A New Path for Lamination Adhesives: Leaping Time Barriers and Erasing Steps

The benefits of a novel one-component waterborne adhesive for automotive interior lamination

ABSTRACT

Automotive manufacturers, especially in North America, primarily use two-component waterborne, reactive hot-melt, and solvent-borne adhesives for laminating TPO, PVC and leather skins to PE and PP foams, as well as for laminating these foils to rigid substrates for such applications as interior door panels, consoles and instrument panels. Although such adhesives are well-known and in common use, OEMs and suppliers of automotive interiors components seek opportunities to improve environmental factors, sustainability, ease of manufacturing and cost effectiveness.

This paper describes the development of a one-component waterborne adhesive that transforms preparation and application processes, leaping over conventional time-consuming processes and erasing some of the most error-prone, complex, costly and physically messy steps involved in preparing and using 2K formulations. Many of the most challenging steps inherent in 2K systems disappear completely. Furthermore, test data for specific applications of such as instrument panels and door panels, demonstrates that a 1K adhesive is versatile and adaptable in production processes, consistently yielding results that meet the specifications of OEMs.

The 2K Disarray

The global automotive industry uses adhesives extensively to laminate thermoplastic olefin (TPO), polyvinyl chloride (PVC) and leather skins with polypropylene (PP) foam, as well as PP and polyurethane (PU) foam to rigid substrates, fashioning interior door panels, consoles and instrument panels.

While assembly lines in the plants of automotive suppliers and OEMs generally are the epitome of efficiency and precision with skilled workers, robots and automated resupply the preparation of both water-based and solvent-based adhesives using a two-component (2K) system often employs inefficient methods, unchanged for many decades. Most laminating adhesives, especially in North America, use a 2K formula in which two components (for example, polyurethane and a hardener) are combined in a pre-mix room away from the line. These hardeners are crosslinking agents that join molecules with covalent bonds to make the adhesive more durable and help it withstand high surface temperatures. The mixing process is time-consuming and requires product to be transported from the pre-mix room to the line. Additionally, a 2K formula requires costly automatic mixing equipment — purchased separately or built into the adhesive price.

One benefit of a 2K mixture is that it produces a fast reaction time at room temperature; but once the reaction begins, it essentially is unstoppable. Therefore, any material mixed with the cross linker and not used while the material is still workable must be discarded, typically resulting in a pot life of four hours. Further, the mixing equipment must be cleaned out before more of the adhesive or a different adhesive formulation can be mixed.

Consequently, manufacturing plants risk losing adhesive materials if they mix too much and, even more significant, risk a line shutdown if they are overly cautious and fail to mix enough to keep up with production. The impact of a shutdown is far costlier than the lost chemicals.

Operating efficiencies with two-component adhesive mixtures are hindered in many other ways, as well. A 2K mixture may require induction time to initiate the curing process, increasing overall mixing time. The 2K process requires facilities to keep several different formulations in stock and to track them to ensure the right chemicals are available for each application, thereby complicating inventory and staffing requirements. Moreover, 2K work environments invariably become chaotic as multiple combinations of chemicals are retrieved for pre-mixing. The atmosphere resembles that of the kitchen in a diner where fast-paced orders arrive and are filled in a hectic manner.

Waste is built into the 2K process

In all, two-component mixing is messy, time-consuming and labor-intensive. To prepare the adhesive and transport it to the line requires 45 minutes. The time-sensitive steps involved in using 2K adhesives must be carefully synchronized with the assembly line, even though they are executed away from the line. For example, workers must be certain to deliver the correct mixed formulation to the correct line in the correct amounts. If operators are not communicating effectively, problems can arise. In one instance, an assembly line has been observed to shut down for a costly 20 minutes because the adhesives had not been pre-mixed.

Once the mixing is completed and the 2K adhesive is delivered to the line, workers have four hours to use it before all of it is cured. Note that the four-hour time limit includes the adhesive that has been applied, so workers have only four hours to completely laminate the part. Rarely do they have the opportunity to use 100 percent of the mixture; so, in effect, waste is built into the 2K adhesive application process.

Eliminating Time, Steps and Waste with a Novel 1K Adhesive

Recently, a formulation developed by Henkel Adhesive Technologies laid the groundwork for a new generation of adhesives, breaching time barriers and erasing process steps. AQUENCE® PL 5101 P referred to in this paper as 5101 P—is a new waterborne, one-component (1K) adhesive that resolves all the issues characteristic of 2K processes by enabling assembly plants to eliminate conventionally troublesome steps and make a wide range of potential problems simply disappear.

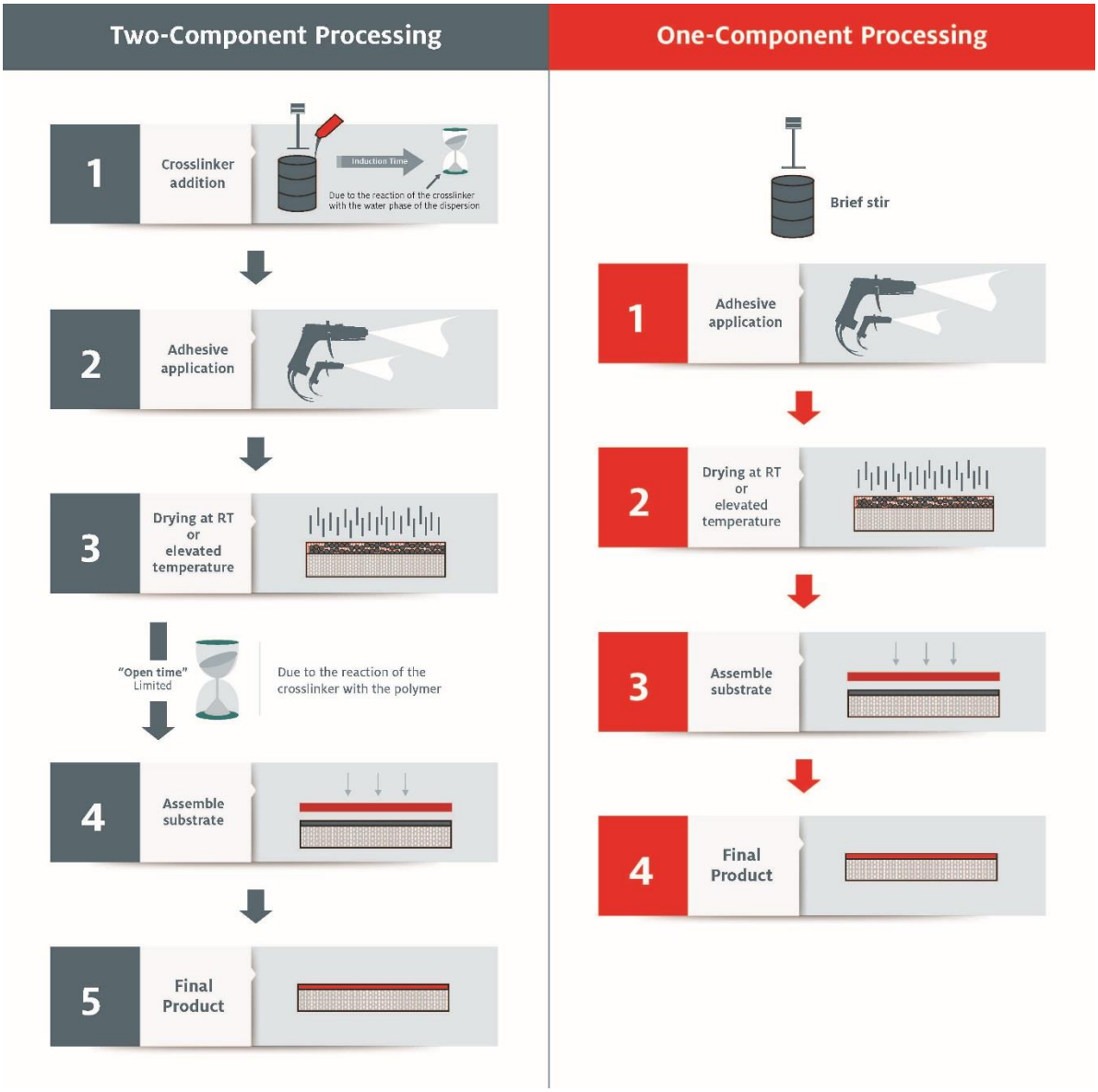
The goals in developing this adhesive technology were to create a 1K product with demonstrated advantages over most 2K formulations; to meet typical OEM specs for adhesion strength, heat resistance and fogging resistance; to offer low levels of volatile organic compounds (VOCs); and to avoid toluene diisocyanate (TDI).

The results demonstrated by a 1K adhesive have been exceptional. The 1K formulation has a six-month shelf life; contains just 6 g/l of VOCs, according to EPA Method 24; and incorporates no TDI. In testing to date, the product meets:

- General Motors GMW14892
- Ford WSS-M15P45-C
- Honda 0095ZSDAA000
- Toyota TSF 7754G

1K is the automotive industry's next leap into a future of highly efficient laminating adhesives. It is a 1K waterborne, heat activated urethane dispersion with process advantages that exceed those of 2K products, making longstanding problems with conventional adhesives disappear.

Figure 1



Leaping time barriers

Because it consists of a single component, a 1K adhesive requires only a brief stir instead of mixing precise formulas. So rather than being prepared in a separate pre-mix room and then being transported to the line, it resides right on the

line, ready to apply, with no open-time limitations, because it activates only when heat is applied above the threshold temperature of 70 C. Therefore, no premature reaction occurs. This one activation step leads to cumulative savings in preparation time and materials that can be immense.

When using 5101 P, manufacturing plants will be able to erase multiple process steps immediately. Because it is a 1K adhesive, the pre-mix room disappears; nothing needs to be mixed. Messy preparation time is erased, as well.

Pot time and open-time restrictions are eliminated, as well as induction time, because it is simply applied directly to the lamination part without requiring stand time for the reaction to begin. As a result, plants have the freedom to separate adhesive application and lamination operations when doing so is convenient.

5101 P produces efficiencies even beyond the plant floor, because facilities no longer need to carry extra inventories of adhesives components. This benefit leads to less complexity for purchasing, warehousing and manufacturing. Furthermore, plant personnel can be allocated more effectively. Since they are not needed to mix and transport adhesives, their skills can be applied to higher-value assignments.

Manufacturers also save from not needing to pay overtime to get adhesives mixed for the day. As previously noted, two component adhesives generally require 45 minutes for mixing and preparing the mixture to go to the line, work that must be accomplished before line operations begin.

Another step is avoided by the fact that 5101 P adheres to high-surface-energy substrates with no pretreatment, including PVC, polystyrene (PS), polycarbonate (PC) and scrim-backed materials. Low-surface-energy substrates need standard pretreatment.

Application savings

A 1K adhesive can be dropped can be dropped onto an existing 2K line without any concerns about transport from a pre-mix room, helping ensure that the line remains in operation without interruptions. During application, workers can use 100 percent of the adhesive; none is wasted in pots or in the application step, unless the user overs prays. Concern about mixing too much or too little adhesive material disappears along with the mixing room, again because no mixing is required.

- It is important to note that, if a 2K adhesive is not mixed precisely, it can lead to high scrap rates for both the adhesive itself and the parts to which it has been applied. Scrap can develop from failing to bond laminated parts with 2K mixed adhesive fast enough or from mixing the wrong proportions of the two components. The scrap rate resulting from the use of 1K adhesive is far lower.

Its novel characteristics allow it to be applied directly to the part, dried by forced heat and air or simply air dried, and then stored for a month or more, if necessary, before using heat to activate the adhesive and complete the lamination process. After applying the adhesive to the B side of the parts, they can be stacked without transfer to the A side for days or weeks in temperatures up to 50 C. With this cure-on-demand approach, the adhesive sits on the parts until the manufacturer is ready to bond the parts together.

Advantages after lamination

Examination of interior components shows that 5101 P continues to offer advantages after the laminated part is installed in the vehicle.

AQUENCE® 5101 P has a high resistance to elevated temperatures in the environment. In testing, it held up to long term heat exposure at the targeted parameter of 95 C, with short-term cyclical exposure to as much as 105 C. Similarly, it has been demonstrated to withstand the extreme environmental changes to which vehicles are exposed in differing weather conditions and locations.

- Creep-test data for instrument panels reveals that 5101 P can withstand deep-draw areas in severely contoured parts and will prevent “snap back” in high-tension areas during the molding process.

Additionally, the contribution from adhesives to fogging of the vehicle glass often caused by emissions from volatile compounds is virtually eliminated, because emissions are near zero with 5101 P.

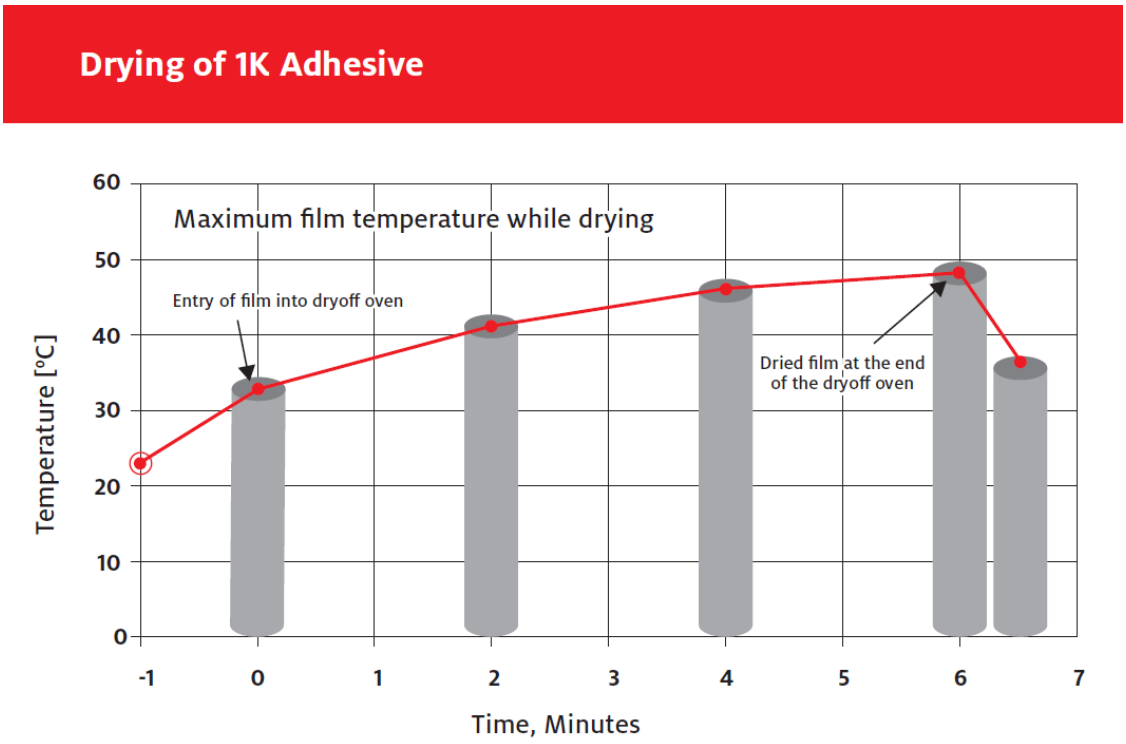
VERSATILE AND ADAPTABLE IN PRODUCTION PROCESSES

AQUENCE® PL 5101 P has proved its versatility and adaptability in studies for automotive manufacturers. Data from these studies shows that this 1K meets manufacturers’ specifications under a number of production scenarios.

Standard processing for rigid part lamination calls for roll-coating or using an HVLP spray system with a 2.0 mm nozzle. It is applied to both substrates, targeting a coat weight of 100 g/m2 (gsm) wet. The coated substrates are allowed to dry in an oven set to 50 C for seven minutes. The substrates are reactivated using an oven set to 160 C for two minutes and immediately bonded together and placed on a press set to reach a bond line temperature above 70 C and minimal pressure using 2 mm shims for one minute. Bonded parts are allowed to cool to room temperature and cure in ambient conditions for three days.

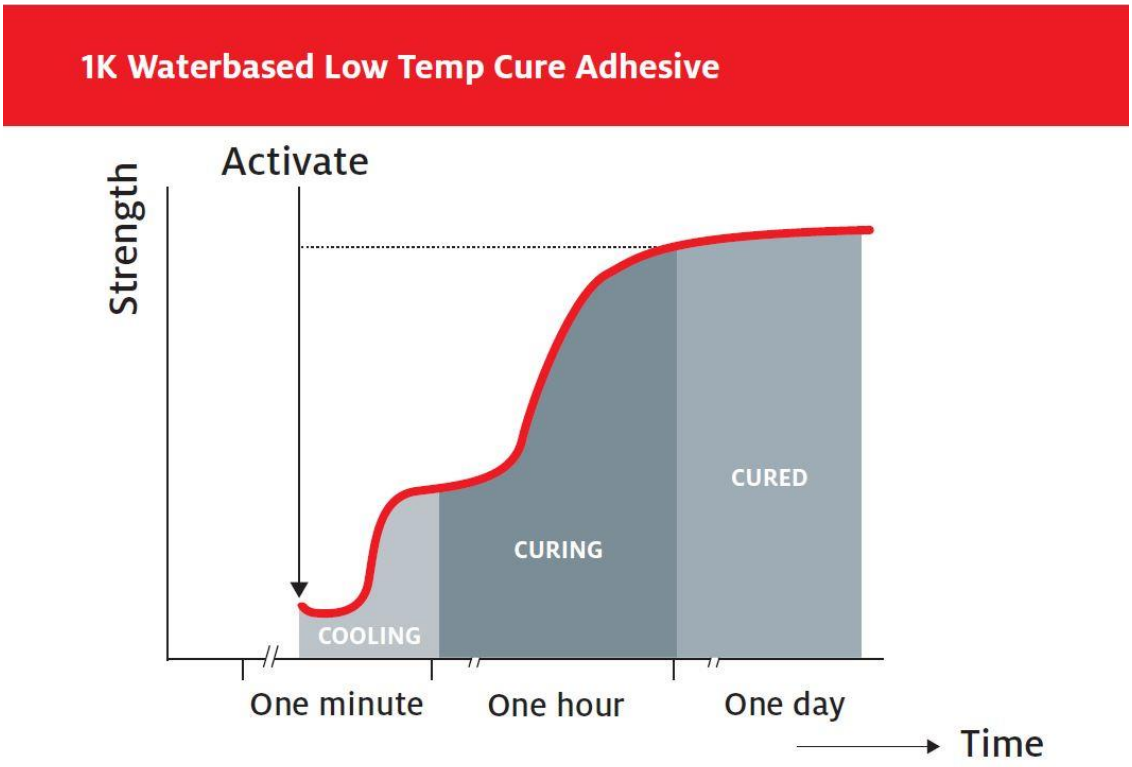
Shown in figure 2 is a typical drying profile. It is important to stay under the maximum drying temperature unless reactivation will follow immediately.

Figure 2



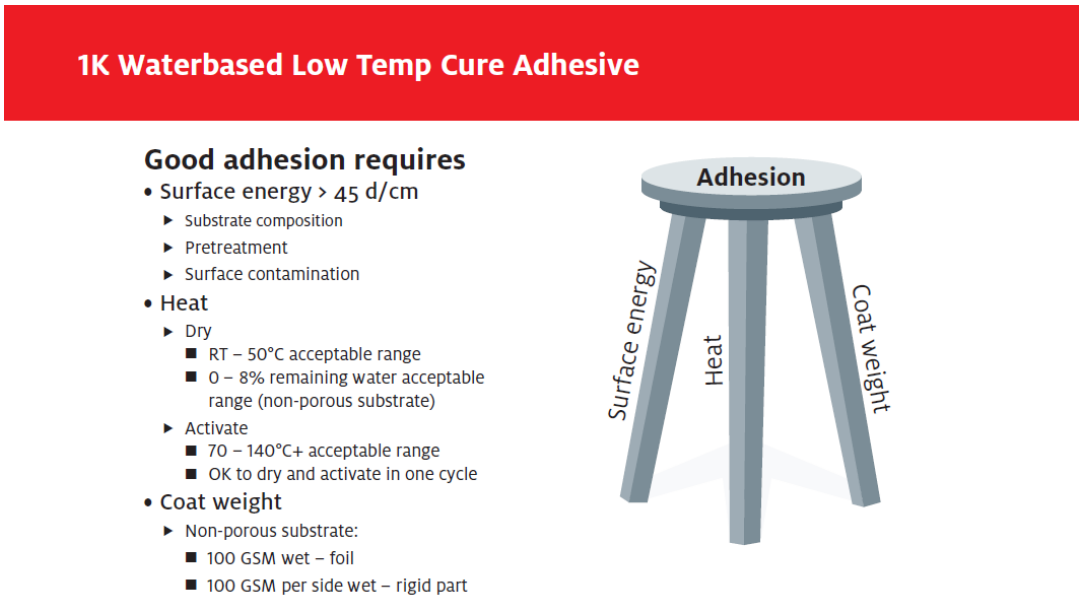
If reactivation will follow immediately, higher drying temperatures can be used to shorten the drying cycle, as exhibited in figure 3.

Figure 3



Finally, if three basic requirements in figure 4 are met, adhesion will be good.

Figure 4

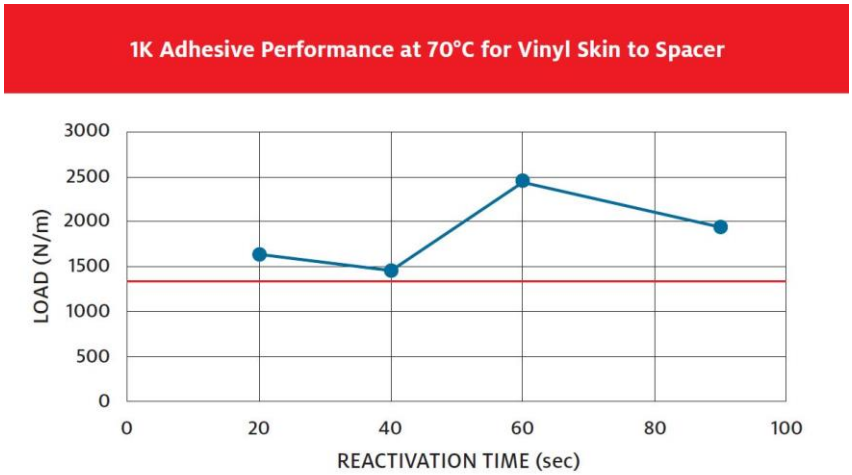


All applications are different, however, and require testing to evaluate the specific needs of the process to pass spec requirements. Two Henkel studies were designed to perform this type of evaluation.

Application to instrument panels

The first study, carried out for a Tier 1 supplier, related to application of 5101P for lamination of the instrument panel area that covers the passenger air bag.

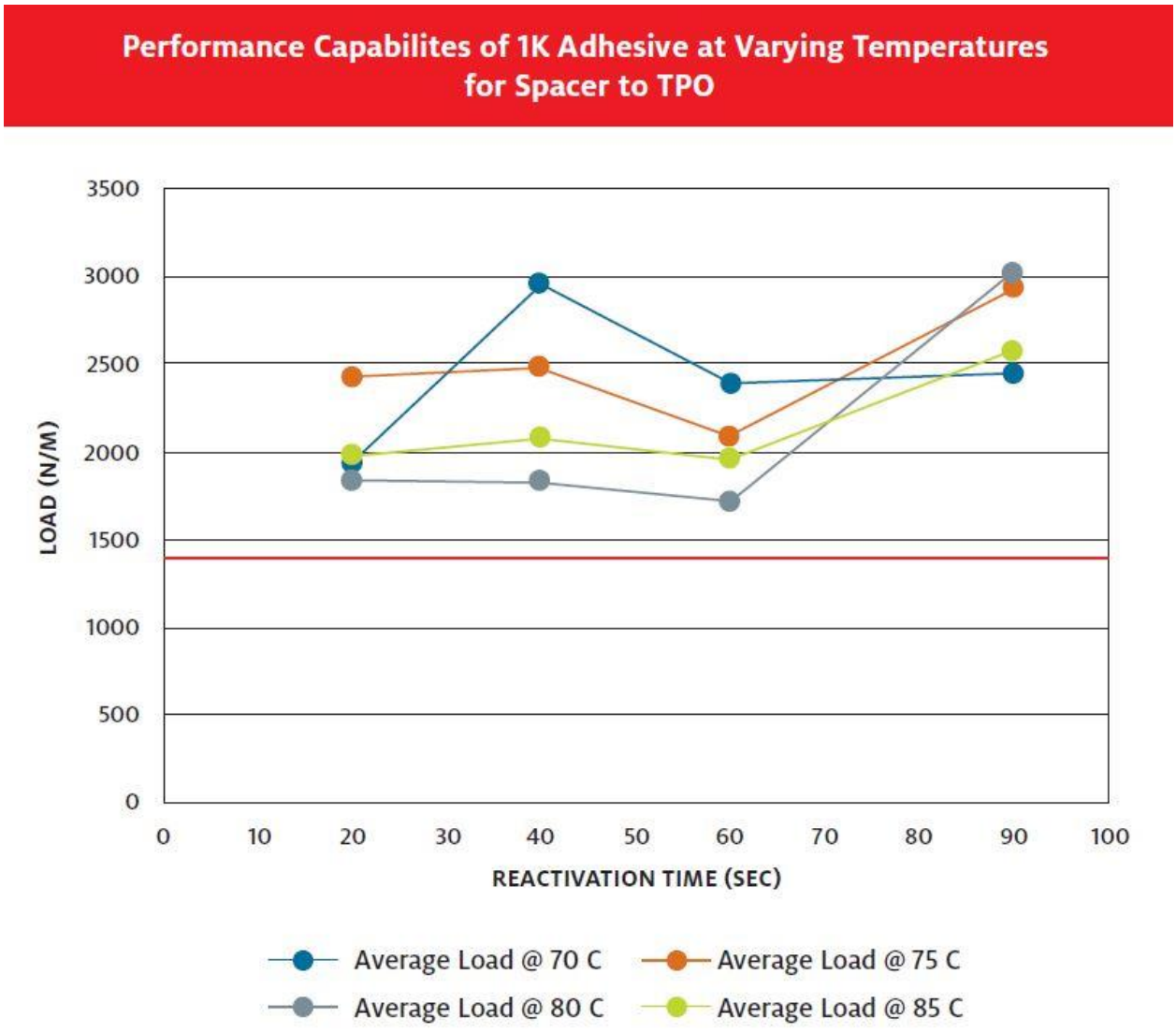
Figure 5



In The manufacturer's specifications called for the ability to pass a peel test at 1,400 N/m for adhesion of a vinyl skin to a Teflon-coated spacer. In figure 5, the red line indicates this spec. Coat weights were 300 gsm wet. The blue line shows that, at a reactivation temperature of 70 C, 5101 P passed the manufacturer's strict specification at 20, 40, 60 and 90 seconds, consistently meeting requirements

When 5101 P was tested for adhesion of the Teflon-coated spacer to TPO, it continued to satisfy the 1,400 N/m spec at temperatures of 70, 75, 80 and 85 C at all relevant time intervals, as illustrated in figure 6. Coat weights were 125 gsm.

Figure 6



To determine the appropriate coat weights, Henkel performed separate studies. Figure 7 demonstrates that, for the vinyl skin to spacer, the coat weight must be 300 gsm or higher to meet the 1,400 N/m spec. To meet this spec for laminating the spacer to TPO, Henkel's studies found coat weights must be 110 gsm or higher, as shown in Figure 8.

Figure 7

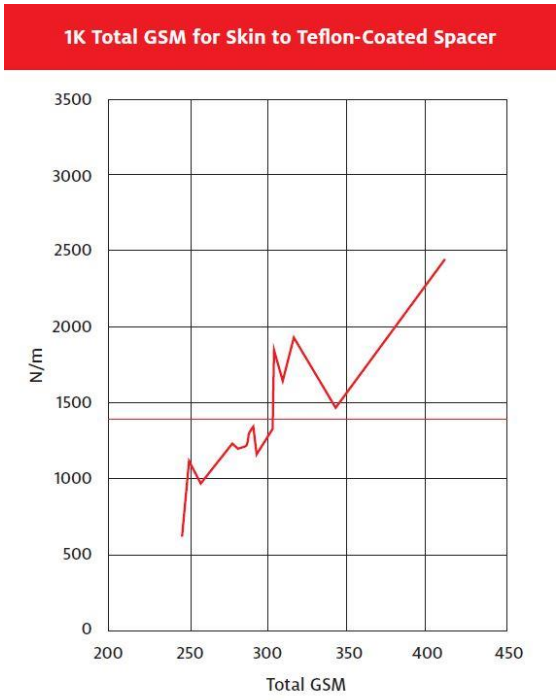
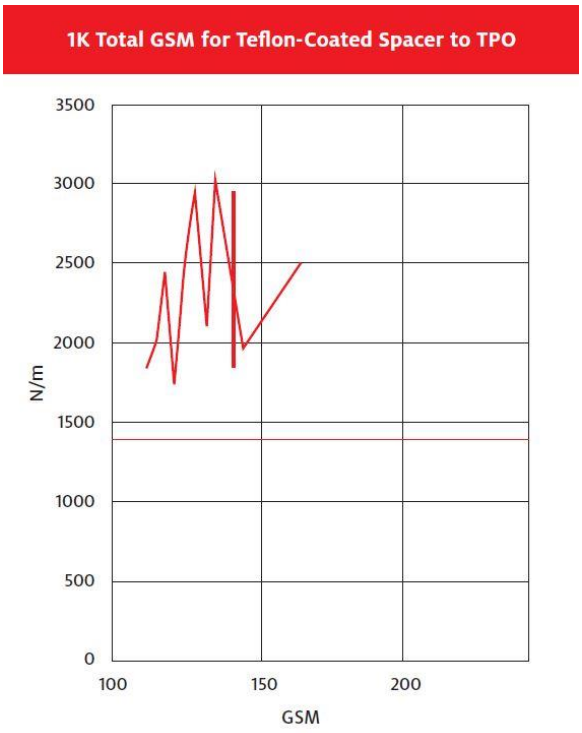


Figure 8



This case shows how a 1K adhesive was successfully applied to difficult substrates, passing strict requirements.

Application to door panels

The second set of studies was carried out for a Tier 2 supplier of door panels. These studies were designed to demonstrate that a 1K adhesive can be processed in multiple ways and consistently yield passing results. The studies employed 180-degree peel tests, and the criteria were 20 N for the control samples and 15 N for climate-tested samples.

In the first scenario, a 1K adhesive was applied to both substrates of a control group of samples and then dried. When reactivated, the skin and the PC-ABS were placed in the oven separately (the “separate” designation in figure 9). The parts were placed together in the lab oven at 120 C for two minutes, then placed on a 70 C press with minimal pressure for one minute and allowed to cool and cure. As indicated in figure 9, this process yielded passing results.

Figure 9

CONTROL

Separate, 120 C for 2 minutes (87°C Bondline)

SAMPLE	LOAD (N)	LOAD (N/M)	FAILURE MODE
1	37.48	1475.59	Cohesive
2	34.76	1368.69	Cohesive
3	72.83	2867.49	Cohesive
4	60.09	2365.67	Cohesive
5	78.92	3107.27	Cohesive
Average	**56.82**	**2236.94**	**Cohesive**

Scenario 2 studied a climate test group in which the parts underwent environmental cycling prior to testing, according to GM 14124 Cycle M. The same parameters used in the control group were applied, with the parts placed separately in the 120°C oven when reactivated and then placed together in the 70 C press with minimal pressure, cooled and cured. Again, this process passed the test, as shown in figure 10.

Figure 10

CLIMATE TEST

Separate, 120 C for 2 minutes (95-100°C Bondline)

SAMPLE	LOAD (N)	LOAD (N/M)	FAILURE MODE
1	82.86	3262.08	Cohesive
2	98.57	3880.60	Cohesive
3	107.27	4223.38	Cohesive
4	80.70	3177.25	Cohesive
5	92.28	3632.88	Cohesive
Average	**92.34**	**3635.24**	**Cohesive**

In a third scenario, the parts underwent the same type of environmental cycling before testing. When reactivated, however, the skin was mated to the PC-ABS prior to being exposed to heat (the “together” designation in figure 11). The parts were placed together in the lab oven at 120 C for four minutes, then placed on a 70 C press with minimal pressure for one minute and allowed to cool and cure. This test, too, yielded passing results. See figure 11.

Figure 11
CLIMATE TEST

Together, 120°C for 4 minutes

SAMPLE	LOAD (N)	LOAD (N/M)	FAILURE MODE
1	81.35	3202.90	Cohesive
2	88.98	3503.34	Cohesive
3	92.29	3633.35	Cohesive
4	91.61	3606.73	Cohesive
5	59.89	2357.75	Cohesive
Average	**82.82**	**3260.82**	**Cohesive**

These studies demonstrate that a 1K adhesive passes manufacturers' criteria for processes using different bonding scenarios, with data that proves the versatility and adaptability of a 1K adhesive in multiple production processes.

CONCLUSION: PROVEN EFFECTIVENESS AND EFFICIENCY

A 1K waterborne adhesive offers numerous advantages, including:

- Shrinks costs because it reduces production steps, materials and waste
- Increases throughput, because mixing is eliminated and inventory is reduced
- Improves cycle time
- Generates faster assembly times
- Streamlines cleanup, because no chemical crosslinking occurs while the product is being used
- Dramatically reduces time and waste management, because operators no longer need worry about a time limit on pot life or cleaning out a pot every four hours if all the material is not used in time
- Reduces inventory to one SKU
- Simplifies placement on the line, because it involves only one component
- Maintains or exceeds customer expectations

Contributing Authors:

Gino Mariani, Marketing Development Manager, Henkel

Barb Wehrle, Business Development, Interior Adhesives, Henkel

John White, Lead Research Chemist, Henkel