



FORD GLOBAL MANUFACTURING STANDARD

CONTROL OF PLASTIC INJECTION MOLDING PROCESSES

W-IMMS

Third Edition



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REVISION NOTES

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1. SCOPE

1.1 GENERAL DESCRIPTION

This standard defines the requirements for the control of plastic injection molding processes. These requirements reflect the following manufacturing concepts:

- Robust part and mold designs lay the foundation of a robust injection molding process.
- Process consistency, shot to shot and run to run, is the first step towards producing quality injection molded parts.
- Startup verification plays an important role in preventing injection molding process mean shift over time.
- In-process machine and process status monitoring is necessary to provide an early warning for potential quality deviations.
- Effective machine and mold preventive maintenance contributes to process consistency in long term production.
- Proper verifications are necessary when changes in process, part, mold, or machine take place.

The manufacturing standard and its appendices include methods and criteria for assessing the robustness of part design, mold design and fabrication, and molding process, as well as methods and frequencies of in-process monitoring. Below is a list of the methods:

- Evaluating the robustness of the design of an injection molded plastic part
- Evaluating the robustness of a production tool
- Evaluating robustness of a production process
- Establishing injection molding process window
- Injection molding process monitoring
- Injection molding machine status monitoring
- Detecting emerging mold maintenance needs
- Establishing instructions for first and last piece inspection

Appendix A: “Part, Mold, Machine, and Process Robustness Assessment” lists the recommended evaluation methods and robustness criteria. If a production process fails to meet robustness criteria, the molder should increase process monitoring frequency and sample size to ensure product quality.

When a plastic part quality issue arises, the Critical Response List is recommended to Ford suppliers as a reference for proper actions during problem solving.

Appendix E: “W-IMMS Compliance Checklist” provides a tool for the molder to assess whether its injection molding system meets the requirements in W-IMMS. The molder should always refer to the main text of this standard for details and clarification of each requirement. To facilitate the assessment, a workbook of the



checklist in Excel format (also known as Ford Specific CQI-23 Assessment) has been developed and the document is available to Ford suppliers.

1.2 APPLICATIONS AND LIMITATIONS

This standard applies to all plastic injection molded production and service parts manufactured by tier 1 and sub-tier suppliers to Ford Motor Company. Exceptions to the standard shall be reviewed and concurred by Ford Supplier Technical Assistance (STA).

The intent of this standard is to deploy specific plastic molding best practices and lessons learned that are proven effective in the development and control of injection molding processes, as well as in the prevention of recurrence of quality issues. For plastic molding general quality practices, molding suppliers to Ford Motor Company are required to conduct self-assessment by using AIAG CQI-23: Special Process: Molding System Assessment.

This standard uses key items in injection molded part design, mold design, and mold construction as design for manufacturing indicators, defines assessment methods, and sets part and mold robustness criteria based on benchmark data. However this standard should not be interpreted as a part design standard or a tooling standard for injection molded parts. Whenever a conflict between this standard and an applicable engineering specification or between this standard and an applicable tooling specification arises, final decision shall be made by a team consisting of Ford Engineering, Ford STA, and the supplier or the suppliers.

In this standard, the word “shall” indicates a requirement. Suppliers need to take immediate actions to address areas that fail to meet the requirements. The word “should” indicates a recommendation. Where the term “such as” is used, suggestions given are for guidance only.

2. GENERAL REQUIREMENTS

2.1 ENGINEERING AND PROCESS SPECIFICATIONS

The molder shall have an engineering drawing or specification that lists engineering requirements of the part. Engineering requirements include the material specification (if applicable, material type and grade), dimensions, and performance requirements.

The molder shall have a mold design that includes specifications for mold components, locking mechanism, ejection mechanism, and cooling lines.

The molder shall establish a process specification that defines operating ranges of machine variables such as barrel temperature, transfer position, and screw velocity etc.



2.2 APPEARANCE APPROVAL STANDARD

The molder shall comply with Ford G-DCAP (Global Decorative Component Approval Process). The document is available to Ford suppliers via Ford Supplier Portal.

Part appearance is a product characteristic designated in the DFMEA with the “YS” symbol (potential significant characteristic). All production parts shall meet appearance requirements for color, texture, gloss, parting lines and other surface defects. The minimum appearance standard is defined by the stickered part signed off by Ford Design Quality along with a corresponding AAR (Appearance Approval Report). For color, production parts shall be in the correct color space trending direction as defined by Ford Design Quality. The molder shall refer to Appendix D for appearance evaluation method.

The molder shall retain the stickered part for the life of a vehicle program. All stickered parts shall be stored in a dedicated and clearly defined location.

2.3 CONTROL PLAN

A written Control Plan is required for the processing of all injection molded parts covered by this standard. The Control Plan shall be linked to Process Failure Mode and Effect Analysis and shall contain proper reaction plans to handle process deviations. The Control Plan should include first and last piece inspection. Parameters that reflect feedbacks from the molding process should be used for process monitoring purpose.

3. PART, MOLD AND PROCESS ROBUSTNESS EXPECTATIONS

The molder shall demonstrate that its part design, mold, and molding process meet robustness criteria detailed in Appendix A. If one or more robustness criteria are not met, the molder should contact a Supplier Technical Assistance engineer who is responsible for either Tier one supplier or the molding supplier directly and consult a Ford subject matter expert for potential mitigating actions.

3.1 PART AND MOLD ROBUSTNESS

The molder shall use a systematic approach to part design, mold design, and mold construction. The design process should include the following steps:

- Material selection
- Basic part design
- Structure analysis if applicable
- Part design review



- Mold flow analysis
- Mold design
- Mold design review
- Mold construction follow-ups

If responsible for part design, the molder shall verify material selection by using material data or benchmark to ensure that the material has the necessary chemical compatibility, material compatibility, temperature and humidity resistance, toughness and other physical and mechanical properties to meet design intent unless otherwise specified by Ford engineering.

The molder shall apply plastic part design principles and follow an applicable design standard or guidelines that are specified, recommended, or concurred by Ford Motor Company. At the minimum, the standard shall include design details such as base wall thickness, radius, and draft angle etc..

The molder shall apply mold design knowledge and follow applicable mold design guidelines (internal or external) that are either recommended or concurred by Ford Motor Company.

The molder shall conduct a benchmark study or run a preliminary mold flow simulation to determine initial size, shape and location of sprue, runner and gate for the mold. Unless deviation is agreed by Ford Motor Company, the molder shall use the knowledge obtained as inputs and conduct mold flow simulations to predict melt flow pattern, locations of knitline and gas trap. Furthermore, when applicable, the molder shall avoid locating knitline and gas trap on surfaces that require high appearance quality or knitline on critical loading path. The options may include modifying part and mold designs such as wall thickness and gate locations, as well as using flow leader or flow restrictor or both.

The molder shall conduct mold cooling analysis aimed at minimizing temperature variations in the part during cooling. If excessive temperature variation is predicted, such as presence of a “hot spot”, the molder should consider modifying the part design (e.g. wall thickness reduction in affected area) to minimize the temperature variation. If part design change is not feasible, the molder should consider adopting or modifying localized cooling options for the mold to minimize the variation. Examples of localized cooling options include traditional local cooling components such as baffles and high conductivity inserts or novel cooling techniques such as CO₂ spot cooling and conformal cooling inserts.

The molder shall take into consideration of the quality history of the commodities in the part and mold designs. For parts that are prone to warpage, in conjunction with cooling analysis, the molder shall perform warpage analysis. If unacceptable level of warpage is predicted, the molder should investigate main factor or factors that cause the warpage and explore options in part and mold designs, as well as processing to minimize warpage.

The molder shall have a system to assess the part and mold from design for manufacturing perspective by using recommended methods and criteria in Appendix A: "Part, Mold, Machine, and Process Robustness Assessment" or by using alternative methods and criteria concurred by Ford Motor Company.



3.2 MACHINE ROBUSTNESS

The molding machine that the molder uses shall have the following functions that are essential to its capability of providing consistent shots:

- Control and monitor pressure in the hydraulic cylinder (for hydraulic machines). Pressure transducer has a resolution of 50 psi at the minimum in the operating range.
- Control and monitor screw velocity. The deviation of actual velocity from set velocity is 20% or less in the operating range.
- Control and monitor stroke. Position transducer has a resolution of 0.2% of the full stroke at the minimum.
- Control and monitor time. The timers have a resolution of 0.05 seconds at the minimum.
- Monitor fill time, peak pressure, cushion size and cycle time during production.

The molder shall have a system to assess the robustness of the molding machines by using the methods and criteria in Appendix A: “Part, Mold, Machine, and Process Robustness Assessment” or by using molder’s own methods and criteria concurred by Ford Motor Company.

3.3 PROCESS ROBUSTNESS

During process development, the molder shall use a systematic approach to establish following process key input variables and record key process output variables:

Key process input variables

- Drying temperature (if applicable)
- Material dwell time in the dryer (If applicable)
- Barrel temperature
- Hot drop/manifold temperature (if applicable)
- Screw RPM
- Back pressure
- Nozzle temperature
- Gate opening and closing sequence (if applicable)
- Screw velocity or velocity profile during fill
- V-P switchover position
- Pack time (if applicable)
- Screw velocity during pack (if applicable)
- Pack pressure (if applicable)
- Hold time
- Hold pressure (set point, upper and lower limits)



- Cooling water (or other medium) temperature
- Cooling water (or other medium) flow rate
- Cooling time

Key process output variables

- Moisture content (if applicable)
- Melt temperature
- Fill time
- Peak pressure (for hydraulic machines)
- Cushion size
- Cycle time
- Peak cavity pressure, or cavity pressure curve, or part weight

During process development, the molder shall verify that melt temperature is within the range recommended by the resin supplier. The molder shall also verify that melt residence time does not exceed the maximum residence time established by material supplier. Any exceptions must be reviewed by a team consisting of Ford Engineering, Ford STA, the material supplier, and the molder.

During process development, the molder shall establish a process window based on cavity pressure, or part weight, or an equivalent (e.g. “torque to fail” for a key screw boss on a part made of 60% glass filled resin material). Within the process window, parts from all cavities shall meet functional and dimensional requirements, as well as minimum appearance standard. In addition, there shall be no processing issues such as part ejection difficulty. Refer to A2.5 for details of establishing a process window based on cavity pressure or part weight.

As an example, shown below is a method for establishing process input variables based on “scientific molding” approach:

- (1) Set barrel temperature, nozzle temperature (hot manifold temperature), screw RPM, and back pressure such that the melt temperature is in the mid-range of resin manufacturer recommended limits.
- (2) Set V-P switchover position.
 - a. If two-stage decoupled molding technique is adopted, set V-P (fill stage to pack/hold stage) switchover position at approximately 95% to 98% cavity full.
 - b. If three-stage molding technique is adopted, set the V-P (fill stage to pack stage) switchover position at approximately 85% to 95% cavity full and set the pack to hold switchover at a target cavity pressure.
- (3) Set screw velocity during fill such that the material viscosity does not change drastically with changes in fill rate (refer to A2.3 for details of in-mold viscosity study).
- (4) Set hold time per gate seal time determination (refer to A2.4 for details).
- (5) Set pack and hold pressure.
 - a. If the two-stage decoupled molding technique is adopted, set the hold pressure such that cavity pressure or part weight is in the mid-range of the process window.



b. If the three-stage decoupled molding is adopted, set both pack and hold pressures such that cavity pressure or part weight is in the mid-range of the process window.

(6) Optimize the cooling time (refer to A2.6 for details) and tool temperature by using design of experiment.

The molder shall also establish or confirm proper production startup procedures including:

- Machine heat soak time
- Number of initial full shots scraped before “first piece” sample (if applicable)

The molder shall have a system to assess the robustness of an injection molding process by using the methods and criteria in Appendix A: "Part, Mold, Machine and Process Robustness Assessment", or by using molder's own methods and criteria concurred by Ford Motor Company.

4. PROCESS CONTROL AND MONITORING EXPECTATIONS

4.1 PROCESS SPECIFICATION (SETUP SHEET)

The molder shall have a documented process specification of key process input variables that are listed in Section 3.3 “Process Robustness”. A set point and an operating window or a limit should be specified for the following key process input variables:

- Drying temperature (if applicable)
- Barrel temperature
- Nozzle temperature
- Hot drop/manifold temperature (if applicable)
- Pack pressure (if applicable)
- Hold pressure
- Cooling water (or other medium) temperature
- Cooling water (or other medium) flow rate

4.2 DRYING

If a plastic material is hygroscopic in nature, it shall be dried prior to being molded. For non-hygroscopic material, drying is recommended as a best practice only.

The molder shall use a regenerative desiccant type dryer to ensure consistent drying when molding hygroscopic materials such as PC and Nylon. Exception may be made only if two conditions are met. First, the part is not used for an application that is critical to safety. Second, the data demonstrates that non-



conforming dryer effectively dries the plastic material over multiple lots and under all ambient conditions. The data should include, at a minimum, moisture content results collected from a period 12 months or longer.

During molding process development, the molder shall verify the capacity of the drying unit to ensure that the dwell time of the material in the drying unit is within the specified process window for the drying time.

The molder shall set dryer parameters such that temperature and dew point are within the range specified by material supplier to prevent either under-drying or over-drying.

When molding hygroscopic materials such as PC and Nylon, the molder shall verify the moisture content at the start of a production run. During the course of a production run, the molder should monitor the moisture content at a minimum frequency of once per day. To ensure sufficient dwell time for the plastic material in the dryer, supplier shall determine and control the minimum material level in the dryer. If a below-minimum-level condition is discovered, the molder shall follow proper procedure defined in Control Plan to address the non-conformance.

4.3 PROCESS STARTUP

4.3.1 STARTUP PROCEDURE

The molder shall standardize startup procedure. The procedure shall include, but not be limited to, the following items:

- Heat soak time (per machine size)
- Opening hopper slide
- Screw RPM during initial charging
- Purging

The molder shall also include in the startup procedure items that are unique to each mold. The items shall include, but not be limited to the ones listed below:

- Short shots
- Number of discarded initial full shots before “first piece” production part (if applicable)

Similarly, the molder should standardize the Machine Shut Down procedure.

4.3.2 STARTUP WINDOW

The molder should establish a startup window in terms of cavity pressure profile, or peak cavity pressure, or part weight, or an equivalent around the middle of the process window developed. The purpose of the startup window is to "center" the process at the startup, restart, or in-process material lot change and thus limit process shift due to uncontrolled changes such as variations in material property and ambient conditions etc.



The molder should refer to Appendix B for a recommended method of establishing a startup window.

4.3.3 STARTUP VERIFICATION

The molder shall verify the following items for each startup and restart:

- Temperature and flow rate of cooling water (or other cooling medium when applicable)
- Material type and grade
- Moisture content (when applicable)
- Key process input variables
- Barrel purging
- No gate blockage (for molds with two or more valve gates)

The molder should verify that the molding process is within the established startup window at production startup, restart, or in-process material lot change. If the process is not within the startup window, the molder should make adjustments to pack and hold pressure and bring the process back into the startup window. For large molds, startup verification should be repeated once cavity temperature has stabilized (e.g. 30 minutes after production has started). If one or more of these machine variables have exceeded their limits in the process specification as a result of the adjustments, the molder should investigate the root cause before starting production.

4.4 FIRST AND LAST PIECE INSPECTION

4.4.1 FIRST AND LAST PIECE INSPECTION WORK INSTRUCTION

The molder shall use a systematic approach to identify and document molding defects that potentially lead to functional failure in assembly or sub-assembly. Shown below are examples of actions:

- Identify potential locations of molding defects from mold flow analysis, molding trials, and benchmarking.
- Identify the molding defects that potentially lead to functional failure in the assembly or sub-assembly by analyzing interactions between the molded part and surrounding parts when assembled. Examples of molding defects that potentially may lead to functional failure include weak weld-line, flash, missing rib, and warpage.
- Document potential locations of molding defects with the aid of a sketch or a picture and label each location with an alphabet or a number. The molder should also specify inspection sequence based on established priority.
- Identify features on the parts that are formed by weak mold components such as a small core pin, but may be overlooked in a typical inspection and document these feature in the inspection instruction whenever possible.

First and Last Piece Inspection Work Instruction shall prioritize molding defects that potentially lead to functional failure in assembly or sub-assembly.



4.4.2 INSPECTION

The molder shall conduct first and last piece inspection based on the inspection instruction established.

In the first piece inspection, the molder should verify

- Absence of molding defects that potentially lead to functional failure in the assembly
- Part appearance at or better than minimum appearance standard for color, texture, gloss, parting lines and other surface defects (evaluated by Quality Assurance personnel)
- Presence of features (when applicable)
- Product characteristics that are designated CC, SC, or HIC (typically dimensions)

In the last piece inspection, the molder should verify

- Absence of molding defects that potentially lead to functional failure in the assembly
- Part appearance at or better than minimum appearance standard for color, texture, gloss, parting lines and other surface defects (evaluated by Quality Assurance personnel)
- Presence of features (when applicable)

4.5 IN-PROCESS MONITORING

4.5.1 MONITORING OF PROCESS CONDITIONS

A molder shall monitor process conditions during the course of a production run. Following key process output variables shall be monitored:

- Moisture content (when applicable)
- Fill time
- Peak hydraulic pressure (for hydraulic machines)
- Cushion size (also covered in 5.1 Machine Status Monitoring)
- Cycle time or screw recovery time (also covered in 5.1 Machine Status Monitoring)

The molder should also monitor following items:

- Cavity pressure curve, or peak cavity pressure, or part weight, or equivalent
- Nozzle temperature
- Hot drop or hot manifold temperature (when applicable)

The molder should refer to Appendix C: "Recommended Methods and Frequencies for In-Process Monitoring" for methods and frequencies recommended in in-process monitoring.



4.5.2 MONITORING OF PART APPEARANCE

Production Part Appearance

Production parts shall meet minimum appearance standard for color, gloss, texture, parting lines and other surface defects. During a production run, color, gloss, and texture of the parts shall be between the Design Intent master and the appearance of the signed-off AAR (stickered) part. For color, production parts shall be in the correct color space trending direction as defined by Ford Design Quality.

Refer to Appendix D: Evaluation Tools for Comparing to Minimum Appearance Standard.

Sample Size and Frequency

Ford Design Quality recommends the following minimum sample size and frequency for in-process monitoring of part appearance:

- One part for each inspection
- Both before and after each color change, material change, or process condition change
- Every eight (8) hours for longer production run without any changes

4.6 PROCESS CHANGES

When one or more key process input variables are changed in the middle of a production run, the molder shall follow first piece inspection instruction (section 4.5) to confirm part quality. The molder should also confirm that the molding process is still within the startup window.

When a Supplier Request for Engineering Approval requires PV testing and the molder specifies a maximum amount of regrind usage in the molding process, the PV samples shall be molded by using the specified maximum amount of regrind. For example, if 20% regrind is the maximum amount of regrind specified, the PV samples shall be molded with 20% regrind.

When a Supplier Request for Engineering Approval involves change of supplier or manufacturing site, the molder shall verify the plastic material used at the new supplier or at the new manufacturing site against the signed-off Bill of Material.

When a capacity mold or a refurbished mold is put into production, the molder shall complete dimensional layout and an assembly trial run before delivery of production parts to Ford Assembly Plants.



4.7 USE OF MATERIAL IDENTIFICATION LABELS

To prevent material cross-contamination or delivering wrong material to the molding machine, material identification labels shall be used throughout the molding system that includes on-site material storage, in-process material storage container (if applicable), drying system (if applicable), and molding machine.

The molder shall also use material identification labels on containers that hold or transport materials that are left in the hopper, or in the in-process storage that feeds the hopper, or both at the end of a production run.

5. MOLD AND MACHINE PREVENTIVE MAINTENANCE EXPECTATIONS

5.1 MOLD SPECIFIC PREVENTIVE MAINTENANCE

The molder shall conduct short term and long term mold preventive maintenance. The list of maintenance items and frequencies should be established by benchmarking and recommendations from mold supplier.

Vent cleaning and removing plastic residual are examples of short term mold preventive maintenance. Short term mold preventive maintenance may be carried out once at the end of a production run or several times during a production run. Greasing ejector pins and descaling or flushing cooling water channels are examples of long term mold preventive maintenance. Long term mold preventive maintenance should be scheduled based on the number of shots and typically involves disassembling the mold, evaluating and cleaning the moving mold components such as slides, ejector pins.

The molder shall identify all moving components and non-permanent features such as ejector and core pins, as well as locations that are susceptible to damage and wear on each mold.

The molder should document these potential “maintenance trouble” locations with the aid of a sketch or a picture (preferably number each location) before volume production starts.

The molder shall verify the integrity of these potential “maintenance trouble” locations before or after each production run. If the integrity of a "maintenance trouble location" cannot be verified directly without disassembling the mold, it may be verified indirectly based on the quality of corresponding locations on the molded part.

5.2 DETECTION OF EMERGING MOLD MAINTENANCE NEEDS

The molder shall have a system to record events in which in-process changes to process input variables are made to correct a molding issue since the molding issue is potentially related to an emerging mold issue. An



example of process record is a note on the log sheet by process personnel regarding an adjustment made to fill speed to eliminate a burn mark during production.

The system should alert the maintenance personnel a potential emerging issue at a specific location on the mold and the maintenance personnel should inspect the suspect location on the mold and schedule preventive maintenance if necessary. An example of the system is to issue a yellow tag to the mold at the end of production to indicate a potential emerging mold issue.

5.3 MACHINE STATUS MONITORING AND PREVENTIVE MAINTENANCE

The molder shall conduct short term and long term machine preventive maintenance. Machine vendors can provide recommendations for maintenance items and frequencies.

The molder should monitor in-process machine status. At a minimum, following parameters should be monitored:

- Screw recovery time (or cycle time)
- Cushion size (or screw position at end of hold)

The molder should refer to Appendix C for recommended frequencies used in machine status monitoring.

The molder should monitor machine characteristics for longer term preventive maintenance purpose. Examples of characteristics include hydraulic injection pressure curve, quality of hydraulic oil, and thermographic characteristics of electrical control box.

The molder shall identify spare part needs for critical components on all production equipment and measuring devices. At the minimum, the molder shall have spare parts on site based on availability, lead time and the impact to delivery of products to Ford Motor Company.

6. ADDITIONAL GUIDELINES FOR SPECIAL APPLICATIONS (WHEN APPLICABLE)

6.1 MOLDING FOR CHROME PLATING

6.1.1 Part Design for Chrome Plating

In addition to general guidelines of designing wall thickness, radius and draft angle (refer to Appendix A), guidelines listed below are conducive to a successful plating-on-plastic application:

- (1) Avoid sharp edges and corners. All edges shall be rounded off to a radius of 0.8 mm or larger. At corners, the minimum inside and outside radii shall be 0.8 mm and 1.6 mm respectively.
- (2) Avoid V-shape grooves and use U-shape grooves instead. Limit the depth to 50% of their width or less.