

GENERAL ELECTRIC COMPANY
Electronic Components Division
Technical Information Series

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THE RELATIONSHIP OF CATHODE LIFE
TO CATHODE TEMPERATURE AND ENVIRONMENT IN
COMMERCIAL CATHODE RAY PICTURE TUBES

P. P. Coppola

I. Introduction

Among others, there are two important questions that often arise in respect to increasing the life of oxide cathodes in commercial cathode ray picture tubes, namely (1) what influence does temperature have on cathode life? and (2) what is the most desirable operating cathode temperature? The answer to the second question follows naturally from the investigation of the first.

Cathode life in general denotes the ability of a cathode to maintain stable emission current of sufficiently high density for a maximum period of time. The availability of such an emission current for many hours of cathode ray tube operation implies an ample space charge cathode condition well beyond the requirements necessary to maintain some desirable electron beam characteristics.

Many basic investigations concerning the relationship of oxide cathode life to cathode temperature have been made in past years and are reported in the literature so that some answers in respect to high and low temperature limits are immediately available.

High temperature limits are imposed on a cathode by several deleterious thermal effects on emission. These include the sintering and evaporation of the emitter material; the evaporation of the base metal and its reducing constituents; and the excessive chemical reaction between the emitter material and the reducing constituents in the base metal. Other problems follow such as loss in vacuum and an increase in leakage due to deposition of evaporants on to internal tube components. Below extreme levels, however, a high cathode temperature can provide a very high reserve of space charge emission current, but certainly at the expense of life.

Some of the principle effects which impose a lower limit on a cathode temperature are the loss of space charge; and an adverse shift in the dynamic equilibrium between constituents responsible for electron emitter activity and oxidizing constituents present in the surrounding environment.

As indicated above, physical and chemical principles do govern the temperature extremes within which an oxide cathode can actually function as a satisfactory emitter. But it is very difficult to predict a specific operating temperature for a specific tube type. In respect to cathode ray picture tubes and for many other commercial tubes as well, the difficulty is due in large part to the presence of many pertinent factors which can affect cathode environment. These would include the number and type of tube component materials present, the processing involved, and the operating conditions to which the tube is subjected during life. Since these factors exert a strong influence on cathode emission characteristics through environment, it is often necessary that the final determination of a satisfactory operating temperature be done

through the empirical variation of cathode temperature in the tube type under question. Such an empirical approach would imply that the environment surrounding each cathode is guaranteed to be nearly the same for all. Such a condition is not likely to be achieved, however, when single cathodes tested at different temperatures in single tubes are compared since the cathode temperature itself can influence the environment. On the other hand, when several cathodes under test at different temperatures in a single tube are compared, a condition of similar environment for all is approached more closely and thus an internal control is automatically obtained.

Since there appeared to be obvious environmental advantages to be gained in the use of a multi-cathode single tube approach for the determination of a desirable cathode operating temperature, this method was used for all of the experimental work described in this report.

II. Experimental Methods

For our investigation a 17 inch, 70 degree tube type with a 2 inch O.D. neck was used. In such a tube, 3 cathodes mounted in 3 electron guns joined together could be accommodated on a single 14 lead stem. Details of the gun assembly are shown in Figures 1 and 2. Each of the cathodes in a tube can be operated at some test temperature independently of the others. All cathodes in a tube can undergo life testing simultaneously.

Two series of tubes were prepared for life test. Series 1 consisted of 7 tubes and Series 2 consisted of 6 tubes. For Series 1, the 3 cathodes in a tube were adjusted to temperatures of 800°C, 875°C, and 950°C respectively; and for Series 2, the cathodes were adjusted to temperatures of 750°C, 800°C, and 850°C respectively. The 800°C temperature for one cathode in all of the tubes tested provided a base line for the comparison of data between tubes of Series 1 and 2.

Factory cathodes were used for all of the tests. These were of the planar indirectly heated disc type using (Ba, Sr, Ca) CO₃ triple carbonate emission coating sprayed to a thickness range of 0.0025-0.0030 inch on to special 330 nickel. The coating density was approximately 1 gram/cc. Other tube component materials and the procedures used for screening, aluminizing, and inside painting of the bulbs were the same as for current factory production. The exhaust, activation, and aging schedules on the tubes were carried out in the laboratory and differed somewhat from the schedules used in the factory since 3 cathodes instead of one were involved. Life and electrical test conditions followed standard factory practice closely.

On exhaust, the tubes were baked at 400°C for 1/2 hour, and cooled. When the pressure in a tube dropped to below 0.005 micron, the 3 ring channel getters (32 mg barium each) were outgassed by RF at a temperature of 700-800°C optical for 1 to 2 minutes. Next, the grid 1 was outgassed by RF at a temperature of 700-800°C optical for 10 minutes. The RF was turned off before activation of the cathodes was started. The 6.3 volt 600 ma heaters of the 3 cathodes were

connected in parallel. The temperature of the heaters was raised gradually so as not to allow the pressure in the tube to exceed 0.04 micron. When the maximum of the heater current range (1.58-2.55 amps) was reached, the heaters were dropped to 1.86 amps, and held until the pressure in the tube dropped to below 0.004 micron. At this point, the heaters were shut off. The tube was tipped off and the 3 ring channel getters were RF flashed simultaneously.

The cathodes in each tube were aged simultaneously. The three heaters were connected in parallel and 11.5 volts were applied for 2 minutes. The heaters were dropped to 9 volts; +4 volts were applied to each grid 1, and +550 volts were applied to each grid 2. These conditions were maintained for 19 minutes. After the aging schedule was completed, each tube was cooled for several hours before proceeding with the initial electrical tests.

The electrical tests were made separately for each cathode operated with 6.3 volts on the heater. The measurement of emission build-up ratio (1), 50 volt emission (2), cut-off voltage (3), and gas ratio (4), were made in proper sequence.

For life test, the heater current of each of the 3 cathodes in a tube was adjusted independently to achieve the desired cathode temperature mentioned previously. The heater current-temperature relationship had been determined previously through thermocouple measurements. A total beam current of 210 microamperes was drawn from the 3 cathodes in each tube. 450 volts were applied to grid 2 and 18,000 volts were applied to the anode of the gun. A full raster was maintained. During life, periodic electrical tests were made after 100, 250, 500 hours, and etc. After each interval, the tube was cooled for at least 3 hours before measurements were made on the first cathode. At least 20 minutes waiting time was allowed before making each of the subsequent measurements on the second and third cathodes. Cathode electrical test sequences were randomized for each tube so as to average out any poisoning effects which might have occurred on the two standby cathodes during the measurement of one.

- (1) Emission build-up is a ratio of cathode DC emission measured in the grid 2 circuit with grid 1 zero bias after 30 seconds and after 3 minutes from the time the heater is switched on.
- (2) 50 volt emission is a measure of the cathode DC emission for a particular gun configuration and cut-off normalized to a 50 volt cut-off condition.
- (3) Cut-off is the amount of grid 1 bias voltage required to decrease cathode DC emission in grid 2 circuit to zero.
- (4) Gas ratio is the relation of positive ion current to beam current in grid 2 circuit. It is a relative measurement of residual gas pressure in a tube through the arrangement of its gun electrodes to serve as an ionization gauge. Factory calibration show the ratio to be a factor of about 10 greater than micron gas pressure.

III. Experimental Results

The life testing of tubes in Series 1 was terminated at 2,000 hours since an indication of the emission build-up ratio and 50 volt emission trends was seen well before this time. However, with Series 2 tubes, wherein a lower cathode operating temperature was maintained, the emission trends were not evident early in life especially at relatively low gas ratios. Thus, life testing was continued well beyond 2,000 hours.

At the present time, the initial or 0 hour factory criteria for tube acceptance are a level of 450 microamperes emission in 30 seconds from the time the heater is switched on to 6.3 volts and a 50 volt emission level of 800 microamperes at equilibrium cathode temperature with the heater at 6.3 volts. For tube life, the factory criteria are 100 microamperes emission in 30 seconds and 55 percent of the original 50 volt emission, both at 2,000 hours life. Further tests to determine standards of life beyond 2,000 hours are in progress.

Representative emission and cut-off data obtained from tubes in Series 1 and 2 are listed in Table 1 a, b, c, and d. Emission results from tubes with relatively low and relatively high gas ratios are compared. The emission results for all of the tubes tested are plotted in Figures 3 to 15 inclusive. The figures include the gas ratio data obtained periodically during life.

Examination of the data in Table 1 b and d, and of the data in Figures 7, 8, and 9 of Series 1; and 13, 14, and 15 of Series 2, obtained at relatively high gas ratios, shows clearly that regardless of the cathode operating temperatures used, a high level of gas can adversely influence both emission build-up ratio and 50 volt emission to a great degree. Such evidence points out how very important the surrounding environmental condition are when examining cathode thermal characteristics.

Examination of the data in Table 1 a and b, and of the data in Figures 3, 4, 5, and 6 of Series 1; and 10, 11, and 12 of Series 2 obtained at relatively low gas ratios shows that thermal conditions as affecting cathode emission and life characteristics can be resolved. For example, temperatures of 875°C and 950°C show a definite drop in 50 volt emission with life well in excess of that obtained at lower cathode temperatures; also, the sensitivity of the emission build-up ratio to high cathode temperatures is shown by a pronounced drop very early in life. The serious drop in emission build-up noted particularly for the 875°C and 950°C cathodes temperatures may have resulted from an excessive gas condition localized in the immediate vicinity of the cathode due to increased material evaporation on to and more energetic bombardment of the grid 1 components.

The results of 50 volt emission at 2,000 hours life taken from Figures 3, 4, 5, 6, 10, 11, and 12 are summarized in Figure 16. It will be noticed in this figure that slightly lower values of 50 volt emission are obtained from cathodes operating at 800°C in series 1 tubes than are obtained from cathodes operating at the same temperature in series 2 tubes. This difference may be a coincidence, however, it is suspected that a slight adverse shift in cathode equilibrium may have occurred in series 1 tubes due to change in the total

environmental condition contributed to by the cathodes operating at considerably higher temperatures. During the planning period of the complete experimental program described in this report, it was believed that just such an effect might occur and thus a base line cathode temperature of 800°C was included as a control in both series of tubes.

The comparison of both the 50 volt emission and emission build-up data collected from all tubes tested under relatively low gas ratios shows that 750°C and 800°C cathode operating temperatures give consistently better results in peak emission for optimum life. A cathode temperature of 850°C is borderline. Temperatures of 875°C and especially 950°C are obviously too high for long life.

Even under the most ideal environmental conditions, it should be expected that an oxide cathode operating temperature of 950°C will give a relatively shorter life when compared to lower temperatures simply through increased evaporation of barium oxide emitter material. Table 2 lists the evaporation of barium oxide in gram per square centimeter area per hour as a function of cathode temperature from a (Ba Sr Ca) O triple oxide emitter coating on passive nickel. These figures were obtained from instantaneous barium oxide evaporation rate data⁵.

It should be pointed out that the actual evaporation of barium oxide from a coating of finite thickness decreases with time, so that its total loss over some period will be smaller than the product of instantaneous evaporation vs. hours time shown in Table 2. However, the instantaneous evaporation rate data do show that a considerably greater loss of barium oxide (a factor of 1,000) can occur at 950°C when compared to 750°C .

In spite of the greater loss factor of the emitter constituent that can result from higher cathode operating temperatures, the experimental test data described in this report show that non-ideal environmental conditions can impose even greater limitations on cathode life than can be due to evaporation as such.

IV. Conclusion

Experimental data have shown that in the test temperature range of 750°C - 950°C used, optimum life is achieved by cathodes operating at temperatures of 750°C and 800°C . Greatest emission decay with life is shown for cathodes operating at 875°C and 950°C . A temperature of 850°C is borderline. For any of the test temperatures investigated, it is shown that where a relatively poor environmental condition exists, namely in the vicinity of approximately 0.05 gas ratio and greater, a severe limitation is imposed on emission and consequently on tube life.

Acknowledgment

The writer wishes to express his thanks to all of the laboratory personnel whose contributions helped toward the successful completion of this work.

- (5) M.D. Gibbons "Evaporation Rate of Oxide Cathodes by X-Ray Emission Spectrometry" paper M-7 of the American Physical Society Summer Meeting in the East, Ithaca, N. Y., June 1958.

TABLE 1

Series #	Part	Tube #	Hours Life	Emission Build-up Ratio	50 Volt Emission Microamperes	% Original 50 Volt Emission	Gas Ratio
1	a	11511B	0 170 540 1019 1571 2000	800° .895 875° .615 950° .485 905 .625 935 .635 880 .145 1019 .029 835 .093 1571 .024 2000 .089 906 .025	800° 1080 875° 1110 950° 1160 1090 1060 1100 1060 1090 1010 980 580 1040 960 1030 760 550 1000 630 470	800° 100 875° 100 950° 100 101 95.6 102 93.5 96.5 88.4 95.6 69.5 92.6 56.7 40.1	.0005 .0005 .0025 .004 .003 .003 .002
Relatively low							
1	b	10381B	0 49 113 255 494 750 1056 1420 1683 1981	920 .955 840 .925 900 .670 971 .900 878 .540 965 .576 300 .300 848 .000 1056 .000 1420 .000 1683 .000 1981 .000	1235 1290 1305 1200 1290 1330 1200 1290 1230 1130 1220 1190 1120 1070 280 750 530 370 560 70 50 30	100 104 97.0 94.5 98.6 94.5 104 91.2 88.4 99.0 82.4 71.6 39.3 27.4 6.3 45.3 27.4 5.7 3.7 2.4	.0025 .002 .002 .002 .0018 .002 .057 .10 .10 .10 .14
Relatively high							
2	c	A28J1B	0 158 251 499 994 1503 1974 2478 2716 3100 4249 4620 5108	750° .930 800° .769 850° .920 894 .963 915 917 .933 763 905 .981 820 918 .943 819 905 .692 1503 .950 1974 .872 312 2478 .838 725 2716 .770 795 3100 .850 480 780 .850 4620 .800 810 5108 .815 250 355 .660 000	750° 1320 800° 1190 850° 1360 1250 1150 1170 1250 1180 1160 1270 1200 1170 1250 1150 1170 1280 1160 1160 1040 920 920 1010 1130 920 905 620 720 396 850 0	750° 100 800° 100 850° 100 94.8 96.7 99.2 100.1 96.5 86.2 94.8 96.7 97.2 85.6 76.6 67.5 67.5 66.5 45.5 52.8 0	.001 .001 .0018 .002 .0025 .0025 .002 .003 .003 .003 .0028 .0025 .0028 .0028 .0028 .0028
Relatively low							
2	d	B26J1B	0 150 238 495 982 1507 2011 2503	.889 .911 625 .703 818 720 269 100 333 100 080 0 10 0 215 0 0	1200 1300 1200 1230 1170 1170 1240 1120 1020 960 620 210 130 55 147 65 55	100 108.3 100 102.5 103.5 85.0 38.2 13.3 8.3 5.4 12.2 4.7	.0038 .0042 .005 .15 .18 .10 .15 .18
Relatively high							

TABLE 2

Coating Temperature	Ba O Evaporation Rate
<u>°C</u>	<u>Gram/cm²/hour</u>
750°	1.8×10^{-9}
800°	1.1×10^{-8}
850°	7.2×10^{-8}
875°	1.8×10^{-7}
950°	1.8×10^{-6}

ENGINEER P.P. Coppola

GLASS _____ GUNS _____
COMPLETE BEST _____ MOUNTS _____
THODE INFORMATION _____

GUNS _____ E. T. I. _____

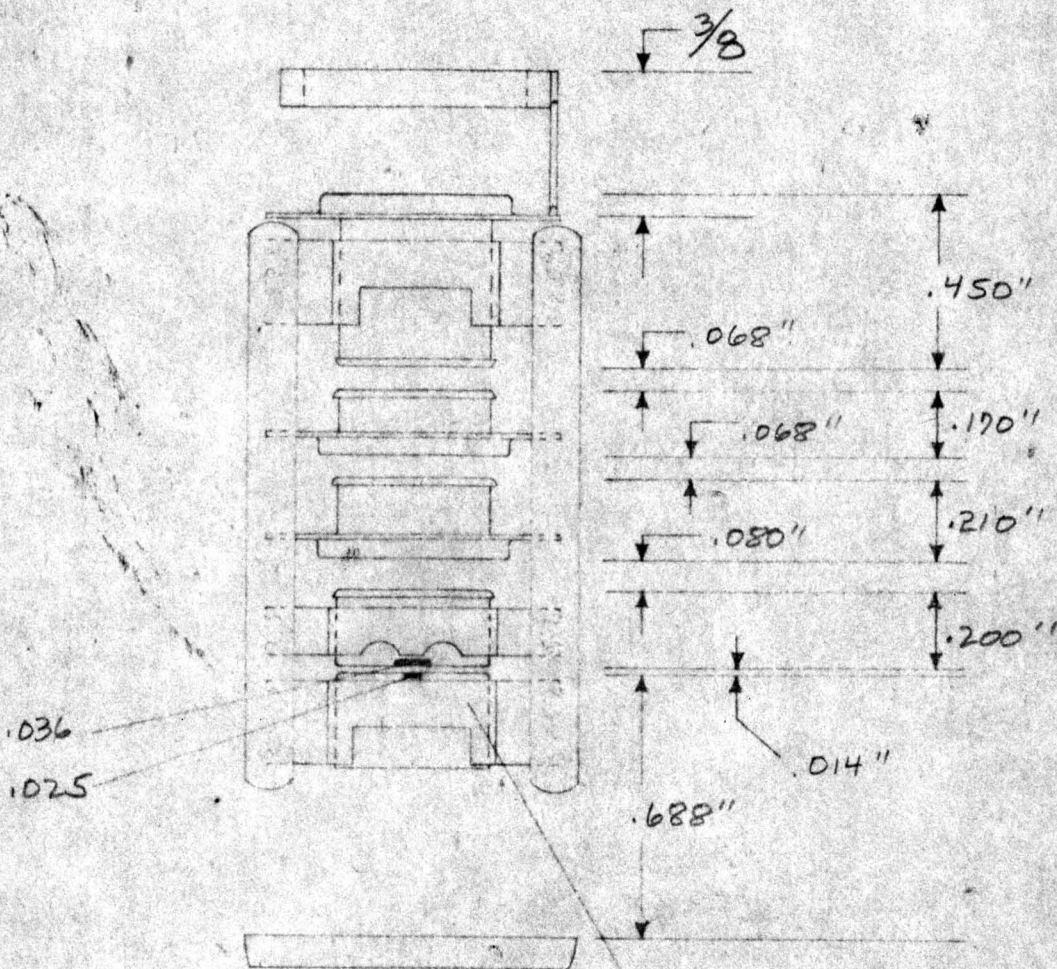
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SPRINGS _____

USE PIN _____

GUNSEAL LENGTH _____
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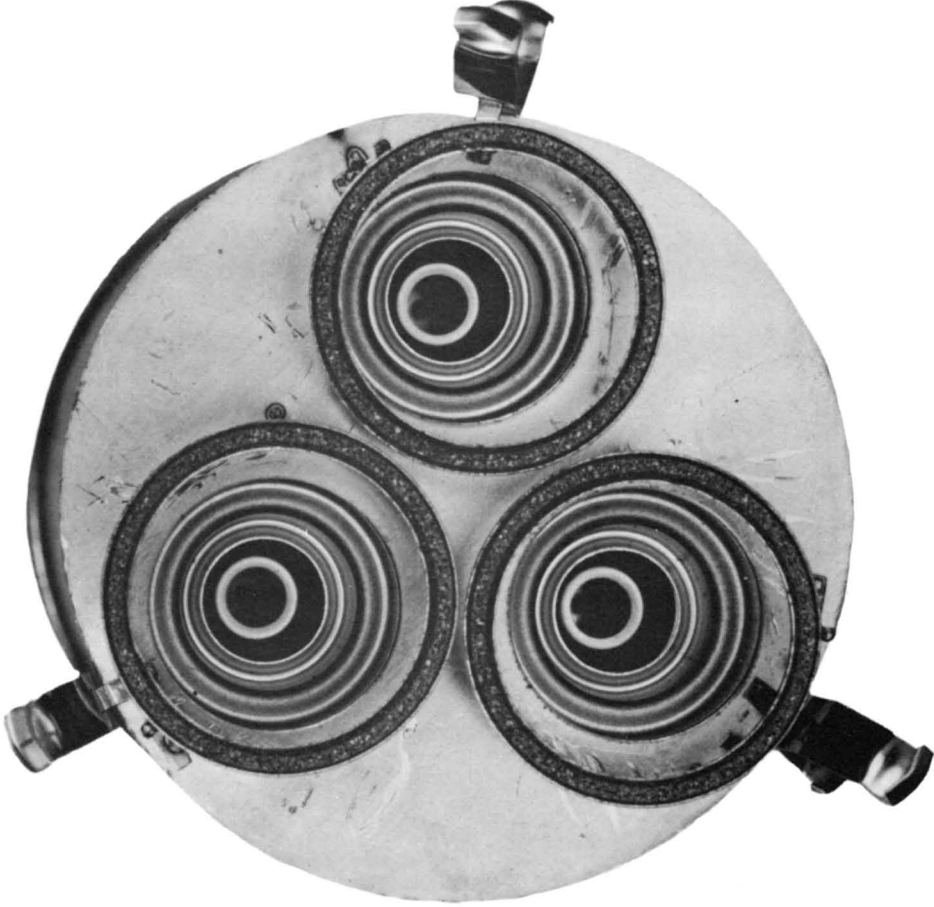
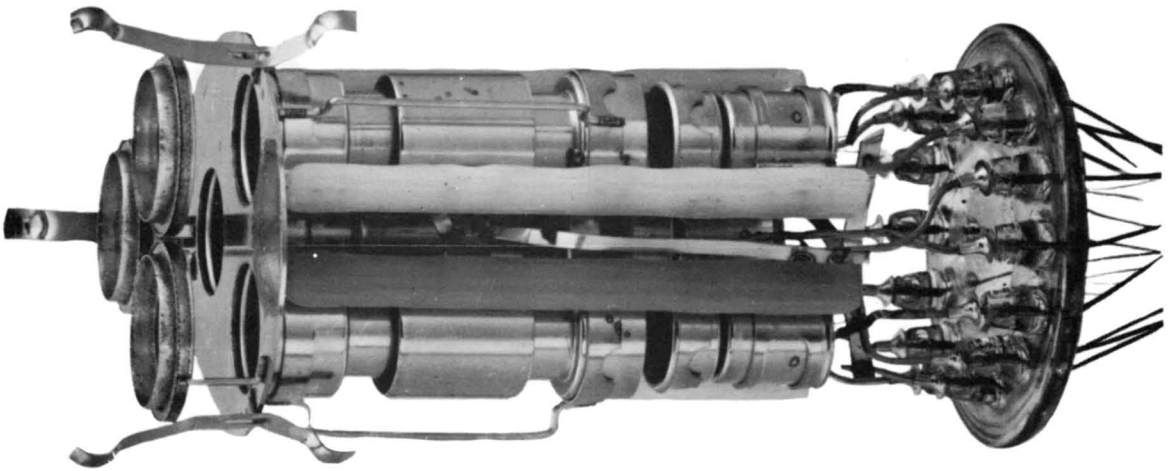
N16063 - MOUNT TYPE



G, K .0085"
GUN NUMBERS

G, DESCRIPTION
COINED AVG. TOP THICKNESS
RECEIVED

FIGURE 1



GUN ASSEMBLY
FIGURE NO. 2

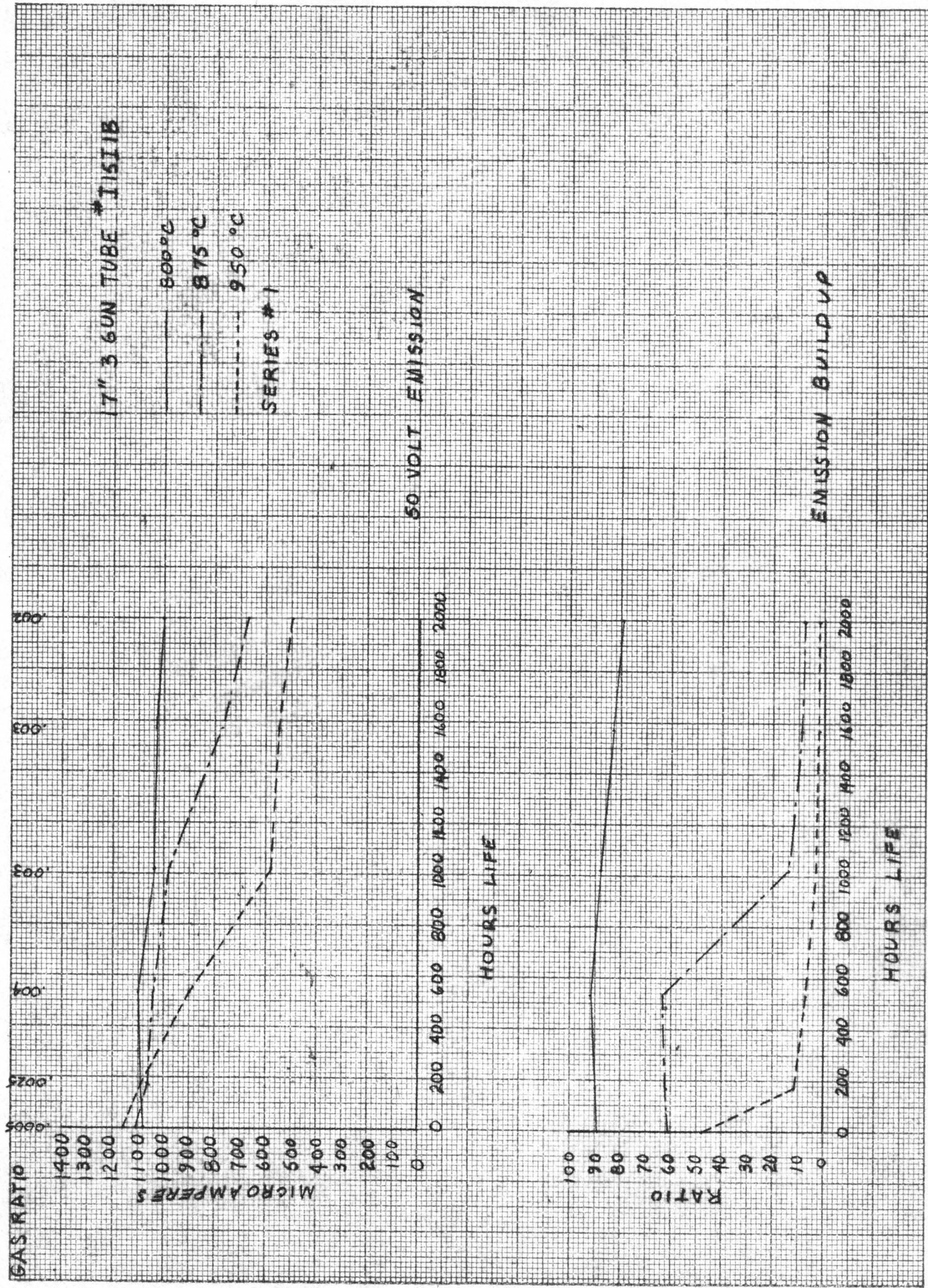


FIGURE 3

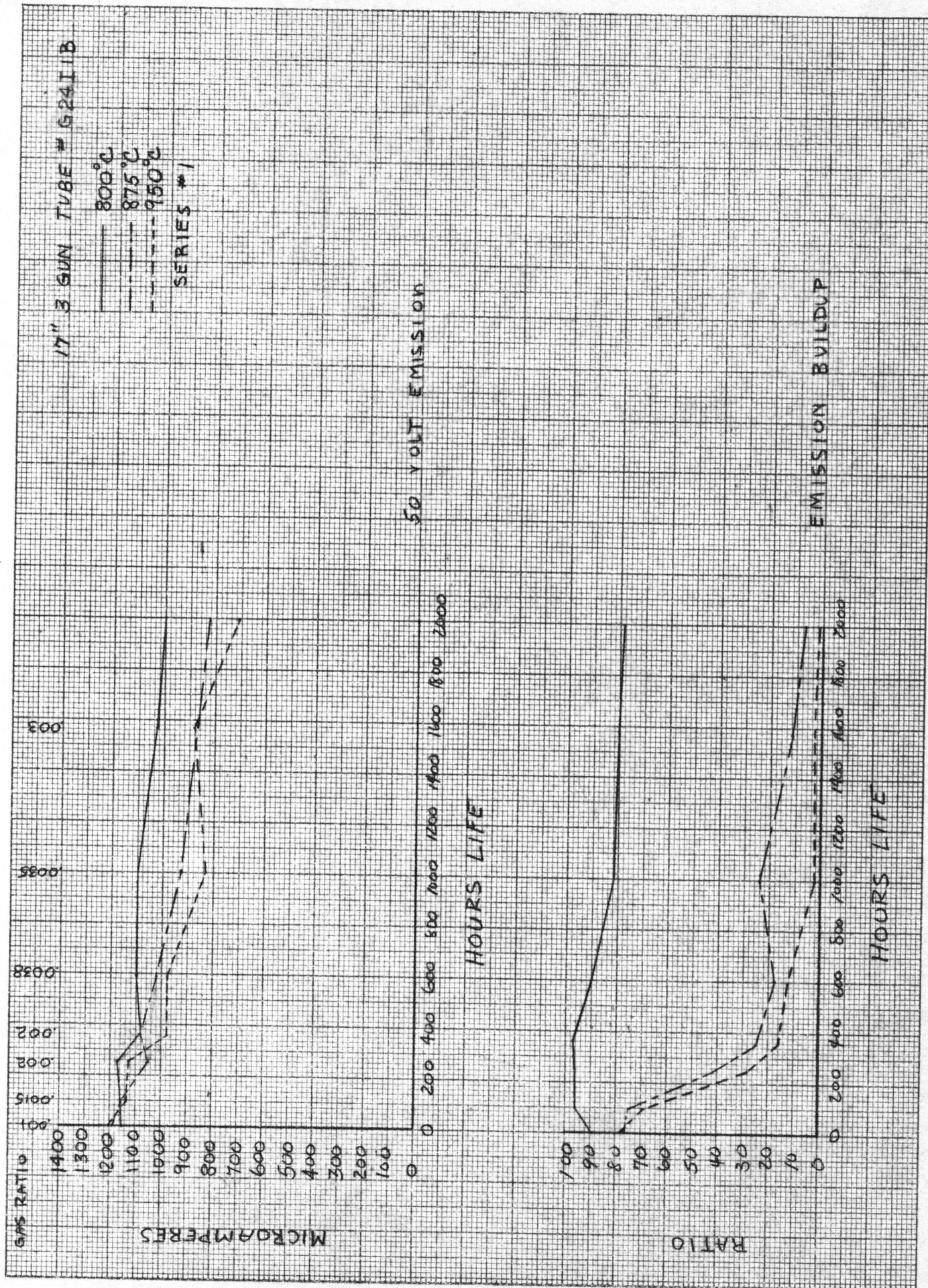


FIGURE 4

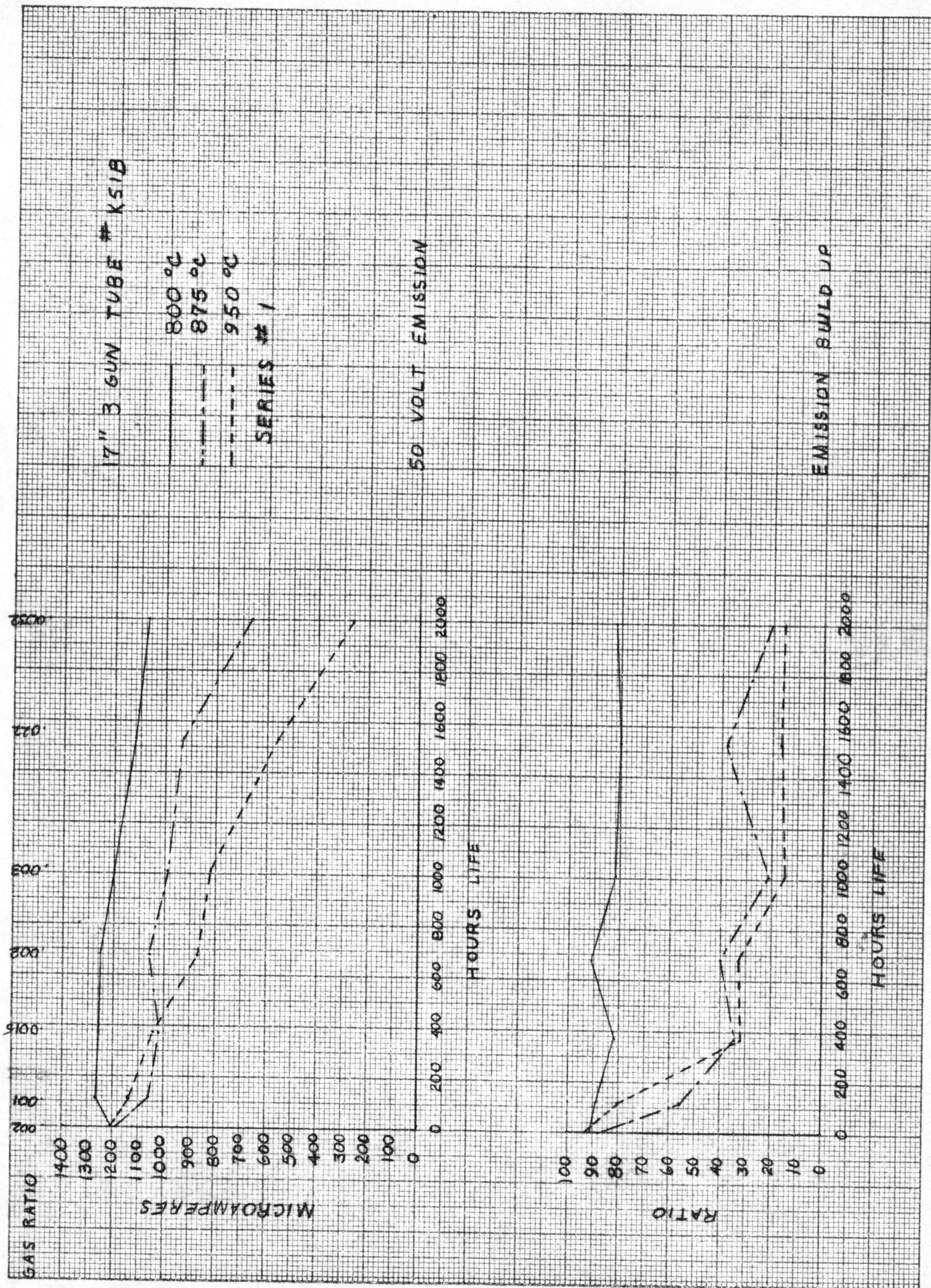


FIGURE 5

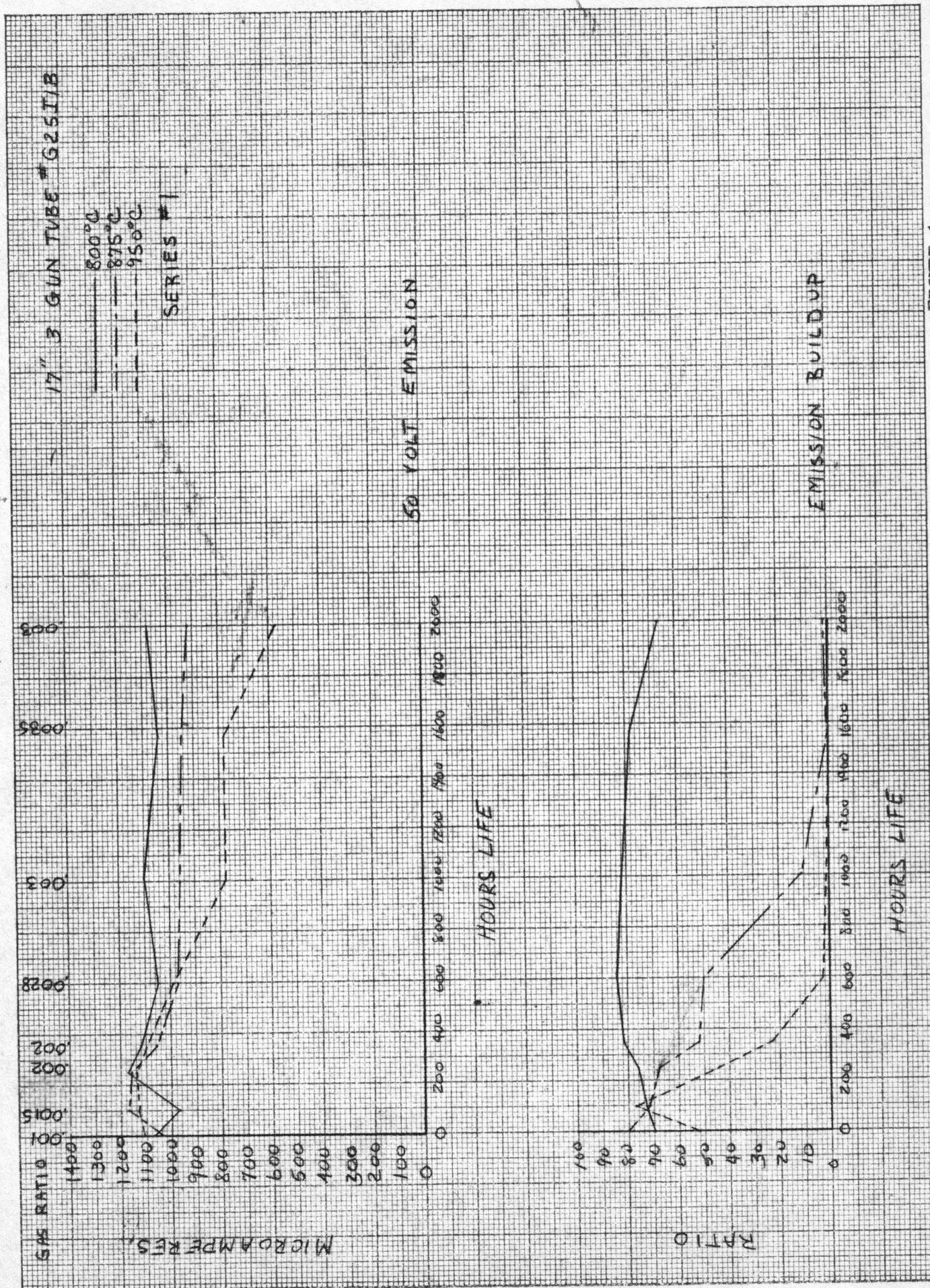


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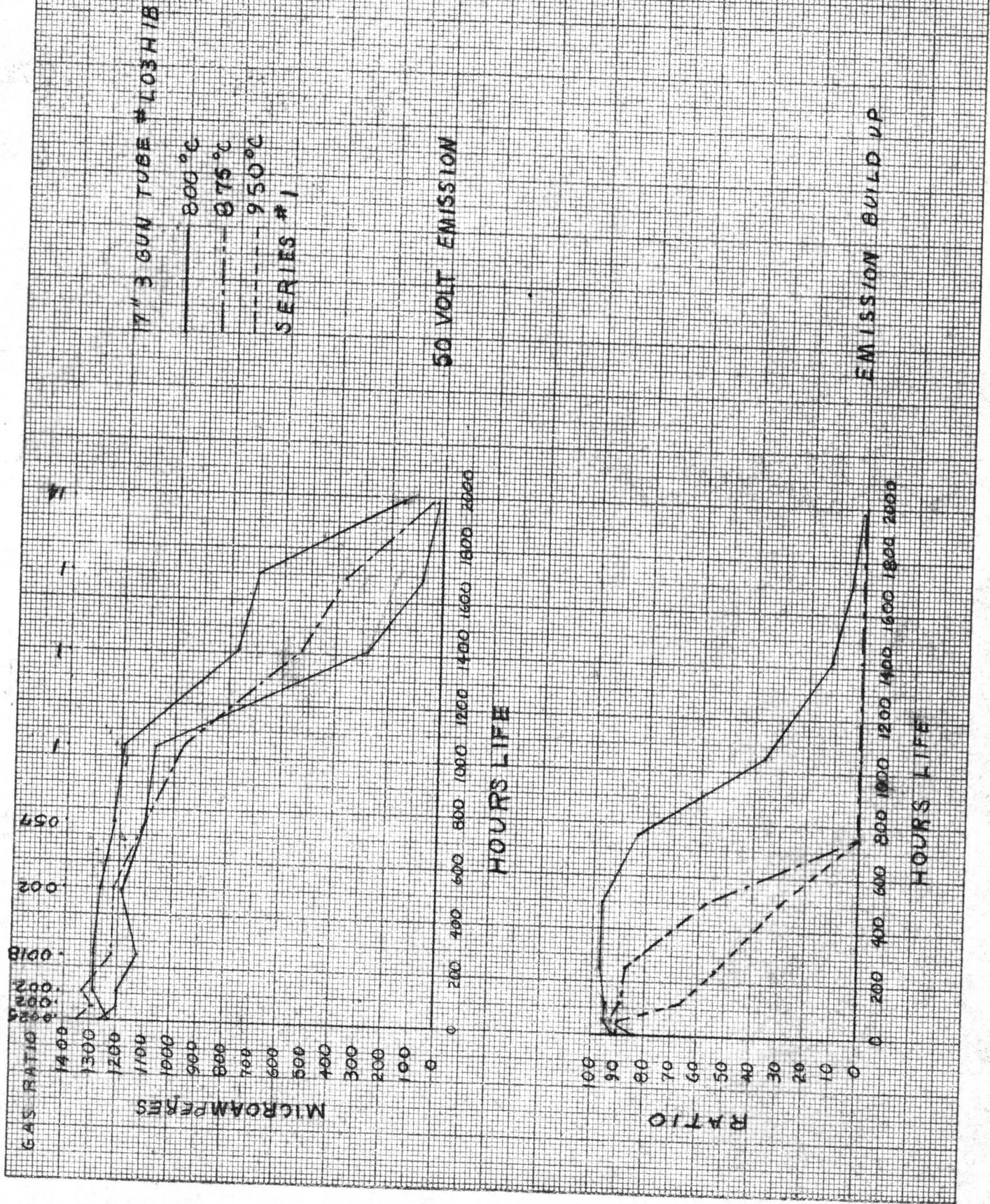


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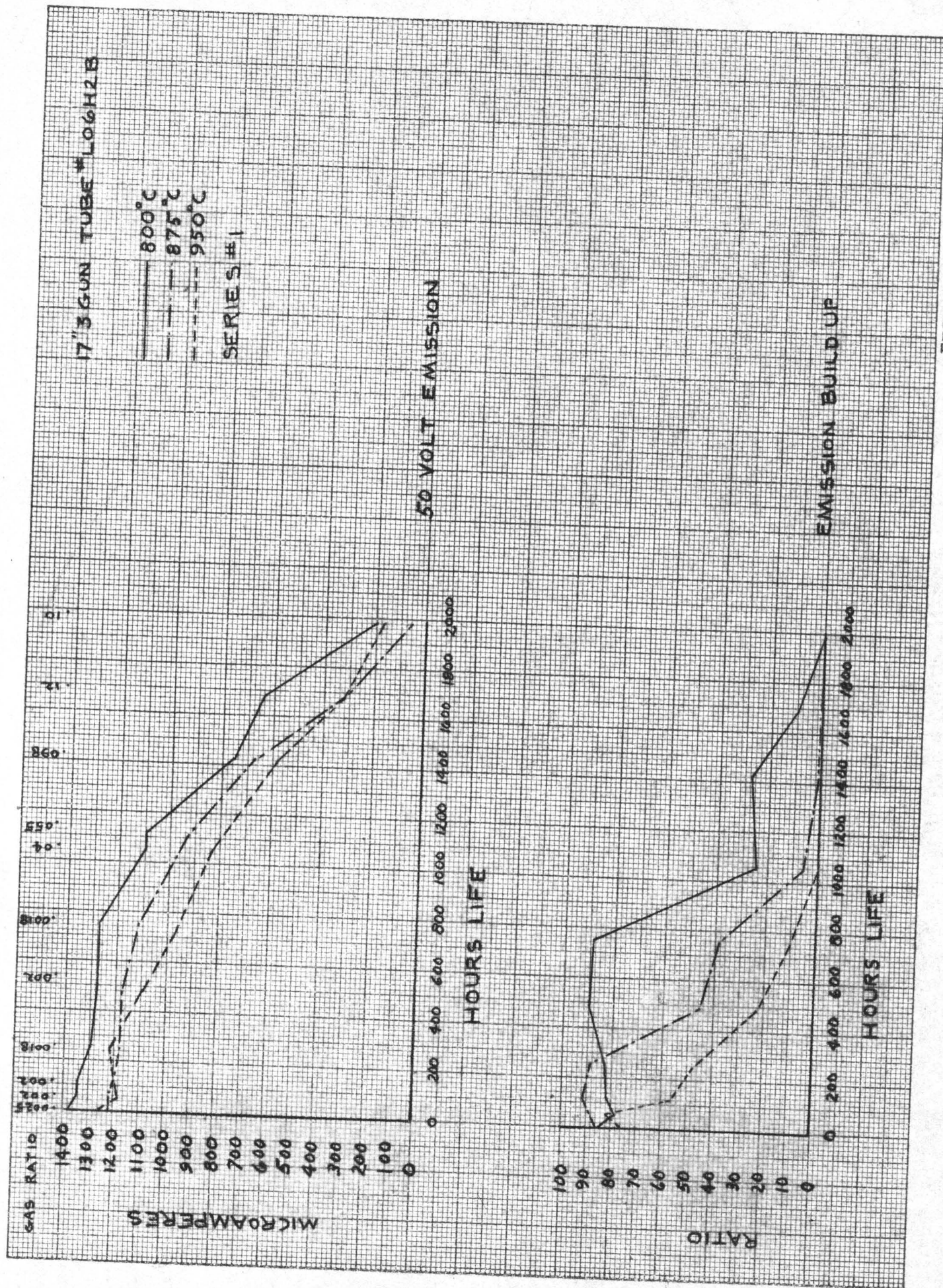


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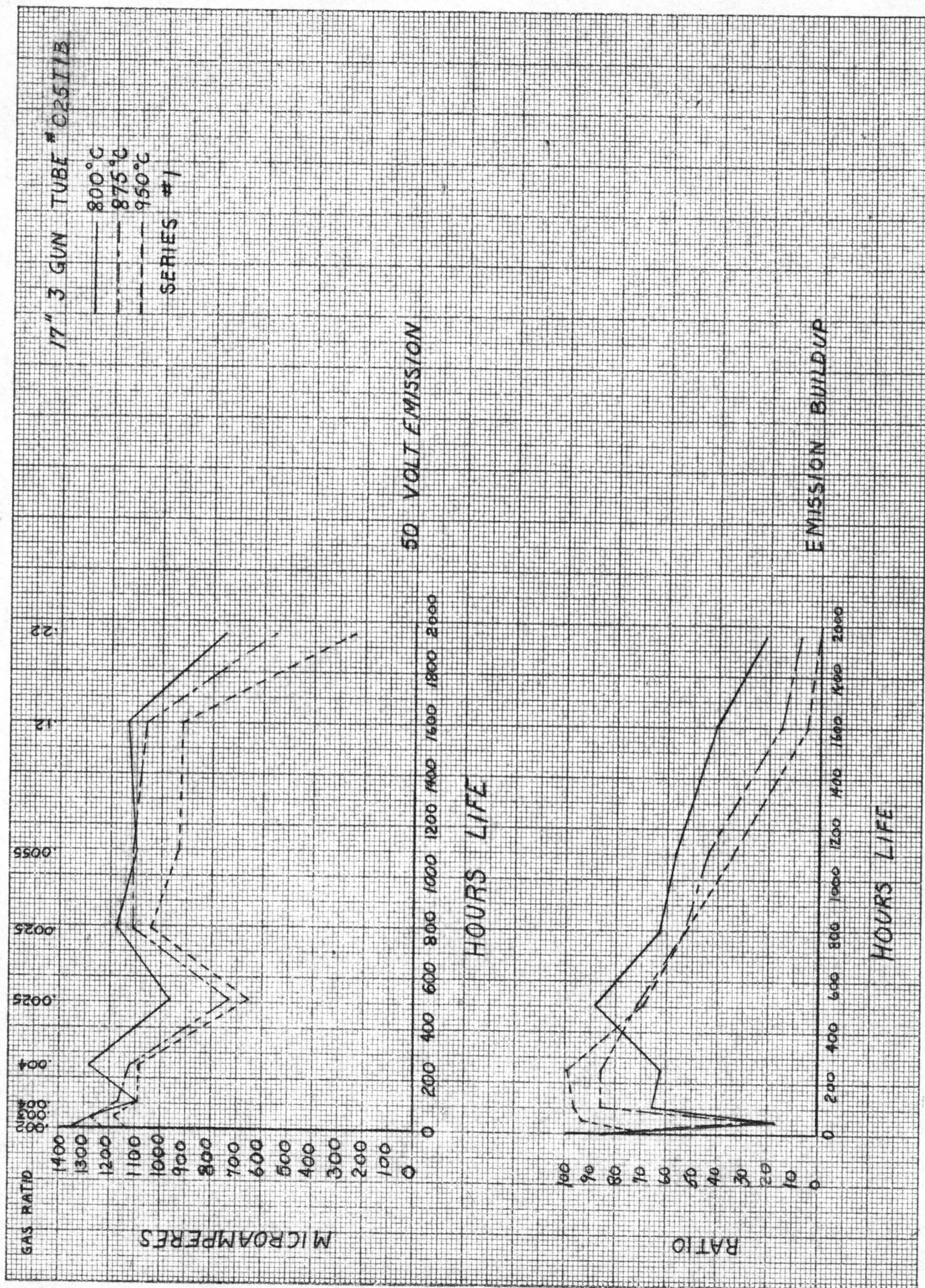


FIGURE 9

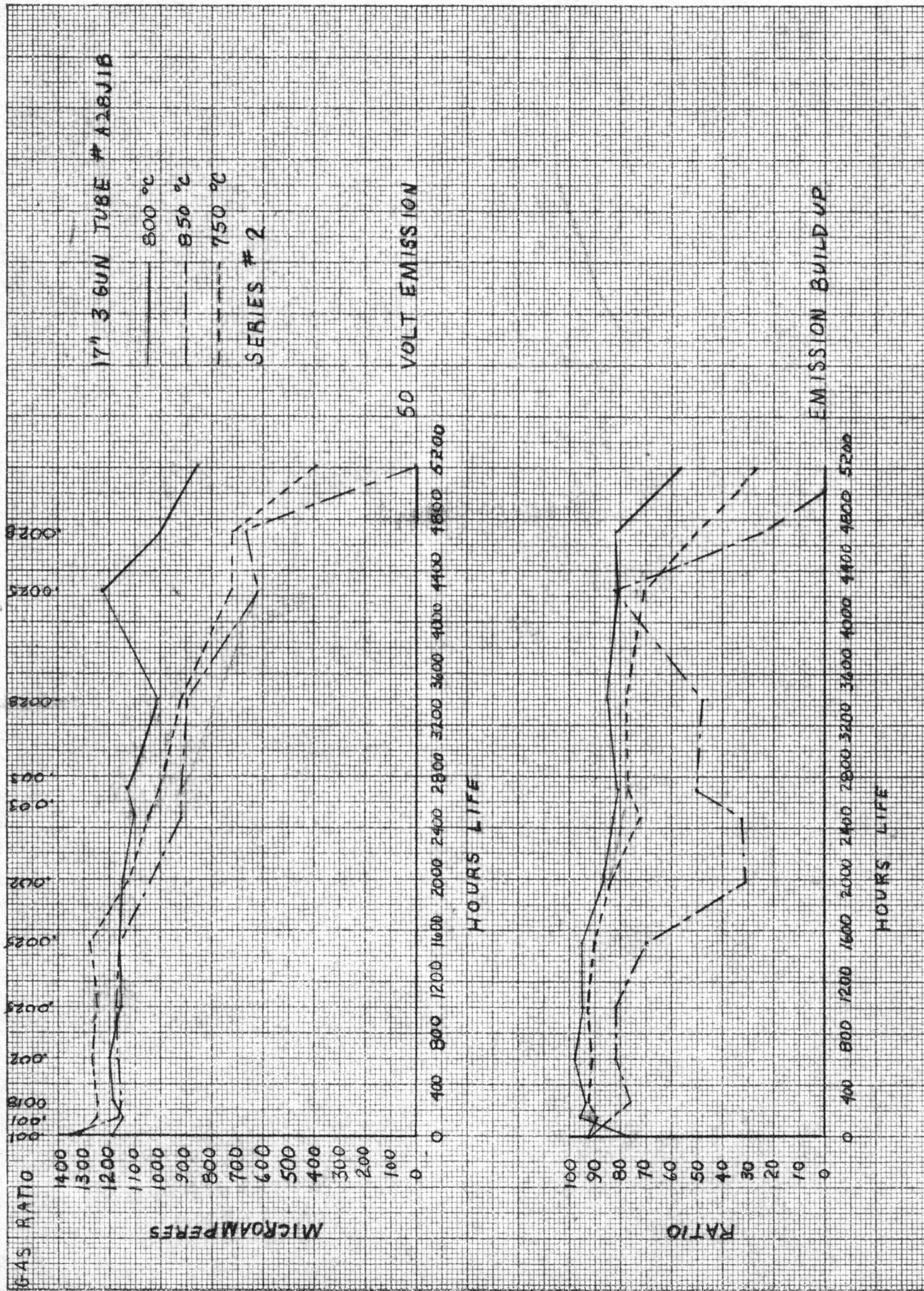


FIGURE 10

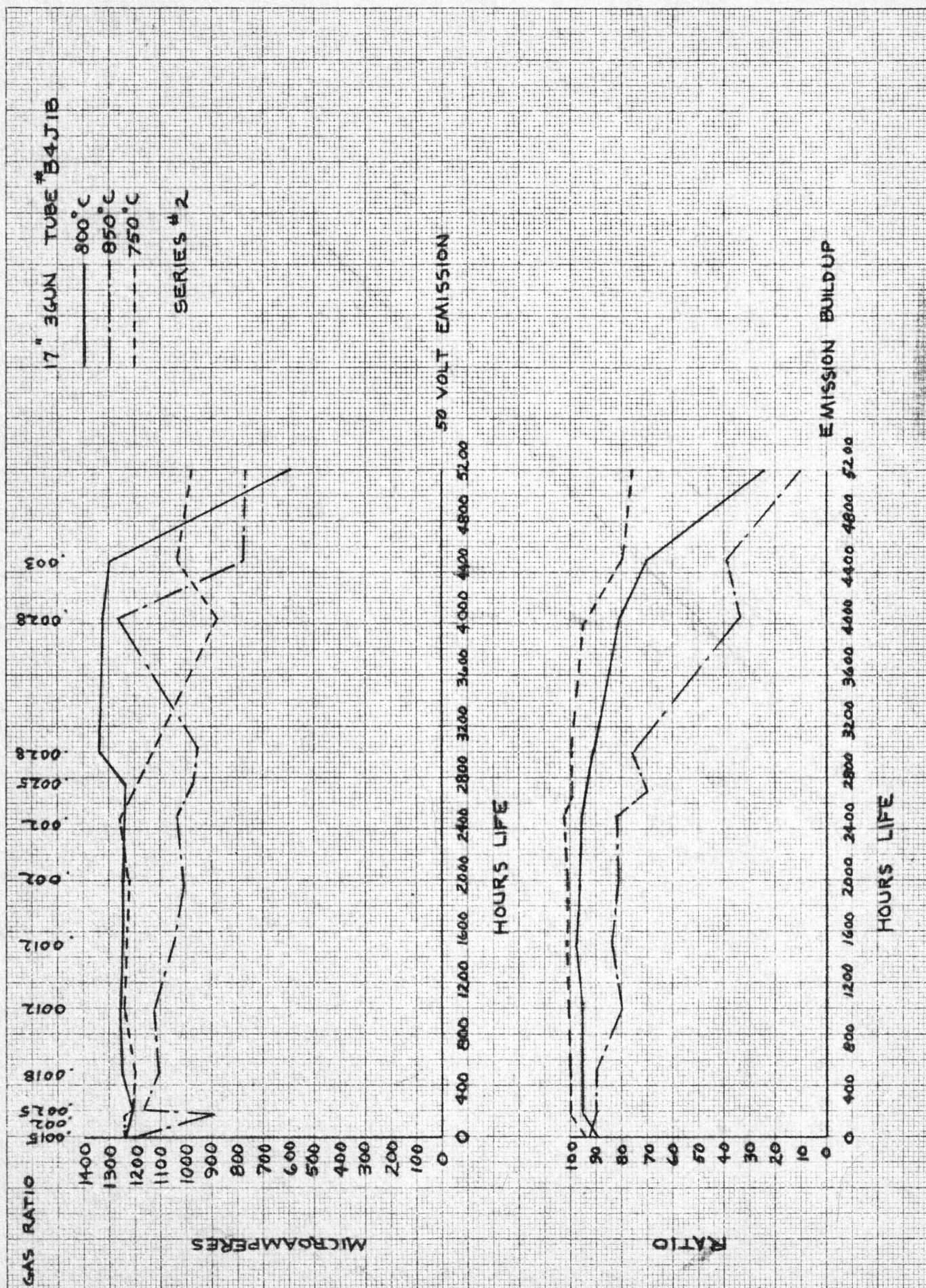


FIGURE 11

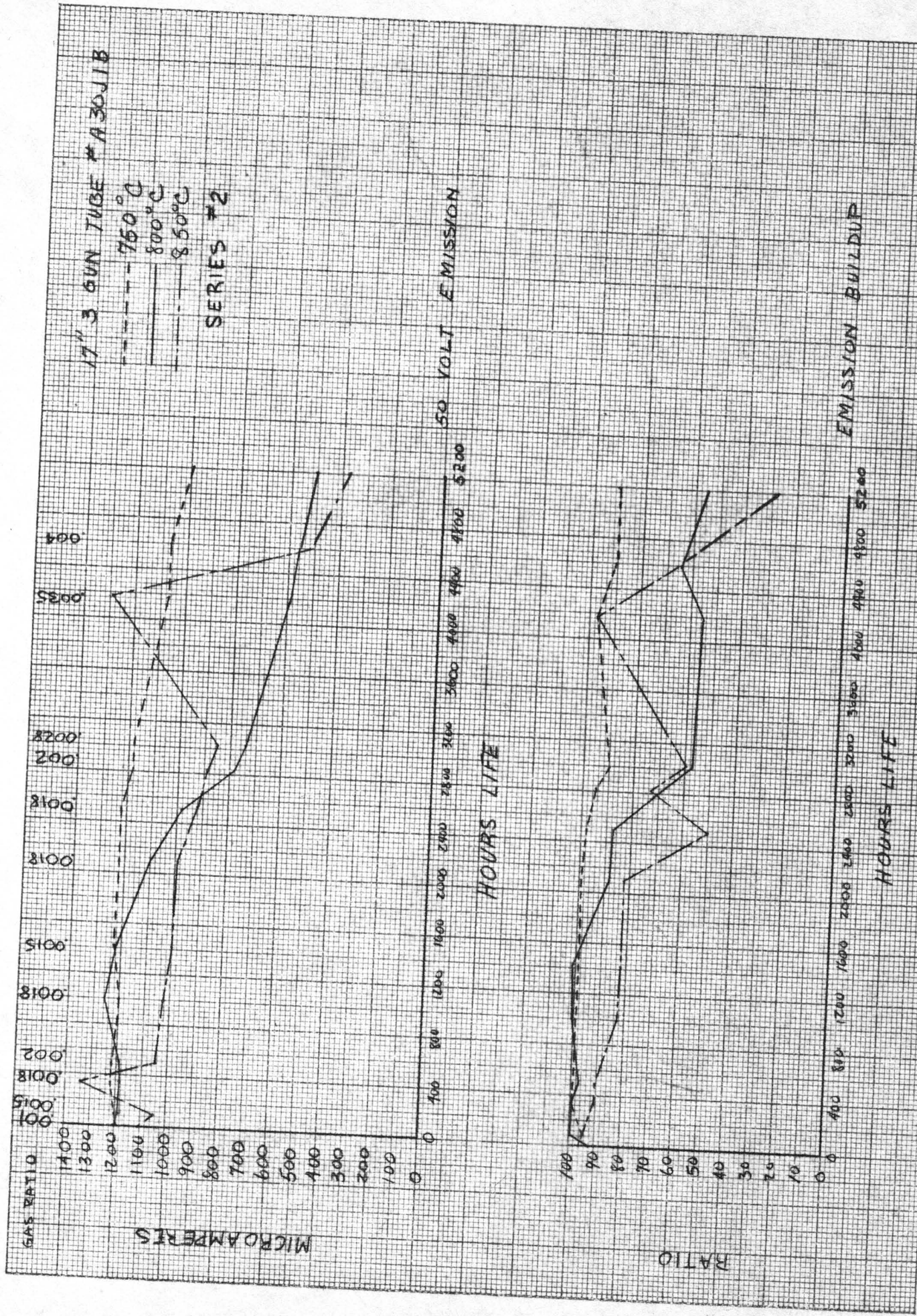


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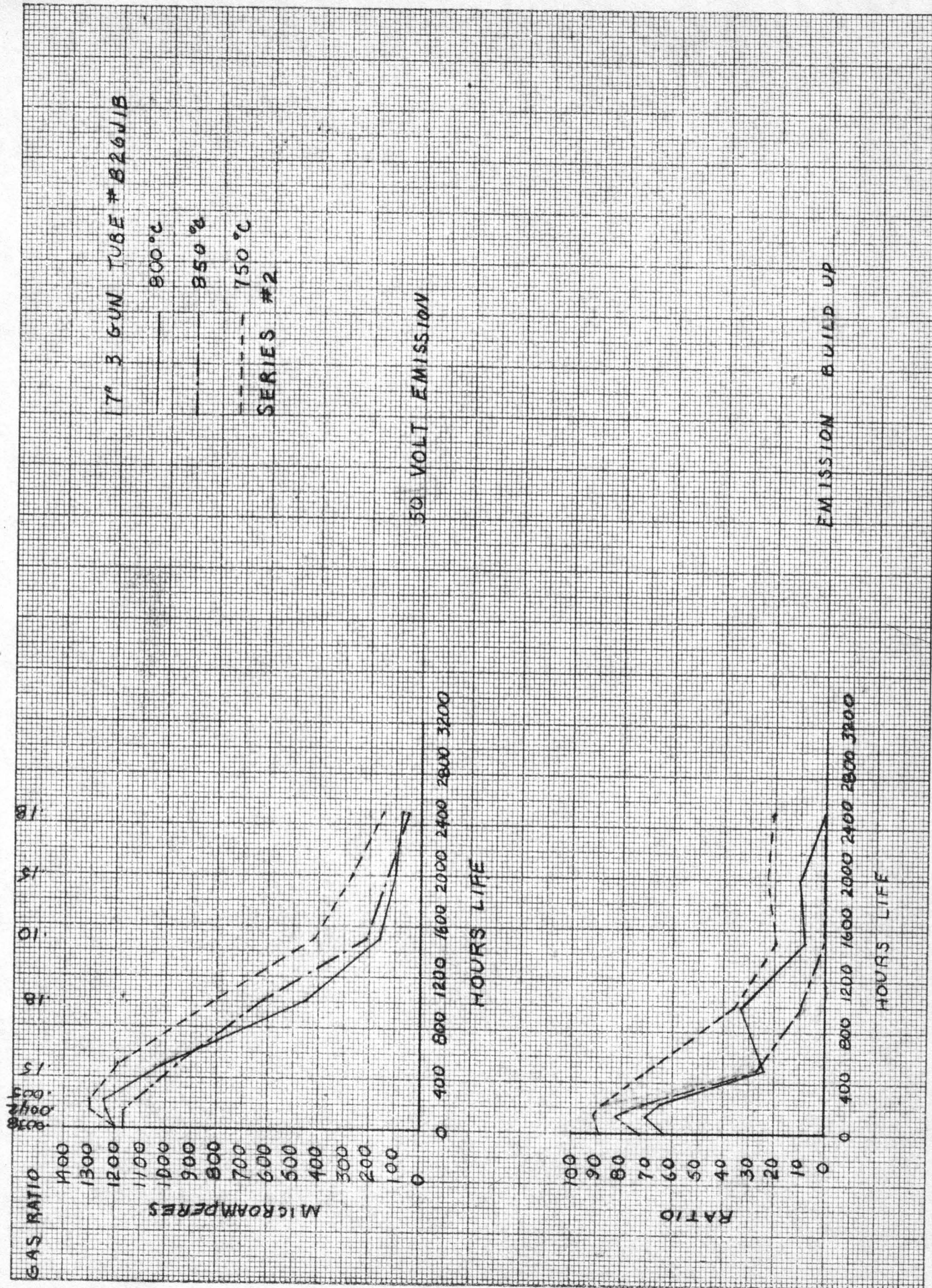


FIGURE 13

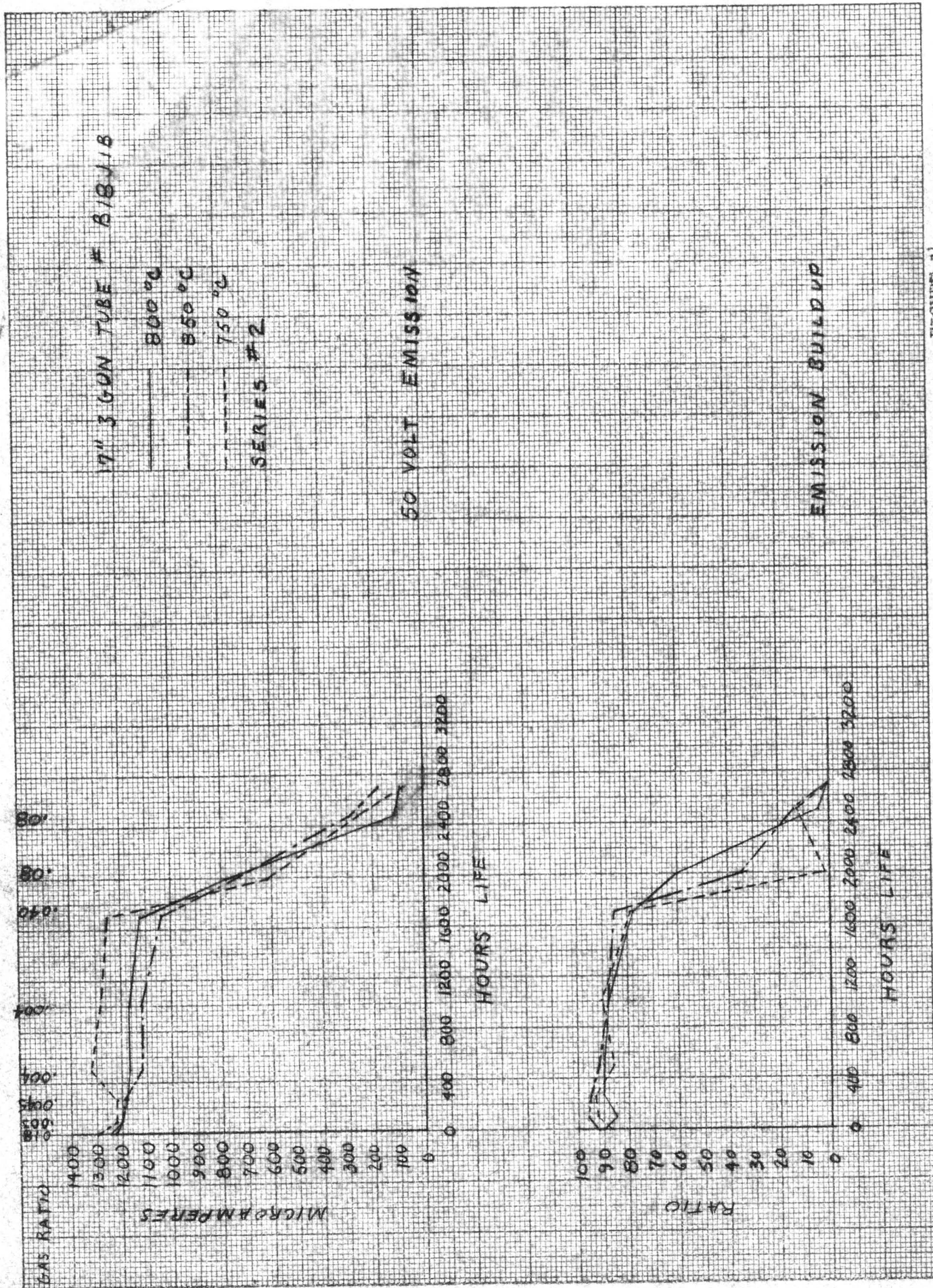


FIGURE 14

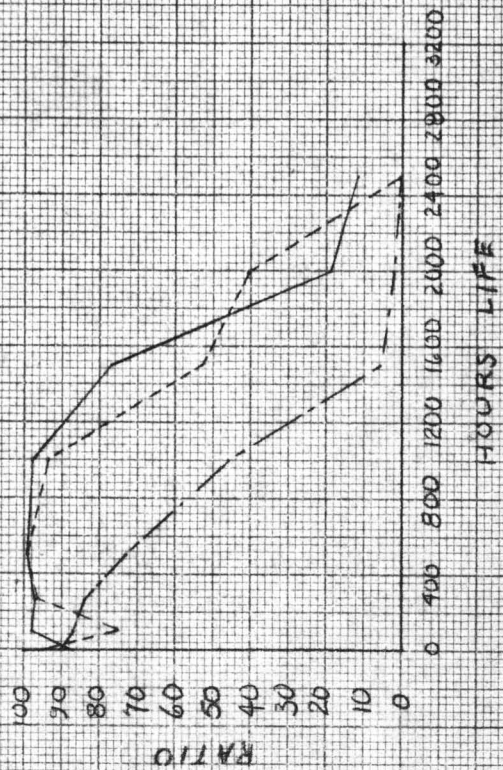
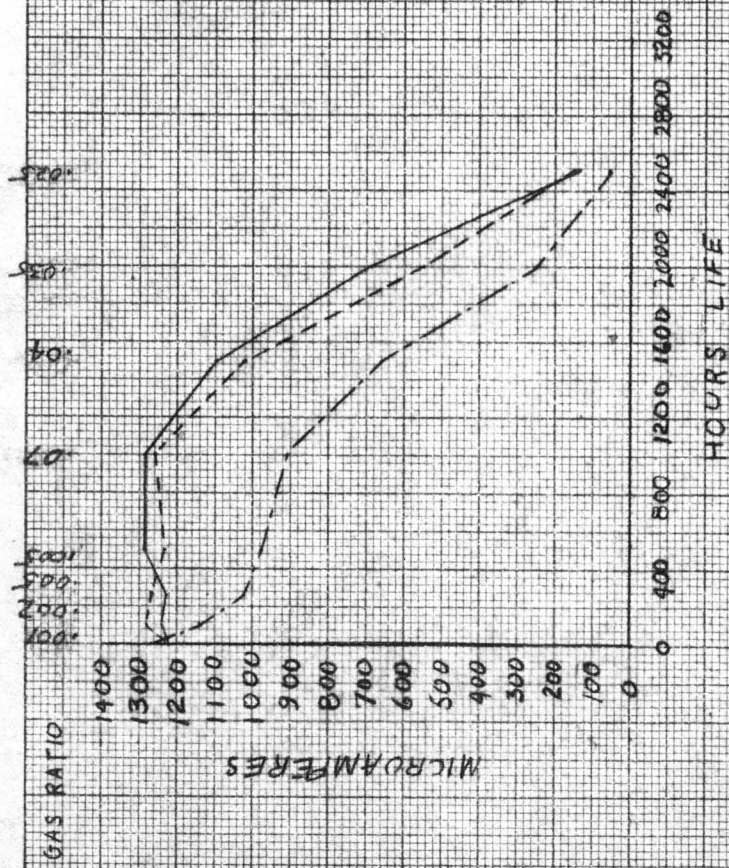


FIGURE 15

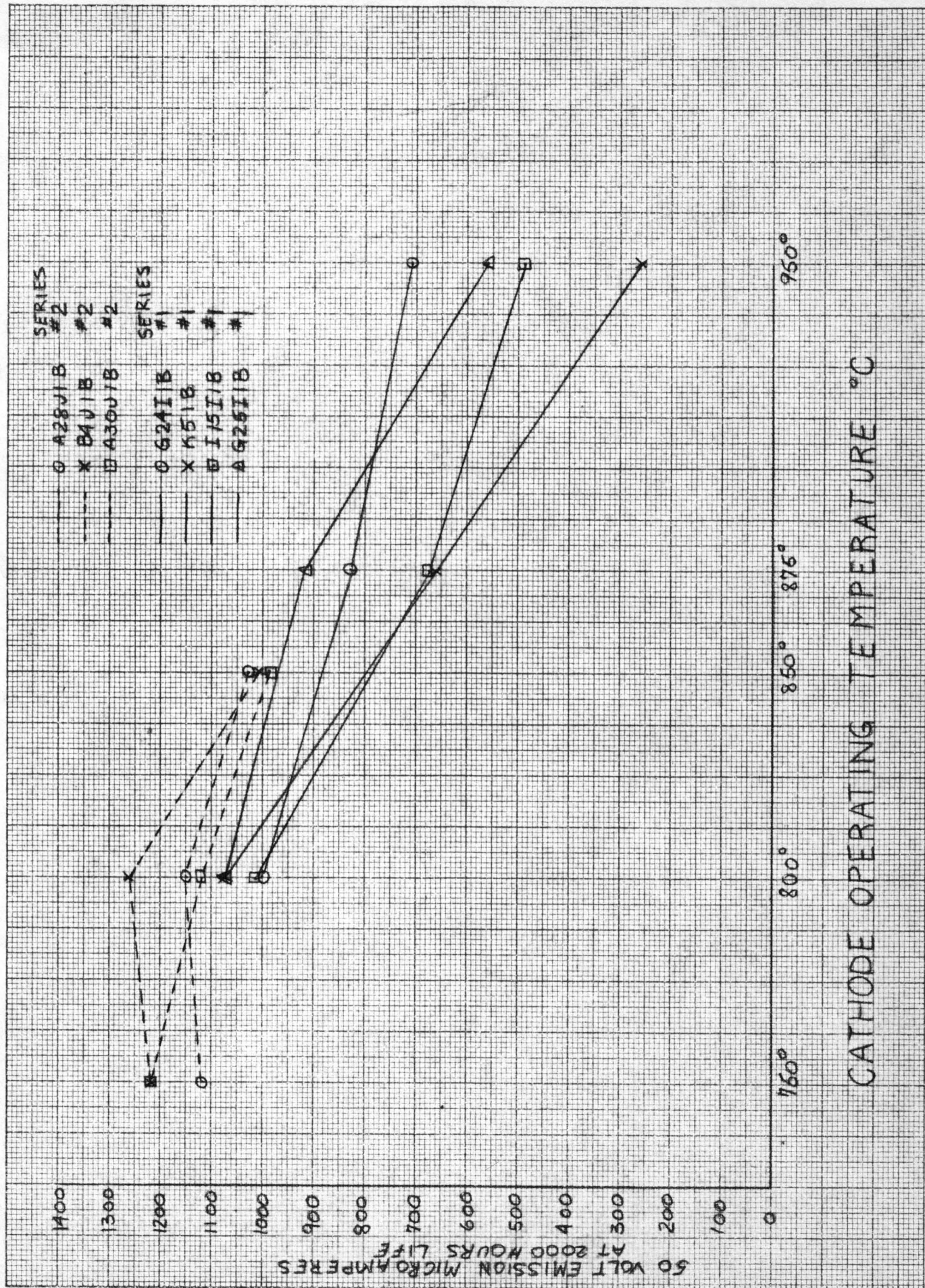


FIGURE 16