Title
OCCLUDED-GAS ION SOURCE

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ABSTRACT

Characteristics of a pulsed, occluded-gas ion source, operating in a magnetic field, have been investigated. Mass spectra of hydrogen- and deuterium-loaded sources are presented. Constructional details of the source and its operating characteristics are discussed.

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The advantages offered by a pulsed, occluded-gas ion source include its compactness and the high ratio of atomic to molecular ion output, as well as the inherent absence of neutral gas in the period between pulses.

The properties of sources of this type have previously been studied and the results have been published.[1] [redacted] However, this work was done with the source operating in the absence of a magnetic field.

For the past several months, the characteristics of an occluded source, operating in a magnetic field, have been investigated.

Basically, the source is composed of a stack of titanium washers separated by thin mica washers of slightly larger outer diameter (Fig. 1). Prior to their assembly in this sandwich, the titanium washers are heated and outgassed in a vacuum system of good quality. They are then allowed to cool in an atmosphere of hydrogen or deuterium. This treatment allows the titanium to occlude approximately 300 cc of hydrogen per gram of titanium metal.

For assembly, the washer stack if held in position with a loading mandrel while the two anode pieces are screwed firmly together. After the mandrel is removed, the stack is held in position solely by compression.

Figure 2 is a block diagram of the associated electronic components presently employed. The pulse line is charged by a variac-controlled -5-kv power supply. The current requirement for this supply is a function of the pulse recurrence frequency, which for this work has been arbitrarily set at 30 per minute. The characteristic impedance of this six-section line is 16 ohms, and as the impedance of the source is only a few ohms, a series resistor is used to match the impedance of the pulse line. The pulse length is 400 microseconds, and with the line charged to the negative 5-kv level, the arc current is 165 amperes. The actual voltage appearing across the arc during operation is in the range of 100 to 125 volts.

The arc is triggered by a pulse from a thyratron-controlled pulse transformer. This pulse also fires a series gap, which in turn triggers the main ball gap, allowing the pulse line to discharge across the washer stack. The plasma, apparently led by the electrons, extends down the tube in line with the magnetic field into the region of extraction. For purposes of extraction the source and its associated equipment are made positive, allowing ions to stream from a slit in this region.

The analysis of the products of the ion source was carried out in a 180° mass spectrometer arrangement, as shown in Fig. 3. Ions were collected at the 180° focal point by means of a traveling Faraday cup, or could be observed by means of a phosphored screen, which could be lowered to intercept the beam.

The serious beam spreading brought about by space-charge forces in the beam after it has passed the extractor must be overcome in order to provide focused beams. Although in a dc isotope separator the time required to neutralize is not of great importance, for pulsed ion beams time is of major concern, as neutralization must be re-established for each ion pulse in a time much shorter than the pulse duration.

This problem was satisfactorily handled by the installation of the beam-neutralizing plates. Before these plates were installed, the beam was so spread apart by space-charge forces that only small amounts were ever collected. These plates, made of aluminum, are so positioned that some of the ions, particularly before the beam is neutral, strike the surfaces at grazing incidence and release secondary electrons. These electrons are effectively trapped by the magnetic field and serve to neutralize the Coulomb repelling forces within the beam.

With this method, evidence of good space-charge neutralization has been observed with residual gas pressures as low as 3×10^{-7}. This pressure represents the base of the vacuum system used, and all work done has been at or very near this pressure.

It was later observed that adequate space-charge neutralization would be obtained even after the lower aluminum surface had been removed, indicating that sufficient electrons were being produced from the upper surface alone to neutralize the beam present.

For the data taken (Fig. 4) definition has not been stressed, and the collimating slit for the Faraday cup was made 1/2 inch wide. The abscissa for each charge represents the cup's position as it is moved one full slit width at a time through approximately 10 inches.

The upper chart, taken at 10 kv extraction potential, covers the spectrum from mass 1 through approximately mass 16. In order to extend the coverage to mass 48, or singly ionized titanium ions, the extraction potential was lowered to 3.4 kv. At this point, deuterium was present at the one limit of the Faraday cup's travel, and singly ionized titanium at the other.

These spectra show that when the occluded source is operated in a magnetic field, its high-mass output does not represent a serious contamination. Hydrogen isotopes represent more than 80% of the ion output of the deuterium loaded source.

Perhaps of more concern than the high-mass output is the rather substantial amount of protons present in the spectrum. As the vacuum was obtained by the use of an oil diffusion pump, it is possible that some of the proton output is the result of hydrogen liberated from the oil pumping fluid. However, it could well be the result of inadequate washer loading techniques.

Washers are presently being fabricated from commercial titanium, and, even though they are well outgassed, considerable quantities of hydrogen may still remain. If this is the case, the use of vacuum-processed metal, in which considerably less hydrogen is initially present, may result in a substantial decrease in the proton level, with a subsequent increase in the deuterium amounts. Attempts in this direction are planned.

With the rather large amount of protons present, it is impossible to gauge the atomic-to-molecular-ion ratio from the deuterium spectrum, as the mass-2 peak includes molecular hydrogen ions as well as atomic deuterium. For this reason the operation of the source with hydrogen-loaded washers was tried.

The spectrum shown in Fig. 5, which is thoroughly representative of the several taken, reveals that the ratio of protons to molecular ions is higher than 90%.

These results with the source operating in a magnetic field are considerably better, both with respect to the ratio of atomic to molecular ion output and to the level of high-mass output, than the results previously reported for which the source was not operated in a magnetic field.

[redacted]

Figure 6 is an exploded view of one of the geometries tested. With this model a single support mounts the source as well as the extractor. The assembly is coaxial, with the shielded quartz ring serving as the high-voltage insulator as well as the extractor mount. The collected ion output is monitored by the carbon cup, which completely surrounds the extracting region. In order to increase the extracting area, this unit incorporates three parallel extracting slits.

The data in Fig. 7 are indicative of the type of outputs obtained. This is the measured output of a two-slit geometry in which the extraction potential was extended to 20 kilovolts. The solid line represents the output of the source after 1 hour of operation or after nearly 1800 pulses. The output of 400 ma at the 20-kv point represents very nearly a space-charge-limited condition for the geometry used. In slit area, this is the equivalent of 7.2 amperes per square inch.

The operation of the source was continued for 11 hours, and it is interesting to note the drop in output measured at the end of this time. This is a decrease of some 20% in level at the 20-kv point after approximately 20, 000 pulses. This apparent decrease in plasma density may well indicate a decreased availability of the occluded gas with time.

A variation in current output is generally observed, as well, between successive pulses. Again this could indicate that the amount of occluded gas liberated during any one discharge is not necessarily a constant.

The ion output is also dependent on the level of the magnetic field. Reproducible decreases in output of 30% have been observed upon lowering of the magnetic field from 4 to 2 kilogauss.

The magnet used for these investigations has an upper limit of 4.5 kilogauss, and all data taken have been at or very near this limit. The effect on ion output of magnetic fields greater than this is not yet known.

[1] Crawford, Gow, Pon, Ruby, An Occluded Gas Ion Source, UCRL-3103, Aug. 1955.

[redacted]

FIGURE TITLES

Fig. 1 Source Structure

Fig. 2 Block Diagram

Fig. 3 Mass Spectrometer Arrangement

Fig. 4 Deuterium Spectrum

Fig. 5 Hydrogen Spectrum

Fig. 6 Single Support Source and Extractor Unit

Fig. 7 Ion Current vs Extraction Potential

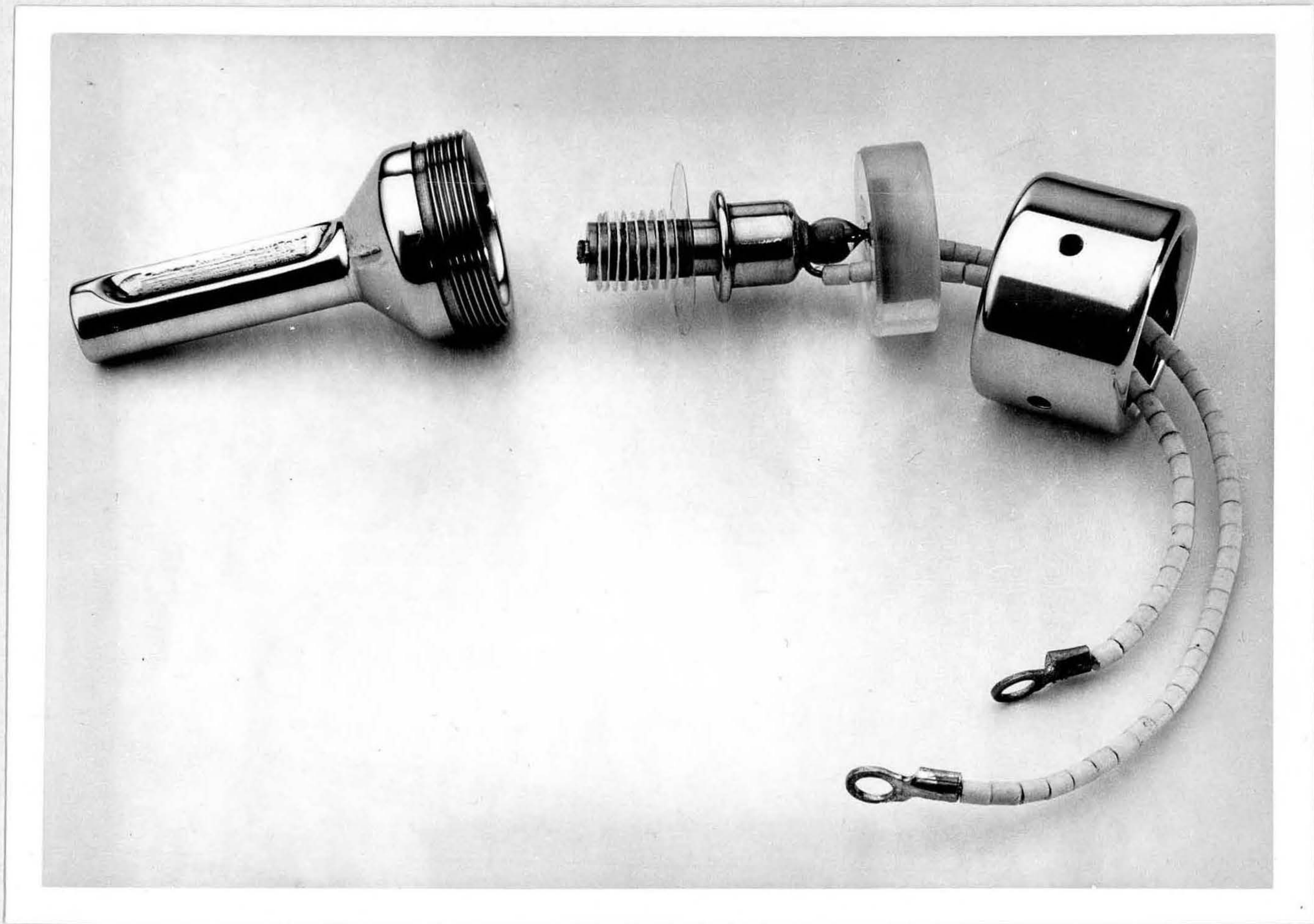


Fig. 1

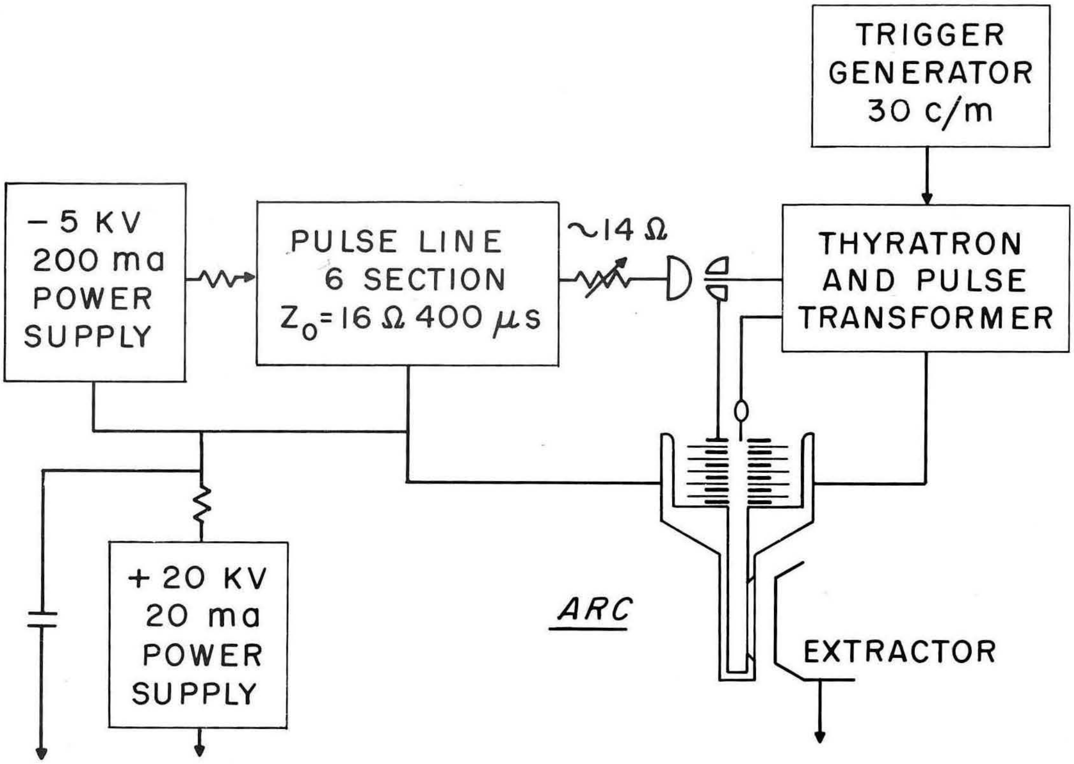

TRIGGER GENERATOR 30 c/m
− 5 KV 200 ma POWER SUPPLY
PULSE LINE 6 SECTION $Z_0 = 16\,\Omega$ 400 μs
~14 Ω
THYRATRON AND PULSE TRANSFORMER
+ 20 KV 20 ma POWER SUPPLY
ARC
EXTRACTOR

Fig. 2

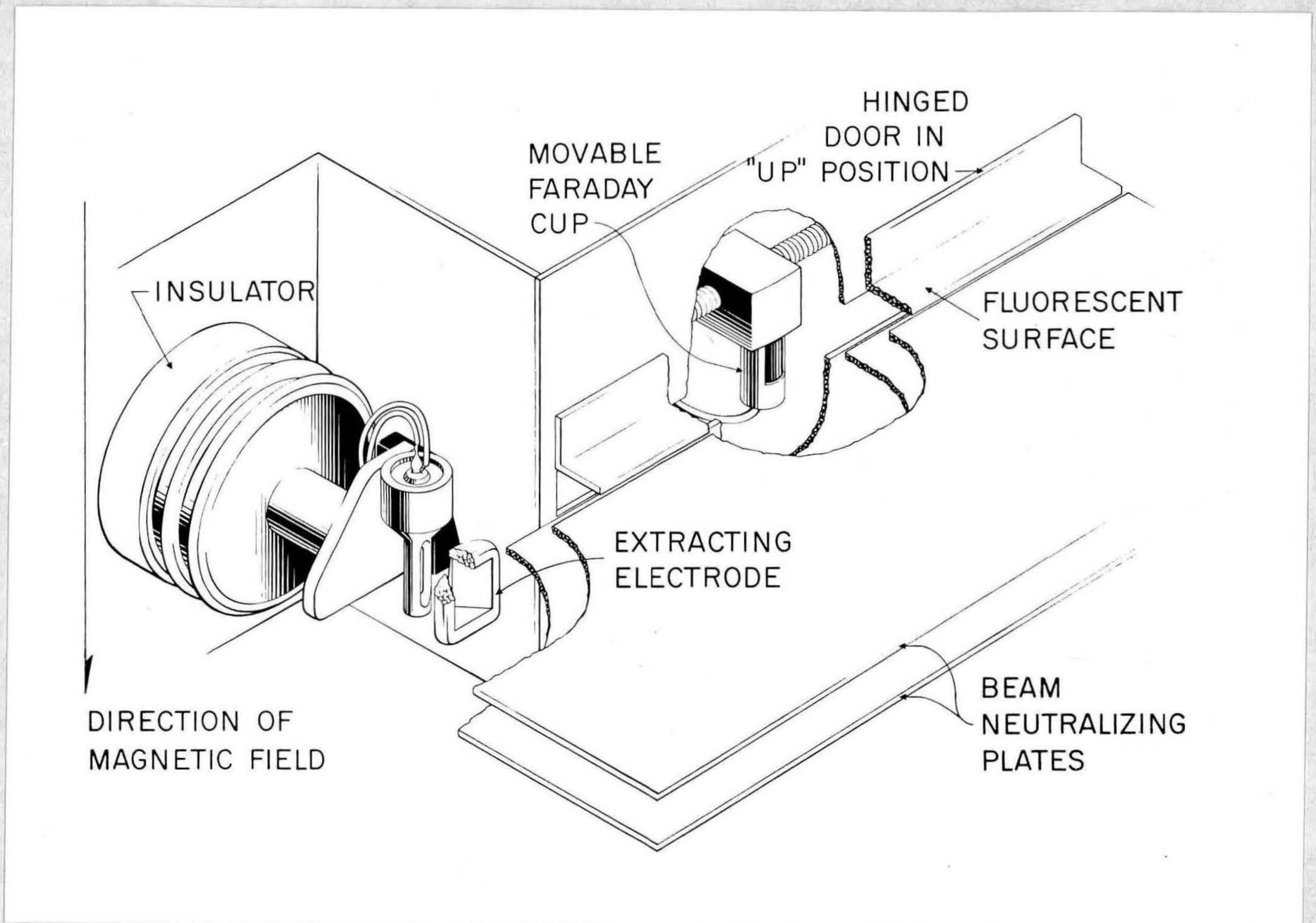

HINGED
DOOR IN
"UP" POSITION
MOVABLE
FARADAY
CUP
INSULATOR
FLUORESCENT
SURFACE
EXTRACTING
ELECTRODE
BEAM
NEUTRALIZING
PLATES
DIRECTION OF
MAGNETIC FIELD

Fig. 3

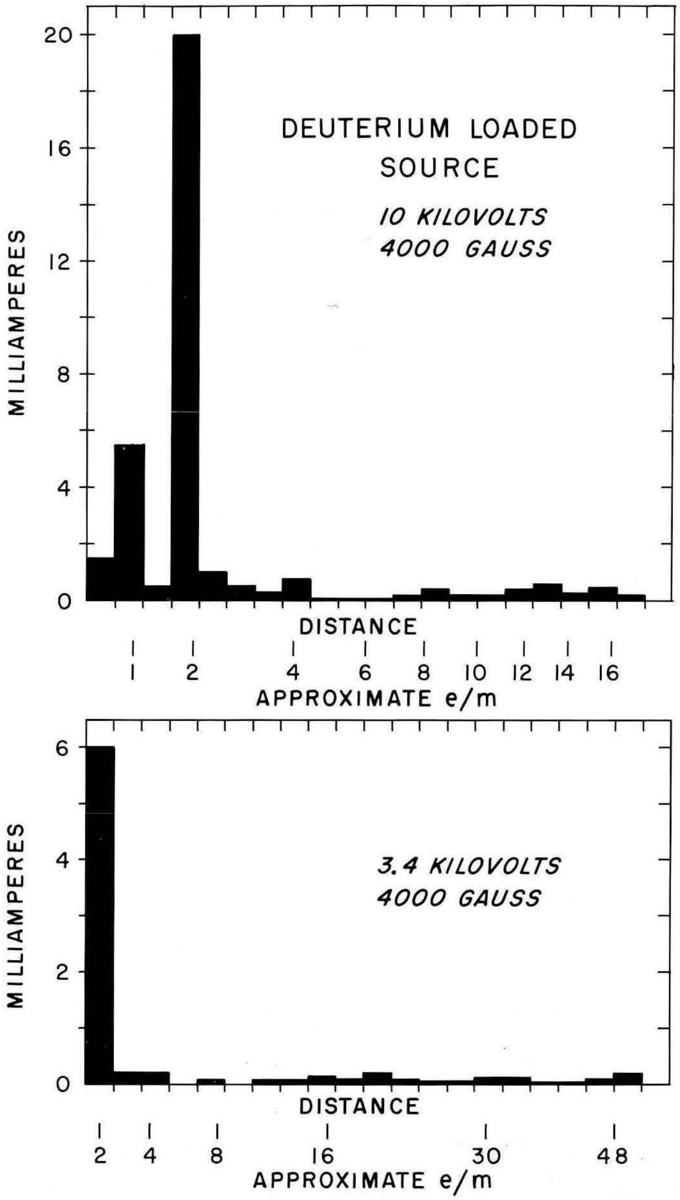

DEUTERIUM LOADED SOURCE
10 KILOVOLTS
4000 GAUSS
MILLIAMPERES
0
4
8
12
16
20
DISTANCE
1
2
4
6
8
10
12
14
16
APPROXIMATE e/m
3.4 KILOVOLTS
4000 GAUSS
MILLIAMPERES
0
2
4
6
DISTANCE
2
4
8
16
30
48
APPROXIMATE e/m

Fig. 4

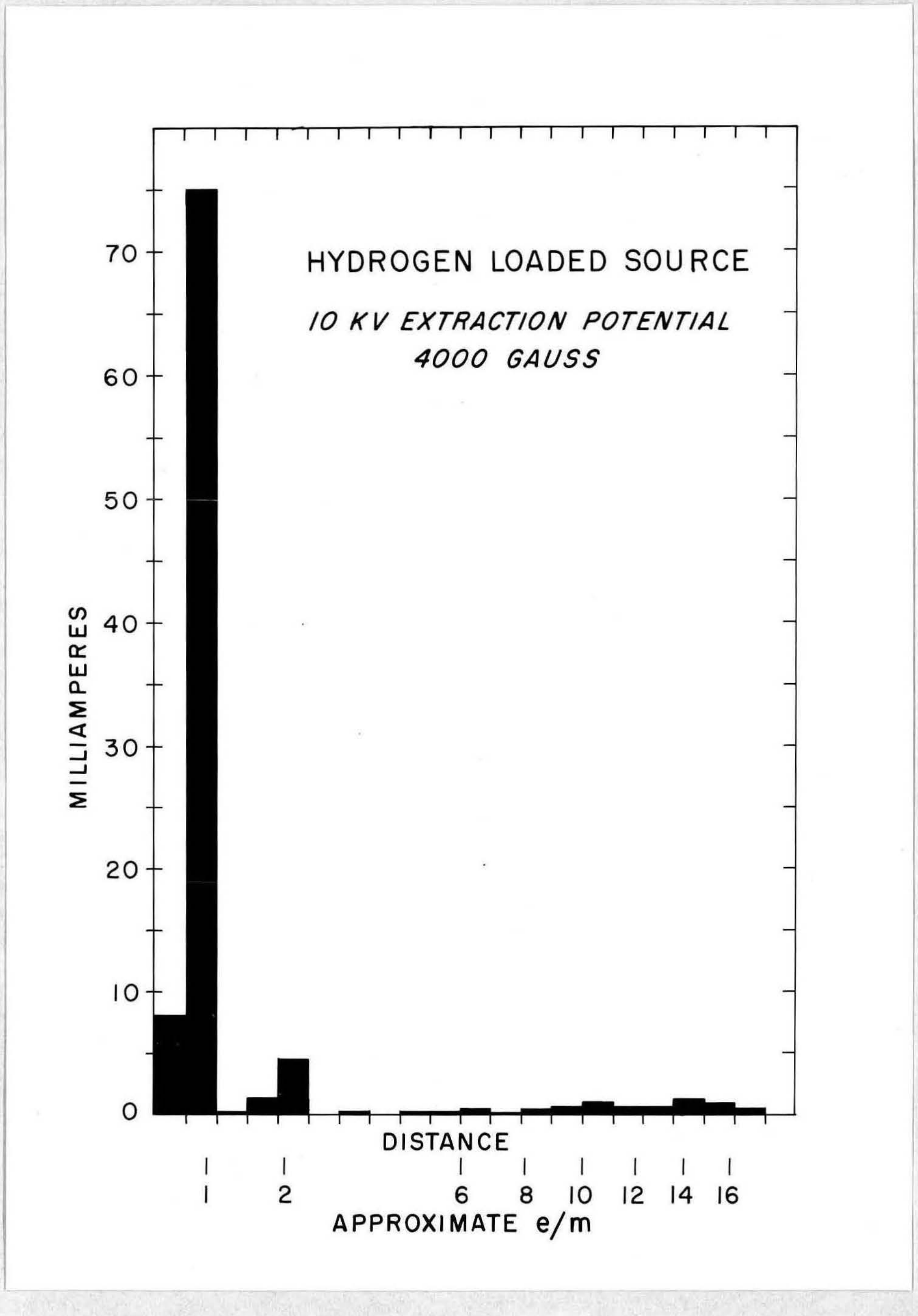

HYDROGEN LOADED SOURCE
IO KV EXTRACTION POTENTIAL
4000 GAUSS
MILLIAMPERES
0
10
20
30
40
50
60
70
DISTANCE
1
2
6
8
10
12
14
16
APPROXIMATE e/m

Fig. 5

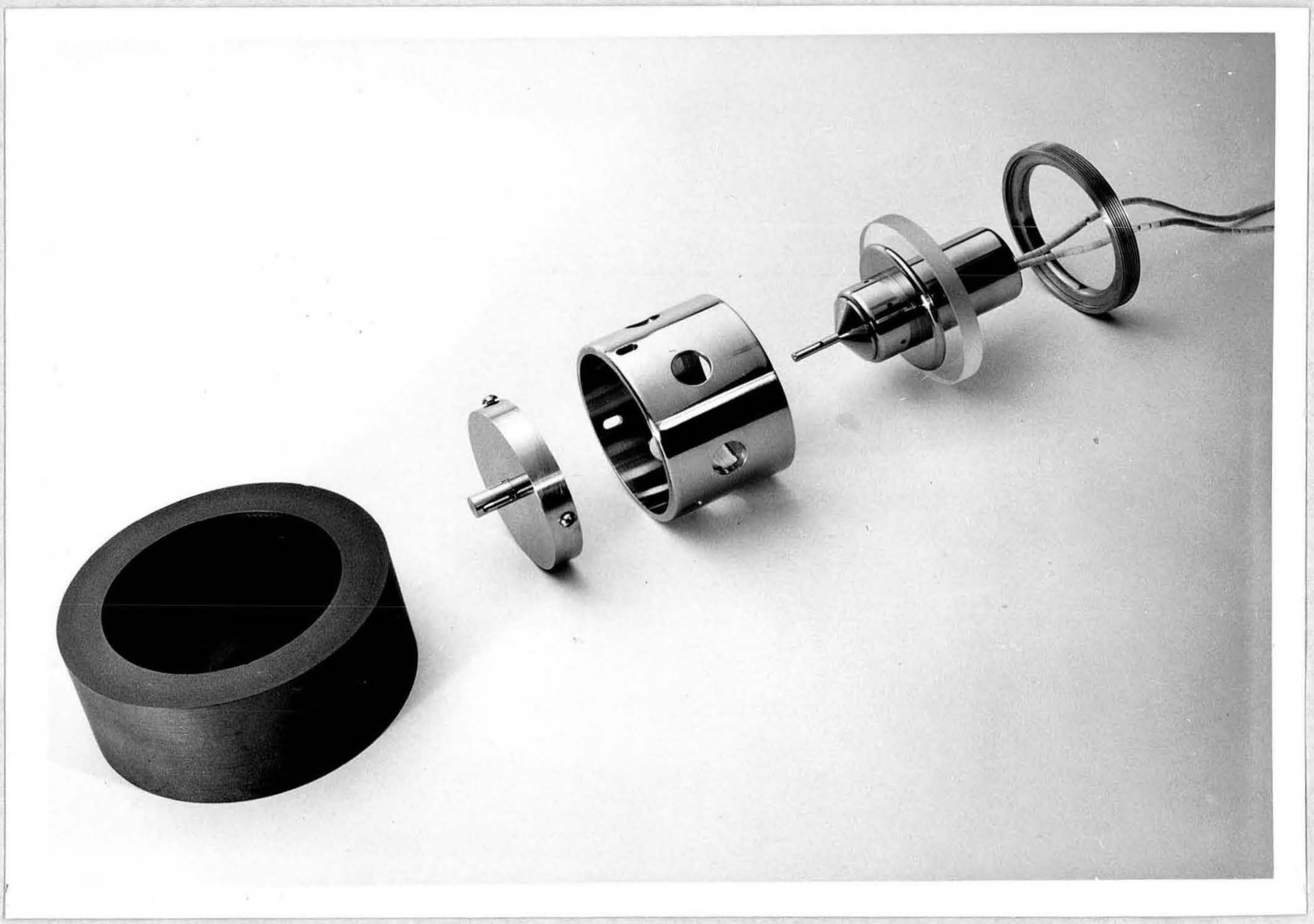
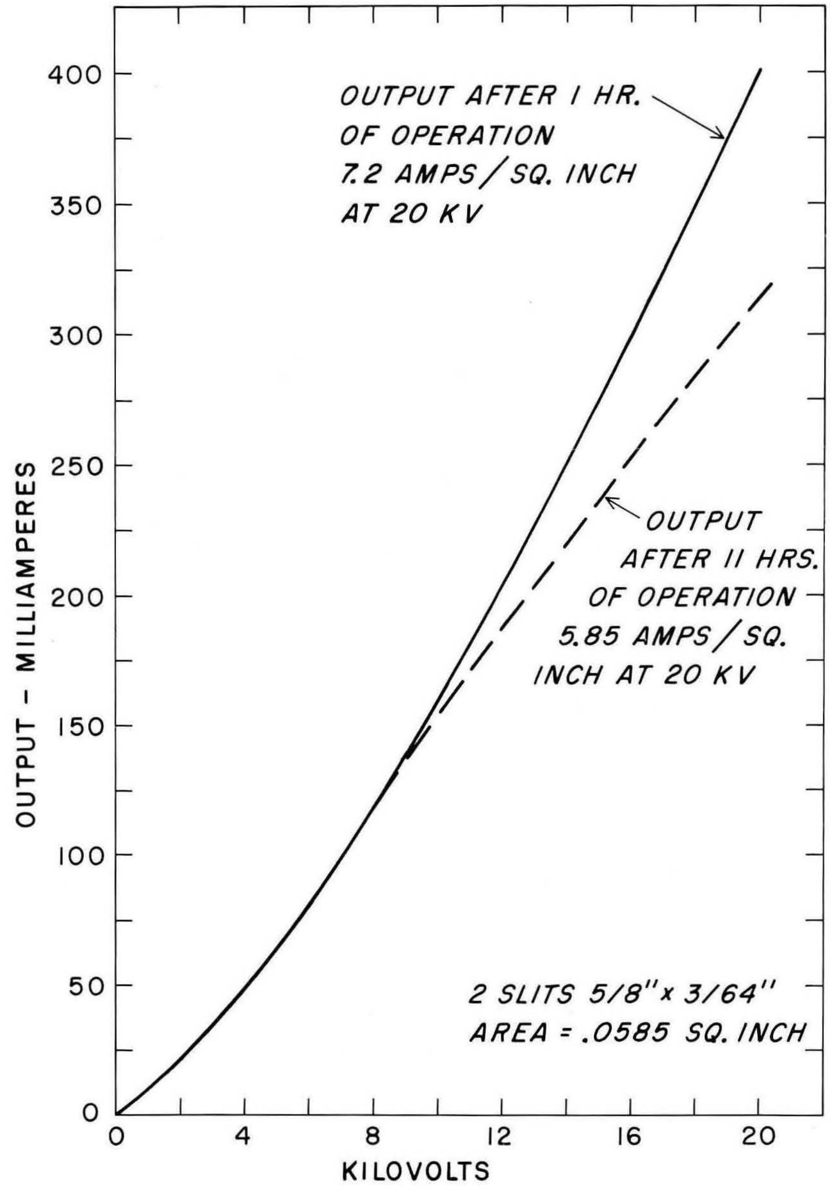


Fig. 6



OUTPUT - MILLIAMPERES
0
50
100
150
200
250
300
350
400
0
4
8
12
16
20
KILOVOLTS
OUTPUT AFTER 1 HR. OF OPERATION 7.2 AMPS/SQ. INCH AT 20 KV
OUTPUT AFTER 11 HRS. OF OPERATION 5.85 AMPS/SQ. INCH AT 20 KV
2 SLITS 5/8" x 3/64"
AREA = .0585 SQ. INCH

Fig. 7