

3.1.1 Content.

3.1.1.1 Physical Content.

Air delivery system components typically define the airflow pathway by various geometries of plumbing, plenums/housings (i.e., larger air volumes), and runners. Plumbing typically communicates airflow from one component to another, while plenums and housings may contain larger volumes of air relative to engine tuning performance. Runners are airflow geometries typically within an intake manifold, which deliver airflow directly to the engine cylinder head ports, and thereafter the engine cylinder combustion chamber(s).

Additionally, air delivery system components such as iCACs and coolant manifolds or plumbing, communicate subsystem coolant flow. Coolant subsystems will typically contain a water pump and possibly coolant control valves, for which debris can cause damage that may be detrimental to part performance and durability over time.

It is also known that for heat exchanges, such as an iCAC, that loose metallic debris within the iCAC coolant cavities may lead to material erosion, and therefore potential iCAC part failure (i.e., leak). iCAC internal leak failure from the coolant-side to air-side, is known to cause potential misfire (gasoline applications), or catastrophic engine damage.

Any of the air-side and coolant-side geometries are and shall be considered suspect to containing or holding debris through the manufacturing processes.

3.1.1.2 Functional Content.

Air delivery subsystems may contain physical mechanisms such as airflow valves, and electronic components such as sensors and actuators (i.e., motors or solenoids), in which additional care may need to be applied relative to cleanliness concerns.

3.1.2 Interfaces.

Many air delivery subsystem components support sealing function with either sealing face or groove geometries, which shall be free of debris detrimental to sealing function. Upon part debris extraction, the sealing interface geometries, and any seals in place after assembly, shall be considered as part of the component debris extraction areas. This would suggest that, if rinsing the interior of the part for debris extraction for example, then these areas of the part shall also be included in the rinsing process.

3.2 Product Characteristics.

In effort to ensure proper engine operation and durability, control and monitoring of the amount of debris particles introduced through the air delivery component and assembly manufacturing shall be utilized over time. This section outlines the required measurement method and monitoring process to be utilized. See Figure A3, Appendix A for rudimentary illustration of overall cleanliness check process.

3.2.1 Part Cleanliness Requirements.

Parts as delivered to GM (i.e., the receipt of part) should be clean and free of debris, residual abrasive material, and corrosion products adversely affecting function or appearance. Debris on and within finished parts shall be regularly monitored and controlled using statistical methods, upper control limits, and procedures approved by the applicable Design Responsible Engineer (DRE) and clearly defined in the supplier process control plan. Cleanliness shall be evaluated with parts from the end of the supplier's manufacturing assembly process, prior to shipping container packaging.

Cleanliness by part type, shall be in accordance to Table A1, Appendix A.

Exterior part debris or residual manufacturing fluids shall not adversely affect the engine or vehicle plant processes or the function of engine components, and shall not detract from any part styling or appearance features.

The applicable part and system level Design Failure Mode and Effect Analysis (DFMEA)s shall be consulted relative to any potential safety and performance concerns.

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3.2.2 Part Debris Extraction.

The method of debris extraction shall be determined based on the product's geometry and evaluation efficiency, and internal cavities or passageways. The method of air-side and coolant-side cavity debris extraction shall be in accordance to either:

- ISO 16232-2 Extraction by Agitation, or
- ISO 16232-3 Extraction by Pressure Rinsing, or
- ISO 16232-4 Extraction by Ultrasonic Techniques, or
- ISO 16232-5 Extraction of Functional Flow Bench.

Note: These extraction methods may be utilized in conjunction with each other, and final chosen method shall be agreed upon by the applicable DRE.

Note: For air flow extraction method, the air flow rate shall be at least 125% of operating engine maximum air flow rate. This procedure may be atypical relative to most supplier's available lab equipment.

Note: The utilization and freedom of these extraction procedures should be based upon the supplier's part type experience, and shall be reviewed in detail with the applicable project DRE.

The supplier shall have the expertise by experience, relative to which extraction method is best applicable by part type. For example, one-part type may be more appropriate for agitation method, while another part type may be more appropriate for pressure rinsing method. The supplier shall utilize the pre-production build stages as the cleanliness procedure routine development.

The extraction method shall be validated per the applicable ISO 16232 extraction method decay curve 10% end-point guideline. The 10% end-point decay curve guideline shall be utilized to how many times the debris extraction shall be applied to each part, and this number of required extractions shall be clearly defined within the part applicable work instructions. The decay process is typically a one-time development phase event, which shall only require being repeated when there may be product, equipment, or process changes requiring it.

For repeatability, in the case of agitation for example, a part fixture may be required to ensure best part orientation. Additionally, the specific part cleanliness work instructions shall illustrate the proper part orientation, regardless of extraction method.

Parts or assemblies utilized for cleanliness evaluation shall not be returned to production. Composite and aluminum material parts free of rinsing agents or other solvents, may be broken down and utilized as regrind/re-melt, according to the specific part regrind/re-melt allowance.

3.2.3 Part Debris Evaluation.

The evaluation method of extracted debris shall be according to:

- ISO 16232-6 Particle Mass Determination by Gravimetric Analysis shall be utilized to determine debris total mass.
- ISO 16232-7 Particle Sizing and Counting by Microscopic Analysis shall be per automatic image analysis method, to determine debris size.
- ISO 16232-8 Particle Nature Determination by Microscopic Analysis shall be utilized to determine elemental composition of the debris.

Although evaluation by human eye may be allowed per the ISO 16232 specification, software driven microscopic analysis (see example equipment in Figure A4, Appendix A) shall be utilized, to ensure the highest level of accuracy and repeatability. By current industry standard, software driven microscopic evaluation is most prevalent.

In the event a cluster of debris is causing difficulty in determining the size of any single debris, if the clump or cluster meets the maximum size requirements, then no further work is required. However, if the cluster is over the maximum size limit or if further debris determination is desired, human intervention may be required to separate the pieces of debris from the cluster, and then re-evaluate. A cluster be considered not part of the measurements applicable to the debris limits, if it can be separated into its various constituents and re-measured.

Additional inspection routine may be required for parts with tortuous geometry to the debris extraction. For such applications, as determined and approved by the applicable DRE, appropriate equipment (i.e., mirrors, lights, bore scopes, probing devices, etc.) shall be utilized to inspect internal passageways for unattached foreign debris not removed by the extraction procedure. Unattached foreign debris that can be removed shall be included

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in the total sediment weight and size measurements. If additional inspection is required, it shall be implemented for each suspect part or assembly of the monitoring frequency plan.

The supplier shall develop a suitable debris evaluation routine in accordance with the specified ISO 16232 standard. The evaluation routine shall be reviewed with the applicable DRE for approval prior to production implementation.

3.2.4 Part Debris Expressed Results.

Debris inspection and measurement results of mass, size, debris type, and number of particles shall be reported according to:

- ISO 16232-10 Expression of Results, on a "per component" basis. Size classes shall be defined per:
- ISO 16232-10, All size class results shall be reported.

Debris particles size and quantity shall be determined and reported per ISO 16232-8, according to the following four (4) categories:

- Metallic and Mineral Debris
- Non-Metallic/Plastic
- Non-Metallic/Fibrous Debris
- Other (may be utilized if there is unidentifiable debris, and shall be fully reviewed with applicable DRE)

Current optical technology can only differentiate between shiny and non-shiny objects, and therefore the difference of plastic and fibrous within the International Organization for Standardization 'other' category shall be based upon difference in size. Fiber is defined as 10:1 or greater length to thickness ratio and is non-metallic (for the purpose of this specification). Debris particle sizing determination shall be per ISO 16232-7 per automatic image analysis method.

3.2.5 Part Cleanliness Monitoring.

Debris cleanliness capability of finished or assembled parts shall be regularly monitored and controlled using statistical methods approved by applicable DRE, and shall be defined in the supplier's process control plan.

The monitoring frequency over time is to be defined by application through the Product Development Team (PDT) according to the sensitivity of the concerned product application and its importance for the overall engine function.

Note: iCAC assemblies must be checked for both air-side and coolant-side circuits.

There are a minimum of five (5) levels of cleanliness check. Cleanliness check Level 0 through Level 4 definition shall be per Table 1.

Table 1: Minimum Level Parameter Definition

Level	Build Phase Applicability	Minimum Sample Quantity	Minimum Duration	Minimum Frequency
0	Early Prototype ^{Note 1}	0 (Not applicable)	Each Build Phase	Clean each part for delivery
	Prototype – Preproduction phase builds ^{Note 2}			Develop debris extraction process, and provide clean parts
1	Production or manufacturing start-up phase	Three (3)	4 Weeks	Start of shift, once every week
2			6 Weeks	Start of shift, once every 2 weeks
3	Production		Product Lifetime	Start of shift, once every 3 months (i.e., Quarterly)
4	Production noncompliance escalation strategy		Daily	Once every day

Note 1: Most often hand built parts, typical for Alpha phase development use. These parts are not required as part of the cleanliness development process.

Note 2: Most often prototype/soft tooled parts, typical of Beta and Gamma phase development usage and Design Validation testing.

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