Exhibit 5

Identification and Comparison of Solid Phase Removers as Alternatives to Methylene Chloride Removal Applications

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ABSTRACT

This study compares the paint removing performance of methylene chloride to 22 solvent-based non-methylene chloride paint removers or solvents proposed as an alternative chloride by chemical manufacturers. Stripping performance of three methylene chloride removers was then compared to 26 non-methylene chloride paint removers and five experimental formulas using alternative methylene chloride solvents. Paint removers were tested on 1 month and 1 year aged wood panels treated with multiple layers of an oil-based alkyd paint solvent-borne epoxy paint and 0 motive coating. For chemically resistant oil-based alkyd paint solvent-borne epoxy paint and 0 motive coatings, only methylene chloride based paint removers were determined to be effective.

BACKGROUND

Methylene chloride has been the preferred solvent for use in paint removers for seventy methylene chloride was introduced, most paint removers consisted of a mixture of benzene volatiles solvents such as methanol, acetone, and methyl ethyl ketone. Formulated with these volatiles solvents are extremely flammable and the flammability of these paint reinfires causing injury and deaths. Based removers were rapidly replaced with the methylene chloride paint removers because methylene chloride paint removers can be for non-flammable and are effective in removing multiple layers of paint. The physical characteristics give the methylene chloride molecule the ability to quickly penetrate multiple layers and to dissolve chemically resistant coatings. Methylene chloride does not deplete the ozone layer and is considered to make negligible contributions to smog formation, the green-house effect. Like other organic solvents, methylene chloride can be harmful to human health if used in

Consumers Use of Paint Removers

Most consumers use paint removers for refinishing antique furniture, or woodworking's moldings, etc.) in older houses. Most items have been painted, and repainted many times of the years. Its results in items having multiple layers of paint containing different chemical different degree of difficulty from removed. Paint removers are also used in the autobody repaint industry to help with vehicle restoration.

Effect of Paint Chemistry and Age of Paint

There is a range of paint types that a consumer can encounter when paint stripping. The chemistries that can be encountered include latex, urethane, 1-part epoxy, 2-part epoxy type), lacquer, varnish, and shellac based paint. In recent times, latex paint has taken industry as the paint technology of choice. Its relatively easy to remove with paints stripping but is also a paint technology that people will not frequently encounter as they are stripping. Historically, enamel alkyd based paint have been the most prevalent. The used paint technology used in alkyd paint dries by an oxidation reaction with oxygen from the air. Solvents has evaporated from the paint. The oxidation reaction irreversibly cross-links the polymers have alkyd resin making it very difficult to remove. The alkyd paint continues to form cross-linking bonds as the paint ages making older painted items even harder to strip. 2-part epoxy paint is by far difficult paint technology to remove. It is frequently used in industrial settings. For th

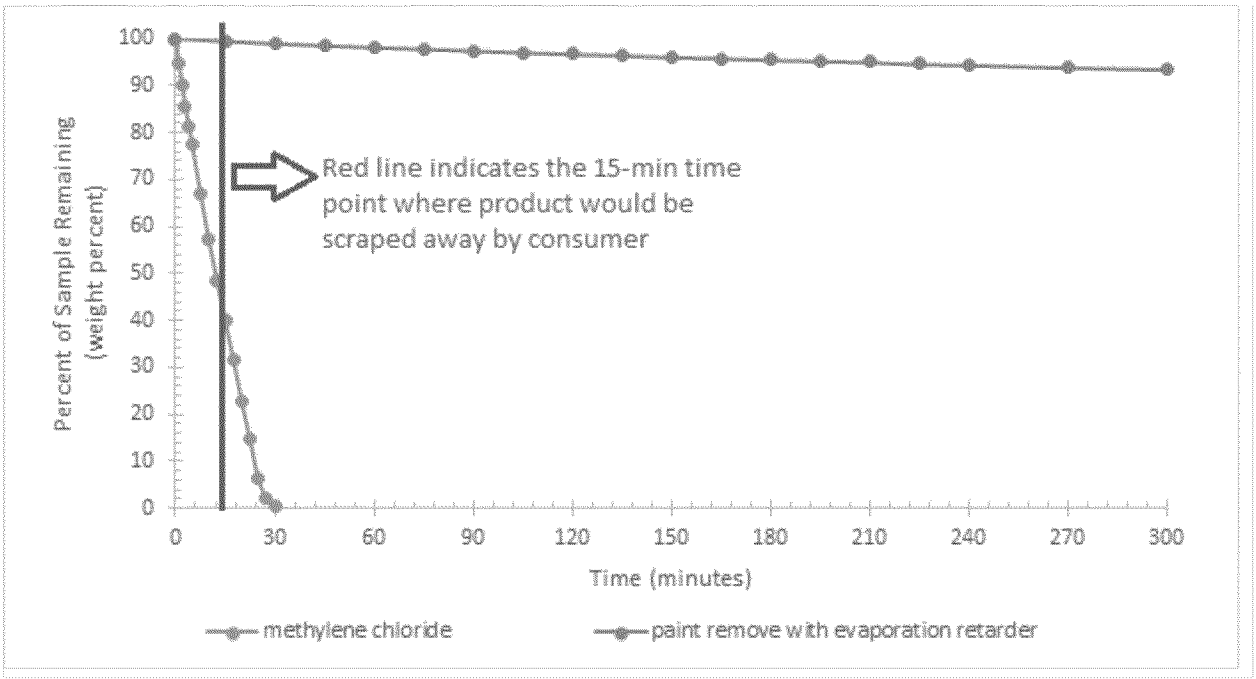
experimental studies outlined in this report will focus on the removal of alkyd, 2-parte
OEM automotive coatings.

Basics of Paint Remover Formulation

A chemical paint remover is composed of a mixture of solvents, additives and sometimes
To be an effective paint remover, the solvent must be able to penetrate multiple layers of p
have solubility to cause the paint to swell which breaks the bond of the paint to the substr
movement of the solvent through the paint remover to the paint layer is call diffusion and is there
the random kinetic movement of the solvent. The rate of diffusion of is affected by the size of the
solvent molecule (molar volume) and the polarity of the molecule. Smaller molecules will
have a higher diffusion rate into the coating than molecules that are heavier or more pola
effective replacements for methylene chloride will be molecules with the following gener
characteristics, small polar or halogenated molecules, five-member cyclic rings or
rings. These types of molecules are generally flammable and will also have heal thands a

Additives, such as surfactants, thickeners and paraffin wax are added to modify the ph
of the paint remover. Surfactants improves the wetting of the surface by the paint remover and p
the use of water for clean-up after the paint has been stripped. Added to the paint
removers to cling to vertical surfaces. The evaporation of methylene chloride and other
solvents in the paint remover, paraffin wax is added. Produces the evaporation of the
solvents by forming a physical barrier between the paint remover and the air. The weight loss of methylene
chloride over a period of five hours was compared to the weight loss of a paint remover con
than 60% methylene chloride and a neva poration retarder with the results shown in **Figure 1.**
Approximately 20 grams of methylene chloride and 20 grams of the paint remover were placed in
separate containers and the weight of the sample remaining was determined at time dinte
30 minutes, only 0.5% of the straight methylene chloride remained in the concentration. The
study showed that evaporation retarder is effective in reducing the evaporation rate of
chloride from the paint remover. As shown in **Figure 1**, 98.9% of the paint remover remained after 30
minutes and 93.5% remained after five hours. The methylene chloride based paint remover
(containing evaporation retardant) is effective after 15 minutes, the amount of
methylene chloride released into the atmosphere during this time is minimal, minimizing
risk to the production. At 15 min, only 0.6% of the methylene chloride based paints tripper formul
has evaporated.

Figure 1. Comparison of weight loss of methylene chloride to a methylene chloride paint remover formulated with a evaporation retarder at 70°F. At 15 min, methylene chloride based paints tripper formula has evaporated.



To increase the performance of the paint remover, an acid or a base is sometimes added. The activator is thought to disrupt the bond between the substrate and the paint and weaken the chemical or physical bonds in the polymer that is used in the paint. Formic acid, ammonium hydroxide and ethanolamine are common activators used in paint removers.

To establish the performance criteria of methylene chloride based paint removers, the different manufactures were evaluated for consumer benefit. The most important criteria include:

A. Fast removal of the coating, starts working within 15 minutes.
B. Removal of many types of coatings including oil-based and epoxy paints for architectural coatings and factory applied automotive paints
C. Removal of multiple layer of coatings

Other criteria considered in the evaluation of the paint remover includes the cost of the product and the VOC content of the paint remover. The VOC content of paint removers is limited to 50 % by weight. When considering viability of a paint remover it must be considered that the paint removed a regenerally older and more chemically resistant than many paints available today. Water-based latex paints are widely available and chemically easily removed, they were common 30 or more years ago. Furthermore, there are coatings in common use today that are

considered more chemically resistant than water-based paint, this study focuses on the more difficult, chemically resistant oil-based alkyd and solvent-born two-parte

MATERIALS AND METHODS

The procedure used to test the performance of these solvents and paint removers is based on modification of the ASTM D6189 (2003) test method (Standard Practice for Evaluating the Efficiency of Chemical Removers for Organic Coatings). Modification of the procedure included the 12 panels instead of 12 panels and the panels were treated with five coats of the oil-based paint instead of three coats as described in the panel preparation procedure in the ASTM D-6189 method. Painted panels amounted were used for screening experiments and painted panels a g year were used for final efficacy evaluation. Solvents and paint removers were applied to the panel using a pipette instead of following manufacturers directions for application as called test method. During the paint removal step, scrapping was performed using moderate force plastic paints crapper.

Solvents Selection—The solvents used in this study were selected from currently used in non-methylene chloride paint removers, solvents recommended as methylene chloride replacement chemical manufacturers, and the EPC Solvents list. Technical grade samples of these solvents were obtained and used in this study's experimental formulations without further purific

Paint Removers Selection—The paint removers used in this study were purchased from hardware stores or from suppliers on the internet. Composition and the flash point of the paint removers ba information found in the Material Safety Data Sets (MSDS) are listed in **Appendix A**. All paint removers were used as is in the experiments.

Experimental Paint Removers—Based on the results of these solvents screening testing, two alter methylene chloride solvents were identified as having some paint remover potential. T were formulated into paint removers that were 50 wt% VOC requirements. The other experimental formulas based on solvent chemistry utilized by paint removers on the mark als of formulated into experimental paint removers with the VOC wt% 50. These experimental paint removers are listed below:

A. a solvent based remover based on toluene, methanol, and acetone
B. a solvent based remover based on 1, 2-dichloroethylene, methanol, and aceto
C. a solvent based remover based on 1, 3-dioxolane, methanol, and acetone
D. a nemulsion based on benzyl alcohol
E. a nemulsion based on dibasic esters (DBE)

Paint Selection—Oil-based alkyd paint was selected to be used since it has historically be predominantly used paint technology and consumers are typically stripping older items multiple layers of this type of paint. Component epoxy paint was also selected because it i the most difficult paint technology to remove and is frequently used in industry applicat used were purchased from a local hardware or paint stores. Purchased for this study are listed in Table 1 along with numbers of layers of paint used on the test panel. Paint was used for each test panel.

Table 1. List of paint, paint type and number of coatings used in study

Paint	Paint Type	Number of Coatings
Rust-Oleum Professional High Performance Protective Enamel Exterior Gloss	Oil-based alkyd paint	5
Sherwin Williams Macropoxy 646	Two component-based epoxy paint	3

1 Month Aged Panel Preparation and Procedure – Sanded birch plywood (4 ft. x 4 ft. x ¼ in.) was cut into approximately 8 x 12 inch panels for a 1-gallon multi-purpose paint roller was used to apply the coat the designated paint to the birch panels as a base layer. The paint was dried for four hours at ambient conditions and then was placed in a box over a tray with water. Each 50 °C layer of paint was tinted to a different color to increase the visibility of the paint layers. The color of the paint layers went as follows: Blue = color of 1st paint layer applied, White = color of 2nd paint layer applied, Green = color of 3rd paint layer applied, Yellow = color of 4th paint layer applied, and Red = 5th paint layer applied. After the red coat of paint was applied, the panels were dry for 5 days in the laboratory. The test panels were then stored at ambient conditions until needed for the stripping tests.

1 Year Aged Panels – Painted panels aged for 1,130 days are only good for giving directional data on the efficacy of a paints behavior. The aged panels are typically used by the formulation chemist to quickly screen new chemistries to see if they have the potential of becoming an effective paint remover. The reality is that consumers are trying to remove multiple layers of paint of a many years old. As mentioned in the introduction, alkyd paint types get harder to remove due to their chemistry. Efficacy validation of a paint remover requires it to be tested on Alkyd painted boards that have been allowed to age for a few years. These boards were initially prepared in the same manner as the 1 month aged boards, but were allowed to sit at ambient conditions for a year prior to testing.

Automotive Panel Preparation – The hood from a 2006 Chevrolet Impala was purchased in good condition with the factory paint intact. The hood was cleaned with a damp cloth and used in testing without further modification to the original paint. The original paint was used on the hood, so the paint job during removal testing was at least 9 years old. The age of this paint is not as of great importance due to the chemistry being stable over time in comparison to the Alkyd paint which continues to react and gets tr

Neat Solvent Screening – Neat solvents screening was done on the aged boards to generate directional efficacy data on chemicals that might be promising to be incorporated in a p formula. A disk marked on the panel with masking tape creating test circles 1½ in. x 1½ in. approximately in. for the stripping trials. Each cell was labeled with the name of the solvent to be test duration time of the test. 31 Large Commercial Grade from 3M was cut to approximately ½ sized 1 in. x 1½ in. x ¼ in. pieces were placed on each test cell to control evaporation and retain the the test area. For each sample, 0.1 ml solvent was applied to the sponge and a timer is started. Additional solvent was added to the sponges as needed to ensure that the solvent remains with the surface of the test panel. At the time intervals, the test area was scraped using scraper and evaluated for the effects on the coatings and the number of layers of paint re

Experimental Paint Remover Screening and Validation Experimental paint remover formulas were tested on 1 month aged boards to get directional efficacy data in comparison to a commercial remover competitive set. This process helps weed out under performing formulas prior to testing valuable 1 year aged boards. The same experiment was then repeated on 1 year aged alkyd painted boards to validate the true efficacy of the experimental and commercially available paint. A grid was marked on the panel with masking tape to create test cells ½ inch x ½ inch approximately 1 dimension. Each cell was labeled with the name of the solvent to be tested and the time duration the test. Approximately 2 of the paint remover was applied to the cell and a timer is started. At time intervals, the test area was scraped using a plastics scraper and judged for the effectiveness of coating and the number of layers of paint removed.

Results

Neat Solvent Screening Neat solvent experiments were conducted on 1 aged painted boards for the sole purpose of getting directional efficacy data to drive future non-methylene chloride development. The results comparing the performance of methylene chloride to the 22 alternative solvents selected are listed below. The performance was evaluated after 15 minutes, 30 and 1 hour with number of layers of paint removed and the effect of the solvent on the paint. Methylene chloride performed the best removing all five layers of oil-based alkyd paint of the two-component oil-based epoxy paint in 15 minutes. 1, 2-dichloroethylene and 1, 3-dioxolane were identified as the best performing alternates solvent removing all five layers of oil-based alkyd paint in 30 minutes. After 1 hour, 1, 3-dioxolane removed two layers of the two-component oil-based epoxy paint, however, trans-1, 2-dichloroethylene failed to remove any layers after an hour. Results from this experiment helped drive decisions on which chemicals could be new experimental paint removal formulas that did not utilize methylene chloride.

Table 2 Neat solvent experiments were conducted on 1 aged painted boards for the sole purpose of

Chemical (Solvent)	Alkyd (5 layers)			Epoxy (3 layers)		
	15 min	30 min	1 hrs	15 min	30 min	1 hrs
methylene chloride	5	5	5	2	2	2
trans-1, 2 dichloroethylene	5	5	5			
1, 3 dioxolane	5	5	5			2
n-methyl-2-pyrrolidone		5	5			
acetone	5	5	5			
dimethoxymethane (methylal)		5	5			
n-butyl propionate			5			
dimethyl sulfoxide (DMSO)			4			
dimethyl carbonate						
benzyl methyl ether						
TOC (2, 5, 7, 10 tetraoxaundecane)						
3-methoxy-3-methyl-1-butyl acetate (MMBA)						
Stepsol MC-10U						
PCBTF/Oxsol 100						
3-methoxy-3-methyl-1-butanol (MMB)						
Eastman Oia (butyl-3-hydroxybutyrate)						
benzyl alcohol						
dibasic esters (DBE)						
dibutoxymethane (butylal)						
propylene carbonate						
Elevance Clean 1200						
soya methyl ester						
glyercol formal						

no effect on coating	
slight softening of paint but no removal with plastics scraper	
paint has softened requiring effort to remove with plastics scraper	
paint has blistered with all layers paint removed with plastics scraper	

getting directional efficacy data to drive future formulas to develop more. Results showing the layers of oil-based alkyd and two component oil-based epoxy removed.

The performance of trans-1,2-dichloroethylene and 1,3-dioxolane in removing O was then compared to methylene chloride and three solvents n-methyl-2-pyrrolidone, be and DBE currently used in commercially available non-methylene chloride paint removes results listed in Table 3. The performance of these solvents was evaluated after 15 minutes, 30 1 hour and 4 hours with number of layers of paint removed and the effect of these solvents on the pa noted in Table 3. Once again methylene chloride performed the best by removed the clear and co coating fifteen minutes. T 1,2-dichloroethylene and 1,3-dioxolane removed the clear an after 30 minutes while NMP, benzyl alcohol and DBE had no effect on the paint after four hours. N the neat solvents, including methylene chloride, stripped all layers of the automotive the primer. Only a formulated paint remover would remove all layers of an automotive coating

Table 3. Results of solvent testing showing the Maximum of Coating paint removed.

Chemical (Nt)	Automotive Coating			
	15 min	30 min	1 hrs.	4 hrs.
methylene chloride				
trans-1,2 dichloroethylene				
1,3 dioxolane				
n-methyl-2-pyrrolidone				
benzyl alcohol				
dibasic esters (LVP				

No effect	
Stripped clear coat and top coat	
Stripped clear coat, top coat and base coat	

Experimental Formulate Removers Screening on 1 Month Aged Boards

Experimental paint remover formulas were not tested on 1 month aged boards to get directional efficacy data in comparison to a commercialized paint remover. Compositions held to Tweed out under performing formulas prior to testing on a glue bolt. Results comparing the performance of three methylene chloride paint removers to 5 experimental formulas and 2 non-methylene chloride paint removers on one month aged boards are presented in Table 4. The panels used in this experiment were evaluated after 5 minutes, 15 minutes, 30 1 hour and 4 hours with the numbers of layers of paints stripped by the paint remover recorded. For test p

paintedwithoil-basedalkydpaint, twoofthethreemethylenechloridepaintremovers, AircraftRemoverandKleanSpremiumStripper, strippedallfivelayersofthealkydpaintaft minutesheThirdpaintremover, KleanSpx-Xcontainslessmethylenechloridedandtook15 minutestostripthefivelayersofthealkydpaint. ExperimentalFormulasA, B, andC stripallfivelayersoftheoil-basedalkydpaintin15minutesweExperimentalFormulaA withtoluene, methanolandacetone. ExperimentalFormulasBthetwoalternate solventsidentifiedinthealternatedsolventstudyandwereformulatedwithtoluene, methanol, andacetoneand1, 3-dioxolane, methanol, andacetone. ExperimentalFormul benzylalcoholemulsionandExperimentalFormulaEbasedonaDBEemulsionfailedtostr ofthealkydpaintafterfourhours. Fifteenofthetwenty-sixcommercialnon-methylenec removerstesteds trippedalllayersofalkydpaintinfourhours. Eightofsixteenpaintr strippedthealkydpaintwereformulatedwithMPtedwithNthesixteenpaintremoverswere formulatedforprofessionalstoremoveautomotiveoraircraftcoatingswerebasedab andhighlevelsofanachievemoriTingtwoformulaswerebasedondimethylSOulfoxide(DM orcaustic.

Forthepanelspaintedwiththetwo-componentoil-basedepoxypaint, twoofthethreemeth chloridepaintremoverstripAircraftRemoverandKleanSpremiumStripper, strippedtwo layersoftheepoxypaintafter15minutesPaintremover, KleanSpwXichcontains lessmethylenechloride, tookfourhourstoremovetwolayersofthepoxypaintanTd

Table 4. Results of paint remover screening showing the layers of oil-based alkyd and two-component oil-based epoxy removed on 1 month aged panels. Promising experimental formulations from this test were later validated on 1 year aged panels with competition.

Company	Paint Remover	Ingredients (MSDS)	Retail Cost (gallon)	Alkyd (5 Layers)					Epoxy (3 Layers)			
				5 min	15 min	30 min	1 hrs	4 hrs	15 min	30 min	1 hrs	4 hrs
W. M. Barr	Klean-Strip Aircraft Remover	methylene chloride/methanol/Tall oil/ammonium hydroxide/xylene	$27.99	5	5	5	5	5	2	2	2	2
	Klean-Strip Premium Stripper	methylene chloride/methanol/Stoddard solvent	$22.98	5	5	5	5	5	2	2	2	2
	Klean-Strip Strip-X Stripper	methylene chloride/methanol/toluene/acetone/xylene	$18.97		5	5	5	5				2
	Citristrip Safer Paint & Varnish Stripping Gel	NMP/DBE	$39.94				5	5				
	Experimental Formula A	toluene/acetone/methanol	$23.88*		5	5	5	5				
	Experimental Formula B	1,2 trans dichloroethylene/acetone/methanol	$42.97*		5	5	5	5				
	Experimental Formula C	1,3 dioxolane/acetone/methanol	$31.55*		5	5	5	5				
	Experimental Formula D	benzyl alcohol emulsion	$39.96*									
	Experimental Formula E	DBE emulsion	$34.00*									
Dumond	Peel Away 1	calcium hydroxide/magnesium hydroxide/sodium hydroxide/water	$68.30			1	3	5				
	Peel Away 5 Soy Based	benzyl alcohol/NMP/soya methyl ester/DBE/water	$78.12					5				
	Peel Away 7	benzyl alcohol/NMP/DBE/water	$90.15									
	Smart Strip	water/benzyl alcohol/water	$50.59									
	Smart Strip Pro	water/benzyl alcohol/formic acid/water	$77.74									
Ecoprocote	EcoFast HD Heavy Duty Paint Stripper	NMP/soy methyl ester/water	$54.99									
EZ Strip	EZ Strip Paint and Varnish Stripper	DBE/triethyl phosphate/water	$38.98									
Franmar	Soy-Gel Paint and Urethane Remover	NMP/DBE/soy ester/water	$81.20					5				
Motsenbocker	Lift Off Paint and Varnish Remover	acetone/2-butoxyethanol/DBE/water	$49.94									
Packaging Service Co.	Crown Paint Strip Next	DBE/DMSO/water	$47.92					5				
PPG	DuraPrep 200 Coating Remover (Gel)	benzyl alcohol\solvent naphtha/2-aminoethanol/nonylphenol, branched ethoxylated	$41.34					5				
	DuraPrep 240 Industrial Coating Remover (Gel)	benzyl alcohol/hydrogen proxide/solvent naphtha/glycollic acid/malic acid/barium bis(dinonylnaphthalenesuphonate)/amines, coco alkyl, ethoxylated	$40.75					5				
	DuraPrep Prep 400 Overspray Remover	benzyl alcohol/petroleum distillates/glycolic acid/quaternary ammonium compounds/hydrogen proxide/water	$127.60					5				
Solvent Kleene	D-Zolve 1012 Powder Coating Remover (immersion tank)	alkyl methyl ester/potassium hydroxide/cyclic amide/water	Not Available		1	2	2	5				
	D-Zolve 15-33R (aircraft)	alkyl methyl ester/petroleum naphtha/benzyl alcohol/methyl phenyl ether/water	Not Available					5				
Sunnyside	Multi-Strip Professional Paint Remover	DBE/NMP/formic acid/water	$49.97					5				
	Ready Strip Pro	DBE/NMP/formic acid/water	$39.97									
	Ready Strip Safer Paint & Varnish Remover	DBE/NMP/formic acid/water	$34.71									
	Ready-Strip Spray	NMP/DBE/monoethanolamine/water	$39.92									
	Ultri-Strip	DBE/NMP/formic acid/water	$66.85					5				
This Stuff Works, Inc.	TSW2 Multi-Master	NMP/DBE/water	$99.95					5				
	TSW2G Multi-Master (Gel)	NMP/DBE/water	$99.95					5				
	TSW3G (GEL) Mason-Master	potassium hydroxide/butyl cellosolve/water	$85.00			1	1	4				
	TSW9 Plasti-Master	DBE/proprietary surfactant/water	$99.95									
Zinsser	Magic Strip Citrus-Action	NMP/DBE/d-limonene/water	$84.32					5				

no layers of paint were removed with plastic paint scraper	
paint has softened requiring effort to remove with plastic scraper	
paint has blistered with all layers of paint removed with plastic scraper	

* Estimated retail price of experimental formulas based on formula, packaging, and manufacturing costs.

thecommercialpaintremoversfailedtostripanylayersofthepolyurethanecoatingwithin15and30 andfourhours.

Sincetheexperimentalformulas A, B, and C performedcomparableefficacywithmonthaged alkyd paintedboardincomparisontothemethylenechloridecontainingformulas theywereall advanceontothevalidationtestsusingyearaged alkydpaintedboard.

Final Efficacy Validation of Experimental Formulas vs Commercial Strippers on 1 Year Aged Alkyd Paint

As shownintheresultsbelow in Table 5, Klean-Strip Premium Stripper took 15 minutes to remove all layers of paintonayearagedpanelbutonly5minutesonthemonthagedpanel. Alternatepaint removersalsorequiredmoretimetostripallalayersofthealkydpaintontheagedpanels stripallalayersincreasedtoanhourormoretoremovefromthe Experimental Formulas A, B, and C. Crown Safe Paint Strip stripped all layers of paint on the three 24 hour aged panels but failed to remove anylayersofpaintonthe1yearagedpanel. See **Appendix B** for a visual comparison of the 1 month and 1 year aged panels used in this validation effort. The results between the 1 month aged panels in Table 4 and Table 5 is due to the inconsistency of alkyd paint cures over a month time. Experiments done in Table 4 were done with one month boards created on different time periods than those used in Table 5. As the alkyd paint ages, the alkyd resin continues to cross link making the paint more difficult to strip. More consistent results are obtained using alkyd paint panels which are aged for one year. 1 month aged panels are used strictly for directional feedback and should not be used for the final efficacy of a paint remover.

Table 5: Validation results of paint removers testing on one month and one year aged Sand 1 Alkyd paint continues to bond and get harder to remove over a period of time. 1 month boards are more realistic of what the consumer will experience while paint stripping. Klean-Strip Premium Methylene chloride based stripper is far superior to the current competitive weekend warrior market. New formulas are extremely flammable and do not offer a safer alternative to current methylene chloride formulations. The difference in results between the 1 month aged panels in Table 4 and Table 5 is due to the inconsistency of alkyd paint cures over a month time. As the alkyd paint ages alkyd resin continues to cross link making the paint more difficult to strip. More consistent results are obtained using alkyd paint panels which are aged for a minimum of one year. 1 month aged panels are used strictly for directional feedback.

Paint Remover	Ingredients (SDS)	Month Old Panel - Alkyd (Sand 1)						Year Old Panel - Alkyd (Sand 1)					
		5 min	15 min	30 min	1 hrs	4 hrs	24 hrs	5 min	15 min	30 min	1 hrs	4 hrs	24 hrs
Klean-Strip Premium Stripper	methylenechloride/methanol/Solvent	5	5	5	5				5	5	5		
Klean-Strip Stripper	methylenechloride/methanol/toluene/acetone/xylene		1	5	5					5	5		
Experimental Formula A	toluene/acetone/methanol		1	5	5						5		
Experimental Formula B	1,2 trans dichloroethylene/acetone/methanol			5	5						5		
Experimental Formula C	1,3 dioxolane/acetone/methanol		1	5	5						5		
Citristrip Safer Paint Varnish Stripping Gel	NMP/DBE					5	5					5	5
Peel Away 1	calcium hydroxide/magnesium oxide/sodium hydroxide					3	5					5	5
Smart Strip	water/benzyl alcohol						5						5
Smart Strip Pro	water/benzyl alcohol/formic acid			1	1	1	5						5
EZ Strip Paint and Varnish Stripper	DBE/triethyl phosphate												
Lift Off Paint and Varnish Remover	acetone/2-butoxyethanol/DBE												
Crown Safer Paint Strip	DBE/DMSO						5						

nol layers of paint removed with plastic paint scraper	
paint has softened requiring effort to remove with plastic paint scraper	
paint has blistered and layers of paint have been removed with plastic paint scraper	

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r emovea ir cr aftcoa tings a ndtookfour hours tor emovethecl ea r andcol or coats .

Ta bl e6 Res ul ts of pa intremovertes tEMgAutomoOl iveCoa ti ng.

Compa ny	Pa ineRrover	Ingredients(MSDS)	Automoti veCoa ti ng			
			15mi n	30mi n	1hrs	4hrs
W. M. Barr	Kl eai nSpAi rcr amfctvRer	methyl enechl ori de/methanol/ethyl ene oxi de/xyl ene				
	Kl eai nSpPemi umStri pper	methyl enechl ori de/methanol/solvent				
	Kl eai nSpSi p,-rXi pper	methyl enechl ori de/metha nol /tol uene/nonyl phenol ethoxyl a te/a cetone/xyl ene				
	Ci tri s arfiepSPntVarnishStri ppingGel	NMP/DBE				
	Experi mental For mul a A	tol uene/a cetone/metha nol				
	Experi mental For mul a B	1, 2trans di chl or oethyl ene/a cetone/metha nol				
	Experi mental For mul a C	1, 3di oxol a ne/a cetone/metha nol				
	Experi mental For mul a D	benzyl al cohol emul si on				
	Experi mental For mul a E	DBEemul si on				
PPG	Dura Rep200Coa tingRmovER (Gel)	benzyl al cohol \s ol ventna phtha /2- a mi noetha nol /nonyl phenol , br a nched ethoxyl a ted				
	Dura Rep240Indus tri al Coa tingRmovER (Gel)	benzyl al cohol /hydr ogenpr oxi de/s ol ventna phtha /gl ycol li ca cid/mal li ca cid/ba ri um bis (di nonyl na phtha l enes uphona te)/a mi nes , cocoa l kyl , ethoxyl a ted				
	Dura Rep Pep4000Cer s pr emoVer	benzyl al cohol /petr ol eum di stil la tes /gl ycol i ca cid/quater na ryammoni um compounds /hydr ogenpr oxi de				
Solvent Kleene	D- Zol ve1028Rer Coa tingRmovER (i mmer si on	a lkyl methyl es ter/hydr oxi de/cyc li ca mi de				
	D- Zol ve15(-33R cr aft)	a l kyl methyl es ter/petr ol eum/benzyl al cohol /methyl phenyl ether				

No effect	
Stri ppedcl ear coa tandtopcoat	
Stri ppedcl ear coat, topcoa tandbas ecoat	

Conclusion

Theper for ma nceof methyl enechl ori dewas compa red122 ol vents s el ectedas pos s i ble
r epl acements for methyl enechl ori dei npai nstr ipper s.Tnductedonthr eetypes of pa ints
us ingwoodpa nel s pa intedwi tha noil - bas edal kydpa int, woodpa nel s pa intwi tha two- c
ba s edepoxypa inta nd EMa utomoti vecoa tings T- 1, 2- di chl or oethyl enea nd1, 3- di oxol a ne

identified as the best performing alternate solvent tested. However, based on the result study, none of the alternative solvents tested were determined to be a nadequate replace methylene chloride.

Based on the results of the solvents screening testing, two solvents, trans-1, 2-dichl dioxolane were selected as having some paint remover potential and were formulated int removers that met the 5% VOC limit for paint removers. The experimental formulas were also formulated based on a toluene, methanol and acetone formula, a benzyl alcohol emu and a DBE emulsion formula. The methylene chloride paint removers were then compared to the f experimental formula and 26 commercially available non-methylene chloride paint rem the results of the paint removers study, none of the experimental formulas or the 26 non-met chloride paint removers were determined to be a nadequate replacement for methylene chl removers. Performance of the experimental formulas based on trans-1, 2-dichloroethyle dioxolane was determined to be no better than the experimental formula based on toluene, and acetone.

Methylene chloride has been the preferred for use in paint removers for seventy. Consume that paint removers to be able to remove many types of coatings, remove multiple layers o and to start working within 15 minutes and quickly remove the coating. The paint remover, the solvent must be able to penetrate multiple layers of paint and have solubili paint to swell which breaks the bond of the paint to the substrate. The solvent molecule and the polarity of the molecule affects rate the solvent penetrates the coating. T solvent from the paint remover to the paint layer is call diffusion and is the resid kinetic of the ra movement of the solvent molecules. Smaller, nonpolar molecules will have a higher diffusion ra the coating than molecules that are larger or more polar. Two replacements for methylene chloride will be molecules with the following general characteristics, small halogenated molecules, five-member cyclic rings or six-member methylene rings. U chloride, these types of molecules are most likely flammable and possibly will have as to heal thands a fety.

Appendix A Composition of Paint Removers and Flash Points Listed in Material Safety Data Sheets

Company	Paint Remover	Ingredients (MSDS)			Flash Point
		Chemical Name	CAS Number	Weight %	
W. M. Barr	Klean Strip Aircraft Remover	methylene chloride	75-09-2	60–100	no flash to boiling
		methanol	67-56-1	5–10	
		ammonium hydroxide	1336-21-6	<5	
		xylene	1330-20-7	<5	
		hydrotreated light distillate (petroleum)	64742-47-8	<5	
		fatty acids soap	68132-50-3	<5	
		ethylbenzene	100-41-4	<3	
	Klean Strip Premium Stripper	methylene chloride	75-09-2	60–100	no flash to boiling
		methanol	67-56-1	10–20	
		Stoddard Solvent	8052-41-2	<5	
	Klean Strip Strip-X Stripper	methylene chloride	75-09-2	30–40	30°F
		methanol	67-56-1	15–26	
		acetone	67-64-1	<10	
		xylene	1330-20-7	<10	
		toluene	108-88-3	<10	
		ethylbenzene	100-41-4	<5	
		ethyl alcohol	64-17-5	<5	
		isopropyl alcohol	67-63-0	<5	
	Citristrip Stripping Gel	n-methyl-2-pyrrolid	872-50-4	30–60	>200°F
		dimethyl adipate	627-93-0	10–30	
		dimethyl glutarate	1119-40-0	10–20	
	Experimental Formula	acetone	67-64-1	40–50	0°F
		toluene	108-88-3	40–50	
		methanol	67-56-1	<10	
	Experimental Formula	acetone	67-64-1	40–50	0°F
		trans-1,2-dichloro	646-06-0	40–50	
		methanol	67-56-1	<10	
	Experimental Formula	acetone	67-64-1	45–55	0°F
		1,3-dioxolane	646-06-0	40–50	
		methanol	67-56-1	<10	
	Experimental Formula	benzyl alcohol	100-51-6	20-40	no flash to boiling
		alcohol ethoxylate (alcohols, c9-11, ethoxylated)	68439-46-	<5	
	Experimental Formula	water	7732-15-5	40–60	no flash to boiling
		dimethyl adipate	627-93-0	10–30	
		dimethyl glutarate	1119-40-0	10–20	
		starch	9005-25-8	5–20	
		alcohol ethoxylate (alcohols, C9-11, ethoxylated)	68439-46-3	<5	

Company	Paint Remover	Ingredients (SDS)			Flash Point
		Chemical Name	CAS Number	Weight %	
Dumond	Peel Away 1	calcium hydroxide	1305-62-0	21	none
		magnesium hydroxide	1309-42-8	16	
		sodium hydroxide	1310-73-2	9	
	Peel Away 5 Soy Based	benzyl alcohol	100-51-6	20–50	>200°F
		n-methyl-2-pyrrolid	872-50-4	25–35	
		fatty acid methyl este	67784-80-	15–20	
		alpha-(4-nonylphen omega-hydroxy-poly(1,2,ethanediyl)brar	127087-0	<3	
		dimethyl glutarate	1119-40-0	25–35	
		dimethyl adipate	627-93-0		
	Peel Away 7	benzyl alcohol	100-51-6	20–40	>200°F
		n-methyl-2-pyrrolidone	872-50-4	10–20	
		alpha-(4-nonylphenyl)-omega-hydroxy-poly(oxy 1,2,ethanediyl)branched	127087-0	<2	
		dimethyl glutarate	1119-40-0	25–35	
		dimethyl adipate	627-93-0		
	Smart Strip	water	7732-18-5	40–60	none
		benzyl alcohol	100-51-6	30–50	
		titanium dioxide	13463-67-	1-5	
	Smart Strip Pro	water	7732-18-5	40–60	none
		benzyl alcohol	100-51-6	30–50	
		titanium dioxide	13463-67-7	1–5	
		formic acid	64-18-6	1–5	
Ecoprocote	Eco Fast HD Heavy Duty Paint Stripper	water	7732-18-5	Trade Secret	non-flammable
		benzyl alcohol	100-51-6	Trade Secret	
		Bio-Based Emulsion	Non-Hazardou	Trade Secret	
		Solvent-Free Thickeners	Non-Hazardou	<1	
		Solvent-Free Surfactants	Non-Hazardou	1–5	
EZ Strip	EZ Strip Paint and Varnish Stripper	dimethyl adipate	627-93-0	3–7	not listed
		dimethyl succinate	106-65-0	5–10	
		dimethyl glutarate	1119-40-0	10–30	
		triethyl phosphate	78-40-0	3–7	
Frammar	Soy-Gel Paint and Varnish Stripper	n-methyl-2-pyrrolid	872-50-4	41	>200°F
		dimethyl adipate	627-93-0	40–45	
		dimethyl glutarate	1119-40-0		
		soy ester	67781-80-	15–20	
		Proprietary Thickening Surfactant Blend	Proprieta	1–5	
Motsenbocker	Lift Off Paint and Varnish Remover	acetone	67-64-1	<10	not listed
		2-butoxyethanol	111-76-2	Not Listed	
		dimethyl adipate	627-93-0	Not Listed	
		dimethyl succinate	106-65-0	Not Listed	
		dimethyl glutarate	1119-40-0	Not Listed	

Company	Paint Remover	Ingredients (SDS)			Flash Point
		Chemical Name	CAS Number	Weight %	
Packaging Services Co	Crown Paints Stripper Kit	dimethyl sulfoxide	67-68-5	20–25	160°F
		dimethyl glutarate	1119-40-0	45–45	
		dimethyl succinate	106-65-0	10–20	
		dimethyl adipate	627-93-0	5–15	
		alcohol ethoxylate surfactant	Not Listed	0–1	
PPG	Durapep 200 Coating Remover	benzyl alcohol	100-51-6	15–40	221°F
		solvent naphtha (petroleum), light ar	64742-95-	1–5	
		2-aminoethanol	141-43-5	1–5	
		nonylphenol, branch ethoxylated	68412-54-	0.1–1	
	Durapep 240 Industrial Coating Remover	benzyl alcohol	100-51-6	15–40	178°F
		hydrogen peroxide	7722-84-1	5–10	
		solvent naphtha (petroleum), heavy aromatic	64742-94-5	3–7	
		barium bis (dinonyl-naphthalenes ulphonate)	25619-56-1	0.1–1	
		amines, cocoalkyl, ethoxylated	61791-14-8	0.1–1	
	Durapep Prep 400 Overspray Remover	2-(methoxymethyl etho propanol	34590-94-8	30–60	203°F
		dimethyl sulfoxide	67-68-5	7–13	
		dimethyl glutarate	1119-40-0	5–10	
		benzyl alcohol	100-51-6	5–10	
Solvent Kleene	D-Zolve 1022 Power Coating Remover	alkyl methyl ester	Proprietary	Trade Secret	170°F
		potassium hydroxide	1310-58-3	2–5	
		cyclicamide	72-50-4	5–30	
Sunnyside	Multi-Purpose Professional Paint Remover	n-methyl-2-pyrrolid	872-50-4	15–35	203°F
		dimethyl glutarate	1119-40-0	20–35	
		dimethyl adipate	627-93-0	5–10	
		dimethyl succinate	106-65-0	5–15	
		formic acid	64-18-6	1–2	
		non-hazardous compo	N/A	20–40	
	Ready Strip Pro	benzyl alcohol	100-51-6	20–35	205°F
		n-methyl-2-pyrrolidone	872-50-4	5–15	
		formic acid	64-18-6	2–15	
		non-hazardous component	N/A	50–65	
	Ready Strip Sfera Paint & Varnish Remover	benzyl alcohol	100-51-6	20–35	205°F
		n-methyl-2-pyrrolid	872-50-4	5–15	
		formic acid	64-18-6	2–15	
		non-hazardous compo	N/A	50–65	
	Ready Strip Spray	n-methyl-2-pyrrolidone	872-50-4	35–50	205°F
		dimethyl glutarate	1119-40-0	20–35	
		dimethyl adipate	627-93-0	5–20	
		dimethyl succinate	106-65-0	3–5	
		monoethanolamine	141-43-5	1–3	
		isopropanolamine mixture	78-96-6	2-5	
			110-97-4		
			122-20-3		
		non-hazardous component	N/A	45–50	

Company	Paint Remover	Ingredients (SDS)			Flash Point
		Chemical Name	CAS Number	Weight%	
Sunnyside	Ready Strip Spray	n-methyl-2-pyrrolidone	872-50-4	35–50	205°F
		dimethylglutarate	1119-40-0	20–35	
		dimethyladipate	627-93-0	5–20	
		dimethylsuccinate	106-65-0	3–5	
		monoethanolamine	141-43-5	1–3	
		isopropanolamine mixture	78-96-6	2-5	
			110-97-4		
			122-20-3		
		non-hazardous components	N/A	45–50	
	Ultra Strip	n-methyl-2-pyrrolid	872-50-4	35–50	>200°F
		dimethylglutarate	119-40-0	20–35	
		dimethyladipate	627-93-0	5–20	
		dimethylsuccinate	106-65-0	3–5	
		formic acid	64-18-6	1–2	
		non-hazardous compo	N/A	5–35	
This Stuff Works Inc	TSW2 Multi-Stripper	n-methyl-2-pyrrolidone	872-50-4	Trade Secret	>212°F
		dimethylglutarate	1119-40-0	Trade Secret	
		dimethyladipate	627-93-0	Trade Secret	
	TSW2G Multi-Stripper (Gel)	n-methyl-2-pyrrolid	872-50-4	Trade Secret	>212°F
		dimethylglutarate	1119-40-0	Trade Secret	
		dimethyladipate	627-93-0	Trade Secret	
	TSW3G (Gel) Mason-Master	potassium hydroxide	1310-58-3	Trade Secret	non-flammable
		butylcellosolve	11-76-2	Trade Secret	
	TSW9 Plastic-Stripper	dimethylglutarate	1119-40-0	Trade Secret	>212°F
		dimethyladipate	627-93-0	Trade Secret	
		proprietary surfactant	Trade Secret	Trade Secret	
Zinsser	Magic Strip Citrus-Action	n-methyl-2-pyrrolidone	872-50-4	25–50	>199°F
		dimethylglutarate	1119-40-0	25–50	
		dimethyladipate	627-93-0	2.5–10	
		dimethylsuccinate	106-65-0	2.5–10	
		monoethanolamine	141-43-5	2.5–10	
		d-limonene	5989-27-5	1.0–2.5	

Appendix B: Photographs comparing test results on new panels painted with a noil-based alkyd paint.

Figure 1: Results of strippings creening panels (1-month-aged) painted with a noil-based alkyd paint. **Column 1** is Kleatn Sprem (methylene chloride based), **Column 2** is Strip-X methylene chloride based (lower levels), **Column 3** is a nexperimental formula containing toluene, **Column 4** is a nexperimental formula containing trans-1, **Column 5** is a nexperimental formula containing 1, **Column 6** is a Citrus strip (coMP and DBE). Blue = 1st paint layer applied, Yellow = 2nd paint layer applied, Green = 3rd paint layer applied, Red = 4th paint layer applied, Black = 5th paint layer applied. Snolayers of paint were stripped.

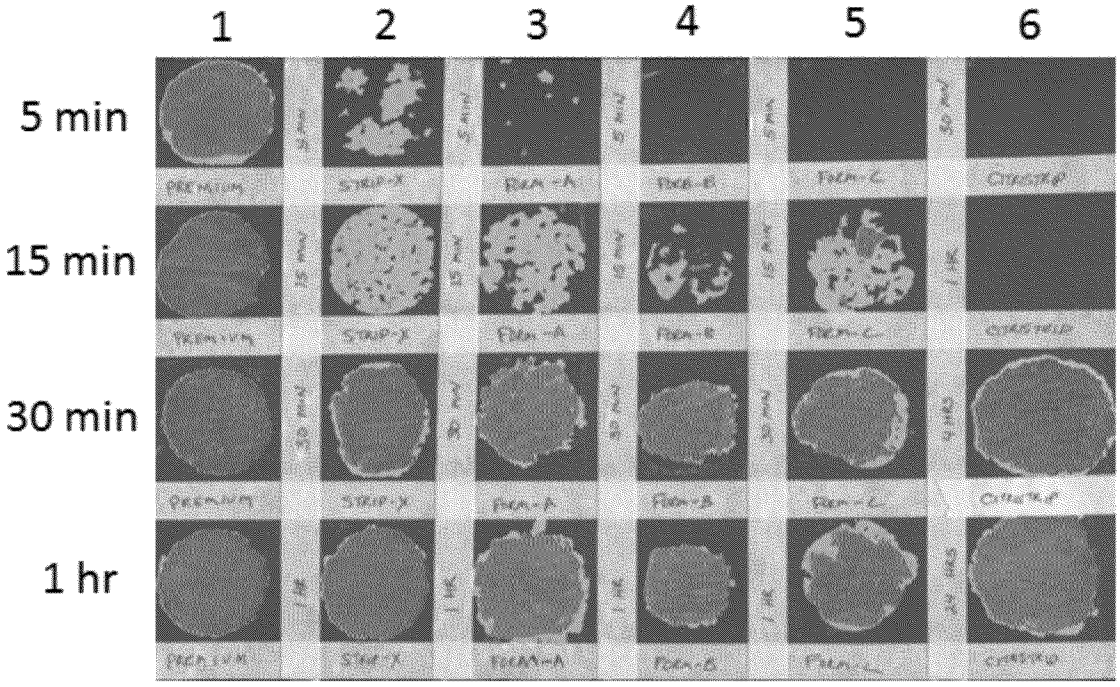


Figure 2. Results of stripping validation test (1-year-aged) (1-year-aged) tested with a noil-based alkyd paint. **Column 1** is Kleatin Spr Premium (methylene chloride based), **Column 2** is Strip-X methylene chloride based (lower levels), **Column 3** is a nexperimental formula containing toluene, **Column 4** is a nexperimental formula containing trans-1, 2-dichloroethylene, **Column 5** is a nexperimental formula containing 1, 6-dioxolsanitrans strip (comp MP and DBE). Blue = 1st paint layer applied, White = 2nd paint layer applied, Green = 3rd paint layer applied, Yellow = 4th paint layer applied, Last = 5th paint layer applied. Red = 6th paint layers of paint were stripped.

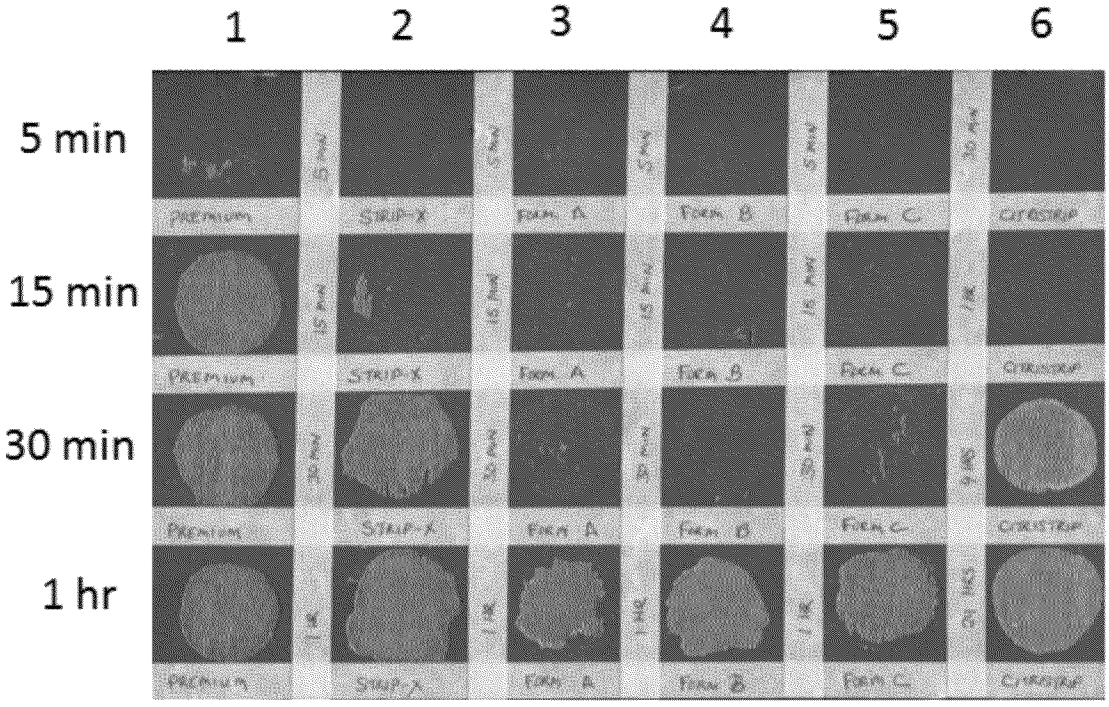


Figure 3. Results of strippings creening tests (1-month-aged) painted with a noil-based alkyd paint. **Column 1** is Peel Away 1 (caustic based), **Column 2** is Smart Strip (benzyl alcohol based), **Column 3** is Smart Strip Pro (benzyl alcohol based with formic acid), **Column 4** is EZ strip (DBE and triethyl phosphate), **Column 5** is Lift Off (acetone and 2-butoxyethanol and DBE based) and **Column 6** is Safer Paint Strip (DMSO and DBE based). Blue = 1st paint layer applied, White = 2nd paint layer applied, Green = 3rd paint layer applied, Yellow = 4th paint layer applied, Red = last paint layer applied. Red = 5 nol layers of paint were stripped. **Ingredients of competitive products cited from MSDS and/or GC analysis.

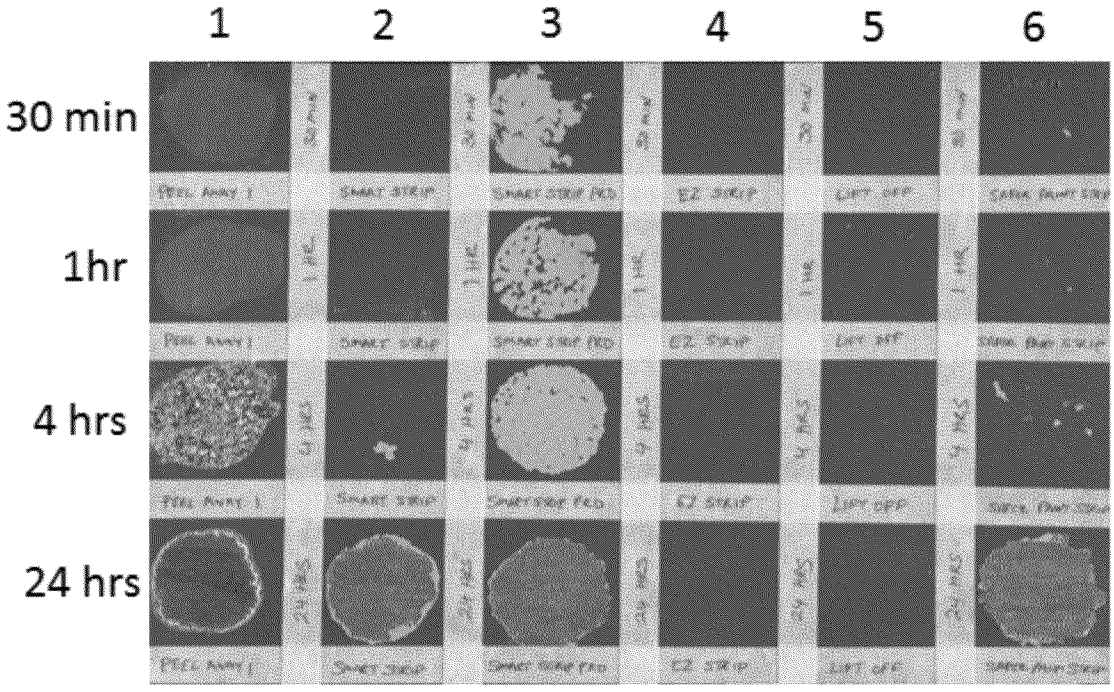
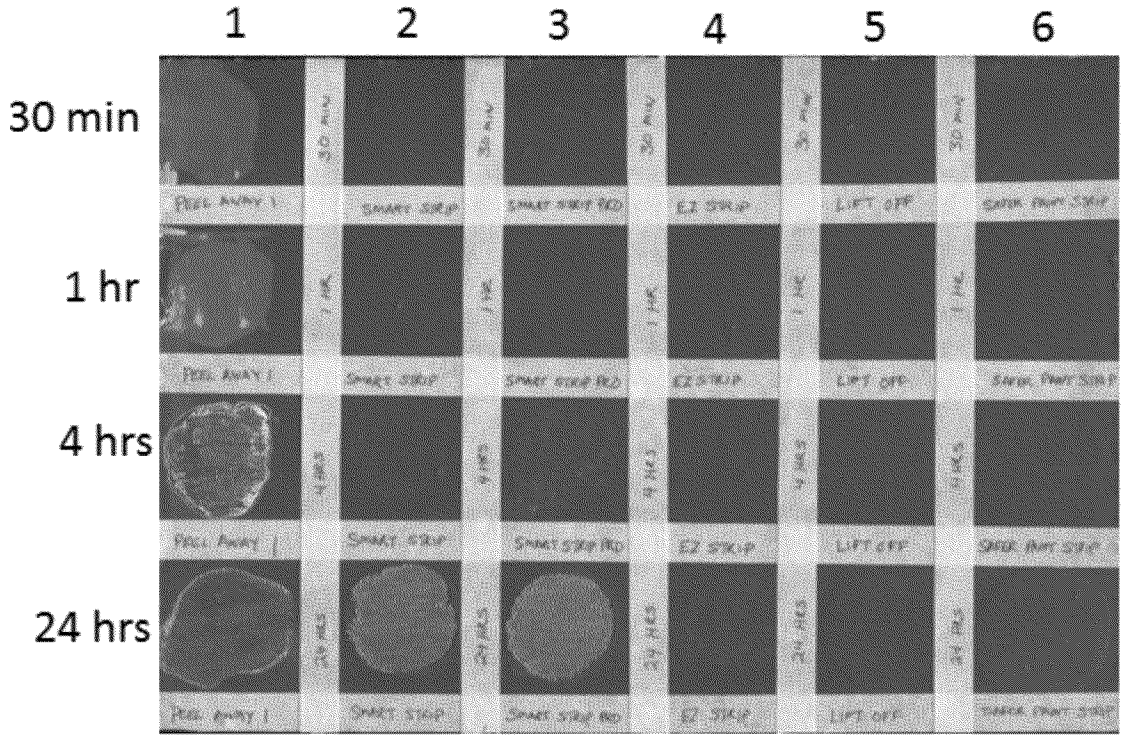


Figure 4. Results of stripping validation tests (1-year-aged) (1-year-aged) tested with a noil-based alkyd paint. **Column 1** is Peel Away 1 (caustic based), **Column 2** is Smart Strip (benzyl alcohol based), **Column 3** is Smart Strip Pro (benzyl alcohol based with formic acid), **Column 4** is EZ strip (DBE and triethyl phosphate), **Column 5** is Lift Off (acetone and 2-butoxyethanol and DBE based) and **Column 6** is Safer Paint Strip (DMSO and DBE based). Blue = 1st paint layer applied, White = 2nd paint layer applied, Green = 3rd paint layer applied, Yellow = 4th paint layer applied, Red = last paint layer applied. **Red = Snol layers of paint were stripped. **Ingredients of competitive products cited from MSDS and/or GC analysis.



Authors

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