

Batch Compounding, Homogenisation, Filtration and Filling of Photoresins

Which Process Variables Must Be Declared and Controlled, and the Evidence That Does Not Yet Exist

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Statement of significance

Photoresin batch manufacture is often described through equipment settings or shop-floor instructions, but such descriptions do not by themselves establish which process variable caused a measured material or printing response. The controlled literature includes an experiment showing that order of addition can be deliberately varied and measured in a ceramic-filled vat-photopolymerisation feedstock. It does not provide a directly read study doing the corresponding work in an unfilled photoresin. This review defines the resulting evidence gap and the minimum coupled experiment required to close it, without disclosing or recommending a manufacturing recipe.

Abstract

Compounding, homogenisation, deaeration, filtration, transfer and filling can be recorded as parts of a photoresin batch history, but a recorded operation is not yet a demonstrated causal variable. The controlled source screen identified one primary vat-photopolymerisation study in which order of addition was deliberately varied and rheology measured [1]. That study concerns a highly filled silicon-nitride ceramic slurry. It demonstrates only that order of addition can be declared, controlled and studied in a VPP feedstock; it establishes nothing about the direction, magnitude or practical consequence of the effect in an unfilled photoresin. A second composite-resin dataset varied filler density and volume fraction while holding its mixing procedure constant [2], and a high-temperature VPP study characterised formulation processing rather than batch-process variation [3]. No directly read study in the controlled corpus varies batch sequence, homogenisation, deaeration or filtration as a declared independent variable in an unfilled photoresin and connects that variable to composition, optical response, rheology and printing or part response. ER-173 therefore presents a bounded evidence-gap review. It defines claim-ready batch records, causal separation and a minimum coupled design, while supplying no order of addition, mixer setting, vacuum condition, filtration grade, acceptance limit or scale-up rule.

Keywords: photoresin manufacture; vat photopolymerisation; compounding; homogenisation; deaeration; filtration; filling; batch history; causal attribution; evidence gap

1. Scope and ownership

ER-173 owns routine batch manufacture of unfilled photoresins as a controlled material-state transition: compounding, order of addition, homogenisation, deaeration and oxygen state, filtration, transfer and filling while preserving identity, composition, optical response, rheology, cleanliness and traceability.

ER-036 and ER-099 retain suspension rheology and dispersant fundamentals. ER-032, ER-080 and ER-081 retain storage, in-container stability and open-vat ageing. ER-172 retains incoming raw-material identity, inhibitor level, functionality distribution, impurity and lot equivalence. Ceramic, metal and other highly filled compound manufacture remains context rather than direct evidence for routine unfilled-photoresin manufacture.

2. A batch operation is not yet a causal claim

A manufacturing record may show that an operation occurred. It does not establish that the operation changed the resin, nor which response it changed. A causal batch claim requires a declared independent variable, controlled alternatives, matched measurements and a response attributable to that variable rather than to a simultaneous composition, temperature, ageing or measurement change.

Accordingly, ER-173 separates three levels of statement:

1. **Recorded operation:** the operation and its material state are documented.
2. **Measured association:** batches made under declared alternatives show a measured difference.
3. **Causal and transferable claim:** the difference survives replication, alternative explanations and a stated transfer boundary.

Only the first level can be supplied by a production record alone. The other levels require an experimental design.

3. The batch state that must be declared

A claim-ready record identifies the formulation and raw-material lots, batch identity and size, sequence of material additions, equipment identity and geometry, mixing or homogenisation history, temperature history, atmosphere or deaeration state, hold intervals, filtration operation, transfer path, filling state and sampling locations. These are categories to be declared, not prescribed settings.

The record must also distinguish set values from measured values. A machine command, nominal vacuum, nominal rotational rate or nominal filter designation does not prove the physical state delivered to the material. Where a claim depends on that state, an appropriate measurement and its uncertainty are needed.

4. Order of addition is experimentally tractable, but transfer is prohibited

Cramer et al. 2025 deliberately varied the order in which dispersant components were introduced relative to powder and measured rheological behaviour in a VPP feedstock [1]. This establishes exactly one proposition for ER-173: order of addition can be declared, controlled and measured as an experimental variable in a vat-photopolymerisation feedstock. The cited system is a highly filled silicon-nitride ceramic slurry with sintering aids and downstream debinding and sintering; therefore no material, setting, direction of effect or process conclusion from that study transfers to an unfilled photoresin.

The source is useful here because it demonstrates experimental tractability, not because it supplies a photoresin manufacturing rule. ER-173 neither predicts that order will matter in an unfilled resin nor predicts that it will not.

5. A screened composite dataset does not close the gap

Beckwith and Gupta 2026 report a rheological dataset for resin and hollow-glass-microsphere mixtures [2]. The independent variables are filler density grade and filler volume fraction. Mixing is held as a constant preparation step. A complete-text examination performed by the independent gate reviewer and recorded in the source-read record found no reported deaeration or filtration experiment. The study was therefore examined and excluded from the direct evidence core: it can inform composite-rheology questions, but it cannot establish the effect of a batch-process variable in an unfilled photoresin.

Meenakshisundaram et al. 2024 likewise provide relevant VPP formulation-characterisation context, particularly for processing viscous resins at elevated temperature [3]. Their study does not compare batch order, homogenisation, deaeration, filtration or filling as the declared independent variable, so it does not close the ER-173 gap.

6. Homogenisation needs a material-state endpoint

Time or equipment speed alone does not define homogenisation. A scientific claim requires a measured state distributed across the batch. Depending on the owned question, that state could be represented by a composition or chemical proxy, an optical response, a rheological response, or another independently justified measure. Sampling must be spatially and temporally declared so that a uniform result is not created by averaging away relevant variation.

The endpoint and sampling plan must be selected before the comparison. ER-173 does not prescribe a mixer, speed, shear rate, duration, energy input, temperature or universal uniformity criterion.

7. Deaeration and oxygen state must not be conflated

A declared deaeration operation and the oxygen state relevant to photopolymerisation are not interchangeable claims. Removing visible bubbles, changing headspace, reducing dissolved gas and changing oxygen replenishment near an exposed surface are distinct observations unless their relationship is measured in the tested system.

A study that varies a deaeration operation should therefore record the material and headspace history and include a direct or justified proxy measurement for the state it claims to change. Cure or print response must then be measured on the same batch families. ER-173 supplies no vacuum level, time, oxygen target or assertion that deaeration necessarily improves cure or print performance.

8. Filtration, transfer and filling require mass-balance discipline

Filtration may change more than the population targeted for removal. A defensible experiment must identify what enters and leaves the operation, define sampling before and after it, and measure any claimed change in composition, optical state, rheology or cleanliness. A filter designation by itself does not demonstrate the retained population or the unchanged state of the resin.

Transfer and filling add surfaces, residence time, atmosphere and possible spatial segregation to the batch history. These factors should be recorded wherever they could confound the chosen response. This is an experimental-accounting requirement, not a specification for equipment, filter media, pore rating, fill temperature or allowable contamination.

9. Minimum coupled design required to close the gap

The minimum study uses one declared unfilled photoresin formulation and one printer. One batch variable is deliberately varied across at least three declared levels while every other batch variable is held and recorded. Each level is manufactured as a repeat batch so that variation between batches can be separated from the imposed variable. Allocation, replication and exclusions are declared before manufacture.

The same batch families are then evaluated using four coupled measurement classes:

1. a composition or chemical-proxy measurement;
2. a viscosity or rheological measurement;
3. a cure-depth or working-curve measurement; and
4. one declared printing or part response.

Measurements must retain batch identity from manufacture to printing. Separate studies performed on unrelated formulations or unmatched batches do not establish the coupling. A null result remains informative if the design and measurement capability are sufficient and must not be rewritten as proof that the variable never matters.

10. Interpretation and transfer boundaries

Any observed effect is bounded to the tested formulation, raw-material lots, batch scale, equipment, process state, storage interval, printer, exposure protocol and response method. A response in rheology cannot substitute for a print response; a working curve cannot prove composition uniformity; and a passing part does not by itself identify which batch state produced it.

Filled systems can demonstrate that a variable is experimentally accessible, but their particle interactions, optical transport, dispersion requirements and downstream processing prevent direct transfer to an unfilled photoresin. Manufacturer and reseller instructions may support implementation within their own declared systems but are not independent primary evidence and cannot establish universal rules.

11. What cannot presently be specified

The controlled evidence does not support a universal order of addition, mixer type, speed, shear rate, mixing time or energy, temperature, vacuum level, oxygen target, hold time, filtration material or grade, transfer condition, fill condition, acceptable entrained-air level, homogeneity limit, contamination limit, batch-size scaling factor or process window.

The absence of a directly read study in the completed controlled screen is an evidence gap, not proof that no such study exists. ER-173 therefore identifies the experiment needed rather than converting current practice into a scientific conclusion.

12. Conclusions

Routine photoresin manufacture can be made scientifically auditable only when batch operations are converted into declared variables, measured material states and linked responses. Cramer et al. 2025 demonstrate that order of addition can be deliberately varied and measured in a ceramic-filled VPP feedstock, while establishing nothing about unfilled photoresins [1]. Beckwith and Gupta 2026 and Meenakshisundaram et al. 2024 were examined but do not vary the owned batch-process variables in the required unfilled-photoresin context [2,3]. The direct evidence gap therefore remains.

The minimum route to closure is a replicated, one-variable batch study that couples composition or chemical-proxy, rheological, cure and printing or part measurements on the same identified batches. Until such evidence exists, batch instructions remain system-specific implementation choices rather than transferable manufacturing laws.

Related Engineering Review boundaries

ER-173 owns routine compounding, homogenisation, deaeration, filtration, transfer and filling of unfilled photoresins. ER-032, ER-080 and ER-081 retain storage and vat ageing; ER-036 and ER-099 retain suspension rheology and dispersant fundamentals; ER-172 retains incoming-material identity and lot equivalence; and ER-035 retains interpretation of critical exposure and penetration depth.

References

1. Cramer CL, Hmeidat NS, Mitchell DJ, Snarr PL, Cakmak E, Bullock SE, Aguirre TG, Martinez MC, Armstrong BL. Rheology improvement for silicon nitride and resin slurries for vat photopolymerization printing and sintering. *npj Advanced Manufacturing*. 2025;2:36. <https://doi.org/10.1038/s44334-025-00051-y>
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Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. The company develops and supplies photoresins and related process materials. No proprietary formulation, manufacturing sequence, process window or comparative product recommendation is disclosed.

Data availability

No new experimental dataset was generated. The source screen, independent gate decision and source ledger are included in the review package. The three cited primary articles are available through their DOI-linked publisher records.

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