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ABSTRACT

A brief discussion of the thermal and electrical characteristics of an arc image unit consisting of a pair of 60-inch parabolic mirrors mounted in a 9-foot diameter sphere, and a pressurized argon plasma source with a current which may exceed 2700 amperes at 65 volts. Curves of the radiant flux profile and density are presented.

THERMAL CHARACTERISTICS OF A 150 KW ARC IMAGE SYSTEM

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The arc image as a source for high flux thermal irradiation studies has received consideration attention in recent years. A review of equipment and research in this area was presented at the 1959 meeting of the High Temperature Symposium at Asilomar by C. P. Butler¹. In October 1962 a conference on Imaging Techniques was held in Cambridge, Massachusetts, at which a number of experimental image units were described. Among these was a carbon arc unit at Southwest Research Institute which was classed as a 400 kw installation². The objective in Berkeley was to develop an efficient tungsten to tungsten argon plasma for imaging which would overcome the principal limitations of the carbon arc--namely, the high electrical losses and the gross material losses associated with carbon electrodes which contaminated the environmental atmosphere. Initial work in this direction began in 1957, when a pair of 60-inch parabolic mirrors were mounted in a 9-foot diameter sphere with a pressurized arc source powered by a 600-volt synchronous converter. This original system did not prove suitable for operation at high power levels, primarily because of the electrical mismatch between the arc and its power supply.

Interest in the facility was revived in 1961 and has led to the development of the unit into a practical tool for high thermal flux studies. Theoretical heat transfer, and preliminary studies in a pressurized chamber

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indicated the way toward development of a tungsten cathode and a composite tungsten-copper anode structure suitable for currents to 3000 amps as supplied by a three-phase silicon rectifier power supply at a nominal 60 volts.

In order to provide for pressurizing the arc plasma up to five atmospheres, the entire assembly was mounted inside a nine-foot diameter sphere. Figure 1 is a photograph of the pressurizing sphere in its present form. The upper half of the sphere may be readily raised with a hoist and moved out of the way to permit full access to the components inside. Figure 2 shows the 60-inch parabolic mirrors and the arc source assembly with plumbing. The receiver assembly is not visible, but is located at the focal point of the mirror on the right. The geometry of the current leads was later changed to decrease the magnetic field effect on the arc. Details of the electrode assembly may be seen in Fig. 3, which shows the starter electrode wire near the anode. The arc is initiated by a 16 kv discharge from this auxiliary electrode. Figure 4 illustrates the electrical characteristics of the system with arc operation at several pressures. In this range of operation, the resistive characteristic of the arc plasma is quite linear and positive as indicated by the slope of the curves. Operation at a substantially higher current appears feasible; however, such operation would severely tax the cooling capacity of the electrodes with their present spacing of approximately 4 cm. This limitation may be relieved in part by an increase in spacing, with a corresponding increase in the applied voltage.

Calorimetric measurements at the image plane were made with two types of calorimeters. Figure 5 illustrates the adiabatic calorimeter used for short irradiation times of less than 5 seconds. The continuous flow unit used for general measurements is shown in Fig. 6. The thermal flux

impinging on the one square centimeter aperture of the continuous flow calorimeter was measured as a function of arc current and ambient pressure. Results of these calibrations are shown in Fig. 7. There is a decreasing return in terms of added flux delivered to the image plane for proportional increases in current and pressure. The highest value of heat flux measured in the tests reported herein would raise a black body surface to equilibrium at 4550° K if conduction losses could be avoided.

A profile of the flux distribution at the image plane is shown graphically in Fig. 8. The flux distribution, as measured with the adiabatic calorimeter, has been plotted in terms of "percentage of maximum reading" in traversing the image plane. An integration of the data used to prepare this profile indicated a delivery of nearly 10 kw to the image plane, and represents an overall equipment efficiency of approximately 5.5%. An approximate breakdown of this overall efficiency is as follows: The plasma converts 45% of the electrical energy to radiation. The first mirror sees 25% of the arc irradiation. Two mirror reflections transmit 50% of the energy, as seen by the first mirror, to the image plane. It should be pointed out here that the optics of this system were designed around readily available searchlight mirrors. A substantial improvement in efficiency would be obtained by optimizing design such that the mirrors could see at least 75% of the arc irradiation. With an improvement in coating reflectivity for the mirrors, an increase in the overall efficiency to 20% would seem reasonable.

In order to consider the use of this equipment for short time irradiation studies, high speed motion pictures were taken during arc initiation and shut down. Figure 9 is a series of photographs taken at 1 millisecond

intervals during start-up. The rapid development of the arc plasma indicates that an optical shutter would be of little assistance in this equipment. The 6 milliseconds required to reach equilibrium on start-up is essentially the same as the time required for arc extinction with sequence in reverse order. The lack of symmetry or "arc blow" noticeable in the plasma photo after 4 milliseconds was later corrected by repositioning the current leads to that shown in Fig. 3.

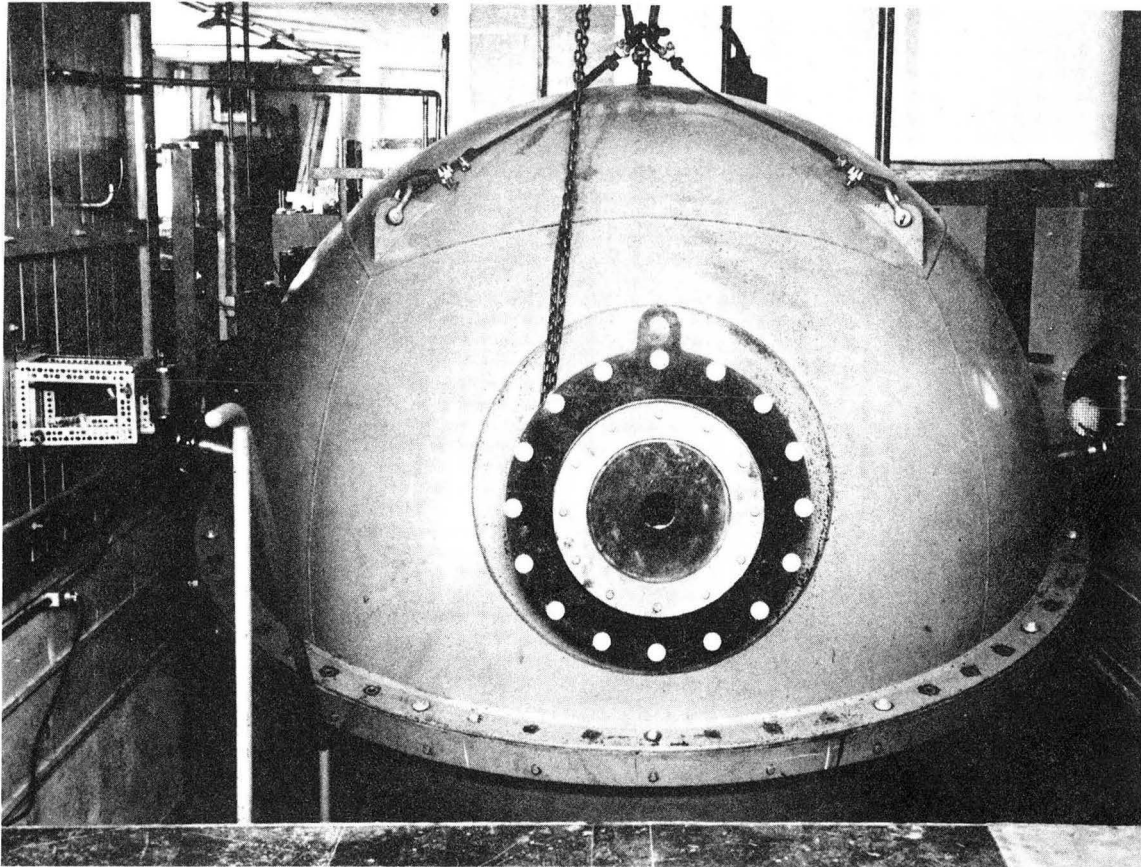
The maximum energy input of 170 kw to the pressurized argon arc in the unit described here gives a plasma radiance comparable to that of the 400 kw carbon arc installation as reported at the Cambridge conference. An additional advantage in using the high current tungsten-argon-tungsten arc in preference to the high current carbon arc is that a substantially longer irradiation time is possible. High current run times exceeding 5 minutes are quite feasible, and arcs at moderate currents under 2000 amperes may be operated for more extended periods.

ACKNOWLEDGMENT

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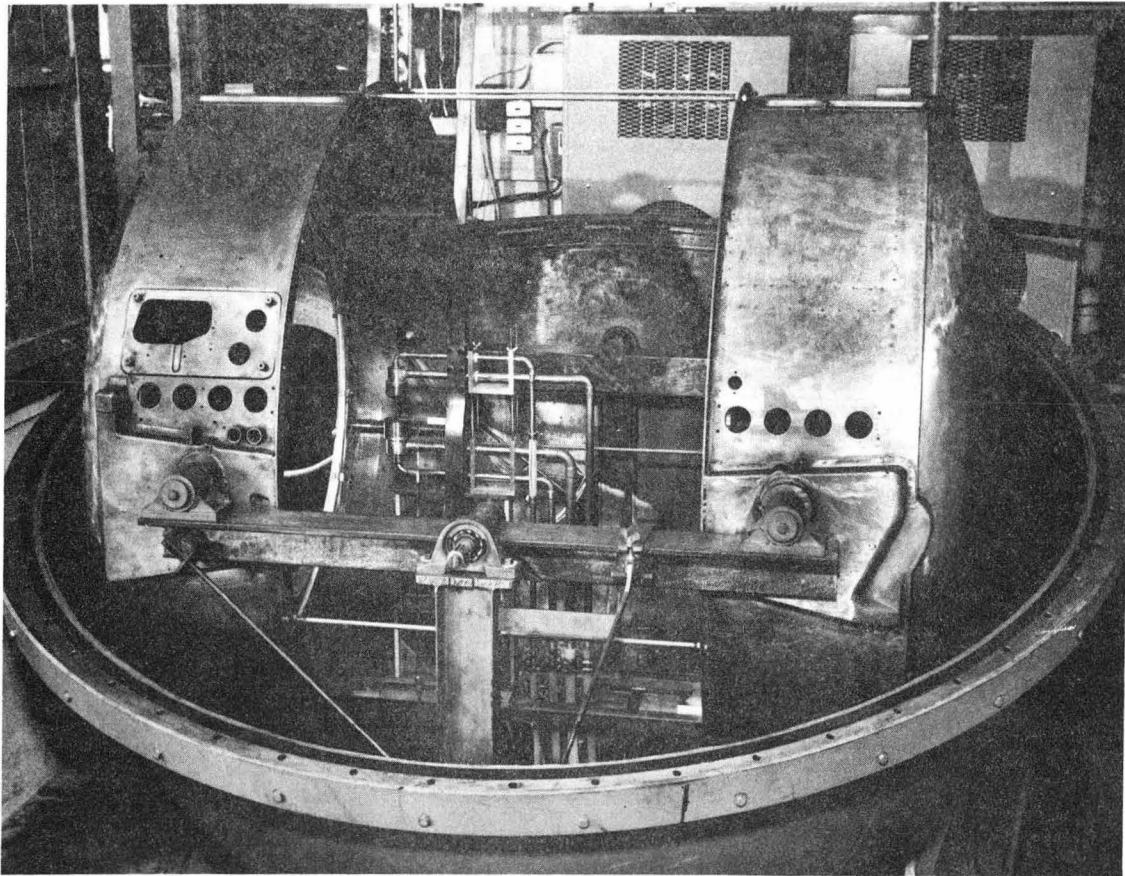
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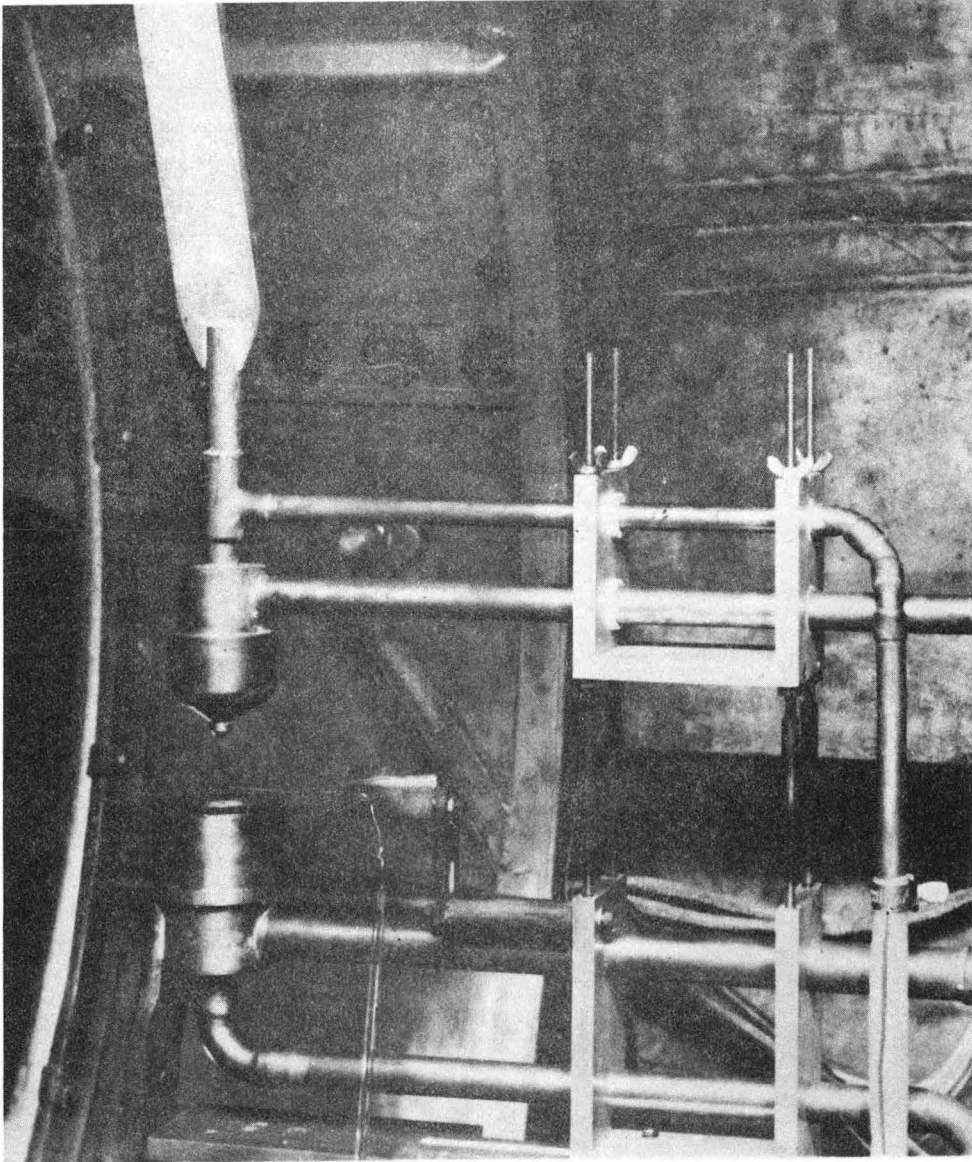
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Fig. 1. General view of the nine foot diameter pressurizing sphere.



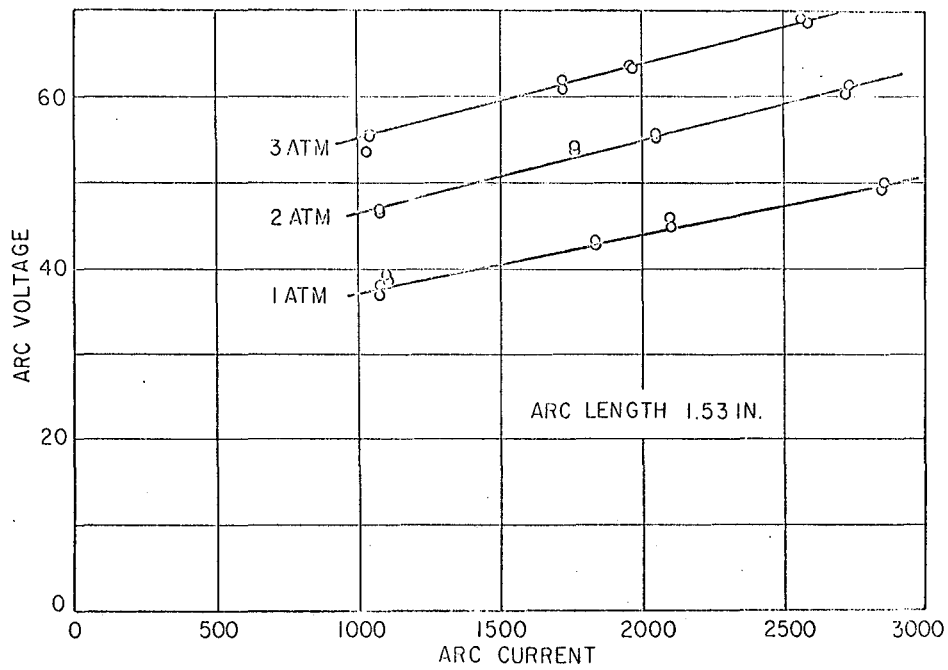
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Fig. 2. Interior view of the environmental sphere showing the mirror mounting and arc electrodes. The receiver assembly is not visible, but is located at the focal point of the mirror on the right.



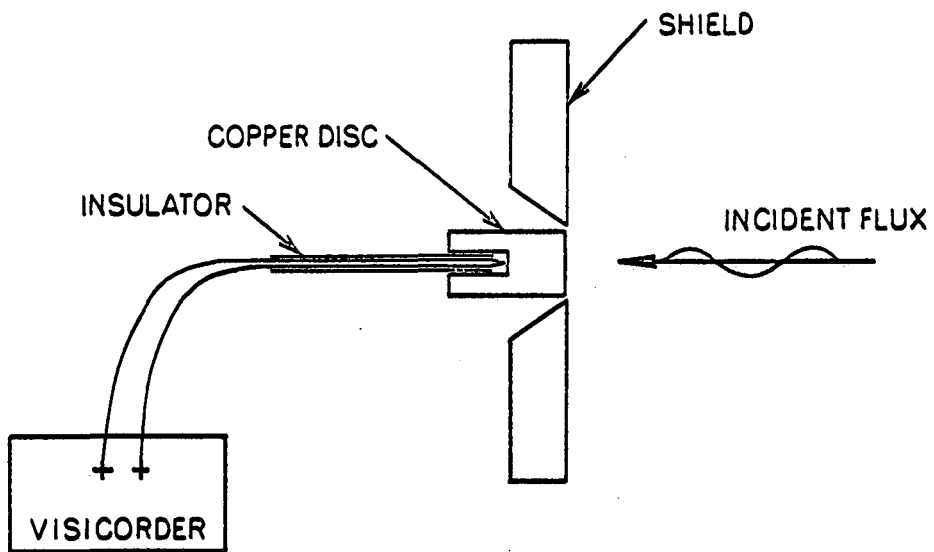
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Fig. 3. Electrode configuration showing power and water leads.



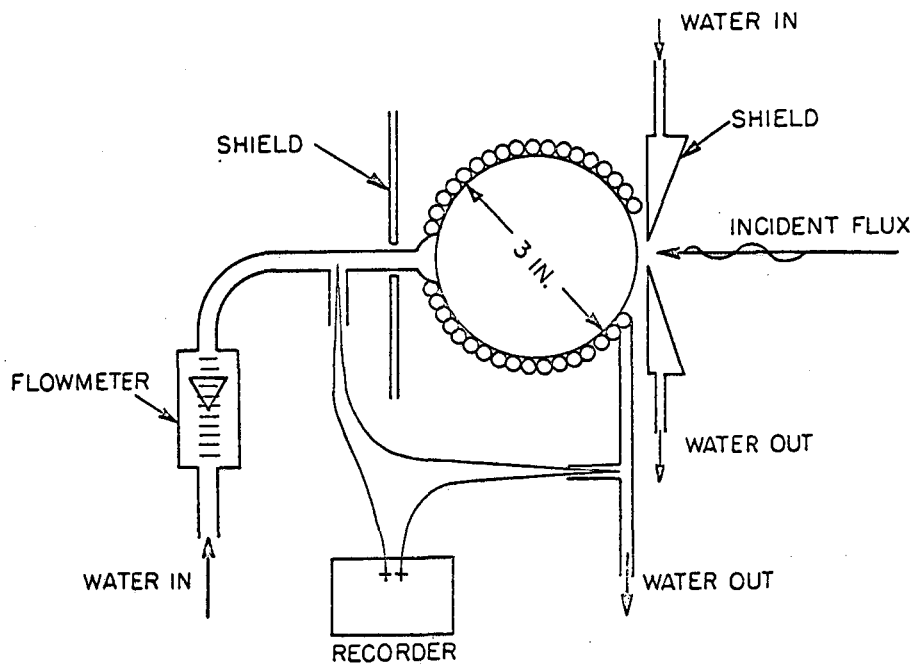
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Fig. 4. Electrical characteristics of the argon arc.



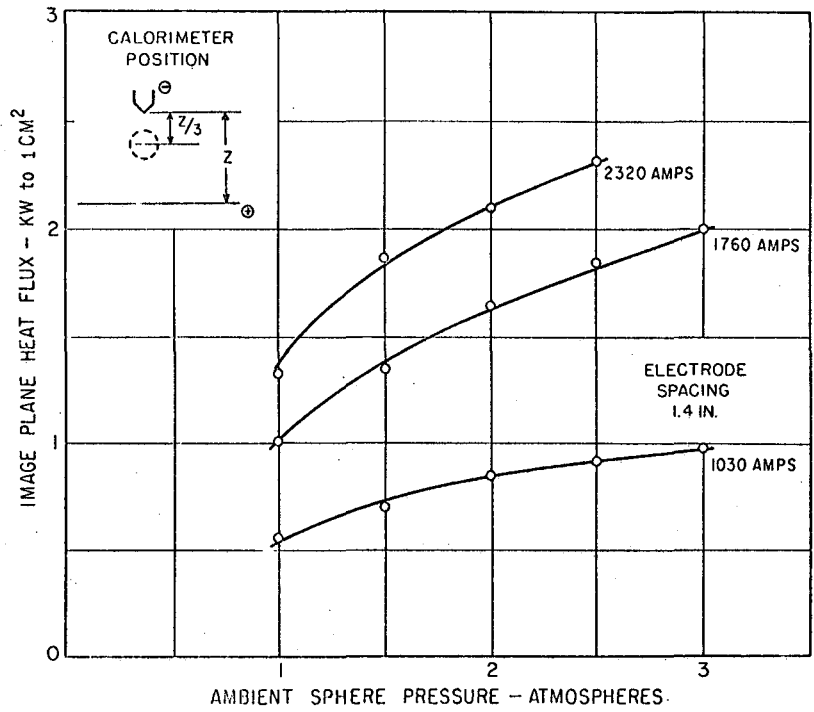
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Fig. 5. Schematic diagram of the adiabatic calorimeter. The 0.25 cm^2 face of the copper "disk" is blackened with acetylene soot.



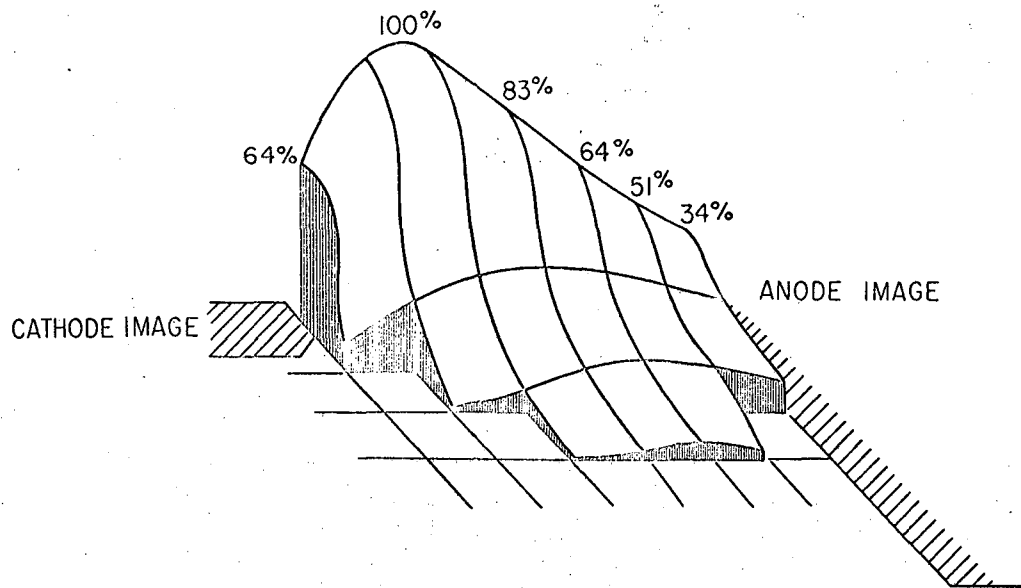
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Fig. 6. Schematic diagram of the continuous flow calorimeter with a 1 cm^2 aperture.



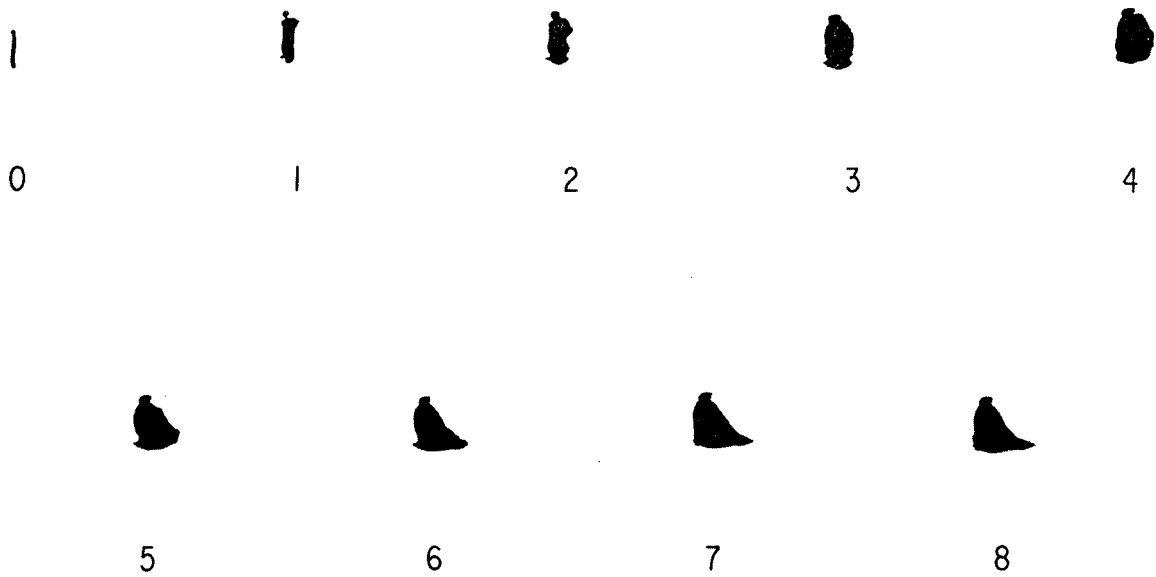
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Fig. 7. The thermal flux at the image plane as measured with the continuous flow calorimeter.



MU-32259

Fig. 8. Image zone flux distribution in a 1.5 inch argon arc as measured with the 0.25 cm^2 aperture adiabatic calorimeter. The grid spacing is 0.25 inch.



ZN-3990

Fig. 9. High speed photographs of arc plasma development. The number under each photo denotes time in milliseconds after initiation: Three atmospheres argon, 2400 amperes, 70 volts.