SMART FACTORY OPTION: POST TEST SYSTEM-BASED PROCESS CONTROL (SPC) SOLUTIONS

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ABSTRACT

Post Test System-based Process Control (SPC) is an innovative, rule-based, real-time detection for Post Test manufacturing non-compliance issues. It facilitates an automated flow of certifying post-test process performance from an initial Tool System concept to a functional database monitoring system. This paper provides high productivity gains by 5%. Overall Equipment Utilization (OEU) improvement on tool stability and defect reduction through a reduced lot scrappage. Its capabilities extend the functions of the supporting applications of Tool's Secs/Gem, Tool Monitoring System, Program Recipe, and other control processes. The design and implementation of this rule-based hard-stop driven project also facilitate the creation of a standardized disposition for Quality assurance protocol. Post Test SPC employs Autoshell to Web programming techniques to automatically generate an Oracle Database where rule value is identified and checked. Furthermore, the Tool's System building block is the main engine for detecting the transaction flow infrastructure supporting the corresponding 12 rules covering lot, quantity, recipe, and tool integrity. The SPC concept provides a turnaround on late detection of non-conforming materials and eliminates manual folder checks performed by Operators, Engineers, and Technicians.

1. 0 INTRODUCTION

Texas Instruments is one of the biggest semiconductor manufacturing firms worldwide. In time and generation, new offloads, ramps, and increased loading have always been challenging due to the possibilities of change in the process that may introduce new risks and variabilities. An essential task in manufacturing planning and control is to ensure that good quality products are shipped to the customers. One challenge for TI factories is having different controls, methods, tools, and software releases, especially at Post Test. There is no standard tool implementation approach and disposition process across each site, and no real-time detection of process control non-compliance issues at post-test. There have been several quality-related incidents and customer excursions in several years from various sites at Post Test *(see Figure 1).*

The general approach is to push for the Smart Factory option, where the strategy is associated with Tests. For Tests, SPC has been generally used to monitor and control process quality, where it can be assumed that the actual tests are performed correctly and the results are valid.

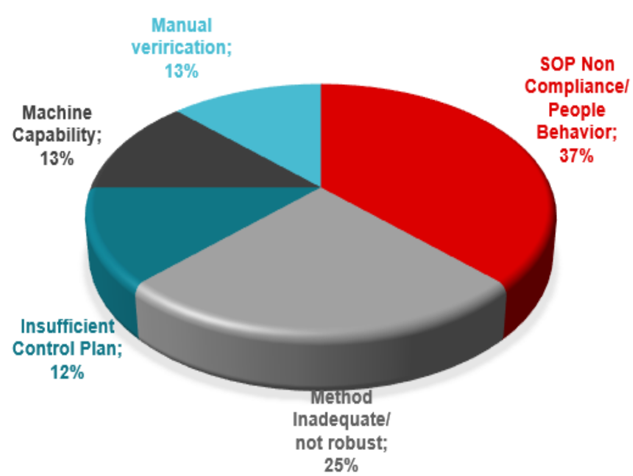


Figure 1. Breakdown of Post Test Root Cause Category

This paper entails a Test like interface that is an efficient and inexpensive method through Tool System enhancement for Secs/Gem capable tools. Its objective is to provide a cost avoidance on reprocessing and scrappage of packing materials, achieve QCI headcount savings, and improve lot movement from Tray or Tape and Reel to shipment, as shown in *Figure 1*. Furthermore, its objective is to detect and analyze small signals within the grasp of a single process method and a centralized database for Post-Testware information. Post Test SPC data will be saved into the same Oracle DB schema, and all the tools and applications in place will be leveraged.

2. 0 REVIEW OF RELATED WORK

Not Applicable.

3.0 METHODOLOGY

3.1 Post Test SPC Rules

The team defined rules that should be complied with 100% to ensure lot processing integrity at Post Test. The 12 rules generally relate to quality escapes at Post Test, including, but not limited to, four categories: lot, Recipe, Quantity, and Tool Integrity.

RULE 1: Machine PM Validation – Check if a machine is due for PM in the Maintenance System The machine will not load or run if a PM is expired. This is to ensure that equipment is calibrated before processing parts.

RULE 2: Tool System Validation – Check if a lot was successfully logged IN/OUT at Tool. This ensures the program is auto-selected on the production server with the certified recipe. The Tool System will check that the uploaded recipe is fully approved and the recipe is available on the server. This is to verify that the correct program recipe is loaded on the machine and matched with the lot to be processed.

RULE 3: Recipe Lock-out, Recipe Integrity – Check that no recipe file has been altered. It will fail the lot that violates the Recipe Parameter Check system or recipe checker. The server-side script generates a release.dat file that includes the checksum for each recipe to verify the authenticity of the recipe file.

RULE 4: Machine Sealing Parameters – Check if the tool is set to correct sealing of Temperature value, seal time, and seal pressure for the Taper2 front and rear area. Verify the operating range on the specs table corresponding to the machine mode, carrier tape part number, and cover tape part number.

RULE 5: Pin1 Orientation - Query the quadrant and Pin1 position on the handler and ensure it is appropriately set based on the settings indicated on the Device Spec. This is to ensure that units are not misoriented on the tape.

RULE 6: Marking Verification—Verify that Optical Character Recognition is always turned ON and that the teach template passed the Teach template verification. This ensures that the units are marked and prevents mixed lots or devices. For teach template verification, it will calculate the acceptable number of units that failed the teaching (e.g., image not found, image corrupted, and symbol spec not found).

RULE 7: Good and Reject Quantity—Check if the machine count and reel count are the same. The pass quantity and reject quantity should match the machine count. During the handler timeout, the tool will send the pass/fail counter to verify no intervention on the quantity.

RULE 8: Reel Size—Ensure that the handler is set to the correct reel size value. At the beginning of the lot, the Tool Monitoring System sends a stop command and error pop-out to the machine window to allow support to correct the reel size setting before starting the handler.

RULE 9: Bake Maximum Exposure Time – Check for the total remaining exposure time from Bake to Pack. For 20 Hrs., Tool System to prevent login if bake expires <16 Hrs. and no Oven Monitoring System (OMS) data. And to prevent log-out if the bake expires <4 Hrs. At Pack, Lot System will prevent login if bake expires <5 mins. This is to avoid moisture, resulting in a popcorn effect.

RULE 10: Vision Settings—Verify any unique vision settings for the tool to work correctly. Ensure that the Top, Side, and In-pocket vision settings are always turned ON to avoid misprocessing the units.

RULE 11: Critical Jams—Tool System will fail in the event of critical jams. No critical jams should be encountered based on the Monitoring System for critical jam list files. The EE or technician will accomplish corrective action for the tool.

RULE 12: Output Quantity – Ensure an accurate count of processed units. It should never have more units than the total units in the lot. If the counter ever exceeds the start quantity, the lot will fail.

3.2 Tool System Building Block

The design objective of the complete SPC system is to facilitate the construction of operational, dynamic, consolidated applications into a centralized Tool System model for Roadmap tools. As shown in *Figure 2*, it consists of the Server, coupled with other systems.

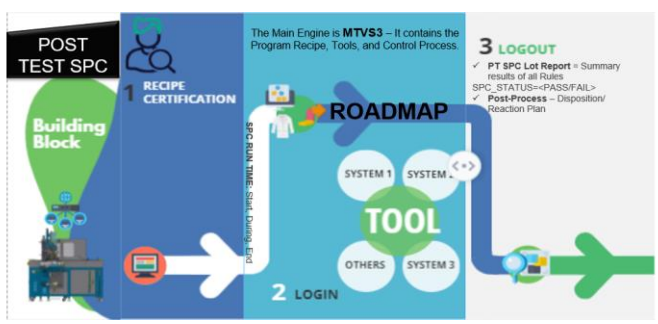


Figure 2. Post Test SPC Building Block

Typically, during a post-test process, a lot will be logged into the Tool System, and only at lot movement will trigger an activity for the lot to be transacted through the Process Control system, where a few rules have been checked. However, given the high number of devices to process, the possibility that the equipment may have been defective or not calibrated during all or a portion of the post-test process is not held. This is not a practical control as the lot has already been packaged into a tray or tape and reel. As the standard practice, a production lot will be reprocessed or de-taped, losing some production time. With the new SPC system, rules will be checked in real-time at the start of a lot, during a lot, and at the end. If a given rule fails during the check, the machine will stop, and the user will have to correct the problem and then retry until the given rule passes before continuing the lot. Other rules need further disposition, so holding the lot will be required, as discussed in *Section 2.3.*

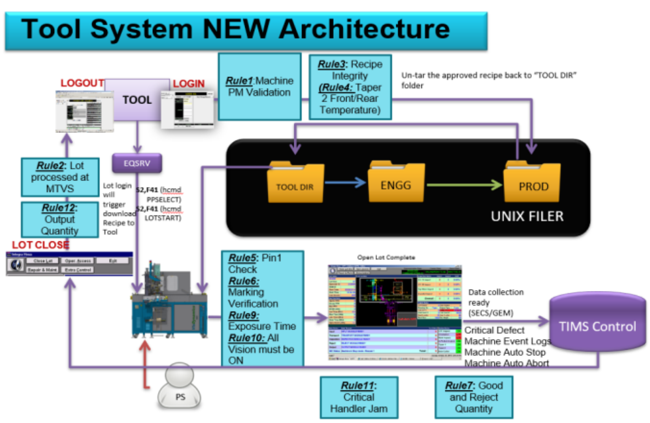


Figure 3. SPC Flow

The new tool system is very comprehensive in terms of the checks required. All required information from the systems is initially validated against the defined rules. The flow shown in *Figure 3* represents a sequence from log-in to log-out on Tool. Once the lot has been opened on the tool, lot information is used to determine the required input settings and validate against handler results.

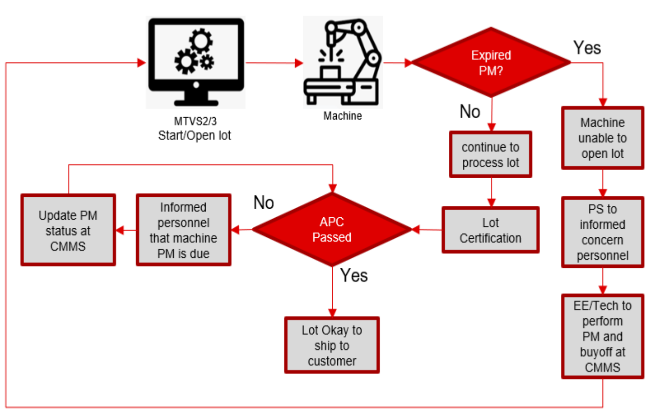


Figure 4. Main System: Tool; Sub-system/ Microservices: Maintenance System

Here is a sample workload for Rule 1—Machine PM Validation. See Figure 4 for the rule requirement. This rule ensures the Tool will not run with expired PMs from the maintenance system. The actual maintenance of the machine must be within the range from the latest due PM to the next scheduled PM. Tool System will not continue to log in and call for EE support for PM activities.

3.3 Tool Monitoring System Model Creation with Secs/Gem Signals for SPC Detection

Tool Monitoring System is a tool monitoring and fault detection application. It enables the collection of data and tracking of equipment and processes to maximize equipment productivity. This system combines data collection, monitoring, fault detection, interdiction, and notification. Post Test SPC expands the control using signals from Tool's Secs/Gem. GEM defines six requirements for gathering data:

1. A set of status variable ID (SVID)
2. A set of equipment constant values
3. A report containing a status variable, data variable, and equipment constant values
4. A host that can define and attach reports to collection events to transmit the report data and the collection event in the same SECS-II message.
5. The host that can define traces so the equipment periodically transmits the specified SVID at a set interval.
6. The host can configure limits monitoring so that the equipment notifies the host whenever a specified variable value transitions across a host-defined limit threshold.

The SVID feature eliminates the need for the host to poll critical values when the host is only concerned when the value becomes too high or low. Multiple limit boundaries can be defined inside. This is the rule requirement for Rule 4 – Machine Sealing Parameters related to pressure and temperature setpoint value.

The SVID feature enables data to be sent to the host as the values become available, reducing the host's obligation to poll for information. This event report data collection also enables the host to gather data related to each event. This is the rule requirement for Rule 5- Pin1 orientation and Rule 8 – Reel Size or SPQ. For example, downtime is incurred on Handler A (or other machine types) when the tool cannot cover one reel. The findings are that the Reel Size is set incorrectly on the handler. The immediate action is to abort the lot and then correct the reel size on the handler tape and reel counter. This scenario kills throughput and is a risk to the overall business. Post Test SPC Rule 8 will immediately fail this on the Tool system login. The detection is real-time of incorrect reel size value set on the handler for Tape-and-Reel output.

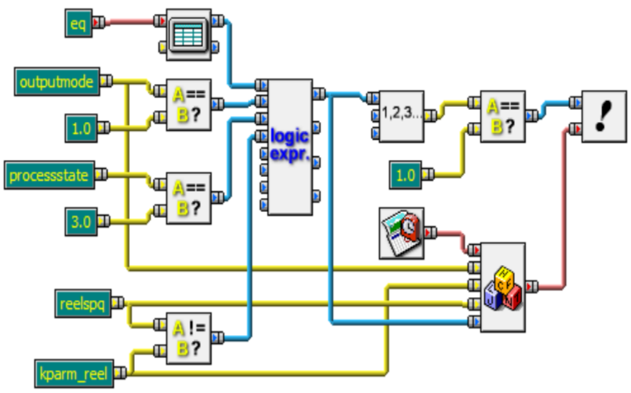


Figure 5. Model for SPC Rule 8 – Reel Size

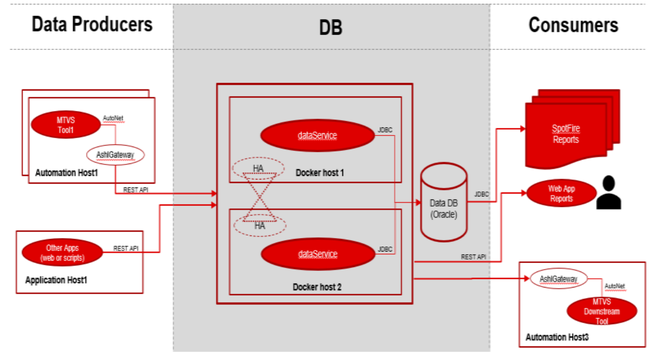
At the beginning of the lot and extended timeouts, system will take the Reel Size value from Secs/Gem SVID for the Handler A machine and compare the SPQ requirement from Device Specs. The system will ensure that the tool is set to the value from the database. The system sends a stop command and error pop-out to the machine window and an auto-email to manufacturing and EE supports. The system will allow the user to correct the Reel Size setting before starting the handler. It will always verify the Reel Size for any intervention during extended timeouts or machine stops.

Another signal for the system control is the Alarm ID (ALID), which will be used for Rule 11- Critical Jams. Enrolment is based on Package crack signals and top critical errors that impact tool stability and quality.

When a lot fails Rule 11- Critical Jams, the lot will automatically be aborted and cannot load a new lot unless the checklists has been accomplished with complete corrective action. All of these controls will be part of the SPC standard disposition.

3.4 High-Level Architecture for Oracle DB

The structure of the Oracle database is well aligned with the needs of Post Test, where no existing application and system stores and retrieves lot-machine information. The objective is to generate Post-test data per lot and a database for reporting spc_rule, spc_status, and spc_enable entries. The requirement is to have an SPC summary report and SQL loader.



Item	Attrib	Attrib_val	Attrib_Details	Update_dttm	Latest
1234567	PT-SPC-RULE1	0	PM overdue since 3 days ago	7/17/2023 5:30PM	N
1234567	PT-SPC-RULE1	1	PM okay - next due 10/17/2023	7/17/2023 8:30PM	Y

Figure 8. Technology used – Oracle DB, RESTFul API, Spring Boot, Python (for Ashl-Web gateway).

For the Application Programming Interface (API) architecture shown in *Figure 8*, the infrastructure will use the capability of Generic Gateway and create a small Signal API to accomplish the DB. Technically, Generic Gateway will act as an interpreter for converting the autoshell command to a web API call and vice versa between Tool system and the Small Signal API. Post Test SPC data will be housed in this new DB and all other small signals-related projects in the future will utilize this database.

Table 2 shows the data sources for each rule. The Main System is where the Rule value is identified and thus will call the save/update. The Disposition is where the user must correct the problem and then retry until the given rule passes before continuing the lot. The Lot-level check or Logpoint is the step in the material flow where the rule value is identified or checked.

Table 2. Post Test SPC – Database Requirement

Application	Main System	Sub-system / Microservices	Lot-Level Check	Logpoint	Disposition
Rule1 - Machine PM Validation	MTVS3	MTVS3, CMMS	Start of Lot	8100	1. Down machine for PM and call for EE 2. Update CMMS and Retry Login
Rule2 - MTVS3 Validation	MTVS3	MTVS3, RMS, APC	Logout data collection	8100	Correct and Retry Login (Recipe, Tape-TR PN, Tape Cover PN, Reel-TR PN, Tray PN ...)
Rule3 - Recipe Integrity	MTVS3??	RPC, Recipe Checker, MTVS3	Mid-of-Lot	8100	1. Down machine and Call for EE 2. Correct parameter settings and continue to run
Rule4 - Machine Sealing Parameters	MTVS3	MTVS3, TIMS	Start/Mid	8100	1. Down machine and call for EE 2. Correct sealing parameters and continue to run
Rule5 - Pin1 Orientation	PTAPC	ATTV 3.0	QCLA	8600	1. Collect and Log 2. Hold Lot
Rule6 - OCR, ATTV Marking Verification	PTAPC	ATTV	QCLA	8600	1. Collect and Log 2. Hold Lot
Rule7 - Good and Reject Quantity	MTVS3	Machine Lot Report	End of Lot	8100	1. Collect and Log 2. Hold Lot
Rule8 - SPQ or Reel	MTVS3	MTVS3, TIMS	Start of Lot	8100	1. Down machine and Call for EE 2. Correct Reel Size and continue to run
Rule9 - Bake Exposure Time	MTVS3	OMS	Start of Lot	8100	1. Unlog to 8075 lpt
Rule10 - Vision Settings	MTVS3??	RPC, Recipe Checker, MTVS3	Start/Mid	8100	1. Down machine and Call for EE 2. Correct parameter settings and continue to run
Rule11 - Critical Jams	MTVS3	MTVS3, TIMS	Mid-of-Lot	8100	1. Down machine and Call for EE 2. Hold Lot
Rule12 - Output Quantity	MTVS3	Machine Lot Report	End of Lot	8100	1. Collect and Log 2. Hold Lot

Database requirements:

1. Save/update and query lot-based rule check result
2. Save to include all Rule check transaction attempts (to show failure rate)
3. Different systems will call the data 'save/update
4. The same data will be updated in different steps of the flow (log point)

5. Different systems will query SPC results (for example reporting web apps, MTVS-3 on the next process)

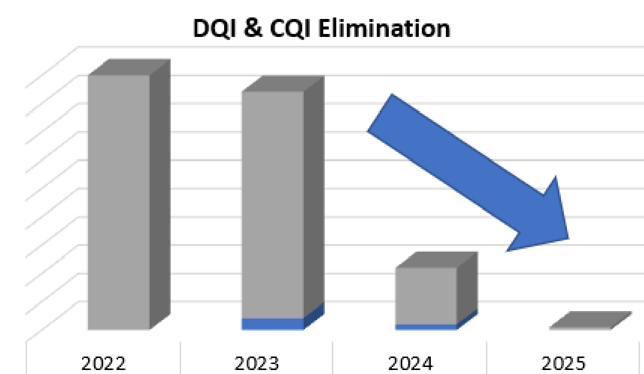
4.0 RESULTS AND DISCUSSION

In any system, the possibility of a variation is present. Determining when the variation is expected and when correction is needed is the key to quality control. Using the SPC Rules, it will be able to meet and ensure product quality. A continuous improvement process directly enhances products, services, or processes. The derived actions from SPC failed rules may achieve breakthrough improvement over time.

4.1 Fall-through Metric Tracking

The team set a fall-through metric tracking for 2023. Based on the data gathered in *Table 3,* there is a significant improvement in the actual operation performance compared to last year. With the activation of rules, a surprising cost was saved due to optimized downtime per equipment support and the prevention of Quality-related incidents from the past. This also shows and indicates that the overall OEU has gradually improved.

Table 3. TIPI Fall-through Metric Tracking



4.2 Percent Completion and Site Status Update

As shown in *Table 4*, TI Baguio is now at 56% completion and is still on track for 100% until 2Q24. The team effectively linked the Maintenance system result (SPC Rule 1) and pushed Tool System compliance (SPC Rule 2) to auto-select the recipe from the production server. The team successfully created a model for Reel size detection (SPC Rule 8) and critical alarms (SPC Rule 11) for the Monitoring system integration. Currently, working on the Exposure Paperless Monitoring for Bake MET Compliance (SPC Rule 9). In parallel, co-working with Tool Software developers for new Secs/Gem requirements on Pin1 Orientation (SPC Rule 5), Sealing Temperature and Pressure (SPC Rule 4), and Taper Quantity (SPC Rule 7 and SPC Rule 12). Vision Software upgrades are also in assessment for advanced marking verification (SPC Rule 10 and Rule 6).

With different tool models running at Post Test, the challenge is driving all equipment into the same SPC standard approach. The tool constraints are on Legacy handlers with no secs/gem connectivity. However, some rules could still be implemented, with lot-machine information as a reference for the detection.

The database has been created and is now in development, generic gateway, and API. The solution will use the Generic Item-Attribute data structure and service, where a lot is just one of the possible items with SPC Rules as the attribute. Enable decoupled architecture (use REST API instead of direct DB access for upstream and downstream applications); refer to *Table 5*.

Table 5. Solution Components Development Requirement

Component	Description
DB schema	DB table structure and relationship
AshlGateway	Link from Automation (MTVS/Autoshell) to Web service
DataService API	Web service application that provides RESTFul API to save and get data to/from the DB
MTVS hook	MTVS update call SPC update in the validation check result logic
SpotFire Report	Summary and historical reports as Mfg/Eng'g need

5.0 CONCLUSION

In general, this project brings the following benefits and advantages:

5.1 Quality

Eliminate manual checks performed by QCIs, EE, and manufacturing. Improve real-time detection of process control non-compliance issues related to established SPC rules. It will standardize the disposition process and the tool implementation approach at Post Test.

- **Customer and Internal Incident Reduction**
    - ~2-4 Incidents reduction per year
    - ~300 CQI reduction

5.2 Cost

Cost avoidance on reprocessing and scrappage of packing materials. The expected QCI headcount savings and improved lot movement from the tray or tape and reel to shipment are also likely.

- **Defects Reduction (reduce lot scrapped)**
    - scrap avoidance in factory
    - scrap avoidance in PDC
    - scrap avoidance in customer

5.3 Tool Stability

Improvement on Parts-Per-Hour (PPH) and Utilization by reducing hold lots and downtime incurred due to incorrect machine settings, overdue PM and bake exposure time, and mismatch on SPQ and Quantity.

- **OEU/Capacity**
    - 5% OEU improvement
    - Saved 30-45 mins of de-taping/ relabeling
    - 70% reduction on LRR
    - Productivity/ throughput improvement

6.0 RECOMMENDATIONS

With a significant improvement based on the gathered results and data monitoring, it is recommended that Post Test SPC be implemented on all Post Test operations – VM, LIS/BIS, Dry Bake, and Dry Pack on TIPI, especially on Roadmap and Legacy tools with connectivity.

Post Test SPC is now a new sub-team on WW Engineering Council and approved to be implemented across A/T Factories, aligning with the rules, technical requirements, and main system set by the team.

7.0 ACKNOWLEDGMENT

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8. WW PostTest IT – Archer Liu (CDAT), Wong Hong Shen (TIEM), Danny Lee (TIM), Steven Wong (TITL)

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9.0 ABOUT THE AUTHORS

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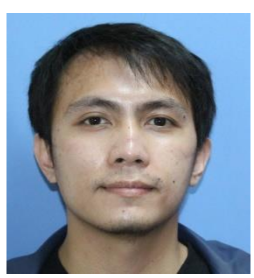

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