Hot melts in pressure-sensitive and heat-seal applications

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Applications for pressure-sensitive and heat-seal adhesives continue to grow. Recent developments include expanded temperature ranges, longer tack times, and electron-beam curing.

The development of new elastomers and tackifiers has expanded the range of applications for hot-melt pressure-sensitive and heat-seal adhesives. Hot-melt pressure-sensitive adhesives (PSA) are no longer confined to use on paper labels. These adhesives are being used on clear film labels, in demanding industrial applications, and in the medical field. The market for heat-seal adhesives in lidding and cap seals continues to grow with the need for tamper-evident packaging. This article reviews some of these new applications.

Pressure-sensitive adhesives

Paper labels

Permanent paper labels are still the largest segment of the hot-melt PSA market. While general-purpose grades for room-temperature application have been available for more than 15 years, the market is far from static. The adhesives industry faces continual challenges in label applications:

- Low-temperature and polyolefin adhesion without sacrificing cohesive strength and convertibility
- Aggressive adhesion to increasingly tougher grades of corrugated board (e.g., recycled and board with strength greater than 275 lb)
- Excellent convertibility at high press speeds without loss of adhesion properties.

Low-temperature adhesives. Products for low-temperature applications are constantly being refined in an effort to balance the specific needs of the converter and the end user. Dynamic mechanical analysis has proved to be an effective formulating tool in efficiently characterizing rubber/resin systems.

For example, **Fig. 1** shows G' (storage modulus) and tan δ (loss tangent) for two grades of adhesive, one a general-purpose grade for use on paper and the other low-temperature (refrigerator) grade. The mechanical T_g (glass transition temperature) is revealed by the tan δ peak. The T_g for the general-purpose grade is approximately 7°C, while the T_g for the low-temperature grade is approximately −18°C. For optimal adhesion at 0°C, the T_g of the low-temperature grade was designed to be at its maximum under standard debonding conditions. Likewise, the general-purpose grade was designed for optimal adhesion at 25°C. Below 15°C, the low-temperature grade also has a lower G' than the general-purpose grade, indicating better bonding (wet-out/tack) at low temperatures.

Adhesives for corrugated board. The challenge posed by some of the tougher grades of corrugated board has been met by developing general-purpose/broad-adhesion grades that also have excellent specific adhesion to recycled and 275-lb burst strength corrugated board.

Convertibility at high press speeds. The loss of adhesion at high press speeds is a complex and challenging problem. Matrix breaks are a common problem in poorly converting adhesive systems. Converting is not only a function of the adhesive's ability to cut cleanly and resist the tendency to flow back; it is also dependent on the adhesive's adhesion to the release liner.

Three major factors contribute to this adhesion:

1. The extent of cure of the silicone liner
2. The speed and angle at which the matrix is peeled away from the liner
3. The degree of interaction between the adhesive and the release liner
4. The overall label construction.

These points can be illustrated with graphs of release (peel values off the release liner) vs. stripping speed. **Figure 2** shows one adhesive's variation in release off silicone liner at four degrees of cure. As expected, the release values are most erratic at low levels of cure. Insufficient cure of the release liner is most troublesome for crosslinking acrylic adhesives, which react with the liner. However, it also can be a problem in some rubber/

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resin systems. The optimal, although possibly impractical, solution is to use fully cured liner.

The release values are relatively constant between the values of 12 in./min and 400 in./min, a range that is consistent with conventional laboratory testing. Erratic press behavior—matrix breaks at 400 ft/min but not 600 ft/min—can only be predicted by looking at high-speed release values.

This point is illustrated once more in **Fig. 3**, which plots release of four adhesives vs. stripping speed from a liner at one level of cure. Differences in the type and level of tackifier in each of the four adhesives contribute to these variations. At conventional testing speeds, release values are relatively constant. However, as seen in Fig. 3, release values can vary greatly at high production speeds.

Release values at production speeds are crucial indicators of a given adhesive's convertibility on a particular liner. If the adhesive has otherwise desirable characteristics, it may be possible to improve the convertibility of the adhesive by choosing a liner that provides optimal release at desired press speeds.

Better adhesives are continually being developed to meet the challenges of the paper label market. One product of particular interest is a general-purpose hot-melt PSA with broad adhesion characteristics and improved convertibility at very low viscosity. Most general-purpose permanent grades have a viscosity between 10,000 cp and 15,000 cp at 325°F. This new adhesive has a viscosity of only 3500 cp at 325°F, allowing use in screen-printing applications. **Table I** shows that, despite the low viscosity of this adhesive, there is no sacrifice in performance or penetration resistance.

Film labels

Paper is still the major face stock for pressure-sensitive labels, but the use of alternative materials is growing rapidly. One estimate projects that 40% of the face stocks will be nonpaper by 1990 (*1*). These alternative materials include a variety of clear and opaque films: polyethylene, polypropylene, polyester, polystyrene, and cellulose-acetate.

One of the fastest-growing applications for film face stock is primary labeling. Primary labeling with clear films has been "heralded as the most exciting and sought after development in package decoration today" (*2*). To achieve the no-label look, clear film labels must be invisible, allowing the package to show through and eliminating the need to match the color of an opaque label to the package.

Labeling with clear polyolefin films presents a special challenge to the hot-melt formulator. Conventional rubber/resin hot-melt PSAs have an affinity for polyolefin films, causing them to swell considerably upon aging. A patent has recently been filed on a novel formulation that does not distort polyolefin films.

This formulation also has water-like clarity, good ultraviolet (UV) stability, and the ability to thoroughly wet-out a package surface in a short period of time. These characteristics are essential in attaining the no-label look. If wet-out is not complete, air entrapment under the label breaks the continuity of the package surface and destroys the no-label image. The ability to attain complete wet-out is especially critical on dark-colored package surfaces. On clear or light-colored packages, clarity and UV stability take precedence.

Removable labels

Removable hot-melt PSAs have been on the market for some time. These products, however, have typically had three drawbacks: excessive build-up in peel over time; large variations in peel with small changes in coating weight; and lack of cohesive strength, leading to wing-up, edge ooze, and penetration into face stocks.

Today's hot-melt removables overcome many of these drawbacks. Peel buildup on aging is typically held to under 1.5 lb/in. of width. Variations in peel are minimal over the normal range of coating weights for self-adhesive labels, as seen in **Table II**. Cohesive strength is comparable with many of the general-purpose permanent grades, i.e., 2.5 h held at 70°F under a 2-kg/in.^{2} load (PSTC-7: 15 min wet-out before applying load). This improved performance is obtained using a novel formulating approach protected by two U.S. patents (*3*).

Industrial applications

Hot-melt PSAs are limited in performance by their thermoplastic nature. Nevertheless, high-performance, noncuring grades are able to meet the demands of many industrial markets. For example, the hot-melt PSAs that are used to back sanding disks perform satisfactorily through the heat generated by mechanical friction. Other grades are able to compete successfully with rubber/resin solvent-based adhesives in the low-end transfer-tape market. Hot melts, however, offer distinct advantages where heavy deposition is required, as in the automotive-carpet-backing market. **Table III** lists the properties of a hot-melt PSA used in this application.

Dynamic mechanical analysis provides an efficient means of characterizing these high-performance adhesive systems. **Figure 4** compares this high-cohesive-strength product with a general-purpose paper label grade. The plot clearly shows that the high-cohesive-strength product has significantly greater resistance to creep at high temperatures. This correlates with far better shear values at high temperatures than the general-purpose product. Beyond this performance level, however, increases in cohesive strength require some type of post cure.

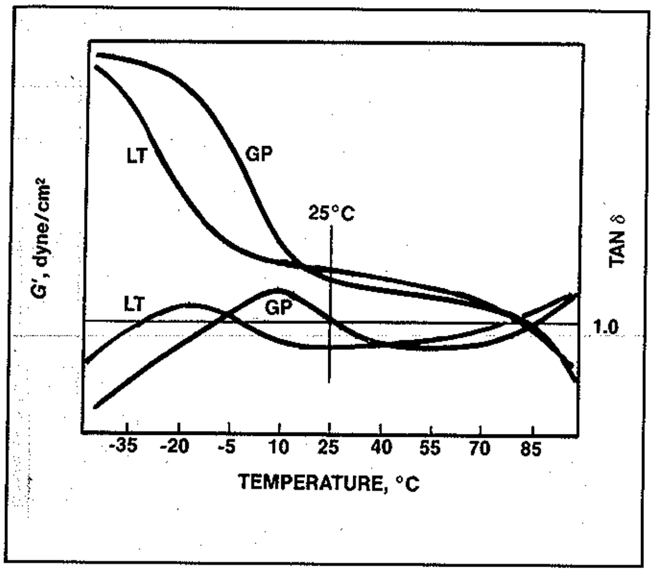
Electron-beam curing provides a way to achieve greatly improved cohesive strength without sacrificing peel and tack. These adhesive systems are formulated with specifically designed crosslinkable elastomers. With one such system, shear-adhesion failure temperature under a 1-lb/in.^{2} load was increased from 175°F to 250°F. Cohesive strength was greatly improved, while tack and peel were essentially unchanged after cure, as seen in **Table IV**.

Health-care applications

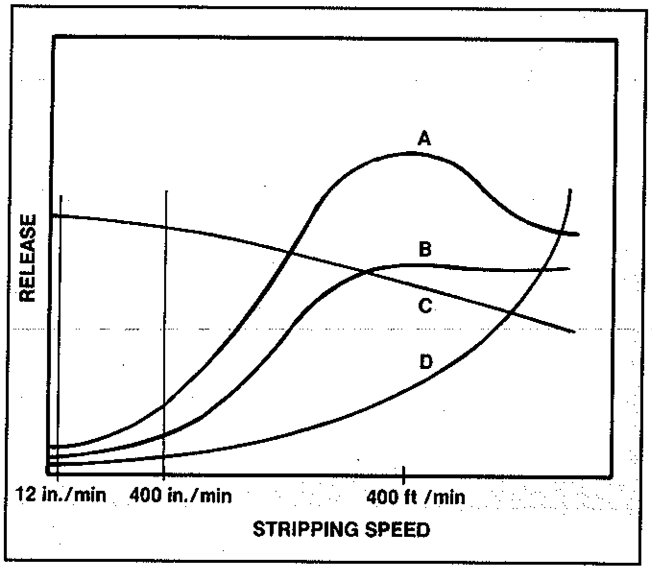
Tapes and devices. Hot-melt PSAs are increasingly used for both surgical tapes and attachment of medical devices. Applications include nonwoven and film medical/surgical tapes in addition to mounts for electrocardiogram electrodes, ostomy applications, etc.

PSAs that come into contact with skin must satisfy a variety of performance criteria. They must adhere well under wet and dry conditions; they must have the ability to be removed cleanly without causing irritation; and they

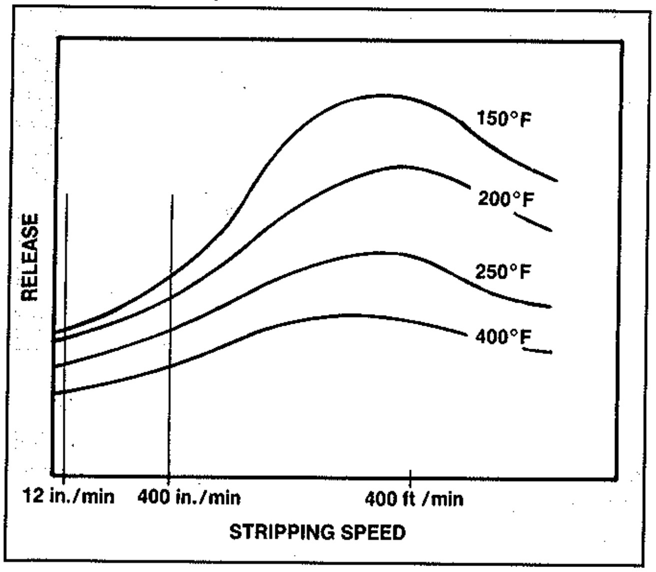
1. Results of dynamic mechanical analysis for a general-purpose (GP) adhesive and a low-temperature (LT) adhesive



3. Release of four adhesives at various rates of stripping speed from a liner at one level of cure. The *x*-axis is a log scale.



2. Adhesive release off silicone liner at various rates of stripping speed. The four curves represent different degrees of cure for the silicone release liner. The *x*-axis is a log scale.



I. Performance characteristics of two hot-melt PSAs, one a low-viscosity adhesive and the other a general purpose adhesive

	Viscosity at 325°F	
	3,500 cp	*15,000 cp*
180° peel,[a] oz/in. width		
20 min	85	*80*
24 h	90	*100*
Hold,[b] h	45	*24*
Tack,[c] oz/in.²	80	*110*

[a]Determined using method PSTC-1.
[b]Determined using method PSTC-7: 15-min wet-out, 4 lb/in.², 72°F.
[c]TLMI loop.

must have a low sensitization potential. Rubber/resin hot-melt PSAs meeting these criteria are currently available. In addition, clear rubber/resin and acrylic grades are now commercially available for clear film tapes.

Transdermal drug delivery. Transdermal drug systems allow delivery of medication directly through the skin. Scopolamine patches for prevention of motion sickness are a common example. The medication can be dispersed directly in the PSA's matrix system or be contained in a separate reservoir and delivered through a diffusion-controlling polymer membrane.

Acrylic solution polymers or silicones are commonly used for drug delivery applications. However, the chemistry of hot melts can provide certain advantages. The elastomers and resins that are used to formulate hot-melt PSAs can be selected to minimize or eliminate chemical functionality, thereby reducing the possibility of medication/adhesive interactions. Acrylics tend to swell when they come into contact with the alcohol used in some medication-dispensing gels. Hot melts, however, are more resistant to this swelling effect.

Heat-seal adhesives

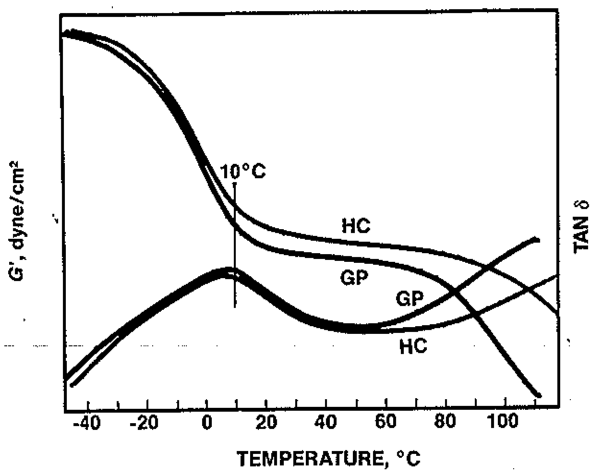
The use of PSAs for labeling has cut into the market for preapplied heat seals. Heat seals are becoming increasingly important, however, in package-closure applications. Such uses are growing as unit packaging expands in response to a combination of consumer preference and tamper-evident seal requirements. Examples include

II. Peel for an improved removable hot-melt PSA at different levels of deposition, temperature, and residence time

Adhesive deposition, lb/ream	*Temp., °F*	*Time*	*Peel,* oz/in. width*
12	70	20 min	10
		24 h	13
		1 week	14
	120	24 h	17
		1 week	20
15	70	20 min	13
		24 h	16
		1 week	16
	120	24 h	19
		1 week	24

* 180° peel from method PSTC-1.

4. Results of dynamic mechanical analysis for a general-purpose (GP) adhesive and a high-cohesive-strength (HC) adhesive

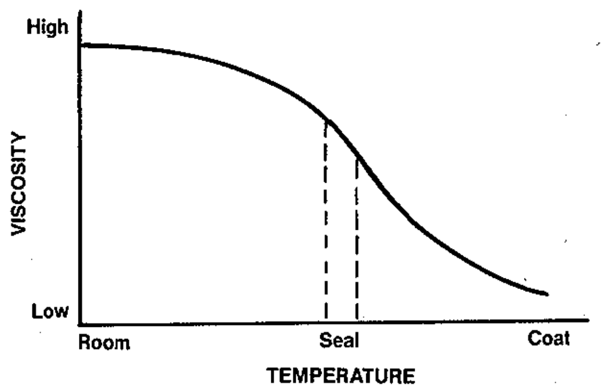


III. Performance characteristics of a carpet-backing hot-melt PSA (no post cure) at a coating thickness of 7.5 mils

180° peel,[a] oz/in. width	197
Hold,[b] h	
4 lb/in.² at 72°F	6
1 lb/in.² at 140°F	47
2 lb/in.² at 140°F	19
Tack,[c] oz/in.²	183

[a]Determined using method PSTC-1: 20 min.
[b]Determined using method PSTC-7: 15-min wet out.
[c]TLMI loop.

5. Optimum temperature/viscosity profile for the hot tack needed in blister-package applications



IV. Performance characteristics of adhesive system[a] before and after cure with an electron beam

	Uncured	*Cured with 5 Mrad*
180° peel,[b] oz/in. width	63	61
Hold,[c] h		
140°F	1	72+
160°F	1	72+
180°F	0	24+
Tack,[d] oz/in.²	72	74
SAFT,[e] °F	175	250

[a]Adhesive transfer-coated at 1.0 mil onto 2-mil PET.
[b]Determined using method PSTC-1: 20 min.
[c]Determined using method PSTC-7: 15-min wet-out, 2 lb/in.²
[d]TLMI loop.
[e]Shear-adhesion failure temp.; 1-in. × 1-in. bond to SS, 15-min wet-out at 72°F before applying 1-lb/in.² load at 75°F. Temperature ramped 25°F every 15 min to failure point.

attachment of lids to unit-portion food packages, carded (blister) packaging, aluminum foil push-through nonprescription drug dispensers, and sealable cap liners for bottle closures.

Solvent-borne heat seals, and to a lesser extent water-borne systems, are widely used for such applications. Improved formulating techniques in tandem with new application equipment are opening up these areas to hot melts.

Blister packaging

In blister packaging, a preformed, rigid plastic covering is placed over the packaged contents and secured to a board stock. Heat-seal coatings, preapplied over printed graphics on the stock, are used to obtain the closure. Commonly used plastics included PVC, polystyrene, and cellulosics.

Adhesive depositions are usually in the range of 3-6 lb/3000 ft². For the current, vehicle-carried products, seal conditions are typically 275-350°F with 2-5 s dwell at 60 lb/in.² pressure. Lower seal temperatures and reduced dwell/pressure are desired.

Blister-packaging end uses have two requirements that are not easily achieved with hot-melt formulations:

1. **Block-resistance** — Heat-seal coatings are preapplied, with the coated boards stacked face-to-back for transport to the filling/sealing line. Nonblocking (tabbing) is essential. A typical test cycle for this property is 24 h at 140°F under 6-lb/in.^{2} compression.
2. **Hot-tack** — Bond strength immediately after sealing must be high enough to support the weight of the packaged contents upon ejection from the sealing unit. The stresses involved can be substantial with heavy items such as hardware.

These two requirements require an adhesive with a narrow heat-sealing range followed by rapid viscosity decrease on further heating for good coating properties. **Figure 5** illustrates desirable temperature-viscosity requirements.

Lidding heat seals

Preapplied heat-seal adhesives are used in unit-packaging applications, which involve securing peelable lids to flanges on molded tubs and trays. Foods and sterilizable health-care products are typical applications. Lid structures include bare aluminum foil, foil in combination with paper or plastic films, various plastics, and paper.

Food packaging. Heat seals used for food lidding must be formulated from ingredients that meet FDA standards for direct contact with food. These heat seals also must be resistant to attack by such food components as oils and acids. Hot tack is needed for foods that are packaged hot for viscosity reduction (e.g., jelly). Packages often tumble off the filling/sealing line, and bonds must be able to withstand the combination of heat and stress. Heat-seal temperature/viscosity profiles similar to those for blister packaging are needed.

Medical packaging. Unit packaging of medical devices and other health-care items involves closure of plastic trays with plastic or paper lids. Filled packages are normally sterilized after sealing. Ethylene oxide gas, autoclaving, and exposure to gamma rays are all used for this purpose.

With ethylene oxide, both the lidding material and the heat-seal adhesive must be porous to the gas. Pattern-deposition of the heat seal in combination with a gas-porous lid, e.g., paper or Tyvek®, is often used. For autoclaving, the seal typically must be capable of withstanding 30 min of 30-lb/in.^{2} pressure at 250–270°F.

Delayed-tack heat seals

Another approach to unit-package closure involves use of in-line, delayed-tack (extended open time) heat-seal adhesives. The adhesive, in this case, is pattern-applied to the tray flange. The tray is then filled, and uncoated lidding stock is sealed to the tray using only pressure. This approach offers line-speed advantages but requires specialized heat seals with open times up to 3 s.

Hot-melt seals with delayed tack also can be used for linerless labeling applications. Open times on these adhesives have been extended to nearly 3 min, which maintains adhesive tack from the time when the coating is applied until the application of the label. A release coating is applied to the surface of the label to prevent blocking before the adhesives sets.

Cap seals

Heat seals also have been used successfully as cap seals. This application involves the use of heat-seal-coated foil, or a foil containing laminate, to seal the mouth of a jar or vial. The adhesive is softened by induction heating in an RF field, which permits bonding to the glass or plastic container. These seals prevent leakage of the package contents, provide evidence of tampering, and can help extend the product's shelf life.

Cap seals are used on food, pharmaceutical, and chemical containers. Resistance to the package contents—water, oil, acids, etc.—is critical. In addition, heat seals used on food and pharmaceutical containers must conform to FDA regulations regarding the composition of materials that come into direct contact with food.□

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