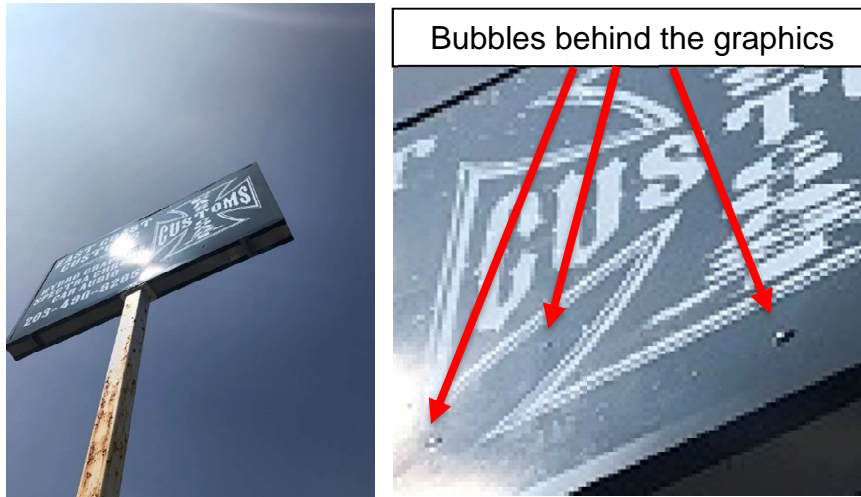




Background Information:

The photo below shows some sign of bubbles in the finished graphics. The substrate material is polycarbonate which was supplied from a polycarbonate supplier.



There may be three explanations for the bubbling:

1. There may be a potential product issue with the adhesive film lifting in specific areas
2. There may have been air trapped during installation process
3. The panel may be outgassing when exposed to higher temperatures

This report will study those three theories and summarize findings.

Products:

Films:

3M™ Scotchlite™ Reflective Graphic Film IJ5100R
3M™ Wrap Film 1080-G10 (White)
3M™ Wrap Film 1080-G12 (Black)
3M™ Scotchcal™ Electrocut™ Graphic Film 7125-10 (White)
3M™ Scotchcal™ Electrocut™ Graphic Film 7725-12 (Black)
Polycarbonate Panels:

Hart Supply – Tuffak Brand – White 0.177 (3/16”) 52” wide
Grimco – Palsun Brand – White

Procedure:

1. Clean a painted metal panel (made by Fruehauf) and polycarbonate panels with IPA/Water (2:1).
2. Apply 10" x 10" sheet of each film on the panels.
3. Place the panels in a 150° F oven.
4. Check the results after a number of hours to see results.
5. Record results with photos.

Results:

The tables below compare the two existing polycarbonate panels (made by Hart/Tuffak or Grimco/Palsun) with the "control" painted panel (made by Fruehauf) which is does not outgas.

"Yes" is indicated in the table if there are bubbles present after heat exposure. The heat exposure is set at 150° F. A "No" is indicated in the able if there are no or very low amounts of bubbles due to installation after exposure to heat.

150° Exposure	F	Panel	5100R	1080-G12	1080-G10	7125-10	7725-12
0 hours		Hart/Tuffak	No	No	No	No	No
1.5 hours		Hart/Tuffak	Yes	No	Yes	Yes	Yes
17.5 hours		Hart/Tuffak	Yes	Yes	Yes	Yes	Yes
24 hours		Hart/Tuffak	Yes	Yes	Yes	Yes	Yes
42 hours		Hart/Tuffak	Yes ¹	Yes	Yes	Yes	Yes
49 hours		Hart/Tuffak	Yes ¹	Yes	Yes	Yes	Yes
73 hours		Hart/Tuffak	Yes ¹	Yes	Yes	Yes	Yes
93 hours		Hart/Tuffak	No ²	Yes ²	Yes ²	Yes ²	Yes ²
160 hours		Hart/Tuffak	No	No	No	No	No

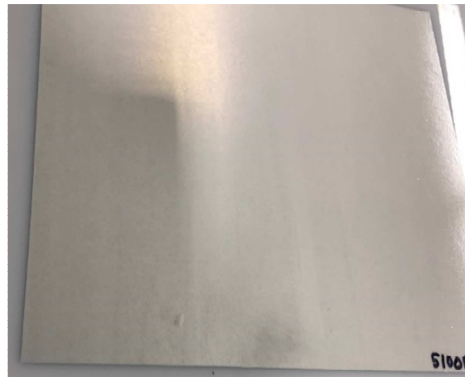
¹ Started to apply new IJ5100R panels to see when outgassing will be completed.

² Applied new panels after outgassing is completed.

Photo of 5100R Outgassing:



Photo of 5100R Not Outgassing:



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Photo of 1080-G12 Outgassing:



Photo of 1080-G12 Not Outgassing:



Photo of 1080-G10 Outgassing:



Photo of 1080-G10 Not Outgassing:



Photo of 7125-10 Outgassing:



Photo of 7125-10 Not Outgassing:



Photo of 7725-12 Outgassing:



Photo of 7725-12 Not Outgassing:



This brand of polycarbonate panel showed similar results as the previous polycarbonate panel other than the 1080-G12 seemed to not be affected as much.

150°F Exposure	Panel	5100R	1080-G12	1080-G10	7125-10	7725-12
0 hours	Grimco/Palsun	No	No	No	No	No
1.5 hours	Grimco/Palsun	Yes	No	Yes	Yes	Yes
17.5 hours	Grimco/Palsun	Yes	No	Yes	Yes	Yes
24 hours	Grimco/Palsun	Yes	No	Yes	Yes	Yes
42 hours	Grimco/Palsun	Yes ¹	No	Yes	Yes	Yes
49 hours	Grimco/Palsun	Yes ¹	No	Yes	Yes	Yes
73 hours	Grimco/Palsun	Yes ¹	No	Yes	Yes	Yes
93 hours	Grimco/Palsun	No ²	No	Yes ²	Yes ²	Yes ²
160 hours	Grimco/Palsun	No	No	No	No	No

¹ Started to apply new IJ5100R panels to see when outgassing will be completed.

² Applied new panels after outgassing is completed.

Photo of 5100R Outgassing:



Photo of 5100R Not Outgassing:



Photo of 1080-G12 Outgassing:

N/A

Photo of 1080-G12 Not Outgassing:



Photo of 1080-G10 Outgassing:



Photo of 1080-G10 Not Outgassing:



Photo of 7125-10 Outgassing:



Photo of 7125-10 Not Outgassing:



Photo of 7725-12 Outgassing:



Photo of 7725-12 Not Outgassing:



The table below shows no sign of “bubbling” when exposed to 150° F oven for extended periods of time.

150°F Exposure	Panel	5100R	1080-G12	1080-G10	7125-10	7725-12
0 hours	Fruehauf/Paint	No	No	No	No	No
1.5 hours	Fruehauf/Paint	No	No	No	No	No
17.5 hours	Fruehauf/Paint	No	No	No	No	No
24 hours	Fruehauf/Paint	No	No	No	No	No
42 hours	Fruehauf/Paint	No	No	No	No	No
49 hours	Fruehauf/Paint	No	No	No	No	No
73 hours	Fruehauf/Paint	No	No	No	No	No
93 hours	Fruehauf/Paint	No	No	No	No	No
160 hours	Fruehauf/Paint	No	No	No	No	No

Photo of 5100R Outgassing:

N/A

Photo of 5100R Not Outgassing:



Photo of 1080-G12 Outgassing:

N/A

Photo of 1080-G12 Not Outgassing:



Photo of 1080-G10 Outgassing:

N/A

Photo of 1080-G10 Not Outgassing:

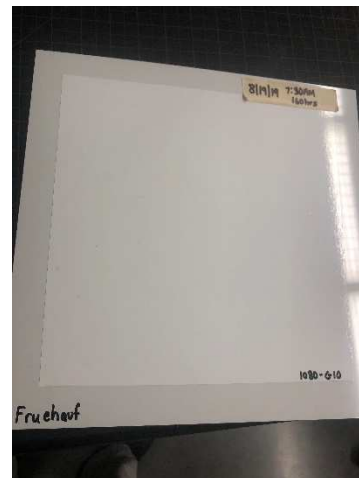


Photo of 7125-10 Outgassing:

N/A

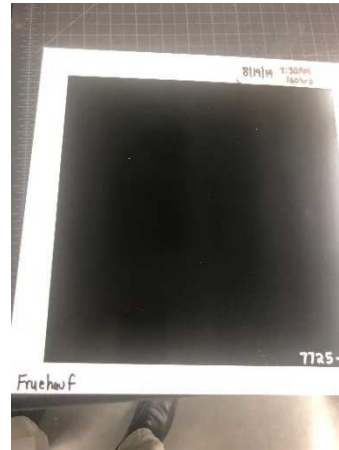
Photo of 7125-10 Not Outgassing:



Photo of 7725-12 Outgassing:

N/A

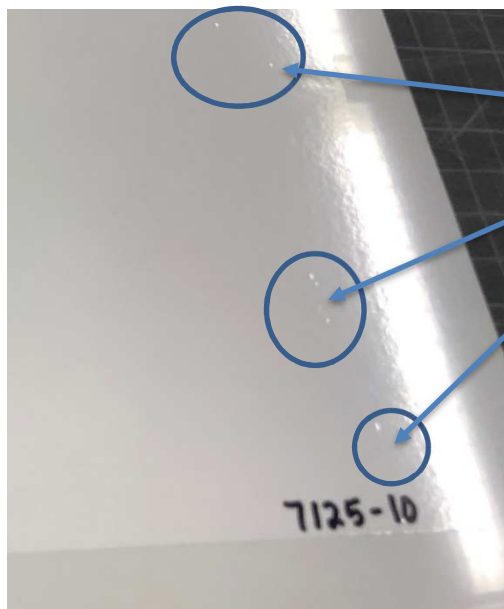
Photo of 7725-12 Not Outgassing:



Analysis:

Regarding the theory that there may be a product concern with the adhesive film lifting in specific areas; the Fruehauf table does not show any bubbling with any of the films tested. Therefore, it does not appear the film is the cause of the bubbling.

Regarding the theory that air may have been trapped during the installation process. The 3M™ Wrap Film 1080-G10 and 3M™ Wrap Film 1080-G12 have a Comply™ feature and no trapped air was present from installation. While there was some evidence of trapped air during the installation of some films such as 7125-10, the films that had trapped air from installation would be the products without an air egress channel like Comply™. These products are the 3M™ Scotchlite™ Reflective Graphic Film IJ5100R, 3M™ Scotchcal™ Electrocut™ Graphic Film 7125-10 and 3M™ Scotchcal™ Electrocut™ Graphic Film 7725-12. Typically, the trapped air would be very small, random bubbles that would not show up in the overall sign. Therefore, the large bubbles are not due to the installation process.



Examples of trapped air during installation.

Regarding the theory that the panel could be outgassing when exposed to higher temperatures; when reviewing the two tables with the polycarbonate panels results and comparing with the Fruehauf/Paint panel results, there is a clear trend that shows the polycarbonate panels are the main contributing factor in the cause of the bubbling. There is strong evidence that after the panels have completed the outgassing and applying a new set of film to the panel, there is no evidence of bubbles. The primary bubbling is coming from the polycarbonate panels.

This fact is also confirmed in an article by Plaskolite which discusses the Tuffak® brand polycarbonate which was tested in this study. The full article is attached in the Appendix section. The article stated:

“ . . . outgassing from water vapor is predictable due to the hygroscopic nature of polycarbonate. Trapped moisture within the sheet often results in bubbling of vinyl film. Pre-drying sheet leads to a surface dryness conducive to good film adhesion. Failure to properly dry the plastic may cause bubbling within the plastic sheet and under the applied film during the heating stage of the forming process.”

Additional Study:

Based upon the results of the testing, a fresh polycarbonate panel which was not exposed to the oven, from each supplier was placed in 225° F oven for a period to dry out the panel. The use of IJ5100R was used to indicate when the panel had finished outgassing. Then new samples of the IJ5100R, 1080G-10 and 1080-G12 were applied and put into the oven. Results are shown in the table below.

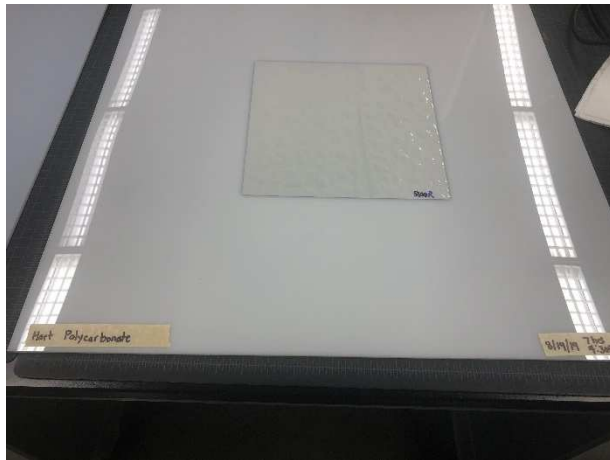
225°F Exposure	Panel	5100R	1080-G12	1080-G10
0 hours	Hart/Tuffak	No		
7 hours	Hart/Tuffak	Yes		
25 hours	Hart/Tuffak	Yes		
46 hours	Hart/Tuffak	No	No	No
0 hours	Grimco/Palsun	No		
7 hours	Grimco/Palsun	Yes		
25 hours	Grimco/Palsun	Yes		
46 hours	Grimco/Palsun	No	No	No
0 hours	Fruehauf/Paint	No		
7 hours	Fruehauf/Paint	No		
25 hours	Fruehauf/Paint	No		
46 hours	Fruehauf/Paint	No	No	No

The results indicate that approximately 24 hours are needed to remove the moisture from the polycarbonate panels.

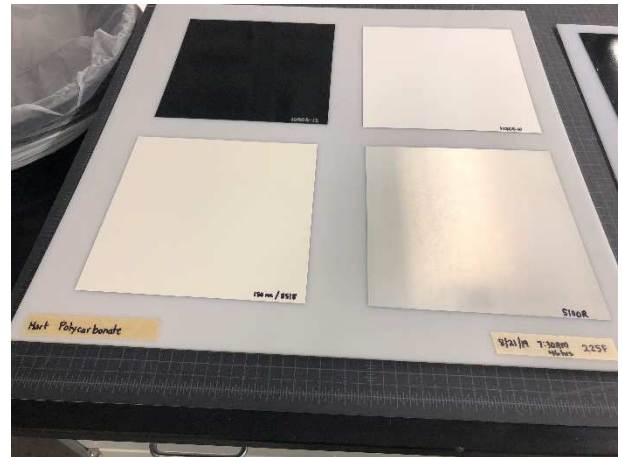
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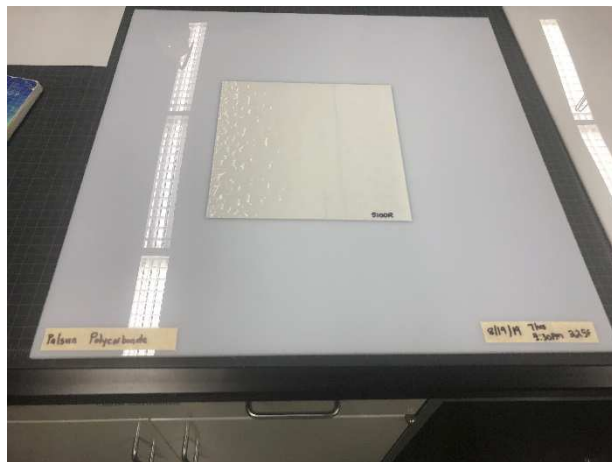
Hart/Tuffak Polycarbonate – 7 hours



Hart/Tuffak Polycarbonate – 46 hours



Grimco/Palsun Polycarbonate – 7 hrs.



Grimco/Palsun Polycarbonate – 46 hrs.



Fruehauf/Paint Panels – 7 hrs.



Fruehauf/Paint Panels – 46 hrs.



Discussion:

The results of this test showed similar results as the previous 150° F oven test but the outgassing process was completed within 24 hours. The bubbles are coming from the polycarbonate panels.

Conclusion:

The root cause of the bubbling is the outgassing of moisture from the polycarbonate panels and not from the film lifting or poor installation.

Recommendation:

To prevent the bubbles in the future, the polycarbonate panel must be dried prior to installation and procedures followed as outlined in the article from Tuffak® (see Appendix).

The information provided in this letter and related material content represents 3M Commercial Solutions Division's knowledge and belief as of the date it is provided.

Alan Miller
Application Engineering Manager
3M Commercial Solutions Division

Appendix

“OUTGASSING” & VINYL APPLICATION to TUFFAK® POLYCARBONATE MONOLITHIC SHEET

Tuffak® polycarbonate monolithic sheets are not known to “outgas” in the traditional sense of the term. For example, new car odors are attributed to plastics, adhesives and sealers found in the interior of automobiles. As these materials continue to cure, they release fumes of Volatile Organic Compounds (VOCs) into the air. Odors may also come from phthalates and other plastic softening chemicals that outgas over time.

Conversely, polycarbonate’s “outgassing” is primarily due to water moisture trapped in an undried sheet. Polycarbonate readily absorbs moisture soon after manufacturing. To remove this moisture, which often interferes with vinyl adhesion resulting in bubbles under the vinyl film, polycarbonate should be dried prior to film application.

Suggestions for successful vinyl application:

- Remove protective masking from the surface which is to receive vinyl film.
- Pre-drying the sheet for a minimum of one hour at 250°F (flash drying) promotes surface dryness conducive to good film adhesion.
- Polycarbonate begins to reabsorb moisture upon cooling. It is imperative that the vinyl application process begins immediately once the sheet has reached room temperature.
- Wipe the sheet with an antistatic rag or blow deionized compressed air over the sheet to remove any built-up electric charge and particles of dust.
- Vinyl is best applied as free film immediately after being stripped away from the release liner.
- The squeegee should be dragged at a shallow angle for effective and stretch free work. Keep the vinyl unattached to the sheet surface for as long as practical by lifting it; this keeps trapped fluid to a minimum and helps avoid wrinkling along the edges.
- When applying graphics, always start in the center of the sheet. Apply enough squeegee pressure to force any application fluid out from under the vinyl and always use overlapping strokes. Lay down and make substrate contact with the area of film to which you can apply high-squeegee pressure. While squeegeeing, work from the center outwards toward the edge and from the top down, in overlapping strokes.
- Re-squeegee the film after 15 minutes from the initial film application. Use the release liner that’s been removed previously and overlay it on top of the applied film. This protects the film from scuffing and scratches by the applicator. Re-squeegee the surface as though it were for the first time. This helps promote adhesion.

Always confirm with the film's manufacturer their product works well on polycarbonate. Once validated, review and verify the film manufacturer's application procedures. If instructions are unclear, ask for guidance from the manufacturer on ways to avoid their film from bubbling up – vinyl film manufacturers may have additional application ideas on how this application may be completed successfully.

Summary:

Outgassing from water vapor is predictable due to the hygroscopic nature of polycarbonate. Trapped moisture within the sheet often results in bubbling of vinyl film. Pre-drying sheet leads to a surface dryness conducive to good film adhesion.

Failure to properly dry the plastic may cause bubbling within the plastic sheet and under the applied film during the heating stage of the forming process.

Outgassing/VOC Test Results:

Plaskolite

Material: TUFFAK® GP 20 mm (0.787") thickness

Testing Parameters	3 Days	28 Days	Emission Class Class A+
	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$
Formaldehyde	<3 (ND)	<3 (ND)	<10
Acetaldehyde	<3 (ND)	<3 (ND)	<200
Toluene	<2 (ND)	<2 (ND)	<300
Tetrachloroethylene	<2 (ND)	<2 (ND)	<250
Xylene Isomers	<2 (ND)	<2 (ND)	<200
1,2,4Trimethylbenzene	<2 (ND)	<2 (ND)	<1000
Dichlorobenzene	<2 (ND)	<2 (ND)	<60
Ethylbenzene	<2 (ND)	<2 (ND)	<750
2-Butoxyethanol	<2 (ND)	<2 (ND)	<1000
Styrene	<2 (ND)	<2 (ND)	<250
Total VOCs	<3 (ND)	<3 (ND)	<1000

ND = non-detect

- C6-C16 expressed in Toluene equivalent ISO 16000-6
- The test stopped (3) days after test loading, since Class A+ rating has been reached. Results after 28 days is a prevision.
- Air sampling was done (3) days after introduction of test specimen in the emission test chamber.
- Markes sorbent tubes (Carbopack C 60/80, Carbopack B 60/80, Carbosieve SIII 60/80) for VOC analysis by GC-MS and using tubes containing silica gel coated with 2,4-dinitrophenylhydrazine (DNPH) for aldehyde analysis by HPLC-UV.
- The test was carried out according to standard UNI EN ISO 16000-9:2006 dated 06/07/2006 "Indoor air - Part 9: Determina the emission of volatile organic compounds from building products and furnishing - Emission test chamber method".
- TEST REPORT No. 310180, 10/29/2013