

Vacuum-Compatible Fluidic and Pneumatic Components Made from Photopolymers: Leakage, Outgassing, Seals and Cycling

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Abstract

Vacuum-Compatible Fluidic and Pneumatic Components Made from Photopolymers is evaluated as the bounded decision of whether a printed component can maintain its assigned vacuum function after conditioning, sealing and repeated pressure cycling. The controlled state comprises resin, geometry, post-cure, bake/conditioning, atmospheric exposure, seal interface, pressure history and temperature. For ER-283, both cited sources are confined to their stated point-of-use evidence roles. ER-283 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: vacuum; SLA; outgassing; leakage; seals; permeation; cycling; photopolymer

1. Significance, scope and ownership

ER-283 owns whether a printed component can maintain its assigned vacuum function after conditioning, sealing and repeated pressure cycling. The review is organised around the decision-specific evidence chain and leaves neighbouring ownership intact.

1.1. Corpus boundary

Vacuum performance is separated from generic gas-barrier physics and from cryogenic service. ER-54 retains molecular permeation, ER-281 reactive microfluidics, and ER-287 cryogenic cycling. ER-283 therefore closes only leakage, outgassing, sealing and repeat-use evidence for printed vacuum or pneumatic components.

2. Subject-specific state model and causal chain

For ER-283, causal interpretation begins by freezing resin, geometry, post-cure, bake/conditioning, atmospheric exposure, seal interface, pressure history and temperature. Leakage, desorption and permeation have different time signatures, so a satisfactory ultimate pressure does not by itself identify which mechanism controls the component response.

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

Radić, Lambrick, Rhodes and Ward measured pump-down and residual-gas behaviour of SLA Clear Resin and reported water as the dominant contaminant in their freshly printed system, with baking changing the material state and enabling high-vacuum use under their conditions. ER-283 uses that evidence to separate outgassing from leakage and permeation. Reference [1] is used for direct SLA high-vacuum pump-down/residual-gas evidence. Reference [2] is used for the incumbent molecular gas permeability/barrier scope.

4. Measurement architecture

The measurement architecture for ER-283 is built around helium or method-appropriate leak rate, pump-down curve, residual gas analysis, outgassing rate, dimensional/seal change, permeation where relevant and repeated cycling. Pump-down behaviour, leak testing and outgassing or residual-gas evidence are assigned to distinct hypotheses before a vacuum limit is accepted.

5. Qualification and transfer

A vacuum component is requalified after resin, bake, seal, geometry or atmospheric-exposure changes with a test that can distinguish leak, outgassing and permeation contributions. A successful pump-down on one configuration is not a generic material property.

6. Failure modes and interpretation traps

The central interpretation trap in ER-283 is that a low ultimate pressure is attributed to low outgassing without excluding leaks; a baked specimen is treated as identical to the as-printed state; one chamber result is generalized to seals and pneumatics. Separate leak, outgassing, permeation, seal and cycling gates prevent the same pressure trace from being interpreted as evidence for mechanisms it did not measure.

7. Non-compensatory release gates

Gate	Minimum evidence	Blocking failure
Component state	Resin, cure, bake and exposure fixed	As-printed/baked states conflated
Leak	Method-appropriate leak rate measured	Ultimate pressure used as leak proof
Outgassing	Pump-down/RGA or rate evidence	Leak/outgassing not separated
Permeation	Barrier contribution bounded where relevant	Long-term ingress ignored
Seal interface	Seal material/geometry/contact controlled	Seal behavior assigned to bulk resin
Re-exposure	Atmospheric re-exposure tracked	Adsorption reset ignored
Cycling	Pressure/temperature cycles represented	Single pump-down generalized
Geometry	Distortion/seal dimensions remeasured	Functional shape assumed stable

8. Minimum verification experiment

Characterize the final component before and after the declared bake/conditioning step, test leak and pump-down independently, collect residual-gas data, then cycle pressure and temperature while monitoring seal integrity and geometry. Atmospheric re-exposure must be treated as a new state when it changes surface adsorption.

9. Knowledge boundary

Direct evidence is strong for specific SLA resin/vacuum configurations, but it does not establish a class-wide outgassing rate, bake schedule, permeation coefficient or seal lifetime for photopolymers.

10. Conclusions

ER-283 closes vacuum or pneumatic use only for the tested component state and history, with leakage, outgassing, permeation and seal behaviour distinguished rather than inferred from one pressure metric.

References

1. Aleksandar Radić, Sam Morgan Lambrick, Sam Rhodes, David James Ward. On the application of components manufactured with stereolithographic 3D printing in high vacuum systems. *Vacuum*. 2025;232:113809. <https://doi.org/10.1016/j.vacuum.2024.113809>
2. Juan Segurola. Gas Barrier and Molecular Permeability in Vat-Printed Photopolymers: Diffusion, Sorption, Network State, Defects and Qualification. ER-54. 3Dresyns Engineering Publications; 2026. Controlled corpus source.

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