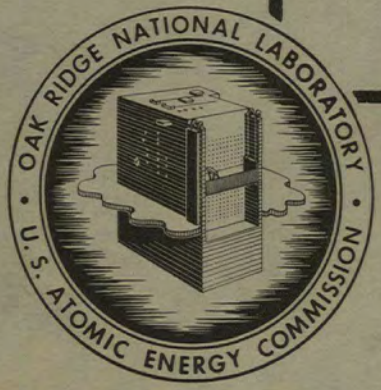
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FILAMENT LIFE EXTENSION IN HIGH-INTENSITY ION SOURCES

O. C. Yonts

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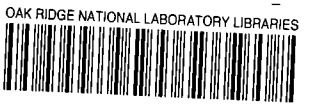
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FILAMENT LIFE EXTENSION IN HIGH-INTENSITY ION SOURCES

O. C. Yonts

ABSTRACT

A new mode of operation is presented which results in increased filament life for high-intensity ion sources.

INTRODUCTION

The normal operation of many arc-type ion sources (in particular, various high-current calutron and cyclotron sources) involves control of the arc by changing filament temperature. This type of control is generally used because it permits independent adjustment of arc voltage and current (Fig. 1).

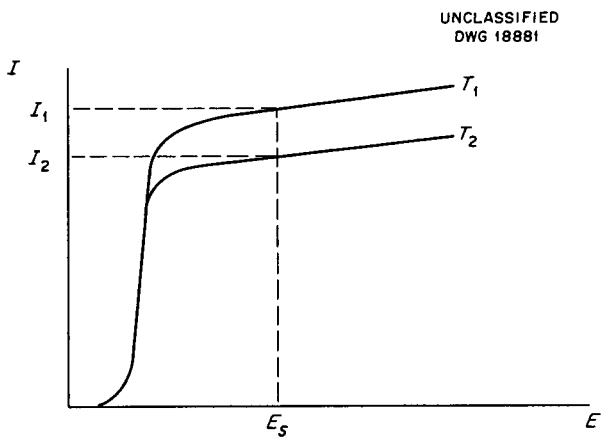


Fig. 1. Normal Operation of Calutron Arc.

This mode of operation is markedly different from that used in gas-filled diodes. Operation in the diode is on the almost vertical section of the emission curve, and the voltage drop across the arc corresponds approximately to the ionization potential of the gas in the tube and is constant over a wide range of emission current. The filaments give extremely long life, provided the velocity of the positive ions does not exceed some critical value (22 volts in mercury vapor diodes) which depends on the type of gas in the tube.[1] Thus, it is possible to use oxide-coated or thoriated tungsten filaments in diode operation. When operation is above this critical value, the excessive ion bombardment causes increased erosion of the filament.

The principal purpose of the experiments reported here was to ascertain whether diode-like operation of the filaments would improve filament life without causing a serious loss in ion output.

EQUIPMENT CHANGES

The arc-current regulator in the calutron operates in the following manner. A rectified a-c signal from current transformers in the primary of the arc-supply transformer is compared with a reference voltage, and the resulting difference signal is amplified by a d-c amplifier. The amplified difference signal is used to control bias on the grid of two thyratrons which control the direct current through a saturable reactor in the primary of the filament transformer. Arc current is varied by changing the reference voltage. An additional control limits the maximum alternating current that passes the saturable reactor and thus determines the maximum current that passes through the filament.

Electrical changes in the arc-current regulator consisted in turning up the reference voltage to its maximum value. A resistance consisting (Fig. 2)

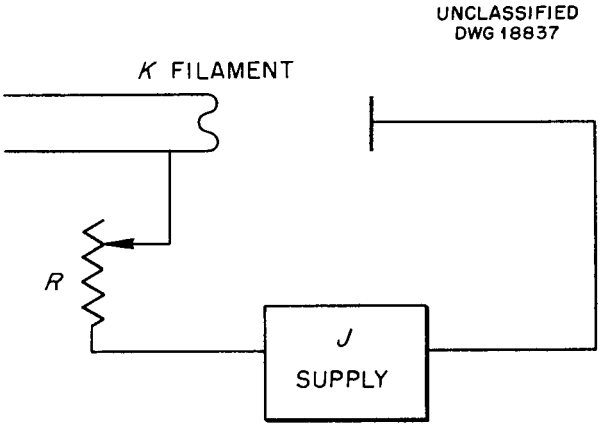


Fig. 2. Circuit Modification for Diode Operation.

[1] *Applied Electronics*, p. 213, John Wiley and Sons, New York, 1943.

of four 150-watt incandescent bulbs in parallel was inserted in series with the arc supply. Arc current was adjusted by changing the supply voltage by means of the induction regulator normally used to change arc voltage. Filament temperature was adjusted by means of the maximum-filament-current control mentioned previously.

Following a preliminary test in a small ("vapor test magnet") unit, cubicle No. 1 (Building 9731, XBX) was selected for use because of its convenient external arc supply. Silicon isotopes were being separated when these experiments started, consequently, the entire series of experiments is based on silicon arc sources. The only change made in the operation of the silicon ion source was the substitution in early experiments of 145-mil tantalum filaments for the 170-mil tantalum filaments normally used. This was done to avoid delay and to permit an economical testing of the operation

PRELIMINARY EXPERIMENT AND RESULTS

A ferrous chloride charge was used in a preliminary experiment that was performed on the vapor test magnet in Building 9731. An arc was operated for 16 hr with an arc voltage drop of approximately 18 volts, as compared with a normal voltage drop of 80 to 100 volts. Figure 3 shows the difference in the erosion of the filament from this run and that of a normal iron run of the same duration. Although the diode-operated filament was virtually unmarked by erosion, it had evaporated from a 145-mil diameter to 126 mils at the bends and 115 mils at the center. A summary of the two runs is given in Table 1.

OPERATIONAL EXPERIMENTS

Eleven experimental runs were made in which the silicon sources mentioned previously were used. Of these 11 runs, three were with diode operation, four were with modified diode operation, three were with normal operation in which a standard arc-current regulator was used, and one was made in which manual control of the arc current was employed.

An operating summary of 17 silicon production runs, including the 11 runs mentioned above, is given in Table 2.

The arc chamber used in runs 1 to 5 was slightly different from that used in runs 6 to 17, hence, results from the first five runs should not be directly compared with the latter.

The preliminary experiment and run 6 indicated that true diode operation reduced output to about half that normally obtained from a standard source unit. Also, visual observation of the arc showed that it did not extend the full length of the arc chamber, it was extremely bright at the filament end and very weak at the opposite end of the chamber. Loss of output appears to be due to this failure of the arc to extend the full distance across the arc chamber.

It was observed that as arc voltage was raised from 45 volts (normal diode voltage for silicon tetrachloride charge) to 80 to 100 volts, the output went back to normal. (Increased voltage across the arc was accomplished by decreasing the filament temperature slightly.) Operation in this fashion, called modified diode operation, showed considerable gain in filament life over that of normal operation and no great loss of output. Typical filament erosion patterns after approximately 24 hr in a $SiCl_4$ arc are shown in Fig. 4.

Run 15 is of special interest, since it was started normally (see Fig. 5, curve Ia) and allowed

TABLE 1. COMPARISON OF PRELIMINARY EXPERIMENTS ON THE VAPOR TEST MAGNET

CONDITIONS	TYPE OF OPERATION	
	Diode	Normal
Bake-out time (hr)	6.5[a]	4
Run time with iron (hr)	10	12
Total run time (hr)	16.5	16
Average arc power (watts)	46	300
Peak ion current (ma)	3.6	5.0
Average ion current (ma)	2[b]	4
Filament diameter[c] (mils)		
Start	145	145
Finish		
At center	115	Badly eroded
At bends	126	126

[a] Two hours of lithium arc discharge in bake-out because of dirty unit.

[b] Ion beam was hitting G-slit during diode operation.

[c] For diode-type operation, entire loss is due to evaporation. For normal operation, loss is due to evaporation and erosion. Loss at bends is due entirely to evaporation.

TABLE 2. SUMMARY OF EXPERIMENTS ON SILICON PRODUCTION RUNS

RUN NO.	TYPE OF OPERATION	FILAMENT DIAMETER (mils)	K-LIFE (hr)	AVERAGE OUTPUT OF Si^{28} (ma)	CHARGE CONSUMPTION (g/hr)	AVERAGE ARC-POWER DISSIPATION (watts)	REASON FOR TERMINATION
1	Normal	170	24	19.63	3.09	342.6	Open K
2	Normal	170	13	18.67	3.24	364.5	Open K
3	Normal	170	15	18.30	3.24	382.6	Open K
4	Normal	170	30	26.55		316.8	Open K
5	Normal	170	26	25.44	2.84	321.1	Open K
6	Normal	170	20	24.95		560.3	Open K
7	Diode	140	24	14.08	2.04	182.5	Scheduled[a]
8	Modified diode	140	24	12.54	2.16	325.5	Scheduled[b]
9	Modified diode	140	47	24.1	2.74	366.1	Open K
10	Diode	140	51	13.45	2.33	184.1	Open K
11	Diode	140	66	9.13	2.86	203.4	Open K[c]
12	Normal	140	17	18.47	1.71	514.6	Open K
13	Manual	140	23	18.91	3.90	526.2	Open K[d]
14	Normal	170	37	32.2	3.90	427.7	Open K
15	Modified diode	170	85	26.9	4.54	225.1	Open K[e]
16	Normal	170	28	33.6	2.86	345.0	Open K
17	Modified diode	170	75	30.1	2.84	280.0	Open K[f]

[a] Runs 7 and 8 stopped after 24 hr for comparison of filament wear.

[b] Floating anode shorted out and reduced output.

[c] Floating anode shorted.

[d] J-regulator bypassed and arc controlled manually.

[e] Normal run until filament current decreased to 4.5 amp, then operated as modified diode until burnout.

[f] Same as run 15 except that when modified diode operation filament current decreased to 4 amp, the run was returned to normal operation.

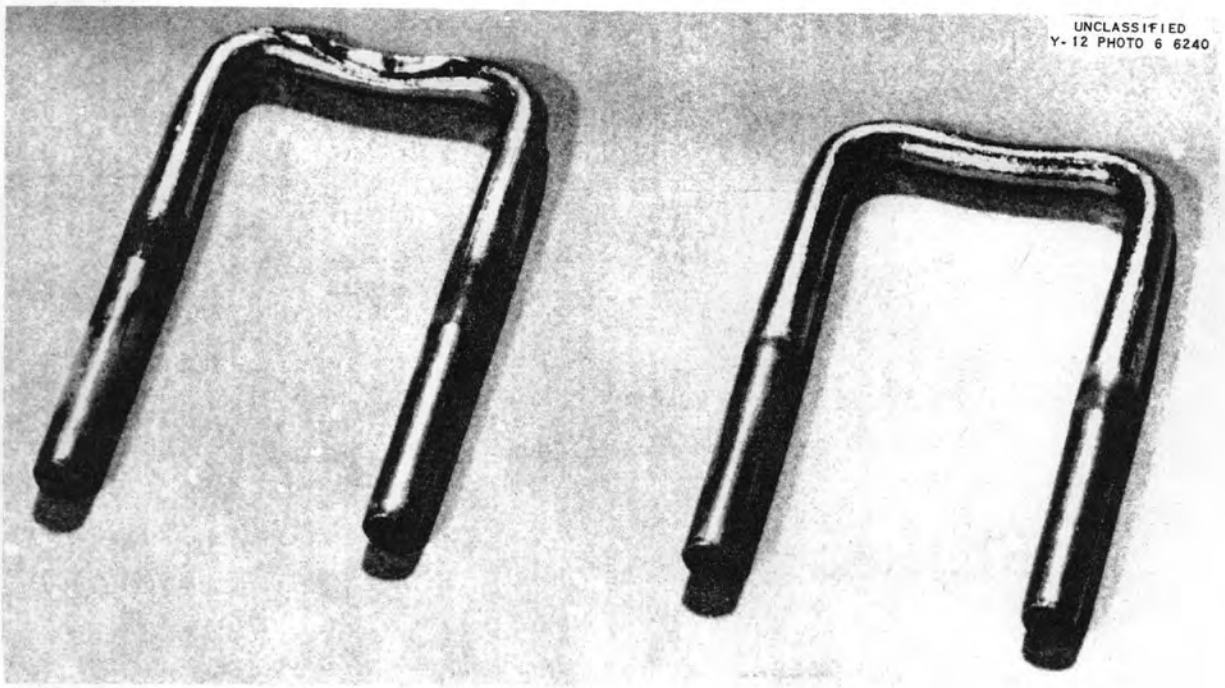


Fig. 3. Normal and Diode-operated Filaments Used in the Preliminary Experiment.



Fig. 4. Representative Filament and Evaporation Wear for Three Modes of Arc Operation. (*a*) Normal (23 hr), (*b*) Modified Diode (24 hr), (c) Diode (24 hr).

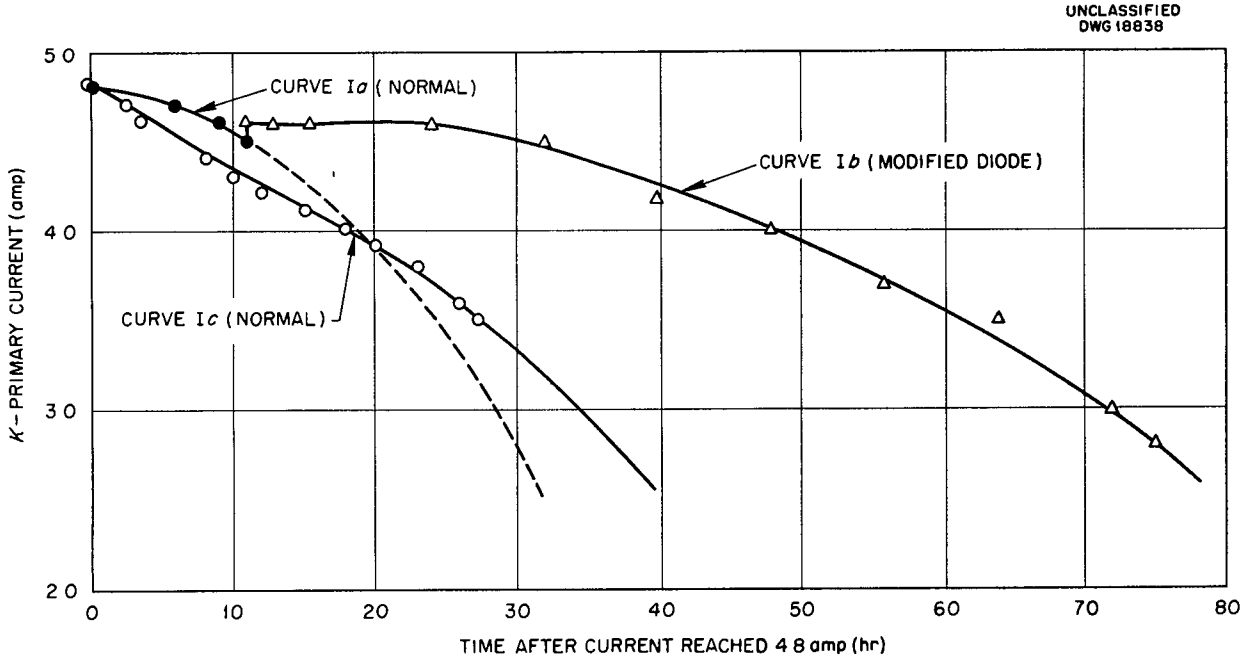


Fig. 5. Comparative Decay of the Filament Primary Current for Runs 15 and 16.

to run until the filament primary current decreased from 5 to 4.5 amperes. At this point, the series resistance was switched into the arc circuit and the run continued with modified diode operation (curve Ib). Note the break in the curve for run 15 at the change-over point.

Curve II (Fig. 6) shows correlation between arc power and filament wear for 145-mil filaments when a gas baffle is placed across the arc chamber $\frac{1}{8}$ in. back of the collimating slot. For comparison, curve III shows correlation between arc power and filament wear for 170-mil filaments with $\frac{1}{8}$-in. gas baffle in the normal silicon runs in tank II. Ordinates are average arc power for an entire run. The abscissas are obtained from filament primary-current decay curves by interpolating or extrapolating the value of filament life at the 3.0-amp primary-current value. Typical decay curves are shown in Fig. 7.

The curve showing power dissipation vs. filament life is apparently affected by the gas-baffle geometry in the arc chamber (Figs. 6 and 8). Further investigations of the effect of this baffle on filament life should be performed.

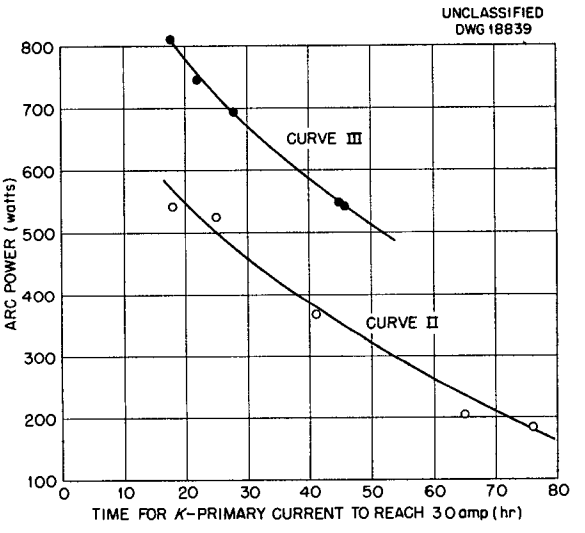


Fig. 6. Influence of Arc Power on Useful Filament Life When $\frac{1}{8}$-in. Gas Baffle is Used.

CONCLUSIONS

It has been shown that true diode operation greatly increases filament life and results in an ion output loss of about 50%, but that modified

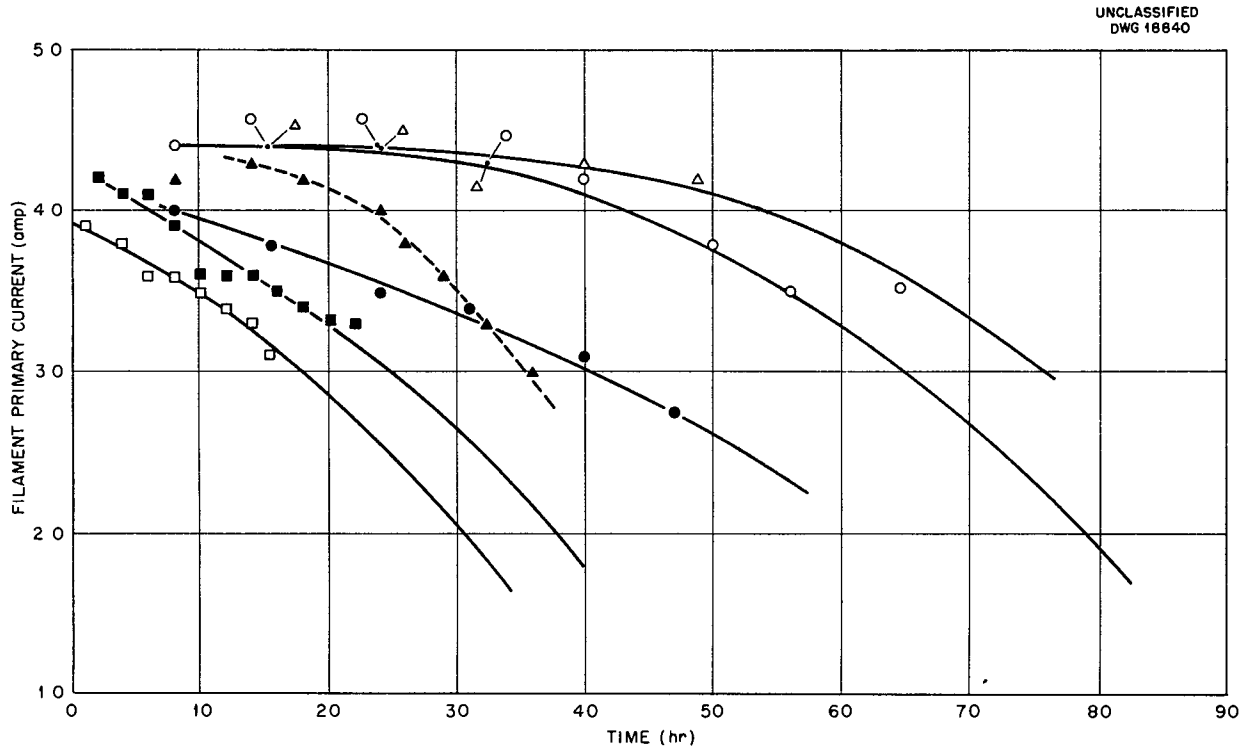


Fig. 7. Typical Decay Curves for Filament Primary Current.

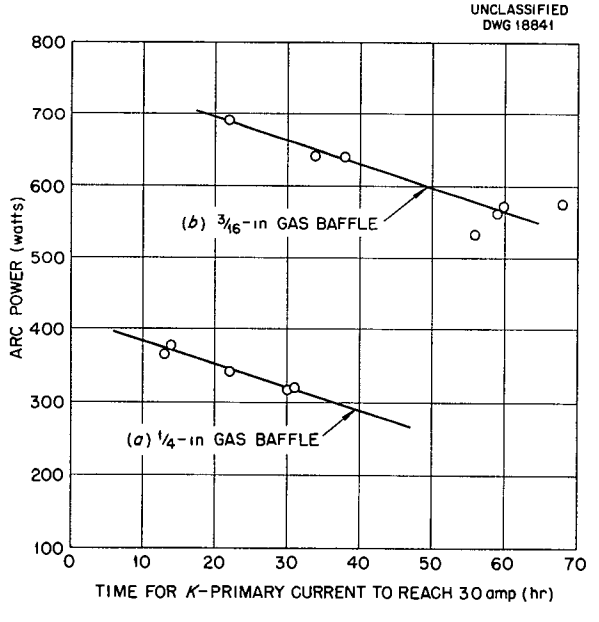


Fig. 8. Influence of Arc Power on Useful Filament Life.

diode operation increases filament life by a factor of 2 to 3 and causes no significant loss in output.

Further experimentation is desirable along the following lines: (1) to investigate applications to other ion sources such as those used in cyclotrons, (2) to study the ion output from the diode type of source as a function of geometry of the arc discharge, (3) to study charge materials other than silicon and iron, (4) to investigate thoriated tungsten or coated filaments, particularly in a cyclotron type of source with deuterium or hydrogen charges, (5) to investigate in detail the effects introduced by gas-baffle geometry.

ACKNOWLEDGMENTS

The author is indebted to G. M. Banic, Jr. for his assistance in the operation of the vapor test magnet, to the operating crews in Building 9731, XBX for their careful handling of the experimental runs on production equipment, and to J. R. McNally, Jr. for his advice and encouragement throughout the course of these experiments.