



Thermoplastic Injection Mold T1 Tryout Protocol

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 standard provides a thorough procedure to help develop a robust and stable injection molding process that has minimal variation and produces a high-quality plastic part. The goal is to produce a part that meets the GM10067 for the Matching 1 event and also to establish the ground work to meet future appearance and dimensional requirements. Additionally, it is important to develop a stable universal injection molding process that can be transferred from the tryout press to the supplier's press with minimal effect on part characteristics. This standard works in conjunction with the manufacturing requirements given in the Statement of Requirements (SOR) Appendix E8 during the sourcing of injection molded parts, and with the GMW16355. Any deviations to this standard must be agreed upon by General Motors Engineering, which will be the Manufacturing Polymer Engineer or the GM Product Engineer if Polymer resources are not assigned to the part.

1.2 Applicability. This specification applies to the required injection mold T1 (GM First Shot) tryouts during the plastic part development phase leading up to the Matching 1 event.

1.3 Remarks. None.

2 References

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

2.1 External Standards/Specifications.

ANSI B151.1 SPI AQ-103

2.2 GM Standards/Specifications.

GMW3059 GMW15850 GMW16355

2.3 Additional References.

- GM10067 Part Submission Requirements
- GM Thermoplastic Injection Mold First Shots Tryout Protocol Excel workbook, contact Manufacturing Polymer Engineer team member
- Statement of Requirements (SOR) Appendix E8

2.3.1 Documentation. Per 3.9, Contact the Design Responsible Engineer for details/access.

- T1 Excel Spreadsheet
- 5.0 Mold Assessment
- Moldflow correlation score card (Also send to Moldflow provider)

3 Test Preparation and Evaluation

3.1 Resources.

3.1.1 Facilities. The injection molding tryout facilities and equipment shall be in good working order. An adequate chilled water supply shall be available to cool the tool; water volumetric flow rates will be of such value as to produce turbulent flow within the cooling channels of the tool; refer to GMW15850 for required coolant flow rates for a given pipe size.

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

3.1.1.2 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.

3.1.2 Equipment.

3.1.2.1 Injection Molding Machine. The trial will be conducted using an injection-molding machine located at a tryout molding facility or in the supplier press located at the "home" facility. The required shot size should be in the range of 20% to 80% of the total barrel capacity. The clamping unit should comply with the requirements specified in GMW15850 for platen size requirements, tonnage capacity and tie bar spacing. Maximum injection rate and ejector stroke must be adequate for the given mold. Documentation needs to be provided showing the press platens have been checked for parallelism and the machine has been leveled properly. All documentation should be current within the previous 24 months and within the machine manufactures specification.

3.1.2.2 Dryers. The material dryer is to be in good working order and able to maintain a sufficient dew point and air flow to properly dry the resin as stated by the material data sheet. Dry throughput needs to be examined to ensure there is enough dry resin to complete the trial.

3.1.2.3 Moisture analysis. A moisture analysis should be conducted before the start of the trial. A moisture specific test is the only acceptable method for testing moisture content.

3.1.2.4 Blending Additives. All additives to the base material should be weighed using a suitable scale and hand mixed or add with a properly calibrated weigh scale blender.

3.1.2.5 Other Equipment. The supplier is required to have the following equipment available to properly evaluate the part and tool during the tryout:

- Calipers
- Digital weigh scale capable of 0.001 kg sensitivity
- Machinist scale
- Pyrometer with emersion probe and contact thermocouples
- Ultrasonic or Magnetic Thickness Measurement Tool (Optional)
- Infrared (IR) Camera (Optional)
- Component Phase 2 Gage(s)

3.1.3 Test Vehicle/Test Piece. Not applicable.

3.1.4 Test Time. Not applicable.**3.1.5 Test Required Information.** Not applicable.

3.1.6 Personnel/Skills. The following personnel are required to attend the tryout:

- Supplier Project Manager
- Tier 1 supplier Process Engineer formally trained in scientific molding
- Tool shop representative
- Resin supplier (Optional)
- Hot runner supplier (Optional)
- Moldflow supplier

3.2 Preparation.

3.2.1 The GM Engineers need to be notified of the tryout date and time a minimum of 3 d before the tryout.

3.2.2 The mold should be in a completed condition for the tryout. End of Arm Tooling is required to be present along with the Component Phase 2 gage. All required items should arrive 1 d before the mold tryout.

3.2.3 Resin and Color. Resin and color concentrate meeting the GM material specification for the part should be present at the tryout facility. The material should arrive in enough time to be properly dried per the material specifications before the start of the trial. The resin and concentrate should be properly labeled with grade name and lot number.

3.2.4 Tryout Time. The scheduled tryout time needs to allow for the full completion of this standard. The expected tryout durations will be 4 h to 8 h of injection molding machine time, not including time to hang the tool, startup procedures or time to run large quantities of parts.

3.2.5 Geometric Dimensioning and Tolerancing (GD&T). The supplier is required to have the latest GD&T documents at the tryout to assist in the dimensional evaluation of the part after it is molded.

3.3 Conditions.

3.3.1 Environmental Conditions. Not applicable.

3.3.2 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.

3.4 Instructions. See Section 4.

3.5 Data. Not applicable.

3.6 Safety.

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

3.6.1 Injection Molding Machine Safety. In support of GM safety policies, all part supplier injection-molding machines for GM mold tooling must comply with ANSI B151.1 safety specifications or equivalent. The injection molding machine should be locked out per GM standards prior to any GM employee entering the area between the tie bars. The part supplier shall identify any corrective actions required and will implement molding machine modifications to comply with this safety specification prior to producing parts at their facility. No GM molds should be placed in a machine that does not comply with these safety specifications including first shot tryouts.

3.7 Test Results. Not applicable.

3.8 Data. Not applicable.

3.9 Documentation. The following documents should be completed with all applicable studies and sent to the GM Polymer engineer within 1 to 2 business days. Contact the Manufacturing Engineer in the Polymer Group for details and/or access to these documents.

- T1 Excel Spreadsheet
- 5.0 Mold Assessment
- Moldflow correlation score card (Also send to Moldflow provider)

4 Requirements and Procedure

4.1 General. The first shot trials will consist of five (5) main studies and a tuning phase.

- **Pressure Loss Study.** Used to identify melt delivery system restrictions that need to be corrected.
- **Fill Pressure Study.** Determine acceptable fill time range.
- **Gate Freeze-off Study.** Determines the time required for gate freeze so the part is properly packed out.
- **Cavity Balance Study.** Identifies cavity to cavity mass differences that need to be corrected.
- **Injection Mold Analysis Correlation.** Compares simulation results with actual molding results to improve future simulations.

4.1.1 Appendix A, Figure A1 shows the main steps of this document as a flow chart. The supplier will use a GM-provided Thermoplastic Injection Mold First Shots Tryout Protocol Excel workbook to capture the necessary information. Examples of this document are in Appendix A, Figure A2 thru Figure A9. If the supplier already has a form to capture all of this information, it may be used, if approved by the GM Engineers in advance of the tryout. To obtain a copy of the GM Thermoplastic Injection Mold First Shots Tryout Protocol Excel workbook, contact Manufacturing Polymer Engineer team member.

4.1.2 For the injection molding machine, document the following:

- Machine name
- Machine tonnage
- Intensification ratio
- Available shot volume in cubic units
- Screw diameter
- Screw type
- Maximum screw stroke
- Maximum injection Rate
- Maximum machine hydraulic pressure
- Tie bar spacing in X and Y direction
- Maximum daylight
- Minimum shut height

4.1.3 Input Press Settings. Input the initial press settings (Temperatures, Pressures, and Times) from the completed molding simulation analysis.

- Mold Temperature. Use material data sheet and simulation results output
- Injection speed. Use simulation output and adjust to meet simulation fill time and part quality requirements.
- Pack pressure. Use zero (0) or minimum machine value
- Pack time. Set to 1 s
- Cooling time. Match simulation
- Screw RPM. As slow as possible, recovery should take no more than 1 s to 3 s before mold opens
- Back pressure- see material data sheet or default to 1000 psi plastic pressure

4.1.4 The process engineer shall verify the press settings recommended by molding simulation and the material supplier match to ensure that physical part performance is not compromised.

4.1.5 Review resin certification data sheet to ensure resin provided is correct and meets requirements.

4.1.6 Run several mold cycles to determine proper tool functionality.

4.1.7 Measure the sprue, runner and gate sizes (width, thickness, land) and compare to molding simulation analysis. Correct gates and runners to match molding simulation if necessary. At a minimum, measure the nominal part thickness of the entire part every 75 mm utilizing a 75 mm × 75 mm grid. Some smaller parts may need to utilize a smaller grid to accurately evaluate the part wall thickness.

4.2 Pressure Loss Study Procedure.

4.2.1 Adjust transfer position to produce a part that is 95% to 99% full with no 2nd stage pressure and 1 s of hold time. A cushion of 3% to 5% of the shot size should be maintained throughout this study. Document the transfer position and hydraulic injection pressure at transfer; label pressure as "part fill pressure".

4.2.2 Adjust the transfer position to produce a part that is 95% to 99% full, mold several parts, retract the injection carriage, and make an air shot. Document the hydraulic injection pressure at transfer; label pressure as "nozzle pressure drop". Ensure machine is using the set point injection velocity, if not the use of a purge plate is required.

4.2.3 If there are issues with filling or packing the part, and pressures are 80% or more of the maximum machine pressure available, sizing of gates, runners, manifold drops, manifold bore, and nozzle orifice will have to be reviewed. Use pressure loss data generated in 4.2.4 thru 4.2.6 to identify potential restriction(s).

4.2.4 Increase transfer position in order to produce a short shot that fills just past each gate. Document transfer position and hydraulic injection pressure at transfer; label pressure as "pressure to fill nozzle, sprue, runner and gate(s)".

4.2.5 For cold runner tooling, continue to increase the transfer position to produce a short-shot that consists of only the sprue and runner. Document transfer position and hydraulic injection pressure at transfer; label pressure as "pressure to fill nozzle, sprue and runner".

4.2.6 Continue to increase the transfer position to produce a short-shot that consists of only the sprue. Document transfer position and hydraulic injection pressure at transfer; label pressure as "pressure to fill nozzle and sprue".

4.2.7 Use the information obtained in 4.2.4 thru 4.2.6 to determine where the Pressure per Square Inch (PSI) loss is highest. That area of the tool should be examined for steel conditions.

4.3 Fill Pressure Study Procedure.

4.3.1 During this study, ram speed is not profiled. Start the study using as high of ram speed that is safe for the tool and remain constant from start of injection to transfer.

4.3.2 Transfer from velocity control to pressure control is to occur at 95% of fill, and transfer is to be triggered based on ram position. A cushion of 3% to 5% of the shot size should be maintained throughout this study.

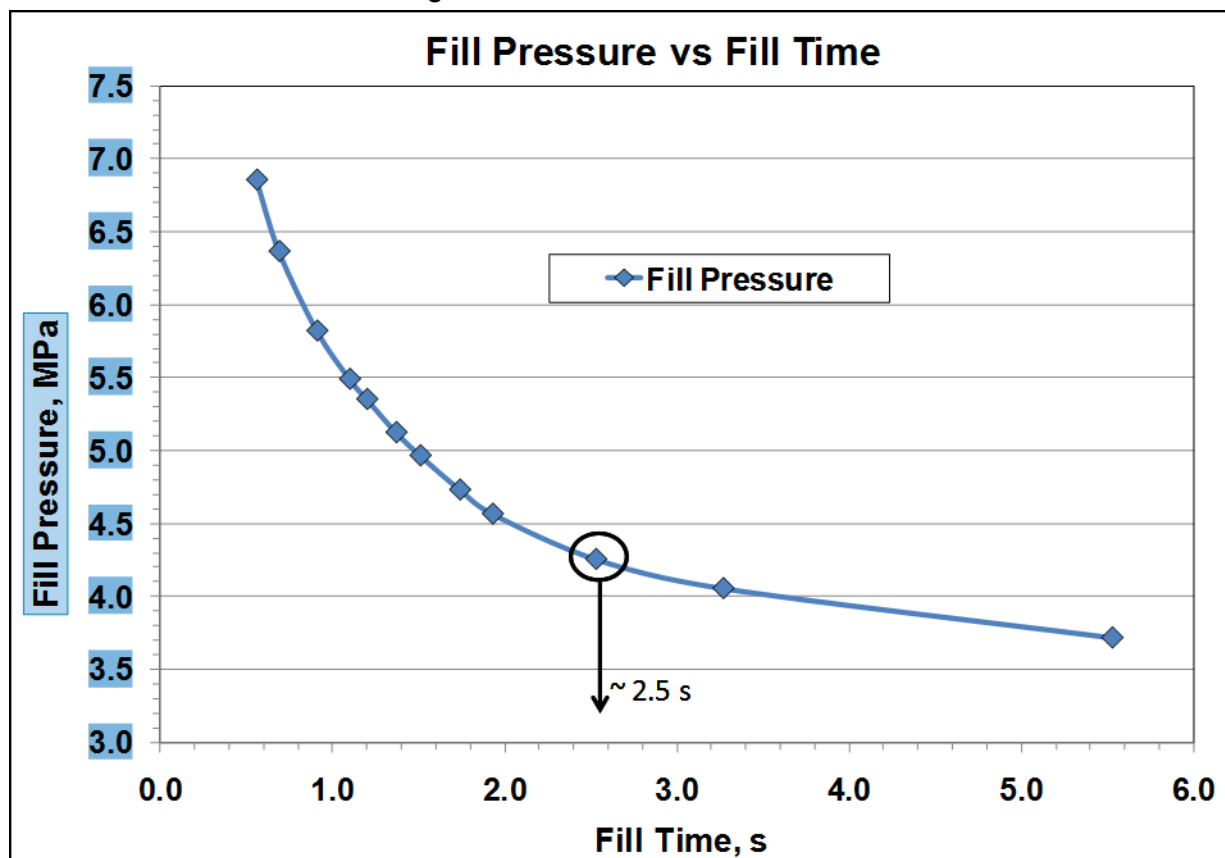
4.3.3 For molds with hot manifolds and Sequential Valve Gates (SVG), all valve gates are to be open from start of injection through transfer. For family molds that produce several parts of very different mass, estimation is required to delay the valve gates controlling the smaller cavities.

4.3.4 The shot limit is to be determined via the short-shot method where pack time is set to 1 s and pack pressure is set to machine minimum.

4.3.5 Generate fill pressure and fill time data by systematically reducing ram speed while keeping the transfer position consistent. A minimum of twelve data points is required. Document the machine velocity setting, hydraulic injection pressure at transfer (fill pressure), time to transfer position (fill time), and cushion.

4.3.6 Plot the fill pressure vs fill time data as seen in Figure 1.

Figure 1: Fill Pressure vs Fill Time



Note: The Figure 1 example shows that choosing a fill time (at the bottom of the curve before it flattens) of approximately 2.5 s from the fill pressure vs fill time curve, allows the process engineer to minimize the static pressure drop across the cavity and minimize the influence of a major factor that contributes to warp.

4.3.7 Convert fill pressure data to viscosity data:

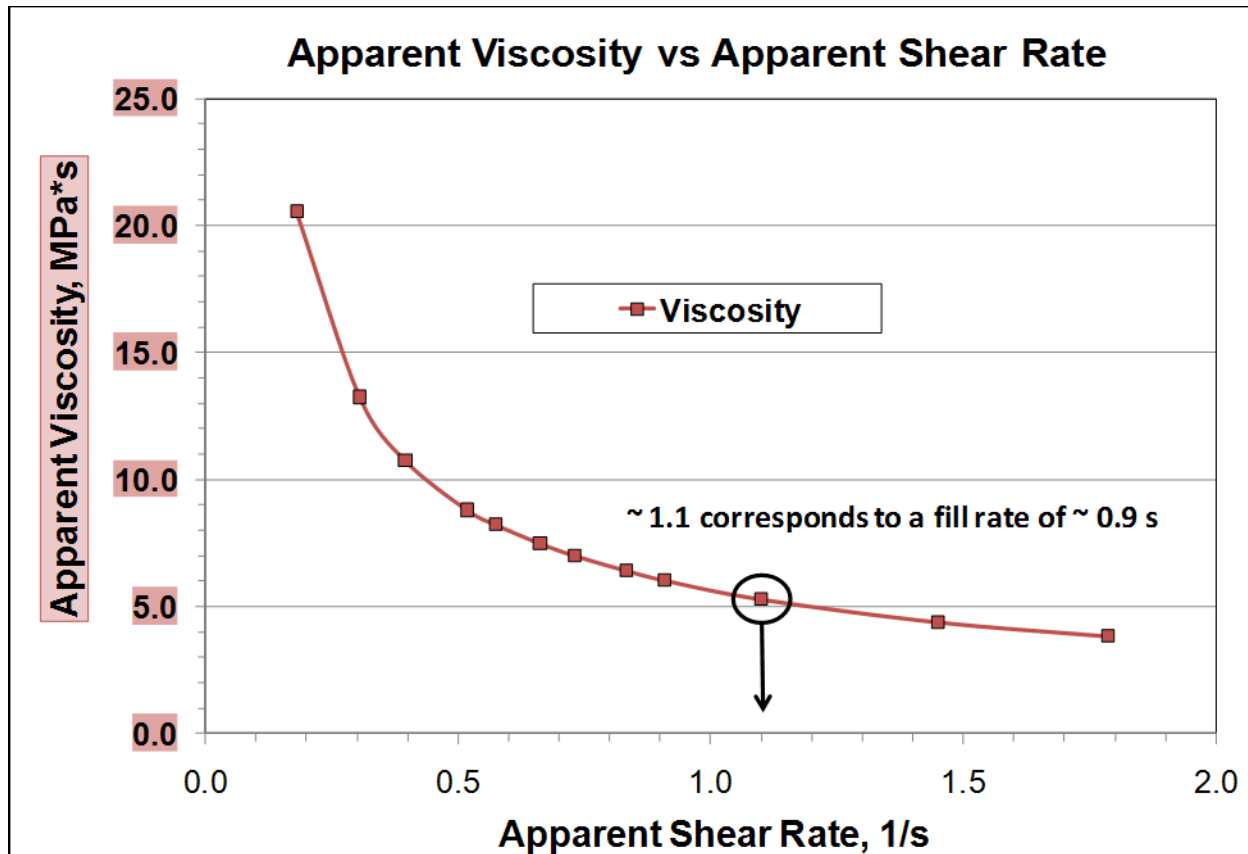
$$\text{Viscosity } (\eta) = \text{Fill Pressure} * \text{Fill Time}$$

and fill time data to shear rate data:

$$\text{Shear Rate } (\gamma) = (\text{Fill Time})^{-1}$$

4.3.8 Plot the viscosity vs shear rate data as seen in Figure 2.

Figure 2: Apparent Viscosity vs Apparent Shear Rate



Note: The Figure 2 example shows that choosing a fill time of approximately 0.9 s, based on a shear rate of about 1.1 s^{-1} from the viscosity vs shear rate curve, allows the process to be robust against minor fluctuations in velocity.

4.3.9 Based on the data generated in the Fill Pressure Study (see Figure 3 example), the acceptable range of fill times will be bracketed by the fill time selected from the viscosity vs shear rate curve and the fill time selected from the fill pressure vs fill time curve. The acceptable fill time range from Figure 1 and Figure 2 would be 0.9 s to 2.5 s, also highlighted in Figure 3.