

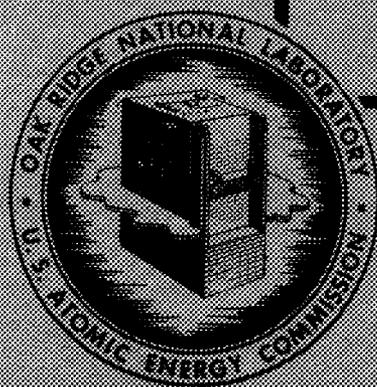
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FILAMENT ACTIVATION WITH GADOLINIUM

O. C. Yonts
L. O. Love



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ABSTRACT

The degree of activation of tungsten and tantalum filaments by gadolinium is given, and a temperature determined above which this activation ceases.

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FILAMENT ACTIVATION WITH GADOLINIUM

O. C. Yonts and L. O. Love

INTRODUCTION

During the processing of gadolinium in the calutron, periods of operation were encountered during which normally stable arc conditions, i.e., filament current, arc current, arc voltage, and ion current, were observed to fluctuate in a regularly periodic manner. Both the period and the amplitude of these fluctuations depended on the conditions at which the arc was running, but the directions of the changes were invariably the same. A period of steady operation was suddenly interrupted by the filament current dropping below its normal value, while at the same time the arc current increased and the arc voltage and ion current decreased. After a brief period of operation at these new conditions the arc went out, the filament current and arc voltage were automatically returned to their initial values, the arc was re-established, and the arc current and ion current assumed their normal values. This sequence of events was then repeated at regular time intervals until brought under control by some adjustment of the arc conditions.

Certain arc conditions were observed to favor the occurrence of these periods of instability. These were: (a) high arc voltage, e.g., above 200 volts; (b) low source temperature and, consequently, low vapor density in the arc; and (c) the use of a floating anode. These same conditions affected the period and amplitude of the fluctuations. High voltage and low temperature resulted in

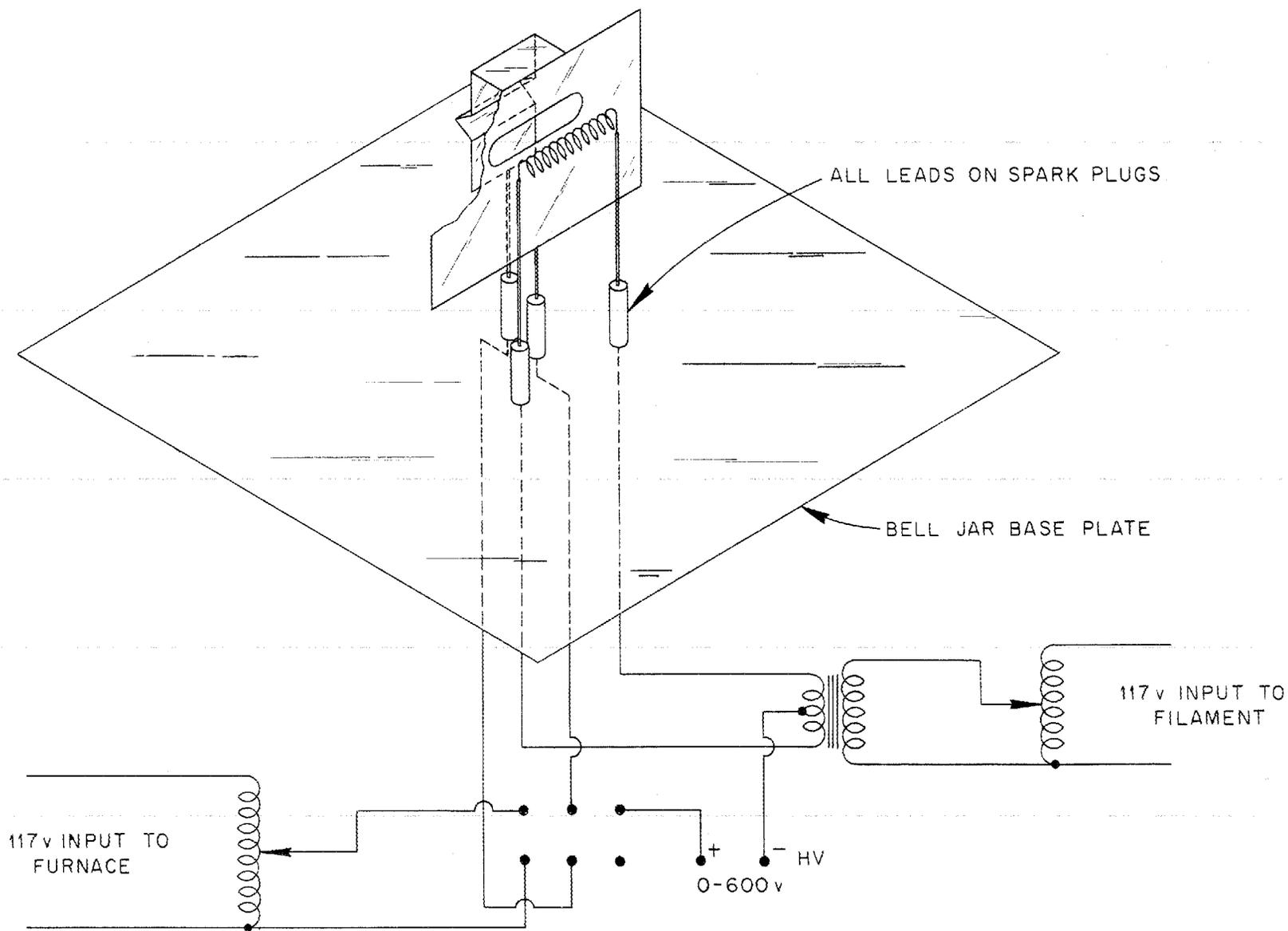
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long period fluctuations of large amplitude, while the floating anode had the effect of shortening the period of fluctuation.

In periods of extreme disturbance, the filament current decreased to zero while the arc current increased and the arc voltage and ion current decreased by approximately half their initial values. The arc persisted under these conditions for as much as a minute even though the filament temperature dropped during this time from about 1800°C to an estimated 1000°C. Persistence of the arc at such low filament temperatures suggested that filament activation was probably a major factor in bringing about the observed sequence of events. Consequently, two investigations were initiated almost simultaneously with the common aim of studying the activating properties of gadolinium. Because of their different approaches to the problem, these investigations have been designated as "Laboratory Studies" and "Production Studies", respectively.

LABORATORY STUDIES

The equipment used in these studies is shown schematically in Figure 1. The test filament, an emission collecting plate, and an oven from which gadolinium could be evaporated onto the filament were mounted in the evacuated space beneath a glass bell-jar. The oven was made of thin sheet tantalum and could be heated by the direct passage of current through it. Filament current and collector plate voltage were variable. The filament temperature was measured with a Leeds and Northrup optical pyrometer, and net current to the collector plate was taken as a measure of total emission from the filament.



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Fig. 1. Circuit and Equipment Schematic Diagram.

In a typical experimental run, a filament of some pure metal was surface-cleaned and outgassed by preliminary heating in vacuum. The filament temperature was then set at some arbitrary value, and successive values of the collector current were observed as the collector voltage was increased step-wise from zero to 600 volts. The filament temperature was then changed to some new value, another plate current-plate voltage series was run, and this was repeated until the temperature range of interest had been covered. The filament was then allowed to cool, a coating of gadolinium was evaporated onto it from the oven, and a similar series of observations was made with the coated filament.

For the pure tungsten filament, the temperature was varied from 1575° to 1980°C, and the maximum emission varied from .025 to 40 ma. The emission curves for the pure tungsten are shown in Figure 2. The same filament when coated with gadolinium gave emissions ranging from .045 to 10 ma at temperatures ranging from 1450° to 1575°C. At 1575°C emission from the gadolinium-coated filament was 400 times that from the pure tungsten filament. The curves of the coated filament together with the pure tungsten for 1575°C are shown in Figure 3. At a somewhat higher temperature, however, emission from the coated filament reverted to values only slightly higher than for pure tungsten, and remained at these low values in all subsequent runs. The curves for tungsten and the residual activation are shown in Figure 4. This deactivation appears to be due to almost complete evaporation of gadolinium from the filament at some rather sharply defined temperature. Emission-voltage curves for the deactivated filament are also shown in Figure 2.

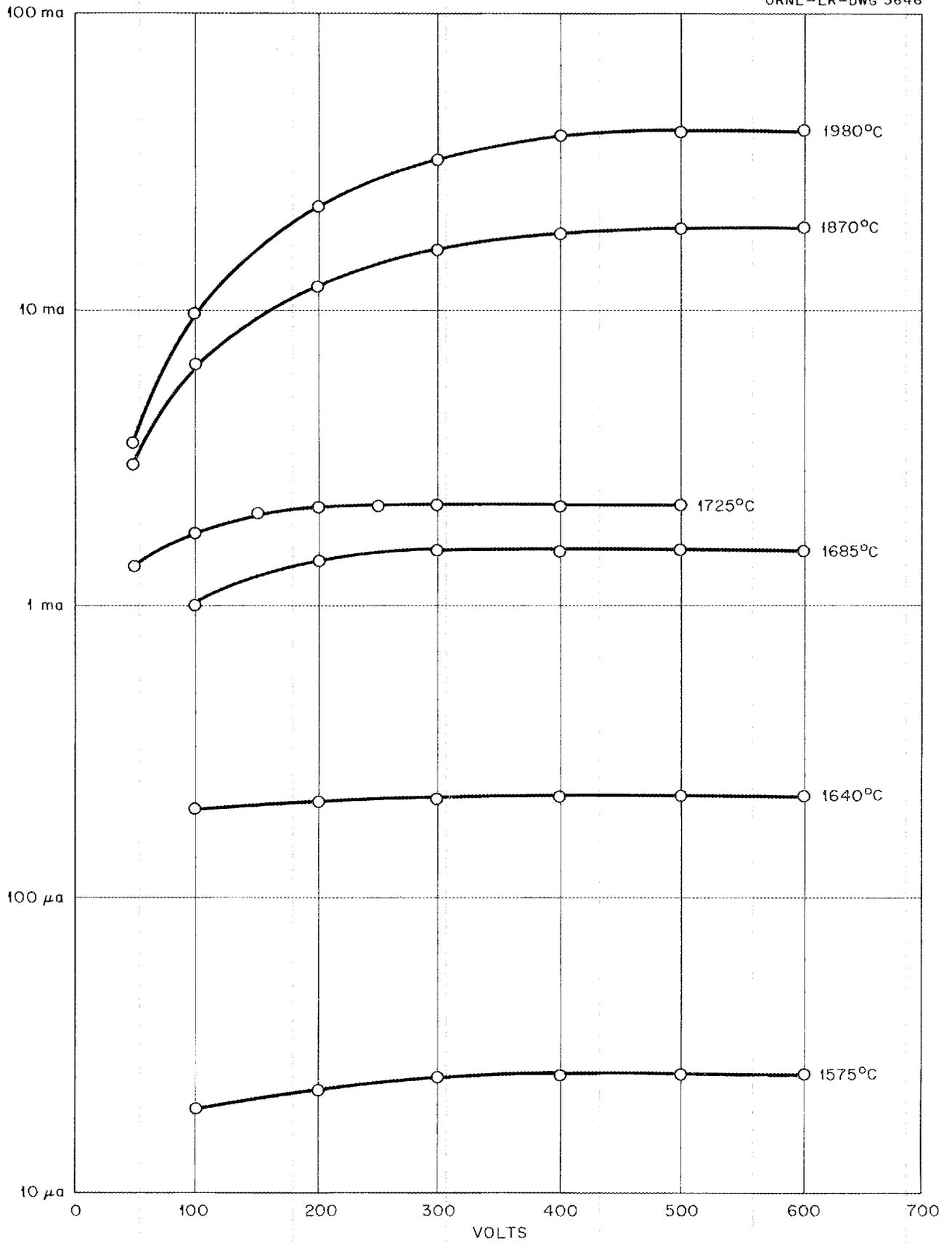


Fig. 2 Emission Curves of Pure Tungsten at Various Temperatures

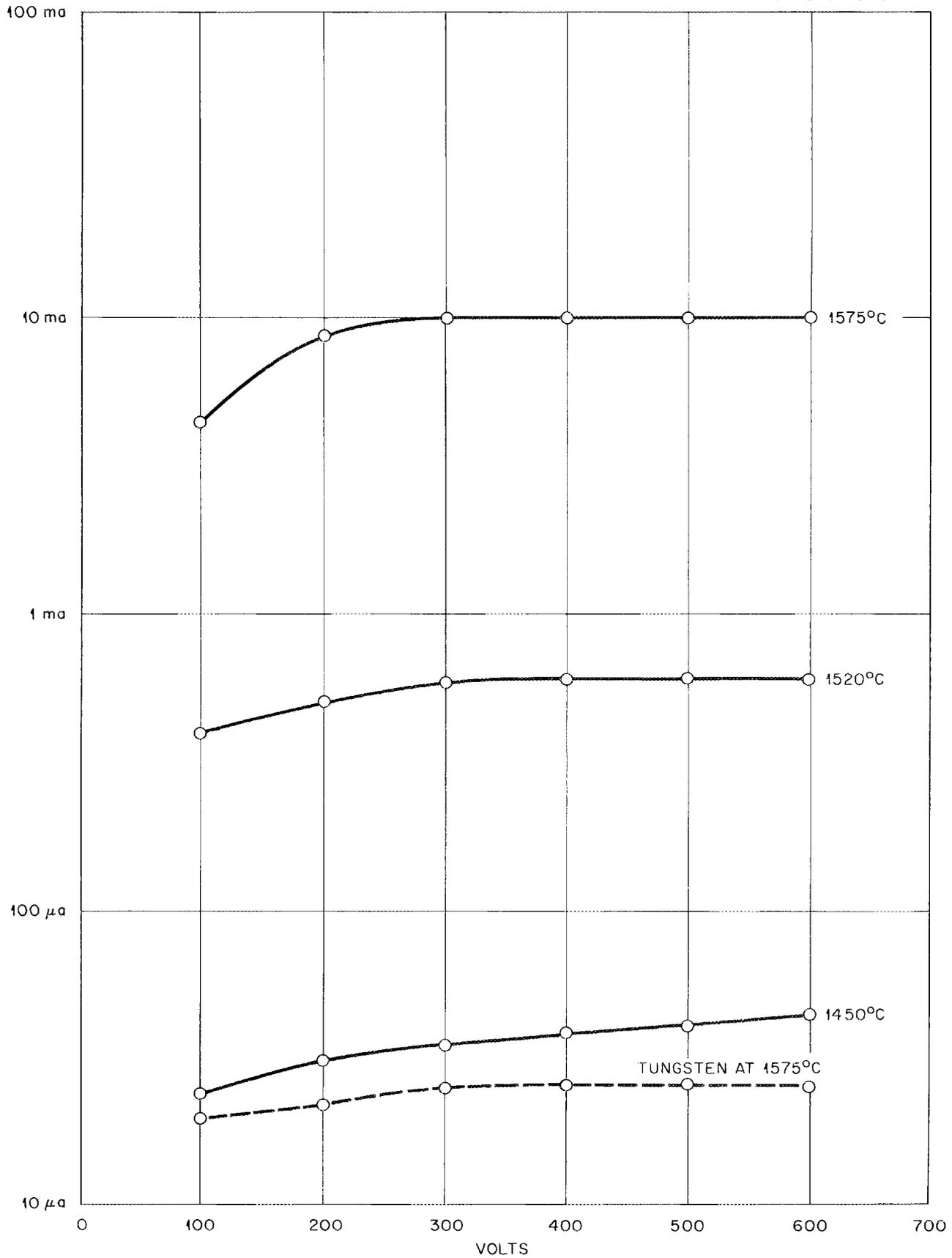


Fig. 3. Emission Curves of Gadolinium-Coated Tungsten.

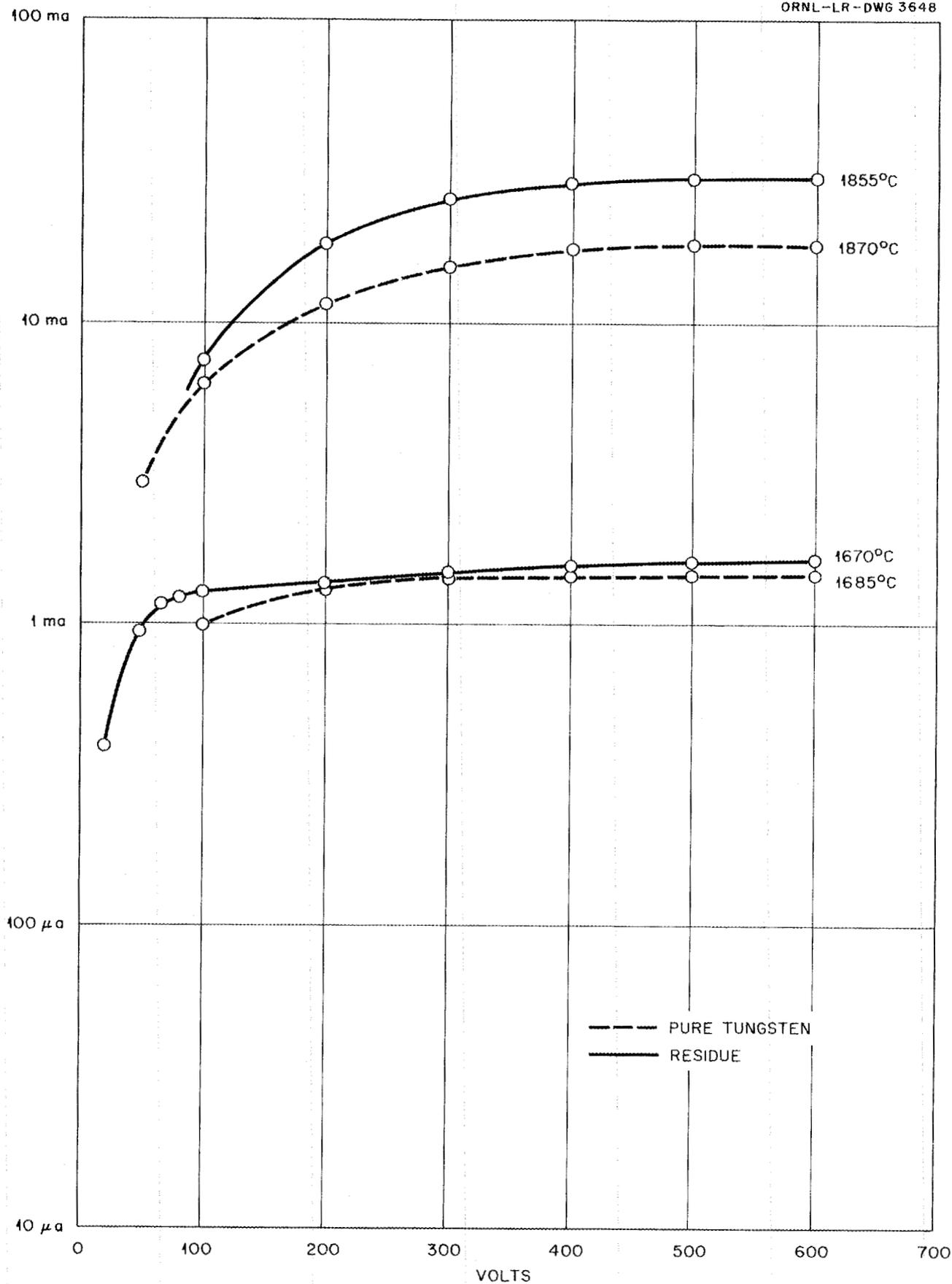


Fig. 4. Emission Curves for Pure Tungsten and Tungsten With Gadolinium Residue.

A similar series of runs was made using a 10-mil tantalum filament, and the results are plotted in Figure 5. Activation appears to be less pronounced in this case in that the emission is increased only 20 fold at 1550°C.

Measurements were made of the temperatures at which deactivation occurred for both tungsten and tantalum filaments. The values found were 1650° and 1670°C, respectively. The close agreement between these temperatures lends support to the presumption that deactivation results from evaporation of gadolinium from the filament.

PRODUCTION STUDIES

These studies were carried out in the production calutrons during the processing of samarium. Standard (170-mil tantalum) calutron filaments, to which gadolinium had been applied in various ways, were run under essentially normal production conditions, and were observed throughout their service life for evidences of activation. Three runs were made using gadolinium-"coated" filaments, and two using filaments which had been "inlaid" with gadolinium. The coated filaments were prepared¹ by placing a filament and a piece of gadolinium metal in intimate contact and heating them in an inert atmosphere to above the melting point of gadolinium. A heavy coating, together with some apparent alloying, resulted from this treatment. One inlaid filament was prepared

¹All filaments used in production studies were prepared by F. R. Duncan of the Stable Isotope Development and Utilization Group.

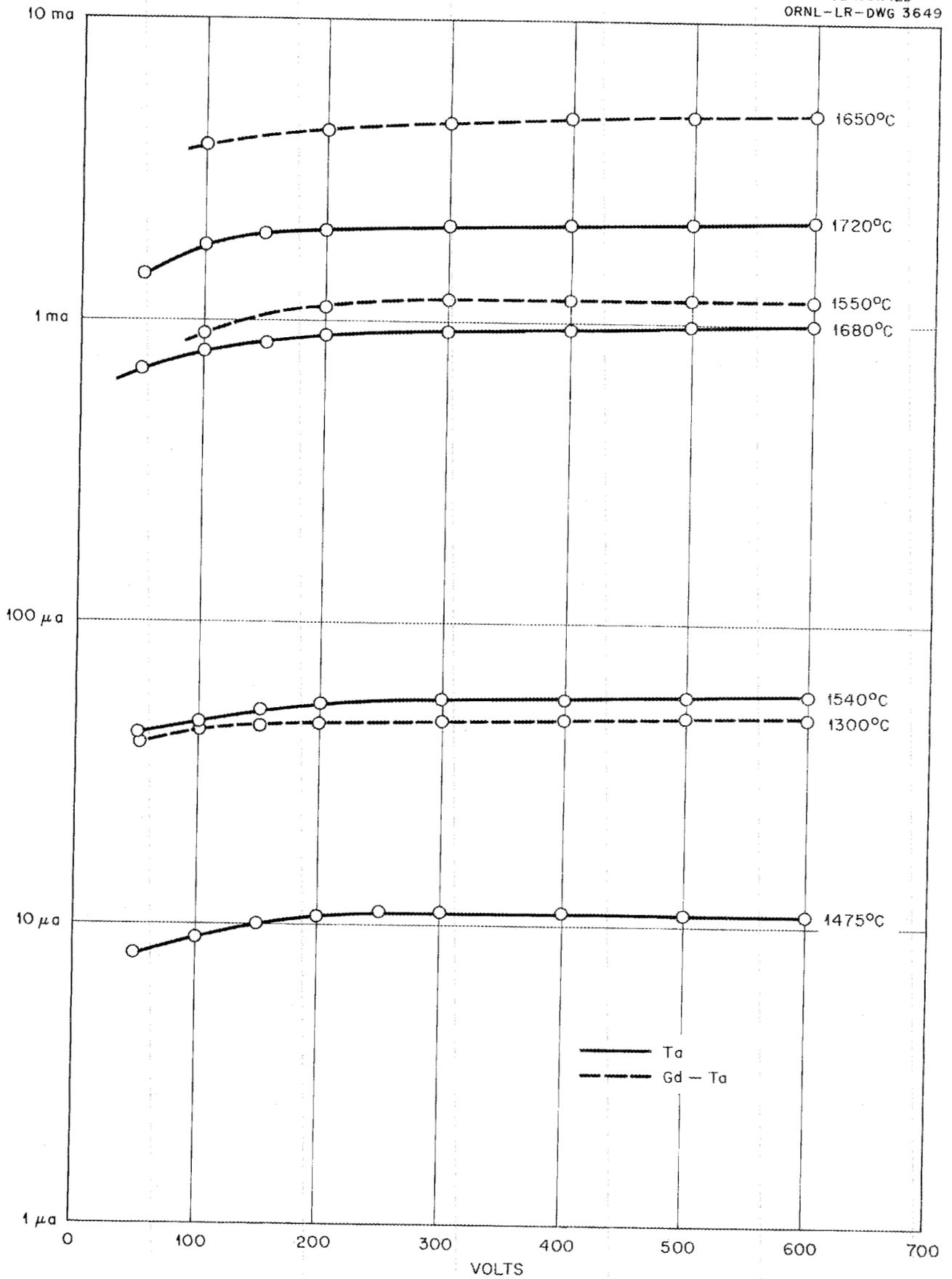


Fig. 5. Emission Curves of Tantalum and Gadolinium-Coated Tantalum.

by peening bits of gadolinium metal into small holes drilled in the face of the filament, and the other by filling similarly placed holes with the molten metal.

In all production experiments, precautions were taken to avoid excessive heating of the filament during the start-up period, since it was realized that gadolinium applied to the filament might be driven off before steady operation was attained. In spite of these precautions, this appears to have occurred in the case of the coated filaments, however, in as much as none of them showed any evidence of activation during operation. With the two inlaid filaments, on the other hand, distinct evidence of activation was observed during the first several hours of the runs in which they were used. This behavior of the inlaid filaments was probably due to the fact that the gadolinium was deeply imbedded in the filament, and hence less susceptible to evaporation.

Activation was evidenced by the abnormally low filament currents at which operation was initiated and continued over the first several hours of the runs. The filament current required to initiate operation with the inlaid filaments was fully 33% below normal; and it remained below normal for approximately nine hours in one case and for approximately 40 hours in the other. During these periods of activation, the filament current required to maintain operation increased continuously; whereas, with normal filaments the required current is a continuously decreasing function of time, due to diminishing filament cross section. The variations of normal and of activated filament primary currents with time in operation are shown in the curves of Figure 6. From these curves it appears that although the inlaid filaments were strongly activated at the

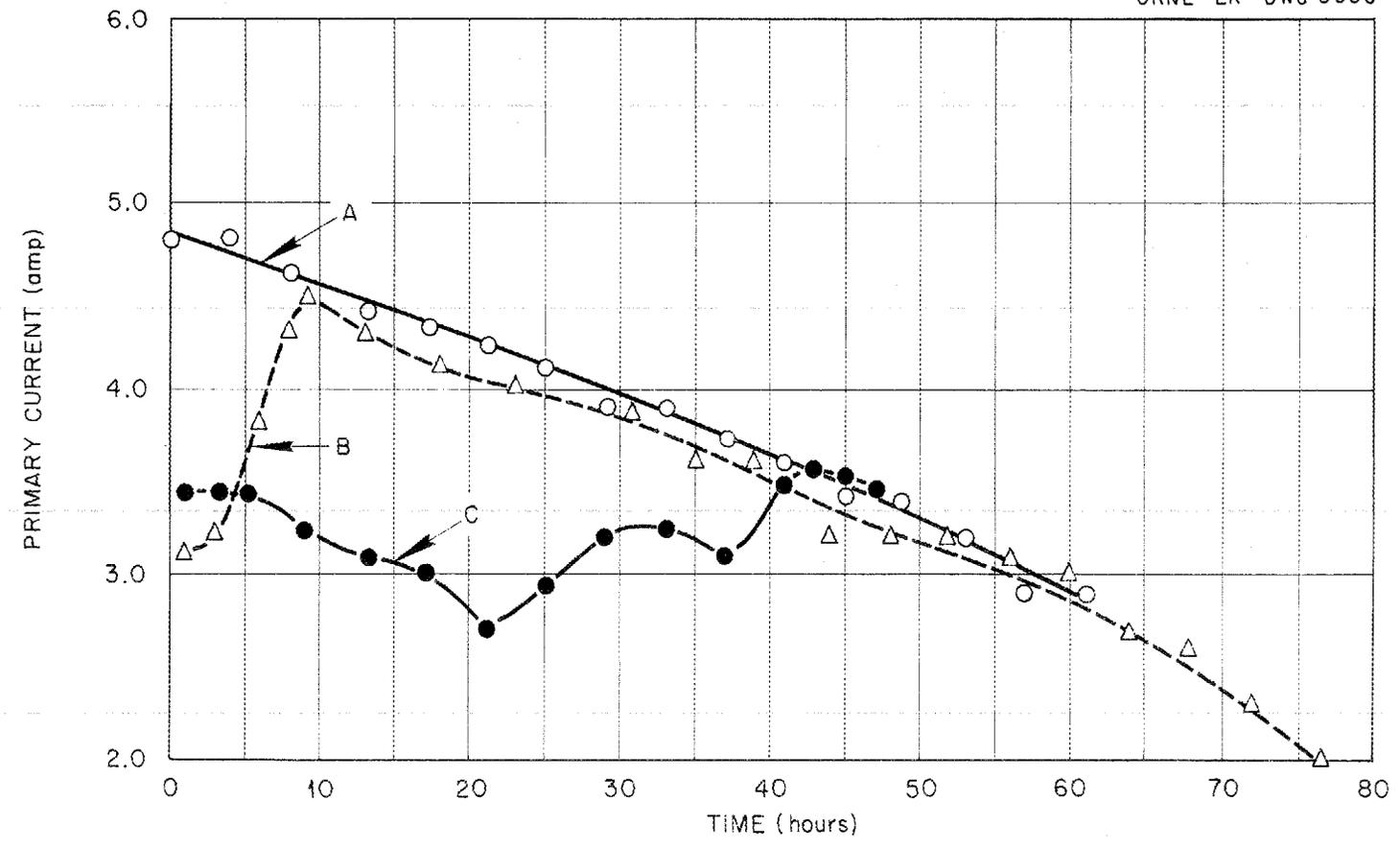


Fig. 6. Change of Filament Primary Current with Time for Normal Filament (A) and Gadolinium-Impregnated Filaments (B and C).

beginning of operation, this activation was lost after a few hours without having contributed significantly to the over-all service life of the filaments.

CONCLUSION

The filament activation observed in the production experiments, and the loss of activation in the course of calutron operation, are in qualitative agreement with the more detailed observations made in the laboratory studies. The fact that activation does not persist for any considerable part of the life of a calutron filament, and that over-all filament life is not increased by an initial period of activation, makes it appear quite unlikely that gadolinium-activated filaments offer any advantage over plain tantalum filaments in calutron production operation.

The fluctuating arc phenomenon whose observation led to these studies being made cannot be explained solely on the basis of filament activation and deactivation as observed in these experiments. No satisfactory explanation of the unstable arc condition has been found on the basis of activation alone. Because of the high temperature of the filament (approximately 1900°C) no gadolinium will be deposited on the filament as a coating. So some secondary process is probably necessary to supply the electrons which start the chain of events leading to the cooling of the filament by the current regulator. After the filament cools slightly, then gadolinium can remain on the surface and activation could become a part of the cycle.

ACKNOWLEDGEMENTS

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