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SUBJECT

Test of Model TBP

Transmitting and Receiving Equipments

(Westinghouse Electric and Manufacturing Company)

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BY

NAVAL RESEARCH LABORATORY

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Test of Model TBP Transmitting and Receiving Equipments
(Westinghouse Electric and Manufacturing Company)

14 May 1937

CONFIDENTIAL
NRL Report No.R-1364
BuEng. Prob. T6-4

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report of Test

of

Model TBP Transmitting and Receiving Equipments

(Westinghouse Electric and Manufacturing Company)

NEW CONSTRUCTION

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 18 Tables - 6 Plates - 8

Authorization: BuEng let.C-NOs-51017(2-5-W8) of 15 Feb.1937.

Date of Test: 1 March to 1 May 1937.

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Distribution: BuEng (10)

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Appendices

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AUTHORIZATION

1. This problem was authorized by Bureau of Engineering letter, reference (a), and additional correspondence pertaining to this problem is listed as references (b) to (h).

(a) BuEng let.C-NOs-51017(2-5-W8) of 15 Feb.1937, to NRL.
(b) BuEng Specifications RE 13A 535A of 6 Aug.1936.
(c) Contractor's (Westinghouse Electric and Mfg.Co.) Descriptive Specification R-930 of September 1936.
(d) Navy Contract NOs-51017 with Westinghouse Electric and Mfg. Co. of 13 Oct.1936, with Contract Notes.
(e) BuS&A let.NOs-51017(SPM) of 2 Nov.1936 to Westinghouse Electric and Mfg. Co.
(f) BuEng let.C-NOs-51017(2-5-W8) of 25 Feb.1937, to NRL.
(g) BuEng let.C-NOs-51017(11-10-W8) of 21 Nov.1936, to INM Hartford.
(h) BuEng let.C-NOs-51017(11-18-W8) of 24 Nov.1936, to INM Hartford.

OBJECT OF TESTS

2. The object of the tests was to determine if the Model TBP portable radio equipment complied with the various governing specifications and requirements, references (b) to (d) inclusive, including the contract amendment, reference (e), and additional contract notes, reference (f). A further object was to determine if the equipment was suitable for Naval use.

ABSTRACT OF TESTS

3. The tests conducted were of two types, field tests and laboratory tests. The field tests consisted of a study of the range of the equipment, cross talk between two communication circuits differing only a small amount in transmission frequency, interference between two adjacent receivers, stability of equipment in field, etc. The laboratory tests consisted of a determination of power output of transmitter, receiver sensitivity, audio frequency fidelity of modulator system, battery life, frequency stability, effect of ambient temperature, etc.

[redacted]

Conclusions

(a) In general, the performance of the TBP equipment is considered good. The equipment does not comply with all provisions of the specifications, however. These exceptions are discussed in the two following paragraphs.

(b) The equipment will not function entirely satisfactorily in so far as radio reception is concerned where two or more equipments must be operated at the same frequency in a congested area; that is, when equipments are placed within a few hundred feet of one another because of interference caused by receiver radiation inherent in a super-regenerative receiver. Usually it is necessary that two receivers be not less than 1/2 mile apart, or thereabout, to allow inappreciable receiver interference.

(c) The equipment exceeds the maximum weight allowed by the specifications, actually weighing in excess of 44 pounds instead of being not more than 32 pounds.

(d) In general, communication between two equipments is satisfactory at distances up to 10 nautical miles with MCW transmission at the lower output frequencies, where a line of sight path of transmission is present. Phone communication is usually satisfactory for distances up to 7 nautical miles.

(e) The equipment is considered suitable for Naval applications which do not require the simultaneous operation of several sets at the same frequency in a congested area; that is, within a few hundred feet of one another.

(f) The equipment is considered suitable for Naval applications which permit simultaneous operation of several adjacent sets on frequencies differing in operating frequency as great as five percent.

(g) The equipment is considered unsuitable for Naval applications which require the simultaneous operation of several sets at the same frequency, where the equipments must be placed within a few hundred feet of one another.

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Recommendations

(a) It is recommended that the final models of the TBP equipment have incorporated therein a variable filament rheostat, adjustable from the panel, to compensate for normal voltage drop in filament batteries occurring with use, with the object of increasing the radio frequency power output. (See par. 16 of this report.)

(b) It is recommended that the final models also contain a filament voltmeter in order to adjust the oscillator filament voltage to its normal value. This instrument may be a combination voltmeter and grid-dip milliammeter, provided with a push-button type of change-over switch. (See par. 16 of this report.)

(c) It is recommended that the mechanical design of the coils be improved in order to decrease the probability of their becoming deformed by handling, placing them in equipment, etc. This may be accomplished by enclosing them with a suitable covering. In addition, coil plugs assuring better contact should be employed. (See par. 14 of this report.)

(d) It is recommended that a battery terminal block be incorporated in the final models in order to facilitate disconnecting the transmitter-receiver unit and battery compartment.

(e) It is recommended that an extra section be added to the antenna of the final models in order that its maximum length be not less than 9-1/2 feet to facilitate tuning to the lower frequencies. (See par. 14 of this report.)

(f) It is recommended that the steel tape for adjusting antenna length be eliminated in the final models. (See par. 26 of this report, comment concerning par. 8.7 of the specifications.)

(g) It is recommended that the MCW emission of the final models be stabilized in order that misadjustment of the antenna may not cause failure to function. (See par. 14 of this report.)

(h) It is recommended that the receiver of the final models of the equipment be stabilized so that inserting the key plug does not cause an audio frequency "howl" in the phones. (See par. 14 of this report.)

(i) It is recommended that, if possible, the strength of crystal harmonics, obtained in adjusting transmitter to the desired frequency, be strengthened in order to facilitate adjustment to any particular frequency. (See par. 26 of this report, comment on par. 6.9 of the specifications.)

(j) It is recommended that all tuning condenser stops be removed in the final models of the equipment. (See par. 26 of this report, comment on par. 6.9 of the specifications.)

(k) It is recommended that the indicating instrument be mounted flush with the panel in the final models, rather than on a bracket as in the preliminary models.

(l) It is recommended that suitable nameplates be affixed to the final models. (See par. 26 of this report, comment on par. 1.12 of the specifications.)

(m) It is recommended that a suitable marker be placed on the key-block of the final models to indicate the position of the change-over switch; that is, to indicate whether the equipment is the <u>transmit</u> or <u>receive</u> position.

(n) It is recommended that the main switch on the panel of the final models have suitable marking to indicate its function.

(o) It is recommended that a suitable number of revised instruction books be furnished in conjunction with this contract.

(p) If the Bureau contemplates purchase of additional similar equipment, it is recommended that the calibrating crystal frequency be 1,000 kilocycles instead of 500 kilocycles, as in this equipment, for calibrating points at 1,000 kilocycle intervals will be suitable and more desirable, as louder beat notes will then be obtained at the higher frequencies.

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MATERIAL UNDER TEST

4. The TBP equipment consists of a portable transmitter-receiver unit housed in one case large enough to hold the necessary dry batteries which serve as the power supply. This apparatus is intended for use by the Marine Corps as portable field equipment. The frequency range covered is from 28 to 65 megacycles, and the equipment may be used either for telephonic or MCW telegraphic communication. The transmitter is of a conventional self-oscillating type; the receiver of the super-regenerative type. A self-supporting telescopic antenna is provided whose length is adjustable for tuning to the various frequencies. A manually controlled switch is provided for changing over from transmit to receive, "break-in" operation not being possible. Three sets of "plug-in" coils are furnished for covering the frequency range, each set consisting of two coils, one for the transmitter, the other for the receiver. This equipment is unlike many other similar types of equipment in that the transmitter and receiver are independent; that is, the equipment is not a transceiver, which is frequently employed for such applications. A canvas knapsack is provided for transporting the equipment on a man's back. A shipping chest is included which also has room for storing certain mobile spares.

5. A wiring diagram of the TBP equipment is shown in Plate 1. Photographs of the equipment are shown in Plates 2 to 4, inclusive.

6. Four complete equipments were supplied by the manufacturer for conducting various tests. These equipments were assigned serial numbers 1 to 4, inclusive. For convenience, hereafter in this report, those equipments are referred to as TBP Set No.1, TBP Set No. 2,etc., for identification purposes.

7. In reference (a), par.2, it was stated that a comparison of the TBP equipment with other types of equipment similar in character, was desired. For this purpose, four Army Signal Corps transceivers, Type BC-222-T3-EI, Serial Nos. 1, 2, 17, and 32, were employed. For convenience, the several pieces of equipment are hereafter designated in this report as Army Set No. 1, No. 2, No. 17, or No. 32.

8. It should be understood that the data and information shown subsequently in this report are the results of the tests of the resubmitted TBP equipment. Prior to these tests, certain data were obtained during the period from March 1 to March 5, 1937, which indicated the equipment to be inadequate for the purpose. It was found that, in general, a communication range of approximately 2 miles was the maximum possible with voice transmission, with the equipments at or near the level of the ground, with a line of sight path between the two equipments. Following a conference at the Bureau, the equipments were returned to the contractor for modifica-

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tion with the object of extending their range of communication. The modified equipments were returned to this Laboratory on March 29. Two of the equipments, TBP sets No. 1 and No.2, had the receiver radio frequency amplifier stage removed: the other two, sets No.3 and No.4, still contained their radio frequency stage of amplification. The reason for the removal of this stage in the case of two of the equipments was that tests during the period that the equipment was returned to the contractor indicated that a loss instead of a gain was introduced by this amplifier, a 1B4 type of tube. On March 31, the radio frequency stage of sets No.3 and No. 4 was also removed by the contractor's representative, thereby making all equipments identical in design. The greater portion of the information shown in this report was made with the radio frequency stages removed from the two equipments, and whether or not the information shown was obtained with or without this stage is indicated in the subsequent data.

METHOD OF TEST

9. The equipment was examined to determine if it was constructed in accordance with the governing specifications. The workmanship, material, etc., were also noted. Various field tests were conducted to obtain information concerning the operation, range of communication, receiver interference, etc. By means of laboratory tests, other pertinent information was obtained. Battery life was determined by output voltage readings at 15-minute intervals over a period of 11 hours operation, and during this test the equipment was operated on the basis of transmission one-half the time, reception the other half. Radio frequency power output was determined by the lamp and photo-cell method. Audio frequency fidelity was determined by conventional methods except that a signal was inserted by means of an audio oscillator placed in series with the microphone circuit. Percentage of modulation was determined with a cathode ray oscillograph. Various frequency measurements were made with a General Radio Type LD-2X frequency meter. Receiver sensitivity data were obtained by a General Radio Type 604B test signal generator.

DATA RECORDED DURING TEST

10. The test data obtained are shown in Tables 1 to 6 inclusive, and in Plates 4 to 8, inclusive.

DISCUSSION OF PROBABLE ERRORS

11. In various data subsequently shown regarding range of transmission, receiver interference, etc., the locations of equipment, distances between equipments, etc., will be indicated, and actual facts noted will be discussed. General statements in so far as possible will be offered. However, it will be difficult to say that the equipment can be expected to perform the same distance under various conditions, for there are many factors which affect wave propagation. Consequently, various statements made regarding the equipment in this respect must be considered rough approximations.

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In the case of the laboratory tests of the equipment, the probable errors are as follows: radio frequency power output of transmitter, 15%; fidelity of audio frequency system, 0.3 decibel; frequency measurement data, 0.005%; percentage of modulation, 10%; battery life voltage data, 0.5%. Regarding receiver sensitivity data, a much greater error may be present. With the best available apparatus for the purpose, which will cover the frequency range of the equipment, it is realized that an error of a factor of 10 may be present.

RESULTS OF TESTS

12. A summary of field tests made with the TBP equipment will be furnished, together with a discussion of the performance of the Signal Corps equipment under the same conditions.

(a) Field Tests of March 29: TBP sets No. 1 and No.3 and Army sets No.1 and No.2 were set up on the ground at this Laboratory near the river bank; and TBP sets No.2 and No.4 and Army sets No.17 and No.32 were set up on the opposite river bank at Hunter's Point, the distance between the two locations being approximately 1-3/4 nautical miles. The path of transmission was line of sight, and substantially over water. TBP sets No.3 and No.4 at this time still had their radio frequency stages incorporated. With the transmission and reception frequencies of TBP sets No.1 and No.2 at 30 megacycles, and TBP sets No.3 and No.4 at 31.5 megacycles, satisfactory and independent telephonic communication was attained when the separation between the equipments at each end was approximately 25 feet. Contact between Army sets was satisfactory but with less receiver output than in the case of the TBP equipment. Next, the frequencies used in communication were altered as indicated. With TBP equipments No.1 and No.2 adjusted to 45 megacycles and TBP equipments No.3 and No.4 on 47 megacycles, satisfactory contact by phone was made. No cross-talk was encountered when the two equipments on the same end were transmitting or receiving, but independent communication with this frequency separation was not satisfactory. When one of the transmitters operating on 45 megacycles was in operation and the receiver at the same end was operating at 47 megacycles, a certain amount of cross-talk occurs in the receiver, when receiving signals from a transmitter across the river, operating at a frequency of 47 megacycles. However, when the receiver is operating in connection with a transmitter across the river at a frequency of 45 megacycles, a transmitter on the same side as the receiver, operating at 47 megacycles introduces no cross-talk in the receiver. This effect may be due to the fact that the frequency separation of 2 megacycles is greater in percentage in the case of 45 megacycles than for 47 megacycles. Next, the two equipments which were adjusted to 47 megacycles (TBP sets No.3 and No.4) were raised in frequency to 54 megacycles, and simultaneous and independent phone communication was attained. Contact was also made between the Army sets, but with considerably less receiver output and with greater distortion. Next the frequencies of TBP sets No.1 and No.2 were changed to 54 megacycles and TBP sets No.3 and No.4 to 57 megacycles. A few contacts were made but in general the communication was unsatisfactory because of weak signals. No effort was made to obtain communication

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with the Army sets at this frequency.

(b) Field Tests of March 30. Two Type TBP sets, No.2 and No.4, and two Army type sets, No.17 and No.32, were placed on the Naval Research Laboratory motor sailer which proceeded down stream; and the other two TBP equipments, No.1 and No.3, and the Army sets, No.1 and No.2, remained on the dock. Using 30 megacycles as a transmission frequency, communication was carried on during the trip by means of any two of the equipments for distances up to approximately 2-3/4 nautical miles. Signals received on TBP sets No.1 and No.2 were usually perceptibly louder than on the other TBP sets; that is, the equipment without the radio frequency amplification stage functioned more satisfactorily. Because of the interaction between receivers tuned to the same frequency, usually only one receiving equipment was in use at any time on either end of the circuit. Moving TBP set No.2 from the bow to the stern of the boat produced an improved signal strength at both ends of the circuit. The antenna system and other conductors apparently affected both transmission and reception. After the boat had proceeded 2-3/4 nautical miles down stream, the engine was cut off (to eliminate ignition interference) and the boat turned broadside. Good phone communication was established with TBP equipment on 30, 40, and 50 megacycles. Communication was also established with the Army sets at frequencies of 30 and 50 megacycles, but with much less receiver output than for the TBP sets.

(c) Field Tests of March 31. Prior to these tests the receiver radio frequency stage of amplification was removed from TBP sets No.3 and No.4, thereby making them identical to the other two similar pieces of equipment. TBP sets No.2 and No.4, and Army set No. 17 were taken to Fort Washington and set up on the parapet; and TBP sets No.1 and No.3, and Army set No.1 were set up on the dock at the Naval Research Laboratory. The transmission path was mostly over water, and the distance between the two locations was approximately 6-3/4 nautical miles. With TBP sets No.1 and No.4 on 30 megacycles and TBP sets No.2 and No.3 on 31.5 megacycles, good phone communication was established at both frequencies. It was possible to communicate using both transmitters simultaneously at one end, and the two receivers simultaneously at the other end, without appreciable cross-talk or interference. This statement held true regardless of which end of the circuit was transmitting or receiving. In an effort to establish independent communication, however, a 30 megacycle transmitter interfered somewhat with a 31.5 megacycle receiver on the same end of the circuit. However, it was found that the reverse was not the case. This effect is similar to that noted in conjunction with the tests of March 29 at 45 and 47 megacycles. Simultaneous reception at the same frequency at the same end was found possible if the receivers were very carefully tuned so that zero beat reception was attained (or possibly the two oscillating detectors actually synchronized) which, however, was accompanied by a noticeable reduction in signal output. It must be understood that much greater care must be used in tuning two adjacent equipments for zero beat reception than is required when one set only is in use. Next, the frequencies of TBP sets No.2

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and No.3 were changed to 36 megacycles, the other two not changed, and good phone contact was made. With this frequency separation, independent phone communication was possible with no appreciable cross-talk. Contact was made by means of the two Army sets No.1 and No.17 at 30 megacycles, but the signals were barely understandable. Next, TBP sets No.1 and No.4 were changed to 45 megacycles, and TBP sets No.2 and No.3 to 47 megacycles. It was found possible to receive simultaneously on either end of the circuit without cross-talk. When independent communication on the two circuits was tried, it was found that some cross-talk was encountered on the receivers tuned to 47 megacycles from the local 45 megacycle transmitters. However, when receiving on a 45 megacycle receiver, a local 47 megacycle transmitter introduced no appreciable cross-talk. Then TBP sets No.2 and No.3 were adjusted to 54 megacycles, the other two remaining on 45 megacycles. Good phone contact was made on both circuits, independent communication being possible without cross-talk. Contact was also established at 45 megacycles between Army sets No.1 and No.17, but barely understandable signals were obtained. From the tests on the Army sets at 30 and 45 megacycles, apparently this is approximately their limit of distance of communication. Next TBP sets No.1 and No.4 were adjusted to 54 megacycles and TBP sets No.2 and No.3 were adjusted to 57 megacycles. It was possible to simultaneously receive on either end without cross-talk. When independent communication was tried, a 54 megacycle transmitter produced a certain amount of cross-talk with a local 57 megacycle receiver. However, a 57 megacycle transmitter produced no perceptible interference with a local 54 megacycle receiver. Simultaneous independent communication was obtained without cross-talk when TBP sets No.1 and No.4 were adjusted to 54 megacycles and TBP sets No.2 and No.3 were operating at 65 megacycles. From these tests it is apparent that the selectivity requirements stated in paragraphs 12.2-1 and 12.2-2 of the specifications, ref.(b), are complied with in this equipment. Also there are definite indications that the lower frequencies are more reliable.

(d) Field Tests of April 1. TBP sets No.1 and No.3 were taken to Hains Point, on the Potomac River side, at a location near the bank about 200 yards below the railroad bridge; and TBP sets No.2 and No.4 were taken to Fort Washington and set up on the parapet. The distance between these two locations was approximately 10 nautical miles, and the transmission path was largely over water. MCW communication was established on 30 megacycles, in general, on a satisfactory basis. Fading of signals was noted at times. Intermittent phone contact was also established at times, but hardly on a satisfactory basis. These contacts were between TBP set No.3 and TBP sets No.2 and No.4. TBP set No.1 failed to function on these tests, and it was later found that the transmitter coil system had become deformed, apparently while inserting it into the equipment, which caused a short circuit of the "B" battery. Next TBP set No.4 at Fort Washington was moved to the river bank near the water's edge, approximately 200 yards from TBP set No.2, and three way contact was then established at the same frequency, satisfactory with MCW and intermittently with phone. Phone reception at Fort

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Washington, in general, seemed somewhat better than at Hains Point. Operation from the elevation afforded by the parapet (approximately 150 feet) gave more reliable communication than from the bank at the river's edge. Shifting the frequency to 45 megacycles did not result in satisfactory communication. No signals were heard at Hains Point; however, TBP set No.2 on the parapet heard TBP set No.3 very faintly.

(e) <u>Field Tests of April 6</u>. In order to get a definite check on the separation necessary between adjacent receivers, to eliminate receiver interaction, the following tests were conducted. TBP set No.1 was placed at this Laboratory on the ground, and TBP sets No.2 and No.3 were taken to Hunter's Point, across the river. The distance between the two locations was approximately 1-3/4 nautical miles and the path of transmission was substantially over water. With TBP sets No.2 and No.3 separated approximately 150 yards, it was possible to simultaneously receive phone transmission at 30 megacycles from TBP set No.1. However, careful receiver adjustment was necessary to eliminate the receiver interference, or to attain zero beat reception. Receiver radiation was detected from either TBP set No.2 or No.3 at TBP set No.1; however, not to an extent to interfere with communication with either of the equipments across the river. Next TBP set No.2 was moved to Roaches Run, approximately 1 nautical mile from Hunter's Point, and approximately 2-3/4 miles from TBP set No.1 at this Laboratory. Satisfactory three-way phone contact at 30 megacycles without objectionable receiver interference was then obtained. The transmission frequency was then shifted to 45 megacycles. Satisfactory three-way phone contact was then established. At TBP set No.1 at this Laboratory, no receiver radiation from either of the other two equipments was discernible. However, some receiver interference was noted between the other two equipments, but not to the extent of causing appreciable interference with reception. Without changing the position of the other equipments, the location of TBP set No.2 was then changed to Capital Overlook on the Mt.Vernon Boulevard, a distance of approximately 1/2 nautical mile from TBP set No.3. Three-way contact was then established at 45 and 60 megacycles, and it appeared that this separation was about the minimum possible to obtain simultaneous reception at the same frequency without appreciable receiver interference, unless special precautions were taken to adjust the receivers for zero beat reception. It may be noted that the necessary distance is much greater than that allowed in par.12.3 of the specifications, ref.(b). A study was also made as to how distant two Army sets must be to substantially eliminate receiver reaction, and although the tests were not as detailed as in the case of the TBP equipment, indications are that they must be located approximately 2 miles apart.

(f) <u>Subsequent Field Tests of April 6</u>. With TBP set No.1 at this Laboratory and TBP set No.2 at Capital Overlook on the Mt. Vernon Boulevard, TBP set No.3 was placed in a truck which proceeded down the highway, through the city of Alexandria to Beacon Hill below the city. The distance between TBP sets No.1

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and No. 2 was approximately 2 nautical miles. The transmission frequency was 60 megacycles. As the truck proceeded down the highway, three-way phone contact was satisfactory until the truck reached radio station WJSV, approximately 2 miles below Capital Overlook, and then TBP sets No.2 and No.3 lost contact for all subsequent tests on this frequency. However, TBP sets No.1 and No.3 had satisfactory phone contact until the truck reached the center of Alexandria. Afterward, no satisfactory phone contacts were made until the truck went up on a hill near the Penndaw Inn, approximately 3 nautical miles from this Laboratory. Next the truck proceeded to Beacon Hill, approximately 4-1/4 nautical miles from the Laboratory, and satisfactory phone contact was again established. In the meantime, TBP set No.2 had moved from a low point on one side of the highway to a higher point on the other side, and had noted a considerable improvement in signal from TBP set No.1. An effort was made to get TBP sets No.2 and No.3 in contact by MCW, but this proved unsuccessful. The signals of TBP set No.3 were heard by No.2, but No.3 was unable to obtain a readable signal from No.2. Judging by the signal received at set No.1, apparently set No.2 was, at that time, improperly functioning on MCW. The antenna adjustment apparently has some bearing on the stability of MCW output, and it is likely that the antenna of set No.2 was improperly adjusted. Next, the transmission frequency on all equipments was changed to 30 megacycles and three-way phone contact was established, which was, in general, satisfactory as the truck proceeded back to Capital Overlook. Fading occured at times while the truck was passing through Alexandria. In one instance, a decreasing signal from set No.3 to set No.1 was accompanied by an increasing signal to set No.2.

13. Summarizing the field tests, the following facts were found: It was found possible to communicate 10 nautical miles with MCW under certain conditions, but it cannot be definitely stated that this range can be expected at all times under all conditions; the equipment conforms with the selectivity requirements of pars. 12.2-1 and 12.2-2 of the specifications, ref.(b); two receivers operating at the same frequency must be approximately 1/2 mile apart to eliminate appreciable receiver interference, instead of operating without reaction at a distance of 25 feet required by par. 12.3 of the specifications, ref.(b); also that two adjacent receivers need not be tuned to exactly the same frequency to interfere with one another, as audible beats may be obtained with the receivers operating at a frequency separation of 1 megacycle or thereabout. It might appear an audio frequency beat should not occur with a frequency difference of this magnitude; however, the radiation from a super-regenerative receiver contains side bands whose frequency may be actually several percent of the main frequency, which can cause these beat notes. The field tests also indicated that, in general, the lower frequencies are more reliable.

14. Regarding the equipment, several other undesirable features of design and operation were found during the field tests, which will be discussed. The mechanical design of the coil system should be improved, as one case of transmitter failure has already

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resulted thereby, as indicated in par.12(d). Possibly the coils may be protected by some sort of guard or cover attached to the coil form to prevent deformation by handling. As discussed in par.12(f) of this report, a misadjustment of antenna length causes failure of the MCW transmission at times. This effect is probably due to an abnormally high load being imparted to the modulating audio oscillator by the radio frequency oscillator, when improperly coupled to the antenna. By adjustment of circuit constants of the audio oscillator, this defect can likely be overcome. It was noted that when the key was plugged into two of the equipments, TBP sets No.2 and No.3, an audio frequency "howl" appeared in the phones, in receive position. In order to obtain reception, it was necessary to unplug the key circuit first. Feedback of some nature is probably the cause of this instability, and some additional filtering or circuit rearrangement would likely eliminate this defect. This action was not noted in the other two equipments. It was also found that the maximum antenna length available is hardly sufficient to tune to the lower frequencies. The present maximum length is 7 feet 9 inches, and if an extra section be provided, the maximum length obtainable would be 9 feet 6 inches, which would likely be sufficient for the purpose. This addition will cause an increase in weight of approximately 1-1/2 ounces. The antenna is constructed of cadmium plated seamless steel tubing, and it was noted that some of this plating rubbed off during the time the equipment was under test. It is possible that in service, all plating may wear off certain portions of it, thereby allowing the antenna to rust.

15. Of the Laboratory tests of the TBP equipment, the battery life curves will first be presented since they have some bearing on other Laboratory tests. The curves in Plate 5 illustrate the decrease in battery voltages with time of operation. These tests were begun with fresh batteries. During this test, the equipment was successively operated first "transmit" then "receive", each for 15 minute intervals, over a total period of 11 hours. The curves indicate the general trend of battery life and do not indicate slight shifts which result when the equipment is shifted from transmit to receive; or vice versa. The antenna current of the transmitter is also shown, which was measured at a point approximately 2 feet above its base. A curve of "Relative Radio Frequency Power Output" is also shown which is based upon the assumption that the output is 100% initially and subsequent values are computed from the radio of the square of the antenna current at that time to the square of the initial antenna current. It may be noted that the power output decreases to 22% of its initial value after 2 hours operation, and to 12% after 10 hours. This decrease in power, which from the curve seems quite serious, does not actually produce an apparent reduction in observed signal strength varying in like proportion, which is probably because of the automatic volume control characteristic of a super-regenerative detector. In actual operation, no great difference in performance is noted when using fresh batteries, or when using batteries near the end of their useful life. "C" battery life data are not shown for there is no appreciable load applied to them, and their useful life should be the same as the shelf life.

[redacted]

It was unnecessary to replace "C" batteries at any time during the various field tests.

16. The radio frequency power output of the TBP equipment under various operating conditions is shown in Table 1. These determinations were made on all three transmitter tuning coils at three frequencies on each coil, at the low frequency end, at the middle of the range, and at the high frequency end. The output power is indicated at two values of plate voltage, one corresponding to the plate voltage supplied by the batteries when relatively new (that is in use approximately 2 hours) and the other when they are at the end of their useful life. It may be seen that under certain conditions the equipment materially fails to deliver an output of 1 watt guaranteed by the manufacturer in par. 12.1 of his descriptive specification, ref.(c), at 59 megacycles producing less than 20% of the required value. A separate study was made of the effect of oscillator plate and filament voltages upon the output, which is shown in Plate 6. Over the range of plate voltage variation caused by battery deterioration, the output is roughly proportional to the square of the plate voltage. However, the value of filament voltage has quite a pronounced effect on the output, which may also be noted in Plate 6. The filament voltage indicated along the abscissa is the actual voltage impressed on the filament at the tube terminals, the difference between these values and the values indicated by the "A" battery voltage curve in Plate 5, being accounted for by a fixed filament resistor (see wiring diagram, Plate 1). As the "A" battery voltage gradually drops from 3 to 2.5 volts, the oscillator filament voltage correspondingly changes from 2.15 to 1.7 volts. The oscillator, a type 38019 tube, has a normal filament rating of 2 volts. From the right hand curve in Plate 6, it may be noted that if some means were provided to keep the filament voltage at 2 volts instead of allowing it to fall to 1.7 volts, a gain in output of approximately 3 to 1 may be obtained. This statement includes the assumption that the plate battery voltage remains unchanged during this period which would not be strictly true, because a decrease in this voltage will also result, which would offset a certain portion of the 3 to 1 gain in output. At any rate, a considerable gain may be expected by providing means for holding the oscillator filament voltage at its rated value, 2 volts. This may be accomplished by placing a variable resistor, controlled by an adjustment on the panel, to compensate for "A" battery voltage drop with use. Reference to the curves in Plate 5 indicates that ample "A" battery reserve is available for this purpose. In order to use such an arrangement effectively, a filament voltmeter should be also incorporated in the equipment. The manufacturer's representative has suggested for this purpose combination grid-dip milliammeter and filament voltmeter, which may be switched from one position to the other by a "push-button", thereby eliminating the need of an extra instrument in the equipment. After means of properly adjusting the oscillator filament voltage has been provided, the load on the plate batteries will be increased to a certain extent, which may act to shorten their life. If this feature is incorporated in the final models this factor should be investigated.

[redacted]

17. An attempt was made to determine the receiver sensitivity and some information is shown relating to this factor, but first, a discussion of the difficulty of obtaining conclusive data in this respect will be presented. A super-regenerative detector is a type of device operated in a sense by shock excitation, and in addition, it inherently possesses a certain amount of automatic volume control characteristics. Such a detector is usually ultra-sensitive, or a very weak input signal will be amplified tremendously by the regenerative action and thereby deliver considerable output. Obviously, a signal generator capable of delivering a fraction of a microvolt would be necessary in determining the receiver sensitivity. Furthermore, a standard signal generator for use at frequencies as great as 60 megacycles is not available. The most suitable device at hand is a General Radio Type 604B Test Signal Generator, which was used in taking some data regarding receiver sensitivity. Conventional receiver testing procedure can not be used in connection with sensitivity determinations of a super-regenerative receiver,in so far as setting the receiver sensitivity to a fixed noise level, for this factor (frequently designated as "hiss level" in the case of this type of receiver) depends greatly on signal input, and decreases as the signal strength is increased. Consequently, receiver sensitivity measurements can not be based on some standard noise level, as is standard practice. The sensitivity test data are shown in Table 2. "Hiss level" is the receiver output with no signal voltage applied; "Background noise", the output with an unmodulated signal applied; and "Receiver Output" is the value found when the signal voltage is modulated 70% at 400 cycles. One other difficulty is found with such measurements, in that the point on the Test Signal Generator Attenuator marked "zero" output actually delivers considerable voltage, and advancing the attenuator setting gradually diminishes the output until a minimum is reached, and thereafter the signal again increases. The point at which the minimum occurs may be changed by altering the manner in which the equipment is grounded, the point at which output lead sheath is ground, etc. From this discussion it is apparent that the test data in Table 2 cannot be relied on quantitatively, but only on a relative basis. No other means is at hand for this purpose which would likely give reliable results. In all data shown a low pass filter (cut-off frequency, 5000 cycles) was placed in the receiver output circuit to eliminate the detector quenching frequency component normally present in the output circuit of super-regenerative receivers.

18. Regarding the fidelity of the audio frequency system, no measurable deviation from a flat audio frequency characteristic was observed over the frequency range from 200 to 2500 cycles. This characteristic is considerably better than required by par. 12.5 of the specifications, ref.(b), which allowed a variation of ± 4 decibels from the value at 1,000 cycles.

19. Regarding the percentage of modulation afforded by the equipment, it was found that the carrier wave of the transmitter could be modulated approximately 70% by either of the two microphones provided. In order to accomplish this, however, it was found necessary to talk with a moderately loud voice directly in

the microphone. In using the equipment for MCW transmission, the carrier wave is modulated approximately 67% at a frequency of approximately 800 cycles. Therefore the requirements of paragraphs 12.6 and 12.7 of the specifications, ref.(b), are met.

20. The data in Table 3 indicates the frequency of the crystal in each of the TBP sets. It may be noted that the equipments comply in this respect with par. 6.11 of the specifications, ref.(b).

21. Variation in the ambient temperature from -10° to $+52.5^\circ$C did not cause any noticeable adverse effects upon the operation of the equipment. The effect of temperature change on the crystal frequency is illustrated graphically in Plate 7. The average temperature coefficient of change in crystal frequency is approximately 1.15 parts/million/degree Centigrade, which is considerably less than a value of 5 parts allowed by par. 6.12 of the specifications, ref.(b).

22. The transmitter frequency drift of the equipment after starting operation is indicated in Plate 8. The total frequency drift noted, approximately 0.12%, is considered quite small in equipment of this nature. If the equipment is allowed a three-minute "warm-up" period, which seems quite permissible in such apparatus, the frequency drift is approximately 0.087%. By re-tuning the transmitter to the crystal harmonic, this small change could be eliminated in actual operation. The specifications have no requirements in this respect.

23. The magnitude of transmitter frequency changes when the vacuum tube potentials vary, because of battery deterioration, was also studied. By simultaneously reducing both filament and plate voltages approximately 15% (in actual operation both voltages drop approximately this amount) a maximum frequency change of approximately 0.03% was noted. This change was so small and from consideration of other factors noted during the test, it is not certain that the observed frequency change was entirely due to the voltage change. However, these tests served to indicate that the equipment is exceptionally free from effects of this nature. The specifications have no requirements in this respect.

24. The question of how great a change in frequency is caused by the operator moving about the set, which is encountered in actual operation, was investigated. The data in Table 4 are indicative of effects of this nature. It may be noted that the change is quite small, and not sufficient to detune the equipment to an extent which would cause failure in contact between two distant equipments for the broadness of tuning characteristic of a super-regenerative receiver would hardly allow this small frequency change to be perceptible.

25. The weights of the parts of the equipment are shown in Table 5. It may be noted that the portion of the equipment normally carried into the field exceeds by more than 12 pounds,

[redacted]

the maximum allowable value stated in par. 5.1 of the specifications, ref.(b). The weights of the Army sets are indicated in Table 6 for comparison.

26. As a matter of recapitulation, compliance with the various paragraphs of the specifications, ref.(b), will be stated:

Par. 1.1 to 1.7 - These requirements are met.

Par. 1.8 - These requirements are met. Mycalox is the insulating material employed for this purpose.

Par. 1.9 to 1.11 - These requirements are met.

Par. 1.12 - No name plates were affixed to these models of the equipment, but it is understood that the final models will comply in this respect.

Par. 2.1 - These requirements are met. Additional description is included as to types of certain parts.

Chest Microphone	- Telephonics Corp. Type RS-38.
Head Phones	- Navy Type CTE 49016.
Handset	- Western Electric make with no identifying type number.
Key	- Navy Type CJB 26001.

Par. 2.2 - No comment.

Par. 3.1 - No stock spares were included with preliminary models.

Par. 4.1 to 4.3 - These requirements are met.

Par. 4.3-1 - See also par. 4.3-1 of manufacturer's Descriptive Specifications, ref.(c). The equipment employs two Burgess No. 4FH, "Little-Six" 1-1/2 volt "A" batteries; four Burgess No. 5308, 45 volt "B" batteries; and three Burgess No. 5540, 7-1/2 volt "C" batteries. However, the descriptive specification stated that eight 4FH batteries, in conjunction with a suitable vibrator and rectifier, would be employed for the entire power supply. The Bureau had knowledge that the contractor anticipated using a power supply comprising batteries entirely, as indicated in references (g) and (h). From available correspondence it is not clear if the contract was amended in this respect. Although no opportunities were available for relative testing of the two power supply systems, it is likely that the system actually used is preferable to the other.

Par. 4.4 and 4.5 - These requirements are met.

Par. 4.6 - The shipping chest is capable of holding the required mobile spares with the exception that space is provided

[redacted]

for containing only one set of spare batteries, not including those installed in the transmitter-receiver unit. Whether or not the set of batteries included in the equipment is to be considered among mobile spares is not clear. But if it was intended that the shipping chest be capable of holding two complete sets of batteries in addition to those in the equipment, the specifications are not met in this respect.

Par. 5.1 - The field equipment does not conform to weight limitation, and exceeds considerably the maximum allowed value of 32 pounds, actually weighing more than 44 pounds.

Par. 5.2 and 5.3 - These requirements are met.

Par. 6.1 - No comment.

Par. 6.2 - Four vacuum tubes are used in the equipment. The r.f. power oscillator and crystal oscillator are Navy type 38019 tubes, the detector is a Navy type 38030 tube, and a Navy type 38033 tube has the triple function of serving as voice or tone modulator when transmitting and as an audio amplifier when receiving. The above types are now standard Navy tubes.

Par. 6.3 - This requirement is met.

Par. 6.4 - This requirement is met, but the following comment is added. The plug connectors on the plug-in coils are not considered suitable for the purpose. It was frequently found necessary to reinsert the coils once or more during various field tests in order to obtain good contact. An improved design of plug should be employed in the final equipments. (See par. 14 of this report.)

Par. 6.5 to 6.8 - These requirements are met.

Par. 6.9 - These requirements are only partially met. Provision is made for checking the transmitter frequency against crystal harmonics, but over the frequency band from 50 to 65 megacycles, the harmonic beat notes produce very weak signals, and some difficulty is encountered in frequency setting for this reason. Possibly certain internal circuits could be coupled more tightly, thereby raising the amplitude of the beat notes. There are no requirements in the specifications regarding amplitude of crystal harmonic beat note output and the previous statement was made to indicate a desirable improvement in the equipment. No satisfactory means has been provided for checking the receiver frequency calibration against the crystal, and this provision was required by the specifications. The failure of the equipment to comply in this respect is not considered serious as the calibration chart is sufficiently ac-

[redacted]

curate and suitable to adjust the receiver to any desired frequency. In order to reduce the probability of accidentally destroying the calibration another minor change is suggested. If the "stops" on the tuning condenser were removed, allowing 360° rotation, the danger of accidentally rotating the plates against the "stop", possibly producing some slippage between condenser shaft and dial (or shifting the calibration) would thereby be eliminated. For the same reason the "stops" should be eliminated from the transmitter tuning condenser. If a spot on condenser shafts were flattened to provide a set screw "seat", this would also be a desirable improvement.

Par. 6.10 to 8.6 - These requirements are met.

Par. 8.7 - These requirements are met in so far as radio frequency power output is concerned. A grid-dip milliammeter is employed as an indicator for correct antenna length adjustment. The antenna length is adjusted so that the reading of the instrument with the antenna on is approximately one-half of the value obtained with the antenna disconnected. In par. 14 of this report, it has been indicated that MCW transmission is sometimes not satisfactory when the antenna is improperly adjusted, and the instrument does not serve as a suitable indicator in this respect. As previously discussed, this defect can likely be most advantageously corrected by circuit changes in the modulating audio oscillator. A flexible steel tape is also provided for setting the antenna length, but use of the grid-dip instrument for this purpose is much to be preferred. This scale may be eliminated in the final model without detriment.

Par. 9.1 - These requirements are met in so far as an examination will indicate. Whether the knapsack material complies with Specification 24-D-4 could not be determined as no suitable test specimen of the material was at hand.

Par.10.1 - See also reference (f), enclosure (A), on comment concerning this paragraph. These chests are made from 1/16 inch sheet steel. Two of the shipping chests are finished on the outside with a smooth black finish, the other two with an olive green finish, whereas all four should have had the olive green finish in order to comply with the specifications. It was not possible to determine if they had been cadmium plated before finishing. In other respects they conform to requirements. In addition, note comment in this report concerning par.4.6 of the specifications.

Par.11.1 and 11.2 - No comment.

[redacted]

Par. 11.3 - This requirement is met with the exception stated in the comment in this report concerning par. 4.6 of the specifications.

Par. 11.4 - No comment.

Par. 12.1 - See also Contractor's Descriptive Specification, ref.(c), par. 12.1; and ref.(f), enclosure (A), on comment concerning this paragraph. The equipment is capable of communicating a distance of 10 nautical miles, line of sight, although contact was obtained only at the lower frequencies under certain test conditions. Receiver output and noise level measurements could not be made because of the impossibility of separating signal and "hiss" level components of the super-regenerative receiver output. The output power at certain frequencies with batteries near the end of their useful life sometimes falls to less than 20% of the value of 1 watt guaranteed by the manufacturer.

Par. 12.2-1 and 12.2-2 - These requirements are met.

Par. 12.3 - This requirement is not met. From tests shown in par. 11(o) of this report, two receiving equipments must be, roughly estimating, 1/2 mile apart, in order to attain inappreciable receiver interference, whereas such operation should have been obtainable at a separation no greater than 25 feet. The failure of the equipment to comply in this respect is considered serious, and may cause the equipment to be unsuitable for the purpose intended. No means can be suggested to eliminate the receiver interference to the degree required, which is compatible with size and weight limitations of the specifications.

Par. 12.4 to 12.7 - These requirements are met.

Par. 13.1 to 14.1 - No comment.

Par. 15.1 - Preliminary instruction books were provided, but since the equipment has been modified since these instructions were prepared, a revision will be necessary.

Par. 15.2 to 15.16 - No comment.

<u>DISCUSSION</u>

27. Several inquiries were made pertaining to the equipment in Bureau of Engineering letter, ref.(a), and those questions will be answered in so far as possible. Regarding the operation of the equipment under unfavorable conditions, mentioned in par.2 of ref.(a), the discussion under par. 12(f) of this report will partially answer this question. Regarding a comparison of the TBP equipment with other similar apparatus, the data in Tables 5

[redacted]

and 6 will give a comparison in weights of the TBP equipment and the Army sets, which are somewhat similar in characteristics. The maximum range of the Army sets, as indicated by the observed data in par. 12(c) of this report is found to be roughly two-thirds the range of the TBP equipment. The TBP sets have one distinct advantage over the Army sets in that the former is comprised of an independent transmitter and receiver, whereas the latter is a transceiver; thereby it is possible to transmit and receive on different frequencies with the TBP equipment, but in the Army equipment, such operation cannot be obtained without retuning or possibly shifting coils. This advantage is, of course, obtained by some sacrifice in lightness and compactness.

28. With regard to the inquiry in par. 3(a) of ref.(a) regarding reduction in weight, no suggestions can be offered which will materially make the equipment lighter, which are compatible with all provisions of the specifications, with the exception of entirely redesigning the equipment. This means would obviously necessitate considerable delay in delivery of the material. If the equipment is to remain in the same general form, the only appreciable weight reduction obtainable will be in the form of elimination of certain items of the field equipment such as the chest microphone or head telephones, or both. Smaller batteries could be employed, but renewals would necessarily be more frequent. Slight reductions in weight may be obtained by employing connecting cords for certain of the accessories somewhat shorter than the required 15 feet, making them possibly only 6 or 8 feet in length. The weight of the key-block could likely be reduced a small amount. It has already been suggested that the steel tape for measuring the antenna length be eliminated, which would reduce the weight a few ounces. Thus it may be seen that provided the equipment remain in its present form, all items specified are to be included in the final equipment and performance requirements are to be kept the same, that no substantial weight reduction may be effected.

29. With regard to the inquiry in par. 3(c) of ref.(a) concerning the effectiveness of the grid-dip meter in indicating satisfactory performance, it has been previously stated in par.14 of this report, that this instrument does not serve as an indicator of proper operation when transmitting with MCW. It is further stated that changes in the design of the circuit of the modulating audio oscillator tube will probably overcome this defect. With this change, the grid-dip instrument will probably be satisfactory as an indicator of satisfactory performance. For phone transmission, this instrument is considered suitable for the purpose in the present equipment.

30. With regard to the inquiry in par. 3(d) of ref.(a) regarding range of communication, reference to par. 12(d) indicates that the equipment has been used for satisfactory communication at 30 megacycles between two points 10 nautical miles apart, between which there was a grazing line of sight path of transmission. Attempts to communicate over this distance at higher frequencies were not successful.

[redacted]

CONCLUSIONS

31. In general, the performance of the TBP equipment is considered good. The equipment does not comply with all provisions of the specifications, however. Those exceptions are discussed in the two following paragraphs.

32. The equipment will not function entirely satisfactorily in so far as radio reception is concerned where two or more equipments must be operated at the same frequency in a congested area; that is, when equipments are placed within a few hundred feet of one another because of interference caused by receiver radiation inherent in a super-regenerative receiver. Usually it is necessary that two receivers be not less than 1/2 mile apart, or thereabout, to allow inappreciable receiver interference.

33. The equipment exceeds the maximum weight allowed by the specifications, actually weighing in excess of 44 pounds instead of being not more than 32 pounds.

34. In general, communication between two equipments is satisfactory at distances up to 10 nautical miles with MCW transmission at the lower output frequencies, where a line of sight path of transmission is present. Phone communication is usually satisfactory for distances up to 7 nautical miles.

35. The equipment is considered suitable for Naval applications which do not require the simultaneous operation of several sets at the same frequency in a congested area; that is, within a few hundred feet of one another.

36. The equipment is considered suitable for Naval applications which permit simultaneous operation of several adjacent sets on frequencies differing in operating frequency as great as five percent.

37. The equipment is considered unsuitable for Naval applications which require the simultaneous operation of several sets at the same frequency, where the equipments must be placed within a few hundred feet of one another.

[redacted]

Table 1

Radio Frequency Power Output
Unmodulated Carrier
TBP Set No. 2

Coil No.	Freq. Mcs.	Tuning Condenser Setting - Divisions	Plate Battery Voltage	Fil. Battery Voltage	R.F. Output Watts
1	28	0	165	2.78	0.92
1	28	0	140	2.78	0.59
1	34	48.6	163	2.78	0.83
1	34	48.6	140	2.78	0.73
1	40	80.2	163	2.78	0.70
1	40	80.2	140	2.78	0.53
2	40.5	23.7	161	2.78	0.48
2	40.5	23.7	140	2.78	0.37
2	46	57.5	160.5	2.78	0.31
2	46	57.5	140	2.78	0.26
2	51.5	81.5	161	2.78	0.32
2	51.5	81.5	140	2.78	0.23
3	52	20.0	160	2.65	0.23
3	52	20.0	140	2.65	0.13
3	59	54.0	160	2.65	0.20
3	59	54.0	140	2.65	0.10
3	65	78.3	176	2.83	0.76
3	65	78.3	160	2.58	0.35

Note: A power output of 1 watt was guaranteed in the manufacturer's descriptive specification, ref.(c), par. 12.1

[redacted]

Table 2

Receiver Sensitivity Data
TBP Set No. 2

Freq. Mcs.	R. F. Input Microvolts*	Background Noise Milliwatts**	Receiver Output Milliwatts#	Hiss Level Milliwatts##
30	None	-	-	0.6
30	8*#	0.1	6.1	-
30	18	0.02	11.0	-
30	30	0.01	15.5	-
30	40	0	19.0	-
30	50	0	21.0	-
30	100	0	29.0	-
30	200	0	36.0	-
37.5	None	-	-	0.21
37.5	8*#	0.04	1.9	-
37.5	18	0.02	2.6	-
37.5	30	0.01	3.9	-
37.5	40	0	4.7	-
37.5	50	0	5.2	-
37.5	100	0	7.3	-
37.5	200	0	9.2	-
42.5	None	-	-	0.38
42.5	18*#	0.28	0.45	-
42.5	30	0.07	3.7	-
42.5	40	0.02	5.8	-
42.5	50	0.01	7.3	-
42.5	100	0	12.4	-
42.5	200	0	17.0	-
49	None	-	-	0.18
49	18*#	0.02	1.7	-
49	30	0.01	2.6	-
49	40	0	3.4	-
49	50	0	4.1	-
49	100	0	6.2	-
49	200	0	8.9	-
54	None	-	-	0.24
54	18*#	0.09	2.0	-
54	30	0.05	2.85	-
54	40	0.02	3.85	-
54	50	0.01	4.8	-
54	100	0	8.2	-
54	200	0	11.8	-
62.5	None	-	-	0.11
62.5	18*#	0.08	0.5	-
62.5	30	0.07	0.8	-
62.5	40	0.02	1.6	-
62.5	50	0	2.1	-
62.5	100	0	3.9	-
62.5	200	0	5.5	-

Table 2
(continued)

Note: All data shown herein should be interpreted following the discussion in par. 17 of this report.

* This value is not necessarily the true signal voltage, but the setting of the attenuator of General Radio Type 604B Test Signal Generator.

** The values shown in this column are the receiver output when the non-modulated carrier signal of amplitude indicated in the "R.F. Input" column was applied to the receiver.

The values shown in this column are the receiver output with a modulated carrier signal (70% modulation, 400 cycles) and include the "Background Noise" shown in the adjacent column.

Receiver noise level with no signal voltage applied.

*# Attenuator setting at which minimum signal is delivered by Test Signal Generator.

[redacted]

Table 3

Crystal Frequency Accuracy
Nominal Frequency of Crystal - 500 kilocycles
Ambient Temperature 26° C.

TBP Set No.	Crystal Frequency Kilocycles	Difference in Frequency from specified value
1	499.979	0.004%
2	500.037	0.007
3	499.959	0.008
4	500.007	0.0014

Note: Allowable difference in frequency - 0.02% at 20° C. The temperature difference of 6° C. will not cause a frequency change sufficient to materially alter the above values. Absolute accuracy of above frequency determinations - 0.005% or to within 25 cycles.

Table 4

Change in Frequency Due to Change in Position of Operator about Equipment.

Equipment on Ground
TBP Set No. 2

	Frequency Mcs.	Frequency Change
Operator leaning over set and grasping transmitter tuning dial and holding handset, as in tuning equipment to any particular frequency.	58,010	-
Operator holding handset and standing 5 feet from equipment.	57,986	0.04%
Operator holding handset and standing 10 feet from equipment.	58,002	0.014%

[redacted]

Table 5

Weight of TBP Equipment

	Weight
Transmitter-receiver unit including tubes, coils, etc., but without batteries or antenna	14 lb. 8 oz.
Two "A" batteries, Burgess No. 4FH, 1-1/2 volt	2 lb. 10 oz.
Four "B" batteries, Burgess No. 5308, 45 volt	12 lb. 8 oz.
Three "C" batteries, Burgess No. 5540, 7-1/2 volt	1 lb. 9 oz.
Antenna	- 10 oz.
Knapsack	5 lb. 3 oz.
Handset, cord and plug	2 lb. 2 oz.
Chest microphone, cord and plug	1 lb. 1 oz.
Headphones, cord and plug	1 lb. 8 oz.
Key, block, cord and plug	2 lb. 5 oz.
Instruction book	- 6 oz.
Total weight of field equipment	44 lb. 6 oz.

Note: The specifications required the total weight of field equipment to not exceed 32 lbs.

Weight of Other Parts of TBP Equipment

Shipping Chest	35 lb. 8 oz.
Spare Tube Container	1 lb. 4 oz.

Table 6

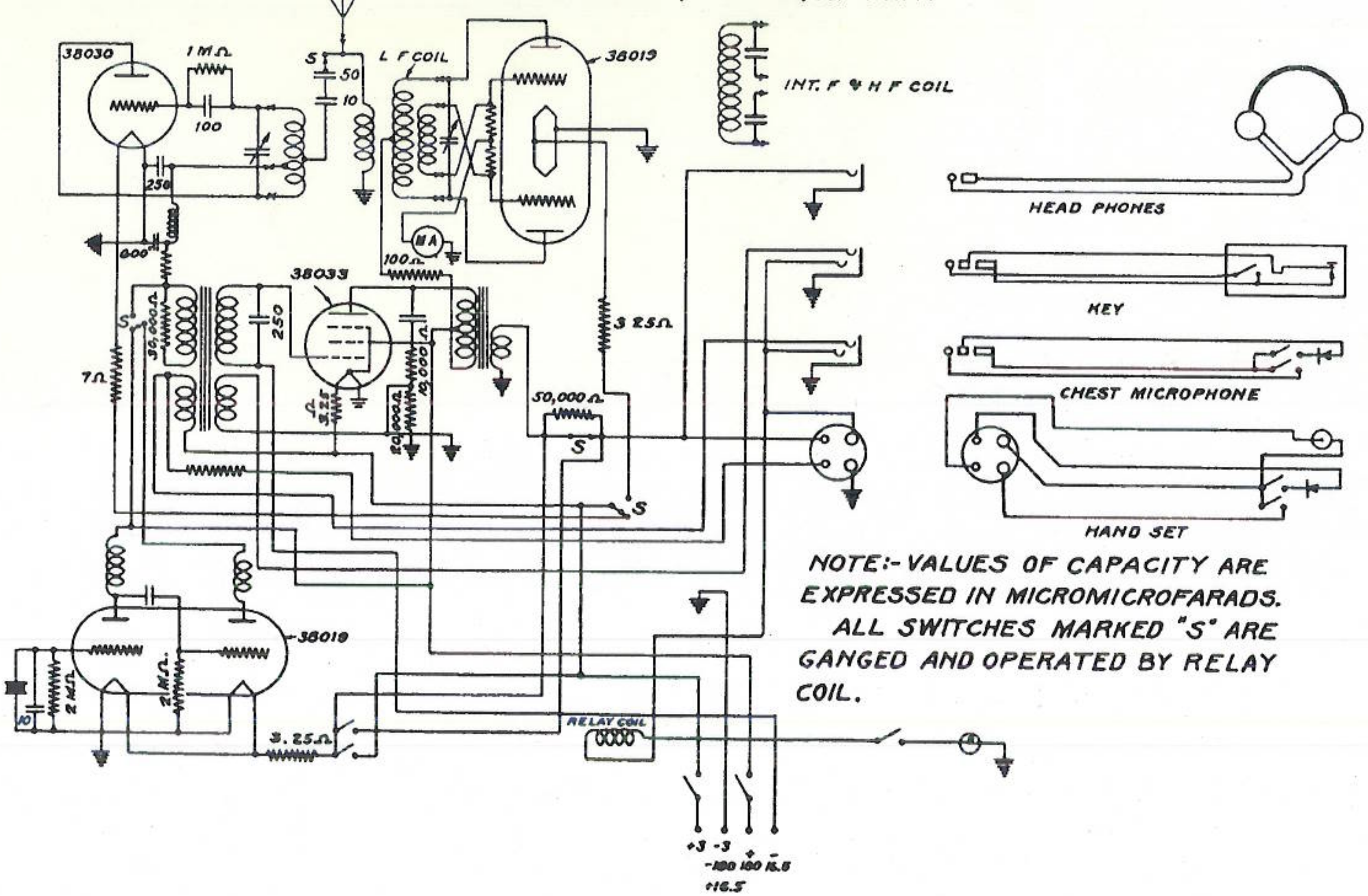
Weight of Army Signal Corps
Type BC-222-T3-EI Equipment

	Weight
Transceiver unit complete except for battery and antenna	7 lb. 10 oz.
Battery, Burgess No. 3F2B108	12 lb. 9 oz.
Antenna	- 8 oz.
Handset, cord and plug	1 lb. 14 oz.
Knapsack	2 lb. 11 oz.
Total	25 lb. 4 oz.

[redacted]

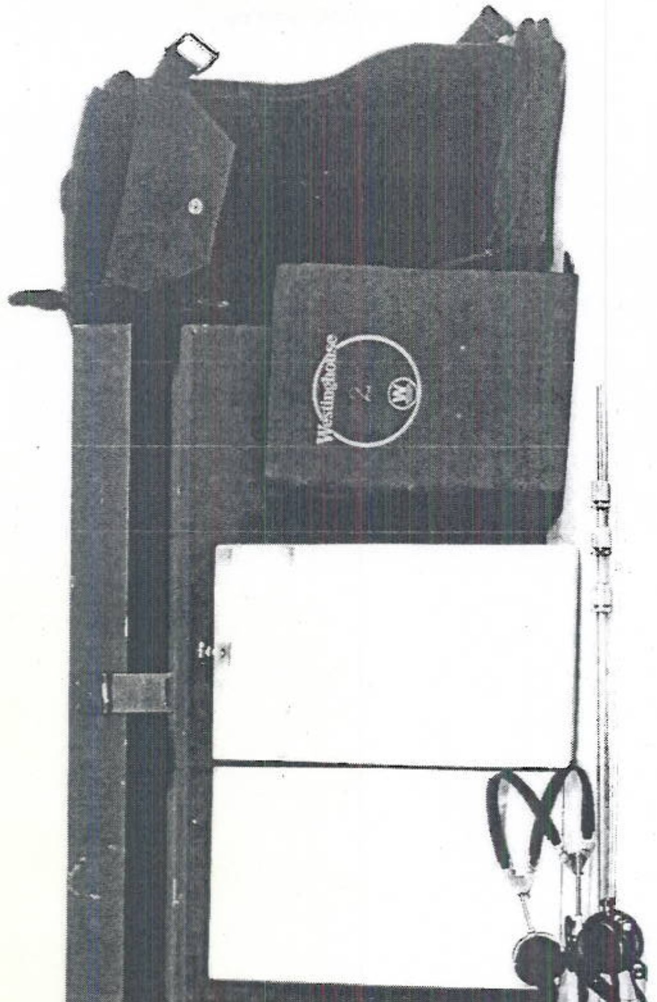
[redacted]

WIRING DIAGRAM, TBP EQUIPMENT



NOTE:- VALUES OF CAPACITY ARE EXPRESSED IN MICROMICROFARADS. ALL SWITCHES MARKED "S" ARE GANGED AND OPERATED BY RELAY COIL.

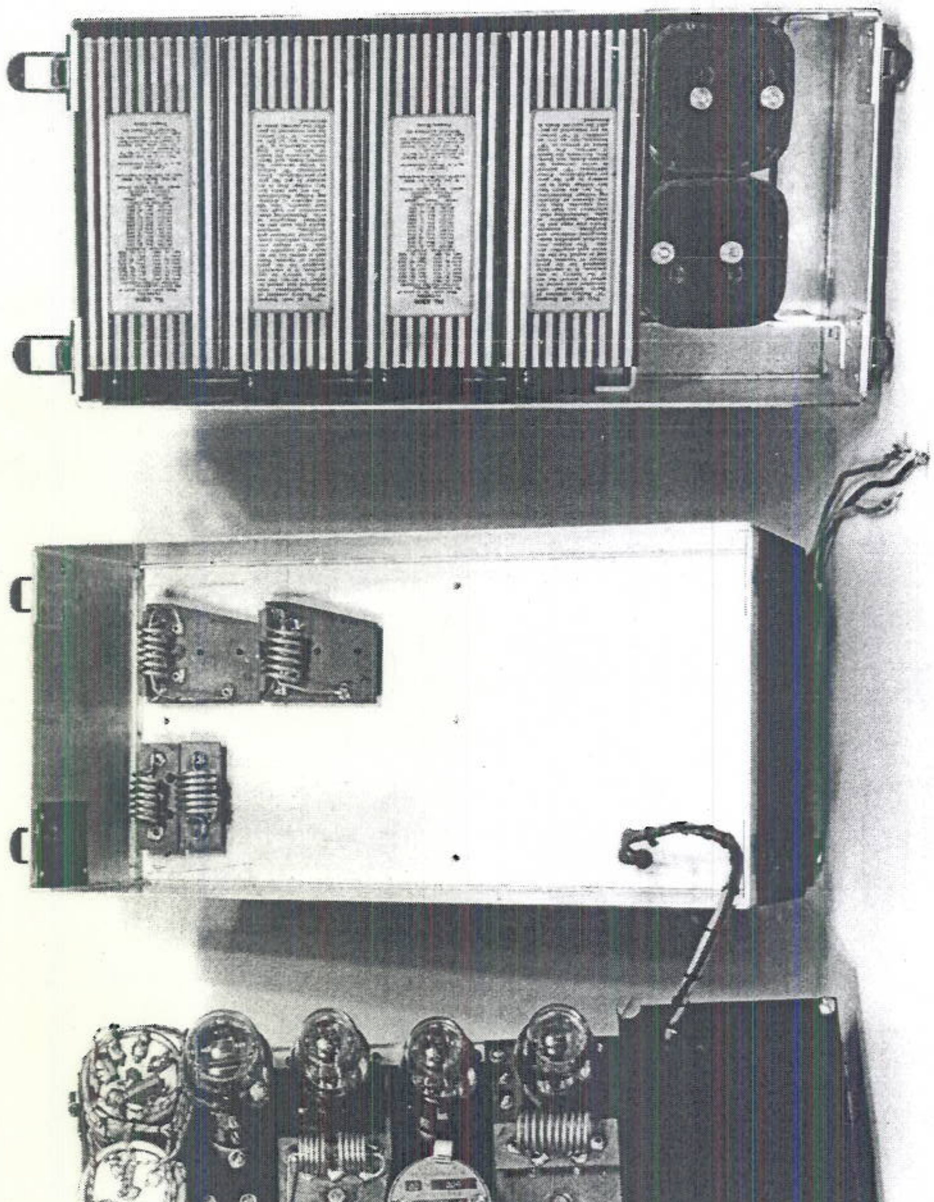
PLATE 1



[redacted]

DECLASSIFIED

Plate 2



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[redacted]

Plate 3

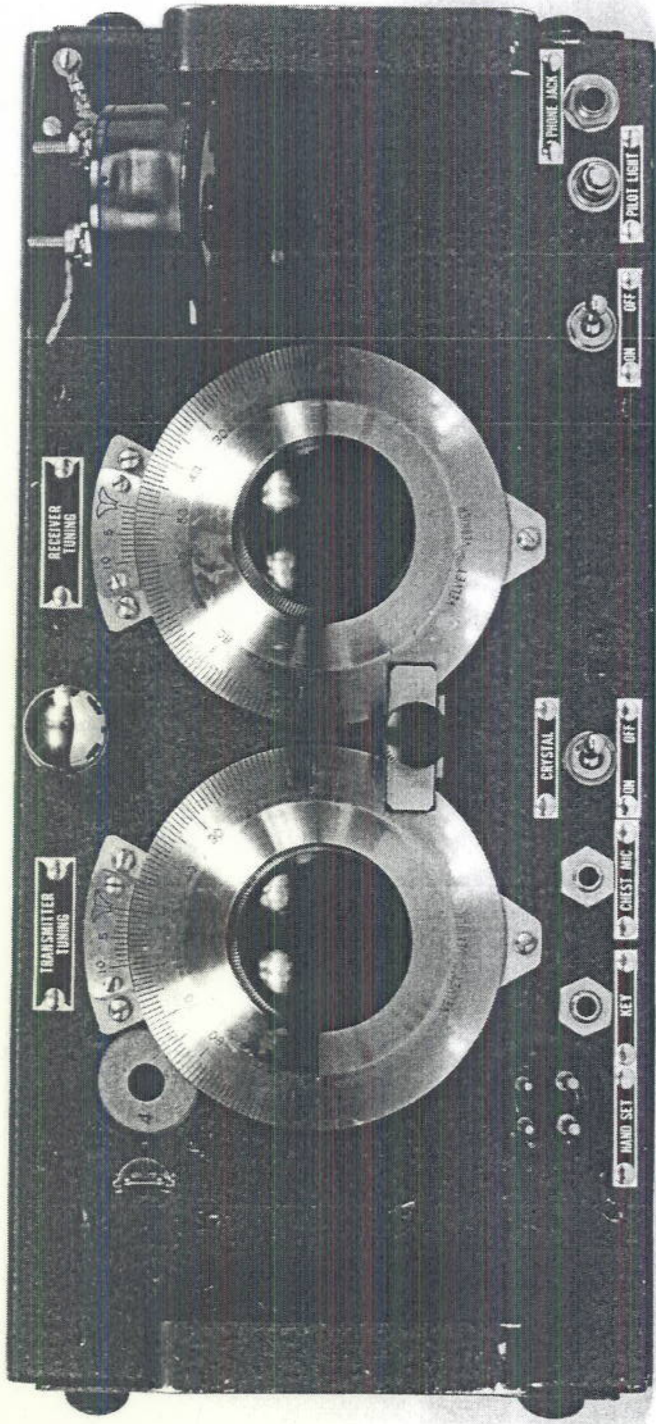

Plate 4

[redacted]

DECLASSIFIED

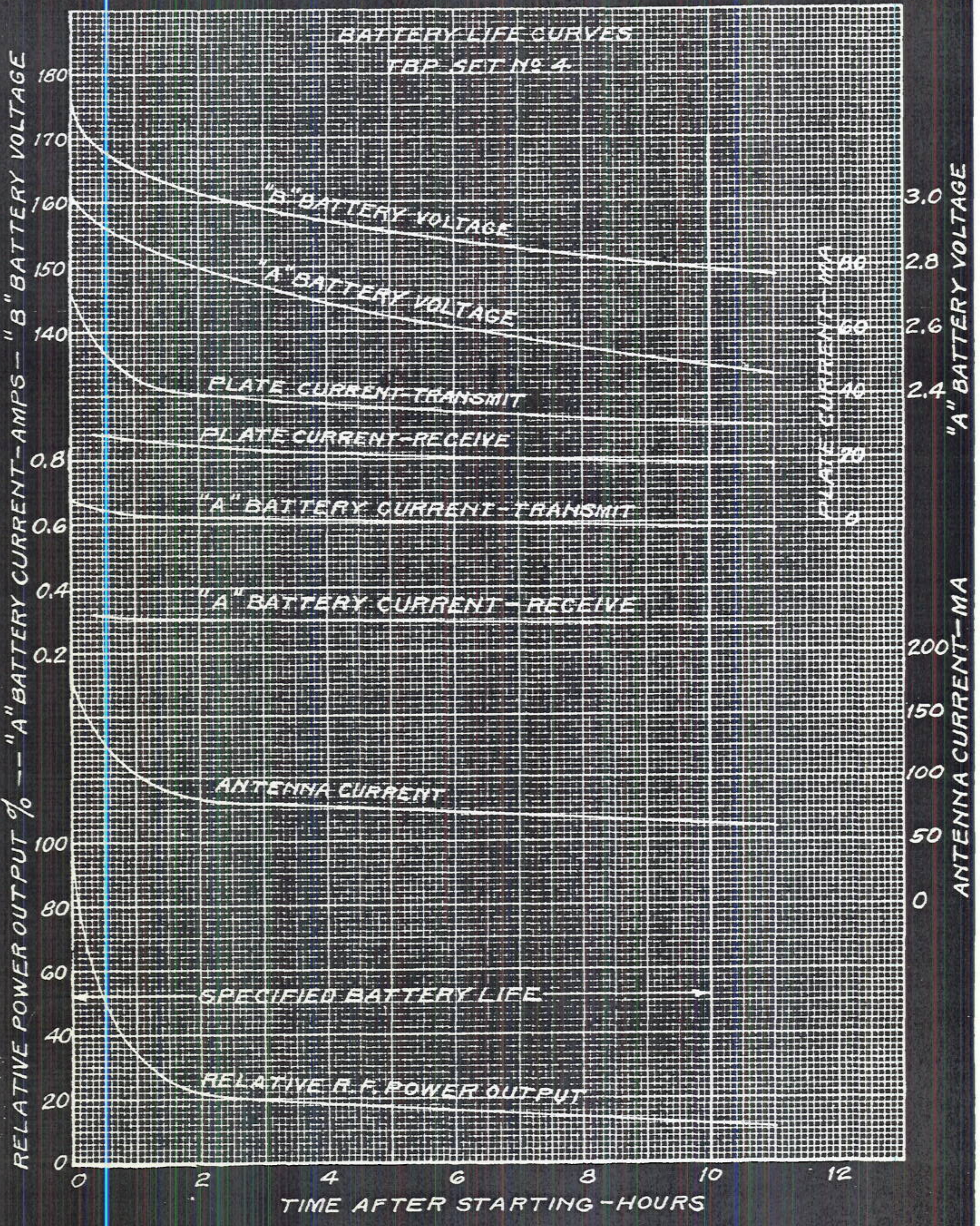

PLATE 5

DECLASSIFIED

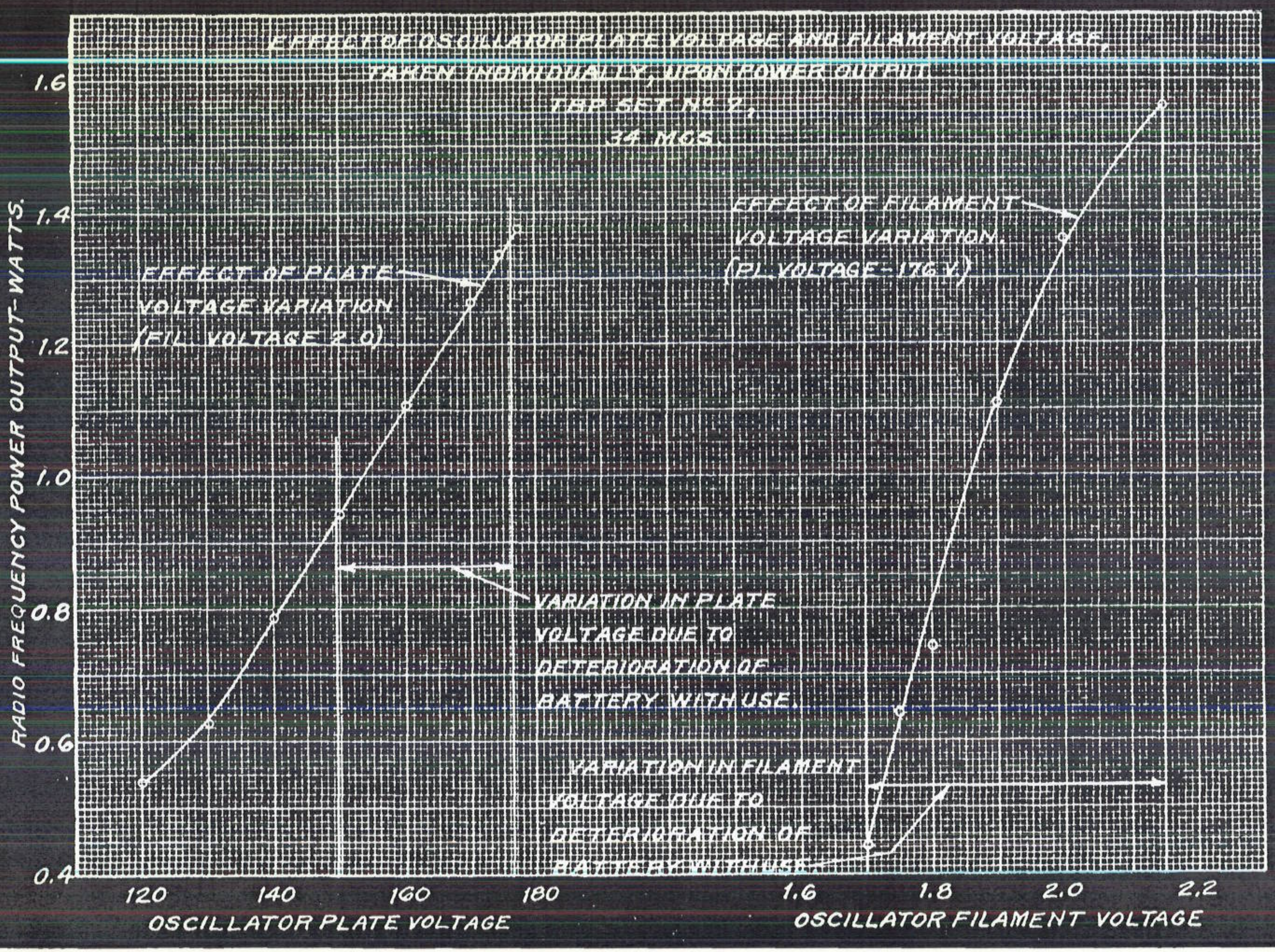

PLATE 6

DECLASSIFIED

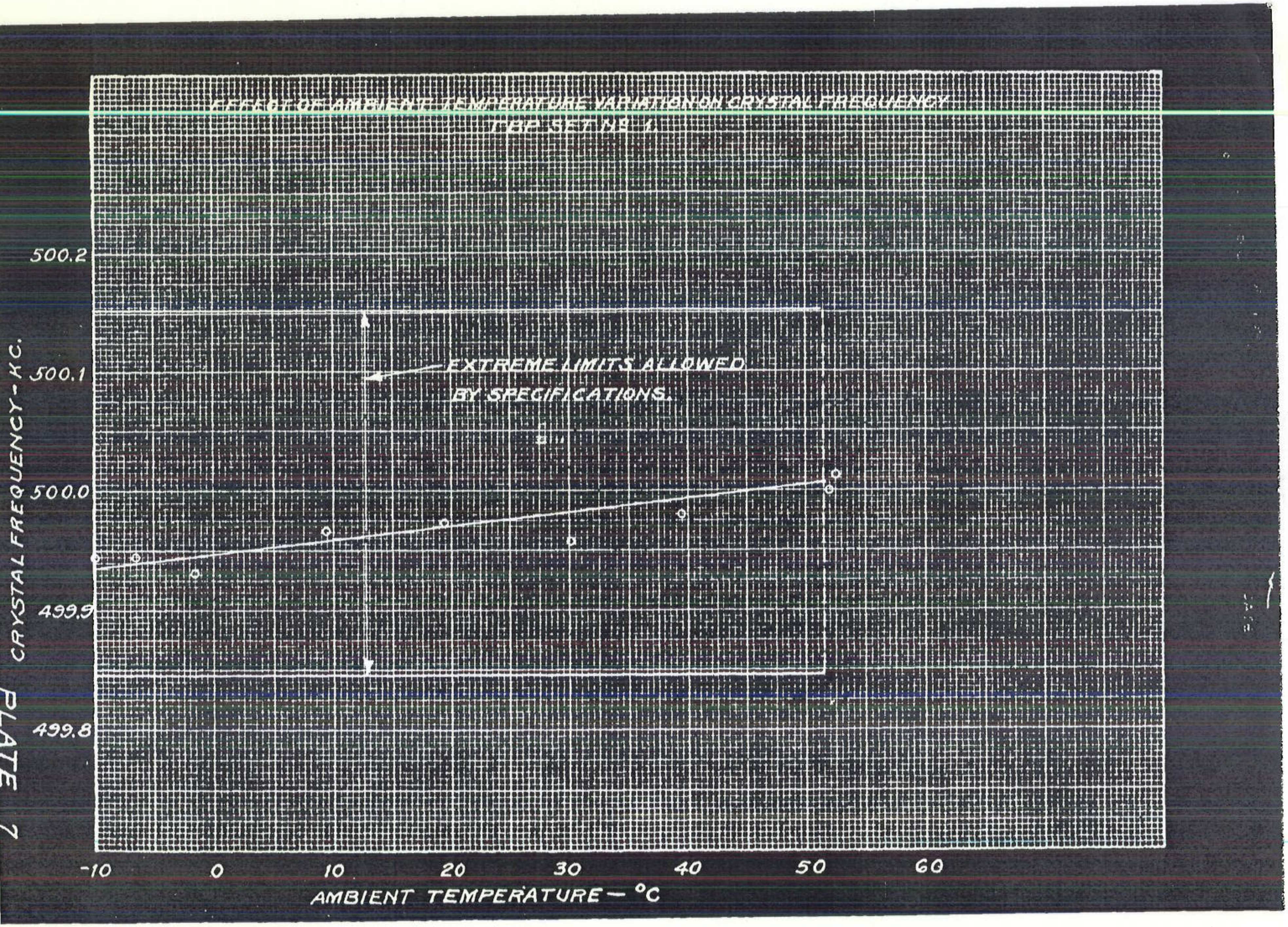
EFFECT OF AMBIENT TEMPERATURE VARIATION ON CRYSTAL FREQUENCY
TBP SET NO. 1
EXTREME LIMITS ALLOWED
BY SPECIFICATIONS.
500.2
500.1
500.0
499.9
499.8
CRYSTAL FREQUENCY - KC.
-10
0
10
20
30
40
50
60
AMBIENT TEMPERATURE — °C

PLATE 7

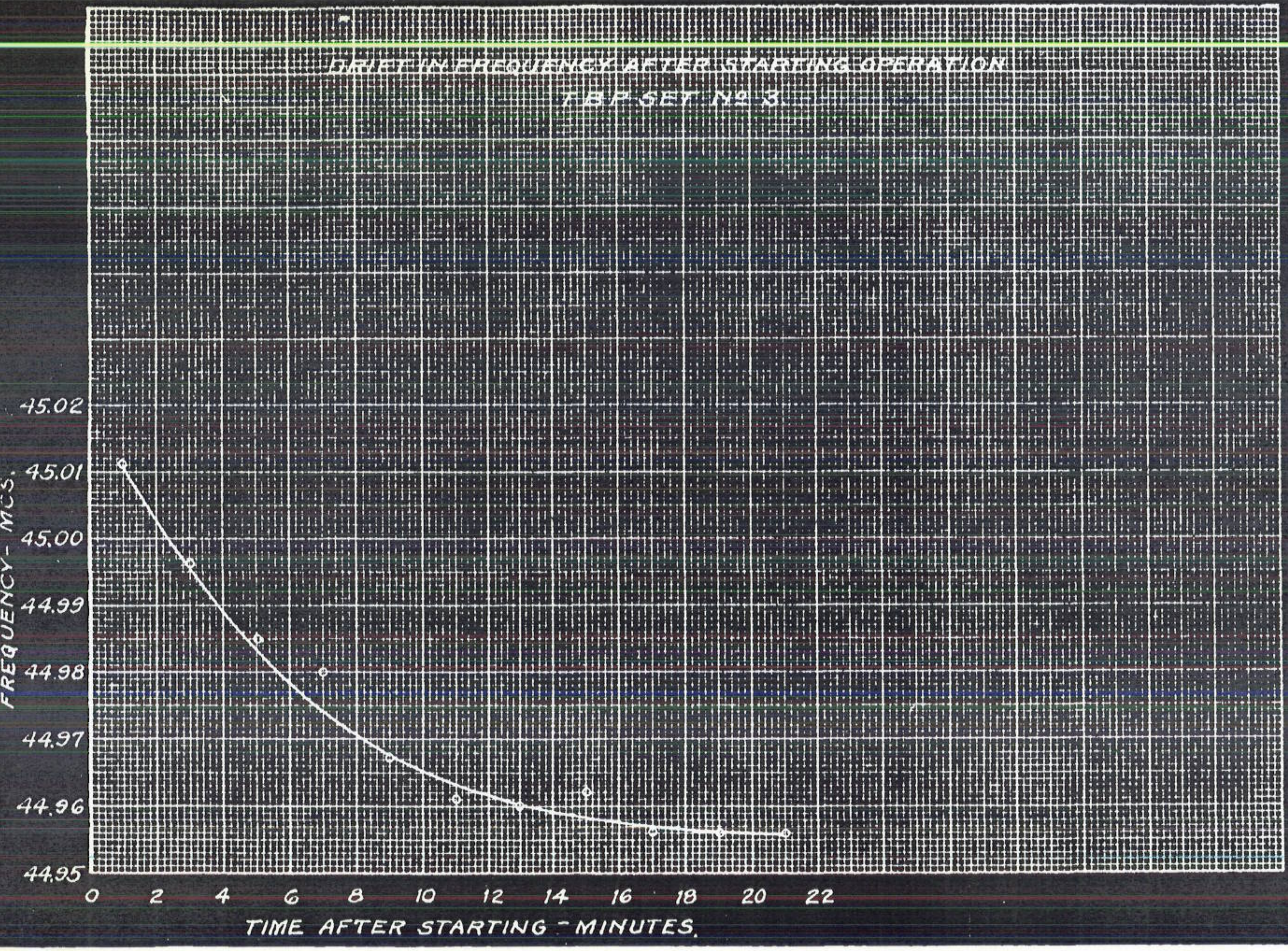
DRIFT IN FREQUENCY AFTER STARTING OPERATION
T.B.P. SET Nº 3.
FREQUENCY - MCS.
45.02
45.01
45.00
44.99
44.98
44.97
44.96
44.95
0
2
4
6
8
10
12
14
16
18
20
22
TIME AFTER STARTING - MINUTES.

PLATE 8