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LIFE TESTS OF ELECTRIC DISCHARGE LAMPS

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ILLUSTRATIONS

LIFE TESTS OF ELECTRIC DISCHARGE LAMPS

SUMMARY

This report gives the results of a study of the cold-cathode electric discharge lamps used in approach lights. The primary purpose of these tests was to increase the useful life of the lamps and thereby reduce the cost of maintenance. To this end, measurements of the effects of varying the voltage, gas pressure, and other characteristics affecting the life and light-output have been made. Possible modifications of the specifications, and accelerated life tests are considered.

INTRODUCTION

The lamps for neon approach lights are tubular cold-cathode neon lamps, 79 inches long and only one-third of an inch in outside diameter[1]. The replacement of these lamps is one of the nuisance tasks that fall to the lot of the airway mechanician. The unwieldy proportions and delicate construction of the lamps make them difficult to handle in the rough and often windy conditions of the approach lanes. Four or five miles may have to be traveled between the airway headquarters building and the unit needing relamping. Often the time cost of replacing a lamp may be out of all proportion to the cost of the lamp itself. The present project has been carried out for the purpose of increasing the life of neon approach-light lamps.

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[1] Neon lamps for approach lights are specified in Civil Aeronautics Administration specification #CAA-8.

The original specification for neon lamps for approach lights required a guaranteed life of 1,000 hours. The lamps furnished varied greatly in life, and a large number of them had to be replaced by the contractor because of failure to last for the guaranteed period. Subsequent specifications eliminated the guaranteed life and set up a method of payment based on the ratio of actual life of selected lamps to the specified life. Some lamps selected from one contract had a test life of more than 15,000 hours, while more than one-third of the lamps selected for life test on the same contract had lives in excess of 10,000 hours. On the other hand, two-thirds of the lamps selected on another contract failed in less than 400 hours.

It is impossible to say from the appearance of a neon lamp whether it will give 200 hours or 20,000 hours of service. There are conflicting opinions among the manufacturers of neon lamps as to what is essential to long life. The great variation in the life of lamps furnished by the same contractor shows that none of the opinions contains the full secret of making uniformly long-life lamps. If some method of consistently making such lamps could be specified, or if an initial test to distinguish between long- and short-life lamps were known, the replacement costs could be considerably reduced.

Some progress has been made towards predicting the life expectancy of neon lamps. This report summarizes and discusses the more significant data obtained in a series of tests covering the operating characteristics of neon lamps throughout the lives of the lamps. The relationship of measured characteristics to the life expectancy suggests a method for estimating the average life to be expected from a lot of

neon lamps based on the results of a 1,000-hour operating test.

SUMMARY OF AVAILABLE DATA

The basic data of this report have been derived from five groups of tests: inspection data and reported life from C.A.A. regional offices, life tests of inspectors' samples sent to the National Bureau of Standards, life tests on refilled lamps, tests on four experimental lamps, and tests on lamps filled to different pressures.

In accordance with the first neon approach-light lamp specification, the measurements of the initial characteristics of the lamps were made during the factory inspection. The lives of the lamps were to be reported by the C.A.A. regional offices. Only one lot of lamps (Manufacturer A) was purchased under this specification. Table I shows the results of the initial measurements and reported lives of those lamps at five airports. Later specifications required that after the factory inspections were completed sample lamps were to be life tested. Measurements of voltage and intensity were made on these samples throughout life.

Tables II, III and IV (Manufacturers B, C, and D, respectively) summarize the initial measurements and life. In table V are presented the results of the initial measurements and life to date of the samples from the last contractor (Manufacturer E). Three of the lamps listed in table III were refilled with neon gas by the manufacturer after they had become inoperative during life tests. The subsequent lives of the lamps, including the life of one lamp refilled a second time, are given in table VI. Table VII lists the initial characteristics and life to date of four experimental approach-light lamps which the manufacturer (F) submitted as having very long lives.

Initial measurements of intensity, operating voltage, and chromaticity of emitted light were made on 15 experimental neon lamps submitted by a manufacturer (G) who was interested in this project. These lamps were alike, except that they were filled with neon gas at different pressures.

LAMP LIFE, OPERATING VOLTAGE, AND INTENSITY

A study of the data for the individual lamps listed in tables I, II, III, and IV shows that there is no very dependable correlation between the initial operating characteristics and subsequent life. The known causes for the variation of the initial characteristics and life of neon lamps include the type of electrodes, the inside diameter of the tube, the internal volume of the lamp, the gas pressure, the purity of the gas, and the degassing technique. The factors involved are so numerous it is not surprising that the initial operating voltage and intensity seem to have little correlation with life.

An examination of the average initial characteristics by groups in each of the above tables shows, however, that there is a tendency for those lamps having lower initial operating voltages to have longer lives. This is true for the lamps listed in tables I, II and IV. In table III the lamps in the middle group depart from this trend. The average voltages of the above three groups differ so little as not to be significant in view of the individual variations and the small number of lamps in each group. This tendency is consistent with the results of operating voltage measurements made on all the lamps of tables II and III during their lives

and the maximum operating voltage characteristic of the transformers with which the lamps were operated. Figure 1 shows the results of several operating voltage measurements made on the lamp having the shortest life and on the lamp having the longest life, of those lamps listed in table III. Similar results for two of the lamps of table II are presented in figure 2. The increasing voltage throughout the life of these four lamps after an initial period of erratic variation is characteristic of all lamps that have been life tested.

The termination of the life is fixed by the maximum voltage which the transformer can provide at the normal operating current. Regular approach-light transformers having a maximum operating voltage of the order of 1,700 volts were used to operate the lamps throughout their lives. The residual life of any lamp operated by one of these transformers, therefore, depends on the rate at which the operating voltage of the lamp increases with time and the voltage the transformer can supply. It follows that for lamps having the same rate of increase of operating voltage, those having lower initial operating voltages should have the longest lives.

The reason for the increasing operating voltage with life can be explained by the generally accepted theory that during the operation of an electric discharge lamp, the gas is absorbed by the sputtered electrode material, and also perhaps by the electrodes. The following test results and observations confirm this theory.

The average results of the measurements of operating voltage, intensity, and chromaticity of the emitted light for each group of three lamps filled to pressures of 3, 4, 6, 8, and 12 mm of mercury, respectively, are shown in figure 3. The chromaticity is represented by the y-coordinate

of the International Commission on Illumination chromaticity diagram. For the color in question, the larger the value of the y-coordinate the yellower the emitted light. These results show that the operating voltage and the intensity increase and the emitted light becomes yellower as the pressure decreases from 12 to 3 mm of mercury.

In addition to the curves showing that the operating voltage increases throughout life, there are also presented in figures 1 and 2 the results of intensity measurements made on the same lamps throughout their lives. The increase of intensity with time of operation during the major portion of life is likewise characteristic of all lamps that have been life tested. It has also been observed that the light emitted by these lamps is perceptibly yellower toward the end of life than it was initially. These changes of intensity, operating voltage, and color with life are compatible with the similar changes of the same quantities with pressure, as evidenced by figure 3, and are in accord with the theory of gas depletion with life.

It has been observed, moreover, that the perceptible deposit of sputtered material near the electrodes increases in area and becomes more opaque, indicating that the electrodes continue to sputter throughout the life of the lamp. That the life of a lamp is not limited because of the failure of the electrode is indicated by the results of the life tests of the refilled lamps listed in table VI.

DISCUSSION

From the tests described, it would appear advantageous to reduce

the minimum initial intensity required by the specifications from 8.5 to 8.0 candles per 6-inch length which is a reduction of only 6 percent.

According to the curves shown on figure 3, decreasing the candlepower would permit a higher initial pressure, hence a greater gas content, by weight, and consequently a longer life. It is noticeable in table II that the lamps with the longest lives had initial intensities of about 8.0 candles. Even the 6 percent sacrifice in intensity is not permanent, as the neon lamps increase in intensity during the greater part of their lives. This change in specifications would also save much time that is required for the repetition of qualification tests, since this requirement has frequently proved the most difficult one to meet.

It would also seem advantageous to reduce the maximum operating voltage requirement from 1,400 to 1,350 volts. This reduction would make unacceptable four of the lamps listed in table IV and one of the lamps in table II. The four unacceptable lamps in table IV had lives of less than 325 hours. Although the unacceptable lamp of table II had a life of 4,204 hours, the average life of all the lamps in the table would be increased from 9,941 to 10,300 hours by eliminating this one lamp.

It would further appear advisable to reduce the minimum operating voltage requirement from 1,150 to 1,000 volts to permit the acceptance of lamps which may have operating voltages less than those listed in table VII. In view of the 1,000-hour test discussed later it is believed that the lamps of this table will have satisfactory lives. One of the lamps had an initial operating voltage less than the present minimum requirement. The 1,000-volt minimum is desirable because the approach-

light transformers might operate at excessive temperatures if they were to operate lamps at voltages much below this value.

Since the lamps listed in tables II and III average well over 3,000 hours, it is evident that such lamps can be made with reasonable consistency. It would therefore be feasible to amend the specifications to require 3,000 hours average life for the life test sample lamps.

A life test for 3,000 hours requires at least 4 months, and if some of the lamps fail much before 3,000 hours, the testing may continue several additional months before all the lamps fail or an average life of 3,000 hours is attained. To save time for the testing laboratory and to make possible an earlier determination of the acceptability of the lamps, it is desirable to have a test procedure which can be carried out in less time and which nevertheless will insure that the ultimate life of the lamps will be satisfactory.

In general, the rate of increase of operating voltage at any time during life is different for each lamp of any one manufacturer. Nevertheless, the average rate of increase of voltage for all the lamps is indicative of the mean life expectancy of the group. A similar relationship holds for the intensity during the major part of the life of the lamps.

These relationships obviously hold in figures 1 and 2 whether one considers the two lamps of one manufacturer or compares lamps of both manufacturers. It follows that the rate of increase of the product of operating voltage and intensity during the first part of life is a more sensitive measure of expected life than either measurement alone, especially for lamps having long life.

The products of voltage and candlepower were computed from several measurements for each lamp listed in tables II, III and VII, for the six lamps of table IV having lives greater than 300 hours, and for the last seven lamps listed in table V. The average increases of these products above the average initial products for various times of operation for the lamps of each manufacturer are presented in figure 4. This increase for the lamps having an average life of 3,422 hours is consistently greater after 500 hours of operation than the corresponding increase for the lamps having an average life of 9,941 hours. Although only one point was obtainable for the lamps having an average life of 569 hours, it is apparent that the rate of increase of the average product for these lamps is quite large.

Thus, the increase in this average product at the end of the first 1,000 hours of lamp operation could have been used as an index of the average life expectancy for each of the groups of lamps for which life data have been obtained. Hence, it should be possible by specifying a maximum increment for the product of the operating voltage and intensity at the end of the first 1,000 hours of operation to insure a satisfactory average lamp life. Since the increments for the lamps of tables V and VII are small, these lamps should have long lives.

The 1,000-hour test can not yet be considered completely reliable, as only two sets of samples having average lives longer than 3,000 hours have been studied. In view of the results shown in table VIII for the lamps having an average life of 3,422 hours, it would appear that the following requirements would establish a practical life test basis.

1. Not more than one of each 10 lamps, or fraction thereof shall fail before 1,000 hours of operation.

2. The increase of the product of voltage and intensity over the initial product of voltage and intensity for not more than one of each 10 lamps, or fraction thereof, shall exceed 5.5 kilovolt-candles at the end of 1,000 hours of operation.

3. The average of the increments of the products of voltage and intensity over the initial products of voltage and intensity for all the lamps operating at the end of 1,000 hours shall not exceed 4.0 kilovolt-candles.

If, however, the samples fail on any one of the above requirements, the group of lamps being tested will not be considered acceptable until the average life of the samples reaches 3,000 hours.

It may happen that the sample lamps will meet the requirements for the proposed 1,000-hour test and yet for some unforeseen reason fail to give 3,000 hours average life. It is believed, however, that such lamps will not be inferior to lamps that would meet the 2,000-hour requirements of the present specification. Should this test be adopted, the sample lamps should be operated, at least for the present, until the end of their lives in order to obtain further confirmation of the reliability of the test.

RECOMMENDATIONS

Summarizing the proposals considered above, the following changes in specification CAA-8 are recommended.

1. The intensity to be not less than 8.0 candles per 6-inch length instead of the present minimum of 8.5 candles.

2. The maximum operating voltage to be 1,350 volts instead of 1,400 volts, and the minimum operating voltage to be 1,000 volts instead of 1,150 volts.

3. The average life of the sample lamps selected by the inspector to be 3,000 hours, instead of 2,000 hours.

4. The specification should be amended to include the 1,000-hour test proposed in this Note as an optional accelerated life test.

TABLE I

Initial Characteristics and Life of Approach-Light Lamps from Manufacturer A
(Listed according to increasing life and divided into 3 groups)

	Group I			Group II			Group III		
	Operating Voltage	Intensity per 6-inch length	Life	Operating Voltage	Intensity per 6-inch length	Life	Operating Voltage	Intensity per 6-inch length	Life
	volts	candles	hours	volts	candles	hours	volts	candles	hours
	1250	8.5	315	1200	8.3	585	1230	8.7	756
	1250	8.0	315	1200	8.5	588	1220	8.3	770
	1230	8.7	324	1230	8.0	588	1180	8.5	960
	1240	7.8	372	1150	8.7	612	1200	8.5	960
	1230	7.8	444	1230	8.3	636	1160	8.5	1080
	1250	8.3	457	1250	9.0	648	1200	9.0	1080
	1200	8.5	516	1240	9.5	666	1200	9.2	1110
	1230	9.0	528	1160	8.5	696	1150	9.2	1125
	1250	8.5	552	1220	9.2	705	1250	9.5	1232
	1250	9.0	576	1150	9.0	750	1190	9.0	1260
	1240	8.5	576	1220	8.5	750	1200	8.3	1394
				1230	7.8	756	1240	9.7	1500
Average	1240	8.42	450	1210	8.61	660	1200	8.87	1100

Average life of all lamps: 748 hours

TABLE II

Initial Characteristics and Life of Approach-Light Lamps from Manufacturer B
(Listed according to increasing life and divided into 3 groups)

	Group I			Group II			Group III		
	Operating Voltage	Intensity per 6-inch length	Life	Operating Voltage	Intensity per 6-inch length	Life	Operating Voltage	Intensity per 6-inch length	Life
	volts	candles	hours	volts	candles	hours	volts	candles	hours
	1280	10.5	3913	1260	9.0	7608	1340	7.9	11983
	1370	8.5	4204	1310	8.5	8205	1240	8.2	12136
	1340	9.0	5080	1200	9.0	8535	1210	9.0	14045
	1350	8.4	5382	1320	8.5	8633	1290	8.2	15520
	1300	9.0	7310	1310	8.6	9068	1270	7.9	16974
				1310	8.5	10882	1180	7.9	19526*
Average	1330	9.08	5180	1280	8.68	8820	1250	8.18	15031

Average life of all lamps: 9941 hours.

* This lamp has not become inoperative

TABLE III

Initial Characteristics and Life of Approach-Light Lamps from Manufacturer C
(Listed according to increasing life and divided into 3 groups)

	Group I			Group II			Group III		
	Operating Voltage	Intensity per 6-inch length	Life	Operating Voltage	Intensity per 6-inch length	Life	Operating Voltage	Intensity per 6-inch length	Life
	volts	candles	hours	volts	candles	hours	volts	candles	hours
	1280	8.7	1896	1270	8.5	3008	1240	8.7	3967
	1260	8.5	2109	1240	8.5	3008	1240	9.0	3967
	1260	8.5	2344	1260	8.5	3038	1250	8.7	4515
	1230	8.7	2400	1280	8.5	3423	1250	8.5	4733
	1260	8.5	2400	1200	8.7	3697	1260	8.6	4885
	1230	8.5	2648	1290	8.5	3967	1240	8.5	5589
Average	1253	8.57	2300	1257	8.53	3360	1247	8.67	4610

Average life of all lamps: 3422 hours

TABLE IV

Initial Characteristics and Life of Approach-Light Lamps from Manufacturer D
(Listed according to increasing life and divided into 3 groups)

	Group I			Group II			Group III		
	1440	8.3	210	1340	8.6	253	1330	9.1	379
	1400	9.8	210	1260	8.0	300	1240	7.8	401
	1340	8.6	228	1390	9.2	322	1180	8.2	886
	1370	8.6	253	1340	8.6	322	1160	8.0	1102
Average	1390	8.82	225	1330	8.60	299	1230	8.28	692

Average life of all lamps: 406 hours

TABLE V

Initial Characteristics and Life of Approach-Light Lamps from Manufacturer E

	Operating Voltage, volts	Intensity per 6-inch length, candles	Life, hours to 8-29-42
	1260	8.7	1500 (inoperative)
	1260	8.5	2016
	1240	8.6	1752
	1240	8.5	2016
	1260	8.8	1516
	1350	9.3	1516
	1240	8.4	1516
	1240	8.7	1516
	1330	9.3	1516
	1330	9.5	1516
	1320	9.2	1516
Average	1279	8.86	1627

TABLE VI

Life of Refilled Neon Lamps

Initial Filling, hours	1st Refilling, hours	2nd Refilling, hours
2344	11035	
2648	5705	
3697	4724	8820

TABLE VII

Characteristics and Life of Experimental Approach-Light Lamps from Manufacturer F

	Initial Operating Voltage volts	Operating Voltage volts (after 1544 hours)	Initial Intensity per 6-inch length candles	Life hours to 8-29-42
	1140	1160	7.8	1953
	1170	1210	9.9	1953
	1170	1140	7.9	1953
	1150	1170	8.4	1953
Average	1158	1170	8.5	1953

TABLE VIII

Operating-Voltage Intensity Increments at 1000 Hours and Life of Lamps Listed in Table III

	Increment at end of 1000 hours kilovolt-candles	Life hours
	6.6	1896
	4.5	2109
	5.7	2344
	5.3	2400
	5.1	2400
	4.1	2648
	4.9	3008
	4.9	3008
	4.6	3038
	3.5	3423
	2.8	3697
	3.6	3967
	3.8	3967
	1.7	3967
	3.0	4515
	3.8	4733
	2.5	4885
	2.3	5589
Average	4.0	3422

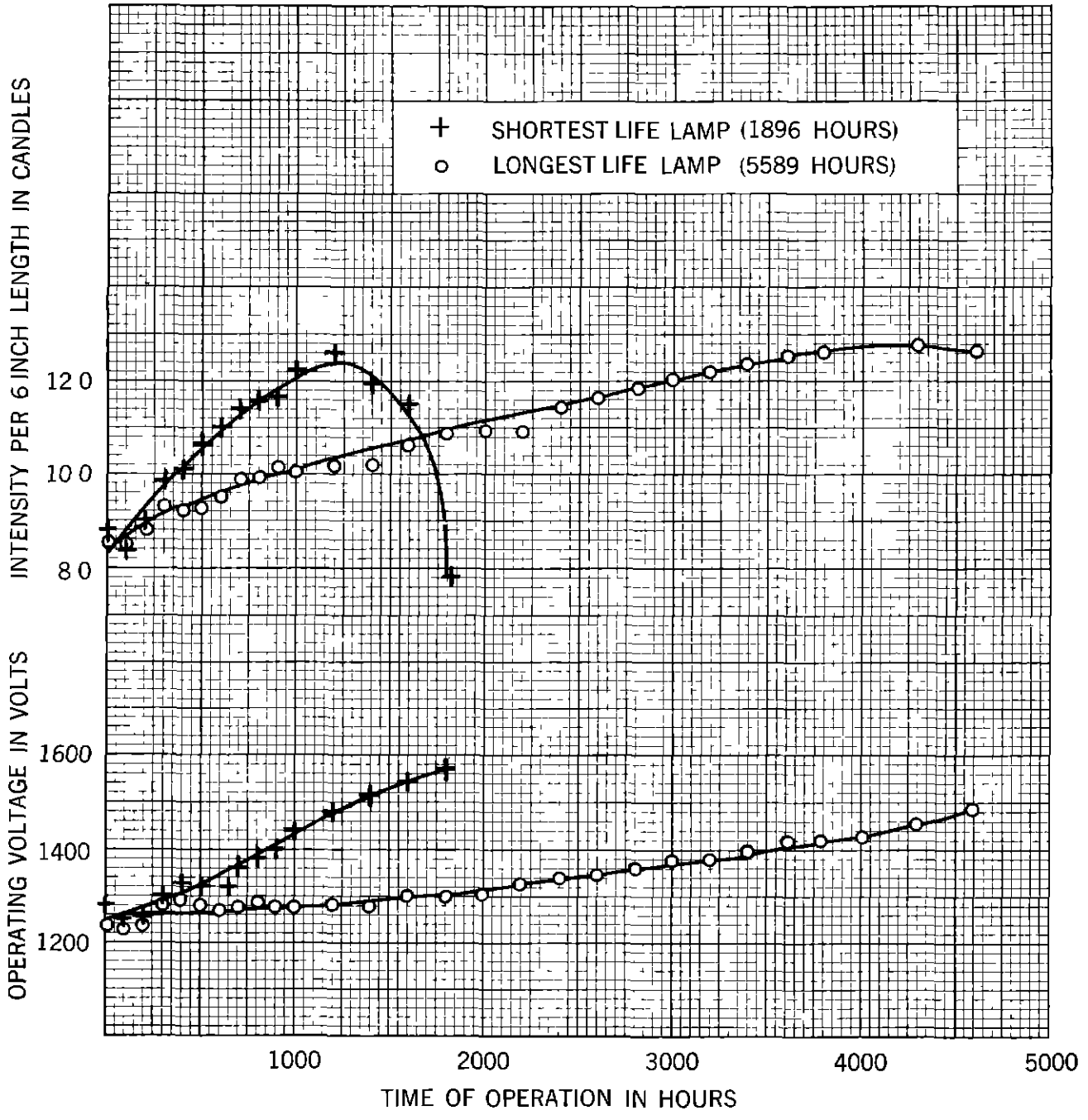

FIGURE 1. Intensity and Voltage During Operating Life.
Two Approach-Light Lamps of Table III.

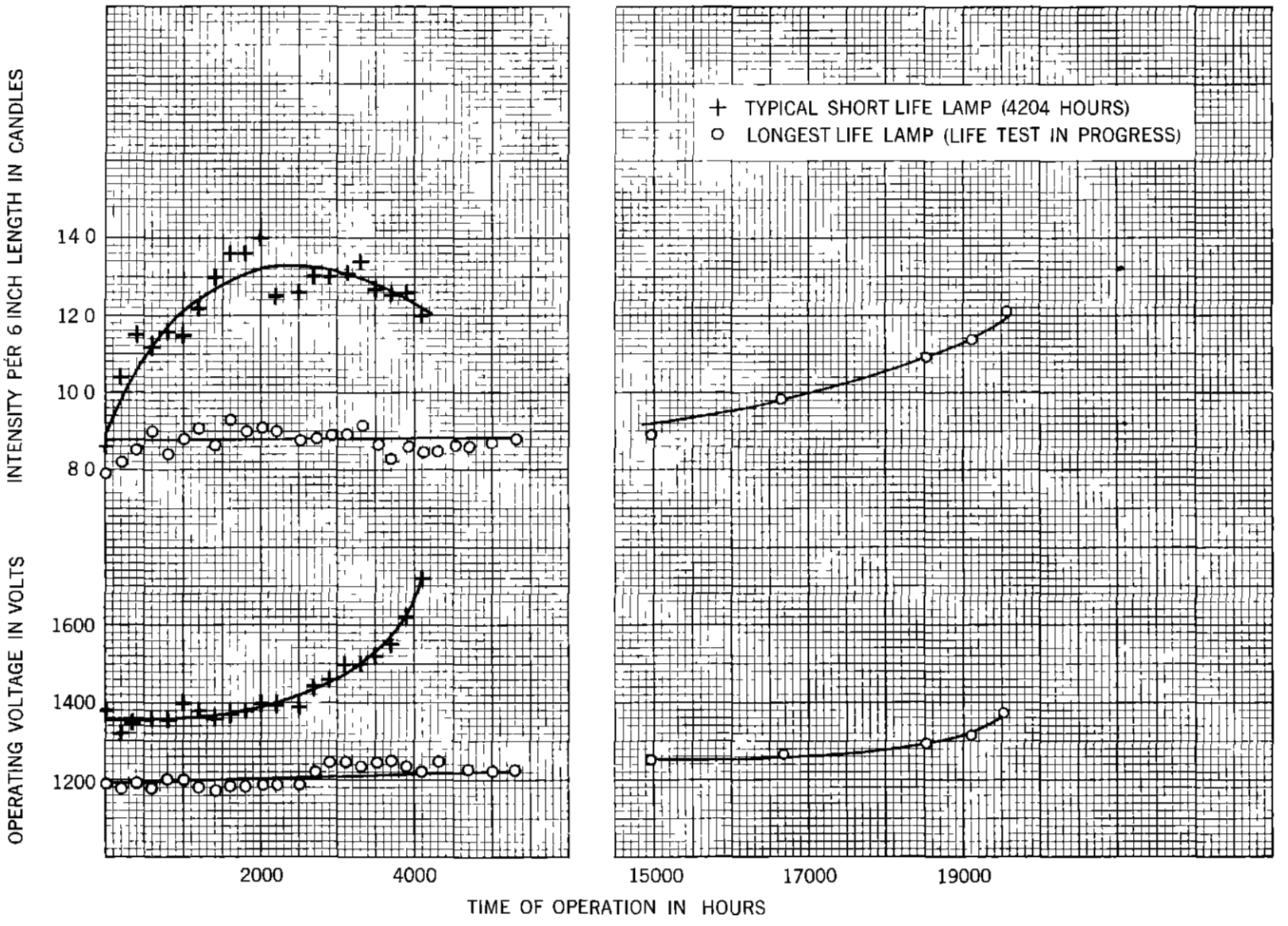

FIGURE 2. Intensity and Voltage During Operating Life Two Approach-Light Lamps of Table II.

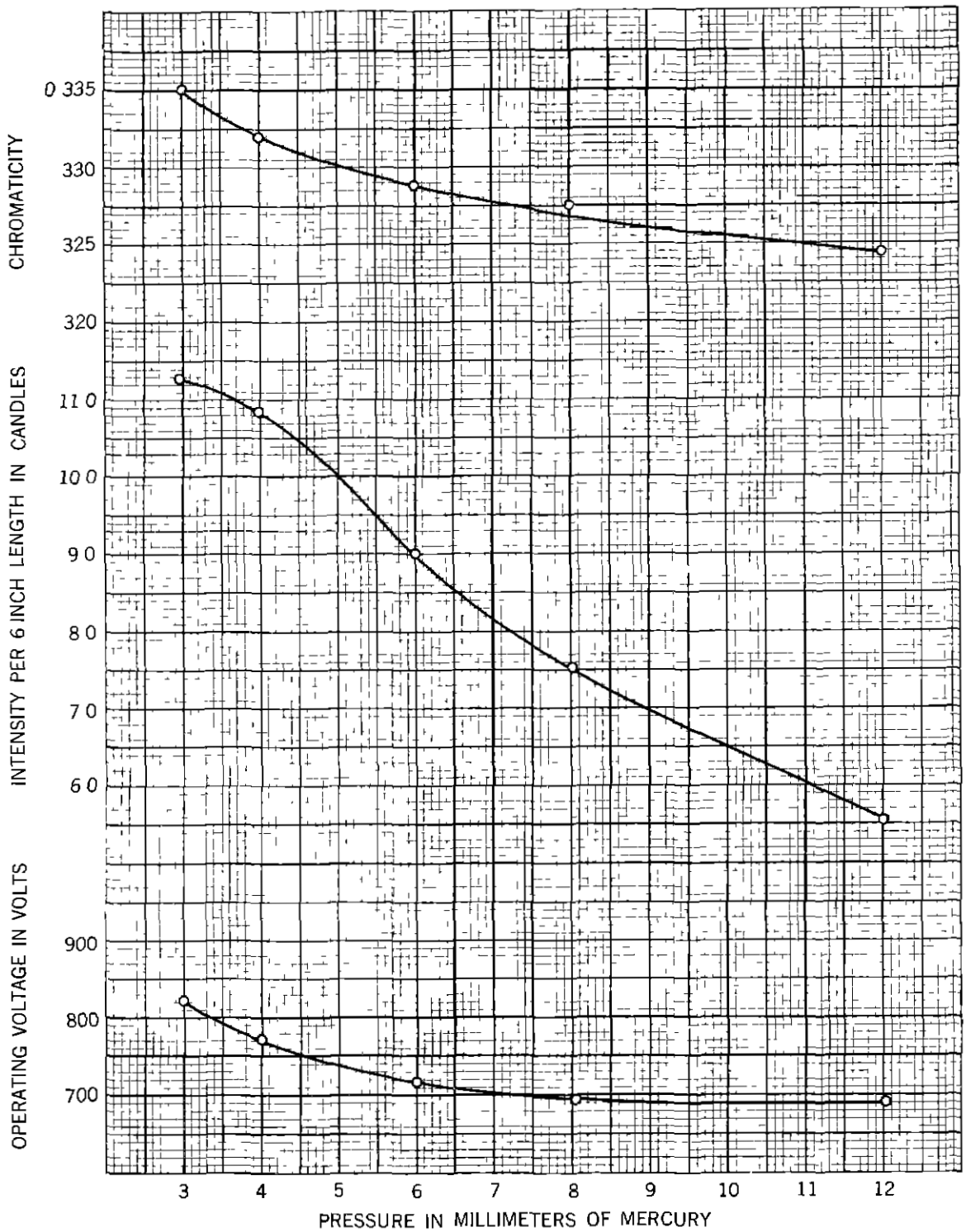

FIGURE 3. Chromaticity (ICI y-coordinate), Intensity and Voltage vs. Pressure Fifteen experimental neon lamps with 60-milliampere current were tested.

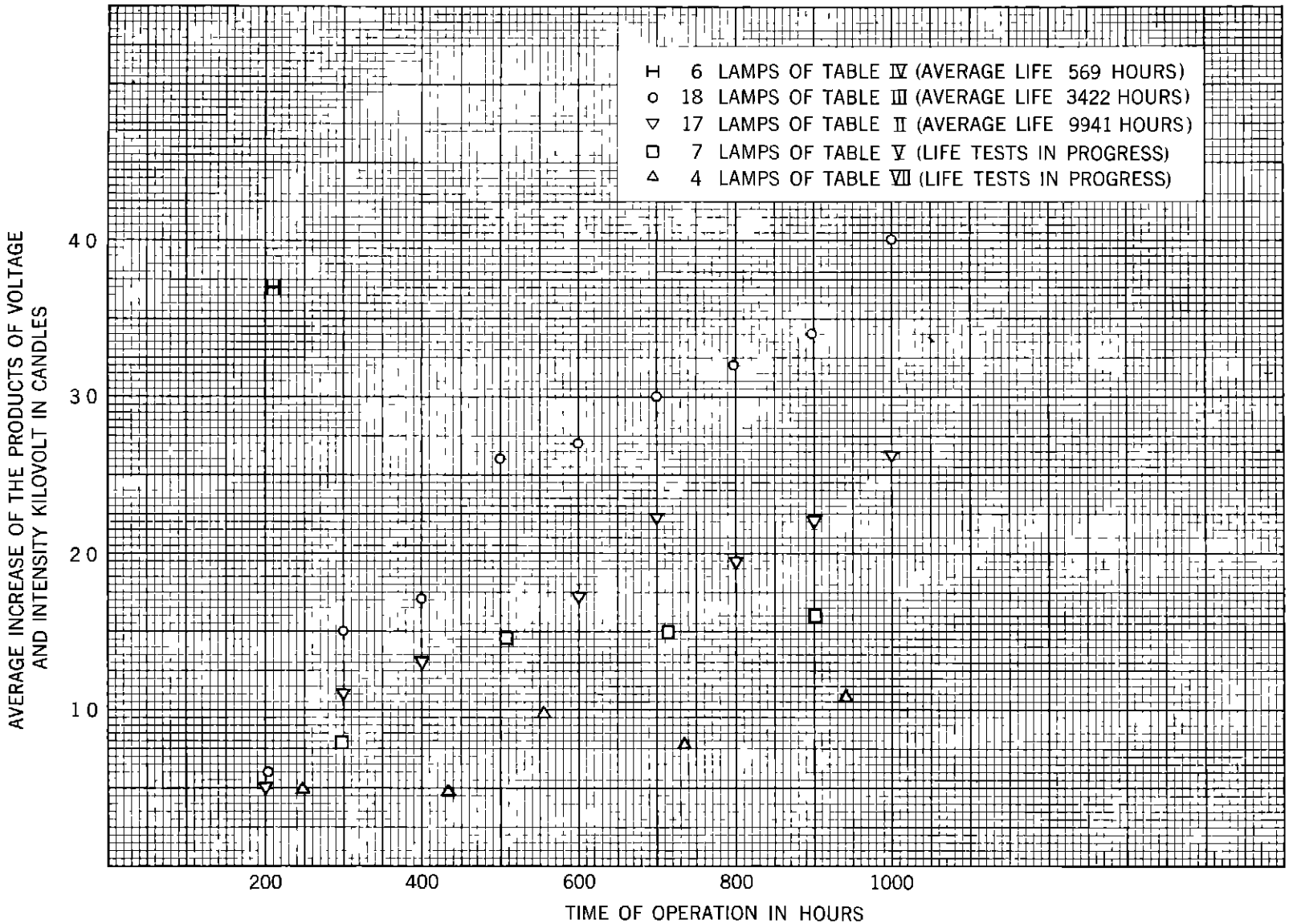

FIGURE 4. Average Increase of the Products of Voltage and Intensity With Time of Operation.