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WIND INSTRUMENTATION RESEARCH FACILITY

AT WHITE SANDS MISSILE RANGE

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WHITE SANDS MISSILE RANGE
NEW MEXICO**

ABSTRACT

The Wind Instrument Research Facility, a closed-circuit type of wind tunnel, has been installed recently at White Sands Missile Range. It is utilized for calibration of and research work on wind instrumentation. Salient features are wind speeds from 0.5 to 85 MPH with control capabilities of 0.1 MPH increments in the low velocities, low turbulence levels in the four by four by six foot test section, and instrumentation including a Prandtl tube, a mean-velocity hot wire, and eddy-shed hot wire wind speed measuring devices, a yaw probe directional device, and a turbulence hot wire system.

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INTRODUCTION

Meteorological data collection for range support is the responsibility of the U. S. Army Electronics Research and Development Activity at White Sands Missile Range (WSMR). The data are utilized for both operational and R&D purposes in such areas as rocket impact prediction, ballistics studies, and acoustic propagation research. These data must be as accurate as possible in order for the various using organizations to depend on the results. The requirements for future systems are becoming more and more rigid as to this accuracy.

The present wind instrumentation employed on the range consists of a variety of the commonly used systems as well as some unique types.

The need has arisen in recent years for more accurate and reliable means of calibration and checking of the operational and research wind instrumentation and has led to the procurement and installation of a Wind Instrumentation Research Facility at WSMR.

DISCUSSION

The Wind Instrumentation Research Facility is a special purpose wind tunnel. It is a closed-circuit system with special features which make it ideal for routine and special calibration and investigation of wind measuring devices. The salient features of the facility include the capability of very low-speed operation, down to 0.5 MPH, the availability of speed control in increments as small as 0.1 MPH in the lower speeds, a low turbulence level on the order of 0.2 per cent (1) in the test section and the incorporation of several different types of instrumentation. The high-speed limitation is approximately 85 MPH. Figure 1 is a perspective view of the entire facility. The blower, turning vanes, and the test section are shown and will be discussed in some detail.

The blower, which has both speed and pitch controls, generates the air movement. The air moves through a round-to-square transition section and then through a gradually increasing square section to the first corner. The square corners are equipped with turning vanes which, for this system, were found to be most efficient (1). The air moves to a second square corner and set of turning vanes and into the contraction section. At the head of the contraction section is a set of four tandem screens of 24 x 24 squares per inch mesh spaced about two inches apart. These screens aid in reducing the turbulence level at this point. The contraction section follows an exponential function and has a ratio of approximately five to one.

From the contraction section the air moves through the four by four by six foot test section, which is isolated from the main structure by foam rubber to reduce vibration transfer. The air then moves through an expansion section, a square-to-round transition, two sets of turning vanes and returns to the blower section.

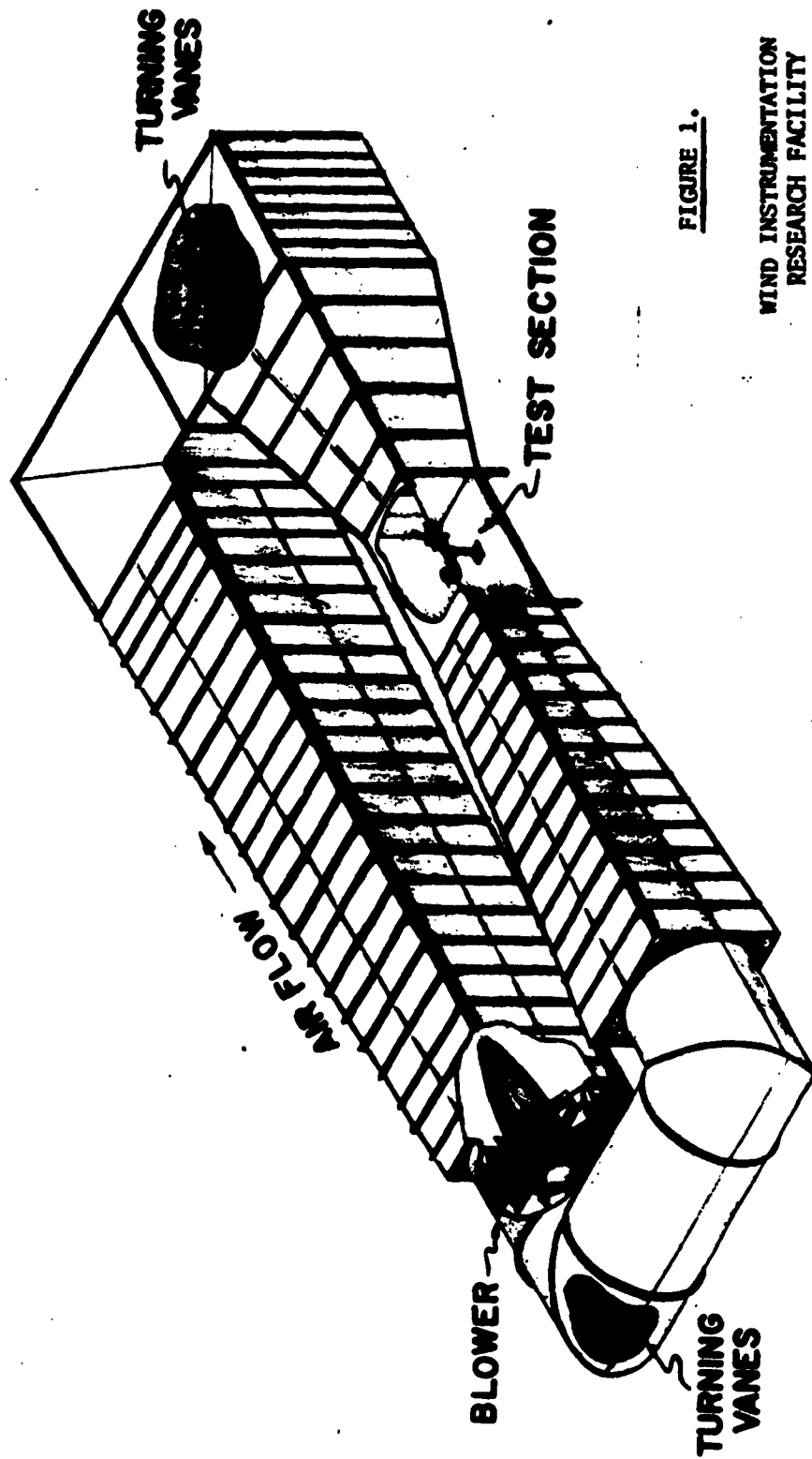


FIGURE 1.

**WIND INSTRUMENTATION
RESEARCH FACILITY**

The blower is depicted in Figure 2 (looking upstream). The fixed vanes, moveable blades, nose cone, and drive belt cover are shown. The maximum speed of the blower is 840 rpm. Figure 3 is a view of one set of turning vanes. These vanes work well at the low speeds used with this facility. These are an additional aid in maintaining a low value of turbulence.

The master control panel shown in Figure 4 is adjacent to the test section. All wind velocity measuring and control functions are accomplished with the equipment shown here. In the left-hand section from top to bottom are the control panels, the blower speed and pitch controls, and a general purpose power supply. The next section contains the frequency counter, an oscilloscope, a precision audio oscillator, and switch panel. The third section houses, from top to bottom, the over-temperature alarm indicators for the blower bearings and other duct points, a general purpose power supply, the hot-wire anemometer controls, and the galvanometer drawer. The last section contains the micromanometer and pneumatic valves for pressure differential measurements.

INSTRUMENTATION

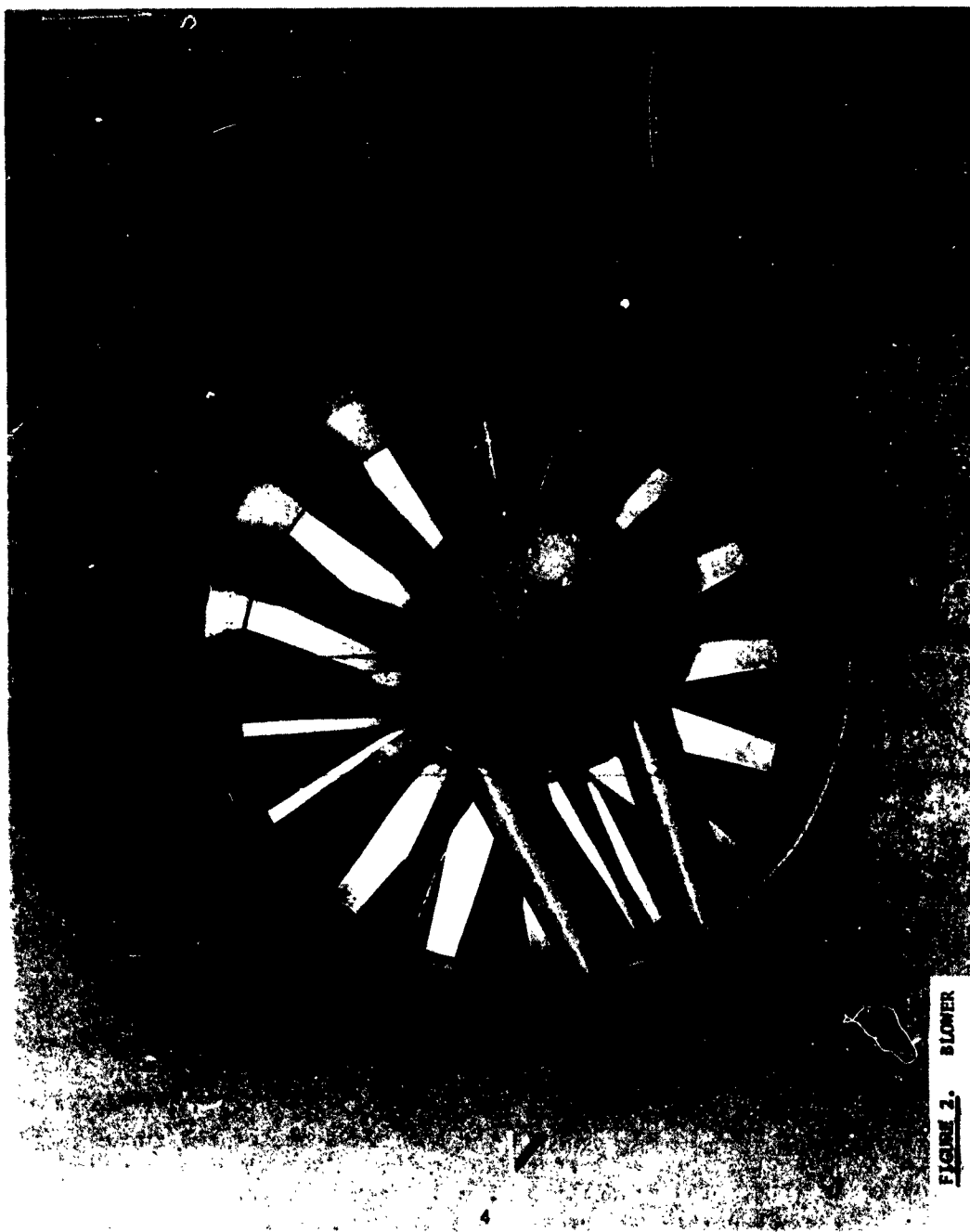
The instrumentation used to measure velocity in the wind facility consists of a Prandtl tube, an eddy-shed hot wire sensor, and a mean velocity hot wire sensor.

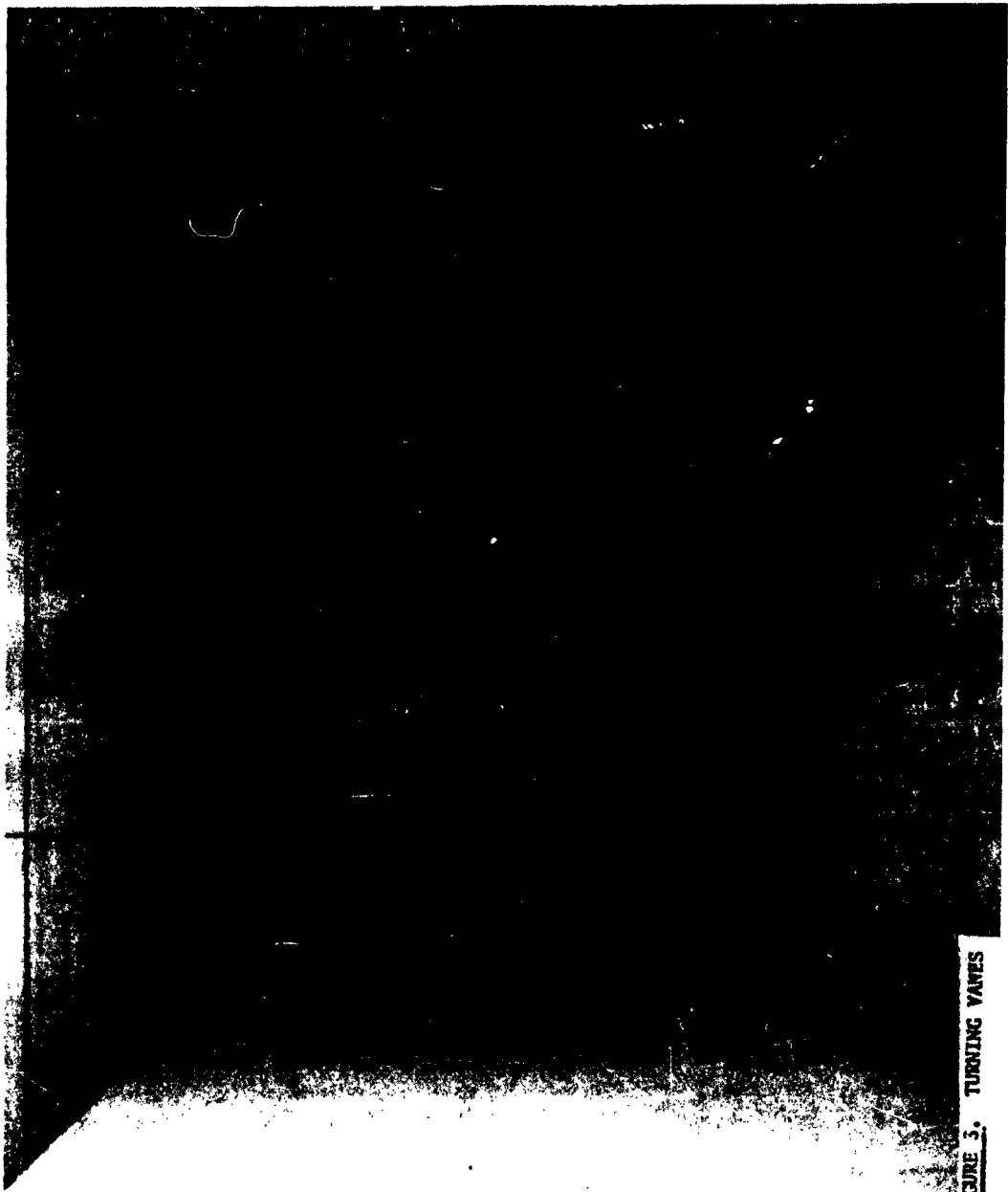
The Prandtl tube is a device which measures the total pressure differential and the static pressure of the air flow in a manner similar to a pitot tube. When the Prandtl tube is connected as shown in Figure 5, the readings on the manometer will be the velocity pressure from which the velocity of the air can be determined by using the formula:

$$V = \sqrt{\frac{2 \text{ (vel. pressure)}}{\text{density of air}}} .$$

The Prandtl tube used is standard and requires no correction (2). The manometer has a sensitivity of ± 0.001 inch of water, and, therefore, the error in the air velocity readings will be less than 1 per cent for velocities greater than 10 MPH. The system error increases for speeds less than 10 MPH due to the small pressure differential being measured; e.g., the error is approximately 10 per cent at 3 MPH. The Prandtl tube is illustrated in the foreground of Figure 6.

The mean velocity hot wire sensor is used to measure the air velocities from slightly less than 10 MPH to the maximum speed of the tunnel. It operates on the principle of heat transfer from a hot wire to the air passing over the wire. The velocity of the air can be determined by a calibration chart which relates the velocity of the air to the current required to keep the wire at a constant temperature. This method requires corrections for the temperature of the air passing over the hot wire, but is independent of pressure variations.





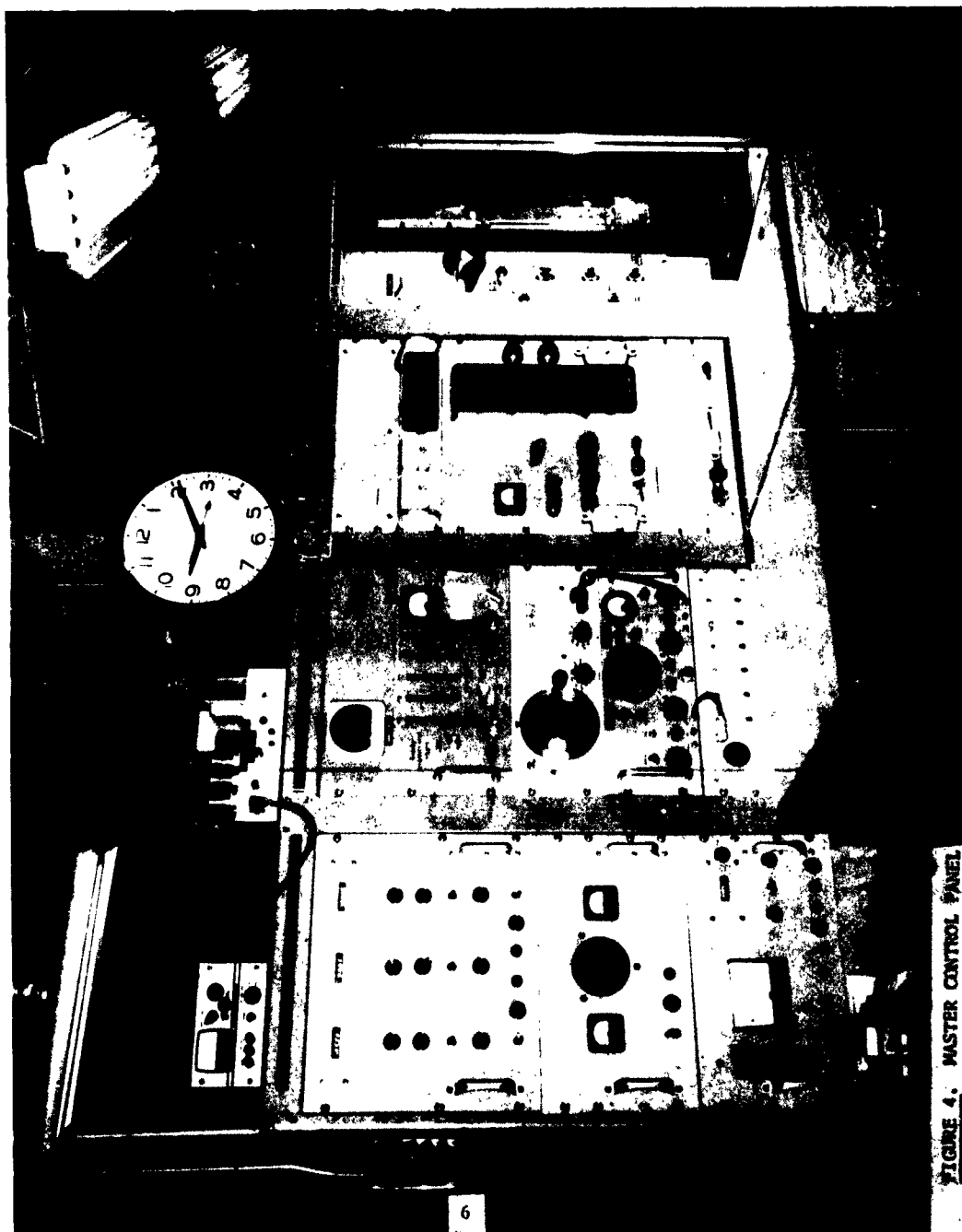


FIGURE 4. MASTER CONTROL PANEL

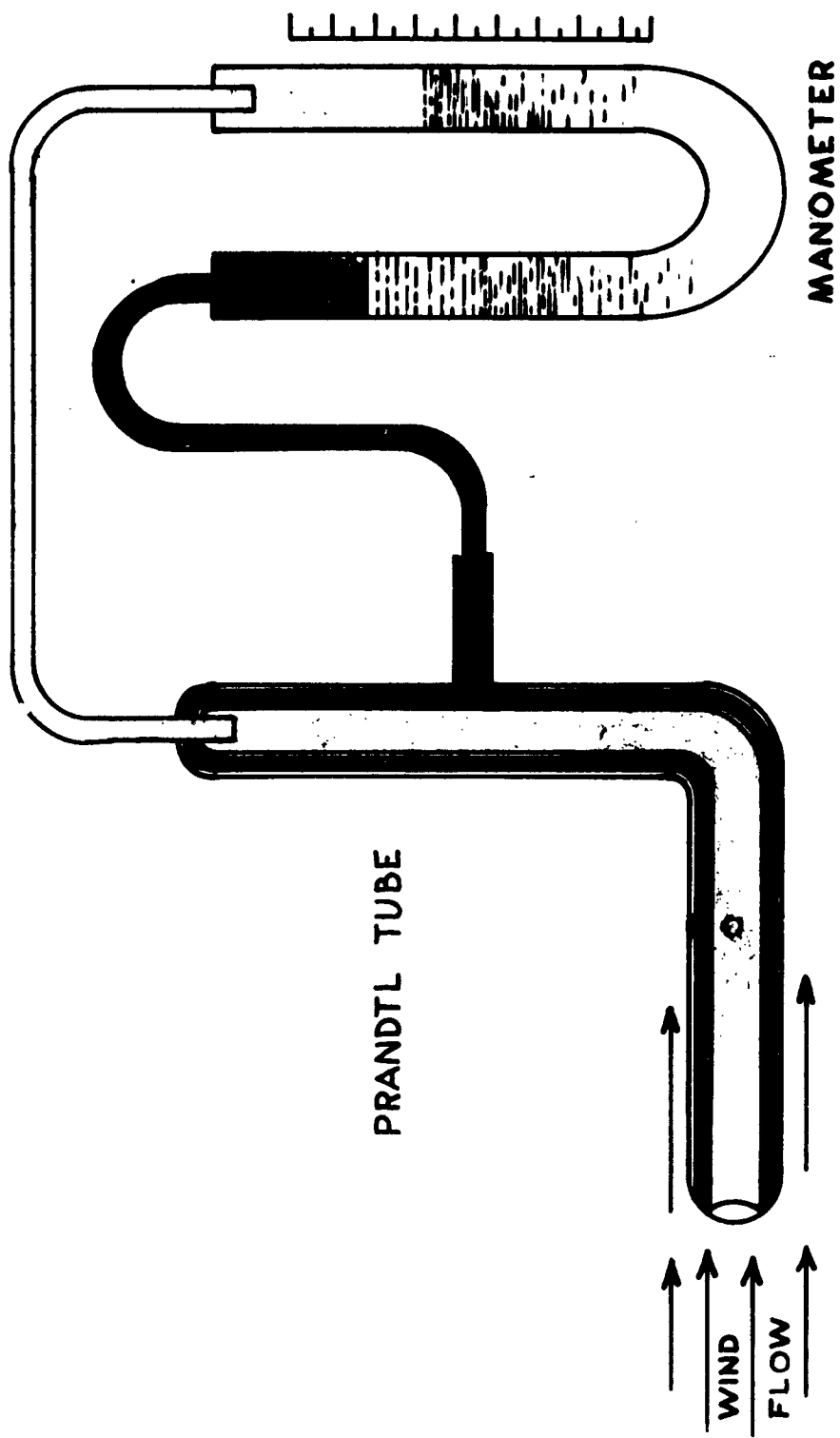


FIGURE 5. PRANDTL TUBE CONNECTED TO MANOMETER



FIGURE 6. PRANDTL TUBE

The eddy shedding hot wire, Figure 6, is used to measure air velocities in the tunnel from 0.5 to 10 MPH. It consists of a cylinder and a hot wire mounted in the wake of the cylinder and functions on the principle that when a cylinder is placed in an air flow, periodic eddies are created down stream (Figure 7). The frequency at which the eddies are shed depends upon the air velocity, the wire diameter, and the flow viscosity according to the empirical equation (3):

$$\frac{nd^2}{v} = 0.212 \text{ Re}^{-4.5}$$

where:

$$\text{Re} = \text{Reynolds number} = \frac{Ud}{v}$$

n = frequency

U = velocity

d = wire diameter

v = flow viscosity.

The eddies shed from the cylinder cause a periodic heating and cooling of the hot wire and thus a voltage change in the circuit which is a sine function.

The frequency of the eddy shedding is measured by obtaining an elliptical Lissajous figure on an oscilloscope in conjunction with a high stability audio oscillator and by a direct reading frequency counter. The eddies shed by the cylinder are stable only for Reynolds numbers between 50 and 150 (2).

A yaw probe, connected to the manometer as shown in Figure 8, measures the direction of the air flow. The two holes in the sphere are placed at 90° and hence, when the yaw probe is positioned such that it points directly into the wind, the manometer will have a zero reading due to the symmetry of the system (3).

The instrumentation is capable of measuring the turbulent quantities of the air stream as it passes through the test section. This is accomplished by two hot wires normal to each other, one to measure the root-mean-square values of the velocity fluctuations in the direction of the mean velocity and the other to measure those values in the direction perpendicular to the mean flow.

Another wind flow measuring device that is included just down wind from the test section is a tachometer generator and six-blade impeller. This is permanently mounted near the top of the section and is utilized to give approximate wind velocity indications to the operator. It is an aid in making preliminary adjustments and is utilized as a primary instrument in certain investigations where accurate velocities are not required.

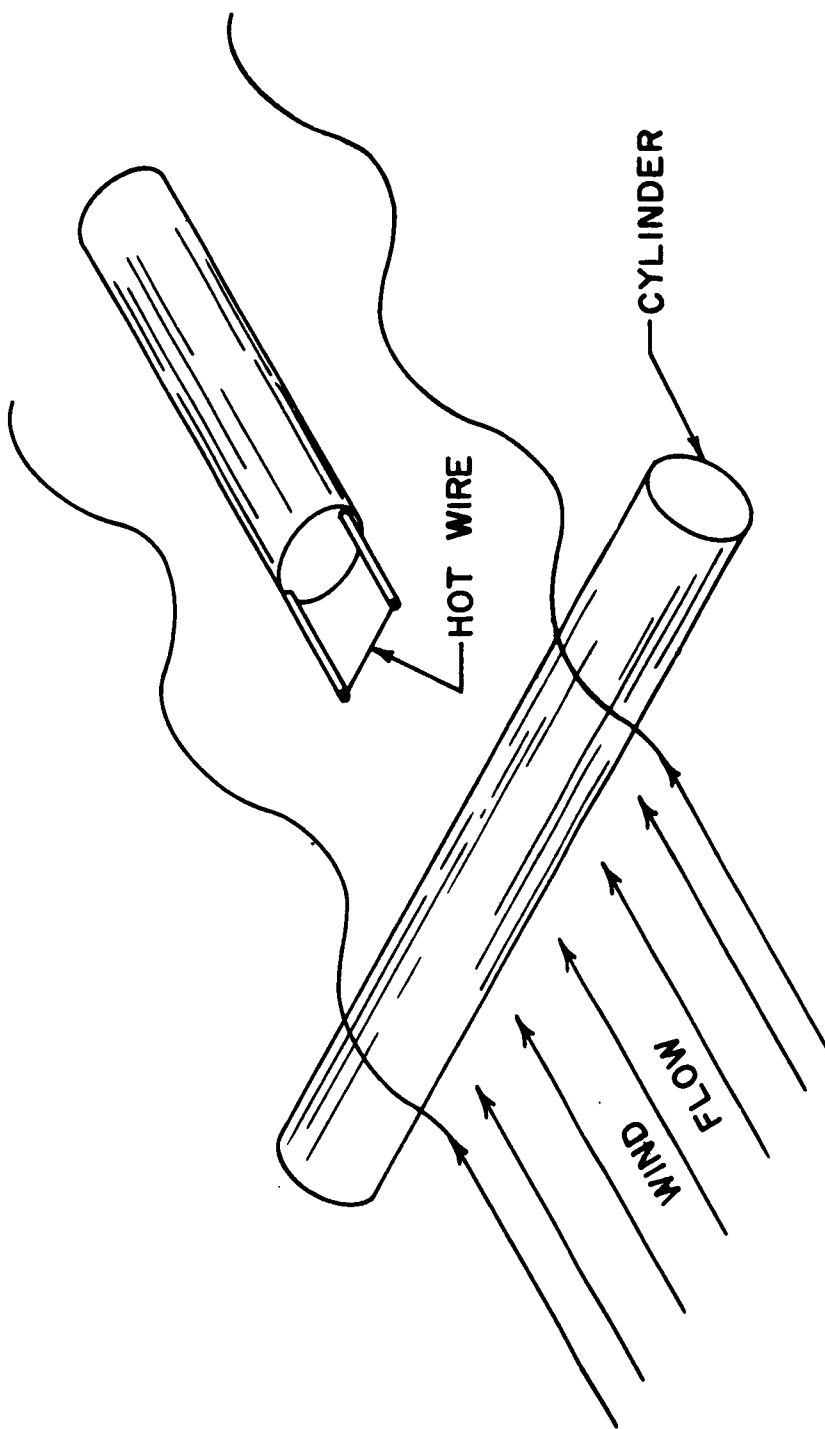


FIGURE 7. EDDY-SHED HOT WIRE

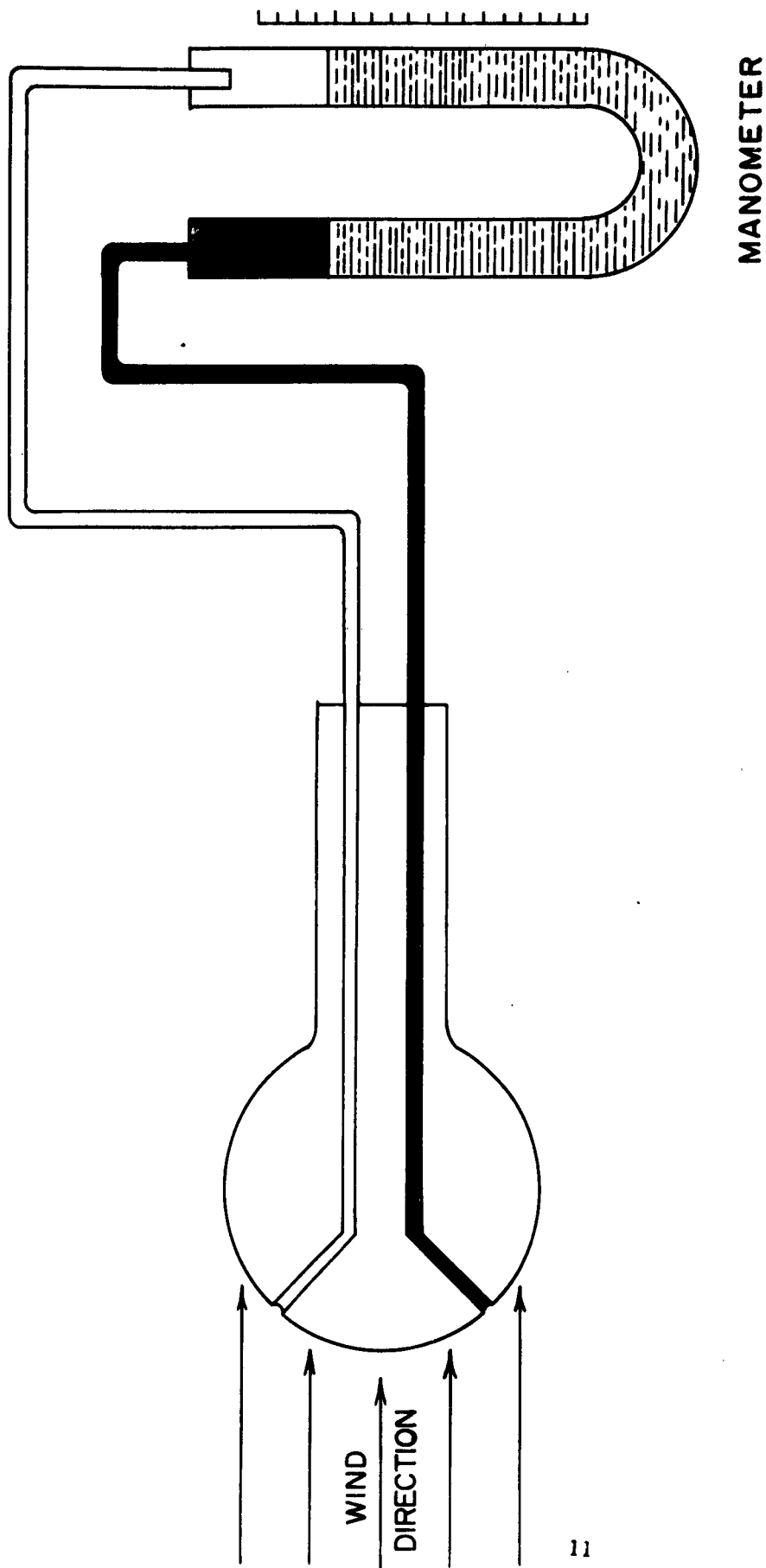


FIGURE 8

YAW PROBE

The facility is also equipped with four copper-constantan thermocouples and a thermocouple bridge which can measure the temperature at almost every point in the test section. These temperatures are used to calculate the density of the air in the tunnel.

IN CONCLUSION

During the first year of operation at WSMR, the instrumentation has been calibrated, and several correlation studies have been made using different sensors having overlapping ranges. These studies indicate that the order of accuracy originally specified has been achieved.

Additional instrumentation is being planned for the facility to include a system to measure the travel time of an acoustic pulse across the test section. Greater accuracy is expected from this system of wind flow measurements.

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1. "Wind Instrumentation Research Facility at White Sands Missile Range," ERDA-24, has been prepared under the supervision of the Environmental Sciences Department and is published for the information and guidance of all concerned.
2. Suggestions or criticisms relative to the form, contents, purpose, or use of this publication should be referred to the Commanding Officer, U. S. Army Electronics Research and Development Activity, ATTN: SELWS-M, White Sands Missile Range, New Mexico.

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