NASA CR-143811

PHOTOELECTRON EMISSION ANALYSIS OF SURFACE ELEMENTS OF THE INTERNATIONAL SUN EARTH EXPLORER

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24 February 1975
Final Report (7 June 1974 through 24 February 1975)

Prepared for
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Greenbelt, Maryland 20771

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30 June 1975
C400-RJG-75-1253

National Aeronautics and Space Administration
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Greenbelt, Maryland 20771

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No

4. Title and Subtitle	5. Report Date
Photoelectron Emission Analysis of Surface Elements of the International Sun Earch Explorer	24 February 1975
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
W. T. Spencer	AVSD-0055-75-RR
9. Performing Organization Name and Address Avco Corporation Systems Division 201 Lowell Stree+ Wilmington, Massachusetts 01887	10. Work Unit No.
	11. Contract or Grant No. NAS-5-20592
12. Sponsoring Agency Name and Address Goddard Space Flight Center Greenbelt, Maryland 20771 Contracting Officer : R. I. Weiss Technical Officer : J. P. Heppner	13. Type of Report and Period Covered Final Report 7 June 1974 through 24 February 1975
	14. Sponsoring Agency Code

15. Supplementary Notes
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16. Abstract
Avco Corporation's Systems Division (Avco/SD) under Contract NAS 5-20592, dated 7 June 1974, measured the photoemission of engineering materials (aluminum; copper, plain; copper, abraded; copper-beryllium; magnesium; silver; In_2O_3 on silica; reflective coating on silica; Teflon; Kapton; and Pyre ML) associated with the International Sun Earth Explorer (ISEE) Satellite. The program complemented a previous Avco/SD effort carried out under Contract NAS 5-11138.

This final report covers Avco/SD's activities under Contract NAS 5-20592 during the period 7 June 1974 through 24 February 1975. It describes the procedures used, including the experimental equipment; discusses the results of the program; presents the conclusions reached; and recommends areas for further work. Data regarding the measured yield of the 11 materials whose surface emission was determined is included in the form of plots of photo-electric yield versus incident light wavelength.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Photoelectron emission, Photoemission, Work Function, International Sun Earth Explorer, Surface electrons, Pulsed and Monochromatic Measurements	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	27	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

PREFACE

A. OBJECTIVE

The objective of this program was to measure photoemissions from engineering materials associated with the International Sun Earth Explorer (ISEE) Satellite.

B. SCOPE OF WORK

The photoemissions of eleven engineering materials (aluminum; copper, plain; copper, abraded; copper-beryllium, magnesium, silver, In_2O_3 on silica; reflective coating on silica; Teflon, Kapton, and Pyre ML) were measured. Test samples were mounted on a turntable in a vacuum chamber. The program was conducted in three steps:

1. The experimental equipment was prepared and preliminary measurements were made.

2. Pulse emission techniques using monochromatic light were employed to measure the photoemissions of the materials checked.

3. The technique used in Step 2., above, were refined to provide increased sensitivity (via incorporation of an electron multiplier).

C. CONCLUSIONS

Two kinds of conclusions can be drawn from this study. First some added data has been obtained on the relative yield of several engineering materials that may be used in satellites such as the ISEE. Second, it has been shown that Channeltron measurements can be made in apparatus that had previously proved inadequate for pulsed monochromatic photoemission measurements.

D. SUMMARY OF RECOMMENDATIONS

If this line of research is continued, the following determinations, all of which would be appropriate for a continuing program of materials study, can be considered.

1. Effect of Channeltron aperture size.

2. Effect of light pulse length.

3. Effect of surface treatment.

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1. INTRODUCTION

In June 1974, Avco was pleased to receive funding to make measurements of photoemission from engineering materials associated with the International Sun Earth Explorer (ISEE) Satellite. The program has been conducted in three steps. In the first, the experimental equipment, which had been idle for more than a year, was reconditioned and some preliminary measurements were made. Step two was the application of the pulse emission technique with monochromatic light. The final step was a further refinement of that technique with an increase in sensitivity through the addition of an electron multiplier.

2. PROCEDURE

Details of the experimental technique and of the equipment design have been given fully in reports (References 1, 2, and 3) on the previous contract (NAS 5-11138). Samples of the test material are mounted on a turntable within a vacuum chamber as shown in Figure 1. By rotating the turntable any one of twelve samples can be placed in the test position. A mercury short-arc lamp is used as the source of ultraviolet light. Light from the lamp is collimated and passes through a grating monochromator. The output of the monochromator enters the vacuum chamber through a sapphire window and strikes that sample which is located at the test position. With the exception of the window, all transmitting optical components are quartz. The wavelength range of interest is 2000 to 4000 Angstrom. A mechanical shutter is used to produce pulses of light when desired.

The first segment of the current work has been the reactivation of the experimental equipment and preliminary measurements on some of the materials scheduled for the program. Aside from the replacement of a vacuum pump, the only major change in the system has been the use of a new electrometer, a Keithley, Model 610B, in place of the E-H electrometer previously used. This change in instrumentation was introduced to better facilitate the pulse measurements which were to be made.

The preliminary measurements, reported in Section 4, served a dual purpose: checkout of various components and the early evaluation of some of the materials. These measurements were of the type conducted in Phases III and IV of the previous contract, that is, the photocurrent has been recorded as a function of the radiation wavelength to which the sample is continuously exposed (the shutter is not used).

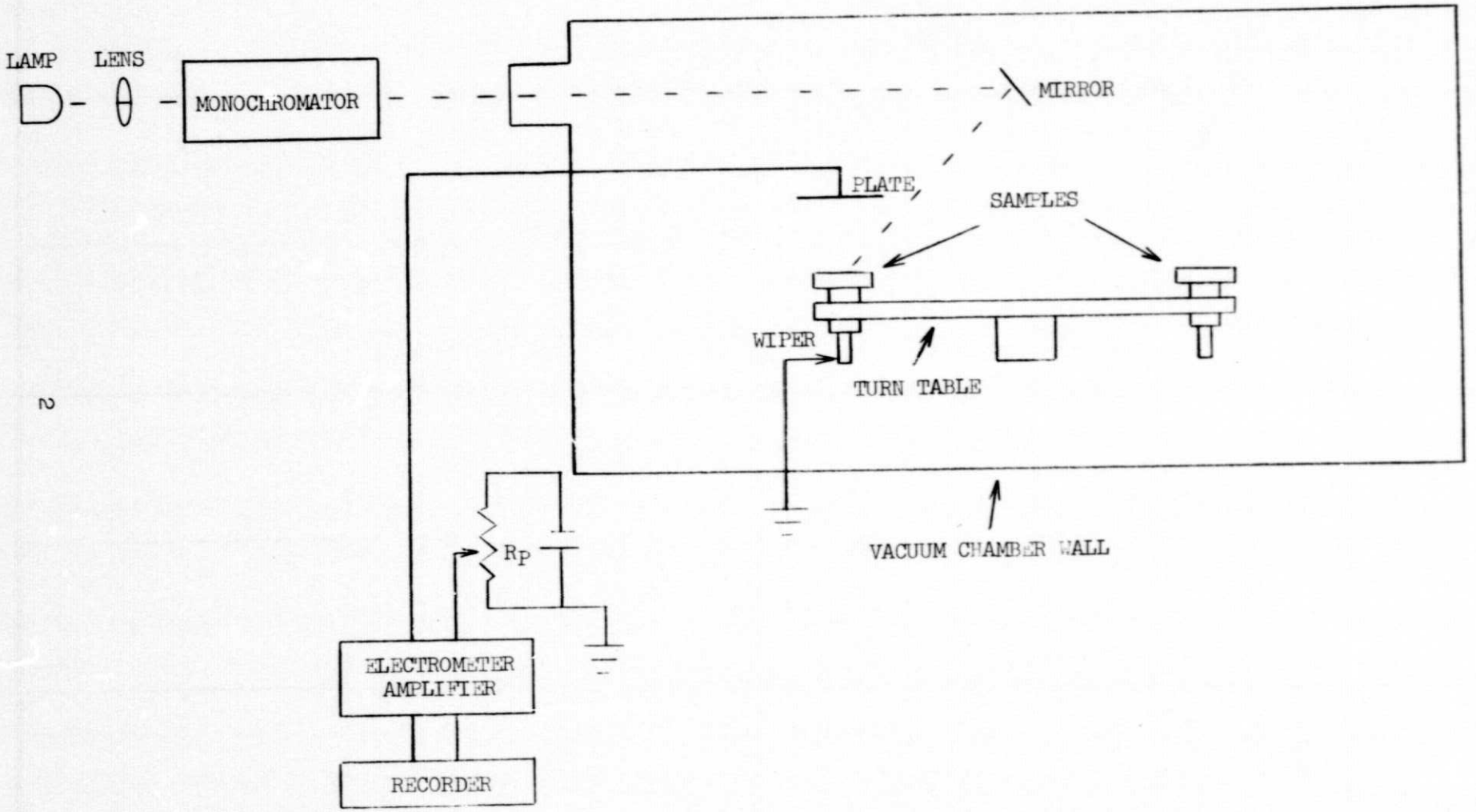

FIGURE 1 Experimental Apparatus

The second group of measurements applied the pulse technique at selected wavelengths of monochromatic radiation. The rationale for the pulse technique is discussed in the earlier reports. Briefly, the argument is that for an insulator only the surface electrons are available for emission. To make relative yield measurements for a comparison of non-conductors one should use a pulse of radiation that will not completely deplete the available supply of electrons. The problem with this measurement, which was anticipated, is that the signal levels are very low.

To overcome the sensitivity problem inherent to the pulsed monochromatic measurements, a third set of measurements has been made. The collector plate (shown above the sample in Figure 1) was replaced by a Channeltron electron multiplier.

With the new geometry it was hoped that sufficient photoelectrons from the sample would enter the aperture of the Channeltron. With a gain of 10^7 or more the output of the multiplier could be amplified and conditioned by conventional pulse circuitry and the number of photoelectrons counted. The Channeltron application is illustrated in Figure 2.

A comment should be made on the condition of the samples prior to the measurements that have been made. With the exception of copper, the samples of the test materials have been supplied by GSFC. The samples were inserted into the vacuum chamber "as received" with no cleaning technique applied. An evaporated film of silver on a copper-beryllium substrate, obtained for the previous contract, was used in silver measurements. Two copper samples have been tested. These were cut from a 0.56-inch thick sheet of material that had been exposed and handled under "shop" conditions for an unknown period. Prior to being placed in the chamber, one sample was abraded with 400-grit emery paper to expose fresh copper; both were rinsed with acetone. As will be seen in the results, this treatment appears to have had a marked effect on the photoemission.

3. RESULTS

Table 1 lists the eleven materials that have been tested during this contract. The photo-current has been recorded as a function of wavelength in the first set of measurements. The normalization calculation with respect to the lamp spectral output was not carried out as in the past. Instead, the relative photoelectric yields of the materials at the single wavelength, 2550 Angstroms are given in Table 2. These results have been scaled so that the yield of silver is one. The dielectric materials have been omitted because this continuous method of measurement is not meaningful in those cases.

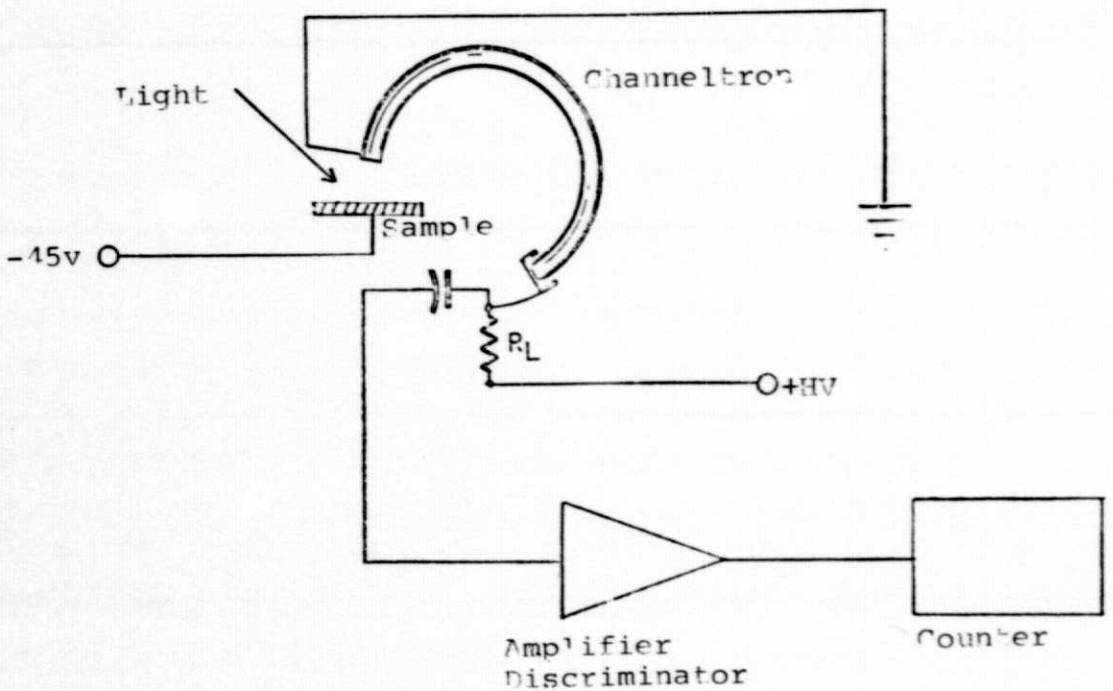

FIGURE 2 Channeltron Set-up

TABLE 1

TEST MATERIALS

Aluminum 3003

Copper (plain and abraded)

Copper - Beryllium

Magnesium

Silver (coating on CuBe)

Fused Silica with conducting coating (In_2O_3)

Fused Silica with blue reflective coating

Teflon

Kapton

Pyre ML on copper-beryllium

TABLE 2

STEP ONE TEST RESULTS - CONDUCTORS

Aluminum 3003	0.015
Copper (plain)	0.012
Copper (abraded)	1.20
Copper - Beryllium	0.026
Magnesium	0.009
Silver (coating on CuBe)	1.00
Fused Silica with conducting coating	0.013

No significant results could be obtained from the monochromatic pulse measurements of step two. Only silver showed a measurable photoemission for a one-tenth of a second pulse. The charge measured was of the order of magnitude one would expect from the continuous method data.

A Channeltron electron multiplier high voltage supply, and charge amplifier/discrimination (supplied by GSFC) were installed within the vacuum chamber for the final part of these experiments. It was found that one or more of these units added significantly to the vacuum system gas load and it was impossible to attain the required pressure (10^{-6} Torr) with the normal pumping system. This limit was overcome through modification of the vacuum system; a liquid nitrogen baffled oil diffusion pump was added. Photoemission was measured at selected wavelengths. The light pulse length, nominally one-tenth of a second, was monitored with a photo transistor (Figure 3). The intensity of the incident radiation was measured with a photomultiplier (Figure 4). To compare the emission data, plots have been made of Channeltron output divided by the pulse length and the wavelength. These plots are reproduced in Figures 5 through 15.

To aid in the evaluation of the results represented by the curves which have been drawn, a threshold curve has been added in Figure 5. The raw Channeltron output ranged between zero and 150 photoelectrons counted for a 0.15-second light pulse. The threshold curve represents the yield corresponding to one photoelectron normalized in the same way as the experimental data.

4. CONCLUSIONS

Two kinds of conclusions can be drawn from this brief study of photoemission.

First, some added data has been obtained on the relative yield of some engineering materials that may be used in satellites such as the ISEE. This data speaks for itself in Figures 5-15.

Second, it has been shown that Channeltron measurements can be made in apparatus that had previously proved inadequate for pulsed, monochromatic photoemission measurements.

If this line of research were to be continued, it is suggested that the following tasks be considered:

1. Effect of Channeltron aperture size.
2. Effect of light pulse length.
3. Effect of sample surface treatment.

These tasks would fit well into a continuing program of materials study.

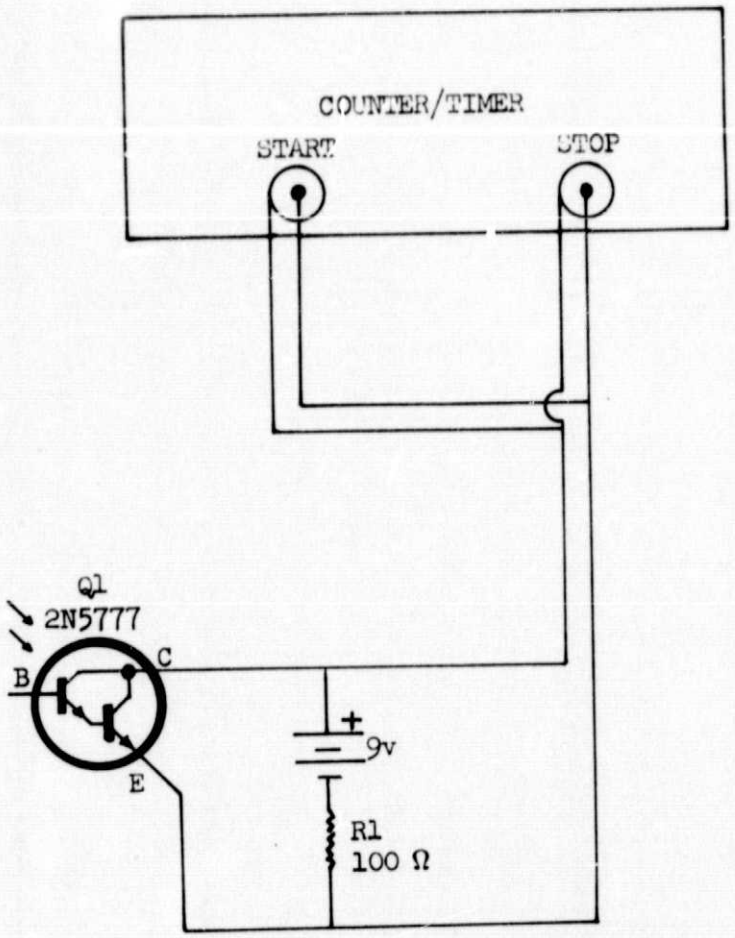

FIGURE 3 Phototransistor Circuit

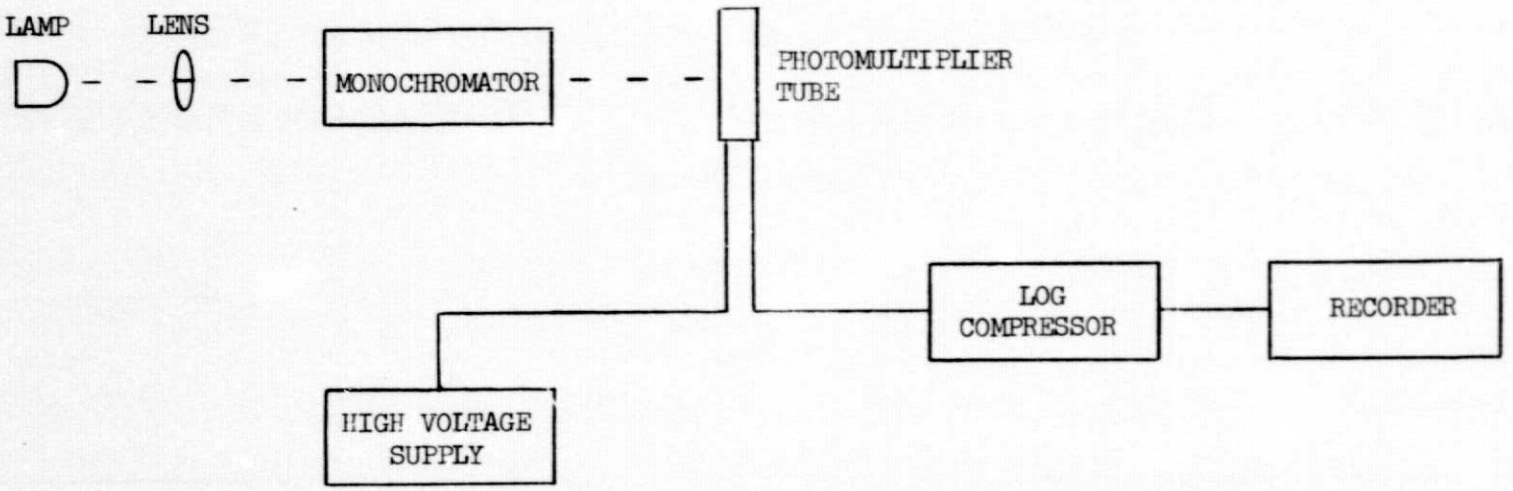

FIGURE 4 Block Diagram, Lamp Output Measurement

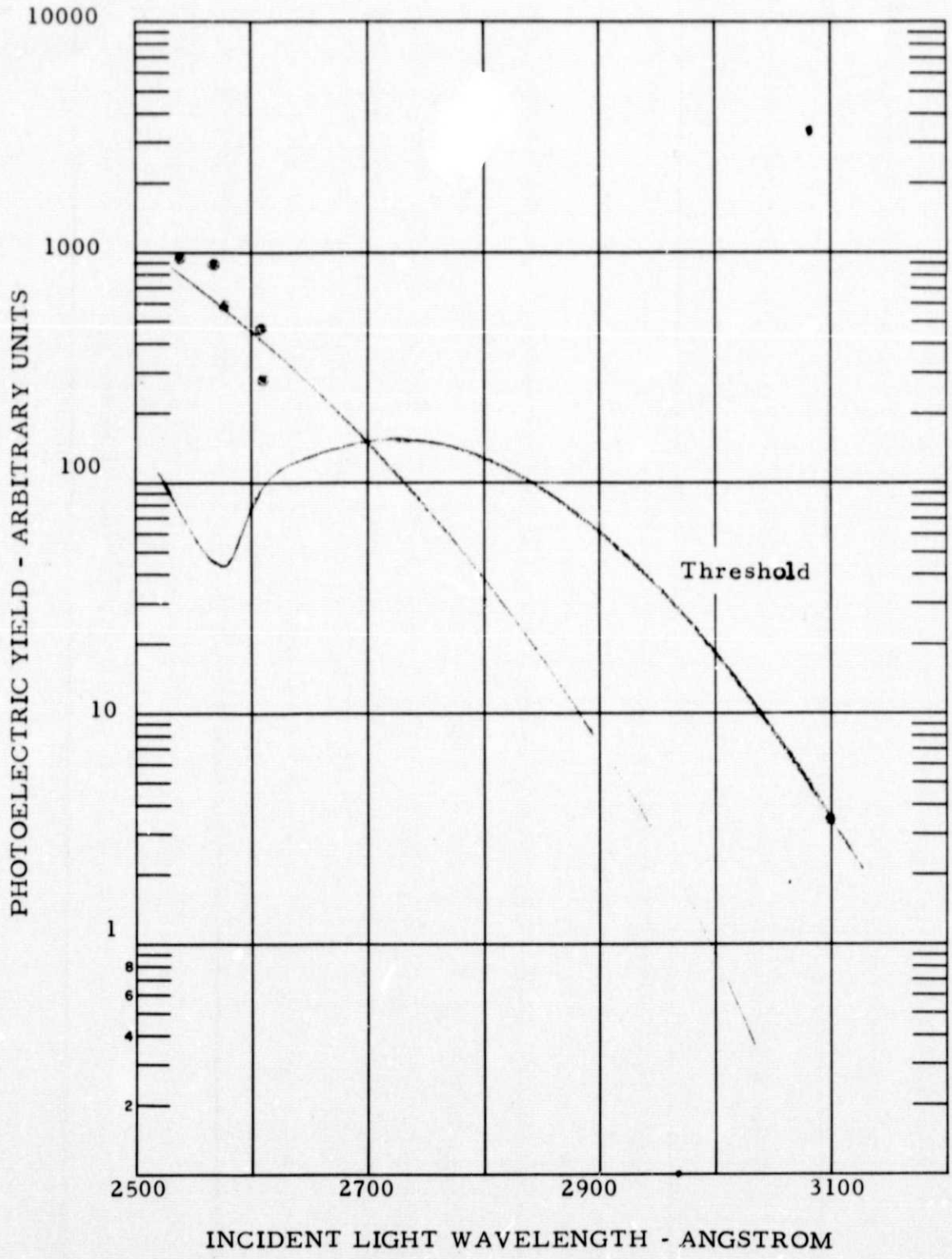

FIGURE 5 Measured Yield of Aluminum

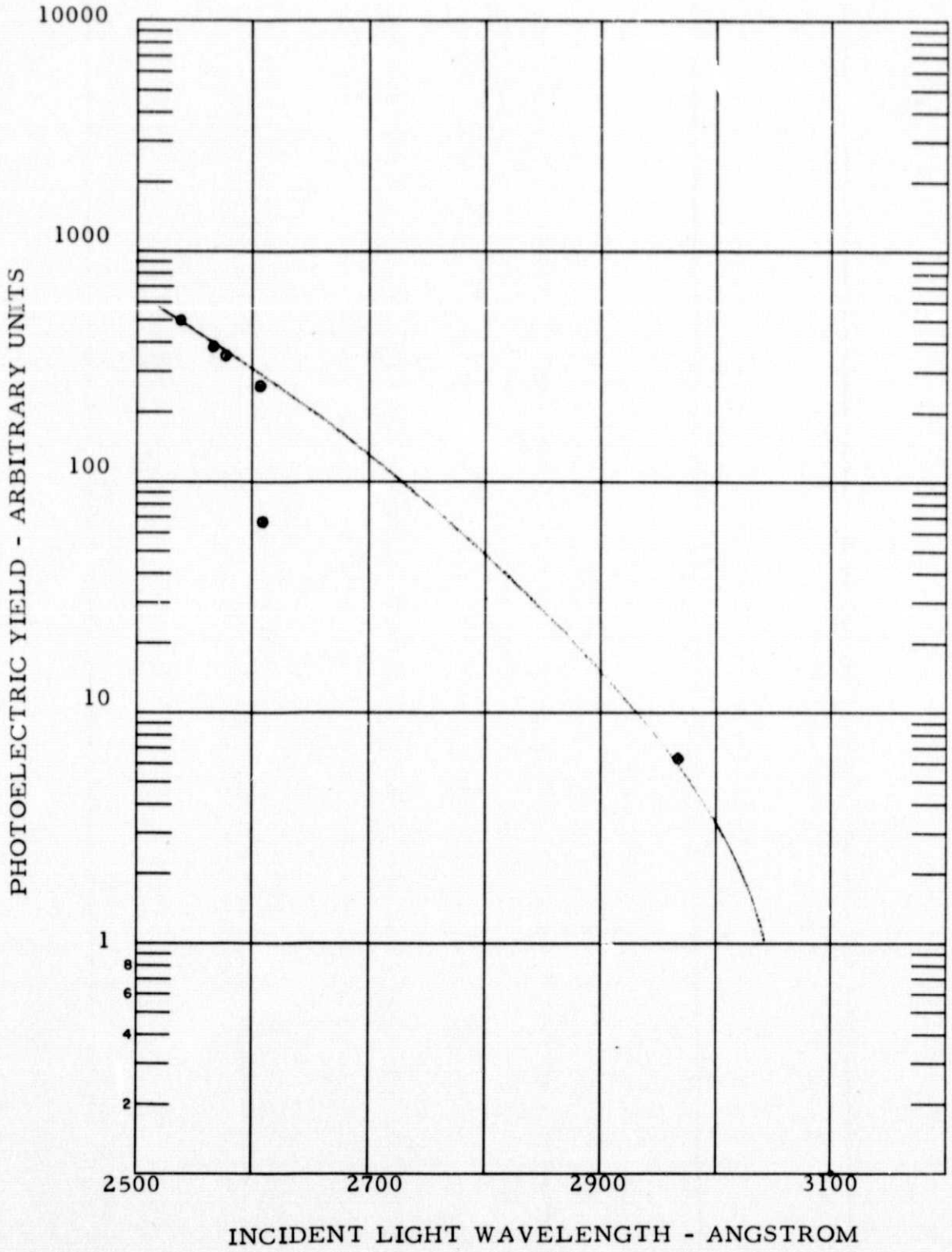

FIGURE 6 Measured Yield of Copper (Plain)

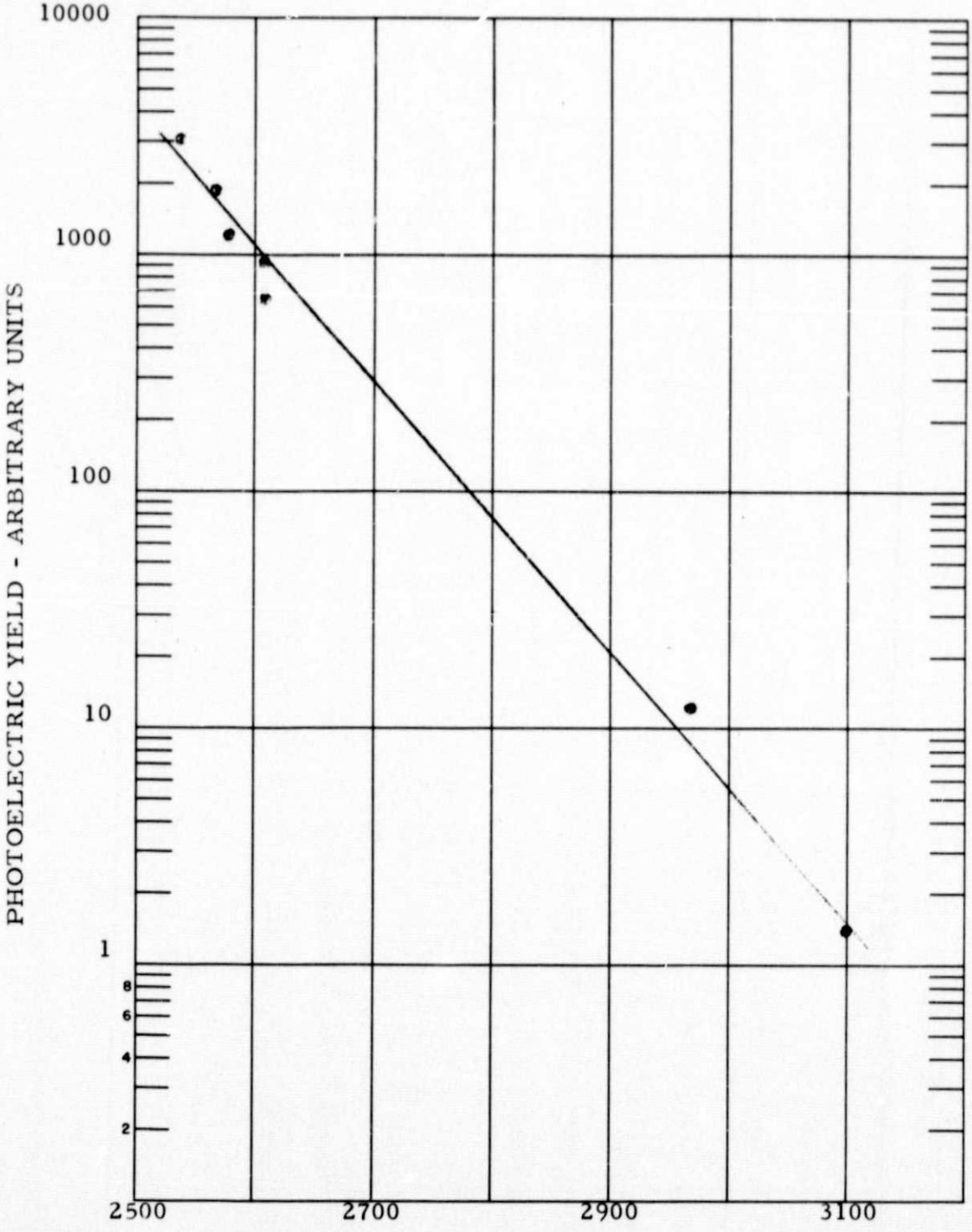

FIGURE 7 Measured Yield of Copper (Abraded)

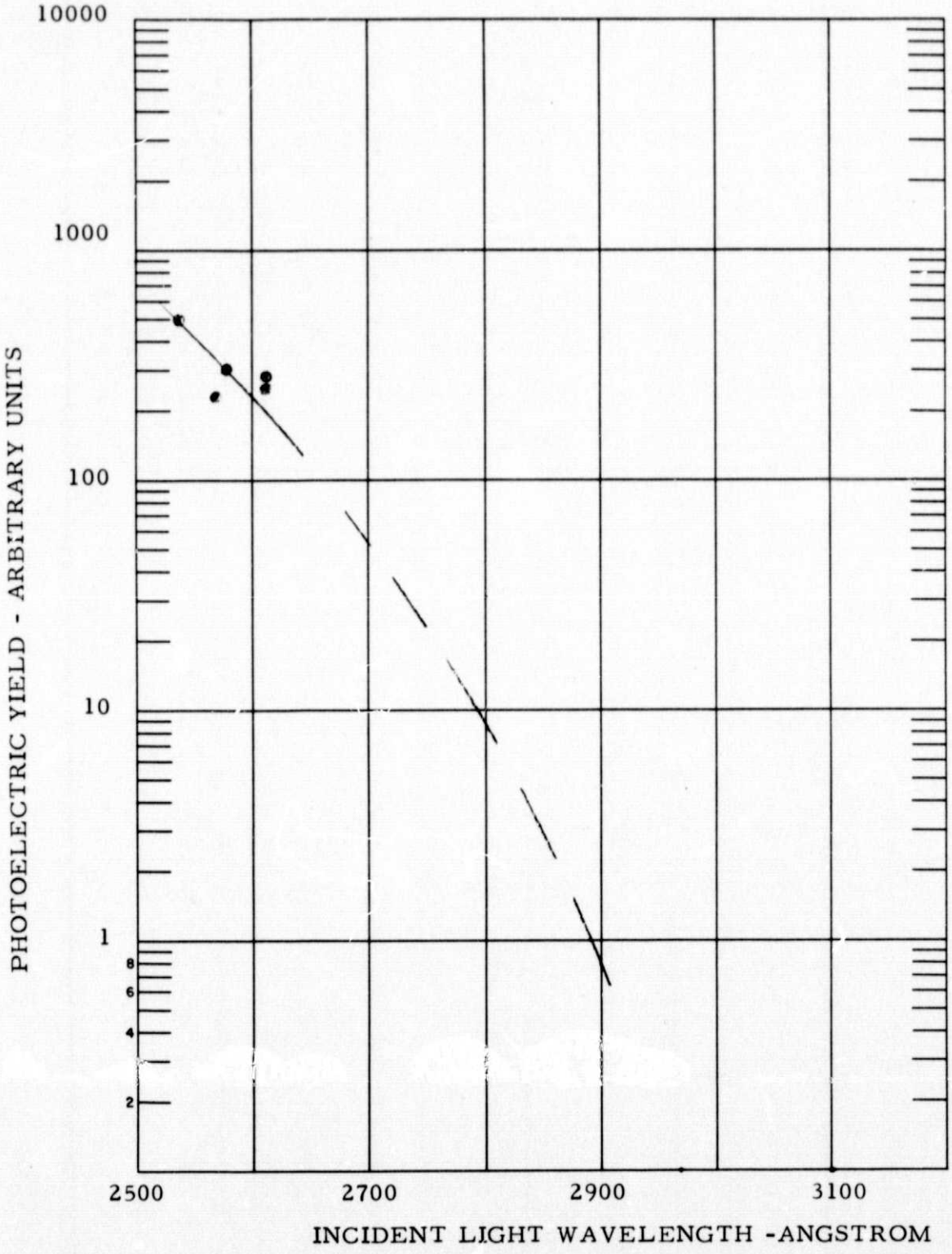

FIGURE 8 Measured Yield of Copper-Beryllium

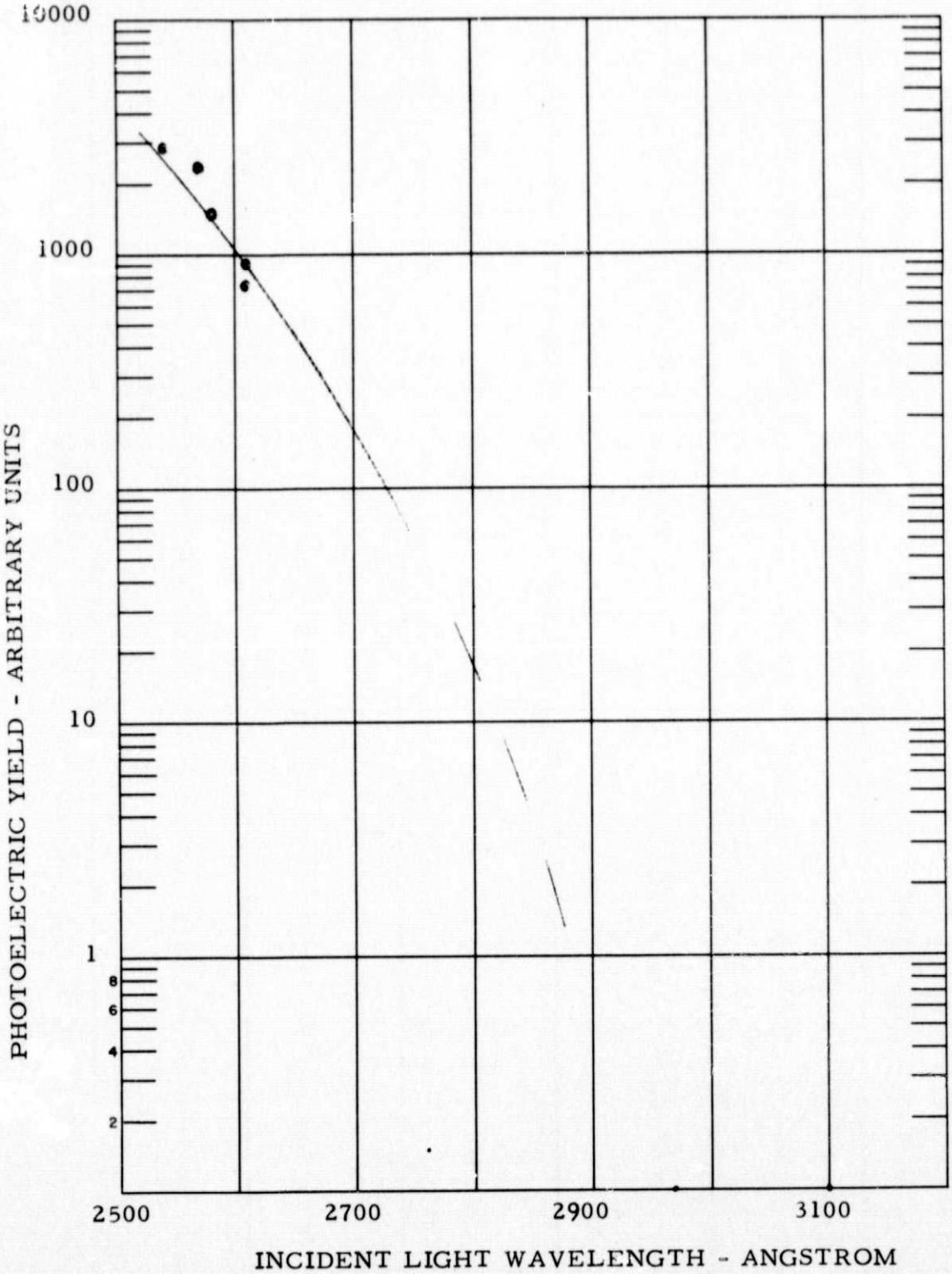

FIGURE 9 Measured Yield of Magnesium

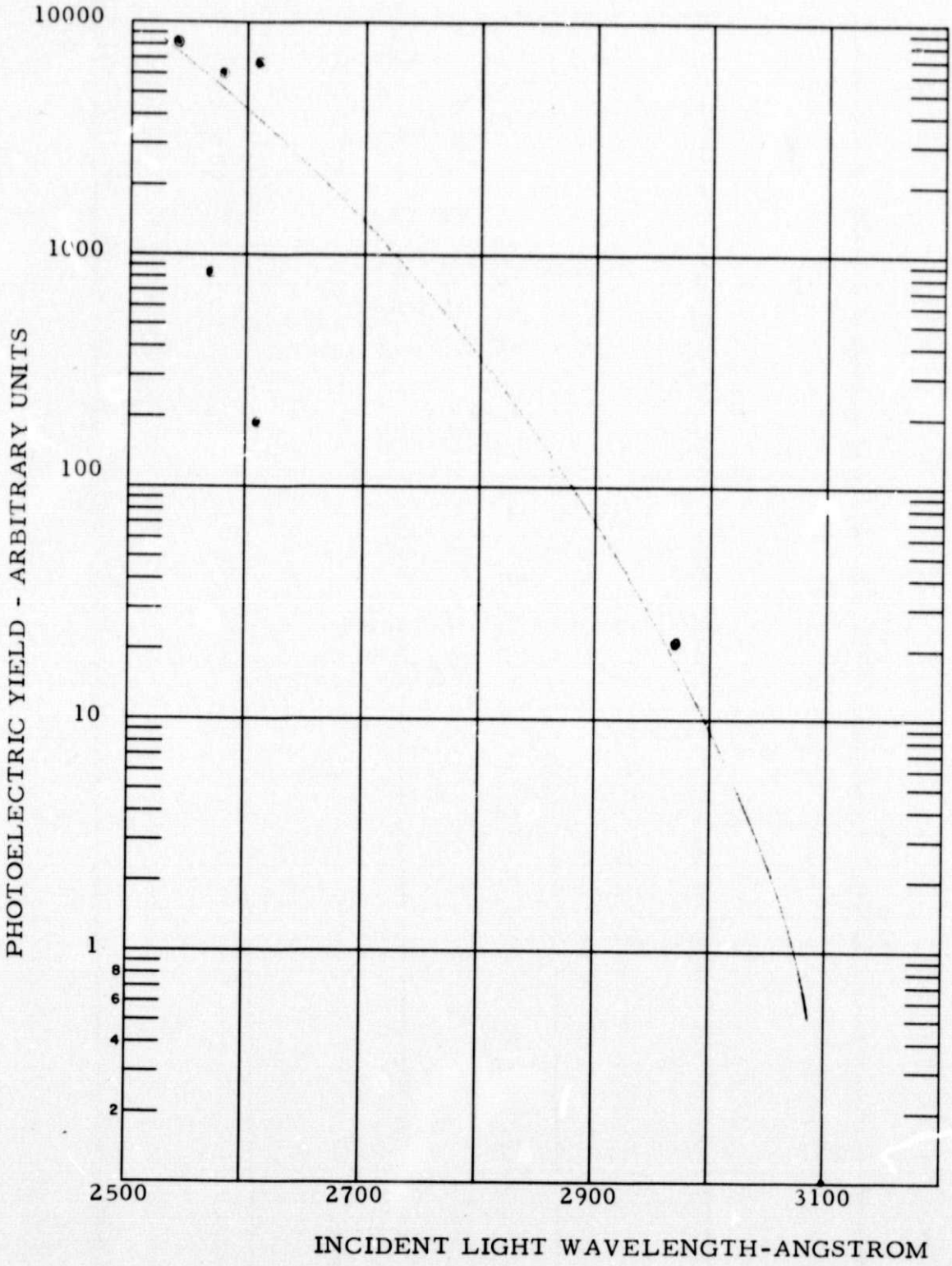

FIGURE 10 Measured Yield of Silver

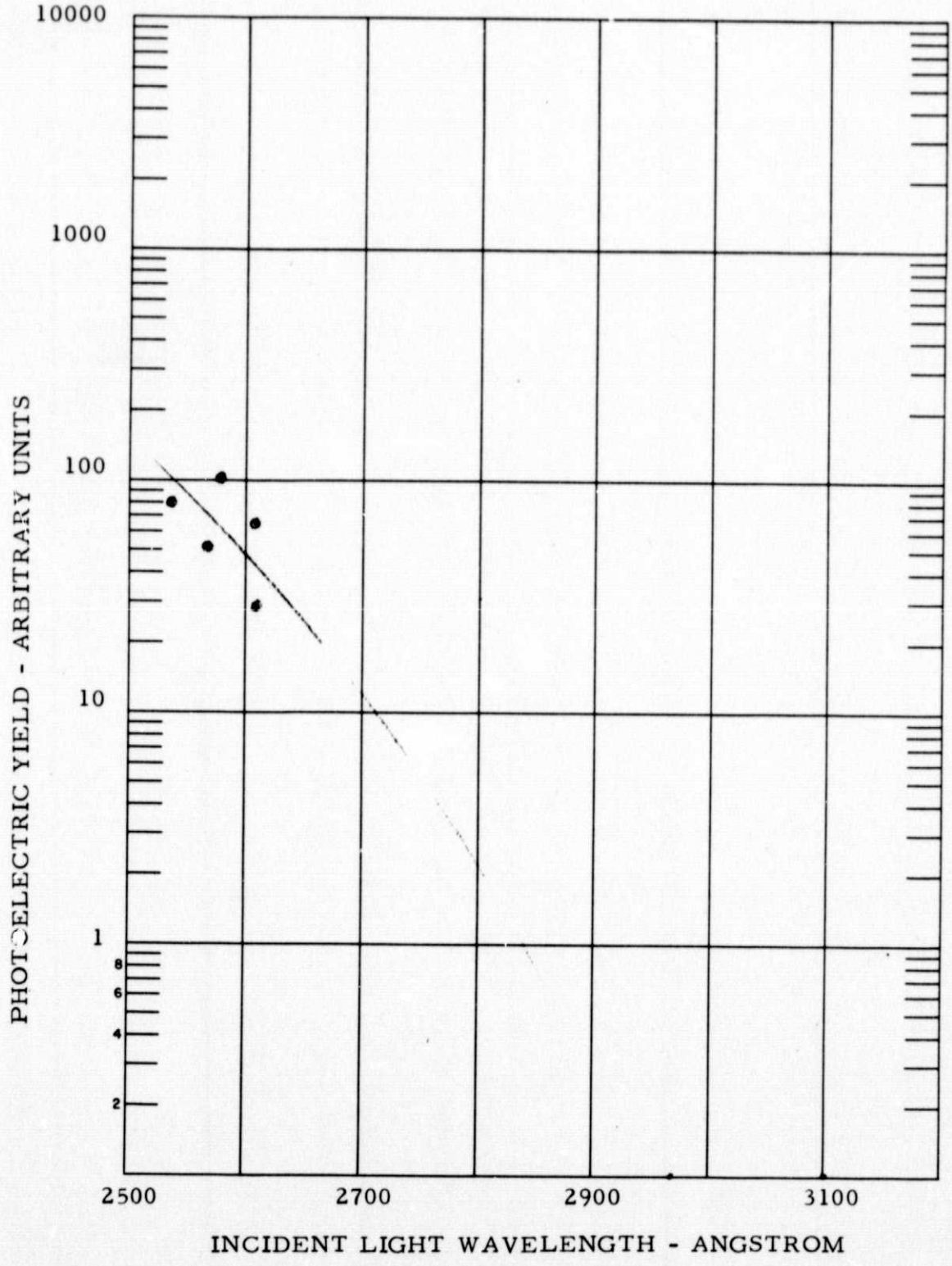

FIGURE 11 Measured Yield of $In_2 O_3$ on Silica

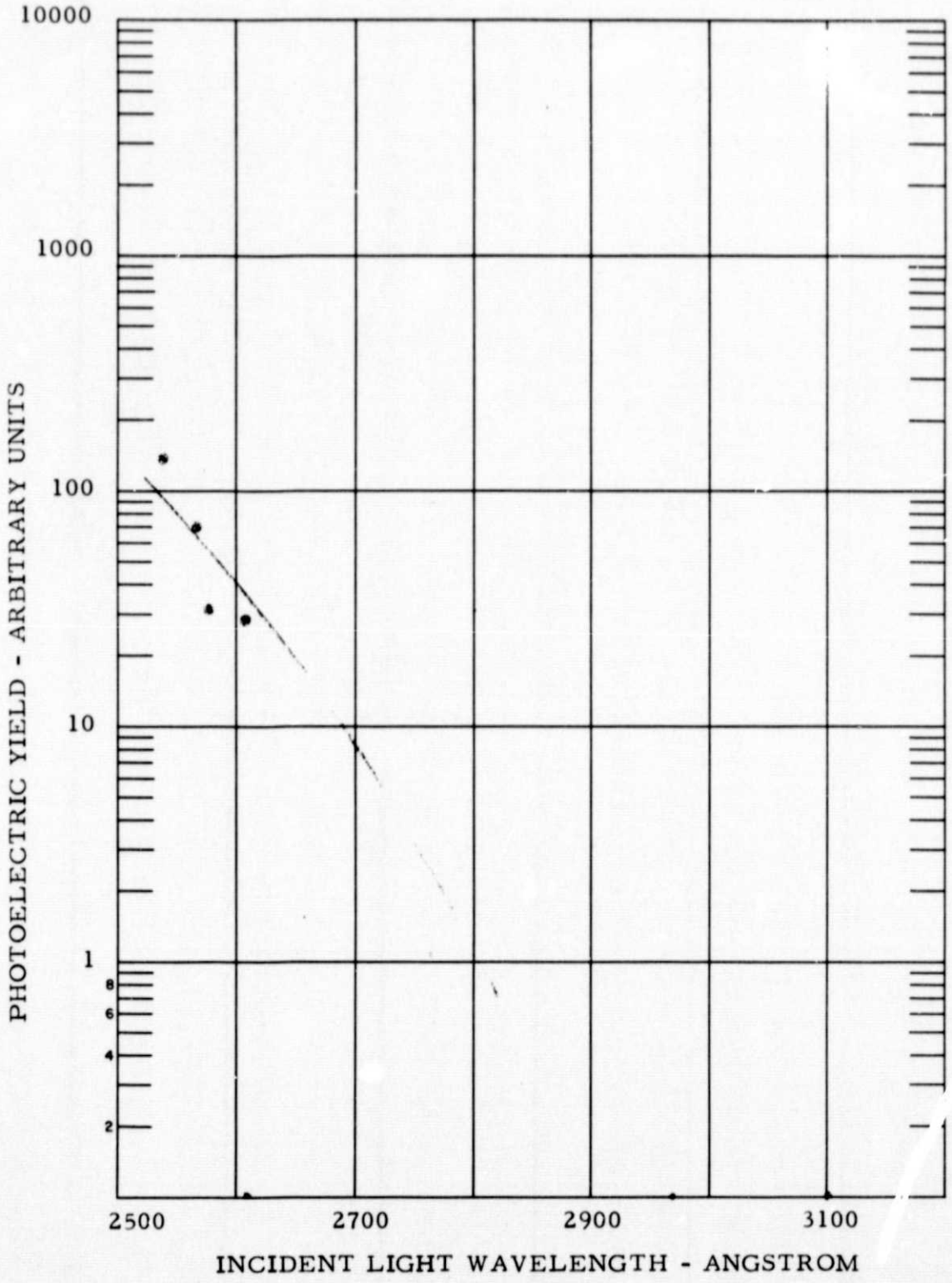

FIGURE 12 Measured Yield of Reflective Coating on Silica

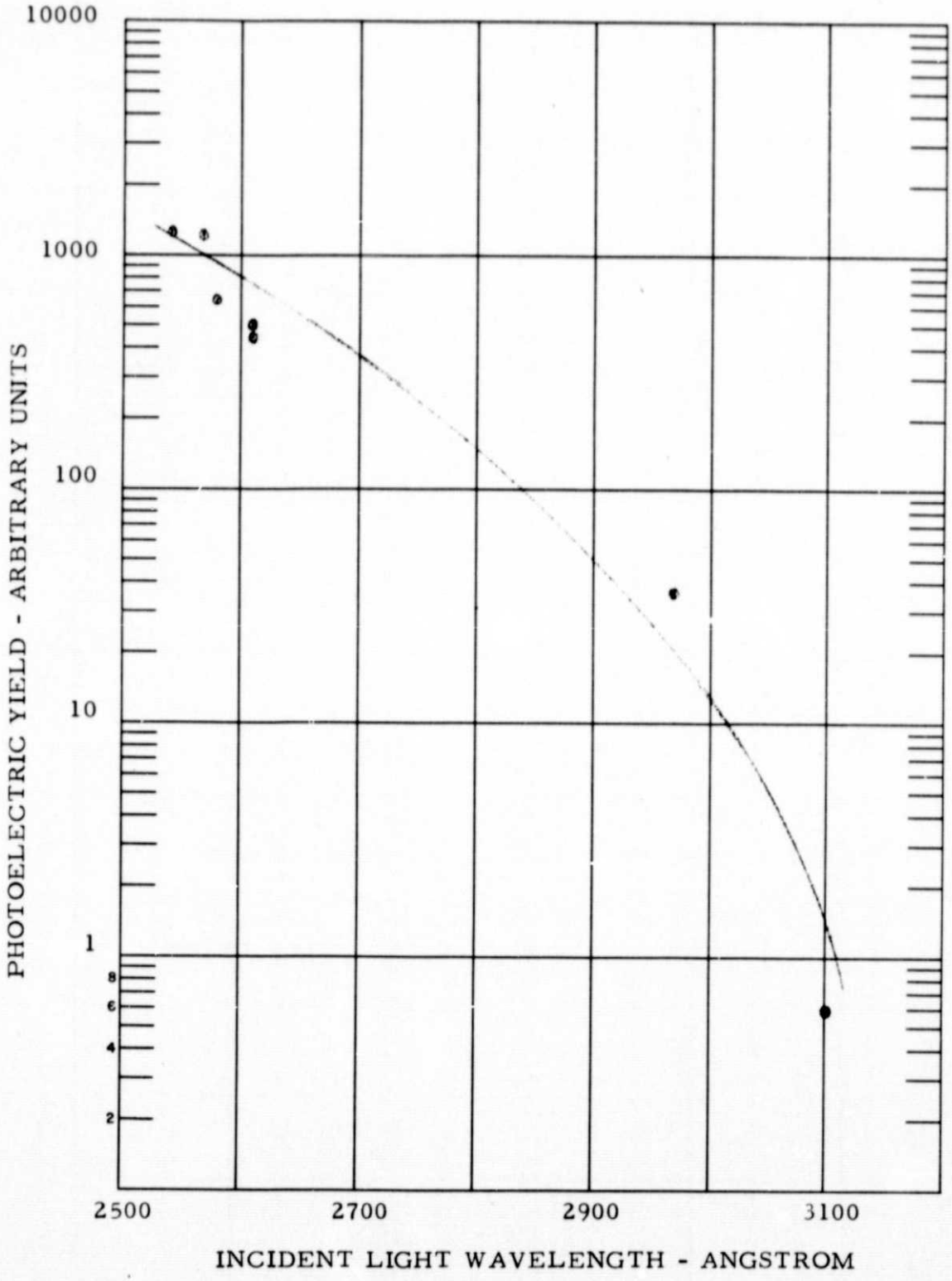

FIGURE 13 Measured Yield of Teflon

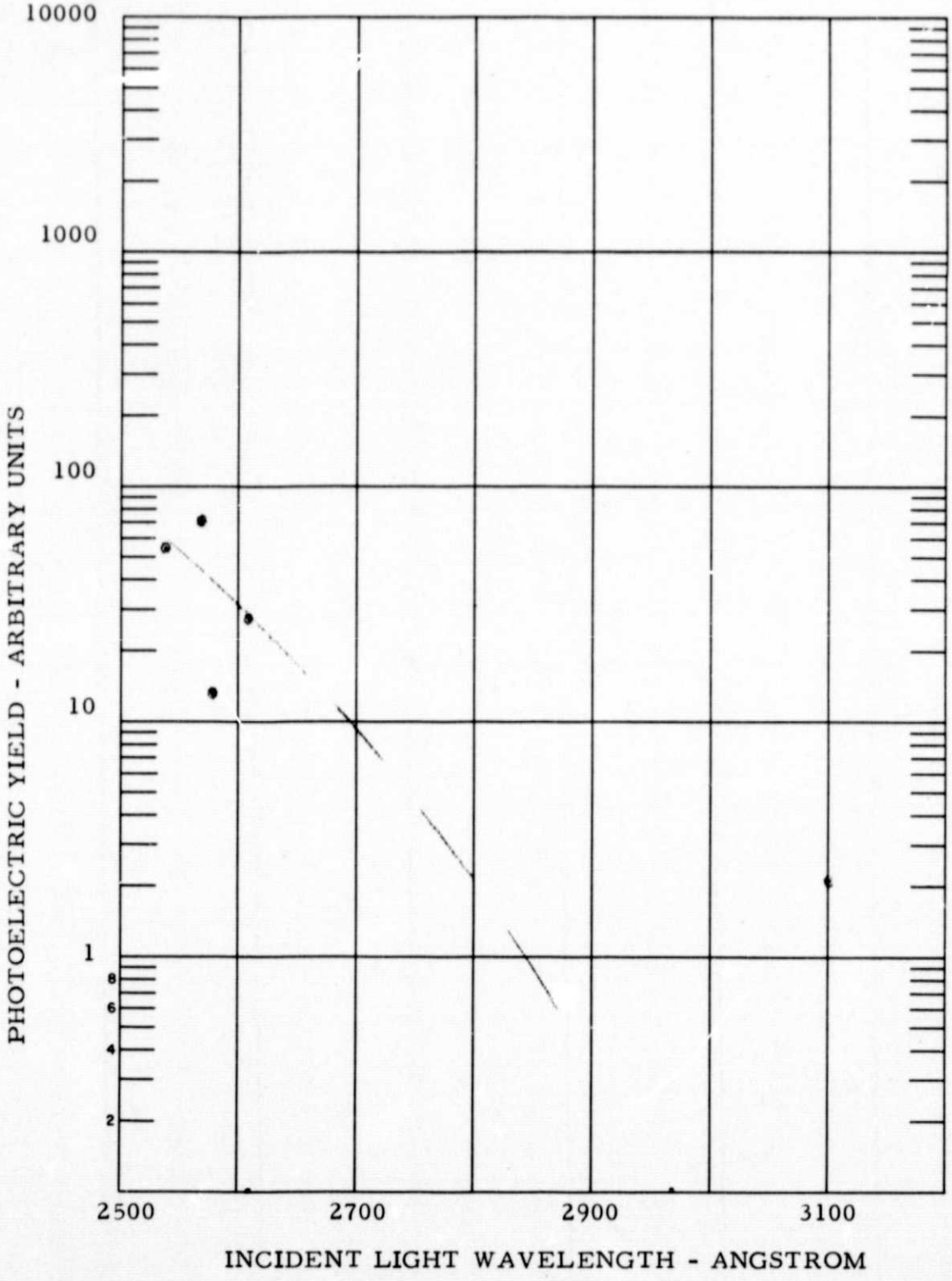

FIGURE 14 Measured Yield of Kapton

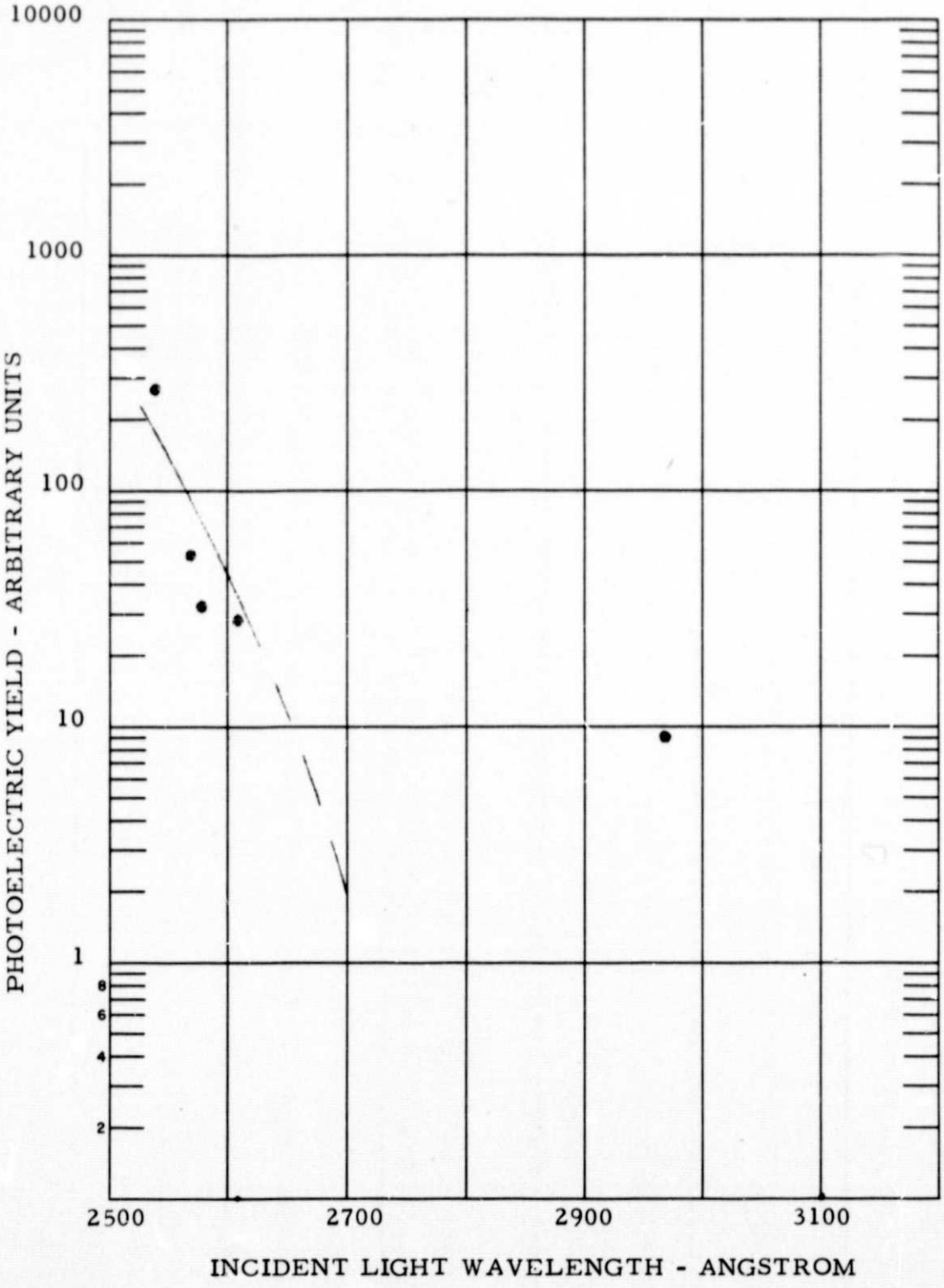

FIGURE 15 Measured Yield of Pure ML

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