



Permeation, Leakage, Background and Breakthrough Testing Evaporative Emissions Guideline

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This document categorizes the types of Hydrocarbon (HC) compounds that a component will be exposed to. Each category of exposure will have a specific procedure that quantifies the HC emissions in grams. The procedures take into account the range of temperatures, fuels and other HC based organic compounds the component is likely to encounter in the vehicle environment. The component responsible engineer (generally Designing Engineer/Design Release Engineer (DE/DRE)) will use the document as the basis (template) for writing comprehensive, component specific validation procedures that demonstrate compliance to the corresponding allocation.

1.2 Applicability. Measurement of Volatile Organic Compound (VOC) or HC emissions from components is necessary to ensure a vehicle to be compliant with the evaporative emissions standards established by government agencies worldwide. Vehicle performance is ultimately dependent on the summation of its component emissions and their contribution to the total as measured in a vehicle Sealed Housing for Evaporation Determination (SHED). This document defines the broad-based procedures to be used to quantify component emissions individually for the purpose of validating component adherence to HC emission allocations.

1.3 Remarks.

1.3.1 Categories of HC Emissions.

1.3.1.1 Vapor Exposure. Vehicle HC emissions due to components used to contain HC bearing vapors (volume percent):

- Engine Air Delivery Vapor (1.0% HC), e.g., intake manifold, Exhaust Gas Recirculation (EGR) valve, Manifold Absolute Pressure (MAP), Positive Crankcase Ventilation (PCV) or other components inward of throttle body or HC barrier

1.3.2 Mechanisms of HC Emissions.

1.3.2.1 Background. Component HC emissions due to chemical compounding or aging of parts, components and/or manufacturing materials themselves (not due to the liquid or vapor they contain):

- Polymeric materials – Vinyl, Plastic, or Rubber

1.3.2.2 Leakage. Component HC emissions due to extra-molecular migration of liquid or vapor contained through a part, component or material:

- O-ring or mating surface imperfection

1.3.2.3 Permeation. Component HC emissions due to intra-molecular migration of liquid or vapor contained through a material:

- Fuel tank body material
- Fuel vapor hose material
- Etc.

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2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

40 CFR Part 86	SAE 970309	SAE J1527	SAE J1737
ASTM D814	SAE J30		

2.2 GM Standards/Specifications.

GMW14680

2.3 Additional References.

- CG4041 Permeation Master
- R8 Guide 24 USCAR02
- United States Council for Automotive Research, LLC (USCAR), Southfield, Michigan, www.uscar.org

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment. Type of HC Measurement Equipment. Either of two basic types of hydrocarbon measurements will be used to quantify component performance. These are constant temperature and variable temperature.

3.2.1 Constant Temperature (CT). Two temperatures, 40 °C and 60 °C, are the minimum requirements to quantify permeation characteristics, but 18 °C, 30 °C and 50 °C are also appropriate. Duration of the measurement is time necessary to measure a significant result. Generally, the SHED enclosure is stabilized in a constant temperature environment. This method is recommended by the United States Council for Automotive Research (USCAR) Low Emissions Partnership (LEP).

3.2.2 Variable Temperature (VT). The SHED interior ambient will follow Environmental Protection Agency (EPA), California Air Resource Board (CARB) or custom diurnal cycle for 24 h. The diurnal temperature range of significance is 18 °C to 40 °C (65 °F to 105 °F) and is completed in the 24 h period. One (1) h at 40 °C constant temperature is also recorded. This method has been used by GM but is more costly and less accurate.

3.2.3 Data generated in either type SHED are the sum result of permeation, leakage, background and breakthrough over the time and temperature range tested. Measurements can be accomplished in a small 1.4 m³ to 5.7 m³ (50 ft³ to 200 ft³) variable temperature SHED. HC quantification can be accomplished using Flame Ionization Detector (FID) measurement techniques, or bag collected and analyzed at a remote lab. The SHED HC measurement must be corrected for alcohol based fuels. Two known methods are used; impinger or innova technologies. See Figure 1. Reference Appendix A enclosure requirements.

3.2.4 Mini SHED technologies inherently create a pressure differential between the interior and exterior of the SHED enclosure. Extreme care will be used when measuring leakage in vapor containing components so that the component results are not impacted by SHED pressure differential. See Figure 2.

3.2.5 Mini SHED temperature range is currently limited in VT SHEDs and will underestimate the impact of hot soak on vehicle emissions. Reference Table 1.

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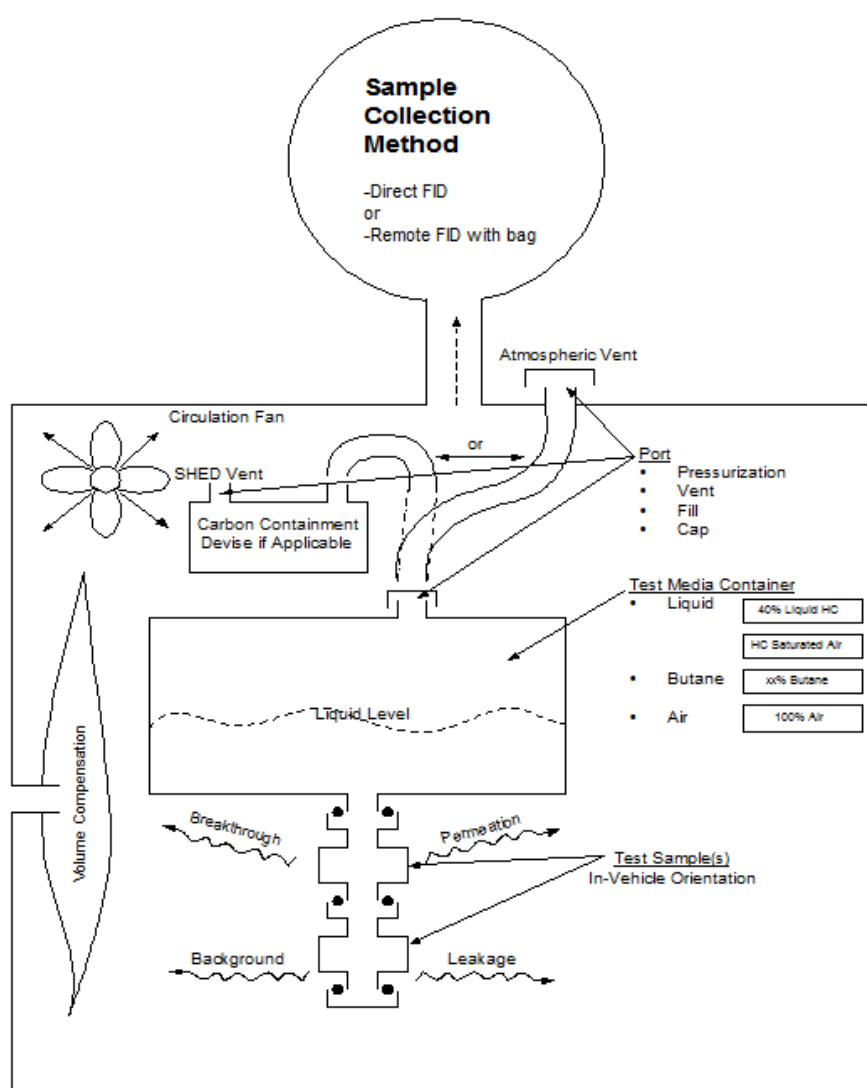
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Table 1: SHED Temperature Capability

Degrees C	Degrees F	CT	VT
< 18	< 65	X	
18	65	X	X
20	68	X	X
30	86	X	X
40	105	X	X
50	122	X	
	140	X	



Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Figure 1: General Mini SHED Setup

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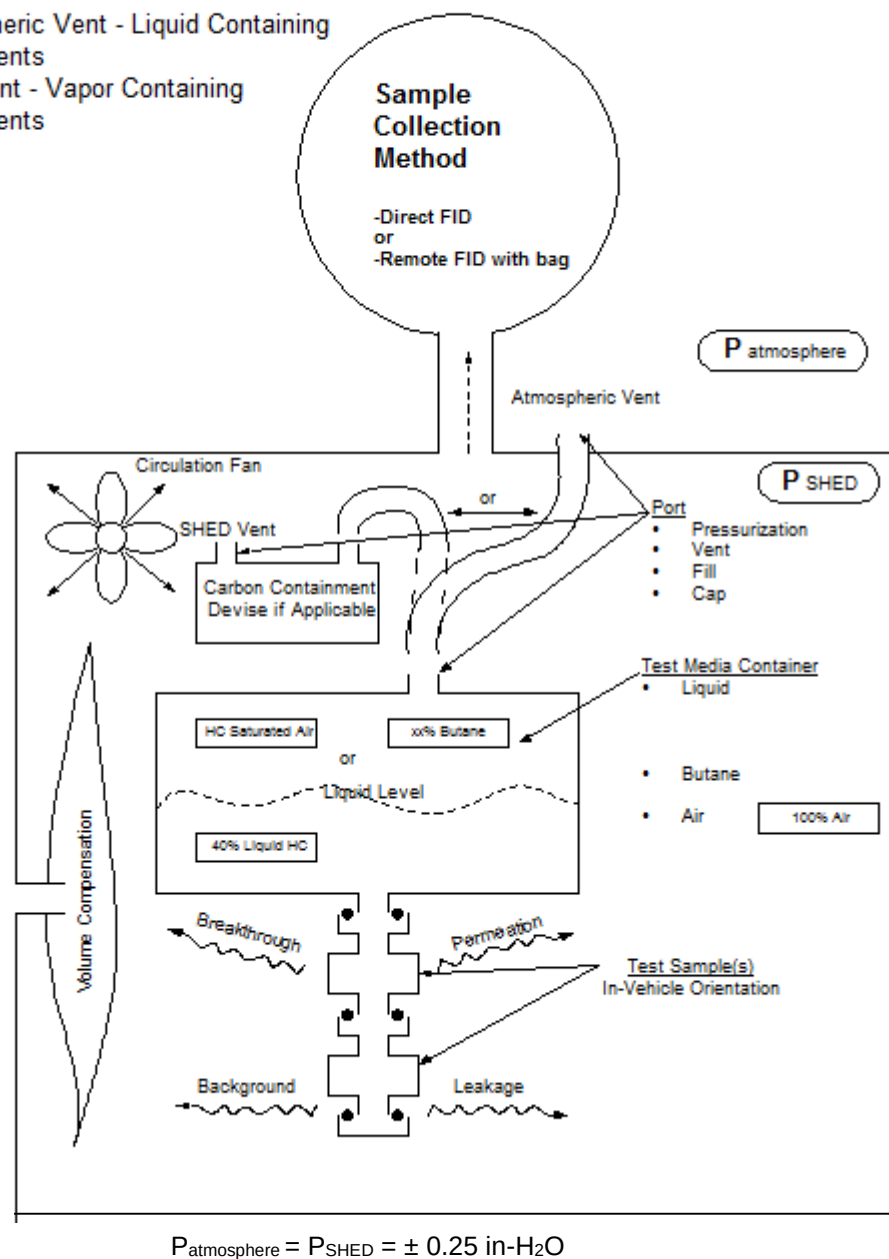
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MINI SHED

Pressure consideration for leakage

- Leakage rate sensitive to pressure
- Unpressurized components should be tested vented
 - Atmospheric Vent - Liquid Containing Components
 - Shed Vent - Vapor Containing Components



$$P_{\text{atmosphere}} = P_{\text{SHED}} = \pm 0.25 \text{ in-H}_2\text{O}$$

or

$$P_{\text{atmosphere}} \neq P_{\text{SHED}}$$

Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Figure 2: Mini SHED Setup (Pressure Consideration for Leakage)

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3.2.6 Hot soak temperatures may require measurements or estimates up to 150 °C. Future VT SHED equipment that ensures 60 °C capability will still underestimate hot soak emissions. SHED data can be extrapolated to higher temperatures if the HC loss mechanism is confined to permeation. Permeation estimates for alternative temperatures and temperature cycles can be projected through modeling using GM EVAPWIN Modeling software, permeation prediction section. The release responsible engineer will input data and provide alternate temperature output to supplier.

3.2.7 Permeation estimates for alternative HC exposure concentrations will be linearly interpolated to zero. For example, a part stabilized using 50% HC concentration but only designed for in use exposure of 5%, would have a correction of 5/50 applied to the raw data. The actual test media HC concentration shall be determined using EVAPWIN at 32 °C (see Table 4). It is important to understand that HC concentration correction can only be applied to the permeation portion of the raw data and not to the allocated leak portion. The following example demonstrates the issue. VAPOR2 is the correct method, however; VAPOR1 incurs a relatively minor conservative error which will be acceptable for component emission determination. Correction of the total LIQUID data without regard for background and leakage is unacceptable. Reference Tables 2 and 3 for examples.

Table 2: Example of Milligrams HC Permeation Result with Large Permeation/Small Leak

	LIQUID		VAPOR1		VAPOR2		Comment
Mechanism	Raw	Mechanism	Raw	Mechanism	Raw	Mechanism	
Back Ground	1	1	1	1	1	1	
Leak1	5	4	3	2	3	2	Butane percent
Leak2	Not applicable	Not applicable	Not tested	Not tested	5	4	Liquid percent
Permeation	30	25	30	27	30	26	
Correction	Not applicable	Not applicable	10:1	2.7	10:1	2.6	
Total	30 Note 1			5.7 Note 2		5.6 Note 2	Allocation

Note 1: If leak and background are completely disregarded the 10:1 correction yields 3.0 which is wrong and makes no distinction between large/small permeation/leak scenarios.

Note 2: If the leakage changes due to component part exposure to gasoline vapors, then neither vapor method will yield the correct result. The test method has altered the performance of the specimen. The only recourse is to test for long term exposure to the actual exposure concentration and to compare the stabilized result to the allocation requirement. Estimates of background and leakage mechanisms would be impossible.

Table 3: Example of Milligrams HC Permeation Result with Small Permeation/Large Leak

	LIQUID		VAPOR1		VAPOR2		Comment
Mechanism	Raw	Mechanism	Raw	Mechanism	Raw	Mechanism	
Back Ground	1	1	1	1	1	1	
Leak1	25	24	15	14	15	14	Butane percent
Leak2	Not applicable	Not applicable	Not tested	Not tested	25	24	Liquid percent
Permeation	30	5	30	15	30	6	
Correction	Not applicable	Not applicable	10:1	1.5	10:1	0.6	
Total	30*			16.5 Note 1		15.6 Note 1	Allocation

Note 1: If the leakage changes due to component part exposure to gasoline vapors then neither vapor method will yield the correct result. The test method has altered the performance of the specimen. The only recourse is to test for long term exposure to the actual exposure concentration and to compare the stabilized result to the allocation requirement. Estimates of background and leakage mechanisms would be impossible.

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3.2.8 The test media container contribution, empty SHED and SHED measurement (injection and retention) errors shall be accounted for by measuring HC emissions such as:

- Without test components (Figure 3)
- Without test components and without test media container (Figure 4)
- Without test components and without test media container, but with known hydrocarbon concentration injected (Figure 4)

3.2.9 Process control will be established (laboratory procedure number is specific to each facility) that defines the magnitude of data corrections if appropriate. The lower Limit of Detection (LOD) of the SHED equipment has been determined by GM to be ± 0.31 mg (this is based on equipment variation studies that have determined the uncertainty of the data is ± 0.31 mg at 2 sigma). No result will be reported less than this value, e.g., 0.0006 mg is inappropriate based on equipment capability and 0.31 mg should be reported. SHED resolution can generally be improved by lengthening the measurement period or by using more parts.

3.2.10 SHED scrubbing procedures will be utilized (laboratory procedure number is specific to each facility) that ensure there is no significant HC hangover from test to test as witnessed by empty SHED testing.

3.3 Test Vehicle/Test Piece. See 4.3.1 thru 4.3.4.

3.4 Test Time. Varies with test type.

3.5 Test Required Information.

3.5.1 Test Media Description and Priority. See Table 4.

- Leakage: Butane
- Breakthrough: Butane
- Permeation: Fuels

Table 4: Test Media Description

Name	Usage	REID Vapor Pressure (RVP)	Saturated HC (Percent at 32 °C)	Actual Oxygenate (Percent)	Validation
CE10	All bench testing	3.2, 3.0 to 3.4	17.1	9.8 ^{Note 2} Ethanol	Required data ^{Note 1}
CAPB Phase 2	LEV2 minimum requirement	6.85, 6.7 to 7.0	38.4	10.8 to 11.2 MTBE	Optional ^{Note 1}
CARB LEV 3	LEV3 minimum requirement	6.7, 6.4 to 7.0	37.7	5.5 to 7.0 Ethanol	For all vapor Components
EPA TIER-3	TIER -3 minimum requirement	8.7 to 9.2	Determined	9.4 to 10.2 Ethanol	Optional
CE85	High ethanol synergisms	2.9, 2.8 to 3.0	16.5	72 minimum Ethanol	Required for FFV/ VFV ^{Note 1}

Note 1: CE10/85 fuel is anticipated to be worst case and data is required for all LEV/PZEV compliant applications. Prior to LEV-3, CARB regulation specifies CARB Phase II fuel (MTBE) for certification even though significant quantities of ethanol are in actual use in California. Prior to the CARB cert fuel change emission performance on both fuels are required:

1. $CAP2 \leq 0.9 \times \text{Standard}$
2. $CE10 \leq 0.7 \times \text{In-use Standard}$

Engineering analysis and/or application specific issues may dictate that optional fuels may have synergistic affects and require verification testing.

Note 2: ASTM Fuel C plus 10% volume denatured ethanol CDA20 (98.0% ethanol + 2.0% rubber HC solvent denaturant J1681 BATF). Fuel C consists of equal parts toluene and Iso-octane (2,2,4-trimethyl-pentane).

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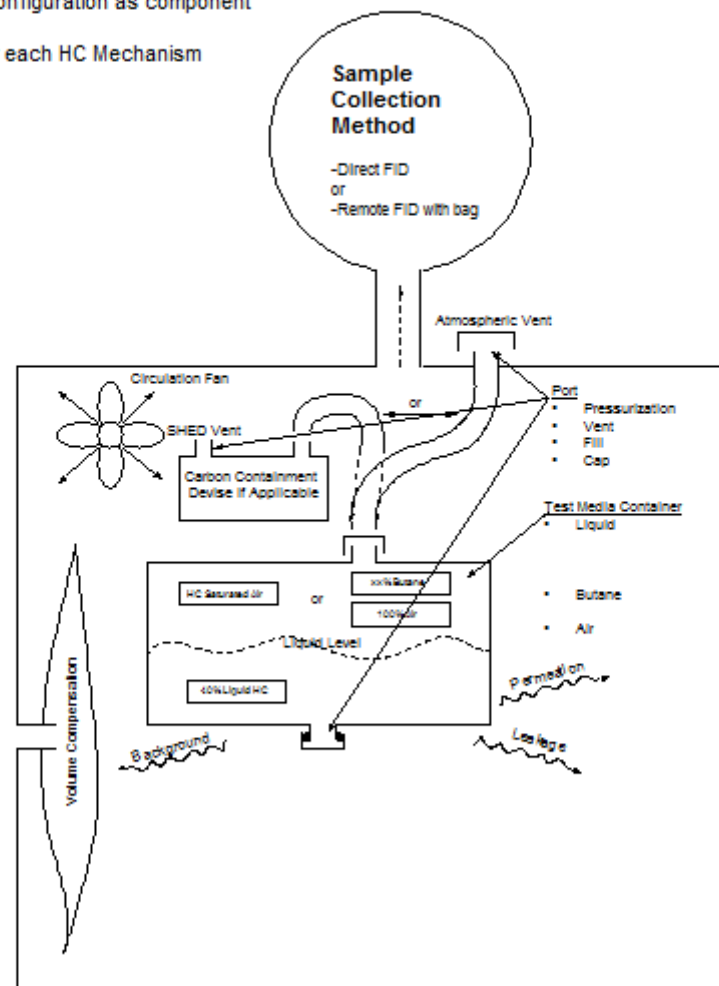
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Test Media Container Contribution

- Measure HC Emissions of fixturing with components removed
- Same configuration as component test
- Test for each HC Mechanism



Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Figure 3: Mini SHED Setup (Test Media Container Contribution) – Test Without Samples

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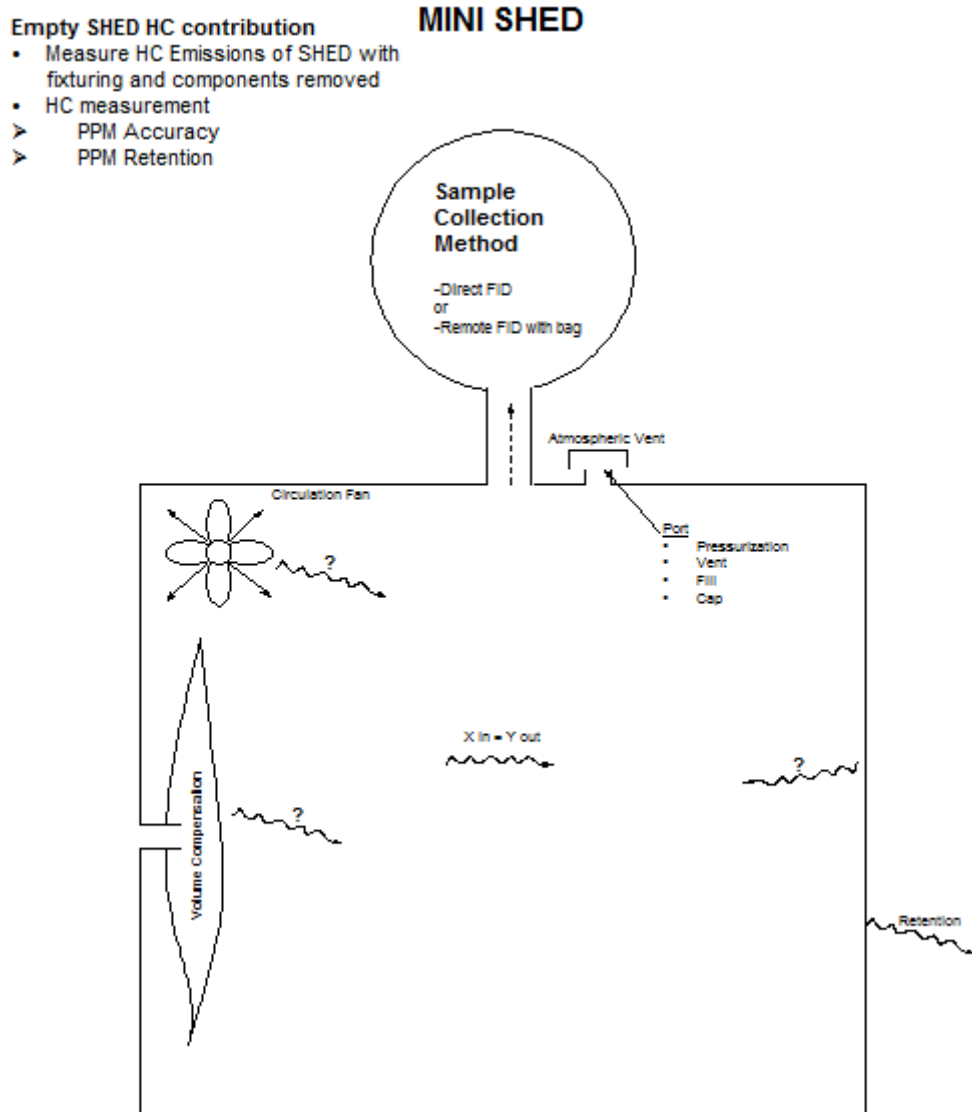
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Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Note: PPM = Parts per Million

Figure 4: Mini SHED Setup (Empty SHED HC Contribution)

3.5.1.1 Lubricating Oil. SAE 5W30 SI engine oil plus 1.17% volume CE10 (equivalent to 5% dilution and 0.5% concentration in crankcase vapor space.)

3.5.1.2 Other. Appropriate liquid described in current owner's manual.

3.5.2 Generalized Test Flow.

1. Applicable emission mechanisms to be quantified; background, leakage, breakthrough or permeation are specified.
2. Test part requirements: A statement of test part quantity, quality and configuration.
3. Test media container design: A definition of critical test fixture features.
4. Set up procedures: A statement of how the test components are configured for testing.
5. Preconditioning: Specific requirements for the handling and storage of the test components and test media container before and during testing.

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6. Evaluation: Specific requirements for determining the HC emissions of the test components.
7. Stabilization: Specific requirements for determining when the HC emissions rate of change due to preconditioning is satisfactory for reporting.
8. Reported data and units of measure: Specific requirements for metrics used to report HC emission results.

3.5.3 Test Sequencing. The SHED measures all HCs regardless of source as follows (See 1.3.2 and 3.2):

- Permeation
- Background
- Leakage
- Breakthrough
- Test Media Container Contribution: SHED HCs due to test fixture
- Empty SHED Contribution: SHED HCs due to enclosure

The following sequencing is required to quantify emissions by mechanisms with appropriate adjustments for Test Media Container Contribution and Empty SHED Contribution:

1. Background: Component HCs after time and temperature stabilization only.
2. Leakage: Component HCs after background testing but before permeation testing.
3. Breakthrough Component HCs after background testing and leakage testing.
4. Permeation Component HCs after background testing, leakage testing and fuel stabilization.

Note: Vehicle allocations to components represent total HCs. Total HCs are quantified by Step 3 or 4. Background and leakage are of engineering and quality control interest only. For example, permeation and background may be managed through material specifications while leakage may be managed by leak measurement.

3.5.4 Test Reference Information.

- ASTM D814 is the standard test method for rubber material properties, vapor transmission of volatile liquids. Weight loss is ± 5 mg at 23 °C using any fuel.
- GMW14680 is the permeability test for low permeation fuel filler hose, liquid and vapor phase. Weight loss is ± 10 mg at 40 °C using TF1 (E10).
- SAE J1527 applies to marine fuel hoses. Weight loss is ± 10 mg at 23 °C using C and CM15.
- SAE 970309 applies to co-relating SHED test results to permeation measurement by recirculation procedures.
- SAE J30 applies to fuel and oil hoses. Weight loss is ± 10 mg at 60 °C using CM15.
- SAE J1737 – Test procedure to determine the HC loss from fuel tubes, hoses, fittings, and fuel line assemblies by recirculation. Charcoal canister weight increase at 60 °C using CM15 and CE10.

3.6 Personnel/Skills. Test engineer or technician capable of setting up and operating equipment and performing the required calculations outlined in this document.

4 Procedure

4.1 Preparation. See 4.3.1 thru 4.3.4 for each individual procedure.

4.2 Conditions.

4.2.1 Environmental Conditions. See 4.3.1 thru 4.3.4 for each individual procedure.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions.

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4.3.1. Liquid Exposure.

4.3.1.1 Applicable Emission Mechanisms.

Background	X
Leakage	X
Breakthrough	
Permeation	X

4.3.1.2 Test Part Requirements.

- Production configuration including end connections.
- Consideration for worst case torque specs and tolerances.
- Life cycle durability testing shall be performed before background testing if it is likely to affect HC emissions.
- Sample size as necessary to achieve adequate SHED resolution.

4.3.1.3 Test Media Container Design.

- Test media container volume (if used) shall be at least 50% larger than test components volume.
- Test media container design shall ensure that component is 100% in contact with liquid.
- Test media container shall control pressure build during HC measurement:
 - Vented external to SHED for components designed for zero pressure
 - Pressurized to design intent for components designed for pressure containment

4.3.1.4 Setup Procedures.

- The test media container (if used) shall be above the components such that the test components are completely submerged in liquid without air pockets.
- Set up as close to production as possible including consideration for:
 - Preloading
 - Side loading
 - Torque application
- Variation due to preload, side load, and torque shall be considered by applying limit values and comparing to allocated allowable tolerances.

4.3.1.5 Preconditioning.

4.3.1.5.1 Background.

- Test component(s), installed on test media container as required, shall be stored in an ambient temperature of 40 °C for 2 weeks (336 h).
- Humidity shall be controlled to 50 grains $\pm$ 5 grains of moisture.

4.3.1.5.2 Leakage. Same as in 4.3.1.5.1.

4.3.1.5.3 Permeation. Same as in 4.3.1.5.1.

- Preconditioning temperature has both short term and long term impact on permeation stabilization. There is an instantaneous change in the permeation rate resulting from a temperature change affecting HC currently diffused in the material. This is followed by a slow change as the material adapts to the new properties of the HC media due to the same temperature change. It has been agreed that the **extreme typical** target customer preconditioning temperature shall be 32 °C for permeation.
- Add HC bearing liquid (reference 1.3.1) to 40% $\pm$ 5% of test media container (if used) volume or component volume.
- Minimum of three (3) months liquid exposure required regardless of stabilization test results.
- The test media container shall be inverted once per working day, for not more than 30 minutes, to ensure the test part is exposed to fresh liquid.
- The test liquid shall be changed every 14 days $\pm$ 3 days but not less than 24 h before the next SHED evaluation.
- Test component(s) shall be continually submerged in liquid except when inverted as in the preceding.

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4.3.1.6 Evaluation.

4.3.1.6.1 Background (see Figure 5).

- Six hours to twelve hours (6 h to 12 h) required at stabilization HC measurement temperature if different from preconditioning temperature.

- Recorded data and SHED type:

Constant Temperature (CT)

Perform SHED HC measurement at 40 °C for 25 h minimum (additional 25 h periods may be added to achieve a significant HC value).

Variable Temperature (VT)

Perform SHED HC measurement at 40 °C for 1 h followed by 24 h CARB, EPA, or custom diurnal.

- Time between 1 h test and 24 h diurnal shall be 6 h to 10 h.
- Evaluation data shall be corrected for test media container contribution (reference 3.2):
 - Test media container contribution
 - Empty SHED HC contribution

4.3.1.6.2 Leakage (see Figure 6 and Figure 7).

- Six hours to twelve hours (6 h to 12 h) required at stabilization HC measurement temperature if different from preconditioning temperature.
- Add fuel to 40% ± 5% of test media container (if used) volume or component volume.
- Leak measurement shall commence 6 h ± 1 h of initial fuel vapor exposure.
- Recorded data (versus SHED type):

Constant Temperature (CT)

Perform SHED HC measurement at 40 °C for 1 h.

Variable Temperature (VT)

Perform SHED HC measurement at 40 °C for 1 h.

- Recorded data shall have background HC subtracted.
- Evaluation data shall be corrected for test media container contribution (reference 3.2):
 - Test media container contribution
 - Empty SHED HC contribution

4.3.1.6.3 Permeation (see Figure 8 and Figure 9).

- Six hours to twelve hours (6 h to 12 h) required at stabilization HC measurement temperature if different from preconditioning or leak test temperature as appropriate.
- Recorded Data (versus SHED Type):

Constant Temperature (CT)

Perform SHED HC measurement at 40 °C and 60 °C (optional) for 1 h and/or 24 h (longer time periods will be tested to achieve a measureable HC value).

Variable Temperature (VT)

Perform SHED HC measurement at 40 °C for 1 h and/or use CARB, EPA or custom 24 h temperature profile.

- Time between 1 h hot soak and 24 h diurnal shall be 6 h to 10 h at 18 °C (65 °F), 22 °C (72 °F) or custom temperatures.
- Evaluation data shall be corrected for test media container contribution (reference 3.2):
 - Empty SHED HC contribution
 - Test media container contribution
 - Hydrocarbon measurement (injection and retention) errors

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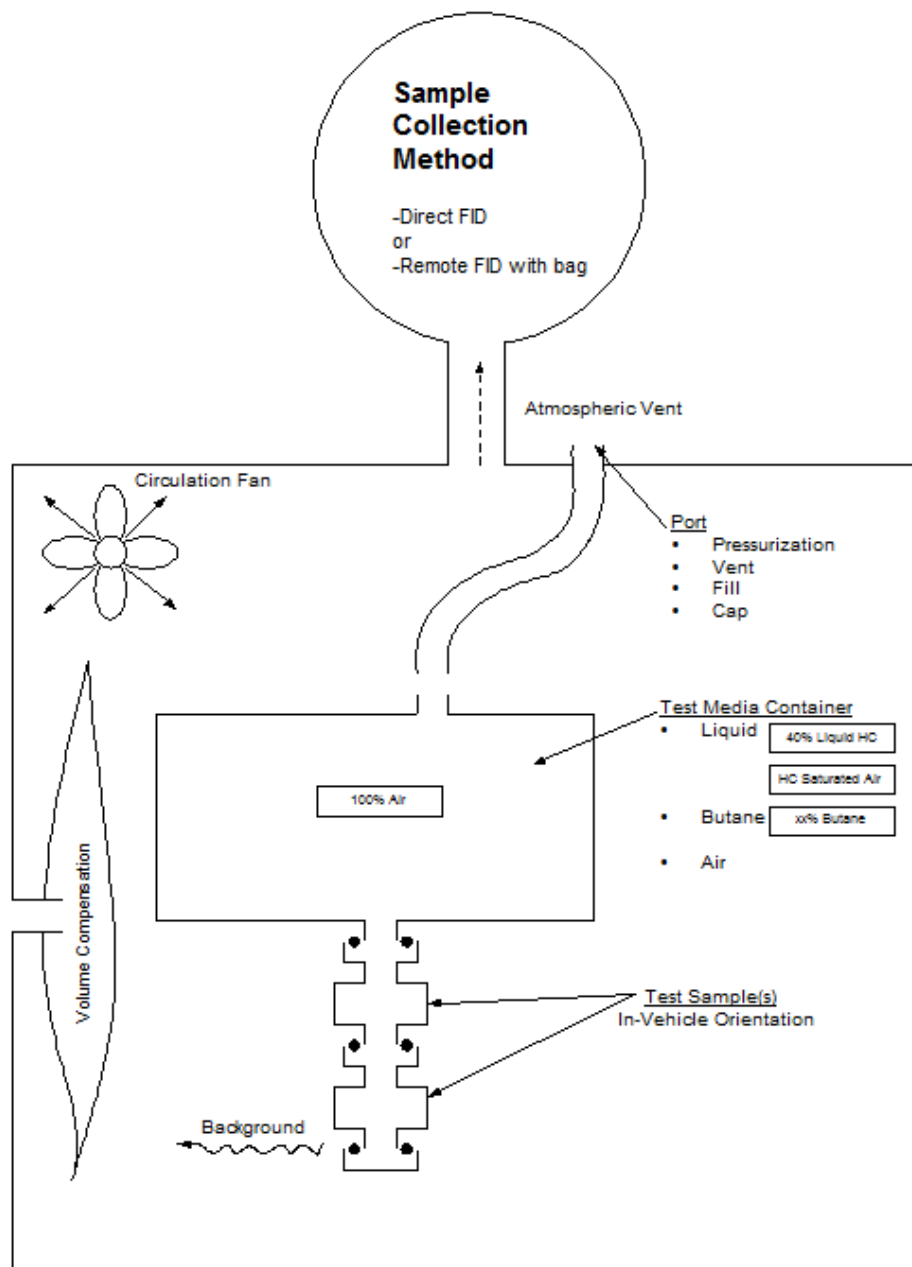
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MINI SHED

Category & Mechanism

- Liquid Exposure
- Background (after time and temperature stabilization)



Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Figure 5: Mini SHED Setup (Liquid Exposure, Background)

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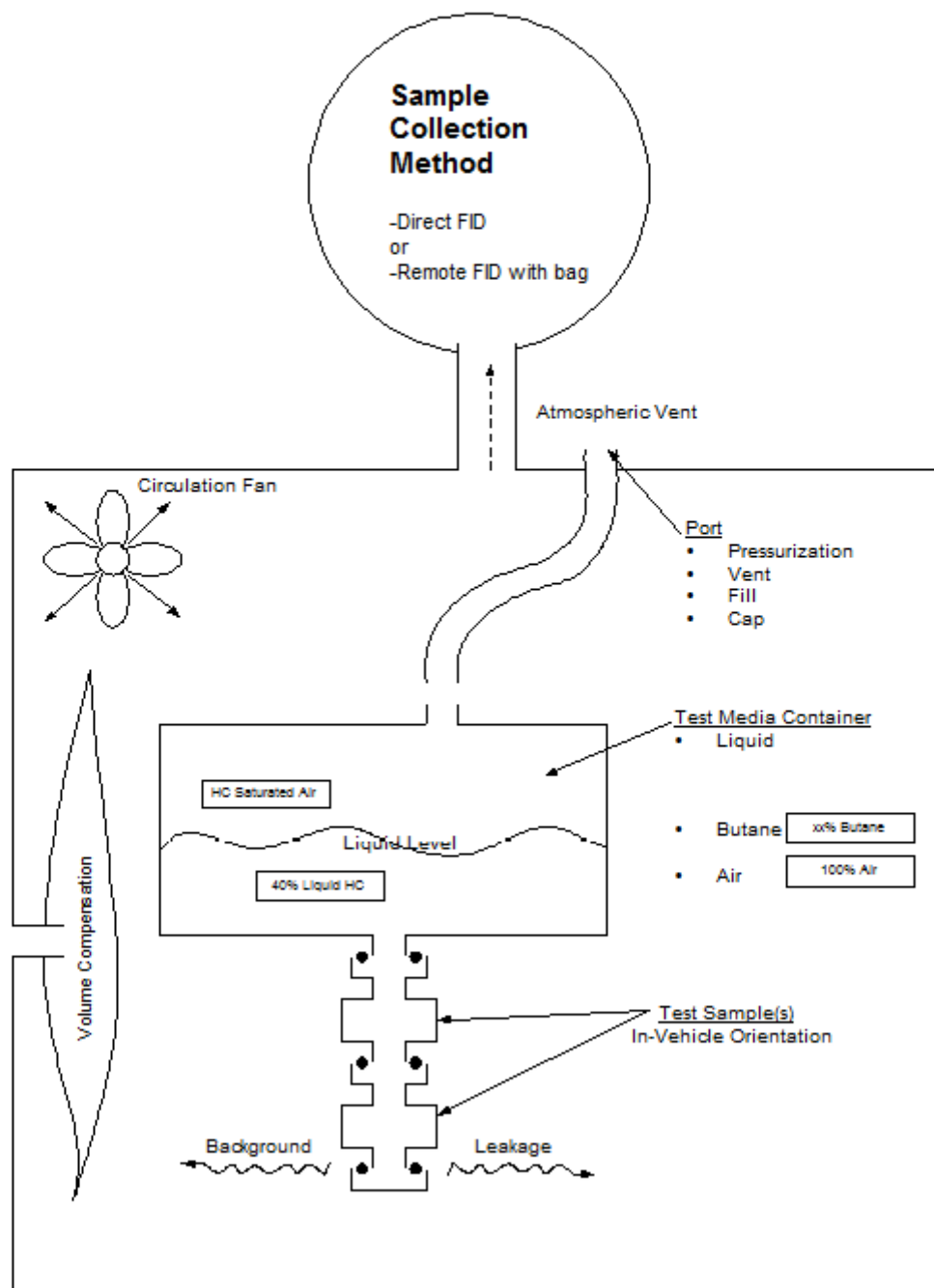
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MINI SHED

Category & Mechanism

- Liquid exposure - low pressure
- Leakage (fuel installation plus 6hrs-test for 1 hr)



Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Figure 6: Mini SHED Setup (Liquid Exposure – Low Pressure, Leakage)

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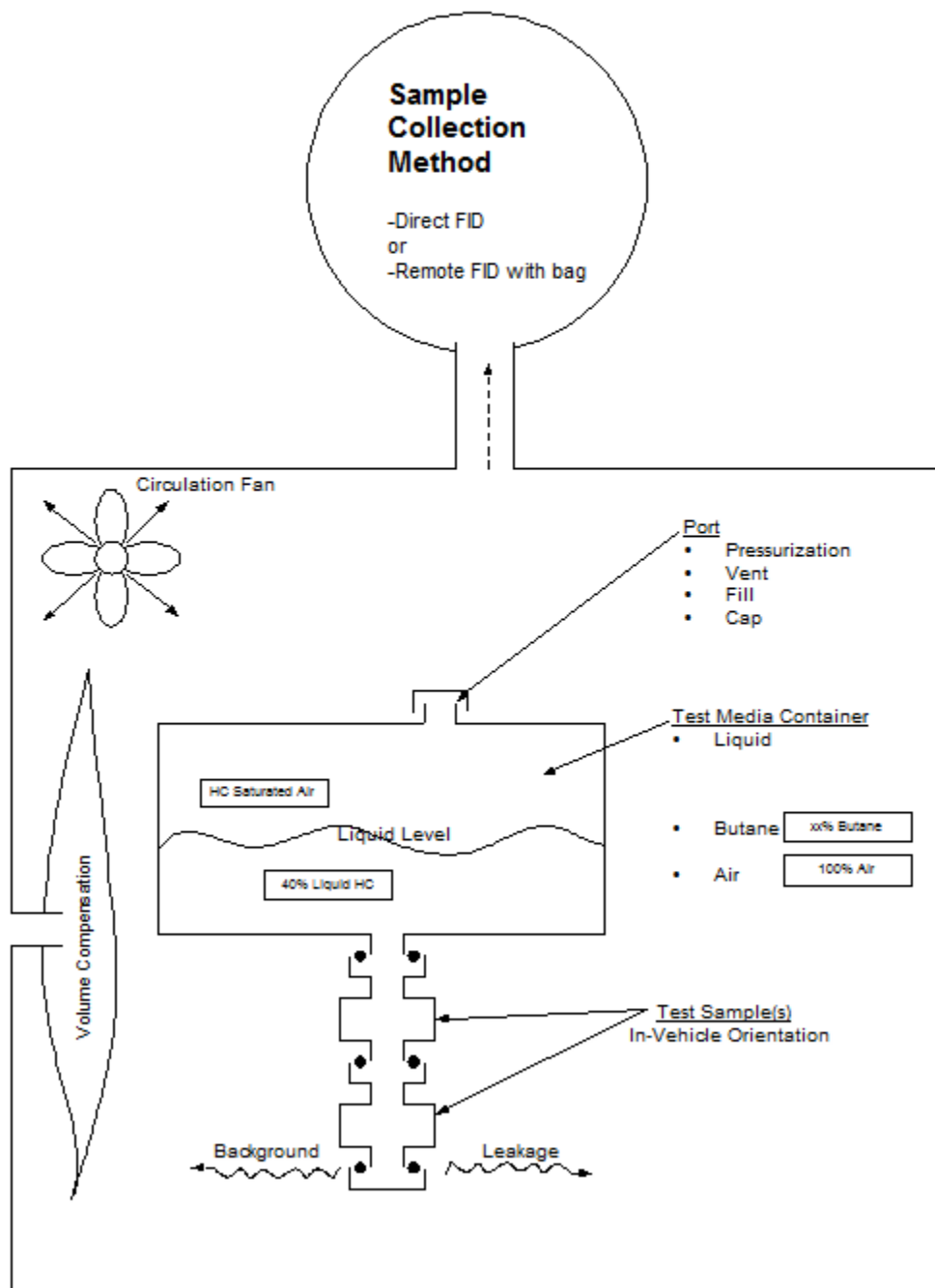
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MINI SHED

Category & Mechanism

- Liquid exposure - high pressure
- Leakage (fuel installation plus 6hrs-test for 1 hr)



Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Figure 7: Mini SHED Setup (Liquid Exposure – High Pressure, Leakage)

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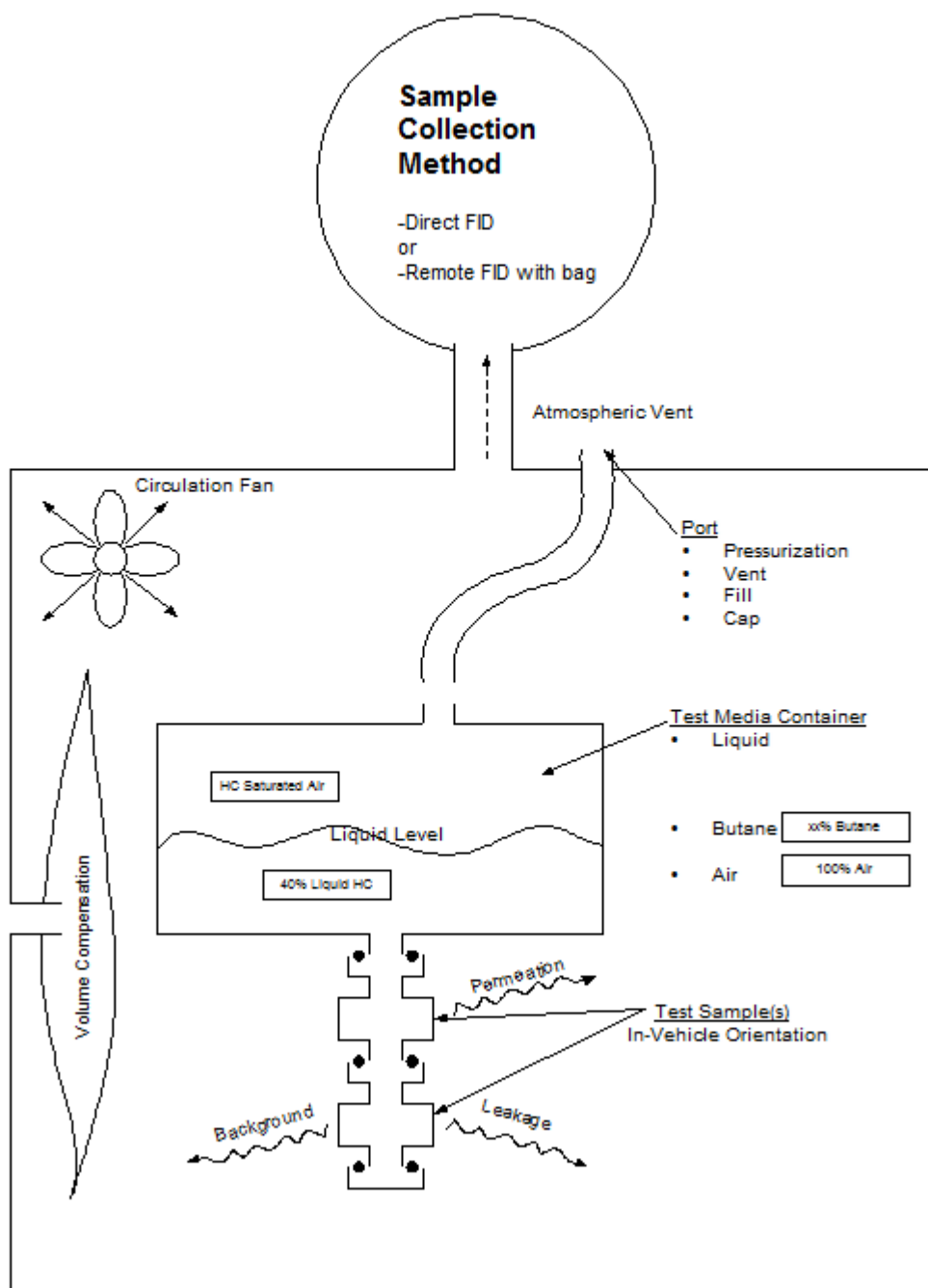
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MINI SHED

Category & Mechanism

- Liquid exposure
- Permeation (after fuel exposure stabilization)



Note: Emission Enclosure: Variable Temperature from 18 °C to 40 °C (65 °F to 105 °F), Constant Temperature at 40 °C and 60 °C.

Figure 8: Mini SHED Setup (Liquid Exposure, Permeation)

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