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SUBJECT

SEVENTH PARTIAL REPORT ON

THE PRECIPITATION STATIC PROBLEM

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19 June 1944

NRL Report No. O-2309

NAVY DEPARTMENT

Seventh Partial Report on the Precipitation Static Problem

NAVAL RESEARCH LABORATORY  
ANACOSTIA STATION  
WASHINGTON, D. C.

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## ABSTRACT

Laboratory experiments are described that analyze three different wick-type static dischargers under various conditions commonly encountered in actual flight. Results are given which show the superiority of a metalized cotton wick over two liquid-impregnated cotton wicks and the superiority of a cotton wick impregnated with an ethylene glycol-water mixture over one impregnated with a glycerin-water mixture at temperatures below 0° C.

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## INTRODUCTION

### A. Authorization

1. This problem is authorized by the Bureau of Aeronautics Project Order No. 832/43, dated 30 June 1943. The work is carried forward under the jurisdiction of the Joint Army-Navy Precipitation-Static Committee consisting of:

Comdr. L. V. Berkner	Bureau of Aeronautics
Major T. S. Banes	Hq. Army Air Forces
Capt. C. I. Stafford	OCSigO
Lt. J. H. Willox	Bureau of Aeronautics
Mr. J. Weichbrod (Secretary)	OCSigO

### B. Statement of Problem

2. A cotton wick discharger impregnated with a glycerin-water mixture has been developed at the Naval Research Laboratory. These dischargers have been found necessary to reduce radio interference due to the accumulation of static electricity on a plane in flight. It is necessary to know, in a quantitative way, the effect on this discharger of various operating conditions in order to improve its operation or to secure a better discharger. The object of this report is to give the results of various laboratory tests comparing two improved dischargers with the older one impregnated with the glycerin-water mixture.

### C. Known Facts Bearing on the Problem

3. The fundamental fact concerning precipitation static is that a static charge is built up on an airplane when it flies through air in which there are precipitation particles. This charge accumulates to a sufficient extent to produce corona discharge at points of small radii of curvature on the plane. This corona discharge causes shock-excitation of the radio circuits giving rise to the phenomenon known as precipitation static. It is obvious that one way to reduce the interference in the radio circuits due to this charge on the plane is to get it off the plane in some interference free manner. A liquid-impregnated cotton wick was developed at the Naval Research Laboratory which acted as a quiet discharger. The liquid used in the wick was a mixture of 80% glycerin and 20% tap water (by volume). Actual flight data has been obtained with these wicks (see N.R.L. Confidential Reports O-1919, O-2025, and O-2271) and the result has been that a plane equipped with six of these dischargers mounted at the proper places on the plane (the points of highest gradient) can maintain radio communication under conditions of precipitation which cause a charging current to the plane about three times as large as that which would cause entire loss of communication on a plane not so equipped.

### D. Theoretical Considerations

4. Previous progress reports included theoretical considerations which do not require amplification or repetition at present.

## E. Narrative of Original Work

5. There were several practical difficulties with the glycerin-water discharger. Glycerin is rather difficult to obtain; it is also rather difficult to mount the tubes, in which the wicks are held, at the points of highest potential gradient. Moreover, the dischargers have to be refilled about every 60 flying hours. There is further some question about the performance of the discharger at low temperatures, say at  $-40^{\circ}\text{C}$ . Therefore the investigation was extended to other impregnating liquids and to chemically processed wicks which required no liquid.

## METHODS

### A. Preparation of Materials

6. Ethylene glycol and Prestone were suggested as substitute liquids since water mixtures of these two liquids satisfied the conductivity and freezing point requirements of any discharger liquid and because they are more easily obtained than glycerin. Preliminary tests, identical with Test 3a, described in paragraph 14 of this report, were run to determine what proportions of water and liquid made the best discharger. All dischargers using ethylene glycol alone were noisy, and the 80% glycerin-20% water, and 80% ethylene glycol-20% water mixtures were found to be best. Liquid mixtures containing a larger percentage of glycol or glycerin made noisy dischargers. Mixtures containing a smaller percentage, though very good for a short time, were found to evaporate, or "dry out", too quickly to be of any practical value on an operating plane. Therefore, the tests discussed in this report were performed using dischargers impregnated with the 80%-20% mixtures.

7. More recently there has been developed at this laboratory a metalized wick to be used as a static discharger (see Appendix I of this report).\* This wick was the same cotton wick as used in the liquid dischargers, but it was chemically treated in such a manner that silver particles were deposited on or in the cotton fibers to give them the necessary conductivity. Thus the problems of refilling, evaporation, freezing point, and liquid supply were automatically eliminated. Preliminary tests, identical with Test 3a described in paragraph 14 of this report, indicated that the metalized wick was notably better than either of the liquid-impregnated wicks. One of these wicks, whose value as a discharger on an operating plane is known, was also used in all the tests described in this report in order to compare its performance with that of the wick impregnated with the glycerin-water mixture.

### B. Description of Experiments

#### I. Laboratory Tests

8. The first test conducted was the temperature variation test. For this test, two Celotex boxes were constructed in which the temperature could be varied from about  $-40^{\circ}\text{C}$ . to about  $25^{\circ}\text{C}$ . One box was large enough to allow only a single discharger to be tested at once; the other was large enough to accommodate all three dischargers. The tests were first made with the small "cold box", in which there was only a single discharger. The interior of the

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\* Prepared by Dr. Peter King, Chemistry Division

box was adjusted to a chosen temperature within the range, and held at that temperature for about one hour in order to be certain that the entire discharger assumed the temperature of the air in the box. The current discharged by the wick at each 10-kilovolt interval up to 60 kilovolts was recorded. Any noise produced by the discharge from the wick was measured in the same manner as noise was measured for the preliminary tests (see paragraph 13 and Plate 9). All three dischargers were quiet at all voltages and temperatures.

9. In order to insure identical atmospheric conditions for each discharger (almost impossible with the small "cold box") the large box was built which would accommodate all three dischargers at once. The separation between dischargers was 10 times the separation between the discharger and the "ground" plate. This factor of 10 was large enough to eliminate substantially the possibility of false data due to shielding of one discharger by another (see Plate 1). The noise measuring apparatus could not be used during this experiment because all three wicks were discharging at the same time. From the data thus obtained the curves in Plates 2, 3, 4, and 5 were plotted. Newly filled liquid dischargers were used. Plate 2 shows voltage vs. discharged current at 23°C. Plate 3 shows voltage vs. discharge at -12°C. Plate 4 shows voltage vs. discharged current at the lowest temperature recorded, -41.9°C. Comparison of these plates shows the superiority of the metalized wick at all temperatures and the superiority of the ethylene glycol-water over the glycerin-water discharger at temperatures below 0°C.

10. Plate 5 shows the effect of temperature on the current discharged by the wicks at 55 kilovolts, wicks negative with respect to the "ground" plate. The freezing point of the glycerin-water mixture is about -7°C, which may account for the sharp decrease in discharged current around that temperature and below. These curves also show the superiority of the metalized wick over the liquid-impregnated wicks and the superiority of the ethylene glycol-water discharger over the glycerin-water discharger at low temperatures. Some type of change takes place in the characteristics, perhaps mainly in the conductivity, of the glycerin-water discharger at about -7°C. It seems possible however, since at that temperature the mixture has its freezing point, that the liquid in the wick might freeze; but when the dischargers were removed from the cold box immediately after having been at -40°C. for over an hour, no evidence of freezing could be detected. However, some liquid had been lost from the wick for there was a small pool of liquid directly beneath the tip of the wick on the ground plate. There was also a small pool of liquid under the ethylene glycol-water discharger of about the same size as that under the glycerin-water one. However, Plate 5 shows that no comparable change took place in the character of the ethylene glycol-water mixture, quite possibly because its freezing point is about -42°C.

11. Plates 2, 3, 4, and 5 were all plotted using data with the dischargers negative with respect to the ground plate, this being the most important case since usually the airplane itself is negatively charged and dischargers on a plane would then be negative with respect to the surrounding medium. The results for dischargers positive with respect to the ground plate were the same as for negative voltages, except that at a given positive voltage the discharged current is always slightly less than at the same negative voltage.

All the curves have the same shape for positive and negative voltages. Plates 6 and 7 are included to show the similarity between the voltages of opposite sign. These plates should be compared with Plates 3 and 5, respectively.

12. The second test was intended to show how the discharged current at a constant voltage varied over a large period of time; in other words, to find out if the dischargers "burned up" when discharging a relatively high current for a long time. For this test the three dischargers were mounted on a plywood board and suspended over the ground plate, the electrical circuit being the same as that shown in Plate 1. A voltage of 60 kilovolts, negative with respect to the ground plate, was applied to the dischargers and the discharged current from each read once every hour while the voltage was on. This test was continued for eight days, giving a total time of 62.5 hours during which the dischargers were actually discharging a current. Results of this test are shown in Plate 8. The metalized wick was best, though its average current decreased 25% over the eight day period. The average current from the ethylene-glycol discharger decreased steadily to about 90% its value at the beginning of the test, while the glycerin discharger decreased steadily to about 50% of its value at the beginning. It should be noticed, however, that the major part of the decrease in the discharge from the metalized wick occurred during the first 18 hours of actual discharge. After that point the decrease in discharge was only about 1% per four hours, about the same as the rate for the ethylene glycol-water discharger. The rate for the glycerin-water discharger was about 5% per four hours.

13. The third "test" was a series of tests performed to determine the effect of rain and "sea" water on the performance of the dischargers, with particular emphasis on the noise produced by the wicks while discharging a current under varying conditions of wetness. Plate 9 shows the apparatus used for this series of tests and the method of measuring noise and discharge. The tests were performed in the following manner and in the order given, using the same three dischargers for all tests. (The -26 decibel noise level was the noise produced by the receiver itself.)

14. Test 3a: Newly made dischargers were tested for discharge and noise at positive and negative voltages up to 60 kilovolts. The voltage vs. discharge curves were the same as those in Plate 2. The dischargers were quiet throughout the test, that is, there was no noise produced which was above the -26 db. level.

15. Test 3b: Dischargers from Test 3a were sprayed with distilled water. Not enough water was put on the wicks to cause droplets to hang at the tips. This test was designed to show what would happen to a wick on an actual plane in a rainstorm if the airstream or some other action prevented the formation of water drops on the tips of the wicks. There was no effect on discharge and the wicks were still quiet.

16. Test 3c: Dischargers from test 3b were sprayed with more distilled water until droplets hung on the tips of the wicks. This test would show what would happen to a discharger on a plane in a rainstorm if water drops were formed on the tips of the wicks. There was no effect on discharge, but a considerable effect on noise. Results are given in Plate 10, voltage vs. noise.

17. Test 3d: Dischargers from Test 3c were soaked in "sea" water (water solution containing 29 g. NaCl and 4g. MgSO<sub>4</sub> per liter) and allowed to stand overnight (for approximately 20 hours). This test would give information about the performance of dischargers which were wet by salt spray when mounted on a seaplane taking off in salt water, and after flying for a while ran into snow or ice or any condition causing precipitation static which would not wet the wicks. There was no effect on discharge and no noise from any of the dischargers.

18. Test 3e: Dischargers from Test 3d were sprayed with distilled water, but not enough water was put on the wicks to cause droplets at the tips. This test would tell something about the performance of the dischargers on a seaplane which had taken off in salt water and then run into rain, supposing that the rain did not cause water drops on the tips of the wicks. There was no effect on discharge and no noise.

19. Test 3f: Dischargers from Test 3e were sprayed with more distilled water until droplets hung from the tips of the wicks. This test shows the effect of a rainstorm on wicks on a seaplane which had taken off in salt water, supposing the rain to cause water droplets to hang on the tips of the wicks, but before enough rain had passed through the wicks to wash out the salt. There was no effect on discharge but all wicks were noisy. Plate 11, voltage vs. noise, gives the result of the noise measurements.

20. Test 3g: Dischargers from Test 3f were placed so that distilled water dropped through the tips (see inset on Plate 12) and left until about one gallon of the distilled water had dropped through the tips of the wicks. Dischargers were then tested while droplets still hung from the tips of the wicks. This test would show the effect of a long rainstorm on the wicks, either on a land-based plane or on a seaplane, since the gallon of water dropping through the tip would do the same thing to the wick regardless of whether there had been a little salt water on the wicks at some previous time or not. Stated differently, this test shows whether the wicks are "washed out" by rain. There was a decrease in discharge currents, about 25% decrease for the glycerin and ethylene-glycol dischargers and about 15% for the metalized wick. The results of noise measurements for this test are shown in Plate 12.

21. Test 3h: Dischargers from Test 3g were squeezed out so that no water drops were hanging on the tips. This test would give data concerning the performance of the dischargers while passing through a heavy rainstorm, supposing no water drops to be on the ends of the wicks. Discharged currents remained at the same decreased level of Test 3g but the wicks were quiet.

22. Test 3i: Dischargers from Test 3h were allowed to stand for about 20 hours with the tips down. This test was performed to find out if the decreased discharge effect after the "washing out" would be overcome by supply of more liquid from the reservoir in the tube in the case of the liquid dischargers and by drying out in the case of the metalized wick. The liquid dischargers returned to the same discharge values of Test 3a but the metalized wick showed no change over Test 3g and 3h. However, the metalized discharger still discharged about 30% more current at a given voltage than the liquid impregnated dischargers.

23. The fourth test that was performed was an "evaporation" test on the liquid dischargers. A cotton wick was saturated with each of the two liquids, the ethylene glycol-water mixture and the glycerin-water mixture, and voltage vs. discharge and noise tests run. These voltage vs. discharge curves were the same as those in Plate 2 for the liquid dischargers, and there was no noise. Then the wicks were removed from the metal tubes and dried over a radiator for 24 hours, replaced in the tubes and again voltage vs. noise and discharge tests run. Plate 13 shows the results of these tests. The wick which had been impregnated with the ethylene glycol-water mixture was entirely useless as a static discharger, while the wick impregnated with the glycerin-water mixture had only decreased by about 15% to 20%. The glycol wick was very noisy; the glycerin wick was quiet.

## II. Flight Tests - Metalized Dry Dischargers

24. Although the foregoing laboratory tests of the metalized dischargers show that they are generally superior to the liquid dischargers, it was considered imperative that additional flight operational tests be conducted with the object of making a direct comparison between two metalized wicks and two liquid type dischargers in flight. A set of four retractable type dischargers was mounted on the wing tips of a B-25. These retractable dischargers could be operated in flight simply by operating a pump installed within the cabin. Moreover, it was possible to retract or extend any single discharger as required. The wing tip dischargers were mounted as shown in Plate 12 of the Sixth Partial Report (N.R.L. Report No. O-2281). Liquid dischargers were installed in the forward retractable mounting on the right wing and in the rear retractable mounting on the left wing. A pair of metalized wicks was similarly installed in the other two mountings. Thus in flight it was practicable to extend first, the two liquid type dischargers and then retracting these, one could extend the two metalized dischargers and make current discharge measurements. In this way the geometrical symmetry was preserved and a direct comparison could be made in flight between the liquid pair and the metalized pair. This comparison was made in the B-25, employing first the artificial method of charging the airplane described in the First and Third Partial Reports (N.R.L. Report Nos. O-1919 and O-2243). The results of this comparison are summarized in Plate 14. This plate shows that the metal and glycerin type dischargers behave in essentially the same manner, at the altitude and temperature existing during the experiments. It is now known that the resistances of these metalized dry dischargers were too high for best performance and, therefore, the two metalized dischargers did not perform as well at high discharge rates as did the two glycerin type dischargers.

25. Because artificial charging methods on the airplane might be criticised by the inexperienced, a further set of experiments was carried on at Watson Lake, Yukon Territory, in snow falling at  $-13^{\circ}\text{C}$ . Precipitation static conditions were severe in this area and a very good operational comparison between the dry metalized and liquid wicks could be made. The results of these experiments are summarized in Plate 15. It will be seen that the performance of the liquid and metalized wicks under these very adverse conditions was essentially the same. Because the dry metalized wicks require no servicing they are much more convenient to install and operate on the aircraft.

## RESULTS AND CONCLUSIONS

### A. Facts Established

26. The following results were noted:

- (1) Metalized wick is least affected by low temperatures, ethylene glycol-water impregnated wick more, and the glycerin-water impregnated one most.
- (2) None of the wicks become noisy at low temperatures.
- (3) Ethylene glycol-water impregnated wick is least affected by discharging a current over a long period of time, metalized wick more, and glycerin-water impregnated wick most.
- (4) After the first 18 hours discharging, the rate of decrease in discharge for the metalized wick and the ethylene glycol-water impregnated wick is about 1% per four hours discharge. The rate for the glycerin-water impregnated wick was five times as large, about 5% per four hours.
- (5) The discharge from the wicks is not affected by the presence of water on the tips. There is no effect on the noise from the wicks unless the water hangs in drops on the tips of the wicks. In this case, the metalized wick is least noisy, and the two liquid impregnated wicks about equal. (Plate 10).
- (6) The presence of "sea water" (water solution containing 29 g. NaCl per liter, 4 g.  $MgSO_4$  per liter) does not affect the discharge or noise from the wicks unless there are water drops on the tips of the wicks. Then the noise is least from the metalized wick and about equal for the two liquid impregnated wicks. (Plate 11).
- (7) All wicks are "washed out" by a large amount of distilled water passing through the tips, and the discharge current is decreased about 25% for the liquid impregnated wicks and 15% for the metalized discharger. The noise, when there are drops on the tips, from the liquid impregnated wicks, is more than for a wick that has not been washed out. The noise from the metalized wick shows no appreciable change.
- (8) After "washing out" the liquid wicks will return to their former discharge values, but the metalized wick will not. However, the metalized wick is still about 30% better than the liquid impregnated ones.
- (9) Evaporation effects are much greater for the wick impregnated with the ethylene glycol-water mixture than for the glycerin-water mixture. (Plate 13).

- (10) The behavior of the metalized wicks under actual operating conditions is essentially the same as the liquid impregnated type. (Plate 15).

B. Opinions

27. The metalized wick also has several advantages which should be emphasized here. They are:

- (1) It needs little or no servicing, that is, refilling, as do the liquid impregnated wicks.
- (2) It can be made as a short flexible cord since there is no need for a liquid reservoir, simplifying greatly the problems of mounting the dischargers on an airplane.
- (3) It is cheap to produce and apply to the plane.
- (4) Relatively more dischargers can be used on a plane with an increase in performance.

C. Conclusions

28. In general, the principal conclusions of all the tests included in this report are:

- (1) The metalized wick is a better discharger under all conditions tested than a liquid impregnated wick.
- (2) The wick impregnated with a mixture of 80% ethylene glycol-20% water is a better discharger than the wick impregnated with a mixture of 80% glycerin-20% water at temperatures below 0°C.

SUMMARY

29. Comparative measurements have been made on static dischargers which differed only in type of treatment used to render the wick conducting. These were:

- (a) Impregnation with glycerin-water solution, wet
- (b) Impregnation with ethylene glycol-water solution, wet
- (c) Impregnation with silver, dry.

These measurements included both laboratory and flight tests. The metalized dry wick was found superior in all respects.

## APPENDIX I

### Preparation of Conducting Wicks

1. Approximately two hundred conducting wicks were prepared according to the following directions. All two hundred were not made at one time; batches of 24 were used.

#### Materials:

Cotton wicking (12") for alcohol lamps from Arthur S. La Pine & Co.,  
Chicago, Illinois.  
Silver Nitrate C.P.  
Ethyl Alcohol 95%  
Sucrose C.P.  
Potassium Hydroxide C.P.  
Ammonium Hydroxide C.P.  
Nitric Acid C.P.

#### Preparation of Silvering Solutions:\*

##### A.Reducing Solution

2. Reducing solution is prepared by dissolving 90 grams of sucrose in 1000 ml. of distilled water. One hundred and seventy-five (175) ml. of ethyl alcohol (95%) and 4 ml. of concentrated nitric acid are added to the sugar solution. This solution is shaken well and allowed to stand at least one week before using.

##### B.Sensitized Silver Solution

3. It is advisable to prepare this solution fresh each day as some decomposition takes place.

4. Twenty grams of silver nitrate are dissolved in 300 ml. of distilled water and concentrated ammonium hydroxide added with constant stirring until the solution first turns a deep brown and then barely clears again. (Approximately 18 ml. required). A large excess of ammonium hydroxide should be avoided. A solution of 10 grams of potassium hydroxide in 100 ml. of distilled water is added with stirring to the ammoniacal silver solution causing it to turn dark brown or black. Ammonium hydroxide is again added with stirring until the solution clears. It should now be straw colored but transparent. A solution of 2 grams of silver nitrate in 30 ml. of distilled water is added slowly until a permanent precipitate is formed. The resulting solution contains considerable suspended matter but is not very dark. This is filtered through cotton or glass wool and is ready for use. The filtering does not remove all suspended matter.

#### Preparation of Cotton Wicks for Silvering:\*\*

5. The outer woven covering was removed from the cotton wicks and a quantity of the loose strands soaked in water containing a small amount of Aerosol OT

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\* From Amateur Telescope Making; Scientific American Publishing Co.

\*\* Prepared by Dr. Peter King, Chemistry Division, Naval Research Laboratory.

(about 1 - 2 ml. of 5% OT in 500 ml. of water and 24 wicks). After wetting, the wicks were thoroughly rinsed with tap water and finally distilled water, and allowed to remain under distilled water until used.

#### Silvering of Wicks:

6. The batch of strands from 24 wicks were squeezed to remove excess water and placed in a two liter beaker. To this was added 360 ml. of distilled water and 240 ml. of the silver solution and all mixed thoroughly. This was then cooled to 15°C in an ice bath, then removed from the bath. Seventy-two ml. of the reducing solution was added immediately and mixed well with the cotton strands and the other solution. The strands darkened rapidly as the silver was deposited. It was necessary to stir the mixture continuously for 10 - 15 minutes until the solution had deposited most of the silver and started to clear somewhat. At the end of this time the exhausted silver solution was decanted and the wicks rinsed with running tap water for approximately 15 minutes and finally with distilled water. The wicks were then dried at 105 - 10°C.

7. After drying, 12 silver strands were bunched and drawn through a 10" section of vinylite tubing (1/4" x 1/64"). The resistance was measured across the 10" portion with a 500 volt "Megger" having a scale covering the range 10,000 ohms to 100 megohms. The resistances of two sets prepared are given in Table I.

8. The initial resistance of the wicks is a function of the voltage applied. Some wicks show an infinite resistance when measured at 500 volts, but at 750 volts have a resistance of about 1/2 megohm. After this the same resistance is found when measured at 500 volts. Others will not break down until 2000 - 3000 volts are applied. Once broken down all wicks show some conductivity when measured at 500 volts.

9. Work is continuing on the preparation of a stable silver solution of sufficient concentration such that an immersion in the solution will deposit enough silver to give the proper conductivity. This would greatly simplify the preparation of the conducting wicks.

APPENDIX I

TABLE I

Batch #1

Batch #2

Resistance in megohms

0.10	0.045
0.12	0.10 (2)
0.17	0.12
0.20	0.14
0.20	0.15 (2)
0.20	0.20
0.25 (4)	0.25
0.30	0.25 (3)
0.40 (2)	0.30
0.45	0.35
0.50 (2)	0.40 (2)
0.60 (2)	0.45
0.80	0.50
0.90	0.60
1.3	0.70
1.5	1.0
2.0	2.0
Infinite	2.75

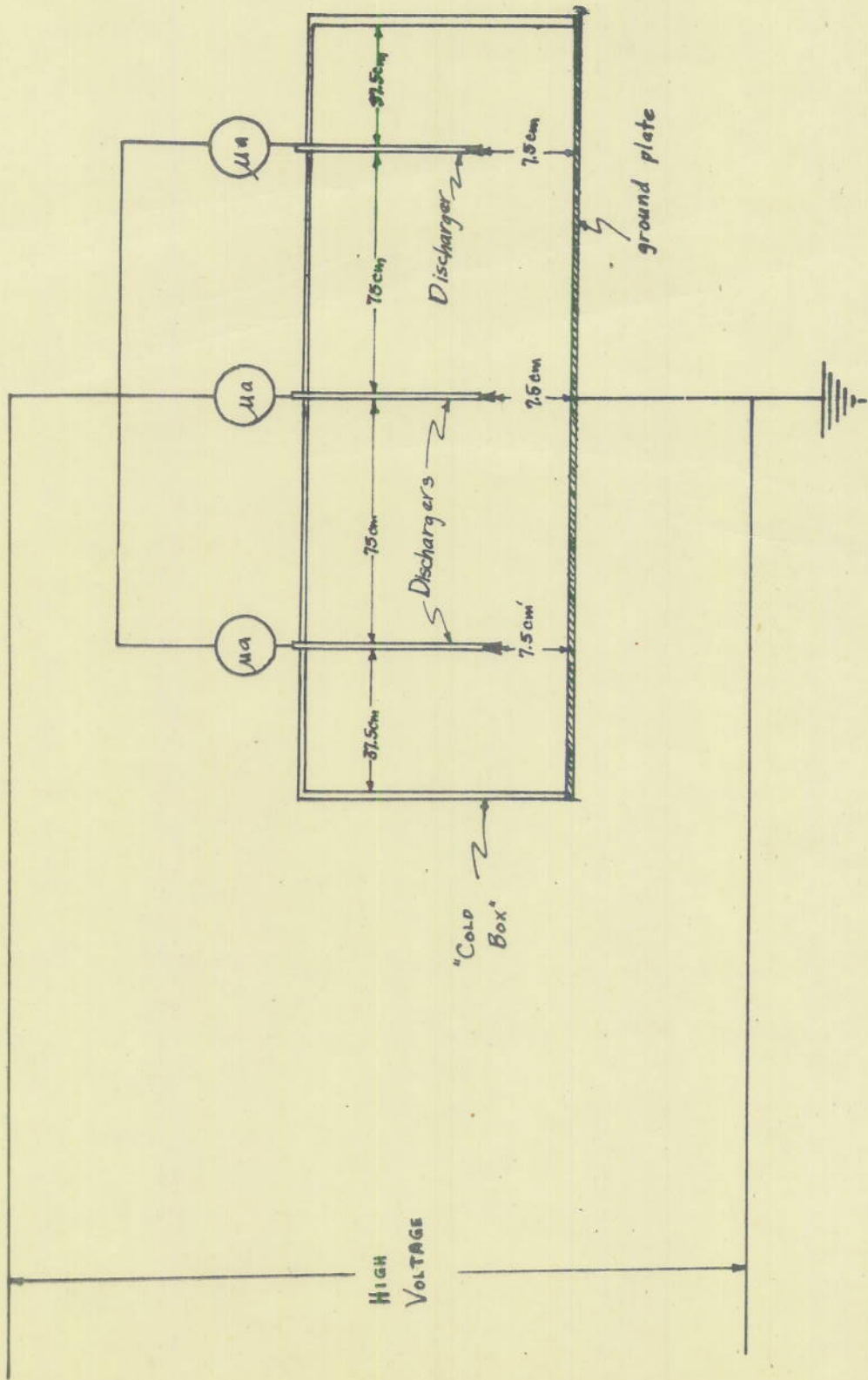
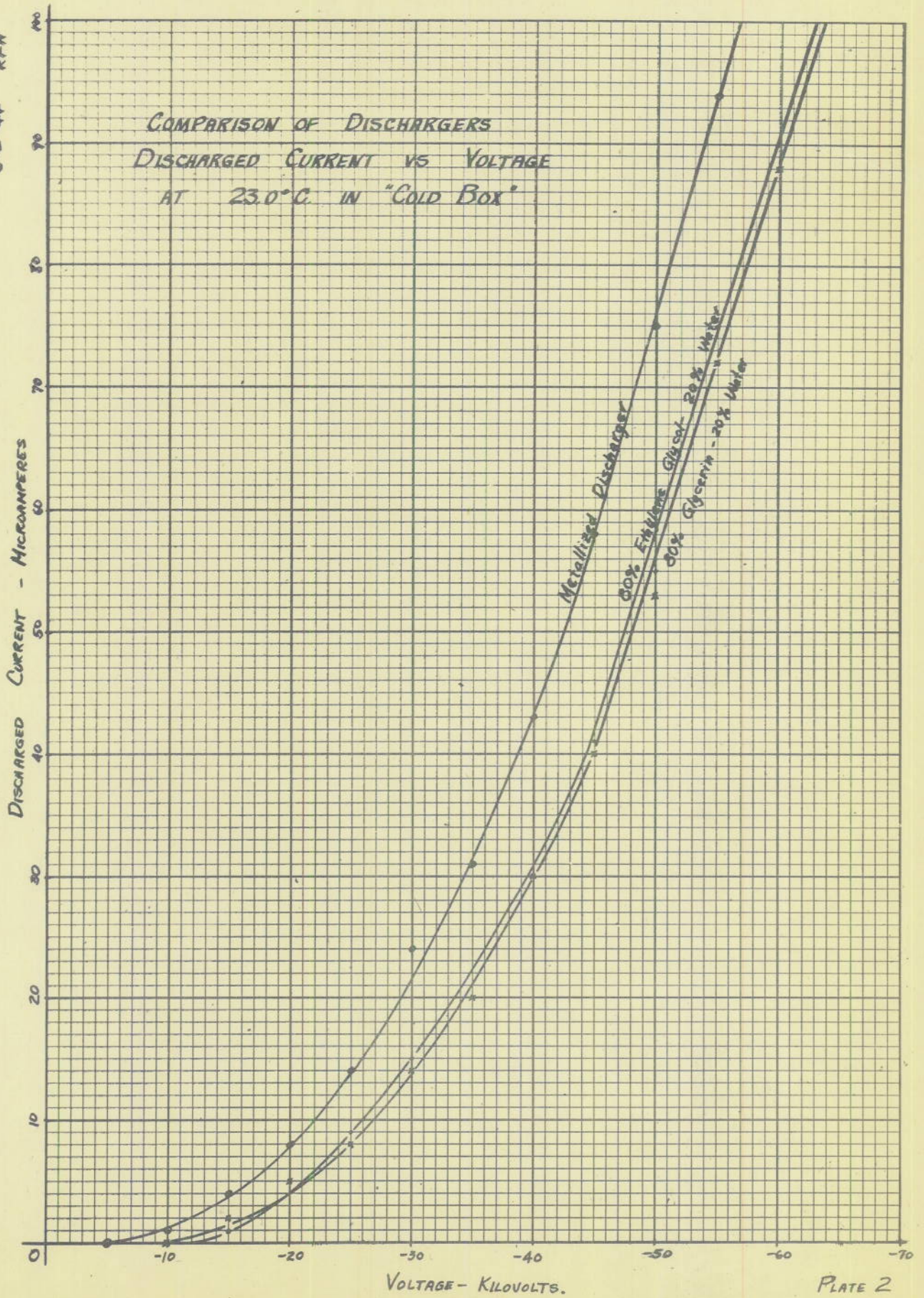


DIAGRAM OF ELECTRICAL CIRCUIT  
FOR TEMPERATURE VARIATION TESTS

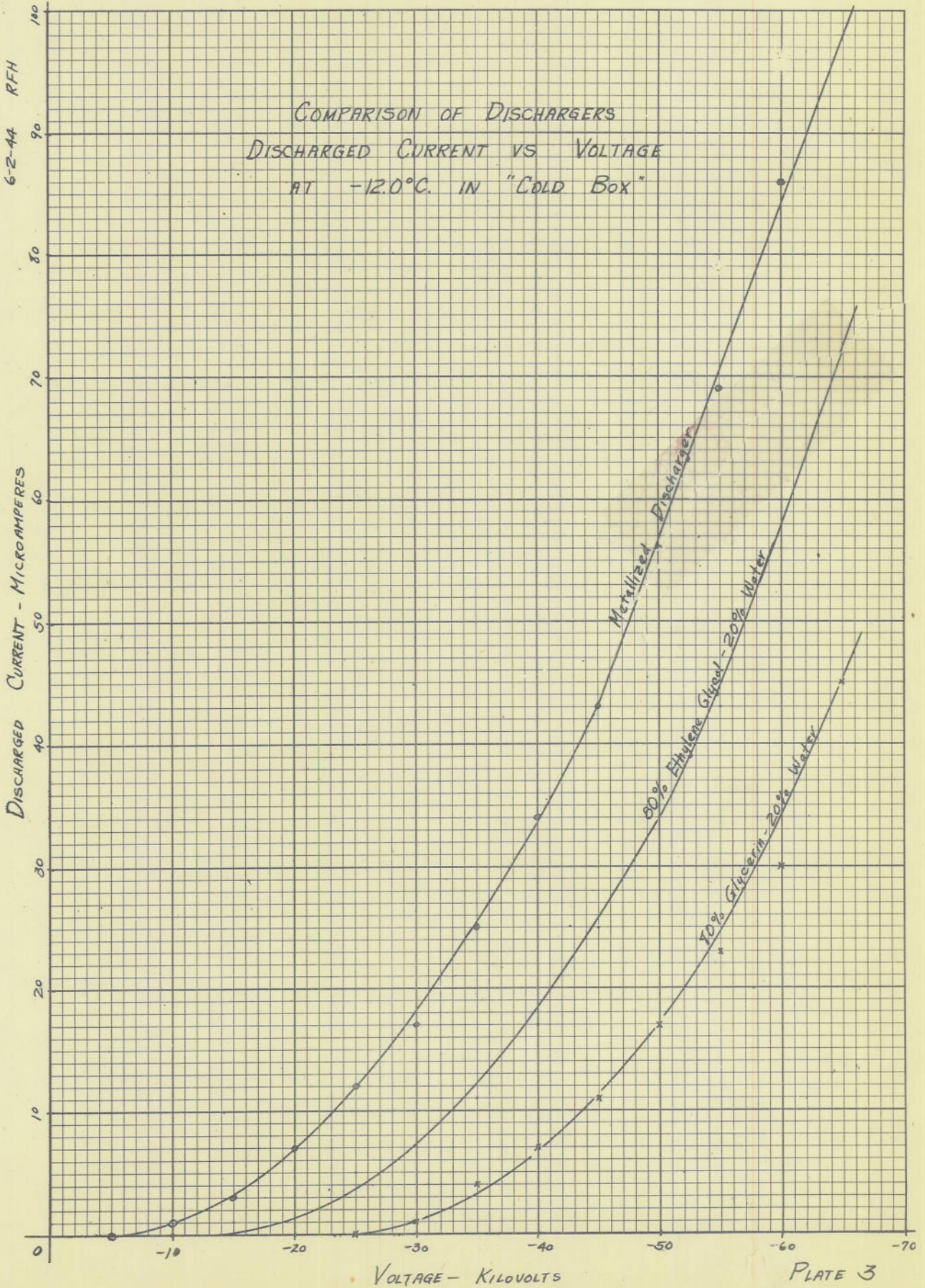
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COMPARISON OF DISCHARGERS  
DISCHARGED CURRENT VS VOLTAGE  
AT 23.0°C IN "COLD BOX"



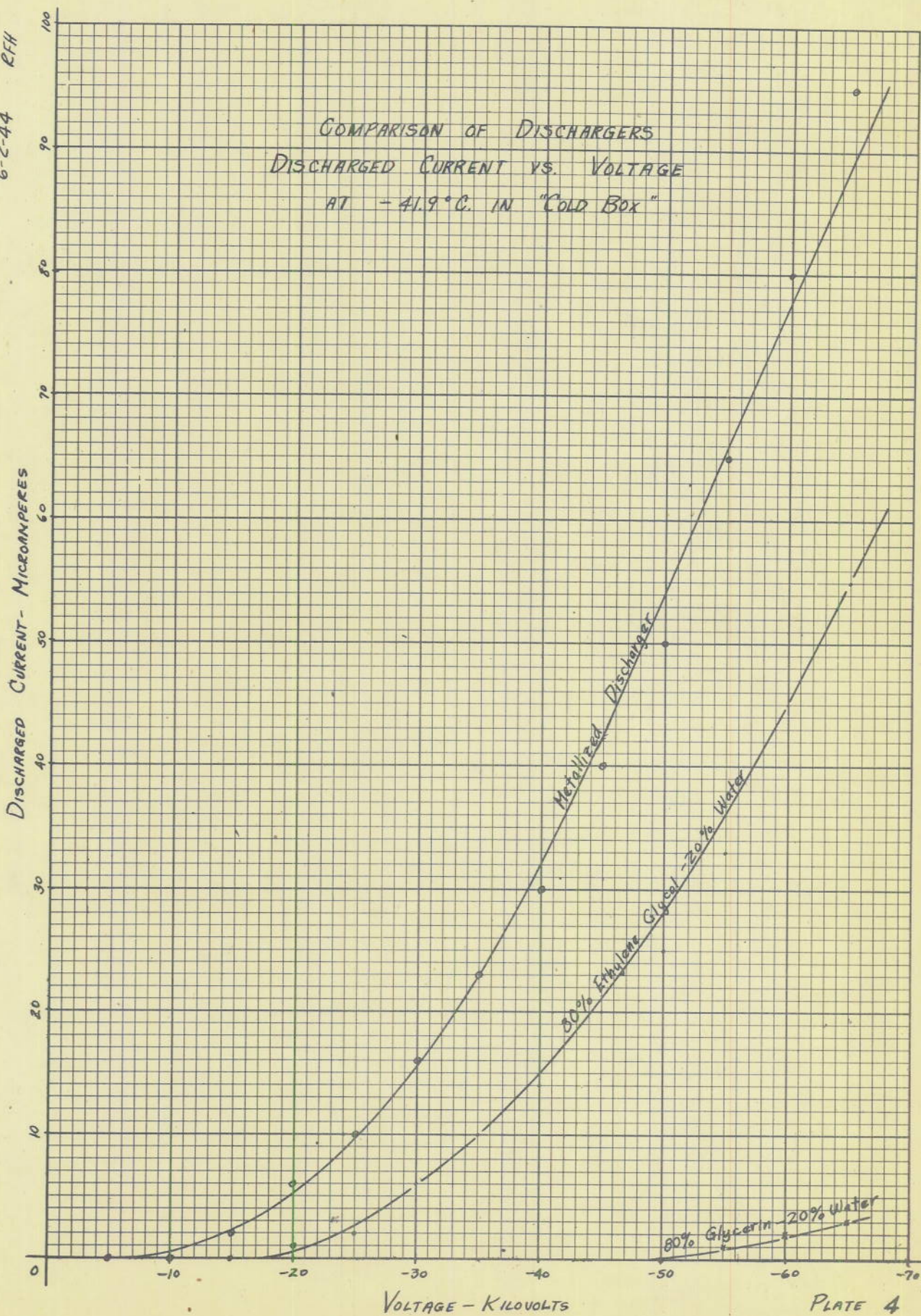
6-2-44 RFH

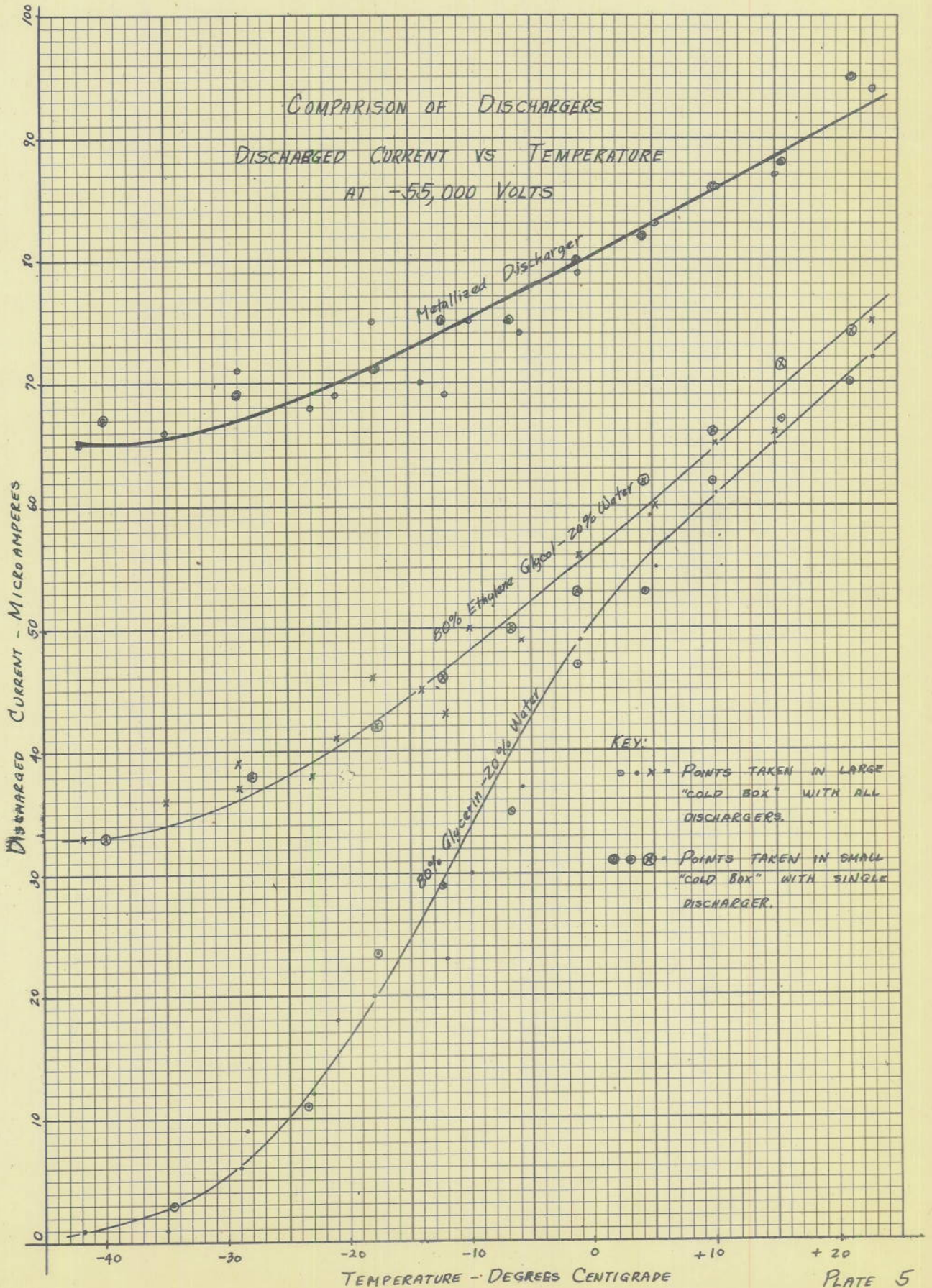
COMPARISON OF DISCHARGERS  
DISCHARGED CURRENT VS VOLTAGE  
AT -12.0°C. IN "COLD BOX"



6-2-44 RFH

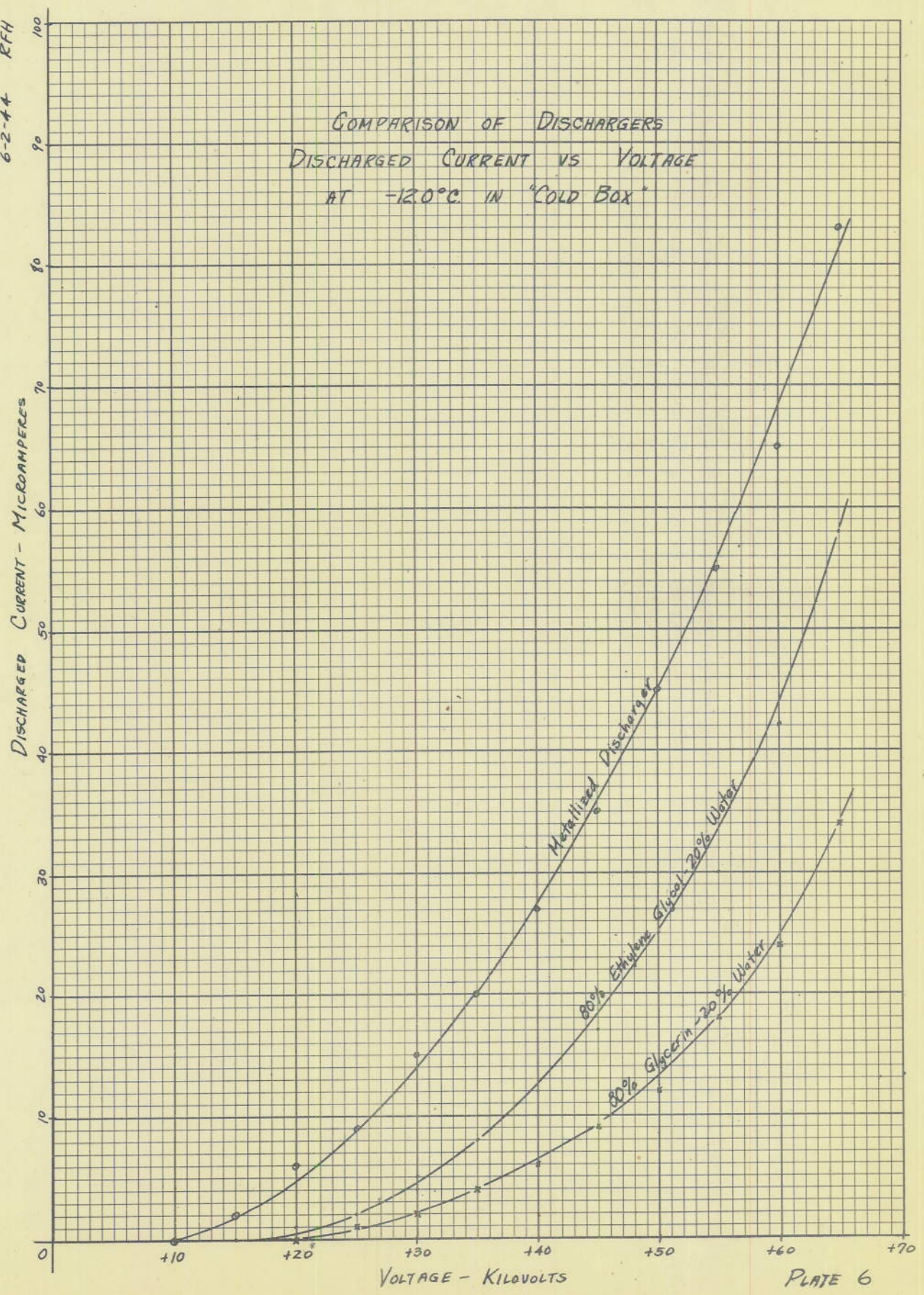
COMPARISON OF DISCHARGERS  
DISCHARGED CURRENT VS. VOLTAGE  
AT  $-41.9^{\circ}\text{C}$ . IN "COLD BOX"





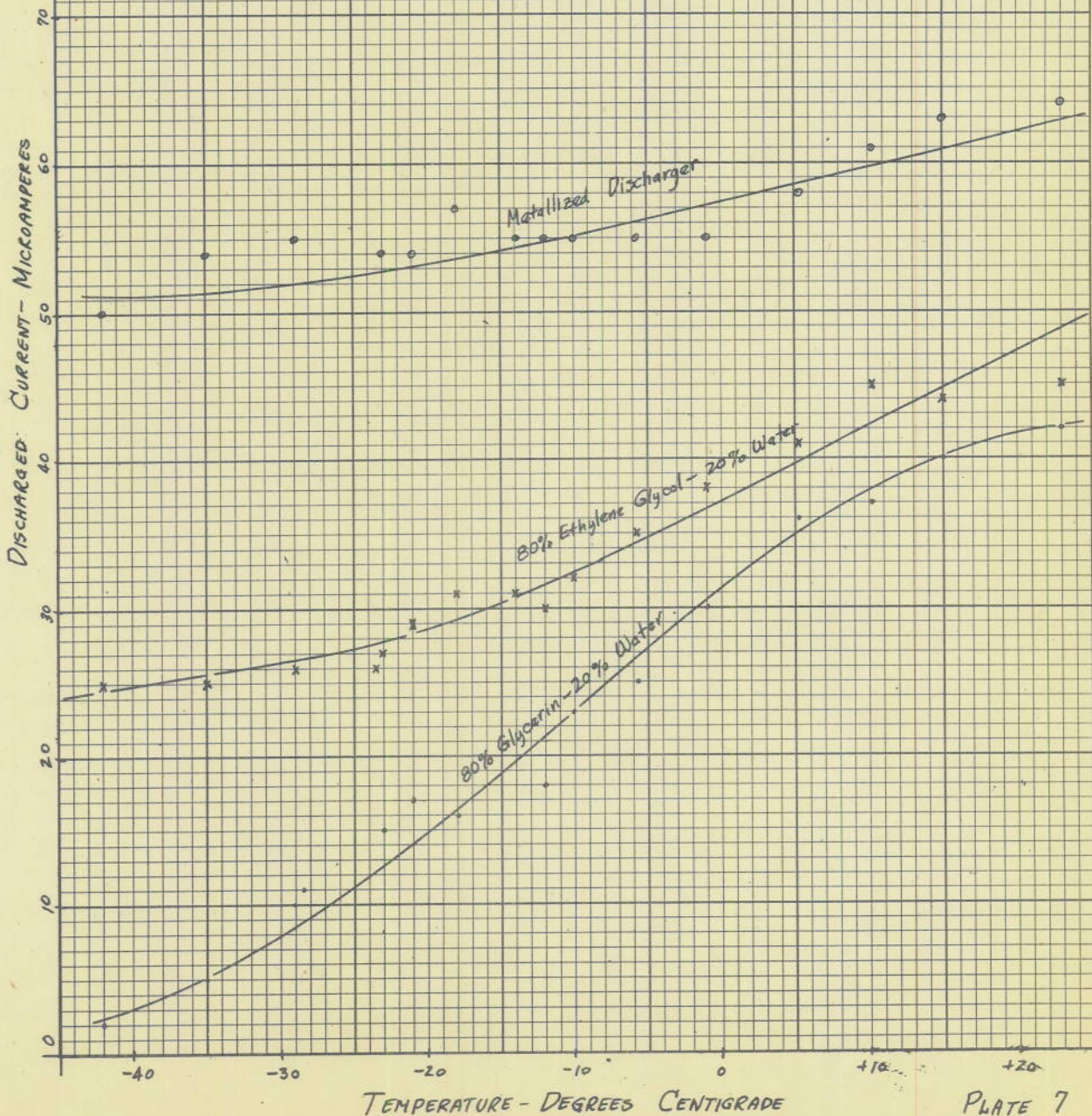
6-2-44 RFH

### COMPARISON OF DISCHARGERS DISCHARGED CURRENT VS VOLTAGE AT -12.0°C. IN "COLD BOX"



6-2-44 RFH

COMPARISON OF DISCHARGERS  
DISCHARGED CURRENT VS TEMPERATURE  
AT +55,000 VOLTS



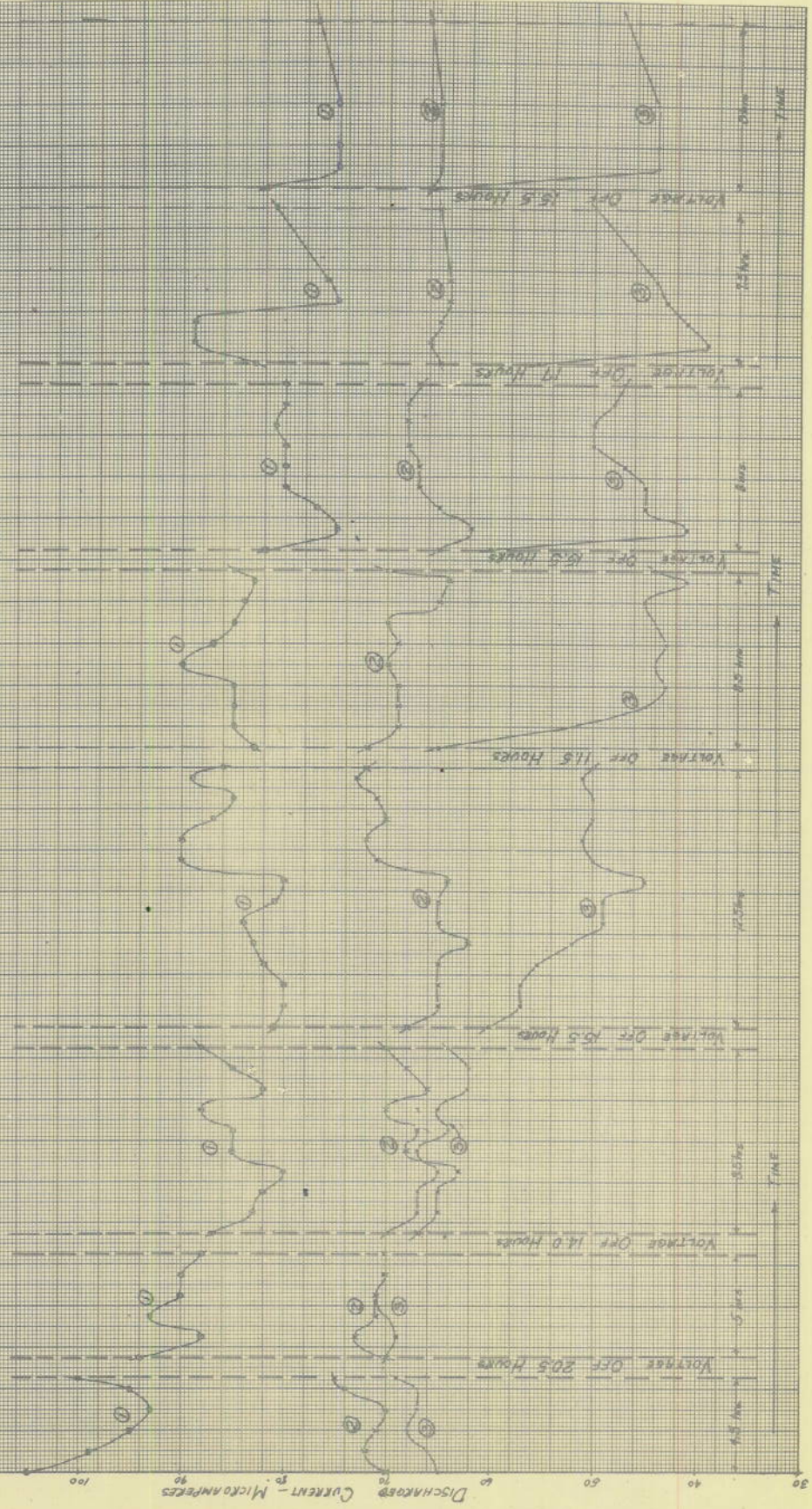
6-2-44 KFH

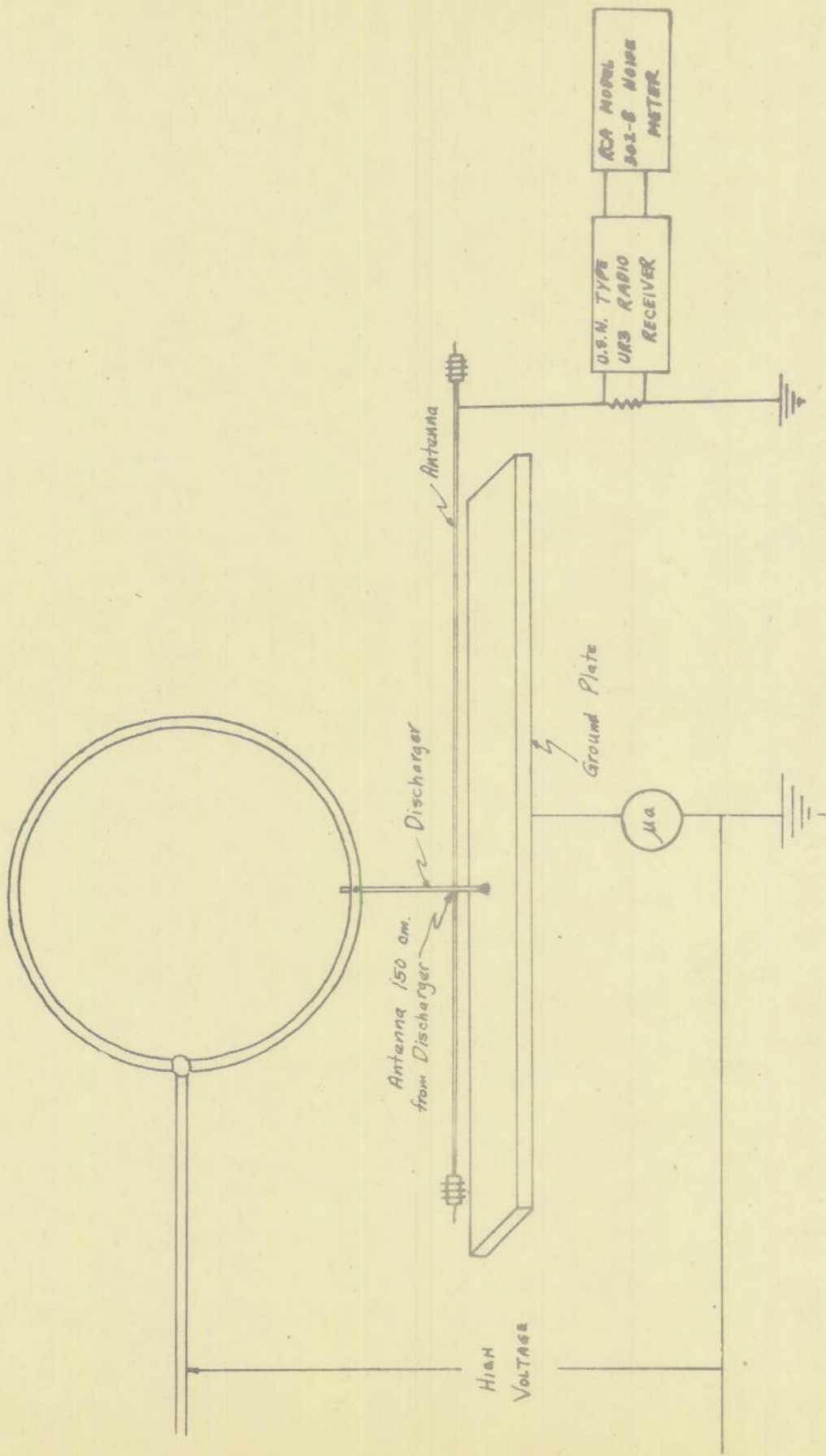
COMPARISON OF DISCHARGES

STABILITY UNDER DISCHARGE OVER A LONG PERIOD OF TIME

AT 60,000 VOLTS

- ① Methyl Disulfide
- ② 80% Ethylene Glycol-antifreeze
- ③ 50% Glycerin - 20% Water





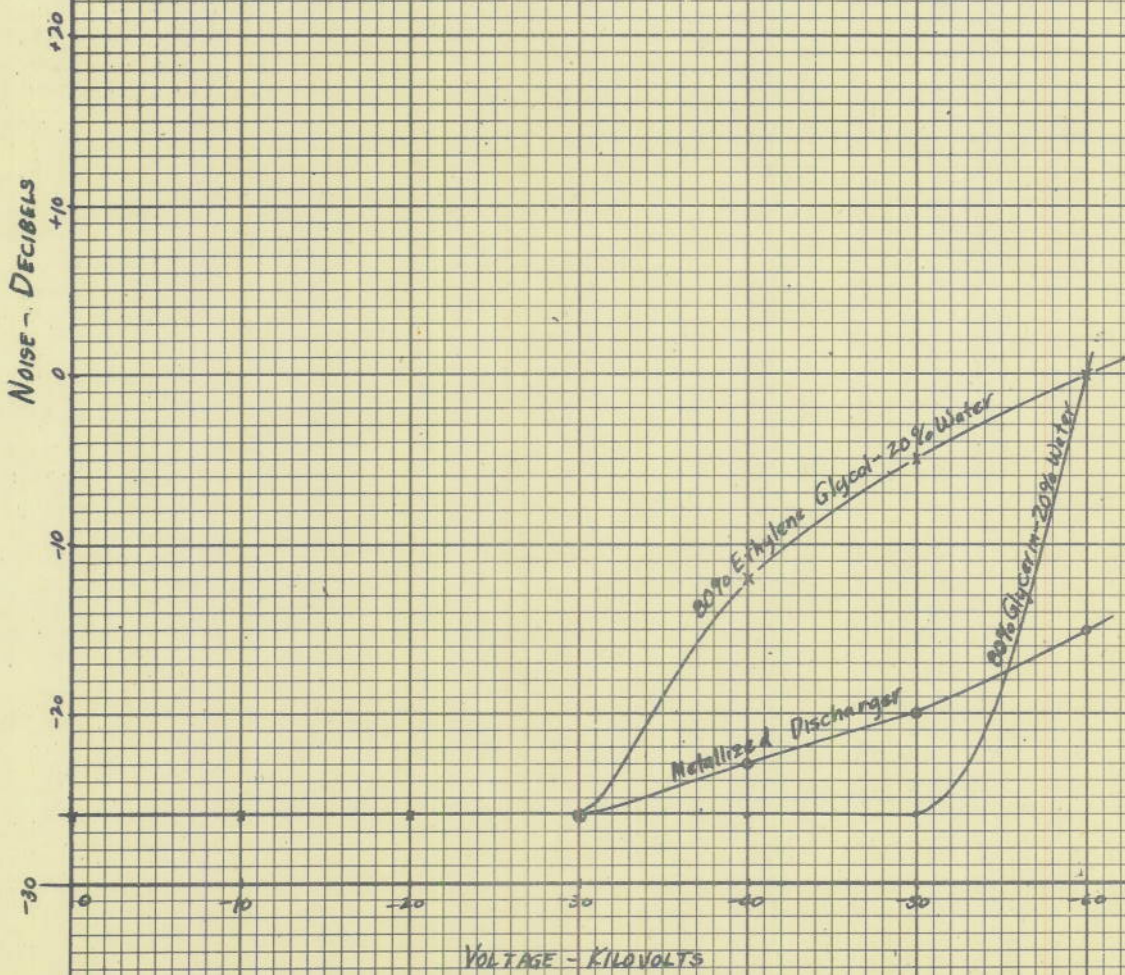
SCHEMATIC DIAGRAM OF DISCHARGER TESTING APPARATUS

6-2-44 RFH

### COMPARISON OF DISCHARGER

#### VOLTAGE VS NOISE

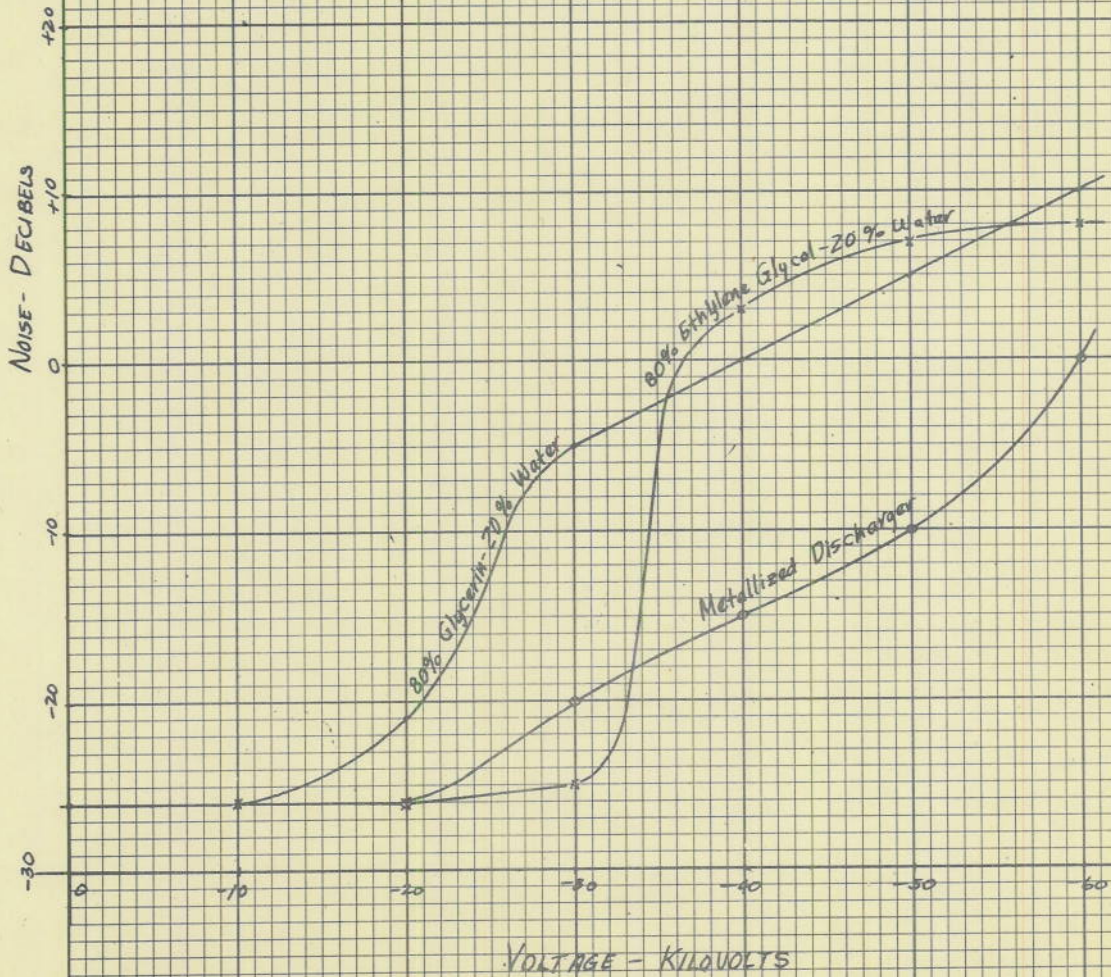
(When dischargers are sprayed with distilled water so that droplets hang on tips.)



G-2-44 RHH

### COMPARISON OF DISCHARGERS VOLTAGE VS. NOISE

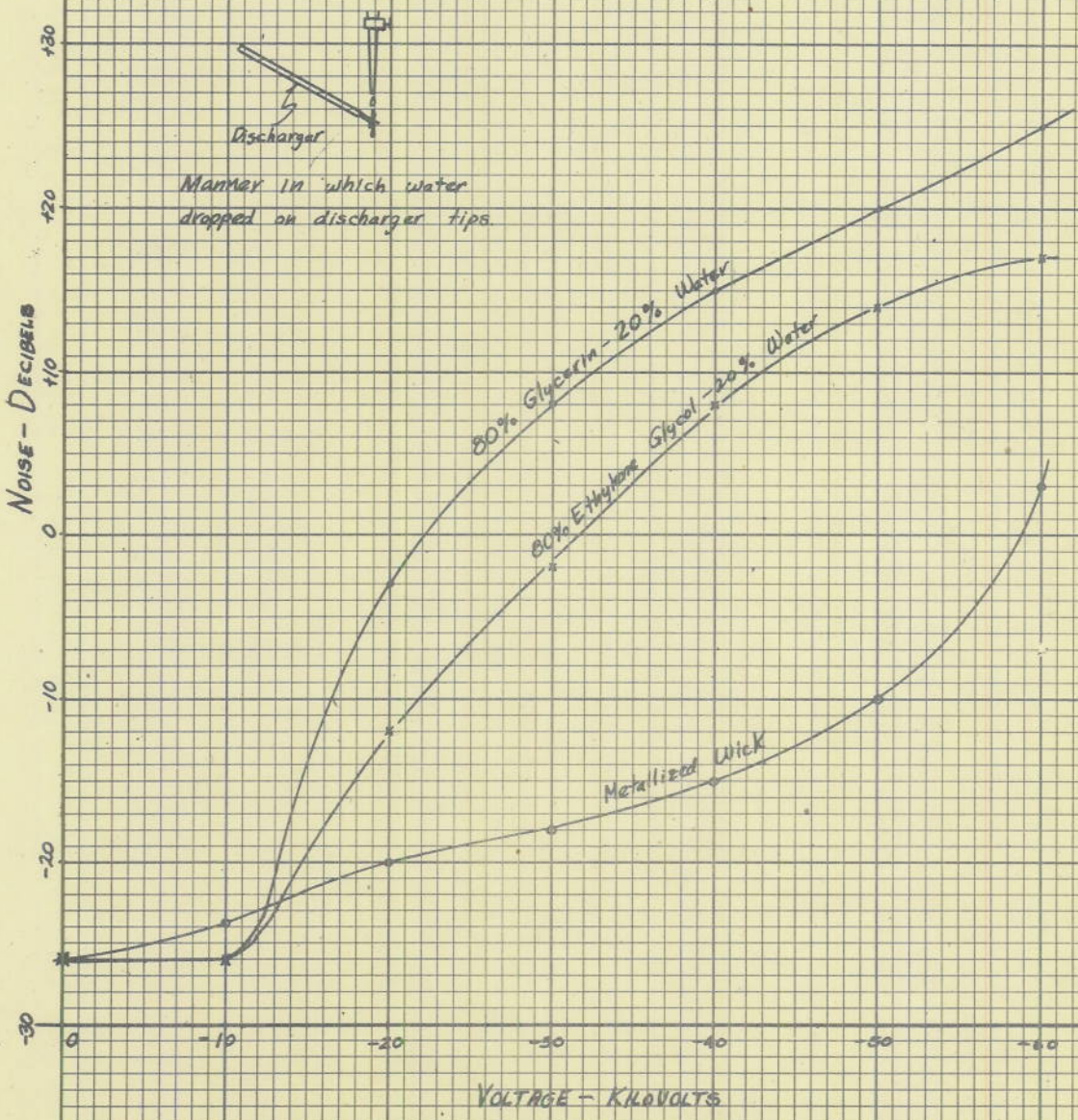
(After dischargers were sprayed with "sea" water [29 g. NaCl per liter, 4 g.  $MgSO_4$  per liter] and left standing 20 hours, then sprayed with distilled water so that drops hung on tips.)



6-2-44 RFH

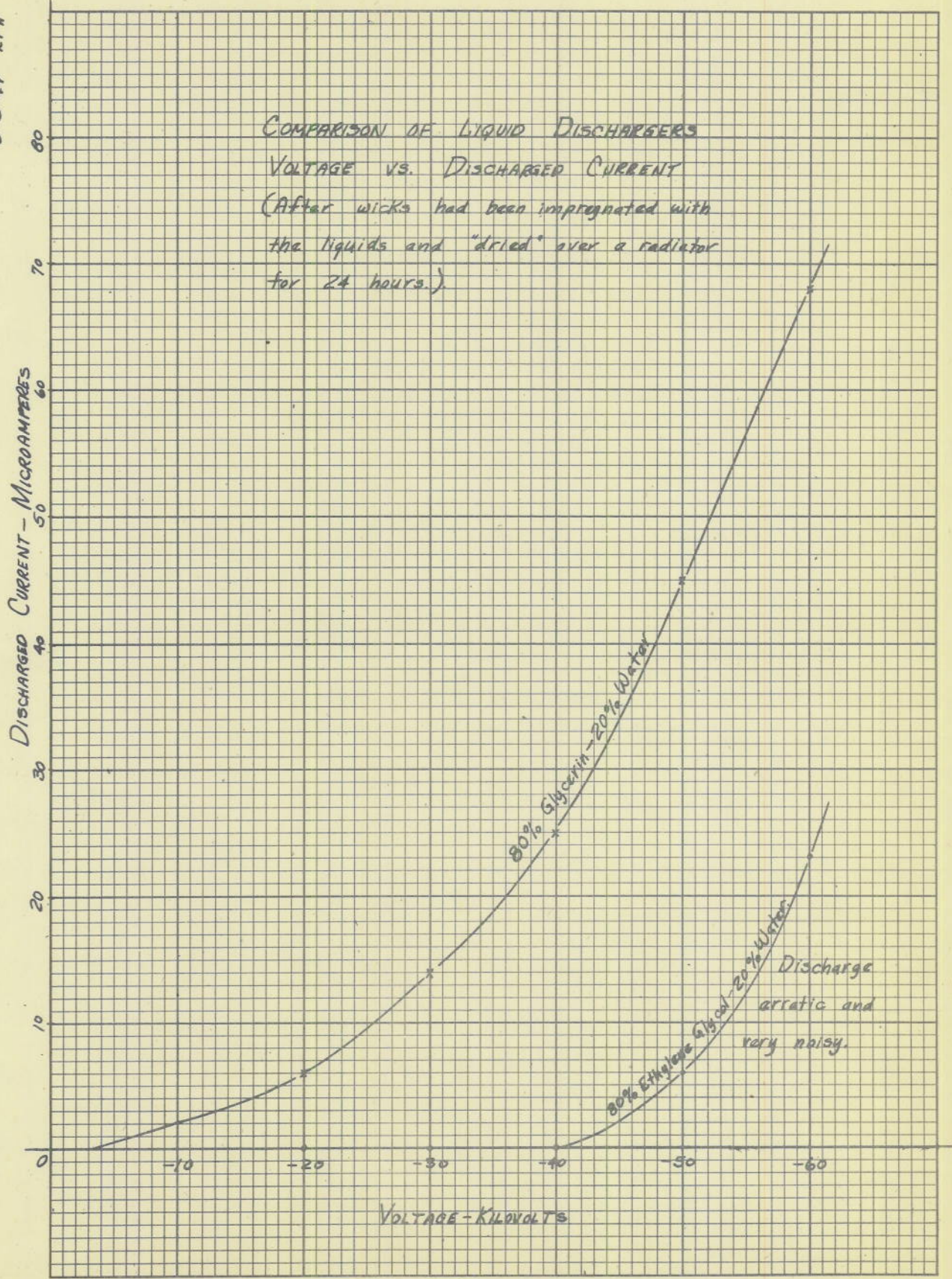
### COMPARISON OF DISCHARGERS VOLTAGE VS NOISE

(After one gallon of distilled water had dropped on tips and water drops hung from tips.)



6-5-44 RFI

COMPARISON OF LIQUID DISCHARGERS  
VOLTAGE VS. DISCHARGED CURRENT  
(After wicks had been impregnated with  
the liquids and "dried" over a radiator  
for 24 hours.)



6-19-44 RFH

COMPARISON OF METALLIZED AND GLYCERIN WICKS  
Charging Current vs. Field

