



AEROSPACE RECOMMENDED PRACTICE

Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

ARP 1195

Issued 7-15-71
Revised

TURBINE NOZZLE AREA MEASUREMENT BY AIRFLOW METHOD

1. PURPOSE

This recommended practice provides a standard basis for airflow measurement of the relative aerodynamic throat area of gas turbine nozzles.

2. SCOPE

This recommended practice covers methods, conditions of measurement, and acceptable standards of accuracy. Equipment known to meet the General Requirements is described. Standard reference nozzles and mounting flanges are specified.

3. GENERAL REQUIREMENTS

3.1 Reference Standards: The following standards are applicable and provide useful information:

3.1.1 Power Test Code, ASME 1940, Part #5, Chapter 4.

3.1.2 ASME report: "Fluid Meters, their theory and application", Part 1, Fifth Edition 1959.

3.2 Standards of Accuracy: The readings should be repeatable within a total spread of 0.25% of throat area, i.e., $\pm 0.125\%$.

3.3 Principle of Measurement: The principle of measurement is to compare master nozzles with the gas turbine engine nozzles, and to establish, from airflow readings, their relative aerodynamic throat areas.

3.4 Method of Measurement: The method of measurement is a comparison of the back pressure generated by airflow through the test piece with that generated by flow through master nozzles of known throat area, as measured by geometrical methods. The masters may be engine parts, similar to the nozzle under test, or may be ASME nozzles (Ref. Para. 3.5.4 below). Two methods known to be capable of meeting the standards of accuracy specified in Para. 3.2 (above) will be described.

3.4.1 METHOD 1: The mass flow through the test nozzle is held constant by critical flow through a valve, supplied at a regulated pressure (normally 15 psig).*

The back pressure from the test piece is measured against a reference pressure which has been set to give a null or known reading against the back pressure of a master. The readout is on a differential pressure gage from the signal provided by a differential pressure transducer, one side of which is connected to the reference pressure, the other to the back pressure of the test piece. A schematic diagram of such a rig is shown in Figure 1.

The back pressures and effective throat areas of test piece and master will be related as follows:

$$\frac{A_m}{A_t} = \sqrt{\frac{P_t}{P_m}}$$

* Higher pressures can be used.

SAE Technical Board rules provide that: "All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

where suffix "m" denotes master, "t" denotes test piece. The dial of the differential pressure gage is a removable card, graduated appropriately for the nozzle under test, as follows:

Dial Increment Angle

$$A = \frac{C}{\sqrt{1 - \left(\frac{B}{b}\right)^2}}$$

where $C = \frac{\Delta p \text{ (reference pressure)} \times \text{Angular Range of gage}}{\Delta p \text{ (1/2 range of gage)} \quad 2}$

$B =$ Baseline Angle (angle of pointer from vertical when master is flowed)

$b =$ Increment of Area.

See Figure 2.

3.4.2 METHOD 2: In this system, the opening of a variable orifice is adjusted to balance its back pressure against the back pressure of the nozzle under test. A bifurcated system is used as shown in Figure 3.

The variable orifice is adjusted to give a null reading on the inclined manometer which reads the pressure differential between the two limbs. A calibration curve is constructed by plotting the "balanced" position of the variable orifice against the known throat areas of a number of masters which bracket the expected range of throat area variation. The effective area of the test piece is measured by the position of the "bullet" of the adjustable nozzle when the differential manometer reads zero.

A minimum of three masters is required. One should be higher than the test piece and the other should be lower. The highest and lowest should not be more than 150% or less than 50% respectively of the nominal test piece area. The third master should be within 10% of the nominal value. The configuration of the variable orifice should be chosen such that the calibration curve is a straight line. This is convenient for repetitive work and in the example shown, is achieved by a parabolic contour of the bullet. A typical calibration curve is shown in Figure 4. Other types of equipment may be used, provided the standard of accuracy specified above is met.

3.5 General Remarks: When making a measurement, the pressure difference across the nozzle must be stable, but its actual value is not critical. Values of 0.5 in. to 45 in. water are in use, with 10 in. - 20 in. being the most commonly used range.

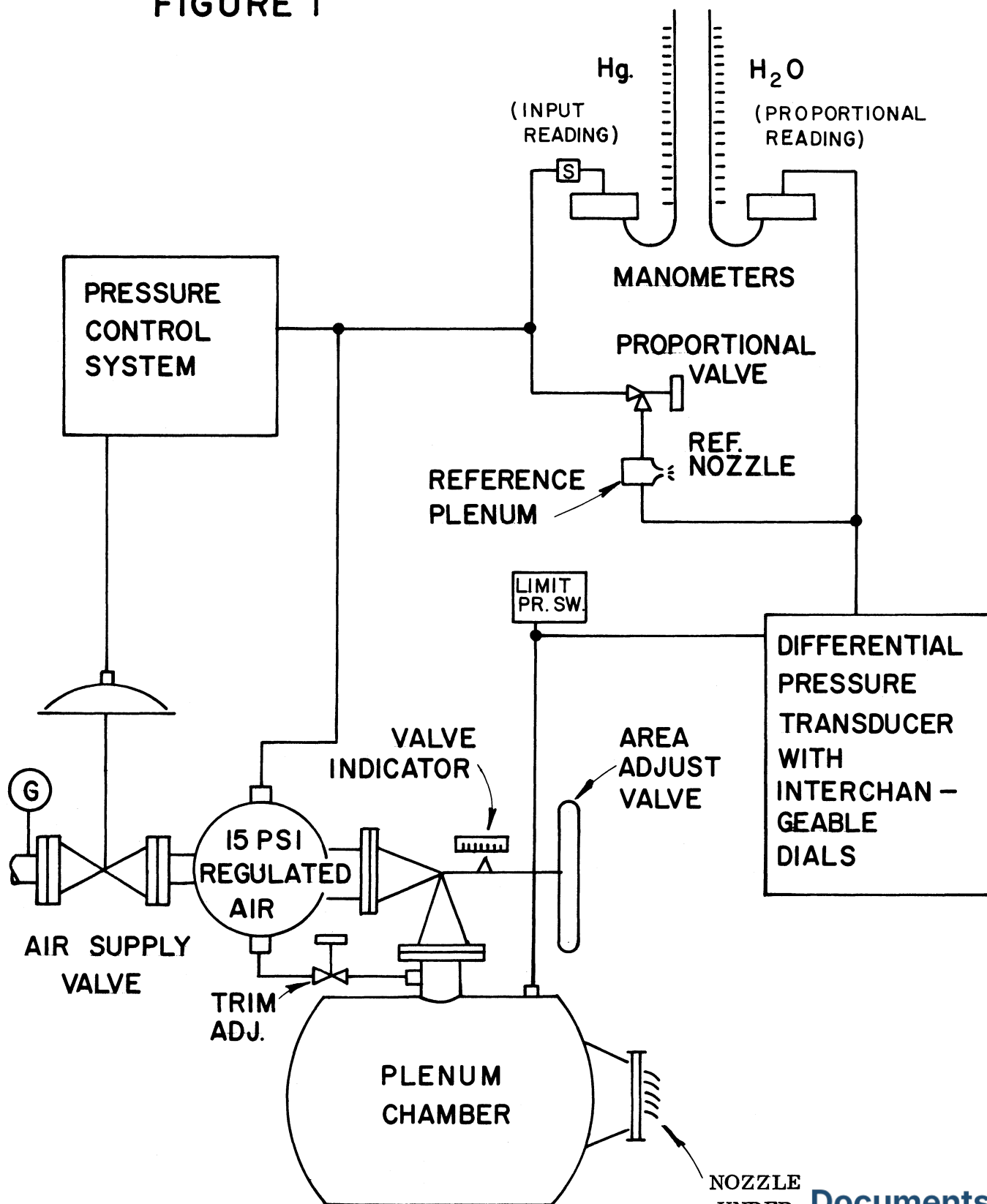
In designing and calibrating airflow comparator equipment, the following factors should be considered:

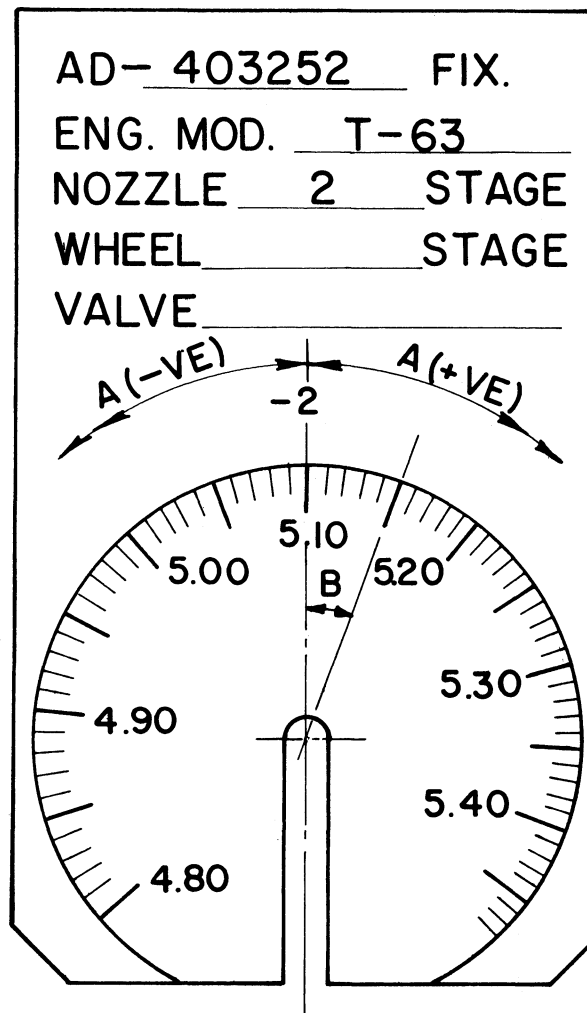
3.5.1 Configuration: Should be such that two parallel flows are compared at the same time on a basis of back pressure or exit area. Rigs which attempt to measure the flow by a venturi or other device in series with the test piece are prone to errors arising from temperature variations in the air and nozzles.

3.5.2 Suction versus Pressure: The two rigs illustrated in this recommended practice employ positive pressure and the workpiece can be mounted at the outlet face, which makes for convenience in use. Suction rigs generally require that the workpiece be mounted between two sections of the rig, because readings of air pressure are more reliably taken upstream of the vane ring, where swirl, etc., does not exist. However, a suction system does have the advantage that air entering the ring may be substantially at ambient conditions, free from the heating effects of a fan, or the cooling effects of recent expansion, which cause dimensional changes. Power requirements for the same pressure drop across the workpiece are lower in the case of a suction rig.

AIR FLOW RIG SCHEMATIC DIAGRAM (METHOD 1)

FIGURE 1





DIAL INCREMENT ANGLE

$$A = \frac{C}{\sqrt{1 - \left(\frac{B}{b}\right)^2}}$$

$$C = \frac{\Delta p \text{ (REFERENCE PRESS.)}}{\Delta P \text{ (1/2 RANGE OF GAGE)}} \times \frac{\text{ANGULAR RANGE OF GAGE}}{2}$$

B = BASE LINE ANGLE

b = INCREMENT OF AREA

NOTE :

BASE LINE ANGLE "B" IS THE ANGLE FROM THE VERTICAL WHICH THE POINTER ASSUMES WHEN REF. MASTER IS FLOWED.

DIAL CARD CONSTRUCTION

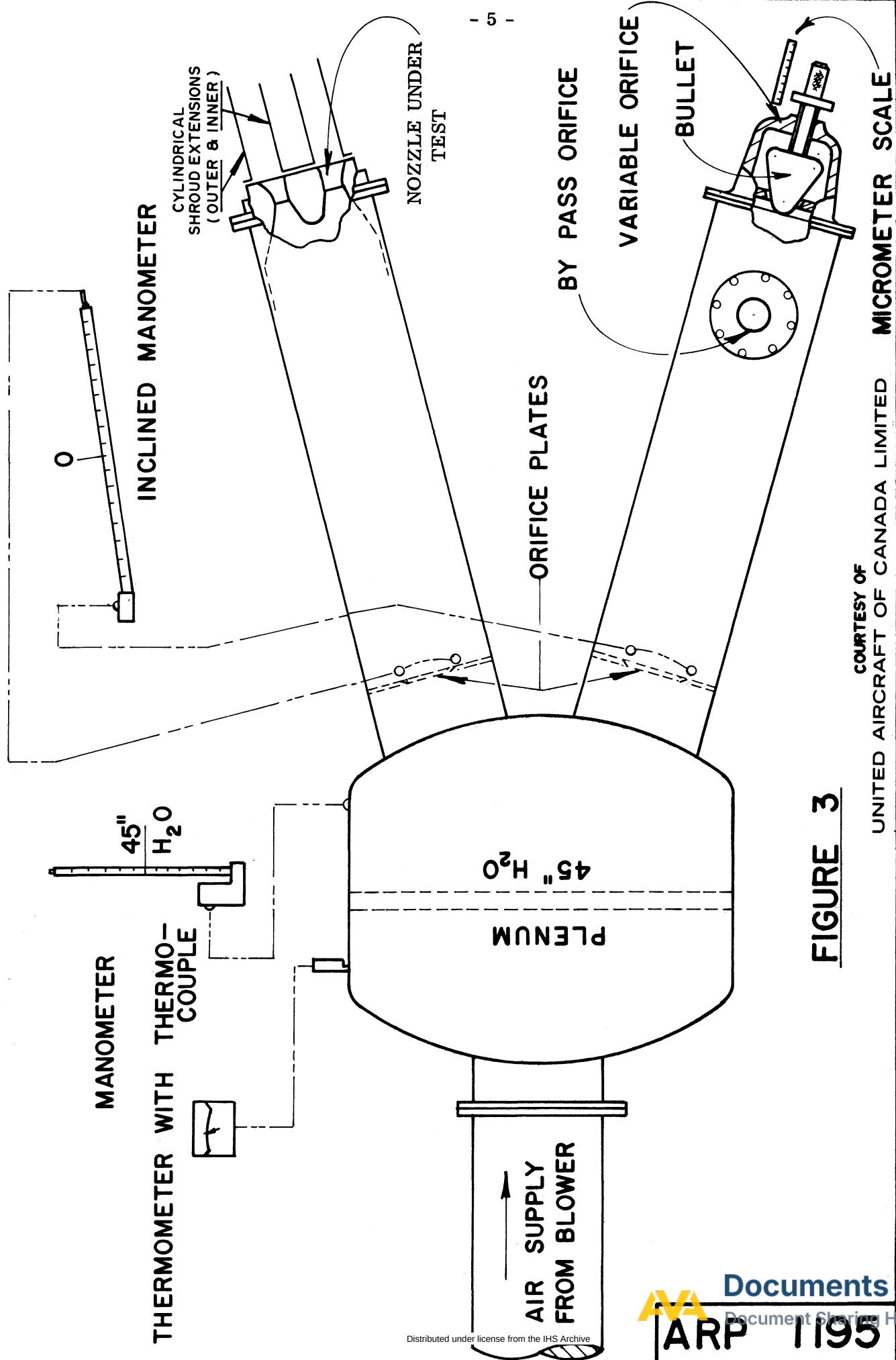
FIGURE 2



Documents

Document Sharing Hub

AIRFLOW RIG SCHEMATIC DIAGRAM — (METHOD 2)



- 5 -

