Commercial Solutions Division

Applied Lifting of 3M™ Print Wrap Film IJ280 and 3M™ Gloss Wrap Overlaminate 8428G

Technical Report

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Contents

Introduction and Background

A novel test method was developed to characterize the lifting performance for print wrap films. The new 3M™ Print Wrap Film IJ280 with 3M™ Gloss Wrap Overlaminate 8428G (IJ280 + 8428G) were designed to provide superior resistance to lifting from recesses on vehicles. IJ280 + 8428G was proven to lift 2X less lifting than other industry leading overlaminated print wrap films.

Films with complex and varying features/properties, such as adhesion and conformability, yield a varying response in their ability to resist lifting. Balancing the final stress of a polymer, such as plasticized PVC, after undergoing stress relaxation [1], and the ability of the adhesive to initially and permanently anchor film to a vehicle can be described. Balancing these properties can be used to design superior product for vehicle wrap application. We needed to develop a representative test method to describe real world applications that encompassed the culmination of these properties.

We observed lifting on vehicles where installers attempted to stretch films either with or without the aid of hot air or heat gun. This included areas where a graphic was not sufficiently post heated. The areas with insufficient post heating could result in higher stress on the film and/or insufficient bonding to the vehicle and in turn may result in lifting. In some instances, installers cold stretched films with the aid of a low friction application glove. One location this was frequently observed was on the rear quarter panel of a Chevy HHR (General Motors, Chevrolet HHR, 2011). In this location the engineering strain during installation of the graphic was estimated to be 5%.

Figure 1. Rear quarter panel of 2011 Chevy HHR indicating representative location for conformability experiential testing.

We explored the feature by screening lifting factors by applying various graphic films and testing the amount they lifted (see Figure 2). To control the test substate and environment we developed a test method closely mimicking the critical factors to evaluate lifting. Some of the critical factors included application technique, temperature during stretch, post heating, geometry, and post application conditioning temperature/humidity.

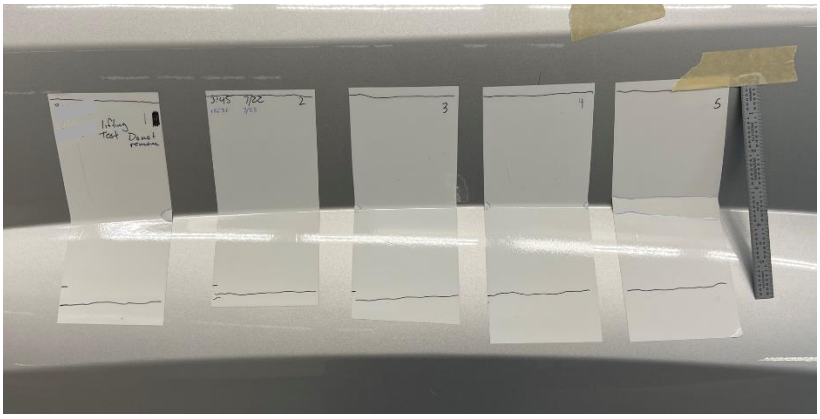


Figure 2. Example of test panel showing 5 film combinations evaluating lifting on the rear quarter panel of a Chevy HHR. Example films 1-5 were example combinations of print films and overlaminates used to explore lifting. Samples

with a were applied with an application squeegee and a 3M™ Roller Small (part number DR500010878; 3M. St. Paul, MN) without the use of heat for stretch post heating.

Experimental Procedure

A variety of films were prepared for evaluation by the novel Applied Lifting test method (see Appendix B). Comparative industry leading print wrap films were chosen for their prevalence in the marketplace (see Table 1). Samples were tested and results recorded for analysis.

Table 1. List of film pairs tested.

	Product Name	
Short Name	Print Film	Overlaminate
IJ180mC + 8518	3M™ Controltac™ Print Wrap Film IJ180mC-10	3M™ Scotchcal™ Gloss Overlaminate 8518
IJ180Cv3 + 8518	3M™ Controltac™ Graphic Film with Comply™ Adhesive IJ180Cv3-10	3M™ Scotchcal™ Gloss Overlaminate 8518
IJ280 + 8428G	3M™ Print Wrap Film IJ280	3M™ Gloss Wrap Overlaminate 8428G
1105 EZRS + 1460Z	Avery Dennison™ MPI1105 SuperCast Easy Apply RS	Avery Dennison™ DOL 1460Z Gloss Overlaminate
SLX + 3210	Arlon™ SLX™ Cast Wrap	Arlon™ Series 3210 Premium Cast Overlaminate

Samples were prepared by laminating a clear overlaminate to an unprinted wrap film. Lamination was completed on a 76.2 cm {30 inch} wide rubber roll laminator at approximately 1.8 meters {6 feet} per minute at 550 kPa {80 psi} laminator input pressure. Care was taken to minimize the input and output lamination tensions. Each sample was cut to 76.2 mm {3.0 inches} wide strips. Samples were cut from adjacent sections of the film to minimize thru roll contributions to variation.

Ten films from 3 lots of each laminated print film and overlaminate film combination were measured for 30 total measurements. Further details can be found in Appendix C. Films were measured in random order.

Analysis Procedures

Data was analyzed with Minitab 19.2020.1 (Minitab, LLC. State College, PA, USA).

Minitab was used to determine if any print film with overlaminate film pair was statistically the same or statistically different than other film pairs. One-way ANOVA with Tukey pairwise comparison was used to identify groups. Grouping by the Tukey pairwise method identified groups either statistically the same or statistically different with a 95% confidence interval (null hypothesis: all means are equal).

The lifting resistance comparison was calculated (1) by the ratio of l_x^{min} , the lower end of the 95% confidence interval for a given film pair divided by the upper end of the 95% confidence interval for a film pair of interest l_i^{max}.

$$R = \frac{l_x^{min}}{l_i^{max}} \quad (1)$$

Results and Discussion

Individual value plot of all data was plotted for visual examination of the results. Visual examination of the individual value plot shows the distribution of lifting by the applied lifting test method (Figure 3).

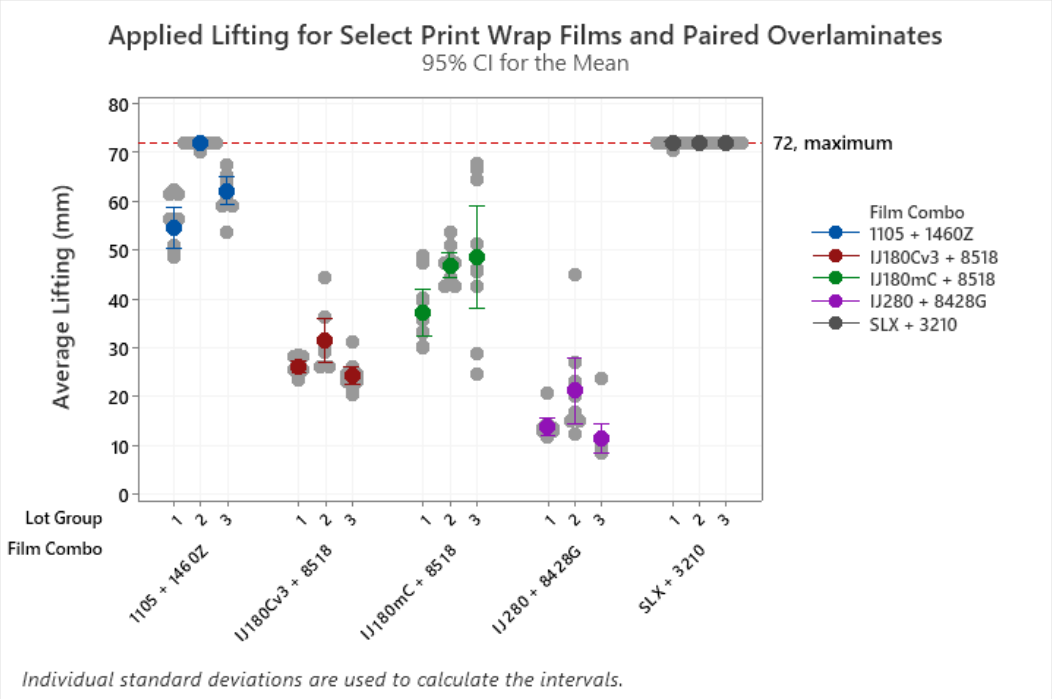


Figure 3. Individual value plot of each film pair organized by product and lot.

The analysis of variance, Tukey pairwise comparison and residuals were reported for the each of the individual film pairs and IJ180Cv3 + 8518, IJ180mC + 8518, 1105 + 1460Z, SLX + 3210 grouped as one comparative population.

Pairwise Comparative Assessment

Examination of the results for the films measured showed the analysis of variance with a P-Value of 0.000, which indicated that we had multiple groups. The new IJ280 + 8428G combination of print wrap film and overlaminate had the lowest average lifting. Each of the film combinations were separated into separate groups.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Film Combo	4	67004	16751.0	329.53	0.000
Error	145	7371	50.8		
Total	149	74375			

Means

Film Combo	N	Mean	StDev	95% CI
1105 + 1460Z	30	62.76	8.21	(60.19, 65.33)
IJ180Cv3 + 8518	30	27.076	4.660	(24.503, 29.648)
IJ180mC + 8518	30	44.17	10.54	(41.60, 46.74)
IJ280 + 8428G	30	15.46	7.33	(12.89, 18.03)
SLX + 3210	30	71.9467	0.2921	(69.3739, 74.5194)

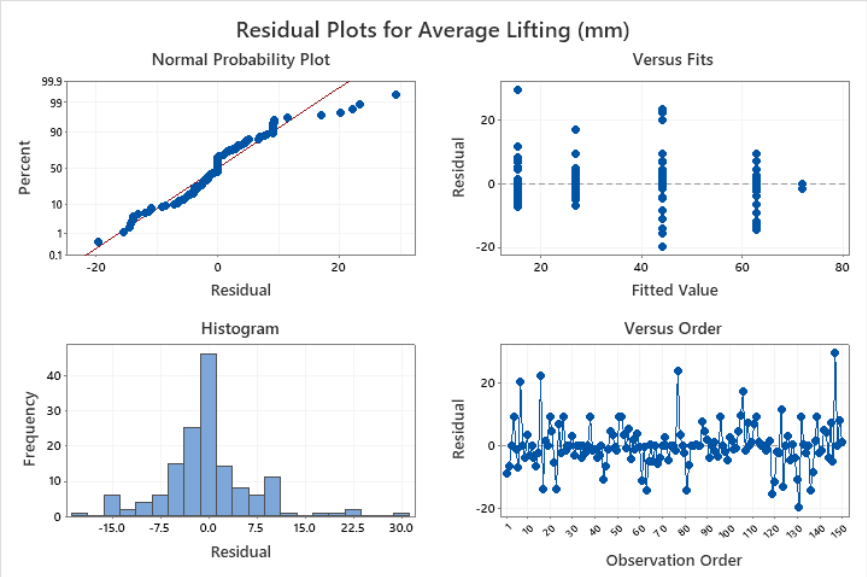
Pooled StDev = 7.12968

Grouping Information Using the Tukey Method and 95% Confidence

Film Combo	N	Mean	Grouping
SLX + 3210	30	71.9467	A
1105 + 1460Z	30	62.76	B
IJ180mC + 8518	30	44.17	C
IJ180Cv3 + 8518	30	27.076	D
IJ280 + 8428G	30	15.46	E

Means that do not share a letter are significantly different.

The residual plots validated the experiment execution sample preparation and random measurement order with a normal distribution.



See Appendix D for complete summary of results.

Grouped Comparative Assessment

Next, we extracted the 95% confidence interval around the mean for comparative films measured as one group.

Means

All but {IJ280 + 8428G} Films	N	Mean	StDev	95% CI
≠ IJ280 + 8428G	120	51.49	18.71	(48.40, 54.57)
IJ280 + 8428G	30	15.46	7.33	(9.29, 21.63)

Pooled StDev = 17.0893

The lifting resistance was compared for each of five films and with the grouped results (see Table 2). IJ280 + 8428G showed the least amount of lifting compared to other products ranging from 1.3X less lifting than IJ180Cv3 + 8518 up to 3.8X less than SLX + 3210. The aggregated ratio showed IJ280 had 2.2X less lifting than other similar products.

Table 2. Lifting ratios of film combinations.

l_x^{min} \ l_i^{max}	IJ280 + 8428G	IJ180Cv3 + 8518	IJ180mC + 8518	1105 + 1460Z
SLX + 3210	3.8	2.3	1.4	1.0
1105 + 1460Z	3.3	2.0	1.2	
IJ180mC + 8518	2.3	1.4		
IJ180Cv3 + 8518	1.3			

≠ IJ280 + 8428G	2.2

Some of the films measured at the maximum lifting value for the range of the test [72 mm {2.8 inches}.] Nearly all the SLX + 3210 films and some of the 1105 + 1460Z lifted completely to the limit of the test method.

Summary and Conclusions

The ability of a film to remain seated in vehicle grooves, recesses, and around complex curvatures after application is an important feature to prevent rework and preserve the aesthetic of the vehicle wrap. Installers may post heat vehicle graphics to relax film stress and build adhesive bonds but if a section was not sufficiently post heated then graphics may lift. We developed a novel test method that mimics lifting performance in real world applications. The new 3M™ Print Wrap Film IJ280 with 3M™ Gloss Wrap Overlaminate 8428G exhibited the least amount of lifting with the novel test method. IJ280 + 8428G showed 2.2X less lifting than other leading industry print wrap films for vehicles.

References

[1] K. P. Mendard, "Rheology Basic Creep-Recovery and Stress Relaxation," in *Dynamic Mechanical Analysis*, New York, CRC Press, 2008, pp. 37-56.

[2] "Instruction Bulletin Deep Recess, Release B," 3M, [Online]. Available: https://multimedia.3m.com/mws/media/1241530O/applying-graphics-to-deep-recesses-and-channels.pdf.

Appendices

Appendix A. Acronyms & Definitions

Acronym	Definition
CTH	Constant Temperature and Humidity
CSD	3M™ Commercial Solutions Division

Appendix B. Test Method Procedure

Equipment and Materials

1. Test film
2. Test panel from ACT Test Panels LLC. Hillsdale, MI, USA. Item number 63246. Coating layers:
    a. EC4027
    b. LP523R
    c. UDCT6466RL
    d. TMAC9000FR
3. Isopropanol
4. Kimwipes
5. PA-1 Gold applicator, bare. 3M. St. Paul, MN, USA
6. Steel ruler
7. Custom end effector tool with 0.65 mm {25 mil} thick suede tape on leading edge
8. Custom panel holder

Procedure

Cut films to 76.2 x 178 mm {3 x 7 inches} oriented so the long axis is in the machine or down web direction of the film.

Whip panels clean with a Kimwipe and isopropanol and dry for a minimum of 15 minutes prior to film application.

Remove the release liner from the film. While holding the film at each end they position the film on top of the test panel taking care not to touch the adhesive in the center of the film or allow the film to stretch or slacken. Aligned the film parallel to the panel near the center (see Figure 4). Tacked in place on the ridges by running a finger along the peaks. Firmly apply the film on the distal faces of the panel with a squeegee.

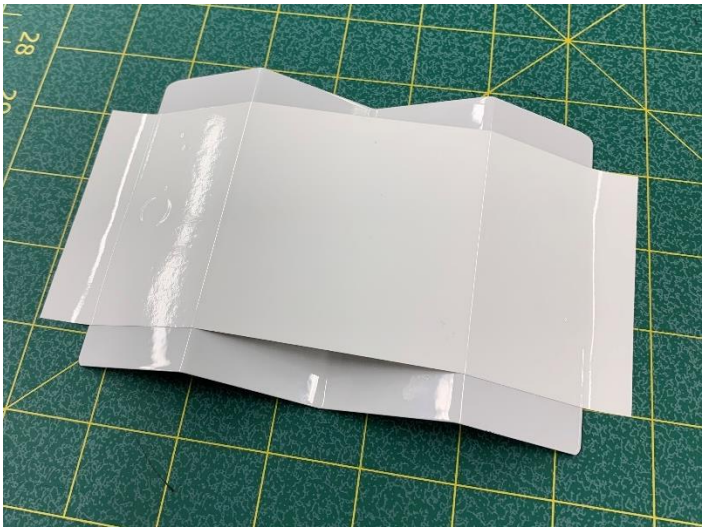


Figure 4. Film laid up on lifting panel prior application.

Press the film into the test panel using an arbor press outfitted with the custom fixture (see Figure 5.) Lower the end effector and seat the film to the bottom of the v-channel of the test panel for approximately 3 seconds. Hold the film in the bottom of the v-channel for 10 seconds with a force of approximately 445 N {100 lbs}. During this time, squeegee the film in place on the proximal faces of the panel with three firm passes on each face. Remove the force. Place the panels in to a CTH environment at 23°C {73°F} and 50% RH for 3 days prior to measurement.

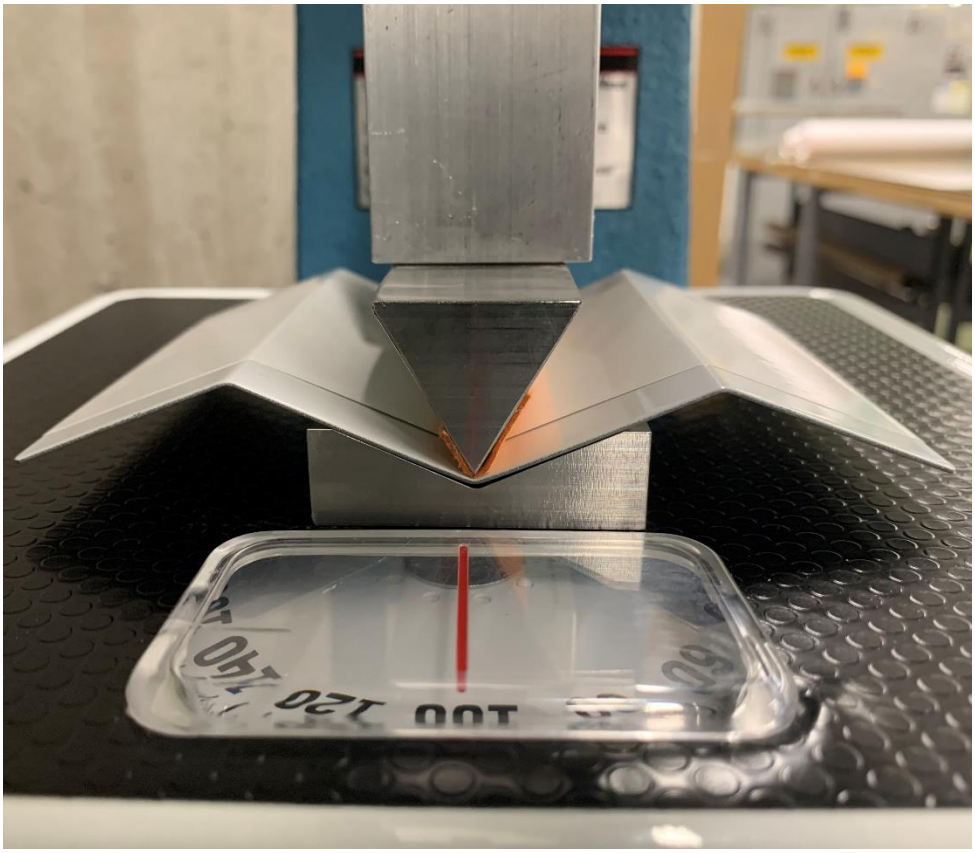


Figure 5. Film pressed into the bottom of v-channel with the lifting resistance end effector.

Record the measurements of the span of lifting at the center, top and bottom of the samples (see Figure 6). Report the average of the three lifting measurements from each panel.

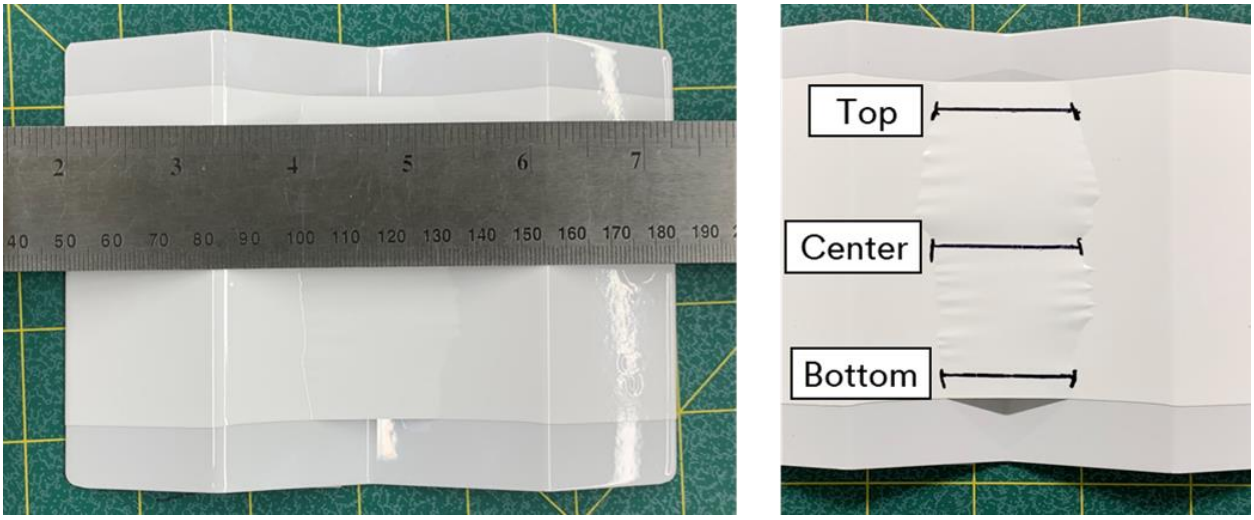


Figure 6. Measurements of lifting were taken with a steel ruler across the gap where the lifted films contacted the panel. Top and bottom measurements were taken 32 mm {1.25 inches} from the center.

Variant 1

To assist in conformability, samples may be heated after being tacked to the ridges of the panel and just prior to stretching the film into the v-channel. This can be accomplished with a heat gun or an oven. For example, samples may be placed in an oven at 50°C {122°F} for 30 seconds just prior to stretching into the grove. If using a heat gun critical factors such as temperature, rate and distance need to be controlled. Film manufactures application recommendations such as heating to 50 – 60°C {120 – 140°F} provide a starting point for exploration for the critical factors [2].

Variant 2

To mimic post heating, samples may be heated after being stretched into the v-channel. This can be accomplished by heating samples to desired temperatures with a heat gun or an oven for given durations. If using a heat gun critical factors such as temperature, rate and distance need to be controlled. Film manufactures application recommendations such as heating to 93 – 107°C {200 – 225°F} provide a starting point for exploration for the critical factors [2].

Precision and Accuracy

MSA on the basic test method without the heating variants consisted of 3 parts with 4 operators and 4 replicates for the primary method. Samples included print films with overlaminates of varying levels of lifting resistance. Lifting measurements were taken 3 days after application. Operators ranged from novice to experienced with this method.

Gage Evaluation

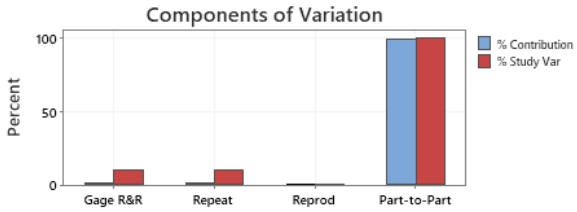
Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	2.7734	16.641	10.32
Repeatability	2.7734	16.641	10.32
Reproducibility	0.0000	0.000	0.00
Part-To-Part	26.7239	160.343	99.47
Total Variation	26.8674	161.205	100.00

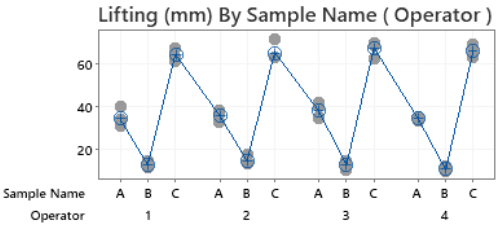
Number of Distinct Categories = 13

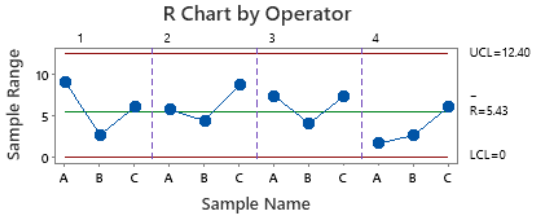
Gage R&R (Nested) Report for Lifting (mm)

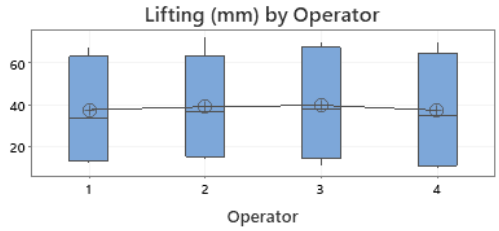
Gage name: Lifting Resistance MSA
Date of study: October 2020

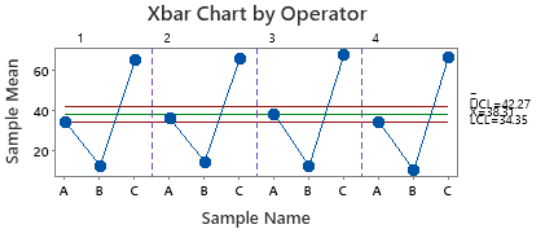
Reported by: Noelle Alexander
Tolerance:
Misc:











Drawings

End Effector

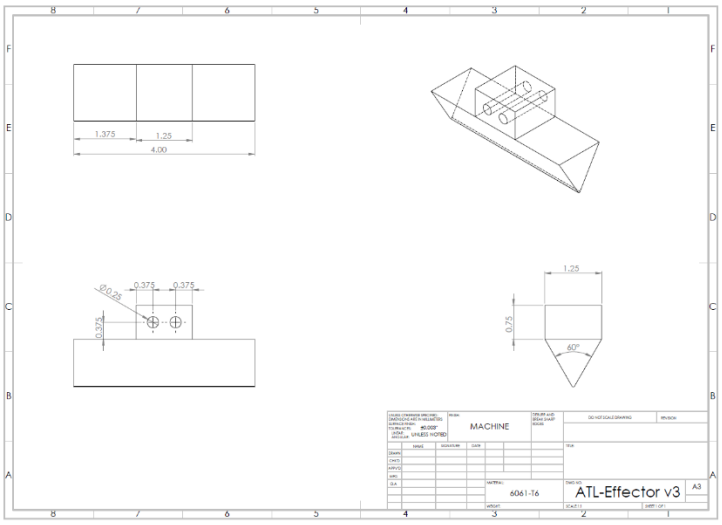


Figure 7. End effector tool used to press film into v-channel.

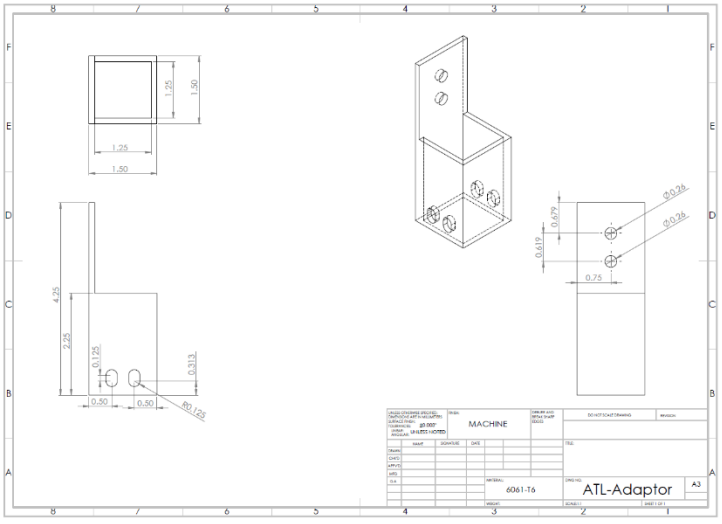


Figure 8. Adaptor connecting end effector to the arbor press.

Receiver

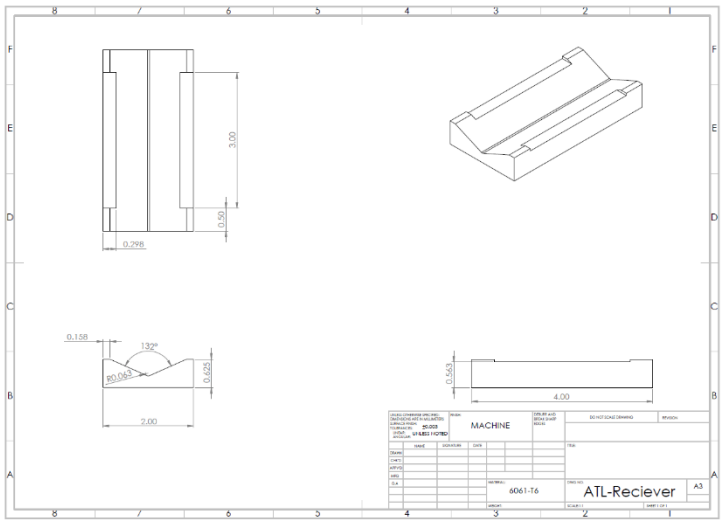


Figure 9. Receiver tool for holding test panels during the application procedure.

Panel Geometry

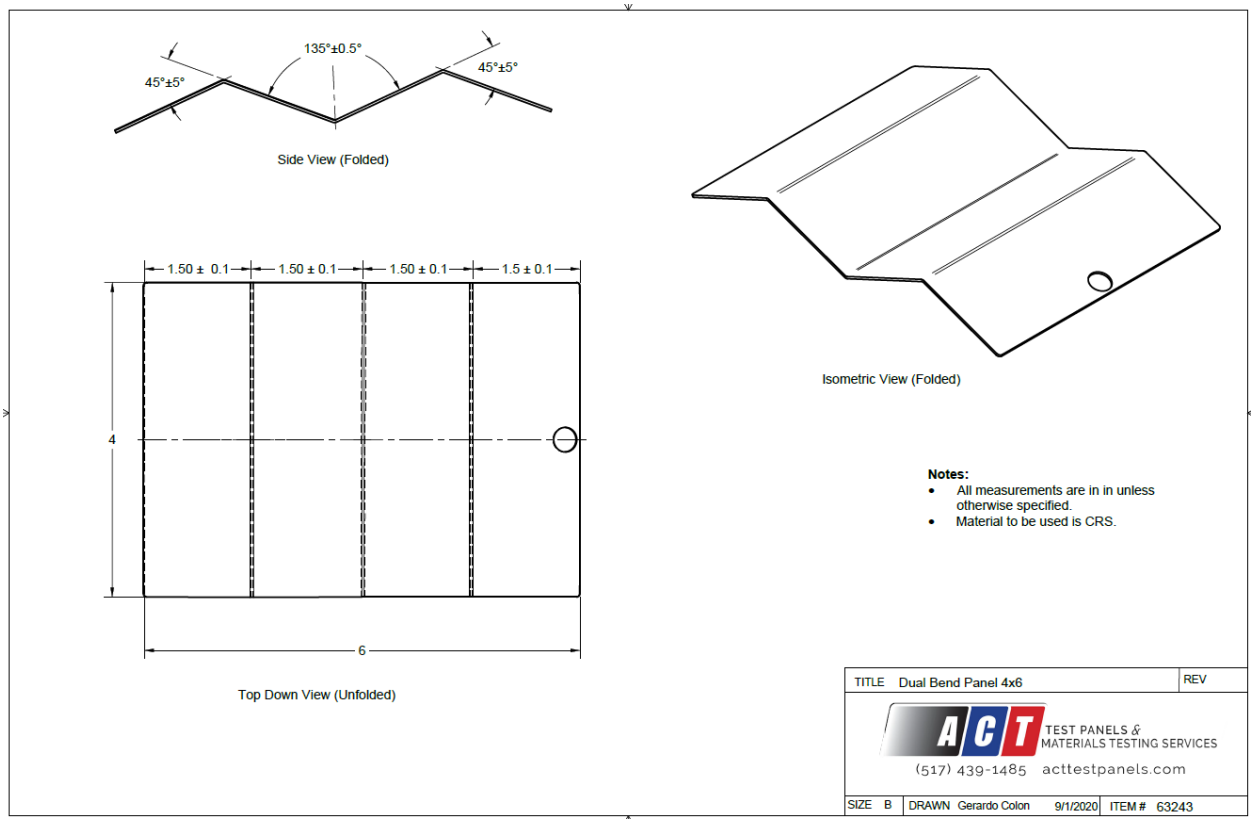


Figure 10. Lifting resistance panel drawing used with permission from ACT Test Panels LLC.

Appendix C. Test Films

Print Film	Lot/Identifier		
	Lot Group 1	Lot Group 2	Lot Group 3
3M™ Print Wrap Film IJ280	A479030	L2024614	L2029408
3M™ Controltac™ Graphic Film with Comply™ Adhesive IJ180Cv3-10	L2001119	L2020308	L2024404
3M™ Controltac™ Print Wrap Film IJ180mC-10	L2016905	L2003305	L2024906
Avery Dennison™ MPI1105 SuperCast Easy Apply RS	ZF2906190L2602111	ZF2906200A2001703	ZF2906200C1000519
Arlon™ SLX™ Cast Wrap	S07160024	S02260104	T07010027

Overlaminate	Lot/Identifier		
	Lot Group 1	Lot Group 2	Lot Group 3
3M™ Gloss Wrap Overlaminate 8428G	G72203	P202400106	P2029401
3M™ Scotchcal™ Closs Overlaminate 8518	P200750318	P202540208	P202640111
3M™ Scotchcal™ Closs Overlaminate 8518	P200030405	P202250119	P202640116
Avery Dennison™ DOL 1460Z Gloss Overlaminate	290E200A080001	ZF2908190G3002103	ZF2906200G2800230
Arlon™ Series 3210 Premium Cast Overlaminate	S04070050	T04200039	S08260122

Appendix D. One-way ANOVA Output

WORKSHEET 2

One-way ANOVA: Average Lifting (mm) versus Film Combo

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Film Combo	5	1105 + 1460Z, IJ180Cv3 + 8518, IJ180mC + 8518, IJ280 + 8428G, SLX + 3210

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Film Combo	4	67004	16751.0	329.53	0.000
Error	145	7371	50.8		
Total	149	74375			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7.12968	90.09%	89.82%	89.39%

Means

Film Combo	N	Mean	StDev	95% CI
1105 + 1460Z	30	62.76	8.21	(60.19, 65.33)
IJ180Cv3 + 8518	30	27.076	4.660	(24.503, 29.648)
IJ180mC + 8518	30	44.17	10.54	(41.60, 46.74)
IJ280 + 8428G	30	15.46	7.33	(12.89, 18.03)
SLX + 3210	30	71.9467	0.2921	(69.3739, 74.5194)

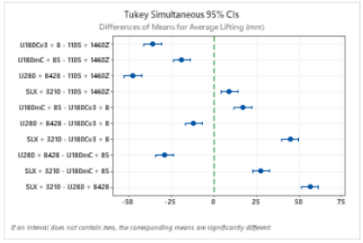
Pooled StDev = 7.12968

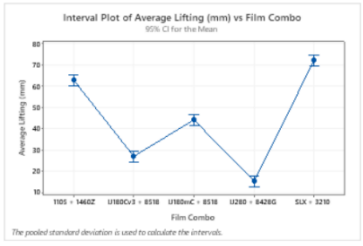
Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Film Combo	N	Mean	Grouping
SLX + 3210	30	71.9467	A
1105 + 1460Z	30	62.76	B
IJ180mC + 8518	30	44.17	C
IJ180Cv3 + 8518	30	27.076	D
IJ280 + 8428G	30	15.46	E

Means that do not share a letter are significantly different.





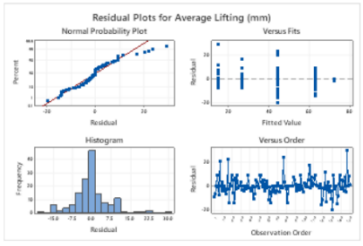


Figure 11. One-way ANOVA with Tukey Pairwise comparison of each film combination.

WORKSHEET 2

One-way ANOVA: Average Lifting (mm) versus All but {IJ280 + 8428G} Films

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
All but {IJ280 + 8428G} Films	2	≠ IJ280 + 8428G, IJ280 + 8428G

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
All but {IJ280 + 8428G} Films	1	31152	31152.0	106.67	0.000
Error	148	43223	292.0		
Total	149	74375			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
17.0893	41.89%	41.49%	40.79%

Means

All but {IJ280 + 8428G} Films	N	Mean	StDev	95% CI
≠ IJ280 + 8428G	120	51.49	18.71	(48.40, 54.57)
IJ280 + 8428G	30	15.46	7.33	(9.29, 21.63)

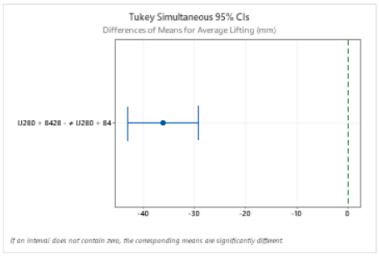
Pooled StDev = 17.0893

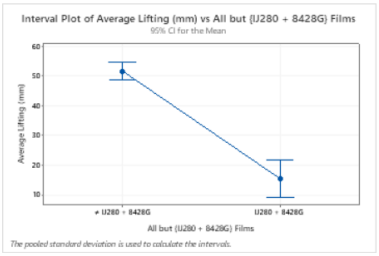
Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

All but {IJ280 + 8428G} Films	N	Mean	Grouping
≠ IJ280 + 8428G	120	51.49	A
IJ280 + 8428G	30	15.46	B

Means that do not share a letter are significantly different.





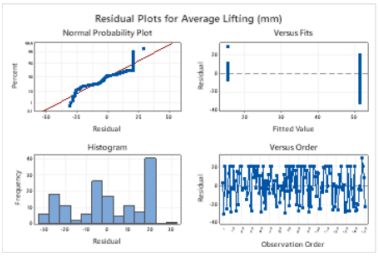


Figure 12. One-way ANOVA with Tukey Pairwise for the grouped comparative assessment.