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JAPANESE INDUSTRIAL STANDARD

Test Methods of Air Cleaners for Automobiles

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Test Methods of Air Cleaners for Automobiles

D 1612-1989

1. Scope

This Japanese Industrial Standard specifies performance test methods of air cleaners of dry type, wet type, oil bath type, cyclone type as well as multi-stage air cleaners combined with these types for automobiles, hereinafter referred to as the "air cleaners".

Further, this Standard may be applied to air cleaners of internal combustion engines, compressors, etc. for other than automobiles.

Remark: The units and numerical values given in { } in this Standard are based on the traditional units and are appended for informative reference.

2. Definitions

For the purpose of this Standard main definitions shall be as given in Appendix 1.

3. Test Items

Tests shall be carried out on following each item.

(1) Air Flow Resistance Test

(2) Efficiency Test

(3) Dust Holding Capacity Test

(4) Rupture and Collapse Test

(5) Recovery Test

(6) Leak Test

(7) Precleaner Performance Test

Applicable Standards:

JIS K 2215-Internal Combustion Engine Oils

JIS Z 8901-Dusts and Aerosols for Industrial Testing

Corresponding International Standard:

ISO 5011 Inlet air cleaning equipment for internal combustion engines and compressors-Performance testing

(8) Scavenged Air Cleaner Performance Test

(9) Oil bath Air Cleaner Performance Test

Remark: (7), (8) and (9) have respectively inherent conditions and test items for respective types of air cleaners, and therefore, test items are specified in arrangement for each type.

4. Measurement Accuracy

The measurement accuracy shall be, as a rule, as follows:

(1) Measure air flow rate within ± 2 % of the set value except for the variable air flow test when accuracy shall be ± 2 % of the maximum value of the cyclic flow rate through the cleaner.

(2) Measure pressure drop and restriction within ± 0.25 mbar ([1]) {± 2.5 mmAq} of the set value.

(3) Measure temperature within ± 0.5°C of the set value.

(4) Measure mass within ± 1 % of the set value.

(5) Measure relative humidity with an accuracy of ± 2 %.

(6) Measure barometric pressure within ± 3 mbar {± 2.3 mmHg}.

Note ([1]) 1 mbar = 100 Pa, 1 mbar = 10.2 mmAq

Remark: The measurement equipment shall be calibrated at regular intervals to ensure the required accuracy.

5. Test Materials and Preparation

5.1 Test Dust The test dust shall be as follows:

(1) The test dust shall be of two grades of Class 7 (coarse) or Class 8 (fine) specified in JIS Z 8901. However, depending upon agreement between the parties concerned with delivery, ISO coarse dust or ISO fine dust may be used as special dust.

The chemical components and particle size distribution are shown in Appendix 2.

Remark: In the case of using ISO dusts, dusts shall be substituted as follows:

JIS Class 7 to ISO coarse dust, and JIS Class 8 to ISO fine dust.

(2) For test dust, the sufficiently mixed and dried dust shall be used.

5.2 Absolute Filter

5.2.1 Absolute Filter Materials The absolute filter materials shall consist of fibreglass of several layers and be used with putting into a suitable container.

The absolute filter shall be of fibreglass of 0.8 to 1.3 μm in diameter treated with thermosetting resin, having thickness of about 13 mm, apparent specific gravity of about 0.01, and mass variation within 1 % when left in atmosphere of relative humidity of 95 % and used with the nap side facing the upstream of air flow.

The size of absolute filter shall have a sufficient capacity to carry out the efficiency test and an air velocity not more than 0.8 m/s when passing at the time of test.

Remark: To reduce measurement error due to carry out of fibres and the like, the absolute filter shall be subject to a flow of at least 110 % of the rated flow of ambient air for 15 min before weighing.

5.2.2 Confirmation of Efficiency of Absolute Filter Material The efficiency of absolute filter material shall be confirmed according to the following:

(1) Arrange two absolute filters in tandem.

(2) Perform an efficiency test of absolute filter according to the test procedure give in 9.5.1 and determine the mass increase of each absolute filter.

$$\eta_a = \frac{A}{A+B} \times 100$$

where η_a: efficiency of absolute fitler (%)

A: mass increase of upstream absolute filter (g)

B: mass increase of downstream absolute filter (g)

5.2.3 Measurement of Absolute Filter Mass The absolute filter mass shall be weighed to the nearest 0.01 g after the mass has stabilized sufficiently.

5.3 Preparation of Specimen Air Cleaner The air cleaner shall, at the time of test, be performed with the preparation shown in Table 1.

Table 1. Preparation of Air Cleaner

Type of air cleaner	Preparation item		
	Scavenge sufficiently air cleaner to dry.	Make the air cleaner element the designated wet condtiion.	Flow the test-room air at a rated air flow rate for 15 min or more.
Dry type	○	—	○
Wet type	○ (2)	○	○
Oil bath type (3)	○	—	○ (3)
Precleaner (cyclone type) (4)	○	—	—
Multi-stage type	○ (2)	△	○
Scavenged air type	○ (2)	△	○

Notes (2) As to wet type air cleaner, remove the filter element.

(3) As to oil bath type air cleaner, the preparation item and the content are different for each test item, and therefore prepare according to 16. Oil Bath Air Cleaner Performance Test.

(4) As to precleaner, cyclone type air cleaner is used in many cases.

(5) The scavenged type is a kind of multi-stage air cleaner combined with a precleaner.

Remarks 1. ○ mark indicates the execution item.

2. △ mark applies to the case where wet type element is used in multi-stage cleaner and scavenged air cleaner.

3. As to air cleaner using dry type and wet type elements, new elements shall be used for eah test except items so specified as to use the element after test.

6. Atmospheric Condition of Test Room

The test shall be performed at room temperature.

Further, atmospheric pressure, temperature and relative humidity before and after each test shall be measured and recorded.

7. Test Equipment

The test equipment shall be as follows:

(1) The test equipment shall be, as a rule, in accordance with Appendix 3.

(2) The constitution of representative equipment to measure the air flow resistance, efficiency, dust holding capacity, rupture and collapse of filter elements shall be in accordance with Figs. 1, 5, 6, 7, 8, 10, 11, 13 and 14 of Appendix 3.

The equipment to be used for scavenged air cleaner test shall be in accordance with Fig. 15 of Appendix 3. The equipment to be used for oil carry-out test shall be in accordance with Figs. 16, 17, 18 and 19 of Appendix 3.

(3) In the case where air cleaner assembly and element single body is tested in a chamber for test, the equipment shall be in accordance with Figs. 1, 5, 6 and 12.

Remarks 1. In the case where whole periphery suction type air cleaner and chimney type precleaner are used, the test shall be performed in a chamber for test which is capable of uniform feeding of test dust to the inlet as shown in Fig. 12 of Appendix 3. The chamber for test shall be able to feed securely all test dusts to air cleaner.

2. In the case where in assembly test and element single body test the precipitation of dusts fed into the chamber for test is caused, set a flexible tube to jet dry compressed air into the chamber for test as shown in Fig. 5 of Appendix 3, and stir the precipitating dust to disperse uniformly.

3. In the case where compressed air is used for floating the test dust, maintain the chamber for test at a negative pressure so as the test dust not to leak to outside from the chamber for test.

(4) The dust feed equipment shall be able to set dust feed amount over the range of designated feed speed ([6]) without varying the particle size distribution of dust and under the uniform distribution condition, and, able to feed to dust injector.

The dust feed equipment shall adjust the feed amount of dust according to the following:

(a) Fill the test dust weighed preliminarily into a dust feed equipment.

(b) Start simultaneously the dust feed equipment and timer.

(c) Measure the added dust amount from the dust feed equipment at intervals of 5 min, and continue it for 30 min.

Note ([6]) It is determined by the test air flow rate determined by agreement between the parties concerned with delivery and mixing ratio of air to dust.

Remark: The accuracy of dust feed equipment shall be less than 5 % of average feed rate in change of dust feed rate at each 5 min.

(d) Adjust the average dust feed rate at ± 5 % of designated feed rate.

(5) As to the dust transfer tube between the dust feed equipment and the dust injector, use a tube difficult for dust to adhere on its wall and having such size as to be able to transfer the dust stably.

(6) Use a dust injector shown in Appendix 3 Fig. 2. The compressed air pressure at air inlet side of dust injector shall be 1 bar {1 kgf/cm^2}.

Remark: The dust injector of Appendix 3 Fig. 2 indicates the one capable of feeding the test dust at 40 g/min at maximum. In the case where the dust feed rate of not less than 40 g/min is required, use not less than two dust injectors.

(7) Use the inlet tube shown in Appendix 3 Fig. 3. Make the sectional area of inlet tube, as a rule, same as that of air cleaner inlet. Allow the dust injector to be apart from the inlet tube as far as possible in the range where the fed dust does not leak outside the inlet tube.

(8) Use the outlet tube shown in Appendix 3 Fig. 3. Make the sectional area of outlet tube same as that of air cleaner outlet.

Remark: In the case where the outlet shape of air cleaner is special, particular outlet tube shape may be required in some cases.

(9) Use a pressure measuring device or pressure drop measuring device for measuring outlet static pressure and pressure drop having the accuracy specified in 4. (2).

(10) Use an air flow meter having an accuracy specified in 4. (1).

Remark: Express the air flow rate by correcting to the standard condition shown in Appendix 4 relative to the variation of atmospheric pressure, temperature and relative humidity at the inlet of air flow meter.

(11) Use the air flow control capable of maintaining air flow rate at ± 1 % of set value in either case of constant air flow rate operation and variable air flow rate operation.

(12) Use the exhauster to flow air into the testing machine which is capable of holding the air flow rate and pressure characteristic required for test and has so sufficiently small pulsation of air flow as to be able to secure the measuring accuracy of air flow rate.

8. Air Flow Resistance Test

8.1 Purpose This test is performed for the purpose to obtain the air flow resistance by measuring outlet static pressure or pressure drop generated when air is allowed to flow in specimen air cleaner.

8.2 Test Conditions Flow air of rated air flow rate with air in test chamber for not less than 15 min until the mass of air cleaner becomes stable to accommodate the air cleaner for test environment.

8.3 Test Equipment The test equipment shall be as follows:

(1) The test equipment of air cleaner assembly shall be in accordance with Figs. 7, 13 or 14 of Appendix 3. Attach the inlet tube and outlet tube with sealing all joint parts to prevent air leakage.

(2) The test equipment for element unit shall be in accordance with Appendix 3 Fig. 8.

8.4 Air Cleaner Assembly Test Method The air cleaner assembly test shall be performed according to the following:

(1) Let the test air flow rate be air flow rates of not less than five stages set at equal intervals in the range of designation agreed upon between the parties concerned with delivery taking the rated air flow rated as the reference. The test air flow rates in the case of setting to five stages shall be 50 %, 75 %, 100 %, 125 % and 150 % of the rated air flow rate, and in case of setting other than these, they shall be subjected to agreement between the parties concerned with delivery.

Remarks 1. Measure the wet type and oil bath air cleaners in the range where the oil carry-out is not generated. For measurement, maintain the air flow rate until the outlet static pressure or pressure drop is stabilized.

2. As to the oil bath air cleaner, after preparing according to 16.3 (4), perform this test.

(2) Record the environmental air pressure, temperature and relative humidity.

(3) Measure the outlet static pressure or pressure drop.

(4) Obtain the flow resistance according to 2. (15) of Appendix 1 and correct to the standard condition according to Appendix 4.

(5) Record the test results according to the mode of Attached Table 3 or the mode similar thereto.

8.5 Element Unit Test Method The element unit test shall be in accordance with the following and, in addition, with 8.4.

(1) Attach the element as shown in Appendix 3 Fig. 8, and measure the static pressure at the pressure taking opening of outlet tube to record it.

(2) Detach the element, and measure the static pressure at the pressure taking out opening of outlet tube to record it.

(3) Obtain the difference of measured values of (1) and (2), and correct the value to the standard condition to take it as the air flow resistance.

9. Efficiency Test

9.1 Purpose This test is performed for measurement of dust removing capacity of specimen air cleaner. This test may be performed at the same time as 10. Dust Holding Capacity Test.

9.2 Test Conditions The test conditions shall be as follows:

(1) Perform this test at either a constant air flow rate or variable air flow rate.

(2) Perform the measurement of efficiency at a constant air flow rate test at the air flow rate agreed between the parties concerned with delivery.

(3) Perform the measurement of efficiency at variable air flow rate at flow rate variable cycle according to 9.6.

(4) Perform the calculation of efficiency according to either absolute filter method or direct weighing method.

(5) The kind of test dust shall be in accordance with 5.1. Make the mixing ratio of air when feeding test dust to test equipment relative to dust, hereinafter referred to as the "dust concentration", 1.0 g/m^3, and keep it constant until the whole dust of dust feed equipment is fed. However, in the case where a special dust concentration is required, select it by taking the using conditions of air cleaner as the reference out of the values shown in Table 2.

Table 2. Special Dust Concentration

Unit: g/m^3

Using condition	Dust concentration
For dust light load	0.25, 0.5
For heavy dust load	2.0, 3.0

Remark: The dust concentration indicates the feeding dust amount per 1 m^3 of test air flow rate.

9.3 Test Equipment The test equipment shall be as follows:

(1) The test equipment for air cleaner assembly shall be in accordance with Figs. 5, 10, 11 and 12 of Appendix 3.

In order to prevent air leakage, seal all joint parts and attach the inlet tube and outlet tube.

(2) The test equipment for element unit shall be in accordance with Figs. 1, 4, 5 and 6 of Appendix 3.

(3) The dust injector shown in Fig. 2 of Appendix 3 shall be used.

9.4 Types of Efficiency Tests The efficiency tests shall be of following three types. However, the intermediate efficiency test shall be performed, as requried.

(1) Primary Efficiency Test The test to measure the test dust when having fed it until reaching either one value of the following conditions.

(a) The test dust amount for air cleaner to be used in ordinary dust condtiion shall be the value whichever is the larger when comparing "20 g" with "number of grams equal to the numericla value of six times the test air flow rate (m^3/min)".

(b) The test dust amount of air cleaner to be used in a large dust amount condition shall be the value, whichever is the larger, when comparing "110 g" with "the required amount by specified dust concentration when the test time is made 30 min".

(2) Intermediate Efficiency Test The test to measure the efficiency by air flow resistance set at the intermediate until reaching the test completion conditions from the primary air flow resistance.

(3) Full Life Efficiency Test The test to measure the efficiency when having reached the test completion conditions.

9.5 Efficiency Test by Constant Air Flow Rate

9.5.1 Test Method (A) Absolute Filter Method This test shall be performed according to the following:

(1) Accommodate (7) the specimen air cleaner for test environment, measure the mass at a unit not more than 1 g and at an accuracy of ± 1 % of preliminarily determined feed dust amount and record it.

Note (7) The gist of accommodation shall be in accordance with 8.2.

(2) Measure the mass of absolute filter after the mass has been stabilized according to the gist of 5.2.3.

(3) Record the pressures, temperatures and relative humidities of test chamber at the times of starting and completion of the test.

(4) Prepare the test dust designated by 5.1 and measure the amount required for the test by using a suitable test container. Measure the mass of container and dust to the unit of 0.1 g and record.

(5) Flow air to the test equipment, stabilize at test air flow rate, and measure the outlet static pressure or pressure drop to record.

(6) Transfer the test dust from the dust container to dust feed apparatus and so regulate the dust feed speed so as to become the dust concentration selected according to 9.2 (5).

(7) Regulate the compressed air pressure at air inlet side of dust injector at 1 bar {kgf/cm^2}, and flow air for dust feeding.

Remark: At this time the outlet static pressure or pressure drop may vary in some cases, and therefore confirm it to record.

(8) Start the dust feed apparatus (at this time the test begins) and flow the dust into a specimen air cleaner. If the dust becomes insufficient during test, add the test dust to the dust feed apparatus.

(9) At the designated time intervals (the nubmer of measuring points until completion of test shall be not less than five points) measure the lapse of time and the outlet static pressure or pressure drop at the test air flow rate to record.

(10) Continue the test until attaining respective test completion conditions for measuring primary, intermedate, and full life efficiencies, and measure the outlet static pressure or pressure drop at completion time to record. Thereafter, stop air of test equipment and dust injector.

(11) In the case of test used of dust adhered on the outer surface of specimen air cleaner as well as of the chamber for test, collect carefully the remaining dust in the chamber for test at inlet side of specimen element and the like and in the test duct, and transfer into a dust container of which mass is measured preliminarily.

(12) Remeasure the mass of dust container and subtract its mass from the mass recorded in (4).

Remark: This mass difference is the Feed Dust Amount to the specimen air cleaner.

(13) Detach the specimen air cleaner from the test equipment so as not to spill the dust. Observe the leakage from the tightly sealed portion or abnormal condition and record. Measure the mass of specimen air cleaner at a unit not more than 1 g and at an accuracy of ± 1 % of feed dust amount. Subtract the mass measured in (1) from this mass.

Remarks 1. This mass difference is the Mass Increase of Specimen Air Cleaner.

2. In full life efficiency test, this mass increase is the Dust Holding Capacity of the specimen air cleaner.

(14) Sweep down the dust adhering on the downstream side of specimen air cleaner on the absolute filter. Detach carefully the absolute filter, repeat the operation of (2) and measure the mass of absolute filter. Subtract the mass measured in (2) from this mass.

Remark: This mass difference is the Mass Increase of Absolute Filter.

(15) Calcualte the increase or decrease of feed dust amount according to the following formula. If the calculated value of α is in the range of 0.98 to 1.02, consider the test to be effective.

$$\alpha = \frac{A+C}{B}$$

where α: increase or decrease of feed dust amount

A: mass increase amount of specimen air cleaner (g)

B: feed dust amount (g)

C: mass increase amount of absolute filter (g)

(16) Calculate the efficiency according to the following formula:

$$\eta=\frac{A}{A+C}\times 100 \quad \text{or} \quad \eta=\frac{B-C}{B}\times 100$$

where η: efficiency (%)

A: mass increase amount of speicmen air cleaner (g)

B: feed dust amount (g)

C: mass increase amount of absolute filter (g)

9.5.2 Test Method (B) Direct Weighing Method This test shall be performed according to the following:

(1) In the case of being capable of using a large type balance of high accuracy, the direct weighing method may be used for performance test of specimen air cleaner.

(2) As to this test, perform the test of air cleaner according to the procedures in absolute filter method of 9.5.1 excepting the operations of (2), (14), (15) and (16).

(3) Calculate the efficiency according to the following formula:

$$\eta=\frac{A}{B}\times 100$$

where η: efficiency (%)

A: mass increase amount of specimen air cleaner (g)

B: feed dust amount (g)

9.6 Efficiency Test by Variable Air Flow Rate The purpose of this test is to measure efficiency by using variable air flow cycle modelled by matching the variation of suction air flow in the case where air cleaner is used in an actual internal combustion engine.

(1) Perform this test instead of constant air flow test of 9.5 by matching the maximum air flow with the rated air flow and by using the variable air flow cycle shown in Figure.

Remarks 1. Instead of the maximum air flow, the test may be performed by the air flow rate according to agreement between the parties concerned with delivery.

2. In the cases of oil bath air cleaner and large air cleaner, the test may be performed by changing the length of each part cycle of variable air flow cycle to 5 min instead of 1 min.

(2) Set the dust concentration so that it becomes the concentration specified in 9.2 (5) at the time of average air flow (60 % of the maximum air flow) at variable air flow cycle. Hold the dust feed speed at constant during the test.

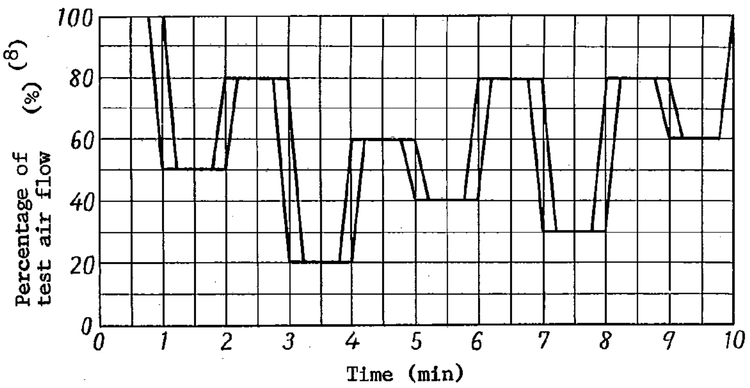
(3) Measure the outlet static pressure or pressure drop at the maximum test air flow in every variable cycle.

(4) Perform the test according to conditions of efficiency test by a constant air flow except cases according to the following:

(a) Measure the outlet static pressure or pressure drop at the maximum test air flow at the completion time point of each cycle.

(b) Measure the efficiency at least after three cycles (after 30 min) if the length of each part cycle is each 1 min, and after each cycle (after 50 min) if the length of each part cycle is each 5 min, and further measure when reached the test completion conditions.

Figure. Variable Air Flow Cycle (9)



Notes (8) The percentage of test air flow indicates the ratio relative to the maximum air flow.

(9) The average air flow is 60 % of the maximum air flow.

10. Dust Holding Capacity Test

10.1 Purpose This test is performed for the purpose of measuring the whole mass of dust which the specimen air cleaner can collect until reaching the test completion conditions. This test may be performed at the same time as 9. Efficiency Test.

10.2 Test Conditions Test conditions shall be as follows:

(1) Perform this test either at constant air flow or variable air flow.

(2) Kind of test dust and dust concentration shall be in accordance with 9.2 (5).

(3) Accommodate air cleaner for test environment according to 8.2.

10.3 Test Equipment The test equipment shall be in accordance with 9.3.

10.4 Test Method This test shall be performed according to the following:

(1) Perform the test according to efficiency test by constant air flow of 9.5 or variable air flow of 9.6.

(2) Draw a curve of air flow resistance increase relative to feed dust amount with taking the ratio of lapse of time to feed dust amount to specimen air cleaner as constant. The measured value of air flow resistance at each time interval shall be in accordance with 9.5.1 (9).

(3) Calculate the feed dust amount at the time of completion of each time interval according to the following formula:

$$B_0 = \frac{T_0}{T} \times B$$

where B_0: feed dust amount at completion time of each time interval (g)

B: feed dust amount (g)

T_0: whole time until completion of each time interval (min)

T: whole time until test completion (min)

(4) In the case where the test completion condition is air flow resistance, except the air flow resistance of test chamber.

(5) Calculate the dust holding capacity according to the following formula:

$$D = A = A_2 - A_1 \quad \text{or} \quad D = B - C$$

where A: mass increase of specimen air cleaner (g)

A_1: mass of air cleaner before test (g)

A_2: mass of air cleaner after test (g)

B: feed dust amount (g)

C: mass increase of absolute filter (g)

D: dust holding capacity (g)

11. Rupture and Collapse Test

11.1 Purpose The purpose of this test is to perform measurement of capability for filter element to endure the designated pressure drop. The pressure drop at the time when the rupture of element is caused is taken as rupture or collapse pressure.

11.2 Test Conditions The element used in full life efficiency test or dust holding capacity test, or new element shall be used in this test.

11.3 Test Equipment The test equipment shall be in accordance with 9.3.

11.4 Test Method This test shall be carried out according to the following:

(1) Increase the air flow rate to flow into test equipment, and if required, feed the test dust by using a suitable feed speed.

(2) Perform the test until the pressure drop agreeded upon between the parties concerned with delivery is reached or until the rupture of element is observed according to decrease of pressure drop or increase of air flow rate.

(3) Record the reasons of the maximum pressure drop reached, and of test completion, and state of element after test.

12. Recovery Test

12.1 Purpose The purpose of this test is to perform the measurement of recovery degree of air flow resistance, efficiency and dust holding capacity in an air cleaner to be used with repeated recovery.

12.2 Test Condtiions Test conditions shall be as follows:

(1) Perform the test after cleaning sufficiently the air cleaner performed with full life efficiency test or dust holding capacity test until it becomes near the condition before the test according to the method agreed upon between the parties concerned with delivery.

Remark: In the case where in a dry type air cleaner there is no cleaning method of element agreed upon between the parties concerned with delivery, blow the clean compressed air at 5 to 6 bar {5 to 6 kgf/cm^2} from inside and outside of element with taking care so as not to break the element and remove the dust as far as possible.

(2) As to the wet type and multi-stage air cleaners, apply (1), as appropriate.

(3) As to oil bath air cleaner, the test conditions shall be in accordance with 16.3 and 16.9.

12.3 Test Equipment The test equipment shall be in accordance with 8.3 and 9.3.

12.4 Test Method This test shall be performed according to the following:

(1) Recovery of Air Flow Resistance Perform air flow at rated air flow for 5 min, and measure the air flow resistance of element unit according to 8.5. Calculate the recovery rate of air flow resistance according to the following formula:

$$R_p = \frac{P_{r0}}{P_{r1}} \times 100$$

where R_p: recovery rate of air flow resistance (%)

P_{r0}: recovery rate of air flow resistance at new good (mbar) {or mmAq}

P_{r1}: air flow resistance after cleaning (mbar) {or mmAq}

(2) Recovery of Efficiency and Dust Holding Capacity 9. Efficiency Test and 10. Dust Holding Capacity Test shall be carried out. However, when not required specially, this test may be omitted.

(a) Express the recovery of efficiency by comparing with the new good value.

(b) Calculate the recovery rate of dust holding capacity according to the following formula:

$$R_d = \frac{D_{r1}}{D_{r0}} \times 100$$

where R_d: recovery rate of dust holding capacity (%)

D_{r0}: dust holding capacity at new good (g)

D_{r1}: dust holding capacity after cleaning (g)

13. Leak Test

13.1 Purpose The purpose of this test is to confirm the existence of dust leak to cleaning side of air cleaner when the pressure drop of element has become large.

13.2 Test Conditions Test conditions shall be in accordance with 9.2.

13.3 Test Equipment The test equipment shall be in accordance with 9.3.

13.4 Test Method This test shall be performed according to the following:

(1) Enter the air cleaner after completion of full life efficiency test or dust holding capacity test into a test chamber shown in Fig. 5 and Fig. 12 of Appendix 3, and feed test dust at the dust concentration specified in 9.2 (5) and at rated air flow into the test chamber for 5 min.

(2) Take out the air cleaner, and observe existence of dust leak at joint surface of downstream side of air from element and on the real surface to record.

14. Precleaner Performance Test

14.1 Purpose The purpose of this test is to measure the performance of precleaner used in combination at the upstream side of main air cleaner. Herein, test conditions, test gist, etc. inherent to precleaner are specified.

14.2 Test Items Test items shall be air flow resistance test, efficiency test and dust holding capacity test.

14.3 Test Conditions Test conditions shall be as follows:

(1) As a rule, perform the test in combination with the main cleaner.

(2) Kind of test dust and the dust concentration shall be in accordance with 9.2 (5).

(3) Perform the test according to the following and for others perform according to each test of 8. Air Flow Resistance Test, 9. Efficiency Test and 10. Dust Holding Capacity Test.

(3.1) The attaching posture of precleaner, unless otherwise agreeded upon between the parties concerned with delivery, shall be of the condition of ordinary using.

(3.2) In the case of precleaner using dust automatic exhaust valve or dust cup, the following conditions apply to exhaust of dust.

(a) For automatic exhaust valve, the tightly closed bottle or container for test may be used instead of it.

(b) The dust cup shall not exhaust the dust until the dust reaches not less than 2/3 of dust cup volume in the dust holding capacity test. Record the number of dust exhaust times on the report.

Remark: The precleaner to be conducted with scavenging for automatic exhaust of dust shall be in accordance with 15. Scavenged Air Cleaner Performance Test.

14.4 Test Equipment The test equipment shall be in accordance with 8.3 (1), 9.3 (1) and 9.3 (3).

14.5 Air Flow Resistance Test Method The measurement of outlet static pressure and pressure drop shall be in accordance with 8. Air Flow Resistance Test.

14.6 Efficiency and Dust Holding Capacity Test Methods

(1) Perform the test at a constant air flow according to 9. Efficiency Test.

(2) Calculate the efficiency of precleaner according to either one of the following formulae:

$$\eta_p = \frac{A_p}{B} \times 100 \quad \text{or} \quad \eta_p = \frac{A_p}{A_p + C + E_1 + E_2} \times 100$$

where η_p: efficiency of precleaner (%)

A_p: mass increase of precleaner (g)

B: feed dust amount (g)

C: mass increase of absolute filter (g)

E_1: mass increase of primary element (g)

E_2: Mass increase of secondary element (applies in the case of being used) (g)

(3) Calculate the efficiency of assembly combined with the main air cleaner according to either one of the following formulae:

$$\eta = \frac{A}{A+C} \times 100 \quad \text{or} \quad \eta = \frac{B-C}{B} \times 100$$

where η: efficiency of assembly (%)

A: mass increase of sum of precleaner and main air cleaner (g)

B: feed dust amount (g)

C: mass increase of absolute filter (g)

Remark: The mass increase of sum of precleaner and the main air cleaner is Dust Holding Capacity.

15. Scavenged Air Cleaner Performance Test

15.1 Purpose The purpose of this test is to measure the performance of scavenged air cleaner. Herein, the test conditions, test equipment, test gist, etc. inherent to scavenged air cleaner are specified.

15.2 Test Items Test items shall be air flow resistance test, efficiency test and dust holding capacity test.

15.3 Test Conditions Test conditions shall be as follows:

(1) Perform the test in combination of precleaner having scavenging function to automatically exhaust the separated dust with the main air cleaner.

(2) Kind of test dust and dust concentration shall be in accordance with 9.2 (5).

(3) The relation formula of air flow rate shall be in accordance with the following:

$$V_B = V_A - V_C$$

where V_A: suction air flow rate (m^3/min)

V_B: clean air flow rate (m^3/min)

V_C: scavenged air flow rate (m^3/min)

15.4 Test Equipment The test equipment shall be constituted as shown in Appendix 3 Fig. 15. The additive test equipment required for this test shall be as follows:

(1) The scavenged exhauster shall be provided with a capability to treat the scavenged flow and, capable of maintaining the stabilized condition during the whole test period.

(2) The scavenged air flow meter shall have the accuracy specified in 4. (1) and be provided with the capability to measure the scavenged air flow rate.

(3) The scavenge pressure taking out equipment shall be in accordance with Appendix 3 Fig. 3.

(4) The scavenge air filter shall be provided in scavenge flow and have efficiency capable of protecting sufficiently the downstream equipment against effect of dust in scavenge flow and dust holding capacity.

15.5 Air Flow Resistance Test Method This test shall be performed for measuring the air flow resistance generated by clean air flow. The measurement of outlet static pressure and pressure drop shall be in accordance with the following and in addition with 8. Air Flow Resistance Test.

(1) For scavenge flow, begin the feed before flowing the clean air.

(2) Stop the scavenge flow at the same time as clean air flow. Before stopping of clean air flow, do not stop the scavenge flow.

(3) Measure the scavenge air flow regulated at the rate according to agreement between the parties concerned with delivery relative to the clean air flow.

Remark: In order to maintain the rate, depending upon the mutual action of scavenge flow and clean air flow, the reregulation of air flow rate is required in some cases.

15.6 Efficiency and Dust Holding Capacity Test Methods This test is performed for measuring the efficiency by clean air flow and dust holding capacity. The efficiency test and dust holding capacity test shall be conducted at a constant air flow according to the following (1) to (7) and in addition according to 9. Efficiency Test.

(1) Generally, the air cleaner applied to this test is large comparatively in shape and therefore the absolute fitler method is desirable.

(2) The scavenge air flow shall be subjected to agreement between the parties concerned with delivery at a definite rate to clean air flow and maintained.

(3) The dust concentration at the time of test shall be the concentration in the suction air flow.

(4) The scavenge flow shall be started in feed before flowing the clean air.

(5) Stop the scavenge flow at the same time as the clean air flow. Don't stop the scavenge flow before stopping of clean air flow.

(6) Calculate the efficiency according to the following formula:

$$\eta=\frac{d_1-d_2}{d_1}\times 100$$

where η : efficiency (%)

d_1 : average dust concentration at inlet of air cleaner $=B/V_1$ (g/m³)

d_2 : average dust concentration at outlet of air cleaner $=C/V_2$ (g/m³)

B : feed dust amount to air cleaner (g)

C : mass increase of absolute filter (g)

V_1 : volume of air sucked in air cleaner (m^3)

V_2 : volume of air exhausted to clean side of air cleaner (m^3)

(7) Calculate the dust holding capacity according to the following formula:

$$D=B\times\frac{V_B}{V_A}-C$$

where B : feed dust amount to air cleaner (g)

C : mass increase of absolute filter (g)

D : dust holding capacity (g)

V_A : suction air flow (m^3/min)

V_B : clean air flow (m^3/min)

16. Oil Bath Air Cleaner Performance Test

16.1 Purpose The purpose of this test is to measure the performance of oil bath air cleaner. Herein, the test conditions, test equipment, test gist, etc. inherent to oil bath air cleaner are specified.

16.2 Test Items Test items shall be air flow test, oil carry-out test, initial wetting of element test, efficiency test, dust holding capacity test and recovery test.

16.3 Test Conditions Test conditions shall be as follows:

(1) Kind of test dust and dust concentration shall be in accordance with 9.2 (5).

(2) The kinematic viscosity of test oil at room temperature shall be as shown in Table 3. However, in the case where the test oil of conditions agreed between the parties concerned with delivery exists, it may be used.

Table 3. Kinematic Viscosity of Test Oil

Unit: mm^2/s {cSt}

Test item	Kinematic viscosity of test oil
Air flow resistance Oil carry out Recovery	85 ± 10
Initial wetting of element Efficiency Dust holding capacity	330 ± 30

Remarks 1. As the basic oil, Class 1 No. 3 for land use of JIS K 2215 is desirable.

2. 1 mm^2/s = 1 cSt

(3) As to the attaching posture of air cleaner, unless specified in each test item, attach horizontally to perform the test.

(4) Before testing, prepare the air cleaner as follows:

(a) Wash sufficiently the air cleaner and dry it.

(b) Measure the mass of assembly in dry condition to record.

(c) Depending upon the test item, select the test oil of the kinematic viscosity specified in Table 3, inject up to the specified oil surface of oil bath.

(d) Flow air at rated air flow rate for 15 min.

(e) Stop feed wind and provide a drop time of oil for 15 min.

(f) Add test oil in addition up to the designated level in oil bath.

(5) Record the environmental air pressure, temperature and relative humidity.

16.4 Test Equipment The test equipment shall be in accordance with the following:

(1) An example of test equipment for oil bath air cleaner with suction tube is shown in Appendix 3 Fig. 11.

(2) In the case of oil bath air cleaner of whole peripheral suction type, perform the test in a test chamber shown in 7. (3) so as to be able to feed test dust at a uniform concentration to the inlet.

(3) The attaching method of oil bath air cleaner in oil carry-out test is shown in Figs. 18 and 19 of Appendix 3. The observation chamber for oil carry-out test which has a target board covered with suitable paper which becomes transparent when oil drop bumps is shown in Appendix 3 Fig. 16 and the bend tube of observation window to observe existence of oil sputtering and condition of sputtering oil is shown in Appendix 3 Fig. 17. For observation equipment for oil carry-out test, either Fig. 16 or Fig. 17 of Appendix 3 shall be used.

16.5 Air Flow Resistance Test Method The measurement of outlet static pressure and pressure drop, after preparing according to 16.3 (4), shall be performed according to the following and, in addition, according to 8. Air Flow Resistance Test.

(1) As far as the oil carry-out is not caused, perform the test up to the air flow rate of not less than 100 % of rated air flow.

(2) Maintain the air flow rate until the outlet static pressure or pressure drop of air cleaner is stabilized.

16.6 Oil Carry-Out Test Method This test is performed to measure the air flow rate at the limit of generating oil carry-out when air is flowed and to measure the existence of oil carry-out at the rated air flow. The measurement of air flow rate at oil carry-out limit and oil carry-out amount shall be as follows:

Remarks 1. As to the attaching posture of air cleaner, there are cases where it is made horizontal and inclined.

2. In this test, the feed of test dust is not conducted.

3. At the time of completion of test at each air flow rate, observe the trace of oil carry-out by using an observation window bend tube for outlet of air cleaner.

4. This test method applies also to the wet type air cleaner.

(1) Measurement of Air Flow Rate at Oil Carry-Out Limit The measurement of air flow rate at oil carry-out limit shall be performed according to the following:

(1.1) Horizontal Attaching Test

(a) Prepare the air cleaner according to 16.3 (4). However, don't perform the procedures of (d) to (f) of 16.3 (4).

(b) Measure the mass of oil entering assembly.

Remark: The difference between this mass and the mass of assembly in dry condition is the oil amount before beginning the test.

(c) Attach the air cleaner as shown in Appendix 3 Fig. 18.

(d) Adjust the air flow rate at the rated air flow, and maintain for 15 min. During this, at each 5 min observe existence of sputtering oil and condition of sputtering oil by means of an observation window of equipment shown in Appendix 3 Fig. 16 or Fig. 17.

(e) Thereafter, detach the air cleaner, and measure the mass of the assembly.

Remark: The value of mass of assembly measured in (b) subtracted by the mass of assembly measured herein is Oil Carry-out Amount in 15 min.

(f) Increase the air flow rate at a rate of 2 to 5 % of rate of air flow, continue the test until the oil carry-out rate exceeds 1 %, and measure the air flow rate at that time. Let the test time to each air flow rate be 15 min.

(g) Calculate the oil carry-out rate according to the following formula:

$$E = \frac{W_1 - W_2}{W_1} \times 100 = \frac{w}{W_1} \times 100$$

where E: oil carry-out rate (%)

W_1: oil amount before starting of test (g)

W_2: oil amount after completion of test (g)

w: oil carry-out amount (g)

(h) The test air flow directly before the oil carry-out rate exceeds 1 % in 15 min shall be taken as Oil Carry Out Limit Air Flow.

(1.2) Inclined Attaching Test Attach the air cleaner at the maximum inclination angle able to be caused during running as shown in Appendix 3 Fig. 19, and perform the test similarly to (1.1).

(2) Measurement of Oil Carry-Out Amount The measurement of oil carry-out amount shall, as a rule, be performed with attaching the air cleaner horizontally. However, it may be attached at the inclination angle agreed upon between the parties concerned with delivery (generally, it shall be the maximum inclination angle able to be caused during running).

(a) Prepare the air cleaner according to 16.3 (4). However, do not perform the procedures of (d) to (f) of 16.3.

(b) Measure the mass of oil entering assembly and attach to the test equipment.

Remark: The difference between this mass and the mass of assembly in dry condition is the oil amount before starting the test.

(c) Attach the air cleaner as shown in Appendix 3 Fig. 18 (for inclination attaching, Appendix 3 Fig. 19).

(d) Regulate the air flow rate at the rated flow rate, and maintain the air flow rate for 60 min.

(e) After flowing air for 60 min, detach the air cleaner, measure the mass of the assembly and calculate the oil carry-out amount.

(f) The value of mass of assembly measured in (b) subtracted by the mass of assembly measured in (e) is the Oil Carry-Out Amount.

16.7 Initial Wetting of Element Test Method This test is performed to measure the minimum air flow rate at which the oil adheres on the whole undersurface of element of oil bath air cleaner.

(1) Prepare the air cleaner according to 16.3 (4). However, do not perform (d) to (f) of 16.3 (4).

(2) Attach the air cleaner as shown in Appendix 3 Fig. 14.

(3) Regulate the air flow rate at 10 % of rated air flow, and flow air for 5 min.

(4) Stop the air flow, detach the oil bath, and observe the oil adhering condition at the filter element undersurface.

(5) Attach the oil bath, increase the air flow rate at a rate of 5 % of rated air flow, continue the test until the oil adheres on the whole surface of filter element lower part, and measure the air flow rate at that time to record.

16.8 Efficiency and Dust Holding Capacity Test Method This test is performed for measuring the efficiency and dust holding capacity of oil bath air cleaner. The efficiency test and the dust holding capacity test shall be performed either at a constant air flow or variable air flow according to the following (1) to (4) and, in addition, to 9. Efficiency Test.

(1) Prepare the air cleaner according to 16.3 (4).

(2) Measure the mass of oil entering assembly to record.

Remark: The difference between this mass and the mass of assembly in dry condition is the test oil amount.

(3) Kind of test dust and dust concentration shall be in accordance with 9.2 (5).

(4) At the time of test completion, perform the air flow rate test at oil carry-out limit ([10]) according to 16.6 (1).

Note ([10]) This test is oil carry-out test, but the test oil used for efficiency and dust holding capacity tests is used as it is.

Remark: In the oil bath air cleaner test, the fact that oil carry-out is not caused at the test air flow is required absolutely.

16.9 Recovery Test Method This test is performed for measuring the recovery degree of air flow resistance according to cleaning in oil tank air cleaner.

(1) After completion of dust holding capacity test, draw out the oil from specimen air cleaner and conduct cleaning of air cleaner according to the gist agreed upon between the parties concerned with delivery.

(2) Enter the oil for air flow resistance test into the oil bath up to the designated oil surface.

(3) Perform the air flow resistance test at the rated air flow without feeding dust for 20 min. During that at each 5 min measure the outlet static pressure or pressure drop to record.

(4) Evaluate the recovery capability of specimen air cleaner by comparing these test results with the test results by new specimen air cleaner.

Remark: The calculation of recovery rate shall be in accordance with the formula of 12.4 (1).

17. Test Result Table

Records obtained by test shall be entered in the test result table and the following items shall be entered in the table clearly. The examples are shown in Attached Tables 1 to 4.

(1) Manufacturer of air cleaner, type, manufacturing number, specifications, test results, test date, atmospehric condition and name of test person.

(2) Diagram of air flow resistance and dust holding capacity.

Attached Table 1

An Example of Result Table of Air Cleaner Reference Test (A)

1. Specimen air cleaner   Model/type No.

Manufacturer's name and manufacturing number ____
Assembly ____
Precleaner ____
Filter element ____

Dust cup ☐ ____ /dust exhaust valve ☐ ____
Tubular inlet ☐ ____ /nontubular inlet ☐ ____
Exit ____

2. Test conditions

Test dust JIS Class 7 ☐/Class 8 ☐/ISO coarse ☐/fine ☐ batch No. ____
Atmospheric pressure before test ____ mbar, after test ____ mbar
Temperature before test ____ °C, after test ____ °C
Relative humidity before test ____ RH %, after test ____ RH %
Rated air flow ____ m^3/min
Test air flow constant ☐ variable ☐ ____ m^3/min
Applied method absolute filter method ☐ direct weighing method ☐
Test completion conditions ____
Dust concentration ____ g/m^3
Dust feed compressed air pressure ____ bar

3. Test results   Reference figure

Outlet static pressure (at test air flow) ____ mbar
Pressure drop (at test air flow) ____ mbar
Air flow resistance (at test air flow) ____ mbar
Initial efficiency (dust feed amount g h) ____ %
Intermediate efficiency pressure difference increase ___ % h ____ %
pressure difference increase ___ % h ____ %
pressure difference increase ___ % h ____ %
Full life efficiency ____ %
Precleaner efficiency ____ %
Dust holding capacity (at test completion conditions) ____ g

4. General comments

Test date	Year month day	Person in charge of test	

1 mbar = 100 Pa, 1 mbar = 10.2 mmAq

Attached Table 2

An Example of Result Table of Air Cleaner Reference Test (B)

1. Specimen air cleaner　　　Model/type No.

Manufacturer's name and manufacturing number ________
Assembly ________
Precleaner ________
Primary element ________
Secondary element ________
Dust cup ☐ ________/dust exhaust valve ☐ ________
Tubular inlet ☐ ________/nontubular inlet ☐ ________
Exit ________

2. Test conditions

Test dust JIS Class 7 ☐/Class 8 ☐/ISO coarse ☐/fine ☐ batch No. ________
Test oil ________
Atmospheric pressure before test ________ mbar, after test ________ mbar
Temperature before test ________ °C, after test ________ °C
Relative humidity before test ________ RH %, after test ________ RH %
Rated air flow ________ m^3/min
Test air flow constant ☐ variable ☐ ________ m^3/min
Scavenged air flow ________ m^3/min
Applied method absolute filter method ☐ direct weighing method ☐
Test completion conditions ________
Dust concentration ________ g/m^3
Dust feed compressed air pressure ________ bar

3. Test results　　　Reference figure

Outlet static pressure (at test air flow) ________ mbar
Pressure drop (at test air flow) ________ mbar
Air flow resistance (at test air flow) ________ mbar
Initial efficiency (dust feed amount g h) ________ %
Full life efficiency ________ %
Precleaner efficiency ________ %
Dust holding capacity (at test completion conditions) ________ %
Cleaning of dust cup ________ times
Oil carry-out amount at single air flow rate Yes ☐ No ☐ ________ m^3/min
Oil carry-out limit air flow (at air flow rate increase) ________ m^3/min

4. General comments

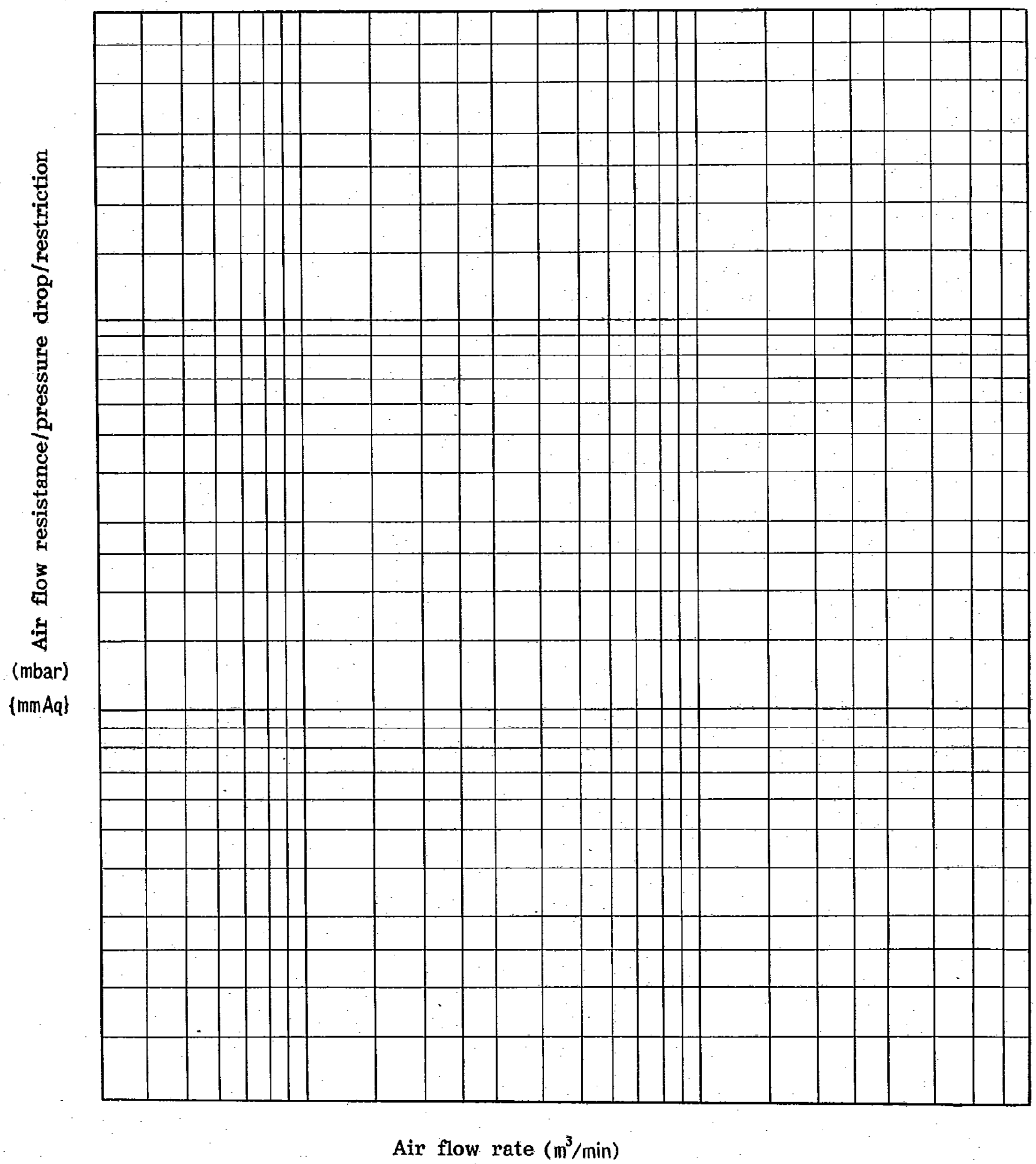
Test date	Year month day	Person in charge of test	

1 mbar = 100 Pa, 1 mbar = 10.2 mmAq

Attached Table 3

An Example of Result Table of Air Cleaner Air Resistance Test

Air cleaner model		Manufacturing number		Test date	Year month day
Atmospheric condition	Atmospheric pressure mbar {mmHg},	Room temperature ℃,	Relative humidity %		
Rated air flow m³/min					

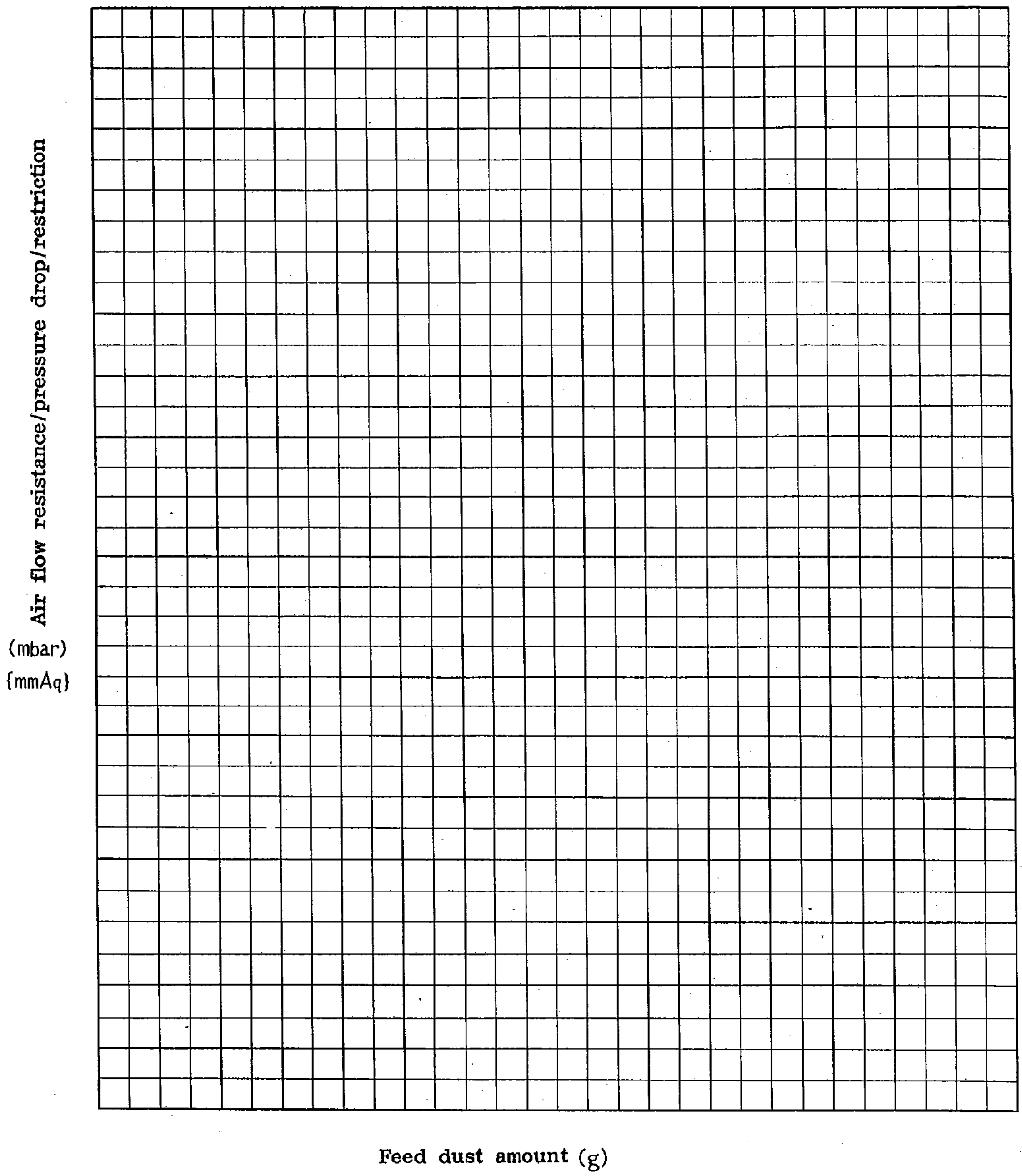


Air cleaner manufacturer		Person in charge of test	

Attached Table 4

An Example of Result Table of Air Cleaner Dust Holding Capacity Test

Air cleaner model		Manufacturing number		Test date	Year month day
Atmospheric condition	Atmospheric pressure mbar {mmHg},	Room temperature ℃,	Relative humidity %		
Air flow rate m³/min	Test dust	Test completion conditions			



Air cleaner manufacturer		Person in charge of test.	

Appendix 1 Definitions

1. Scope

This Appendix specifies definitions used in test methods of air cleaners for automobiles.

Remark: The English equivalent in ( ) is given for informative reference.

2. Definitions

For the purpose of this Standard, the following definitions apply:

(1) KYŌ SHI EA KURĪNA (air cleaner under test) A filter element unit or a complete air cleaner assembly to be offered to test.

(2) KAN SHIKI EA KURĪNA (wet type air cleaner) An air cleaner using filter materials such as filter paper, unwoven fabric, etc. in dry condition as the filter element.

(3) SHITSU JUN SHIKI EA KURĪNA (wet type air cleaner) Air cleaner which is used for filter material such as filter paper, expanded urethane foam, etc. to be used for filter element in the condition impregnated with non-volatile oil.

(4) YUSŌ SHIKI EA KURĪNA (oil bath air cleaner) Air cleaner which collects dust primarily by impacting in-flow air to the oil surface in oil bath provided at the lower part and further collects dust secondarily by filter element having filter net.

(5) SAIKURON SHIKI EA KURĪNA (cyclone type air cleaner) Air cleaner whch separates dust from air flow by centrifugal force generated by rotating in high speed in the case by utilizing inertia force of suction air.

For combination methods of cyclone type air cleaner and main cleaner, there are method to build in cyclone structure in outer periphery of filter element and the method to set cylone type air cleaner separately from main air cleaner.

(6) PURI KURĪNA (precleaner) Auxiliary air cleaner used for removing a part of dust before the dust reaches filter element of main cleaner. Usually it is the dust separating equipment by using centrifugal force style (cyclone type) or inertia style and in many cases the cyclone type is used.

(7) TADAN SHIKI EA KURĪNA (multi-stage air cleaner) Air cleaner combined with filter styles of not less than two stages, in which the first stage is precleaner and at the downstream the main air cleaner is arranged.

In the case where two filter elements are used in main air cleaner, the element at upstream side of flow is called Primary Element, and the element at downstream side Secondary Element.

(8) SŌKI SHIKI EA KURĪNA (scavenged air cleaner) Air cleaner connected with ejector or the like to generate scavenged flow in order to automatically and forcedly exhaust the dust collected by precleaner. It is a type of Multi-Stage Air Cleaner.

(9) SHIKEN KŪKI RYŌ (test air flow) Air flow rate which in performance test flows out from air cleaner outlet per unit time. The air flow rate is corrected to standard condition and expressed by unit of cubic meter per minute (m^3/min).

(10) TEIKAKU KŪKI RYŌ (rated air flow) The maximum air flow of air cleaner designated by agreement between the parties concerned with delivery. Generally, it is used as the test air flow.

(11) SŌKI KŪKI RYŌ (scavenged air flow) The air flow rate used for forcedly exhausting the dust collected by precleaner from the precleaner. It is expressed by percentage (%) to the air flow rate passing through main air cleaner.

(12) SEI ATSU (static pressure) Pressure in a duct in the measured air flow rate and is the pressure measured by connecting pressure measuring devices with one or more holes opened in the duct wall.

In the test specified in this Standard, the static pressure is measured as the negative differential pressure to atmospheric pressure, and in calculation formula it is treated as positive value.

(13) DEGUCHI SEIATSU (restriction) Static pressure directly measured at downstream of air cleaner under test.

(14) ATSURYOKU KŌKA (pressure drop) Difference between the static pressure measured at upstream of air cleaner under test and the static pressure measured at downstream.

(15) TSŪKI TEIKŌ (air flow resistance) Difference between the whole pressure at upstream side of air cleaner generated by air flow and the whole pressure at downstream side. This corresponds to energy loss generated by air cleaner and is "ATSURYOKU SONSHITSU (pressure loss)" of corrected difference between the pressure drop measured at measuring point and the dynamic pressure head.

Further, the whole pressure is the sum of static pressure and dynamic pressure.

(a) In the Case of Air Cleaner Sucking Air through Inlet Tube Measure the pressure drop (ΔP_d) of air cleaner and correct the dynamic pressure head difference generated by difference of sectional areas of duct at the pressure taking-out points of upstream side and downstream side for confirming the air flow resistance of air cleaner.

Calculate the air flow resistance of air cleaner according to the following formulae:

$$\Delta P_t = \Delta P_d - \Delta P_c = (P_2 - P_1) - \Delta P_c$$

where ΔP_t : air flow resistance (mbar) {mmAq}

ΔP_d : measured pressure drop (mbar) {mmAq}

ΔP_c : dynamic pressure head difference between measuring points (mbar) {mmAq}

P_1 : upstream side static pressure of air cleaner (mbar) {mmAq}

P_2 : restriction (mbar) {mmAq}

$$\Delta P_c = 0.01 \times \left(\frac{\rho \cdot v_2^2}{2} - \frac{\rho \cdot v_1^2}{2}\right)$$

where v_1 : air speed in duct at pressure taking-out point at upstream side (m/s)

v_2 : air speed in duct at pressure taking-out point at downstram side (m/s)

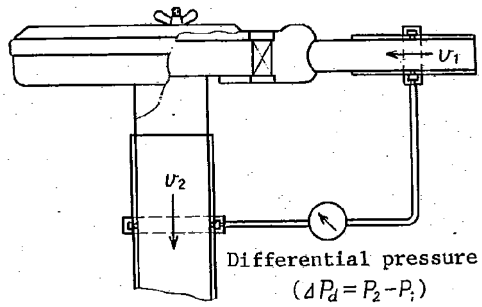
ρ : density of air (kg/m^3), in standard condition ρ = 1.20 kg/m^3

$$\Delta P_c = \frac{\gamma v_2^2}{2g} - \frac{\gamma v_1^2}{2g}$$

{where γ : weight of air per unit volume (kg/m^3), in standard condition $\gamma = 1.20$ kgf/m^3

g : acceleration of gravity = 9.8 (m/s^2)}

Appendix 1 Fig. 1



(b) In the Case of Air Cleaner Sucking Air Directly from Atmosphere
Because the upstream side pressure is equal to atmospheric pressure, measure the static pressure (restriction) in downstream side duct, calcualte the dynamic pressure head (P_v) required for accelerating air to speed in downstream side duct from the static conduction, and obtain the air flow resistance of air cleaner.

Calculate the air flow resistance of air cleaner according to the following formulae:

$$\Delta P_t = \Delta P_r - \Delta P_v = P_2 - P_v$$

where ΔP_t: air flow resistance (mbar) {mmAq}

ΔP_r: measured restriction (mbar) {mmAq}

P_v: dynamic pressure head in duct at downstream side pressure taking-out point (mbar) {mmAq}

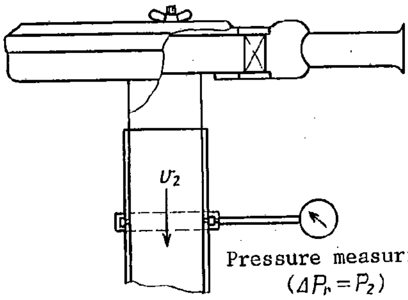
$$P_v = 0.01 \times \frac{\rho \cdot v_2^2}{2}$$

where ρ and v_2 are same as in (a).

{ $P_v = \frac{\gamma v_2^2}{2g}$

where γ and g are same as in (a). }

Appendix 1 Fig. 2



Appendix 1 Table. Relation of Upstream Side Static Pressure, Restriction and Air Flow Resistance of Air Cleaner

Unit: mbar

Term	(a) Air cleaner to suck in air through inlet tube	(b) Air cleaner to suck in air directly from atmosphere
Upstream side static pressure of air cleaner	P_1	–
Restriction Downstream side static pressure of air cleaner	$\Delta P_r = P_2$	$\Delta P_r = P_2$
Pressure drop	$\Delta P_d = \Delta P_r - P_1$ $= P_2 - P_1$	–
Air flow resistance (pressure loss)	$\Delta P_t = \Delta P_d - \Delta P_c$ $= (P_2 - P_1) - 0.01 \times \frac{\rho \cdot v_2^2 - \rho \cdot v_1^2}{2}$	$\Delta P_t = \Delta P_r - P_v$ $= P_2 - 0.01 \times \frac{\rho \cdot v_2^2}{2}$

(16) ABUSORYŪTO FIRUTA (absolute filter) Filter arranged at downstream of air cleaner under test for collecting dust which has passed through air cleaner under test at the time of efficiency test.

(17) SEIJŌ KŌRITSU (efficiency) Ratio of mass of dust collected by air cleaner according to capability of air cleaner to remove dust from air to mass of fed dust expressed by percentage (%).

Depending upon measuring time of dust feeding time, there are initial efficiency, intermediate efficiency, and full life (final) efficiency.

(18) DASUTO HOJIRYŌ (dust holding capacity) Mass of dust collected by air cleaner under test until the air flow resistance and the like reach the designated test completion conditions.

(19) ABURA MOCHISARI (oil carry over) Condition where oil is carried over to air cleaner outlet according to air flow in oil bath and dry type air cleaners.

(20) ABURA MOCHISARI RITSU (percentage of oil carry over) Ratio of oil amount carried over from oil bath and wet type air cleaners by air to the initial oil amount expressed by percentage (%).

(21) ABURA MOCHISARI GENKAI KŪKIRYŌ Air flow rate at the time when percentage of oil carry over has reached 1 % according to air flow increase.

(22) ROKAMŌ NO ABURA NURE (initial wetting of element) Condition at the time when oil has adhered on the whole lower part surface of filter net according to air flow increase in oil bath air cleaner, and it is expressed by air flow rate at that time.

(23) FUKUGEN SEI (recovery) Ratio of air flow resistance after cleaning of tested air cleaner to air flow resistance of new product, expressed by percentage (%).

Fruther, in dust holding capacity test, ratio of dust holding capacity at the period of new product to the dust holding capacity after cleaning, expressed by percentage (%).

(24) SHIKEN SHŪRYŌ JOKEN (test terminal condition) Condition to determine performance of air cleaner, and, when having reached the condition, the test is terminated.

As to examples of test terminal conditions, there are following matters.

(a) Restriction or pressure drop reaches designated value.

(b) Efficiency or other performance characteristic values lower until the designated value.

(c) Oil carry over is generated.

(d) Dust cup is filled fully.

Apopendix 2 Test Dusts

1. Scope

This Appendix specifies test dusts used in performance tests of air cleaners for automobiles.

2. Classification

Classification of test dusts shall, as a rule, be as follows:

(1) Standard Dust The standard dust shall be classified into Class 7 (coarse particle) and Class 8 (fine particle) specified in JIS Z 8901.

(2) Particular Dust The particular dust shall be classified into coarse dust (coarse particle) and fine dust (fine particle) of 5.1 of ISO 5011.

3. Chemical Components

Chemical components of test dusts shall be in accordance with Table 1 and Table 2 of Appendix 2.

Appendix 2 Table 1. JIS Class 7 and Class 8 Dusts

Chemical component	Mass percentage %
SiO_2	34 to 40
Fe_2O_3	17 to 23
Al_2O_3	26 to 32
CaO	0 to 3
MgO	3 to 7
TiO_2	0 to 4
Ignition loss	0 to 4

Remark: True density of dust: 2.9 to 3.1 g/cm^3

Appendix 2 Table 2. ISO Coarse Dust and Fine Dust

Chemical component	Mass percentage %
SiO_2	67 to 69
Fe_2O_3	3 to 5
Al_2O_3	15 to 17
CaO	2 to 4
MgO	0.5 to 1.5
Total alkali amount	3 to 5
Ignition loss	2 to 3

Remark: True density of dust: 2.6 to 2.7 g/cm3

4. Particle Size Distribution

The particle size mass distribution measured by Andreason pipette method shall be in accordance with Table 3 and Table 4 of Appendix 2.

Appendix 2 Table 3. Dust for JIS Test

Unit: mass percentage %

Particle size µm	Over sieve	
	Class 7	Class 8
2	—	—
5	88±5	61±5
10	76±3	43±3
20	62±3	27±3
30	50±3	15±3
40	39±3	9±3
75	20 以下	3 以下
125	—	—

Appendix 2 Table 4. Dust for ISO Test

Unit: mass percentage %

Particle size µm	Over sieve	
	Coarse	Fine
2	—	82.5±2.5
5	90 ±1	65 ±3
10	80.5±1.5	51 ±3
20	68 ±2	33 ±3
30	—	—
40	49 ±2	16 ±3
75	15.5±5.5	2 ±2
125	1.5±1.5	—

Remark: In ISO 5011, under sieve marking is used, but over sieve marking is used herein for accommodation with JIS Z 8901.

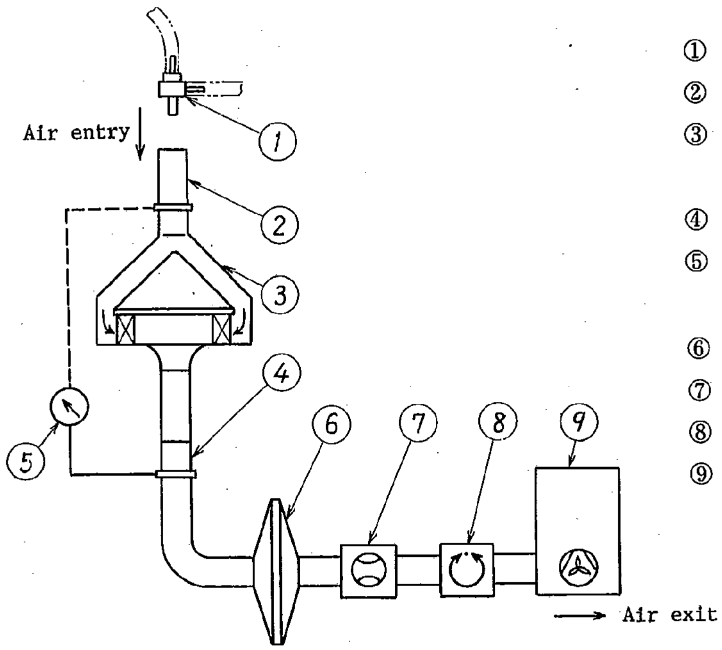
References 1. Dust for JIS test is available from the Association of Powder Process Industry and Engineering Japan, incorporated association.

2. Dust for ISO test is available from the Association of Powder Process Industry and Engineering Japan, incorporated association, AG Rochester Div., General Motors Corp., Flint, MI. in USA or P.T.I. (Powder Technology Incorporated in U.S.A.)

Appendix 3 Test Equipment

This Appendix indicates the test equipment used for performance test of air cleaners for automobiles.

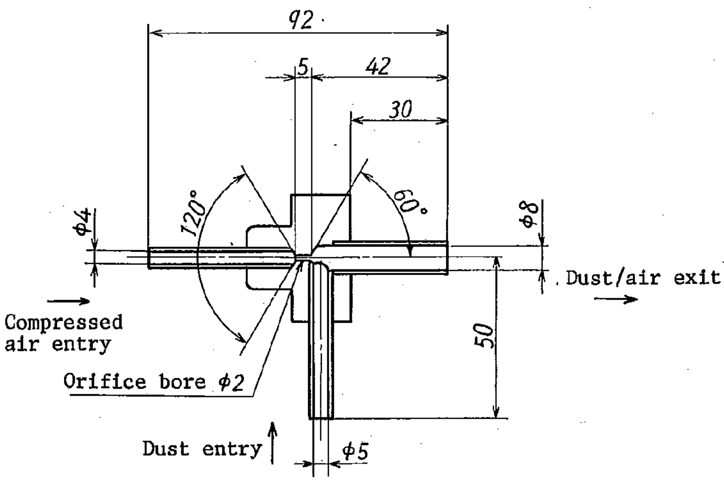
Appendix 3 Fig. 1. Test Equipment for Filter Element Efficiency and Dust Holding Capacity



① Dust injector (Appendix 3 Fig. 2)
② Inlet tube (Appendix 3 Fig. 3)
③ Test shroud (Appendix 3 Fig. 4)
④ Outlet tube (Appendix 3 Fig. 3)
⑤ Pressure measuring device (Differential pressure gauge)
⑥ Absolute filter
⑦ Air flow meter
⑧ Air flow control
⑨ Exhauster

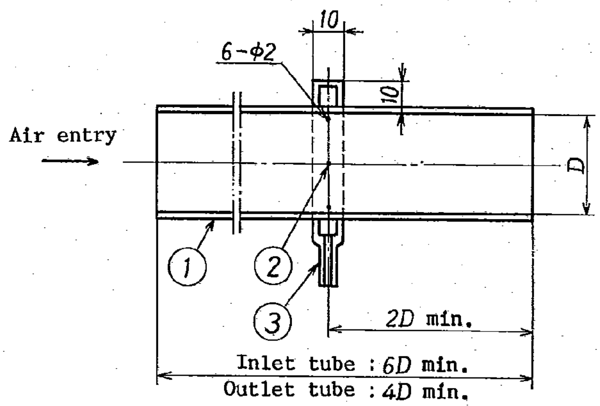
Appendix 3 Fig. 2. Dust Injector

Unit: mm



Appendix 3 Fig. 3. Inlet Tube and Outlet Tube

Unit: mm

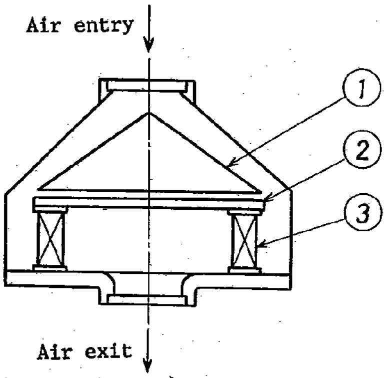


① Tube

② Holes equally spaced

③ Pressure tapping

Appendix 3 Fig. 4. Filter Element Test Shroud



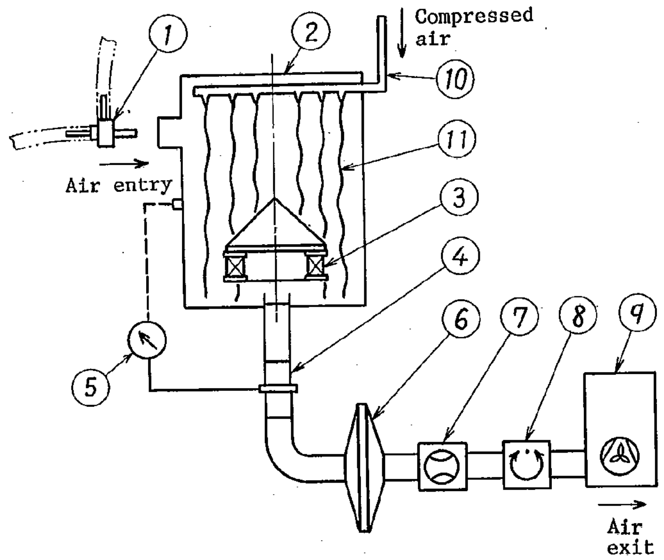
① Diffuser cone

② Sealing plate

③ Unit under test

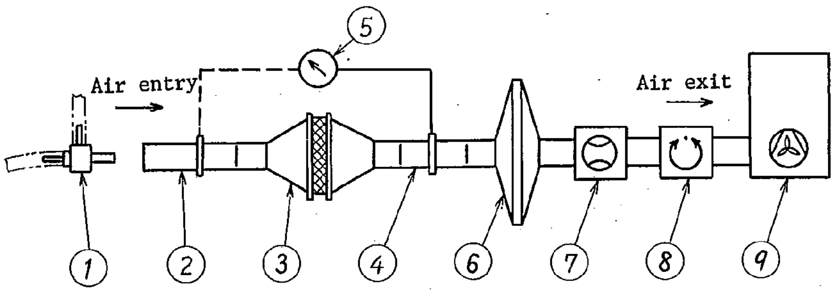
Appendix 3 Fig. 5. Test Equipment for Efficiency Using Dust Chamber and Dust Holding Capacity

(In This Figure a Single Filter Element is Installed)



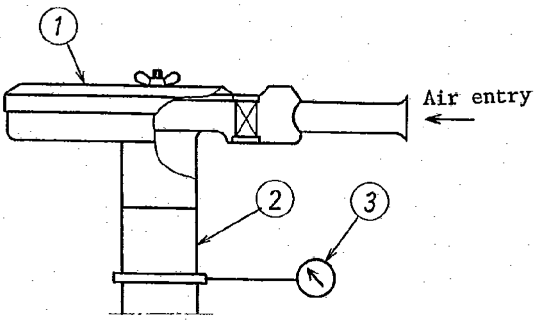
① Dust injector (Appendix 3 Fig. 2)
② Dust chamber
③ Air cleaner under test with diffuser cone
④ Outlet tube (Appendix 3 Fig. 3)
⑤ Pressure measuring device (Differential pressure gauge)
⑥ Absolute filter
⑦ Air flow meter
⑧ Air flow control
⑨ Exhauster
⑩ Compressed air feeding tube
⑪ Comrpessed air feeding flexible tubes

Appendix 3 Fig. 6. Test Equipment for Panel Filter Element Efficiency and Dust Holding Capacity



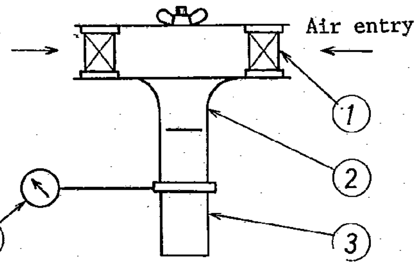
① Dust injector (Appendix 3 Fig. 2)
② Inlet tube (Appendix 3 Fig. 3)
③ Panel filter element test chamber
④ Outlet tube (Appendix 3 Fig. 3)
⑤ Pressure measuring device (Differential pressure gauge)
⑥ Absolute filter
⑦ Air flow meter
⑧ Air flow control
⑨ Exhauster

Appendix 3 Fig. 7. Test Equipment for Air Cleaner Assembly Air Flow Resistance (Restriction)



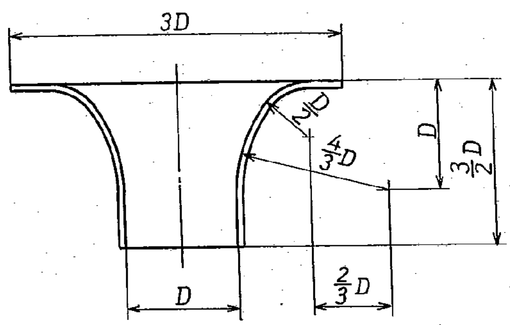
① Air cleaner under test
② Outlet tube (Appendix 3 Fig. 3)
③ Pressure Measuring device

Appendix 3 Fig. 8. Test Equipment for Filter Element Air Flow Resistance

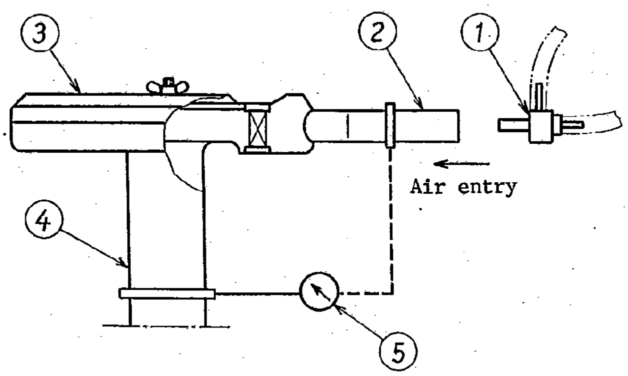


① Element under test
② Ideal flow orifice (Appendix 3 Fig. 9)
③ Outlet tube (Appendix 3 Fig. 3)
④ Pressure measuring device

Appendix 3 Fig. 9. Ideal Flow Orifice ($D=D$ of Appendix 3 Fig. 3)

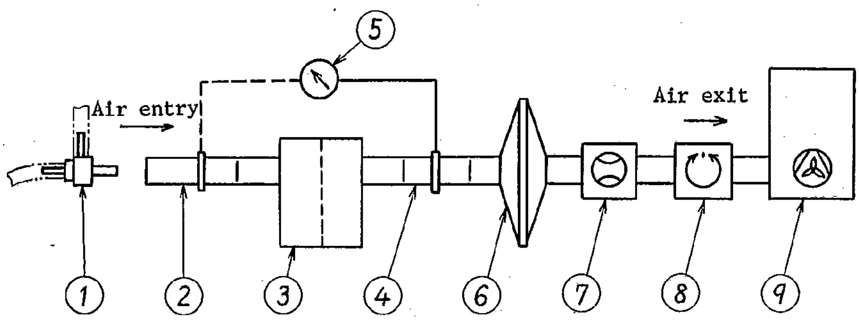


Appendix 3 Fig. 10. Test Equipment for Air Cleaner Assembly Efficiency and Dust Holding Capacity



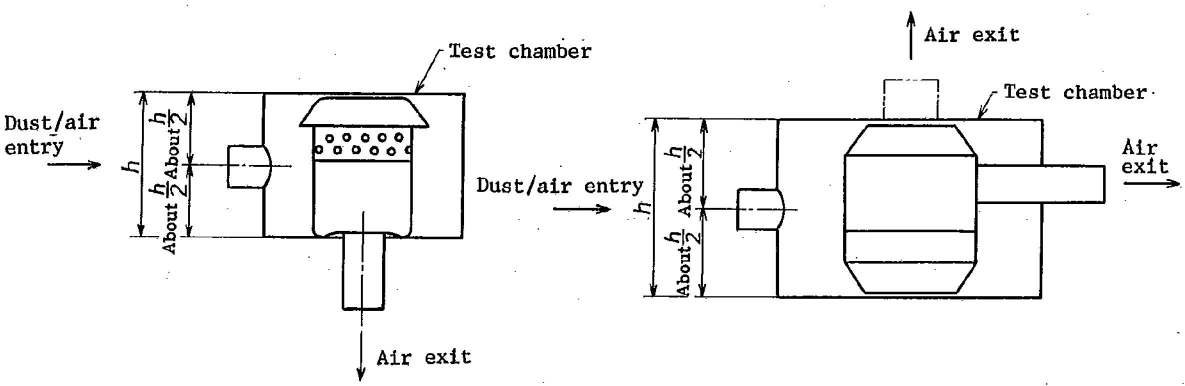
① Dust injector (Appendix 3 Fig. 2)
② Inlet tube (Appendix 3 Fig. 3)
③ Air cleaner under test
④ Outlet tube (Appendix 3 Fig. 3)
⑤ Pressure measuring device (Differential pressure gauge)

Appendix 3 Fig. 11. Test Equipment for Tubular Inlet Air Cleaner Efficiency and Dust Holding Capacity

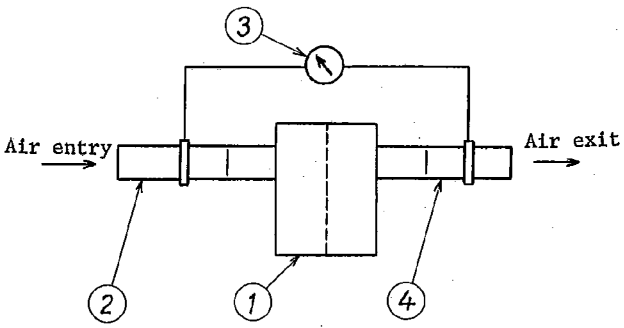


① Dust injector (Appendix 3 Fig. 2)
② Inlet tube (Appendix 3 Fig. 3)
③ Air cleaner under test
④ Outlet tube (Appendix 3 Fig. 3)
⑤ Pressure measuring device (Differential pressure gauge)
⑥ Absolute filter
⑦ Air flow meter
⑧ Air flow control
⑨ Exhauster

Appendix 3 Fig. 12. Non-Tubular Inlet Air Cleaner Test Chamber

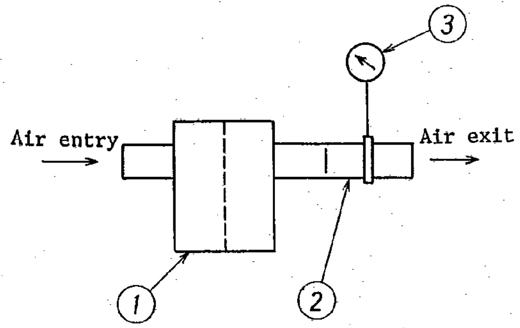


Appendix Fig. 13. Test Equipment for Air Cleaner Assembly Air Flow Resistance (Pressure Drop)



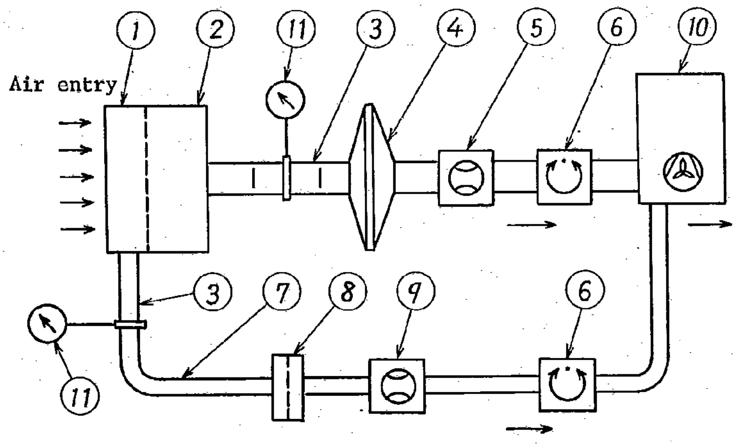
① Air cleaner under test
② Inlet tube (Appendix 3 Fig. 3)
③ Pressure measuring device (Differential pressure gauge)
④ Outlet tube (Appendix 3 Fig. 3)

Appendix 3 Fig. 14. Test Equipment for Air Assembly Air Flow Resistance (Restriction)



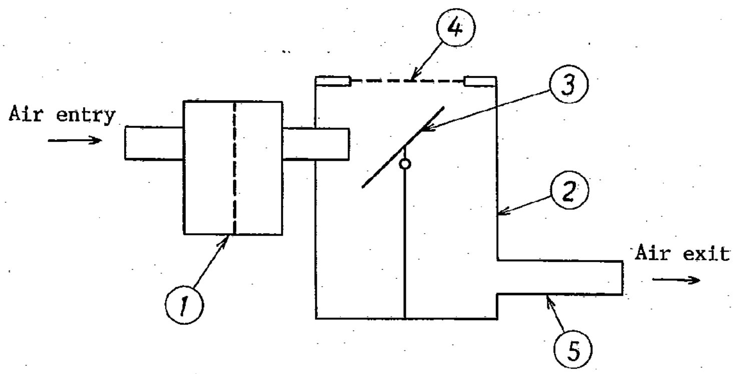
① Air cleaner under test
② Outlet tube (Appendix 3 Fig. 3)
③ Pressure measuring device

Appendix 3 Fig. 15. Test Equipment for Scavenged Air Cleaner Efficiency and Dust Holding Capacity



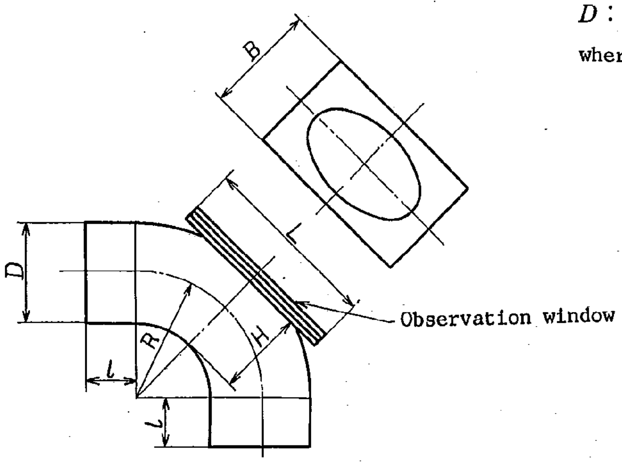
① Precleaner
② Main cleaner
①+② Air cleaner under test
③ Outlet tube
(Appendix 3 Fig. 3)
④ Absolute filter
⑤ Air flow meter
⑥ Air flow control
⑦ Scavenge air duct
⑧ Scavenge air duct filter
⑨ Scavenge air duct flow meter
⑩ Exhauster
⑪ Pressure measuring device

Appendix 3 Fig. 16. Observation Chamber for Oil Carry-Over Test



① Air cleaner under test
② Observation chamber
③ Target plate covered with paper
④ Observation window
⑤ Outlet to air exhauster

Appendix 3 Fig. 17. Observation Window Bent Tube for Oil Carry-Over Test



D : Piping outer diameter of test equipment

where, $R=1.25\,D$

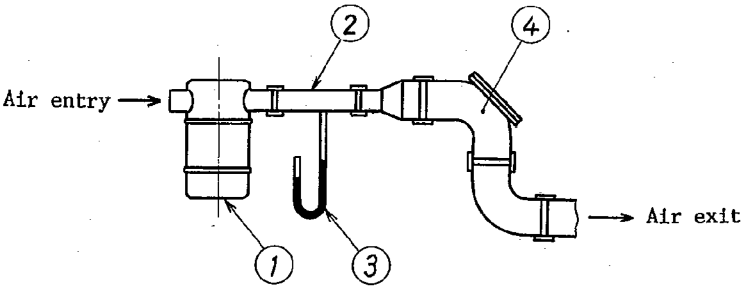
$l=0.5\,D$

$H=0.875\,D$

$L=1.90\,D$

$B=1.10\,D$

Appendix 3 Fig. 18 Air cleaner Horizontal Attaching Method in Oil Carry-Over Test



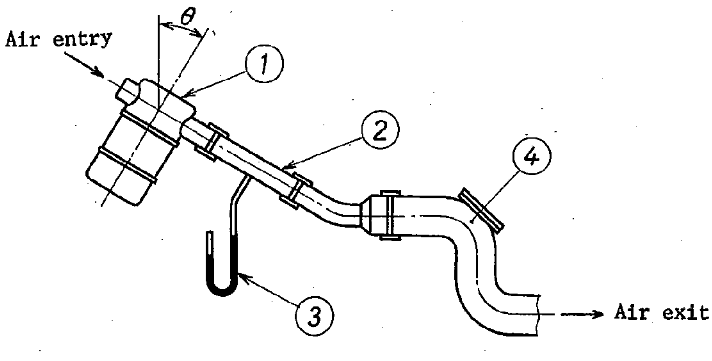
① Air cleaner under test

② Outlet tube (Appendix 3 Fig. 3)

③ Pressure measuring device

④ Observation window bent tube (Appendix 3 Fig. 17)

Appendix 3 Fig. 19. Air Cleaner Inclination Attaching Method in Oil Carry-Over Test



① Air cleaner under test

② Outlet tube (Appendix 3 Fig. 3)

③ Pressure measuring device

④ Observation window bent tube (Appendix 3 Fig. 17)

Appendix 4 Air Flow and Resistance Corrections to Standard Conditions

1. Scope

This Appendix specifies the gist to correct the values of air flow, air flow resistance, etc. measured by using air cleaner test method for automobiles to the standard conditions.

Remarks 1. The standard conditions shall be temperature: 20°C, atmospheric pressure: 1013 mbar (760 mmHg), and relative humidity: 65 %.

2. For correction there are method to correct air flow value and method to correct air flow resistance value and the like.

2. Air Flow Correction

In the case of converting air flow to standard condition, it shall be conducted according to the following formula:

$$Q_0=\frac{\rho}{\rho_0}\times Q$$

where Q_0 : air flow converted to standard condition (m^3/min)

Q : measured air flow (m^3/min)

ρ_0 : density of wet air under the standard condition (kg/m^3) [or weight per unit volume γ_0 (kgf/m^3)]

ρ : density of wet air under the measuring condition (kg/m^3) [or weight per unit volume γ (kgf/m^3)]

However, in the case of temperature not higher than 30°C, even if air density is calculated as dry air, the error due to conversion is within 1 %, and therefore it may be calculated according to the following formula which is introduced by using dry air density.

$$Q_0=\frac{293}{P_0}\times\frac{P}{273+t}\times Q$$

where P : air pressure at measuring point (mbar) {mmHg}

P_0 : air pressure under standard condition (mbar) {mmHg}

t : temperature at measuring point (°C)

The relation diagram of conversion factor calculated according to the above formula $\left(\frac{\rho}{\rho_0}=\frac{293}{P_0}\times\frac{P}{273+t}\right)$, P and t is shown in Appendix 4 Fig. 1.

In the case where the temperature exceeds 30°C, calculate according to the following formula which is introduced by using wet air density.

$$Q_0=\frac{293}{P_0}\times\frac{P-0.378\cdot\phi\cdot F}{273+t}\times Q$$

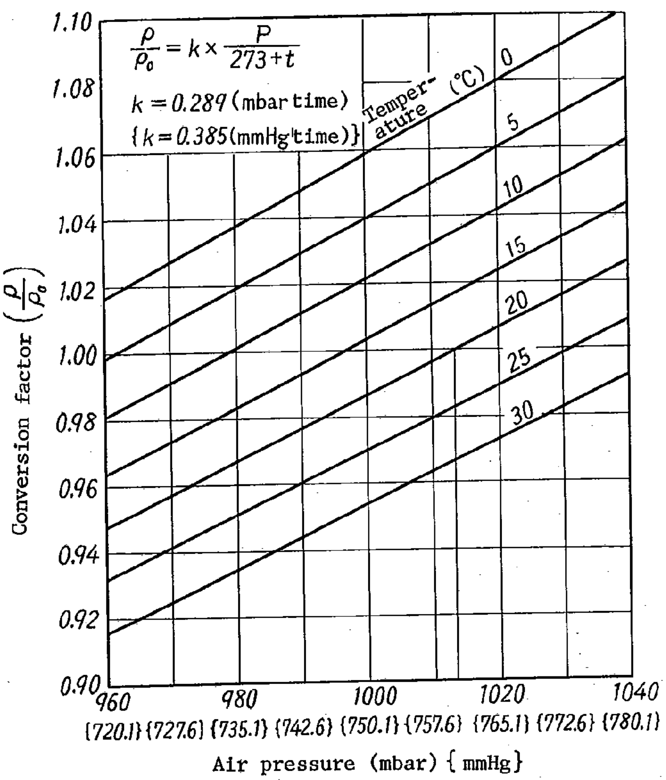
where ϕ: relative humidity (%)

F: pressure of saturated steam at t℃ (mbar) {mmHg}

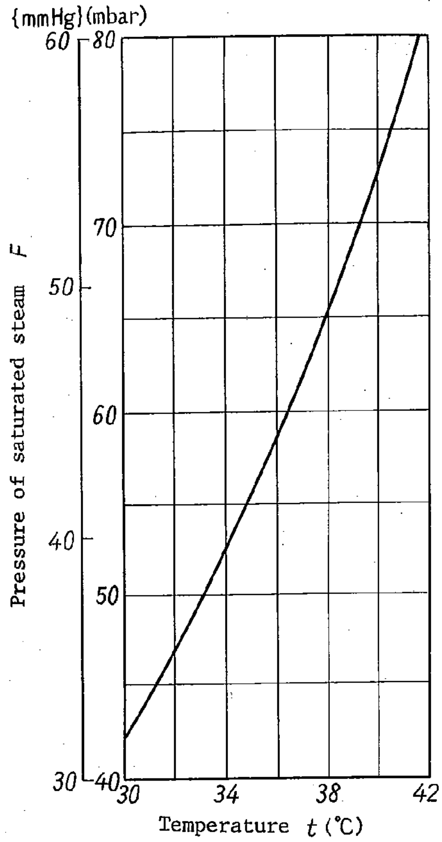
provided that the wet air density under the standard condition is taken as $\gamma_0=1.20\ \text{kgf/m}^3$) (weight per unit volume $\rho_0=1.20\ \text{kg/m}^3$).

Pressures of saturated steam in the case of temperature not lower than 30°C are shown in Appendix 4 Fig. 2.

Appendix 4 Fig. 1. Conversion Factor of Air Flow



Appendix 4 Fig. 2. Pressure of Saturated Steam



3. Corrections of Restriction, Pressure Drop, Air Flow Resistance

Air cleaner resistance (ΔP) can be marked according to the following formula:

$$\Delta P=K_1\mu V+K_2\rho V^2$$

where ΔP: restriction, pressure drop or air flow resistance

K_1: empirical constant

K_2: empirical constant

μ: dynamic viscosity (mm^2/s)

ρ: air density (kg/m^3)

V: volume flow (m^3/h)

m: mass flow (kg/h)

Substituting $V=\frac{m}{\rho}$

$$\Delta P=K_1\mu\frac{m}{\rho}+K_2\rho\left(\frac{m}{\rho}\right)^2$$

and rearranging terms

$$\rho\cdot\Delta P=K_1\mu m+K_2 m^2$$

Thus by maintaining mass flow constant and limiting the variation in ambient temperature to keep the change in viscosity small, $\rho\cdot\Delta P$ will remian constant.

Therefore,

$$\rho_0\cdot\Delta P_0=\rho\cdot\Delta P$$

where subscript 0 indicates the values of restriction, pressure drop or air flow resistance at standard condition.

$$\Delta P_0=\frac{\rho}{\rho_0}\times\Delta P$$

Measured restriction, pressure drop and air flow resistance values shall be corrected to standard conditions by using the following formula:

$$\Delta P_0=\frac{P-0.378\cdot\phi\cdot F}{P_0}\times\frac{293}{273+t}\times\Delta P$$

or

$$\Delta P_0=\frac{293}{P_0}\times\frac{P-0.378\cdot\phi\cdot F}{273+t}\times\Delta P$$

where P, P_0, t, ϕ, F (1) are same as in 2.

ΔP: measured value (mbar) {mmHg} of ΔP_r (restriction), ΔP_d (pressure drop) or ΔP_l (air flow resistance)

Note (1) In the case where the temperature is not higher than 30°C, even if $F=0$, the error is small, and the saturated steam pressure in the case where the temperature exceeds 30°C are shown in Appendix 4 Fig. 2.

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