

Statistical Process Control for Photopolymer Manufacturing: Sampling, Control Charts, Drift and Multivariate Signals

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Abstract

Statistical Process Control for Photopolymer Manufacturing is evaluated as the bounded decision of whether process data distinguish common variation, assignable drift and measurement artefact early enough to protect released product. The controlled state comprises measurand definition, sampling position/time, measurement system, subgroup logic, process state, control limits, alarms, interventions and post-intervention baseline. For ER-296, both cited sources are confined to their stated point-of-use evidence roles. ER-296 defines measurements, transfer logic, failure modes and release gates specific to this subject; no universal process window, product recipe or compliance conclusion is inferred.

Keywords: SPC; statistical process control; control charts; sampling; drift; multivariate; photopolymer manufacturing

1. Significance, scope and ownership

ER-296 owns whether process data distinguish common variation, assignable drift and measurement artefact early enough to protect released product. The review is organised around the decision-specific evidence chain and leaves neighbouring ownership intact.

1.1. Corpus boundary

SPC is used here to distinguish stable common variation from assignable change; it does not validate the measurement system or define failure causality. ER-295 retains PFMEA, ER-297 calibration management, and ER-291 digital lineage. ER-296 owns sampling, chart logic, drift detection and multivariate signal interpretation.

2. Subject-specific state model and causal chain

For ER-296, causal interpretation begins by freezing measurand definition, sampling position/time, measurement system, subgroup logic, process state, control limits, alarms, interventions and post-intervention baseline. Chart behaviour is interpretable only after the measurement system and subgroup logic are stable enough that an alarm can be distinguished from measurement noise or sampling structure.

3. Direct evidence and point-of-use source map

ISO 11462-1:2026 gives current guidance for implementing SPC systems and techniques across industrial supply chains. ER-296 applies that architecture to photopolymer manufacturing where correlated optical, rheological, thermal and dimensional signals can drift together. Reference [1] is used for current SPC implementation guidance. In ER-296, reference [2] supplies the production-qualification context relevant to this control problem.

4. Measurement architecture

The measurement architecture for ER-296 is built around measurement-system capability, rational subgrouping, univariate charts, autocorrelation, multivariate statistics where justified, false-alarm/missed-detection behaviour and linkage from signal to process action. Sampling design, chart limits and multivariate signals are validated against known process states or injected disturbances before they are used as production alarms.

5. Qualification and transfer

SPC rules are transferred only after confirming that the new process has a comparable stable baseline, measurement capability and sampling structure. Limits inherited from another line or material can otherwise manufacture false alarms or hide real drift.

6. Failure modes and interpretation traps

The central interpretation trap in ER-296 is that specification limits are used as control limits; unstable data are used for capability indices; sampling is too sparse for the drift timescale; multivariate alarms cannot be interpreted operationally. Measurand, measurement system, subgrouping, baseline stability and alarm-performance gates prevent charting software from creating an appearance of control where the data structure is unsuitable.

7. Non-compensatory release gates

Gate	Minimum evidence	Blocking failure
Measurand	Characteristic and unit operationally defined	Proxy drifts from intended state
Measurement system	Repeatability/bias adequate	Gauge noise dominates
Sampling/subgroup	Cadence matches process dynamics	Sparse convenience samples
Baseline stability	Stable baseline before limits/capability	Unstable data used
Chart logic	Distribution/autocorrelation considered	Wrong chart assumptions
Alarm performance	False/missed detection understood	Rules copied blindly
Multivariate signal	Variables interpretable and scaled	Opaque alarm
Intervention	Cause/action/new baseline controlled	Chart reset hides drift

8. Minimum verification experiment

Choose one critical process characteristic and one coupled secondary signal, establish measurement repeatability, collect a stable baseline with rational subgrouping, apply control rules, then challenge the system with a bounded known shift to quantify detection delay and false alarm behaviour.

9. Knowledge boundary

Control-chart performance depends on stationarity, sampling and measurement quality. There is no universal subgroup size, alarm rule or multivariate model that fits all photopolymer process dynamics.

10. Conclusions

ER-296 applies SPC only after the measurand, measurement system, sampling structure and baseline are fit for distinguishing process drift from noise.

References

1. International Organization for Standardization. ISO 11462-1:2026 Implementation of statistical process control (SPC) — Part 1: Statistical process management — Elements, tools and techniques of SPC. Geneva: ISO; 2026.
2. International Organization for Standardization and ASTM International. ISO/ASTM 52920:2023 Additive manufacturing — Qualification principles — Requirements for industrial additive manufacturing processes and production sites. 2023.

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