H.B. Fuller | Connecting what matters.™

Flexel™ Reactive Film Adhesive

An Intriguing Potential Solution for Interior Automotive Trim Lamination

H.B. Fuller's new Flexel™ reactive film adhesive (RFA) delivers excellent bond strength and is resistant to heat, moisture, and chemicals. Films can be stored unrefrigerated, are cleaner and simpler to use compared to hotmelts and liquid adhesives. Flexel RFA cures rapidly during the hot press cycle and develops full strength as it recrystallizes which may enable the assembler to reduce finished goods inventory while maintaining a short lead time. Automotive interiors can be challenging, both in use and in assembly. In vehicle operation, interior trim has to withstand physical handling, extremes of temperature, and do it all over the ever-longer life of modern vehicles. In assembly, the adhesives used to assemble trim components should be affordable; clean; and easy to store, handle, and apply. Traditional water-borne interior trim adhesives are affordable and have been proven effective, and users already have the equipment and training necessary to use them. But they can be challenging to store, and to mix and use. They take time to cure. And they can introduce isocyanates into the workplace. New adhesive films address all of these challenges.

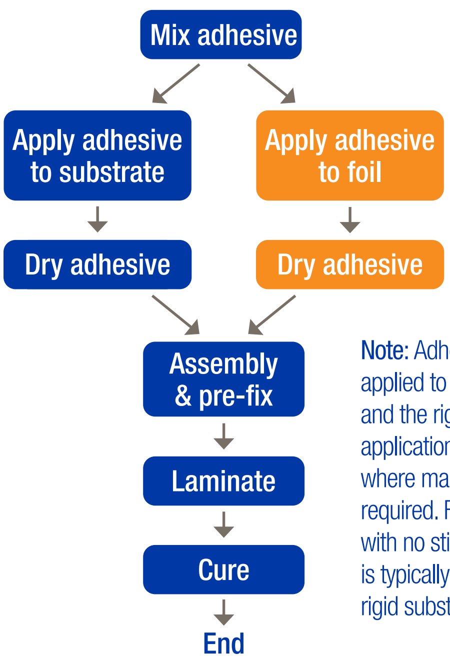
H.B. Fuller's new Flexel reactive film adhesive has significant potential for use in interior automotive trim applications. Once applied, the film delivers excellent bond strength and is resistant to heat, moisture, and chemicals. Its high elongation keeps it very flexible, both in application and in use. The film is neat and easy to handle and can significantly speed up manufacturing. Unlike water-based adhesives it doesn't require drying time, and its low activation heat protects substrates and sensitive materials like textiles and leather. The film can be stored unrefrigerated, is clean in use, and requires no mixing. And while it does contain isocyanates, it does reduce risk by not requiring spray application which atomizes the adhesive into the air. And it has significant advantages over other film adhesives as well. All of these factors combine to make it an interesting option for use by Tier 1 producers, and its ease of use may allow initial adhesive application to be moved from Tier 1 suppliers to Tier 2 suppliers.

While Flexel reactive film adhesive (RFA) offers similar adhesion performance to existing liquid, hot melt, and film adhesives, it outperforms all three in usability. Compared to reactive hot melts and liquid adhesives, Flexel is far cleaner and simpler to use. It is simply cut to shape and placed between the material to be bonded or pre-applied to one material and then bonded to the other. Or it can be pre-applied to one material and then stored or even shipped, greatly improving the flexibility of the process. Aside from scrap removal, there is no messy cleanup required, and bonded components can be handled almost immediately. Flexel cures during the hot pressing cycle, and develops full strength quickly as it recrystallizes. Reactive hot melts and multi-component water-borne systems cure after the bonding process and are more influenced by variations in ambient conditions. Because of its faster strength development Flexel may let the assembler reduce inventory of finished goods while maintaining a short lead time.

Of course existing films offer some of the same benefits, but Flexel outperforms ordinary film adhesive in several ways. Its lower cure activation temperature, typically 75 to 110°C, saves energy and reduces cost, but more importantly is safer for heat sensitive materials. And while activation temperature is low, the cross-linked adhesive stands up better than ordinary thermoplastic films to elevated temperatures. At the same time, unlike typical thermosetting films, which can become brittle as they cure, Flexel™ maintains its flexibility after curing for tougher adhesion under a variety of conditions. This flexibility after cure is beneficial for bonding rigid to flexible substrates.

Two-component waterborne systems have been the performance benchmark for bonding interior trim in a variety of materials including TPO. The reasons for their wide use are simple: they are affordable and well-understood, they meet challenging automotive interior performance criteria, they are well adapted to the range of materials used, and they are readily available globally. Processing parameters for a 2K waterborne system are well understood, and depending on the application their processing can be done by hand or by semi-automatic assembly. Hand application is typically used in more complex systems that include stitching.

Process flow for hand applied 2K waterborne adhesives typically looks like this:

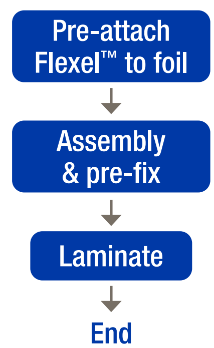


Note: Adhesive is typically applied to both the foil and the rigid substrates in applications with stitching where manual assembly is required. For applications with no stitches, adhesive is typically applied to the rigid substrates.

Multi-component water-borne systems are mixed and typically spray-applied to both the rigid substrate and the flexible foil. In a manual process, 2K water-borne adhesive is applied to both substrates. The handmade process is used when the foil is stitched to assure proper alignment. Adhesive is applied to both surfaces in manual application to ensure constant quality when human variability is a factor. If there are no stitches and glue application process can be automated then the water-borne adhesive is applied only to the rigid substrate. Spray applications accommodate three dimensional substrates typically used in automotive interior trim, but can be messy and require a skilled operator to control adhesive coating weight and spray pattern. Spray application systems in general are messy and overspray is unavoidable. Depending on part geometry and operator skill, overspray can be as low as 30 percent or as high as 100 percent of the application rate. Once applied, the waterborne system must be dried, typically to < 10 percent water content. This can be a challenge.

Achieving satisfactory drying depends on ambient conditions, which can vary with location and change with the seasons or even from day to day. Effective control of drying can require specialized and costly equipment and oversight. Inadequate drying can reduce adhesion, and if drying temperature gets too high the adhesive may start to activate prematurely, reducing ultimate performance. Even under the best conditions, two-part waterborne adhesives have a short usable window—about four hours at 20°C and even less at higher temperatures. In contrast, bonding parts with Flexel reactive film adhesives is a simpler, more forgiving process.

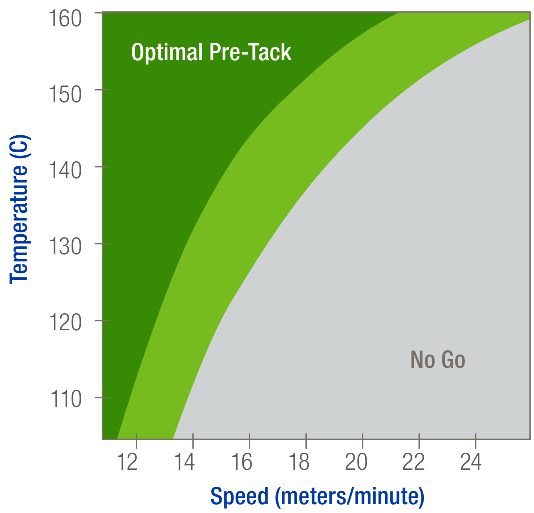
Not only is the process of using Flexel reactive film adhesives simpler and cleaner, it also has the added advantage of reducing factory footprint. We estimate a lamination line using Flexel can reduce factory floor space by up to 80 percent compared to 2K water-borne process.



Flexel reactive film adhesives (RFA) can be pre-attached to foils. The RFA softens and becomes tacky at 45 to 55°C, but onset of cure does not occur until 75 to 110°C. This allows the user to pre-attach the film adhesive to the foil without initiating cure. Pre-attached adhesives remain stable for several months, depending on the foil. Using film adhesive also eliminates the need for drying ovens in the trim assembly operation, eliminating valuable floor space and saving energy in the process. As the RFA is pre-attached to foils, the process can be done in advance of the final lamination process. Pre-attachment can even be done in a completely separate location, enabling adhesive attachment to move up the value chain and be done by tier 2 suppliers.

Pre-attachment of RFA can be accomplished with a short cycle heated press, or in a continuous process using a hot roller. Continuous processes are a convenient way to pre-attach RFA to foil roll stock and later die cut to size.

Pre-Attaching Flexel™ RFA

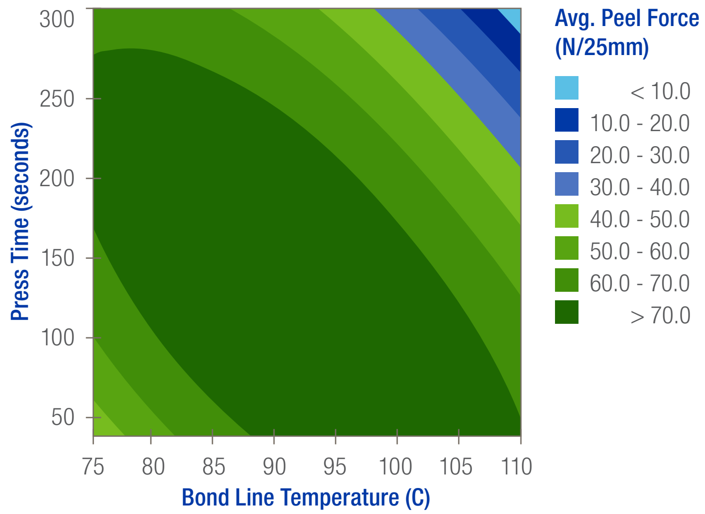


The chart above illustrates the pre-attaching processing window for Flexel™ RFA. Flexel is supplied in roll form with a siliconized paper release liner. The film can be hot nipped with heated rollers to TPO foil roll goods in a continuous process, then rewound and stored for later use. Pre-attaching is done at a temperature that softens and attaches the film but does not activate it. The dark green area in the chart illustrates optimal processing window for nip roll temperature and roller speed. Foils with pre-attached Flexel, can then be die cut to size. The protective release liner is removed immediately prior to final bonding to ensure a clean defect-free part.

As shown in the chart below, final bond performance depends on the processing parameters used to make the bond. Peel strength is a good way to measure bond quality. In tests, a flexible nylon fabric was bonded to rigid polycarbonate substrate using Flexel FN1000. Samples were prepared over a range of bond line temperatures and times at a constant 0.22 MPa pressure. Ideal performance of this grade of Flexel was achieved in the dark green area of the chart. It's interesting to note that more temperature is not always better; at bond line temperature ≥ 110°C during cure, the peel strength of this grade of Flexel FN1000 drops.

FN1000-50 Cure Activation DoE

Peel Strength PC to Nylon



Flexel cures quickly during the heating cycle, and full strength typically develops after the RFA has been allowed to cool and recrystallize. Testing has shown that maximum shear strength on a polycarbonate-to-polycarbonate bond of FN1000 develops approximately 30 min after bonding and is not affected much by ambient conditions.

This fast cure is a significant benefit. It reduces process lead time, allowing the customer to reduce inventory of finished goods to meet their own customer lead time requirements. Depending on ambient temperatures, 2K WB systems typically take 24 to 72 hours to build full strength. Flexel's reduced lead time lets the manufacturer reduce work in progress time and the cost associated with holding inventory, while maintaining a high level of service to their customer.

Performance on Automotive TPO substrates

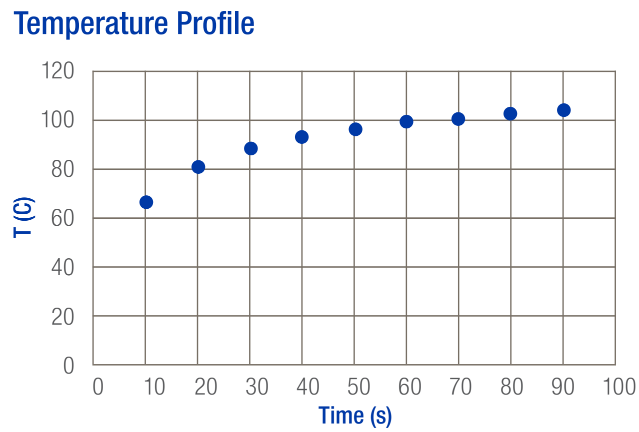
Automotive grade TPO was bonded with Flexel™ FN1000 to screen for performance on a variety of rigid materials including ABS/PC blends, PC (polycarbonate), and plasma treated polypropylene (PP). Primed and unprimed TPO foil were both tested in the screening study. Typically we observed adhesion failure to unprimed TPO, so the data presented below is exclusive to primed TPO.

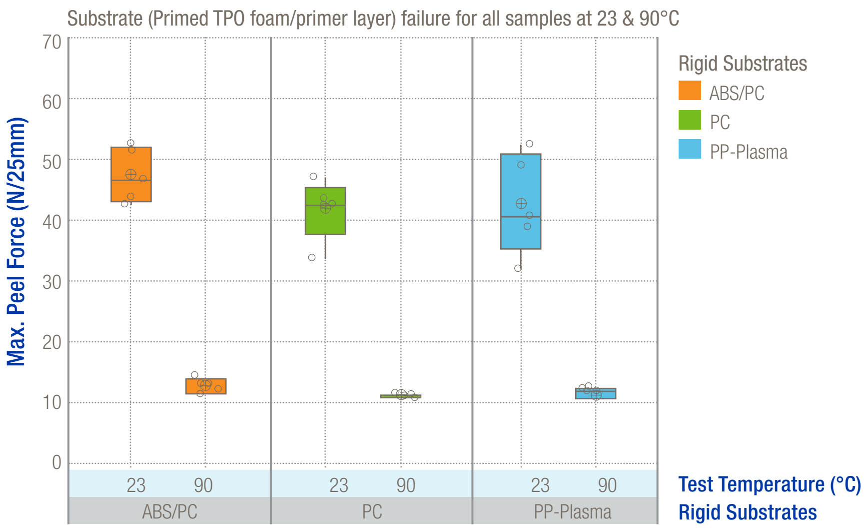
Study 1:

For Study 1, we laminated the primed TPO directly to rigid materials using a hot press. Bonds were prepared by pressing the parts for a total of 90 seconds at 0.05 MPa. The actual bond line temperature was measured using a thin thermocouple and a typical temperature profile is presented below.

From the graph we see the bond line temperature (BLT) between 90 and 110°C was achieved for about 60 seconds. Bonds were then conditioned for 24 hours at 25°C and 50 percent relative humidity (RH) before 180°C peel testing.

Peel strength was tested at 25 °C and 90 °C. In all cases we observed TPO failure.



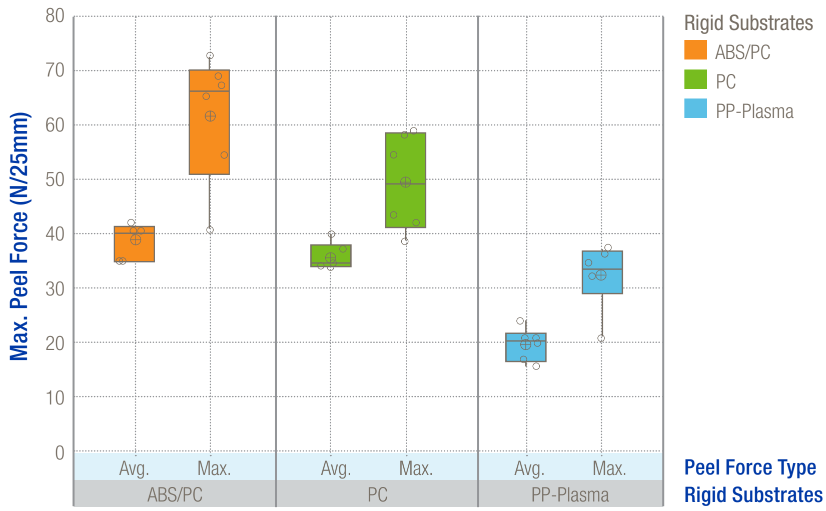


Failure mode of laminations of primed TPO to ABS/PC with Flexel FN1000 after peel testing at 25°C, which is typical of all the rigid substrates, including PC and plasma treated PP, tested this way.

Failure mode of primed TPO to ABS/PC laminated with Flexel FN1000 and peel tested at 90°C, again typical of the failure mode we observed on other rigid substrates.

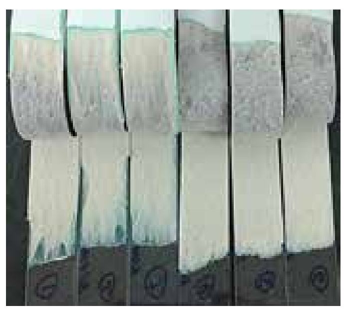
Study 2:

For Study 2, the Flexel™ FN1000 was pre-attached to the primed TPO foils. The film was pre-attached to the TPO using a hot nip at a speed of approximately 12 meters/min and roll temperature of 125°C. Primed TPO with pre-applied Flexel FN1000 laminated to rigid ABS/PC, PC, and plasma treated PP subsets were prepared the next day, and peeled after conditioning for 24 hours at 25°C, 50 percent RH. Bonds were prepared by pressing the parts for a total of 90 seconds at 0.05 MPa. BLT between 90 and 110°C was achieved at about 60 seconds (refer to temperature profile plot shown in Study 1 section). In this data set we observed slightly different results.

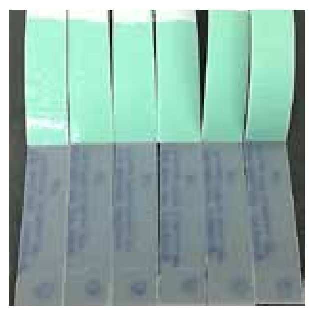


The data to the left show maximum and average peel force for materials tested at 25°C. On ABS/PC and PC substrates we observed TPO failure; however, when testing the plasma treated polypropylene at room temperature we observed adhesion failure to the plasma treated PP.

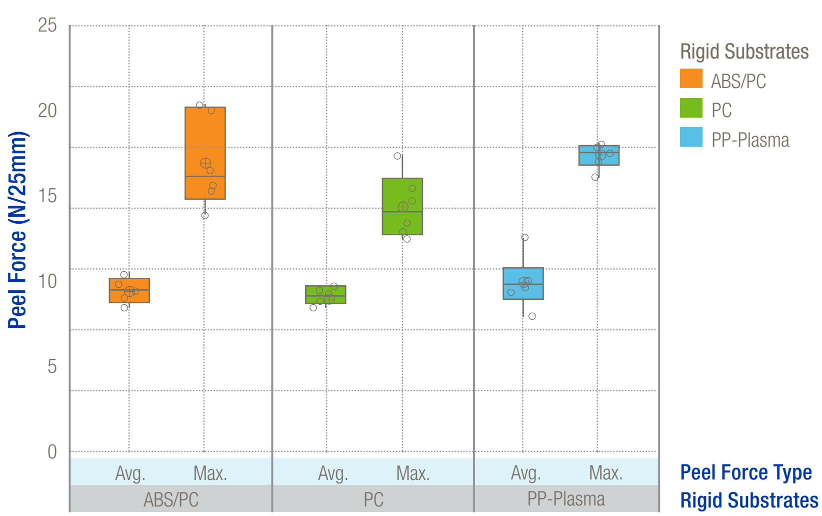
Primed TPO to ABS/PC failure mode at 25°C; TPO failure.



Primed TPO to PC failure mode at 25°C; TPO failure.



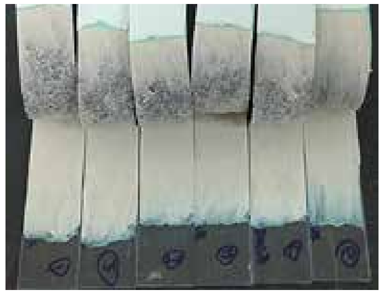
Primed TPO to plasma treated polypropylene failure mode at 25°C; adhesion failure to plasma treated polypropylene.



Interestingly, we observed TPO failure in all cases at the elevated temperatures.

Left: Peel strength data when bonds were tested at 90°C.

Failure mode on ABS/PC at 90°C.



Failure mode on PC at 90°C.

Failure mode on plasma treated PP at 90°C.

Finally there is the matter of cost. On a cost-per-square-meter basis, film adhesive material is more expensive than 2k water-borne or other adhesives. In considering total cost, however, a film adhesive like Flexel™ has a number of advantages that can compensate for the higher material cost. Reactive film adhesives eliminate the need to spray or roll apply wet adhesives, saving space, time, and labor cost. They eliminate the need for drying, reducing energy consumption, and saving both money and time. They cure quickly and can reduce work in process. Overall, they reduce lead time, and their lower activation temperatures can allow the use of new kinds of material. And finally, by taking the glue application process out of the Tier 1 supplier assembly operation and moving it up stream to the foil producer, they can support overall better efficiency in the entire process. All of these potential benefits make Flexel RFA an intriguing potential solution of interior automotive trim lamination, and one worth exploring further.