# Appendix E – L6 Diesel LZ0 MY28 Cam Housing Asm

P/N 40009546 - HOUSING ASM-CM/SHF (Assembled with caps, bolts, and dowels installed)

P/N 40009545 - CARRIER ASM-CM/SHF (Machined Drawing)

P/N 40009544 - CARRIER CM/SHF (Casting Model)

**Change Log**

|  |  |  |
| --- | --- | --- |
| **Published** | **Section Number** | **Change Description & Impact** |
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For questions and concerns regarding the context of this Appendix E, please contact GM Manufacturing Responsible Engineer Matt Kenworthy at (248) 794-3317; or email at [matt.kenworthy@gm.com](mailto:matt.kenworthy@gm.com)

## 10.0 CSS 50V6 – CAM HOUSING ASSEMBLY MACHINING FEATURES & PROCESS

*Revised March 19, 2024 by Matt Kenworthy, Manufacturing Responsible Engineer- GPS Central Manufacturing Engineering*

Part prints for finish machining and casting models are under development. This document, along with the part model files provided, identify the features on the 50V6 ladder that require machining for the purpose of providing a quotation for providing a finished Cam Housing Assembly, aka Cam Carrier Assembly, aka Ladder Assembly. Future updates and revisions may include additional features and / or RPO variations. The machining system must be capable of determining the casting variant type and performing the appropriate machining operations.

Please note that there will be changes to machining and test contents upon final release of part prints.

Parts are to be delivered to GM in a finished state. All parts are to be washed and free of cutting fluid, die release agents, soap, and residue. Parts are to be free of burrs and sharp edges that may be detrimental to assembly, safe handling, or function of the part. Retained sediment in the part is to not exceed 20 milligrams when tested per GMW16037.

Manufacturing system environmental controls are critical to maintain dimensional control of finish print requirements. Coolant temperature control is a requirement (see section 11.12).

Impregnation of Cam Housing Assembly Castings is not permitted.

The casting provider is responsible to remove all gates and risers.

## 11.0 FINISH MACHINING FEATURES

Features to be machined on the Cam Housing are as listed in Table 1. The windows specified are as follows:

**Window A** – XYZ Locate, prior to cap assembly

**Window B** – ABC Locate

Datum -XYZ- is defined by resting on the cast X, Y, and Z locators on the ladder.

#### Table 1 – Cam Ladder Machining Content

*(Subject to changes upon release of final part prints. The part print is the final authority on tolerances)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Feature Name** | **Datum** | **Machining**  **Window** | **Locating**  **Datum** | **Tolerance** |
| Cast Locators | XYZ | N/A | N/A |  |
| **Head mounting face** |  |  |  |  |
| Finish Mill Cylinder Head Joint Face (S1000) | A | A | XYZ | Profile 0.3 XYZ(DR)  Flatness: 0.200 overall (DR)  Ra 1.4 (DR),  Rz 11 (DR),  Rz1Max 14 (DR)  Wt 14 (DR) |
| Drill / ream B/C locators  (H1001, H1002) | B/C | A | XYZ | Position .25 XYZ (DR)  Perp 0.1 A  Spread 0.1  Dia +/- 0.013 |
| Drill injector Bracket Mounting Holes  (H2110-2115) |  | A or B | XYZ | Position 0.5 ABC  Perp 0.1 M  Dia +/-0.10 |
| Injector Sealing Surfaces (PIP Seal Groove bottom surfaces)  (S1100-1118) |  | A | XYZ | Profile 0.3 ABC  Depth 4.9+/-0.25  Ra 1.4 (DR),  Rz 11 (DR),  Rz1Max 14 (DR)  Wt 14 (DR) |
| Gasket Groove Side Wall |  | A | XYZ | Position 0.25 ABC on the sidewall ID  Groove Width 2.9+/-0.1 |
| Gasket Inspection Relief Surfaces  (S1120-1125) |  | A | XYZ | Profile 0.5 ABC  Dia +/-0.1 |
| Drill Cam Shaft Oil Supply Holes  (H2040-2053) |  | A | XYZ | TP 0.5 ABC  Perp 0.1 A  Dia +/- 0.1 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Feature Name** | **Datum** | **Machining**  **Window** | **Locating**  **Datum** | **Tolerance** |
| Mill cam Bearings mounting surfaces.  (S2000-2012) |  | B | ABC | Profile 0.35 ABC (DR)  Flatness .2 (DR)  Ra 1.4 (DR),  Rz 11 (DR),  Rz1Max 14 (DR)  Wt 14 (DR) |
| Mill Injector Mounting Surfaces  (S2100-2015) |  | B | ABC | Profile 0.35 ABC  Ra 1.4 (DR),  Rz 11 (DR),  Rz1Max 14 (DR)  Wt 14 (DR) |
| Drill/ream/tap cam cap mounting holes.  (H2001-2014, H2020-2033 |  | B | ABC | TP .25  Pattern .1 individual pairs at counterbore dia.  Counterbore Dia +/-0.013  Tap Position 0.2 to counterbore |
| Drill/Ream Rear Bearing Cap Dowel Holes  (H2035-H2036) |  | B | ABC | Dia +/-0.013  Position 0.3 ABC  Spread 0.1 (2036 to 2035(D))  Perp 0.1 E |
| Drill/chamfer Cam Cover Mounting Holes  (H2120-2126) |  | B | ABC | Dia +/-0.1  Position 0.5 ABC  Perp 0.1 M |
| Drill/chamfer Ladder Frame Mounting Holes  (H2220-H2235) |  | B | ABC | Dia +/-0.1  Position 0.5 ABC  Pattern 0.3 |
| Ball Mill Cam Shaft Bearing Faces  (S6601-6606, S6701-6706) |  | B | ABC | Position 0.2 ABC  Dia 22.26 +/-0.1 |
| Ball Mill Rear Cam Shaft Bearing Surfaces  (S6607, S6707) |  | B | ABC | Position 0.2 ABC  Dia 24.26 +/-0.1 |
| Machine Injector Holes  (H2101-2106) |  | B | ABC | Position 0.3 ABC  Perp 0.1 M  Dia +/-0.050 |
| Mill Manufacturing Transfer Locating Surfaces  (S3000, 3100, 4000) |  | B | ABC | Profile 0.5 ABC |
| Machine Manufacturing Transfer Locating Holes  (H3001, 3101, 4001) |  | B | ABC | Position .25 ABC  Spread 0.1 (3101 to 3001)  Dia +/- 0.1 |
| **Wash Part to Print Specification** |  |  |  | In no case shall debris exceed 20mg when measured per Test Method GMW16037 |
| **Leak Test Injector Sealing Area per print specification** |  |  |  | 12cc/min max at 140kPa |
| **Install 2 Dowel Pins for Rear Cam Shaft Bearing Cap** |  |  |  | Depth per part print specification +/-0.1mm |
| **Install 2 Dowel Pins for Cam Housing Locator Holes for Cylinder Head** |  |  |  | Depth per part print specification +/-0.1mm |
| **Install Intermediate Cam Caps with bolts & Rear Cam Cap with bolts. Tighten to 2Nm.** |  |  |  |  |
| **Laser etch 2D matrix PUN information** |  |  |  |  |

## 11.1 FINISH MACHINING PROCESS REQUIREMENTS

The information provided in Table 1, defines the baseline process requirements for machining. Deviations from this process require discussion and written approval from the DRE and Cylinder Head Manufacturing Responsible Engineer Matt Kenworthy in GM Manufacturing Engineering.

The supplier must provide process flow diagrams, with station by station descriptions, identifying which features are processed at each station, fixture designs, as well as detailed machining process dimensional information for those features at three different stages:

1. **Prototype Beta/Gamma Fixture initial approval process.**
2. **Production Fixture Design Approval Process**
3. **At Non-saleable PPAP**

All revisions must include details of which operations will be done in house and which (if any) will be sent to a tier II and or tier III supplier. If machining is outsourced, the potential sources must be approved by GM Product and Manufacturing Engineering and must be reviewed in the tech review. GM maintains an approved list of potential sources.

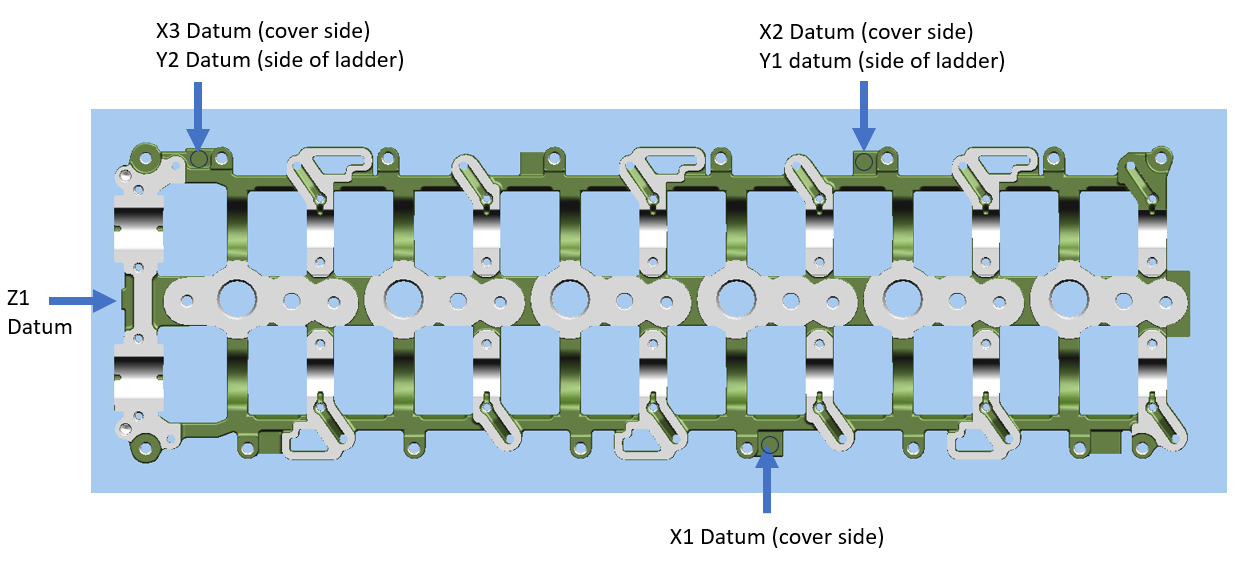
Fixtures must be reviewed and approved by GM Manufacturing Engineering prior to the supplier releasing them for build.

#### 11.1.1 Datums

The supplier must use the XYZ cast locator system as the initial datum for machining the cam carrier. The carrier machining process shall not hydraulically clamp on the cast locator system more than twice. Pneumatic clamping is permissible in ancillary operations. No damage to the primary cast locator surfaces is allowed.

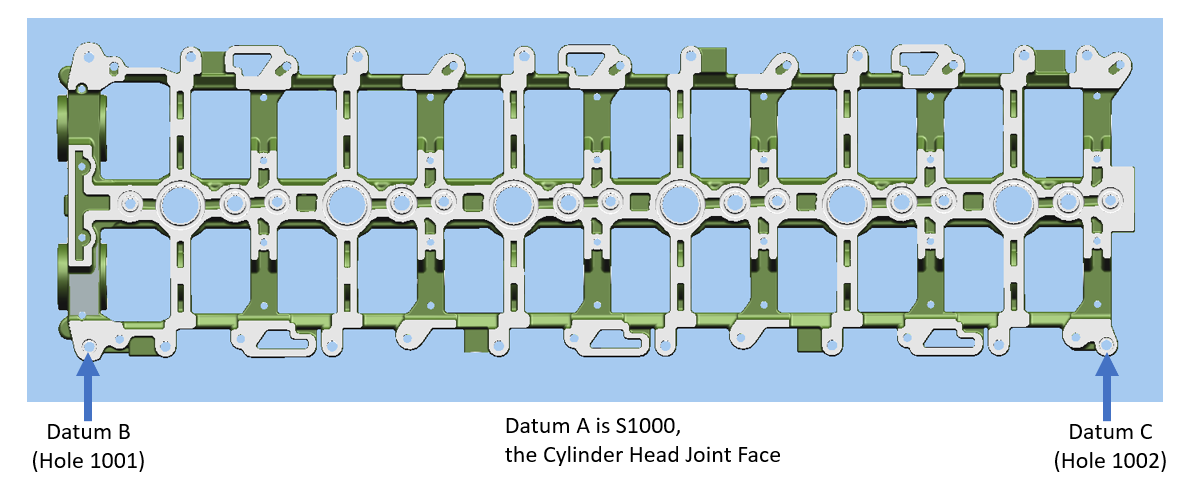
**FIG 1:**

Fig 1 shows the location of the Casting datums. When fixturing the Ladder Frame for Machining, additional work supports are required to properly support the part.



**FIG 2:**

Fig 2 shows the location of the ABC Fixture datums. When fixturing the Ladder Frame for Machining, work supports are required in addition to the fixed support to properly support the part.



#### 11.1.2 SE Requirements

The machining supplier will be required to attend simultaneous engineering meetings at GM GPS to assure common gaging strategies and location schemes with GM GPS. Meetings to be coordinated through DRE.

The supplier must provide process flow diagrams, with station by station descriptions, identifying which features are processed at each station, as well as detailed machining process dimensional information for those features, as part of the GM GPS ME approval process.

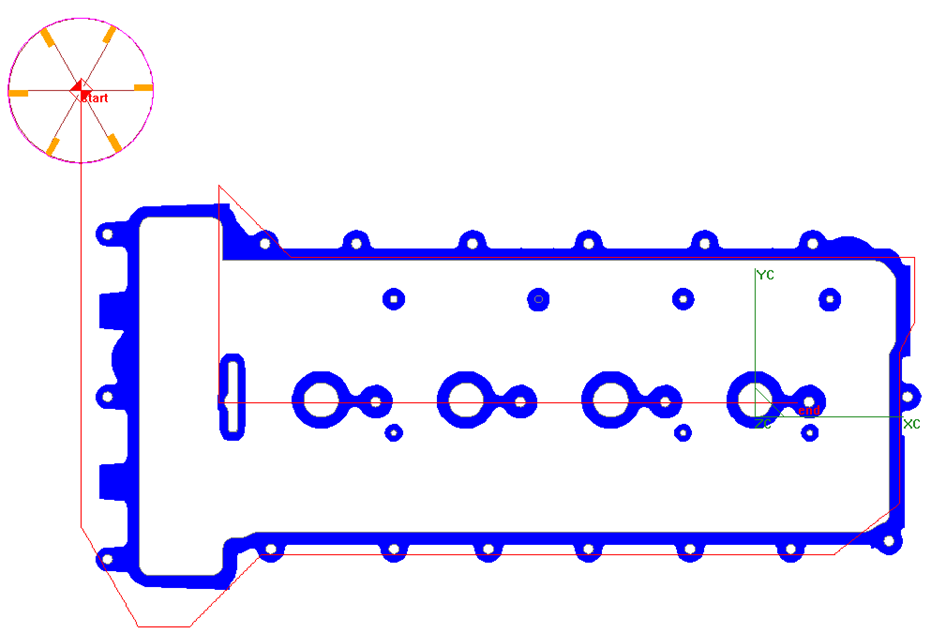
#### 11.1.3 Deburring Requirements

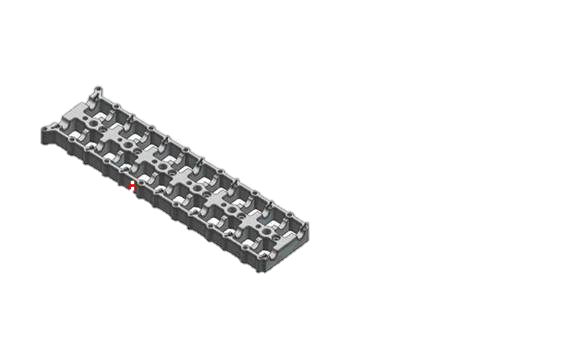
The following surfaces require deburring by means of a nylon or silicon carbide brush while in the machining center. Please refer to GMPT Global M&E Cutting Tool Specifications (see section 11.1.4)

1. Ladder mounting surface

#### 11.1.5 Ladder Rail Machining Process and Tooling

The following path is to be utilized for milling the ladder rail surface. This path may be further developed by GMPT, or in conjunction with the selected provider.





A surface

X,Y

X,Y

X,Y

Z

A 165 mm diameter cutter with 6 teeth is required. The following process parameters are to be used: PCD is required.

* Feed Rate: 0.125 mm/tooth
* Spindle speed: 10,000 rpm

First pass is to leave 0.25-0.5mm stock. Finish pass is to finish print dimension. Finish in a single pass is not allowed.

Any deviations in process must be approved by GMPT DRE and Manufacturing Responsible Engineer.

#### Table 2 - Required Process

|  |  |
| --- | --- |
| **Operation** | Description of Operation |
| **5** | Load casting. Serial number for part generated based on date/time (see section 11.6 for specific requirements of PUN). Serial to be tracked on RFID tag and utilized for part tracking in subsequent operations. |
| **10**  **4 axis CNC**  **(Window A)** | Locate on -X- cast locators, push against -Y- cast locators, and on -Z- locator. Clamp part on the designed clamp pads (note: final fixture clamp locations must be approved by GM). Advance and lock all work supports (work support location to be approved by GM).  Machine all features in window A, section 11, table 1. |
| **20**  **4 axis CNC**  **(Window B)** | Locate on –ABC-. Clamp part on the designed clamp pads  (note: final fixture clamp locations must be approved by GM).  Machine all features in Window B, section 11, table 1 |
| **30** | Wash and dry parts. Hydraulic clamping is not permitted (pneumatics recommended). ABC locating features and clamp / bolt locations must be clean, dry, and residue free. |
| **40** | Leak test / Laser mark 2D – Combined high and low pressure oil tests required, per print specifications. 2D matrix with cleaning pass to be applied to good parts only (See section 11.5) utilizing serial generated in OP5. |
| **50** | Install dowel pins, cam caps, and front cap |
| **60** | Visually inspect parts / Unload - GP-12 / Care in-line (Quality Gate). Parts to be packaged and segregated by part number. |

Any deviation from the above process in Table 2 needs to be detailed by the supplier and approved by GM GPS DRE and Manufacturing Engineering.

## 11.2 FIXTURING REQUIREMENTS

All machining equipment fixture designs shall adhere to the specific part orientation, locating feature, and clamping point requirements described in Section 11.1 and Table 2. Any deviations from the locating and clamping points in Table 2 need to be detailed by the supplier and approved by GM Manufacturing Engineering.

The following requirements apply to all fixtures utilized for machining processes:

* All CNC work holding fixtures must utilize hydraulic power for all part clamping, locating, and equalizing motions, including all work supports and any wedge or sleeve locking mechanisms.
* All part locating surfaces (i.e. fixture rest pads) must have an orifice in each pad, connected to an air circuit with a pressure switch, to verify that the part is seated properly in the fixture.
* All fixture locating pins must have an air pressure circuit to detect broken locating pins. This circuit may be combined with (1) of locator pad surfaces
* Provisions must be made for coolant flushing on the fixture, to clear chips away from the locating pads, between every machine cycle, during part exchange.
* Provisions for consistent coolant temperature control, with coolant temperature monitoring, and clean coolant filtration are required.
* If an adaptor plate is utilized, fastening requirements and torque sequences are to be validated by GMPT Manufacturing engineering process manager during simultaneous engineering
* Rest pad sizes are to be approved by GMPT Manufacturing engineering process manager.
* All clamp and work support locations to be approved by GMPT Manufacturing engineering process manager
* Where work supports are required, Kosmek LC or LD series hydraulic advance work supports, Vektek TuffGrip, or comparable system, upon approval by GMPT DRE and Manufacturing Engineering are to be utilized

The supplier shall provide fixture design concept approval drawings to GM Manufacturing Engineering prior to building any tooling or equipment. GM ME may find it necessary to conduct finite element modeling and analysis to evaluate clamping or cutting load distortions prior to approval. GM ME reserves the right to accept, deny, or otherwise require modification to the machining supplier’s fixture design concepts, at the supplier’s expense, if any of the above dimensional and handling requirements are not satisfactorily met. One (1) set of work holding fixtures shall be built for initial tryout and acceptance prior to building the remaining fixtures.

The machining supplier retains complete responsibility and accountability for all aspects of their manufacturing process, systems, equipment, fixturing and tooling performance, including operational success, equipment delivery timing, and providing parts per print to General Motors.

## 11.3 EQUIPMENT PERFORMANCE DATA

Supplier tool layouts and CNC programs for all machining operations, including tool paths, speeds, feeds and cycle times shall be provided to GM GPS Manufacturing Engineering. Cycle time breakdowns are “part-to-part” and must include loading, clamping, probing, processing, unclamping, unloading, and transfer/indexing time. Additional CNC machine tool performance characteristics, including acceleration, deceleration, and tool change time may be required for cycle time and throughput capacity simulation.

At minimum, the supplier must include in their quote, the information shown in the example data template shown in Table 4 below.

Table 4: Machining System: Overview of Equipment and capacity planning

*(Note: This is only an example template data table. Please fill the specific info for the system you are planning in the quote)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Time base for LCR** | | 20 hrs. /day, 5 days/wk (Example) |  |  |
| **System LCR planned** | | 1000/day(Example) |  |  |
| **Operation** | **Equipment** | **Cycle time(s)**  (incl. load/ unload, etc.) | **Capacity**  @ 100% OEE  (per day) | **Machine Qty** | **No. of fixtures per Op.** | **No. of tools per Op.** |
| Op.05 | Load |  |  |  |  |  |
| Op.10 | CNC |  |  |  |  |  |
| Op. 20 | CNC |  |  |  |  |  |
| Op. 30 | Wash |  |  |  |  |  |
| Op. 40 | Leak Test & 2D Matrix |  |  |  |  |  |
| Op. 50 | Assembly |  |  |  |  |  |
| Op. 60 | Inspection &  Download |  |  |  |  |  |

## 11.4 MATERIAL HANDLING REQUIREMENTS

Provisions must be made to minimize or eliminate handling damage to all part surfaces:

* No part-to-part touching is allowable on any automated conveyor or material handling system.
* No finish machined surfaces are to be used as a transport surface on conveyor or material handling system
* Under no circumstance is the part to be “skidded” on any machined surface.
* Parts shall not be placed directly on the floor or stacked on top of each other.
* If a part is “dropped” on the floor, it must be considered a scrap part.
* The supplier shall use wood or plastic dividers between parts for all “in-process” manual material handling.

The above part handling damage concerns must be considered in the supplier’s PFMEA analysis, including specific application to the manufacturing holes, and fixture locating surfaces.

## 11.5 CNC CAPABILITIES

The machining centers utilized by the supplier must meet the minimum following requirements –

* Clamping, crowding, and work supports (where required) must be on independent hydraulic circuits
* Required coolant temperature monitoring must have controls interlock to machining center
* Coolant temperature to be held to 20° C +/- 1.5°
* Where work supports are required, Kosmek LC or LD series hydraulic advance work supports (or comparable system, upon approval by GM Manufacturing Engineering) are to be utilized
* No probing or compensation is permitted.
* Probes utilized within a machining center must have periodic challenge and verification
* The use of expanding locators is prohibited
* **At Tech Review CNC Machine Manufacturer to be reviewed and approved.**
* Sufficient hydraulic, pneumatic, and coolant circuits need to be available for all control needs—extended use of sequencing circuits is not allowed.
* CNC’s with Glass scale for axes positioning highly recommended
* CNC work envelope shall accommodate complete part surface for milling, different portion milling is not allowed which will result in step on surface.
* CNC machine axes accuracy & vibration reports to be submitted to GM ME.
* Rest pads & dowel pins must be cleaned or flushed before loading new raw part for machining
* Added rotary union / coupling on top of fixture may be necessary to provide needed control circuits, op. 10 is likely fixture in need of this addition.
* Pressure reducing valves are required on the 3 unique clamping circuits. This will allow for first low pressure / soft clamp, especially for Z and Y clamps then hard clamp after final part positioning.
* Sequencing of clamping will need to be learned based on part, locator, and clamp positions to minimize potential rocking of part as clamping is sequenced.
* Individual machine coolant systems, if used, must be tied into control circuit of CNC and must have set point limits that control when can the CNC run.
* Broken tool detection within CNC is required
* CNC must track coolant temperature and trigger a fault whenever this goes below or above the limit required. Allow the operation to finish the process any part present in it but prevent further processing until temperature reaches limit range.
* Unless the above hydraulic and pneumatic circuit requirements are met, no two-part fixtures are allowed.
* Use of manually applied hydraulic connection to fixture while loading / unloading is not permitted.

**Operation requirements**

* Tool change control system needs to be provided
* Quality system structure tied to tool change plan
* Part traceability via the PUN needs to be established for leak tester and final visual inspection as well as being related to reject parts from CNCs and parts inspected on CMM.
* Leak tester & masters shall be in temp controlled environment.
* Part temperature must be +/- 3°C with atmosphere before entering into Leak tester. After the washer, a cooling tunnel shall be implemented.
* Coolant supply provisions for consistent coolant temperature control, with coolant temperature monitoring, and clean coolant filtration are required
  + Coolant supply to CNC, whether central coolant or individual coolant machine supply must be 20 °C +/- 2 °C. The main premise is to be constant throughout the complete manufacturing process. This includes machining, washing, and leak testing.
  + Coolant temperature data must be control charted to create log that must be provided to GM on a regular basis (or as determined by DRE, ME)
  + Effective use of chillers recommended for soaking hot castings before entering into CNC’s. Adequate cooling time of part must be used to achieve a part temperature of 20 °C +/- 2 °C prior to machining.

## 11.6 PART IDENTIFICATION REQUIREMENTS

This part requires a Part Unique Number (PUN) to be generated and marked on each part. The information to be included in the PUN and the format is described in Attachment C of GQR120.57 specification attached.

The part shall be directly and permanently marked with the PUN. The part-marking format shall provide both human-readable alphanumeric and machine-readable 2D matrix codes.

Please note following requirements:

1. Part marking **must** be done with a laser marking system.
2. A ‘clean-up pass’ with the laser **is required**, to etch the area to be marked. This will ensure better contrast and readability after marking.
3. A quite zone must be left around the 2D matrix mark. See the SP-E-DPM specification for details.
4. The PUN must be read immediately after marking by an electronic scanner (optical reader or camera) to verify the readability/quality of the mark and meet requirements as defined in the SP-E-DPM specification.
5. Exact size and location of part marking requirements will be refined after supplier selection.

Additional traceability marking is to be planned for - i.e. manufacturing line (cell or module) number, station # and fixture #. The location, content, method and format for these marks depends on the process plans, and are to be determined along with the GM Manufacturing Engineering during part development. If drill-points are going to be used for traceability by the supplier, this must be accounted for the in the machine cycle time calculations. Drill point markings need the approval of GMPT product engineering and manufacturing to ensure proper wall stock under worst case conditions and appearance as seen by final customer is not degraded.

The casting variant/type are to be coded into the PUN number. The final PUN format will be developed by the PDT and defined in the Quality Document.

Use GM Specification for part identification: SP\_E\_DPM, and 22 digit PUN format; see attachements.

The “production-intent” part identification system shall be utilized for all MRO parts, and Gamma level parts forward.

## 11.7 CASTING TRACEABILITY REQUIREMENTS

Cast times and cast date codes are the normal traceability method for castings.

Ladder castings shall be traceable through the machining process, such that any “Special” identification applied by the foundry, on the castings or packages must be maintained through the supplier’s process.

## 11.8 PART WASHING REQUIREMENTS

The machining supplier’s final part washer must provide the ability to meet the following part dryness, and part cleanliness specifications, as well as make provisions for controlling part exit temperature, which is important for leak test stability:

Parts as delivered to the GMPT engine plant shall be clean and free of debris, residual abrasive material, and corrosion products adversely affecting function or appearance. Debris on finished parts shall be regularly monitored and controlled using statistical methods, upper control limits and procedures approved by GM Powertrain Materials Engineering and defined in the Supplier Process Control Plan. The **total** debris shall not exceed **20 milligrams**, when measured per test method GMW16037. Table 4 shows further restriction of the maximum allowable debris in specific areas of the part as received at GMPT.

Table 4: Retained Material Spec. for specific areas of the part

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | Passage / Cavity | Condition  As cast/Machined | Max. allowed (mg.) | Special Characteristic |
| 1 | Entire part | Machined | 20 | DR |

Monitoring of each individual washer’s performance shall be conducted on a daily basis, according to the “Sediment Test Procedure” guidelines, which supplements test method GMW16037.

Parts must be washed on all external and internal surfaces, and be free of machining coolants, chips, and contaminants from previous operations. Cam ladders must be loosened and separated (minimum 10mm separation) prior to wash. Washer performance verification testing needs to include placing contaminants (dirt and chips) in all drilled holes, and then visually inspecting the holes after washing, to confirm proper nozzle alignment, and verify all holes and surfaces are free of contaminants.

100% complete part dryness when exiting the washer is necessary to insure accurate leak test results. A vacuum dry system is requirement to achieve the 100% part dryness requirement.

Temperature of finish washed and dried part is critical to leak testing. Exit temperature must be controlled via cooling tunnel or finish rinse water temperature control. Ambient plant temperature +/- 3°C is target range.

## 11.9 LEAK TESTING REQUIREMENTS

#### 11.9.1 Part Condition & Environment

All parts to be tested must be at ambient temperature, within +/- 3 deg. C. Parts with temperatures outside of this specification shall not be tested. (Note – parts above ambient can produce negative leak rates that can mask defective parts. See table 5 below for controlling negative limit values in the leak tester)

Note: If the plant ambient temperature varies by more than +/- 2 deg. C per hour, the leak test units shall be re-calibrated and compensated per manufacturer’s documented procedures.

Leak testing requires the castings to be thoroughly dried (free of all standing water) to ensure accurate leak test results.

#### 11.9.2 Part Specific Information

The carrier features, cavities, parameters, and specifications required for leak testing are listed in Table 5.

Table 5

|  |  |  |  |
| --- | --- | --- | --- |
| Leak Test Feature | Cavity/Circuit Tested | Test Pressure | Max. Leak Rate Spec. |
| Ladder assembly | All low and high pressure oil to include: cam cap oil feed holes, and injector holes/mounting/pivot holes to low pressure oil | 140kPa | 12 cc/min |

The Supplier is responsible to determine the test volumes of the cavities from the 3D model, and provide GM a cycle-time diagram of the leak test cycle.

#### 11.9.3 Additional Leak Test Operation Requirements

Parts that have passed all leak test requirements are to be marked with 2D matrix. Location is to be agreed upon and indicated on the print or Quality Document.

Leak test results are to be stored (referencing PUN created with 2D matrix) in QDAS, and be made available to GMPT on request.

#### 11.9.4 Masters

The machining supplier shall procure, provide and maintain all leak test calibration and verification masters. This includes:

- Zero Leak Master Parts (used for setup and calibration of the leak test machine)

- Reject Master Parts (for periodic challenging of equipment)

- Certified Leak Orifices (for calibration of leak test machine)

Leak Test Masters are to be made from production parts acquired from the Tier 1 casting supplier at the expense of the supplier. The supplier shall also provide and maintain a second spare “back-up” set of “zero” and “reject” masters.

Typically the Zero Leak Master is a three-time impregnated part to ensure no-leaks exist in the master part.

#### 11.9.5 Equipment Capacity & Re-Leak Testing

20% excess leak test capacity is required to accommodate re-testing of leak rejects.

All leak test rejects should be re-tested (a second time) on the in-line leak tester to verify the reject status of the part before going to the diagnostic dunk tester. Re-testing all first-time rejects will reduce the quantity of “false rejects” being diagnosed at the dunk test. The supplier must provide the ability to manually load parts into (or ahead of) the leak test machine for the purpose of re-testing previously rejected parts. *However, the part marking for leak testing shall be done on only those parts “accepted” by the in-line leak test machine.*

#### 11.9.6 Diagnostic/Audit Dunk Testing

The machining supplier shall provide one (1) “off-line” manually operated, semi-automatic clamp, dunk test station for diagnostic purposes, capable of performing all of the required leak tests. The audit and “in-line” leak test seal designs and leak test operating parameters must be identical. Audit dunk testers will be used to diagnose the location of a leak on the casting and/or verify in-line air decay leak test seal problems. **Parts may only be accepted for leak test on the in-line leak test machine.**

#### 11.9.7 PFMEA Analysis & Error-Proofing

Leak Test PFMEA analysis shall include the possibility of accepting “bad” parts and rejecting “good” parts. Provisions to error-proof, or minimize, the possibility of these occurrences shall include calibration frequencies, verification masters, washer part temperature and dryness controls, monitoring the correlation error between parallel leak testers, and avoiding the possibility of “seal creep” (soft seals).

Verification that all leak test equipment is functioning properly, including proper reject part handling, is required on a daily basis. A verification audit shall be performed, on each leak test machine, at the frequency of, (at least once per shift), as defined on the PCP. For audit verification purposes, re-running the “zero”-master part through the leak test, needs to result in leak rate values within 0 cc +/- 10% of the full leak limit.

Note: The results of the daily audit “zero” master leak rate values need to be control charted.

## 11.10 VISUAL INSPECTION REQUIREMENTS

The machining supplier shall provide for 100% visual inspection of each part produced. The visual inspection process shall occur after final wash. Inspection shall include verifying the presence and readability of the serial ID number, sorting for handling damage, casting breakout, machining burrs, no-clean-up / shy-of-stock, and surface porosity. The scope of the visual inspection process shall include, but is not limited to, all machined internal and external surfaces. Inspection of all machined surfaces for porosity shall be according to the standards provided in the part drawings.

Notes: 1) The Tier I casting supplier is responsible for the inspection of all as-cast surfaces to applicable porosity acceptance standards for those surfaces.

The supplier shall provide material handling capability to roll over the part for complete visual inspection, proper lighting for inspection, boundary samples for inspection criteria, and material handling to remove defective parts at the point of detection.

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## 11.11 DIMENSIONAL MEASURING SYSTEM REQUIREMENTS

Supplier quality shall be maintained by strict adherence to an approved Process Control Plan. The supplier’s Process Control Plan (PCP) will establish the required frequency of gage checks. The machining supplier must submit their PCP to GM Manufacturing Engineering and Supplier Quality Engineer for approval.

The machining supplier must have temperature controlled measuring, temperature controlled machine coolant, and parts washers, to ensure the dimensional accuracy, control and stability of the parts produced. The machine coolant temperature must be monitored with control limits to ensure consistent part temperature to maintain part quality.

Cast locator to machined datum measuring must be done with a fixture gage or a CMM program that replicates the machining fixture. Additional, GMPT requires that CMM’s be used as the “gage of record” for all feature’s requiring location, position, profile, angularity, perpendicularity, roundness, runout, and flatness measurements and hole depths dimensioned to datum features other than the entry surface. All gages must show correlation with GMPT CMM results. The inspection frequency to be approved by SQE, DRE, and process manager. For quotation purposes, assume a minimum frequency of once per shift per stream for CMM; diameter inspection once every 50 parts. Control plan may dictate increased frequency for features.

All profile and diameter measurements are scanned with a CMM, not discrete point measurements.

Any features machined to datums other than those referred to in the feature location tolerance specifications must have tolerance stack-up calculations to support the in-process tolerances used to generate that feature. Inspection reports must include measurement of both the “in-process” (I/P) feature tolerances, as well as the final “part-print” (P/P) feature tolerances.

All necessary long-term production-intent gaging equipment and tooling must be present, and certified as being accurate & repeatable, (including CMMs, CMM fixtures and CMM programs) prior to production-intent machine qualification. Additionally, production-intent gauging and tooling must be utilized for qualification and acceptance of all Gamma level parts and above.

GMPT reserves the right to accept, reject, or require modification to the supplier’s PCP, or require modification to the supplier’s CMM programs, fixture gage designs, and/or hand gages to the extent that the above requirements are not satisfactorily met to insure that all feature tolerance requirements are measured accurately and completely. Measurement systems must be consistent between manufacturing locations.

## 11.12 ERROR-PROOFING REQUIREMENTS

A critical aspect of the machining system is the development of error proofing strategies, to protect the customer by preventing the possibility of shipping defective components to the GMPT engine plant. Areas where error-proofing verification efforts are required include:

* Broken tool detection including the application of probes that physically detect the presence of the machined features (holes, surfaces, etc.) and/or physically detect the presence of the tools.
* Methods to ensure that the washer is not inadvertently bypassed by manual material handling methods and to insure part temperature and part dryness requirements are satisfied.
* Go/no-go “verification” master-parts for all leak test equipment (for set-up, tryout and periodic verification)
* Boundary sample parts for all visual inspection accept/reject criteria (displayed at visual inspection station)
* Any 100% (of production) inspection devices, such as in-line, automatic in-process, or post-process gaging

Note: All error-proofing “verification” measures shall be performed periodically, at the frequency defined on the Process Control Plan (PCP), including automatic gage calibration procedures and frequencies.

The supplier shall present a complete PFMEA analysis of their entire manufacturing system early enough in the program to include effective error-proofing methods into the initial production-intent equipment design. The PFMEA needs to be reviewed and approved by GMPT SQE, DRE, and ME process manager, no later than the Gamma build phase.

#### 11.12.1 Part-Type ID Probes

Machining centers and ancillary equipment must have the ability to determine part type of a part, and machine / process appropriately.