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DATE 24 May 1934

SUBJECT

Test of Model TBG Transmitting Equipment

BY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Test of Model TBG Transmitting Equipment

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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Date of Test: March 27 to May 15, 1934.

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Distribution: BuEng (4)

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Appendices

1. AUTHORIZATION

The tests herein reported were authorized by the Bureau of Engineering in letter NOs-30926(3-16-W8) of 20 March 1934 to Director, Naval Research Laboratory.

2. OBJECT OF TESTS

, The object of the tests was to determine compliance with the requirements of the applying contract specifications and the presence of desirable features over and above the specific requirements.

3. REFERENCES

(a) BuEng let.NOs-30926(3-16-W8) of 20 March 1934 to N.R.L.
((b) Specifications RE 13A 465A.
(c) Manufacturer's Descriptive Specifications
(d) Type Test Data furnished with the TBG Equipment.
(e) Schedule 900-6414 (Engineering)

4. MATERIALS UNDER TEST

The materials under test consisted of one complete Model TBG transmitting equipment Serial Number 4. The equipment includes the following units:

Transmitter
Motor-Generator
Motor Starter
Filter Unit
Crystal Frequency Indicator

The frequency range of the transmitter is 300 to 600 kilocycles and 2000 to 18,100 kilocycles, operating as a crystal controlled transmitter in the high frequency range. The rated output of the transmitter is 200 watts. The equipment was received at the Naval Research Laboratory on March 27, 1934, and is destined for re-shipment to U.S.S. HERON, Naval Station, Cavite.

5. ABSTRACT OF TESTS

The following is a summary wherein it is desired to point out, briefly, such items of the equipment as fail to meet completely the requirements of the governing specifications.

(a) The Model TBG equipment does not constitute an assembly wherein the workmanship is of the best quality. (par.2-4 of specs.)

(b) Bakelite is used to insulate potentials in excess of 500 volts. (par.2-8 of specs.)

(c) The plate overload relay does not protect tubes from overloads unless the overload approaches the proportions of a short circuit. (par.2-11 of specs.)

(d) Open circuiting the antenna in certain portions of the frequency range causes the power amplifier tubes to draw dangerous currents. (par.2-16 of specs.)

(e) It is believed that tubes would be broken if the equipment is subjected to the rolling and pitching of a vessel. This is due to the design of flexible mounting used for supporting the vacuum tubes. (par.2-19 of specs.)

(f) Shock of gun fire or severe vibration would endanger tubes. The leads used on the I.F. antenna load coil would have a tendency to short to ground.

(g) The thermostats supplied as spares were not interchangeable with the thermostat supplied with the transmitter proper. (par.2-28 of specs.)

(h) Tap switch "X" and variometer control "Y" are numbered in such a manner that increasing numbers produce opposite effects upon the controlled function. (par.2-30 of specs.)

(i) 200 watts output cannot be obtained in all types of antennas specified. (pars.3-7 and 3-40 of specs.)

(j) Antenna terminals are numbered but no information is given as to which are loop terminals and which are flat top terminals.

(k) The manner of engraving the control legends does not present a good appearance. (par.3-16 of specs.)

(l) The locking devices, while effective, are likely to injure an operator's hand. (par.3-22 of specs.)

(m) Power output cannot be varied continuously from 100% to 25%. (par.3-26 of specs.)

(n) Inadequate provision has been made for bolting the transmitter to the deck. (par.3-35-2 of specs.)

(o) The terminal board on the transmitter is very inaccessible. (par.3-35-3 of specs.)

(p) The variation of resonant frequency per division of marking is exceeded in some portions of the frequency range. (par.3-44 of specs.)

(q) The antenna coupling circuit does not operate satisfactorily over the entire frequency range. (par.3-45-5 of specs.)

(r) In certain portions of the high frequency range it is impossible to obtain satisfactory output or satisfactory tuning. (par.3-46 of specs.)

(s) The construction of the crystal cabinet is unsatisfactory from the standpoint of servicing the thermostat. The clips holding the crystal containers in place do not perform their function satisfactorily. The threads in bakelite parts are stripped. (par.3-53 of specs.)

(t) The voltage regulation of the plate motor generator exceeds 5%. (par.6-21 of specs.)

6. METHOD AND RESULTS OF TESTS

Tests were conducted to determine the output power delivered by the TBG transmitter when operating into dummy antennas of the characteristics outlined in paragraphs 3-6 and 3-7 of reference (b). Further tests were conducted to determine compliance with the contractor's guarantee as required by paragraph 8-2 of reference (b).

In Tables 1 to 6 inclusive the designations "Set I", "Ext I", "Set Watts", and "Ext Watts" are used. These terms are explained as follows:

"Set I" denotes the antenna current as observed on the ammeter mounted within the transmitter unit.

"Ext I" denotes the antenna current as observed on an ammeter inserted in the ground side of the dummy antenna circuit external to the transmitter.

"Set Watts" denotes the power output calculated from the current reading obtained on the antenna ammeter mounted within the transmitter.

"Ext Watts" denotes the power output calculated from the current reading obtained on the ammeter inserted in the ground side of the dummy antenna circuit external to the transmitter.

Table 1 lists the results of tests conducted when operating into antenna constants simulating those of a submarine loop. The 0.001 mfd capacity contained in the transmitter was used during these tests. The capacities designated in paragraph 3-7 of reference (b) were actually employed in the external dummy antenna. It will be noted that when operating under these conditions full power output could not be obtained and that flash-overs and corona occurred within the transmitter.

Table 2 lists the results of tests similar to those shown in Table 1 except that the series capacity of 0.001 was replaced by one of 0.0005 mfd, this latter value being used at the time measurements were made to determine the constants of submarine loops. It will be noted that the power output obtained under these conditions is greatly reduced and that arcing and corona occurs within the the transmitter when operating at frequencies below 400 kilocycles.

The method used in conducting the above tests, however, does not coincide with the interpretation placed upon the loop data by the manufacturer. Since the series loop condenser incorporated into the TBG equipment is of 0.001 mfd capacity instead of 0.0005 mfd the effective value into which the transmitter operates was 770 uuf obtained as follows:

(1) $$\frac{1}{\frac{1}{500\ \text{uuf}} + \frac{1}{C_{loop}}} = 435\ \text{uuf} \quad \text{(at 300 kcs)}$$

(2) $$C_{loop} = 3350\ \text{uuf}$$

(3) $$\frac{1}{\frac{1}{1000\ \text{uuf}} + \frac{1}{3350\ \text{uuf}}} = 770\ \text{uuf} \quad \text{(at 300 kcs)}$$

Table 3 shows the results of tests conducted using a dummy antenna proportioned in accordance with the above mentioned method. It will be noted that full output was obtained and no corona or flash-overs occurred within the transmitter.

Table 4 shows the results of power output tests conducted at intermediate frequencies with the transmitter operating into dummy antennas simulating the constants of submarine flat top antennas. It will be noted that the required output, 200 watts, was not obtained when the calculations were based upon antenna current values obtained with a meter connected in the ground side of the dummy antenna.

Table 5 shows the results of power output tests conducted at intermediate frequencies with the transmitter operating into dummy antennas simulating the constants of flat top antennas employed on surface craft. With the higher values of capacity and resistance here employed no difficulty was experienced in obtaining more than the required output of 200 watts.

Table 6 compares the data submitted with the transmitter with the data obtained during tests at the Naval Research Laboratory. A representative of the manufacturer visited the Naval Research Laboratory and conducted tests in an effort to reconcile the differences in output power noted in the type test data and the data obtained at the Naval Research Laboratory. During these tests the output power was increased somewhat above the NRL values but with antennas of low resistance and low capacity exceedingly minute adjustments were required to obtain this output. In some instances, however, 200 watts could not be obtained, the limit ranging between 180 and 190 watts.

Tables 7 and 8 list the results of tests conducted to determine the performance of the TBG equipment when operating as a crystal controlled transmitter in the high frequency band, 2000 to 18100 kilocycles. It will be noted that no difficulty is experienced in obtaining more than the required output over most of the range.

A phenomena was encountered, however, which made it impossible to obtain the required output at 12405 kilocycles and the tuning of the power amplifier circuit at this point was so indefinite that resonance could not be detected through the medium of the plate ammeter. An investigation revealed that this difficulty was due to the wiring of the antenna circuit. The low side of the antenna circuit is connected to the antenna ammeter which is located in the upper compartment of the transmitter. From thence a lead proceeds for a distance of approximately four feet to the break-in keying relay which is located in the 2nd IPA compartment. When this lead was short circuited directly at the ammeter the transmitter functioned normally and gave excellent output as will be noted by referring to column 4 of Table 8. Apparently the lead between the antenna ammeter and the keying relay possesses sufficient inductance and capacity to produce an anti-resonant condition in the 12 megacycle band.

Representatives of the manufacturer endeavored to correct this condition by changing the configuration of the antenna ground lead. As a result of this change normal operation was secured at 12,405 kilocycles. However, after tuning the transmitter over the entire range of frequency between 2000 and 18,100 kilocycles it was discovered that no satisfactory operation could be obtained between 14,000 and 15,000 kilocycles. The change in the antenna lead merely resulted in moving the "blind spot" up to 14,000 kilocycles.

It appears, therefore, that with the TBG transmitter in its present condition, the only way in which it will be possible to obtain normal operation over the entire frequency range will be to ground the antenna ammeter directly to the frame of the transmitter in the upper compartment. It is doubtful whether sufficient space is available to move the keying relay up into the compartment which contains the antenna ammeter and even if it were possible to do this the relay would be wholly inaccessible. If the antenna ammeter is grounded directly the break-in feature is eliminated.

The antenna coupling systems, both intermediate and high frequency, are not entirely satisfactory. In the case of intermediate frequency operation three degrees of coupling may be obtained by the use of coupling switch "W". This three step coupling adjustment does not provide sufficient flexibility. At certain frequencies the minimum coupling provided caused the power amplifier tubes to draw more than the rated power when the antenna was brought into resonance and full plate potential was applied to the tubes. It was necessary either to reduce the plate voltage or to detune the antenna circuit slightly in order to limit the plate current to a safe value.

It was also found that the two controls governing the antenna tuning and loading gave opposite effects with an increase in dial markings. The variometer control "Y" decreased inductance with higher values of dial setting and the tap switch "X" increased inductance with higher values of the switch setting.

In the case of the antenna coupling circuit employed when operating in the high frequency band objectionable features were also noted. The principal objection lies in the fact that all the antenna controls react upon each other and upon the power amplifier tank tuning to such an extent that resonance can be obtained by an almost infinite number of combinations. In the 2000 kilocycle band the P.A. tuning "I" loses all trace of resonance as indicated by plate current dip and the coupling variometer "J" assumes the function of P.A. tuning. This condition of affairs makes it exceedingly difficult to arrive at the optimum adjustment when operating into an actual antenna.

Table 9 shows the effect of short circuiting and open circuiting the antenna while operating at various frequencies. It will be noted that when the antenna is open circuited while operating in the 2000 and 3000 kilocycle band, where rather tight antenna coupling is required, the P.A. plate current rises to dangerous values. This condition would endanger the P.A. tubes if it were permitted to persist for any length of time. The plate current overload relay does not operate on overloads of this magnitude even when adjusted for minimum current. Thus, the tubes do not receive proper protection, in fact, the overload must approach the magnitude of a short circuit before the overload relay will function.

Table 10 covers tests wherein the line voltage was varied between the limits of ± 10% and also between the limits of +37% and -23%. During the first test the filament and plate voltage controls were not readjusted; during the latter test these controls were readjusted in order to maintain the filament and plate potentials within safe limits. The frequency variations resulting from the change of line voltage were very small and well within the requirements of the specifications.

Table 10 also lists the results of a test conducted to determine the power required from supply lines. The requirements of the specifications are complied with.

Paragraph 3-26 of reference (b) states "It must be possible to vary the power output of the transmitter from the maximum value specified to a minimum value not in excess of 25% by means of a single control located on the front panel, and it must be possible to thus vary the power while the set is transmitting. The control of power output by a continuously variable generator field rheostat is desired where power is obtained from a motor generator equipment."

Reference to Table 11 reveals that the power output may be varied from 100% to 46% by means of the generator field rheostat when the "Tune-Operate" switch is on "Operate". When the "Tune-Operate" switch is set on "Tune" the maximum power obtainable is 22% of full power and this may be reduced to 18% by means of the generator field rheostat. Thus it will be seen that it requires the manipulation of two controls to vary the power and that it is not possible to obtain power output in the range of 46% to 22% of full power. In this connection it is pointed out that paragraph 3-26 may be subject to misinterpretation. The power output of the TBG equipment can be varied from 100% to less than 25% (22%) by means of one control, namely, the "Tune-Operate" switch. In order to avoid misunderstanding it is suggested that paragraph 3-26 be worded as follows: "It must be possible to vary the power output of the transmitter <u>continuously</u> from the maximum value specified to a minimum value not in excess of 25% by means of a single control located on the front panel, and it must be possible to thus vary the power while the set is transmitting."

Table 12 is a comparison of CW and MCW operation. The reduction in power sustained when changing from CW operation to MCW operation is less than 40%, thus complying with the specification requirements. The percentage of modulation and the frequency of modulation also complies with the specification requirements.

Table 13 shows that the accuracy of reset of the Model TBG transmitter when operating in the Intermediate Frequency range complies with the specification requirements.

The percentage variation of resonant frequency of the intermediate frequency master oscillator per division of marking exceeds 0.05% in some sections of the frequency range. The excess, however, is small and no difficulty is experienced in properly adjusting the transmitter. The controls are subject to considerable lost motion and back-lash, especially in the range of 500 to 600 kilocycles. The major portion of the error resulting from back-lash can be avoided by approaching settings from one side only. The actual data collected during these tests is shown in Table 14.

Reference to Table 15 shows that the voltage regulation of the motor generator is 8% whereas the specifications call for a voltage regulation of 5%. In this connection it may be stated that variation of plate voltage does not greatly affect the output frequency of the transmitter either in the intermediate frequency or the high frequency range. It was also noted that the transmitter appears to possess an inherent regulation of such a character that when the plate voltage varies plate current variations are not proportional but are of a considerable less degree. Thus, while the specification requirements of paragraph 6-21 are not complied with the result of this non-compliance does not affect the operation of the transmitter to any great degree.

All quartz crystals supplied with the Model TBG equipment including both the regular sets and the spares for the transmitter proper and for the crystal frequency indicator were checked. The crystals complied with the specifications in all respects. The deviations from the assigned frequency are listed in Table 16.

Table 17 lists the results of a test wherein the TBG crystal frequency indicator was subjected to variations in ambient temperature ranging from 8° to 60° Centigrade. The crystal frequency indicator is not provided with temperature control. In the normal range of ambient temperatures the variation per degree Centigrade is very small. As the extremes of temperature are approached the variations in frequency are of greater magnitude. The maximum variation in frequency observed over a period of 5-1/2 hours during which time the ambient temperature varied 52° C was 510 cycles in 500 kilocycles or 0.102%.

The crystal frequency indicator is a well constructed piece of apparatus and meets the requirements of the governing specifications. It produces an excellent signal and all adjustments are simple and easy to make.

Table 18 shows the results of a two hour locked key test at 500 kilocycles, full power. No excessive heating occurred within the transmitter during this test and no parts suffered injury. The ambient temperature was essentially constant during the test but the line voltage was varied between the limits of $\pm$ 10% of normal. Allowing the usual 20 minute period for the transmitter to approach temperature equilibrium it will be noted that the frequency change during the subsequent period of the two hour run did not exceed the specification requirement of 0.05%, in fact, the variation was only 0.016%. The frequency variation during the entire two hour test from a cold start was only 0.047%.

Table 19 shows the results of a two hour test wherein the self-oscillating master was used for high frequency operation. During this test the ambient temperature varied about 3.5° Centigrade and the line voltage was varied between the limits of 100 volts to 125 volts. After the 20 minute preliminary heating period the frequency variation noted during the remainder of the test was 908 cycles in 2000 kilocycles or 0.045%. During this test it was noted that large variations in supply line voltage and plate voltage had an almost negligible effect upon the output frequency. However, when the transmitter is operating under these conditions; namely, using the self-excited master at high frequencies, the effect of vibration is very noticeable. Sudden frequency shifts of considerable magnitude result when the transmitter is submitted to even moderate vibration or to light shocks. The effect of vibration is not noticeable when operating as a crystal controlled transmitter and vibration does not seriously affect intermediate frequency operation.

Table 20 covers a test conducted to determine the frequency stability of the TBG transmitter when operating on crystal control. The test was conducted over a two hour period during which time the ambient temperature was substantially constant. The line voltage was varied between the limits of 90 and 127 volts. The frequency variation noted during this test was 21 cycles in 3326 kilocycles, or 0.00063%. It will be observed that most of the frequency change which did occur may be attributed to voltage variations, since the highest frequency observed occurred when the plate voltage was at a minimum and the lowest frequency occurred when the plate voltage was at a maximum.

Keying tests were conducted up to speeds of 100 words per minute and the results observed by means of an oscillograph. Satisfactory operation was secured.

Listening tests were conducted on nearby receivers. The crystal controlled note is exceedingly clear and free from undesirable modulations. The output on intermediate frequencies is also clear and free from lilt and modulation. The motor generator is equipped with an automatic governor to compensate for voltage fluctuations. Under certain conditions of line voltage the action of this governor influences the note of the transmitter by introducing a slight lilt. This effect is noticeable generally only under locked key condition and is not of sufficient magnitude, with the particular transmitter tested to interfere with communications.

Table 21 lists the dimensions of the Model TBG equipment. It will be noted that in some instances the actual over-all dimensions exceed somewhat the specification requirements. The only dimension, however, which exceeds the specification requirements by more than a fraction of an inch is the height of the transmitter unit. This additional 1-1/2" in height is due to the projecting antenna terminals and these may easily be removed during handling if they should interfere with the passage of the transmitter through restricted doors or hatches. Attention is invited to the fact that the motor generator equipment is decidedly smaller than the dimensions permitted by the specifications. In spite of this reduction in size no trouble was experienced with the motor generator equipment and no signs of overheating or breakdown were observed.

In order to determine the effect of changes in ambient temperature upon the Model TBG transmitter the equipment was installed in the temperature controlled chamber at the Bureau of Standards. Tables 22 to 29 inclusive and Plates 1 to 8 inclusive show in detail the results of these tests.

Table 22 and Plate 1 cover a test wherein the transmitter was operating at a frequency of 500 kilocycles and the ambient temperature was varied between the limits of 25 and zero degrees Centigrade. Table 23 and Plate 2 cover a similar test except that the ambient temperature was varied between the limits of 25 and 43° Centigrade. It will be noted that variations in temperature in the range above 25° caused somewhat greater frequency shifts than variations in the range below 25°. The greatest frequency change per degree Centigrade in the range below 25° occurred between 5° and zero and was approximately 15 cycles. The greatest frequency change per degree Centigrade in the range above 25° occurred between 35 and 43 degrees and was approximately 31 cycles. The requirements of paragraph 3-24-3 of referenbe (b) are complied with.

Table 24 and Plate 3 cover a test conducted at 2000 kilocycles using the self excited master oscillator, wherein the ambient temperature was varied between the limits of 25 and zero degrees, while Table 25 and Plate 4 cover a test conducted under similar conditions except that the ambient temperature was varied between the limits of 25 and 43 degrees Centigrade. An examination of this data discloses that the frequency drift per degree Centigrade is approximately twice as great in the range between 25 and zero degrees as it is in the range between 25 and 43 degrees Centigrade. The frequency variation incident to a change of 5° Centigrade between the limits of zero and 43° complies with the requirements laid down in paragraph 3-24-3 and 3-58 of reference (b).

Tables 26, 27, 28, and 29 and Plates 5, 6, 7, and 8 cover tests conducted to determine the behavior of the Model TBG transmitter operating on crystal control while the ambient temperature was varied between the limits of zero and 43°. These tests were conducted at two frequencies, 3078.75 and 3326.25 kilocycles. These particular frequencies were selected since matched crystals were available. One of the crystals of each frequency was placed in the TBG transmitter while the corresponding crystals were used in the Model LH frequency measuring equipment.

It will be noted that the frequency in all tests was exceedingly constant regardless of the change in ambient temperature indicating that the temperature control equipment incorporated in the TBG transmitter operates successfully over the range of zero to 43° Centigrade. The largest frequency variation noted per degree change of ambient temperature was approximately one cycle in 3000 kilocycles. The only variation in frequency of any magnitude occurs during the interval when the key of the transmitter is opened and closed. Thus it will be noted that if the transmitter is operated key locked for a period of one hour after which the key is opened for ten minutes and then re-closed, a frequency change of approximately 50 to 60 cycles in 3000 kilocycles is apparent. Under normal operation, handling of traffic, this change in frequency would be far less. The requirements of paragraphs 3-24-3 and 3-58 of referenbe (b) are complied with.

During all of the tests covered by Tables 22 to 29, the transmitter functioned satisfactorily and no signs of overheating or breakdown were observed. The note of the transmitter was clear and steady on all types of operation and no frequency "jumps" or "fluttering" was observed.

A careful survey of the constructional details of the Model TBG equipment discloses a number of factors which are unsatisfactory.

The construction of the temperature controlled crystal compartment is such that it is exceedingly difficult to install or remove the adjustable mercury thermostat. The crystal box contains a heavy metal plate upon which the crystals rest. This plate is 6-3/8" deep by 7-1/4" wide. The inside dimensions of the heater box are 7-1/2" deep by 7-1/2" wide. However, the crystal selector switch with its wiring projects into the box 1-1/2" at the front, leaving 6" in the clear, while at the back of the box the wiring projects another 1/4". Whenever a thermostat is placed in the box it is necessary to remove the metal plate in order to accomplish this. However, due to the crowded condition it is practically impossible to make the change without breaking off leads or injuring the thermostat. One thermostat was broken while attempting to install it. Two spare thermostats were supplied and it was discovered that the spares were of different dimensions than the one supplied with the equipment. This difference in dimensions causes one of the contact rings to fall directly under the securing clamp which holds the thermostat in place. Therefore, the arrangement had to be modified and a new method of securing the thermostat improvised. The thermostats supplied with the transmitter are of the adjustable or metastatic type. It is believed that the use of this type of thermostat should be prohibited in Naval radio transmitting equipment. It is generally necessary to adjust the thermostat to the proper operating temperature and this adjustment requires rather painstaking effort and considerable time. In addition, such adjustment subjects the thermostat to the possibility of breakage even though unusual care is exercised. The use of fixed type thermostats is recommended. These thermostats can be obtained with an accurate point of regulation and are not subject to breakage or injury to as great a degree as the adjustable type.

The crystal holder springs do not possess sufficient flexibility and are so short that when a crystal holder is inserted the springs are forced out of position to such an extent that uncertain contact with the crystal holder results. Two of the four screws by means of which the crystal block is secured in the box stripped. These screws are tapped into bakelite studs and the bakelite has insufficient strength to permit the screws to be withdrawn and replaced every time it is found necessary to service the thermostat. In several other places screws are tapped into bakelite and it is felt that an assembly of this nature lacks strength. The entire wiring of the crystal compartment does not present a workmanlike appearance and is of such a nature that broken leads are likely to occur. As stated above, leads did break while attempting to replace the thermostat.

Several other items in the construction of the transmitter are open to criticism. The terminal board is very inaccessible and extreme difficulty is experienced in making the proper connections. The numbers designating the various studs cannot be seen and sufficient space is not available for properly tightening the connections. The clearance between certain items, which are at high potential, and ground is very meager.

Resistor clip no. 63070 does not clear the grounded sheath of cables by more than 1/8" and high voltage stud no. 4 clears grounded metal by about the same distance. The leads to the intermediate frequency antenna loading coil are of small litz wire with sufficient slack in them to reach the grounded shield of the transmitter. Under the influence of vibration or the roll and pitch of a vessel, it is feared that these leads might ground themselves. Several switches are employed where the common connection is carried through a length of flexible stranded wire. This wire in turn is soldered to a thin flexible support of German silver or phosphor bronze. When the switch is operated this flexible support of spring material takes up the slack in the flexible lead. In some of the switches the movement is so great that it is feared that either the lead will break or the spring element will break. It must be stated, however, that no difficulty of this nature occurred during the course of the tests, although some of the flexible strands showed signs of becoming frayed.

The flexible mountings upon which the vacuum tubes rest are of such design that the tubes are free to move sufficiently to bring up against nearby parts. The intermediate amplifier tube clears a condenser by about 1/4" and the slightest degree of motion causes the tube to strike this condenser.

A number of the controls are of the "push-pull" type. When these controls are operated it is necessary to pull them out, move them to the new position and then push them back in. In order to make contact a pin must enter a drilled plate. Difficulty was experienced in properly seating this type of control. Greater ease of operation could be obtained if the end of the pin were rounded off and the holes in the plates were slightly countersunk or chamfered. After considerable use, it was found that these controls operated more smoothly.

No adequate means are provided for securing the transmitter to the deck. The gusset plates in the bottom corners of the transmitter unit are so inaccessible that great difficulty would be experienced in trying to bolt through these plates. The bottom of the transmitter rests flush on the deck so that the external wiring between the transmitter and the filter unit would have to be brought up through a hole in the deck unless the transmitter were mounted on an auxiliary base.

The engraving of the transmitter panel does not present a workmanlike appearance and at temperatures in excess of 40°Centigrade the wax becomes so soft that it has a tendency to run, and if touched it soils the panel.

In a number of instances bakelite is used to insulate potentials in excess of 500 volts which is not in accordance with the requirements of paragraph 2-8 of reference (b). Potentials as high as 2700 volts are carried on the bakelite terminal panel.

The TBG transmiter is equipped with four antenna terminals either one of which may be selected by means of an antenna selector switch. The terminals are numbered to correspond to the numbers of the selector switch but no indication is given, either on the transmitter or in the instruction book to indicate which are loop terminals and which are flat top or vertical antenna terminals. In order to avoid the possibility of connecting to the wrong terminal definite instructions should be given as to which are loop and which are antenna terminals.

The locking devices on the transmitter controls consist of a knurled metal member which projects beneath the dial control. While this device performs its function as a lock the edges of this metal member are sharp enough to cut an operator's hand if he should come in contact with it while turning the control at a rapid rate. Due to the small clearance between the locking device and the control handle when the handle is in the down position, this is very likely to occur.

The spares provided with the equipment agree with the lists furnished with the instruction books and with the lists contained in the spare parts box. It is pointed out, however, that these lists do not agree with the list of spare parts submitted with the contractor's descriptive specifications. It is believed, however, that the spare parts supplied are adequate for the purpose intended.

The preliminary instruction books furnished with the Model TBG equipment while adequate for placing the equipment into commission could be improved by the addition of calibration data. No such information is furnished with the transmitter except the data contained in the type test report, which is separate from the instruction book. Even this data is insufficient to enable an operator who is not familiar with the equipment to proceed with the calibration of the transmitter without difficulty. It would also be helpful if an actual wiring diagram were included. The instruction books as submitted contain only a schematic diagram.

7. DISCUSSION

The principal basis for criticism of the Model TBG equipment lies in the fact that the mechanical construction does not reflect the best of workmanship. The interior wiring does not present an orderly appearance and certain features of design are such that it is feared that uninterrupted operation will not be obtained over a long period of time. The inaccessibility of various parts, such as the terminal panel and the crystal compartment, constitutes a serious drawback. It is believed that accessibility could have been improved through refinement in design and re-arrangement of parts in spite of the congested condition of the transmitter.

The main criticism which may be directed against the Model TBG from the electrical standpoint lies in the fact that the antenna coupling systems, especially on high frequency operation, are such that it is difficult to determine when optimum adjustments have been arrived at.

On the other hand the performance of the transmitter is comparable to that obtained with equipment of larger physical dimensions. The emitted note on all types of operation was of a good character free from excessive lilt and undesirable modulation. In spite of the congested condition of the transmitter resulting from the rather severe requirements of the specifications under which it was constructed, the equipment has functioned for long periods of time under key locked conditions without serious overheating or breakdown.

Table 1

Test per paragraph 10-2-3 of Specifications RE 13A 465A

DETERMINATION OF POWER OUTPUT

Intermediate Frequency performance using Series Capacity of 0.001 mfd

(Submarine Loop Antenna)

Column	1	2	3	4
Freq.kcs	317*	355	375	600
E line	112	112	112	111
I line	14	14	14	17
E plate	2630	2600	2580	2830
"U"	637	1156	1267	2336
"V"	53	50	54	94
"W"	2	3	3	3
"X"	4	4	4	2
"Y"	0	42	51	65
P A I_p	185**	200	200	200
Ant Cap.	470	470	470	583
Ant Res.	2.5	2.5	2.5	4.4
Set I	6.5	7.3	7.5	8.0
Ext I	5.4	5.8	6.0	6.0
Set Watts	105.7	133	140.5	281.6
Ext Watts	73	84	90	158.4

Note: * 317 kcs is the minimum frequency to which transmitter would tune.

** Maximum power which could be obtained without flash overs occurring in set. Corona present when P.A. tubes were drawing 185 m.a.

Table 2

Test as per paragraph 10-2-3 of Specifications RE 13A 465A

DETERMINATION OF POWER OUTPUT

Intermediate Frequency performance using Series Capacity of 0.0005 mfd instead of 0.001 mfd supplied in Transmitter (Loop).

Column	1	2	3	4
Freq. kcs.	347*	355	375	600
E line	112	112.5	112	111
I line	13	15	14	17
E plate	2400	2600	2540	2820
"U"	1020	1156	1267	2336
MO I_p	70	77	74	107
"V"	56	52	54	94
"W"	2	3	3	3
"X"	4	4	4	2
"Y"	0	28	40	60
P A I_p	185**	180**	194**	200
Ant. Cap.	470	470	470	583
Ant. Res.	2.5	2.5	2.5	4.4
Set I	6.0	6.5	6.9	8.0
Ext I	4.5	4.6	5.0	5.4
Set Watts	90	105.5	119	281.6
Ext Watts	50.6	52.9	62.5	128.5

Note: * Minimum frequency to which transmitter would tune.

** Maximum power which could be drawn without flash overs occurring within transmitter.

Table 3

DETERMINATION OF POWER OUTPUT

Submarine Loop Operation; Antenna constants adjusted to agree with manufacturer's interpretation of loop constants.

Column	1	2	3	4
Freq.kcs	300	600	450	450
"U"	331	2336	1723	1723
"V"	42	89	72	75
"W"	3	2	1	1
"X"	3	1	1	1
"Y"	42.8	93	51.5	52
"N"	3	3	3	3
MO I_p	90	100	84	95
PA I_p	200	200	200	200
Ant. Res.	2.66	4.04	4.04	2.83
Ant. Cap.	0.0035 mf	19.2 uh	0.012 mf	0.012mf
Ant I	8.77	7.11	7.9	9.02
Output Watts	205	204	252	230
E_p	2850	2600	2600	2850

Above data obtained under supervision of manufacturer's representative.

Table 4

Test as per paragraph 10-2-3 of **Specifications** RE 13A 465A

DETERMINATION OF POWER OUTPUT

Intermediate Frequency performance when operating into antenna constants simulating the flat top antenna of submarines.

Column	1	2	3	4
Freq.kcs.	300	355	375	600
E line	111	111	111	111
I line	16.5	16.5	16.5	17
E plate	2850	2840	2830	2810
"U"	331	1156	1267	2336
M O I	85	85	88	106
"V" P	34	48	57	93
"W"	3	3	3	33
"X"	4	4	3	2
"Y"	60	87	62	86
P A I_p	200	200	200	200
Ant Cap	583	583	583	583
Ant Res.	3.3	3.3	3.3	3.3
Set I	7.8	8.2	8.3	8.8
Ext I	6.6	6.8	7.0	7.2
Set Watts	200.6	222	227	255
Ext Watts	144	152.5	161.5	171

Table 5

Test as per paragraph 10-2-3 of Specifications RE 13A 465A

DETERMINATION OF POWER OUTPUT

Intermediate Frequency performance when operating into antenna constants simulating the flat top antenna of surface craft.

Column	1	2	3	4
Freq.kcs	300	355	375	600
E line	111	111	111	109
I line	16.5	16.5	16.5	17
E plate	2840	2830	2820	2820
"U"	331	1156	1267	2336
M O I_p	84	85	86	106
"V"	48	36	44	93.5
"W"	2	2	2	3
"X"	4	3	3	1
"Y"	79	67	72	95
P A I_p	200	200	200	200
Ant Cap.	800	800	800	1000
Ant Res.	6.7	6.7	6.7	4.02
Set I	6.6	6.9	7.0	8.95
Ext I	6.0	6.0	6.05	7.8
Set Watts	292	319	328	322
Ext Watts	241.2	241.2	245	244

Table 6

DETERMINATION OF POWER OUTPUT

Comparison of data obtained at NRL with RCA data contained in Routine Test Data Pamphlet of March 29, 1934, sheets 3 and 4.

Flat Top Antenna

Column	1	2	3	4	5	6
Data at:	RCA	NRL	RCA	NRL	RCA	NRL
Freq.kcs.	300	300	500	500	600	600
Line E	115	110	118	112	117	111
Line I	15	16.5	15	16.5	15.4	17
Input Watts	1730	1815	1770	1850	1810	1885
M O I_p	83	85	90	92	100	106
HF-IF	IF	IF	IF	IF	IF	IF
P A I_p	200	200	200	200	200	200
E_p	2700	2840	2700	2810	2700	2810
P A Input	540	568	540	562	540	562
"U"	324.5	331	2022	2022	2336	2336
"V"	31	32	73	82	82	95
"W"	1	1	1	1	1	1
"X"	2	4	1	1	1	1
"Y"	19	88	35	42	67	69
Ant.Res.	2.2	2.09	2.2	2.09	2.9	3.07
Ant. I	9.3		9.28		8.3	
Set I		9.7		10.2		9.5
Ext I		8.5		8965		7.7
Ant. Cap.	860	875	570	583	587	583
Output Watts	203		200.7		205	
Set Watts		207		218.4		277
Ext Watts		151.7		157		182
		*159		*164.3		*188

Note: *Allowing 0.1 ohm for losses in dummy antenna capacitor.

Table 7

Test as per paragraph 10-2-3 of Specifications RE 13A 465A

DETERMINATION OF POWER OUTPUT

HIGH FREQUENCY PERFORMANCE USING CRYSTAL CONTROL

Column	1	2	3	4	5	6
Freq.kcs	2067.5	2117.5	2436	3035	3101.25	4135
Line I	15	14	14	14	14	14
Line E	110	112	112	112	112	113
E_p	2300	2310	22310	2180	2180	2020
C	CO	CO	CO	CO	CO	CO
Cl	1	1	1	1	1	2
D	487	774	1906	3264	3370	4169
Cry RFI	25	25	30	20	44	48
Cry I_p	95	60	52	40	55	60
"E"	1	1	1	1	1	1
"F"	558	642	1120	1650	1687	2136
1st IPA I_p	45	40	46	35	46	44
"G"	568	656	1122	1650	1695	1166
2nd IPA I_p	47	44	45	45	43	36
"H"	1	1	1	11	1	2
"I"	129	409	842	1692	1755	605
PA I_p	200	200	200	200	200	200
"J"	1108	1118	1100	0	0	0
"K"	0	0	0	0	0	0
"L"	23	20	3	0	0	0
"M"	HF	HF	HF	HF	HF	HF
"N"	3	3	3	3	3	3
Ant. I	2.5	3.1	-	-	-	-
Ant. Res.	Lamp	Lamp	Lamp	Lamp	Lamp	Lamp
Photo Cell	98	100	135	109	100	100
Watts Output	245	248	283	260	248	248

Note: The lamp used for a load resistance was approximately 105 ohms D.C.

Table 8

Test as per paragraph 10-2-3 of Specifications RE 13A 465A

DETERMINATION OF POWER OUTPUT

HIGH FREQUENCY PERFORMANCE USING CRYSTAL CONTROL

Column	1	2	3	4
Cry Pos.	6	6	1	5
Cry Freq	4135	4135	4517	3101.25
Line I	14	18	20	18
Line E	112	110	109	113
Plate E	2300	2750	2775	2720
"C"	CO	CO	CO	CO
"C1"	2	2	2	2
"D"	4155	4155	4465	2155
Cry RFI	55	42	71	54
Cry I_p	50	61	96	108
"E"	2	2	2	2
"F"	2353	2353	2433	2036
1st IPA I_p	36	70	80	75
"G"	2310	2772	2822	2616
2nd IPA I_p	50	60	93	83
"H"	2	2	2	2
"I"	2100	2753	2822	2402
PA I_p	200	200	200	200
"J"	1488	2377	2460	2307
"K"	2561	2628	2726	2270
"L"	0	0	0	0
"M"	HF	HF	HF	HF
"N"	3	3	3	3
Ant Res.	Lamp	Lamp	Lamp	Lamp
Photo Cell	134	70	56	165
Watts Output	282	215	198	312
Output Freq.	8270	16540	18068	12405

Note on Column 4: In order to obtain output at 12405 kcs, it was necessary to short circuit the antenna ammeter to ground directly at the ammeter. When the antenna was grounded through the keying relay satisfactory operation could not be secured at 12405 kcs.

Table 9

Test as per paragraph 2-16 of Specifications RE 13A 465A

EFFECT OF SHORT CIRCUITING AND OPEN CIRCUITING ANTENNA

Freq. kilo-cycles.	I_p Antenna Normal	I_p Antenna Shorted	I_p Antenna Open
450	200 ma	200 ma	190 ma
2000	200	160	400
3000	200	110	450
18000	200	170	120

Table 10

Test as per paragraph 3-24-4 of Specifications RE 13A 465 A

VARIATION OF LINE VOLTAGE

	Line Current	Line Volts	Plate Volts	Filament Volts	Frequency kcs	Frequency Change
	14.5	115	2620	10.0	500.183	
+ 10%	14.5	126.5	2670	11.3	500.184	+ 1 cycle
− 10%	14.8	103.5	2510	9.2	500.155	−29 cycles

(No controls adjusted during above test)

	Line Current	Line Volts	Plate Volts	Filament Volts	Frequency kcs	Frequency Change
	14.5	115	-	10.0	500.085	
+ 37%	12.0	157.5	2600	11.1	500.062	−23 cycles
− 23%	18.5	88.5	2650	10.0	500.067	−18 cycles

(Plate and filament controls adjusted during above test)

POWER REQUIRED FROM SUPPLY LINES

Test as per paragraph 6-5 of Specifications RE 13A 465A

	Volts	Amps.	Watts
Starting	110	43	4730
Full power, key locked	110	18	1980

Specifications required that not more than 3 kw be drawn from supply lines for full power key locked operation.

Table 11

Test as per paragraph 3-26 of Specifications RE 13A 465A

CONTROL OF POWER OUTPUT

Frequency - 300 kcs	Watts Output	% of Power
Generator field rheostat set at maximum and "Tune-Operate" Switch on "Operate":	224	100%
Generator field rheostat set at minimum and "Tune-Operate" Switch on "Operate":	104	46%
Generator field rheostat set at maximum and "Tune-Operate" Switch on "Tune":	50	22%
Generator field rheostat set at minimum and "Tune-Operate" Switch on "Tune":	39	18%

From the above data it will be seen that two controls must be manipulated to obtain the necessary control of power output and that it is impossible to obtain power output in the range of 46% to 22% of full power.

Table 12

Test as per paragraph 3-41 of Specifications RE 13A 465A

COMPARISON OF CW AND MCW OPERATION

Column	1	2	3	4
Freq kcs	600	600	300	300
Type of Signal	CW	MCW	CW	MCW
Line I	15	15	15	15
Line E	112	112	112	112
MO I_p	92	72	82	66
PA I_p	200	180	199	171
E_p	2560	2560	2580	2580
Ant I	5.4	4.4	6.6	5.2
Ant Res	4	4	4	4
Ant Cap	583	583	583	583
Set Watts	117	77	174	78

Difference in output between Column 1 and 2 - 37%
" " " " " 3 and 4 - 35.5%

Permitted by specifications - 40%

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Percentage Modulation

Negative peaks - 76 %
Positive peaks - 25 %

Required by specifications - 50 %

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Frequency of Modulation - 850 cycles

Table 13

Test as per paragraph 3-42 of Specifications RE 13A 465A

Accuracy of Reset

Frequency - 500 kcs.

Operator No.1	Deviation from Avg.	Operator No.2	Deviation from Avg.
500.050 kcs	117 cycles	500.000	82 cycles
087	80	183	101
450	282	183	101
250	83	033	49
000	167	092	10

Avg. Freq. - 500.167 kcs   Avg.Freq. - 500.082 kcs

Avg.Deviation - 146 cycles   68 cycles

Table 14

Test as per paragraph 3-44 of Specifications RE 13A 465A

Variation of resonant frequency of master oscillator per division of marking - Intermediate frequency performance.

Frequency	Kcs per Div.	% per Div.
300 kcs	0.066	0.022
375	0.250	0.067
500	0.333	0.066
600	0.310	0.052

Test for lost motion and back-lash

Frequency	Divisions back-lash	Kc back-lash
300 kcs	2	0.132
375	1	0.250
500	8.1	2.70
600	8.4	2.60

Table 15

Test as per paragraph 6-21 of Specifications RE 13A 465A

Voltage Regulation of Motor Generator

No load: 2500 volts
Full load: 2300 volts

Regulation, no load to full load - 8%
Permitted by specifications - 5%

Table 16

FREQUENCY CHECK OF QUARTZ CRYSTALS SUPPLIED WITH TBG EQUIPMENT

CRYSTAL FREQUENCY INDICATOR

				(Spare Crystals)		
Assigned Frequency	Measured Holder No.	Frequency kcs	Percent Diff.	Measured Holder No.	Frequency kcs	Percent Diff.
355	426	355.03	0.0084	354	355.028	0.0079
375	380	375.00	0.0	404	375.008	0.0021
434	373	434.05	0.0115	394	433.986	0.0032
500	414	500.045	0.009	436	500.005	0.001
544	409	544.018	0.0033	439	543.988	0.0022

Percentage difference permitted by specifications - 0.025%

TRANSMITTER CRYSTALS

Holder No.	Assigned Freq.	Measured Freq.	% Deviation
88	2067.5	2067.45	0.0024
15	2117.5	2117.20	0.014
89	2436.0	2436.04	0.0016
24	3035.0	3034.60	0.013
95	3101.25	3100.97	0.009
59	4135.0	4135.98	0.023
75	2067.5	2067.95	0.021
68	2117.5	2117.39	0.005
39	2436.0	2436.58	0.023
93	3035.0	3034.79	0.0059
106	3101.25	3101.22	0.001
41	4135.0	4134.69	0.0075

Percentage deviation permitted by specifications - 0.025%

Table 17

Determination of temperature coefficient of 500 kc crystal in TBG crystal frequency indicator.

Time	Temperature Degrees C.	Beat Note
1030	24.0	627 cycles
40	23.0	630
50	20.8	633
1100	18.0	631
15	16.0	615
25	14.0	606
35	13.0	591
45	12.0	578
55	11.0	564
1230	9.2	533
1300	8.5	512
15	8.0	500 low
25	15.0	500
35	41.0	534
45	41.0	626
1410	37.0	718
25	55.0	762
40	52.0	841
55	48.0	880
1515	60.0	949
45	55.0	1000
1600	53.0	1010 high

Maximum change in temperature - 52 degrees
Maximum change in frequency - 510 cycles or 0.102%
Change approximately 10 cycles per degree Centigrade.

Table 18

Test as per paragraph 10-3-8 of Specifications RE 13A 465A

Two hour locked key run at 500 kilocycles

Time	Frequency	Ambient Temperature	Line Volts	Antenna Current	Pr Amp Ip
0955	500.158	21.0	105	6.6	200
1005	500.053	22.0	122	6.6	200
1015	500.003	21.9	120	6.6	200
1025	499.971	22.4	111	6.5	200
1035	499.955	22.5	100	6.5	200
1045	499.935	22.0	113	6.5	200
1055	499.923	22.3	112	6.5	200
1105	499.933	22.3	113	6.5	200
1115	499.980	22.6	97	6.5	200
1125	499.983	23.0	115	6.6	200
1135	499.979	23.6	114	6.5	200
1145	499.988	23.0	125	6.6	200
1155	499.985	22.6	113	6.6	200

Greatest difference between 1015 and 1155 - 80 cycles
or 0.016%

Maximum difference during two hour test - 235 cycles
or 0.047%

Table 19

Test of frequency stability of TBG transmitter, using self-oscillating master, over two hour locked key period; line voltage varied between limits of 100 volts and 125 volts.

Frequency - 2000 kcs.

Time	Line Volts	Plate Volts	P.A. Plate Current	Ambient Temp C°	Freq. kcs
0815	117	2000	210	22.5	2001.000
25	116	2000	209	22.9	2000.680
35	114	2000	207	23.1	2000.390
45	114	2000	203	23.7	2000.300
55	114	2000	202	23.0	2000.085
0905	111	1950	199	23.0	2000.007
15	110	1940	199	24.0	1999.960
25	125	2050	211	23.1	1999.740
35	100	1860	185	24.8	1999.735
45	100	1860	186	25.0	1999.715
55	125	2060	211	25.3	1999.580
1005	109	1950	198	25.6	1999.521
15	110	1950	198	26.0	1999.482

Maximum change between 0835 and 1015 - 908 cycles
or 0.045%

Change permitted by specifications - 0.05%

Note: A remarkable feature of the master circuit was the fact that a voltage variation of 100 to 125 volts caused only a negligible frequency shift. The filament voltage was not corrected to compensate for this variation and changed from 8 volts to 12 volts. Likewise, only a few cycles shift resulted from changing from "Tune" to "Operate".

Table 20

Test of frequency stability of TBG transmitter, operating crystal controlled, over two hour key locked period. Line voltage varied between limits of 90 volts to 127 volts.

Crystal frequency - 3326 kcs
Output frequency - 3326 kcs

Time	Line Volts	Line Amps	Plate Volts	PA Plate Current	Ambient Temp C°	Crys. Cab.	Beat Note
0900	112	15.5	2490	200	22	49.0°	821
10	111	15.5	2470	198	22	49.0	819
20	120	15.5	2520	200	22.1	49.0	814
30	119	15.2	2510	199	22.2	49.1	813
40	102	15.6	2400	186	22.2	49.1	821
50	113	15.5	2460	194	22.9	49.1	816
1000	113	15.5	2460	192	22.3	49.0	817
10	113	15.2	2460	192	23.0	49.0	813
20	113	15.2	2460	192	23.0	49.0	812
30	127	14.8	2540	202	21.2	49.0	806 low
40	127	14.8	2540	202	20.0	49.0	809
50	90	16.0	2340	181	19.0	49.0	827 high
1100	115	15.0	2460	196	20.0	49.0	815

Maximum change - 21 cycles or 0.00063%

Table 21

	Specification Requirements	Actual Dimensions of Frame	Actual Overall Dimensions
TRANSMITTER			
Height	60"	60"	61-1/2"
Width	32"	31-1/2"	32-1/4"
Depth	14"	12-1/2"	14-1/2"
MOTOR GENERATOR			
Length	61"		44"
Height	15"		15-1/4"
Width	25"		15"
STARTER			
Height			22-1/2"
Width			15-1/4"
Depth			12-1/4"
FILTER UNIT			
Height			18-3/8"
Width			12-1/4"
Depth			6-3/4"
CRYSTAL FREQUENCY INDICATOR			
Height	12"	12"	12"
Width	8"	8"	8"
Depth	8-1/2"	6-1/8"	7-7/8"

Table 22

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

500 kilocycles
(Self-excited M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0830	25.6	48.5	500.600	117
40	24.8	49.0	.485	118
50	25.0	49.0	.463	117
0900	25.2	49.0	.470	117
10	25.0	49.0	.468	117
20	25.0	49.0	.467	117
30	25.2	49.0	.474	117
40	25.0	49.0	.483	116
	Key open 10 minutes while temperature was changed.			
0950	9.8	49.0	500.572	118
1000	9.8	49.0	.455	117
10	9.9	49.0	.460	117
20	10.0	49.0	.455	116
30	10.0	49.0	.452	116
40	9.8	48.8	.455	116
50	10.0	48.7	.452	117
1100	10.0	48.7	.444	117
	Key open 10 minutes while temperature was changed.			
1110	5.5	48.7	500.592	117
20	5.2	48.7	.490	117
30	5.0	48.6	.492	117
40	4.8	48.5	.502	117
50	4.8	48.5	.500	117
1200	5.0	48.5	.500	117
10	5.0	48.5	.498	118
20	5.0	48.5	.494	118
	Key open 10 minutes while temperature was changed.			
1230	0.0	48.5	500.680	117
40	0.0	48.5	.585	117
50	-0.2	48.5	.580	116
1300	0.0	48.5	.580	118
10	0.0	48.5	.578	117
20	0.0	48.5	.575	117
30	0.0	48.5	.572	116
40	0.0	48.5	.568	114
	Key open 10 minutes while temperature was changed.			
1350	24.8	48.5	500.584	114
1400	25.0	48.5	.478	110
10	25.0	48.5	.480	110
20	25.2	48.5	.456	111
30	24.8	48.7	.436	111
40	25.0	48.7	.412	110
50	25.2	48.7	.394	111
1500	25.0	49.0	.420	116

Table 22 (cont'd)

Difference between readings taken at 0940 and 1100
Ambient temperature - 15.0°C
Difference in frequency - 39 cycles
Difference per degree Centigrade - 2.6 cycles, .0005%

Difference between readings taken at 1100 and 1220
Ambient temperature - 5.0°C
Difference in frequency - 50 cycles
Difference per degree Centigrade - 10 cycles, .002%

Difference between readings taken at 1220 and 1340
Ambient temperature - 5.0°C
Difference in frequency - 74 cycles
Difference per degree Centigrade - 14.8 cycles, .0029%

Difference between readings taken at 1340 and 1500
Ambient temperature - 25.0°C
Difference in frequency - 148 cycles
Difference per degree Centigrade - 5.9 cycles, .0012%

Difference between readings taken at 0940 and 1500
Ambient temperature - none
Difference in frequency - 63 cycles, .0126%

Table 23

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

500 kilocycles
(Self-excited M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0830	24.5	47.7	500.960	116
40	25.0	46.7	.770	115
50	25.0	46.0	.710	116
0900	25.2	46.6	.668	115
10	25.0	47.8	.654	115
20	25.0	48.8	.648	114
30	25.0	49.0	.645	114
40	25.0	49.0	.646	115
Key open 10 minutes while temperature was changed.				
0950	30.0	49.0	500.640	114
1000	30.0	49.0	.560	113
10	30.0	49.0	.575	114
20	30.2	49.0	.565	114
30	30.0	49.0	.590	114
40	30.2	49.0	.580	116
50	30.0	49.0	.594	116
1100	30.0	49.0	.580	116
Key open 10 minutes while temperature was changed.				
1110	35.0	49.0	500.572	116
20	34.8	49.0	.500	116
30	35.1	49.0	.520	116
40	35.0	49.0	.567	116
50	35.0	49.0	.582	116
1200	35.0	49.0	.588	116
10	35.0	49.2	.610	116
20	35.0	49.2	.626	115
Key open 10 minutes while temperature was changed.				
1230	43.0	49.2	500.562	116
40	43.2	49.2	.550	116
50	43.2	49.2	.620	116
1300	43.0	49.2	.720	117
10	43.2	49.3	.800	115
20	43.0	49.3	.830	116
30	43.0	49.4	.875	116
40	43.0	49.4	.877	115
Key open 10 minutes while temperature was changed.				
1350	24.9	49.4	500.865	118
1400	25.0	49.3	.738	117
10	25.0	49.2	.662	116
20	24.8	49.2	.593	117
30	25.0	49.0	.540	117
40	25.0	49.0	.498	116
50	25.0	49.0	.474	116
1500	25.0	49.0	.483	116

Table 23 (cont'd)

Difference between readings taken at 0940 and 1100
   Ambient temperature - 5.0°C
   Difference in frequency - 66 cycles
   Difference per degree Centigrade - 13.2 cycles, .0026%

Difference between readings taken at 1100 and 1220
   Ambient temperature - 5.0°C
   Difference in frequency - 46 cycles
   Difference per degree Centigrade - 9.2 cycles, .0018%

Difference between readings taken at 1220 and 1340
   Ambient temperature - 8.0°C
   Difference in frequency - 251 cycles
   Difference per degree Centigrade - 31.4 cycles, .0062%

Difference between readings taken at 1340 and 1500
   Ambient temperature - 18.0°C
   Difference in frequency - 394 cycles
   Difference per degree Centigrade - 21.8 cycles, .0044%

Difference between readings taken at 0940 and 1500
   Ambient temperature - none
   Difference in frequency - 163 cycles, .032%

Table 24

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

2000 kilocycles
(Self-excited M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0810	25.8	49.0	2000.785	117
20	25.0	49.0	.433	118
30	25.0	49.0	.286	118
40	25.0	49.0	.188	118
50	25.0	49.0	.118	118
0900	25.0	49.0	.068	118
10	25.0	49.0	.078	118
20	25.0	49.0	.046	118
Key open 10 minutes while temperature was changed.				
0930	10.0	49.0	2000.975	118
40	10.0	49.0	.722	117
50	10.0	49.0	.615	116
1000	10.2	49.0	.800	116
10	9.8	48.8	.785	116
20	10.0	48.8	.948	115
30	10.0	48.8	2001.138	115
40	10.0	48.8	.188	115
Key open 10 minutes while temperature was changed.				
1050	5.0	48.6	2001.803	116
1100	5.0	48.6	.633	115
10	5.0	48.7	.678	116
20	5.0	48.7	.742	115
30	5.0	48.6	.923	116
40	4.8	48.5	2002.043	116
50	5.0	48.5	.028	116
1200	5.0	48.5	.043	116
Key open 10 minutes while temperature was changed.				
1210	0.0	48.5	2002.378	117
20	-0.2	48.5	.194	116
30	0.0	48.5	.202	116
40	0.0	48.5	.338	116
50	0.0	48.5	.433	117
1300	0.0	48.5	.463	116
10	0.0	48.5	.578	116
20	0.0	48.5	.590	116
Key open 10 minutes while temperature was changed.				
1330	25.2	48.5	2002.188	115
40	25.0	48.5	2001.364	115
50	25.0	48.5	2000.878	114
1400	25.2	48.5	.505	115
10	25.0	48.6	.250	115
20	25.0	48.7	.125	115
30	25.0	48.8	.020	115
40	25.0	49.0	1999.965	115

Table 24 (cont'd)

Difference between readings taken at 0920 and 1040
Ambient temperature - 15.0°C
Difference in frequency - 1142 cycles
Difference per degree Centigrade - 76 cycles, .0038%

Difference between readings taken at 1040 and 1200
Ambient temperature - 5.0°C
Difference in frequency - 855 cycles
Difference per degree Centigrade - 171 cycles, .0085%

Difference between readings taken at 1200 and 1320
Ambient temperature - 5.0°C
Difference in frequency - 547 cycles
Difference per degree Centigrade - 109 cycles, .0054%

Difference between readings taken at 1320 and 1440
Ambient temperature - 25.0°C
Difference in frequency - 2625 cycles
Difference per degree Centigrade - 106 cycles, .0053%

Difference between readings taken at 0920 and 1440
Ambient temperature - none
Difference in frequency - 81 cycles, .004%

Table 25

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

2000 kilocycles
(Self-excited M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0820	24.6	49.0	2001.828	112
30	25.0	49.0	.308	112
40	25.0	49.0	.055	112
50	25.2	49.0	2000.900	111
0900	25.0	49.0	.892	115
10	25.0	49.0	.875	114
20	25.0	49.0	.860	114
30	25.0	49.0	.840	114
Key open 10 minutes while temperature was changed.				
0940	29.8	49.0	2001.113	114
50	30.0	49.0	2000.632	112
1000	30.0	49.0	.440	112
10	30.0	49.0	.320	112
20	30.0	49.0	.190	112
30	30.2	49.0	.098	111
40	28.8	49.0	.178	110
50	30.0	49.0	.226	113
Key open 10 minutes while temperature was changed.				
1100	34.8	49.0	2000.466	113
10	35.0	49.0	.066	113
20	35.0	49.2	1999.926	113
30	35.0	49.2	.958	113
40	35.0	49.2	.926	113
50	35.0	49.2	.853	113
1200	35.0	49.2	.893	114
10	35.0	49.3	.888	114
Key open 10 minutes while temperature was changed.				
1220	43.0	49.3	2000.178	114
30	42.8	49.3	1999.683	114
40	43.0	49.4	.440	113
50	43.0	49.4	.325	113
1300	43.2	49.4	.218	113
10	43.0	49.4	.268	114
20	43.0	49.4	.215	113
30	43.0	49.5	.180	113
Key open 10 minutes while temperature was changed.				
1340	25.0	49.4	2000.328	114
50	25.0	49.4	.608	115
1400	25.0	49.4	.860	115
10	25.0	49.3	.835	114
20	25.0	49.2	.736	114
30	25.0	49.2	.738	114
40	25.0	49.0	.718	113
50	25.0	49.0	.625	113

Table 25 (cont'd)

Difference between readings taken at 0930 and 1050
Ambient temperature - 5.0°C
Difference in frequency - 614 cycles
Difference per degree Centigrade - 126.8 cycles, .0061%

Difference between readings taken at 1050 and 1210
Ambient temperature - 5.0°C
Difference in frequency - 338 cycles
Difference per degree Centigrade - 67.6 cycles, .0033%

Difference between readings taken at 1210 and 1330
Ambient temperature - 8.0°C
Difference in frequency - 708 cycles
Difference per degree Centigrade - 88.5 cycles, .0044%

Difference between readings taken at 1330 and 1450
Ambient temperature - 18.0°C
Difference in frequency - 1445 cycles
Difference per degree Centigrade - 80.3 cycles, .004%

Difference between readings taken at 0930 and 1450
Ambient temperature - none
Difference in frequency - 215 cycles, .01%

Table 26

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

3078.75 kilocycles
(Crystal controlled M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0820	24.8	49.0	3078.750	116
30	25.0	49.0	.700	115
40	24.8	49.0	.695	115
50	25.0	48.8	.695	114
0900	24.8	49.0	.692	114
10	24.8	48.8	.695	114
20	25.0	49.0	.692	113
30	25.0	49.0	.690	117
Key open 10 minutes while temperature was changed.				
0940	9.8	49.0	3078.750	116
50	10.0	48.8	.690	115
1000	10.0	48.8	.687	114
10	10.5	48.8	.690	114
20	9.8	48.8	.688	114
30	10.0	48.7	.688	114
40	10.0	48.7	.689	114
50	10.0	48.7	.685	114
Key open 10 minutes while temperature was changed.				
1100	4.8	48.7	3078.750	114
10	5.0	48.7	.688	115
20	5.0	48.7	.690	115
30	4.8	48.7	.691	114
40	5.0	48.6	.691	115
50	5.0	48.5	.692	114
1200	5.0	48.5	.690	114
10	5.8	48.5	.690	114
Key open 10 minutes while temperature was changed.				
1220	0.4	48.5	3078.766	114
30	0.0	48.5	.695	114
40	-0.2	48.5	.695	114
50	0.0	48.5	.695	114
1300	0.0	48.4	.695	113
10	0.0	48.5	.690	114
20	0.0	48.4	.694	113
30	0.0	48.5	.695	113
Key open 10 minutes while temperature was changed.				
1340	25.0	48.5	3078.692	116
50	25.0	48.5	.700	117
1400	25.0	48.5	.698	115
10	25.2	48.5	.697	114
20	25.0	48.6	.690	115
30	24.8	48.8	.688	115
40	25.0	48.8	.687	115
50	25.0	49.0	.690	115

Table 26 (cont'd)

Difference between readings taken at 0930 and 1050
   Ambient temperature - 15.0°C
   Difference in frequency - 5 cycles
   Difference per degree Centigrade - 0.33 cycles, .00001%

Difference between readings taken at 1050 and 1210
   Ambient temperature - 5.0°C
   Difference in frequency - 5 cycles
   Difference per degree Centigrade - 1 cycle, .000033%

Difference between readings taken at 1210 and 1330
   Ambient temperature - 5.0°C
   Difference in frequency - 5 cycles
   Difference per degree Centigrade - 1 cycle, .000033%

Difference between readings taken at 1330 and 1450
   Ambient temperature - 25.0°C
   Difference in frequency - 5 cycles
   Difference per degree Centigrade - 0.2 cycles, .0000065%

Difference between readings taken at 0930 and 1450
   Ambient temperature - none
   Difference in frequency - none

Table 27

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

3078.75 kilocycles
(Crystal controlled M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0810	25.0	48.7	3078.750	117
20	25.0	48.8	.697	118
30	25.2	48.8	.683	117
40	25.0	49.0	.684	117
50	24.8	49.0	.681	116
0900	25.0	49.0	.685	115
10	25.0	49.0	.683	115
20	25.0	49.0	.681	114
Key open 10 minutes while temperature was changed.				
0930	29.8	49.0	3078.750	115
40	30.0	49.0	.683	115
50	30.0	49.0	.684	115
1000	30.0	49.0	.683	115
10	30.0	49.0	.680	115
20	30.0	49.0	.678	114
30	30.0	49.0	.683	114
40	30.0	49.0	.675	115
Key open 10 minutes while temperature was changed.				
1050	35.0	49.2	3078.736	115
1100	35.2	49.2	.682	115
10	35.0	49.2	.676	115
20	35.0	49.2	.678	115
30	35.2	49.2	.680	115
40	35.0	49.2	.680	115
50	35.0	49.2	.676	115
1200	35.0	49.2	.678	115
Key open 10 minutes while temperature was changed.				
1210	43.0	49.4	3078.726	115
20	43.2	49.3	.681	115
30	43.2	49.3	.671	114
40	43.2	49.5	.671	114
50	43.0	49.4	.673	114
1300	43.2	49.4	.676	114
10	43.0	49.5	.666	114
20	43.0	49.5	.671	115
Key open 10 minutes while temperature was changed.				
1320	25.0	49.5	3078.726	115
30	25.0	49.3	.670	115
40	25.0	49.2	.663	116
50	25.0	49.3	.665	115
1400	25.2	49.3	.666	115
10	24.8	49.2	.666	116
20	25.2	49.0	.673	116
30	25.0	49.2	.669	115

Table 27 (cont'd)

Difference between readings taken at 0920 and 1040
Ambient temperature - 5.0°C
Difference in frequency - 6 cycles
Difference per degree Centigrade - 1.2 cycles, .000039%

Difference between readings taken at 1040 and 1200
Ambient temperature - 5.0°C
Difference in frequency - 3 cycles
Difference per degree Centigrade - 0.6 cycles, .000019%

Difference between readings taken at 1200 and 1320
Ambient temperature - 8.0°C
Difference in frequency - 7 cycles
Difference per degree Centigrade - 0.87 cycles, .000028%

Difference between readings taken at 1320 and 1440
Ambient temperature - 18.0°C
Difference in frequency - 2 cycles
Difference per degree Centigrade - 0.11 cycles, .0000035%

Difference between readings taken at 0920 and 1430
Ambient temperature - none
Difference in frequency - 12 cycles, .00039%

Table 28

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

3326.25 kilocycles
(Crystal controlled M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0810	25.0	49.0	3326.250	118
20	25.0	49.0	.228	119
30	25.2	49.0	.224	119
40	24.8	49.0	.224	118
50	25.0	49.0	.220	118
0900	25.0	49.0	.217	118
10	25.0	49.0	.214	118
20	25.0	49.0	.216	118
Key open 10 minutes while temperature was changed.				
0930	10.0	49.0	3326.674	119
40	9.6	49.0	.216	119
50	10.0	49.0	.213	119
1000	10.0	48.8	.216	119
10	10.0	48.8	.219	118
20	10.0	48.7	.224	118
30	10.0	48.8	.222	117
40	10.0	48.7	.225	117
Key open 10 minutes while temperature was changed.				
1050	5.0	48.6	3326.258	117
1100	5.0	48.5	.229	117
10	5.2	48.5	.226	118
20	5.0	48.5	.229	118
30	5.0	48.6	.227	118
40	4.8	48.6	.225	117
50	5.0	48.6	.226	118
1200	5.0	48.6	.229	118
Key open 10 minutes while temperature was changed.				
1210	0.0	48.5	3326.264	117
20	0.0	48.5	.230	118
30	0.0	48.5	.229	118
40	0.0	48.5	.229	118
50	0.0	48.5	.228	118
1300	0.0	48.5	.228	117
10	0.0	48.5	.230	117
20	0.0	48.5	.231	116
Key open 10 minutes while temperature was changed.				
1330	24.8	48.5	3326.264	115
40	25.2	48.5	.236	116
50	24.8	48.5	.234	115
1400	25.0	48.7	.234	116
10	25.2	48.6	.234	116
20	25.0	48.8	.224	116
30	25.0	48.8	.227	116
40	25.0	49.0	.230	116

Table 28 (cont'd)

Difference between readings taken at 0920 and 1040
    Ambient temperature - 15.0°C
    Difference in frequency - 9 cycles
    Difference per degree Centigrade - 0.6 cycles, .000018%

Difference between readings taken at 1040 and 1200
    Ambient temperature - 5.0°C
    Difference in frequency - 5 cycles
    Difference per degree Centigrade - 1 cycle, .00003%

Difference between readings taken at 1200 and 1320
    Ambient temperature - 5.0°C
    Difference in frequency - 2 cycles.
    Difference per degree Centigrade - 0.4 cycles, .000012%

Difference between readings taken at 1320 and 1440
    Ambient temperature - 25.0°C
    Difference in frequency - 1 cycle
    Difference per degree Centigrade - 0.04 cycles, .0000012%

Difference between readings taken at 0920 and 1440
    Ambient temperature - none
    Difference in frequency - 14 cycles, .00042%

Table 29

TBG Transmitter Serial No. 4

EFFECT OF CHANGE IN AMBIENT TEMPERATURE

3326.25 kilocycles
(Crystal controlled M.O.)

Time	Ambient °C	Crystal °C	Actual Frequency	Line Volts
0820	25.0	48.7	3326.250	118
30	25.0	49.0	.215	118
40	25.2	49.0	.217	118
50	25.0	49.0	.221	118
0900	25.0	49.0	.215	118
10	25.2	49.0	.212	117
20	25.0	49.0	.211	118
30	25.0	49.0	.209	116
	Key open 10 minutes while temperature was changed.			
0940	29.8	49.0	3326.237	117
50	30.2	49.0	.213	116
1000	30.2	49.0	.215	117
10	30.0	49.0	.219	116
20	30.0	49.0	.213	116
30	30.0	49.1	.209	115
40	30.0	49.0	.215	114
50	30.0	49.0	.211	113
	Key open 10 minutes while temperature was changed.			
1100	34.8	49.0	3326.245	113
10	35.0	49.2	.215	114
20	35.0	49.2	.215	112
30	35.0	49.0	.217	112
40	35.0	49.0	.215	114
50	35.0	49.2	.217	114
1200	35.0	49.2	.217	115
10	35.0	49.2	.213	113
	Key open 10 minutes while temperature was changed.			
1220	42.8	49.2	3326.255	113
30	43.0	49.3	.226	113
40	43.2	49.3	.227	113
50	43.0	49.4	.225	112
1300	43.0	49.4	.225	112
10	43.0	49.4	.220	113
20	42.8	49.4	.224	113
30	43.0	49.5	.225	113
	Key open 10 minutes while temperature was changed.			
1340	25.0	49.4	3326.235	113
50	25.0	49.3	.195	114
1400	24.8	49.3	.190	115
10	25.0	49.2	.197	115
20	24.8	49.2	.192	114
30	25.0	49.2	.194	114
40	25.0	49.0	.198	114
50	25.0	49.0	.199	115

Table 29 (cont'd)

Difference between readings taken at 0930 and 1050
  Ambient temperature - 5.0°C
  Difference in frequency - 2 cycles
  Difference per degree Centigrade - 0.4 cycles, .000012%

Difference between readings taken at 1050 and 1210
  Ambient temperature - 5.0°C
  Difference in frequency - 2 cycles
  Difference per degree Centigrade - 0.4 cycles, .000012%

Difference between readings taken at 1210 and 1330
  Ambient temperature - 8.0°C
  Difference in frequency - 12 cycles
  Difference per degree Centigrade - 1.5 cycles, .000045%

Difference between readings taken at 1330 and 1450
  Ambient temperature - 18.0°C
  Difference in frequency - 26 cycles
  Difference per degree Centigrade - 1.4 cycles, .000042%

Difference between readings taken at 0930 and 1450
  Ambient temperature - none
  Difference in frequency - 10 cycles, .0003%