

# Adhesives And Hardener Applications in Lamination: Technical Report

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**Abstract**—This technical report provides a comprehensive analysis of adhesive systems and hardener applications in lamination processes, focusing on their chemistry, performance, and sustainability implications. It examines major adhesive families—water-based, solvent-based, solventless polyurethane (PU), hot-melt, UV/EB-curable, pressure-sensitive, and epoxy—highlighting their curing mechanisms, ingredient composition, and industrial applications. Special emphasis is placed on pot life management, a critical parameter in two-component systems that influences process stability and bond integrity. The report compares solvent-based and solventless technologies in terms of environmental impact, operational efficiency, and compliance with food-contact regulations (e.g., 21 CFR standards). Chemical reaction pathways for PU and epoxy adhesives are detailed to explain property development and performance under thermal and mechanical stress. Additionally, the report addresses ESG compliance strategies, including VOC reduction, adoption of bio-based raw materials, and recyclable mono-material laminates, aligning with global sustainability frameworks such as ISO 14001 and the EU Green Deal. Visual aids—including diagrams, charts, and an infographic—summarize adhesive types, pot life behaviour, performance attributes, and application sectors. A troubleshooting guide and root cause vs. solution chart are provided to assist converters in resolving common lamination defects. This integrated approach equips stakeholders with actionable insights for optimizing adhesive selection, improving process reliability, and advancing sustainability in flexible packaging and technical laminates.

## I. INTRODUCTION

Lamination relies on adhesives to bond multiple webs (films, foils, papers) into composites with tailored barrier, mechanical, and aesthetic properties. Core adhesive families include water-based, solvent-based, solventless reactive (often polyurethane), hot-melt, UV/EB-curable, pressure-sensitive, and epoxy

formulations (Henkel Adhesives, n.d.; Ashland Global, n.d.).

## II. TYPES OF ADHESIVES IN LAMINATION

Water-based systems (e.g., PVA/acrylic dispersions) offer low VOCs for paper and food-contact labels; solvent-based systems deliver strong bonds and chemical resistance but require oven drying and ventilation. Solventless two-component polyurethanes cure via chemical reaction without solvents, enabling higher line speeds and reduced emissions. Hot-melts bond on cooling, UV/EB-curable polymerize under radiation, PSAs bond under light pressure, and epoxies provide high chemical/thermal resistance for technical laminates (Ashland Global, n.d.; Henkel Adhesives, n.d.; Converting Quarterly, 2025).

## III. ROLE OF HARDENERS AND POT LIFE

In two-component adhesives, pot life is the period after mixing when viscosity remains low enough for application; it is often defined as the time for the mixed viscosity to double at 25 °C. Pot life depends on temperature, batch size (exotherm), mix ratio, and formulation, and must be distinguished from working/open time on the substrate (Incure Inc., 2025; EPO-TEK, n.d.).

## IV. CHEMICAL REACTION DETAILS

Polyurethane curing involves isocyanate ( $-NCO$ ) reacting with hydroxyl ( $-OH$ ) groups to form urethane linkages ( $R-NH-CO-O-R'$ ). Epoxy systems cure when amines open oxirane rings to form a crosslinked network. These reactions determine final properties such as flexibility, heat resistance, and chemical durability (Henkel Adhesives, n.d.; EPO-TEK, n.d.).

V. COMPARISON: SOLVENT VS. SOLVENTLESS ADHESIVES

Solvent-based lamination applies adhesive with a solvent carrier and requires oven drying; it can leave residual solvent and has higher VOCs. Solventless lamination mixes components at the coater, cures chemically without ovens, reduces energy and emissions, and improves food safety when properly formulated and cured. Regulatory alignment for food-contact laminations includes 21 CFR 175.105 and performance temperature classes (177.1390/1395) (Converting Quarterly, 2025; Enercon Industries, 2023).

VI. APPLICATION METHODS AND INDUSTRIAL CONTEXT

Typical equipment includes rotogravure/roll coaters and heated/cold nips. Meter-mix units ensure precise ratios for solventless systems. Ink compatibility, surface cleanliness, coat weight, web tension, and

curing conditions are critical to avoid defects such as retained solvents and poor heat resistance (Converting Quarterly, 2025; Enercon Industries, 2023).

VII. ESG COMPLIANCE EXAMPLES AND FUTURE TRENDS

Environmental initiatives prioritize water-based and solventless systems to reduce VOCs and energy, adoption of bio-based polyols, and recyclable mono-material laminates. Social priorities include worker exposure reduction and food-contact safety. Governance aligns with ISO 14001 and regional frameworks (e.g., EU Green Deal; India CPCB guidelines). Vendors such as Henkel (LOCTITE LIOFOL) and Ashland provide solventless/water-based portfolios supporting these outcomes (Henkel Adhesives, n.d.; Ashland Global, n.d.; Converting Quarterly, 2025).

Illustrative Pot Life Curve

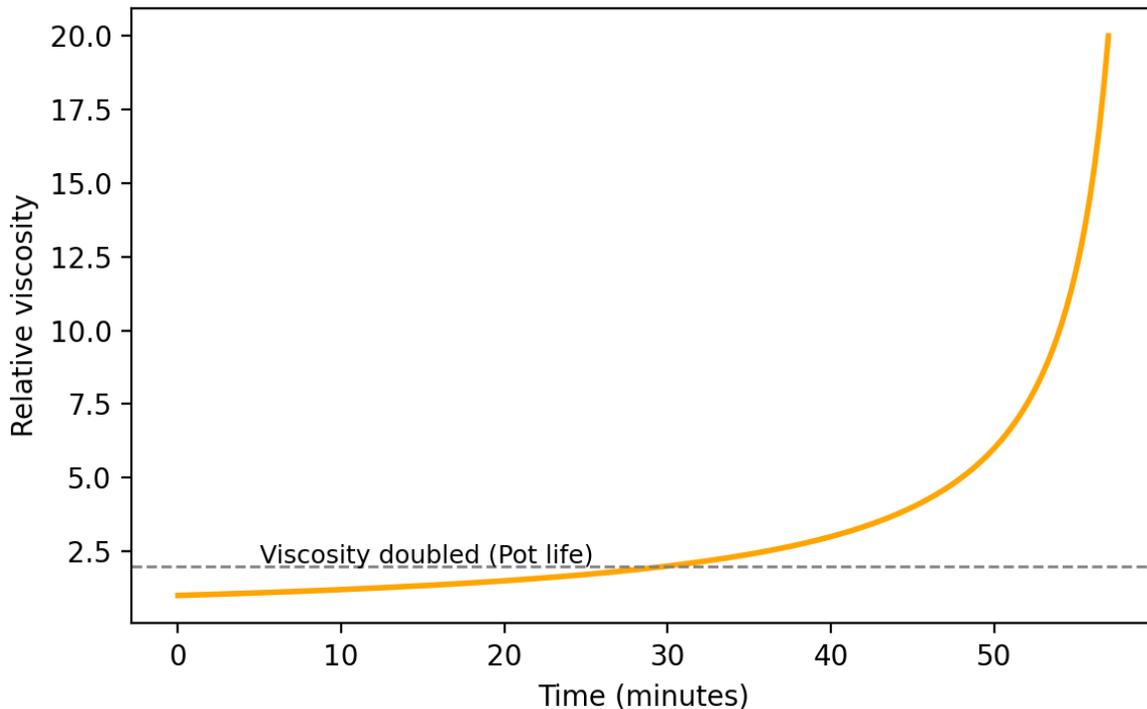
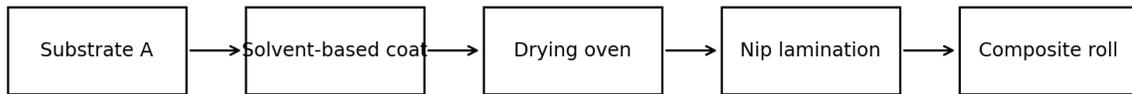


FIGURE 1. ILLUSTRATIVE POT LIFE CURVE SHOWING RELATIVE VISCOSITY VERSUS TIME. NOTE. POT LIFE OCCURS AT VISCOSITY DOUBLING (INCURE INC., 2025; EPO-TEK, N.D.).

**Solvent-based lamination**



**Solventless lamination**

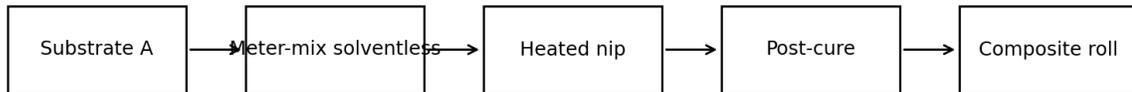


FIGURE 2. PROCESS FLOW COMPARISON OF SOLVENT-BASED VS SOLVENTLESS LAMINATION. NOTE. SOLVENT-BASED REQUIRES OVEN DRYING; SOLVENTLESS USES MIX-METER AND CHEMICAL CURE (CONVERTING QUARTERLY, 2025; ENERCON INDUSTRIES, 2023).

**Adhesive Types Used in Lamination**

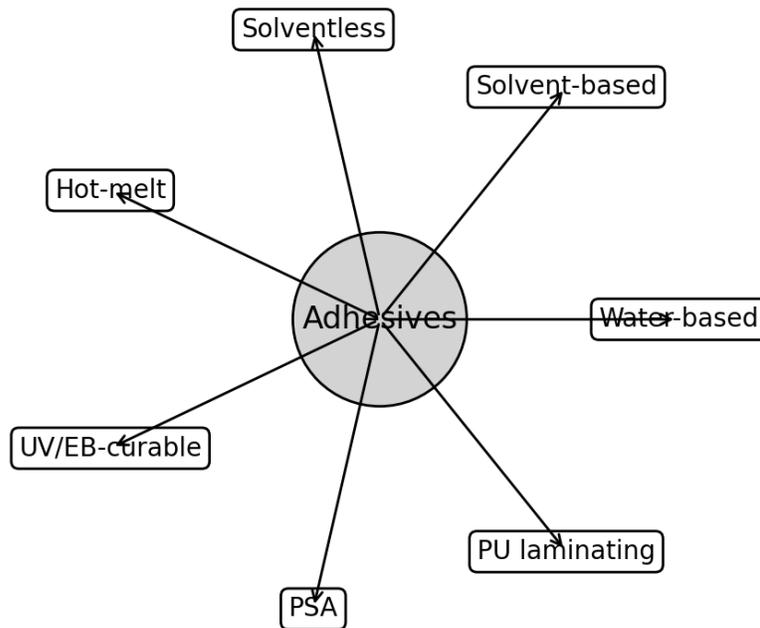


FIGURE 3. ADHESIVE TYPES MAP FOR LAMINATION. NOTE. FAMILIES INCLUDE WATER-BASED, SOLVENT-BASED, SOLVENTLESS, HOT-MELT, UV/EB, PSA, AND PU LAMINATING ADHESIVES (HENKEL ADHESIVES, N.D.; ASHLAND GLOBAL, N.D.).

VIII. CHARTS

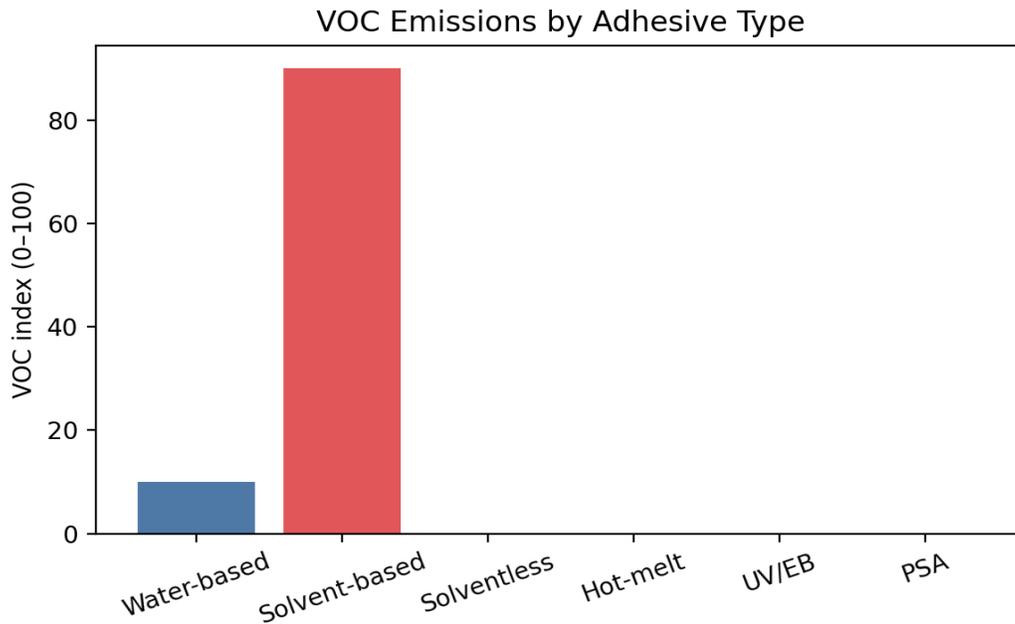


FIGURE 4. VOC EMISSIONS BY ADHESIVE TYPE (ILLUSTRATIVE INDEX). NOTE. SOLVENT-BASED ADHESIVES EXHIBIT HIGHER VOCs THAN WATER-BASED, SOLVENTLESS, HOT-MELT, UV/EB, AND PSA SYSTEMS (ASHLAND GLOBAL, N.D.; HENKEL ADHESIVES, N.D.).

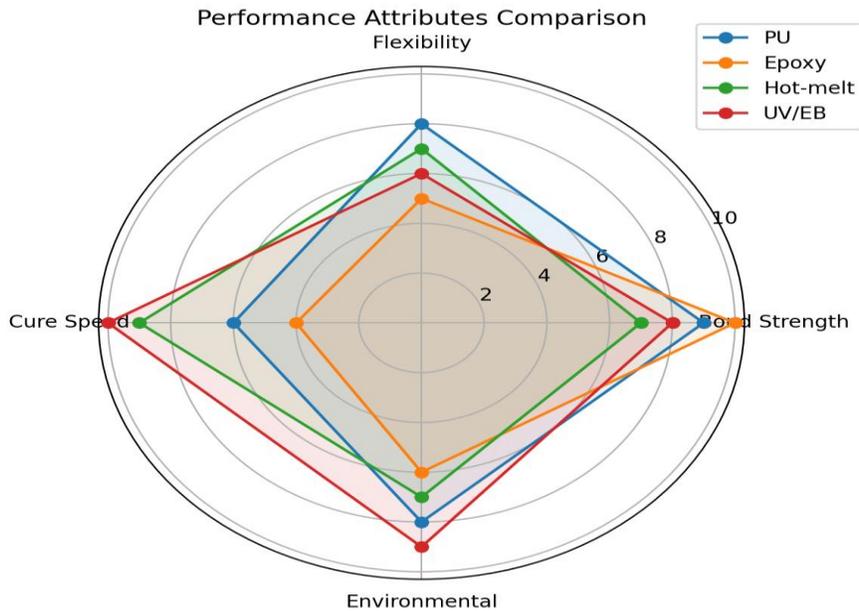


FIGURE 5. PERFORMANCE ATTRIBUTES (BOND STRENGTH, FLEXIBILITY, CURE SPEED, ENVIRONMENTAL) FOR PU, EPOXY, HOT-MELT, AND UV/EB ADHESIVES (ILLUSTRATIVE). NOTE. ATTRIBUTE TRENDS ALIGN WITH VENDOR TECHNICAL DATA AND INDUSTRY PRACTICE (HENKEL ADHESIVES, N.D.; CONVERTING QUARTERLY, 2025).

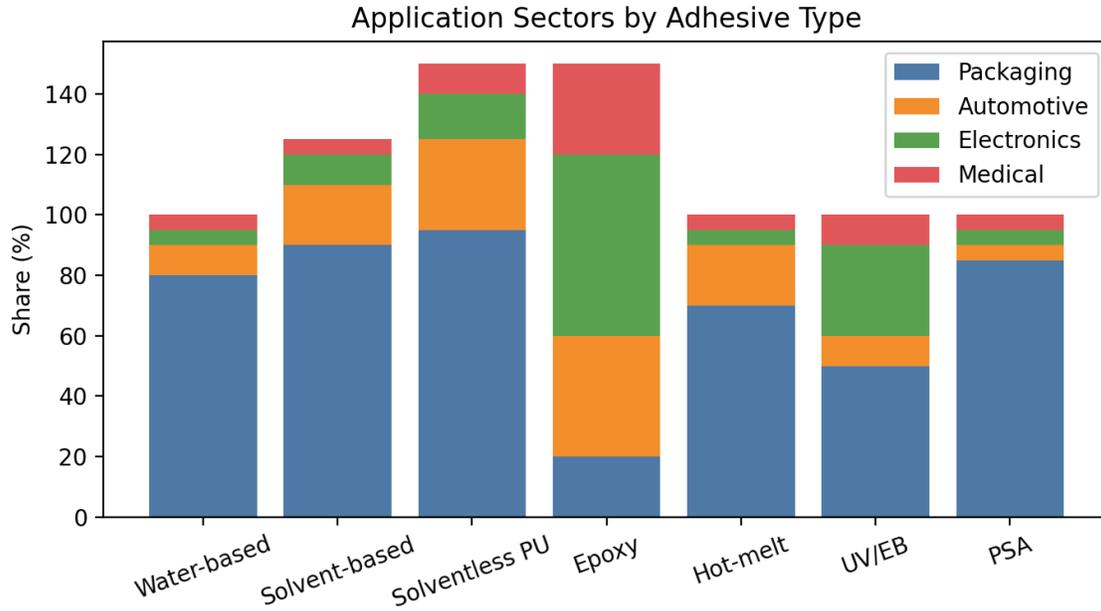


FIGURE 6. APPLICATION SECTORS BY ADHESIVE TYPE (ILLUSTRATIVE DISTRIBUTION). NOTE. PACKAGING DOMINATES WATER-BASED, SOLVENT-BASED, SOLVENTLESS PU, AND PSA; ELECTRONICS FAVOR EPOXY AND UV/EB (HENKEL ADHESIVES, N.D.; ASHLAND GLOBAL, N.D.).

IX. ROOT CAUSE VS SOLUTION CHART

Issue	Root Cause	Solution
Low bond strength	Under-cure; wrong mix ratio; low coat weight; poor surface treatment	Verify mix ratio & pot life; increase coat weight; improve corona; raise nip temp/pressure; extend cure time
Retained solvent / odor	Incomplete ink drying; oven under-drying; high-boiler ink additives	Increase oven temperature/airflow; allow ink to fully dry; select low-retain inks; extend aging before slitting
Bubbles / blisters	Trapped solvent/air; excessive line speed; high moisture in substrates	Reduce speed; increase drying; precondition substrates; use heated nip and proper lay-on angle
Ink smear / appearance defects	Adhesive/ink incompatibility; solvent attack; high slip additives	Check ink–adhesive compatibility; switch solvent system; lower nip temperature; choose compatible adhesive grade
COF drift	Over-coating; migration; adhesive interacting with slip/antiblock	Optimize coat weight; choose low-interaction adhesive; respect curing schedule; test alternative film
Curl / gauge bands	Tension mismatch; uneven nip pressure; differential shrink from drying	Match web tensions; calibrate nip; reduce oven temperatures; allow post-cure relaxation

Poor lamination to metallized film	Aggressive solvents; inadequate surface energy; under-cure	Use suitable adhesive grade; minimize solvent aggressiveness; increase corona; extend cure
Short pot life issues	Exotherm in large batches; high ambient temp; catalyst overdose	Mix smaller batches; control temperature; verify pump calibration; select slower hardener
Bleed-through on paper	Low viscosity; high solvent; excessive coat weight	Reduce solvent/dilution; increase viscosity; lower coat weight; use cold nip for paper
Seal failure / hot tack loss	Incompatible adhesive near seal layer; retained solvent	Use seal-compatible adhesive; ensure full cure; manage drying and aging before sealing

### X. CONCLUSION

Adhesives and hardener systems are the backbone of lamination technology, enabling the creation of high-performance, multi-layer structures for packaging, automotive, electronics, and medical applications. This report highlights:

- **DIVERSE ADHESIVE FAMILIES:** Water-based, solvent-based, solventless PU, hot-melt, UV/EB-curable, PSA, and epoxy systems each offer unique advantages and limitations.
- **POT LIFE MANAGEMENT:** Critical for two-component systems to ensure process efficiency and bond integrity.
- **CHEMICAL FOUNDATIONS:** PU and epoxy reactions define mechanical and thermal properties, influencing application suitability.
- **PROCESS COMPARISONS:** Solventless systems outperform solvent-based in sustainability, speed, and compliance, aligning with global ESG goals.
- **FUTURE OUTLOOK:** Industry trends favour bio-based raw materials, recyclable laminates, and energy-efficient curing technologies to meet environmental and regulatory standards.

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