

SURFACE VEHICLE RECOMMENDED PRACTICE

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Air Cleaner Test Code

Foreword—The basic performance characteristics of greatest interest are airflow restriction or pressure drop, dust collection efficiency, dust capacity, and air cleaner structural integrity. This test code, therefore, addresses itself to the measurement of these parameters.

The objective of the test code is to provide a uniform means for evaluating the performance characteristics of air cleaners on bench test equipment. The data collected by this test code can be used to establish standards of performance for air cleaners tested in this manner. The actual field operating conditions (humidity, vibration, contaminant, etc.) are difficult to duplicate. However, by use of these standard test methods, the test conditions are controlled, and comparisons of lab performance of filters may be made with a high degree of confidence.

The equipment specified in these standard tests assures that all particles of test dust are evenly dispersed, eliminating agglomerates, to a degree not possible in prior standard tests. For this reason, apparent filtration efficiency and dust capacity by these tests can be significantly lower than if the same filter were tested by the older methods. These results are more repeatable and reliable than the earlier test methods and correlations among the laboratories using these methods are now possible.

To simplify and improve the clarity of this test code, Section 1, covers general information and definitions applicable to all air cleaner testing covered in this test code. Section 4 covers the testing of dry type air cleaners normally used on automobile internal combustion engines. Section 5 covers the testing of industrial dry type air cleaners and precleaners for mobile and stationary internal combustion engines. Section 5 covers the testing of oil bath air cleaners used for mobile and stationary internal combustion engines.

1. Scope—The air cleaner test code has been established to cover dry type and oil bath air cleaners used on internal combustion engines and to present a uniform method of determining and reporting air cleaner performance.

1.1 Purpose—The purpose of this test code is to establish and specify uniform testing procedures, conditions, equipment, and a performance report to permit the direct laboratory performance comparison of dry type and oil bath type air cleaners, respectively.

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1.2 Measurement Accuracy

- 1.2.1 Measure the airflow rate within 2% of the actual value.
- 1.2.2 Measure the pressure drop and restriction within 0.25 mbar (0.025 kPa) of the actual value.
- 1.2.3 Measure the temperature within 0.5 °C of the actual value.
- 1.2.4 Measure the weight within 1% of the actual value except where noted.
 - 1.2.4.1 Weigh the absolute filter(s) to ± 0.01 g.
- 1.2.5 Measure the relative humidity with an accuracy of 2% R.H.
- 1.2.6 Measure the barometric pressure within 3 mbar (0.3 kPa).
- 1.2.7 The measurement equipment shall be calibrated at regular intervals to ensure the required accuracy.

1.3 Test Conditions and Material

- 1.3.1 The test dust contaminant shall be standardized and shall be of two grades labeled FINE and COARSE. The following chemical analysis (Table 1) is typical:

TABLE 1—CHEMICAL ANALYSIS OF TEST DUST

Chemical	% of Weight
SiO ₂	65 – 76
Al ₂ O ₃	11 – 17
Fe ₂ O ₃	2.5 – 5.0
Na ₂ O	2 – 4
CaO	3 – 6
MgO	0.5 – 1.5
TiO ₂	0.5 – 1.0
V ₂ O ₃	0.10
ZrO	0.10
BaO	0.10
Loss on Ignition	2 – 4

- 1.3.1.1 Before using the test dust, a quantity sufficient to cover test requirements shall be mixed in a sealed container for a minimum of 15 min. This test dust shall then be dried to a constant mass at a temperature of $105\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$. The test dust shall then be allowed to become acclimatized to a constant mass under the prevailing test conditions.

NOTE— To ensure a constant rate of dust feed with some dust feeders, it may be found necessary to heat the dust prior to being fed to the injector.

- 1.3.2 The particle size distribution by volume as measured with an L & N Microtrac Analyzer shall be as follows in Table 2:

TABLE 2—PARTICLE SIZE DISTRIBUTION BY VOLUME, %

Size, Microns	Fine Grade (% less than)	Coarse Grade (% less than)
5.5	38 ± 3	13 ± 3
11	54 ± 3	24 ± 3
22	71 ± 3	37 ± 3
44	89 ± 3	56 ± 3
88	97 ± 3	84 ± 3
176	100	100

- 1.3.2.1 (Reference Only)—The particle size distribution by mass as measured by the Andreason method is given in Table 3:

TABLE 3—PARTICLE SIZE DISTRIBUTION, ANDREASON METHOD PERCENTAGE BY MASS

Size μm	Fine Grade %	Coarse Grade %
< 125	----	98.5 ± 1.5
< 75	98 ± 2	84.5 ± 5.5
< 40	84 ± 3	51 ± 2
< 20	67 ± 3	32 ± 2
< 10	49 ± 3	19.5 ± 1.5
< 5	35 ± 3	10 ± 1
< 2	17.5 ± 2.5	----

- 1.3.2.2 (Reference Only)—The particle size distribution as measured by a Roller analyzer and described in % weight is given in Table 4.

TABLE 4—PARTICLE SIZE DISTRIBUTION BY WEIGHT, %

Size, Microns	Fine Grade	Coarse Grade
0 – 5	39 ± 2	12 ± 2
5 – 10	18 ± 3	12 ± 3
10 – 20	16 ± 3	14 ± 3
20 – 40	18 ± 3	23 ± 3
40 – 80	9 ± 3	30 ± 3
80 – 200	----	9 ± 3

- 1.3.2.3 Test Dust (Coarse and Fine) is manufactured by Powder Technology Inc. Dust capacity differences may occur between different dust batches. Therefore, it is recommended that comparison testing of filters be performed using a single batch of dust per test program whenever possible.

- 1.3.3 ABSOLUTE FILTER MATERIALS—The absolute filter shall consist of fiberglass media with a minimum thickness of 12.7 mm and a minimum density of 9.5 kg/m³. The fiber diameter shall be 0.76 to 1.27 μm and the moisture absorption shall be less than 1% by weight after exposure of 49 °C and 95% relative humidity for 96 h. The filter shall be installed with nap side facing upstream in an airtight holder that adequately supports the media. The face velocity shall not exceed 50 m/min to maintain media integrity.

To reduce any subsequent errors in the measurements caused by loss of fibers or materials, the absolute filter shall be subject to a flow of at least 110% of the rated flow of ambient air for 15 min before the test weighings.

- 1.3.4 ABSOLUTE FILTER WEIGHT—The absolute filter shall be weighed to the nearest 0.01 g after the weight has stabilized and while in a ventilated oven at 105 °C ± 5 °C.

NOTE— If stabilization cannot be determined, a minimum time of 4 h is required.

- 1.3.5 TEMPERATURE AND HUMIDITY—All tests shall be conducted with air entering the air cleaner at a temperature of $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and a relative humidity of $55\% \pm 15\%$, the permissible variation at each weighing stage throughout each single test being $\pm 2\%$ (relative humidity).

NOTE— Since atmospheric conditions affect the test results, when comparing the performance of the filters designed for the same application, the tests should be conducted within the narrowest range of temperature and humidity possible.

- 1.3.6 AIR DRYER—To prevent the dust from caking and to prevent icing of the injector nozzle, an effective air dryer of sufficient size should be installed in the air supply line.

- 1.3.7 See Appendix A for:

- a. test material supplier list
- b. test equipment supplier list

2. References

- 2.1 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

- 2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001. The latest issue of SAE publications shall apply.

SAE J1124—Glossary of Terms Related to Fluid Filters and Filter Testing
SAE TSB 003—Rules for SAE Use of SI (Metric) Units

- 2.1.2 ASME PUBLICATIONS—Available from ASME, 22 Law Drive, Fairfield, NJ 07007.

Fluid Meters—Their Theory and Application—6th Edition 1971

- 2.1.3 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO5011—Inlet air cleaning equipment for internal combustion engines and compressors—Performance testing

3. Definitions

- 3.1 Air Cleaner—For the purpose of this test code, the air cleaners shall be of the dry type or oil bath type and may consist of one or more stages of filtration which remove particles suspended in the fresh charge as it is drawn into the engine.

- 3.1.1 DRY TYPE AIR CLEANER—An air cleaning device consisting of one or more layers of filter media that may or may not have a wettant added to the media. Filtration is accomplished by removal of the contaminant as air passes through the filter media.

- 3.1.2 OIL BATH AIR CLEANER—An air cleaning device in which dust laden air is directed on a reservoir of oil where some of the dust is collected. This air, carrying a mist of oil from the reservoir, then passes upward through the filter element for further filtering. The oil returning to the reservoir carries with it dust that was collected in the filter element.

- 3.2 Unit Under Test**—Either a single air cleaner element, a precleaner, or a complete air cleaner assembly.
- 3.3 Single-stage Air Cleaner**—An air cleaner that does not incorporate a separate precleaner.
- 3.4 Multistage Air Cleaner**—An air cleaner consisting of two or more stages, the first usually being a precleaner followed by one or more filter elements. If two elements are employed, the first shall be called the primary element, and the second one shall be called the secondary element.
- 3.5 Precleaner**—A device usually employing inertial or centrifugal means to remove a portion of the dust prior to reaching the filter element. Precleaners may be integral with the air cleaner housing, attached to the housing or separate. They may employ a scavenge airflow, an unloader valve, atmospheric discharge, or other means to remove or store separated dust.
- 3.6 Test Airflow**—A measure of the quantity of air drawn through the air cleaner outlet per unit time. The flow rate shall be expressed in cubic meters per minute corrected to standard conditions.
- 3.7 Rated Airflow**—The flow rate specified by the user or supplier and may be used as the test airflow. When rated airflow is not known, for test purposes, it can be approximated using the formula described in Appendix B.
- 3.8 Scavenge Airflow**—A measure of the quantity of air employed to remove the collected dust from a precleaner, expressed as a percentage of the test airflow, typically 10%.
- 3.9 Pressure Drop**—(ΔP_d) A measure, in mbar (kPa), of the difference in static pressure measured immediately upstream and downstream of the unit under test.
- 3.9.1 Refer to Appendix C for correcting the recorded pressure drop values to the standard conditions.
- 3.10 Static Pressure**—Pressure in a duct at the observed airflow rate, measured by connecting a pressure gage to a hole or holes drilled in the wall of the duct.
- In the tests specified herein a static pressure is measured by a manometer (usually a liquid manometer) as a negative pressure difference against the atmospheric pressure and in the formula is treated as a positive value.
- 3.11 Pressure Loss**—Measure of the loss of energy caused by an air cleaner at the observed airflow rate, expressed as the pressure drop corrected for any difference in the dynamic head at the measuring points.

When pressure drop across an air cleaner has been measured ($P_2 - P_1$ in Table 5), any difference in the cross-sectional area of the ducts at the upstream and downstream pressure tapping points must be taken into account in determining the pressure loss across the air cleaner. The pressure loss across the cleaner is given by the equation:

$$\Delta P_1 = \Delta P_d - \Delta P_c \quad (\text{Eq. 1})$$

where:

ΔP_d is measured pressure drop

$$\Delta P_c = \frac{\rho \cdot V_2^2}{2} - \frac{\rho \cdot V_1^2}{2} \quad (\text{Eq. 2})$$

in which:

ρ is the density of the air

V_1 is the velocity of the air in the duct at the upstream pressure tapping point

V_2 is the velocity of the air in the duct at the downstream pressure tapping point

TABLE 5—PRESSURE DROP

Term	Air Cleaner Drawing Air from the Atmosphere	Air Cleaner Drawing Air Through an Inlet Duct
Static pressure upstream of air cleaner	----	P_1
Restriction = Static pressure downstream of air cleaner	$\Delta P_r = P_2$	$\Delta P_r = P_2$
Pressure drop	----	$\Delta P_d = \Delta P_r - P_1 = P_2 - P_1$
Pressure loss	$\Delta P_1 = \Delta P_r - P_{\text{dynamic}}$ $= P_2 - \frac{\rho \cdot V_2^2}{2}$	$\Delta P_1 = \Delta P_d - \Delta P_c$ $= (P_2 - P_1) - \frac{\rho}{2}(V_2^2 - V_1^2)$

When the upstream pressure is equal to atmospheric and therefore only the static pressure in the downstream duct has been measured, the pressure loss across the air cleaner can be calculated from the dynamic head required to accelerate the air from rest to its velocity in the downstream duct. The pressure loss across the cleaner is then given by the equation:

$$\begin{aligned}\Delta P_1 &= P_r - P_{\text{dynamic}} \\ &= P_2 - \frac{\rho \cdot V_2^2}{2}\end{aligned}\quad (\text{Eq. 3})$$

where:

$P_r = P_2$ is the restriction/static pressure at the downstream pressure tapping point

ρ is the density of the air

V_2 is the velocity of the air at the downstream pressure tapping point

- 3.12 Restriction**—(ΔP_r) A measure, in mbar (kPa) gage, of the static pressure measured immediately downstream of the unit under test.
- 3.13 Assembly Restriction/pressure Drop**—The airflow pressure resistance across the complete assembly (test shroud and/or housing and element).
- 3.14 Tare Restriction/pressure Drop**—The airflow pressure resistance across the test shroud and/or housing only (no element).
- 3.15 Element Restriction/pressure Drop**—The assembly restriction/pressure drop minus the tare restriction/pressure drop.
- 3.16 Terminating Restriction/pressure Drop**—The airflow pressure resistance across the unit under test at which the capacity is measured.
- 3.17 Absolute Filter**—The filter downstream of the unit under test to retain the contaminant passed by the unit under test.
- 3.18 Efficiency**—The ability of the air cleaner or the unit under test to remove contaminant. This will be expressed by the following formulas:

3.19 Automobile Air Cleaners

$$\text{Efficiency, \%} = \frac{\text{Increase in weight of unit under test}}{\text{Increase in weight of unit under test} + \text{Increase in weight of the absolute filter}} \times 100 \quad (\text{Eq. 4})$$

3.20 Industrial Air Cleaners

$$\text{Efficiency, \%} = 1 - \frac{\text{Increase in weight of absolute filter}}{\text{Weight of dust fed}} \times 100 \quad (\text{Eq. 5})$$

3.21 Capacity—The quantity of contaminant removed and defined as follows:

3.22 Automobile Air Cleaners—The total weight GAIN in grams of the unit under test at the terminating restriction or pressure drop.

3.23 Industrial Air Cleaners—The total weight in grams of the test dust fed to the air cleaner to produce a specified terminating restriction or pressure drop.

3.24 Precleaners (Collection Type)—The total weight in grams of test dust collected when the dust collected reaches the recommended servicing level.

3.25 Standard Condition—All airflow measurements are to be corrected to a standard condition of 20 °C at 1013mbar (101.3 kPa).

3.26 Oil Carryover—The appearance of oil at the air cleaner outlet.

3.27 Units of Measurement—For the purpose of this test code, all airflow measurements will be expressed in cubic meters per minute (m³/min). All pressure measurements will be expressed in bar followed by kilopascals (kPa) and temperature measurements will be expressed in degrees Celsius.

3.28 Useful Equivalent Conversions

1 kPa = 4.019 in H₂O
 1 kPa = 0.2953 in Hg
 1 kPa = 0.1450 psi
 1 m³/h = 0.58858 cfm
 1 m/min = 3.2808 ft/min
 1 l = 61.024 in³
 1 in H₂O = 0.2488 kPa
 1 in Hg = 3.3865 kPa
 1 psig = 6.895 kPa
 1 cfm = 1.699 m³/h
 1 ft/min = 0.3048 m/min
 1 cfm = 0.028 316 8S m³/min
 1 bar = 100 kPa

4. Automotive Air Cleaner Test Procedures

4.1 General—The automotive air cleaner test code has been established to cover the dry type air cleaners generally used in automobiles. The air cleaners used in truck, off-highway, construction, and some industrial applications are classified as industrial types and are covered in Section 5. The oil bath air cleaner test code is covered in Section 6.

4.2 Test Equipment—To determine the resistance to airflow, contaminant holding capacity, contaminant removal characteristics, sealing characteristics, and rupture/collapse characteristics, use equipment described in Figures 1 to 6 (test setups).

4.2.1 Use a dust metering device, which when used with the dust injector with sufficient compressed air supply, is capable of metering dust over the range of delivery rates required. This dust feed system shall not change the primary particle size distribution of the contaminant. The average delivery rate shall be within 5% of the desired rate and the deviation in delivery rate from the average shall be no more than 5%. The recommended minimum supply pressure is 1 bar (100 kPa).

4.2.1.1 Validation of the Dust Feed System

4.2.1.1.1 Charge the dust metering device with a preweighed amount of dust.

4.2.1.1.2 Simultaneously start the dust feed system and timer.

4.2.1.1.3 At 5 min intervals, determine the weight of the dust dispensed. Continue the weight determinations of the dust increments for 30 min.

4.2.1.1.4 Determine the average delivery rate and the maximum deviation in delivery rate.

4.2.1.2 Use a dust transfer tube sized to maintain a minimum velocity of 914 m/min for dust suspension.

4.2.1.3 Use the dust injector described in Figure 8. The specified injector has been shown satisfactorily to feed test dust at rates up to 40 g/min. The injector is operated with a minimum supply pressure to the nozzle of 1 bar (100 kPa). It should be noted that the design of the system feeding test dust to the injector may affect this maximum rate of dust feed. Where dust feed rates greater than 40 g/min are required, the dust injector shown in Figure 16 shall be used.

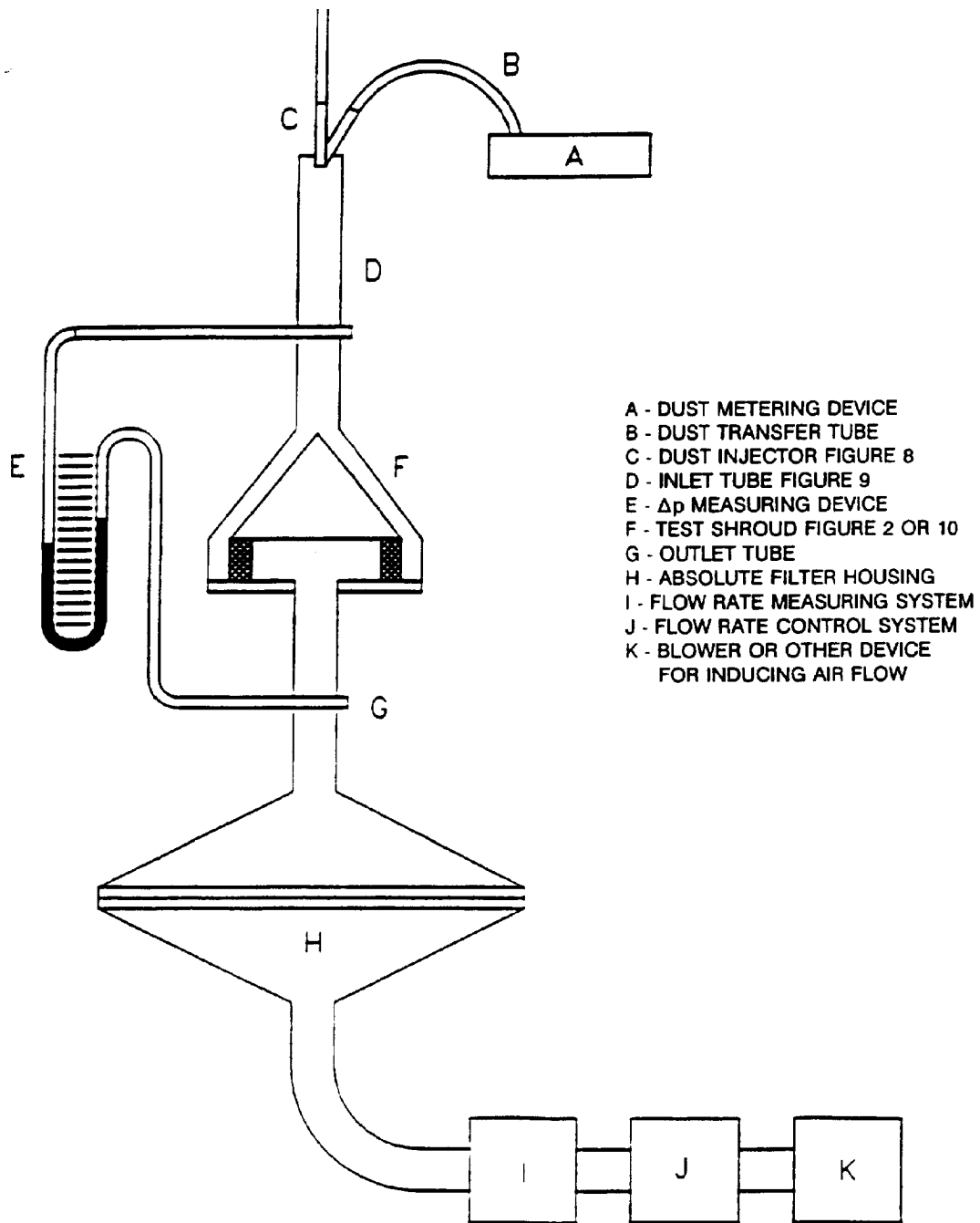


FIGURE 1—EFFICIENCY/CAPACITY AIR FILTER ELEMENT TEST SETUP

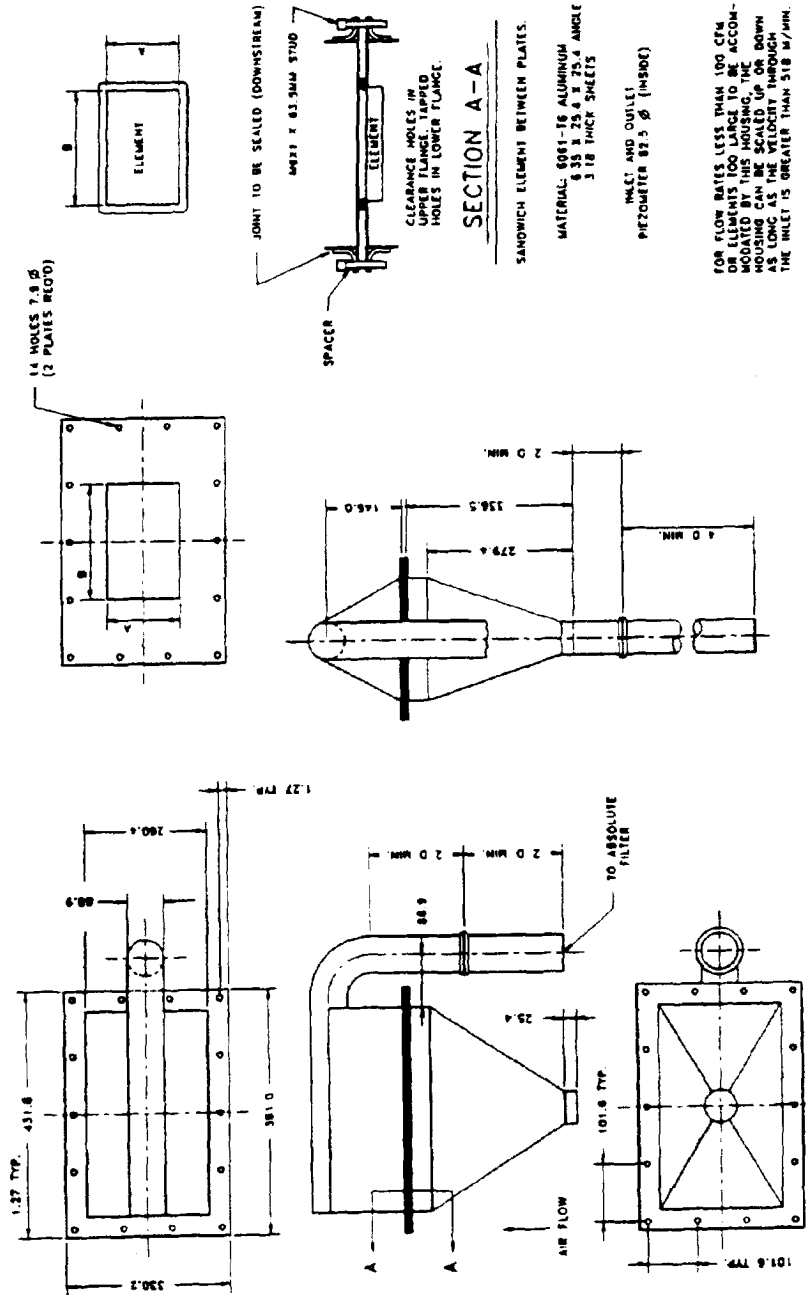


FIGURE 2—PANEL FILTER UNIVERSAL TEST HOUSING

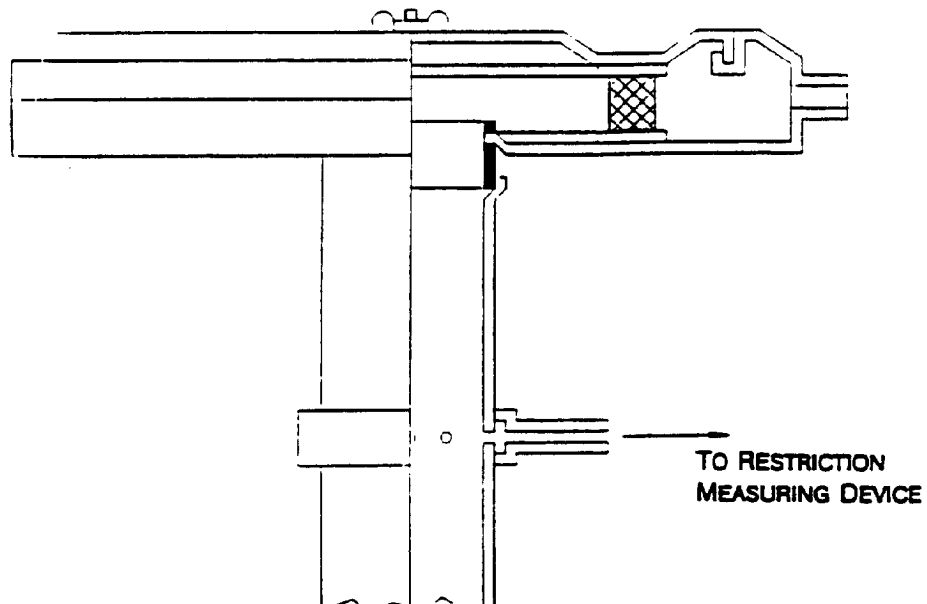


FIGURE 3—AIR CLEANER ASSEMBLY RESTRICTION TEST SETUP

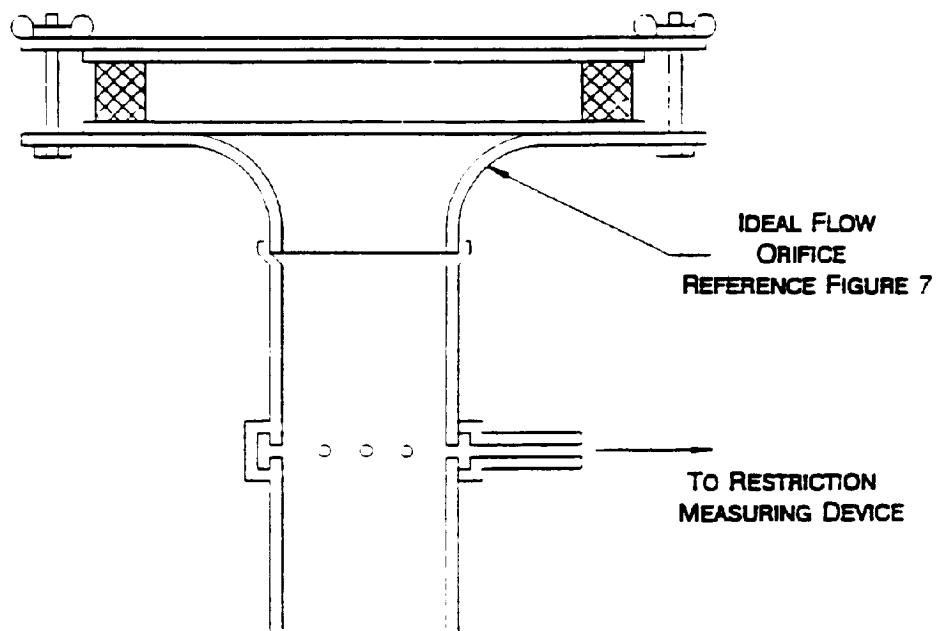


FIGURE 4—ELEMENT RESTRICTION TEST SETUP

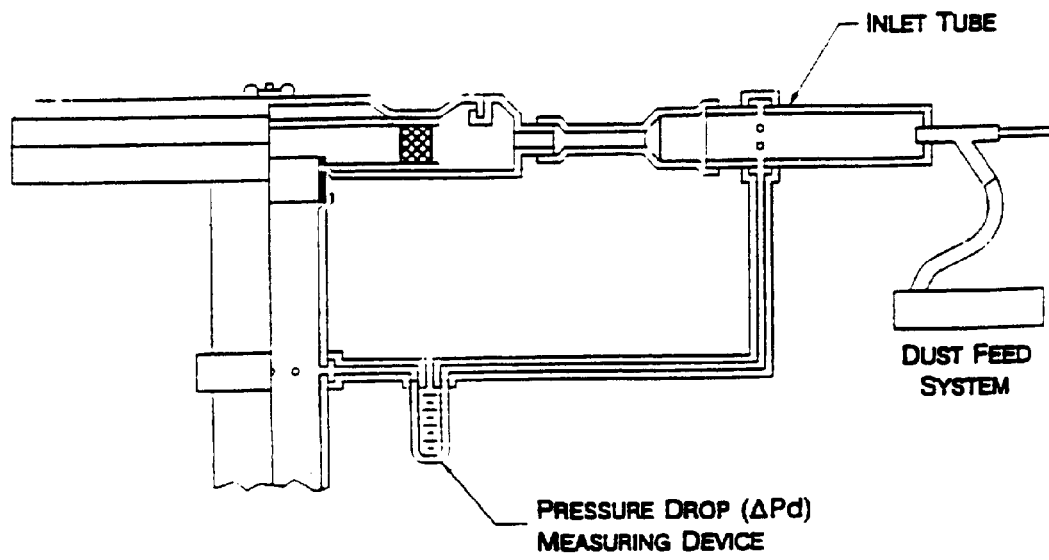


FIGURE 5—EFFICIENCY CAPACITY AIR CLEANER ASSEMBLY TEST SETUP

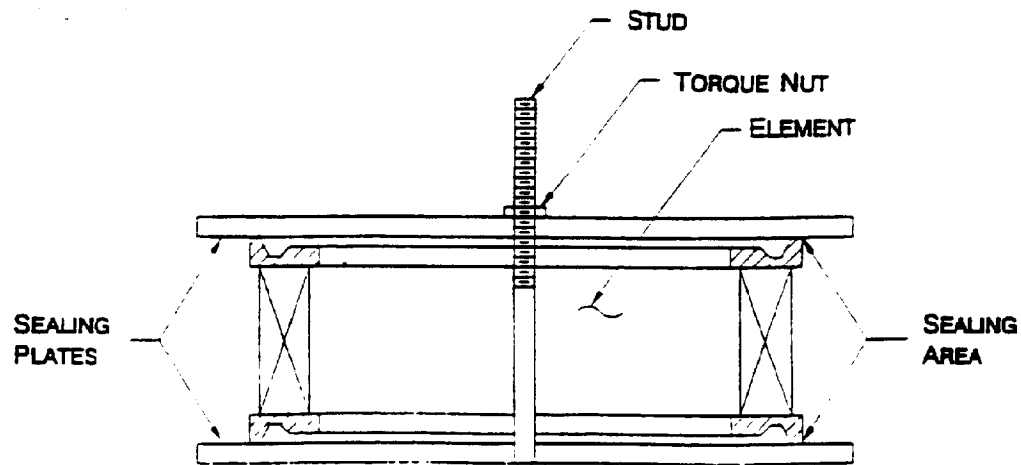


FIGURE 6—TEST ASSEMBLY

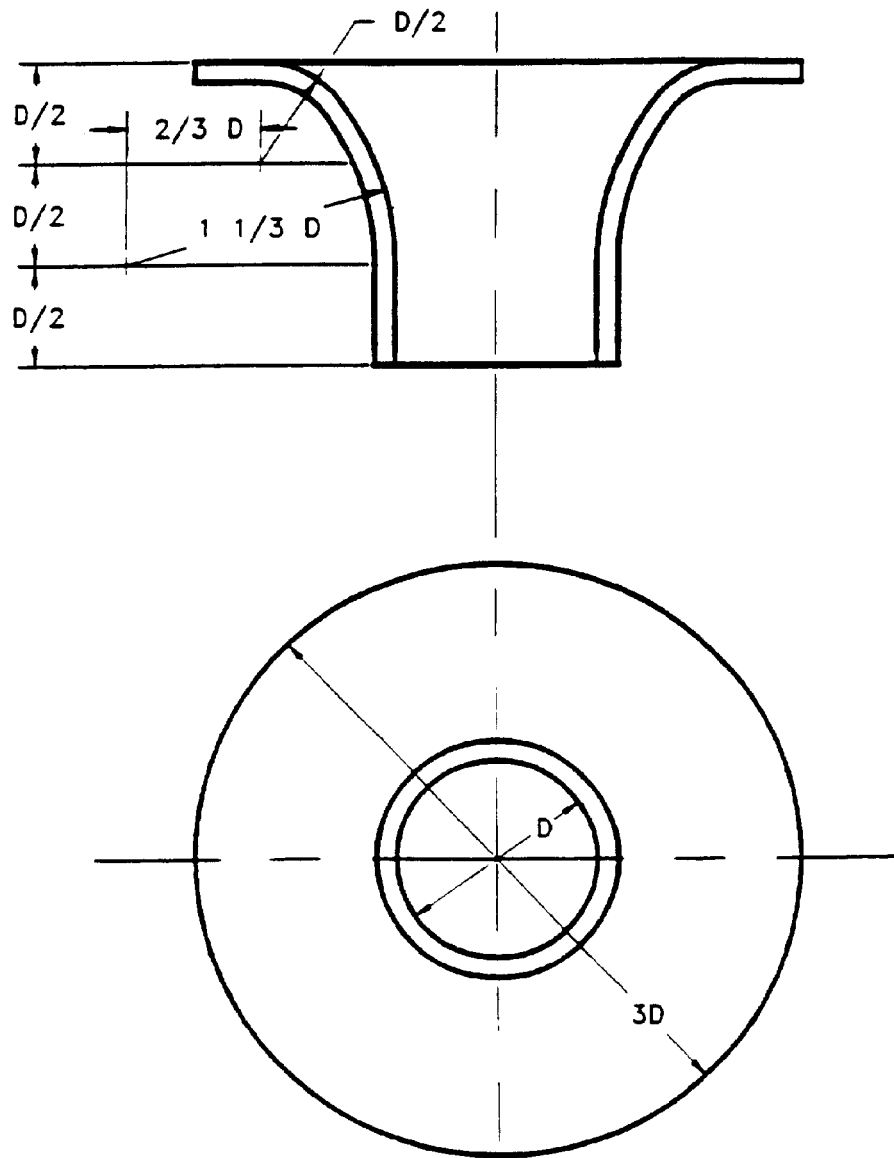
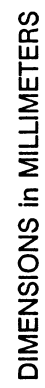


FIGURE 7—IDEAL FLOW ORIFICE



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