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PROTON AND ULTRA-VIOLET IRRADIATION OF THE TARGET SPHERE MATERIAL ON RAE-A IN A SYSTEM ALLOWING FOR IN-SITU OPTICAL MEASUREMENT

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GSFC — GODDARD SPACE FLIGHT CENTER —
GREENBELT, MARYLAND

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ABSTRACT

One inch diameter, diffuse samples of the RAE-A target material, zinc titanate over lexan, were exposed to low energy protons and also to low energy protons and ultra-violet radiation sequentially.

A system was designed and assembled with available components to carry out the test in-situ. Degradation was monitored by the percent change in the total solar absorptance $(0.3\text{-}2.4)\mu$, as obtained from optical reflectance measurements of the sample compared to an MgO reference.

Very little degradation was seen for total proton fluxes below 10^{15} protons/cm^2 at both 10 Kev and 15 Kev. Above 10^{15} protons/cm^2, the change in solar absorptance increased rapidly, being greater for the 15 Kev beam.

Degradation was enhanced by both protons and U.V. at first, with a leveling off at higher total proton fluxes, depending on the equivalent sun hours (ESH) of U.V. irradiation received.

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I. INTRODUCTION

Some approximation as to the amount of degradation of the coating covering the six inch spherical camera targets on RAE-A was desired. The coating is made from General Electric 10 mil thick Lexan (trade name) covered by 0.5 mil of zinc titanate.

Making use of an existing ion source and vacuum components, a test environment was set up to look at the results due to protons at 10 Kev and 15 Kev, these being the highest energies attainable at present with our ion source. Further, fluxes at energies below 100 Kev are higher and more significant to degradation than at a few hundred Kev.[1] An approximate value of 7×10^{7} protons/cm^2-sec was taken for the proton flux seen by RAE-A in an orbit of about two earth radii. This is somewhat higher than that given for 100 Kev protons.[2]

Figure 1 gives an indication of the time in orbit needed to get a particular total flux. For nearly three years in orbit, a value of about 6×10^{15} protons/cm^2 is seen. This was considered high enough for the objective of this test. For the purpose of having a practical running time, accelerated fluxes were used, of the order of 6.8×10^{11} protons/cm^2-sec.

To better approximate space conditions, some samples were exposed to protons followed by U.V. at one solar constant (0.140 watts/cm^2).

Vacuum and sample temperature were monitored throughout the tests.

II. DESCRIPTION OF APPARATUS

The equipment consists of three main systems.

1. Sample chamber and vacuum system

[1] NASA CR-1024 p 106

[2] Radiation Trapped in the Earth's Magnetic Field – M. McCormac p 222

2. Proton source and U.V. source

3. Reflectance measuring system

Figure 2 is a block diagram of the apparatus. The U.V. source, which is a Spectrolab X-25 Solar Simulator is not shown. When the spectrophotometer and sphere are moved out of the way, the X-25 would face the sample chamber.

1. <u>Sample Chamber and Vacuum System</u>

The chamber is stainless steel with interior dimensions of five inches in diameter by three inches in depth. The sample holder runs along the diameter of the chamber and can be rotated about it. This movement allows the sample to face the proton beam and then be rotated 90° to face the X-25, and DK-2A. See Figure 3.

A Faraday Cup with a biased guard ring, for returning secondary electrons back to the cup, is mounted at right angles to the sample for monitoring the proton beam current. Readout is on a Keithley picoammeter.

Sample cooling is accomplished by circulating water through the sample holder. Thermocouples are connected to the holder and sample, for temperature measurement. Electrical feedthroughs for these thermocouples and also for the Faraday cup, can be seen on the upper right side of the chamber in Figure 3. Also in the figure behind and below the chamber are the two Ultek ion-titanium sublimation pumps. Rough pumping down to 10^{-3} torr is done with a mechanical pump and an LN_2 cold trap.

Figure 4 shows the chamber with the DK-2A rolled back. A stainless steel cover, with a 1/16 inch thick sapphire window, is held by vacuum to the chamber using a Viton seal.

2. <u>Proton and U.V. Sources</u>

Due to the vacuum requirements necessary for obtaining a proton beam, the ion source is connected to and pumped by the same system used on the sample chamber. An ORTEC R-F ion source with accelerating and focusing lenses, along with a magnetic analyzer, supplies the particle beam. At present, insulation problems limit the beam energies to 15 Kev, whereas up to 30 Kev will be possible. Figure 5 shows the ion source and lenses. A screened shield surrounding the source has been removed, although a portion of it can be seen to the left of the sample chamber.

The U.V. source is a Spectrolab X-25 Solar Simulator using a 2500 watt Xenon lamp. The simulator is set approximately six feet from the face of the sample chamber.

3. Reflectance Measuring Unit

A Beckman DK-2A Spectroreflectometer with an integrating sphere, is moved up to the sapphire window, on a special mount which allows exact fitting of the sphere port to the window. The instrument is then locked in place so that not the slightest movement occurs during measurement. See Figure 6.

III. EXPERIMENTAL PROCEDURE

The process of irradiation and measurement of a sample in vacuum is lengthy and difficult. Pumping out the system usually takes about three hours each time the chamber is opened. Vacuum recovery after proton irradiation though is quite rapid, taking about ten minutes.

Before a sample is put in the chamber, a fluorescent zinc sulfide test sample is placed in the chamber, in order to look at the proton beam. Since the source produces both H_1^+ and H_2^+ beams, the magnetic analyzer must be set to separate the two, so as to have a pure proton beam, H_1^+. Figure 7 shows a plot of beam current versus analyzer settings. Once a spread-out beam is obtained, the analyzer and controls are set to get a desired beam current reading composed of protons.

The intensity of the U.V. radiation is highly uniform over the sample. A "Hy-Cal" radiometer was used for detection, adjustments being set to obtain one solar constant (0.140 watts/cm^2). Figure 8 shows the intensity output of the X-25 against the solar output. From Table 1 and Figure 8, the output ratio of the X-25 to the solar energy (Johnson's Curve) in the U.V. is 1.08.

A copper-constantan thermocouple was mounted behind the lexan, to monitor temperature and compare it with that of the sample holder. Vacuum in the chamber was 1×10^{-6} torr.

Reflectance measurements of the sample were made relative to a smoked MgO reference. This reference in turn was compared before each set of measurements with a calibrated "Vitrolite" sample. This corrects for any change in the one-hundred percent line. Repeated reflectance measurements on the sample showed that variations of about 1.5% occur in sample positioning. After each irradiation the sample was measured upon returning to its initial temperature and after the vacuum in the chamber was at its original value. i.e., During proton runs, the pressure would rise to about 2×10^{-5} torr.

Sample temperature during the proton irradiations rose by about 2°C above that of the sample holder. Again it should be noted, that this is not a surface temperature, but that existing at the interface of the lexan and aluminum sample holder disc. During the U.V. irradiation however, the temperature rose as high as 22°C above that of the sample holder.

IV. RESULTS

1. For a total proton flux, at either 10 Kev or 15 Kev, under 10^{15} protons/cm^2, less than 2.0% increase in a_s occurred. See Figure 9.

2. Above 10^{15} protons/cm^2, the percent change in a_s with total flux increased rapidly. For a total flux approximating three years in orbit, an increase in a_s of about 11.0% occurred for 15 Kev proton irradiation.

3. For samples exposed to both protons and U.V., the degradation is enhanced at lower values of the total proton flux. This levels off with increasing total flux. See Figure 10. For larger amounts of ESH (Equivalent Sun Hours) of U.V. irradiation, this leveling off appears less.

4. Figure 11 shows the percent increase in a_s with ESH, after an initial total flux had been accrued on the sample.

V. CONCLUSIONS

The results show that degradation takes place to a considerable extent, due to protons, with a high enough dosage, above 10^{15} protons/cm^2. There appears to be an additive effect with both protons and U.V., but a quantitative amount is not known at present.

Further degradation tests on coatings will be made more efficient and faster with the completion of the Quad-Sample System, to be described in a future report.

Table 1

Test Lamp Output

M 61 X 25

WAVELENGTH	TEST LAMP ENERGY	SOLAR ENERGY	RATIO TESTLAMP/SOLAR
	PER 10NM WAVELENGTH INTERVAL		
255.	0.154	0.073	2.11
265.	0.217	0.166	1.30
275.	0.339	0.166	2.04
285.	0.355	0.291	1.22
295.	0.355	0.457	0.78
305.	0.417	0.478	0.87
315.	0.503	0.593	0.85
325.	0.561	0.748	0.75
335.	0.610	0.832	0.73
345.	0.662	0.873	0.76
355.	0.703	0.873	0.81
365.	0.749	0.925	0.81
375.	0.791	0.946	0.84
385.	0.813	0.863	0.94
395.	0.584	0.946	0.62
405.	0.875	1.351	0.65
415.	0.893	1.435	0.62
425.	0.922	1.362	0.68
435.	0.928	1.341	0.69
445.	0.948	1.570	0.60
455.	0.948	1.622	0.58
465.	1.211	1.611	0.75
475.	1.137	1.601	0.71
485.	1.052	1.528	0.69
495.	1.054	1.528	0.69
505.	0.978	1.455	0.67
515.	0.940	1.435	0.66
525.	0.934	1.445	0.65
535.	0.931	1.476	0.63
545.	0.929	1.466	0.63
555.	0.936	1.445	0.65
565.	0.933	1.414	0.66
575.	0.937	1.435	0.65
585.	0.940	1.414	0.66
595.	0.912	1.403	0.65
605.	0.895	1.341	0.67
615.	0.903	1.310	0.69
625.	0.914	1.289	0.71
635.	0.889	1.258	0.71
645.	0.871	1.237	0.70
655.	0.847	1.216	0.70
665.	0.848	1.206	0.70
675.	0.876	1.175	0.75
685.	0.885	1.143	0.77
695.	0.859	1.112	0.77
705.	0.838	1.123	0.75
715.	0.801	1.071	0.75
725.	0.804	1.060	0.76
735.	0.795	1.040	0.76

Table 1 (Continued)

M 61 X 25

WAVELENGTH	TEST LAMP ENERGY	SOLAR ENERGY	RATIO TESTLAMP/SOLAR
	PER 10NM WAVELENGTH INTERVAL		
745.	0.789	1.008	0.78
755.	0.809	1.008	0.80
765.	0.772	0.967	0.80
775.	0.738	0.936	0.79
785.	0.701	0.925	0.76
795.	0.620	0.904	0.69
805.	0.690	0.884	0.78
815.	1.222	0.863	1.42
825.	2.006	0.852	2.35
835.	1.831	0.821	2.23
845.	1.267	0.800	1.58
855.	0.928	0.780	1.19
865.	0.789	0.759	1.04
875.	1.084	0.748	1.45
885.	1.770	0.738	2.40
895.	2.102	0.717	2.93
905.	2.064	0.686	3.01
915.	2.358	0.676	3.49
925.	2.007	0.665	3.02
935.	1.637	0.655	2.50
945.	1.550	0.634	2.44
955.	1.550	0.613	2.53
965.	1.550	0.603	2.57
975.	1.550	0.603	2.57
985.	1.550	0.572	2.71
995.	1.550	0.561	2.76
1005.	1.221	0.541	2.26
1015.	0.788	0.530	1.49
1025.	0.788	0.520	1.52
1035.	0.541	0.509	1.06
1045.	0.501	0.499	1.00
1055.	0.494	0.489	1.01
1065.	0.487	0.478	1.02
1075.	0.493	0.468	1.05
1085.	0.425	0.457	0.93
1095.	0.487	0.447	1.09
1150.	0.382	0.394	0.97
1250.	0.251	0.315	0.80
1350.	0.177	0.254	0.70
1450.	0.247	0.206	1.20
1550.	0.165	0.168	0.98
1650.	0.123	0.139	0.88
1750.	0.096	0.115	0.83
1850.	0.071	0.097	0.74
1950.	0.068	0.082	0.83
2050.	0.113	0.070	1.62
2150.	0.120	0.059	2.02
2250.	0.043	0.051	0.85
2350.	0.055	0.044	1.26

FOR PROTONS OF 100 Kev OR LESS IN ENERGY AN AVERAGE FLUX IS 1×10^7 P/cm^2-sec, INCREASE TO 7×10^7 P/cm^2-sec. THE ABSCISSA GIVES THE TIME NEEDED TO REACH THE TOTAL FLUXES PLOTTED AS ORDINATES.

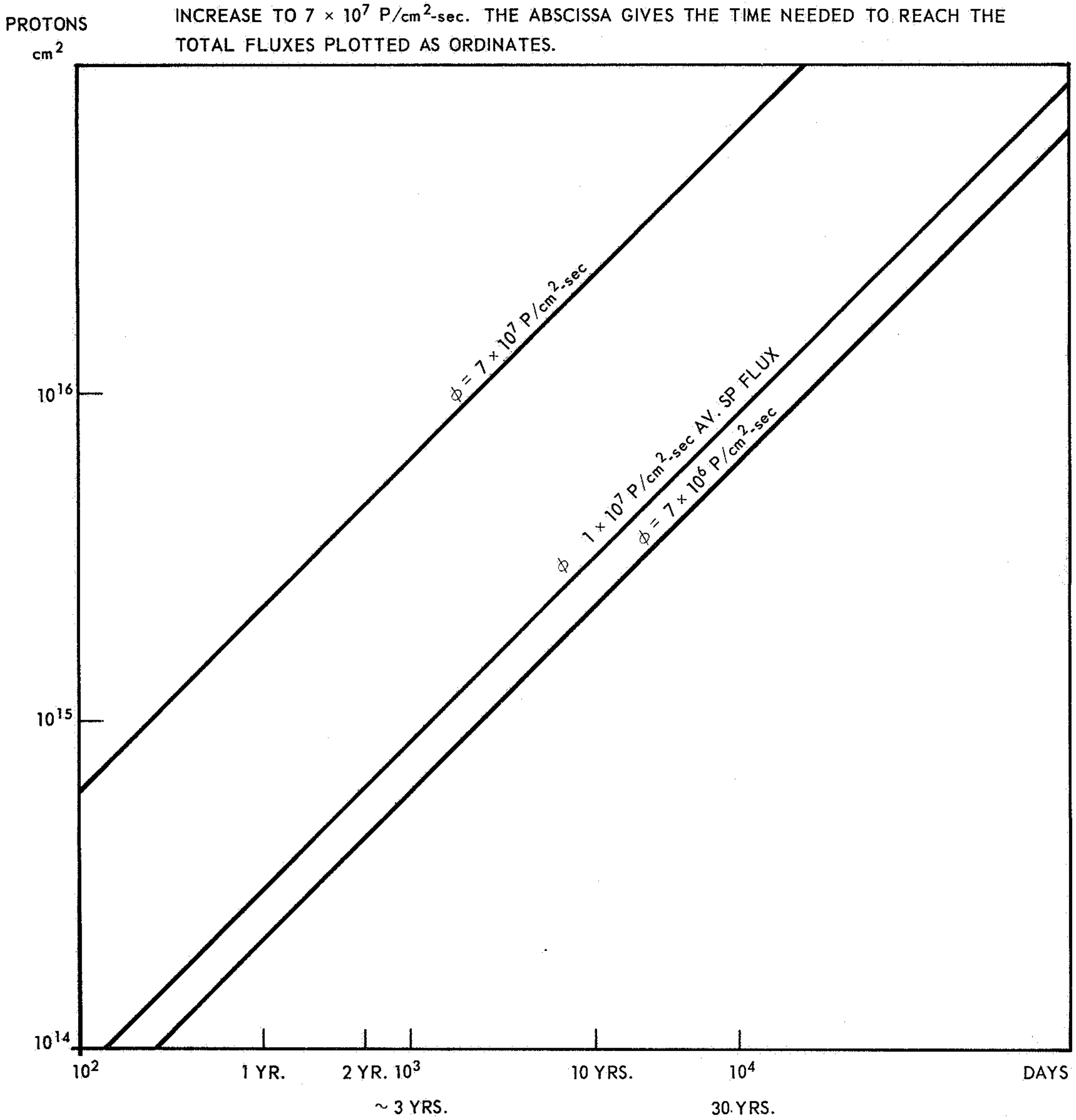


Figure 1

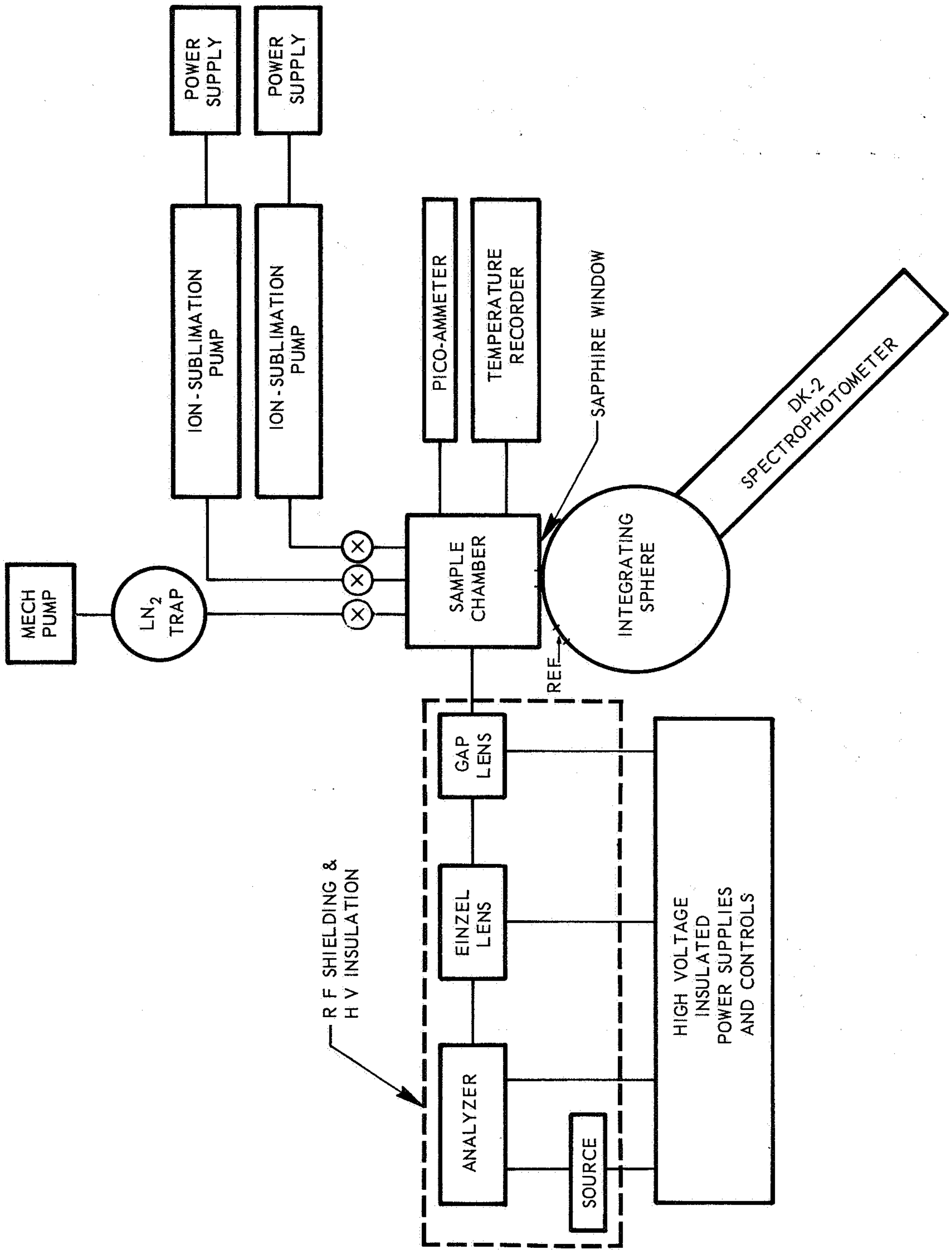

MECH PUMP
LN2 TRAP
POWER SUPPLY
POWER SUPPLY
ION-SUBLIMATION PUMP
ION-SUBLIMATION PUMP
PICO-AMMETER
TEMPERATURE RECORDER
SAPPHIRE WINDOW
DK-2 SPECTROPHOTOMETER
SAMPLE CHAMBER
INTEGRATING SPHERE
REF
R F SHIELDING & H V INSULATION
GAP LENS
EINZEL LENS
ANALYZER
SOURCE
HIGH VOLTAGE INSULATED POWER SUPPLIES AND CONTROLS

Figure 2

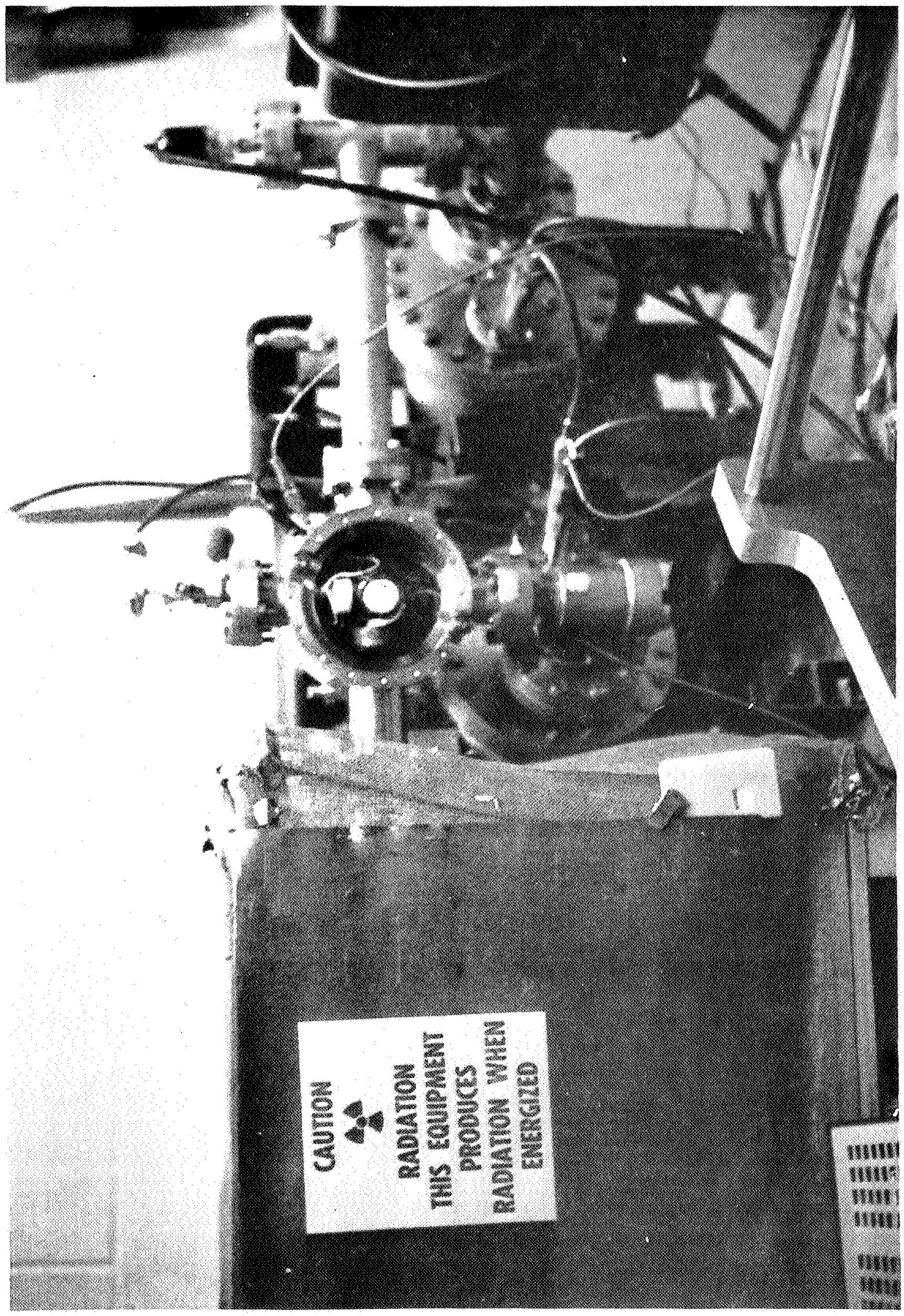

CAUTION
RADIATION
THIS EQUIPMENT
PRODUCES
RADIATION WHEN
ENERGIZED

Figure 3

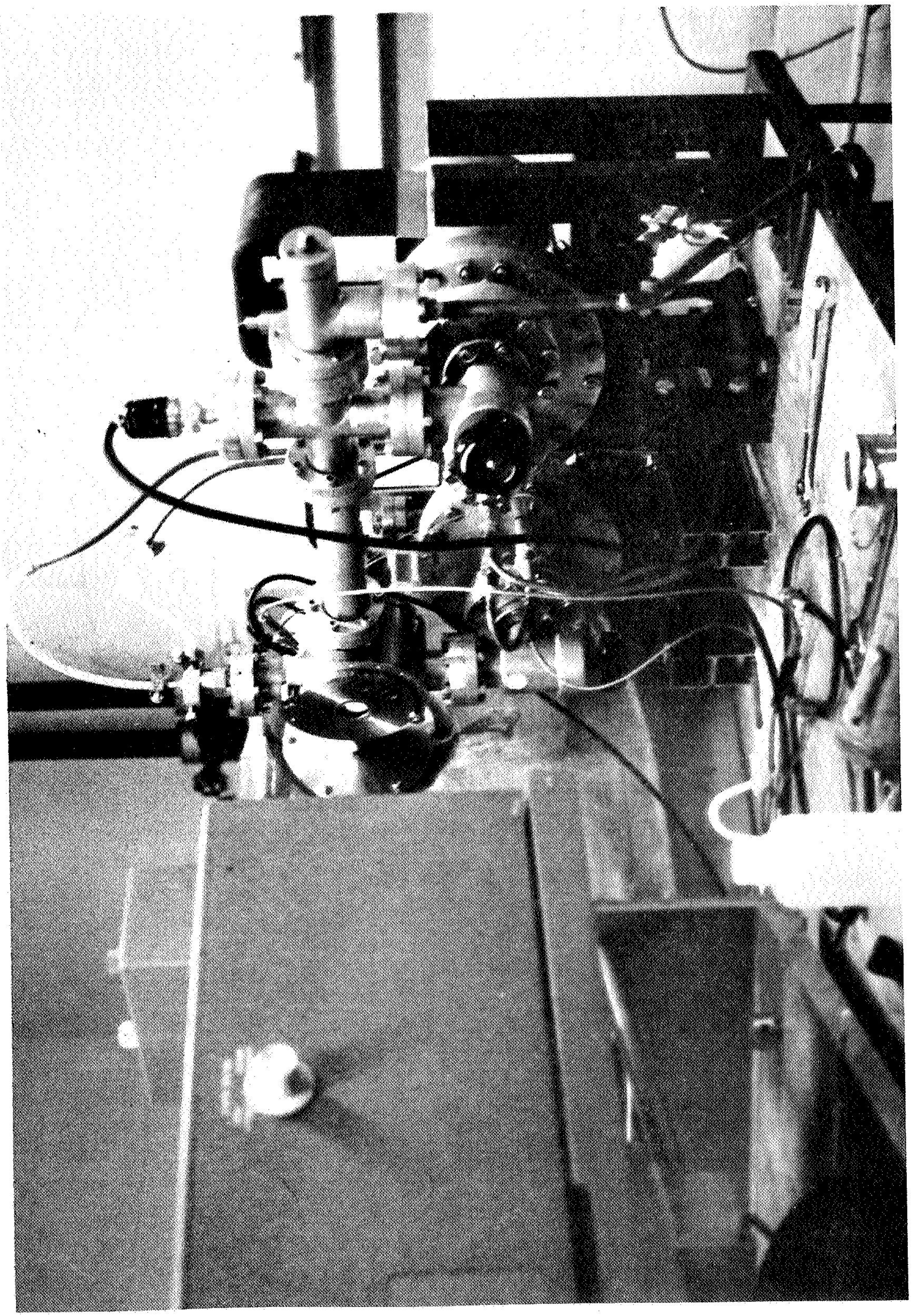


Figure 4

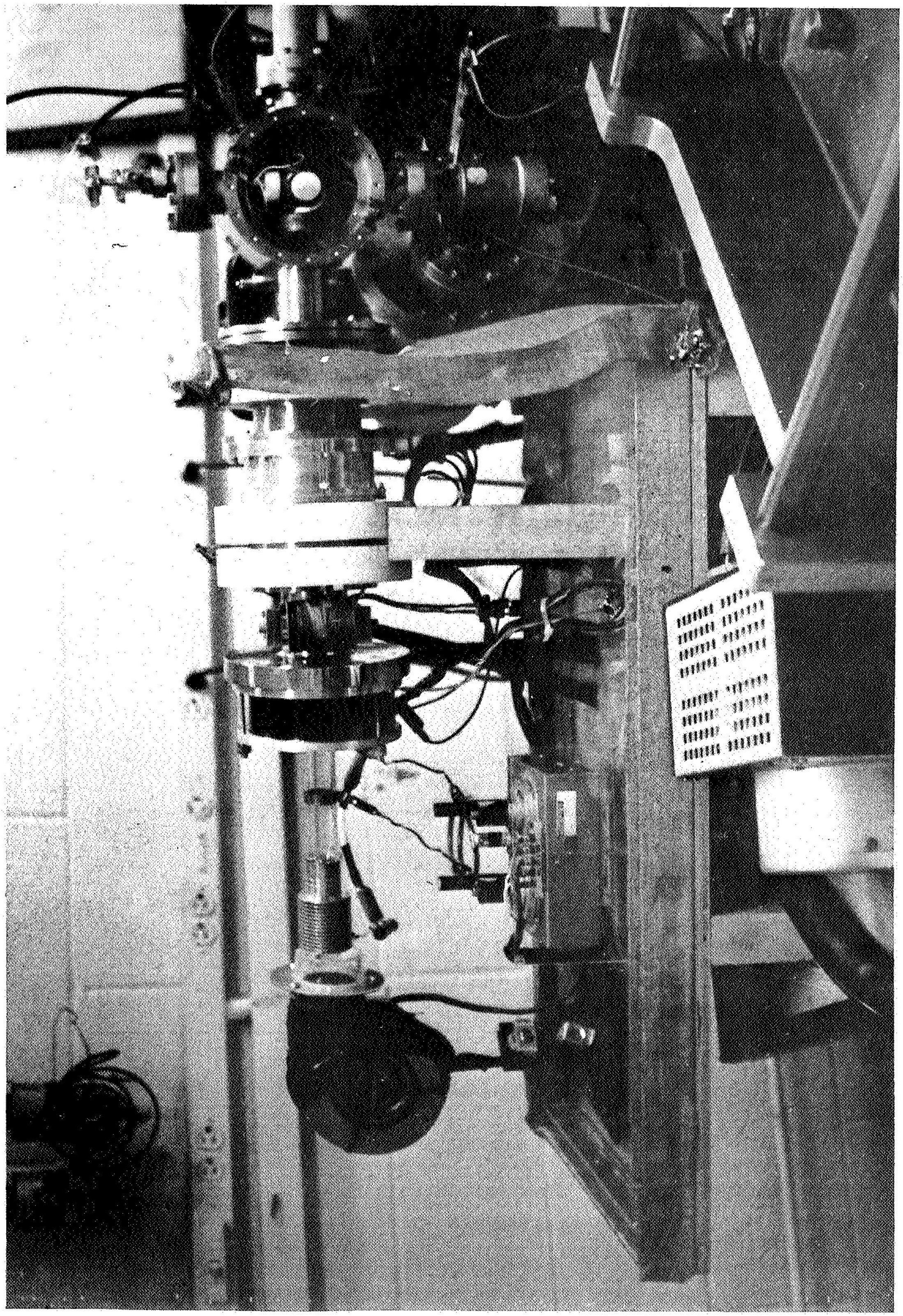


Figure 5

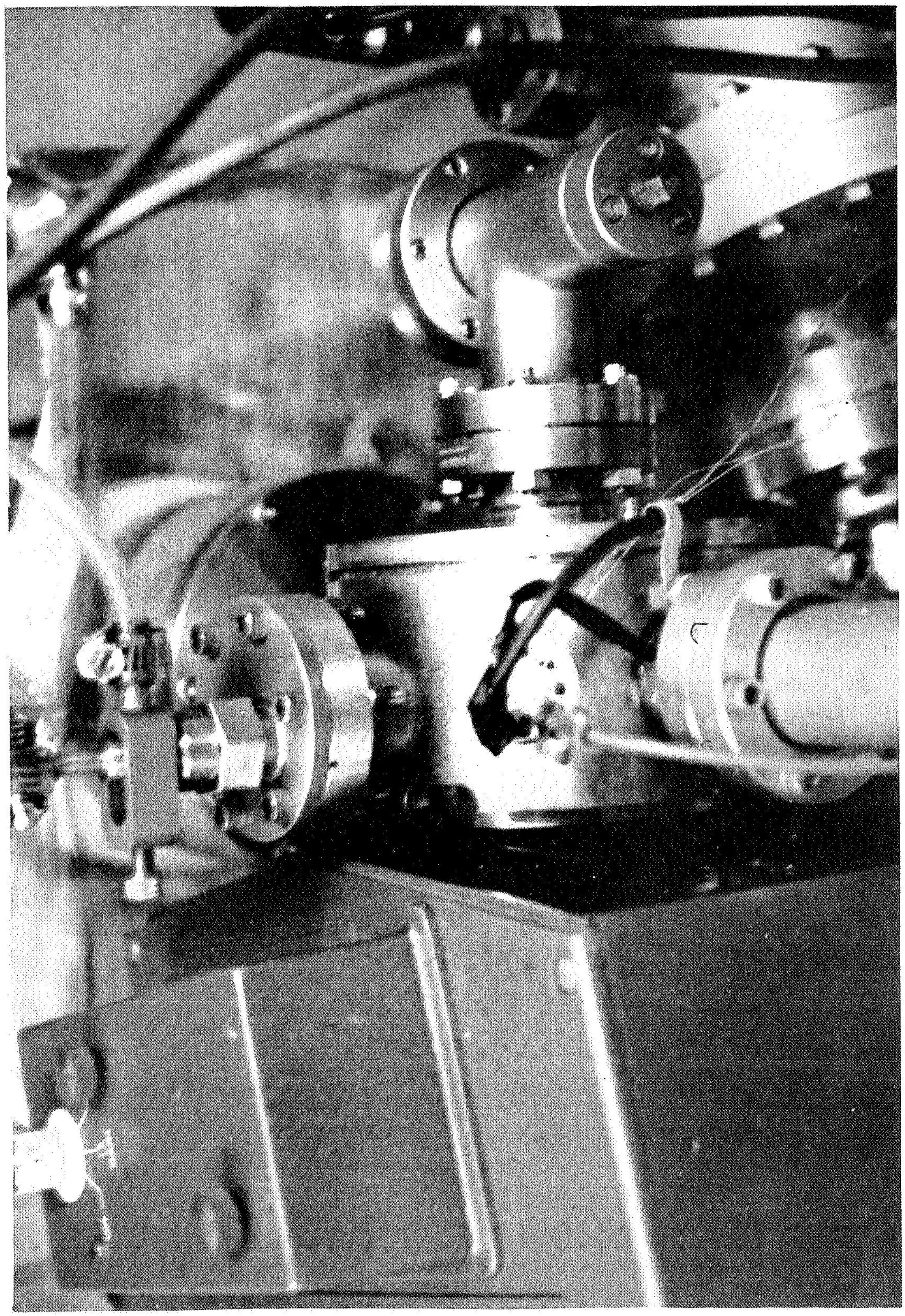


Figure 6

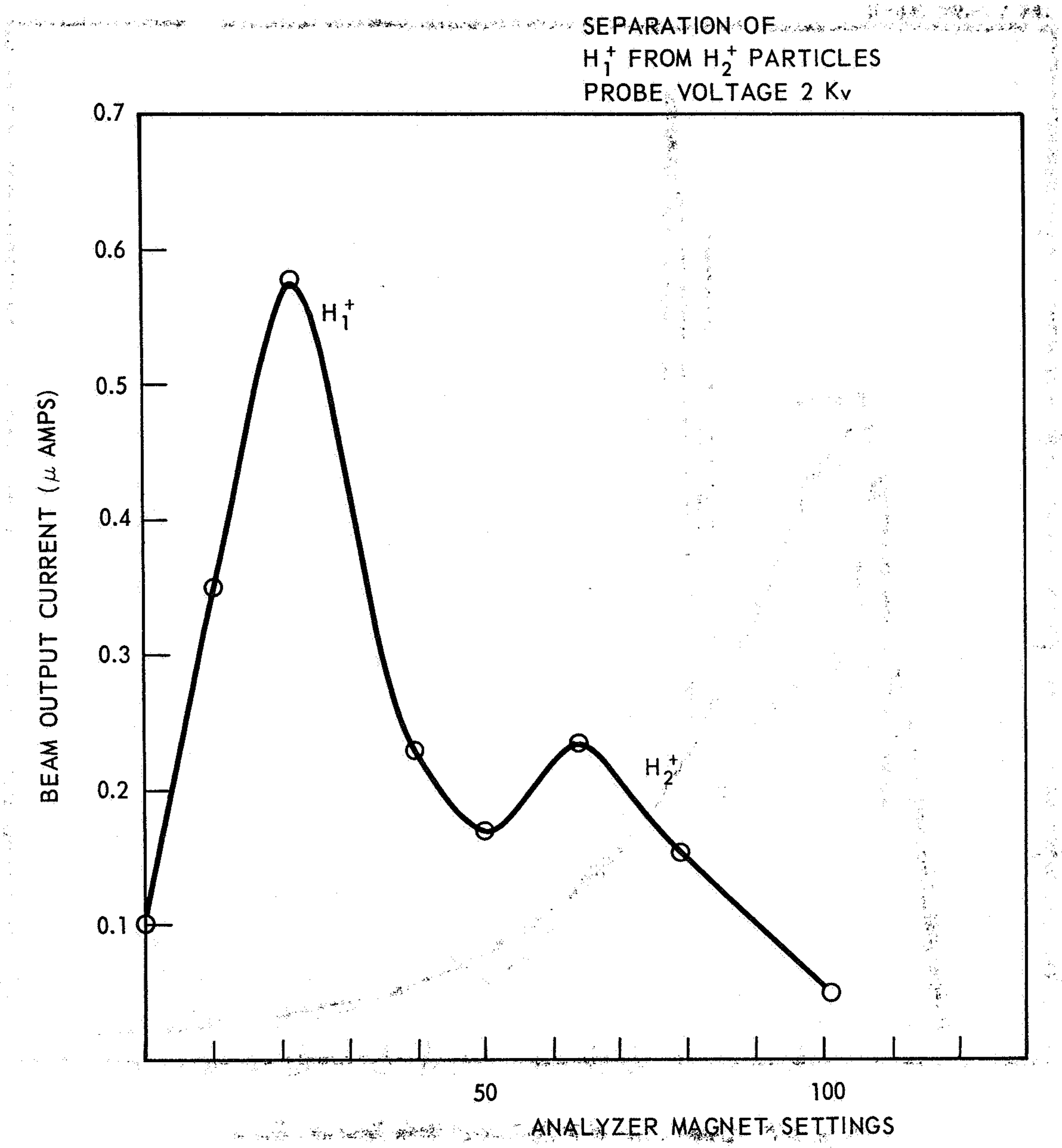

SEPARATION OF
H_1^+ FROM H_2^+ PARTICLES
PROBE VOLTAGE 2 Kv
BEAM OUTPUT CURRENT (μ AMPS)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
H_1^+
H_2^+
50
100
ANALYZER MAGNET SETTINGS

Figure 7

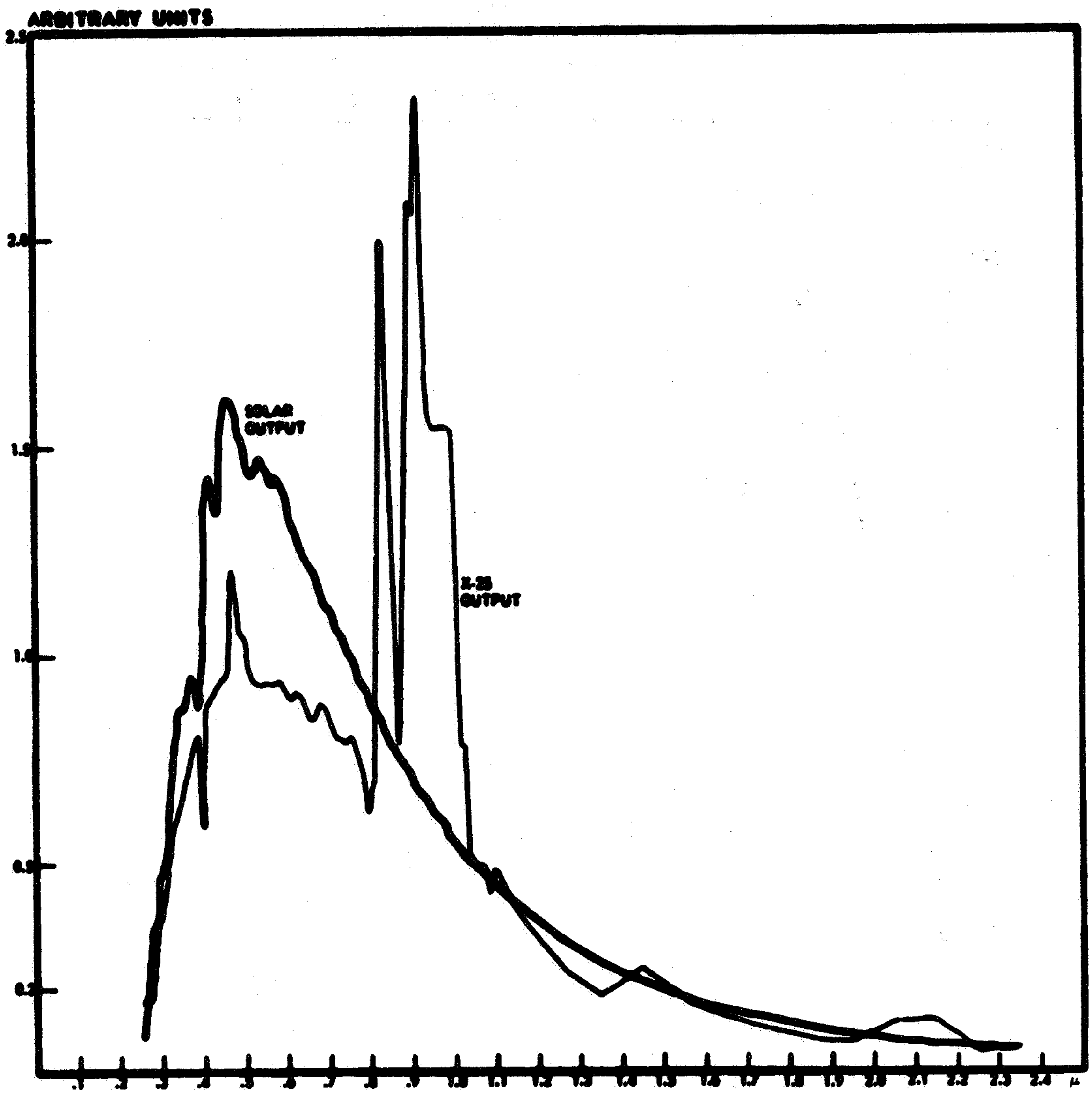


Figure 8. Comparison of X-25 Output With Johnson Curve

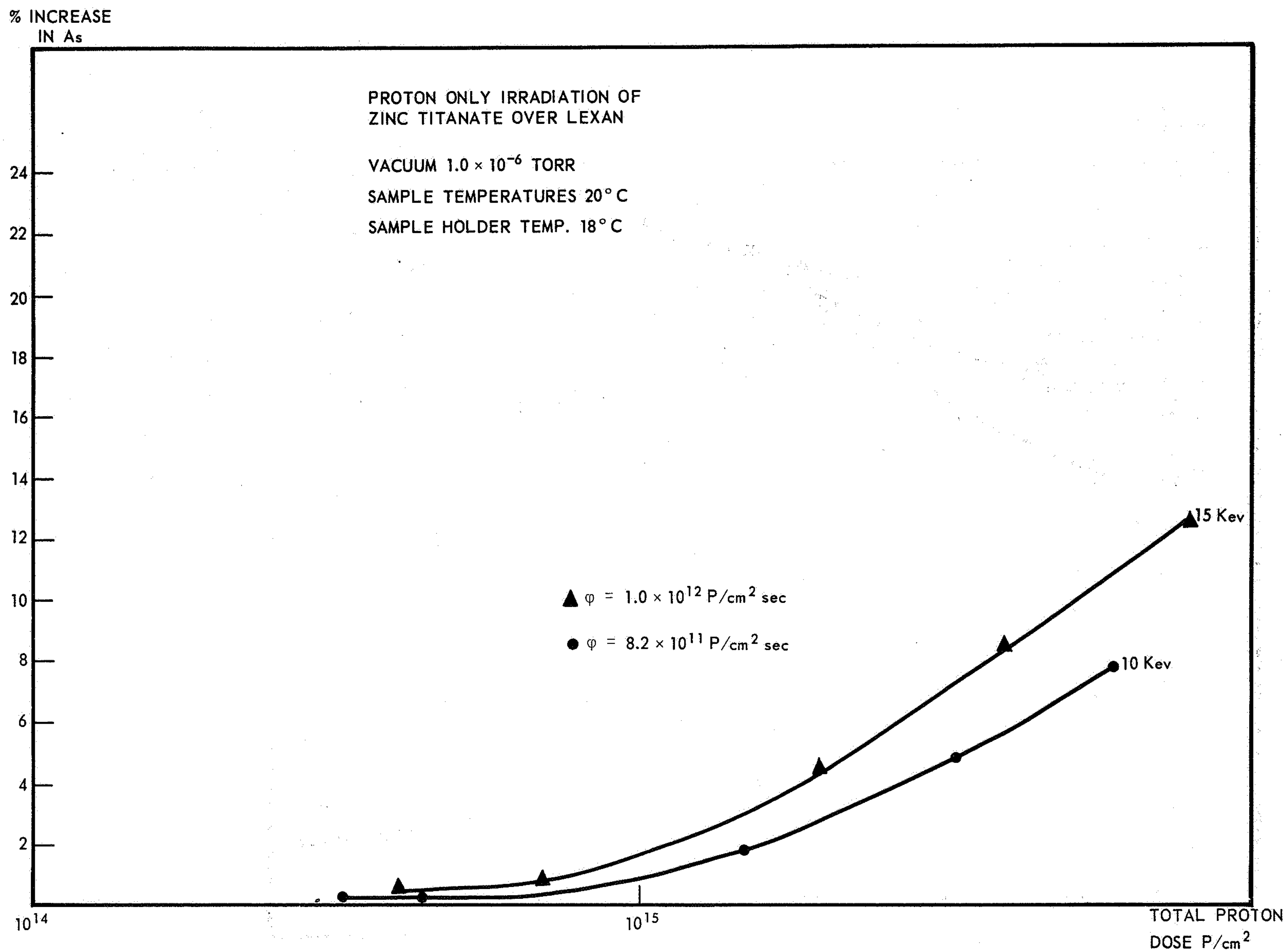
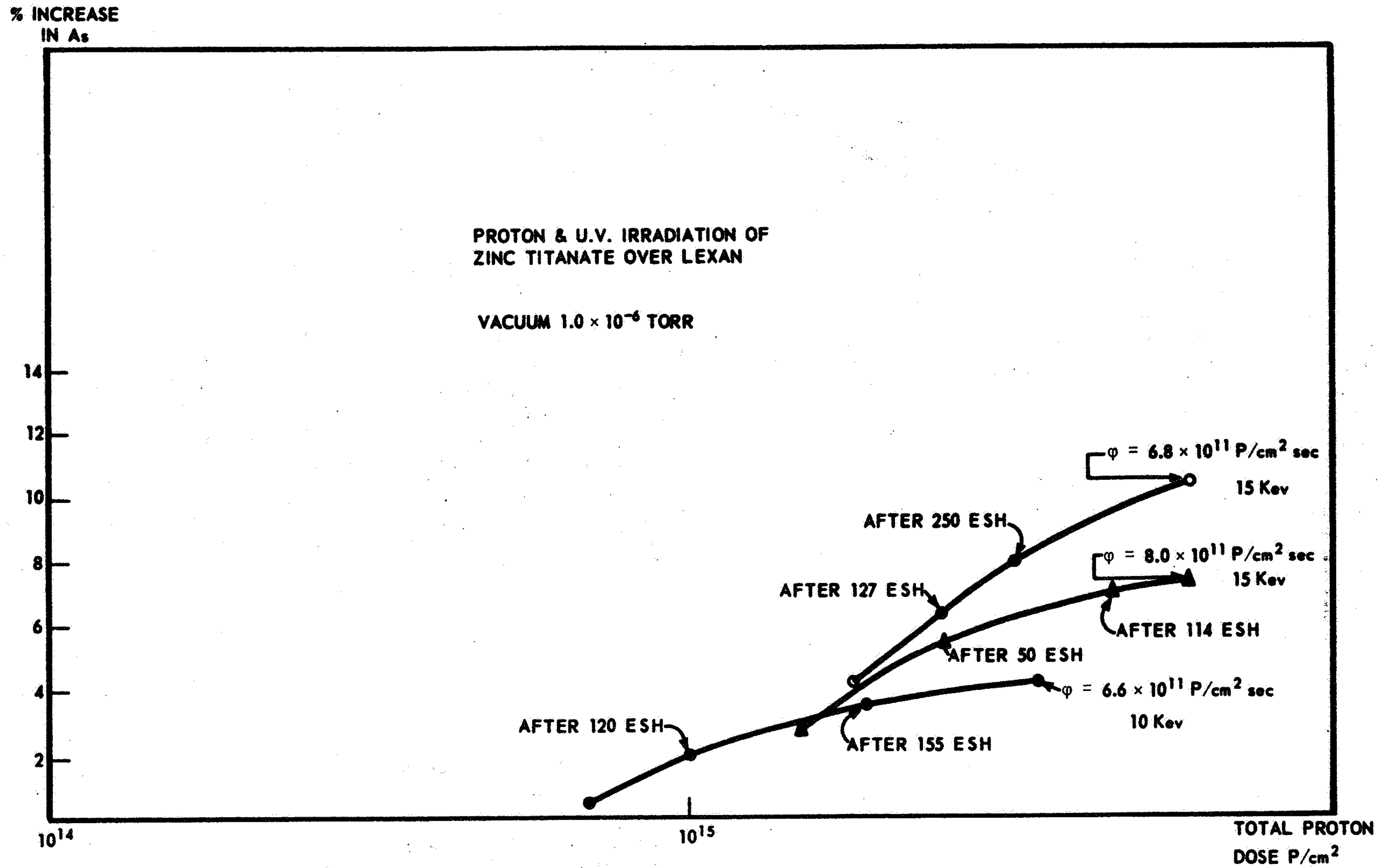

% INCREASE IN As
PROTON ONLY IRRADIATION OF
ZINC TITANATE OVER LEXAN
VACUUM 1.0×10^{-6} TORR
SAMPLE TEMPERATURES 20° C
SAMPLE HOLDER TEMP. 18° C
$\varphi = 1.0 \times 10^{12}$ P/cm^2 sec
$\varphi = 8.2 \times 10^{11}$ P/cm^2 sec
15 Kev
10 Kev
24
22
20
18
16
14
12
10
8
6
4
2
10^{14}
10^{15}
TOTAL PROTON DOSE P/cm^2

Figure 9



% INCREASE IN As
PROTON & U.V. IRRADIATION OF
ZINC TITANATE OVER LEXAN
VACUUM 1.0 × 10⁻⁶ TORR
14
12
10
8
6
4
2
AFTER 250 ESH
AFTER 127 ESH
AFTER 120 ESH
AFTER 155 ESH
AFTER 50 ESH
AFTER 114 ESH
φ = 6.8 × 10¹¹ P/cm² sec
15 Kev
φ = 8.0 × 10¹¹ P/cm² sec
15 Kev
φ = 6.6 × 10¹¹ P/cm² sec
10 Kev
10¹⁴
10¹⁵
TOTAL PROTON
DOSE P/cm²

Figure 10

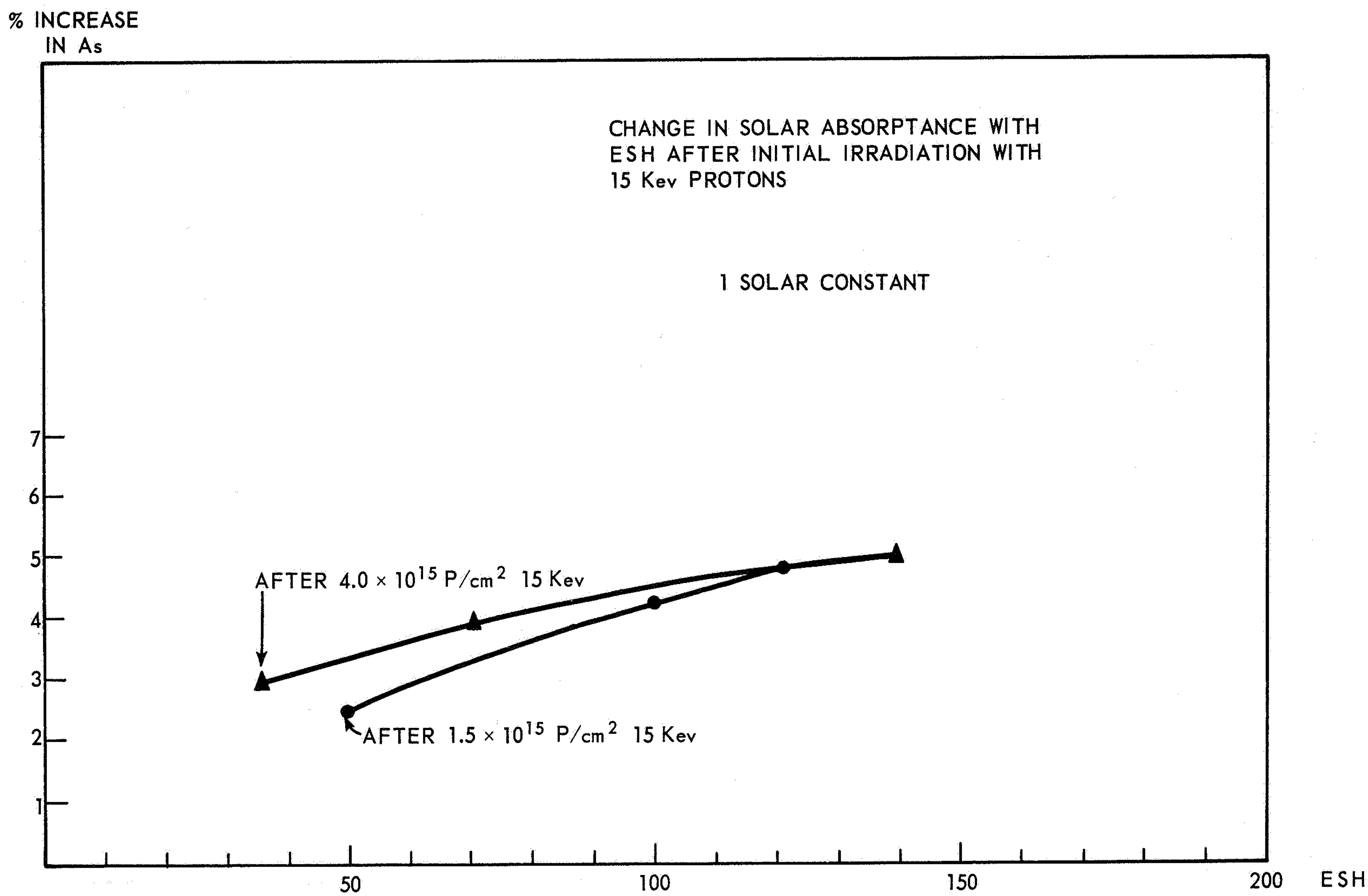

% INCREASE
IN As
CHANGE IN SOLAR ABSORPTANCE WITH
ESH AFTER INITIAL IRRADIATION WITH
15 Kev PROTONS
1 SOLAR CONSTANT
AFTER 4.0 × 10^15 P/cm^2 15 Kev
AFTER 1.5 × 10^15 P/cm^2 15 Kev
7
6
5
4
3
2
1
50
100
150
200
ESH

Figure 11