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TECHNICAL PAPER

VOC Compliant Coating Solutions for the Industrial and Wood Markets

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VOC Compliant Coating Solutions for the Industrial and Wood Markets

This paper was made possible through a contribution from the following Ameron (New Zealand) Pty. Ltd. Colleagues:

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All co-authors have served the surface coating industry for at least 10 years. Their combined efforts at Ameron (New Zealand) Pty. Ltd. represents in excess of 50 years of developmental work on traditional technologies and more recently Polysiloxane and UV curable chemistries.

Introduction

The need to reduce environmental pollution is one of the most pressing R&D drivers of coatings companies in industrialised Western economies. Newly legislated VOC laws are either:

I. Forcing Finishing companies to change the way in which they treat environmental pollution this, in short, means using new coatings (or in some cases pursuing a variety of abatement options).

II. Forcing Finishing companies to gravitate to Industrialised economies where environmental pollution laws are not regulated.

The preferred choices for the future, from a coatings perspective are either to move to High Solids, UV (solvent free, solvent containing or water-borne), Powder (UV or low temperature cure options) or solvent free technologies. RadTech North America uses the terminology e/5 - environmentally friendly, efficient enabling, economical and energy savings - I guess this sums it up!

This paper will describe some new technologies under development commercialisation designed in the main for the Wood and General Industrial markets.

Brief overview of legislative change in Europe/USA

Changes in European VOC laws and legislation are a good 'indicator' as to what 'will eventually happen' in our part of the world. In this context, it is good to look at some relatively new VOC legislation that has filtered through the European Community. The first legislation to briefly review is the "Paints, Varnishes and Vehicle Repair Directive (2004/42/EC)". Commonly known as the Paint Products Directive (PPD). This legislation relates to specific VOC limits being placed upon paints, varnishes and vehicle repair coatings and will equate to significant reductions in VOC emissions being removed from the marketplace i.e. at the moment the VOC emissions of coatings (relating to the Decorative Market in Europe) equate to something like 800 ktonnes of VOC emission ca. 5% of all VOC emissions from all sources in Europe. Table One has a summary of the coatings types and the required VOC's with requirement dates.

This legislation when coupled with the Solvent Emissions Directive (SED 1999/13/EC) has created a strong platform for Coatings VOC reduction and/or Abatement Control in Europe. The SED relates to certain activities and installations – a summary of the Emission limits and the Fugitive emission limit values is given in Table Two.

The message that these two pieces of legislation send is very clear - substantial reductions in VOC and/or compulsory use of abatement technology (with monitoring requirements) for coatings supplied to these sectors are legal requirements. Abatement techniques can only be applied to the European Directive 1999/13/EC.

Table 1. Emission Limit Values. Application to Solvent Emissions Directive (SED (1999/13/EC)

Process	Solvent Consumption Threshold (tonnes/year)	Emission Limit Value in waste gases (mg C/Nm³)	Fugitive Emission Limit Value (% solvent Input)
Vehicle Coating	<15	50	25%
Vehicle Refinishing	>0.5	50	25%
Coil Coating	>25	50	5%
Coating of Wooden Surfaces	15-25 >25	100 50/75	25% 20%
Adhesive Coating	5-15 >15	50	25%
Surface Cleaning (R45, R46, R49, R60, R61 or R40)	1-5 >5	20	15% 10%
Other Surface Cleaning	2-10	>75	20% 15%
Wood and Plastic Lamination	5	30	N/A
Other (includes coating metal, plastic, textile fabric, film, paper coating)	5-15	100	20%

Table 2. VOC Content - Paints, Varnishes and Vehicle Repair Directive (2004/42/EC)

Product Category	Type	Phase I (g/l) 1.1.2007	Phase II (g/l) 1.1.2010
(a) Interior matt walls and ceilings (with a 60º gloss ≤ 25 units)	WB SB	75 400	30 30
(b) Interior glossy walls and ceilings (with a 60 º gloss > 25 units)	WB SB	150 400	100 100
(c) Exterior walls of mineral substrate (e.g. masonry, brick or stucco)	WB SB	75 450	40 430
(d) Interior / exterior trim and cladding paints for wood and metal	WB SB	150 400	130 300
(e) Interior / exterior trim varnishes and woodstains, including opaque woodstains	WB SB	150 500	130 400
(f) Interior and exterior minimal build woodstains	WB SB	150 700	130 700
(g) Primers	WB SB	150 700	130 350
(h) Binding primers	WB SB	50 750	30 750
(i) One-pack performance coatings	WB SB	140 600	140 500
(j) Two-pack reactive performance coatings for specific end use such as floors	WB SB	140 550	140 500
(k) Multi-coloured coatings – coatings designed to give a two-tone or multiple colour effect, directly from the primary application	WB SB	150 400	100 100
(l) Decorative effect coatings – coatings designed to provide special aesthetic effects over specially prepared prepainted substrates or base coats	WB SB	300 500	200 200

A survey of the rapid technology changes occurring in the Wood market in the USA (more correctly compliant technologies being utilised) can be located on: www.epa.gov/ttn/atw/wood/low/casebyco.html

In all cases UV, Water-borne, High Solids or Powder are the new generation technologies being utilised. These case studies clearly illustrate the 'way forward' and the coatings technologies which will rapidly grow in future years. Figure One, graphically, illustrates the predicted trends for growth in coatings by type and by region – enough said!

Table 3. Comparison of differing coatings systems for Industrial / Wood at spray application

Coating Type	Solvent Content	Utilisation	Air Pollution	Waste Water Pollution	Occupational Hygiene Level
Nitrocellulose	65-80%	50%	High	Yes	Medium
2k System	30-80%	50%	Medium-High	Yes	Low
Unsaturated Polyester (Peroxide Cure)	0-50%	50%	No – to medium	Yes	Low
UV Cure (Solvent Type)	0-40%	50%	Medium to No	Yes	Medium
Water-borne	5-10%	50%	Low	Yes	High
Powder	Ca.0%	95%	No	No	High

Table 4. Comparative properties of Nitrocellulose lacquer of High Solids acid catalysed, NISO High Solids, Polyurethane and Solvent based UV topcoats (all high gloss white topcoats)

Attribute	Acid Catalysed	Polysiloxane	P/U	UV (solvent)	Typical N/C Lacquer
Weight Solids (%)	59%	66%	59.5%	80.0%	27%
Volume Solids (%)	43%	52%	44.3%	72%	16%
VOC (g/l)	490	420	490	200	700
Gloss (60%)	91%	94%	92%	96%	85%
Pencil Hardness after 24 days	F-H	F-H	F-H	3H	F-H

Developments in Wood Coatings - UV Coating Developments

For flat board end use i.e. block/stack end uses, UV is a preferred option as the rapid curing process is time saving, packaging is instant, labour utilisation is excellent, VOC compliant options can be exercised, either water-borne IR/UV, solvent free, or solvent containing (still VOC compliant).

Some performance data of a medium solids P/U coating cf. a UV cured topcoat (both high gloss white samples) is submitted in Table Six for critical appraisal and analysis. Table Five details 'wood market coating prerequisites' for any technology that is considered to be suitable for the coating of kitchens and furniture.

Table 5. Wood Market Coating Pre-Requisites

Fast turnaround of coated furniture to block stack/package/handle
Low spread of flame/burning attributes (nice to have but not critical)
Low VOC if possible whilst not losing coating mechanical properties
High crosslink density (i.e. good solvent and mechanical property attainment) with excellent Wet Heat, Dry Heat, Stain, Chemical Resistance whilst maintaining cold crack resistance properties
Overspray recovery would be a nice option
Worker Health and Safety – no Isocyanate, no Peroxide, no Formaldehyde emissions would be advantageous from a worker health perspective
Good pot life – infinite pot life would be nice (i.e. IK)
Adoption of technology with no DG, storage, compliance issues would be advantageous from and insurance premium, property loss perspective
Preferably a low energy cure process (i.e. preferably no IR or convection oven requirements)
1 to 2 coat finish, without waiting for the second coat to dry out
No sanding between each coat

Figure One. Predicted Growth of Technology by Region/by Technology. (Courtesy Radtech Europe 2005)

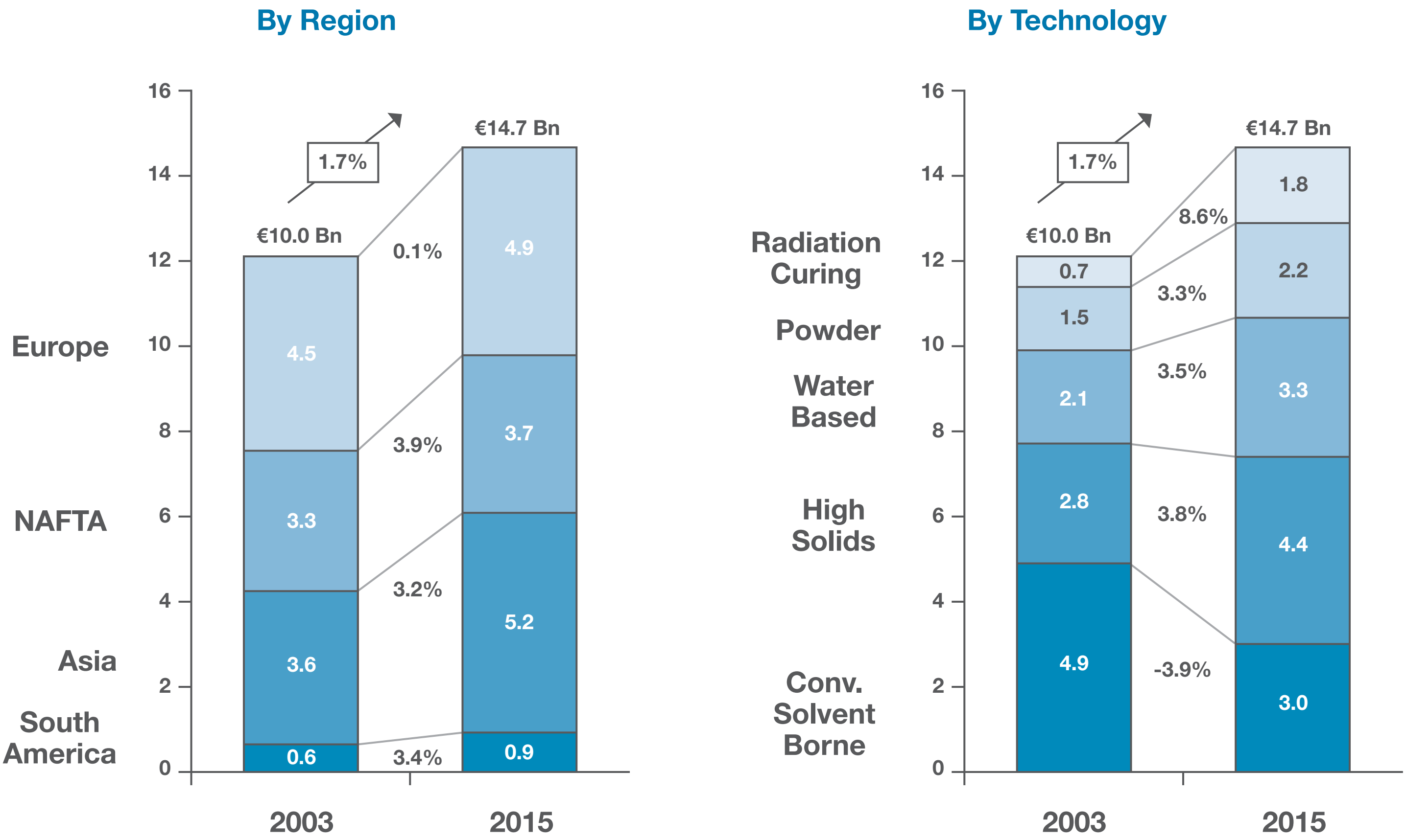

Table 6. Technical Differences between 2K P/U and IK UV Coating for the coating of furniture Chemical Resistance at Room Temperature. BS EN 12720 : Resistance to marking by liquids (1 hour covered)

	2K P/U Conventional Coating	IK UV Coating
Acetone	2 marked surface	N/A
Toilet Spirit	3	N/A
Ethanol 48%	5	5
Tea	5	5
Coffee	5	5
Disinfectant (phenol)	4	5
Disinfectant (chloro)	4	5
Paraffin Oil	5	5
Blackcurrant Juice	5	5
Ammonia Solution	5	5
Acetic Acid (4.4% solution)	5	5
Olive Oil	5	5

	2K P/U Conventional Coating	IK UV Coating
Resistance to Mechanical Damage BS 3962 : Part 6 Resistance to mechanical		
Crosscut Adhesion	5	5
Scrape, surface penetration	5 (11N at point of entry)	5 (8.4 N at point of entry)
Scrape substrate penetration	5 (>26 N at point of entry into MDF substrate)	5 (21.1 N point of entry into MDF substrate)
Impact	4 (slight cracking)	4 (slight cracking)
Resistance to Wet Heat BS EN 12721		
55ºC	4	5 No damage
70 ºC	4	5 No damage
85 ºC	4	5 No damage
Resistance to Dry Heat BS EN 12722		
85 ºC	4 (just visible)	5 No damage
100 ºC	4 (just visible)	5 No damage
120 ºC	N/A	5 No damage
140 ºC	N/A	5 No damage
160 ºC	N/A	2 Yellowing of surface
Resistance to Oils/Fats BS EN 12720		
Oils (solid vegetable oil)	5	5
Fats (butter)	5	5

Furniture manufacturers often use 2K Polyurethane coatings as they are well researched, well utilised and are essentially foolproof from a performance perspective. A negative with 2K P/U coatings is the respiratory sensitisation /worker H & S stigma that 'travels' with these coatings. Strict OSH requirements are needed to handle 2K Polyurethane Technologies and heavy penalties are already in force for non compliance with H&S Regulatory Requirements. Added pressure is also mounting on the use of Formaldehyde releasing coating technologies- recent changes in the way that formaldehyde is viewed is of special interest. NICNAS have just recently reviewed the carcinogenicity ratings for formaldehyde and have classified it as a Category 2 carcinogen "may cause nasal cancer by inhalation". From an Occupational Health and Safety Regulatory Control viewpoint NICNAS are suggesting that the current standard be changed from.

Current standard

1 ppm (1.2 mg/m^3) 8h TWA
2 ppm (2.4 mg/m^3) STEL

Recommended Standard

0.3 ppm (0.36 mg/m^3) 8h TWA
0.6 ppm (0.72 mg/m3) STEL

From a coatings viewpoint then, pressure is being brought to bear on solvents, Formaldehyde and use of Isocyanate containing coatings. The use of Peroxide containing coatings has its own set of issues, various Regulatory Standards are making the use of Peroxides unattractive to pursue from a manufacturing, storage and a labelling Risk Phrase Regulatory viewpoint. Peroxide systems can carry the following Risk Phrases.

- Risk Phrases for Peroxide cure systems
- R 20 Harmful by inhalation
- R 21 Harmful in contact with skin
- R 22 Harmful if swallowed
- R 36 Irritating to eyes
- R 37 Irritating to respiratory system
- R 38 Irritating to skin

The careful handling requirements of peroxide based materials is well documented. Peroxide incompatibility with a range of reducing agents, oxidising agents, metals, acids and bases is well known- the results can be a violent exothermic reaction (i.e. explosion).

New Technology VOC Compliant and High Solids

VOC Compliance is best portrayed via use of an Independent yardstick, as a case in point we shall choose VOC compliance of Wood Coatings extracted from the UK – Environmental Protection- Air Quality- Process Guidance Note 6/33 (04). Refer Table Eight for a brief summary.

It is clear from this Table that Spray applied, Curtain Coated or Dip Technologies are expected to be higher in VOC cf. Coatings which can be applied by Vacuum or Roller techniques. This is sensible when one ascertains that these later techniques open up the avenues of using a number of technologies inherently lower in VOC i.e. UV technologies and Waterbased systems. Conventional Wood technologies for spray application are far higher in VOC, 520 g/l for pigmented and 475 g/l for clear technologies.

Recent developments have seen the emergence of a new generation siloxane technology which is low in VOC, non Isocyanate, fast curing and performs well when tested in accordance with FIRA 6250 methodology. The data in Table Seven compares this new generation siloxane technology with some older generation NISO Technology. This test performance data illustrates that this new technology has benefits not only in VOC but in dry heat testing, wet heat testing, surface scrape and penetration to substrate. In addition this new class of coatings passes all of the requirements of AS/NZS 1530 Part 3 1999 (refer Table Ten). The advantage of a coating system with low flame spread and moderate mean smoke release is of importance when providing coatings solutions for kitchen and internal working environments. Lower VOC Siloxane technology (lower than 420 g/l) is available as well, potentially rapid cure systems with VOC's approaching 120 g/l can be formulated with this newly patented Siloxane technology. Another extra benefit of siloxane systems is its anti-graffiti properties, this potentially too is an extra benefit for coatings which are exposed to Kitchen environments.

Moving forward technology options will be a mix and match of coating solutions which meet all production and performance requirements as well as VOC and worker H+S legislation. The 'big three' Technologies that are being globally promoted for the future are UV, Waterborne and Powder Technologies, these technologies in combination with High Solids and Solvent free technologies will dominate the coatings scene in future years. Advantages/Disadvantages of this technology are detailed in Table Nine.

Table 7. NISO cf. New Generation Siloxane FIRA Standard 6250 1999 "Specification for Domestic and Contract Furniture". Horizontal Surfaces (excluding kitchen worktops) in severe and general use

Test	Requirements horizontal surfaces in general use	Submitted sample New Generation Siloxane System		Submitted sample Older Generation NISO System	
		Test Results	Comments	Test Results	Comments
Crosscut	3	5	No finish removed	5	No finish removed
Scrape surface penetration	2	8.7N	5	4.7N	4
Penetration to substrate	3	3.5N	5	>26	5
Indent	3	2*		2*	
Wet heat 55°C 70°C 85°C	 3 2 2	 5 5 4	 No damage No damage Few isolated marks	 4 4 4	 Few isolated marks Few isolated marks Few isolated marks
Dry heat 85°C 100°C	 3 2	 5 5	 No damage No damage	 4 4	 Few isolated marks Few isolated marks
Ethanol 96%	3	2*	Strong mark	2*	Circle just visible
Ethanol 48%	4	5	No damage	4	Few isolated marks
Tea	5	5	No damage	5	No damage
Coffee	5	5	No damage	5	No damage
Oil	5	5	No damage	5	No damage
Fat	5	5	No damage	5	No damage

Table 8. Wood Coating VOC Compliant Coatings extracted from Process Guidance Note 6/33 (04)

Coating Type	Coating	VOC in grams per litre of coating (less water)
A	Fillers	370
B	Clear coating applied by vacuum or roller coating methods	220
C	Clear coating applied by vacuum or roller coating methods	265
D	Pigmented coating applied by spray, curtain or dip techniques (except pencil lacquer)	520
E	Clear coating applied by spray, curtain or dip techniques (except pencil lacquer)	475
F	Clear coating applied by spray, curtain or dip techniques where all other coats are waterborne containing no more than 10% by weight of VOC	600

Table 9. Advantages / Disadvantages of UV Cure / Water-borne and Powder as Compliant Technologies

	Advantages	Disadvantages
UV Cure Technology	• Worker H&S advantages • Insurance premium savings • Ideal for flat sheet applications • Formulation options are strong with a variety of polymers/diluents • Very compact machinery and plant • Formulations can be '0' VOC • Water-borne IR/UV offers low viscosity, high MW low VOC options • Block stacking, instantaneous packaging • Lines can be mechanised, hence low labour costs • Spray, roller coat options available	• 3D objects difficult to cure, must rely on dual cure systems • Specific colours make'through cure' difficult • Film builds must be carefully controlled • Oxygen inhibition (surface cure inhibition) can be problematic • Obtaining lower gloss systems can be difficult
Water-borne Coatings (non UV)	• Low solvent content (VOC compliant) • Good gloss retention • Reduced yellowing developed upon cure • Worker H&S advantageous • DG storage advantages • Insurance premium savings • Transportation of nonflammable finished goods is easy with no restrictions	• Micro foam can be troublesome • Curing is temperature/humidity dependant • Force drying or rapid air circulation is best option to remove water assist with film coalescence • 'Open time' can be an issue • Clarity of film (optical properties) in clear coats can sometimes be problematic • Reformulation can be difficult • Retrofit of solvent lines (S/Steel etc) can be costly
Powder Coating Technology	• Zero VOC option • Recycling of overspray is relatively easy • Hard chemically resistant coatings can be formulated • 'Textured Films' available in low temp cure powder, high gloss options generally require use of IR/UV technology • Worker H & S advantages re: transportation/shipping	• Low temperature cure powder is best applied to MDF cf. wood • Obtain correct 'conductivity' of substrate difficult • IR cure is a pre-requisite for curing of MDF • Long term storage of low temperature cure powders can be problematic • Colour changes can be difficult • Obtaining low gloss and/or high gloss with low temperature cure powder technology is difficult

Table 10. AS/NZS 1530.3 1999 Test Results for High Solids Siloxane Coatings

Mean Ignition Time (seconds)	0
Mean Flame Propagation Time (seconds)	0
Mean Heat Release Integral (KJ/m^2)	0
Mean Smoke Release (Density/m)	0.09409
This coating system is graded as a Class C Coating used for example on Walls and Floors in buildings of less critical areas	

The use of Siloxane technology in the Light and General Industrial markets is not as common as that observed in the Heavy Duty and Marine markets. In the main this is due to differing requirements from these markets. Correctly formulated Siloxane technology offers advantages in Anti-graffiti resistance, Chemical resistance, Corrosion resistance, extreme benefits in aesthetic durability i.e. vast improvements in Gloss and Colour retention as well as significant worker Health and Safety advantages over coatings which are based on 2K Polyurethane technology. Some of the drawbacks of Siloxane technology have been the need for improvements in low temperature cure and improvements in flow/gloss (off the gun). Also extreme solids VOC compliant technologies based on siloxanes are not ideally suited for low dry film thickness applications (i.e. obtainment of low film builds (ca. 20- 40 μm's) is difficult with coatings having volume solids of 90+per cent.)

The differences in Gloss retention (Allunga 5 degree exposure data) for a typical NISO System, Polyurethane System and two Polysiloxane Technologies (aliphatic Epoxy Siloxane and Acrylic Epoxy Siloxane) is detailed in Figure Two.

Table Eleven provides information on the "handleability index" (i.e dry time and through cure attributes) of various Siloxanes compared with non compliant Polyurethane and NISO technologies. Table Twelve details the chemical resistance properties of these Siloxane technologies as compared with conventional Polyurethane and NISO technology.

Figure Two Allunga Gloss retention 60 degree data for a 120 g/l Siloxane, 420

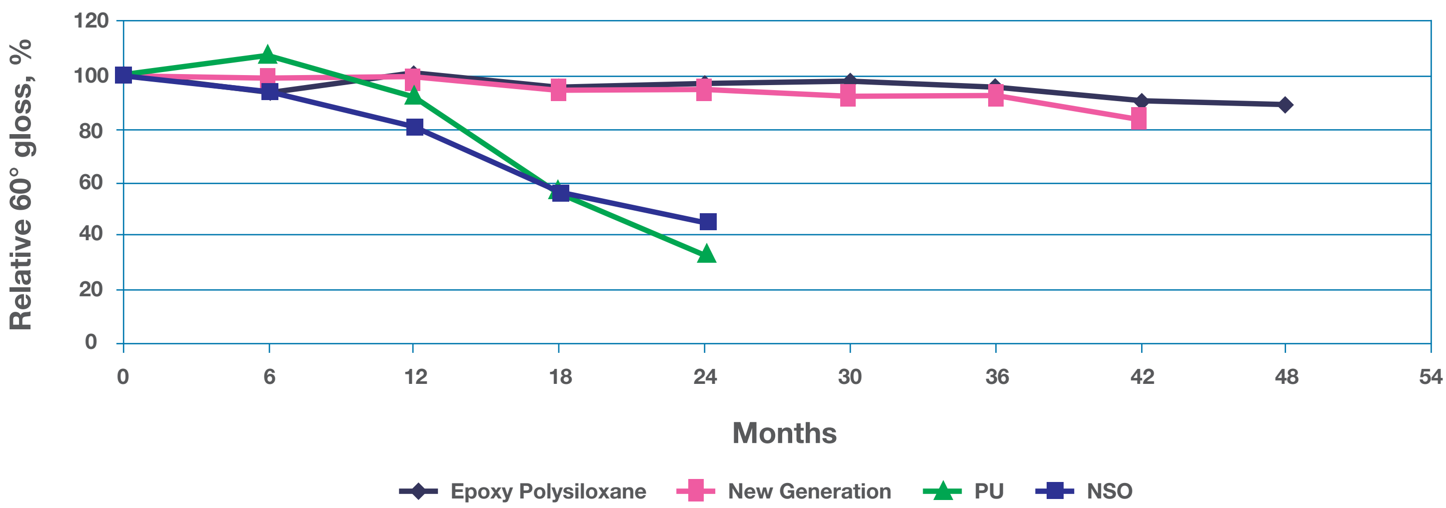

Table 11. Sward Hardness Developments in Siloxane cf. NISO and Conventional Polyurethane technologies.

Sward Hardness Development ASTM D2134	New Generation Siloxane $$ (420 g/l)	New Generation Siloxane (120 g/l)*	Epoxy Siloxane (120 g/l)	Acrylic Polyurethane (530 g/l)	NISO Acrylic / Acrylic 2K system (530 g/l)
1 day	18	12	10	26	20
2 days	28	26	20	28	22
3 days	32	34	28	38	34
7 days	32	34	46	44	36
42 days	34	36	54	48	44

$$ Dust free 4 mins, Tack free 31mins, Print free 60 mins

Table 12. Chemical Resistance properties of Siloxane topcoat Technologies as opposed to conventional non compliant NISO and Polyurethane Technologies

Coating system	New Generation Siloxane (420 g/l)	New Generation Siloxane (120 g/l)	Epoxy Siloxane (120 g/l)	Acrylic PU (530 g/l)	NISO Acrylic / Acrylic (530 g/l)
Chemical resistance ASTM D1308 modified					
10% Acetic acid	7	7	8	7	7
50% Sodium Hydroxide	8	7	10	8	10
Conc. Ammonium Hydroxide	8	8	10	8	6
Acetone	10	10	10	0	4
95% Ethyl Alcohol	10	10	10	0	4
MEK double rubs (NCCAII/ 18)	200+	200+	200+	150	200+

Ranking: 10 = Excellent 0 = Failure

Summary

Worker health and safety issues are starting to become problematic for coating technologies which either emit formaldehyde (alkyd UF technology in the main), utilise aliphatic or aromatic isocyanate curatives (2K Polyurethanes) or deal with the inherent instability and incompatibility of peroxide based surface coatings.

VOC legislation, worker health and safety and enhanced consumer expectations for "green technologies" is creating added momentum for the continued development and exploitation of low VOC coatings technologies. UV coatings offer inherent formulation advantages over conventional coatings technologies in that attainment of zero or very low VOC is imminently possible. This feature coupled with the excellent performance attributes of the cured coating finish mean that UV technology will continue to grow rapidly and will continue to provide cost effective environmental solutions for flat sheet requirements. 3D curing of UV coatings is a challenge, a challenge which is being taken up by many technologists globally. Needless to say use of 3D curative technology is not common place.

New high solids siloxane technology is being introduced to the market as it offers enhanced coatings performance properties, excellent flow/ gloss and build, low VOC options with rapid cure at ambient and low temperature. Options to utilise this technology at VOC's substantially lower than 420 g/l are available and are under laboratory test and evaluation. Additional advantages of this technology over conventional technologies is its ability to offer a surface which has low spread of flame attributes and an inherently low surface tension which may assist with the coatings damage and marking resistance properties.

The big "three" low VOC technologies that are growing globally for coating wood and wood composites are solutions based on water, UV and Powder. High solids and extreme high solids options will compliment these Technologies in future years.

Further Reading

1) Solvent Emissions Directive OJ 42 (L85) : 22 pp, 29 March 1999

2) European Paint Directive OJ 47 (L143) : pp 87-96 30 April 2004

3) The Solvent Emissions (England and Wales) Regulations, Statutory Instrument 2004 NO 107, January 2004, 33 pp

4) Directive 2004/42/EC on the Limitation of Emissions of VOC.., Official Journal of the European Union, 47(L143), pp 87-96, 30 April 2004.

5) Process Guidance Note 6/33(04), Secretary of States Guidance for Wood Coating. Published March 2004

6) Fast Curing Siloxane Compositions, US Patent 2006/0058451.

7) Dangerous Properties of Industrial Chemicals , N. Irving Sax