USING TEMPERATURE TO SIMULATE THIXOTROPY IN 100% SOLIDS UV/EB COATINGS

THURSDAY SEPTEMBER 05, 2024

PRESENTER:

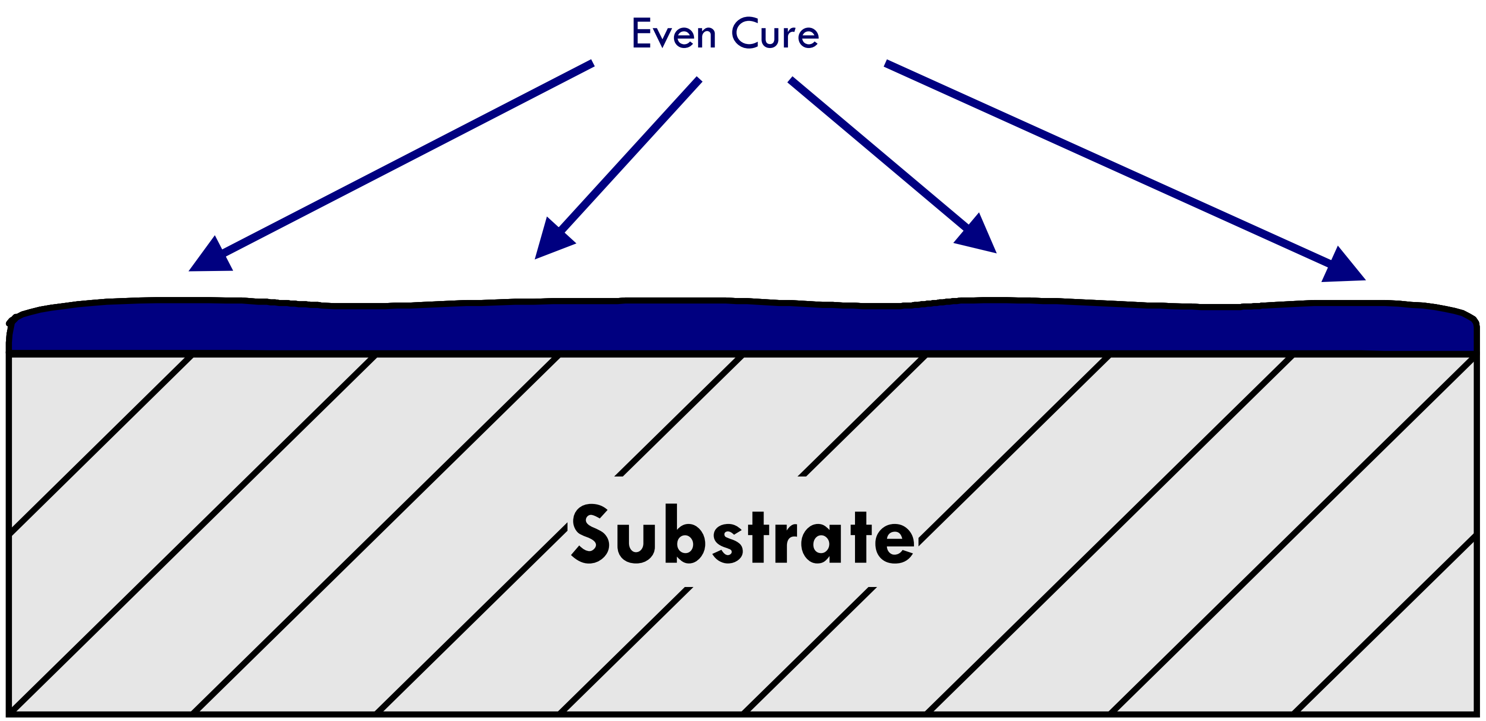
MICHAEL R. BONNER
VICE PRESIDENT – ENGINEERING & TECHNOLOGY

WHY DO WE PAINT THINGS?

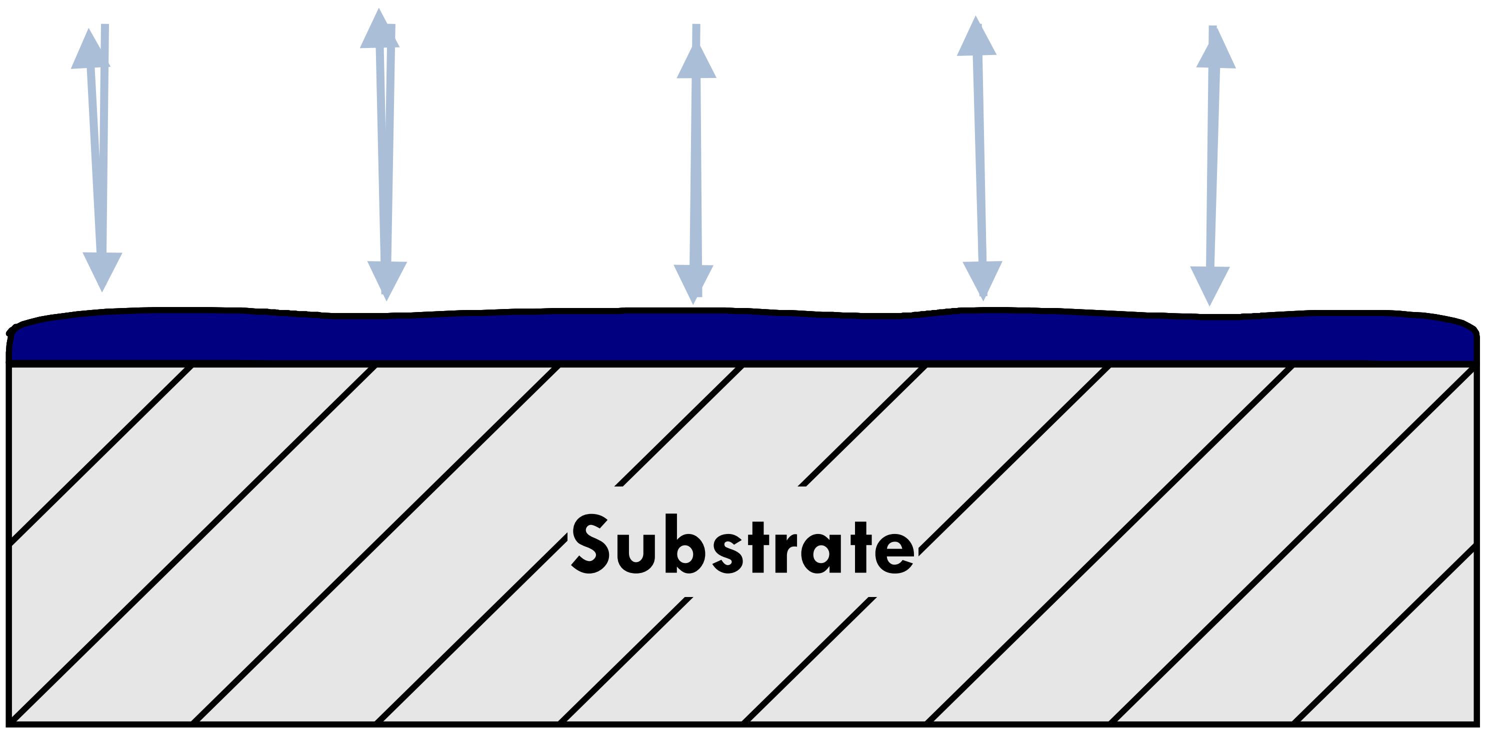
- AESTHETICS
  - APPEARANCE
  - PROTECTION
- PROTECTION
  - ELEMENTS
  - LONGEVITY
- FUNCTION
  - AERODYNAMICS
  - HYDRODYNAMICS

Image Courtesy of
OLSON'S AUTO BODY

THE PERFECT FILM



THE PERFECT GLOSS



- DESIGNERS AND MANUFACTURERS OF ADVANCED POINT-OF-USE TEMPERATURE AND VISCOSITY CONTROL SYSTEMS FOR INDUSTRIAL FLUID DISPENSING PROCESSES SINCE 1990
- SPECIALIZING IN BOTH RECIRCULATING AND "DEAD-END" SYSTEMS WITH MORE THAN 3500 ACTIVE INSTALLATIONS
- LOW VISCOSITY (<1 CPS) TO HIGH VISCOSITY (>1,000,000 CPS) APPLICATIONS STANDARD AT PRESSURES FROM 0.4 BAR (5 PSI) – 400 BAR (6000 PSI)

SO, WHO CARES?

THOSE 3500+ TEMPERATURE AND VISCOSITY CONTROL INSTALLATIONS INVOLVED SOME OF THE TOUGHEST APPLICATIONS IN PARTNERSHIP WITH DEMANDING CUSTOMERS LIKE:

CONVENTIONAL vs. 100% SOLIDS COATINGS

CONVENTIONAL vs. 100% SOLIDS

- CONVENTIONAL (THERMAL CURE)
  - SOLVENTBORNE, WATERBORNE
  - CURED BY BAKING
  - HIGH ENERGY CONSUMPTION
  - VOLATILE ORGANIC COMPOUNDS
    - FLAMMABLE
    - HAZARDOUS
    - REMEDIATION REQUIRED

- 100% SOLIDS
  - UV, UV-LED, ELECTRON BEAM (EB)
  - CURED BY LIGHT WAVES OR HIGH-ENERGY ELECTRONS
  - LOW ENERGY CONSUMPTION
    - UP TO 95% LESS!
  - 100% SOLIDS (NO SOLVENTS USED)
    - NO VOC'S
    - NO REMEDIATION REQUIRED

CONVENTIONAL vs. 100% SOLIDS

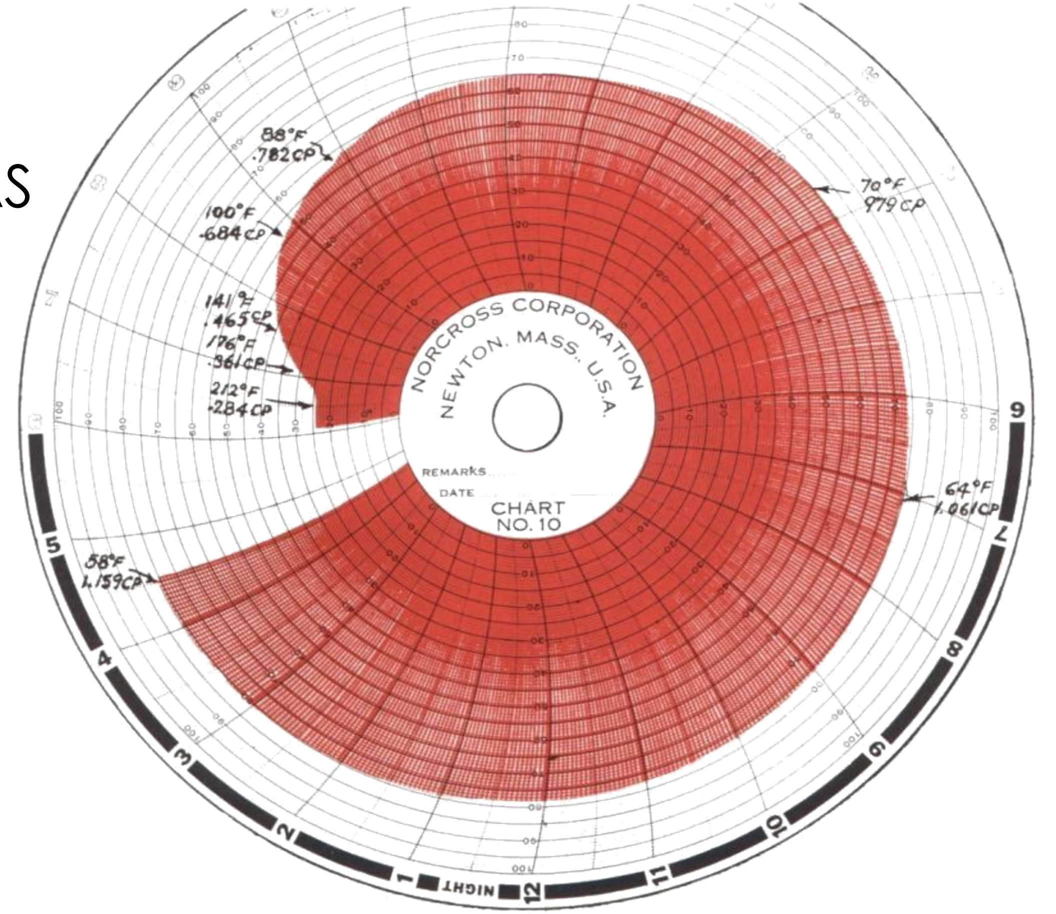
- CONVENTIONAL (THERMAL CURE)
  - PRIMARY SOLVENT EVAPORATION STARTS IN FLASH TUNNEL
  - REMAINING SOLVENTS EVAPORATE IN OVEN
  - FILM FORMATION IN FLASH TUNNEL
  - CURE (CROSS-LINKING) IN OVEN
  - TIME FOR FILM ADJUSTMENT THROUGH ENTIRE PROCESS

- 100% SOLIDS
  - NO SOLVENTS TO FLASH OFF
  - NO OVEN REQUIRED
  - FILM FORMS AFTER APPLICATION
  - CURE RIGHT AFTER APPLICATION
  - CURE IMMEDIATE AND THOROUGH

THE FUNDAMENTALS

IT'S ALL ABOUT VISCOSITY

- ALL LIQUIDS CHANGE VISCOSITY AS A FUNCTION OF TEMPERATURE
  - EVEN WATER GOES THROUGH A VISCOSITY CHANGE OF 2:1 BETWEEN 10°C AND 40°C (50°F - 104°F)
- ALL COATINGS, SEALERS AND ADHESIVES FOLLOW THIS SAME PATTERN
  - THIS IS A PHYSICAL PROPERTY NOT A DEFECT AND CAN THEREFORE BE EXPLOITED IN OUR PROCESS

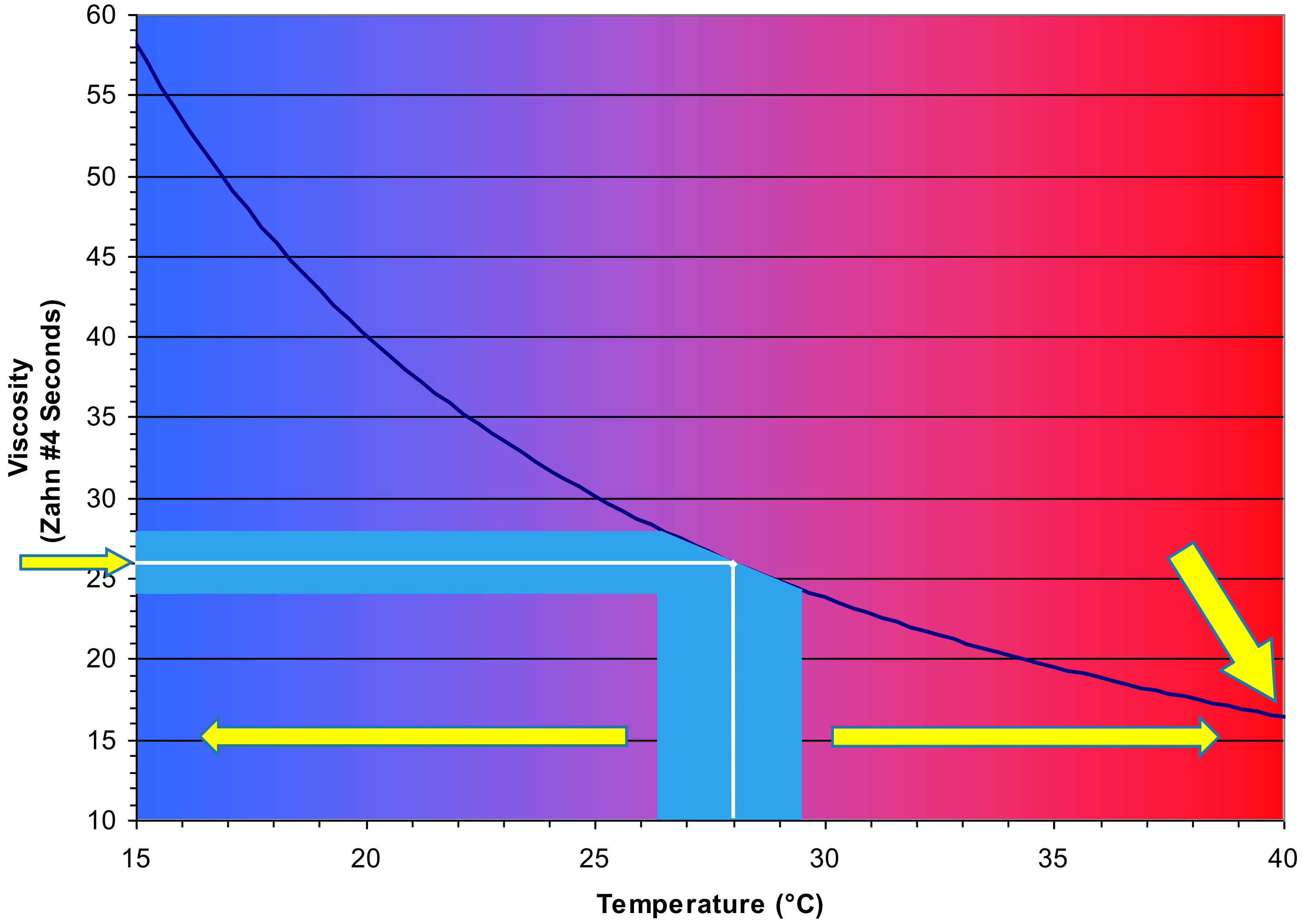


Graph courtesy of Norcross Corporation

WHAT IS VISCOSITY?

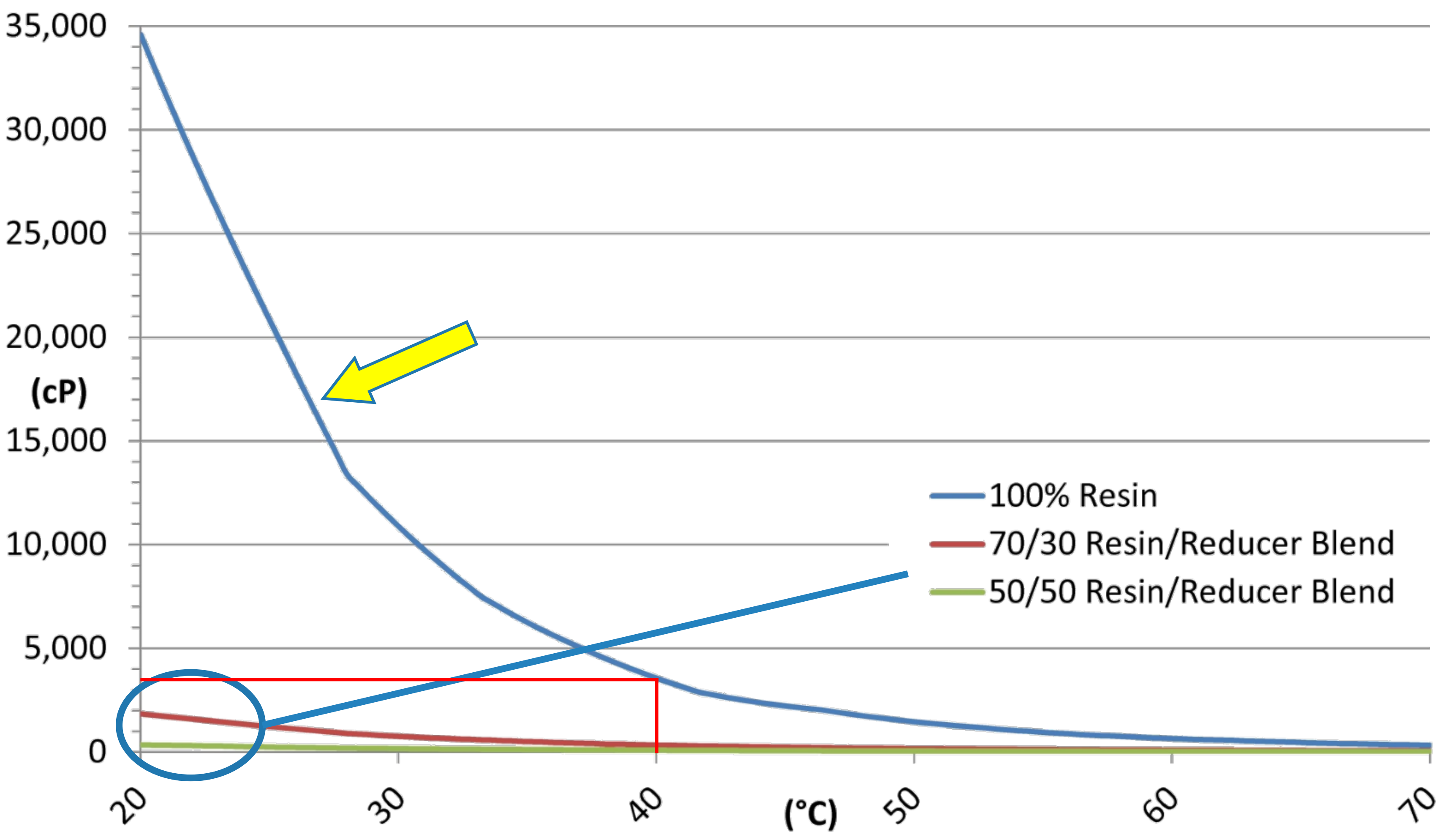
- A relatively simple explanation is "*the property of resistance to flow in a fluid or semifluid*."
- Think of Honey in the refrigerator vs. Honey in the sun on a hot day.
- The change in how it flows represents viscosity change.

CONVENTIONAL COATINGS

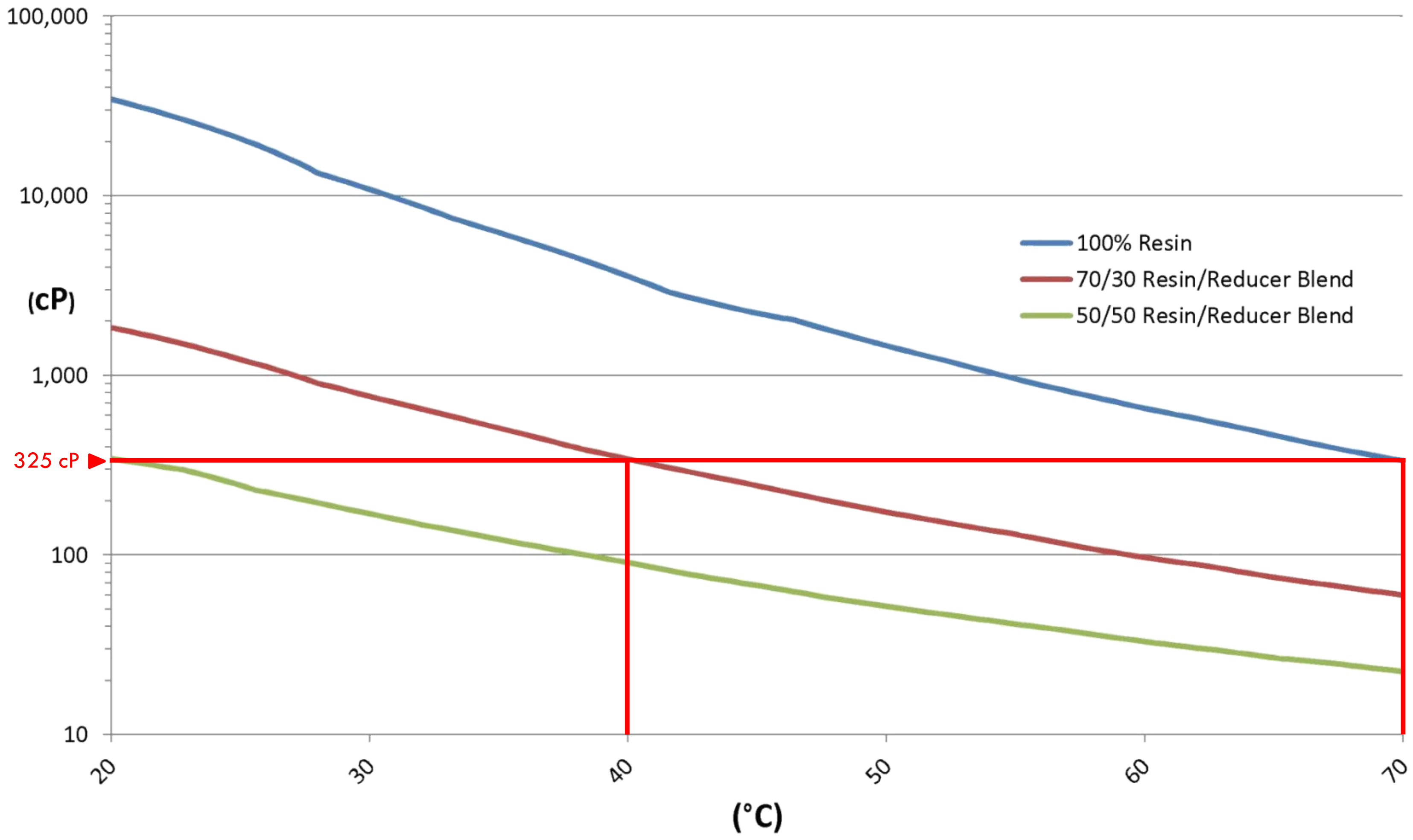


(Valspar - 080 White Polyester)
Data Courtesy of
Alsco Metals Corporation

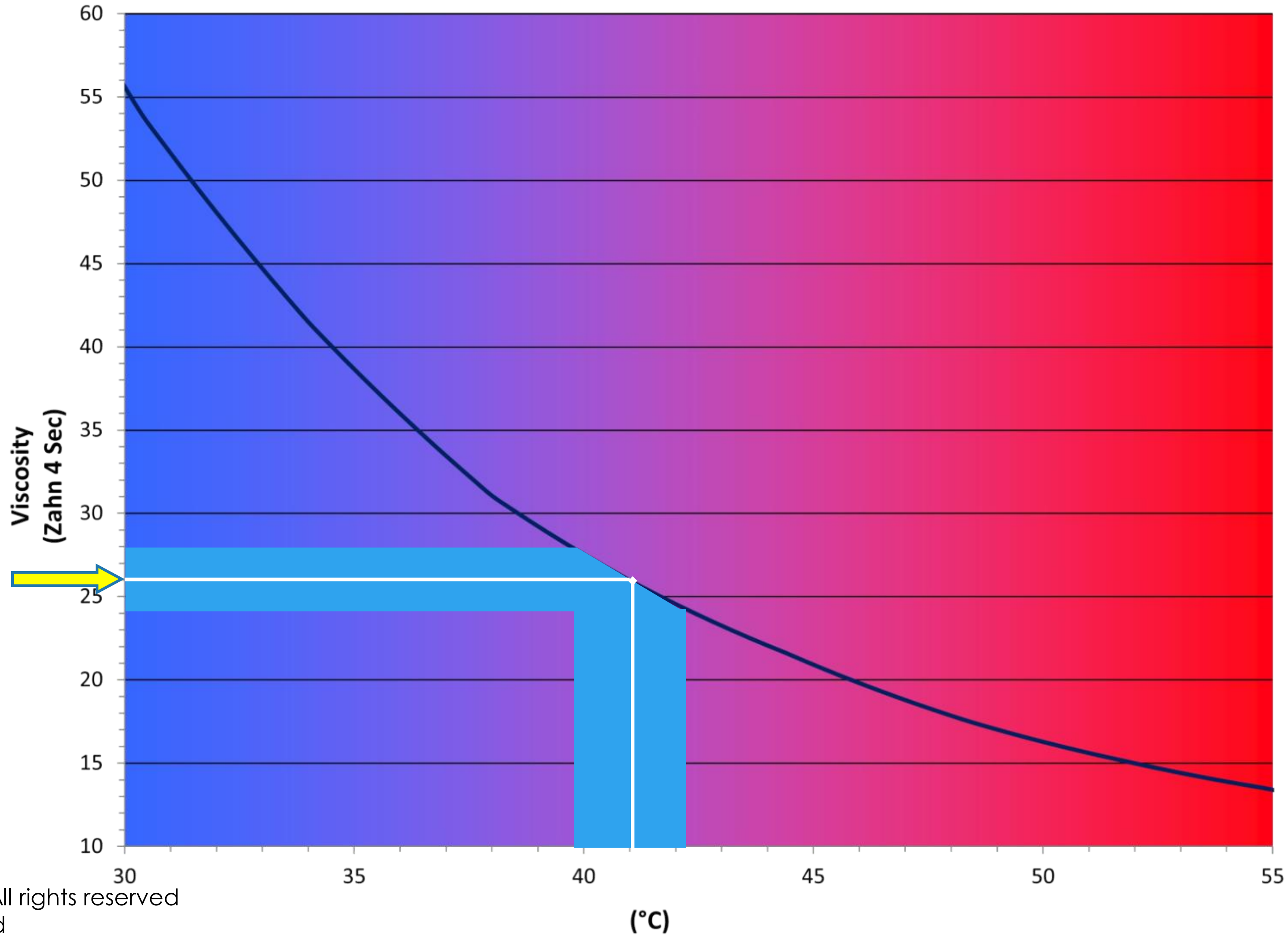
100% SOLIDS COATINGS



VISCOSITY VS. TEMPERATURE BY BLEND



100% SOLIDS REPLACEMENT

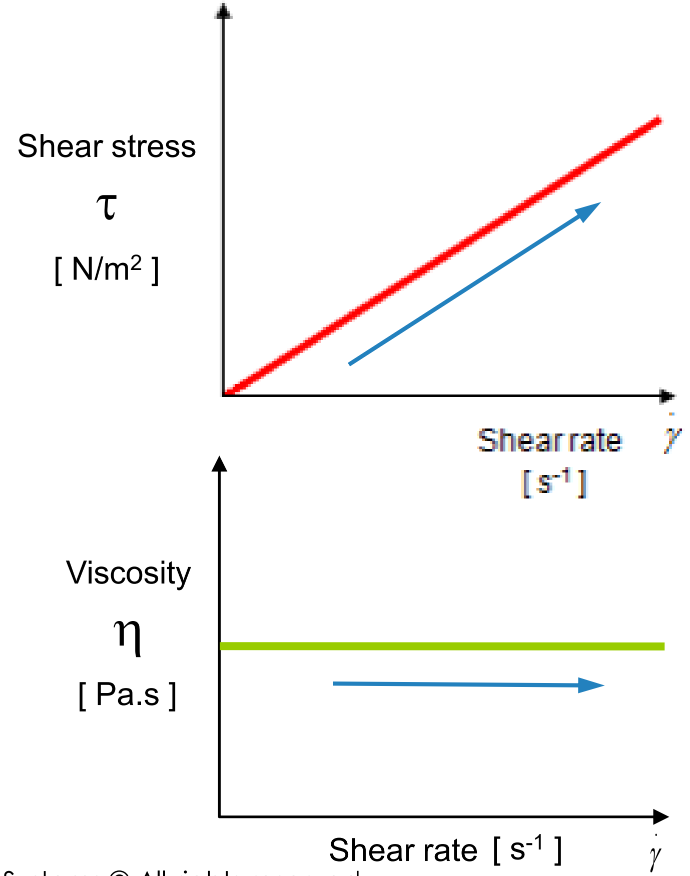


70/30 Resin/Reducer Blend

NEWTONIAN VS. NON-NEWTONIAN FLUIDS

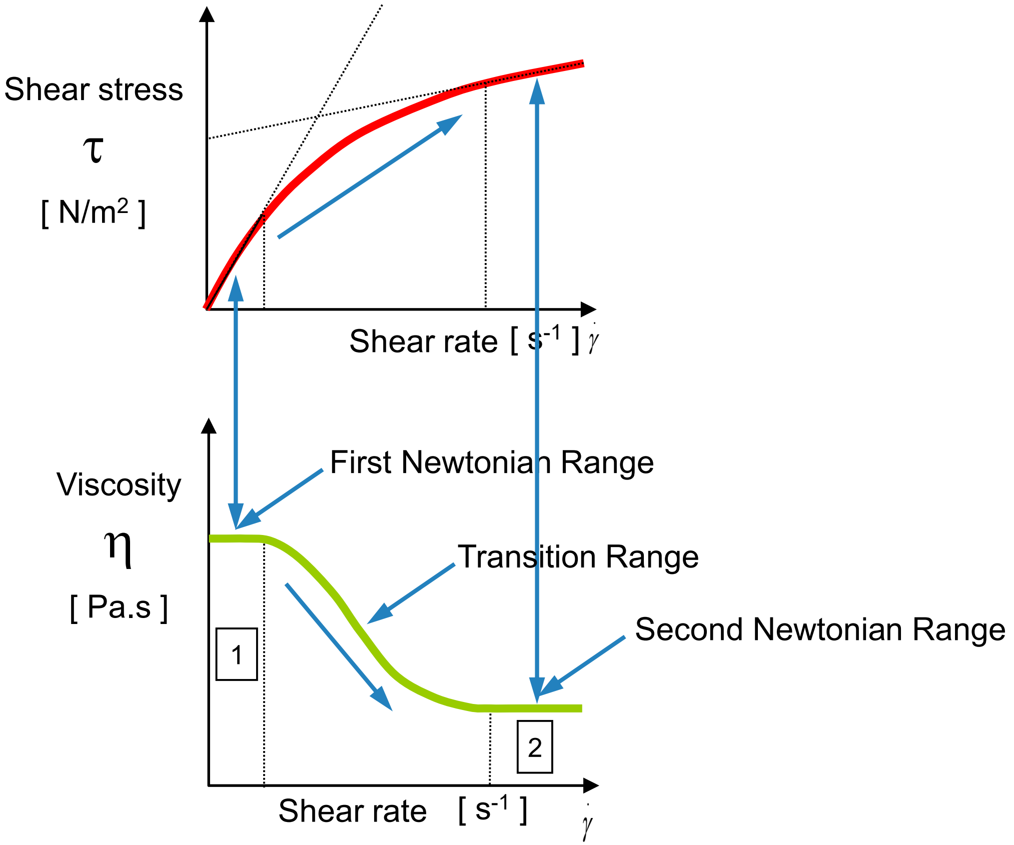
- **Newtonian fluids:**

At constant temperature and pressure, ***the viscosity doesn't vary with shear rate and time***

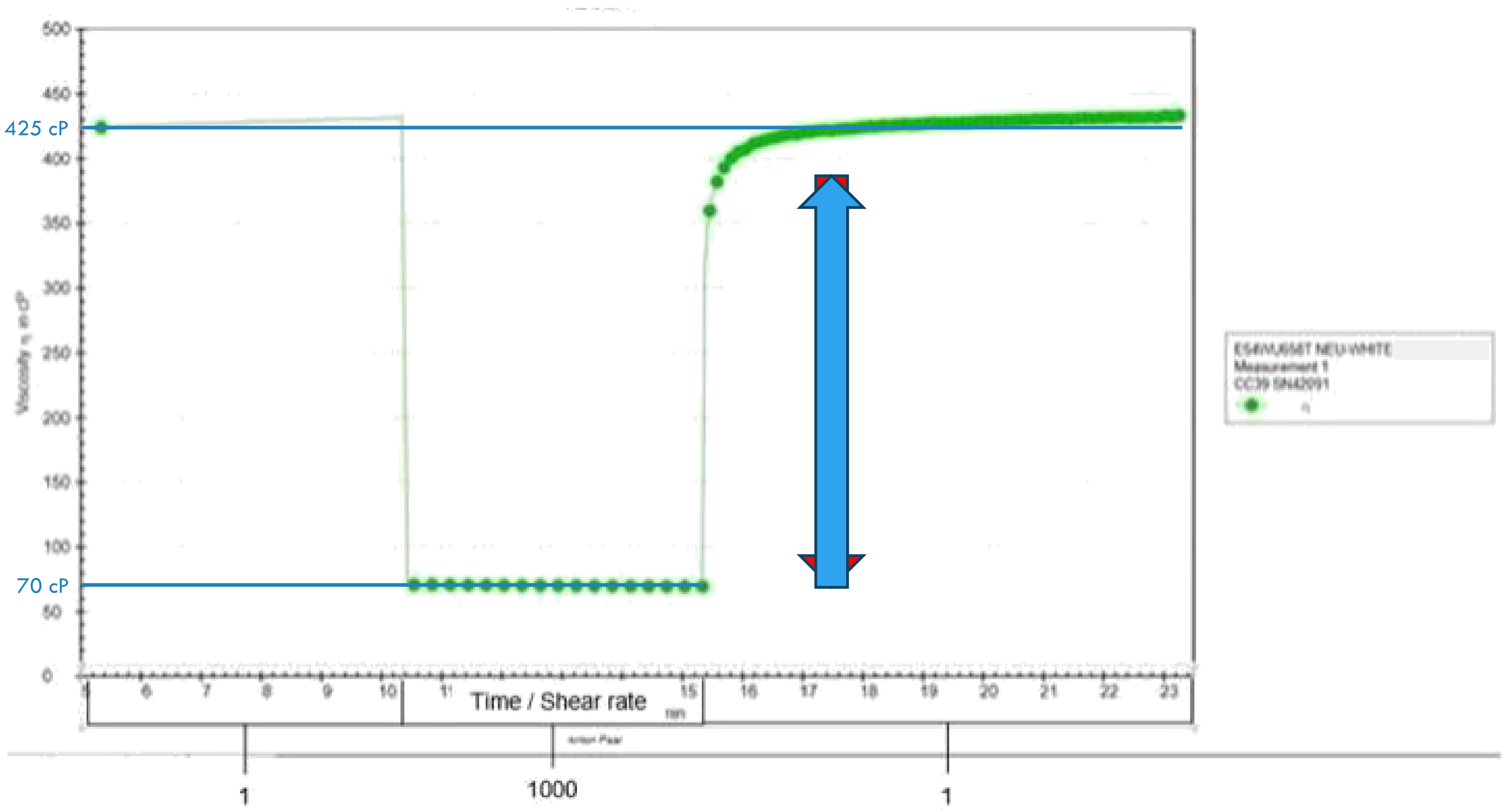


- **Non-Newtonian fluids:**

Viscosity varies with shear rate (flow, stirring…) and / or time

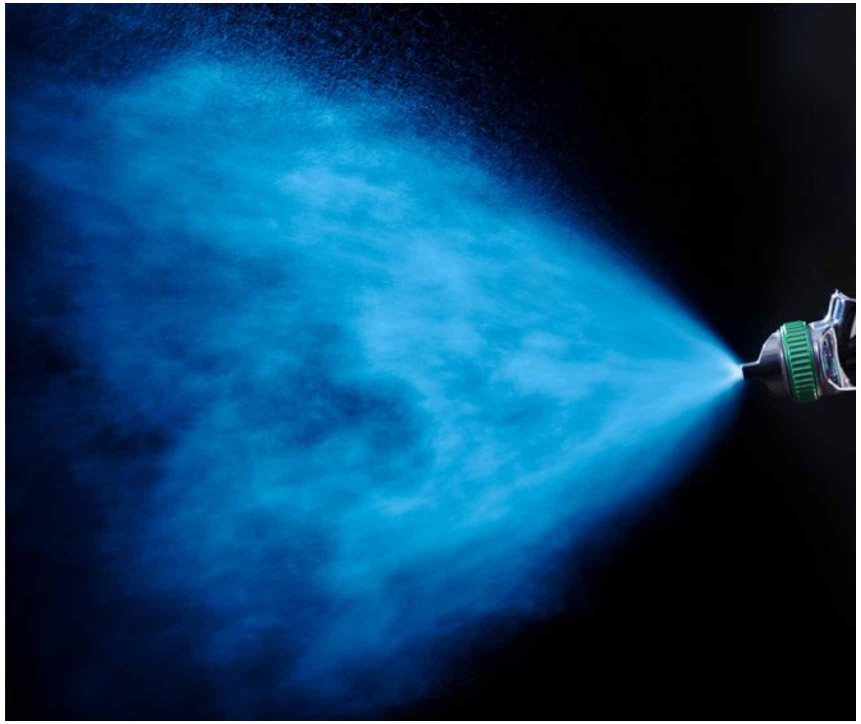


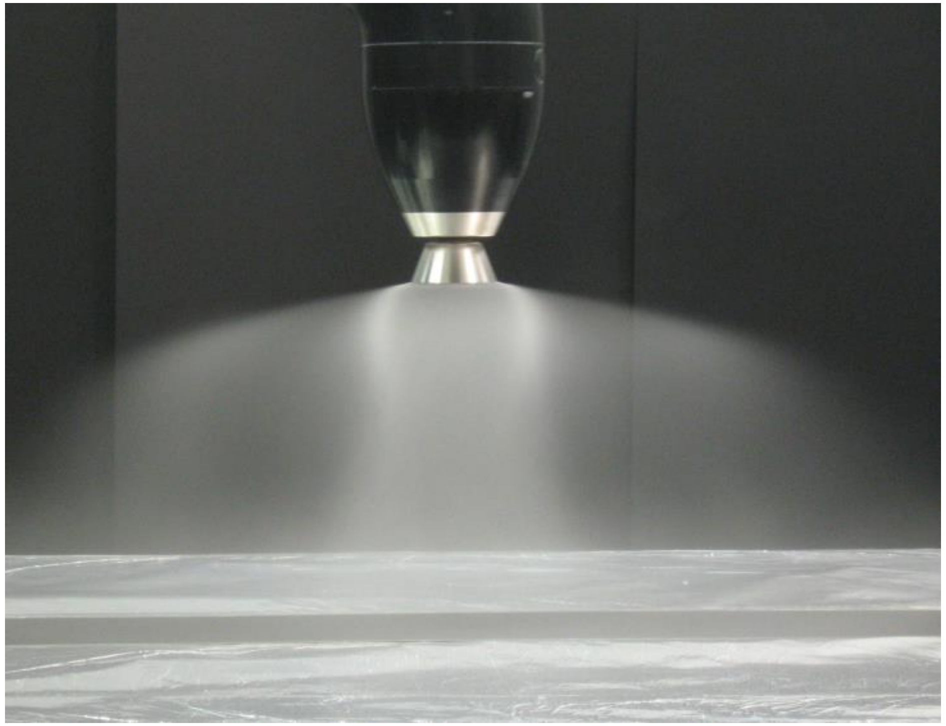
AN AUTOMOTIVE EXAMPLE



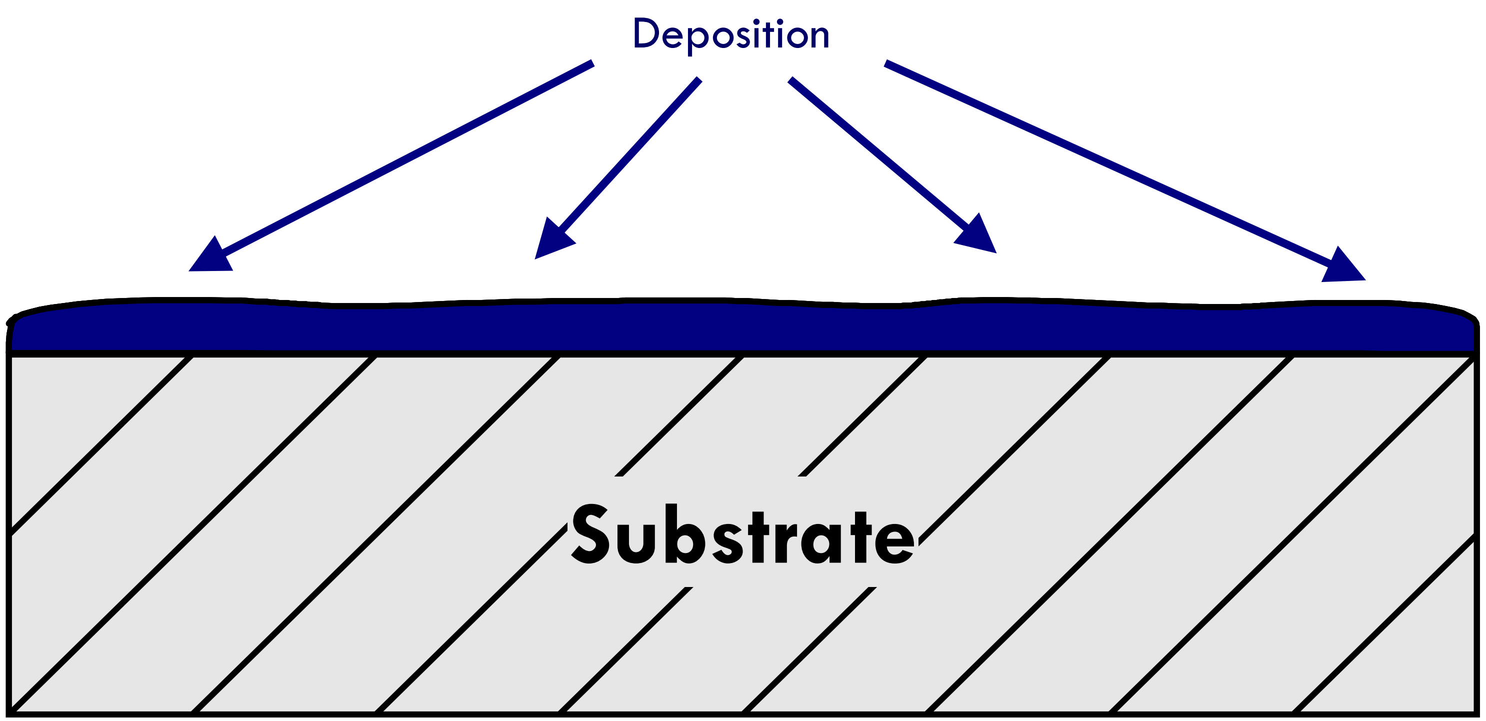
PROCESS RAMIFICATIONS

SPRAYING IS A HIGH-SHEAR PROCESS

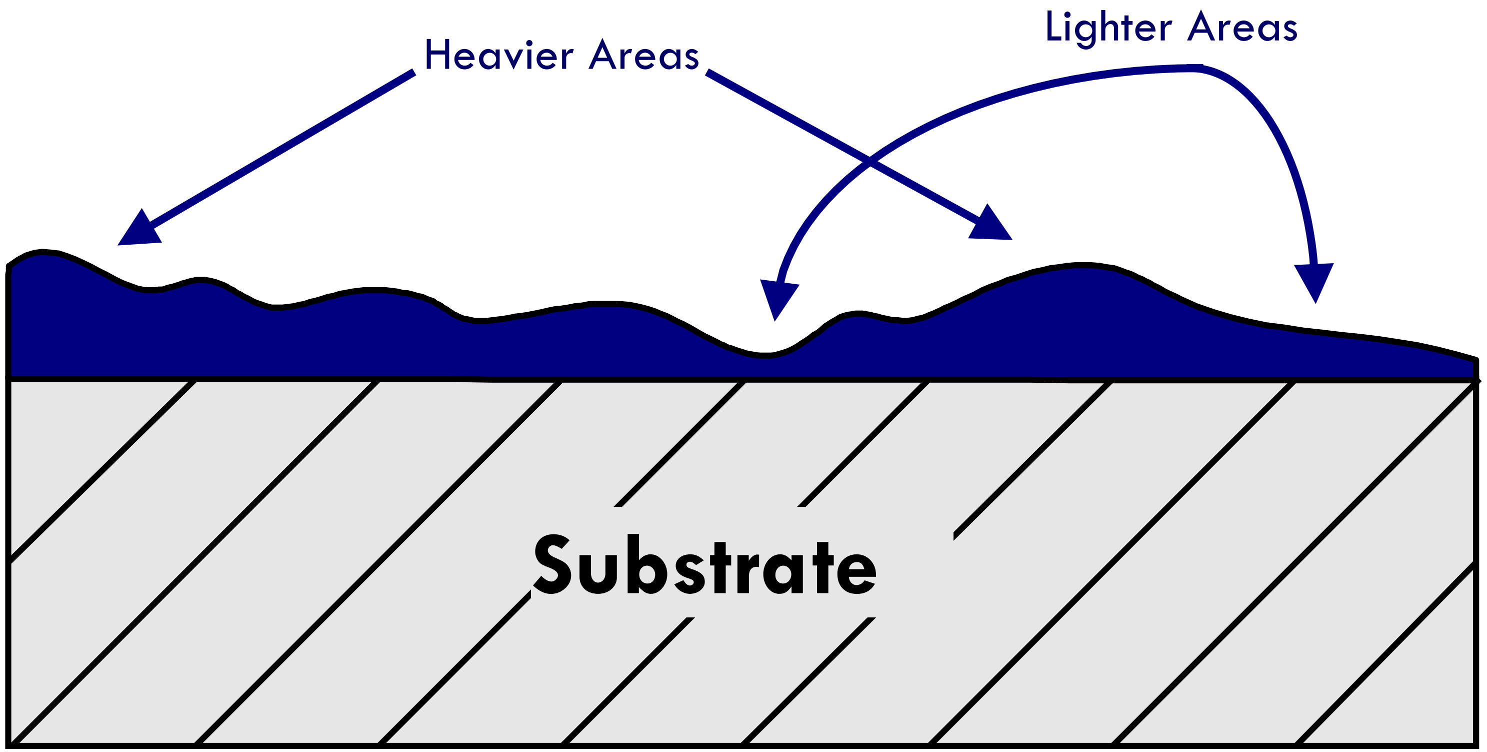




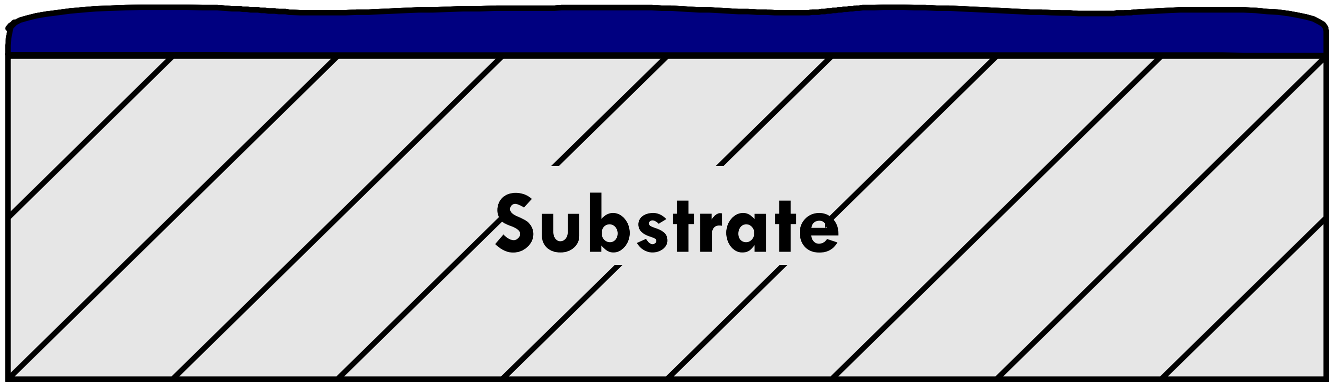
THE PERFECT FILM



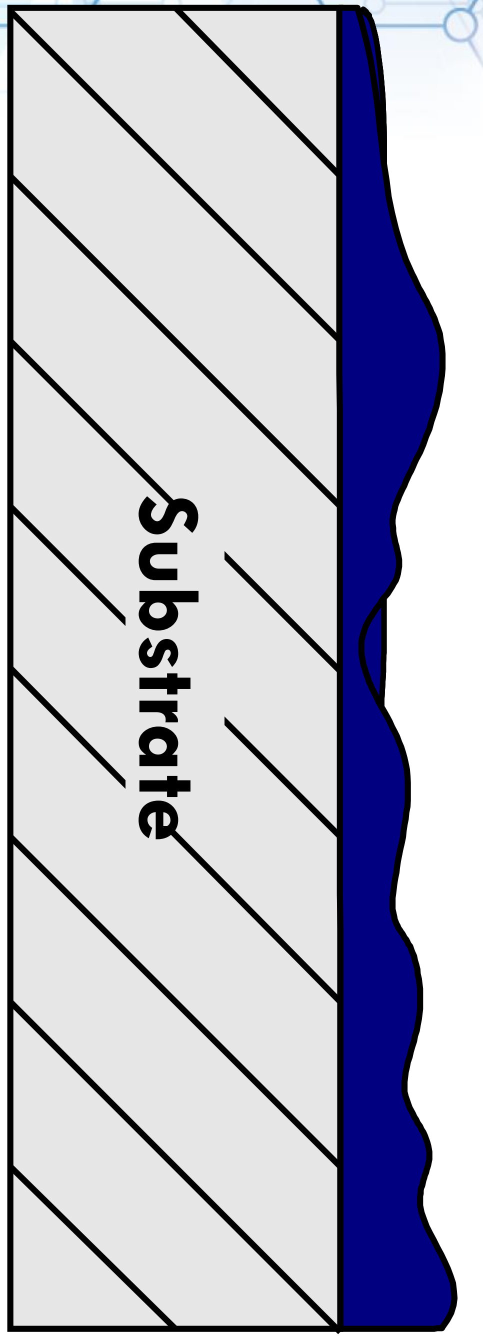
THE EFFECT OF VISCOSITY ON FILM FORMATION



THE PERFECT FILM



THE "MAGIC" OF THIXOTROPY



THE TEMPERATURE HIERARCHY

Substrate	• Greatest Thermal Mass • Orders of magnitude greater than the fluid • Impacts Fluid Behavior at Interface
Fluid	• Medium Thermal Mass • Orders of magnitude greater than the air
Air	• Lowest Thermal Mass • Less influence on fluid or part

THE COMMON MYTH

"IF I TIGHTLY CONTROL MY AMBIENT ENVIRONMENT, I DON'T HAVE TO WORRY ABOUT TEMPERATURE-BASED PROCESS FLUCTUATIONS"

saint clair systems
TEMPERATURE & VISCOSITY CONTROL

Coatings Trends & Technologies SUMMIT

GUNS VS. BELLS

2018 Quarter 2
Vol. 4, No. 2

UV+EB TECHNOLOGY

Global Trends in Automotive Design

Lightweighting with 3D-Printed Foam

PVC Wide-Web EB Curing

Applying UV-Cure Coatings

RADTECH THE ASSOCIATION FOR UV&EB TECHNOLOGY Official Publication of RadTech International North America

By Michael R. Bonner, vice president, engineering and technology, Saint Clair Systems

Guns vs. Bells – What's the Best Way to Apply UV-Cure Coating?

The goal of any finishing operation – whether solventborne, waterborne or UV cure – is to apply a consistent and contiguous coating to the subject part. This coating serves many purposes:

1) To improve the aesthetic appearance of the part.
2) To protect against such things as scratches, corrosion, UV damage, etc.
3) To improve performance in the part's final application – for instance, increasing moisture resistance, reducing aerodynamic drag (i.e. – automobiles, airplanes, rockets), hydraulic drag (i.e. – boats, ships, torpedoes), etc.

There are many ways to apply these coatings, including dipping, brushing, rolling or flow coating, but this discussion focuses on spray operations.

In a spray operation, the coating is atomized into a pattern of droplets and applied to the surface of the part, where the droplets rejoin one another and flow out to form a film. The primary devices used to perform this atomization function are guns and bells.

Comparing guns and bells

Similarities: Because both do the same job, there are many similarities between guns and bells. Both atomize the coating into a cloud, creating a fan pattern that can spread out over the surface of the target part. Both use compressed air to "shape" the fan pattern. Both can be used in electrostatic applications, where the coating particles are charged at a high voltage and the part is grounded to create an "attraction" between the atomized droplets and the part. This helps reduce overspray, gets more of the liquid coating on the part and increases transfer efficiency.

Differences: While both create a fan pattern, Figure 1 shows that the patterns created can be very different. This is due to the differences in the way the atomized cloud is created. We will explore that in detail shortly.

Bells are larger and heavier than guns. This makes guns more suitable to manual spray applications, providing an operator greater control with less stress and fatigue. Bells generally are limited to automated applications. While any coating applicator is susceptible to maintenance and cleaning issues, bells are more complex, with lots of moving parts. In general, bells require more maintenance than guns.

page 40 ▶

FIGURE 1. *Gun[1] vs. bell[2] atomizers*

◀ *page 44*

strength of each. But, it's important to understand that neither can overcome the problems created when the coating being delivered to them is out of control. This is especially true with UV-cure materials.

Coating Parameters				
Distance to Part:	10	in	254	mm
Thermal Conductivity (k):	2.595	BTU in/ft² hr °F	0.374	W/mK
Specific Gravity:	1.200		1.200	g/cc
Specific Heat (Cp):	0.500	BTU/lb °F	2.093	J/g °C
U-Value of Air:	0.2	BTU/ft² hr °F	1.136	W/m² °C
Air Temperature:	77.0	°F	25.0	°C
Inlet Paint Temp:	104.0	°F	40.0	°C

	Bell		Gun		
	min	max	min	max	
Particle Speed:	150	300	300	600	mm/s
Particle Speed:	5.91	11.81	11.81	23.62	in/s
Time to Part:	1.69	0.85	0.85	0.42	s
Particle Size (Diameter):	26	28	39	65	µm
Particle Surface Area:	2.1237E-09	2.4630E-09	4.7784E-09	1.3273E-08	m²
Particle Size (Diameter):	1.0236E-03	1.1024E-03	1.5354E-03	2.5591E-03	in
Particle Surface Area:	3.2918E-06	3.8177E-06	7.4065E-06	2.0574E-05	in²
Particle Volume:	5.6159E-10	7.0141E-10	1.8954E-09	8.7748E-09	in³
U-Value of Paint:	5069.95	4707.81	3379.96	2027.98	BTU/ft² hr °F
System U-Value:	0.20	0.20	0.20	0.20	BTU/ft² hr °F
Thermal Gain/(Loss):	-5.8061E-11	-3.3668E-11	-6.5317E-11	-9.0715E-11	BTU
Particle ΔT:	-2.6546602	-1.2325171	-0.8848693	-0.2654503	°C
Particle Temp at Part:	37.35	38.77	39.12	39.73	°C

FIGURE 9. *Particle temperature change calculations*

Temperature as a tool

Using temperature as a tool to manage the viscosity fed to your atomizer of choice is especially important in UV-cure coatings for several reasons. First, many UV-cure coatings are 100% solids, so there are no "solvents" to flash off to start the curing process and slow flow-out to hold the coating in place. These coatings will continue to flow at the same rate until exposed to the UV source, at which point the cure is virtually instantaneous. But, this can work to our advantage, as 100% solids coatings will not "shrink" in the cure process: The wet film is applied at the same thickness as the desired dry film. Thus, there is less wet coating available to flow out into a smooth, contiguous coating. Coating viscosity and droplet size (atomization) must be carefully balanced and controlled, especially where Class A finishes are required, to get the proper flow-out at this lower applied volume.

Knowing that temperature remains fairly constant between the atomizer and the part changes our perspective on control at the point of application. This is especially true when we use elevated temperature to reduce the amount of monomer in our blend. Using the example above, when applying the 50/50 blend at 40°C (104°F) to maintain a low application viscosity (to allow use with a bell, for instance), a fairly small reduction in temperature will cause a significant increase in viscosity, due to the steep viscosity vs. temperature curve. If we maintain the booth air and part at 25°C (77°F), we can select the atomizer to allow a smooth, even coating and then depend on the cooling imparted by the substrate to increase the coating viscosity to hold it in place until it is cured. In short, temperature can be used in place of evaporation (flash-off) – which is especially good for vertical surfaces.

Coating viscosity and droplet size (atomization) must be carefully balanced and controlled...

Conclusion

Each applicator style has its place, and it is not uncommon to use them in combination, taking advantage of the strength of each. The specific methods of atomization and delivery must be matched closely with the coating formulation, and that coating must be carefully controlled when delivered to assure that the atomizer/coating system functions properly. This is especially critical with UV-cure materials. ◆

Acknowledgements

1. Gun photograph provided courtesy of FreeImages.com.
2. Bell atomizer photograph provided courtesy of Carlisle Fluid Technologies.
3. Paint temperature vs. viscosity data provided courtesy of Alsco Metals Corporation – Roxboro, NC.
4. Viscosity conversion data provided courtesy of Norcross Viscosity Controls. http://web.viscosity.com/download-viscosity-conversion-tables
5. Bell and gun particle velocity data provided courtesy of Carlisle Fluid Technologies.

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AMBIENT IMPACT ON PARTICLE TEMPERATURE

Application Parameters				
Distance to Part:	10	in	254	mm
Thermal Conductivity (*k*):	2.595	BTU in/ft² hr °F	0.374	W/mK
Specific Gravity:	1.200		1.200	g/cc

Air Temperature:	77.0	°F	25.0	°C
Inlet Fluid Temp:	90.0	°F	32.2	°C

	min	max	min	max	
Particle Speed:	150	300	300	600	mm/s
Particle Speed:	5.91	11.81	11.81	23.62	in/s
Time to Part:	1.69	0.85	0.85	0.42	s
Particle Size (Diameter):	26	28	39	65	µm

Particle Surface Area:

Particle Size (Diameter):

Particle Surface Area:

Particle Volume:

	Bell		Gun		
	min	max	min	max	
Particle ΔT:	-1.278	-0.593	-0.426	-0.128	°C
Particle Temp at Part:	30.94	31.63	31.80	32.09	°C

WORTH 1000 WORDS…

SUBSTRATE TEMPERATURE

TEMPERATURE vs. THIXOTROPY WITH CONVENTIONAL COATINGS

- SUBSTRATE > COATING TEMPERATURE
  - VISCOSITY FALLS AT THE INTERFACE
    - BELOW THE SECOND NEWTONIAN RANGE VISCOSITY
    - LOW FILM, RUN & SAG, POOR BUILD ON SHARP CORNERS, ETC.
  - SOLVENT FLASH-OFF INCREASES
    - PREMATURE FILM SET
    - ORANGE-PEEL, GLOSS, MOTTLE ISSUES, ETC.

TEMPERATURE vs. THIXOTROPY WITH CONVENTIONAL COATINGS

- SUBSTRATE < COATING TEMPERATURE
  - VISCOSITY INCREASES AT THE INTERFACE
    - ABOVE THE SECOND NEWTONIAN RANGE VISCOSITY
    - INSUFFICIENT FILM FORMATION
    - ORANGE-PEEL, GLOSS, MOTTLE ISSUES, ETC.
  - SOLVENT FLASH-OFF SLOWS
    - RUN & SAG, POOR FILM BUILD ON SHARP CORNERS, ETC.
    - CAN LEAD TO BLISTERS AND SOLVENT POP

TEMPERATURE vs. THIXOTROPY WITH 100% SOLIDS COATINGS

- SUBSTRATE < COATING TEMPERATURE
  - FILM FORMATION AT LOWER VISCOSITY
  - VISCOSITY INCREASES AT THE INTERFACE
    - SETS THE FILM
    - HOLDS THE FILM
  - CURING BY EXPOSURE TO LIGHT
    - NO HEATING AND WARM-UP TIMES
    - INSTANTANEOUS AND THOROUGH
    - THIXOTROPIC PERFORMANCE WITH FEWER HEADACHES

SUBSTRATE TEMPERATURE

THANK YOU!!

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