Univ. of Toronto

N65 10816
(ACCESSION NUMBER)
(PAGES)
CR-59317
(NASA CR OR TMX OR AD NUMBER)
(THRU)
1
(CODE)
11
(CATEGORY)

FACILITY FORM 602

PERFORMANCE STUDY OF A HIGH ENERGY MOLECULAR BEAM APPARATUS AND MEASUREMENT OF MOMENTUM ACCOMMODATION COEFFICIENTS UNDER SATELLITE CONDITIONS

Semi Annual Status Report

for period

Mar. 1/64 to Aug. 1/64

for work performed under

NASA Grant NsG-367

OTS PRICE

XEROX $ 1.00 FS

MICROFILM $ 0.50 mf

J. B. French
Principal Investigator

REPORTS CONTROL No. 2

[redacted]

Summary

The two portions of the program are reported as separate projects below, taken from the 1964 UTIAS Progress Report which is now being prepared.

The results of the initial performance study of the skimmed beam system are being reported in UTIAS Technical Note 75, copies of which will be forwarded to NASA as soon as possible. Some of this work was also reported at the 4th International. Symposium on Rarefied Gas Dynamics, Toronto, July 14-17, and will appear in the Proceedings.

At present, improvements suggested by this work are being incorporated into the system. These were listed briefly in the First Annual Status report, and are described in more detail below. Combination of the heated tungsten tube high pressure source, rotating disc velocity analyser, and double omegatron detection system should allow a complete optimization study of the system for producing internal beams in the 10eV range. Incorporation of these improvements has taken longer than expected, but the beam will be operational again by November.

The optical lever is operational and calibrated, and this work is at present in preparation as UTIAS Tech. note 81. This lever provides the basic measuring device for both momentum and energy accommodation coefficient measurements. The basic ultra-high vacuum chamber and pump (G. E. 500 litre/sec getter ion triode pump) for the experiment has been purchased, with delivery in October. A special problem has been the design of a large diameter rotating seal for the ultra-high vacuum system used. This was necessary because the optical lever must be mounted outside the region of bake-out, and looks in at the mirror and torsionally-mounted target through an optically flat window in the ultra-high vacuum system. Rotation of the entire assembly allows variation of the angle of incidence of the beam molecules on the test surface, an important interaction parameter. The seal utilizes Indium which is melted when rotation is desired. The design is complete and out for quotation at present. It is estimated that assembly of the experimental equipment will take until the end of the year, at which time we hope to commence the detailed study of accommodation coefficients listed in the original proposal.

During the past two months, the principal investigator has been writing by invitation a survey article for the AIAA Journal on the high energy molecular beam generation problem. This should appear about January, of course with recognition of NASA sponsorship. Reprints will be forwarded to NASA as soon as available.

Perhaps it is best to conclude this summary of the first

eighteen month's work with a list of publications generated under this grant and their present status.

(1) "Initial Performance Study of a Skimmed Beam System"
D. R. O'Keefe, UTIAS Tech. Note 75, in printing at present.

(2) "Omegatron Studies of a Skimmed Beam System"
J. B. French and D. R. O'Keefe. Proc. Fourth Int. Symp. on Rarefied Gas Dynamics, Toronto, July 1964. Academic Press, to be published.

(3) "The Optical Lever as a Force and Energy Transducer"
E. J. Moskal, UTIAS Tech. Note 81, in preparation.

(4) "Continuum Source Molecular Beams"
J. B. French, AIAA Journal Survey article, to be published.

and in planning for the next eighteen months:

(5) "A Large Rotatable Ultra-High Vacuum Seal"
G. McMichael, to be submitted to Rev. Sci. Instruments.

(6) "Electron Beam Studies of the Flow Field of a Skimmed Free Jet Expansion"
G. McMichael, J. B. French, D. Rothe

(7) "Optimization Study of a High Energy Continuum Source Beam"
J. H. Davis Jr., UTIAS Report.

(8) "Accommodation Coefficients for High Energy Molecules on Known Surfaces"
E. J. Moskal, UTIAS Report

(9) Selected aspects of all this work will also be presented at the 5th Rarefied Gas Dynamics Symposium.

J-1 HIGH ENERGY MOLECULAR BEAM FACILITY - NASA, DRB

(D. R. O'Keefe, H. J. Davis, Jr.)

Some initial performance studies employing the UTIAS high energy molecular beam facility have been completed and reported in UTIAS Technical Note No. 75. A traversing impact probe for studying the radial flux distribution of the beam downstream of the skimmer was used (Fig. J-1. 1). This probe was connected to an omegatron mass spectrometer, allowing an analysis of the mixed beam to be made.

A mixture of 99.0 mole percent helium and 1.0 mole percent argon was expanded through the source orifice (.031" diameter) and into the low density wind tunnel (10^{-3} torr). A stainless steel conical skimmer (orifice dia. = .014") was placed in the flow to extract the beam. The source temperature and pressure were maintained at 300^{o}K and 139 torr respectively, throughout all of the measurements taken.

The first results (Fig. J-1. 2) show the variation of total flow of helium and argon through the skimmer as a function of nozzle-skimmer separation. This flow was obtained by using the omegatron peak height as a measure of the background pressure of each species in the collimation chamber, and then employing a calibration between known flows and this peak height. In this manner it was possible to account for the fact that the pumping speed and ionization cross-section was different for each gas species. A theoretical prediction of the helium flow was made, based on an assumed isentropic expansion. The correlation between theory and experiment for the large nozzle-skimmer separations is not interpreted as signifying a tendency of experiment towards isentropic behaviour, as the flow is a rather insensitive function of Mach number at these large values of x/d_o. It does suggest, however, that skimmer interference is negligible beyond a separation of about 22 nozzle diameters.

Figure J-1. 2 can be used to calculate the increase in the mole fraction of argon for the flow passing through the skimmer. A ratio σ' is plotted in Fig. J-1. 3 which is the ratio of the mole percentage of argon measured in the final flow to that of the original mixture (1% - 99%). The σ' value increases with nozzle skimmer separation, attaining a value of about 4 at a distance 22 nozzle diameters away from the skimmer.

A second enricnment factor $\mathfrak{S}''$ can be obtained from the measured centreline fluxes of the argon and helium in the beam at the impact probe position (46" downstream of skimmer). $\mathfrak{S}''$ is the ratio of the mole percentage of argon as measured on the centreline of the beam at the impact probe to that of the original mixture. This parameter shows a similar variation to $\mathfrak{S}'$ with a value of about 9 at a nozzle-skimmer separation of 22.0. At the same position downstream and for the same nozzle-skimmer separation ($x/d_o \approx 22$), the centreline beam fluxes have been found to be about 5×10^{13} and 5×10^{14} molecules/cm^2sec for the argon and helium respectively.

The use of a traversing probe system in the collimation chamber, which could be operated either as an impact pressure measuring device or used to obtain the background pressure, made it possible to determine the radial distribution of molecular flux of the beam. Figure J-1.4 shows a typical radial traverse taken at an x/d_o (nozzle-skimmer separation) of 24.2. The points indicated by circles and triangles are for argon and helium respectively, in the mixed beam. The squares are for the same flow of argon as used in the mixture, but with the helium flow shut off. A marked collimation effect is illustrated for the case where the helium gas is present. Also taken (but not shown here) were radial distributions for positions up close to the skimmer. These showed a broadening effect with possible skimmer interference.

Presented in UTIAS Technical Note No. 75, but too lengthy to discuss here, is an attempt to correlate the Mach numbers obtained from an analysis of the above radial distributions with the flow Mach numbers which might be expected in the free jet expansion.

Following this work, extensive modifications to the molecular beam facility were begun and are now nearing completion. These changes were necessary for the forthcoming experimental study of the parameters affecting the expansion and skimming process used to form the high energy beam. The modifications will also facilitate use of the beam as a source of high energy particles for surface interaction experiments.

A new source chamber (see Fig. J-1.5) for the free jet expansion has been designed and constructed. The chamber is designed to produce stagnation temperatures up to 2500^{o}K and a source pressure variable from 100 torr to 2300 torr (approx. 3 atoms). The gas is heated by passing it through an ohmically heated tungsten rhenium alloy tube. The tube has machined in it the nozzle for the free jet, and has two translational and two rotational degrees of freedom which are motor driven and remotely controlled. One of the translational motions allows the distance from the nozzle to the skimmer to be varied from 0 to 11 inches while the other motions are necessary for precise alignment of the nozzle with the rest of the system.

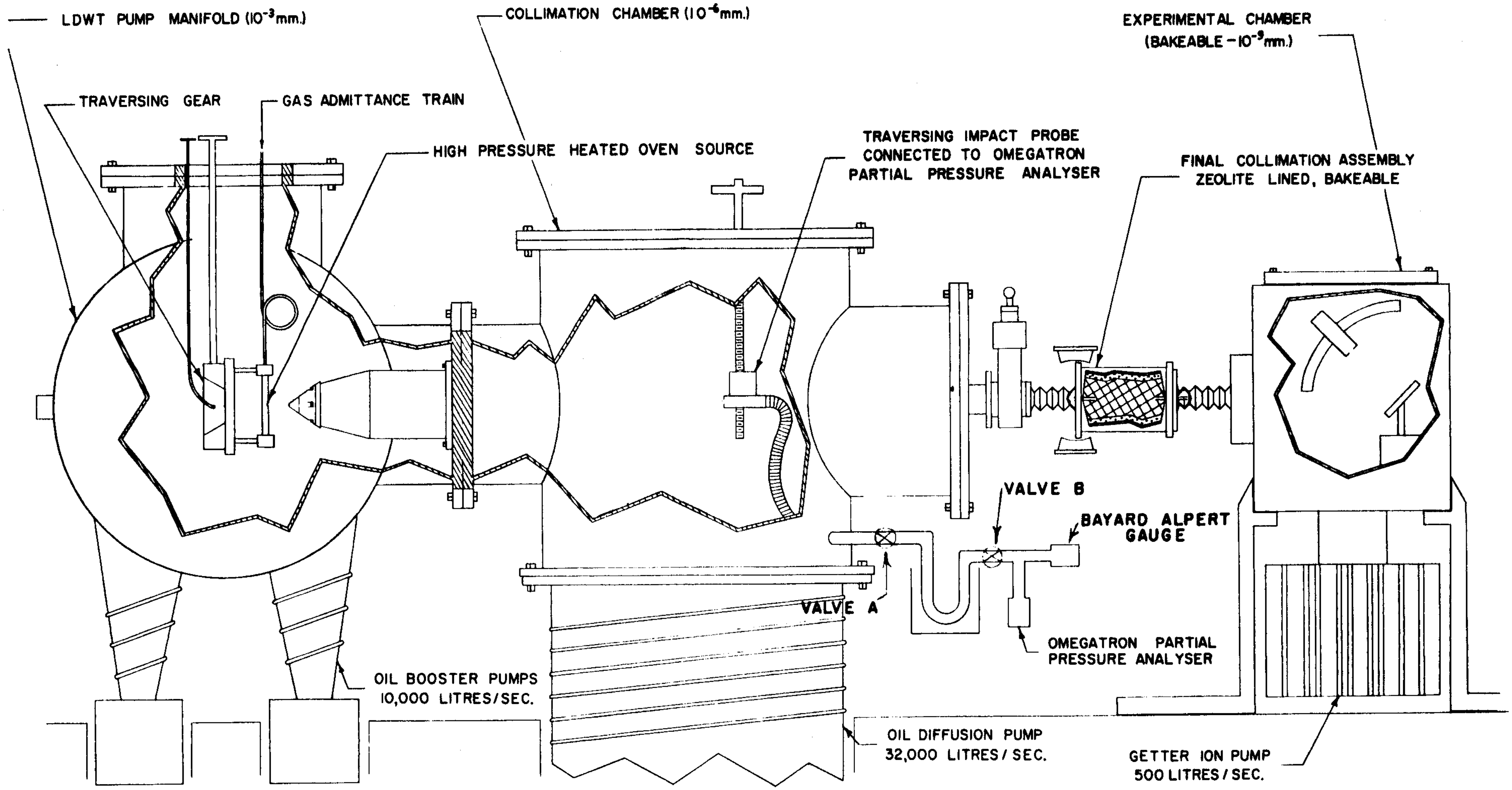
A 750 litre/sec oil diffusion pump and a mechanical vacuum pump have been installed in series with the 32, 000 litre/sec oil diffusion pump which pumps the collimation chamber. The new arrangement makes the collimation chamber pumping completely independent of the low density wind tunnel. This allows the collimation chamber to be pumped continuously with one or more of the three pumps and pump down time for experiments is minimized even if other experiments are being performed or installed in the low density tunnel. Automatic safety devices have been incorporated so that the pumping system will not be damaged by either an electric power failure or by a rupture in the vacuum chamber.

The machining of the parts for the multi-disc velocity selector is complete and the parts are shown assembled on the selector motor in Fig. J-1. 6. The final assembly (with proper alignment of the slots in the discs), balancing and mounting of the selector in the collimation chamber is now in progress. The selector has six 0. 040 in. thick aluminum discs mounted on steel hubs. Around the periphery of the discs are machined 185 radial slots 0. 020 in. wide and 0. 150 in. deep. The slots on successive discs form helical paths. The selector is placed in the molecular beam with the beam molecules impinging on the outer edge of the discs as shown in Fig. J-1. 6. With the selector being driven by the motor the helical paths will allow only molecules within a small prescribed velocity range to pass through the selector. The selector is designed to pass molecules with a directed velocity of 8000 m/sec at a rotational speed of 333 rps. The synchronous electric motor to drive the selector, a variable frequency power supply for the motor and an electric counter for measuring the rotational speed of the selector have proved satisfactory in bench tests.

Double omegatron mass spectrometer gauges (one gauge measures background flux while the other measures beam flux plus the background flux) will be used to measure the molecular flux through the velocity selector and to measure the radial spacial distribution of flux of each component of gas in the beam. The double omegatron system was a necessary improvement over the single omegatron used in previous experiments in order to obtain a signal-to-noise ratio high enough to make useful measurements of the flux passing through the velocity selector. The stainless steel probe heads (see Fig. J-1. 7) which are positioned inside the collimation chamber are connected to the glass encased omegatrons outside the collimation chamber through a matched set (same length, number of bends and angle of bends) of 1 in. O. D. stainless steel tubes. The entire system is suspended from ball bushings which run on a 1-1/2 in. D. shaft and is moved across the beam by a drive located outside the collimation chamber. The seal in the collimation chamber is maintained by welding the 1 in. O. D. tubes into the closed end of a 4-1/2 in. O. D. stainless steel pipe. The pipe slides through the wall of the collimation chamber and is sealed by an "O" ring. The probe heads may be moved completely out of the beam so that surface interaction experiments may be performed downstream of the collimation chamber. The viewing windows located on the back of each probe head and the adjustments provided in the probe head mounts allow precise alignment with the molecular beam. In its final configuration the entire gauge volume will be bakeable to 300°C.

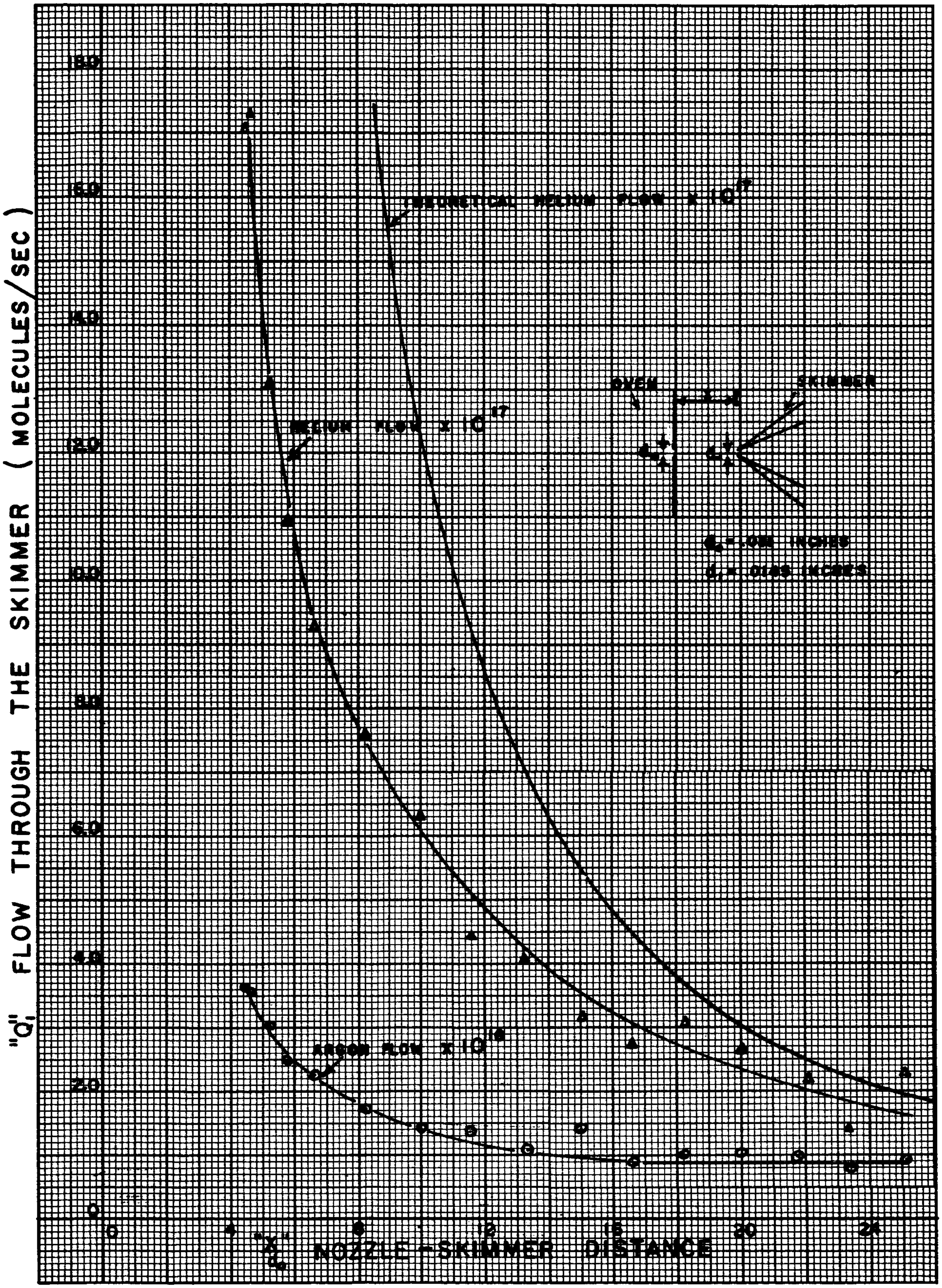
Modifications to the existing collimation chamber were necessary in order to mount the double omegatron system. The additional pipes and flanges have been built and are being welded into the collimation chamber.

Present estimates are that experiments with the beam should start again in November.



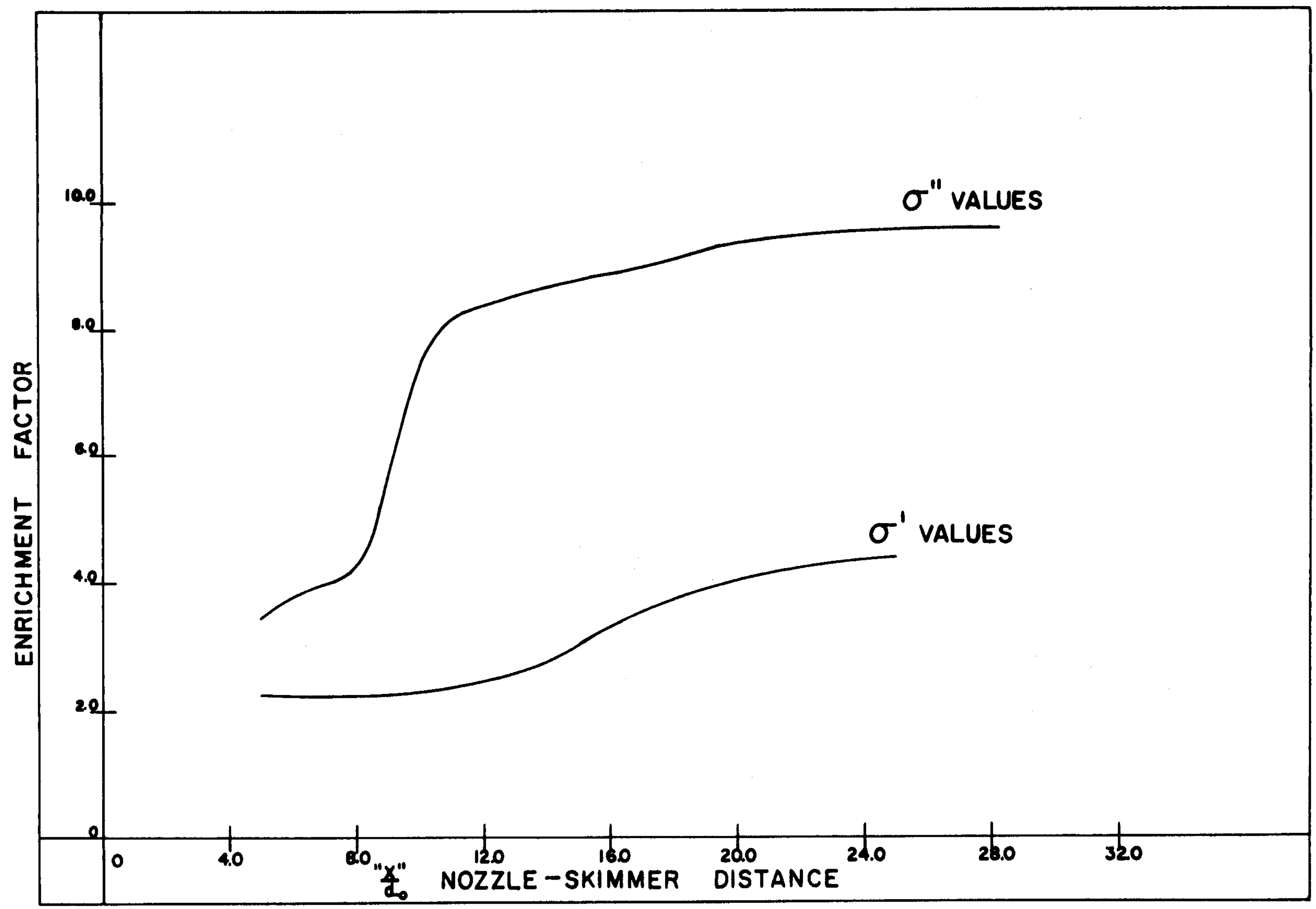
UTIA HIGH ENERGY MOLECULAR BEAM FACILITY

FIGURE J.1-1



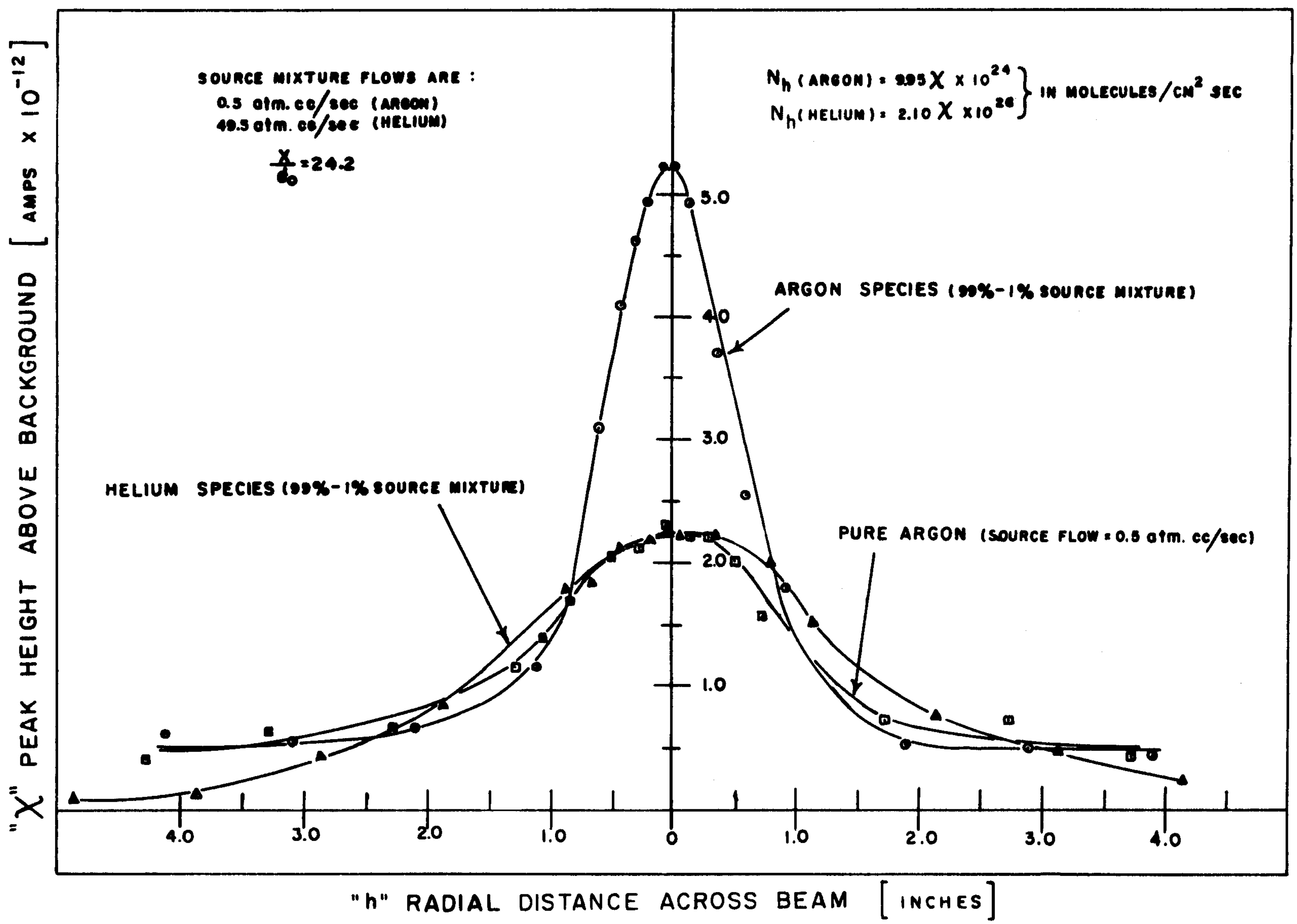
"Q_1" FLOW THROUGH THE SKIMMER (MOLECULES/SEC)
"X/d_o" NOZZLE - SKIMMER DISTANCE
THEORETICAL HELIUM FLOW x 10^{17}
HELIUM FLOW x 10^{17}
ARGON FLOW x 10^{16}
OVEN
SKIMMER
X
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
4
8
20
24

FIGURE J.1-2



σ'' VALUES
σ' VALUES
ENRICHMENT FACTOR
10.0
8.0
6.0
4.0
2.0
0
0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
"X"/d₀ NOZZLE-SKIMMER DISTANCE

FIGURE J.1-3



RADIAL FLUX DISTRIBUTION OF THE GAS SPECIES IN THE COLLIMATION CHAMBER

FIGURE J.1-4

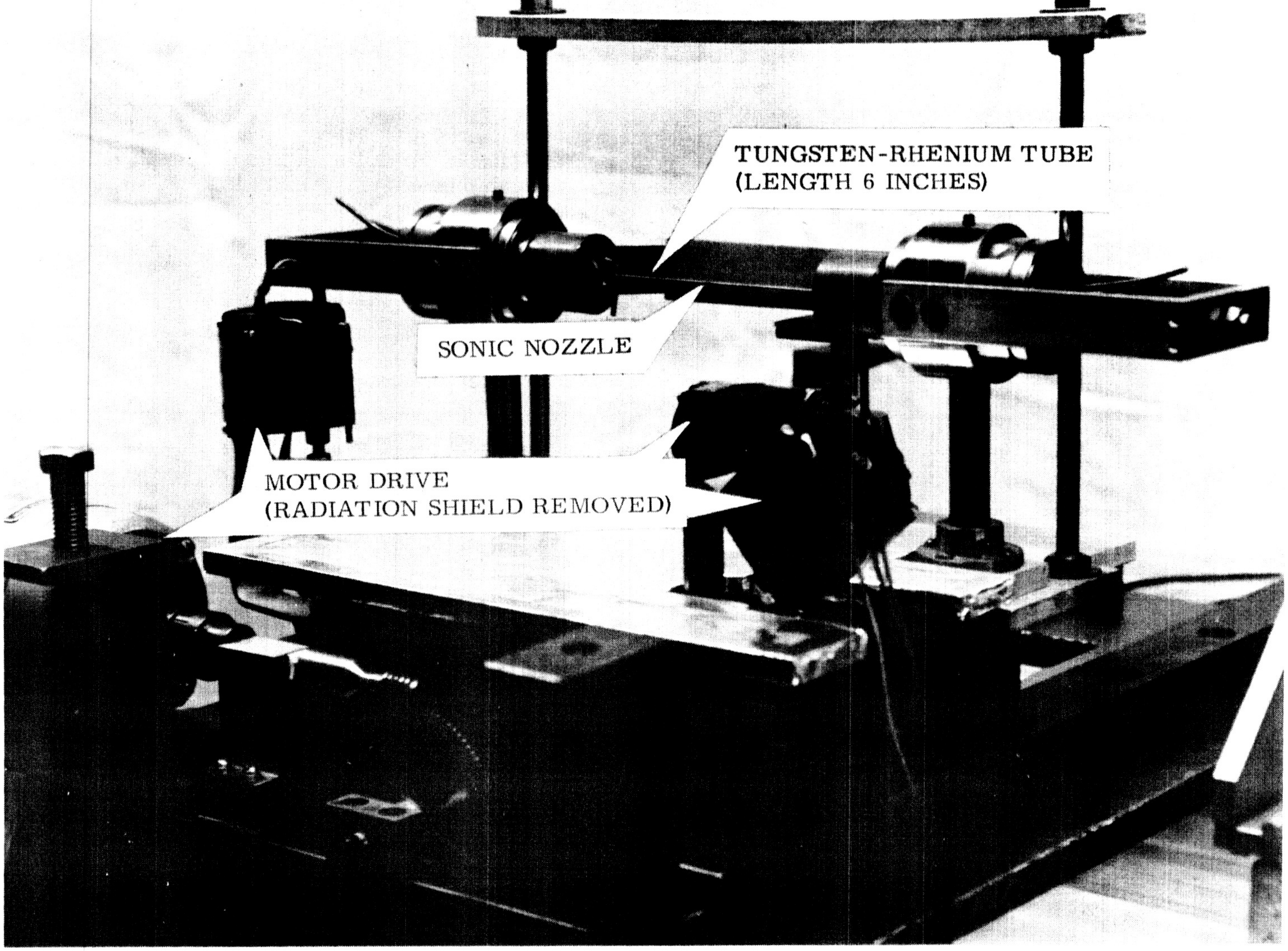


FIG. J-1.5 MOLECULAR BEAM SOURCE

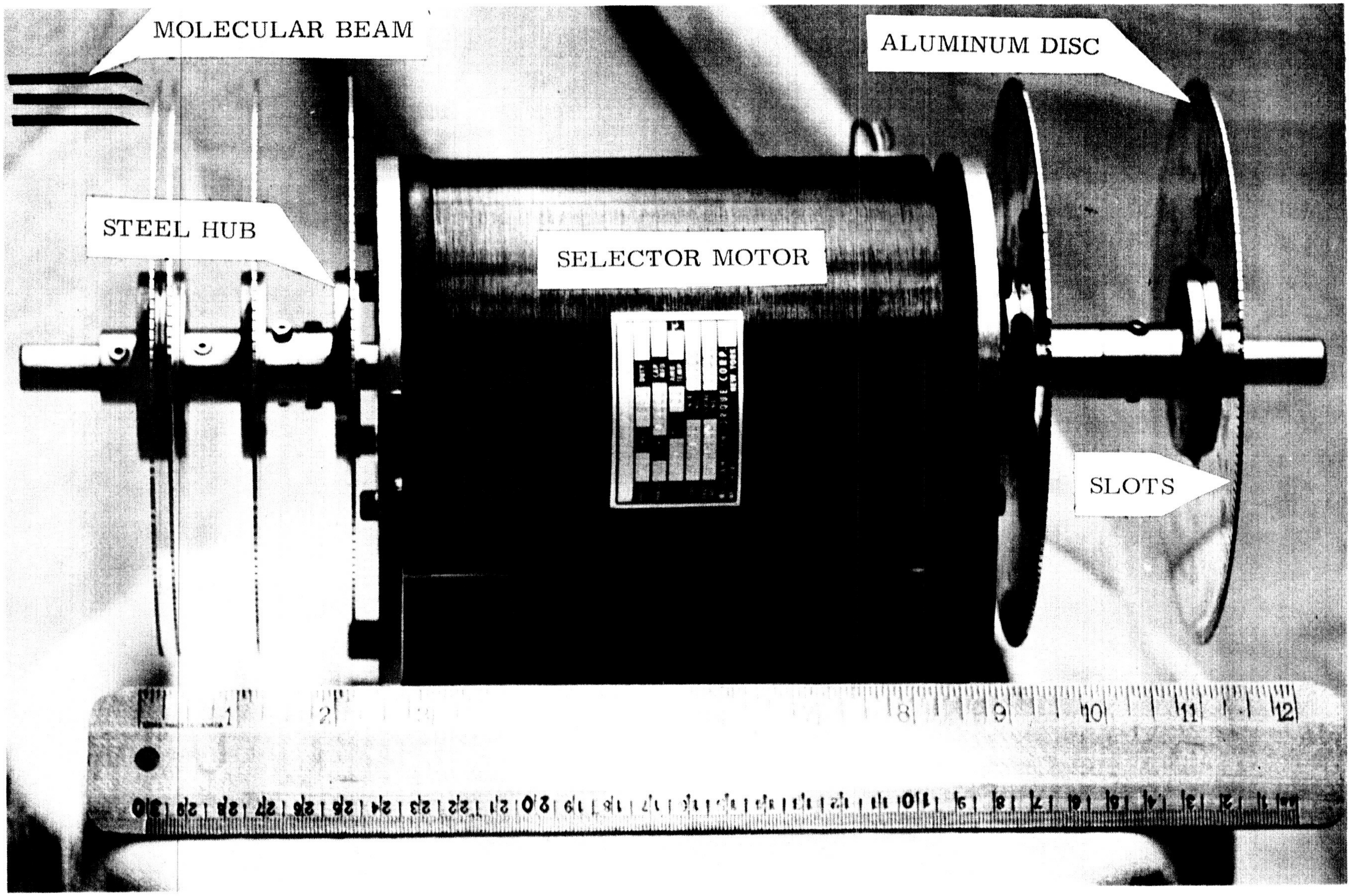


FIG. J-1.6 MULTI-DISC VELOCITY SELECTOR

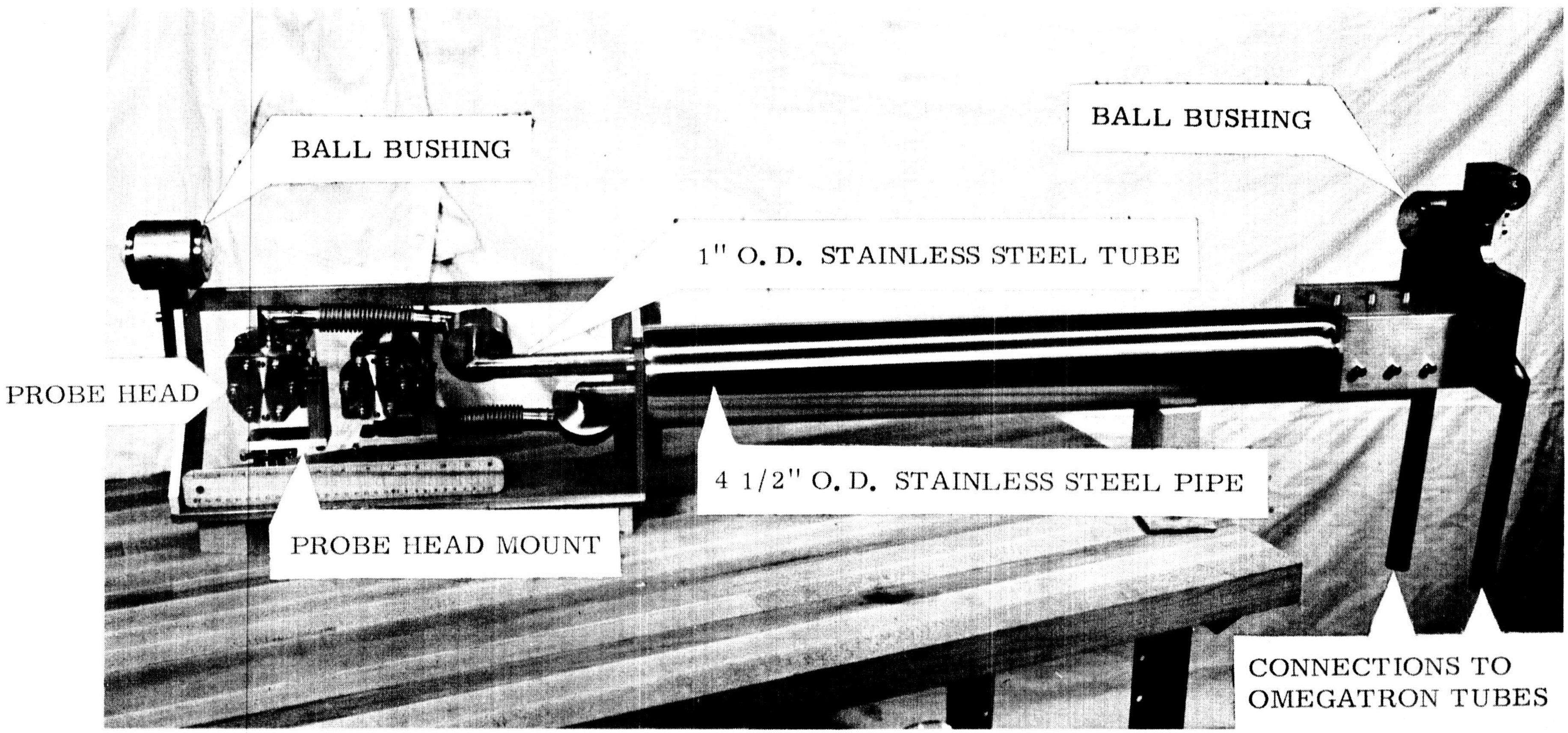


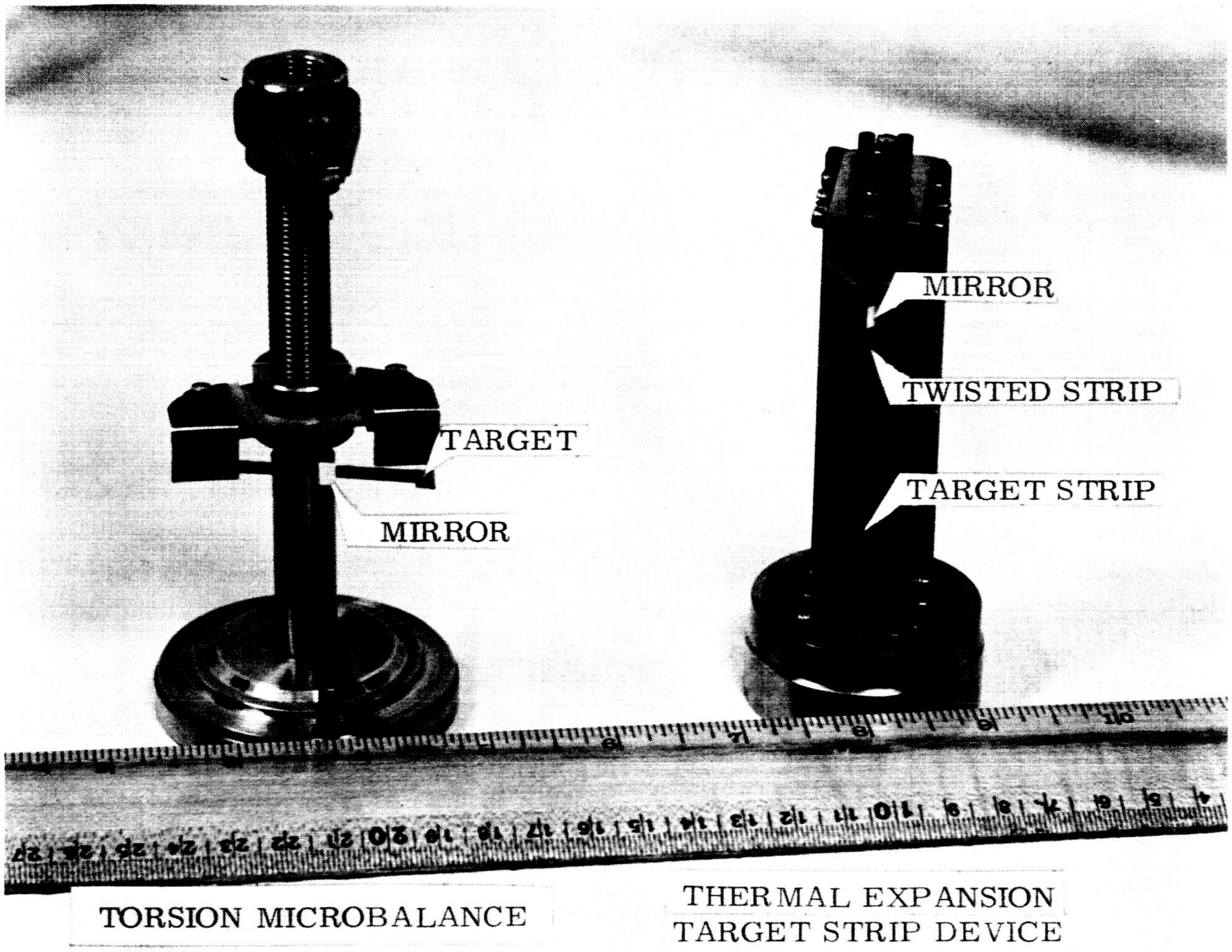
FIG. J-1.7 DOUBLE OMEGATRON GAUGE SYSTEM

J-3 OPTICAL LEVER FORCE AND ENERGY TRANSDUCER - NASA, DRB (E.J. Moskal)

The forces produced by the high energy molecular beam impinging on a test surface, will be detected by mounting this surface on a torsion microbalance. The energy input from the molecular beam incident on a thermal expansion target strip device (see Fig. J-3.1) will give a linear expansion which is converted into the rotation of a mirror. The angular deflections produced by both the above systems (of the order of micro-radians) will be measured by the optical lever (see Fig. J-3.2). The past year has been spent in dealing with the techniques of construction of the lever components, associated electrical circuitry, suspension systems and vibration isolation mounting.

The vibration isolation platform has been completed, and a temporary glass vacuum chamber has been mounted and put into operation for preliminary testing of lever performance. A full investigation of the amount of vibration isolation has not yet been made, but it is known by experiment that less than 10% of the input vibration reaches the test platform. The most severe source of vibration is due to nearby vacuum pumps which operate at 6 c.p.s. Using a 75 litre/sec getter-ion pump, a pressure of 5×10^{-7} mm Hg. has been achieved in the glass cross with a volume of approximately 175 litres.

Final calibration of the optical lever is now in progress. A calibration system has been designed and constructed which will give direct rotation of a mirror in the 10^{-6} to 10^{-8} radian range. A sensitivity of 10^{-7} radians/μv has been achieved with the optical lever. Using the calibration system mentioned above, a noise level of 4 μv was observed when the optical lever was mounted in the open air on the vibration isolation platform. This noise level is due to convection current effects, and will be reduced when the lever is mounted in vacuum. With a torsion balance having a constant of 0.3 dynes per radian, sensitivity on the order of 3 x 10^{-8} dynes/μv can be realized. This work will be reported in UTIAS Technical Note No. 81 now in preparation.



TARGET
MIRROR
MIRROR
TWISTED STRIP
TARGET STRIP
TORSION MICROBALANCE
THERMAL EXPANSION
TARGET STRIP DEVICE

FIG. J-3.1

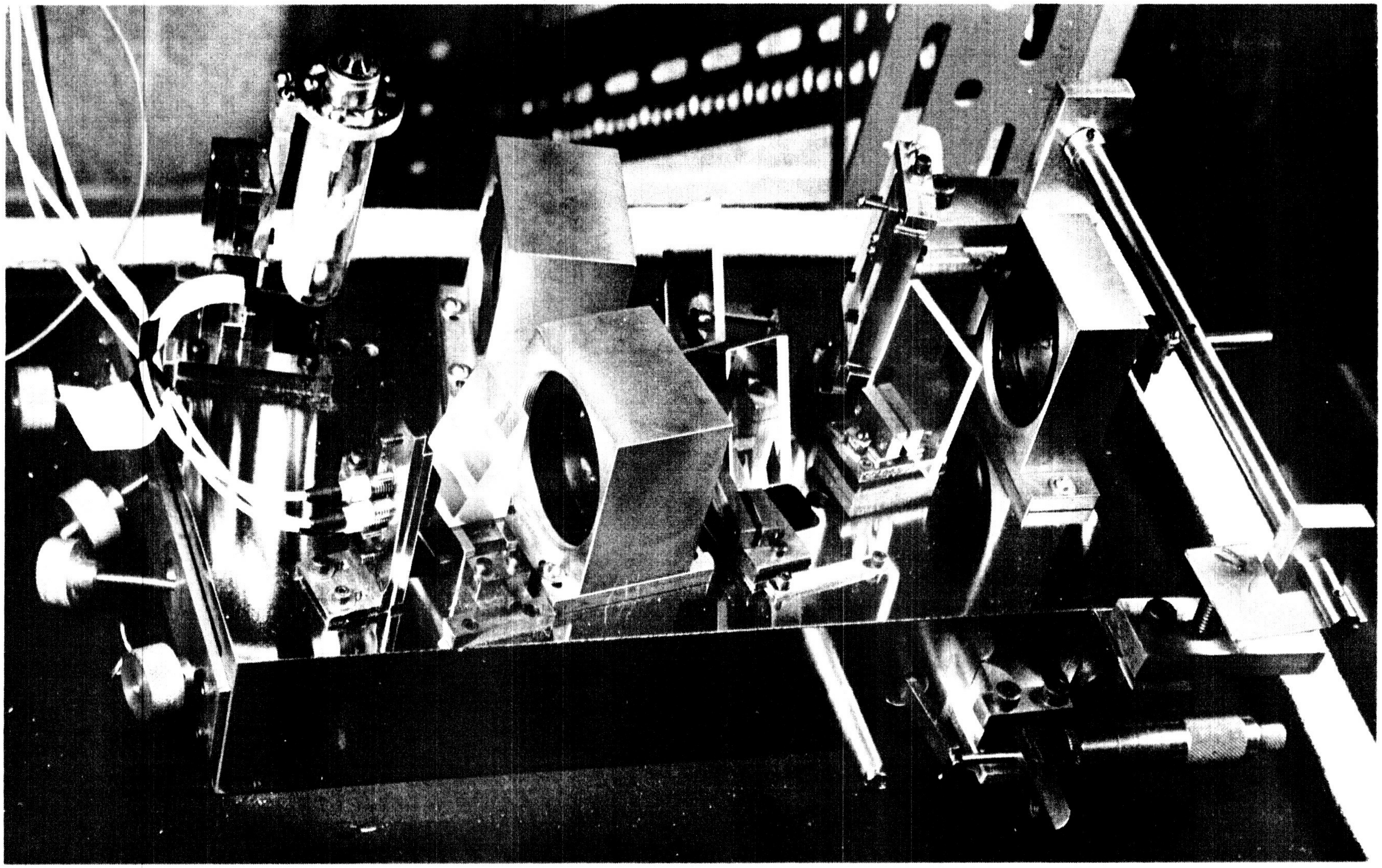


FIG. J-3.2 OPTICAL LEVER ASSEMBLY