SURFACE VEHICLE TECHNICAL REPORT

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Engine Intake Air Water Separation Test Procedure

RATIONALE

The working group has reviewed this document and come to the conclusion that no technical changes will be made during this revision. All changes currently included are editorial in nature to bring it up to current SAE style guidelines.

1. SCOPE

This water separation technical report has been established to cover heavy-duty engine intake filter systems. It may also be applicable to some automotive and industrial air inlet systems where water separation is an issue.

1.1 Purpose

The purpose of this document is to establish and specify a uniform test method to permit a general evaluation of the water separation performance of engine intake systems.

The performance and reliability of internal combustion engines and other equipment employing intake air filtration or separation systems is affected by the performance of the intake system in removing contaminants including water from the intake airflow. Water vapor or pure liquid in small quantities is not generally considered detrimental to an engine. Water vapor or liquid in sufficient quantities, however, can reduce the quality and reliability of the intake filtration system in at least three ways. First, it can cause the pressure drop to increase across the filter. This increases the restriction to the engine and may reduce filter life or capacity. Second, water in sufficient quantities can facilitate the passing of fine particles in suspension and salt and other contaminants in solution, through the filter. Once on the clean side of the filter, the contamination particles, precipitates, or consequential corrosion residue are able to enter the engine and cause damage to the engine and engine management systems. Third, water vapor or liquid in sufficient quantities can cause filter media degradation, even to the point of burst for condition of wet media at high pressure drops.

Experience has shown that engine intake air water separation systems, which perform on the order of 80% or higher efficiency, as measured by this procedure, will usually avoid water ingestion problems.

It is therefore desirable to provide a procedure for uniformly measuring the effectiveness of intake systems in separating or otherwise removing water from the intake system.

Actual field conditions will vary widely and are difficult to duplicate. The intent of this procedure is to specify the most important variables involved, which will promote uniform laboratory evaluation and comparison of the water separation performance of intake filter systems and components.

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There are other variations of water separation testing that have been suggested. The objective of these tests is typically to evaluate the water ingestion sensitivity of an intake system (including filter element). This type of test typically involves logging the restriction level at the air cleaner outlet over time, while feeding water spray droplets. This might be done before and/or after feeding air cleaner test dust, or it might be done on a field-loaded element. Relative performance is evaluated by the sensitivity to water ingestion, measured by the degree of rise and subsequent recovery of restriction levels as the feed water is initiated and halted.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.1.1 ASABE Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ANSI/ASAE S572.1 W/Corr. 1 MAR2009 (R2013), “Spray Nozzle Classification by Droplet Spectra”

2.1.2 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ISO 5011 Inlet Air Cleaning Equipment for Internal Combustion Engines and Compressors - Performance Testing

ISO TS 11155-1 Road Vehicles - Air Filters for Passenger Compartment

3. ADDITIONAL EQUIPMENT

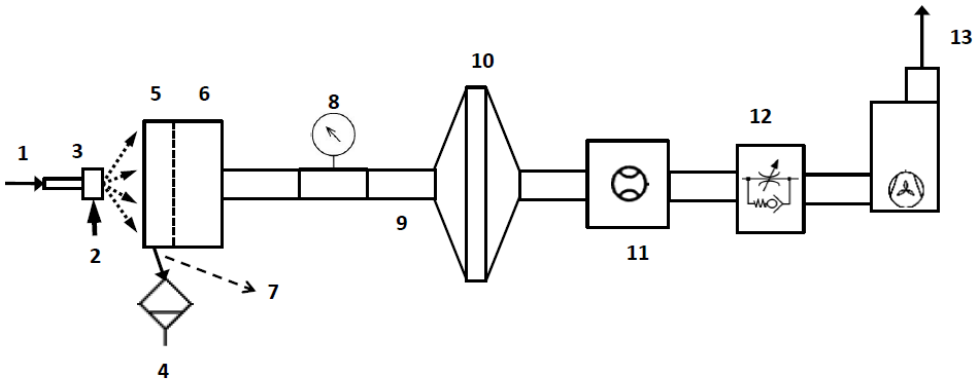
A typical test arrangement is shown in Figure 1. Test setups described in Appendix B, Figures B.7, B.12, and B.16 of ISO 5011:2014 also generally apply, with the replacement of the dust feed system by a water feed and collection system. In addition to the airflow test equipment required in ISO 5011, the following test equipment is required to conduct water separation tests.

3.1 Water Feed System

The water feed system shall consist of a pump or other means of supplying water at a fixed and controlled temperature, and flow rate or pressure, to the spray nozzle(s).

3.2 Water Collection System

A system of pre-weighed collection containers and/or other means shall be provided to quantify the water separated by the inlet system under test. For most tests, the water collection system will consist of containers placed at all locations where collected or separated water is drained or removed. This will vary with the design of the system under test. Scavenged air cleaner or precleaner systems will require more elaborate means of collecting the separated water.



1. Air Supply System
2. Water Supply System
3. Spray Nozzle(s)
4. Water Collection System
5. Pre-cleaner or Separator
6. Main Air Filter
7. Scavenging System if Present
8. Restriction Measuring Device
9. Outlet Tube
10. Absolute Filter
11. Air Flow Meter
12. Air Flow Controller
13. Exhauster

Figure 1 - Water separation efficiency test setup

3.3 Water Injection Spray Nozzles

Water injection is accomplished with a spray nozzle system. Due to the fact that the efficiency of most separators is dependent on droplet size, test results will be sensitive to the droplet size distribution produced by the spray nozzle. Droplet sizes generated are controlled by the nozzle design and operating parameters (e.g., air and/or water supply pressure). For direct comparison, the same spray nozzle(s), air pressure (if used), water pressure (if applicable), water temperature, nozzle distance and angle from inlet, and water flow rate shall be used. The water droplet size shall be determined either from the manufacturer specifications, or by measuring the droplet size at a specific distance away from the nozzle. This distance shall be the same as the distance from the nozzle to the separator being tested.

3.4 Rain Droplet Size

Rain droplets can generally range in size from 0.1 to 10 mm in diameter. Road spray from other vehicles, or fog conditions, can expand droplet size range both smaller and larger. Since a wide range of conditions exists, there may be interest in water separation performance at various conditions for various applications. Droplet sizes for most frequently encountered conditions are listed in Table 1. Instrumentation for the precise measurement and control of water droplet size is not readily available. Nozzle manufacturers can usually provide general droplet size information at specific operating conditions of flow and pressure. Nozzle wear, corrosion, or buildup of mineral deposits can alter nozzle performance. It should be recognized that inspection, maintenance, and replacement of nozzles or affected parts is necessary. Spray patterns and nozzle position relative to the inlet should be guided by a preference toward attempting to cover as much of the inlet area with challenge spray as possible. It is recognized that inlet locations vary widely on vehicles, and depending on wind and vehicle speed and directions, it may be desirable to run tests with the spray nozzle oriented in directions other than being aligned with an extension of the inlet. It has been suggested that an array of nozzle positions might be used to simulate a range of operating conditions. Multiple nozzles may be used for better coverage, if total flow rate and water droplet size effects are considered and accounted for.

Table 1 - Water droplet size

Condition	Droplet Size Range
Fog and Mist	1-100 µm
Drizzle and Rain	100-10000 µm

4. MEASUREMENT ACCURACY

Measurement accuracy specified in Section 4 of ISO 5011 shall apply with the following additions:

4.1 Measure water flow rate within 5% of the actual value.

4.2 Measure spray nozzle pressures within ±1 kPa.

4.3 Measure water temperature within ±1.0 °C.

4.4 Measure weight of water, fed or separated and collected, to within ±1% of the weighed value or 1 gram, whichever is greater.

5. TEST CONDITIONS AND MATERIALS

5.1 Water used for testing should be chosen per the nozzle manufacturers specifications or should have a conductivity lower than 20 µS/cm to reduce maintenance and variation in performance of the spray nozzle. Water supply temperature shall be maintained within ±2 °C of the temperature of the air entering the test system.

5.2 Temperature and Humidity

This procedure currently does not attempt to fully account for water evaporation, although the control over water temperature should reduce variability due to water evaporation. Since evaporation of water entering the system under test will have an effect on results, the temperature and humidity of the test airflow should be maintained for consistent results. All tests shall be conducted with the air entering the air cleaner or separator system at a temperature of 23 °C ± 5 °C and a relative humidity of 55% ± 15%. Water temperature should be sprayed at a temperature of 20 °C ± 10 °C. This condition should be understood to prevail only before water injection spray is begun, or in the ambient airstream before mixing with the water spray.

6. TEST PROCEDURE

The intent and scope of this procedure is primarily to evaluate inertial separation, and coalescing devices in the inlet ductwork or filter housing entrance. Therefore, most testing would be conducted with a clean filter element.

6.1 Set up the air cleaner intake system as shown in Figure 1.

6.2 Adjust the water feed system to deliver a feed rate to the nozzle of (a) 500 mL/min for airflows up to and including 2540 m^3/h, or (b) 1000 mL/min for airflows above 2540 m^3/h.

6.3 Adjust the airflow through the test system to the desired rate. (Tests may be run at several flow rates to establish performance at less than system rated airflow.) Perform test at 50%, 75%, and 100% of rated flow to establish system performance.

6.4 Single Nozzle

With the system running, adjust the placement of the injection nozzle relative to the inlet so that the water spray covers as much of the inlet cross section as possible without over spray. Inlets which have long narrow cross sections should be tested with the nozzle placed at a variety of locations to determine potential sensitivity to spray inlet location.

6.5 Multiple nozzles may be used to cover the area if care is taken to ensure that the droplet size generated is within the recommended range.

6.5.1 Use multiple nozzles to cover inlet cross section without overspray and without overlap, if possible. Document/report nozzle spray overlap and overspray if required.

6.6 Testing has determined that the mean water droplet size coming from a nozzle changes as you get further from the nozzle. The operator shall make sure the nozzle is either at least 6 inches away from the separator inlet, or a minimum distance specified by the manufacturer.

6.7 For applications where overspray is desirable to approximate actual field condition, the overspray needs to be collected and subtracted from the amount fed before calculating the water separation efficiency.

6.8 Place pre-weighed containers at all locations where collected or separated water is to be removed. This varies with the design of the system under test. Scavenged systems will require a secondary water removal system.

6.9 Condition the test system by feeding water at the recommended feed rate specified in 6.2 until water is flowing out of all drain points on the air water separator at steady state.

6.9.1 Record the time it takes to come to steady state.

6.9.2 Empty all containers which will be used to collect separated water before beginning the efficiency test.

6.10 Begin the efficiency test by injecting water at the recommended flow rate until at least 4000 grams of water has been fed.

6.10.1 Time between conditioning and the start of the efficiency test must be recorded and shall be no more than 10 minutes. Repeat conditioning per 6.9 if the water spray has been stopped for more than 10 minutes.

6.11 After a minimum 4000 grams of water has been fed into the air/water separator, stop the water injection.

6.11.1 Let the system run for 30 seconds ± 2 seconds before shutting down the flow.

6.11.2 After terminating the airflow, wait at least 5 minutes or until the drips stop, whichever comes first, for complete drainage.

6.11.3 Determine the amount of water fed and the amount separated by the system under test.

6.11.4 Record the time between air shut down and water collection.

6.12 A qualitative indication regarding the adequacy of the water separation performance may be obtained by weighing the air cleaner filter element before and after the test and using a pre-weighed cloth to absorb and weigh any water in the housing.

6.13 Determine and record the water separation efficiency:

$$\text{Efficiency, \%} = \frac{\text{Weight of water collected and removed by the separator system}}{\text{weight of water fed to the system}} \times 100 \quad \text{(Eq. 1)}$$

6.14 Sections 6.10 through 6.13 should be repeated a minimum of three times or until repeatability is demonstrated at each set of airflow and water injection conditions. Variability in efficiency may indicate more conditioning of the system per 6.9 is required. The time between finishing 6.13 and restarting at 6.10 shall not exceed 10 minutes; if more time is required, then 6.9 should be repeated before restarting at 6.10.

6.15 Test data shall include the following:

- Airflow
- Water feed rate
- Spray nozzle model and manufacturer
- Number of nozzles used
- Water and air pressures
- Water temperature
- Orifice size
- Water droplet size (as per the manufacturer's specifications or by lab testing)
- Room temperature and RH%
- Element dp increase
- Time between conditioning and the efficiency test
- Time between air shut down and when the water was collected and weighed
- Number of test runs
- Water separation efficiency for each run

NOTE: Include standard deviation and averages of all the data for the three runs. The test data may also include initial and final weight of the primary filter element if practicable.

- Distance and angle of the nozzle to the inlet

7. NOTES

7.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE AIR CLEANER TEST CODE STANDARDS COMMITTEE