the said AC voltage;
- (c) means responsive to said sense signal and said response signal for generating a drive signal for said stepping means when said sense signal and said response signal are different from one another in magnitude.

10. Apparatus, as in claim 9, where said response signal generating means includes switch means for switching said interpolating potentiometer from one of said trimming potentiometers to another in response to changes in the ship's speed.

11. Apparatus for measuring the speed of a ship, said apparatus being of the type which employs a sensor to generate a sense signal in response to the flow of water by the hull of the ship where the sense voltage is employed

to control the device for indicating said ship speed, said apparatus comprising:

- (a) means for discretely stepping said speed indicating device to a plurality of discrete positions, each being indicative of a speed of said ship, said stepping means including a first shaft, the angular position of which corresponds to the ship speed and said apparatus including means for determining the distance travelled by said ship including integrator means having a second shaft for integrating the ship speed with respect to time to obtain distance by translating the angular position of said first shaft to a speed of rotation of said second shaft which corresponds to the distance travelled by said ship and torque amplifier means for amplifying the torque produced by said second rotator including a stepping motor responsive to a plurality of input signals for producing said amplified torque and stepping transmitter means responsive to said rotation of said second shaft for producing said plurality of signals for said stepping motor;
- (b) means for generating a response signal indicative of the speed of said ship from said means for discretely stepping the speed indicating device; and
- (c) means responsive to said sense signal and said response signal for generating a drive signal for said stepping means when said sense signal and said response signal are different from one another in magnitude.

12. Apparatus for varying the amplitude of an input signal, said apparatus comprising:

- (2) an auto transformer responsive to said input signal;
- (b) a plurality of tapping points connected along the length of said autotransformer;
- (c) interpolating potentiometer means having at least three movable taps, two potentiometers each connected between two of said three taps, and a common wiper for said two potentiometers; said three taps being connected to a successive three of said tapping points; and
- (d) means for (1) driving said wiper along one of said two potentiometers and thereby developing said varying input signal at said wiper and (2) for moving one of said three taps to another of said tapping points other than said three successive tapping points whenever said wiper is driven from one of said two potentiometers to the other.

13. Apparatus, as in claim 12, including a plurality of trimming potentiometers, the wipers of which respectively correspond to said tapping points and the other two terminals of each potentiometer being connected to terminals on said autotransformer.

14. Apparatus for measuring the speed of a ship, said apparatus being of the type which employs a sensor to generate a sense signal in response to the flow of water by the hull of the ship where the sense signal is employed to control a device for indicating said ship speed, said apparatus comprising:

- (a) means for discretely stepping said speed indicating device through a plurality of positions, each of said positions being indicative of a discrete speed of said ship, said stepping means including stepping motor having a plurality of input terminals for respectively receiving a plurality of input signals which rotate the rotor of said motor in the one direction or the other depending on whether the ship speed is increasing or decreasing and where said apparatus includes a logic circuit for generating said plurality of input signals, said logic circuit having first input terminals for receiving said drive signals when the ship speed is increasing and a second input terminal for

17

- receiving the drive signals when the ship speed is decreasing;
- (b) means for generating a response signal indicative of the speed of said ship from said means for discretely stepping the speed indicating device; 5
- (c) means responsive to the difference in magnitude of said sense signal and said response signal for generating an error signal when said difference exists; 10
- (d) means for generating a drive signal for said stepping including oscillator means; 15
- (e) gating means responsive to said error signal for gating said drive signals to said stepping means; and
- (f) remote control means for setting the speed indicating device from a location remote from the said apparatus, said remote control means including means for switching the output of said oscillator means to either of the first and second inputs to the logic circuit input terminals.
15. Apparatus for measuring the speed of a ship, said apparatus being of the type which employs a sensor to generate a sense signal in response to the flow of water by the hull of the ship where the sense signal is employed to control a device for indicating said ship speed, said apparatus comprising:
- (a) means for discretely stepping said speed indicating device through a plurality of positions, each of said positions being indicative of a discrete speed of said ship; 25
- (b) means for generating a response signal indicative of the speed of said ship from said means for discretely stepping the speed indicating device; 30

18

- (c) means responsive to the difference in magnitude of said sense signal and said response signal for generating an error signal when said difference exists;
- (d) means for generating a drive signal for said stepping including oscillator means;
- (e) gating means responsive to said error signal for gating said drive signals to said stepping means; and
- (f) test means for checking the functioning of said apparatus including means disconnecting said sensor from said means responsive to the difference in magnitude of said sense signal and said response signal and connecting thereto a test signal whose magnitude simulates the magnitude of a sense signal.

References Cited

UNITED STATES PATENTS

1,771,919	7/1930	Germain	336—148
2,695,353	11/1954	Witschonke	336—148 X
2,841,775	7/1958	Saunders	73—181
3,064,191	11/1962	Dever et al.	324—99
3,072,846	1/1963	Belcher	324—99
3,114,260	12/1963	Soller et al.	73—181
3,119,960	1/1964	Kenyon	73—181
3,228,025	1/1966	Welch	324—99

FOREIGN PATENTS

744,485	2/1956	Great Britain.
---------	--------	----------------

LOUIS R. PRINCE, *Primary Examiner.*30 NEIL B. SIEGEL, *Assistant Examiner.*