#### Herein are the minimum requirements that shall be incorporated into the manufacturing process for the impregnation of castings. This Process Specific Statement of Requirements (Process SOR) is in addition to and not intended to replace any requirements as outlined in the GM Supplier Quality SOR (GM 1927-03).

The required tasks indicated below are based on experience, best practices, and lessons learned to improve part quality. They are applicable to all Tiered casting suppliers in the supply chain.

In the event of any conflicting wording between this document and any similar document received from General Motors Product Engineering, the wording in the Product Engineering document shall prevail.

*Note:* “Shall” in this document is mandatory. “Should” is highly recommended.

It is intentional that this document is NOT GM Confidential.

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1. **General Description**

This Process Document is for the impregnation of a wide variety of castings which are used in automotive applications. High Pressure Die Castings in particular are often impregnated.

This Process Document is not a Work Instruction for how to impregnate a casting. It is not a Control Plan. It is most similar to a PFMEA. It is a consolidation of Lessons Learned. It is content typical of impregnation applications which have very good recovery and quality metrics.

1. **Approval to Impregnate Castings**
   1. Impregnation of castings is common in the automotive industry. This does not mean that suppliers can impregnate parts without any customer approval process.
   2. Suppliers must request approval from GM Product Engineering (PE) for each specific part number application. PE will review the request in detail. Common questions include, but are not limited to:
      1. Is Program Timing or Delivery Quantity affected? Is Part Functionality affected? There is a legitimate business need to pursue approval of impregnation?
      2. Why does the part leak? What is the leak path?

Fine shrinkage porosity and small gas bubbles will usually seal easily with impregnation. “Through the wall” defects such as cold shuts, misruns, hot tears, open joints, folds, cracks, thin walls, or similar discontinuities must not go to impregnation. These may temporarily seal, but will reopen in service.

* + 1. The supplier must learn why the parts are leaking and collect leak rate data. The data are usually bi-modal. Fine shrinkage porosity and small gas bubbles will have low leak rates. “Through the wall” defects such as cold shuts, misruns, hot tears, open joints, folds, cracks, thin walls, or similar discontinuities will have high leak rates.
    2. The intent is to separate the bi-modal distribution.

Okay for the low leak rate fine shrinkage porosity and small gas bubbles to go to impregnation. Not okay for the high leak rate “Through the wall” defects such as cold shuts, misruns, hot tears, open joints, folds, cracks, thin walls, or similar discontinuities to go to impregnation.

* + 1. A common air decay upper limit is 50 cc/min for a single leak path. Because most air decay cannot distinguish if there is one leak path or many leak paths, the 50 cc/min is a cumulative upper limit.
    2. Water dunk testing has an advantage in this analysis. A multitude of fine “fizzy” leakers, each individually less than 50 cc/min, collectively may be several hundred cc/min, and will usually seal easily with impregnation.
    3. Where does the part leak? Is it at a highly stressed feature in the Finite Element Analyses? Low stress features are low risk to impregnate. High stress features may be high risk to impregnate.
    4. Therefore, Product Engineering may Approve impregnation of certain features of a casting, but not other features on the same casting. This gives water dunk analyses an advantage. It is easy to figure out where the leaks originate.
    5. Has the supplier made a reasonable effort to eliminate the leakage without impregnation? Leaker rejects are being tracked by cast date? Leak paths known? Action Plans with documentation of results?
    6. In general, GM considers impregnation to be a temporary activity until robust solutions can be implemented which eliminate the leakage.
    7. What is the proposed process flow? Impregnate as raw castings? Partially machined or assembled? Finish machined? Parts have been leak checked prior to impregnation? Parts have not been leak checked before impregnation? Sometimes impregnating machined castings creates more failure modes than impregnating the raw castings. There is no single answer for the process flow. Alternatives must be discussed in detail with PE. PE has the final decision.
    8. When the leakers bubble from as-cast surfaces on finish machined castings, it suggests that impregnating the raw castings might work. PE may approve impregnation without leak testing the raw castings first. In these cases, there must be supporting data. A supplier often must start out with leak test before impregnation in order to generate data.
    9. During the data collection for approval to impreg, some parts need to be labelled and tracked through the proposed process flow. What was the leak rate before impreg? What was the leak rate for that same part after impreg? Data must include leakers at the upper limit being requested to go to impregnation.
  1. If the process flow for a part includes heat-treating, the impregnation must be after the heat-treating.
  2. If the castings become very hot in service on the vehicles, over 149C, impregnation cannot be Approved.
  3. Impregnation is normally done before any component assembly.

If a part has had some component assembly, Product Engineering must decide on a case-by-case basis if it can be impregnated without disassembly.

* 1. A typical GM Approval allows impregnation of a component once as a raw casting, and/or once as a finish machined casting.
  2. If impregnation was not part of the original process flow, then packaging/handling must be discussed. A finish-machined part going to impreg may incur so many nicks and dents on sealing surfaces that the scrap for the nicks and dents is greater than the original leaker scrap.
  3. The GM Manufacturing Plant(s) that would use the impregnated components may require a PTR (Production Trial Run) prior to production implementation to confirm quality indicators.

1. **Approval of Impregnation Sealants (Resins)**
   1. The supplier must tell GM PE exactly which sealant will be used. GM Materials Engineering may have questions concerning the compatibility of the sealant with part function. GM Product Engineering may have questions concerning potential harmful failure modes resulting from impregnation. Final decision belongs to Product Engineering.
   2. GM does not allow impregnation with sodium silicates. GM does not allow impregnation with clay slurries.
   3. GM does allow many Anaerobic and Heat Cured (Thermoset) sealants.

Examples include, but are not limited to: • GM 9985463 – Anaerobic, thermoset type (Henkel Loctite Resinol RTC)

• GM 9985682 - Heat cure thermoset type (Ultraseal PC504/66)

• GM 9985734 - Heat cure, thermoset type (G&W 95-1000AA)

• GM 9985791 - Heat cure, thermoset type (Henkel Loctite Resinol 90C)

• Opel B 040 0682 - (Henkel KID 88C and KID 90R; Henkel Loctite Resinol RTC; Vakuumdichttechnik IMTEC 100 and IMTEC 300; Maldaner IM3000; Ultraseal MX2, Rexeal 100 and PC504/66; Degussa 5140)

• Anaerobic, thermoset type, no GM part number (Chemence Anaseal RT20)

• Heat cure, thermoset type, no GM part number (Chemence Anaseal HC-90, TeknoSeal TSP99)

* 1. In general, sealants which meet the criteria for MIL-I-17563 Class 1 are likely to be Approved.

1. **Approval of the Impregnation Source**
   1. GM must approve the impregnation source which would perform the impregnation. All impregnation sources must have common Quality System Documentation such as PFMEAs, Control Plans, and Work Instructions. TS16949 certification is desirable. The source must Pass any assessments by GM Supplier Quality. Final Approval belongs to GM Product Engineering.
   2. This Approval is site specific and equipment specific. Approval for one impregnation process flow at an impregnation source is not Approval for all process flows which may be available.
   3. Specifications.
      1. Impregnation sources are not responsible for what customers are sending to them. However, it is a Best Practice for the impregnation sources to ask and document what they are getting. What is the leak spec for the parts received? Have the parts been leak tested? What are the leak rates as received?
   4. Incoming.
      1. Customer containers must be unloaded indoors. The parts must not be exposed to moisture, dust, or any other contamination.
      2. Every container must be tagged such that traceability through the entire process is obvious and clear for everyone. Designated storage areas do not eliminate the need to tag the containers.
      3. Castings waiting for impreg must be covered and stored in a clean place.
   5. Repackaging.
      1. Containers to be used for impregnation baskets must be clean. Any trays, dividers, spacers, plastic netting must be clean. The intent is that the castings do not get contaminated.
      2. There must be a Work Instruction for each part number, with photos, clearly showing the orientation of the parts in the baskets, the number of parts in the basket, and the packaging trays, dividers, spacers, plastic netting.
      3. Machined surfaces must be protected such that these surfaces do not get damaged. It is unacceptable for the impregnation source to be damaging the machined surfaces on the castings. A lack of control over material handling is a common reason to Not Approve an impregnation source.
   6. Cleaning and Rinsing.
      1. This particular process activity needs to be discussed with the Supplier and GM Product Engineering. If the parts being sent to impregnation are thoroughly dry and clean, it is usually best to skip this step at the impregnation source. (Explanation in the next section about Drying.)
      2. Wash and rinse tanks must be cleaned on a regular basis. There must be an inspection with criteria for determining if cleaning becomes necessary ahead of a regular interval.
      3. If the rinse water is used too many times, the parts may have dark stains on them.The dark stain is not harmful. It can usually be removed with hot, damp towels.
      4. Both wash and rinse tanks must have thermocouples and they must have heat capability. Steam pipes and electric immersion are common. The temperature of the water in the wash and rinse tanks shall be over 20C. The heaters may not need to be ON year-round, depending on ambient conditions.
   7. Drying.
      1. The dryness of the leak path is a critical feature of the impregnation process. The leak path in the castings must be thoroughly dry and open when the casting is impregnated with sealant.
      2. A common failure mode is that the leak path is wet. The sealant does not fully enter the leak path. The impregnation may not seal the leak, or it may not penetrate deeply. The leak path may re-open in service.
      3. Blowing the casting off with an air wand is not a dryer. Allowing the castings to ambient drip dry is not a dryer. Setting a basket of parts outside in the sunshine is not a dryer.
      4. Most impregnation sources today do not have hot air convection dryers. They are using vacuum autoclaves. Vacuum autoclaves are not dryers. They do remove most of the moisture. They are not as robust as hot air convection dryers.
      5. This is why the Cleaning and Rinsing activity mentioned previously needs to be discussed with the Supplier and GM Product Engineering. If the parts being sent to the impregnation source are thoroughly dry and clean, it is usually best to skip this step at the impregnation source. The vacuum autoclave after Cleaning and Rinsing may not get the leak path as fully open as it was when received direct from the Supplier. Choose the process flow which is most robust to assure that the leak path is not wet.
      6. When vacuum autoclaves are used, the equipment parameters for Dryness must be clear on the Work Instruction.
      7. When hot air convection ovens are used, the time at temperature for given quantity of castings must be clear on the Work Instruction.
   8. Sealant (Resin) Tanks
      1. The impregnation equipment may be wet vacuum, dry vacuum only, or dry vacuum and pressure.
      2. The sealant impregnation step must be fully automated. There must be a program for each part number. Control panels must be locked to prevent unauthorized access.
      3. Sealant tanks must be cleaned regularly.  There must be daily audits with criteria for determining if cleaning becomes necessary ahead of a regular interval.  Common audits include: checking the viscosity of the sealant using Zahn cups, specific gravity, powdered metal blocks, curing test tube samples of the sealant in a hot water chamber.
      4. Sealants may darken the appearance of the parts. It is not harmful.
      5. Sealant tanks must have thermocouples and they must have temperature control.
   9. Sealant (Resin) Rinse / Wash
      1. Removing the excess sealant is an important aspect of the impregnation process. Automated methods, such as centrifuge, are preferred. Ultrasonic may work for some applications. Manual air wands are not desirable; however, they may be appropriate for some features such as blind holes.
      2. Sealant (Resin) Rinse / Wash tanks must be cleaned on a regular basis. There must be an inspection with criteria for determining if cleaning becomes necessary ahead of a regular interval.
      3. Sealant (Resin) Rinse / Wash tanks must have thermocouples and they must have heat capability. Steam pipes and electric immersion are common. The temperature of the water in these tanks shall be over 20C. The heaters may not need to be ON year-round, depending on ambient conditions.
   10. Hot Cure.
       1. Thermoset type sealants require hot curing. The hot curing tank temperature must be controlled. Steam pipes and electric immersion are common. A target temperature of 90C is common. A minimum curing time must be controlled.
   11. Inspection by Impregnation Source.
       1. Castings must be 100% inspected to assure that there is no residual sealant on the castings. Ultraviolet lights are common. Inside of threaded holes is of particular concern. Frequency of inspection can be reduced to an audit if 100% inspection data are always acceptable.
       2. The method used to remove any residual sealant must be agreed upon with the customer. Hot damp towels are common. GM does not allow solvents such as WD-40 to be used. Threaded holes may require tapping.
       3. Castings which have been impregnated must have a permanent identifying mark made by the impregnation source after the impregnation is completed. The location of the mark and the method of marking must be agreed upon with GM Product Engineering.
       4. The impregnation source must have a regular audit using Master samples to monitor the impregnation process. Powdered Metal blocks are common.
   12. Repackaging for Shipment
       1. There must be a Work Instruction, with photos, for how to stack parts into the return customer containers. The containers must be clean. Any trays, dividers, spacers must be clean.
       2. The surfaces of machined castings must be protected from nicks and dents.
       3. All containers must be covered.
       4. All containers must be loaded for shipment indoors. The parts must not be exposed to moisture, dust, or any other contamination.
   13. Recovery Rate
       1. The impregnation source should track the leak test recovery rate for each customer part number.
       2. Impregnation sources are usually not responsible for leak testing the parts which were sent to them. However, it is a Best Practice for the impregnation sources to ask and document what the Recovery was at their customer.
   14. Inspection by Supplier
       1. Suppliers must have an incoming inspection audit of the parts returned from the impregnation source. Common inspections include, but are not limited to:
       2. Permanent identifying mark present for impregnation
       3. Blacklight inspection for residual sealant (resin).
       4. Damage on machined surfaces
       5. Suppliers must re-leak test the impregnated parts to the original PE specification. Parts which Pass leak testing after impregnation must have a permanent identifying mark made by the supplier. The location of the mark and the method of marking must be agreed upon with GM Product Engineering.
       6. Suppliers must analyze impregnated parts which failed to Pass the re-leak test. Why did impregnation fail to seal the leak? Leak rate was not checked before impregnation? Leak rate was over 50 cc/min to start with? A “through the wall” defect was sent to impregnation? Parts were not completely dry going into the resin tank? Leak test is not accurate? Other?
       7. These analyses of the impregnated parts which failed to Pass re-leak test must be reviewed with GM Product Engineering. Do the criteria for sending parts to impregnation need to be modified? Can the process flow be made more robust? Depending upon the analyses, what corrective action is appropriate? What frequency should the supplier continue to analyze failed parts?
       8. The supplier must track the Recovery rate from impregnation; preferably by cast date.
       9. For castings impregnated after machining, there is a low frequency Lesson Learned that “liquid” gasketing materials such as RTV may not stick tightly to the machined surfaces after impregnation. The supplier must compare the adhesion of the RTV on parts which were not impregnated with the adhesion of the RTV on parts which were impregnated.
       10. There is a “Dyne Surface Tension Test” which can measure the force necessary to remove the RTV. However, the difference is obvious when manually pulling on the RTV. Again, this Lesson Learned concerning the RTV is low frequency. It is unusual. The corrective action is to wipe the surfaces where the RTV will be applied with LPS Precision Clean.

**5. SUPPLIER Acknowledgement of CG5301 Impregnation of Castings SOR REQUIREMENTS**

The supplier must acknowledge they have read and understand this document. Please complete this page and submit it as part of the request for impregnation approval. If you do not complete this form, you will not obtain approval.

Full name of the supplier: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Specific address of the supplier: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Supplier Representative Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Supplier Representative Title (function):\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Appendix A** – Revision History

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| **Rev** | **Date** | **Remark** | **Responsible** | **Approver** | **Approving Organization** |
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