A Novel Waterborne Binder System for Industrial Joinery Applications

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Abstract

The growth of waterborne systems for industrial joinery has largely been driven by improved technical performance over traditional solventborne technologies rather than environmental issues. Coating processes employed in the manufacture of joinery items are performed on a highly automated basis which place performance demands on the coatings. Amine neutralized waterborne systems require continuous pH monitoring to ensure that coating properties are not compromised by the loss of volatile amine, and surfactant stabilized waterborne systems may have strong foaming tendencies on recirculation. We introduce a novel waterborne technology which is both amine and surfactant free. Additional benefits of this technology include small polymer particle size providing penetration consistency into wood of varying density, optical clarity and gloss.

Introduction

The joinery coatings market is an important segment of the industrial wood coatings market and depends very much on the economic factors impacting building and construction activity. The European market for industrial joinery products was estimated to be approximately 105,000MT/year in 2009[i].

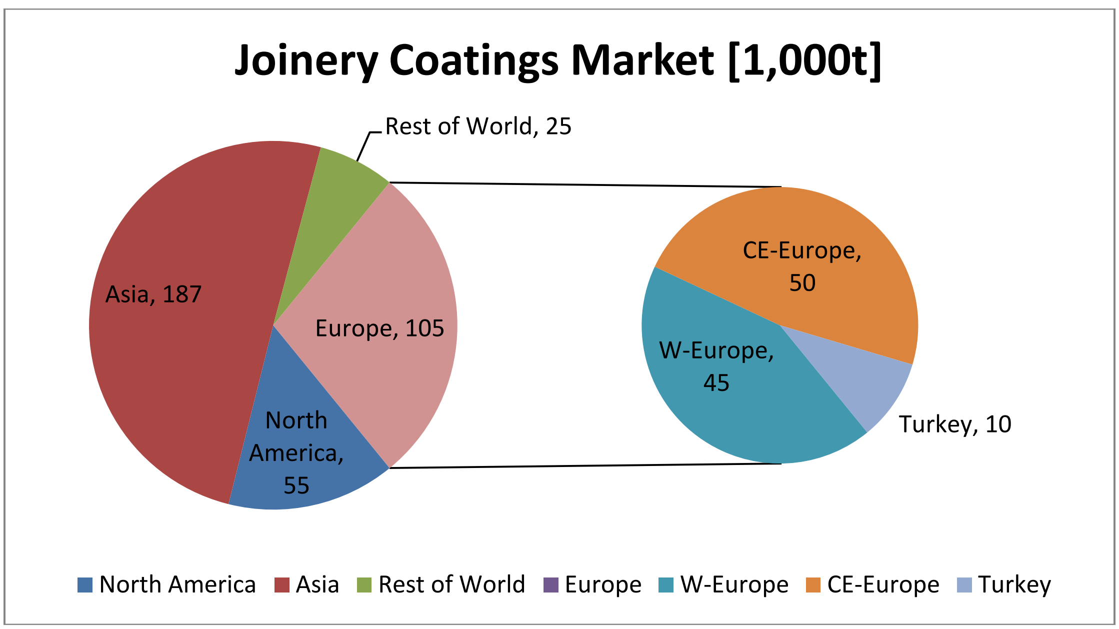


Figure 1 Estimated joinery coatings volumes in 2008

Europe is the principal global market for wooden exterior window frames and doors with significant production. While PVC is the dominating material of choice, wood and wood/metal combinations have an important share with ~20%[ii]:

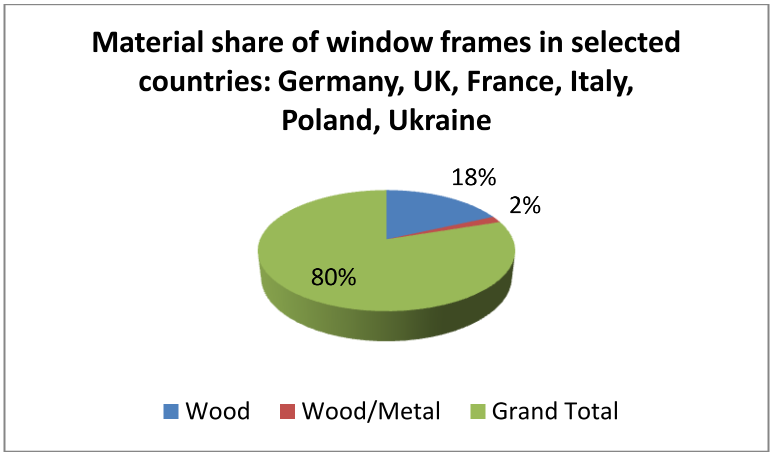


Figure 2 Market share of wooden windows in selected countries

This market has been growing at a relatively steady rate year on year and unlike other applications in which solventborne coatings still retain a major presence, this market appears to be highly suited to the use of waterborne coating products, particularly acrylic dispersions, which provide relatively good application properties combined with low cost and, importantly, non-yellowing characteristics. Other widely used technologies for this application sector include alkyd based emulsion systems.

During extensive interviews and discussions with coatings customers and applicators, several areas of improvement for current waterborne coating systems were highlighted. These included pH drift due to loss of volatile amine neutralizers causing variable application viscosity (particularly in hot climates), variable penetration into the wood substrate due to polymer particle size and strong foaming tendency on recirculation.

The deficiencies highlighted above are also commonly observed as problem areas in other industries – for example waterborne printing systems – and are all issues which Eastman Chemical Company had addressed several years ago with a unique family of resins and dispersions based upon water dispersible polyester chemistry.

Waterborne inks produced from Sulfopolyester polymers require no amine for solubilisation or surfactant for dispersion stability and, depending on the composition of the polymer, little or no organic solvent in their formulations. They are ideally suitable for gravure printing applications with outstanding viscosity stability, low foaming tendency and rapid drying characteristics[iii]. The very low particle size of the Sulfopolyester dispersions produces ink films with exceptional clarity and gloss. The similarities between the performance requirements for both the ink and wood coating industry led to Eastman Chemical Company embarking on an evaluation of this family of polymers for wood applications. This work is described in part later in this paper and was performed in co-operation with a widely respected consultancy firm 3P in Germany who has many years of experience in the formulation and testing of wood coating systems.

Sulfopolyester Polymer Chemistry

Sulfopolyester polymers are based upon monomer building blocks[iv], acids and 5-(sodiosulpho) isophthalic acid (SSIPA). By varying the ratio of the glycols in the formulation, the hydrophobicity and stiffness of the final product can be altered to give varying final film properties whilst sufficient SSIPA is incorporated into the polymer backbone to facilitate dispersibility into water. It is the inherent ionic nature of the SSIPA component in the polymer backbone which allows the polymer to disperse in water whilst the glycol level determines many of the physical characteristics of the products. The use of SSIPA to provide dispersibility in water eliminates the need for amines and provides electrostatic stabilization which reduces the need for surfactant.

Figure 3 illustrates the different polymer dispersions in our range of Sulfopolyester polymers with varying glycol and SSIPA content.

Properties	Sulfopolyester Polymers				
	1000	1100	1200	1300	1400
Water dispersability	++	+++	+	++	++
Glass Transition temperature Tg °C	38	55	63	36	29
Minimum Film Forming temperature MFFT °C	<5	5	27	12	<5
Hydroxyl Number	5.0	5.3	<10	<10	5.0
Solids, wt%	30	33	30	30	30
pH	6.0	6.2	6.6	6.0	6.0
Viscosity, cP	60	89	99	14	15
Particle diameter. nm	27	20	13	54	34

Figure 3 Sulfopolyester Dispersion Types

The key features of the product range are: neutral pH, relatively low solution viscosity and exceptionally small particle size. It will also be observed that the solids content of the dispersions are all between 30-33 wt%. All of these key features can be explained by an understanding of how the Sulfopolyester products are dispersed and stabilized in water.

Sulfopolyester Electrostatic Stabilization

Figure 4 illustrates diagrammatically the principle of electrostatic stabilization exhibited by Sulfopolyester polymers in water. Such dispersions are neither clear like a true solution polymer nor opaque like a traditional latex dispersion. They are actually colloidal dispersions consisting of a suspension of very

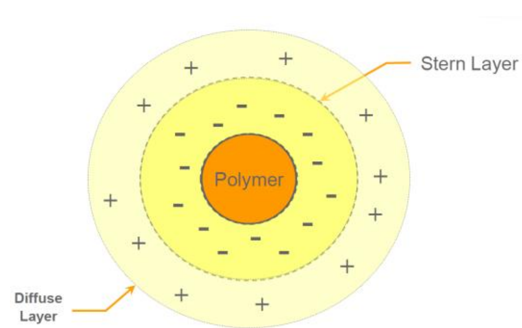


Figure 4 Electrostatic Stabilization

small particles with the SSIPA molecules orientated to the outside of the particle's surface. Since the SSIPA is ionised in water, the polymer particle is negatively charged. The sodium counter ions are located further out in the water resulting in a double layer which provides the electrostatic stabilization due to repulsion forces between other similarly charged particles. This stabilization mechanism limits the level to which the polymer particles can be crowded together resulting in typical solids contents of Sulfopolyester dispersions around 30%. If this level is exceeded, this results in a rapid increase in viscosity due to increased repulsion of the polymer particles. Prior to this point, the solids content of the Sulfopolyester dispersions can be increased without significant increase in viscosity. Figure 5 illustrates the viscosity solids relationship for the product range whilst Figure 6 shows the viscosity vs shear rate plot for one of the products in the range -Polymer 1100 as a function of solids content.

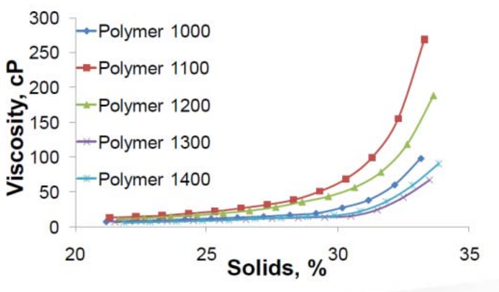


Figure 5 Viscosity/solids relationship

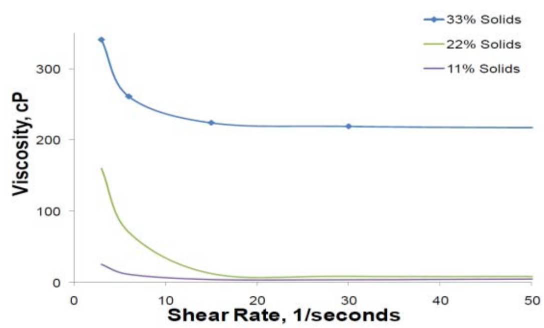


Figure 6 Viscosity/shear rate Polymer 1100

This rapid rise in viscosity with solids content is enhanced when the dispersion is applied onto a porous substrate such as wood or paper resulting in rapid drying of the coating layer.

One important point to remember with Sulfopolyester dispersions is that, due to their ionic nature, the dispersion stability can be adversely affected by the presence of soluble ionic species. Therefore when formulating coatings, it is important to control the level of soluble ionic compounds introduced from pigments, surfactants or other ingredients. For this reason it is also important that softened or deionized water is used in the preparation and dilution of the coating system, particularly in hard water areas.

A further interesting feature of the Sulfopolyester resins is that, due to the monomer composition, there is not a direct relationship between the glass transition temperature (T_g) of the polymer and the minimum film forming temperature of the corresponding dispersion in water. Thus it is possible to obtain relatively high T_g films with low overall demand for film forming aids such as co-solvents. Indeed in many instances, it is possible to utilize a low CHDM content polymer from the range as an additive to plasticise a harder grade with a corresponding decrease in co-solvent demand.

Viscosity and pH Stability

Sulfopolyester polymers do not utilize carboxyl functionality to obtain solubility and as a result, the viscosity of the dispersion is not dependent on pH level. Coatings based upon the Sulfopolyester polymers are best formulated to be in the near neutral pH range where they have maximum stability. This differs from conventional waterborne dispersions which are often stabilized at high pH with volatile amines, and it has been reported that in many automated coating systems such as Vacumat equipment and flow coating lines, constant pH monitoring and adjustment may be required to ensure viscosity stability. This can be particularly true in hotter climates and environments. Sulfopolyester based formulations exhibit excellent viscosity control during long processing runs. Additionally the Sulfopolyester dispersions exhibit excellent viscosity stability at both high and low pH; however, long term storage of such dispersions at extremes of pH level should be avoided to prevent hydrolysis and/or saponification.

A further advantage of near neutral pH level is the lack of interaction and possible colour change resulting from reaction of the coating with acidic extractable materials present in many wood species. Figure 7 illustrates the excellent viscosity control of Sulfopolyester dispersions with varying pH level.

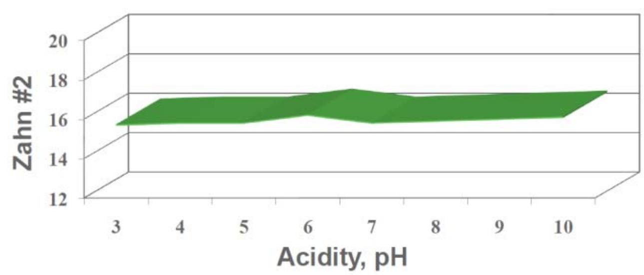


Figure 3 Viscosity stability with pH

Film Properties

During the drying process of a Sulfopolyester film, it can be observed that the exceptionally small polymer particles coalesce which helps to provide excellent clarity and gloss. Since the dispersion does not contain any solution polymer, the Sulfopolyester dispersions have no tendency to skin during drying which allows the water to escape rapidly from the drying film. This characteristic also prevents drying of coating residues on the container walls which could fall back into the bulk solution resulting in spray nozzle blockages or film contamination typical of acrylic or alkyd emulsion based systems. The high gloss and clarity are of particular interest in wood coating applications, since in many cases, the large particle size of traditional coating resin dispersions can result in poor optical characteristics and the alteration of the appearance of the wood. Very often coatings formulators and applicators describe the appearance of waterborne coatings on wood as being ‘cold’ or ‘green’ which is probably a direct result of this effect. Work performed on Eastman’s behalf by 3P in Germany has indicated that coating films formulated with Sulfopolyester dispersion (Polymer 1200) had appearance similar to a solventborne shellac-based coating, long recognised as

being of exceptionally high visual quality. This level of appearance was said to be almost unknown in a waterborne system.

Investigation into the Performance of a Sulfopolyester Dispersion for Joinery Applications

An extensive program of work was performed on Eastman's behalf by the consultancy company 3P in Germany. This work focussed on the performance of one of our range of Sulfopolyester dispersions (Polymer 1200) which was selected since its properties had originally been optimized to possess the highest level of water and alcohol resistance in our product range for ink applications. This work is still ongoing but some of the important results highlighted to date are shown below.

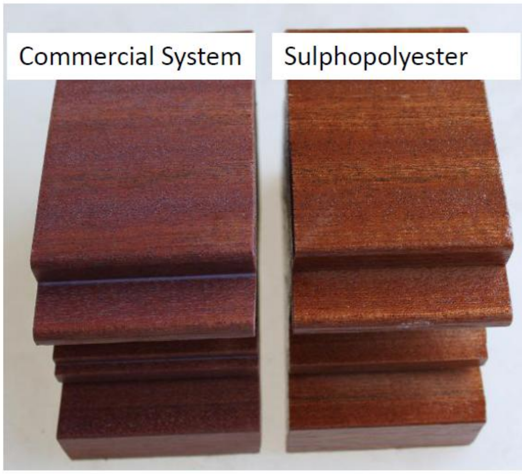
The work at 3P initially focussed on the use of the Sulfopolyester resin dispersion in comparison to various commercial systems in the initial impregnant layer of a wood coating typically used for windows. The second phase of this evaluation will determine the performance of the product in the intermediate layer of such coating systems.

The work focussed on the following performance areas:

- Impregnation behavior & appearance
- Resistance to UV light exposure
- Drying performance
- Humidity resistance and crack/blister performance
- Resistance to mechanical damage/hail

Impregnation behaviour & appearance

As predicted, the exceptionally small particle size of the Sulfopolyester dispersion results in excellent penetration and impregnation performance into various wood species. Photograph 1 illustrates the appearance of a Polymer 1200 based impregnating primer into a solid wood profile compared to a commercial impregnation primer. The Eastman system was observed to have equivalent penetration to an alkyd emulsion system but both were far better than an acrylic based system. Alkyd emulsion

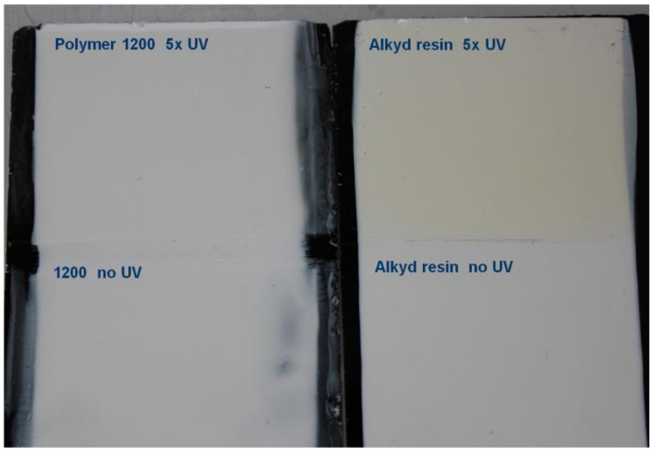


Photograph 1 Comparison of penetration & appearance

based systems are recognised as being particularly advantaged in terms of their small particle size and therefore excellent penetrating behaviour but are typically disadvantaged in terms of poor yellowing performance under UV light - mainly influenced by the high oil length of the base alkyd resins. Their slow drying rate can also often lead to problems with blocking resistance and plant throughput. Acrylic based dispersions have excellent non-yellowing characteristics but their penetration is generally poor due to their large particle size. As a result formulators tend to combine Acrylics with Alkyds to maximize the performance but this is at best a compromise.

Resistance to yellowing under UV light

To simulate the effect of yellowing under UV light, a test regime was performed where a white pigmented primer system formulated with the Sulfopolyester dispersion was subjected to a measured dose of UV light in a UV tunnel. Each test piece was passed through a Beltron UV tunnel a total of five times to give an accumulated UV dose of 12500 mJ/cm^2. Photograph 2 illustrates the appearance of the Eastek 1200 based system in comparison to the best in class alkyd emulsion based formulation with similar pigmentation levels.



Photograph 2 Yellowing under UV radiation 15000 mJ/cm^2 doseage

It can be clearly seen that the Sulfopolyester based coating has superior yellowing resistance to the alkyd coating which additionally can be seen to contain surface defects and cracking as a result of the UV radiation. The yellowing data is shown in chart 1.

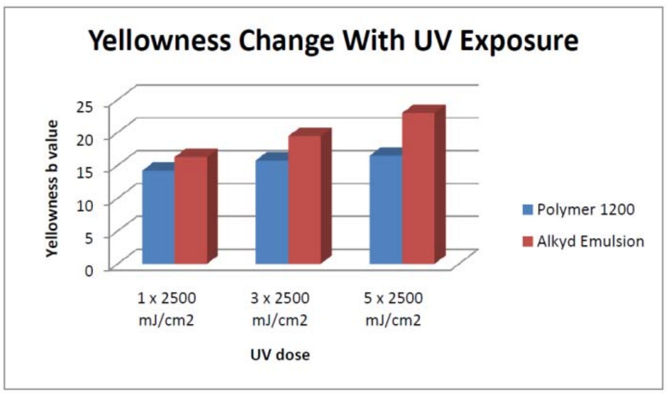
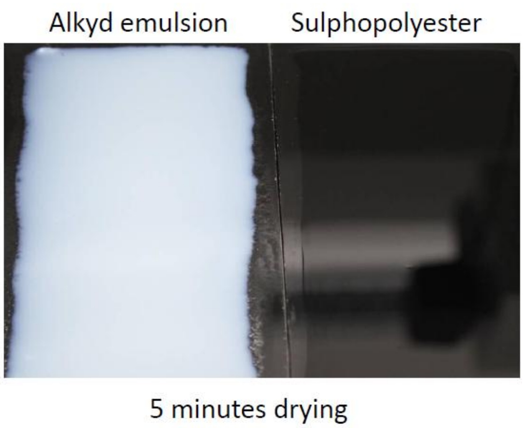
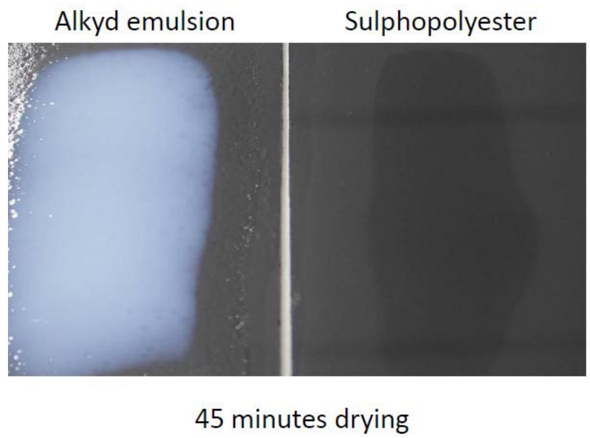


Chart 1 Yellowness value with UV exposure

Drying performance

As mentioned earlier, the electrostatic stabilization of the Sulfopolyester based dispersion can give rise to exceptionally fast drying characteristics compared to other waterborne polymer types. This effect can clearly be seen in photographs 3 and 4 where 200µm films of both an alkyd emulsion and the Sulfopolyester dispersion were observed after 5 minutes and 45 minutes respectively. The alkyd film remains opaque for a very long period of time compared to the Polymer 1200 based film. Although the drying rate of a penetrating primer type formulation is also greatly influenced by the level of absorption into the wood, the Sulfopolyester dispersion would appear to offer interesting drying behaviour in an industry looking to improve productivity and throughput.





Photograph 3 appearance on drying 5 minutes

Photograph 4 appearance on drying 45 minutes

Water Vapour Permeability Testing & Crack/Blister Performance

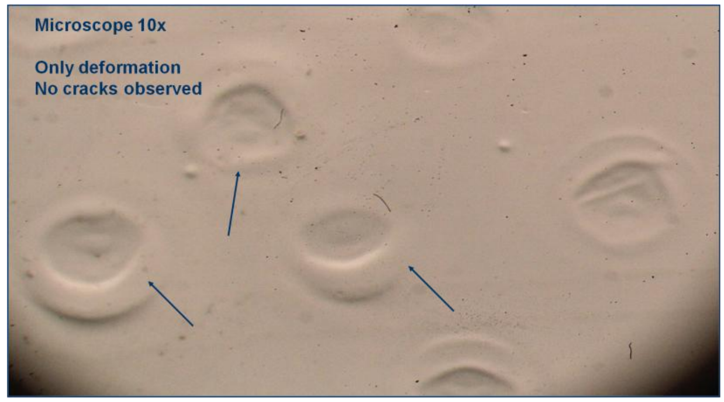
One of the most important tests for a joinery coating to pass is the resistance to humidity and water vapour permeability where no cracking or blistering of the coating surface can be observed. The Polymer 1200 based formulations developed by 3P were independently evaluated by the IHD Institute in Dresden, and their performance was confirmed to be equivalent to commercial benchmark products.

Impact Resistance

The impact resistance of the Polymer 1200 based formulations was compared against commercial coating systems and found to provide equivalent performance with all systems passing. This test is designed to simulate damage to joinery coating systems which could be caused by hail, etc. Any damage or cracking observed in this test would normally be a concern since this could introduce a pathway for water ingress and premature failure. Photograph 5 illustrates the excellent performance of the

Sulfopolyester based dispersion when used in an impregnating primer compared to a standard commercial product based upon alkyd acrylic binders. Photograph 6 shows the resistance of a white pigmented coating based upon Polymer 1200 applied onto a non-flexible glass substrate also subjected to a falling steel ball hailstone simulation test. The coating surface has deformed but has fully resisted cracking which indicates excellent flexibility and toughness.

Photograph 5 Hailstone Test on wood



Photograph 6 Hailstone Test on Glass

Conclusions

In this paper we have introduced a unique family of water dispersible polyester polymers for use in industrial joinery coating systems.

Work performed on Eastman's behalf by the independent consultancy firm 3P has identified that these polymers give alkyd emulsion-like penetration into various wood species but with non-yellowing characteristics similar to acrylic dispersions. Furthermore the exceptionally small particle size of the dispersions provide unprecedented clarity and appearance on natural wood substrates which can even be compared very favourably to solventborne shellac coatings noted for their remarkable aesthetics.

The chemical and physical nature of the Sulfopolyester dispersions produce tough, flexible coating systems which are fast drying and non-yellowing and possess exceptional gloss and clarity. Furthermore the electrostatic stabilization of the Sulfopolyester dispersion eliminates the need for amine and surfactant based neutralization giving advantages of viscosity stabilization and low foaming demanded in highly automated recirculation lines utilized by joinery coating companies.

Other benefits identified in independent screening of the Sulfopolyester dispersions for industrial wood coating systems included non-skinning properties in the coating container. This is in marked contrast to acrylic and alkyd systems where dry film/particulate contamination of the bulk paint is common with frequent spray nozzle

blockage problems. The clean-up of the Sulfopolyester resin dispersions was particularly easy with simple water washing which is again in stark contrast to existing commercial systems.

In summary we can demonstrate the following properties and values:

1. Very small particle size – translucent solution
2. Low odour
3. Non skinning
4. Fast drying and hardness development
5. High flexibility
6. Non yellowing
7. Excellent penetration
8. Very high gloss and clarity
9. Excellent appearance and harmonizing effect

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[i] Irfab, Global Industrial Coatings Market
[ii] IC Inter Consulting, April 2010
[iii] Martin F. Schick, Hieu D. Phan 'Water-based Sulfopolyester polymers for printing inks' American Ink Maker March 1998
[iv] K. R. Barton 'Sulfopolyesters: New resins for Water Based Inks, Overprint Lacquers and Primers' American Ink maker, Vov 71, No. 10 (1993) pp. 70-72