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THE THERMAL ANALYSIS OF ANODE AND CATHODE REGIMES IN AN ELECTRIC ARC COLUMN

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prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HEAT TRANSFER LABORATORY

MECHANICAL ENGINEERING DEPARTMENT

UNIVERSITY OF MINNESOTA

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October 1, 1965

CONTRACT NAS 3-2595

Project Manager
NASA - Lewis Research Center
Cleveland, Ohio
Spacecraft Technology Division
James Sovey

HEAT TRANSFER LABORATORY
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MINNEAPOLIS, MINNESOTA

INTRODUCTION

The Heat Transfer Laboratory at the University of Minnesota is engaged in a program of theoretical and experimental investigation of the heat transfer phenomena occurring in electrical arcs under NASA Contract No. NAS 3-2595. The project manager for the contract is Mr. J. Sovey of the Electrothermal Technology Section, Lewis Research Center. This report covers work performed during the period from June 28, 1965 to September 30, 1965. This ninth reporting period was devoted to the complete design of the test apparatus (arc tunnel modification). The construction of this apparatus is already well under way. In addition, some preliminary tests with a cylindrical anode in the former test section were performed.

Test Apparatus (Arc Tunnel Modification)

During this reporting period the complete design of the arc tunnel modification has been worked out. The construction work was initiated at the beginning of September and is now well under way. By requesting overtime for the workshop, we expect the new tunnel should be operable in November, 1965.

Figure 1 shows the existing arc tunnel, while the modified version is shown schematically in Figure 2. A welded aluminum construction will be used throughout, and O-ring seals employed in all the joints and flanges.

The gas flow as provided by the transfer pump will be controlled by means of a throttling valve and a by-pass valve. A Venturi tube will provide an accurate flow measurement.

Figure 3 shows the arcjet assembly. The upstream plenum chamber is made of a 4 inch aluminum tee with welded flangles. It acts as a settling chamber as well as cathode housing. A converging nozzle is made of a teflon piece, 8 inches O.D. and 4 inches long. This teflon piece also provides sixteen water passages and eight electrical connections to the different anode segments.

The anode consists of a brass holder and a copper insert. The brass holder will be 3 inches O.D. and 2 inches long. A magnet can be situated and slid along the holder. The inside diameter of the anode can be readily changed by installing a different size copper insert. A half inch insert will be used for the first experiments.

The design of the anode and its holder incorporates several useful features. First, the entire assembly can be easily removed. Second, eroded anode copper inserts may be simply exchanged. Finally, a segmented anode which retains only the general outline of the anode holder can be readily installed.

The thoriated (2%) tungsten cathode is held parallel to and in the center of the anode by means of a special water-cooled cathode holder. The cathode tip will be adjustable in all three dimensions, and the diameter of the tungsten cathode can be changed by changing the tungsten insert. A 1/4 inch tungsten insert will be used for the first experiments.

The anode assembly protrudes into a double wall water-cooled welded aluminum chamber of 23 inches inside diameter and a length of 54 inches. Four 10 inch diameter, and two 6 inch diameter openings are fitted around the test chamber for optional use as viewing windows and/or feedthroughs. Two heat exchangers are installed inside the test chamber. One of them consists of a coil made of 3/8 inch copper tubing mounted in an aluminum casing which can be moved horizontally either close to the anode to encompass the entire plasma jet for energy balance measurements, or moved back to the second heat exchanger in order to permit the observation of the discharge. The second heat exchanger is a stationary finned-tube device which was purchased from the Trane Company and has specially made copper heads and a non-magnetic alloy casing to avoid magnetic field distortions.

A throttling valve is located between the test chamber and the aluminum cross (see Fig. 2) to help control the pressure in the test chamber. If necessary, a liquid nitrogen cold trap can be put into the aluminum cross.

A DS-300 vacuum pump will be installed in order to provide a sufficient gas flow for open-loop studies with ammonia.

Preliminary Experiments with a Non-Segmented Cylindrical Anode

Preliminary tests with a cylindrical anode and without superimposed magnetic flux have been conducted in the test section of the present arc tunnel. Besides the three different arc modes which were described in the last summary report, a periodic voltage fluctuation was detected which could be traced to gas flow fluctuations caused by the transfer pump, with a frequency of approximately 50 cycle per sec. The maximum amplitude of these voltage fluctuations was about 1 volt at a pressure of 1 atm and rather high flow velocities. The flow fluctuations were in the range of ±8%. These values were measured by using a hot wire anemometer. Investigations in lower pressure ranges showed that the disturbance caused by the transfer pump is not so severe. It is anticipated that this effect will be further reduced in the new test section, which is located upstream of the transfer pump.

PROPOSED WORK

The next quarter of the contracting period will be devoted primarily to the following tasks:

1) Completion of the construction of the new test loop as shown schematically in Figure 2.
2) Probing of the anode nozzle exit velocity profiles with the arc turned off to establish uniformity of the flow.
3) Calibration of the Venturi tube, water flow meters, and thermocouples.
4) Design and construction of a magnet.
5) Preliminary tests with the new assembly.

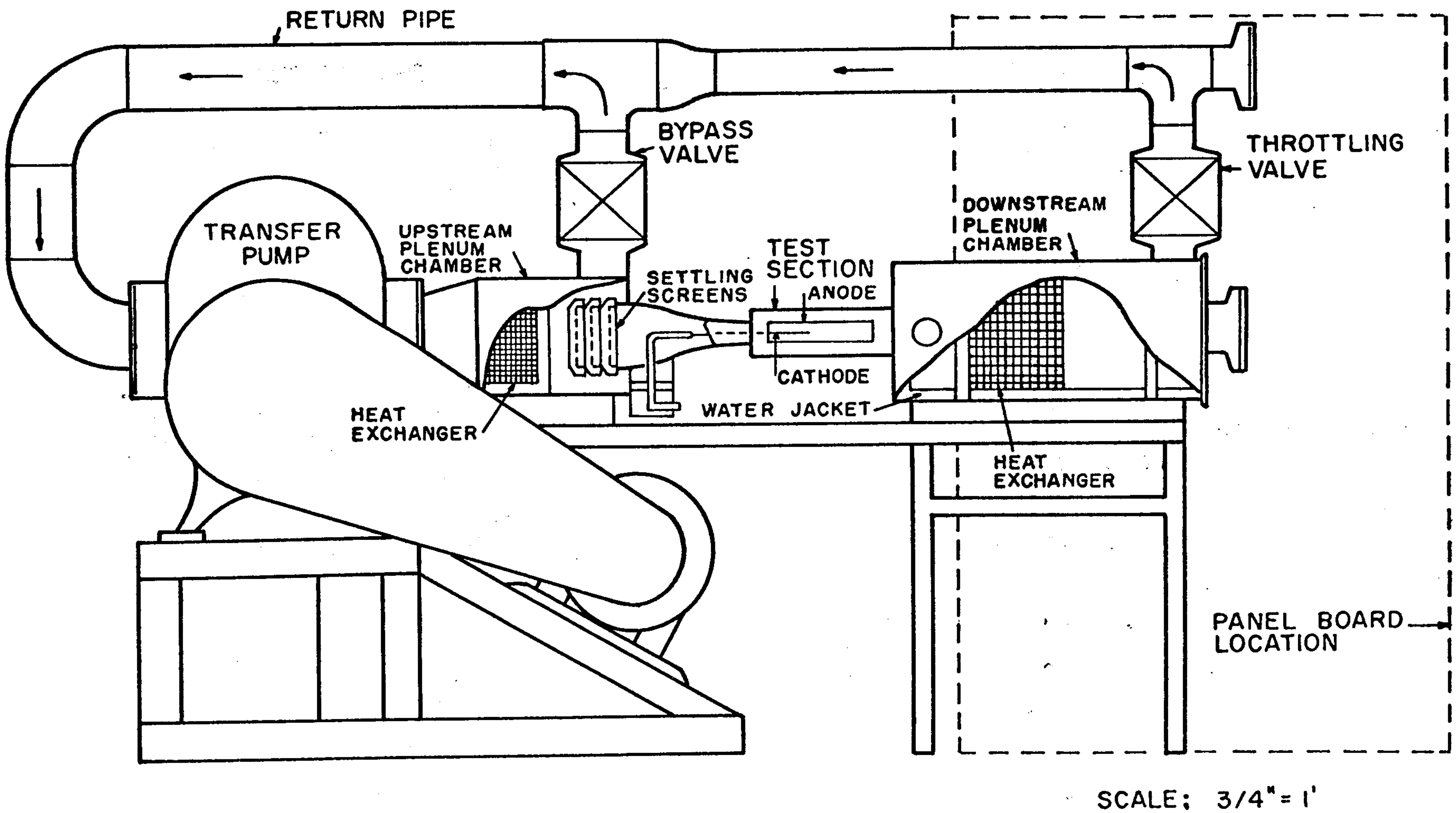
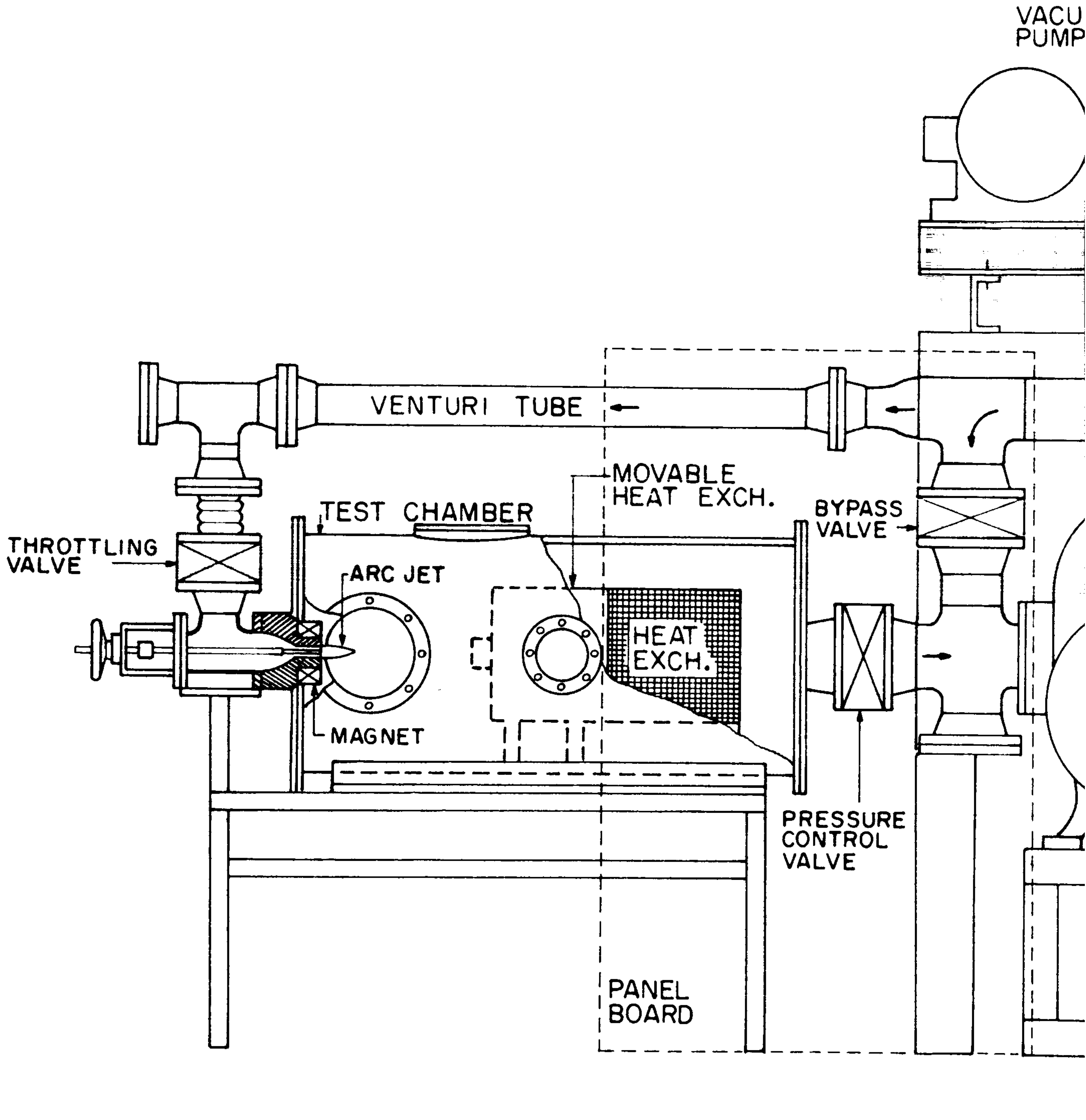


FIG. 1: ARC TUNNEL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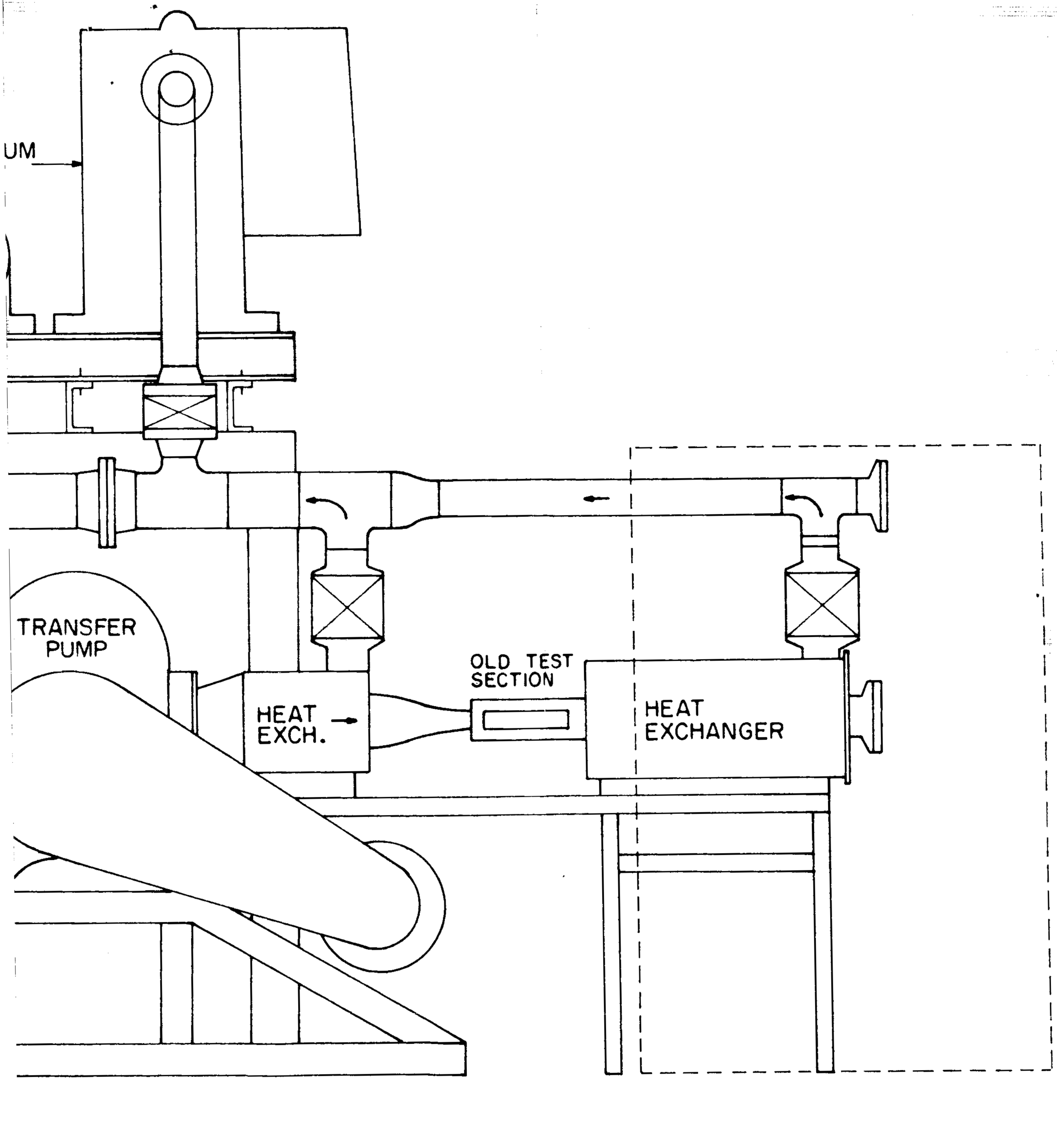
PUMP
VENTURI TUBE
MOVABLE
HEAT EXCH.
TEST CHAMBER
BYPASS
VALVE
THROTTLING
VALVE
ARC JET
HEAT
EXCH.
MAGNET
PRESSURE
CONTROL
VALVE
PANEL
BOARD

FIGURE 2 ARC



TUNNEL MODEFICATION

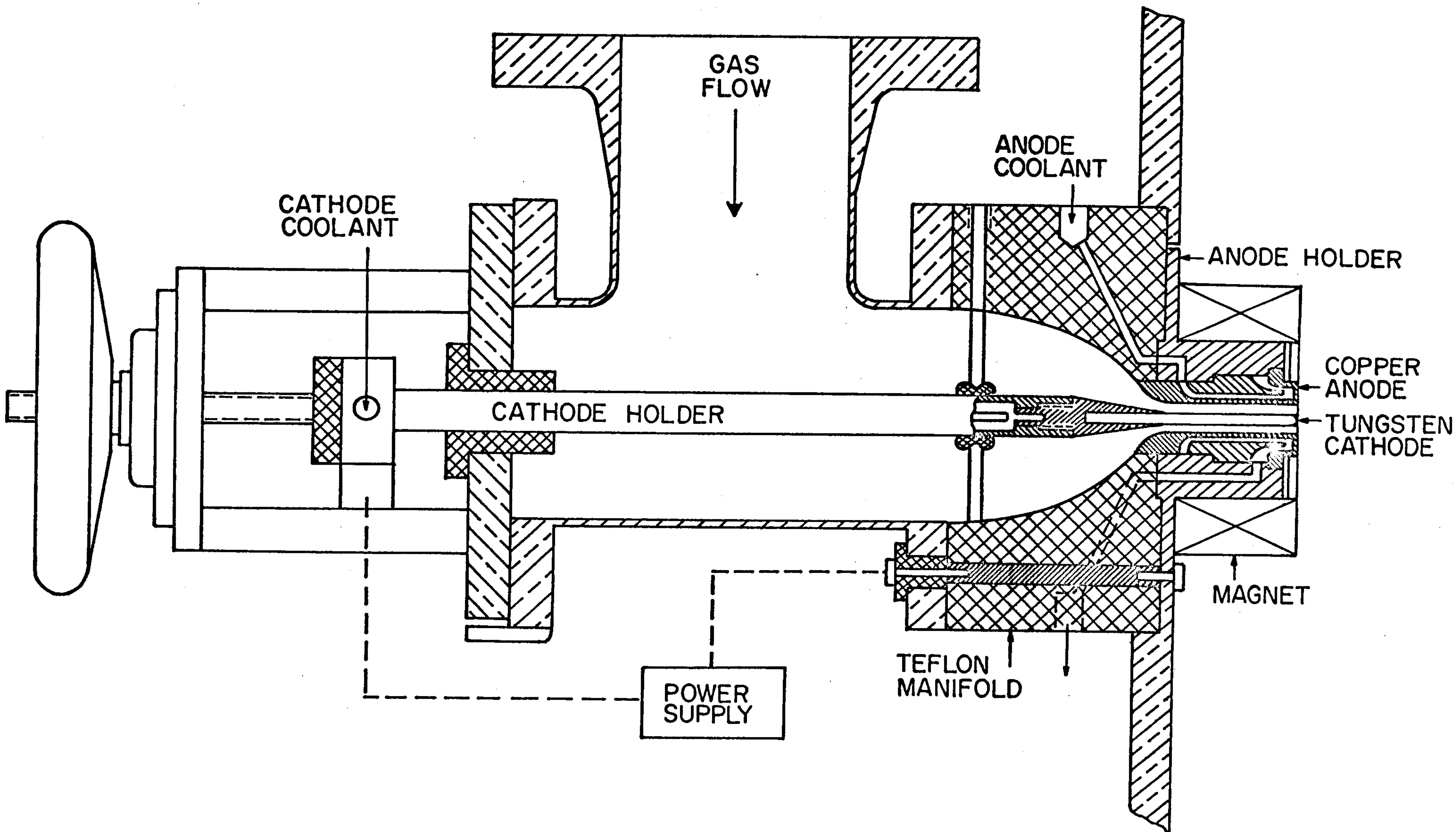


FIGURE 3 ARCJET ASSEMBLY

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