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SUBJECT

The Modification and Test of the Model CXFR Jamming

Transmitter

FR-2291

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SEARCH RADAR SECTION

Radio Division, U.S. Naval Research Laboratory

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NRL Report R-2291
Problem S623T-C

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Navy Department

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The Modification and Test

of the Model CXFR

Jamming Transmitter

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Naval Research Laboratory

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1. AUTHORIZATION FOR TEST.

1-1. This problem was authorized by the Bureau of Ships letter of reference (a). Additional references pertinent to this problem are listed as references (b) through (d).

Reference (a) BuShips letter C-S67-5(920-Df), C-920-5810 to NRL dated 15 February 1944.
(b) NRL letter C-S67-5 to BuShips dated 17 February 1944 Assigning Problem S623T-C.
(c) NRL Report R-2232, dated 18 February 1944 on "Radar Cross Section of Ship Targets, II".
(d) NRL letter C-S67-5/RCM(375:LWB) to BuShips dated 27 April 1944 on "Radar Countermeasures - Ambiguity in the Measurement of Carrier Frequency on the AN/APR-1 Receiver".

2. OBJECT OF TESTS.

2-1. The object of the electrical tests was to determine what changes would be required to make the equipment perform satisfactorily, and it was requested in the letter of reference (a) that this be done "without making any substantial changes that would require other components or a major increase in the work of production", since the equipments were in an advanced stage of production at the time the problem was assigned, and shipment of completed equipments to operational areas was desired by 28 February.

2-2. The object of the operational tests was to determine, as quantitatively as possible, the effectiveness of the equipment against representative types of radar equipment, after necessary changes had been incorporated in the CXFR.

3. ABSTRACT.

The first CXFR unit received at this laboratory was operationally tested on 11 February 1944 aboard the U.S.S. Quincy (CA), using radar equipment at the Naval Research Laboratory Chesapeake Bay Annex. Poor performance on these tests resulted in the further tests requested by the letter of reference (a), and this CXFR unit was set up for these tests in the laboratory. Subsequently, three more CXFR equipments were received at the laboratory, the last two containing modifications which had been incorporated as a result of the tests at this laboratory. One of these modified models was operationally tested under several different conditions and against various radar equipments at the Chesapeake Bay Annex, with comparatively satisfactory results. A unit of the model CXFR-1 (airborne) equipment was also tested in the laboratory. During the operational tests of CXFR, the Radio Research Laboratory's experimental model magnetron jammer (similar to CXFR) and the type AN/APT-2 ("Carpet") jamming transmitter were tested for the purpose of comparing their performance with that of the CXFR.

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3-1. Conclusions.

3-1-1. The CXFR equipment as represented by the first two units received at this laboratory was unsatisfactory. The radar jamming performance was ineffective because of the presence of non-random modulation components (pulses, etc.).

3-1-2. The desired random noise modulation of the CXFR output was not obtained because of improper wiring arrangement in the modulator unit, insufficient shielding of the low level video stages in the modulator, and insufficient r-f and video filtering of the power leads entering the modulator unit and interconnecting the video amplifier stages.

3-1-3. With the additional shielding, re-wiring, and lead-filtering incorporated in the modulator to eliminate the undesirable modulation components, the performance of the CXFR is comparatively satisfactory. It equals the performance of the Radio Research Laboratory magnetron jammer (experimental model), and provides approximately 8 db greater effective jamming power per channel than the AN/APT-2. (The modulation bandwidth of the CXFR is greater than that of the AN/APT-2).

3-1-4. The CXFR equipment is not capable of protecting large ships in to very close ranges (say, less than 5,000 yards) against radar equipment of high performance characteristics (equivalent to, say, U.S. Navy Mark 4). The CXFR does represent, however, a considerable improvement in both simplicity of adjustment and in power output level over any other equipment currently available for operation in the same frequency range. It also covers a much greater frequency range than other available jammers.

3-1-5. It is possible to tune the CXFR to the frequency of a radar signal received on the APR-1 receiver, at ranges representative of operational conditions. The type APA-6 pulse analyzer is an effective accessory to the APR-1 for both setting the CXFR on frequency and for determining that the modulation is of the proper character. The type RDK Panoramic Adapter is of some help in setting the APR-1 "on frequency". Some experience is required, however, in order to make certain that the CXFR is actually tuned to the proper frequency and not to one of several "spurious response" frequencies which may be obtained with the APR-1.

3-1-6. The power output of the CXFR varies over the frequency range, and is only 50 to 70 percent of the values of cw power output of the type ZP-579 tube reported by other laboratories during the developmental work on the oscillator.

3-1-7. The life of the ZP-579 magnetrons during the tests was comparatively short, usually being less than 5 or 6 hours. This may be in part due to abnormal stresses incurred during experimental adjustments. The data on tube life obtained during the tests is insufficient to warrant a definite conclusion. However, it is believed that the majority of failures, which take the form of cracks in the glass at the base (between the electrode pins), are caused by excessive heating due to r-f losses in the glass. This is, in part, due to insufficient cooling by the air blast from the blower, either because of improper placement of the slot through which the air blast enters the tube chamber, or because the blower is too small.

3-1-8. Various mechanical features of the equipment are unsatisfactory, though not of such nature as to cause complete failure of the equipment. These features are described in the body of this report in paragraph 6-1-14.

3-2. Recommendations.

3-2-1. A further study of this type transmitter should be made to determine:

(a) Possible additional improvement in the modulator, since the modulation of the oscillator is still somewhat critical as to loading, frequency, condition of magnetron, etc.

(b) The optimum bandwidth of modulation to be used. Since this is essentially a spot jammer, power in side bands beyond about 1 Mc may very likely be wasted. The minimum bandwidth, which will permit the operator to set frequency accurately and effectively, should be used.

(c) The reason for the low r-f power output. The output from the CXFR obtained at this laboratory was about one-half that reported by other laboratories during developmental work on this transmitter.

(d) The reason for the short life of the type ZP-579 magnetron tube.

3-2-2. The CXFR could be monitored and set on frequency with the AN/APR-1 receiver, but this procedure is greatly facilitated by using the AN/APA-6 pulse analyzer and the RDK panoramic adaptor with the APR-1. It is recommended that, where possible, the APA-6 and RDK be provided.

3-2-3. During the progress of the work on this problem, recommendations for changes have been made. In most instances action was taken by the Bureau of Ships to have the manufacturer make corrections in the production models. The following items were handled in this manner:

(a) A 1000 ohm resistor was placed across the peaking coil in the plate of the third amplifier stage to flatten the response curve.

(b) Power for the screens of the 813 tubes was obtained from the amplifier supply rather than the 813 plate supply. (This was incorporated in the revised models).

(c) The negative d-c voltage to the magnetron was re-routed to avoid passage through the modulator.

(d) A shield was placed over the entire bottom of the modulator chassis, and the shields of individual stages were extruded so they could be fastened to the bottom plate. (The first half was incorporated).

(e) All possible wiring in the modulator was routed through a channel outside, and by-passed upon entry to chassis. (Done to some extent on production models).

(f) The modulator unit, excluding the 813 tubes and their output circuit, was shielded from the oscillator. (Done in revised model).

(g) The antenna radiation meter was changed to a 0-3 milliameter.

(h) All lugs were soldered.

(i) The chokes in the cathode of the ZP-579 were changed.

(j) The air slot magnetron cooling was repositioned to afford more effective cooling. (This was included in the revised models).

4. DESCRIPTION OF CXFR TRANSMITTER.

The nominal characteristics of the equipment are as follows:

*(a) Frequency range: - 350-800 Mc.
(b) Power Output: - 150 watts.
(c) Modulation: - Random noise.
(d) Modulation bandwidth: 5 Mc.

(*750 Mc is probably a better figure for the upper frequency limit of the CXFR; this varies from tube to tube, but has never been found higher than 750 Mc.)

4-1. The CXFR transmitter unit is shown in the photograph of Plate 1. The oscillator and modulator units, which may be pulled forward out of the main unit, are shown in Plates 2 and 3. The shield cover has been removed from the oscillator. By removing the r-f output line connection from the top panel, the hoses carrying the magnetron cooling liquid, and the five large thumb screws in the front, the entire oscillator-modulator shelf may be pulled out for inspection.

4-2. The power supplies and control circuits (not shown in photographs) occupy the space below the oscillator and modulator. The high voltage rectifier supplies the power for the oscillator and modulator, while a lower voltage supply provides voltage for the noise generator and video amplifiers.

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4-3. The noise generator consists of a 931-A photo-multiplier tube excited by a low voltage lamp. The video amplifier consists of three broad band stages using 6AC7 tubes, followed by an 807 driver stage. The 807 stage drives the modulators, two 813 tubes in parallel.

4-4. The oscillator, a type ZP-579 magnetron, is operated with the anode and r-f circuit at d-c ground potential. A single control, operating a sliding shorting bar on a balanced Lecher line, tunes the oscillator, and a second control, which can be optionally coupled to the tuning control or operated independently, varies the position of the output line coupling tap on the tuning frame. The magnetron filament is heated by a special low-capacity transformer; the modulation lead from the 813 plate circuit is connected, through a d-c blocking condenser, to one side of the magnetron filament.

4-5. Panel controls are provided for tuning and coupling, exciter lamp intensity, magnetron filament voltage, modulator filament voltage, and plate voltage (magnetron and modulator). Meters are provided for magnetron filament voltage and current, modulator filament voltage, modulator grid and cathode current, modulator plate voltage, antenna radiation, and for the rate of flow of the magnetron anode cooling liquid (Prestone). The antenna radiation meter is energized by a diode pick-up unit mounted near the antenna.

4-6. The types of antennas available for use with the CXFR are shown in Plates 4 and 5. The broad band type shown in Plate 4 is the one originally planned for use with the CXFR, and can be used over the entire range of the oscillator. Over this range the transmission line standing wave ratio does not exceed 2:1, and the radiation pattern shifts only slightly. The direction of maximum radiation is approximately perpendicular to the axis of the cones, varying somewhat over the frequency range.

4-7. The antennas shown in Plate 5 together cover the CXFR frequency range; the CAKZ-66AHM unit (right) covers the lower part of the range, and the CAKZ-66AHN (left) covers the upper part, with some overlap. These antennas have some directivity, and a power gain of approximately 3 db over the broad band antenna of Plate 4. The direction of maximum radiation is perpendicular to the radiators, and away from the reflectors. The antennas are all made for use with RG-17/U solid dielectric coaxial cable.

5. METHOD OF TEST.

5-1. The preliminary tests of the CXFR were made in the laboratory, using a water-cooled resistor type of dummy load for measurement of transmitter power and laboratory oscilloscopes for observation of the character of the modulation.

5-2. The operational tests of the CXFR were made at the Chesapeake Bay Annex of the laboratory, where the CXFR was installed aboard both the laboratory patrol boat Navajo (YP-564) and such warships as happened to be available for this purpose during the period over which tests were conducted. The CXFR was then operated against those radar equipments at the Annex which operate within its frequency range.

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5-2-1. The tests of jamming performance were made using a somewhat unique method, which gives results of a quantitative nature. This method involves the use of a pulsed ultra high frequency signal generator in conjunction with the radar equipment. The output of this generator is fed into the receiver input line, through a decoupling resistor, along with radar echo signals from the antenna. The generator has panel controls for adjusting the pulse length, synchronizing with the radar pulse repetition rate, and adjusting the pulse "delay" (or time phase relation to the radar transmitter pulse). The generator pulse may thus be made to appear at any desired "range" on the radar indicator and will thus appear as an "artificial echo".

5-2-2. The amplitude of the artificial echo pulse from the generator is controlled by a calibrated precision attenuator in the r-f output line. The attenuator calibration is in decibels. Measurements of echo strength are made by placing the artificial echo alongside the echo to be measured, and adjusting the height of the former, using the attenuator, to match that of the latter. The difference in attenuator readings thus obtained on different target echoes gives quantitatively the relative strength of the signals, expressed in decibels.

5-2-3. To allow measurements by this method on an "absolute" basis, several "standard radar targets" have been set up at convenient locations on the bay; these targets have known reflecting areas and are at known heights above the water. Absolute measurements of the reflecting area of any target may be made by measuring its strength, using the signal generator as described above, relative to the strength of a standard target. Measurements of this kind have been made on various types of U.S. Navy vessels, as described in Naval Research Laboratory report of reference (c).

5-2-4. The measurements of jamming transmitter performance were made by pointing the radar antenna at the boat or ship carrying the jammer, and simultaneously feeding an artificial echo into the radar receiver as described in paragraph 5-2-1. The amplitude of the artificial echo was then adjusted to the level <u>just below</u> that at which the echo was barely detectable through the jamming signal. The attenuator reading and the range of the boat carrying the jammer were recorded for this condition. The attenuator setting thus obtained was compared with that which gave a signal equal to that from the standard target. These measurements were made for various ranges of the jammer, so that a curve of "jammed echo" strength (db above or below standard target) as a function of range could be plotted. Plotting such a curve for each of several jamming transmitters allows comparison of their relative effectiveness. Furthermore, when similar curves of echo strength of various types of ships as a function of range are plotted to the same scale, it is found that they intersect the jamming curves. The range at which the curves intersect is the range beyond which the jammer would self-screen the given type of ship against the given type of radar equipment, for the particular radar and jammer antenna heights used. It is, further, possible to make corrections to the curves to obtain information for other particular conditions of radar or jammer performance (power, antenna height, etc.). It is therefore considered that

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this method of operational testing represents a notable advance in radar countermeasures engineering which will allow accurate evaluation of jamming transmitter performance. Such evaluation will both allow setting up design requirements for jamming transmitters to meet given performance requirements, and provide data of value in tactical employment of existing transmitters.

6. RESULTS OF TESTS.

The results of the CXFR tests are separable into (a) the results of the electrical tests in the laboratory, and (b) the operational tests at the Chesapeake Bay Annex.

6-1. Laboratory Tests. The primary purpose of the CXFR tests, as set forth in the Bureau of Ships letter of reference (a), was the determination of what changes were necessary in the original CXFR design in order to make it operate satisfactorily "without making any substantial changes that would require other components or a major increase in the work of production". The need for this work arose from the "defective operation as found in an operational test conducted on 11 February 1944" at the Naval Research Laboratory Chesapeake Bay Annex.

6-1-1. The fact that the defective operation described above was primarily due to improper modulation of the signal was determined almost immediately, and the work centered on the problem of remedying this condition. The appearance of the detected signal on a cathode ray oscilloscope or radar indicator was not that of "random noise". Although there was a considerable noise component to the modulation, there were also pulses and sine wave components which were due to oscillation of the modulator video amplifier and motor-boating or pulsing of the oscillator. The extent and type of these undesirable modulation components were dependent on the adjustment of the oscillator output coupling and on the frequency of operation; better operation was obtainable in some parts of the frequency band than in others.

6-1-2. Inspection of the modulator indicated that the wiring, shielding, and interstage decoupling did not meet the requirements for stable high-gain video amplifier operation. As a first step, therefore, the modulator was re-wired. Power leads common to two or more stages were routed through a shielded channel along the side of the chassis and filter condensers of the "feed-through" type were used wherever such leads entered the chassis. A copper baffle shield was placed on the side of the chassis toward the oscillator. This extended along the entire length of the modulator, and was as high as the top of the 813 tube envelopes. These changes resulted in some improvement, but did not completely stop the oscillation.

6-1-3. Extension power cables were made to allow operation of the modulator on a bench near the transmitter. Experiments with additional shielding indicated that the remaining cause of oscillation was r-f pick-up by the low level video stages. The oscillation was at a fairly high frequency, in the neighborhood of 5 megacycles. This frequency was

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probably due to resonance of the video response compensating circuits. However, damping of these circuits with resistors failed to provide a cure.

6-1-4. A second major revision of the modulator was next made, using the modulator of another CXFR unit; a second unit had been shipped to the laboratory by the manufacturer, at the request of the Bureau of Ships, in order to expedite the laboratory's investigation. This modulator was even more completely re-wired than the one first revised, including decoupling resistors in the first three stages, and a completely enclosing shield cover was placed over the modulator stages preceding the 807 driver stage. In addition, shield plates were placed under the chassis and between the front panel and the phototube. Interstage shield partitions under the chassis were fitted with tapped bent-over edges for screw connection with the bottom cover and were re-positioned in the first two stages to fall across the tube sockets, providing tight interstage shielding between the low level 6AC7 amplifiers.

6-1-5. With this second revised modulator, stable operation was obtained, insofar as absence of oscillation in the modulator was concerned. Pulsing or motor-boating of the oscillator still occurred under some conditions of adjustment, but it was possible to secure fairly proper modulation over most of the frequency range with careful adjustment.

6-1-6. Under some conditions, it was found that severe modulation of the output at a 60 or 120 cycle rate occurred. This was not directly apparent on a radar indicator, but was observed when the output of the transmitter was detected by a diode and the resultant signal applied to the vertical deflecting plates of an ordinary oscilloscope, with the horizontal sweep generator synchronized to operate at a sub-multiple of 60 cycles. The signal was thus observed to be severely modulated at 60 or 120 cycles, and under some conditions to be completely interrupted at the same rate, resulting in a sort of square-wave envelope, with noise modulation during the oscillating periods. It was deduced that this effect was caused by the action of the magnetic field set up in the magnetron by the heavy filament current (40 amperes r.m.s., 60 cycle a.c.). The flux density resulting from this current is apparently sufficiently great, compared with the flux density of the permanent magnet, to adversely affect the magnetron operation during the peak amplitude portions of the filament current cycle. It was recalled that this phenomenon was known by early workers in the development of magnetrons. The view that this explanation of the observed behavior is correct was strengthened by the observation that the effect was diminished by reducing the magnetron filament current to 60 or 70 percent of the normal value. Fairly good power output could be obtained with this reduced filament current by increasing the magnetron anode voltage to bring the anode current up to about normal operating value; this resulted in added "back heating" of the cathode by electron bombardment, raising its temperature to compensate for the reduced filament current. This procedure cannot be carried too far, however, without reaching an unstable condition such that the tube refuses to oscillate.

6-1-7. The effect described above was more severe with some tubes than with others, and usually occurred at either the high or

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low end of the frequency range. It is likely that the effect occurs, therefore, under conditions such that the magnetron is not a strong oscillator. The occurrence of this modulation or interruption of oscillation sometimes at a 60 cycle rate and sometimes at 120 cycles is thought to be dependent on whether or not the axis of the magnetron is perfectly parallel to the magnet field, thus making the effect of the filament current flux on both halves of the cycle symmetrical with respect to the magnet flux, or slightly tilted, so that the effects on alternate halves of the cycle are unsymmetrical. The former condition would result in 120 cycle modulation, while the latter would result in a combination of 60 and 120 cycle modulation.

6-1-8. In addition to the above effect, some motorboating or "quenching" of the oscillation at a frequency higher than 120 cycles (but not at super-audible frequency) was observed under some conditions. This condition could always be made to occur by reducing the noise excitation of the 813 modulators. This is possibly explained by the fact that the modulators are grid-leak biased. With reduced excitation and consequently reduced bias, their plate voltage may decrease to a value below the screen voltage value, and their high plate resistance pentode characteristic then disappears. Their damping effect on the negative resistance characteristic of the magnetron is thus lessened, providing favorable conditions for quenching or motor-boating of the oscillator. With proper adjustment of the modulation amplitude no difficulty with this motorboating was experienced.

6-1-9. A check of the strength of the permanent magnets of the two CXFR units was made at one point during the tests in the laboratory, and it was found that they were below the rated minimum value of 1500 gauss. Therefore some re-magnetizing coils were wound and the magnets re-energized. The magnet strengths were thus brought up to about 1530 gauss.

6-1-10. The modifications of the modulator which resulted in improved operation were communicated to the manufacturer via Bureau of Ships representatives, and were immediately incorporated in the production units. A unit incorporating the recommended changes was received on 29 February 1944, and was found to operate satisfactorily in the laboratory.

6-1-11. Although extensive tests of power output and frequency spectrum had not been made in the laboratory, it was decided that operational tests of the CXFR should not be held up to allow making these measurements, because of the urgent need for immediate determination of the performance characteristics under field conditions. No satisfactory method of making an extensive analysis of the frequency spectrum was available at the laboratory. With such apparatus as was available, it was determined that the bandwidth of the transmitted signal varies considerably over the frequency range, and varies also with adjustment of panel controls. A complete study of the spectrum would have required more time than it was desired to spend. Similarly, a careful series of measurements of power output as a function of frequency was not made. From the sketchy information obtained on the frequency spectrum, it can be said only that the signal

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bandwidth varies. over the tuning range, from values perhaps as low as one megacycle to values possibly higher than 10 megacycles. Power output of from 60 to 90 watts was measured, the lower figures being obtained at the upper end of the frequency range. In no case were values measured as high as the 150 to 200 watts which the ZP-579 is reputed to be capable of delivering. All measurements were made with modulation applied.

6-1-12. Of the twenty or more type ZP-579 magnetron tubes which have failed, two developed open filaments, one had a short circuit between the filament support rod and the circular metal disc, used to shield the glass envelope from electrom bombardment, through which the support rod passes, and the remainder failed as a result of cracks in the glass. The cracks were in all cases through the base, passing between the electrode pins, and appeared to be due to heating developed by r.f. losses in the glass. The life of the tubes that failed did not exceed five or six hours, before a modification of the magnetron air cooling system was made. The slot through which the air from the blower enters the oscillator shield cover was originally positioned improperly, and, after its position was changed in the laboratory (and in the later models by Auto Ordnance), tube failure was less frequent (tube life was approximately doubled). If the capacity of the blower were greater, the slot probably could remain in the original position.

6-1-13. Plate 8 shows the results of tests made on the Auto Ordnance CXFR broad band antenna. Tests were made to determine the percent reflection over a frequency range of 300-800 Mc with the antenna connected to 17 feet of RG-17/U cable, and a comparison was made with the results obtained from a developmental model constructed at this laboratory. Recommendations were made to decrease the spacing of the cones and to provide more positive means for locking the upper cone to the supporting spike. It was thought that the greater spacing of the cones was the reason for the high percentage reflection at frequencies above 500 Mc, so 1/8" separation was requested.

These improvements were incorporated in a second production model; the results, while not as good as those obtained from the Naval Research Laboratory experimental model at the lower end of the band, indicated the elimination of the high peaks above 500 Mc, and show that, on the whole, the antenna functions very well.

6-1-14. Various mechanical features are unsatisfactory, although not of such nature as to necessarily cause complete failure of the equipment. These are listed below:

(a) It was noticed that great care must be exercised when adjusting the coupling to a minimum value to avoid damaging the spring "fingers" on the shorting bar. If the antenna coupling tap is pulled beyond a critical value, the solid metal of its support slides under the contacts of the tuning slider; after this has been done several times, the "fingers" fail to make good contact with the side. This was found to be a source of arcing in the oscillator.

(b) It was further noticed that the clamps on the 813 modulator tubes failed to hold the tubes securely in the sockets. Examination

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showed that the socket holes in the chassis were smaller than the tube bases; thus, since the socket was under the chassis, the tube pins went into the socket only enough to make contact; further, the spring clips of the socket tended to push the tube out rather than grip the pins. It is probable that the tube clamps would function properly if the tubes were properly seated in the sockets.

(c) The "Prestone" cooling fluid leaked badly from the pump; if the gland were tightened sufficiently to stop leakage, the resultant friction on the shaft was too great for the starting torque of the motor. It is thought that this Prestone fluid leakage and soaking into the high voltage transformer was a contributing factor to its failure.

(d) Some of the lugs, which are squeezed onto the wire ends, were very loose; while they were being soldered on, several became detached from the wire.

(e) Examination of the time delay relay, after the plate power relay failed to make, showed that the cams on the motor shaft had slipped around so that they were inoperative. Several times during the tests the cams had to be repositioned and the set screws tightened.

(f) The voltage regulator for the magnetron filament in the CXFR was extremely inefficient; this unit was disconnected from all of the CXFR models tested.

6-2. <u>Operational Tests</u>. Operational tests of the CXFR were made on several occasions. The first was that made on 11 February, with the CXFR aboard the U.S.S. Quincy, as described in paragraph (3).

6-2-1. After the first modification of the CXFR modulator was made, the transmitter was installed aboard the laboratory patrol boat Navajo (YP-564) at the Chesapeake Bay Annex on 22 February. It was found that very good performance was obtained at the FD frequency (700 Mc), but that performance was poor at the Mark 5 radar frequency (400 Mc). At the latter frequency, the modulation contained pulses and "railings" superimposed on the random noise voltage, and the echo signals could be seen even when their amplitude was considerably less than that of the jamming.

6-2-2. It was found that the same transmitter, with a new ZP-579 installed, performed well at the lower end of the frequency range (including the Mark 5 frequency), but would not operate properly at above 600 Mc. It thus appears that there is some variation in tube characteristics, and that not all tubes will allow proper operation over the entire frequency range. This same phenomenon was observed subsequently with other tubes.

6-2-3. On 24 February the same CXFR unit mentioned in paragraph 6-2-1 was taken to Annapolis and installed aboard the U.S.S. Franklin (CV), for further operational tests against the radar equipment at the Chesapeake Bay Annex, particularly the Mark 5 and "Hot Dog" (simulated German "Wurzburg", 560 Mc). However, on the scheduled date of the

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tests, 25 February, the equipment failed to operate properly, and successful tests could not be obtained.

6-2-4. On 1 March tests were made with several jamming transmitters installed aboard the Navajo. The first of these was the CXFR which had been modified as described in paragraph 6-1-4. The second was the manufacturers' "Revised" model (paragraph 6-1-10). The third was the RRL Magnetron jammer (laboratory model), which is basically similar to the CXFR, but differs somewhat in physical layout and modulator circuit details. The fourth unit was the "Carpet", or AN/APT-2. This was included for purposes of comparison, since it represents a basically different type of jammer. It has lower power output than the magnetron jammers, but has also less bandwidth, and a directive antenna. The oscillator tube type is an ultra high frequency triode, plate modulated with random noise.

6-2-5. On 7 March further operational tests of the CXFR were made to corroborate previous results and to obtain additional data. In the afternoon of this date the performances of the CXFR and "Carpet" on the FD, "Hot Dog", and Mark 5 radar frequencies were demonstrated to a group including representatives of the Bureau of Ships, the Radio Research Laboratory, and the General Electric Company. The effect of using various types of antennas was demonstrated, in addition to the general demonstration of comparative performance of the equipments. The type CAKZ-66AHM and CAKZ-66AHN antennas (Plate 5) were found to have approximately 3 db gain relative to the "broad band" CXFR antenna (Plate 4).

6-2-6. The letter of reference (a) requested "field tests .... using the AN/APR-1 receiver for setting on frequency". Considerable difficulty was experienced in setting the jammer on frequency with the AN/APR-1 received because of the many strong responses received over the range of the receiver. If the radar frequency is known, the jammer may be set approximately "on frequency" by means of the calibration chart furnished with the equipment. It is important to note that the frequency changes drastically with different tubes, so the chart may be relied upon only within 5 or 10 Mc. However, if the radar frequency is unknown, positive identification of carrier frequencies will be very difficult. In the letter of reference (d), it is stated that, at a range of five miles, eleven responses to the signal from the Mark 4 radar (690 Mc) were observed on the APR-1 receiver; four on the "A" tuning head, and seven on the "B" head. In addition, two "false" carrier-image separations of 60 Mc were found on the "A" head (90-150 Mc, and 150-210) as well as the 60 Mc gap from 690-750 Mc due to the true and image response on the "B" head. Discrimination between the responses is based upon their relative amplitudes, but, since the relative amplitudes varied considerably depending upon the orientation of the receiving antenna, the determination of the correct radar frequency might have been seriously in doubt had not the frequency of the Mark 4 been known. It was recommended in the letter of reference (d) that the APA-6 pulse analyzer be used in conjunction with the APR-1, and that two or more APR-1 receivers be used simultaneously for rapidly checking a frequency. In the same letter were three tables containing the responses, their relative amplitudes, and the reason for the i-f responses for frequencies of 270 Mc, 690 Mc (Mk 4), and 560 Mc (Hot Dog). The output meter on the APR-1 can be used to great advantage while setting the jammer on frequency, and the RDK panoramic adaptor is helpful. This latter item would be of much greater usefulness if the sweep were 10 Mc rather than 3 Mc. Since the bandwidth of the noise signal is (at some portions of the range) greater than 3 Mc, the RDK is ofttimes inadequate. With experience, the APR-1, APA-6, and RDK may be efficiently used to set the jammer on frequency, but, as it has been pointed out, great difficulties must be overcome before effective results may be assured.

6-2-7. All the magnetron jammers described above performed satisfactorily and about equally well. Actually the RRL jammer performance, as measured using the methods described in paragraph 5-2-4, was 2 or 3 db better than that of the CXFR transmitters; however, this difference may be of the same order of magnitude as the probable experimental error. What was most interesting was that the "Carpet" performance was equal to that of the magnetron jammers when it was operated with its directive antenna, and the magnetron jammers were operated with the non-directive broad band antenna shown in Plate 4. When the magnetron jammers were operated with the "Carpet" directive antenna, their performance was about 8 db above that obtained with "Carpet". This 8 db agrees with the known power gain of the "Carpet" antenna relative to the CXFR broad band antenna. If the "Carpet" is assumed to have 3 watts output at the frequency at which the test was made (700 Mc), then the 8 db better performance of the magnetron jammers would indicate that their <u>effective</u> power output is approximately 20 watts. Since the magnetron jammers are known to deliver more actual power than this, the discrepancy must be explained. It is due to one or both of the following:

(a) The power output of the magnetron jammers is spread over a wider frequency spectrum than that of the "Carpet". If the latter is assumed to have 2 Mc bandwidth, then a CXFR band width (at 700 Mc) of from 6 to 10 Mc would completely explain the results obtained relative to "Carpet", assuming a CXFR total power of 60 to 100 watts at 700 Mc.

(b) The modulation used with "Carpet" may, for some as yet unexplained reason, be more effective than that which is obtained with the magnetrons. This possibility is purely conjectural; facilities for determining whether or not such an effect exists are not at present available.

6-2-8. Plates 6 and 7 are plots of the results obtained in operational tests of the CXFR at the Chesapeake Bay Annex, with curves of echo strength received from various types of warships, as described in the report of reference (c), plotted to the same scale. The signal level received from the standard target ("Baker Dolphin"), to which all measurements were referred, is taken as zero decibels. The meaning of the "jamming" curves is given in paragraph 5-2-4. The actual measurements were made with the jamming antennas at 12 foot height above water level, since this was the greatest height conveniently attainable aboard the Navajo. The curves shown (Plates 6 and 7) for greater antenna heights were based on the measurements at 12 foot height, and were drawn by using values calculated assuming the jamming signal strength at the radar antenna to vary in proportion to the second power of the jamming antenna height. This assumption

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is valid for ranges at which the jamming antenna is below the height of the first "maximum" lobe of the radar vertical interference pattern. For ranges at which the jamming antenna is in the first maximum of the radar pattern, or above it, the jamming performance curves will deviate from a straight line, as shown, dropping to "minus infinity" as the jamming antenna comes into the "null" of the radar antenna interference pattern. Thus, for jamming in to close ranges it may not always be that the highest possible location of a jamming antenna (on a ship) is the best. In fact, for a given radar installation, it will be seen that to "jam" to any specified range, there is an optimum height for the jamming antenna. This optimum is the height of the radar antenna first "maximum" lobe at that given range. The height of this lobe may be computed if the radar frequency and antenna height are known.

6-2-9. On 20 March 1944 the CXFR was operated aboard an escort carrier (CVE) at the Chesapeake Bay Annex, with the jamming antenna at approximately 85 foot height above water level. The results obtained agreed within a few db with the curve of Plate 6 for 80 foot height, although measurements at close range could not be made.

7. CONCLUSIONS.

7-1. The CXFR equipment as represented by the first two units received at this laboratory was unsatisfactory. The radar jamming performance was ineffective because of the presence of non-random modulation components, (pulses, etc.).

7-2. The desired random noise modulation of the CXFR output was not obtained because of improper wiring arrangement in the modulator unit, insufficient shielding of the low level video stages in the modulator, and insufficient r-f and video filtering of the power leads entering the modulator unit and interconnecting the video amplifier stages.

7-3. With the additional shielding, re-wiring, and lead-filtering incorporated in the modulator to eliminate the undesirable modulation components, the performance of the CXFR is comparatively satisfactory. It equals the performance of the Radio Research Laboratory magnetron jammer (experimental model), and provides approximately 8 db greater effective jamming power per channel than the AN/APT-2. (The modulation bandwidth of the CXFR is greater than that of the AN/APT-2).

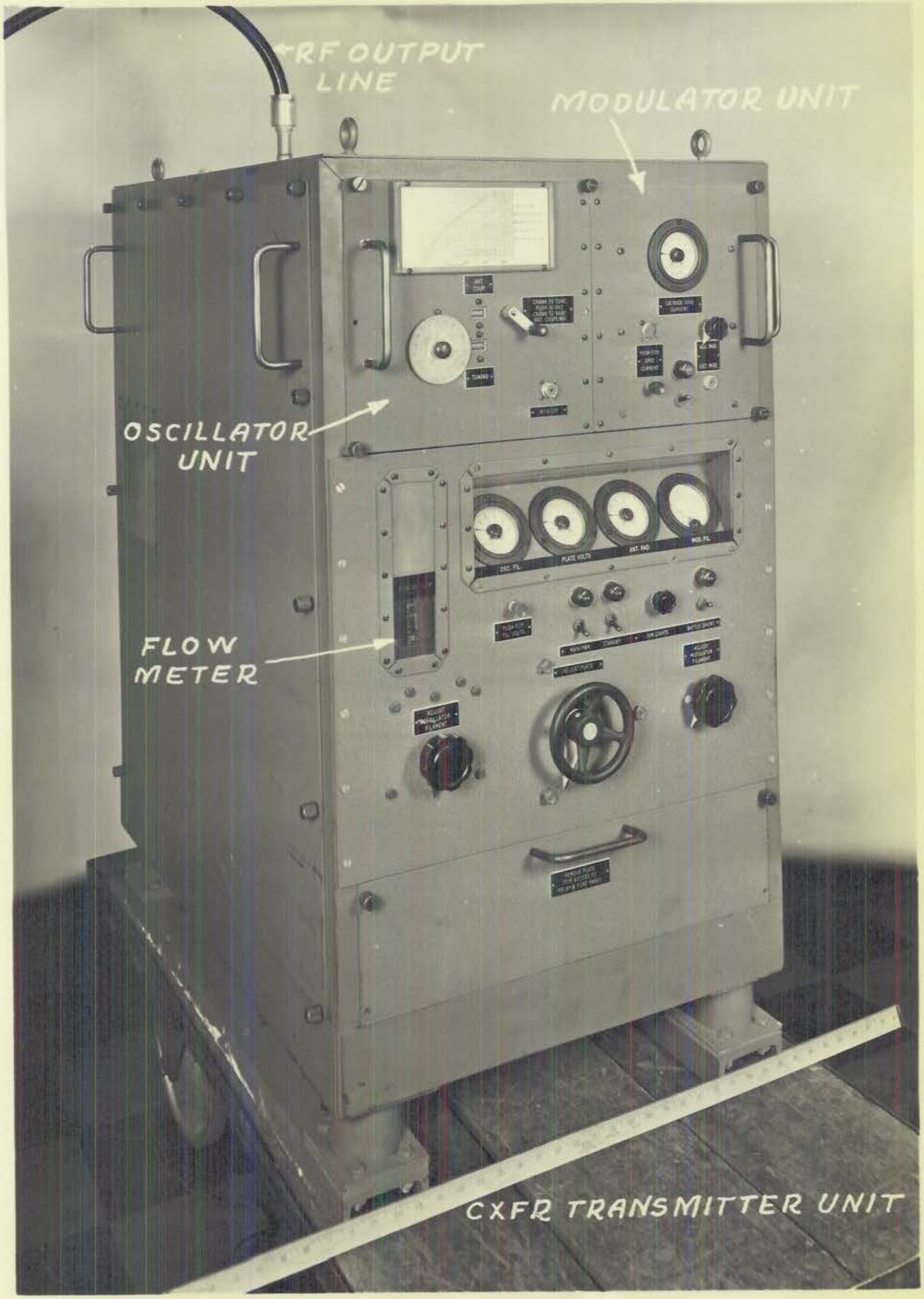
7-4. The CXFR equipment is not capable of protecting large ships in to very close ranges (say, less than 5,000 yards) against radar equipment of high performance characteristics (equivalent to, say, U.S. Navy Mark 4). The CXFR does represent, however, a considerable improvement in both simplicity of adjustment and in power output level over any other equipment currently available for operation in the same frequency range. It also covers a much greater frequency range than other available jammers.

7-5. It is possible to tune the CXFR to the frequency of a radar signal received on the APR-1 receiver, at ranges representative of operational conditions. The type APA-6 pulse analyzer is an effective accessory to the APR-1 for both setting the CXFR on frequency and for determining that the modulation is of the proper character. The type RDK Panoramic Adaptor is of some help in setting the APR-1 "on frequency". Some experience is required, however, in order to make certain that the CXFR is actually tuned to the proper frequency and not to one of several "spurious response" frequencies which may be obtained with the APR-1.

7-6. The power output of the CXFR varies over the frequency range, and is only 50 to 70 percent of the values of cw power output of the type ZP-579 tube reported by other laboratories during the developmental work on the oscillator.

7-7. The life of the ZP-579 magnetrons during the tests was comparatively short, usually being less than 5 or 6 hours. This may be in part due to abnormal stresses incurred during experimental adjustments. The data on tube life obtained during the tests is insufficient to warrant a definite conclusion. However, it is believed that the majority of failures, which take the form of cracks in the glass at the base (between the electrode pins), are caused by excessive heating due to r-f losses in the glass. This is, in part, due to insufficient cooling by the air blast from the blower, either because of improper placement of the slot through which the air blast enters the tube chamber, or because the blower is too small.

7-8. Various mechanical features of the equipment are unsatisfactory, though not of such nature as to cause complete failure of the equipment. These features are described in the body of this report in paragraph 6-1-14.


RF OUTPUT
LINE
MODULATOR UNIT
OSCILLATOR
UNIT
FLOW
METER
CXFR TRANSMITTER UNIT

DECLASSIFIED

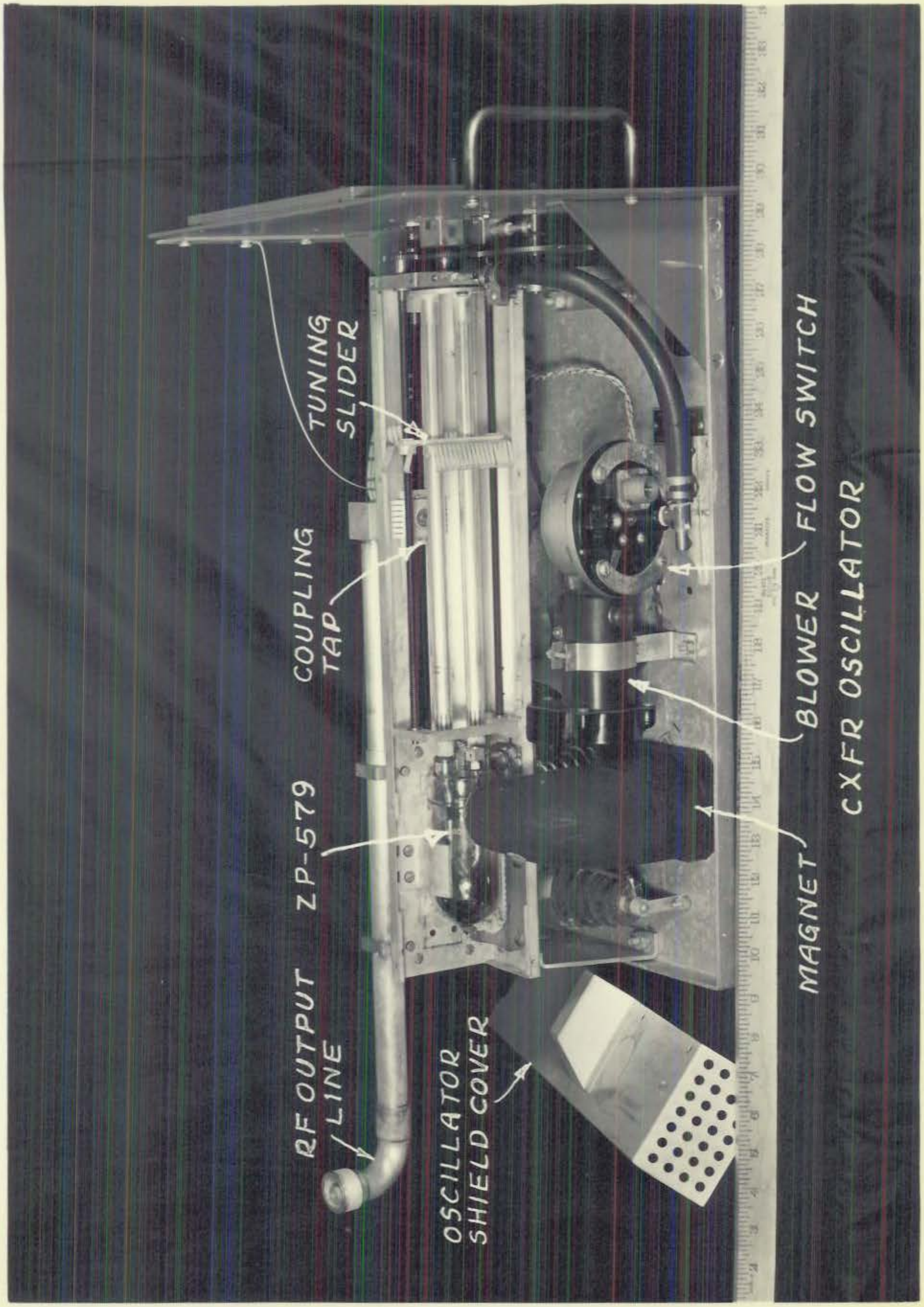


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PLATE 3

CONFIDENTIAL

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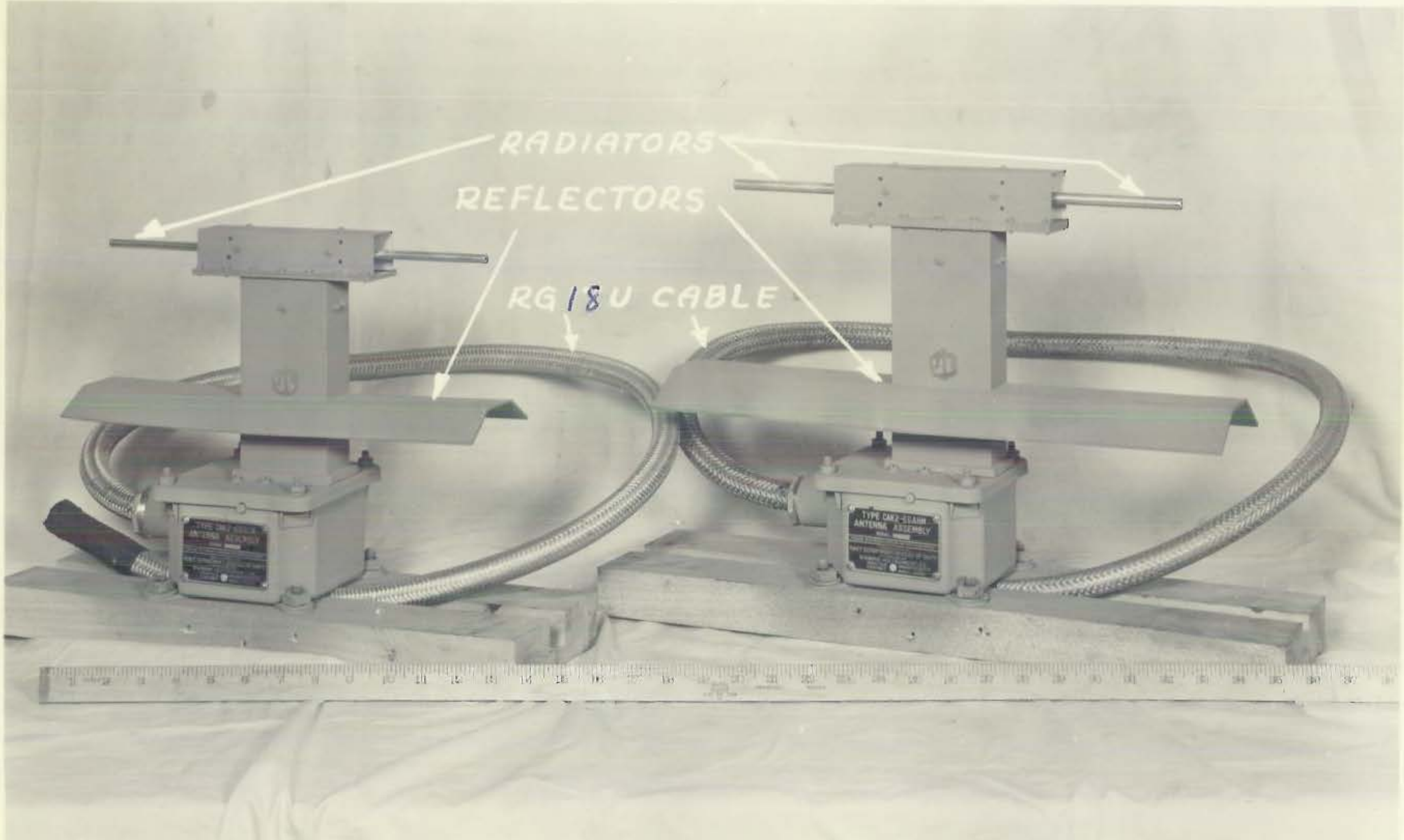
BROAD - BAND ANTENNA
FOR CXFR

PLATE 4

CONFIDENTIAL



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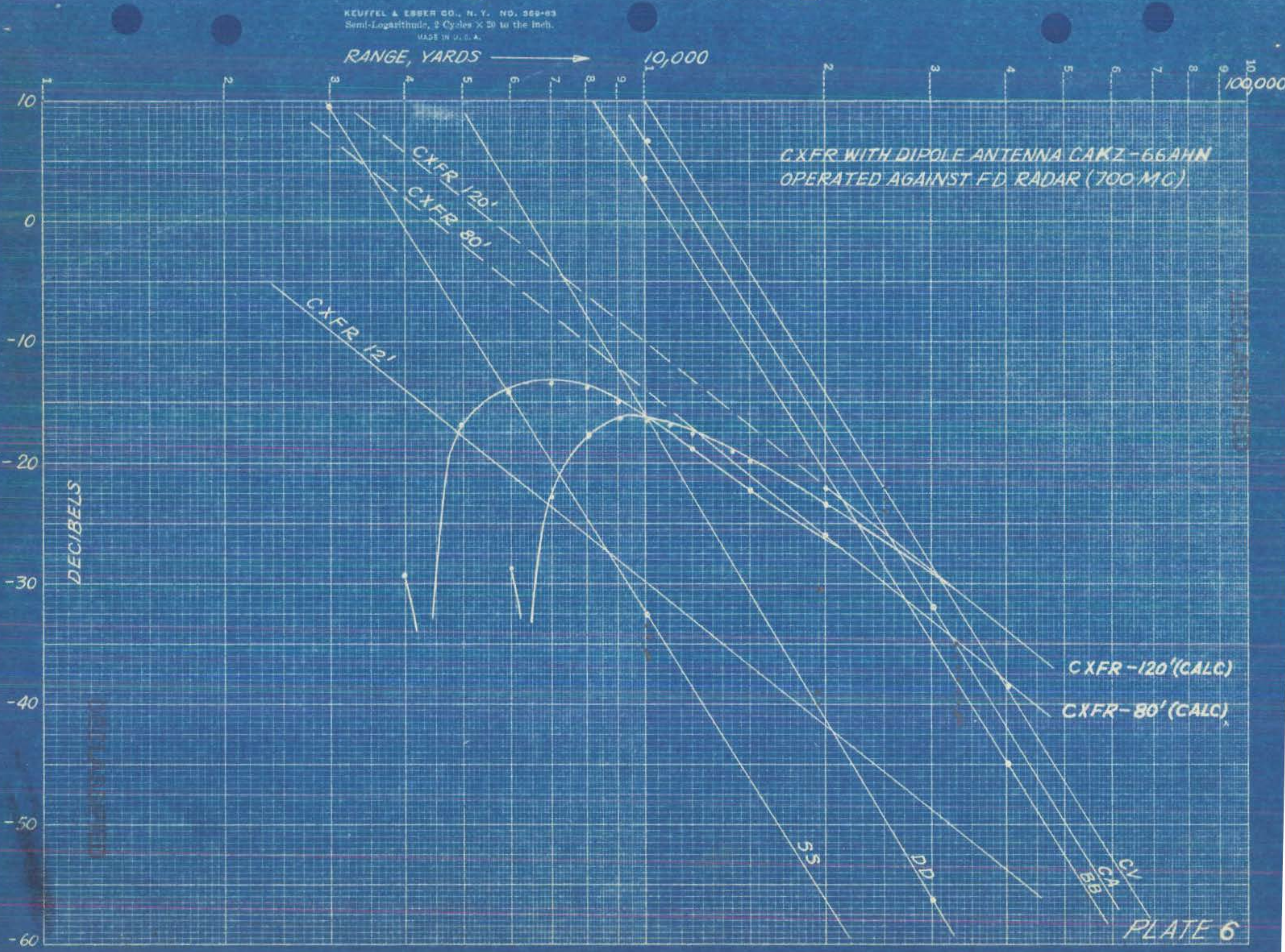
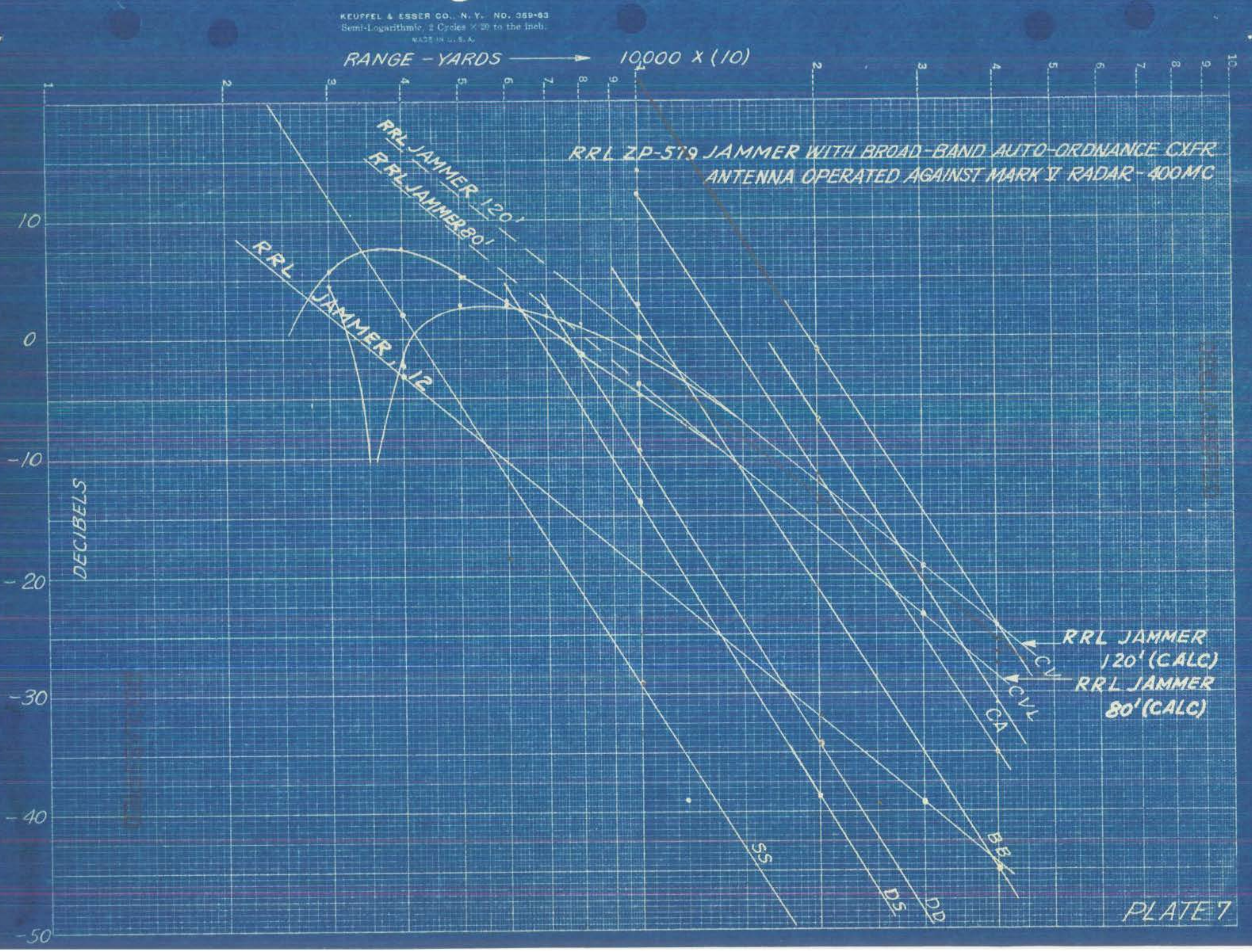
TYPE CAKZ-66AHN (LEFT) AND
CAKZ-66AHM (RIGHT) ANTENNAS
FOR CXFR

PLATE 5



KEUFFEL & ESSER CO., N. Y. NO. 359-63
Semi-Logarithmic, 2 Cycles × 20 to the Inch.
MADE IN U.S.A.
RANGE, YARDS
10,000
100,000
DECIBELS
10
0
-10
-20
-30
-40
-50
-60
CXFR WITH DIPOLE ANTENNA CAKZ-66AHN
OPERATED AGAINST FD RADAR (700 MC).
CXFR 120'
CXFR 80'
CXFR 12'
CXFR-120'(CALC)
CXFR-80'(CALC)
SS
DD
CV
CA
BB

PLATE 6


KEUFFEL & ESSER CO., N.Y. NO. 359-63
Semi-Logarithmic, 2 Cycles × 20 to the inch.
MADE IN U.S.A.
RANGE - YARDS → 10,000 X (10)
DECIBELS
RRL ZP-579 JAMMER WITH BROAD-BAND AUTO-ORDNANCE CXFR
ANTENNA OPERATED AGAINST MARK V RADAR - 400MC
RRL JAMMER 120'
RRL JAMMER 80'
RRL JAMMER 12
RRL JAMMER 120' (CALC)
RRL JAMMER 80' (CALC)
CV
CVL
CA
BB
DD
DS
SS
PLATE 7