



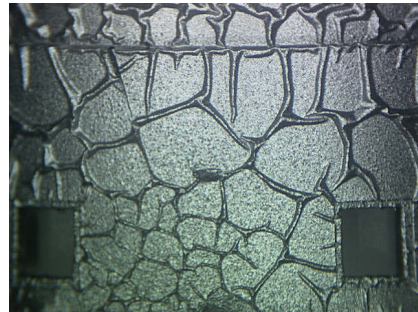
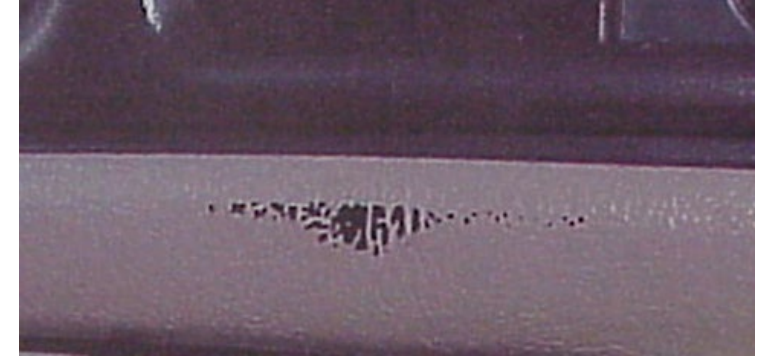
DECORATING  
& ASSEMBLY

# Quality Decorated Plastic

How to Ensure Products Survive in the Field

Paul Uglum

Consultant



**All things made for sale ought to be well done and suitable for their use.  
Shakers 1790**



# Ensuring Durable Products

## Why do we test?

**Because our customers require testing.**

**To understand the initial properties of the coating or decoration and the impact of the process of applying it.**

**To understand the performance initially and over time in the expected use environment.**

**To ensure that we provide our customers with robust products that meet their needs.**



# Types of Tests

## **Conformance Tests**

**Appearance and Physical Characteristics**

## **Performance Tests**

**Based on the use environment**

## **Accelerated Performance Tests**

**Elevated Temperature**

**Beware of Foolish Failures**

## **Combined Stress**

**Simultaneous exposure to Chemicals and Environment**

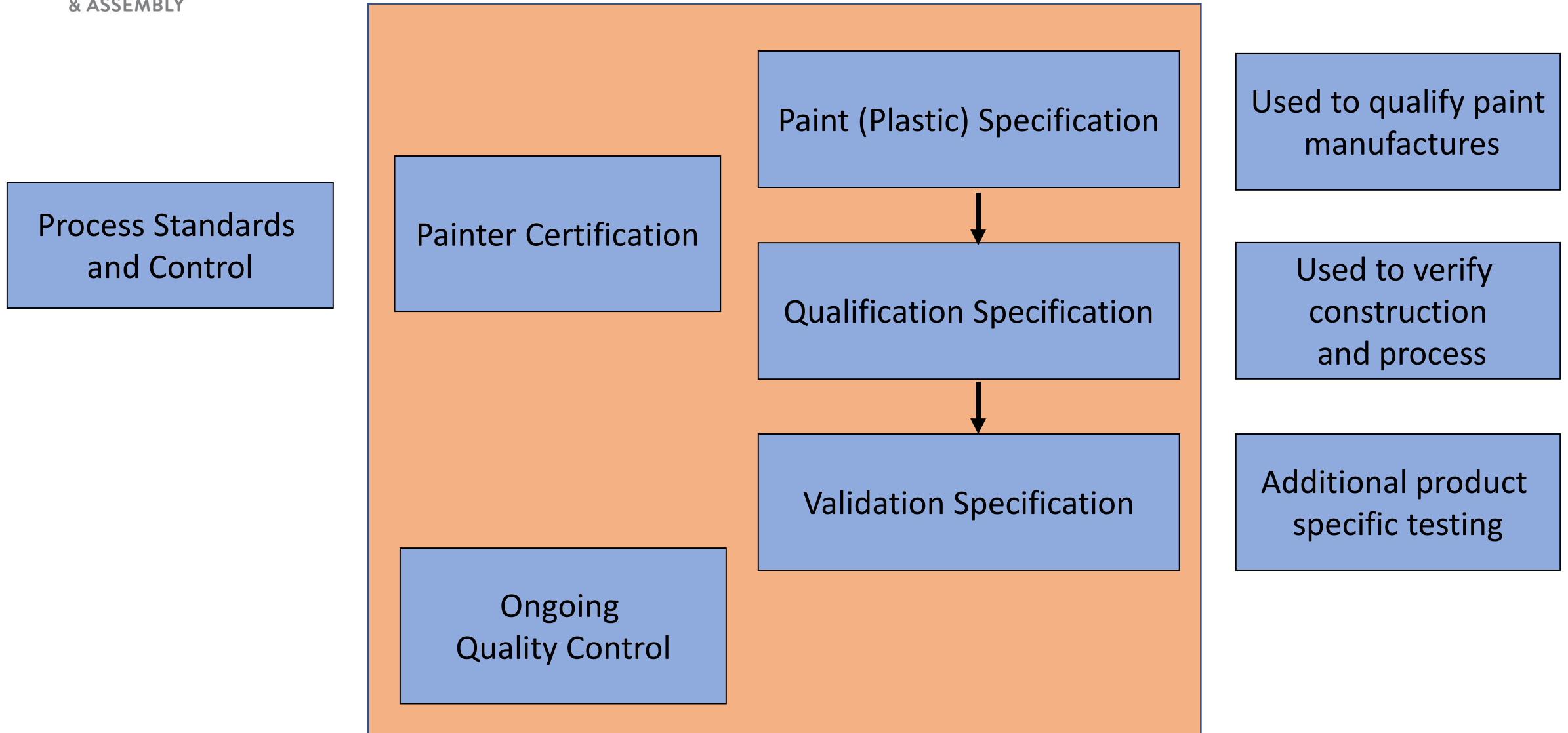


# Test Specifications

## Primary OEM Coating Test Specifications

<b>General Motors</b>	<b>GMW 15520</b> <b>GMW 14797</b>
<b>Ford</b>	<b>WSS-M2P 188-B1</b>
<b>Fiat Chrysler</b>	<b>MS 90053</b>
<b>BMW</b>	<b>GS 97045-2</b>
<b>VW</b>	<b>TL-226</b>

# Automotive Sequence of Testing

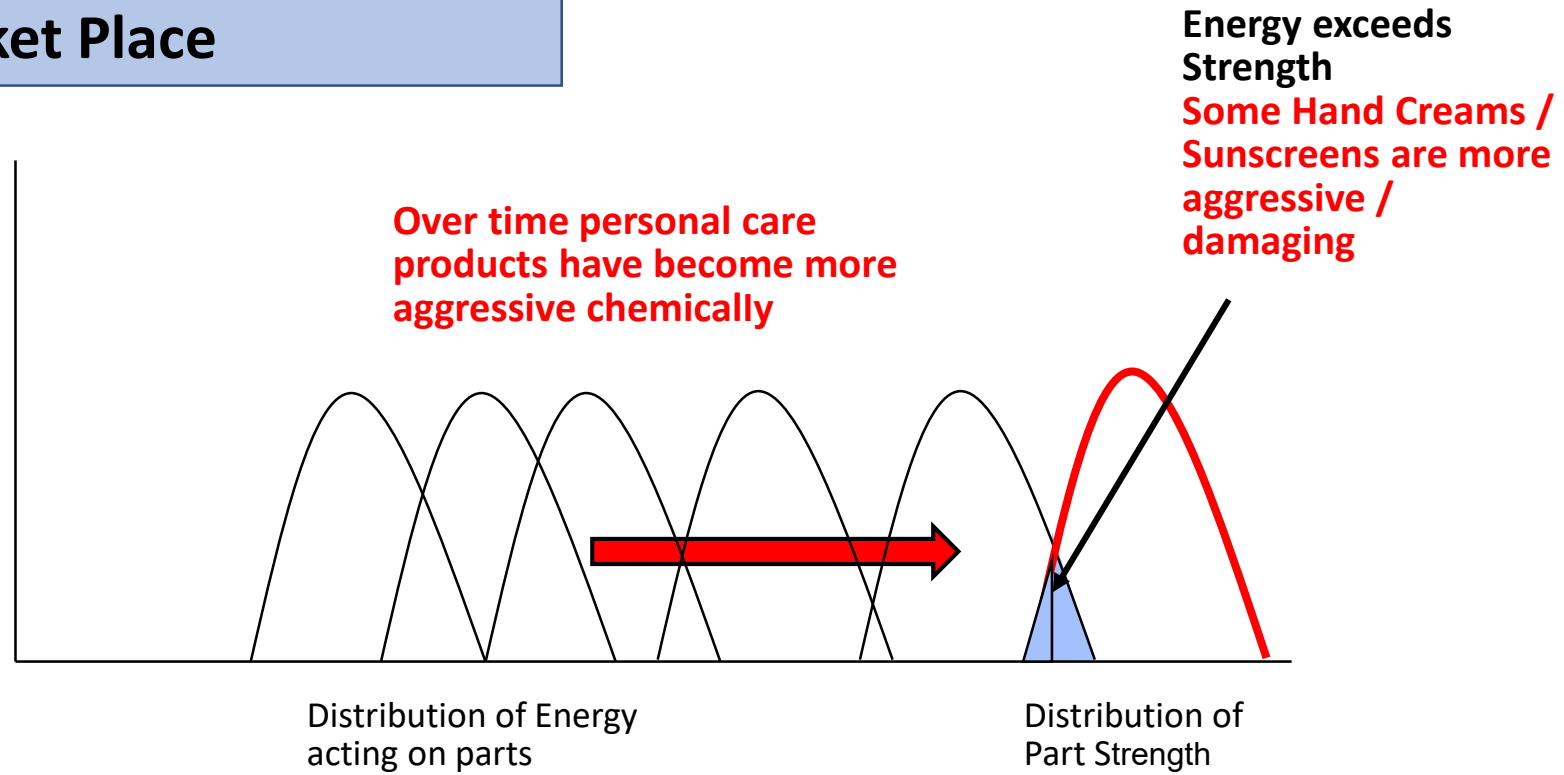




# What do Tests Tell Us?

# Strength / Energy Concept Diagrams

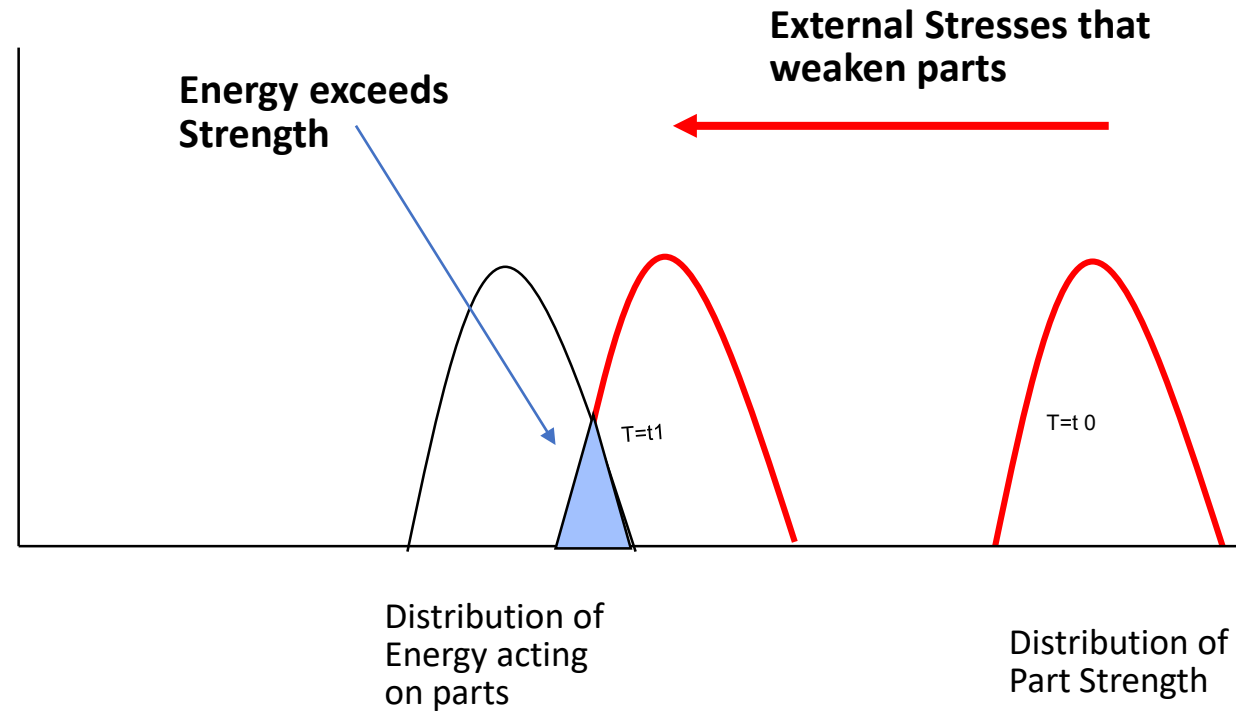
**60,000 Personal Care Products  
in the Market Place**





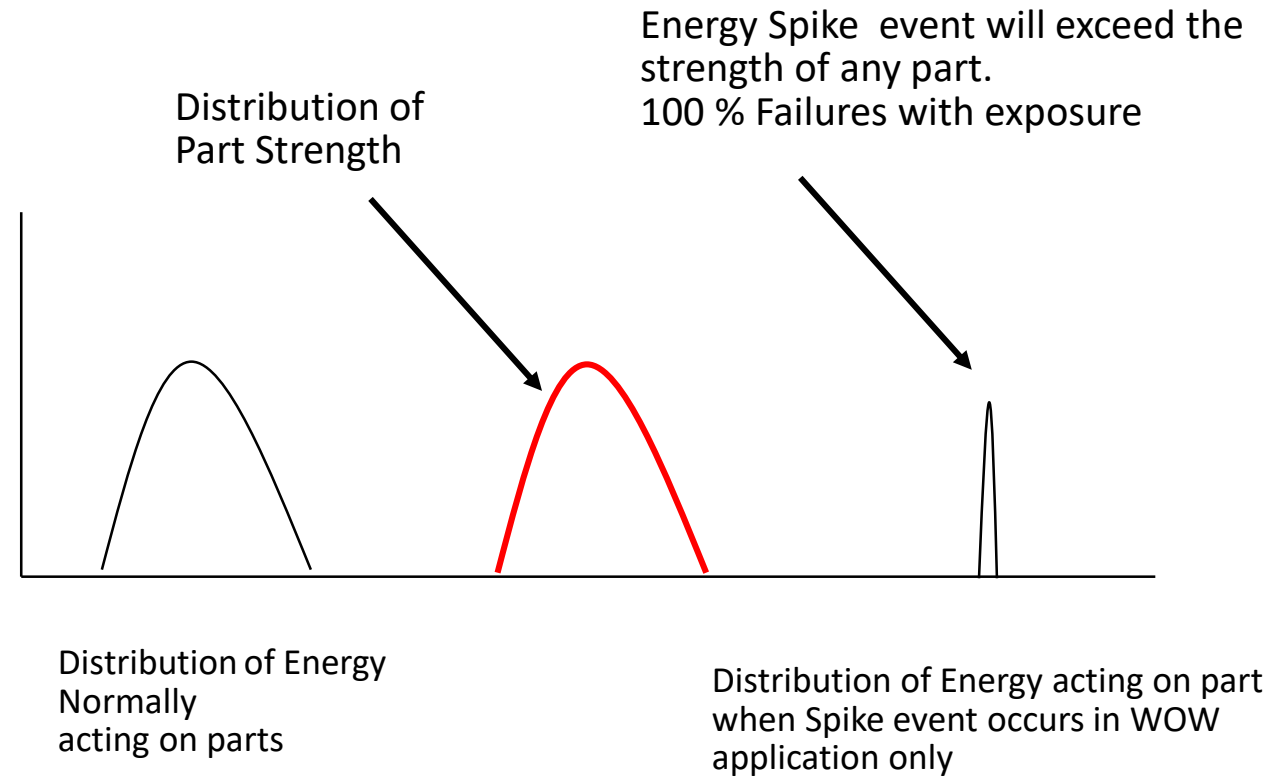
# Strength / Energy Concept Diagrams

Chemical Exposure can weaken the coating to substrate bond strength without causing an obvious failure

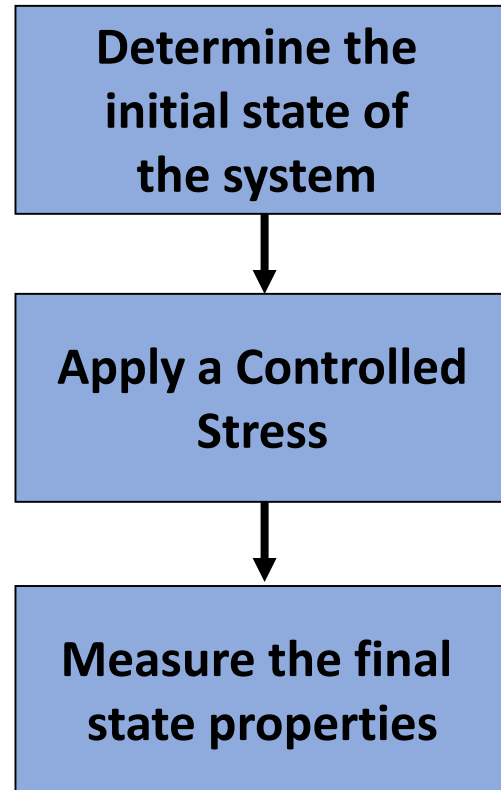


# Strength / Energy Concept Diagrams

Watch for new  
damaging exposures  
by analyzing  
customer return  
parts



# Test Sequence



Have a clear standard for pass / fail prior to starting the test

Variable data is best if possible

Observe and investigate any unexpected changes



# **Understand What the End Points Actually Tell Us**

# Tape Adhesion

The test ASTM D3359 was intended for use with paint on metal – when used with rigid paint on plastic it lacks reproducibility.

Tapes are specified based on pull off force from glass and metal – significant variation exists from paint to paint

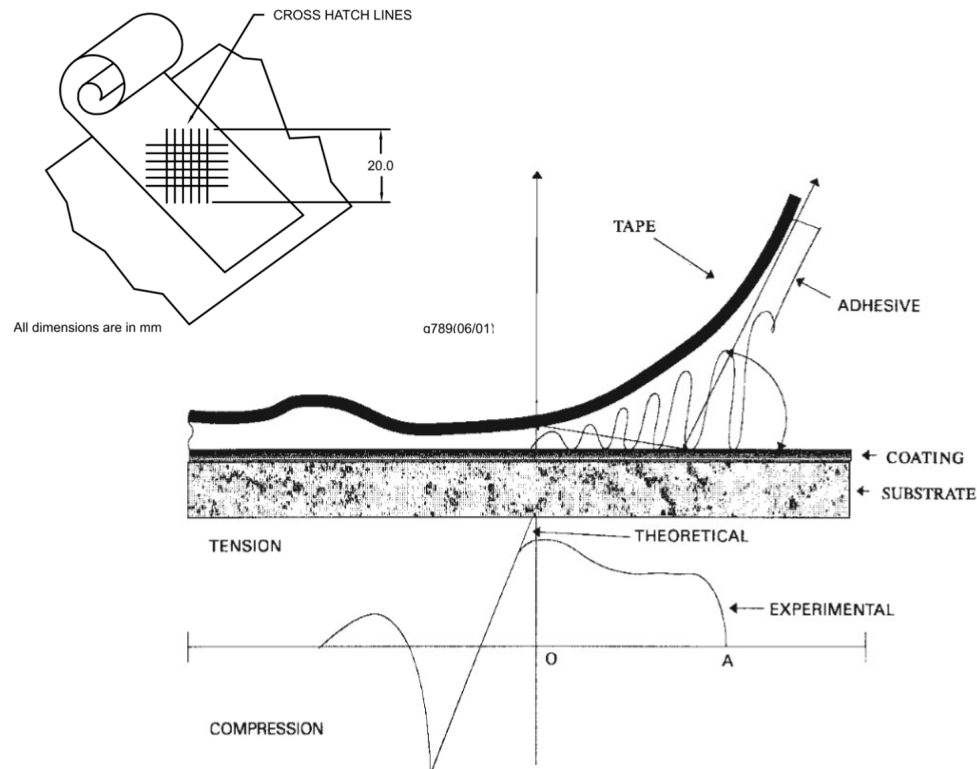


FIG. X1.1 Peel Profile (6)

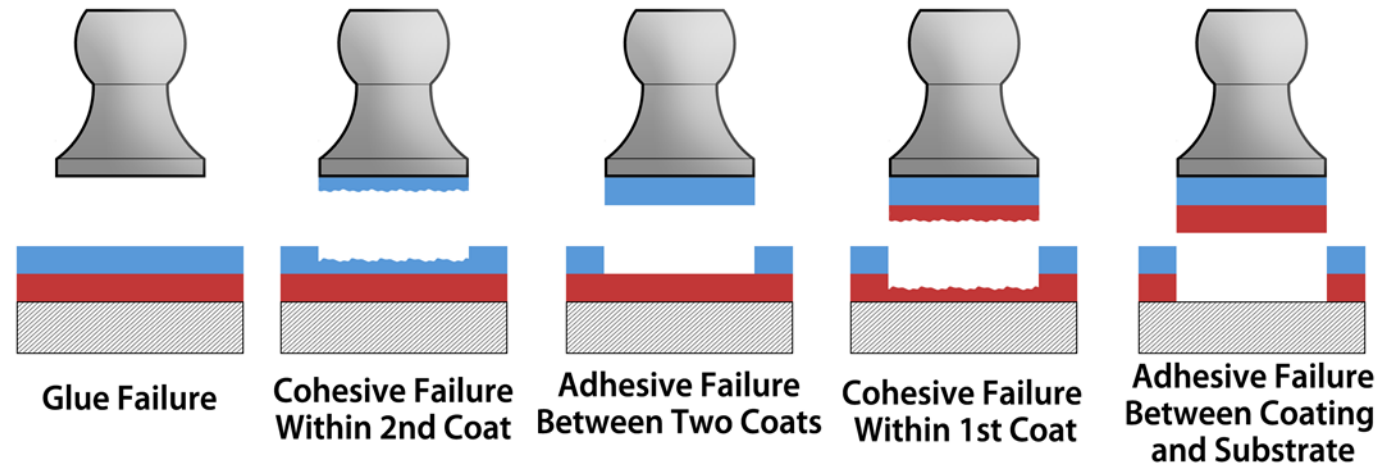
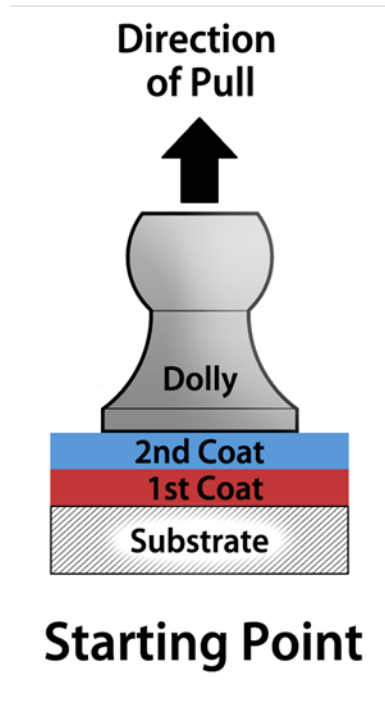
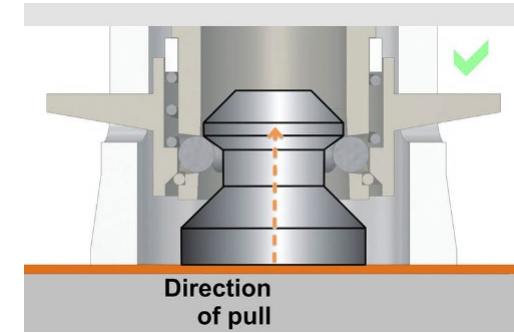
Surface of crosscut area from which flaking has occurred	None					Greater than 65%
<b>Rating (classification)</b>	0	1	2	3	4	5

Figure A2: Adhesion Performance for Test Method A (Crosshatch)

# Tape Adhesion A Better Solution

## Types of Products

Anvil Pull tests base on ASTM D4541 provides both variable data to compare coatings and provide more data based on failure mode



1

2

3

4

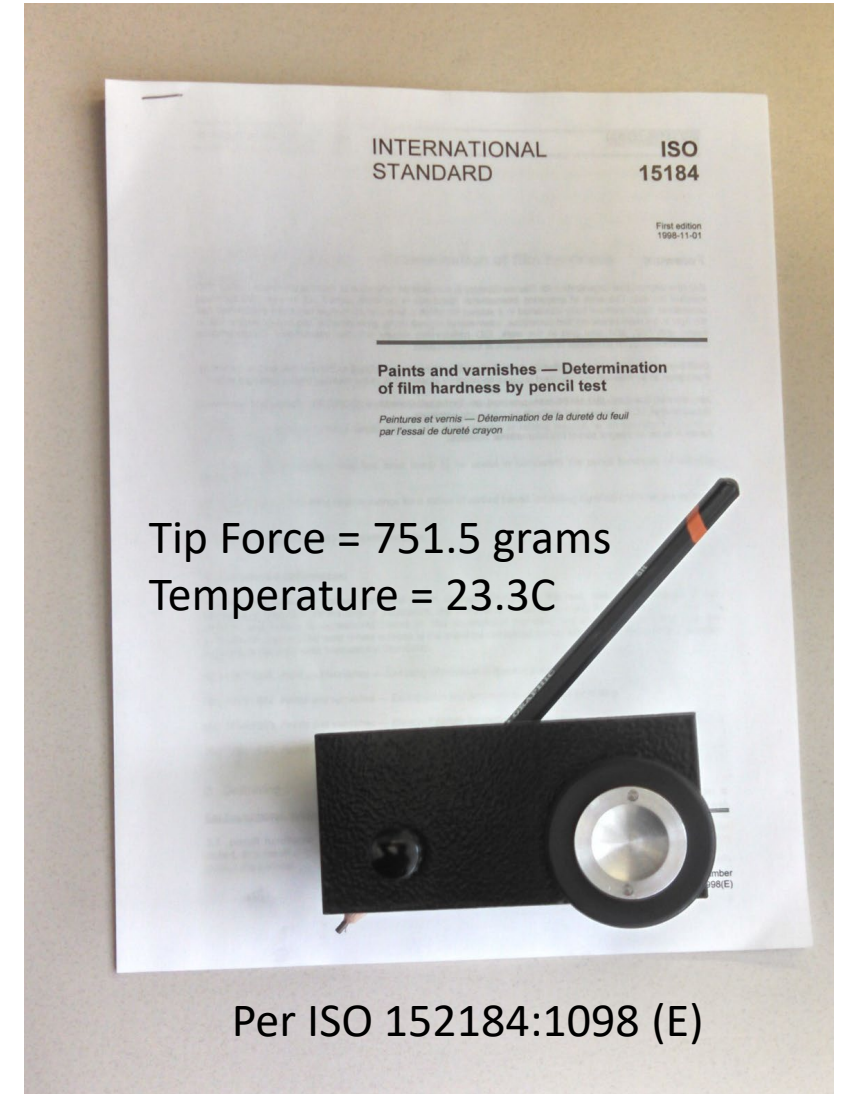
5

# Pencil Hardness

Pencil lead varies lot to lot  
and brand to brand

The test is operator  
dependent

The result varies  
depending on the  
substrate hardness – can  
cause more than two unit  
difference for the same  
paint





# Sun Screen and Hand Cream End Points

**Crosscut test according to DIN EN ISO 2409 with subsequent abrupt removal of adhesive tape; requirement: crosscut characteristic value  $\leq 1$**

**Erichsen hardness testing device with a load of 10 N and a test needle according to Bosch (0,75 mm tip)**

**No change in appearance (swelling, crow's feet) and haptic characteristics (softening, tackiness) compared to as-received condition**



Figure 3 – Cracks in paint film extending to the substrate (due to paint softening)



Figure 4 – Cracks in, and scratches through, the paint coating



Figure 5 – Crow's feet



Figure 6 – Swelling of paint



# Evaluate the Chemical Exposure in the Environment

## Chemical Exposure

A major driver in decorated plastic developments



# **Chemical Exposure: An Ongoing High Risk**

## **Cleaning Products**

**People use what is readily available not what is recommended**

## **Personal Care Products**

**Many in use and constantly changing formulations**

## **Sun Screen**

**Aggressively attacks polycarbonates**

## **Insect Repellants**

**DEET is aggressive to both coatings and plastics**

## **Air Fresheners**

**Many different formulations and mechanisms of attack**

# Sunscreen Testing

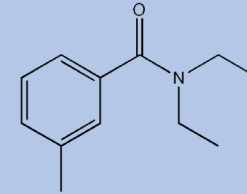
## GM 4 Old Test

Commercial Product

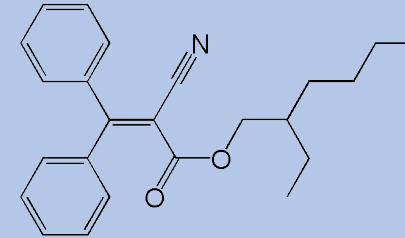
Coppertone  
Water babies  
SPF 30

## GM Current 4 Solvent Test

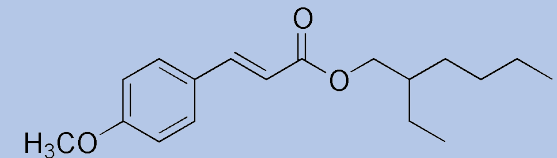
- Diethyltoluamide – DEET



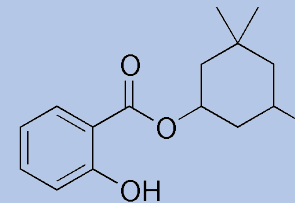
- Octocrylene



- Octyl methoxycinnamate



- Homosalate



# Sunscreen Testing

## VW Old Hand Cream

**Kamill Cosmetics Classic Hand &  
Nagel Cream, made in Germany:**

water, glycerin, ethylhexyl stearate, glyceryl stearate SE, liquid paraffin, hydrogenated coco-glycerides, cetearyl alcohol, chamomilla recutita (matricaria) flower extract, chamomilla recutita (matricaria) flower oil, bisabolol, glucose, dimethicone, alcohol, carbomer, stearic acid, palmitic acid, perfume (hexyl cinnamal, linalool, butylphenyl methypropional, benzyl salicylate, limonene, citronellol, alpha isomethyl ionone, hydroxyisohexyl 3-cyclohexene carboxaldehyde, cinnamyl alcohol, citral, coumarin), sodium hydroxide, phenoxyethanol, methylparaben, ethylparaben, butylparaben, propylparaben, isobutylparaben.

## Sun Screen

**Delial Plus Vitamine-Sonnenilch SF  
30:**

water, C12-15 alkyl benzoate, caprylic/capric triglyceride, alcohol, glycerin, ethylhexyl salicylate, 4-methylbenzylidene, camphor, titanium dioxide, polyglyceryl-3 polyricinoleat, butyl methoxydibenzoylmethane, diethylhexyl butamido triazone, octocrylene, tocopheryl acetate, sodium chloride, cetyl dimethicone, sodium ascorbyl phosphate, phytantriol, disodium EDTA, perfume.

**Three chemically  
different versions  
at one time**

## VW New

### Cream A

**Commercial Like Standard  
based on Sun Screen**

### Cream B

**Commercial Like Standard  
based on Hand Cream**

# Sunscreen Testing

Current Coppertone SPF 30 contains:

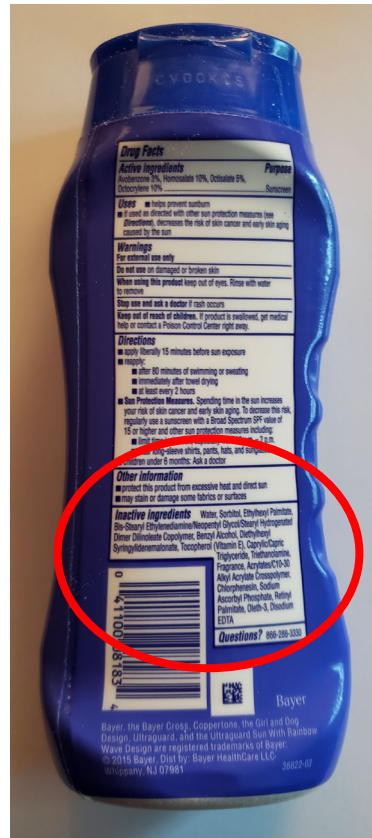
Avobenzene

Homosalate \*

Octocrylene \*

Oxybenzone

Current FDA Approved List contains 15 compounds. An increase from the 3 approved when the initial GM specification was created



The environment is dynamic and personal care product formulas are constantly undergoing revision

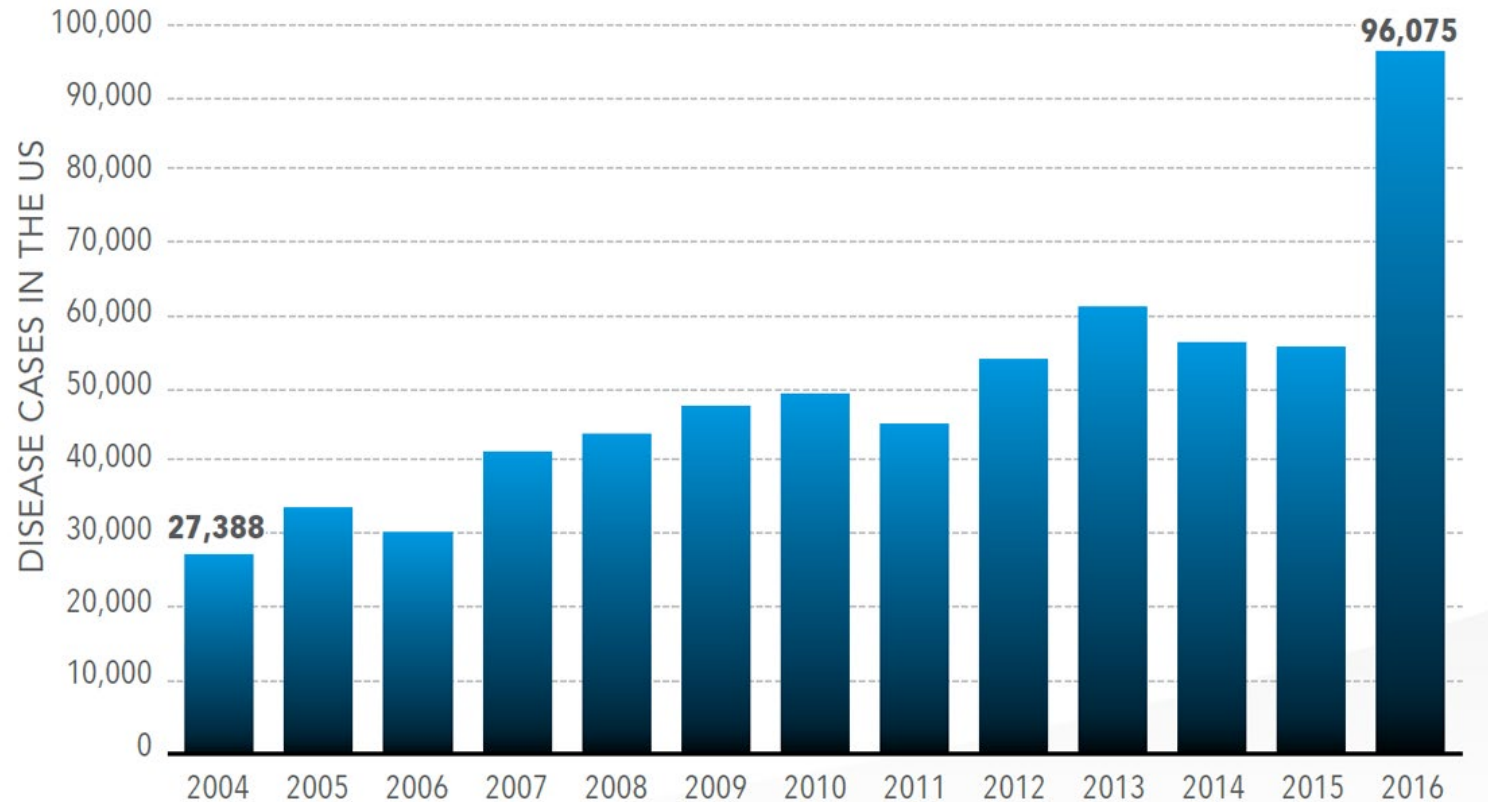


# Illnesses from Mosquito, Tick, and Flea Bites Increasing in the US

**Disease cases from infected mosquitoes, ticks, and fleas have tripled in 13 years.**

**3x. Disease cases from mosquito, tick, and flea bites tripled in the US from 2004 to 2016.**

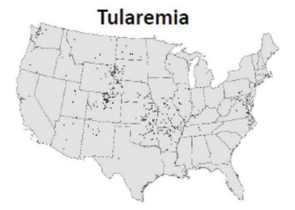
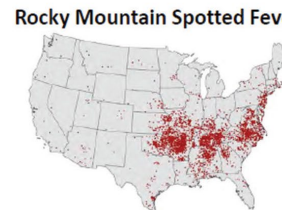
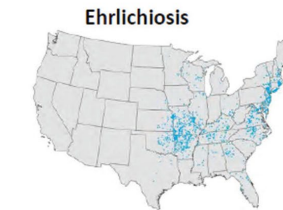
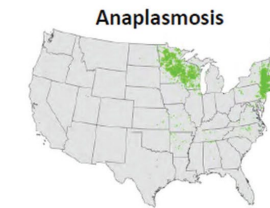
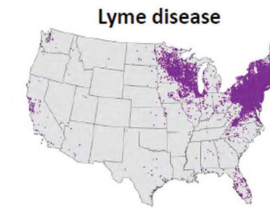
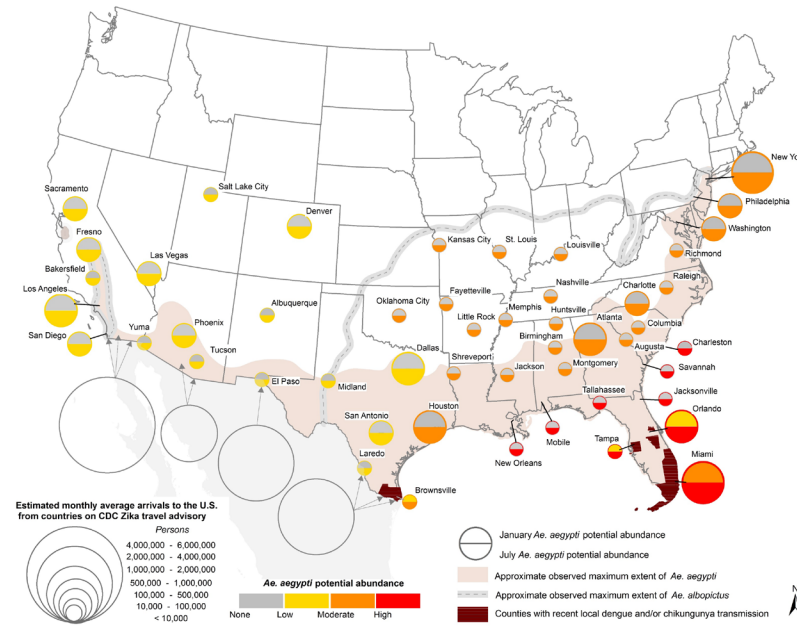
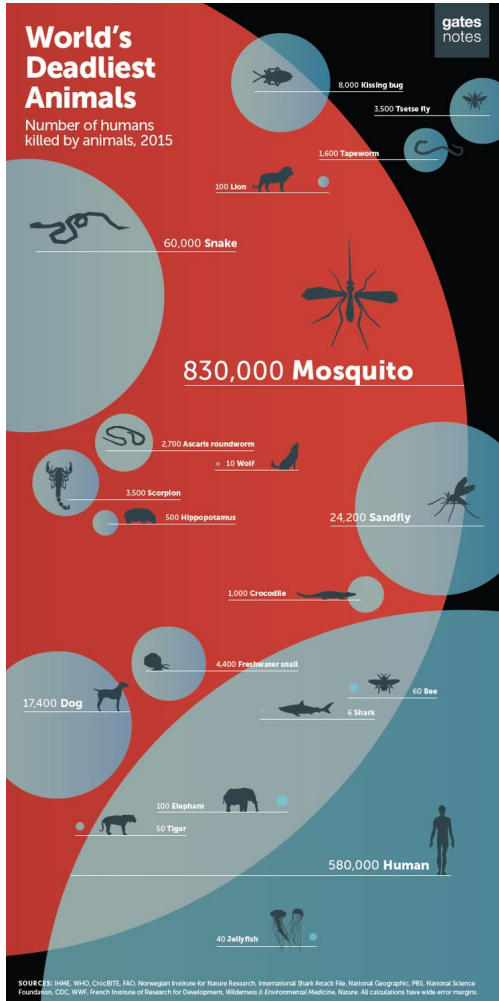
**Nine new germs spread by mosquitoes and ticks have been discovered or introduced since 2004.**



## Ticks and Lyme Disease Are a Threat for Cities, Too

An examination of black-legged ticks in New York City raises concerns about Lyme disease spreading in urban communities.

# Insect Repellant - Risk



Each dot represents a reported case in the county of residence



# **Insect Repellant**

## **CDC List of Repellants**

**DEET**

**Picaridin (also know as KBR 3223 and icaridin outside of US)**

**IR3535**

**Oil of lemon eucalyptus (OLE)**

**Para-menthane-diol (PMD)**

**2-undecanone**

## **Other Sources Include**

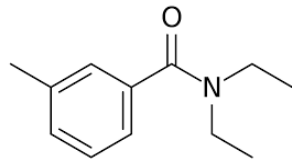
**Oil of Citronella**

**Catnip Oil**

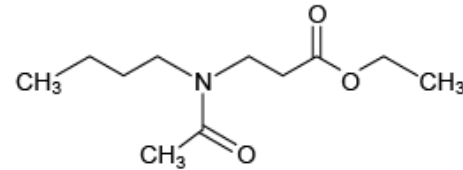


# Insect Repellent

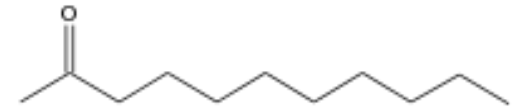
**DEET** N,N-Diethyl-3-methylbenzamide



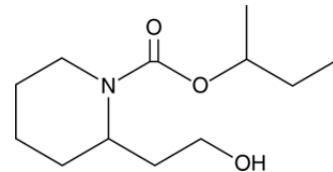
**IR3535** Ethyl butylacetylaminopropionate



**2-Undecanone**



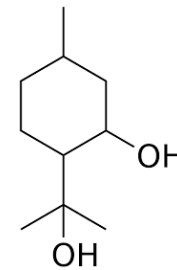
**Picaridin** 1-piperidinecarboxylic acid 2-(2-hydroxyethyl)-1-methylpropylester



**Oil of lemon eucalyptus (OLE)**

mixture – essential oil

**Para-menthane-diol (PMD)**



# Insect Repellant

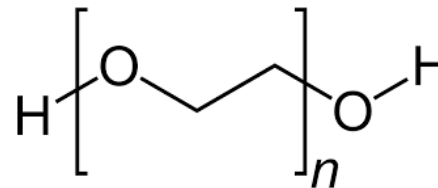
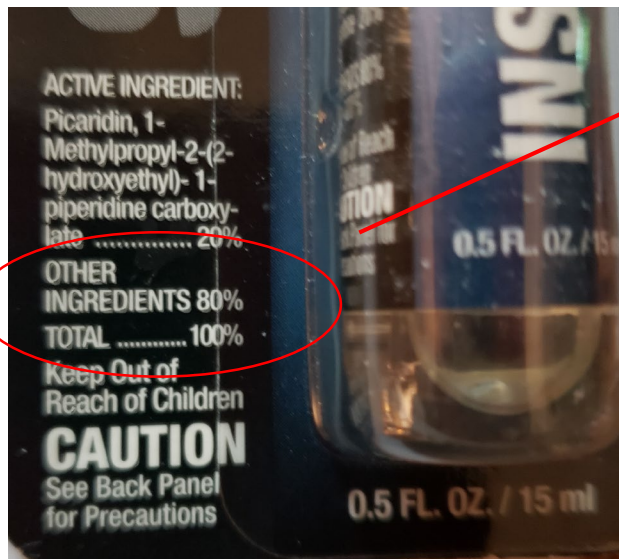
		Inert	IR 3535	Picaridin	2 Undecanone	DEET	Oil of Soybean	Oil of Citronella	Oil of Peppermint	Oil of Cedar	Oil of Lemongrass	Oil of Geranium	Oil of Lemon Eucalyptus	Catnip Oil	Glycerine	Essecial Oils
1	All Terrain Herbal Armor	73.95%					11.50%	10.00%	2.00%	1.50%	1.00%	0.05%				
2	Repel	70.00%											30.00%			
3	Inovagreen	x													x	x
4	Coleman SkinSmart	80.00%	20.00%													
5	Repel 100	1.89%				98.11%										
6	Pipingrock Catnip Oil	0.00%											100.00%			
7	Sawyer Lotion	80.00%	20.00%													
8	Natrapel	80.00%	20.00%													



# Insect Repellent

DEET was still the most damaging insect repellent found but others including Picardian formulations caused damage

Contains 12 compounds  
Polyethylene Glycol 400?



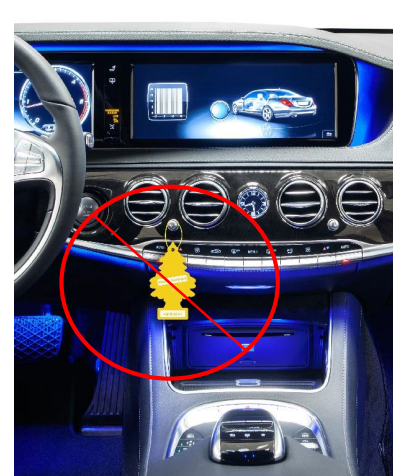
## Air Freshener

**Automotive Air Fresheners are not intended to be in contact with any surfaces in the vehicle**

**The volatile organic compounds (VOCs) released by air fresheners are intended to be inhaled by humans**

**There are no specific federal standards regulating air fresheners. Manufacturers and importers are not required to evaluate carefully the risk posed by the product.**

**The American Association of Poison Control Centers (AAPCC) documented more than 14,000 calls involving actual exposure in 2005. More than 2500 exposures resulted in injuries of some type including one death**



# Air Freshener

## What we found in Commercial Air Fresheners:

**Benzene**  
**Formaldehyde**  
**Terpenes**  
**Phthalates**  
**Amines**  
**Amides**  
**Toluene**  
**Fragrances**

The frequency of contact still appears low, but the certainty of damage if extended contact occurs is large.

More work needs to be done

# Where can I find out what is in products



The **Environmental Working Group (EWG)** is an American Environmental Organization that specializes in research and advocacy in the areas of toxic chemicals and corporate accountability. <http://www.ewg.org/skindeep/>



HAPPI (household and personal products Industry) magazine covering the global personal care, household and industrial and institutional cleaning market. [www.ritacorp.com](http://www.ritacorp.com)



Product Labels can be of varying use since nomenclature can be unclear and relative amounts are not included.



Safety Data Sheets (SDS) are required by the Occupational Health and Safety Administration and contain some content information.



EPA, CDC, FDA and other government agencies.



# Change Involves Risk

# Manage Changes

The first step when considering a change is to complete a DRBFM (Design Review by Failure Mode). What is changing and what weaknesses can result from it.

**Only test for those properties that can reasonably be expected to be a risk**

**Table 1 –Test Requirements for Process and Product Validation (Note 2)**

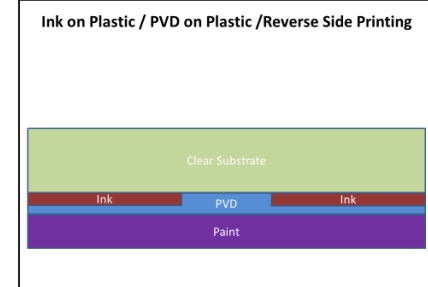
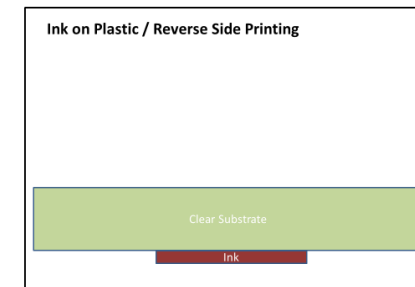
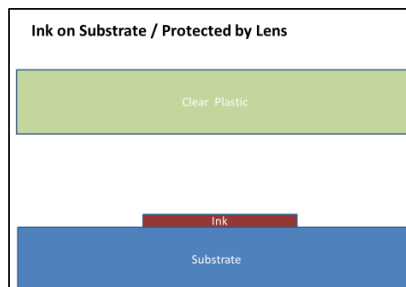
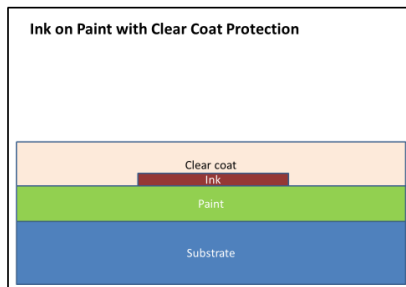
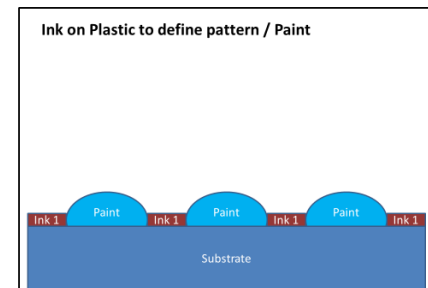
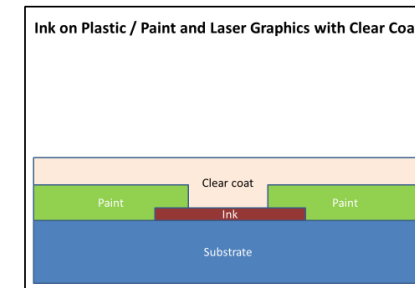
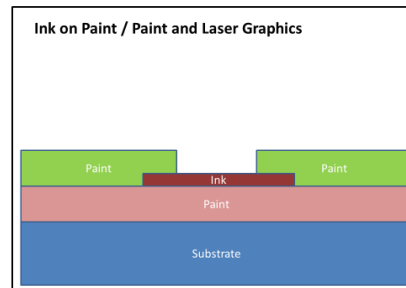
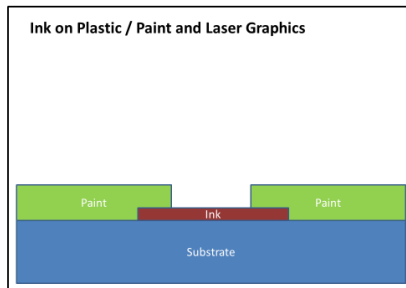
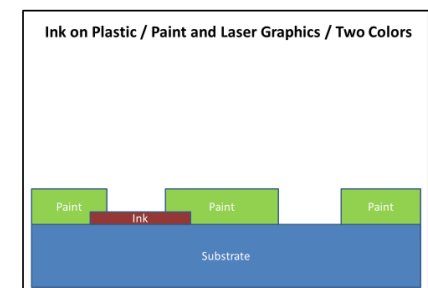
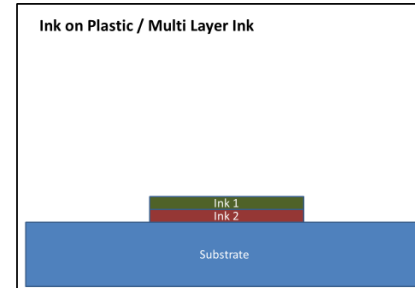
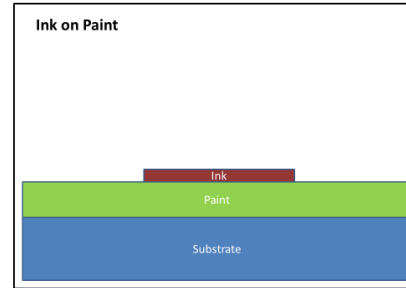
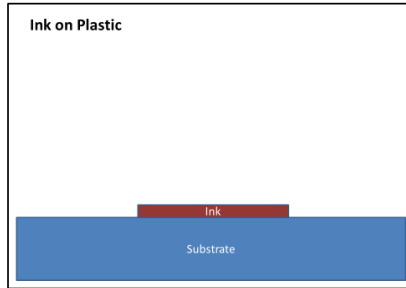
		Column 1	Column 2	Column 3	Column 4
	Sample size per color	New Applicator/ Facility or Non Approved Applicator	Change in Approved Paint System, Primer, or Substrate	New Paint Technology	New Part/New Color existing paint technology (signed MCDCC), approved applicator and substrate
Test Colors		One light, one dark, & one metallic	One light, one dark, & one metallic	All	Each
3.2.6	Film Thickness	X	X	X	X
3.3	Appearance	X	X	X	X
3.4.1	Adhesion	X	X	X	X
3.4.2	Water Resistance	X	X	X	X





# **Interfaces are Often the Weakest Point**

# Pad Print Execution Options



## **Actions you can take**

### **Be Aware of Changes in the Environment**

**Be aware of trends**  
**Identify new risks**

### **Monitor and Analyze Field Failures**

**Watch for increases in failure rate and identify causes**

### **Learn Problem Solving Tools**

**Six Sigma**  
**Shannin Problem Solving**

### **Choose the Most Robust Construction**

**Test to failure not just to the specification**

### **Test Intelligently**

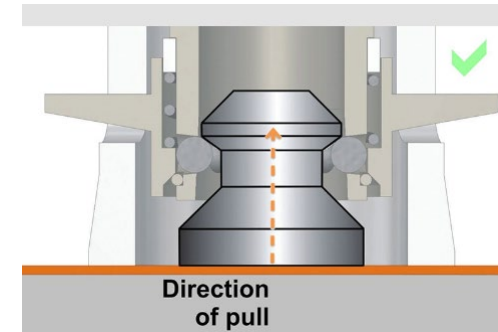
**Test to add value**



**Backup**

# Latent Failures after Chemical Exposure

- ◆ Exposure to various chemicals
  - 1hour room temperature
  - 1hour elevated temperature
- ◆ Dry time
  - 1 week room temperature
- ◆ End Point
  - Visible Damage
  - Softening
  - **Pull Off Force – Modified ASTM D4541-02**



**Poison Model**

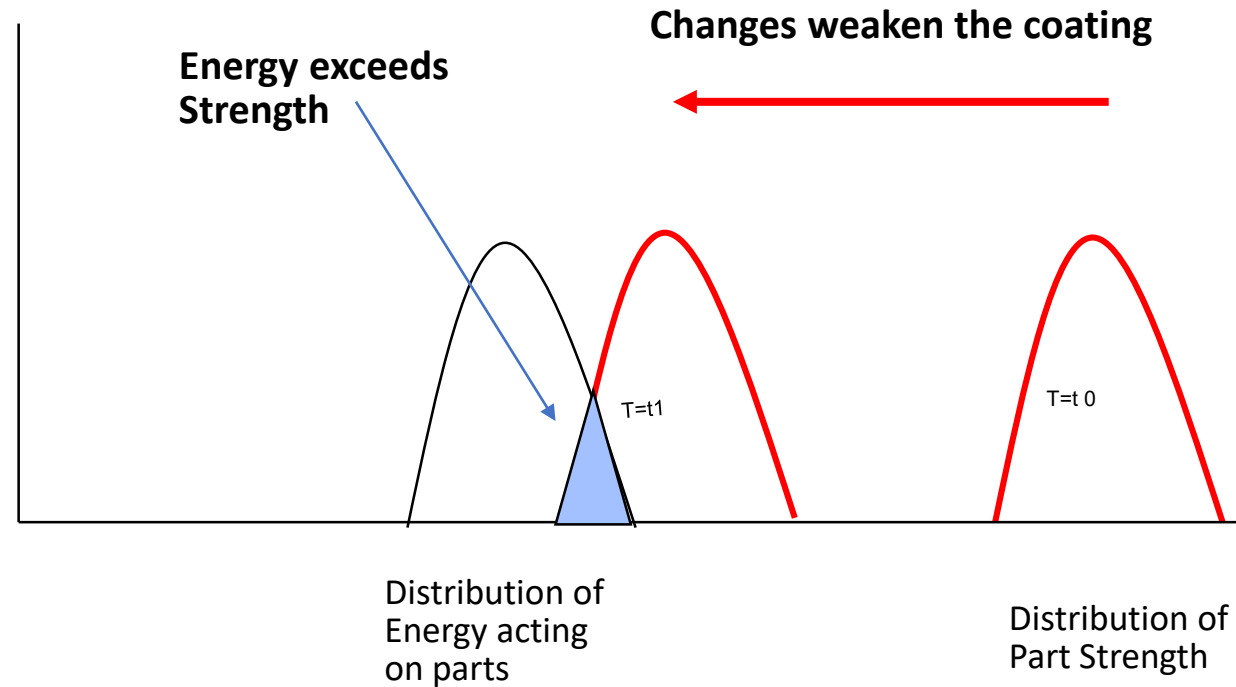
**Dosage  
Pathway  
Acute vs Chronic**



- ◆ Studies show reduced bond strength after chemical exposure
  - Data from previous studies not yet published

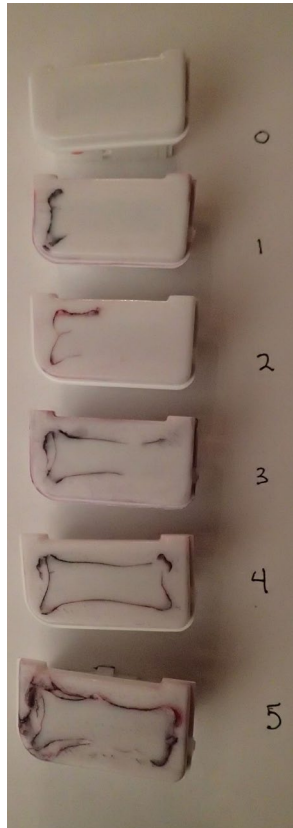
# Strength / Energy Concept Diagrams

Changes in the paint formulas or variation in the process reduce the strength of the coating



# Effect of Cream A (Sunscreen) on Polycarbonate

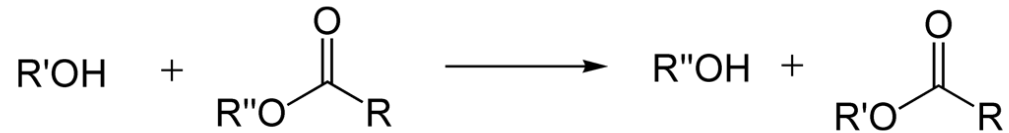
- **Obvious Physical Damage**
  - Pitting and deformation
- **Polycarbonate softening**
  - Fingernail damages surface
  - Plasticizes plastic
- **Surface analysis shows high concentration at surface**
- **Deep penetration of cream into plastic**
- **Migrates through paint into plastic**



# Effect of Cream A (Sunscreen) on Polycarbonate

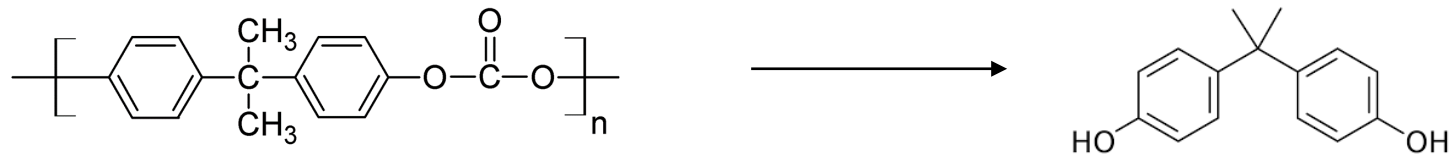
- Loss of Cross Link Density

- Transesterification



Accelerated by  
temperature  
moisture  
quantity

- Chain Scission







# Specific Tests

- **Appearance (Optical)**
  - Color
  - Gloss
  - Travel
  - Flop
  - Sparkle
  - Grain
- **Physical Characteristics**
  - Smoothness
  - Texture (Topology)
  - Uniformity
  - Hiding Power (Opacity)
  - Hardness
  - Coefficient of Friction
  - Permeability
  - Feel
  - Odor
  - Surface Energy
- **Process**
  - Thickness
  - Cure
  - Defect Rate
  - Laserability
  - Sag
  - Radius thickness
- **Wear Resistance**
  - Abrasion
  - Impact
  - Scratch, Scuff, and Mar
  - Crocking
  - Flexibility
- **Stability**
  - Blooming
  - Out gassing
  - Fogging
  - UV Exposure



# Specific Tests

- **Chemical Testing**
  - Hydrolysis
  - Chemical Resistance
  - Flammability
  - Perspiration
  - Staining
  - Migration
- **Humidity**
  - Hydrolysis
  - Long Term Humidity
    - Chemical Migration
- **Thermal**
  - Aging
  - Thermal Cycling
  - Thermal Shock
  - Heat & Humidity Cycle
- **Adhesion**
  - Initial
    - » To Substrate
    - » Inner Layer
    - » To Interfaces
  - Water Soak
- **Biological Testing**
- **Weather Exposure**
  - Artificial UV
  - Artificial UV + Humidity
  - Xenon Arc
  - Florida Sunlight
  - Arizona Sunlight

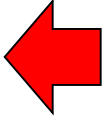
# How Coatings Fail with Chemical Exposure

- **Chemicals Dissolves the Paint**
  - Catastrophic Failure
- **Chemicals Soften the Paint**
  - Chemicals plasticize the paint
  - Results in paint which is susceptible to wear and physical damage
  - Can be reversible (Purell)
- **Chemicals Damage the Structure (Integrity) of the Paint System**
- **Chemicals Penetrate to the Paint Plastic Interface (Adhesion Failure)**
  - Weakens the bond by accumulating at interface and creating a barrier, breaking bonds or changing surface energy
  - Sun screen, Hand cream, Air Freshener
- **Chemicals Penetrate to the Plastic and Attack the Plastic (Adhesion Failure)**
  - Damages or dissolves the plastic
  - Amines attack polycarbonate
- **Chemicals Migrate from the Paint or the Plastic to the Interface (Adhesion Failure)**
  - After production chemicals migrate into each other causing physical properties to deteriorate

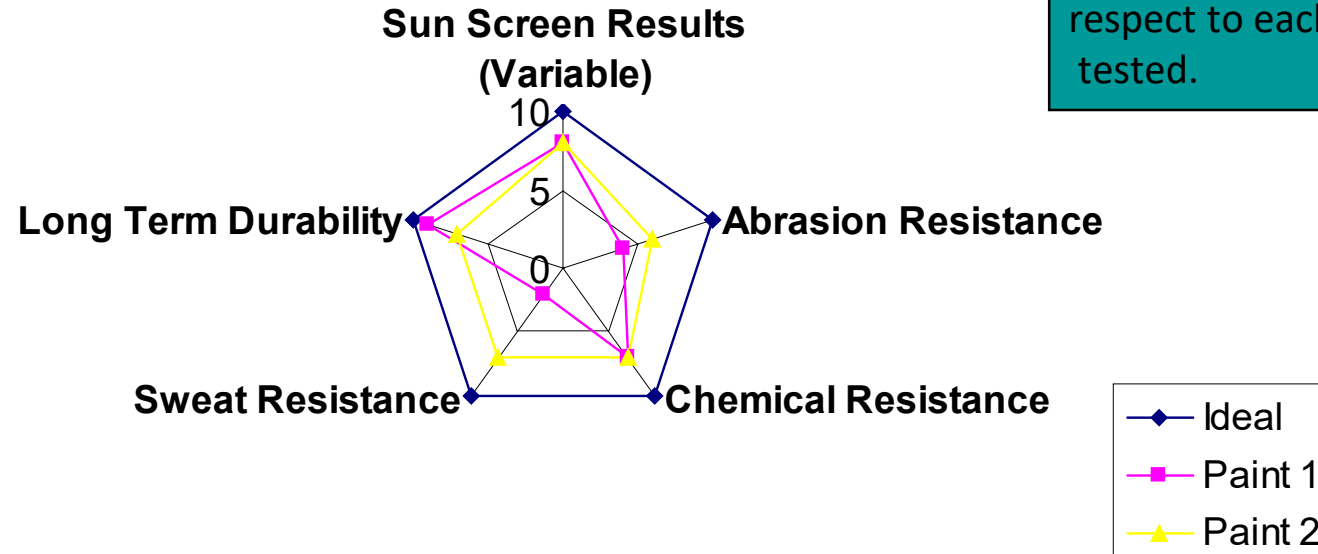
Captured by OEM  
Test Methods

Not Always  
Captured by OEM  
Test Methods

# Chemical Failures Caused by Coatings

- Solvent Damage to the Substrate (During Use) 
  - Chemical attack and weakening of Substrate properties
- Blooming
  - Chemicals migrate to the surface of the paint
- Staining
  - Chemicals migrate from the paint into adjoining parts causing visual changes
- Chemicals Penetrate to the Plastic and Attack the Plastic
  - After drying and curing chemicals migrate from the paint into the substrate and cause damage to the substrate
- Out Gassing
  - After drying and curing chemicals (low boilers) evaporate from the coating and may be deposited elsewhere in the vehicle
  - Fogging
  - Crazeing

## Paint Characteristics



The performance of paints can vary significantly with respect to each characteristic tested.

Since paints are complex mixtures and the process affects the performance variable testing of a number of key performance requirements is the best way to compare paints. Most OEM's test only to a set standard.



# Ensuring Durable Products

## Important Concepts

**Know what the test is trying to accomplish – Is it reasonable, does it add value, does it answer a question?**

**Many tests are only pass fail – Test to failure provides variable results which are more useful in making choices.**

**Monitor and Evaluate Changes to the Environment.**

# How Paints Fail

