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Notes on the Modification of the Models YE and YG Homing Beacon Equipments for Increased Security

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APPENDICES

AUTHORIZATION

1. The development of a system for modifying the Model YE and YG Homing Equipment to increase the degree of security of this equipment was conducted under the authority contained in reference (a).

Reference: (a) BuShips ltr S-F42-1/69(938) Serial No. 05531 of 4 August 1943.
(b) Preliminary Instruction Book IB-38050 for Model YE Homing Beacon Equipment.
(c) Preliminary Instruction Book IB-38163 for Model YG Homing Beacon Equipment.
(d) NRL ltr S-F42-1/69H of 15 October 1943 to BuShips.

INTRODUCTORY

2. The Homing Equipment modification has been developed at the Naval Research Laboratory for the purpose of providing greater security for the Models YE and YG Homing Beacon Equipments. Greater security is obtained through a remote control system which energizes the homing equipment in response to a signal transmitted from an aircraft and which limits homing transmission to a period of slightly over one minute. In this way transmission takes place only at such times as required by aircraft in homing.

3. The Models YE and YG Homing Equipments as now constituted radiate a coded signal indicating compass bearings from an aircraft carrier or airfield for the guidance of returning aircraft. The 360 degrees of the compass are divided into twelve equal sectors of 30 degrees so that a differently coded signal is transmitted in each successive sector by means of a directional antenna rotating at 2 r.p.m. and a keyer unit synchronized to the antenna rotation. The keyer unit keys each code signal twice as the antenna rotates through each sector; the coded signals are letters of the alphabet. For homing reception, the equipment required on the plane consists of a quarter wave non-directional antenna and Model ZB-RU or Model ZBX Receiver. When the homing equipment is in operation, the aircraft pilot receives two or three of the 12 coded signals as the antenna is radiating in his general direction. One of these signals will be stronger than the others, and so the direction of the carrier or airfield will be indicated to the pilot by the code signal received with the greatest strength. Complete descriptions of the Models YE and YG Equipments are given in references (b) and (c).

4. Security of the homing transmissions at present is maintained by applying a radio frequency modulation in the MF range to a 246 m.c. carrier. The coded signals key the r-f modulation only. Homing transmissions are transmitted continuously during the greater part of the time a flight is in progress, however, tests have shown that signals can be heard only during 60 degrees of the antenna rotation, or for one sixth of the total time the homing equipment is in operation. This means that the signal can be heard for approximately 5 seconds out of each 30 seconds revolution of the antenna. The proposed modification would give the aircraft pilot remote radio control of the Models YE and YG transmitters thereby limiting the transmission of

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homing signals to such time as needed. This system appears to be the only feasible means for appreciably increasing the security of the Model YE/YG Equipments.

5. The following is a brief description of the proposed system. A unit of small physical dimensions is required in the aircraft for the purpose of modulating one of the four r-f channels of the V.H.F. communication transmitter with a control signal. Installation of this unit on a plane does not require modification of the communication equipment nor loss of any channels for communication purposes. Transmission of the signal is controlled by the aircraft pilot by operation of a small lever. A V.H.F. receiver is required at the Model YE or YG location for reception of the V.H.F. transmissions from the aircraft. Special circuits connected to the V.H.F. receiver output select the control signal and reject undesired signals including voice and noise. This action allows only the control signal to operate relays which place the homing transmitter into operation. The length of time the homing transmitter remains energized can be set as desired beforehand up to two minutes.

DESCRIPTION OF AIRCRAFT EQUIPMENT

6. The additional aircraft equipment consists of an audio oscillator and a timing mechanism in one case. This equipment is compact (6x5x5 inches) and light in weight (5 lbs.). Modification of the aircraft transmitting equipment with which it will be used is not necessary. The unit is mounted in the plane at some convenient place within reach of the pilot. Plate 1 shows a block diagram of the aircraft equipment.

7. Audio Oscillator. A Hartley circuit was used in the design of the audio oscillator. A Navy type 28D7 dual beam power tube with both sections connected in parallel is employed in the oscillator circuit. This tube is designed for use in aircraft radio equipment and may be operated with 28 volts on the plate and filament. A schematic diagram of the oscillator is shown in Plate 3. The tank circuit inductor is wound on a toroidal permalloy core and the inductance value is 50 millihenries. The oscillator frequency is variable in six steps of 200 cycles each from 5500 to 6500 cycles per second by means of a rotary tap switch which varies the total capacitance across the tank inductor. As the switch is rotated from position 6 to 1, several fixed capacitors plus one mica trimmer capacitor are added to the circuit at each switch position. The trimmer condensers are used as a vernier adjustment to set each channel to the exact frequency. A Secondary or output winding on the tank circuit inductor is tapped so that the output voltage can be varied with the frequency in order to maintain a constant percentage of modulation of the V.H.F. transmitter. This is necessary due to decreasing amplification in the V.H.F. transmitter's audio system as the modulation frequency increases. Data for the adjustment of these taps was obtained from the measured characteristics of Model AN-ARC-5-VHF (274N) and Model AN-ARC-4 (233A) transmitters. These output taps are connected to a switch which is ganged with the frequency change switch insuring that the audio voltage impressed upon the modulator will increase with increase in frequency, thus maintinaing a constand percentage of modulation. Plate 5 shows the input voltage required to modulate a Model AN/ARC-4

transmitter to 100 percent over the range of 5500 to 6500 c.p.s.

8. The power requirement of the oscillator from the aircraft 28 volt power source is 11.35 watts. Vacuum tube heaters, screen, and plates all operate from the 28 volt source, The heater current is 400 milliamperes and the total screen and plate currents are 5-7 milliamperes. The frequency stability of the oscillator is such that over the temperature range of +50° C to -30° C the frequency drift does not exceed $\pm$15 cycles per second. The output of the oscillator is introduced into the inter-communication system (ICS) control box thru a WD-2/U microphone cable plugged into the microphone connection. The microphone then connects thru a jack on the aircraft unit. Loading of the ICS circuit by the oscillator output coil during normal operation is prevented by disconnecting the output coil from the ICS circuit. This disconnection is accomplished automatically by a contact on the timer. This feature eliminates the necessity for modification of the ICS control box and allows normal voice operation on the inter-communication system and radio channels.

9. Timer. The mechanical timer, which determines the length of time the oscillator is energized and thus the length of the control signal is a modified telephone dial. The dial employed is furnished with a notched cam which actuates the pulsing contacts on the return rotation. The dial modification requires this cam to be replaced by another cam with one raised portion and one notched portion. The design of the cam is such as to cause the pulsing contacts to close only once during the return rotation of the cam. These contacts connect the oscillator cathode to ground and thus start and stop oscillation. The length of time the contacts are closed depends primarily on the length of the raised portion of the cam. The cam spring tension and adjustment of the governor also affect the timing. For this equipment the finger plate furnished with the dial has been replaced with a handle, gear, and ratchet mechanism which simply makes it necessary for the pilot to turn the handle clockwise thru a 120 degree arc to operate the timer. As the handle nears the end of its travel the ratchet trips the cam mechanism free from the handle and allows the cam to return to its normal position, closing the timing contacts on the way. The addition of the handle allows operation of the timer by a gloved hand and the ratchet-trip eliminates the possibility of interference with the speed of rotation. At the end of the 120 degree rotation, the handle can be released at will and a spring, separate from the one on the timer cam, returns it to the normal position and causes the ratchet to re-set for another operation. The timer contains another pair of contacts, controlled by a small heart shaped cam, which closes when the control handle is first turned in a clockwise direction and remains closed until the time mechanism has completed its return rotation. These contacts are used to automatically place the transmitter in operation before the audio signal is applied to the modulator and to cut off the transmitter after the signal has been transmitted.

DESCRIPTION OF CARRIER EQUIPMENT

10. The control equipment required on the carrier is considerably larger and more intricate electrically than the equipment required in the plane. This

results from the fact that the equipment on the plane has been kept as compact as possible, while the bulkier equipment has been placed on the carrier where the additional weight would be of less concern. While a shipboard Model of the Carrier equipment has not been constructed, constructional drawings covering the design of such an equipment have been completed. Using these drawings as a basis the size of the Carrier equipment will be 21x20x30-1/4 inches or approximately that of the Model YG transmitter. The weight is approximately that of the Model YG transmitter. The weight is approximately 180 lbs. In the contemplated design the components are arranged on three decks in a cabinet; this includes the receiver which is placed on the bottom deck. The cabinet, similar in design and appearance to that of the Model YG transmitter, houses the units and is intended to mount near the Model YG or YE equipment, Plate 2 shows a block diagram of the Carrier equipment.

11. The control signal, transmitted from the plane, is received by a non-directional antenna and is fed thru a 50 ohm transmission line to a Model RCK VHF Receiver. The receiver output passes thru a high-pass filter designed to cut-off below 4800 c.p.s. which eliminates a large percentage of the voice and noise interference present in this frequency range. The high-pass filter output connects to a mixer circuit where the control signal of a frequency between 5500 and 6500 c.p.s. beats with a local oscillator whose frequency is set to give a beat note of 2000 c.p.s. The 2000 c.p.s. output of the mixer passes thru an amplifier - buffer stage into a 2000 c.p.s. band-pass filter. This filter highly attenuates any noise or undesired signals which have not been eliminated by the high-pass filter and oscillator-mixer circuit. The output of the band-pass filter is transformer coupled to a voltage amplifier. This amplifier compensates for the loss sustained in the band-pass filter at 2000 c.p.s. and has excess gain in order to insure operation under widely varying signal and noise levels. The output of the voltage amplifier controls the grid of a thyratron tube which operates a relay connected in its plate circuit. Operation of this relay applies a d.c. voltage to an electronic time circuit controlling the grid of a triode. When a signal of the correct duration is received, relays in the triode circuit operate. These relays cause the operation of the control relays which place the Model YE or YG homing equipment into operation the length of time necessary for the antenna to make slightly more than two revolutions. Throughout the detailed description of the Aircraft Carrier equipment which follows, reference is made to the schematic diagram appearing on Plate 4 and the interconnection diagram on Plate 10.

12. <u>Antenna</u>. The V.H.F. Antenna intented for use with this equipment is of the ground plane type consisting of four horizontal radial conductors, a quarter wave vertical radiator and an impedance matching stub. The antenna is required to be mounted so as to have a non-directional receiving characteristic in a horizontal plane.

13. <u>Receiver</u>. As previously mentioned, a Model RCK receiver is used. This receiver utilizes a superhetrodyne circuit and provides four crystal controlled channels in the V.H.F. range from 115 mc to 156 mc. The sensitivity of the receiver is 6 microvolts for a signal to noise ratio of 10 to 1 with a 30% modulated signal. The r-f input is designed to operate from a 50 ohm

is driven positive, is limited to a few microamperes by the series resistor R307. Therefore, the thyratron bias voltage is very stable. The differential of grid signal voltage required to ignite and extinguish the thyratron is reduced to a minimum by inserting a 150,000 ohm resistor between the shield grid and ground.

20. Signal Responder. The function of the responder is to complete the operating circuit of control relays K304 and K305 only when the signal voltage applied to the thyratron exists longer than 0.3 but not in excess of 0.5 second. Contacts 8 and 9 on K301 and 4 and 5 on K303 are connected in series and must be closed concurrently to complete the operating circuit to the control relays. Relay K303 closes when the signal voltage duration exceeds 0.3 seconds and reopens 0.2 second after closing regardless of the duration of the signal voltage. Termination of the signal voltage at any time between 0.3 and 0.5 seconds results in the closing of K301 contacts 8 and 9. Since contacts 4 and 5 of K303 are closed during the same period, operation of the control relays results. A signal voltage existing for less than 0.3 seconds or more than 0.5 seconds fails to operate the control relays as the contacts of K301 and K303 are not closed concurrently during that time. The delayed action of K303 in the plate circuit of the type 6SN7-GT tube is controlled by an RC circuit consisting of capacitor C306 and resistors R313 and R314 operating against the bias of the tube. Charging of the RC circuit is governed by contacts 2 and 3 of K301. Discharging of the RC circuit is effected by opening contacts 1 and 2 of K302. K302 is energized by the closing of K303 and is "self-sealing". The "seal" of K302 is broken only by the release of K301 with termination of the control voltage. Contacts 1 and 2 of K301 in series with contacts 2 and 3 of K303 connect the RC circuit to ground, during the deenergized periods, preventing accumulation of static charges on the RC circuit. An indicator lamp controlled by contacts 7 and 8 of K301 indicates when relay K301 operates. This indication is useful in adjusting the gain control as explained under "Special Circuits". (See Par. 27).

21. Control Relays. The control relays consist of a circuit control type and a time delay type. When momentarily energized, the circuit control relay K304 closes two pairs of contacts. One pair of contacts close the primary circuit of the plate supply transformer of the Model YE or YG homing equipment. The homing signal is transmitted only when these relays are operated by the responder circuit. The other pair, which are in series with the normally closed contacts of K305, "seal in" the operating coils of both K304 and K305. The time delay relay K305 immediately begins timing and after a period of a minute and a quarter opens and breaks the "seal in" circuit, deenergizing both relays and the transmitter plate supply. An energized period of a minute and a quarter has been selected, permitting two complete series of homing signals to be transmitted in any directions. However, the time interval can be varied between 10 seconds and 2 minutes by means of a small knob on the time delay relay. An indicator light is provided which indicates when these relays, and hence the homing equipment, are in operation.

22. Power Supply. The power supply unit utilizes a full wave rectifier,

choke input "L" type filter, and an electronic voltage regulator. This unit supplies all circuits with the exception of the Model RCK receiver, which has a built-in power supply. When the main line switch S301 is closed, power is applied to the primary of all filament transformers and time delay relay K306. This relay applies line voltage to the primary of the plate supply transformer T306 30 seconds after the filament transformers are energized. A switch S302 is provided in series with the relay contacts so that the plate transformer may be turned "on" and "off" independently, after the relay contacts have closed. A Navy type 5U4G tube is used as the rectifier tube. The filter consist of a 15 henry choke followed by a 3 mfd. 1000 volt capacitor. The electronic regulator consists of a Navy type 6SJ7 tube so connected as to vary the conduction of two Navy type 6B4G tubes as required to maintain the output voltage constant. The output voltage can be adjusted by means of an adjustable potentiometer which controls the bias on the 6SJ7 tube. Once this control is set the output voltage remains constant. A d-c voltmeter is provided to indicate the output voltage.

23. Power Circuits. The Aircraft Carrier equipment operates from a 115 volt 60 cycle a-c supply. Switch S301 controls power for all circuits except the oven heaters. A pilot light I303 indicates when Switch S301 is closed. Heater power is controlled by switch S204, and regulated by thermostat K201. K201 maintains the "oven temperature" at 40°C + 2°. Although a line switch and fuses are provided in the receiver, it is intended that the receiver switch remain closed at all times and that control be accomplished thru switch S301. Interconnection wiring between decks is broken by disconnect jacks and plugs when a deck is removed from the cabinet frame.

24. External Connections. The R.F. Transmission line enters the cabinet thru an appropriate opening directly behind the R.F. chassis connector on the receiver. The a-c supply and the control circuit leads from the Model YE or YG transmitter enter the cabinet thru two terminal tubes mounted in the lower rear wall of the cabinet. A switch is introduced in the control circuit between the cabinet and the transmitter for the purpose of providing manual control of the homing transmitter in the event of failure of the remote control equipment. A red light indicates when remote control is cut out. Neither the Model YE or YG Transmitter is arranged for external control of the plate voltage supply. However, in each case, connection facilities are available on the terminal board to bring out the required control circuit.

SPECIAL CIRCUITS

25. Two auxiliary circuits are provided in the Aircraft Carrier equipment to facilitate test and adjustment of the equipment. These are a test test oscillator-timer and a volume level indicator. Both circuit are included in the schematic diagram of Plate 4.

26. Test Oscillator-Timer. The test oscillator-timer is provided to facilitate alignment tests of all circuits with the exception of the Model RCK receiver and for determination of the operating time limits of the responder. The test oscillator-timer consists of a single frequency audio

29. **Range.** A discussion of the relative operating ranges of the control system described herein and of the Model YE and YG equipments will be considered as it has a definite bearing on many of the factors discussed in this section. To insure successful remote control operation, the control signal which operates the Model YE or YG Transmitter must have a positive operating range at least equal to the maximum homing range under the same propagation conditions. Although the maximum homing range varies somewhat from day to day due to variations in the lower atmosphere which affect the propagation of v-h-f waves, the influence of these variations on the maximum propagation range of both the control frequency and homing frequency will be approximately the same. Thus, it was needless to conduct a long series of tests to determine the dependable range of the control signal. It was necessary only to determine the range of the control frequency transmission relative to the homing frequency transmission.

30. It is considered desirable to give some consideration to the theoretical range of the two transmission systems and compare the results with measured ranges of the two systems. The maximum theoretical range of the control system is a function of the following factors:

(a) Transmitter power.

(b) Type of transmitting antenna.

(c) Height of transmitting antenna.

(d) Transmission distance.

(e) Height of receiving antenna.

(f) Type of receiving antenna.

(g) Receiver sensitivity.

(h) Minimum signal to noise ratio which will give positive operation of the circuit controlling the homing transmitter.

In most cases it is difficult to obtain absolute values for the above factors but in general it is possible to determine the ratio of these factors as between two radio circuits with reasonable accuracy. The ratio of these various factors for the Model YG Homing Equipment and the proposed remote control system for the homing equipment are tabulated in the following paragraph.

31. Data comparing the transmission ratio of the Model YG Equipment and the control system, in which it is assumed that the respective antenna heights are 70 and 10000 feet with 100 miles separation, are as follows:

34. Aircraft Security. In the present YE/YG homing system there is no radiation from the plane, hence the security of the plane is 100 percent. The proposed modification of the homing equipment to provide for increased Aircraft Carrier security, reduces the aircraft security slightly. However a minimum loss of aircraft security is assured by reducing the duration of the control signal to an absolute minimum. The absolute minimum signal duration is limited by several factors. As the duration is shortened, the operating time of the signal responder relays becomes a greater percentage of the total time, thus increasing the influence of relay inaccuracies. Also static noise pulses and short voice articulations of the correct frequency tend to increase the number of false operations when the signal duration is reduced to a compparable length. Tests indicate that with the responder adjusted to operate on signals of 0.4 second duration, false operations from such interference rarely occur. Maintenance of aircraft security further requires the limiting of the VHF carrier transmission time, which requires the energizing of the VHF carrier immediately before transmission of the control signal and de-energizing immediately after transmission. This requirement made it necessary to provide transmitter operating contacts on the timer in the aircraft equipment.

35. Size and Weight Factors of the Aircraft Equipment. In view of the limited space within modern aircraft, it is necessary to minimize the size and weight of the added aircraft equipment. This requirement was satisfied by the addition of a simple unit which controls the operation of and supplies timed modulation to an aircraft transmitter available as standard equipment in the plane.

36. Modulation Frequency of Aircraft Equipment. Utilization of the aircraft V.H.F. communication equipment requires that the control signal modulation frequency exceed 5000 c.p.s. in order that the voice frequencies on the shared communication channel will not produce false operation. The upper limit of the audio modulation is governed by the increased distortion in the audio system of the V.H.F. communication equipment. Recent developments in the design of V.H.F. aircraft equipment has lead to the introduction of artificial attenuation into the audio circuit of the equipment of a nature to produce a decreasing frequency characteristic for frequencies above 5000 c.p.s. To utilize this equipment. for the transmission of the control signal required that the aircraft unit be arranged to overcome the attenuation introduced. The output voltage for each modulation frequency can be varied independently and this permits the equipment to be adjusted for 100 percent modulation at each modulation frequency. It should be pointed out that the range of the control equipment is approximately proportioned to the square root of the percent modulation, thus it is essential that the percentage modulation be maintained at 100 percent.

37. Multiple Channel Operation. Operation of several aircraft carries in a task force necessitates a selective control system by means of which a plane controls only the homing equipment on its base carrier. However, it is also considered advantageous to provide means by which a plane may control the homing equipment of any one of the carriers. To provide for such operation requires incorporating within the aircraft equipment, several

several frequencies of control modulation and a means for frequency selection. Six control frequencies are considered sufficient for present requirements. Although the six control frequency might be spread over a range from 5000 to 7500 c.p.s. or slightly higher, the channel spacing has been held to 200 c.p.s. to provide room for a future increase of channels. The frequency range selected is 5500 to 6500 c.p.s. in six equal steps of 200 c.p.s. Any further change in the audio characteristics of the AN/ARC-4 transmitting equipment may alter number of available frequency channels.

38. Signal Selection Control. Multiple channel operation entails provision for channel selection within the aircraft carrier equipment. The audio output characteristic of the Model RCK receiver is essentially uniform over the range of audio control frequencies so that selection of the control signal must be accomplished by a filter following the receiver output. Two possible means may be employed for channel selection. One requires an individual band-pass filter for each control frequency while the other requires reduction of each control frequency to a single frequency, thereby permitting selection with one band-pass filter. The latter means of frequency selection is employed in this equipment as the materials available were not sufficiently refined to produce filters of the required selectivity at the control frequencies of 5000 c.p.s. and above. With the materials and facilities available a band-pass filter of the required frequency characteristic of 20 db attenuation at 150 cycles off resonance was practical at 2000 c.p.s.

39. A filter frequency of 2000 c.p.s. requires the beat oscillator to operate either between 3500 to 4500 c.p.s. or 7500 to 8500 c.p.s. for frequency conversion. Frequency stability considerations led to the use of the low frequency range in this equipment. Maintenance of a high degree of stability in the action of frequency conversion necessitated separate tubes for the beat oscillator and frequency converter. The use of frequency conversion presents the problem of erroneous operation from 2000 c.p.s. hetrodynes resulting from frequencies below 5000 c.p.s. For example a frequency of 1500 c.p.s. produces a difference frequency of 2000 c.p.s. when combined with the 3500 c.p.s. converter frequency. To overcome this condition, a high-pass filter with high attenuation is required. For this filter to be effective it is necessary that the filter attenuate frequencies below 4600 by at least 30 db.

40. Cross Channel Modulation. If several channels of the control signal are being used simultaneously in the same geographical area, there is the danger of cross channel operation resulting from a signal of maximum strength in the adjoining channel. To prevent such operation the 2000 c.p.s. band-pass filter must possess sufficient attenuation at the adjoining channel frequency to insure against operation of the signal relay and associated thyratron under the most adverse condition. The degree of filter attenuation required to insure such operation is best explained with the aid of Figure 1.

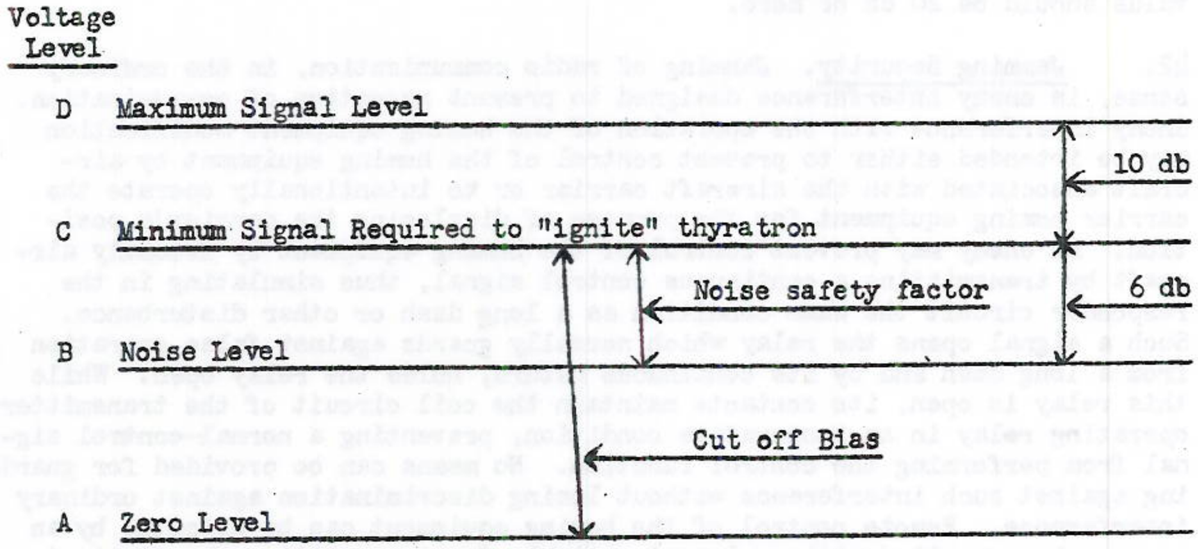

Figure 1

Level "C" represents the minimum voltage which when applied to the grid of the thyratron will result in operation. This is the limiting condition and represents operation over the maximum transmission range or a signal of minimum field strength. Level "D" represents the maximum voltage applied to the thyratron. This condition obtains for minimum range signals or signals of maximum field strength. The range differential between levels "D" and "C", as determined from the characteristics of the Model RCK receiver is 10 db. Thus, this amount of attenuation must be provided in the band-pass filter to overcome the range differential. With this degree of attenuation, a signal of maximum strength on the adjoining channel and a signal of minimum strength on the operating channel will produce equal voltages on the thyratron. To prevent operation by the strong signal, the strong signal voltage must be further attenuated to the non-operating point.

41. The degree of attenuation required to reduce the signal to the non-operating point, again can be explained with the aid of Figure 1. Level "B" represents the noise level under the operating condition. This level is held below the ignition value of the thyratron (Level "C") by the "noise safety factor". Experimental data indicate that a satisfactory factor of safety is obtained if the differential between levels "C" and "B" is 6 db. To fully insure against cross channel operation the band-pass filter must attenuate the adjoining channel voltage to a value equivalent to level "B". The total attenuation of the filter to the adjoining channel signal, therefore, must be 10 plus 6 or 16 db. The nominal channel separation is 2000 c.p.s. ± 200 c.p.s. Because of the instability of the modulating oscillator in the aircraft equipment and other causes, the frequency of the adjoining channel signal may drift to within 150 c.p.s. of the pass frequency. This condition requires that the selectivity of the band-pass filter provide at least 16 db. attenuation at 150 c.p.s. off resonance. To provide a factor of safety this

value should be 20 db or more.

42. Jamming Security. Jamming of radio communication, in the ordinary sense, is enemy interference designed to prevent reception of communication. Enemy interference with the operation of the homing equipment modification may be intended either to prevent control of the homing equipment by aircraft associated with the aircraft carrier or to intentionally operate the carrier homing equipment for the purpose of disclosing the carrier's position. An enemy may prevent control of the homing equipment by friendly aircraft by transmitting a continuous control signal, thus simulating in the responder circuit the same condition as a long dash or other disturbance. Such a signal opens the relay which normally guards against false operation from a long dash and by its continuous nature, holds the relay open. While this relay is open, its contacts maintain the coil circuit of the transmitter operating relay in an inoperative condition, preventing a normal control signal from performing the control function. No means can be provided for guarding against such interference without losing discrimination against ordinary interference. Remote control of the homing equipment can be effected by an enemy, when supplied with equipment suitable for transmitting the required control signal. Certain inherent features of the homing modification, however, make it difficult for an enemy to produce these two forms of interference. Utilization of VHF transmission limits the effective interference range to the line-of-sight distance. Modulation frequency discrimination of ± 50 c.p.s. and modulation interval timing of 0.4 ± 0.1 seconds require the enemy to determine and duplicate these characteristics of the signal to a high degree of accuracy. The enemy must also know the r-f carrier frequency. All these signal characteristics must be duplicated to production operation designed to disclose the position of the aircraft carrier and all but the timing characteristic must be duplicated to block operation of the homing equipment modification by aircraft operating from the carrier. Such enemy interference to the modification is shown by the continuous illumination of one of the indicator lamps on the shipborne equipment. The effectiveness of this type of enemy jamming can be eliminated by simply operating a switch which gives continuous transmission of homing signals. Obviously, such action nullifies the protective features of the modification, but homing signals would be available for the Carrier's planes.

RESULTS OF TESTS

43. Flight tests to determine the transmission range of the homing equipment modification using an AN/ARC-4 transmitter and receiver of sensitivity comparable to the Model RCK receiver are discussed in detail in reference (d). Briefly the homing equipment modification operated over a distance of 110 miles on the first flight test and a 125 miles on the second test. The shorter range obtained on the first flight test resulted from a threefold increase of noise level at the receiving point. This condition occurred when the plane was at the 110 miles distance. During these tests the receiving antenna was elevated 70 feet above sea level and the plane was flying at an altitude of 10,000 feet. These results were in substantial agreement with the theoretical computations.

44. Certain changes as proposed in paragraph 16 of reference (d) have been made in the homing equipment modification. These proposed changes are listed below:

(a) Increase the frequency stability of the audio oscillator. (Aircraft Unit).

(b) Increase the frequency of the audio oscillator (Aircraft Unit).

(c) Increase the filter pass-band frequency to correspond with the frequency increase of the audio oscillator.

(d) Shorten the transmission time of the control signal to 0.4 second.

(e) Improve the ruggedness and accuracy of the time-selector by substituting vacuum-tube-operated, low-sensitivity relays for the high-sensitivity relays formerly employed.

With the exception of item (c), these changes have been incorporated in the homing equipment modification. Condition 44(c) was taken care of by change of design. The present frequency stability of the audio oscillator is discussed in paragraphs 47, 48, and 49, and the oscillator frequency has been increased to six spot frequencies between 5500 and 6500 c.p.s. The transmission time of the control signal has been reduced to 0.4 seconds. A discussion of the accuracy of timing is presented in paragraphs 51 and 52 below. The ruggedness and accuracy of the responder has been improved by substitution of a Navy type 6SN7 tube and "AQA" telephone relays for the relays formerly employed.

45. No further flight tests were made to test the operation of the equipment after the changes were incorporated. However, laboratory tests showed clearly the effect of changes in the various circuits. The results of the tests indicate that the present system gives improved overall operation and increased security. The results of these tests are given in the following paragraphs.

46. Power Requirements, Aircraft Equipment. The total power drain of the aircraft equipment is 11.35 watts. Table 1 lists the individual circuit requirements.

47. Effect of Supply Voltage Change in Audio Oscillator Frequency, Aircraft Equipment. As may be seen from Table 2, the change of the supply voltage over the range normally experienced in aircraft service does not exceed 4 c.p.s. This frequency change is negligible.

48. Effect of Altitude on Audio Oscillator Frequency, Aircraft Equipment. The data obtained from a test in which the oscillator was operated in a chamber of varying degrees of rarification indicate that the oscillator frequency increases as higher altitudes are approached. However, a major portion of the change, amounting to about 10 c.p.s., occurs in the first 10,000 feet of elevation. The data taken are listed in Table 3.

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49. Variation of Ambient Temperature, Aircraft Equipment. The temperature characteristic of the oscillator is such that the generated frequency decreases as the temperature is reduced. Over the temperature range of from +50 degrees C to -30 degrees C a frequency change of the order of 24 c.p.s. was measured as indicated in Table 4. When this effect of temperature change is compared with the effect of altitude change reported in paragraph 48 above, a compensating action is noted, since normally the atmospheric temperature decreases with respect to increasing altitude. Thus assuming a temperature of -30 degrees C at elevations between 10,000 and 50,000 feet, the actual audio frequency drift in the oscillator will be 24 minus 10 or 14 c.p.s. Design considerations of the control systems requires that the audio oscillator in the aircraft equipment should be maintained within +50 c.p.s. of the desired frequency. The tests in the above paragraphs indicate that this condition has been met.

50. Oscillator Output Voltage, Aircraft Equipment. The audio voltages required to fully modulate the AN/ARC-4 transmitter at each of the six audio frequencies employed are listed in Table 5, column 6. Columns 4 and 5 list the voltage range of each tap for the maximum and minimum positions of the vernier control. It is evident that the range of the control permits adjustment to the required voltage for each of the six audio frequencies.

51. Repetition Accuracy of Timer, Aircraft Equipment. As indicated in Table 6, the period of the timer when operated in a constant ambient temperature repeats with an accuracy ±4%.

52. Effect of Temperature on Period of Timer, Aircraft Equipment. Plate 9 indicates that the time length of the audio pulse will vary from 0.33 to 0.51 second when the ambient temperature changes from +50 degrees C to -30 degrees C. This operating time range of 0.18 second, however, was possible only when all bearings and gearing of the timer were lubricated with WS-334 low temperature grease. Before application of the low temperature grease, the operating time was 2.0 seconds. The responder circuits of the carrier equipment were designed to operate for control signal periods between 0.3 and 0.5 second. Thus the variation in the timing accuracy of the aircraft equipment must not exceed these limits.

53. Vacuum Tube Potentials, Carrier Equipment. Table 7 tabulates the measured potentials and currents of the various vacuum tubes employed in the carrier equipment. The values shown are for normal operating conditions.

54. Frequency Response of High-Pass Filter, Carrier Equipment. The curve shown on Plate 6 illustrates the frequency characteristic of the high-pass filter developed for this equipment. The filter cuts off sharply between 5250 and 4500 c.p.s. Except for a slight rise to 27.5 db between 4500 and 3000 c.p.s., the low-frequency attenuation equals or exceeds 30 db for all frequencies below 4550 c.p.s. In order to prevent cross modulation in the mixer circuit, the attenuation of this filter must exceed 20 db for all frequencies below 4500 c.p.s.

55. Frequency Characteristic of Band-Pass Filter, Carrier Equipment. The measured frequency characteristic of the band-pass filter is plotted in Plate 7.

At the pass frequency, the filter has an inherent loss of 20 db, which is taken as the zero level in discussing the filtering action. A requirement of the filter was to produce an attenuation of at least 20 db at 150 c.p.s. off resonance. On the high frequency side, the filter attenuation is 25 db below the pass-band level and on the low side the attenuation is 30 db below this level. Thus on either side of the pass frequency more than the required attenuation is realized.

56. Effect of Ambient Temperature Change on Characteristics of Band-Pass Filter, Carrier Equipment. Plate 8 shows the detuning effect produced in the band-pass filter by variation of the ambient temperature between the limits of +50 and -10 degrees C. A marked detuning of the filter occurs as the temperature is reduced below +20 degrees C. This test points to the need for operating the band-pass filter in a temperature controlled compartment.

57. Conversion Efficiency of Mixer Circuit, Carrier Equipment. A test was conducted to determine the efficiency of the mixer circuit in converting the control signal frequency to 2000 c.p.s. The results of this test are shown in Table 8.

58. Variation of Timing Accuracy of Test Oscillator-Timer with Temperature, Carrier Equipment. The timing accuracy of the test oscillator-timer is 2 percent or less over the ambient temperature range of +50 degrees C to -20 degrees C. When the timer is operated within a temperature controlled compartment, a greater degree of accuracy should result. The results of a test, conducted to determine the timer accuracy are tabulated in Table 9. The accuracy of this timer is well within the design requirements.

SUMMARY

59. A system has been developed which considerably increases the security of Naval vessels equipped with the Model YE or YG Homing Beacon Equipment, by limiting the time the homing signal is radiated. A control signal of 0.4 second duration, transmitted from a plane, controls the homing transmitter operation. Any one of six homing transmitters or an equal number of carriers may be controlled from an aircraft by placing a selector switch to the position designating the carrier desired. The additional equipment required on the aircraft weighs approximately 4-1/2 lbs., while the additional carrier equipment required approximates the Model YG transmitter in size and weight. The modification required in the existing Model YE and YG equipments is limited to a minor change in the transmitter control wiring. Flight tests and theoretical computations indicate that either the Model YE or YG Homing Equipment may be controlled up to a distance of 125 to 135 miles, which is the maximum average homing range.

TABLE 4

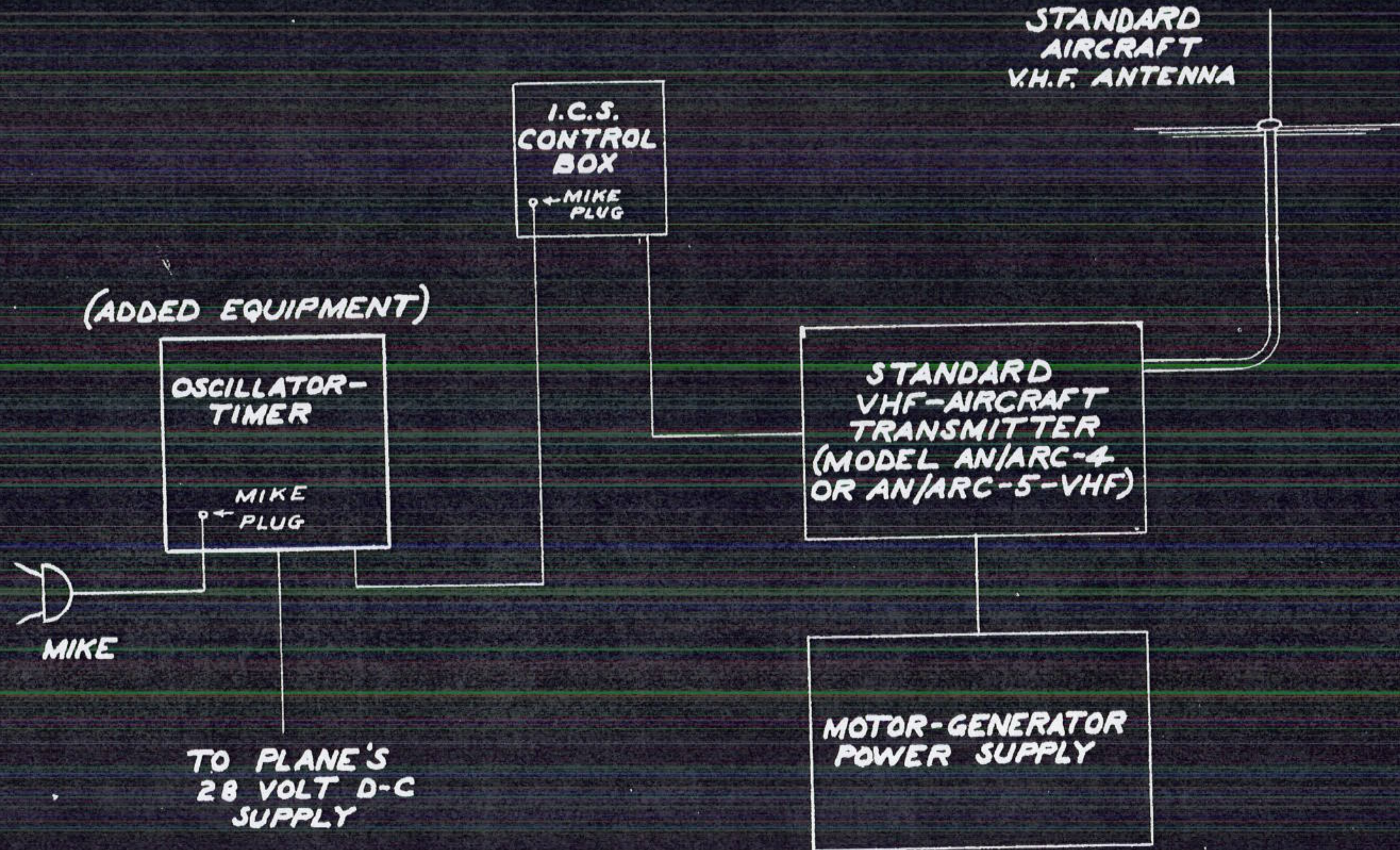
AIRCRAFT EQUIPMENT

AUDIO OSCILLATOR FREQUENCY CHANGE
WITH VARIATION OF AMBIENT TEMPERATURE

Time	Temp. °C	Frequency c.p.s.	Stabilized Frequency c.p.s.	Frequency Change c.p.s.
1305	50	----	----	---
1335	50	6342	----	---
1405	50	6342	6342	---
1430	25	6330	----	---
1500	25	6336	----	---
1530	25	6330	6330	-12
0840	23	6324	----	---
0910	23	6324	----	---
0940	23	6324	6324	---
1020	0	6318	----	---
1050	0	6315	----	---
1120	0	6315	6315	-9
1205	-30	6312	----	---
1235	-30	6312	----	---
1305	-30	6312	6312	-3

Total frequency change over temperature range of +50 to -30 degrees C. - 24 c.p.s.

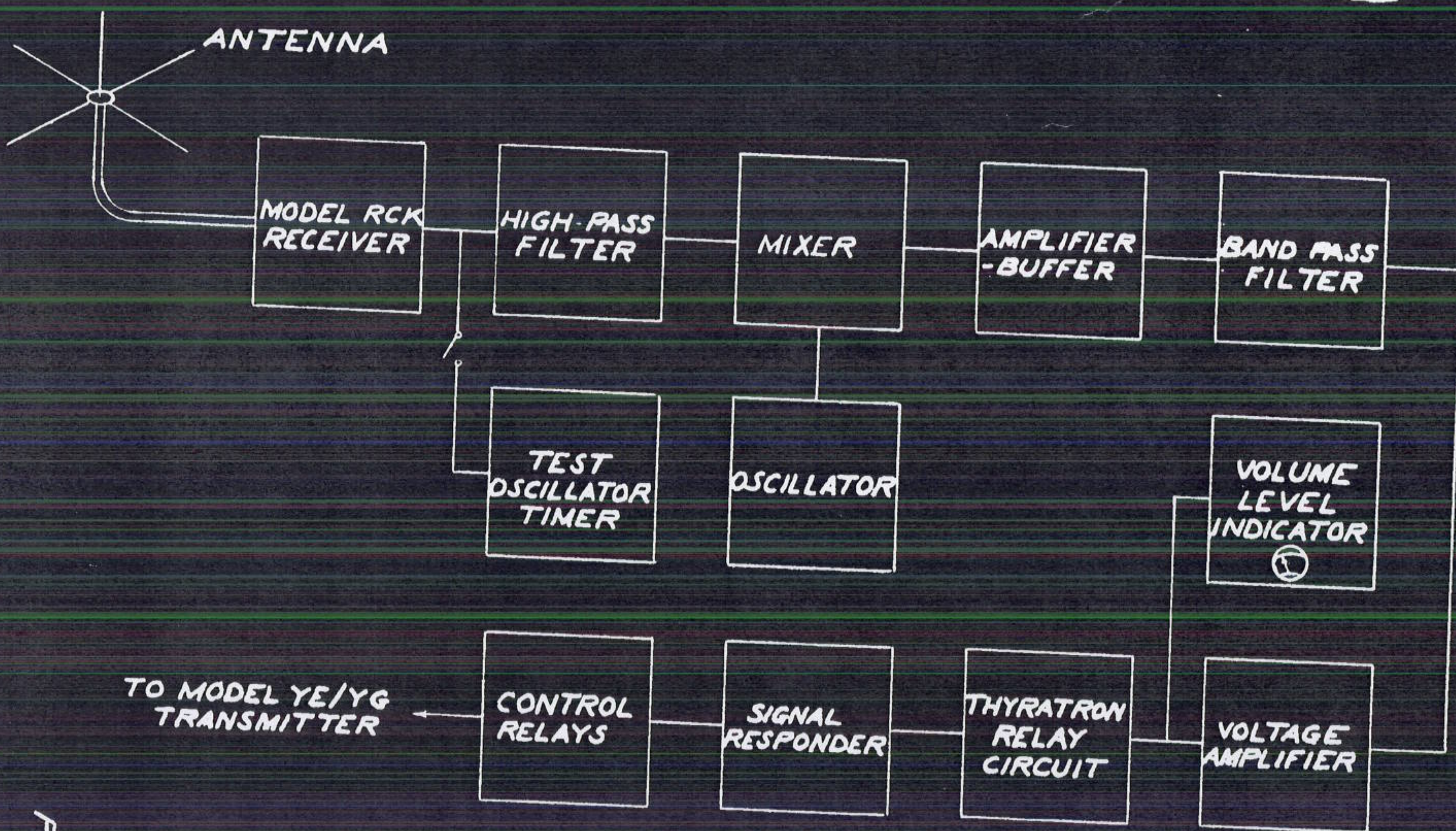
[redacted]



EQUIPMENT ON PLANE

PLATE 1

DECLASSIFIED



AIRCRAFT CARRIER EQUIPMENT

PLATE 2

DECLASSIFIED

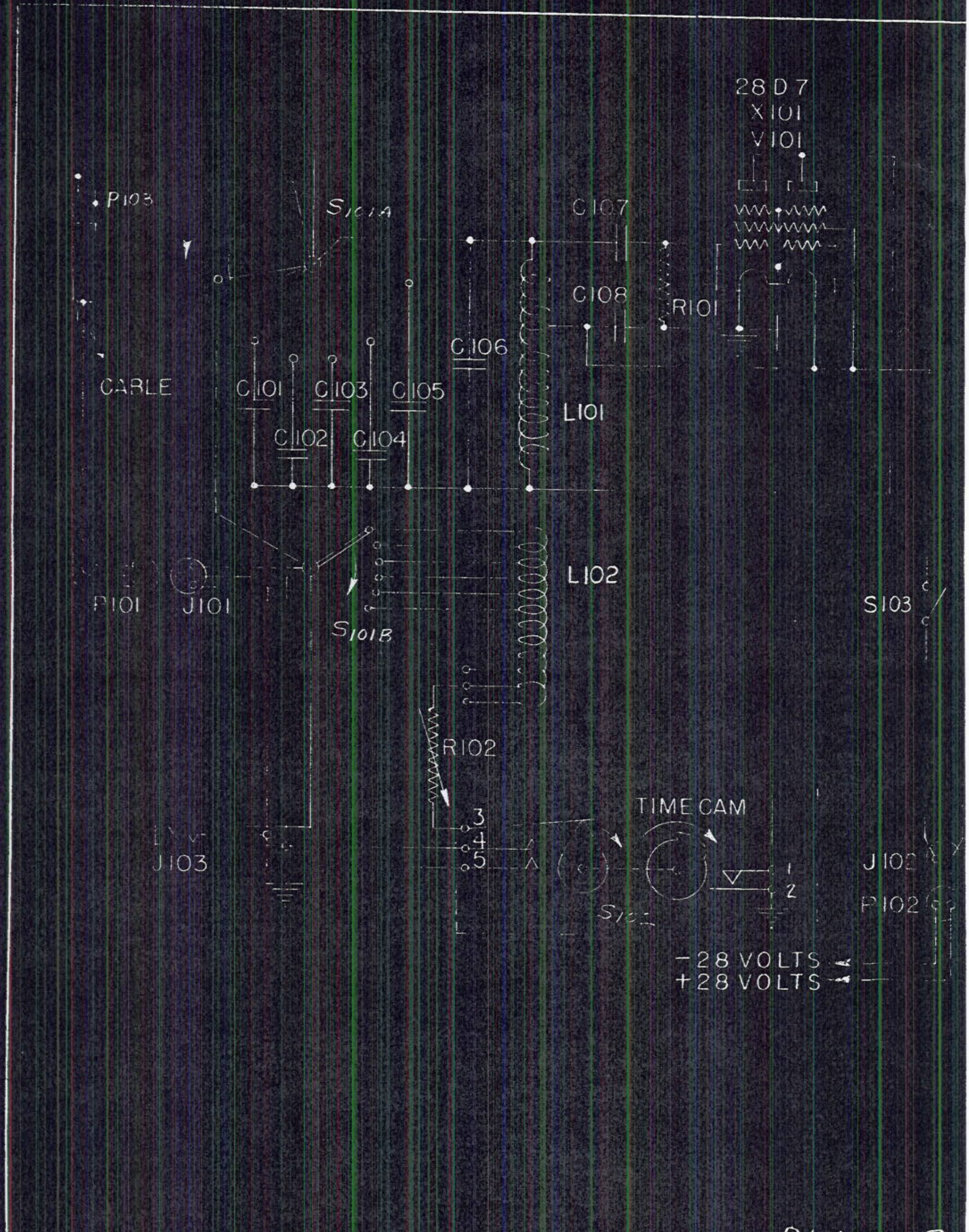
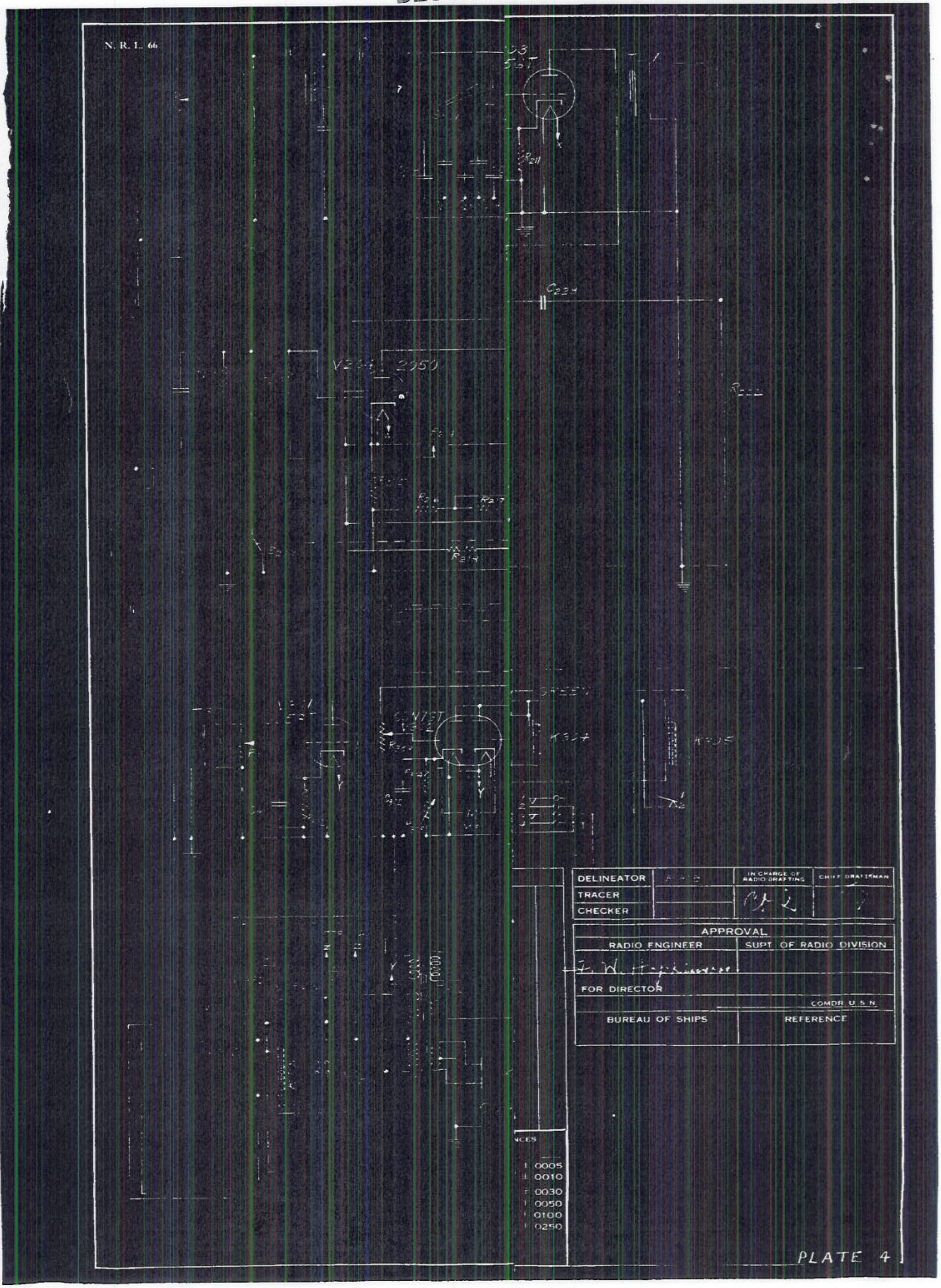

28D7
X101
V101
P103
S101A
C107
C108
R101
C106
CABLE
C101
C103
C105
C102
C104
L101
L102
P101
J101
S101B
S103
R102
3
4
5
TIME CAM
J103
J102
P102
1
2
-28 VOLTS
+28 VOLTS

PLATE 3


N. R. L. 66
C224
R211
2050
DELINEATOR
IN CHARGE OF RADIO DRAFTING
CHIEF DRAFTSMAN
TRACER
CHECKER
APPROVAL
RADIO ENGINEER
SUPT OF RADIO DIVISION
FOR DIRECTOR
COMDR U.S.N.
BUREAU OF SHIPS
REFERENCE
0005
0010
0030
0050
0100
0250
PLATE 4

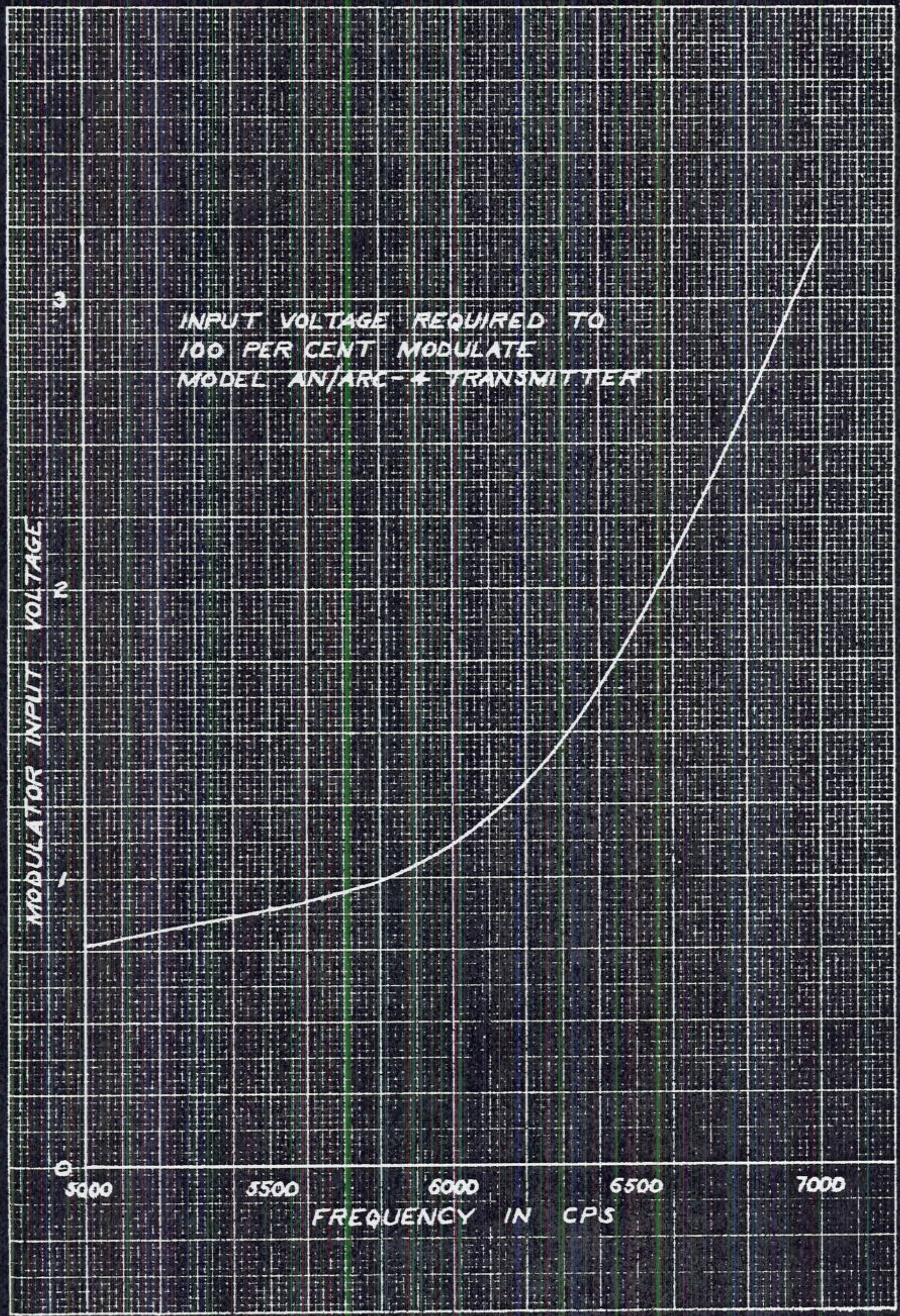

INPUT VOLTAGE REQUIRED TO
100 PER CENT MODULATE
MODEL AN/ARC-4 TRANSMITTER
MODULATOR INPUT VOLTAGE
0
1
2
3
5000
5500
6000
6500
7000
FREQUENCY IN CPS

PLATE 5

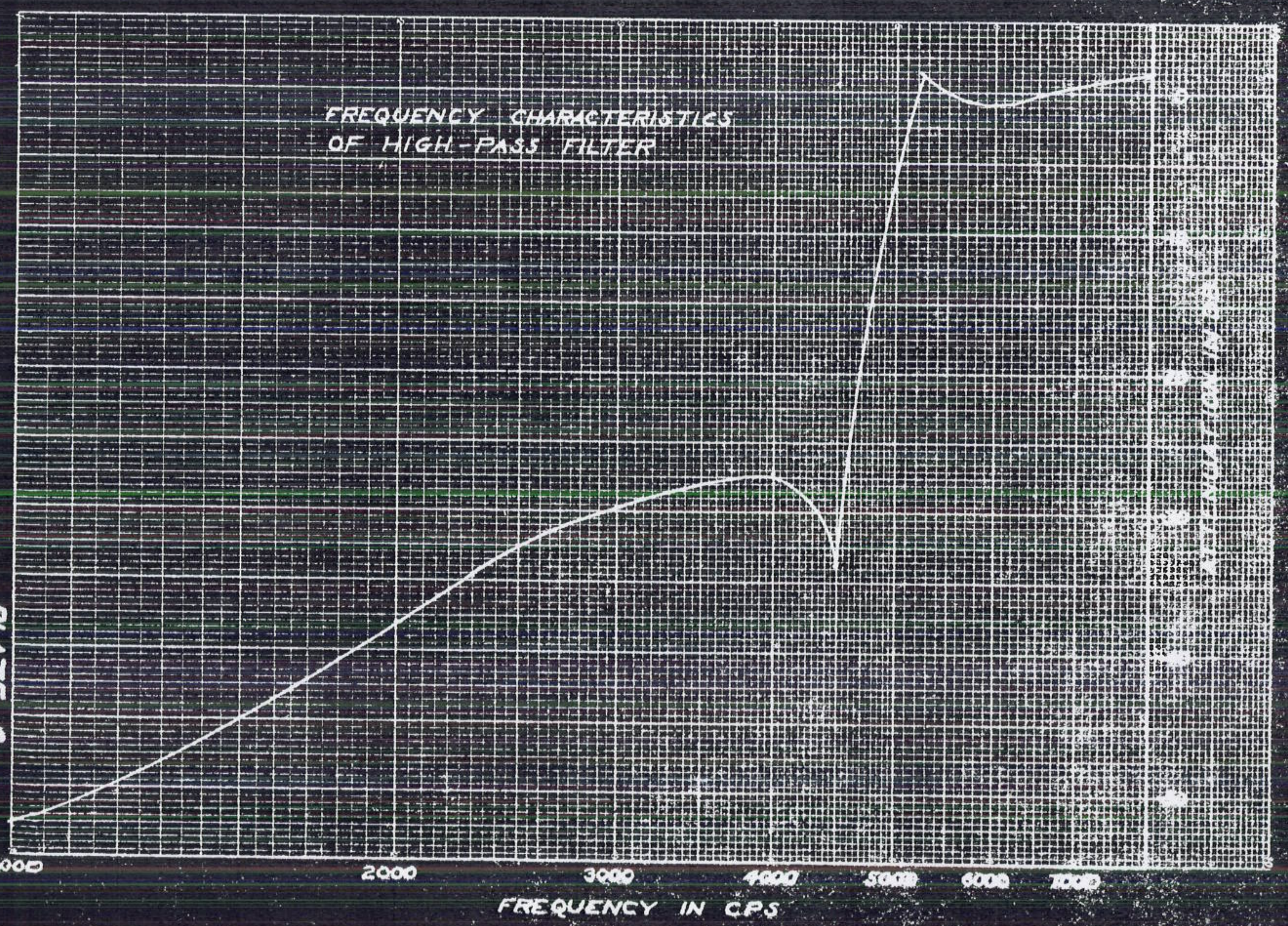

FREQUENCY CHARACTERISTICS
OF HIGH-PASS FILTER
1000
2000
3000
4000
5000
6000
7000
FREQUENCY IN CPS

PLATE 6

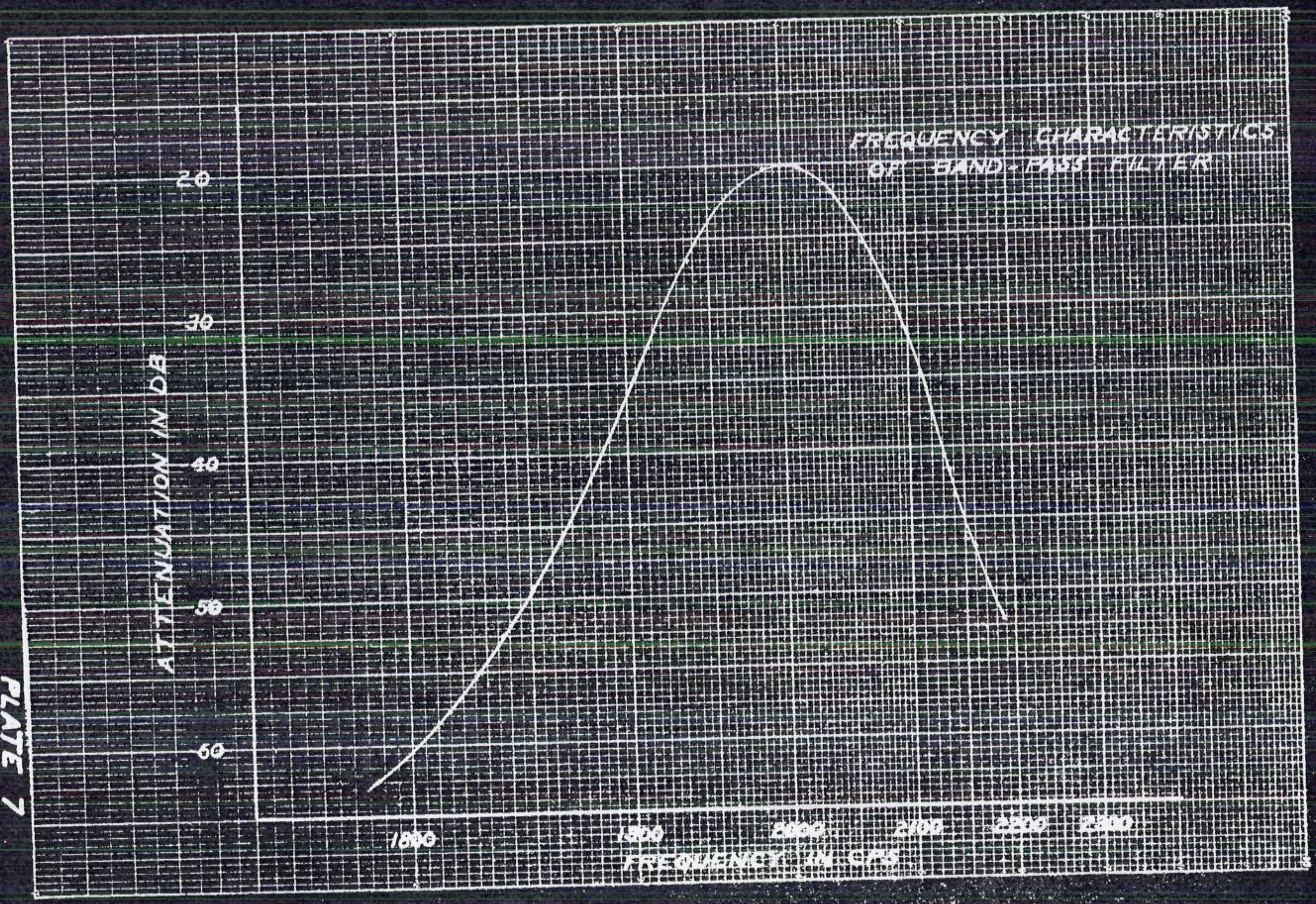


PLATE 7

DECLASSIFIED

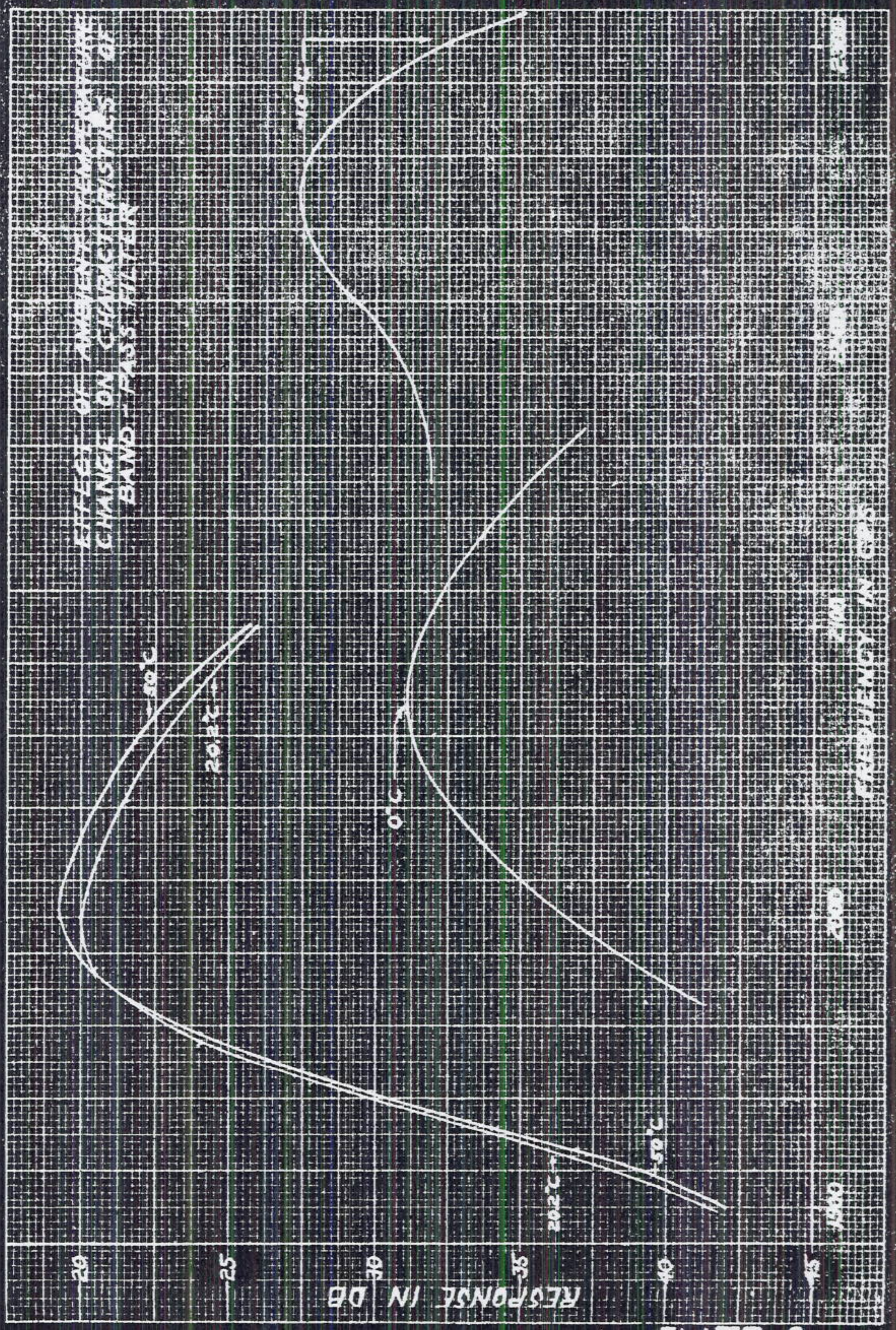

EFFECT OF AMBIENT TEMPERATURE CHANGE ON CHARACTERISTICS OF BAND-PASS FILTER
RESPONSE IN DB
FREQUENCY IN CPS
20
25
30
35
40
45
1900
2000
2100
2200
2300
0°C

PLATE 8