16-FOOT TRANSONIC TUNNEL LASER

VELOCIMETER SYSTEM

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16-FOOT TUNNEL FACILITY

The Langley 16-Foot Transonic Tunnel was originally constructed in 1941 for engine cooling and cowling investigations. The most recent modifications permit operation from Mach 0.2 to 1.3. The tunnel is a single return atmospheric tunnel with slotted test section (figure 1). The test section is vented to the surrounding 9.75 m diameter plenum through slots at the corners of the octagon. The static pressure in the plenum drops from 1 atmosphere at low speeds to 0.36 atmospheres at Mach 1.3 plenum. Temperature can vary from -17°C, in winter, to a maximum of 77°C in summer.

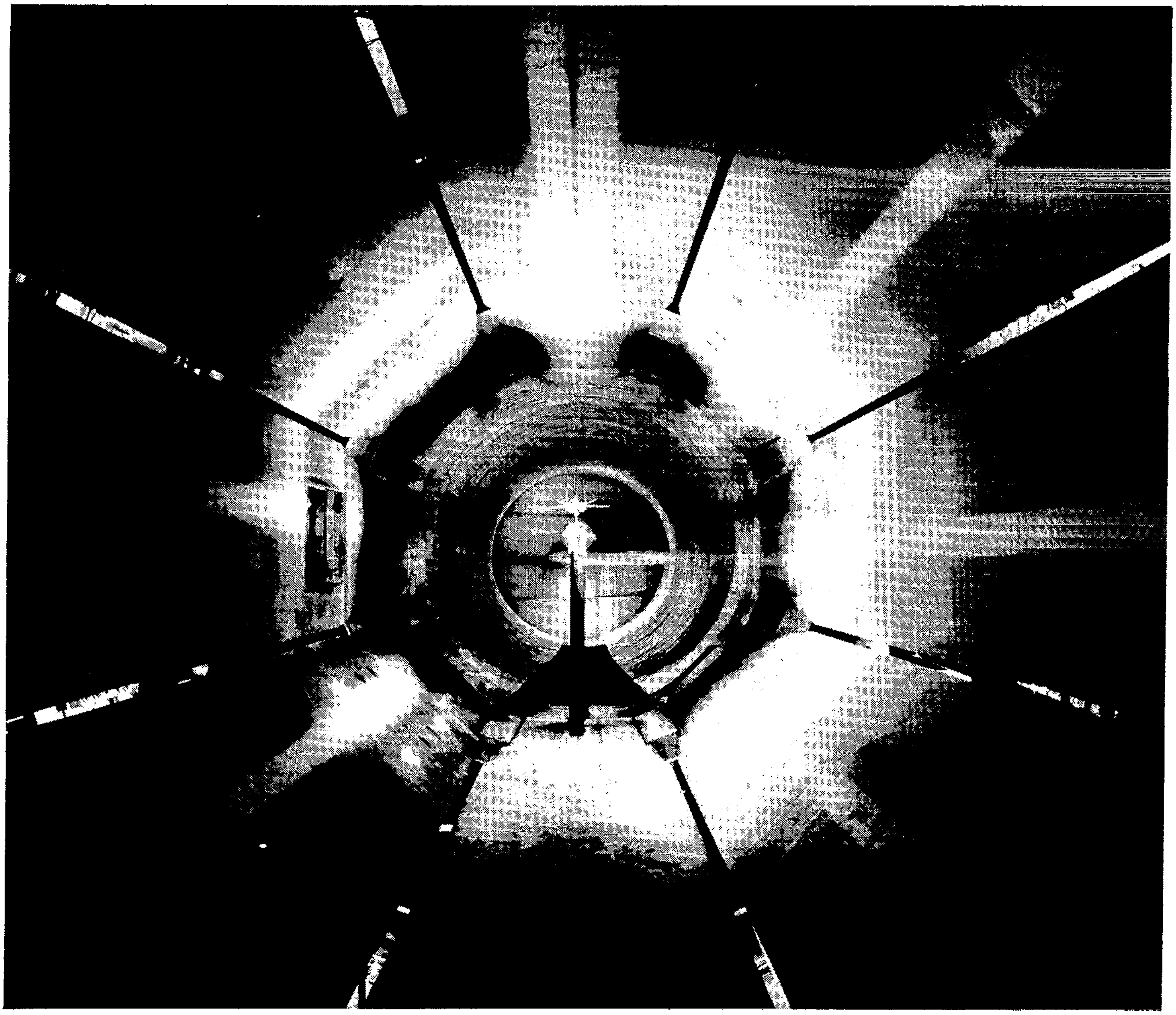

Figure 1

SYSTEM CONFIGURATION

To minimize the separation between the flow and the laser velocimeter, and avoid the losses and cost of a second window, the velocimeter is mounted in the plenum chamber. Figure 2 is an artist's rendition of the installed system. The outer frame is fixed; the next inner frame assembly is driven vertically with stepper motors and jack screws. The innermost frame is translated parallel to the tunnel axis by stepper motors and jack screws. Translation of the sample volume across the tunnel is accomplished with zoom optics.

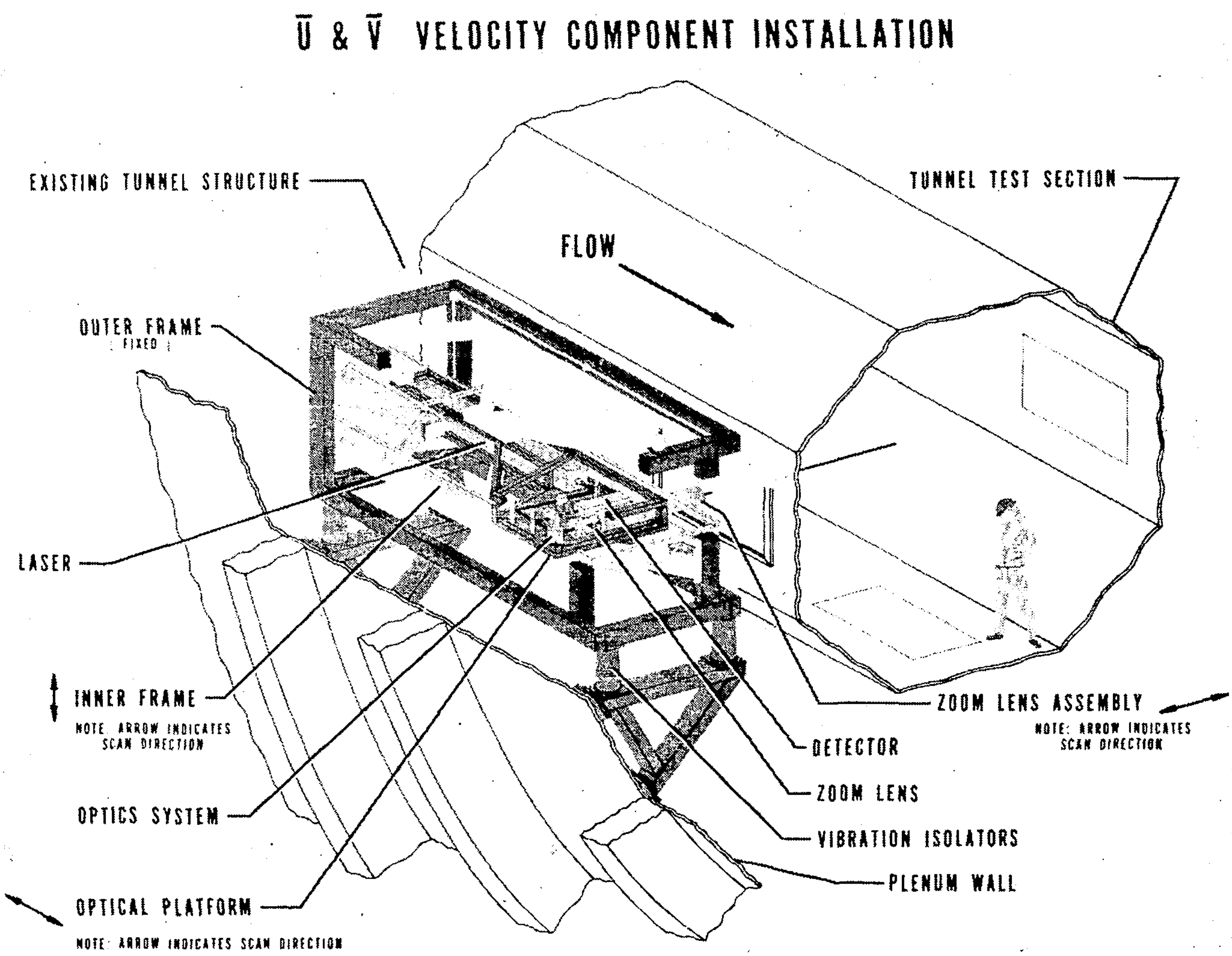

Figure 2

OPTICAL LAYOUT

A schematic of the optical components of the laser velocimeter is shown in figure 3. The system is a two color, two component, Bragg cell, coaxial, backscatter configuration. A 12 watt argon ion laser is used to supply approximately 2.5 watts on 488 nm and 514.5 nm. The polychromatic output is separated into discreet wavelength beams and the 488 nm and 514.5 nm beams are selected and used to form a two by two matrix of beams. Two 514.5 nm beams form the vertical component system and two 488 nm beams form the u or horizontal component system. The matrix of beams passes through the pierced mirror and is focussed into the tunnel by the scanning optics. The final objective has a clear aperture of 250 nm.

The same scanning optics are used to collect the light scattered by smoke particles passing through the sample volume. The collected radiation is relayed, by mirrors, back to the receiver where extraneous light is rejected with a pinhole. The remaining optical signal is separated with a dichroic beamsplitter to isolate the 488 nm and 514.5 nm radiation. Separate photomultiplier tubes are used to detect each wavelength.

A photograph of the assembled optics is shown in figure 4.

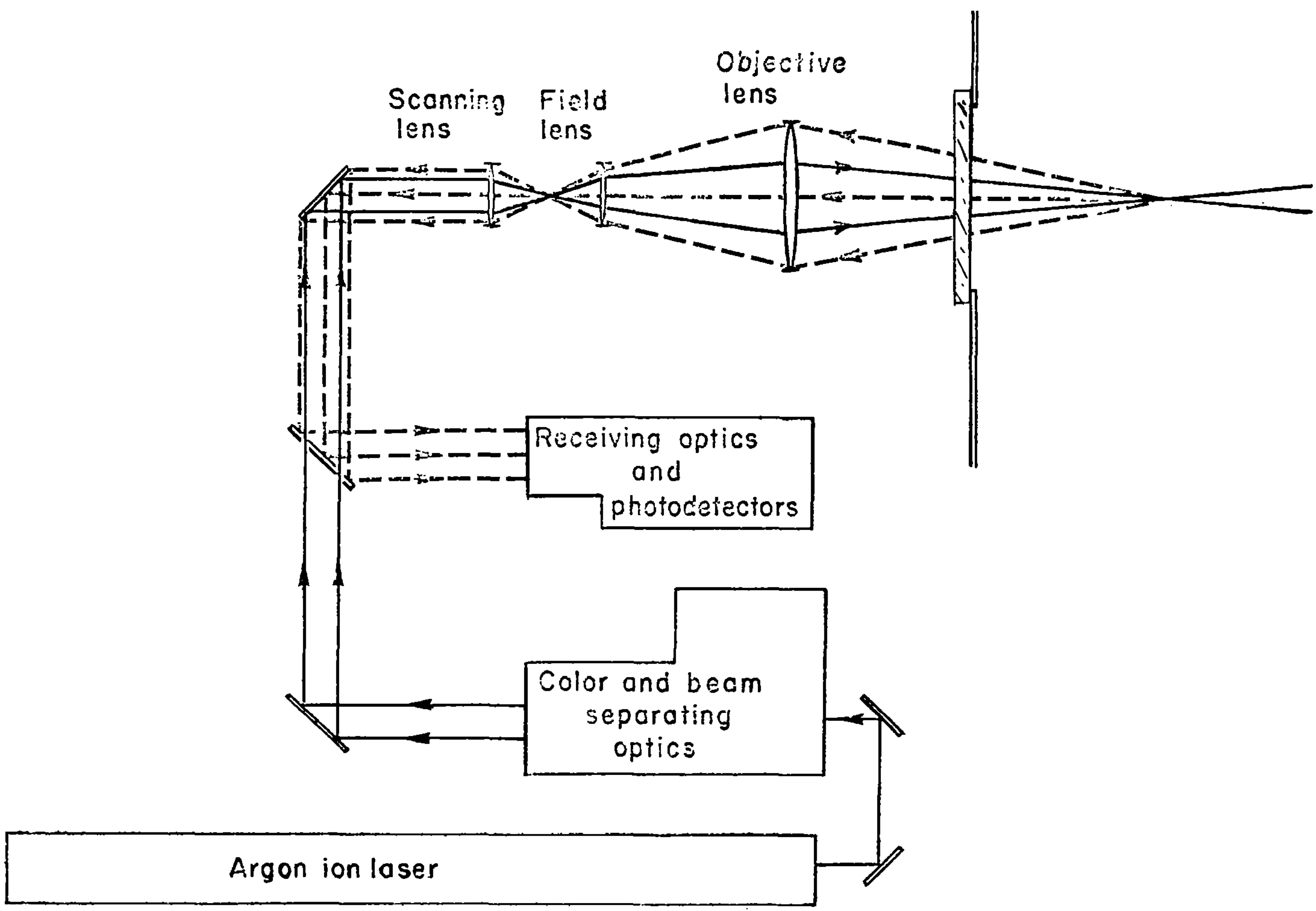

Figure 3

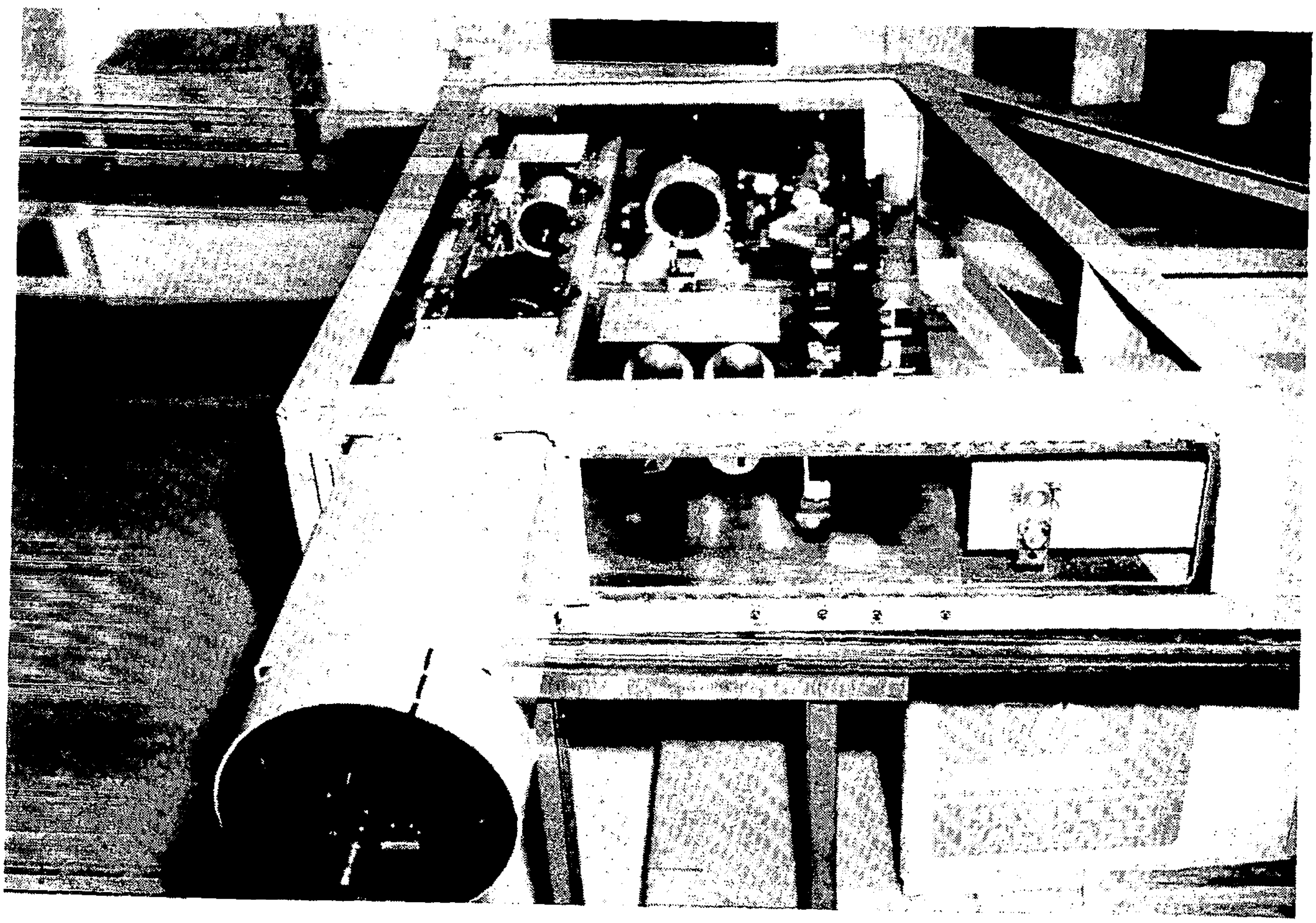

Figure 4.- Assembled optical system.

LASER COLOR SEPARATOR

The color separator is unique to this instrument. It produces parallel monochromatic beams from a multiwavelength laser. The beam to beam separation is easily adjusted and alinement is simple. The optical layout of the separator is depicted in figure 5. The incident beam is dispersed according to wavelength by the two 60^{o} prisms. The dispersed beams are returned parallel to themselves by action of the Porro prism retroreflector. By reciprocity of the dispersing prisms, the beams then exit the color separator parallel to each other and to the incident beam. The beam to beam separation is easily varied by moving the retroreflector closer or farther from the dispersion prisms. Unwanted wavelengths are removed with a simple mask.

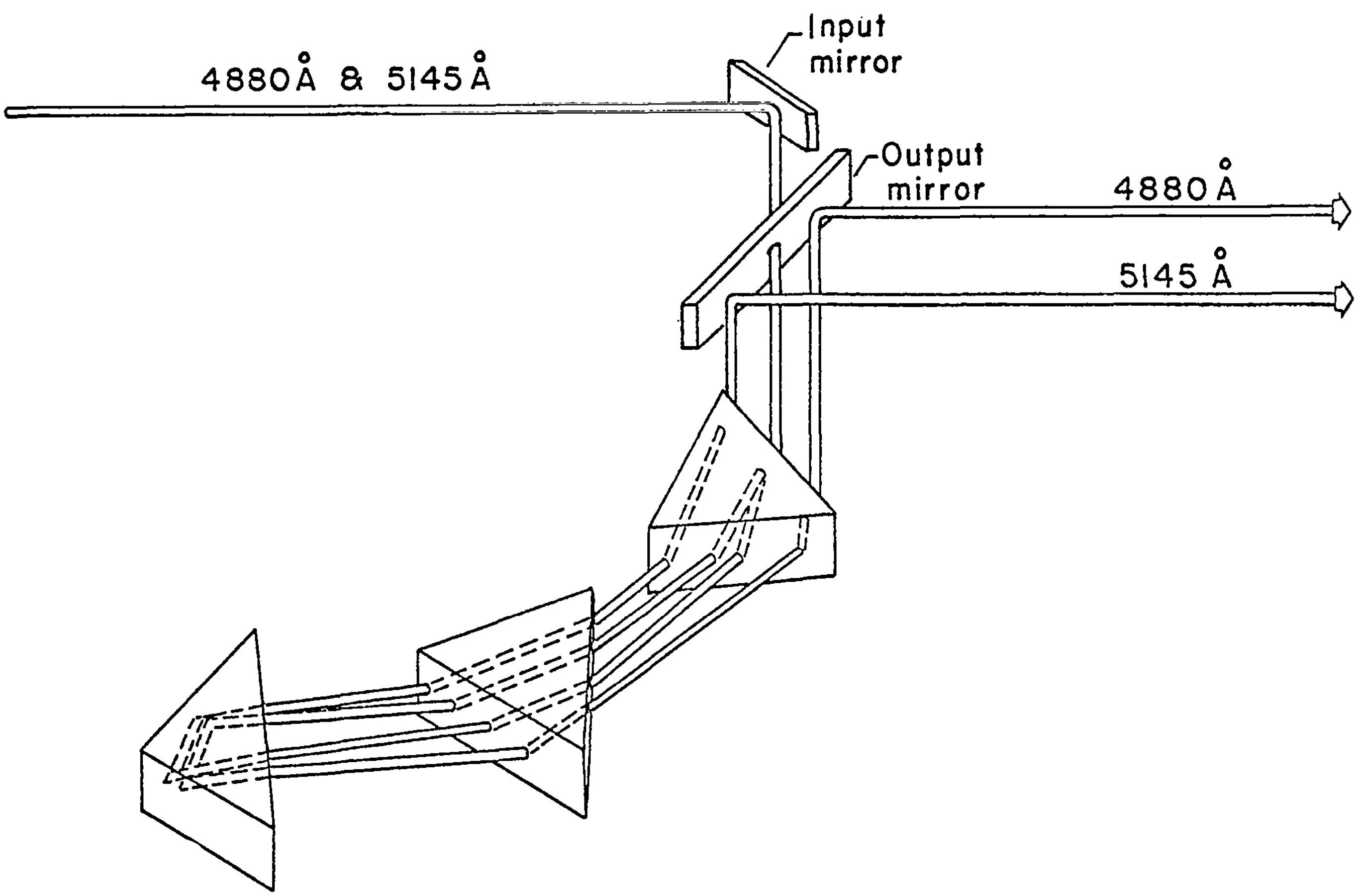

Figure 5

OPTICAL RECEIVER

The optical receiver (figure 6) consists of the input lens, spatial filter, recollimating lens, dichroic beamsplitter, line filters and photomultiplier tubes. The input lens accepts the collimated scattered light from the scanning lenses and focusses it down on the spatial filter. The spatial filter is used to reject stray scattered light and background tunnel lighting. The light is then recollimated with a 10X microscope objective. The dichroic beamsplitter passes the 514.5 nm light and reflects the 488 nm light. Line filters are used to further reduce crosstalk between channels.

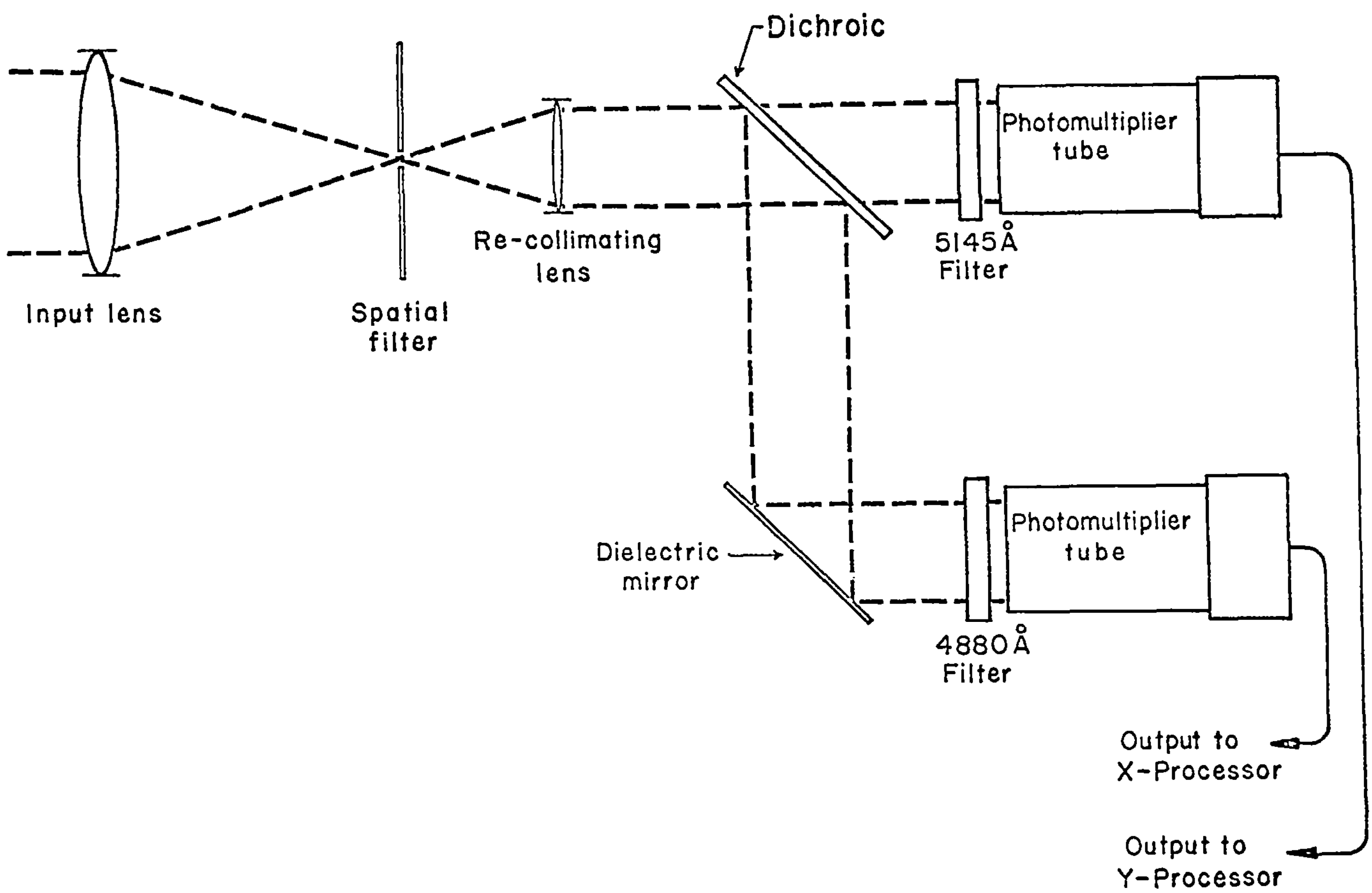

Figure 6

TUNNEL WINDOW

A major optical component that is not normally considered to be a part of the laser velocimeter but which can heavily impact the cost and construction time is the window. The window mounted in the 16-foot tunnel flat measures .965 m by 1.32 m and is 63.5 mm thick. The time between the original order date and delivery (figure 7) was four years. The cost was in excess of $80,000. The window is mounted in a frame (figure 8) which in turn is mounted behind the tunnel flat. The window is covered by a wooden panel when technicians are working in the test section. Future plans include making a storage vault and steel blank to store and replace the window during periods when the instrument is not being used.

Figure 7

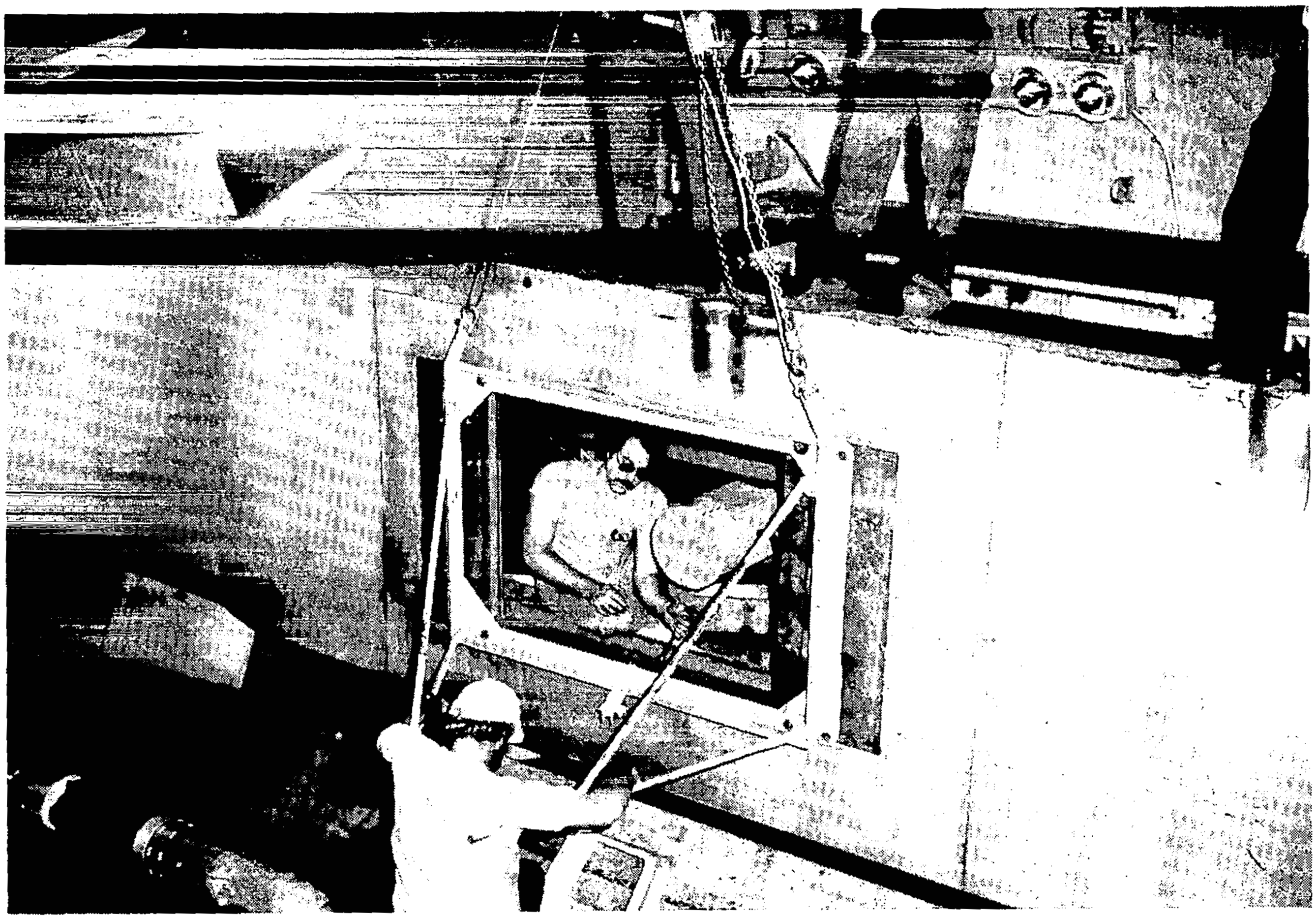

Figure 8.- Installation of tunnel window.

SEEDING GENERATORS

The seeding generators, designed by W. V. Feller, are of the shearing jet design. Operation of the generator is controlled by controlling the high pressure air supply. Figure 9 shows two generators installed on a five generator manifold. This arrangement was mounted on the turning vanes of the tunnel upstream from the test section (figure 10). The final system will employ a matrix of generators with electric solenoid air valves on each. The generators can then be independently turned on or off according to the sample volume position. The fluid used is kerosene, which produces a nominal 1-1.5 micron droplet.

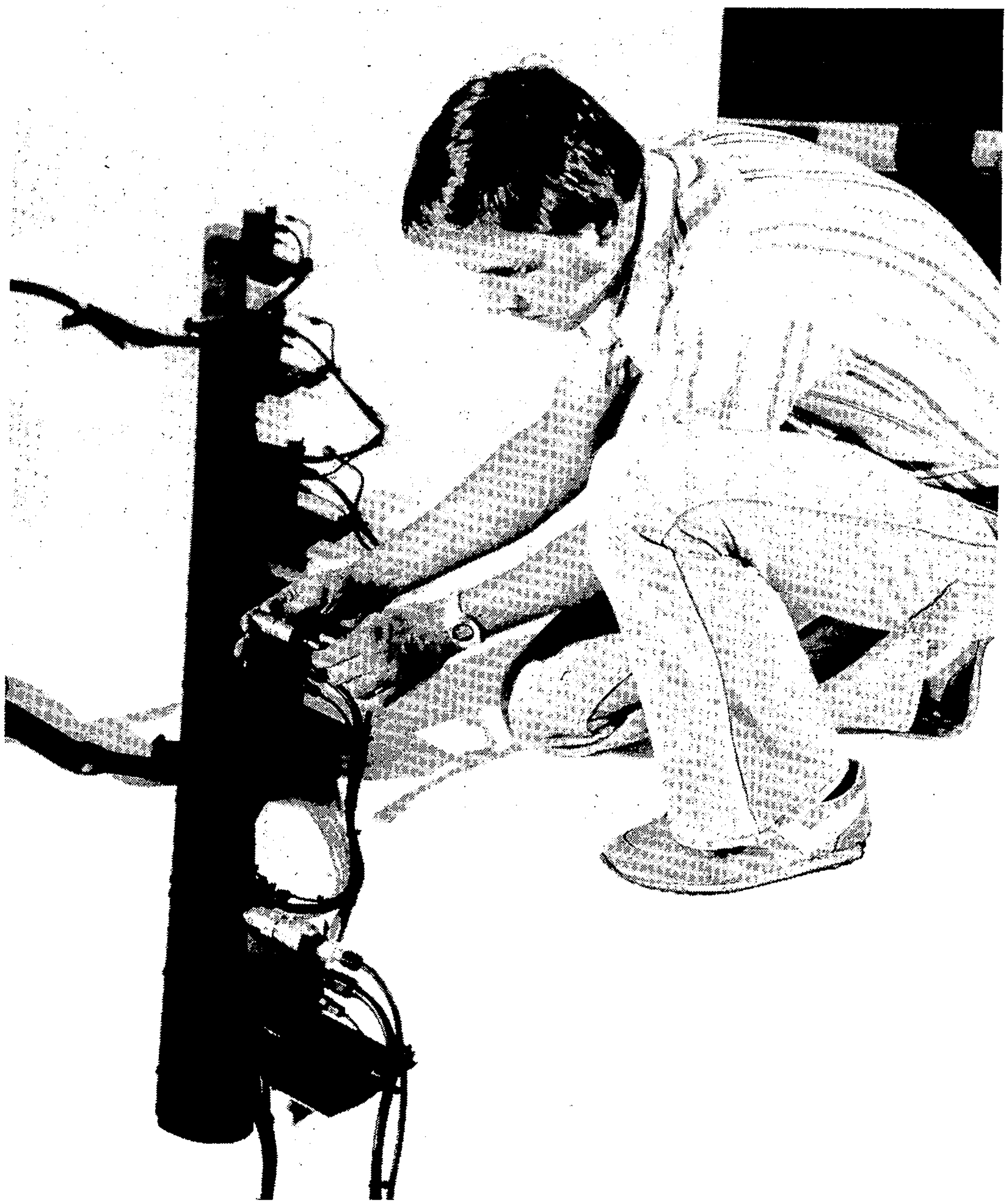

Figure 9

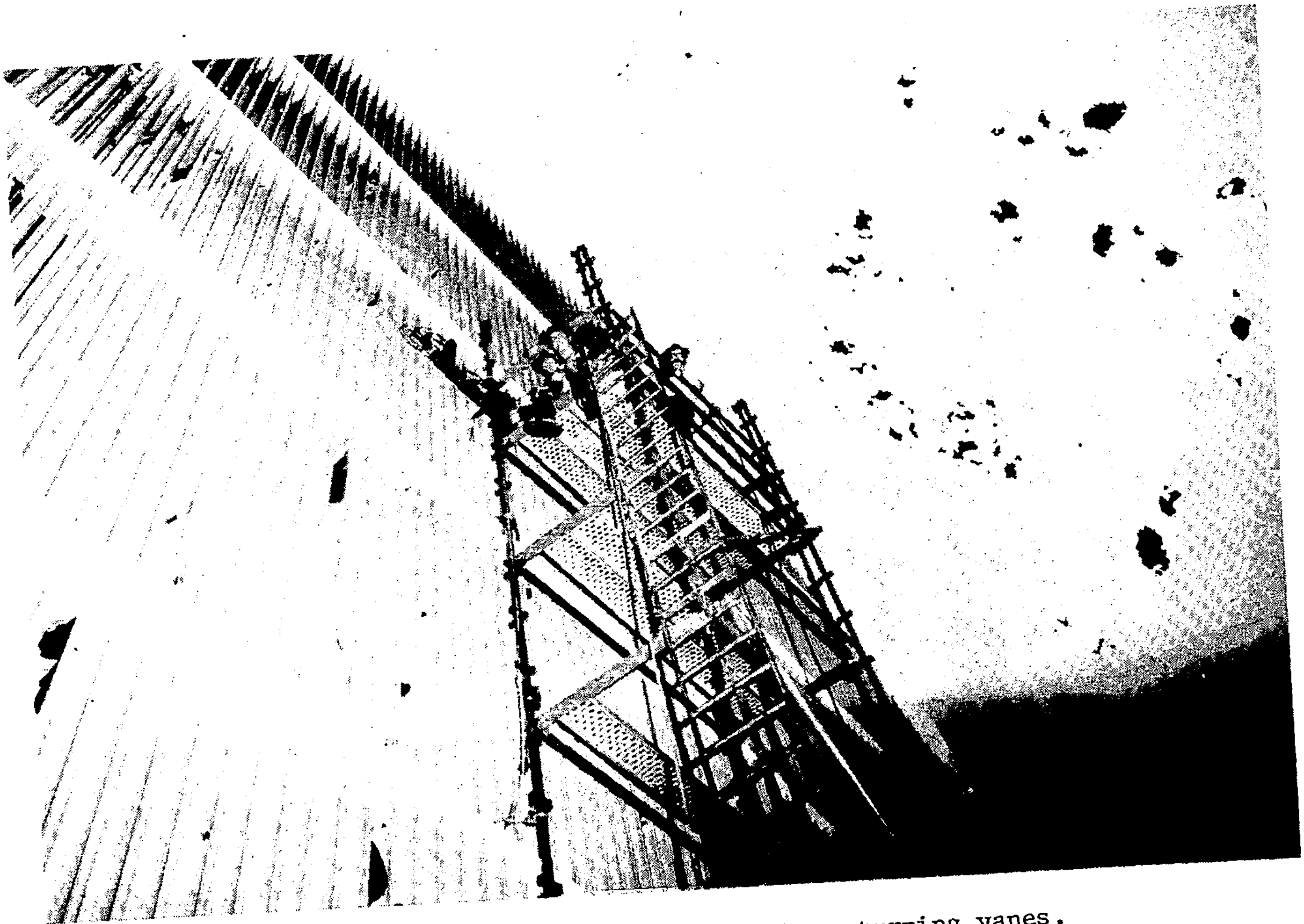

Figure 10.- Installation of bank on turning vanes.

CONDENSATION

A problem with atmospheric tunnels with air exchange is condensation. Tunnel runs made during periods of high ambient dewpoint will result in water vapor condensation in the test section air flow. The probability of fog formation increases with humidity and tunnel Mach number. The condensation occurs first in the annular layer of air adjacent to the test section wall (figure 11). At higher Mach numbers the condensation can occur throughout the test section (figure 12). Presence of large amounts of condensation inhibits operation of the laser velocimeter. By limiting the air exchange, and thereby heating the flow, the condensation can be minimized but not entirely eliminated.

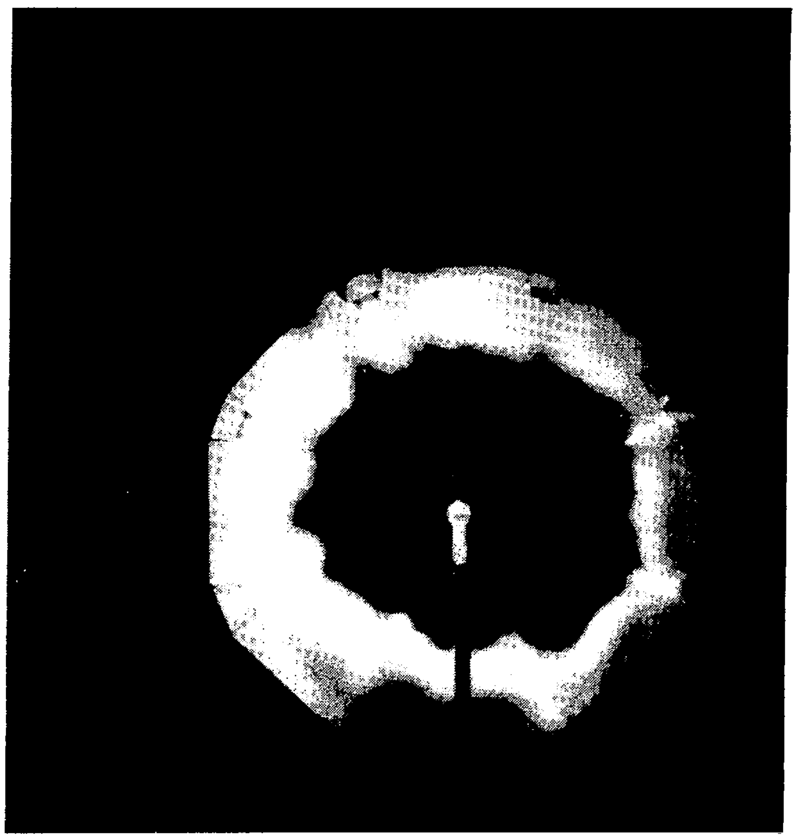

Figure 11

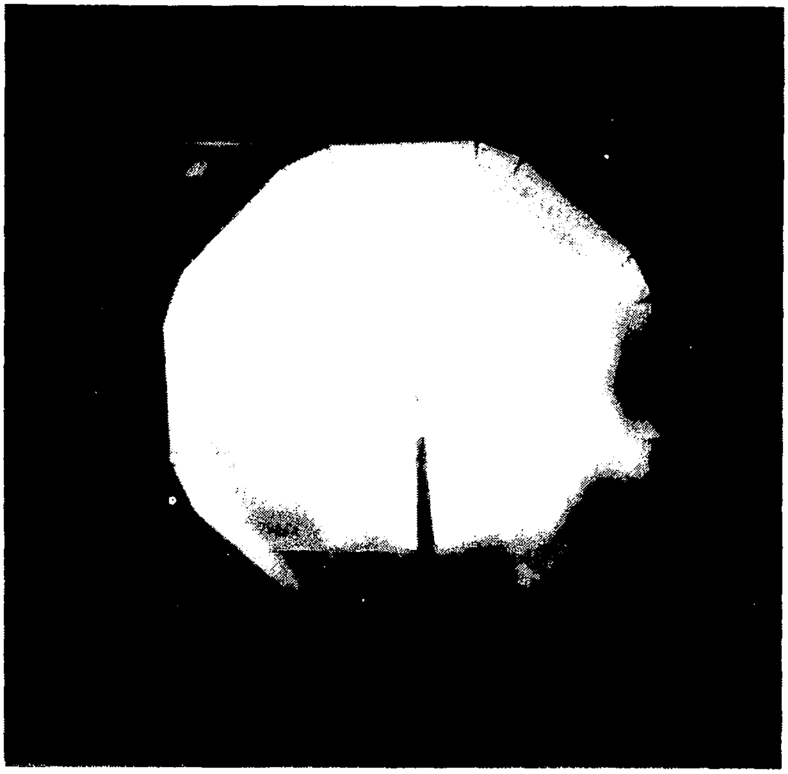

Figure 12.- Condensation at high speeds/humidity.

VIBRATION

The final problem to be discussed is a dominant problem with installation of sensitive optics in any tunnel of this large a scale. The problem is vibration. After the scan rig and optical components had been installed, accelerometer measurements were made on the support frame, optics bed, and laser enclosure. A pneumatic vibration isolator had been installed to support each of the four corners of the scan rig. Accelerometer measurements as a function of Mach number indicate vibration levels were either insignificantly affected by the isolators or in some cases increased (figure 13). The isolators were left in place but are not operational and will eventually be removed. The ineffectiveness of the isolators indicates that the major source of vibration coupling is acoustical. The influence of vibration on the optical components was reduced by mounting all but one of the components on a common plate with short stiff mounts.

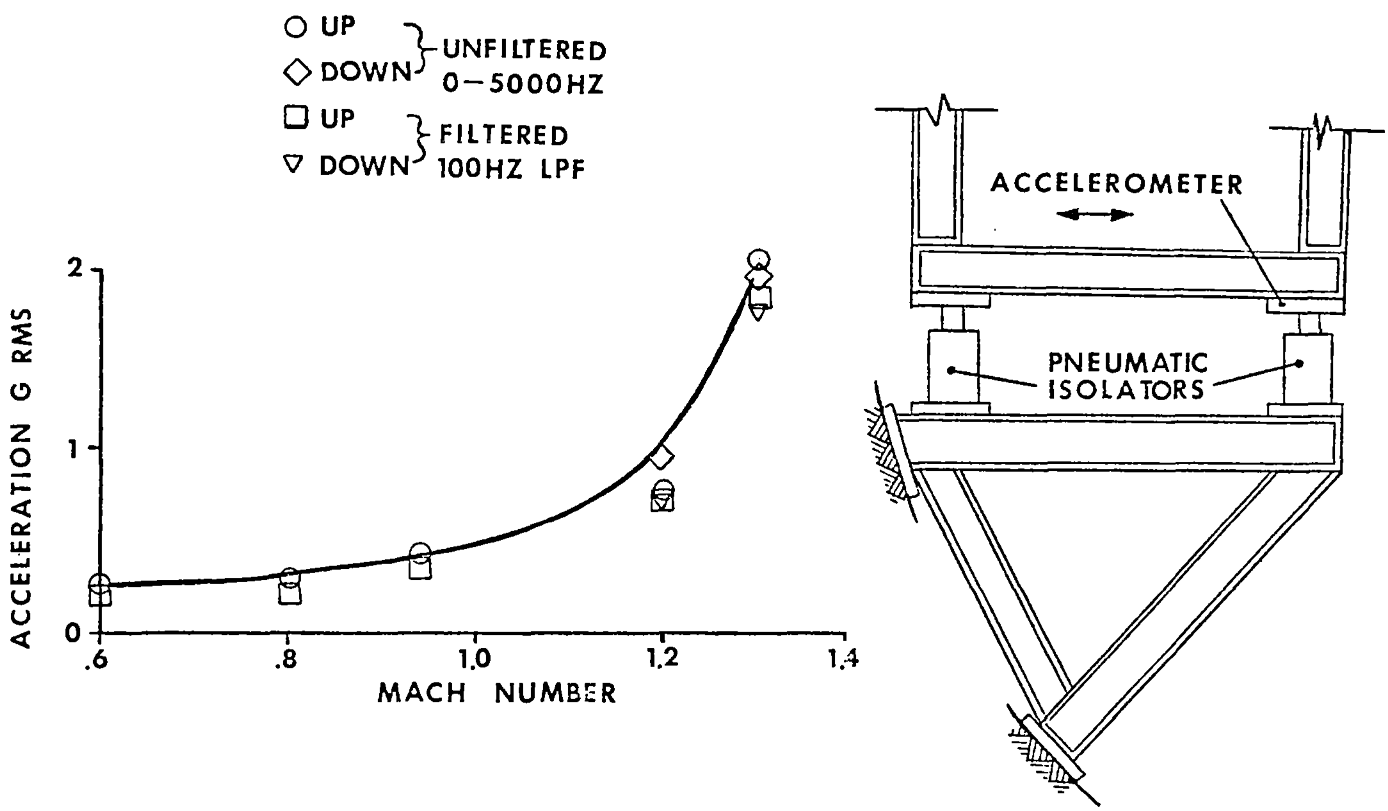

Figure 13

INITIAL RESULTS

A shakedown test was made to check out the instrument and identify areas requiring further work. A simple cone-cylinder-boattail model was mounted at zero angle of attack (figure 14). A limited survey was made above the model. Measurements were made with only the 488 nm u-component channel. Lasing on the 514.5 nm line would cease when the tunnel was operative and return when the tunnel was stopped. This problem is still being investigated. The results from the u-component channel are very encouraging. Figure 15 is a velocity profile measured above the model compared with a profile by William B. Compton, III done in 1975 with a strain gauge pressure transducer rake. The lowest sample volume location was acquired with the beams passing only 0.4 nm above the model.

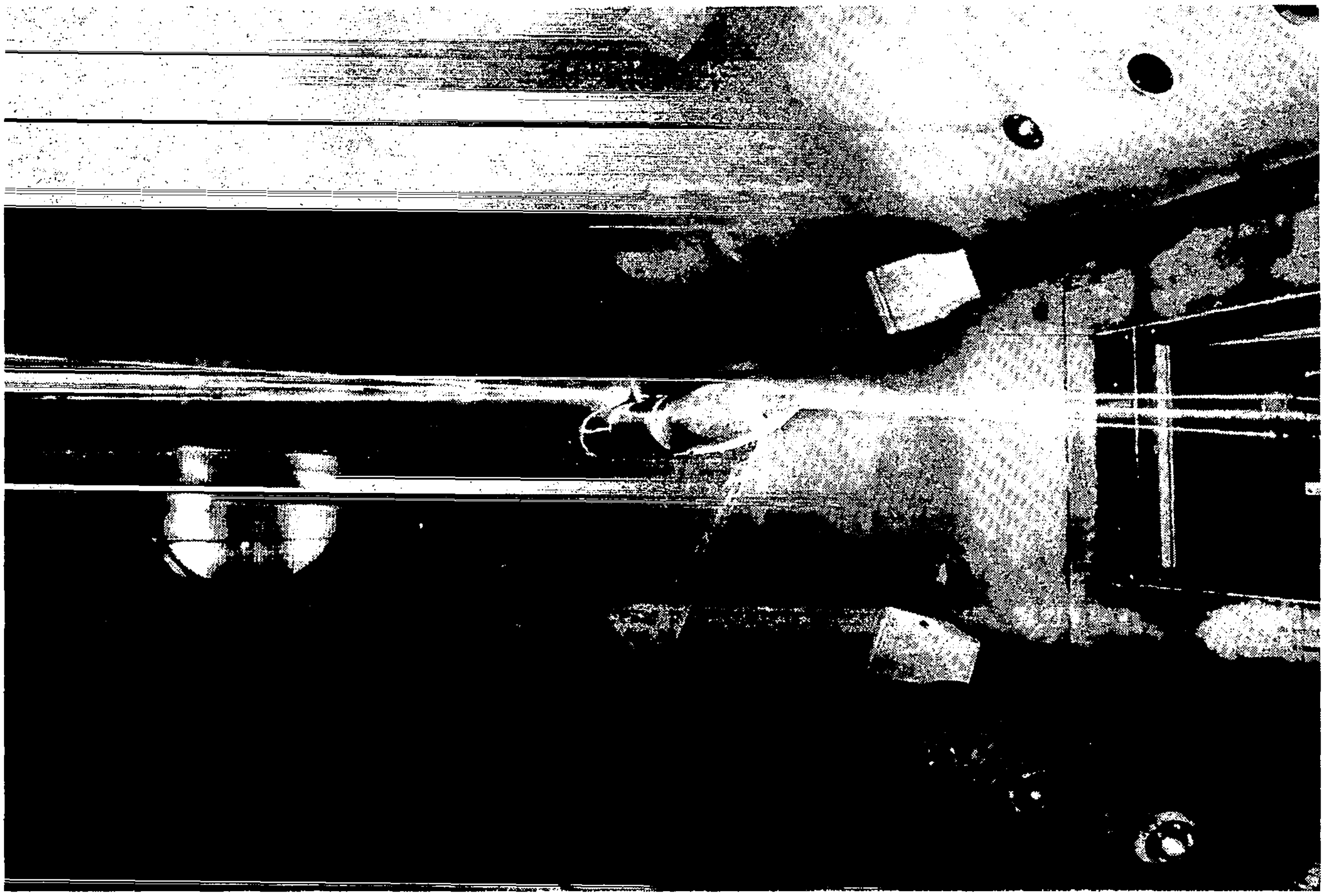

Figure 14

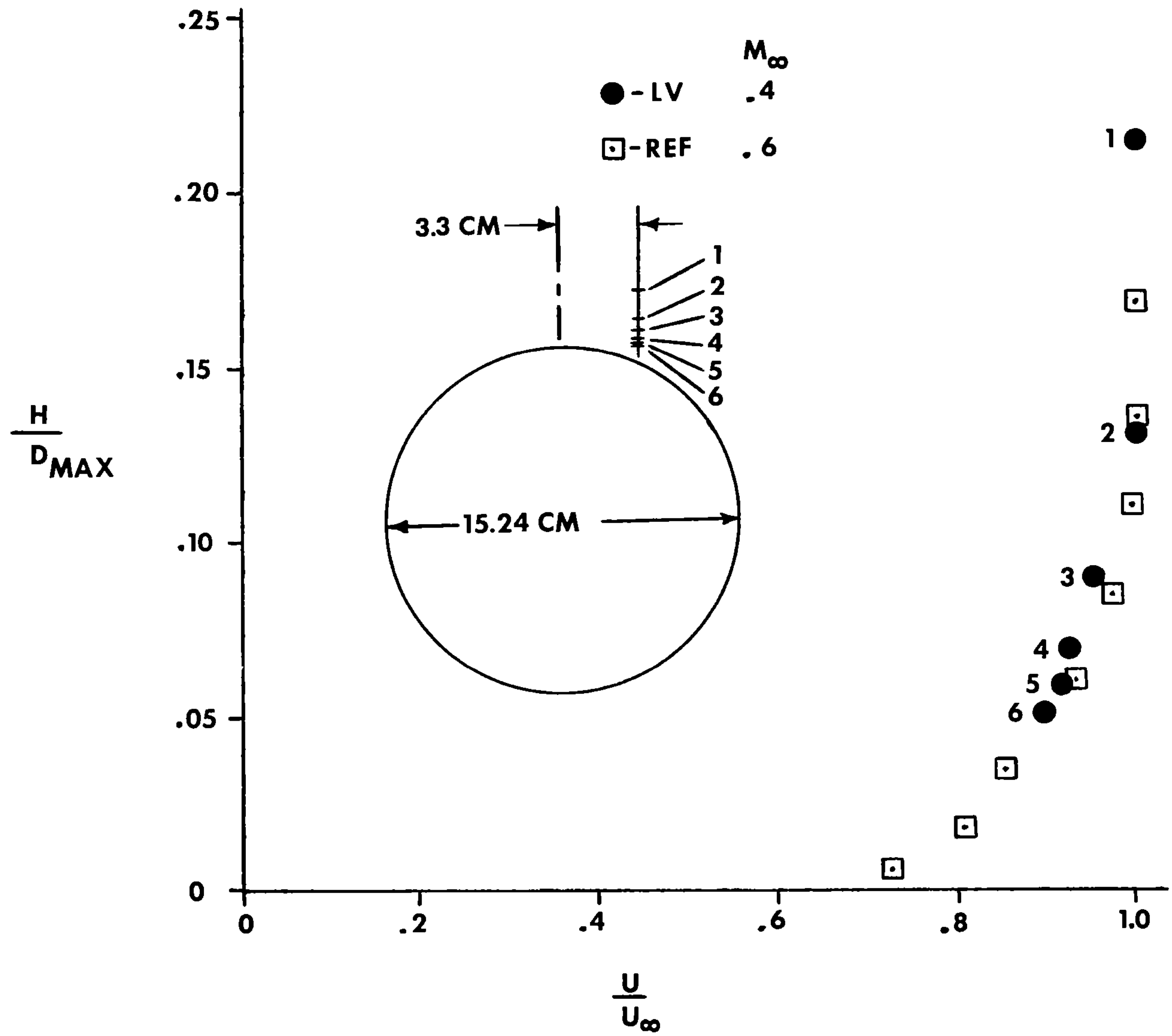

Figure 15.- Test results of vertical profile scan.