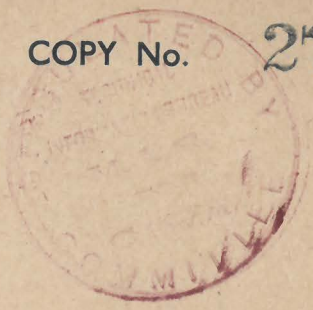
ITEM No. 1 & 15
FILE No. XXX-114

COPY No. 275



SECRET

ACOUSTIC TORPEDO PISTOL PI-KIEL

SECRET

COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

SECRET

ACOUSTIC TORPEDO PISTOL PI-KIEL

Reported by
Lieut. H.H. HART, U.S.N.R.
Mr. A.E. BACHMANN
NavTecMisEu

CIOS Target Numbers 1/106 & 15/4
Mines, Radar

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
G-2 Division, SHAEF (Rear) APO 413

SECRET

SUMMARY

The Pi-Kiel torpedo pistol was a German Development which was not yet operational. It is a pistol utilizing the active-acoustic or pinging principle in which the firing of the torpedo charge is accomplished through a sudden decrease in the time interval between the pinge and the reception of the echo. This decrease in time interval is caused by the shorter echo time. from the hull of the ship contrasted to the echo time from the water surface. This report discusses the development of the Pi-Kiel pistol and briefly compares it with the other known active acoustic pistols, namely; Pi-Berlin and Pi-München (also known as Pi-Otto or Pi-Atlas).

TABLE OF CONTENTS

SECRET

ACOUSTIC PISTOL PI-KIEL

1. Introduction

The following information on the torpedo pistol Pi-Kiel was obtained from Dr. Fahrentholz, Electrocustic Company, Kiel. Dr. Fahrentholz worked in the field of supersonics concerned with mine and torpedo developments and was a member of the Unter Kommission Torpedozundung (Torpedo Pistol Sub-Commission). The information supplied by Dr. Fahrentholz was obtained in part from reports prepared by him at the request of U.S. Navy personnel and through interrogation.

2. Development of Pi-Kiel.

(a) Operational Frequency.

(1) When the problem to develop an acoustic pistol based on the "pinging" principle was first set fourth, a decision concerning the suitable operational frequency was necessary. As in the case of all acoustic devices the satisfactory functioning depends upon a favorable relationship of signal/background; particularly with an active pistol. (An active pistol is one which functions independent of the acoustic output of the target). The background noise is made up of the torpedo self-noise, which arises from the propulsion noise; and peak disturbances resulting from the flow of water at high speeds past the magnetostriction receiving unit. In addition, other acoustic disturbances may be employed as countermeasures by the enemy. It is essential that the pistol remain unaffected by all these disturbances.

(2) First must be considered the elimination of these disturbances by means of a suitable directional pattern; although, this alone will not suffice. If a very narrow beam is employed many targets are likely to be "missed", since the beam will not always be vertical due to the pitch and roll of the torpedo during its run. The self-noise of the torpedo decreases with increase in

2. Development of Pi-Kiel (a)(Cont'd.)

frequency, as is the case with all propeller drives. Therefore, the operational frequency must be selected as high as possible. The upper limit is determined by the physical dimensions of the projector and hydrophone, and these dimensions are influenced by the choice of beam pattern and the required transmitting power. The desirable frequency limit lies between 50 and 100 kilocycles. To meet all requirements 25 kilocycles was selected.

(b) Investigations of Various Mountings for the Projector and Hydrophone.

(1) The choice of 25 kilocycles was also made because simple and reliable magnetostriction units operating at that frequency were already available. It was known that, from the development of "Zaunkönig", the greatest pressure area on the warhead of the torpedo was suited to the fitting of the acoustic gear. It was first required by the German Navy that Pi-Kiel be inserted as a complete unit with batteries in the pistol pocket of the G7a. (In contrast, the Luftwaffe demanded that the Atlas Co. insert its Pi-München, also known as Pi-Otto and Pi-Atlas, in the top of the warhead as an independent entity).

(2) The early form of the Pi-Kiel was the same as that shown in Figure 1. With this pistol several shots were made which showed that the principle was reliable. When the torpedo ran under a target, firing took place below the second half of the target. The projector and hydrophone were first located behind a sheet metal nose in a water-filled compartment. This compartment had to be free of air bubbles. The construction was simplified by adopting the arrangement shown in Figure 2. However, this arrangement caused a slight increase in the length of the torpedo. When the plan for an improved design was approved the tube-form gear which was known to be too long and unwieldly was abandoned.

(3) The pistol was now to be built into the casing which had been developed for the "Amsel". The projector and hydrophone installation shown in Figure 3 was then constructed. The first series of experimental shots with this

2. Development of Pi-Kiel (b)(Cont'd).

arrangement resulted in many prematures. Since all components were tested to the most exact degree in the laboratory and worked perfectly electrically it had to be assumed that the new gear, in regard to the acoustic characteristics, was strongly differentiated from that shown in Figures 1 and 2.

(4) Shots for oscillographing the external noise under various conditions were then systematically made. All alternating currents which came from the amplifier were shown on a recording oscillograph mounted in the torpedo. It was apparent from these recordings that an unfavorable relationship of signal/background existed when the gear shown in Figure 3 was used. Since comprehensive water tunnel tests had shown that no cavitation took place in the vicinity of the receiver at great speeds (50 knots), the main cause for the external disturbances had to be looked for in the propeller noise. In comparatively long investigations electrical disturbances, noise transmitted through the torpedo body, and acoustic disturbances transmitted from the water through the torpedo body were separated, and it was shown that the screening of the receiver against the propeller noise had to be improved.

(5) The next step was to adopt the single projector-hydrophone shown in Figure 5. The number of unexplained misfires decreased considerably. However, the relationship of signal/background did not hey appeat to be sufficient for all occurring relationships, particularly considering counter-measures with explosive bodies and noisemakers. The external noise at the hydrophone could not be noticeable improved through minor changes in the nose form of the forward section. The only alternative for improving the signal/background ratio was to increase the transmitting energy.

(c) Main Points in Development of Eletrical Gear for Pi-Kiel.

(1) In the early models of Pi-Kiel the essential elements were a "shock" circuit for exciting the projector, a receiver amplifier, a noise eliminator, and the firing circuit. This arrangement was similar to that used in the German "Echo" mines, AE1 and AE101. German Army tubes and batteries were

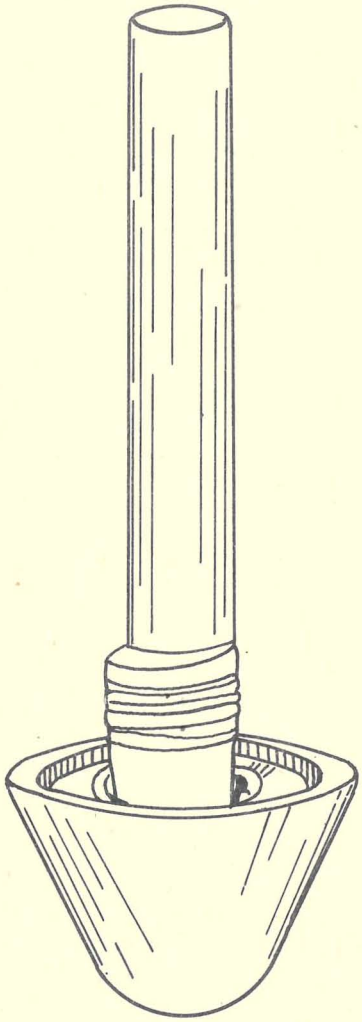


Fig. 1 - Early Model of Pi Kiel. Projector and Hydrophone Mounted Behind Sheet Metal Nose.

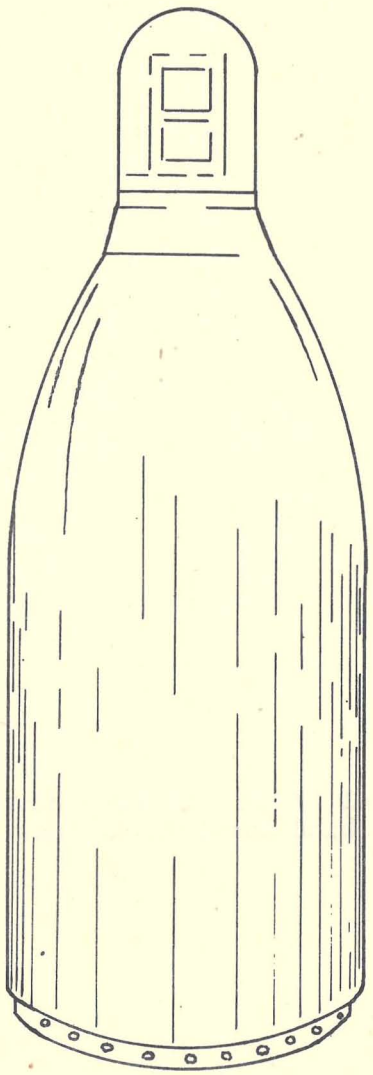


Fig. 2. - Modified Pi Kiel With Hydrophone and Projector In Contact With Water.

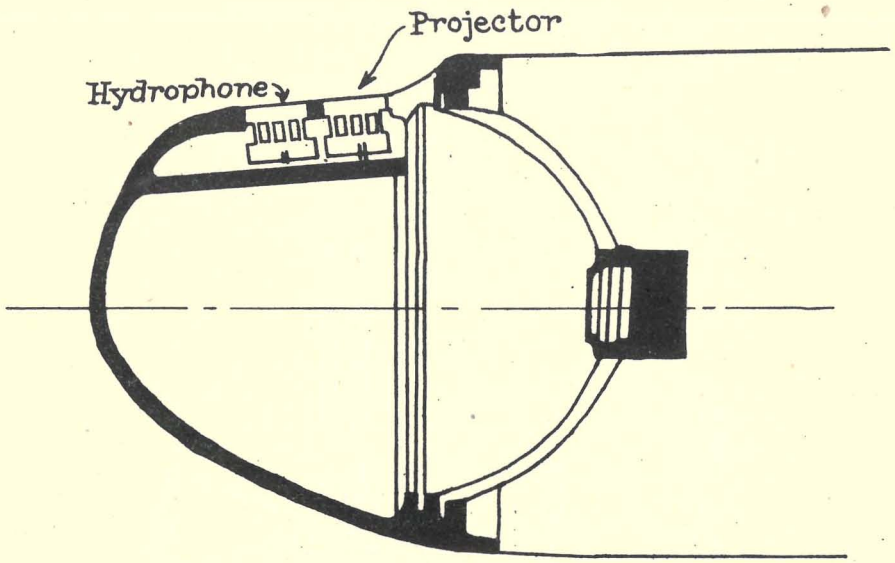


Fig. 3. - Pi Kiel Construction for "Amsel" Casing.

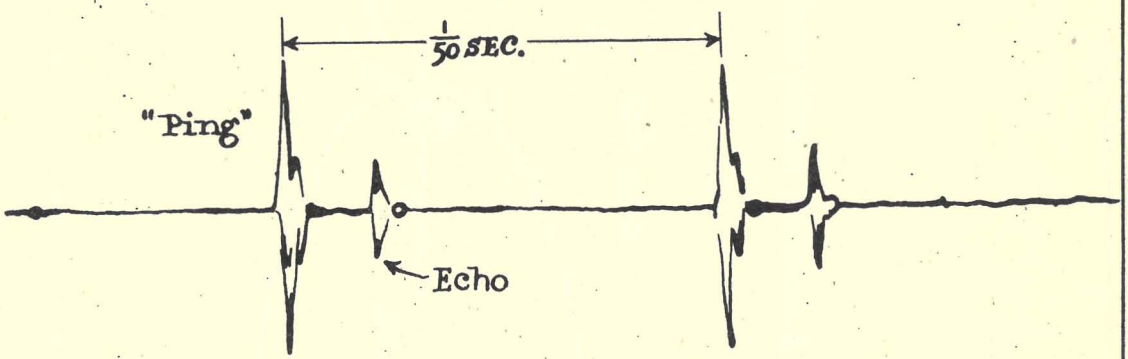


Fig. 4. - Tracing of Oscillograph Recording.

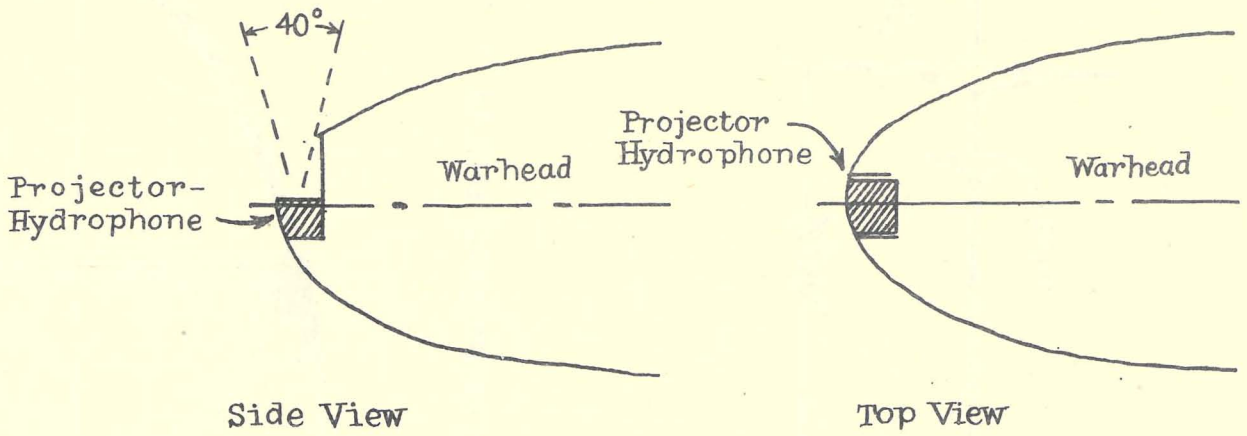


Fig. 5 - Sketch of Projector-Hydrophone Mounting.

2. Development of Pi-Kiel (c)(Cont'd.)

used. The generation of the impulse series was achieved by the use of a motor with mechanical interruptors corresponding to that in AE1. Next, the transmitting power was increased in the "shock" circuit. Three (3) condensers were charged in parallel from the anode battery of about 200 volts and discharged in series across the projector winding. (These tests were carried out with the designs shown in Figures 1 and 2).

(2) In preparation for mass production Pi-Kiel was to be changed so that it would take the "E" (6.3 volts) series of tubes. Trials were held to shorten the filament heating time by applying voltages greater than 6.3 volts.

(3) In order to excite the projector with more power a vacuum tube oscillator was adopted. Rotating mechanical parts were replaced by purely electrical circuits (relaxation oscillator principle). Since the vacuum tube oscillator produces an undamped wave impulse of 25 kilocycles the width of the band of the receiving amplifier could be reduced so that one could get a further increase in signal/background ratio. The "pinging" rate was increased from 15 to 50/second.

(4) Along with the development of the pistol circuit investigations were also carried out concerning the suitability of various relays and tubes. It was learned that the relays had to be imbedded in a shock absorbing material, and that very sensitive relays, e.g., the mid-position type, are to be avoided. Therefore the firing circuit, in contrast to the one in mine AE1, was changed. A vacuum tube circuit for the exciting of a stable, insensitive relay was introduced. There were also trials which aimed to replace the firing relay by a thyratron and by a gas triode (anode current controlled over a portion of the grid voltage curve). In addition, an oscillator feeding the firing relay through a transformer was tried.

(5) A selector mechanism was developed in order to obtain oscillograph records of the various signals and voltages during the torpedo's run. In Figure 4 a tracing of

2. Development of Pi-Kiel (c)(Cont'd.)

an oscillograph strip is shown which, during a shot, is taken with a recording cathode ray oscillograph. The velocity of the film during recording periods was 2.5 meters per second, but by use of the selector mechanism control the film was stopped intermittently. Since no other strips are to be found this tracing must serve as an example of the kind of recordings made during the investigations. The transmitting impulse and echo of Figure 4 were taken without the blocking circuit of the receiver amplifier functioning. The outside disturbances at 40 knots are still so small that noises on the recording strips cannot be recognized.

(6) After the trial apparatus using dry batteries was developed, a second design was constructed using 12 volt nickel-cadmium batteries (made by the Friemann and Wolf Company, Zwickaw/Sachsen) coupled to a vibrator, transformer and rectifier. Parallel with the building of this gear the German Navy also conducted experiments on a "universal" generator for torpedoes.

(d) Testing of the Apparatus.

The acoustic performace of the pistol was tested in air by means of "pinging" off a reflecting disk. This disk, a sheet metal or wooden plate, can be adjusted in height by means of a rope and pulley arrangement. Slow up and down motions of the disk correspond to torpedo variations in depth (pitch) or depth changes due to waves. Faster changes in disk height correspond to the sudden change in depth caused by a torpedo passing under a ship. The functioning of the electrical circuits are recorded in detail with a cathode ray oscillograph.

(e) Comparison of Pi-Kiel, Pi-Berlin and Pi-München:

(1) Pi-Kiel and Pi-München work according to the same principle, but are distinguished by the construction of the projector and hydrophone mountings and the circuits of the noise eliminator. In Pi-Kiel a projector-hydrophone operating at 25 kiolcycles is installed at the tip of the torpedo nose. Pi-Munchen, however, uses two (2) magnetostriction

2. Development of Pi-Kiel (e)(Cont'd.)

units, one as projector and one as hydrophone, tuned to 30 kilocycles. The projector and hydrophone are mounted one behind the other in the top of the after end of the warhead. The additional noise eliminator circuit in Pi-Kiel is effective when the enemy uses countermeasures, particularly because the signal/background ratio is improved through the use of a vacuum tube oscillator in the transmitting circuit.

(2) Pi-Berlin uses a projector and a hydrophone each tuned to 50 kilocycles. More recently the hydrophone was located in the same place as in Pi-Kiel; the projector being mounted somewhat higher than, and aft of, the hydrophone. The pinging rate in Pi-München and Pi-Berlin is about 15/second; in Pi-Kiel 50/second.

(3) Pi-Kiel and Pi-München use only the pinging principle for recognizing depth variations. In Pi-Berlin an attempt was made to combine an acoustic depth gage with a bellows depth gage. If the torpedo runs, for example, at a depth of 10 meters echoes will be received when "pinging" on the water surface. In Pi-Berlin these echoes were to be suppressed by means of a blocking circuit controlled by the bellows. Only when echoes arrive from distances less than 8 meters do they enter outside the blocking time of the receiver amplifier. They are then operative on the firing circuit. The disadvantages of this kind of circuit are, apart from the increased use of circuit components, the increased vulnerability to countermeasures and the tendency to misfire which occurs because the bellows blocking control does not always function quickly and accurately--particularly when there are variations in the depth of running (pitch) of the torpedo. It is also considered that the addition of a 65 kilocycles noise discriminating circuit in the Pi-Berlin will not give reliable performance.

(4) In order to conclude which was the best hydrophone and projector installation of the three (3) parallel developments, it was planned to run comparative tests to determine which installation and circuit performed most reliably; particularly with regard to countermeasures. It was intended to install a Pi-Kiel hydrophone-projector and

2. Development of Pi-Kiel (e)(Cont'd).

adjusted electronic gear in the Pi-Berlin and Pi-München warheads.

(f) Conclusions.

(1) With Pi-Kiel an extensive torpedo firing program was carried out to determine the acoustic background noise. At a speed of 40 knots the relationship of signal/background for a G7a varied from 10:1 up to 50:1 depending upon the condition of the water surface. Variations in running depth which were produced artificially did not lead to misfires.

(2) Shots in large swells and firing under the wake of "S" boats or similar boats have not been tried. Preliminary trials showed that under certain circumstanses it must be expected that there will be misfires when using large amplification in the receiving gear.

3. Operation of Pi-Kiel.

(a) General Performance

(1) The Pi-Kiel is an acoustic pistol operating on the echo principle. Acoustic transmission and reception is accomplished by a single magnetostriction projector-hydrophone built in the nose of the torpedo warhead. The distance of the torpedo below the reflecting surface is determined by the transmission-reception time interval. In addition it is recorded whether the depth remains constant, changes slowly, or changes suddenly. When running under a ship, the sudden decrease in transmission reception time interval results in firing. The pistol is designed for the G7a torpedo and the torpedo is always to be run at a depth of 10 meters.

(2) Current is supplied by a 500 cps. 36 volt generator. However, in the first test models batteries were used, and in one test model a 12 volt nickel-cadmium battery connected to a vibrator, transformer and rectifier supplied the required 220 volts d.c.

(3) A circuit diagram of the pistol is shown in Figure 6.

3. Operation of Pi-Kiel (Cont'd.)

(b) Arming Run.

After a 100 meter run an arming impeller mechanism closes switches 1 and 2, thereby turning on the voltage to the pistol circuit. A short time after 1 and 2 close another switch (not shown on the diagram) closes connecting the detonator circuit across the contacts of R_2; contacts R_2 remaining open.

(c) Protection Against Broaching.

In order to prevent detonation through broaching a hydrostatic switch is provided, independent of the pistol circuit, which removes the detonators from the firing circuit when the torpedo reaches a predetermined depth. This depth was not yet definitely specified, but it is believed that it would be about 3 meters.

(d) Voltage Supply.

By use of the two transformers, 1 and 2, and the corresponding rectifiers the high voltage for the transmitting tube, the 250 volt anode voltage for the receiver amplifier, and the necessary bias voltage is provided from the single 36 volt generator. In addition, there are two heating circuits, H_1 and H_2, not drawn in the diagram which supply tubes EF112, EF13, EC50, EF12 and EDD11 with 6.3 volts a.c. and which also supply tube LS50 with 12 volts.

(e) Transmitting Circuit.

(1) A high frequency generator functioning as a relaxation oscillator produces 50 impulses per second, having a duration of 1.5 milliseconds and a frequency of 25 kilocycles. At a torpedo speed of 40 knots the water surface is "pinged" at intervals of 40 centimeters. A vacuum tube oscillator LS50 generates the high frqqency voltage in the tuned 25 kilocycles circuit. The 25 kilocycles voltage passes through transformer 4 which is coupled to the projector. The feedback in 3 is so selected that a grid current in LS50 sets in when the tube starts to oscillate. This grid current produces a negative

3. Operation of Pi-Kiel (e)(Cont'd).

charge in the capacity 5 connected in the grid circuit. In this way the tube is again automatically blocked after heating. The negative charge of 5 flows across resistors 6 having such a value that 50 impulses are produced.

(2) In order to convert the electrical energy into acoustic energy with the greatest possible degree of efficiency the projector -hydrophone must be pre-polarized with a direct current of about 3 amperes. The polarizing current is obtained from the 1.2 volt battery NC5 which is connected in series with the choke 7 to prevent "shunting" losses at 25 kilocycle. The capacity 8 blocks the flow of current through the winding of transformer 4. The electrical energy given off by the oscillator during an impulse amounts to about 160 watts. The acoustic energy amounts to about 80 watts; thus giving an efficiency of approximately 50 percent.

(3) To maintain the acoustic interference from the propellers at a minimum the projector-hydrophone is shielded by mounting it in the extreme end of the warhead as shown in Figure 5. The directional pattern of the projector-hydrophone has an opening angle of about 40 degrees around its axis. Distortion of the pattern, however, exists due to the interference effects produced by the "back-wall", of the torpedo warhead.

(f) Receiver Amplifier.

(1) The full-wave rectifier unit 10 short circuits the voltage which appears across the grid of EF;;2 during transmission so that the input tube is not too heavily loaded. As a result automatic blocking of the receiver amplifier takes place right up to the time during which echoes are beginning to arrive. (The resistance of the rectifier unit is high at voltage values generated by the received echoes.) All returning echoes are converted into a.c. in the projector-hydrophone. Across winding 9 of the transformer and across the resostor on the grid of EF;;2 the converted voltage is coupled to the receiver amplifier. The real amplifier consists of tubes EF112 and EF13 plus the tuned circuits 11 and 12 operating at 25 kilocycles. The output of the amplifier consists

3. Operation of Pi-Kiel (f)(Cont'd.)

of positive half-waves and is coupled to the grid of thyratron EC50. The threshold level of EC50 is pre-set by a negative voltage in order to prevent spontaneous firing of the pistol. Through the positive peaks of the echoes the thyratron is ignited, and as a result condenser 13, which is always charged across resistor 14, is discharged. The change in voltage which appears on the anode of EC50 at the moment of "firing" is fed to the polarized relay R_1 (distance measuring relay) through the condenser 15 which has about a 2 millisecond time-constant.

(2) The rectifier 16 has the function of feeding the voltage peaks to relay R_1. Contact r_1 connects condensers 17 and 18 together at the arrival of an echo (target echo). The condenser 17 is charged during transmission through rectifier 20 from the voltage in winding 19. During reception condenser 17 discharges itself through resistor 21. The voltage on condenser 17 is a function of the time interval between transmission and reception of a "ping"; thus a measure of the distance between the projector-hydrophone and the reflecting "surface". The distance measuring relay R_1 then allows the distance measuring voltage on condenser 17 to be applied to the "ignition" circuit.

(3) The degree of amplification of the receiver amplifier is approximately 10^4, and the amplitude of the echo when entering the amplifier, i.e., voltage across winding 9, is between 5 and 10 millivolts.

(g) Blocking.

Blocking has the function of making the receiver amplifier active for only those echoes which return from a distance of 2 to 12 meters and also to block the amplifier during transmission. The second half, 22, of the tube EDD11 is coupled in as a feedback oscillator and is tuned to about 6 kilocycles. Across the transformer 24 lies the oscillator frequency of 6 kilocycles. This voltage is coupled to the suppressor grid of EF13 through the rectifier 25 and acts as a negative blocking voltage. As long as 22 oscillates the receiver amplifier is blocked. At the moment of transmitting

3. Operation of Pi-Kiel (g)(Cont'd.)

the first impulse, after the arming run, the large negative voltage on the grid of 22 (resulting from the rectified transmission voltage passing through 22)stops the tube from oscillating. The negative charge of the suppressor grid in EF13 decreases, and after 2 meters distance time (corresponds to "ping" travel of 4 meters) the receiver amplifier is ready to function. The discharging of grid condenser 26 continues long enough to allow echoes to be received from surfaces 12 meters distance from the projector-hydrophone. Then 22 begins to oscillate and again blocks the receiver amplifier until the next transmitting impulse, etc.,etc. By the use of this blocking circuit the transmitting functions have no detrimental effect on the receiving circuits.

(h) Anti-Disturbance Circuit

(1) This circuit serves to sift out thereal echoes from all acoustic imoulses. The tube EF12 functions as a 50 cps. oscillator having screen-grid feedback. A frequenct of 50 cps. was chosen so as to match the "pinging" rate. From transformer 27 the sine voltage reaches the suppressor grid of EF112, and in series with this a.c. voltage a fixed positive bias voltage lies across the potentiometer 28. The bias voltage has a value such that, in spite of the 50 cps. voltage of 27, the suppressor grid of EF112 possesses cathode potential. The rectifier 29 permits only negatives half-cycles of the sine voltage to be effective because it shortcircuits the positive half-cycles.

(2) If, when an echoe is received the thyratrin EC50 "fires" a tuned circuit 30 connected to condenser 31 is "shocked". This circuit is likewise tuned to 50 cps. The 50 cps. sine voltage resulting from this "shocking" synchronizes the 50 cps. oscillating voltage in such a manner that 50 cps. oscillating voltage is a maximum when an echo is received. In tube EF112, therefore, the received echo and the "peak" of the 50 cps. voltage are superimposes.

(3) Through the constant firing of EC50 there arises in transformer 32 voltage that is coupled to the rectifier bridge. The resultant negative voltage across resistor 35 is

3. Operation of Pi-Kiel (h)(Cont'd.)

then connected in series with 27 and 28. The superimposing of the fixed positive voltage 28, the 50 cps. echo-synchronized sine voltage 27, and the regulating voltage 35 results in the input tube EF112 being open only during that short time in which the echoes are "expected" to arrive at the projector-hydrophone. Every echo controls the blocking of the amplifier in such a way that the amplifier is ready again to receive when the successive echo of the next pinging period occurs. Consider transmission impulses 1, 2, 3, 4, ... n, and the corresponding echoes 1, 2, 3, 4, ...n. Echo 3 from impulse 3 controls the blocking of the amplifier in such a way that it will be open only during the time echo 4 from impulse 4 is "expected" at the projector-hydrophone.

(4) If the thyratron EC50 no longer fires regularly the suppressor grid of EF112 becomes again slowly more positive and thereby the amplifier assumes its "normal" open condition. Only the blocking described in paragraph (g) is still in operation. Therefore, in this manner only regularly returning echoes can cause relay R_1 to operate and allow the distance measuring voltage to be applied to the firing circuit. The "oscillogram" diagrams shown in Figure 7 illustrates the timing between various voltages and signals.

(i) Firing Circuit.

(1) It was previously described how relay R_1 operated upon the reception of an echo and closed contact r_1. According to the distance from which the echo returns a definite distance measuring voltage is applied to condensers 18. During the torpedo's run condenser 18 is charged and remains charged as long as the echoes come from the same distance, e.g., the surface of the water. If the torpedo runs under a ship, condenser 18 is suddenly subjected to a larger voltage whereby a positive voltage "shock" arises at the grid of the negatively voltaged firing triode 34 of EDD11. The change in plate current results in the closing of the contact of relay R_2; thus firing the detonators. The sensitivity (amplitude) of the firing circuit is adjusted by means of the potentiometer in the bias circuit 33. The rate of change in depth necessary for firing was not definitely specified, but it is believed to

3. Operation of Pi-Kiel (i)(Cont'd.

be about 3 meters per second.

(2) The pistol is designed to meet only those requirements specified by the German Navy for targets having a draft of more than 3 meters. Slow changes of charge on condesner 18 which result from slow changes in depth will not cause firing.

(3) It can be seen from the circuit diagram that during the initial warming up of tubes and the charging of condensers, particularly 18, the firing circuit must be rendered safe. This allows the distance measuring comparison voltages, 17 and 18, to assume their proper "relationship" during the first few water surface echoes. This safety feature was pointed out in paragraph (b).

(j) Voltage Diagrams.

Figure 7 shows the relationship between the various voltages, and each diagram presented therein is described below.

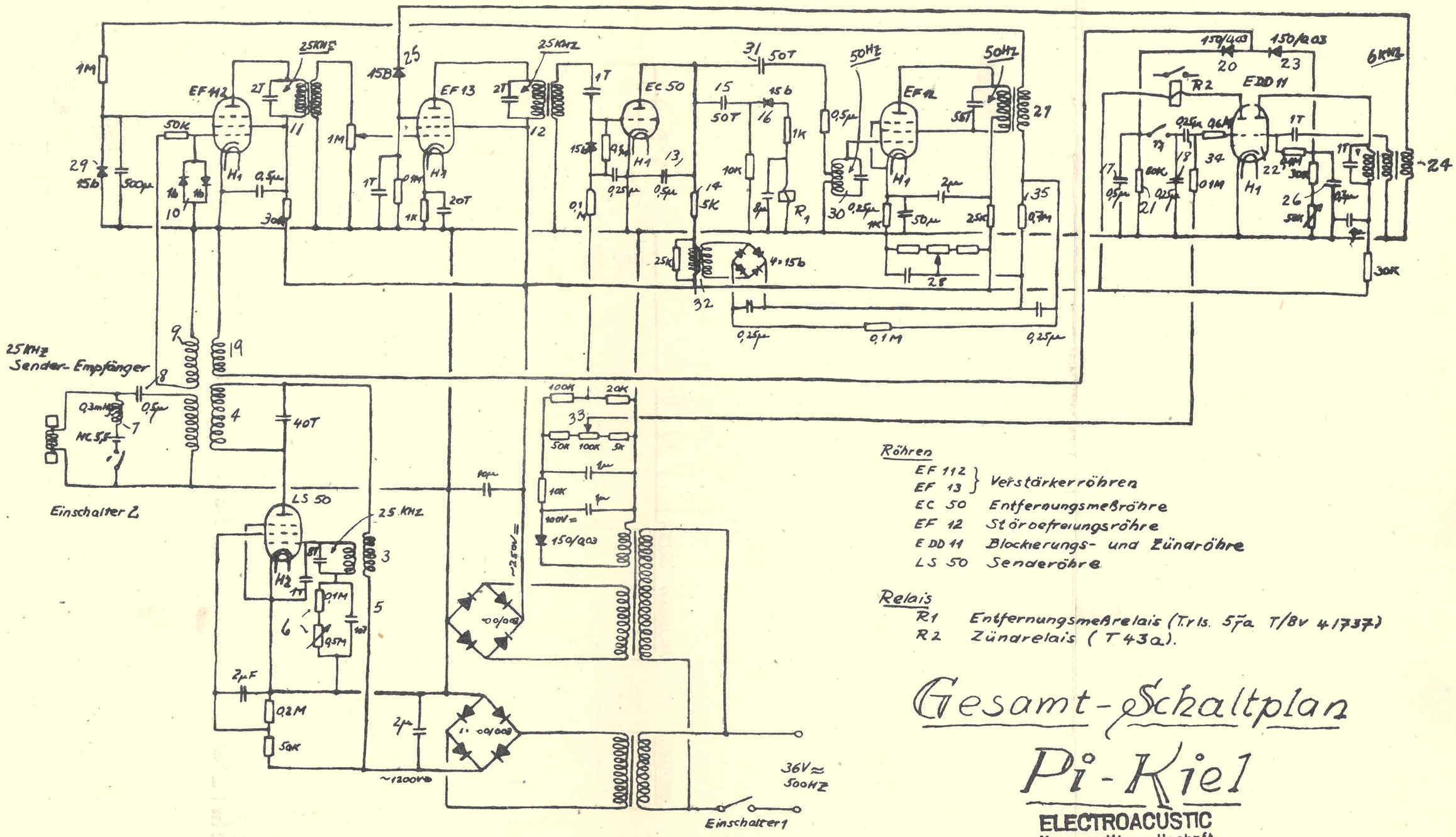
(a) shows the transmitting impulses which are produced at intervals of 1/50 second.

(b) denotes the periodic charging and discharging of the distance measuring dondenser 17. At the moment of transmission the condenser is quickly charged and during the receiving period slowly discharged.

(c) shows blocking time at the suppressor grid of EF13. Of the total "distance-time-interval" of 15 meters (corresponding to the 50 cps. oscillator frequency) only echoes from distances 2-12 meters can be received. From 12-15 meters and from 0-2 meters the amplifier is blocked.

(d) shows regularly returning echoes. These echoes cause the distance measuring voltage,

Kommanditgesellschaft
KIEL



Röhren

EF 112, EF 13	Verstärkerröhren
EC 50	Entfernungsmeßröhre
EF 12	Störbefreiungsröhre
EDD 11	Blockierungs- und Zündröhre
LS 50	Senderöhre

Relais

R1	Entfernungsmeßrelais (T.r.ls. 5fa. T/BV 41737)
R2	Zündrelais (T 43a).

Gesamt-Schaltplan

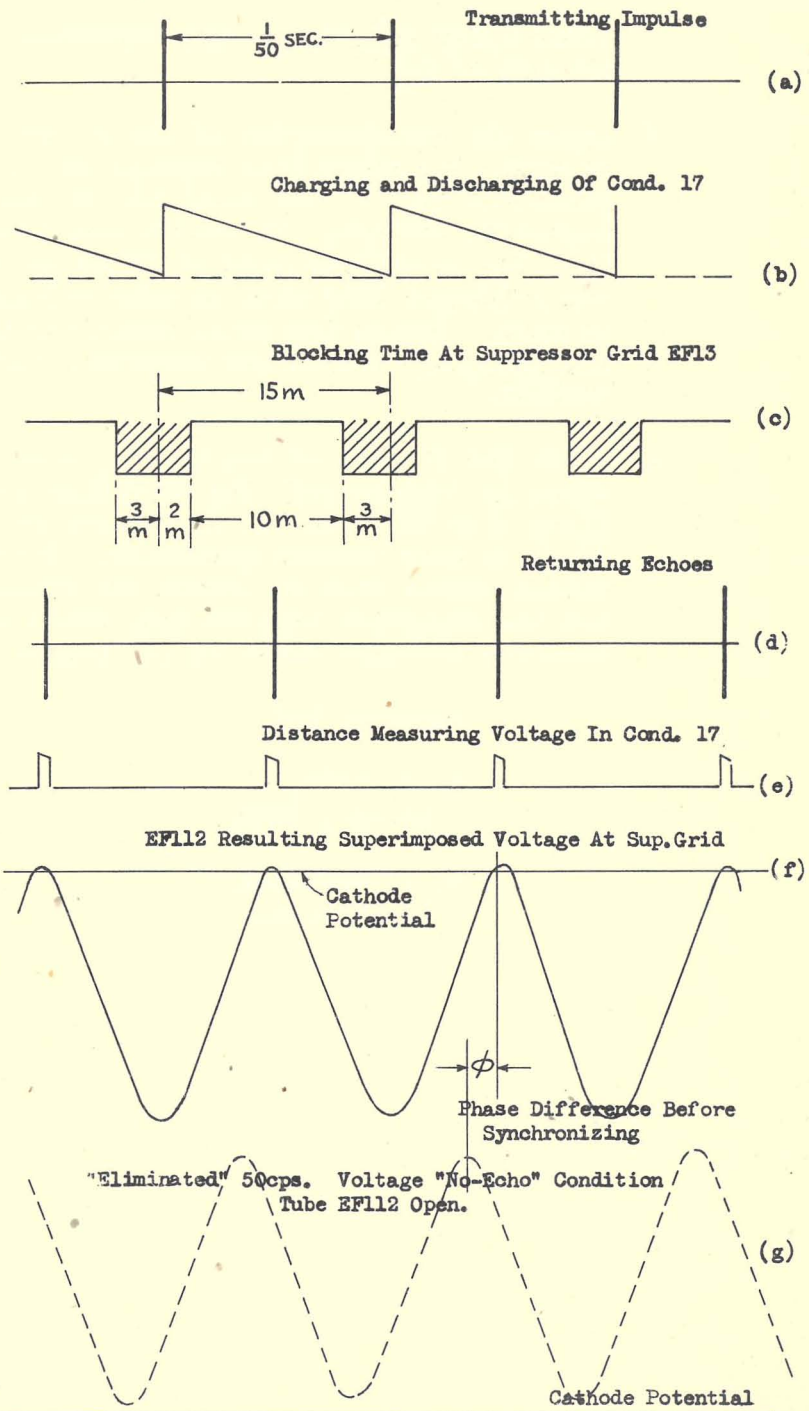
Pi-Kiel

ELECTROACUSTIC
Kommanditgesellschaft
KIEL

Fig. 6 - Circuit Diagram Of Pi-Kiel.

Fig. 7 - Voltage Diagrams.

A.E.B.
June 16, '45



ELECTROACUSTIC
Kommanditgesellschaft, Kiel

3. Operation of Pi-Kiel (j)(Cont'd.)

shown under (e), to go from condenser 17 by closure of R_1.

(f) shows the superimposing of the 50 cps. sine voltage, the fixed bias voltage 28, and the generated bias of the rectifier bridge in the thyratron circuit. It can be seen therefore, that the suppressor grid of EF112 is at cathode potential only when an echo voltage is present. During the total remaining time of the "pinging" period the receiving circuit is blocked.

(g) shows the portion of the 50 cps. sine wave which is "eliminated" (by rectifier 29 and fixed bias 28) when the suppressor grid of EF112 is near cathode potential. This condition exists when no echoes are received, and the amplifier remains open until the blocking voltages shown in (c) arise.

Prepared by:

H. H. HART,
Lieut., USNR.

A. E. BACHMANN,
Technician.