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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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Email: custsvc@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

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_2O_3	11 – 17
Fe_2O_3	2.5 – 5.0
Na_2O	2 – 4
CaO	3 – 6
MgO	0.5 – 1.5
TiO_2	0.5 – 1.0
V_2O_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 °C ± 5 °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/m^3. 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 °C ± 5 °C and a relative humidity of 55% ± 15%, the permissible variation at each weighing stage throughout each single test being ± 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:

r 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	$\Delta P_1 = \Delta P_r - P_{dynamic}$ $= P_2 - \frac{\rho \cdot V_2^2}{2}$	$\Delta P_1 = \Delta P_d - \Delta P_c$ $= \left(P_2 - P_1\right) - \frac{\rho}{2}(V_2^2 - V_1^2)$

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:

$$\Delta P_1 = P_r - P_{dynamic} \qquad \text{(Eq. 3)}$$

$$= P_2 - \frac{\rho \cdot V_2^2}{2}$$

where:

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

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

3.20 Industrial Air Cleaners

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

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 (m^3/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 H_2O
1 kPa = 0.2953 in Hg
1 kPa = 0.1450 psi
1 m^3/h = 0.58858 cfm
1 m/min = 3.2808 ft/min
1 l = 61.024 in^3
1 in H_2O = 0.2488 kPa
1 in Hg = 3.3865 kPa
1 psig = 6.895 kPa
1 cfm = 1.699 m^3/h
1 ft/min = 0.3048 m/min
1 cfm = 0.028 316 8S m^3/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.

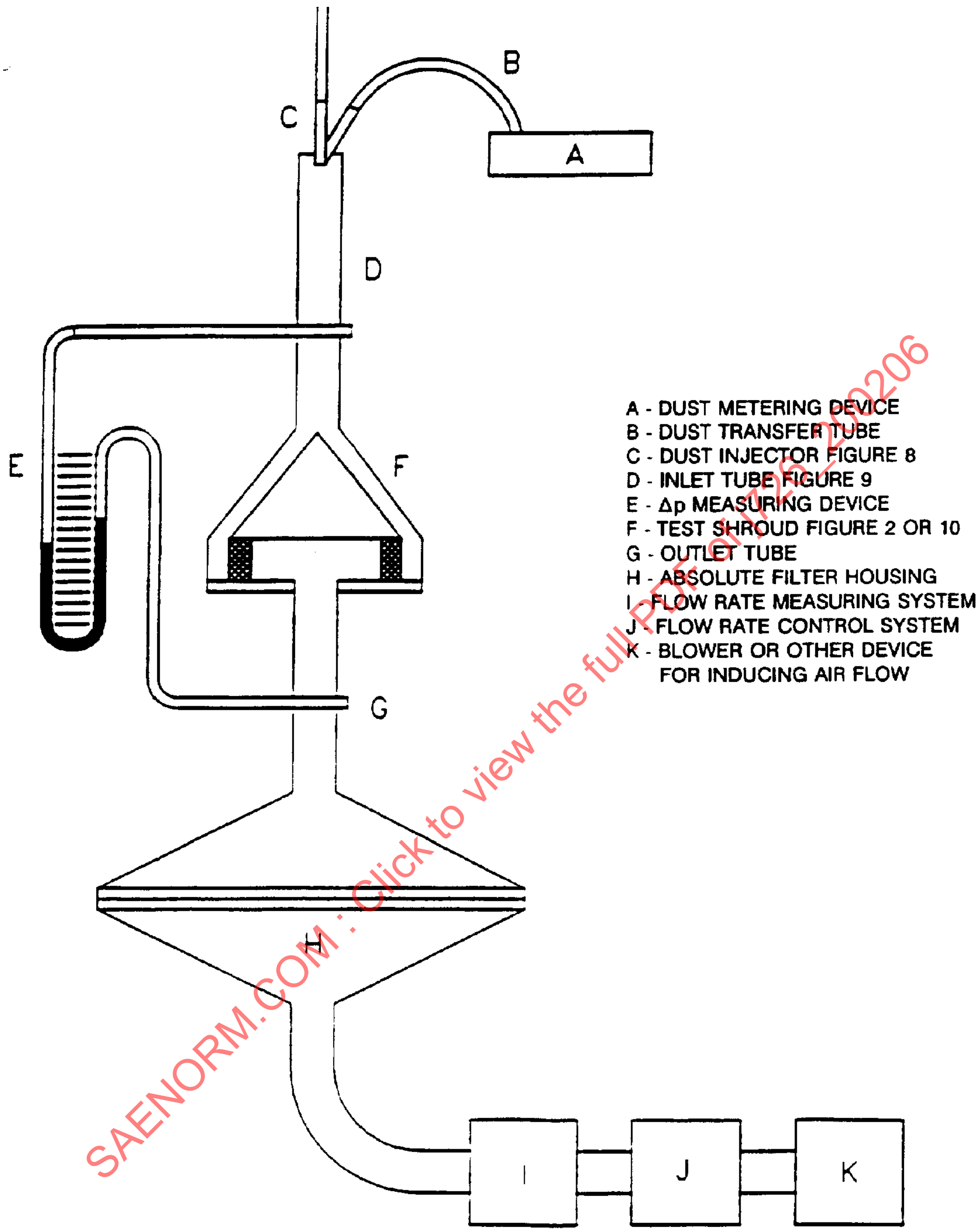


FIGURE 1—EFFICIENCY/CAPACITY AIR FILTER ELEMENT TEST SETUP

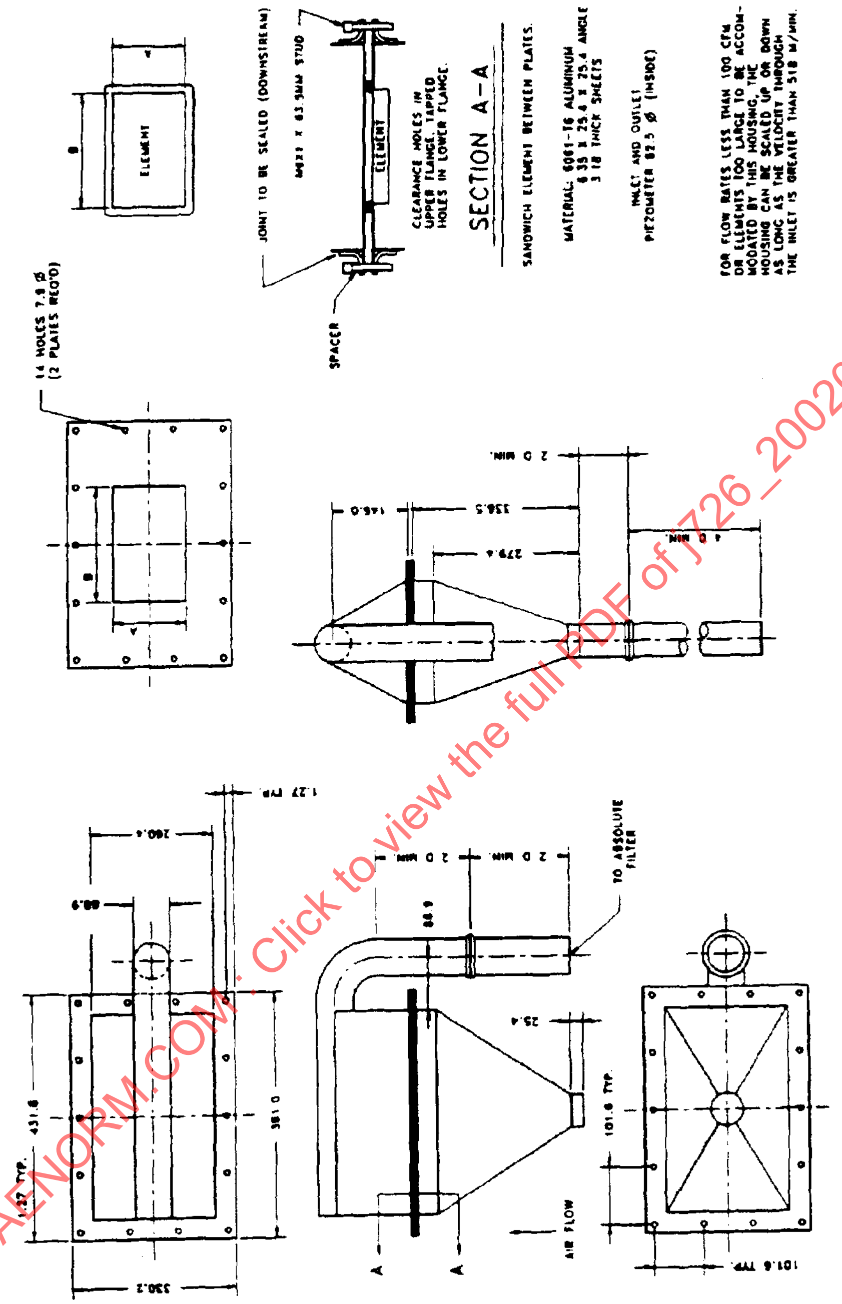


FIGURE 2—PANEL FILTER UNIVERSAL TEST HOUSING

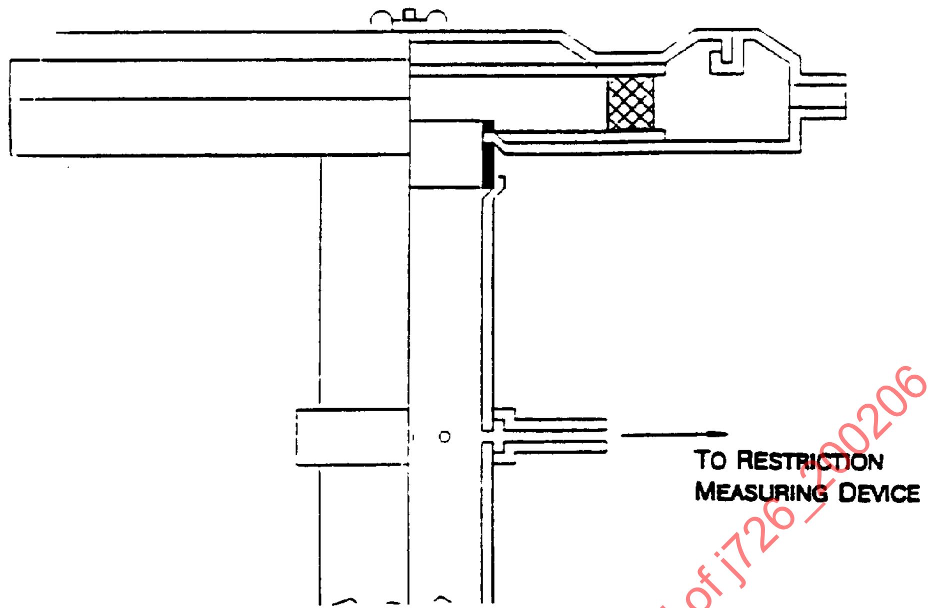


FIGURE 3—AIR CLEANER ASSEMBLY RESTRICTION TEST SETUP

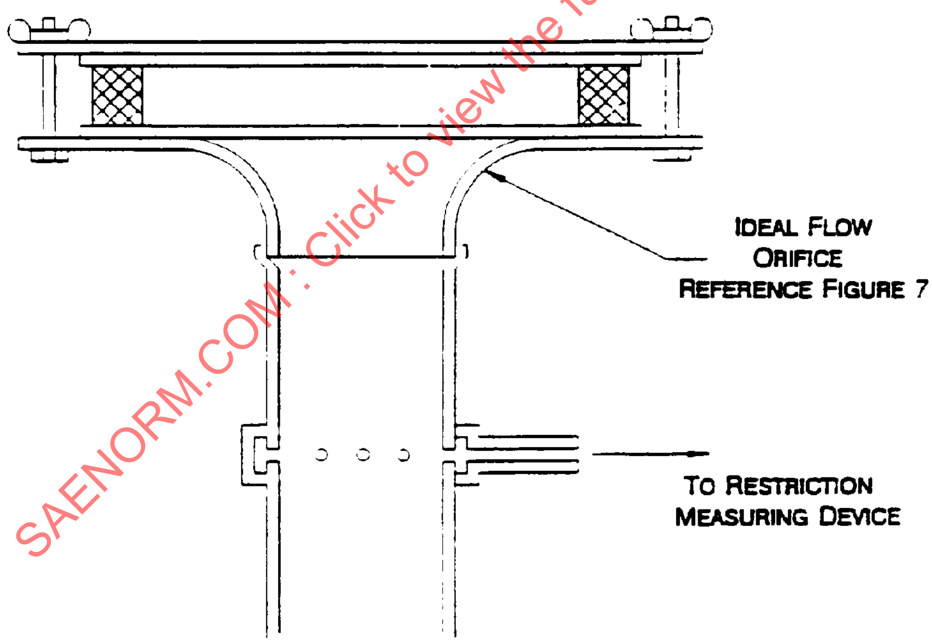


FIGURE 4—ELEMENT RESTRICTION TEST SETUP

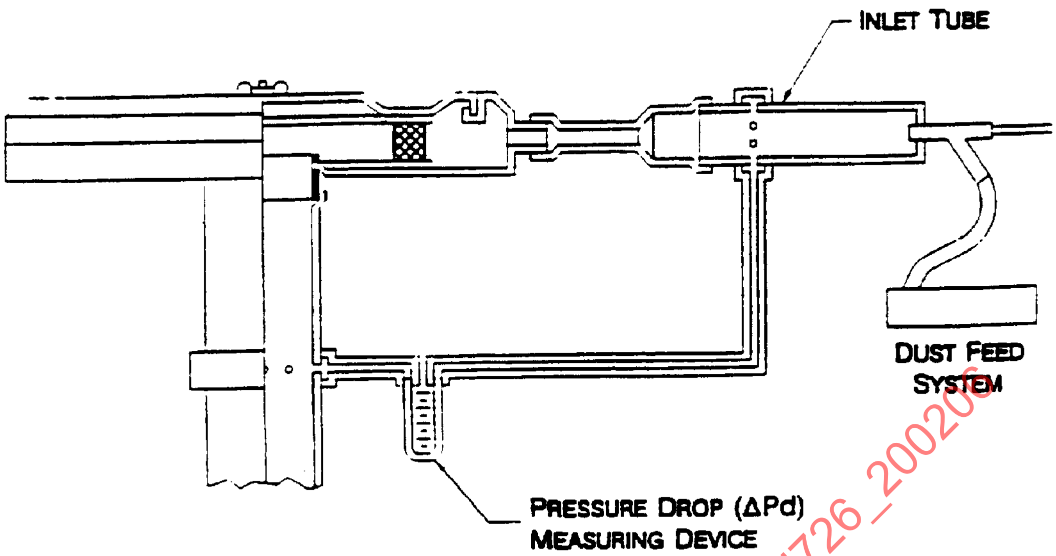


FIGURE 5—EFFICIENCY CAPACITY AIR CLEANER ASSEMBLY TEST SETUP

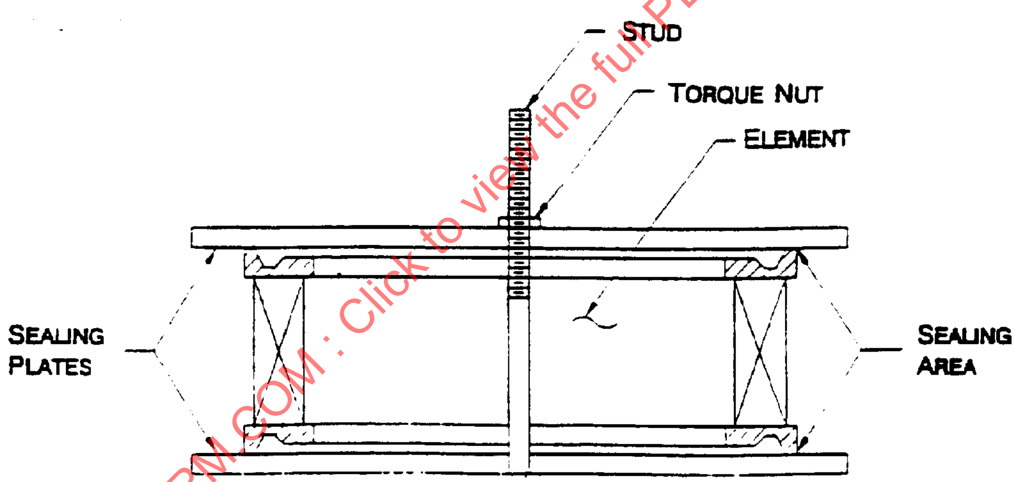


FIGURE 6—TEST ASSEMBLY

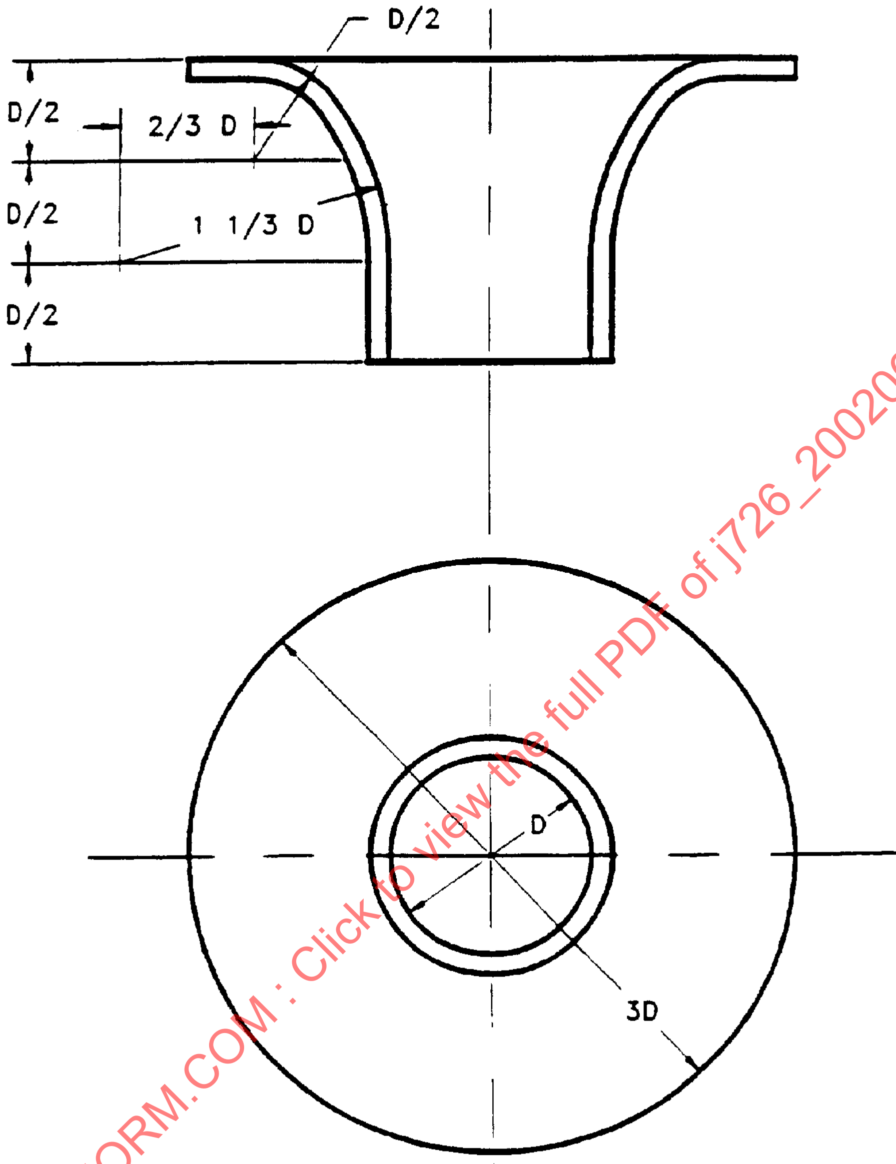


FIGURE 7—IDEAL FLOW ORIFICE

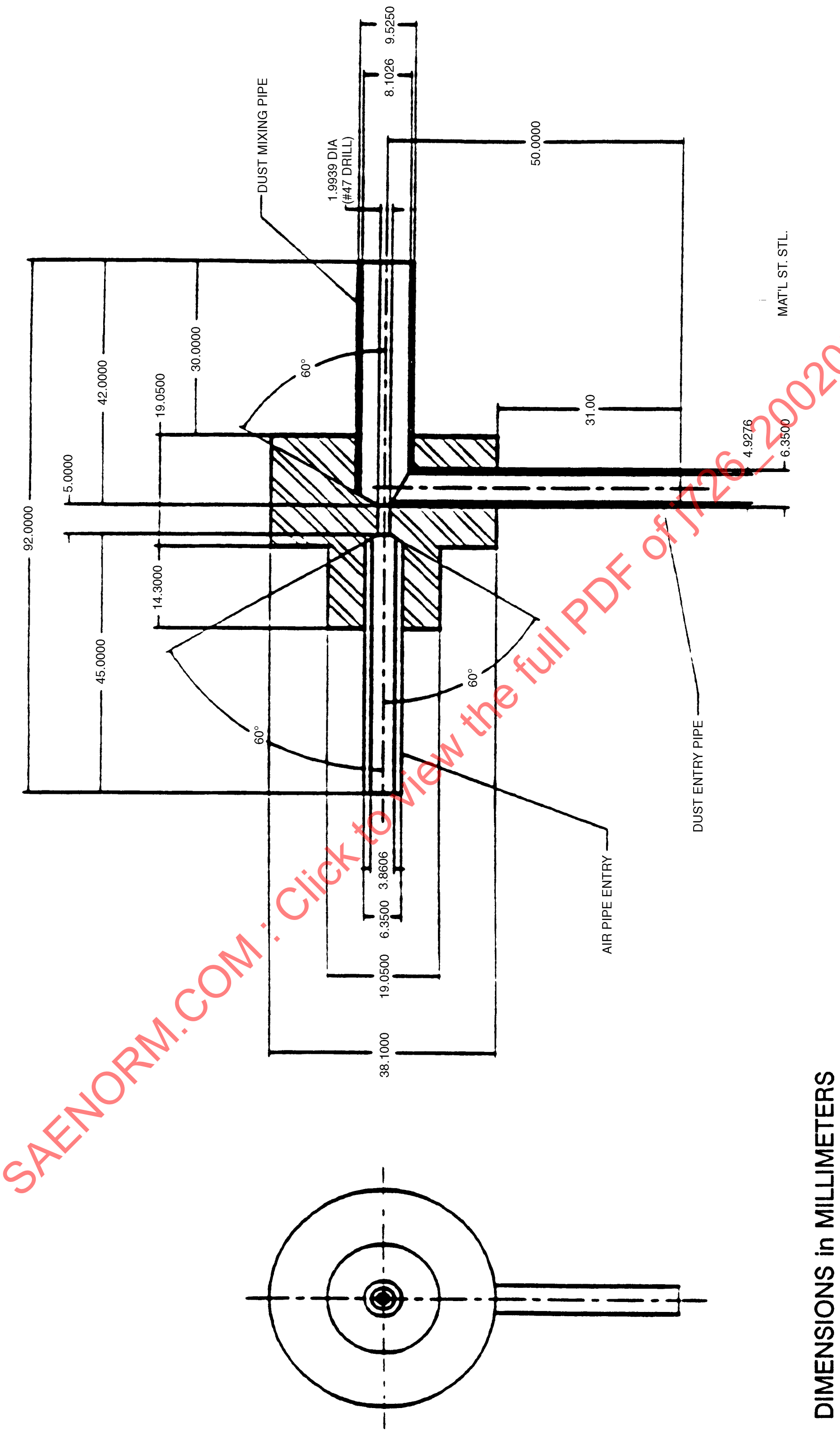
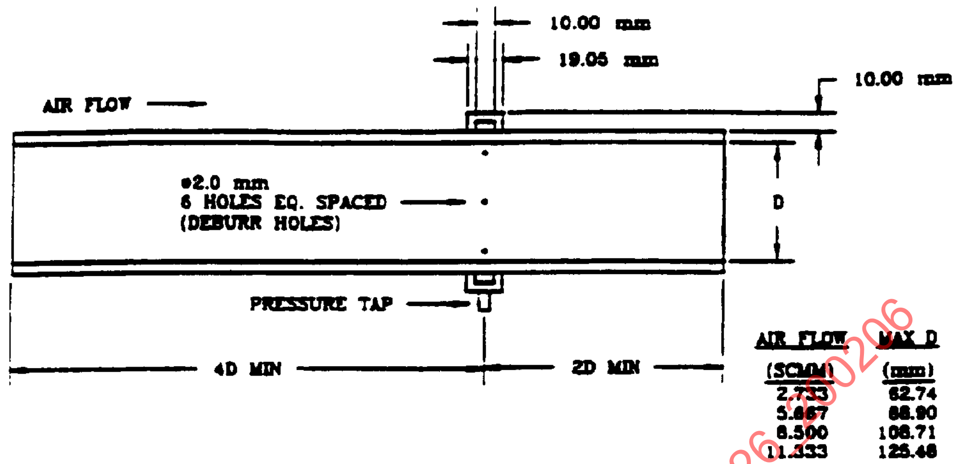


FIGURE 8—DUST INJECTOR FOR LIGHT-DUTY OR AUTOMOTIVE USE ONLY

4.2.1.4 Use an inlet tube conforming to Figure 9.



D to be such that air velocity is not less than 914.4 m/min for dust suspension.

For variable air flow cycle use the average test flow.

NOTE—Previous dimensions shown in J726 JUN87.

FIGURE 9—INLET TUBE

4.2.1.5 Use a manometer or other differential pressure measuring device with the accuracy described in 1.3.2.

4.2.1.6 For air filter element testing, use a test shroud conforming to Figure 2 or 10.

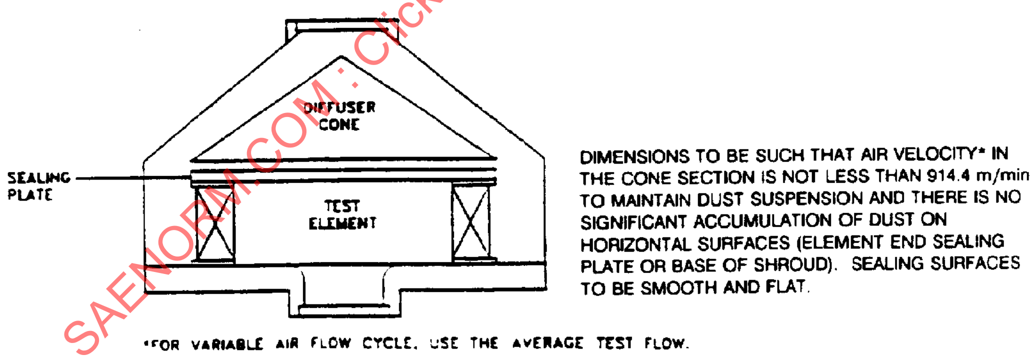


FIGURE 10—TEST SHROUD

4.2.1.6.1 For air cleaner assembly testing use a housing and setup agreed on by the supplier and user (Reference Figure 5).

4.2.1.7 Use an outlet tube conforming to Figure 9 except that the overall length is 4 diameters min (air velocity is not critical).

4.2.1.8 Use an absolute filter whose efficiency is a minimum of 99% for the contaminant presented to it and whose size is such that the air velocity through it does not exceed 50 m/min.

NOTE— Refer to 1.3 for materials that have been found to meet this validation requirement.

4.2.1.8.1 Validation of the absolute filter efficiency.

4.2.1.8.1.1 Weigh the absolute filters per 1.3.4.

4.2.1.8.1.2 Arrange two absolute filters in tandem.

4.2.1.8.1.3 Perform a filter efficiency test and determine the weight increase of each absolute filter.

$$\text{Absolute filter efficiency (\%)} = 1 - \frac{B}{A} \times 100 \quad \text{(Eq. 6)}$$

where:

A = Weight increase of upstream absolute filter
B = Weight increase of downstream absolute filter

4.2.1.9 Use an airflow rate measuring system having the accuracy described in 1.3.1.

4.2.1.9.1 Validate the airflow rate measuring system according to ASME Fluid Meters, Sixth Edition. The airflow meter shall be an accepted design, such as a calibrated orifice, traceable, once removed to a standard calibrating source. Corrections shall be made for variations in absolute pressure and temperature at the meter inlet and the airflow rate shall be expressed in cubic meters/min corrected at 20 °C at 1.103 bar (101.3 kPa).

4.2.1.10 Use an airflow rate control system capable of maintaining the indicated flow rate within 1% of the selected value during both the steady-state and variable airflow operation.

4.2.1.11 Use a suitable means for inducing the airflow through the system having sufficient flow rate and pressure characteristics for the filters to be tested. The pulsation of the flow rate shall be low enough so it is not measurable by the flow rate measuring system.

4.3 Airflow Restriction and Pressure Drop Test

4.3.1 The purpose of this test is to determine the static pressure drop across the unit under test, which will result when air is passed through under predetermined conditions.

4.3.2 Condition the unit to be tested at least 15 min under the temperature and humidity conditions equivalent to those in the test area. The tests should be performed at a temperature range of 23 °C ± 5 °C with a relative humidity range of 55% ± 15%.

4.3.3 For test unit restriction, set up a test stand as shown in Figure 2, 3, or 4. Seal all the joints to prevent air leaks. Connect the pressure taps.

4.3.4 Measure and record the static pressure drop versus the flow rate over the range of interest or as specified. A minimum of five readings at approximately 50%, 75%, 100%, 125%, and 150% of rated flow are recommended.

4.3.5 For tare restriction, use the setup shown in Figure 2, 3, or 4 without the air cleaner. Repeat 4.3.4.

NOTE— It is possible, due to inertial effects, for this value to be greater than the assembly restriction.

4.3.6 Determine the test unit net restriction by subtracting the values obtained in 4.3.5 from the values obtained in 4.3.4.

4.3.7 Record the data.

4.4 Efficiency Test

4.4.1 The purpose of this test is to determine the retention capabilities of the unit under test. This test can be conducted with either constant or variable airflow and with coarse dust or fine dust contaminant. If desired, the efficiency tests can be performed concurrently with 4.5.

4.4.2 Three types of efficiency tests can be performed. These are:

4.4.2.1 Full life efficiency determined when terminating pressure drop (ΔP_d) is reached.

4.4.2.2 Incremental efficiency is determined at 10, 25, and 50% of the terminating pressure drop (ΔP_d) minus the initial pressure drop (ΔP_d).

4.4.2.3 The initial efficiency is determined after the addition of 20 g of contaminant or the number of grams numerically equivalent to 0.0973% of the test airflow in SCMH, whichever is greater.

4.4.3 The determination of efficiency at constant test airflow can be performed at the rated airflow or any percentage thereof as agreed on by the user and supplier.

4.4.3.1 Based on the test flow, calculate the dust contaminant feed rate using a dust concentration of 1.0 g/m^3 of air: in special cases (e.g., small filters) 0.25 and 0.50 g/m^3 may be allowed.

4.4.3.2 Condition the unit under test according to 4.3.2 and then weigh, in grams, to within 1% of the actual value.

4.4.3.3 Weigh the absolute filter per 1.3.4.

4.4.3.4 Set up the test stand as shown in Figure 1 or Figure 11 for air filter elements. Seal all of the joints to prevent air leaks.

NOTE— The panel filter elements can be tested with a setup similar to Figure 1 using the panel filter test housing from Figure 2.

4.4.3.5 Record the temperature and relative humidity.

4.4.3.6 Weigh out the specified test dust equal to 125% of the estimated capacity of the test unit. Record the weight to the nearest 0.1 g and place in the dust metering device.

4.4.3.7 Weigh and record the dust feed system with dust, in grams, to within 1% of the actual value.

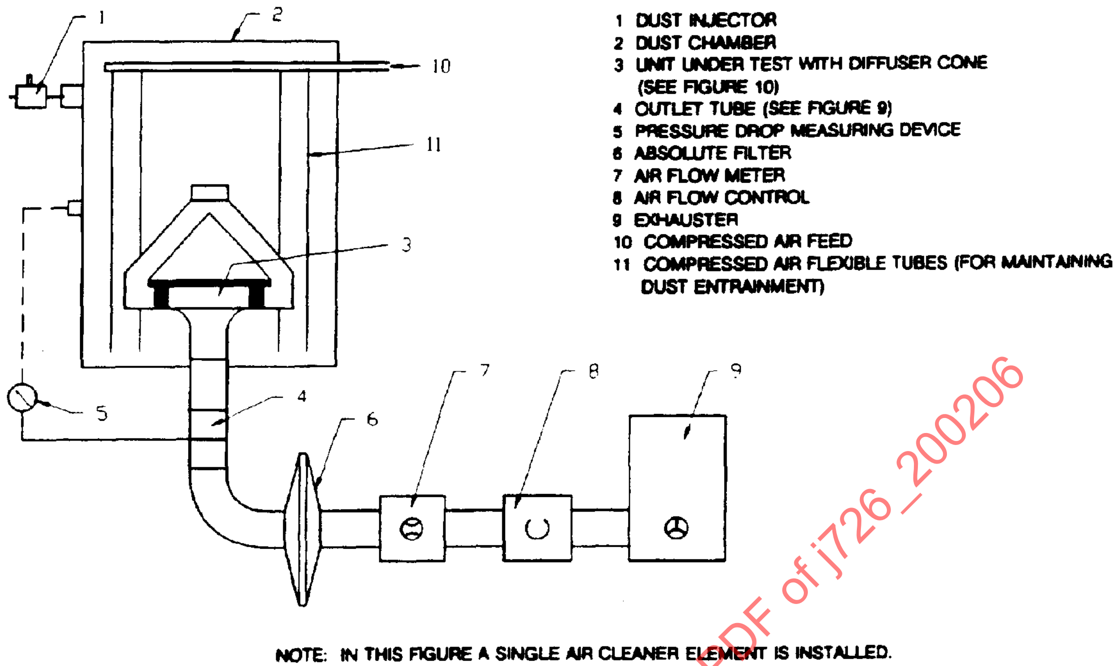


FIGURE 11—EFFICIENCY/CAPACITY TEST SETUP USING A DUST CHAMBER

4.4.3.8 Start the airflow through the stand and stabilize at the test flow. Record the pressure drop (ΔP_d).

4.4.3.9 Set the flow rate to that at which the test dust is to be added if this is different from the test flow rate used in 4.4.3.8.

4.4.3.10 Start the dust feeder and adjust the feed rate to inject dust at the concentration calculated in 4.4.3.1.

4.4.3.11 At prescribed time intervals (a minimum of five points is recommended), record the pressure drop (ΔP_d) at test flow and elapsed test time.

4.4.3.12 Continue the test until the terminating pressure drop is reached.

4.4.3.13 Repeat 4.4.3.5.

4.4.3.14 Repeat 4.4.3.7 and determine the difference in weight. This amount is the dust fed.

4.4.3.15 Carefully remove the unit under test without losing any dust. Note any evidence of seal leakage or any unusual conditions. Weigh, in grams, to within 1% of the actual value. The increase in weight of the unit under test is this weight minus the weight determined in 4.4.3.2.

4.4.3.16 Brush any observed dust on the downstream side of the test unit onto the absolute filter. Carefully remove the absolute filter. Repeat 4.4.3.3 and determine the difference in weight. This is the increase in weight of the absolute filter.

4.4.3.17 Calculate the material balance of the test dust. This value must be within the range of 0.98 to 1.02 to be a valid test.

$$\text{Material balance of test dust} = \frac{\text{Increased weight of absolute filter} + \text{Increased weight of unit under test}}{\text{Total weight of dust fed}} \qquad \text{(Eq. 7)}$$

4.4.3.18 Calculate the efficiency by the following method:

$$\text{Efficiency, \%} = \frac{\text{Increase in weight of unit under test}}{\text{Increase in weight of unit under test} + \text{Increase in weight of the absolute filter}} \times 100 \quad \text{(Eq. 8)}$$

4.4.4 Variable airflow efficiency can be determined by using a variable airflow cycle similar to Figure 12. In the case of large air cleaners (e.g., flow rate > 5 m^3/min), the duration of every partial flow section may be 5 min instead of 1 min.

4.4.4.1 Based on the average test flow for the cycle being used, calculate the dust feed rate as in 4.4.3.1. The dust feed rate should remain constant.

4.4.4.2 All pressure drop determinations are to be made at the maximum airflow.

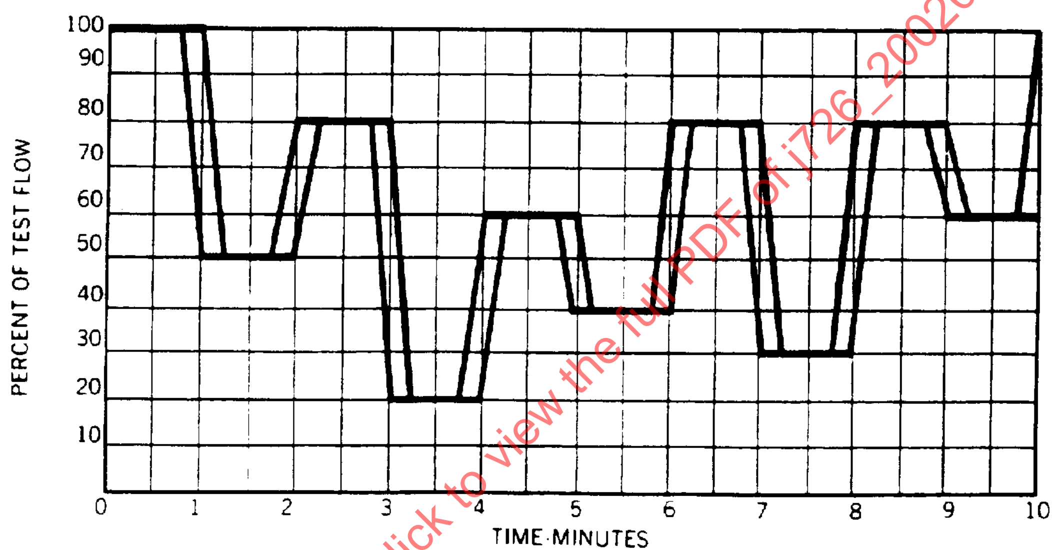


FIGURE 12—TYPICAL VARIABLE FLOW CYCLE AVERAGE FLOW 60%

4.4.4.3 Perform the test as in 4.4.3 using variable airflow in place of the constant airflow; however, with the following changes:

After the end of each cycle the pressure drop shall be determined at the maximum flow. The efficiency shall be determined at least after 3 cycles if the duration of partial flow section is 1 min, and after every cycle if the duration of partial flow section is 5 min, and after the end of test.

4.5 Capacity Test

4.5.1 The purpose of this test is to determine the total weight gain of the unit under test at the terminating pressure drop. This test can be conducted with either constant or variable airflow and with coarse or fine test dust contaminant. If desired, capacity determination can be performed concurrently with 4.4.

4.5.2 Perform the test as described in 4.4.3.1 through 4.4.3.15.

4.5.3 Assuming a constant ratio of elapsed time versus weight gain of the test unit, plot curve of restriction versus weight gain. Refer to 4.4.3.11 for restriction and time interval data. Use the following formula to determine the weight gain values:

$$\text{Weight gain at end of each time interval} = \frac{\text{Total time to end of interval}}{\text{Total time to end of test}} \times \text{Total weight gain of unit under test} \quad \text{(Eq. 9)}$$

4.5.4 The capacity of the test unit is the point at which the curve reaches the terminating restriction. This restriction does not include the restriction added by the dust metering device and test shroud.

4.6 Flow Pressure Collapse Test

4.6.1 The purpose of this test is to determine the ability of an air filter element to withstand a specified differential pressure and/or the differential pressure at which collapse occurs.

4.6.2 Set up the test stand to perform the basic dust capacity test as per Figure 1 or 5, or Figure 1 with modification for panel filter test housing (Figure 2). An element from a prior capacity or efficiency test or a new element can be used for this test.

4.6.3 Increase the airflow through the stand and, if necessary, feed dust at any convenient rate until the specified pressure drop (ΔP_d) is reached or the element collapse is evidenced by any decrease in pressure drop (ΔP_d) or increase in airflow.

4.6.4 Record the maximum pressure drop (ΔP_d) attained, the reason for the terminating test, and the condition of the element after the test.

4.7 Seal Effectiveness Test

4.7.1 The purpose of this test is to determine the seal effectiveness of the air filter elements.

4.7.1.1 Locate the filter element between the two transparent plates as shown in Figure 6 and torque to specified requirements.

4.7.1.2 Check visually for any irregularities or voids in the seal area. Proper sealing can normally be identified by a dark or wet appearance continuous through the sealing contact area.

4.7.1.3 Report and comment on the seal quality and the torque required to effect a seal.

4.8 Temperature Extreme Test

4.8.1 The purpose of this test is to determine the effectiveness of the air filter to withstand temperature extremes.

4.8.2 Locate the filter element between the two temperature resistance plates as shown in Figure 6 and torque to specified requirement.

4.8.3 Subject the assembly to the specified hot and cold cycle. In absence of the specific values, the following is recommended:

24 h at 121 °C ± 3 °C
24 h at –40 °C ± 3 °C
24 h at 121 °C ± 3 °C
24 h at –40 °C ± 3 °C

Allow the unit under test to adjust to room temperature between cycles.

4.8.4 After the test cycle, allow to adjust to room temperature. Remove the plates and inspect the element for conditions that will impair performance. If necessary, repeat 4.4.

4.8.5 Report all conditions of the test and visual observations.

4.9 Presentation of Data

4.9.1 The purpose is to standardize a test data reporting form. Refer to Figure 13.

5. Industrial Air Cleaner Test Procedures

5.1 General

5.1.1 This section of the air cleaner test code has been established to cover dry type air cleaners generally used in heavy trucks, construction equipment, agricultural tractors, and industrial applications. Air cleaners used in automobiles are classified as automotive and are covered in Section 4. The oil bath air cleaner test code is covered in Section 6.

5.1.2 The performance tests shall be performed on a precleaner or a complete air cleaner including precleaner, primary element, and secondary element, if normally provided. The tests shall consist of an airflow restriction/pressure drop test, an initial efficiency test, and a combined efficiency and dust capacity test.

5.1.3 TEST DUST AND CONCENTRATION—It is difficult, if not impossible, to select a test dust size distribution and concentration which will be representative of all service conditions. Therefore, based on primarily practical considerations, the different types of air cleaners have been classified as to their most probable service conditions, and the test dust grade and concentration selected accordingly. See Table 6.

TABLE 6—INDUSTRIAL AIR CLEANER RECOMMENDED DUST SELECTION AND CONCENTRATION

Air Cleaner Type	Test Dust	Concentration
Single Stage	Coarse or Fine	1 g/m^3
Multistage	Coarse or Fine	2 g/m^3
Precleaner	Coarse	2 g/m^3

TEST UNIT DESCRIPTION ______________________ DATE ____________

MANUFACTURED ______________ TEST CONDUCTED BY __________ EQUIPMENT NO. __________

TEST CONDITIONS

RATED AIR FLOW ______ scmh TEST AIR FLOW ______ scmh STEADY ______ VARIABLE ______

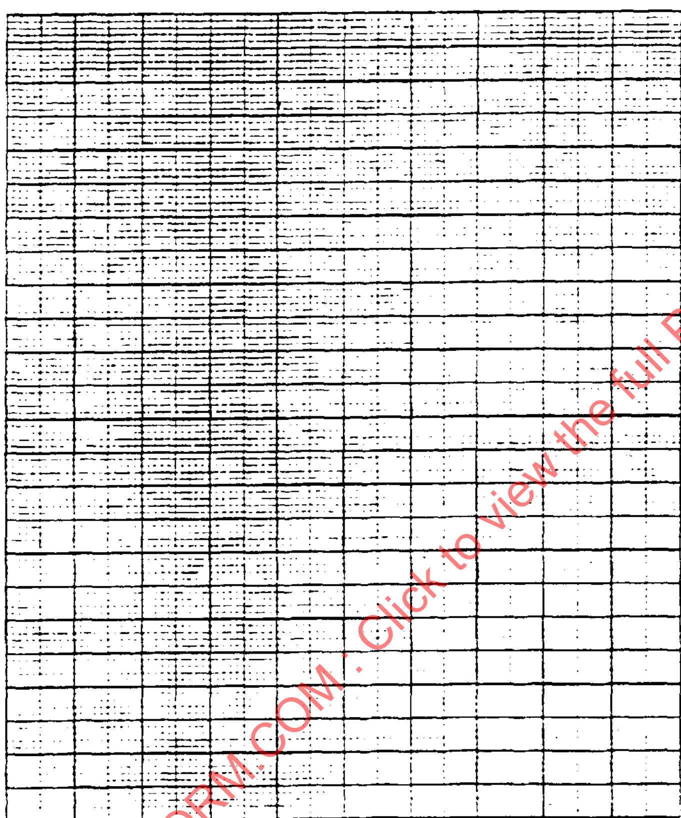
TEST DUST: Fine ____ Coarse ____ BATCH NO. __________ TERMINATING RESTRICTION OR PRESSURE DROP __________

RELATIVE HUMIDITY BEFORE TEST ________ % AFTER TEST ________ %

BAROMETRIC PRESSURE BEFORE TEST ________ kPa AFTER TEST ________ kPa

TEMPERATURE BEFORE TEST ________ °C AFTER TEST ________ °C

TEST RESULTS



FULL LIFE EFFICIENCY __________ %

INITIAL EFFICIENCY

__________ % __________ g

INCREMENTAL EFFICIENCY AT PER CENT OF TERMINATION

@ 10% Eff. __________ %

@ 25% Eff. __________ %

@ 50% Eff. __________ %

INITIAL RESTRICTION

__________ kPa @ __________ scmh

(See Graph)

CAPACITY

g __________ to __________ kPa

(See Graph)

MATERIAL BALANCE FOR VALIDATION OF TEST __________

FLOW PRESSURE COLLAPSE REMARKS

____

SEAL TEST REMARKS

____

TEMPERATURE EXTREME TEST

Hours each __________

Hot __________ °C Cold __________ °C

Times Repeated __________

Remarks __________

GENERAL COMMENTS __________

FIGURE 13—TEST DATA REPORTING FORM SECTION 3—AUTOMOTIVE AIR CLEANERS

5.2 Test Equipment

5.2.1 TEST DUCT—The test duct shall consist of the following major components and be arranged as shown in Figure 14.

a. Dust feeder
b. Dust injector
c. Dust mixing duct with piezometer ring
d. Air cleaner and/or precleaner under test
e. Downstream piezometer tube
f. Absolute filter
g. Airflow meter
h. Scavenge airflow meter (if required)
i. Scavenge filter (if required)

5.2.2 DUST FEEDING SYSTEM—The dust feeding system shall consist of a dust feeder and a compressed air operated dust injector. The dust feeder shall feed the test dust at a continuous and uniform rate and the quantity fed shall be determined by weight measurement to the nearest 0.1 g. The open tray type dust feeder as shown in Figure 15 is recommended, but other types are optional.

The purpose of the dust injector is to effect a consistent high degree of dust dispersal and shall not change the particle size distribution of the contaminant. Use the dust injector described in Figure 16.

The dust injector must be located 25 mm from the end and on the centerline of the inlet or dust mixing duct.

5.2.3 UPSTREAM DUST MIXING DUCT

5.2.3.1 Tubular Air Cleaner Inlet—The cross-sectional area of the dust mixing duct and upstream piezometer tube shall be the same as the air cleaner inlet. The overall length shall be six diameters with the piezometer ring placed four diameters for the duct inlet Figure 14. For concentrated inlets of noncircular area, use a transition to a circular area and treat as a tubular inlet.

5.2.3.2 Rectangular or Open Face Inlet—Same as 5.2.3.1, except the overall length and placement of the piezometer shall be 24 and 16 times the hydraulic radius, respectively. (Hydraulic radius = area ÷ perimeter.)

5.2.3.3 Peripheral Air Inlet or Stack Type Precleaners—The peripheral air inlet or stack type precleaners shall be tested in a chamber which ensures the even distribution and delivery of test dust to the inlet of the unit. Care should be taken in the design of the chamber to ensure that all the test dust is fed to the unit under test. If dust settling occurs, then compressed air jets may be used to re-entrain the test dust. Typical examples of chambers are shown in Figure 17.

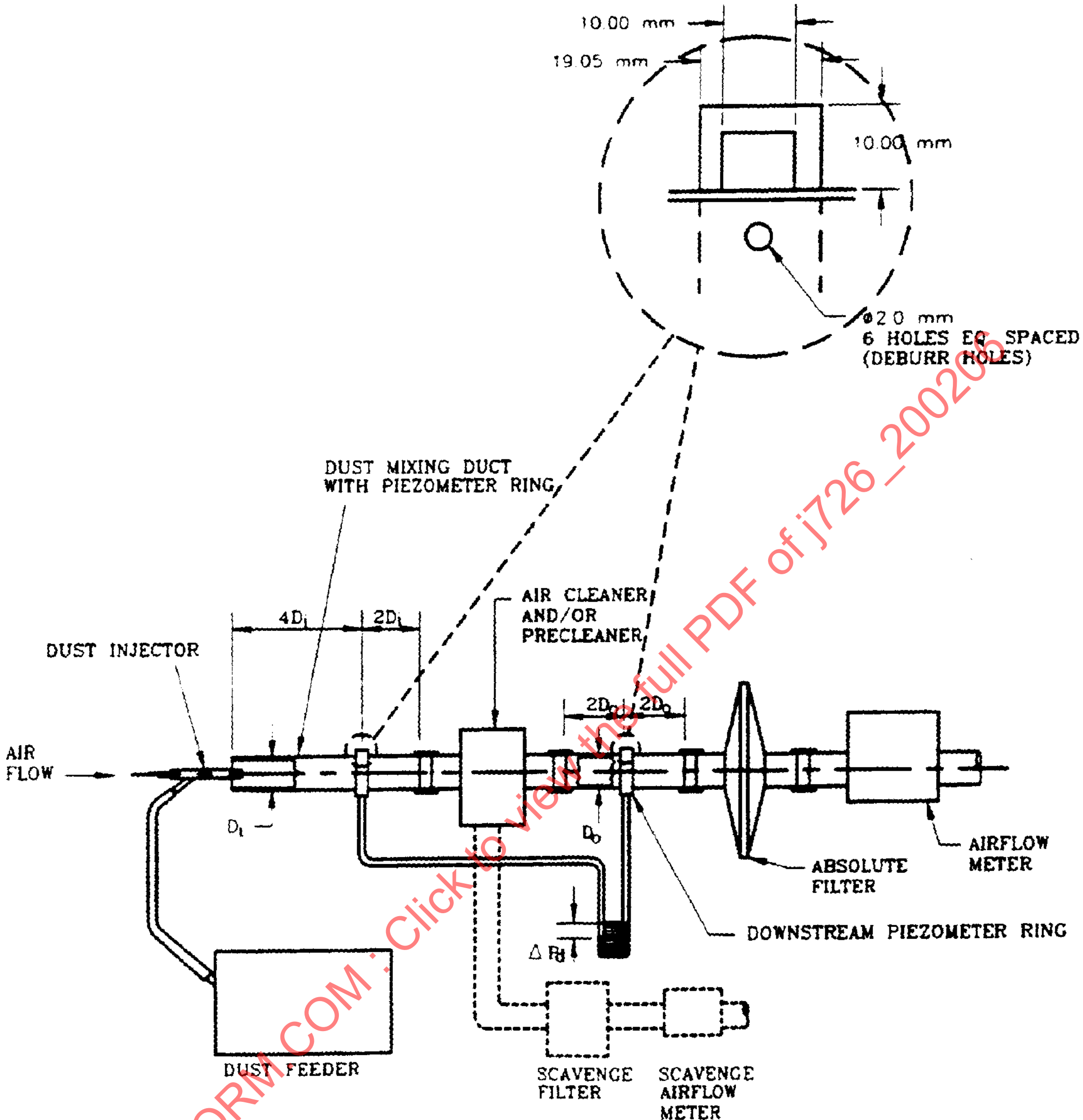


FIGURE 14—TUBULAR INLET AIR CLEANER TEST DUCT ASSEMBLY

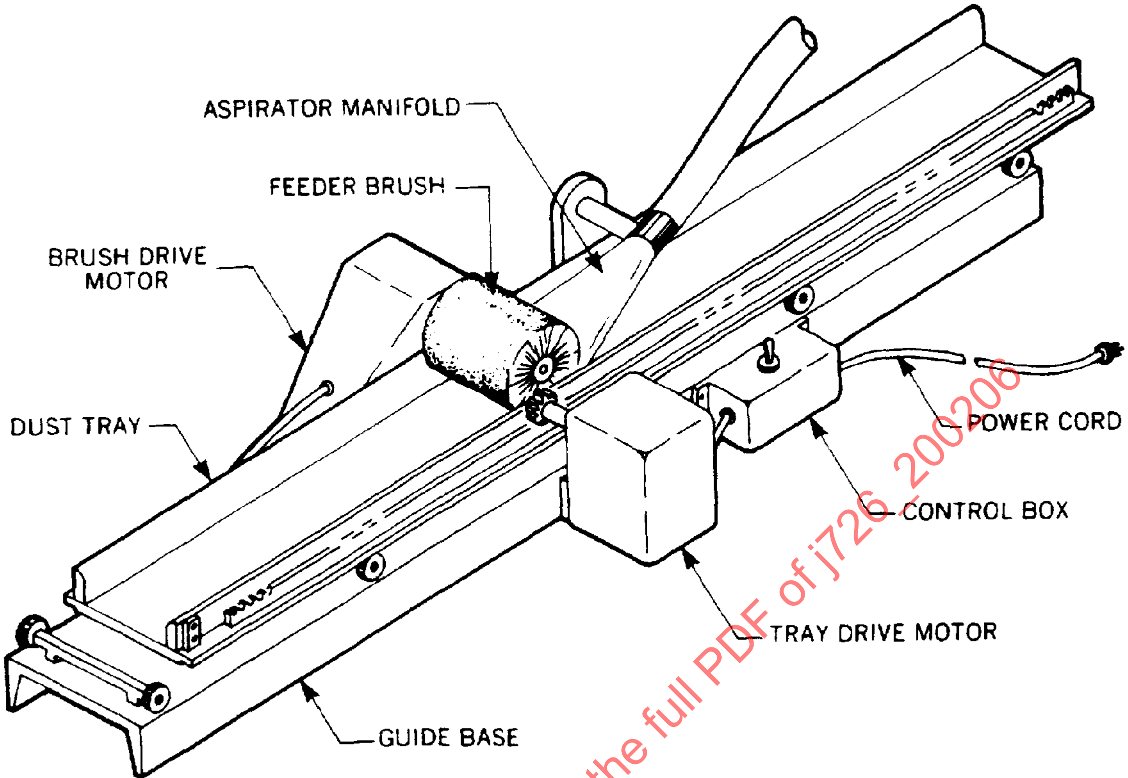
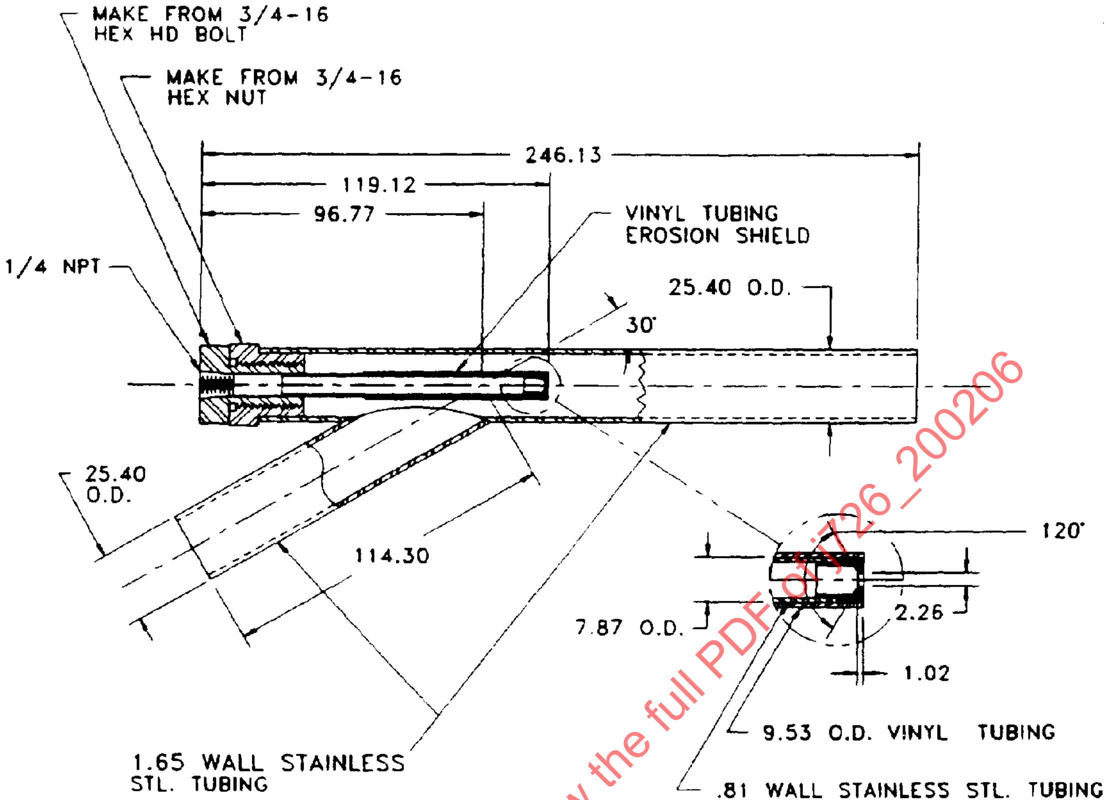


FIGURE 15—DUST FEEDER



MAXIMUM TEST AIRFLOW PER INJECTOR*	
AIR CLEANER TYPE	
SINGLE STAGE	MULTI-STAGE
3400 m3/h	1700 m3/h

*BASED ON MAX. DUST FEED RATE OF 50 g/min.

FIGURE 16—DUST INJECTOR FOR HEAVY-DUTY OR INDUSTRIAL USE ONLY

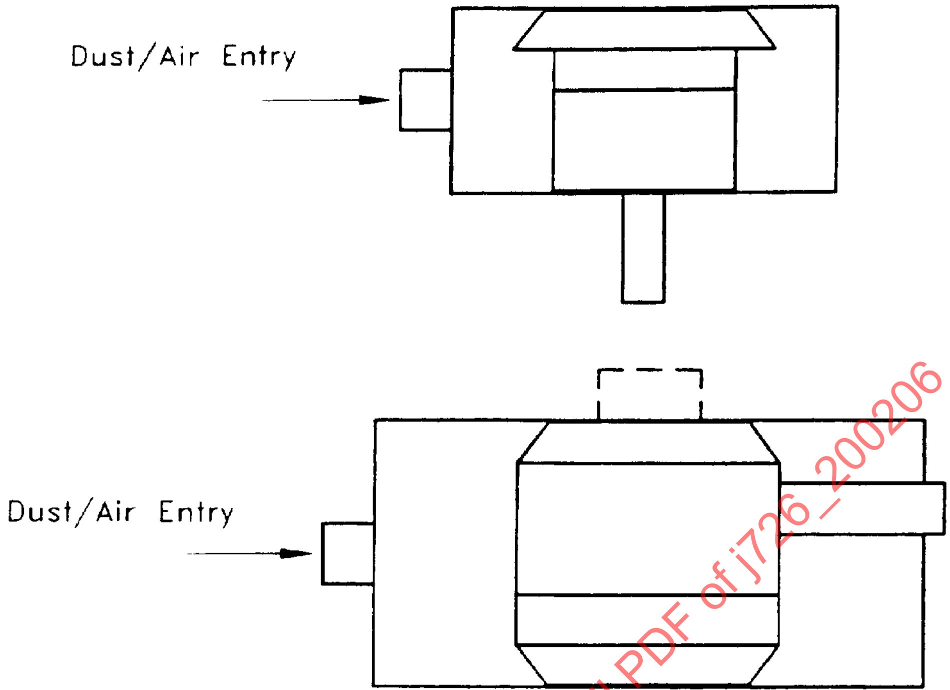


FIGURE 17—NONTUBULAR INLET AIR CLEANER TEST CHAMBER ASSEMBLIES

When using compressed air for agitating dust, care should be taken not to eject dust out of the chamber. To ensure that no dust is ejected, a negative pressure should be maintained between the chamber interior and the atmosphere.

5.2.4 DOWNSTREAM PIEZOMETER—The inside diameter of the downstream piezometer shall be the same as the air cleaner outlet tube. (See Figure 14.)

5.2.5 ABSOLUTE FILTER—The absolute filter shall contain the material specified in 1.3.3.

5.2.6 AIRFLOW METER—The airflow meter shall be calibrated annually to assure a known accuracy of ± 2%, by using a flow meter conforming to the construction set forth in ASME Fluid Meters, Sixth Edition.

5.3 Airflow Restriction and Pressure Drop Test

5.3.1 The purpose of this test is to determine restriction/pressure drop/pressure loss across the unit under test which results when air is passed through under predetermined conditions. Airflow restriction or pressure drop (see 3.9) is measured with a clean filter element, or elements, at five equally spaced airflows between 50 and 150% of rated airflow or as agreed upon between the user and the manufacturer.

5.3.2 AIRFLOW RESTRICTION (ΔP_R)

5.3.2.1 Set up the air cleaner per Figure 18.

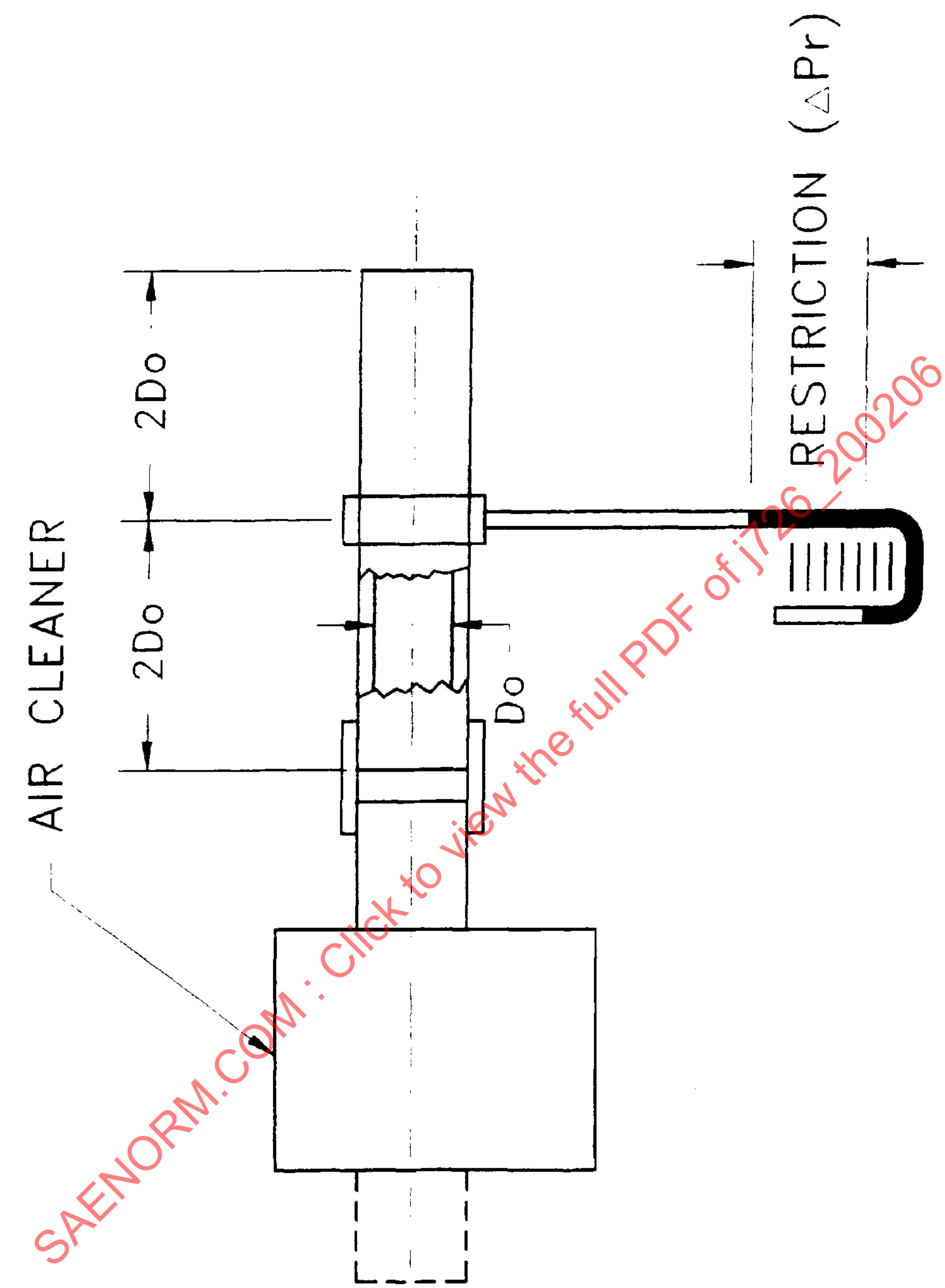


FIGURE 18—RESTRICTION TEST SETUP

5.3.2.2 Record the downstream static gage pressure at 50%, 75%, 100%, 125%, and 150% of rated airflow.

5.3.2.3 Record the ambient temperature, pressure, and relative humidity.

5.3.2.4 Correct the recorded restriction values to standard conditions per Appendix C and plot as shown in Figure 19 indicating restriction on ordinate.

5.3.3 PRESSURE DROP (ΔP_D)

5.3.3.1 Set up the air cleaner per Figure 20.

5.3.3.2 Record the difference in static pressure measured upstream and downstream of the air cleaner at 50%, 75%, 100%, 125%, and 150% of the rated airflow.

5.3.3.3 Record the ambient temperature, pressure, and relative humidity.

5.3.3.4 Correct the recorded pressure drop values to standard conditions, per Appendix C, and plot as shown in Figure 19 indicating the pressure drop on ordinate.

5.4 Initial Efficiency

5.4.1 The air cleaners covered within the scope of this test code exhibit a collection efficiency that is dependent on airflow, increases with dust load on the filter element, and decreases with dust particle size.

Two efficiency determinations are thus made: an initial efficiency test, and an accumulative efficiency conducted during the dust capacity test.

5.4.2 PROCEDURE

5.4.2.1 Set up the air cleaner using the clean filter element(s) per Figure 14 and condition the unit to the airflow at which the unit is tested for at least 15 min under temperature and humidity conditions specified in 1.3.5.

5.4.2.2 Weigh the absolute filter per 1.3.4.

5.4.2.3 Set and maintain the air cleaner airflow at test flow ±2%, and scavenge flow, if used, at the manufacturer's recommended percentage.

5.4.2.4 Feed a quantity of test dust equal to 11 g/m^2 of the primary element media area at a continuous rate for 30min.

5.4.2.5 Reweigh the absolute filter per 1.3.4 and compute air cleaner efficiency, per 2.2.16.2, based on the total dust fed to the air cleaner. Record on Figure 21.

5.5 Dust Capacity and Accumulative Efficiency

5.5.1 The air cleaner dust capacity is a function of air cleaner size, airflow, terminal restriction/pressure drop, and the grade of test dust employed. To permit a comparison between different air cleaners, the dust capacity is, therefore, determined at test airflow to a terminal restriction/pressure drop of 60 mbar (6 kPa), or as specified, with several intermediate points. This restriction does not include the restriction added by the dust metering device and test shroud. After correcting the observed restriction/pressure drop data to standard conditions, the values are shown plotted in curve form versus the weight of dust fed.

AIR CLEANER DESCRIPTION

ITEM MODEL/PART NO.

Assembly ____________________
Precleaner ____________________
Primary Element ____________________
Secondary Element ____________________

Mfg. ____________________
Type ____________________
Rated Flow ____________________ scmh
Scavenge Airflow __________ %
Dust Cup ________ Unloader Valve ______________

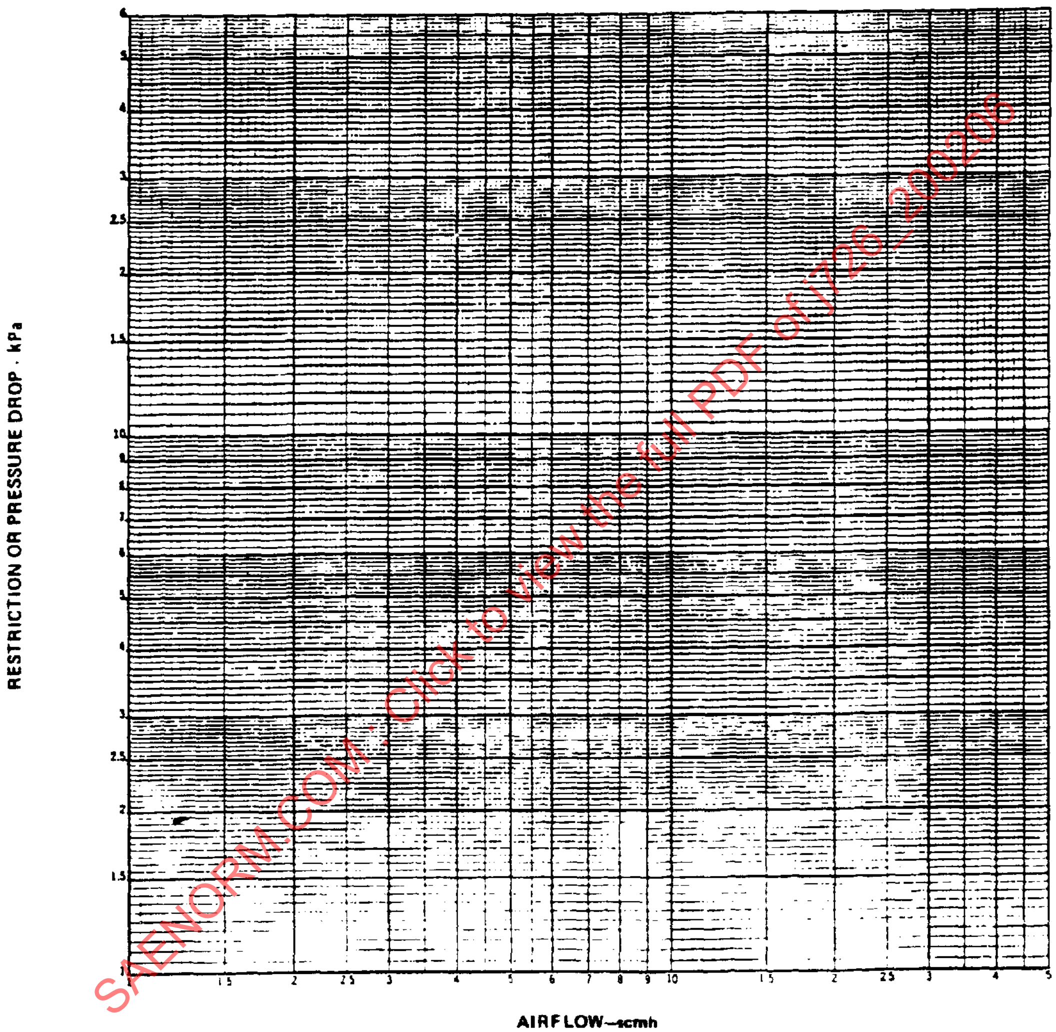


FIGURE 19—AIR CLEANER RESTRICTION/PRESSURE DROP AIR CLEANER TEST CODE SECTION 4—INDUSTRIAL AIR CLEANERS

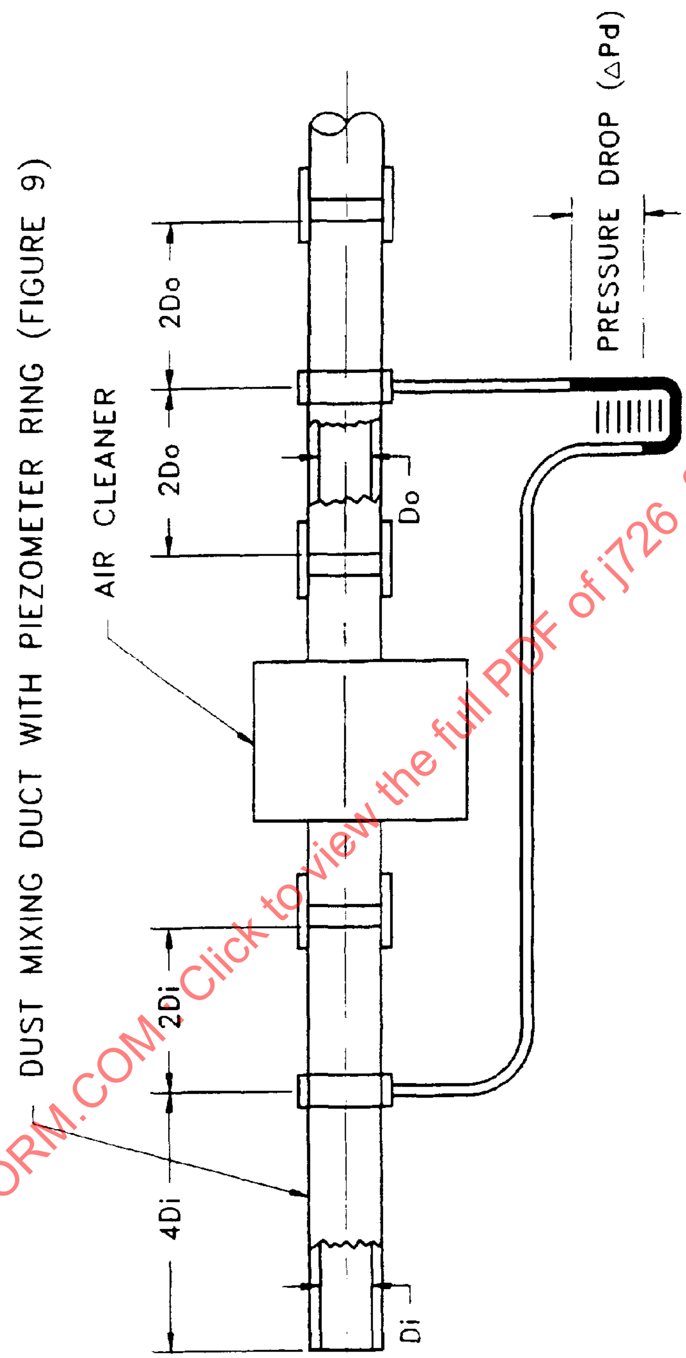


FIGURE 20—PRESSURE DROP TEST SETUP

AIR CLEANER DESCRIPTION

ITEM MODEL/PART NO.

Assembly ____________________
Precleaner ____________________
Primary Element ____________________
Secondary Element ____________________

Mfg. ____________________
Type ____________________
Test Flow ____________________ scmh
Scavenge Air Flow ____________________ %
Dust Cup ________ Unloader Valve ____________

TEST CONDITIONS AND RESULTS

Initial Efficiency ____________________ %
Test Dust Fine Batch ____________________
Dust Fed ____________________ g
Initial Restr/Press. Drop ____________________ kPa
Final Restr/Press. Drop ____________________ kPa
Relative Humidity ____________ %
Temperature ____________ °C

Dust Capacity __________ g __________ scmh
Test Dust ____________ Batch ____________
Concentration ____________________ g/m³
Accumulative Eff. ____________________ %
Precleaner Eff. ____________________ %
Dust cup serviced ____________________ times

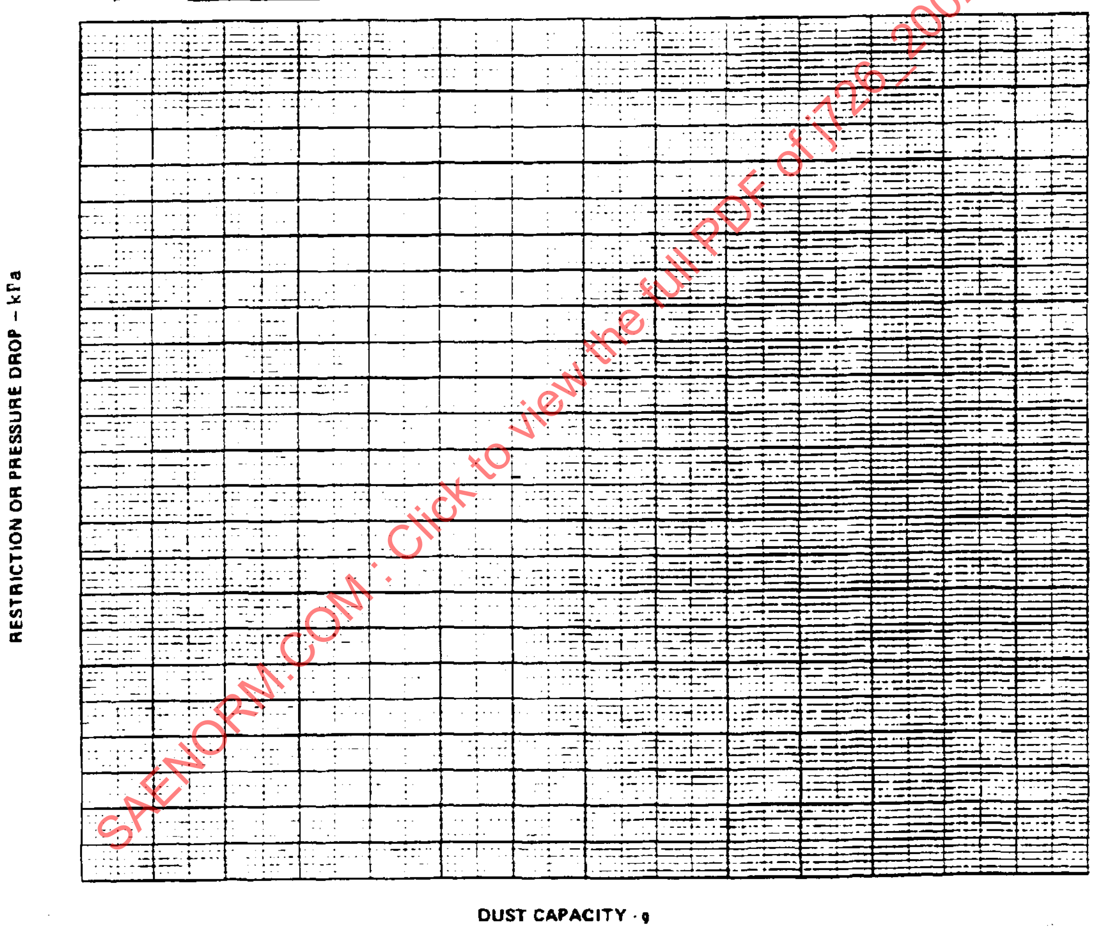


FIGURE 21—AIR CLEANER DUST CAPACITY AND EFFICIENCY AIR CLEANER TEST CODE SECTION 4—INDUSTRIAL AIR CLEANERS

5.5.2 PROCEDURE

5.5.2.1 Set up the air cleaner using clean filter elements per Figure 14 or 17 and condition the unit to the airflow at which the unit is tested for at least 15 min under temperature and humidity conditions specified in 1.3.5.

5.5.2.2 Weigh the absolute filter per 1.3.4.

5.5.2.3 Set and maintain the air cleaner airflow at test flow ± 2%, and scavenge flow, if used, at the manufacturer's recommended percentage.

5.5.2.4 Feed the test dust of and at the grade and concentration specified in 5.1.3, until the restriction/pressure drop reaches 60 m bar (6 kPa), or as specified.

5.5.2.5 Record several intermediate values of the weight of test dust fed to the air cleaner and the corresponding restriction/pressure drop at approximately uniform time intervals.

5.5.2.6 Correct the restriction/pressure drop values to stand conditions per Appendix C, and plot versus dust fed to the air cleaner, per Figure 21. Label ordinate either restriction or pressure drop, as appropriate.

5.5.2.7 Reweigh the absolute filter per 1.3.4 and compute the air cleaner efficiency, per 3.16.2, based on the total weight of dust fed to the air cleaner at the corrected restriction/pressure drop value of 60 mbar (6kPa), or as specified.

NOTE— Certain types of air cleaner, e.g., cyclone air cleaners, have no limiting dust capacity. In such cases, the test shall not be stopped before the cleaner has been fed with a sufficient quantity of dust for its efficiency to be determined as accurately as required. The minimum quantity shall be 50 g of dust.

5.5.3 PRESENTATION OF DATA—Use Figure 19 to present data on restriction/pressure drop. Use Figure 21 to present data on efficiency and capacity.

5.6 Precleaner Performance Test

5.6.1 PRECLEANER DUST REMOVAL—When testing with precleaners that employ either a scavenge flow, an automatic dust unloading valve, or a dust cup, the following provisions are to be made:

5.6.1.1 *Scavenge Flow*—The scavenge flow recommended by the manufacturer shall be maintained during all the tests. The dust feed rate shall be based on the test airflow plus the scavenge airflow. (See 5.8).

5.6.1.2 *Automatic Unloader Valve*—For test purposes, a sealed jar or container may be substituted for the unloader valve.

5.6.1.3 *Dust Cup*—The dust cup shall not be emptied during the dust capacity test until at least two-thirds full. Also, the number of servicings shall be noted in the performance report.

5.6.1.4 When the unit under test is a precleaner only (e.g., when tested as an add-on unit), the provisions of 5.1 through 5.3 and Figures 14, 17, 18, and 19 remain applicable.

5.6.1.5 Care should be taken to insure that the position and orientation of the dust injector does not significantly enhance or detract from the precleaner performance.

NOTE— The user should be aware that the previous provisions insure optimum air cleaner performance and is advised to consult the air cleaner manufacturer for specific instructions or test procedures for any given air cleaner installation.

5.6.2 PRECLEANER EFFICIENCY—The precleaner efficiency may be determined during the dust capacity test of the air cleaner system, or as a separate component. Efficiency is based on the total weight of dust fed to the air cleaner system or precleaner component and with the sum of the gain in weight of the primary and secondary elements and absolute filter, or the weight of dust removed by the precleaner. When testing an external precleaner, efficiency should be determined throughout its recommended airflow range.

5.7 Secondary Air Filter Test Procedure

5.7.1 GENERAL

5.7.1.1 This section of the air cleaner test code has been established to cover dry type secondary air filters generally used in applications as prescribed under 5.1.1. The intended purpose of a secondary filter element is to provide engine protection in the event of a catastrophic failure of the primary filter or its omission or improper installation. The secondary filter is not intended to provide improved efficiency or capacity.

5.7.1.2 Two different test setups are specified reflecting current industry practice.

One of these, hereafter referred to as the multistage test setup, includes a complete air cleaner with precleaner and secondary element installed. A failed primary element is simulated by removal of the primary filter media but with the end caps and guard sleeves retained.

The other setup, hereafter referred to as the single-stage test setup, includes only the secondary element in a special test shroud and sized to match the element.

A secondary element can be tested in either setup, regardless of its application. However, the two setups will each yield a different efficiency and dust capacity for the same element.

5.7.1.3 *Test Dust and Concentration*—(See Table 7.)

TABLE 7—TEST DUST AND CONCENTRATION

Test Setup	Test Dust	Concentration
Single Stage	Fine	0.1 g/m^3
Multistage	Coarse	1 g/m^3

Dust concentration shall be reduced if necessary to provide a minimum test duration of 30 min.

5.7.2 TEST EQUIPMENT—For the multistage test setup, the test equipment is identical to that used for the complete air cleaner test (see 5.2).

For the single-stage test setup, the test equipment is also described by 5.2, except the “air cleaner under test” is replaced by the test shroud, as shown in Figures 22 and 23.

NOTE— Figures 22 and 23 assume the element is cylindrical. If it is not, a special shroud must be constructed and thoroughly described in the test report.

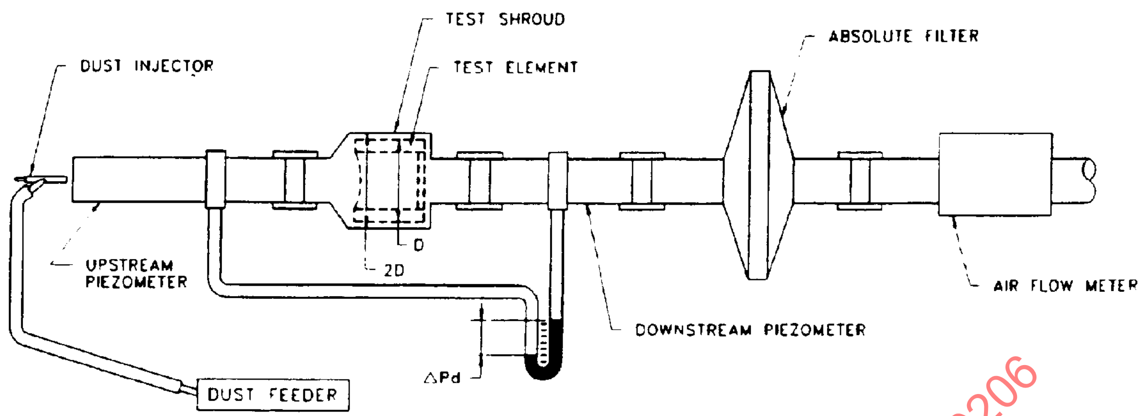


FIGURE 22—SINGLE-STAGE SETUP FOR SECONDARY ELEMENTS

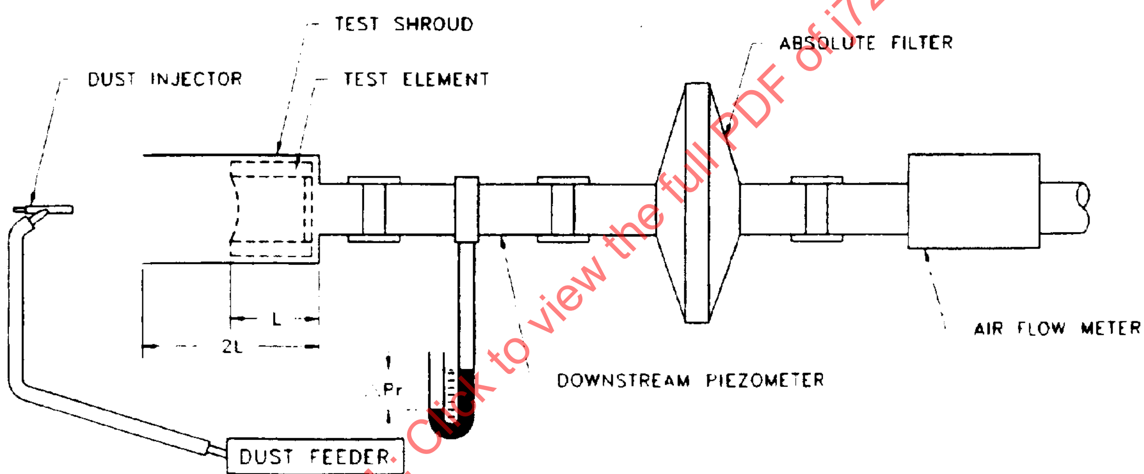


FIGURE 23—SINGLE-STAGE SETUP FOR SECONDARY ELEMENTS

5.7.3 AIRFLOW RESTRICTION AND PRESSURE DROP TEST—For the multistage test setup, repeat the tests specified in 5.3.2 or 5.3.3 with a normal primary element installed (not the simulated primary element described in 5.7.1.2). Do this both with and without a secondary element installed. The difference between pressure readings in the two tests is the restriction or pressure drop of the secondary element.

For the single-stage test setup, repeat the tests in 5.3.2 or 5.3.3 with Figure 19 replaced by Figure 22 and Figure 18 replaced by Figure 23.

5.7.4 EFFICIENCY AND DUST CAPACITY

5.7.4.1 Weigh the secondary element to the nearest 0.1 g.

5.7.4.2 For the multistage test setup, set up the air cleaner per Figure 14 or 17, using the clean secondary element and the simulated primary element per 5.7.1.2.

For the single-stage test setup, set up per Figure 22 or 23.

5.7.4.3 Weigh the absolute filter per 1.3.4.

5.7.4.4 Set and maintain the test airflow ±2%. For the multistage test setup, set and maintain any scavenge flow at the manufacturer's recommended value ±2%.

5.7.4.5 Feed a quantity of test dust 5.7.1.3 at a continuous rate until the restriction/pressure drop reaches 60 mbar (6 kPa), or as specified. The feed rate should be set to reach terminating restriction in a period of 30 min or longer.

5.7.4.6 Reweigh the absolute filter per 1.3.4.

5.7.4.7 Reweigh the secondary element to the nearest 0.1 g.

5.7.4.8 For the single-stage test setup, report the dust capacity as the weight gain of the element.

For the multistage test setup, report both the total dust fed and the weight gain of the element.

5.7.4.9 For the single-stage test setup, report efficiency per 3.16.1.

For the multipurpose test setup, report efficiency per 3.16.2.

5.7.4.10 Clearly indicate on the test report whether the multistage or single-stage test setup was used and whether the test setup was per Figure 14, 17, 22, or 23.

5.8 Scavenged Air Cleaner and/or Precleaner Performance Test

5.8.1 GENERAL

5.8.1.1 This clause describes those variations in the test procedures specified in this SAE Standard that are necessary for the testing of air cleaners that are scavenged in operation by a proportion of the air input that is bled off for that purpose.

5.8.1.2 The flow equation is as follows:

$$\dot{V}_B = \dot{V}_A - \dot{V}_C \quad \text{(Eq. 10)}$$

where:

$\dot{V}_A$ is the inlet airflow
$\dot{V}_B$ is the cleaned airflow
$\dot{V}_C$ is the scavenged airflow

5.8.2 ADDITIONAL EQUIPMENT—A typical test arrangement is shown in Figure 24.

5.8.2.1 *Exhauster*—An exhauster shall be provided to handle the scavenged flow and shall be capable of maintaining it at a steady state during the whole test.

5.8.2.2 *Airflow Meter*—An airflow meter shall be provided to measure the scavenged airflow rate within ±2%.

5.8.2.3 *Pressure Tapping*—The pressure tappings used shall conform to Figure 9.

5.8.2.4 *Scavenged Air Filter*—A filter shall be provided in the scavenged airflow of sufficient efficiency and capacity to protect the apparatus downstream from it against the effect of the dust in the scavenged airflow.