# United States Patent [19]

**Jensen**

[11] **3,884,170**

[45] **May 20, 1975**


[54] **CONTROL SYSTEM FOR TORPEDOES**


[75] Inventor: **Harvey M. Jensen,** State College, Pa.

[73] Assignee: **The United States of America as represented by the Secretary of the Navy,** Washington, D.C.



[22] Filed: **Feb. 26, 1960**

[21] Appl. No.: **11,384**

[52] **U.S. Cl.** ................................ **114/20 R;** 340/3 R
[51] **Int. Cl.**.. **F42b 19/10;** F42b 19/01; F42b 19/06
[58] **Field of Search** ............ 114/20, 21.1, 21.2, 23, 114/25, 24; 340/1, 2, 3, 5, 6


[56] **References Cited**

UNITED STATES PATENTS


2,913,700 11/1959 Brody .................................... 340/1

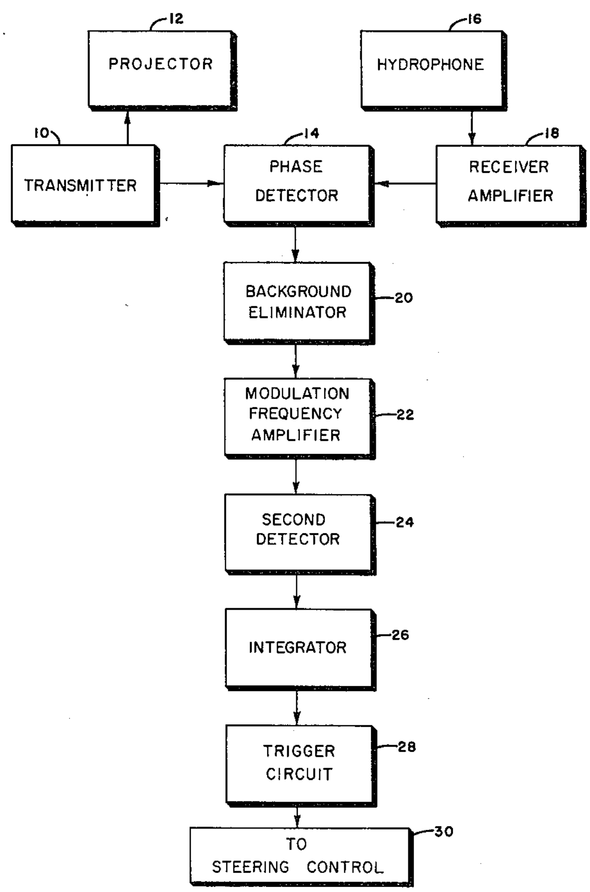


*Primary Examiner*—Benjamin A. Borchelt
*Assistant Examiner*—Thomas H. Webb
*Attorney, Agent, or Firm*—R. S. Sciascia; Henry Hansen


## EXEMPLARY CLAIM

1. In a detection system, the combination comprising: transmitter means capable of driving a projector with a continuous-acoustic signal; receiver means adapted to receive said signal transmitted by said transmitter; phase detection means capable of detecting the phase difference between said continuous transmitted signal and said received signal, and trigger means adapted to respond to phase differences produced by the characteristics of medium between said transmitter means and said receiver means.

**6 Claims, 2 Drawing Figures**



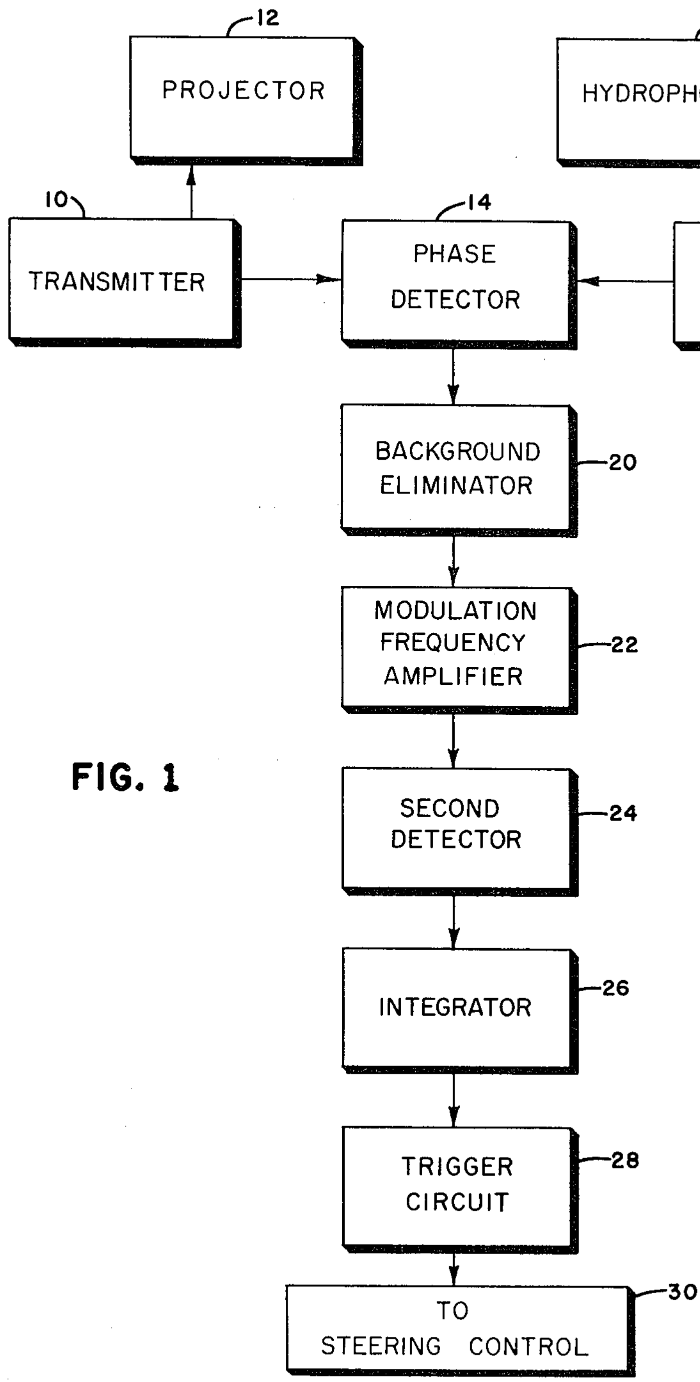



FIG. 1

HARVEY M. JENSEN
INVENTOR.

BY

V.C. Muller
ATTORNEYS

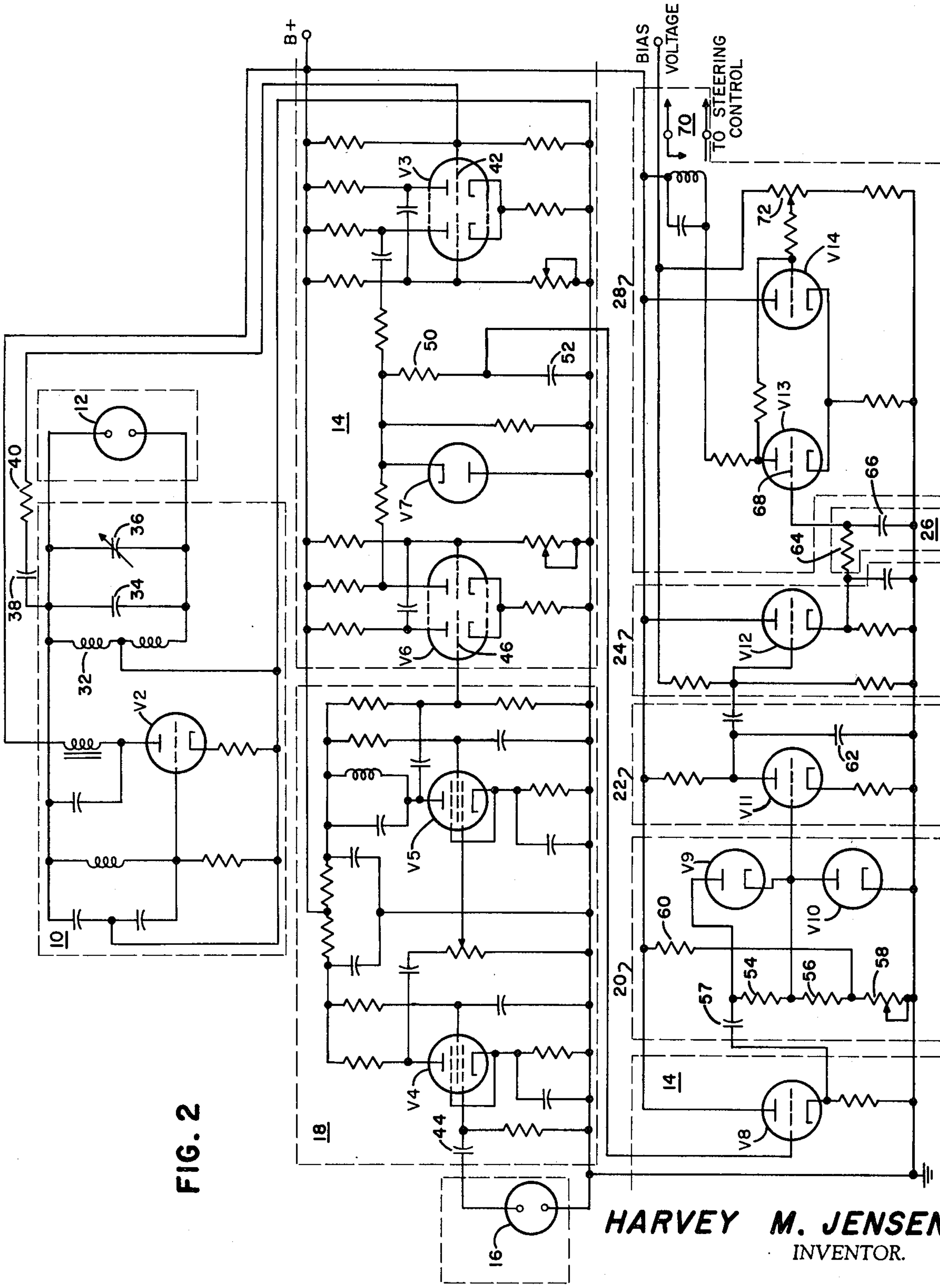



FIG. 2

HARVEY M. JENSEN
INVENTOR.

BY

V.E. Muller
ATTORNEYS

## CONTROL SYSTEM FOR TORPEDOES

This invention relates to a control system for self-propelled torpedoes, and more particularly to a system adapted to guide the torpedo down the wake of a target vessel until it collides with the vessel.

Numerous systems are in existence for guiding self-propelled torpedoes to a target vessel. Some of these are acoustical in nature, depending upon the detection of the sound from the target vessel to actuate steering mechanisms. Other systems project acoustical vibrations to the target vessel and detect the reflective waves coming therefrom to actuate steering means designed to direct the torpedo to the target. The devices of the type described depend upon the clear detection of acoustical waves over long distances in the water, and the rejection of unwanted waves. The present invention depends upon the detection of the wake emanating from the target vessel and the actuation of a control mechanism to steer the self-propelled torpedo along the wake towards the target until it collides with it. This invention is designed to detect the wake by providing a device that will respond to a phase variation between a transmitted acoustical signal and a received signal caused by the effect of bubbles in the wake.

It is the object of this invention, therefore, to provide a wake detecting-guiding means for a self-propelled torpedo that will automatically guide the torpedo down the wake in the direction of the target vessel causing the torpedo to collide with it.

Another object of this invention is to provide a means whereby the wake of a vessel may be positively and surely detected.

Still another object of this invention is to provide an electronic phase-detecting device capable of detecting phase variation caused by minute bubbles in water.

Referring to the drawings:

FIG. **1** represents a block diagram of the system.

FIG. **2** indicates a schematic diagram of the blocks shown in FIG. **1**, showing the electrical components and wiring.

Referring now to FIG. **1**, transmitter **10** drives the projector **12** to emit acoustical vibrations to the water and at the same time, furnishes a comparison voltage to the phase detector **14** for a later comparison with the received signal. The hydrophone **16** receives, through the water, the transmitted signal which is amplified by receiver amplifier **18** and applied to the phase detector **14** for comparison with the transmitted signal. Phase detector **14** is of the conventional type such that the output is substantially a direct voltage, proportional to the phase angle between the transmitted and received signal. The output of phase detector **14** is introduced to background eliminator **20**, also of the conventional type, designed to remove or suppress the phase angle fluctuation or phase modulation produced as a torpedo moves through the water outside of the wake. The phase modulation above a predetermined level is passed by the background eliminator **20** and amplified by conventional modulation-frequency amplifier **22**; the output of which is applied to the second detector **24**, which detects peak values of the phase modulation. The direct voltage of the second detector, proportional to the positive peaks appearing at its input, is passed into integrator **26**, consisting of a conventional resistance-capacitance network having a time delay to prevent triggering upon a disturbance of very short duration. The integrator **26** is designed to operate so that when a predetermined level of modulation in its input persists for a given duration, the trigger circuit **28** will be actuated. By this means, the circuit will not operate upon false signals, but is sensitive enough to respond to the wake signals received. The modified Schmitt trigger circuit **28**, in turn, puts into operation steering control device **30** which programs the torpedo's rudder (not shown) to steer the torpedo down the wake until it collides with the target vessel.

In the present embodiment of this invention, the transducer head (not shown) is comprised of the projector **12** and the hydrophone **16** which consists of two barium titanate piezoelectric transducers (not shown) mounted in the forward portion of the torpedo. Although other transducers may be used, with appropriate modification, they must be sufficiently omnidirectional to permit direct transmission from the projector to the hydrophone. The electrical impedance of the transducer used is approximately represented by its capacitive reactance which is inversely proportional to the frequency. The equivalent capacitance of the transducer is about 1,200 micro-microfarads; hence, the reactance at a frequency of 27 kilocycles is 4,910 ohms. To achieve a sufficient signal-to-noise ratio, a projector current of about 50 milliamperes is necessary; thus, requiring a projector voltage of about 245 volts obtained by parallel tuning of the projector **12.**

Referring now to FIG. **2**, the primary function of transmitter **10** is to drive the projector **12** at the required frequency and voltage. This is accomplished by a modified Colpitts type oscillator operating in a parallel-tuned load. The load for the transmitter tube $V_2$ is comprised of a center-tapped toroid inductor **32**, a fixed capacitor **34**, a trimmer capacitor **36**, and the projector **12** connected in parallel so that resonance is obtained at a frequency of 27 kilocycles.

Although the output of the projector is a fraction of a watt of acoustic power, it is sufficient for operation of the system. A reference voltage is taken from the transmitter through capacitor **38** and resistor **40** and is connected to the grid **42** of tube $V_3$ in phase detector **14.** This tube presents a high impedance load and, hence, does not effect the resonance circuit appreciably.

The hydrophone **16** is connected through capacitor **44** to the receiver amplifier **18** comprised of vacuum tubes $V_4$ and $V_5$. The receiver amplifier is a two-stage tuned amplifier of conventional design for obtaining a voltage suitable for the operation of the phase detector. Sufficient gain of, for example, 50 to 80 decibels is provided to maintain an adequate phase-detector input for a low-hydrophone output signal. With such an arrangement, phase detection is relatively unaffected by variations of signal amplitude. The bandwidth of the amplifier at the 3-decibel-down points is preferably 300 cycles per second, which is sufficiently narrow to provide an adequate signal-to-noise ratio, but wide enough to pass the carrier side band required for detection of the phase modulation. The phase detector **14**, comprised of vacuum tubes $V_6$, $V_7$, $V_3$, and $V_8$, produces a direct voltage which varies in proportion to the phase angle between the receiver amplifier output voltage and the transmitter voltage input to the phase detector. The output signal of the receiver amplifier **18** is connected to the grid **46** of vacuum tube $V_6$ and the reference signal from the transmitter is connected to grid **42** of vacuum tube $V_3$. The transmitter signal is subsequently constant in amplitude and phase, and provides a reference by which phase variation of the signal from the receiver amplifier may be detected. For example, when a phase modulation at a rate of 100 cycles per second occurs, the detector output from the cathode follower of tube $V_8$ will be a direct voltage with a 100 cycle per second alternating voltage superimposed upon it.

Vacuum tubes $V_6$ and $V_3$ are cathode-coupled clippers which produce square-wave output signals of nearly constant amplitude with inputs in a range of about 2 to 100 volts. Addition to the two square-wave output signals of tubes $V_6$ and $V_3$, rectification of the combined signals by tubes $V_7$, and integration thereof by the resistance-capacitance circuit, **50** and **52,** provide a direct voltage that is proportional to the phase angle between the two input voltages. The direct voltage is applied to the cathode-follower tube $V_8$ which gives the proper impedance match for supplying the output signal of the phase detector **14** to the background eliminator **20.**

The background eliminator **20** is of a conventional type comprised of resistors **54** and **56,** capacitor **57,** a voltage divider network consisting of resistors **58** and **60,** and two diodes, $V_9$ and $V_{10}$. The direct voltage component of the phase detector output is blocked by capacitor **57,** allowing only the alternating voltage component to pass. Outside of the wake, this alternating component has a small amplitude and is known as background noise. When a wake is encountered, the amplitude of the component is substantially increased. To obtain a greater signal-to-background ratio at the trigger input, a background eliminator **20** is provided to eliminate the background noise. Variable resistor **58** provides a variable and adjustable cutoff level. Resistor **58** may be adjusted to provide 0 to 5.5 volts wherein an increase in the voltage will raise the level of modulation to be eliminated.

Signal variations above the previously mentioned background noise which are passed by the background eliminator **20,** are amplified by the conventional modulation frequency amplifier **22** comprised of vacuum tube $V_{11}$. The modulation frequency amplifier should have a frequency response which eliminates low and high frequency components. Capacitor **62** eliminates any of the carrier voltage (27 kilocycles) which may still be present at the output of the modulation-frequency amplifier **22.** The bandwidth of the modulation-frequency amplifier is approximately 2 kilocycles with the 3-decibel-down points at approximately 40 cycles per second and 2,000 cycles per second.

The second detector **24,** comprised of vacuum tube $V_{12}$ and the conventional integrator **26,** consisting of resistor **64** and capacitor **66,** produces a direct voltage output proportional to the positive peaks occurring at the grid of tube $V_{12}$. The integrator is a resistance-capacitance network with a time constant of about 0.1 seconds and is so designed to prevent triggering on a disturbance of very short duration. The output signal of the integrator is applied to the grid **68** of the tube $V_{13}$. The trigger circuit **28** is a modified Schmitt trigger comprised of tubes $V_{13}$, $V_{14}$, and relay **70** and adapted to provide positive operation of relay **70,** when the input voltage to the trigger circuit **28** exceeds a predetermined level. The triggering level of the trigger circuit is rendered adjustable by the means of a potentiometer **72.** Relay **70** is used to initiate steering of the torpedo.

A steering control system **30,** actuated by relay **70,** automatically guides the torpedo down the wake in the direction of the target until it collides with it. Although various well known means employing servomechanism techniques could be devised to cause the torpedo to proceed along the wake towards the target, the present embodiment of this invention, a simple steering control system, is used to demonstrate the wake detection and guidance capability of this system. At the first encounter of the wake, relay **70** initiates full rudder deflection in a preset direction to cause the torpedo to turn in the direction of the target vessel until it again encounters the wake. A turn in the opposite direction is then initiated, and in this fashion, the torpedo proceeds along the wake in a weaving course.

A steering control system (not shown) of a type well known in the art is comprised of two auxiliary relays and a motor-driven timer with four cam-operated switches. At each wake encounter, relay **70** is kept energized for a sufficient time to avoid more than one steering operation while passing through the wake. The cam-operated switches alternately connect port and starboard rudder solenoids at successive wake encounters, causing the torpedo to steer a weaving course down the wake until it strikes the target vessel.

While the present invention has been described in its preferred embodiment, it is realized that modifications may be made, and it is desired that it be understood that no limitations upon the invention are intended other than may be imposed by the scope of the appended claims.

Having now disclosed our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

**1.** In a detection system, the combination comprising: transmitter means capable of driving a projector with a continuous-acoustic signal, receiver means adapted to receive said signal transmitted by said transmitter; phase detection means capable of detecting the phase difference between said continuous transmitted signal and said received signal, and trigger means adapted to respond to phase differences produced by the characteristics of medium between said transmitter means and said receiver means.

**2.** In a wake-detection system for torpedoes, the combination comprising: a projector adapted to transmit acoustic signals; a transmitter for driving said projector; a hydrophone disposed adjacent to said projector for receiving said projector's acoustic signals; first amplifying means connected to said hydrophone adapted to amplify the output signal of said hydrophone; phase-detector means capable of receiving the output signal of said amplifier means and the output signal from said transmitter, whereby said signals are combined and rectified to produce a phase-detector output signal proportional to the phase difference between said transmitter and amplifier means output signals; blocking means for receiving said phase-detector output signal adapted to block variations of said signal below a predetermined level; second amplifier means capable of amplifying the output signal of said blocking means above a predetermined level; a trigger circuit adapted for receiving and being actuated by said output signal of said blocking means; and rudder-control means actuated by said trigger circuit adapted to control the direction of travel of said torpedo.

3. The combination as claimed in claim 2 in which said second amplifier means is comprised of a detector means and an integrator means.

4. The combination as claimed in claim 2 in which said projector means and said hydrophone is each comprised of a piezoelectric transducer.

5. The combination as claimed in claim 4 in which said transmitting means is comprised of a Colpitts type oscillator having a parallel load.

6. The combination as claimed in claim 5 in which said trigger means is comprised of a Schmitt trigger-type circuit adapted to operate when its input voltage exceeds a preset level.

* * * * *