METHOD FOR SCREENING THE MINIMUM APPLICATION AND SERVICE TEMPERATURES OF PRESSURE SENSITIVES

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With decreasing temperature, pressure sensitive adhesives first lose tackiness and the ability to wet out onto substrates, then lose the toughness to effectively resist mechanical stresses. Many applications, including tapes for exterior building and construction and labels for frozen foods, require that pressure sensitive products can be both applied and serve at low temperatures without failure. The minimum application and service temperatures of an adhesive are often estimated from the rheological glass transition temperature (T_g), but this method is far from an industry standard and fails to account for differences in tape construction, environmental conditions, and application surface. This study proposes a straightforward method to screen the minimum application and service temperatures of a pressure sensitive adhesive with a selected construction and application surface. Here, hand peels of a paper label construction on corrugated board are compared to rheological measurements of the T_g across a range of adhesive technologies to demonstrate the value of a minimum application and service temperature test method that reflects real world usage. Wider implementation of this method will allow for better selection of pressure sensitive products according to the end-use application.

For this paper, we will be focusing on two key temperature related performance metrics. The first being an adhesive's minimum application temperature and the second being their minimum service temperature. An adhesive's minimum application temperature is the lowest temperature at which the adhesive can be effectively applied onto a substrate. The adhesive's ability to wet-out is significantly impacted once temperatures below this threshold are reached. The minimum service temperature is the lowest temperature at which an adhesive is able to maintain it's adhesive properties after being applied to the substrate. The adhesive is likely to become brittle and detach from the surface below the minimum service temperature.

Minimum service and application temperature are dependent upon many factors including the chemistry of the adhesive, adhesive coatweight, the face stock, and the intended application. It is because of these variety of factors that the adhesive's glass transition temperature (T_g) is frequently utilized to predict the adhesive's low temperature performance. There are limited options for a standardized method which evaluates performance at lower temperatures. FINAT FTM 9 – Quick Stick (Peel Adhesion at Low Temperatures) is one of the few options that exist. However, these standardized methods do not simulate realistic application conditions. While standardized methods are valuable for benchmarking products, we believe that hand peels would be a better choice for practical evaluations. In addition to the practicality of using hand peels, they are also more cost effective. Standard tests require specialized equipment, controlled environments, and extensive sample preparation.

Based on this situation, the goal of this work was to develop a simple screening method for minimum service and application temperature that could be implemented in a number of testing labs. This method can then be adopted to a wide range of different face stocks, substrates, and applications.

Equipment and Set-Up

We focused on the following factors to develop our new method:

- Our ability to condition and test in a wide low temperature range (40°F through -40°F)
- A standardized face stock and panel for our benchmarking
- Standardizing the adhesive coat weight we would be evaluating

To condition our samples, we used a traditional chest freezer. This was done to maintain a low-cost approach to this method. The top of the chest freezer was lined with PE film to better insulate the freezer while it was open.

Figure 1. Top-Down Image of The Chest Freezer Used

Paper labels were run on a standardized corrugate board for our initial benchmarking. The adhesives were then coated at 1 mil using any suitable coater. The samples were coated onto release liner and then transferred onto the paper stock. Below is an image of a representative hand peel sample.

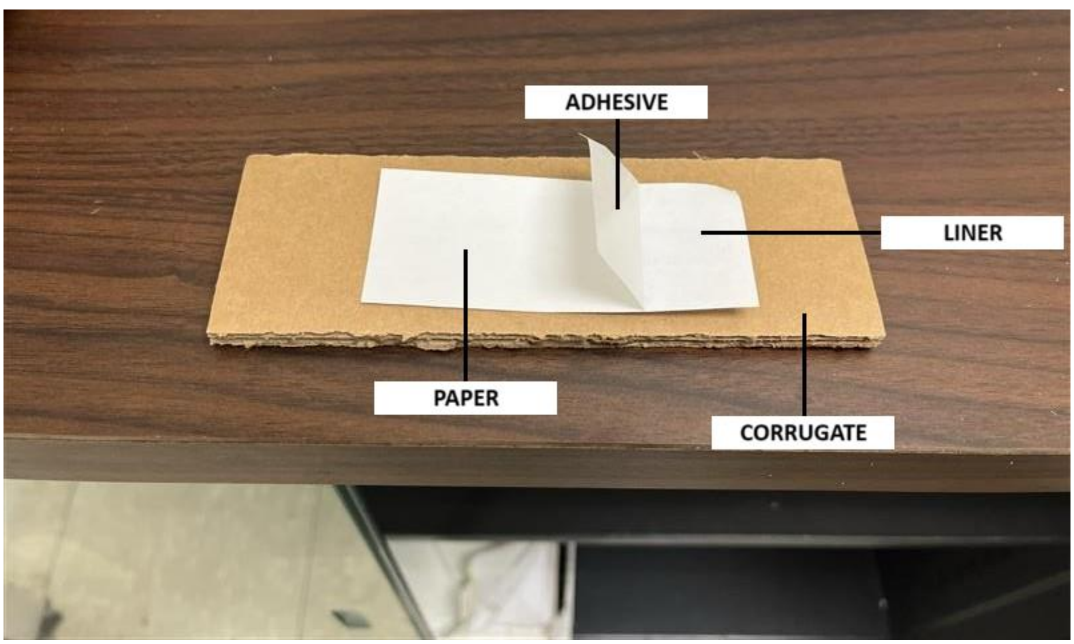

Figure 2. Example of The Paper Label on Corrugate.

Low Temperature Testing Methodology

Temperature testing was conducted at -20°F as a baseline. If the adhesive performed well at this temperature, then the temperature would be lowered by an additional 10°F and a new sample would be tested again; however, if the adhesive performed poorly, the temperature would be increased by an additional 10°F and a new sample would be tested again. Paper labels were prepared by coating adhesive onto a release liner and then laminating the sheet onto standard copy paper. These sheets were then cut into 3.5”x1.5” (machine direction x cross direction) labels.

For minimum service temperature testing, the paper label and corrugate board were conditioned at room temperature prior to testing. The paper label is then applied onto the corrugate using light finger pressure at room temperature. The samples were allowed to dwell at room temperature for 30 minutes. The completed paper label and substrate construction is then placed into the conditioned freezer for 24 hours. After the designated conditioning time, cotton gloves are worn, and the paper labels are peeled at a 30° angle at a moderate and consistent rate inside of the freezer. The paper labels are then rated either a pass or fail depending on the amount of resistance felt. A failed paper label will either fall off during conditioning or pop off during the peel. Figure 4 shows a passing paper label which remains attached throughout the entire peel. This state would not be possible for a label with a failing rating as it would have already popped off.

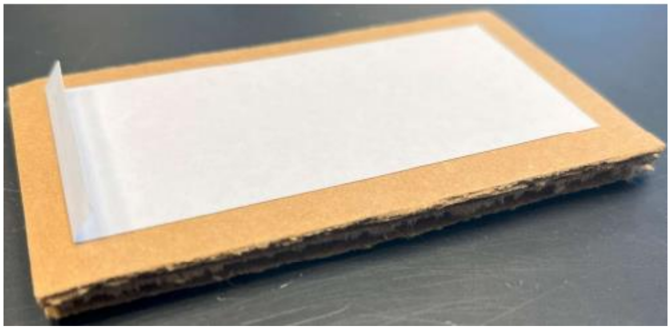

Figure 3. A Completed Paper Label And Substrate Construction

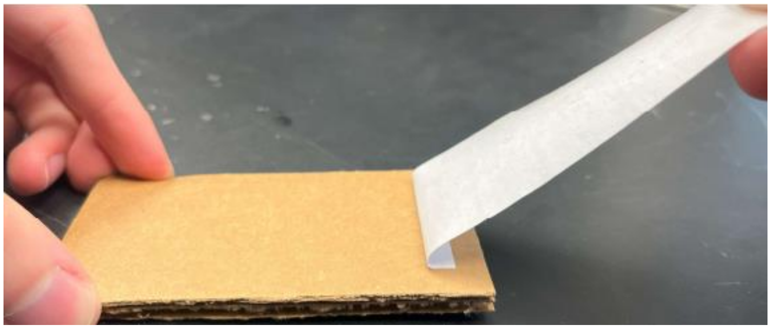

Figure 4. Image of a Passing Label Remaining Adhered Throughout The Full Peel

There are subtle differences for testing the minimum application temperature. The same size samples are used and the same substrate is as well. However, these samples are conditioned *separately* at the desired temperature prior to being applied. The paper label and substrate are conditioned for 30 minutes at the lower temperature, the label is then applied inside of the freezer via light finger pressure, and the samples are conditioned for an additional 30 minutes inside of the freezer. The label is then peeled by hand and rated using the system described.

Adhesive Selection for Testing

Table 1 depicts the commercial grade adhesives selected for this preliminary screening. These adhesives were selected so we would cover a wide range of pressure sensitive technologies.

Table 1. Adhesive Selection for New Screening Method

Adhesive	Technology	Comments
Adhesive A	UV Acrylic	General purpose adhesive
Adhesive B	UV Acrylic	Low Temperature PSA
Adhesive C	UV Acrylic	Removable PSA
Adhesive D	WB Emulsion	General purpose adhesive
Adhesive E	WB Emulsion	Low Temperature PSA
Adhesive F	WB Emulsion	Removable PSA
Adhesive G	HM Rubber	General purpose adhesive
Adhesive H	HM Rubber	Low Temperature PSA
Adhesive I	HM Rubber	Removable PSA

Results

Table 2. illustrates the performance of the various adhesives at lower temperatures. This set of data was generated using the paper label and corrugate substrate depicted in Figure 3. From this data, it was observed that the minimum service temperature of these adhesives is much more robust than the application temperature. However, -40°F was the lower limit of our freezer's temperature range. A differentiation could have been observed if the samples could have been tested at lower temperatures. Exposing the adhesive to colder temperatures does not have as much of an impact once the bond has formed at room temperature. However, the minimum application temperature, when the bond is formed at lower temperatures, is where we begin to see differentiation between products developed for lower temperature applications. The materials designed for lower temperature, as well as the removable grades, performed better than the general-purpose adhesives of the same chemistry. This was key for us in continuing to develop this method, since this differentiation was observed across all three chemistries evaluated.

Table 2. Minimum Service & Application Test for Adhesives Screened

Adhesive	Min Service Temp (°F)	Min Application Temp (°F)
Adhesive A	-40	20
Adhesive B	-40	0
Adhesive C	-40	-10
Adhesive D	-40	10
Adhesive E	-40	-10
Adhesive F	-40	-10
Adhesive G	-40	30
Adhesive H	-40	10
Adhesive I	-40	-20

Based on these results, we decided to compare the findings on the minimum application temperature to the glass transition temperature of the adhesive. The T_g shown in Table 3 were all obtained via DMA. From this comparison depicted in Figure 5, it is clear that the T_g of the adhesive does not translate directly to the adhesives performance at lower temperatures. The glass transition temperature can serve as a predictive method, but depending on the end user's substrates and facestock, this is where the new screening method can bring additional value.

Table 3. Comparing T_g vs Min Application Temp of Adhesives Screened

Adhesive	Min Application Temp (°F)	T_g (°F) via DMA/rheology	T_g (°F) via DSC
Adhesive A	20	10	-12
Adhesive B	0	-36	-62
Adhesive C	-10	-23	-45
Adhesive D	10	-29	-60
Adhesive E	-10	-38	-61
Adhesive F	-10	-40	-69
Adhesive G	30	53	-25
Adhesive H	10	10	-54
Adhesive I	-20	-27	-61

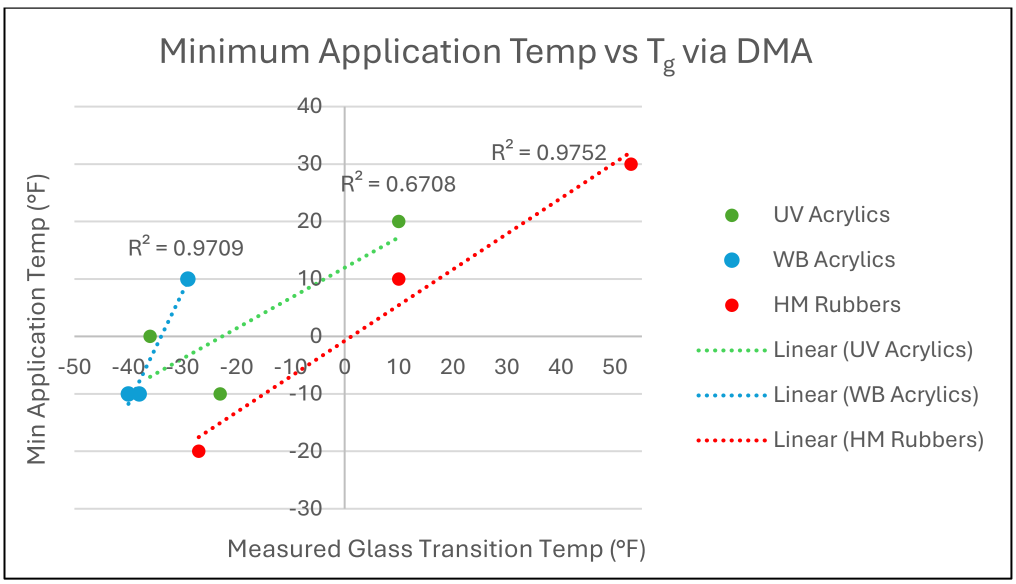

Figure 5. Comparing Minimum Application Temperature to T_g obtained via DMA

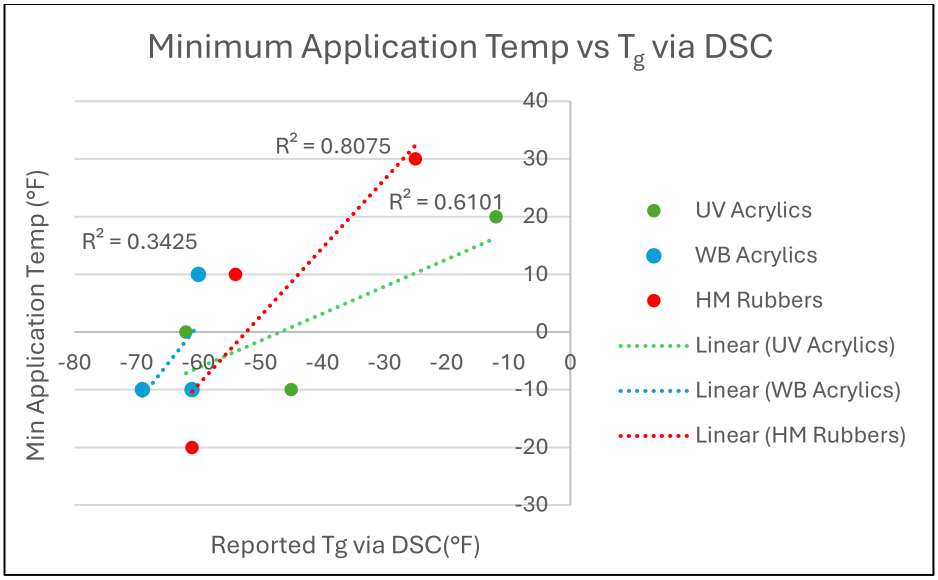

Figure 6. Comparing Minimum Application Temperature to T_g obtained via DSC

From Figure 5 and 6 we can determine that the T_g may work as a better predictor for specific technologies. The rubber hotmelts seemed to show minimal disparity between their T_g and the minimum application temperature determined via this screening method. This could be due to the rubber hotmelts more aggressive nature and having higher initial tack. These samples are dwelled for 30 minutes prior to being evaluated for their application temperature, so that initial tack could impact the result significantly.

Due to the limited sample size, a broader range of adhesives were then tested via this method to determine if the Tg could be used as an effective predictor for real world performance.

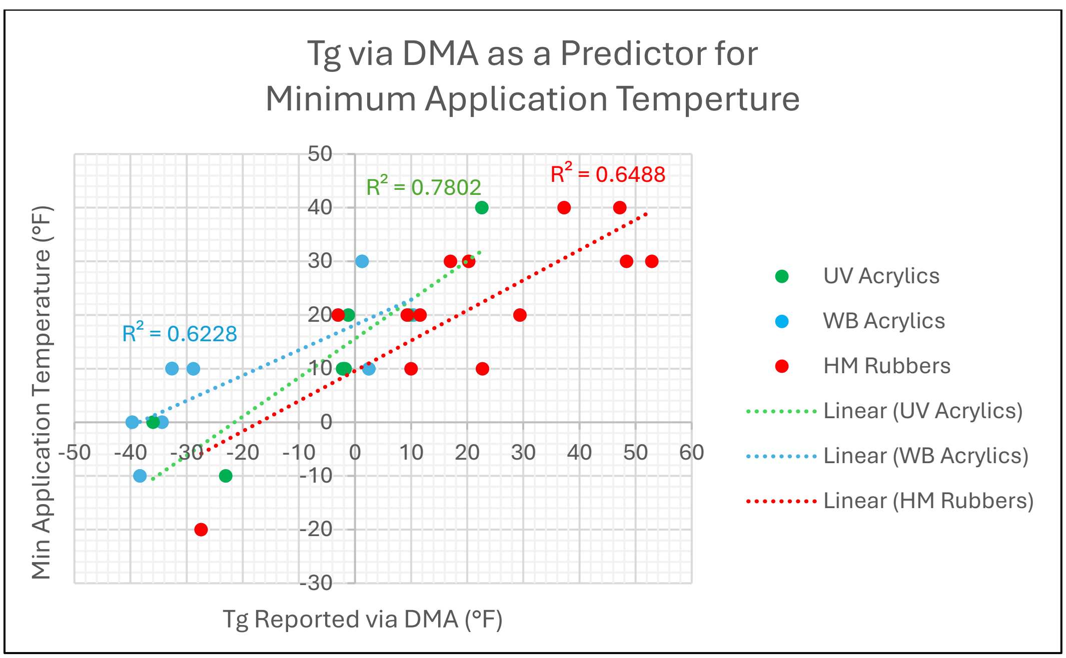

Figure 7. Broader range of adhesives tested via this method and then compared against their T_g via DMA

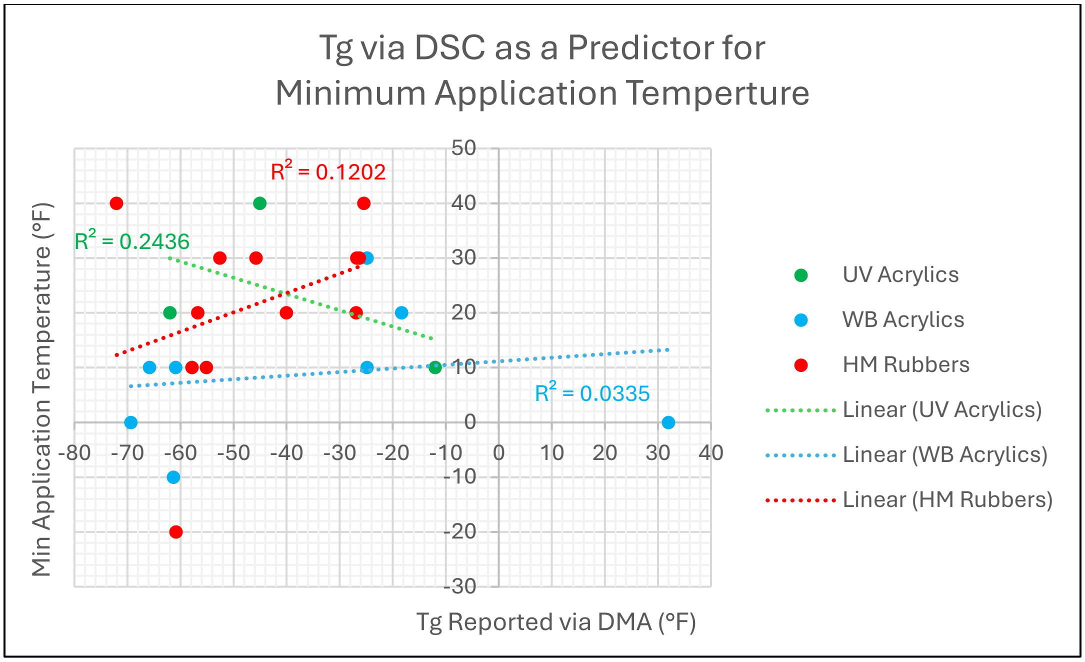

Figure 8. Broader range of adhesives tested via this method and then compared against their T_g via DSC

Based on Figures 7 and 8, we can conclude that for this data set, the Tg of the adhesive obtained via DMA is a better predictor for real world performance. The minimum application temperature data shows little to no correlation to the DSC results.

Future Work

The substrates utilized for specific applications are crucial. This method was developed around the use of paper labels on corrugate board and would need to be tailored to the specific substrates being used. For example, for tape applications, are able to modify the face stock and the panel to customer specific materials. Currently, work is being done to evaluate this method using PET face stock and plywood panels. The principles of the method would be the same, and in this case, the amount of resistance required for a pass/fail may be easier to detect due to the possibility of wood fibers being plucked as the hand peel is conducted.

Conclusions

1. We have developed a simple and cost-effective screening method for determining the minimum service and application temperature of pressure sensitive adhesives.
2. The service temperature of the PSAs tested were determined to be significantly more robust than the application temperature of the material.
3. Practical testing is crucial for determining the performance of the adhesives at these lower temperatures. Evaluating them under real world conditions is valuable as the T_g did not accurately predict performance for these materials.

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