

## **New Flow Promoter for Environmental Friendly Coatings Systems**

**Authors:** Ming Zhao  
Augustin T. Chen  
John D. Jacquin  
Uwe Kubillus

**Presented by:** U. Kubillus

**Company:** Cytec Industries (Thailand) Ltd  
Thailand

Telephone: + 662 753 0922  
Fax: + 662 384 5892

# **New Flow Promoter for Environmental Friendly Coatings Systems**

by

Ming Zhao - Cytec Inc, Springfield, MA, U.S.A.

Augustin T Chen - Cytec Inc, Springfield, MA, U.S.A.

John D. Jacquin - Cytec Inc, Springfield, MA, U.S.A.

Uwe Kubillus-Cytec Industries (Thailand) Ltd, BKK, Thailand

At

*4 th. ASIA PACIFIC COATINGS MARKET*

*5 – 6 March 2002*

*Sheraton Grande Sukhumvit Hotel*

*Bangkok*

## **Abstract**

Defects in powder coatings are often caused by undesirable surface flow during the film formation stage. The use of a flow modifier at a low level in the powder coating formulation helps to create even surface tension across coating film surface. Flow additives assist in the control of surface flow and minimize the formation of surface defects in powder coatings. This paper describes the development of a new flow modifier which enhances the film formation in terms of flow and levelling, and the coating performance with respect to inter-coat adhesion, surface defect control, and cross-compatibility.

## **Introduction**

Powder coatings provide the industry with a unique balance of performance, cost and environmental sustainability. However, the appearance properties of powder coatings are an obstacle for growth in some decorative applications. These limitations are being overcome through the development of new chemistries and technologies. The reliance on additives such as flow modifiers is instrumental to the expansion of powder technology into new fields of applications like automotive coatings.

Thermoset powder coatings are inherently more susceptible to flow related defects than liquid coatings. The absence of a solvent reduces the capability of the coating to wet out the substrate and to flow.

A powder system relies on heat to provide flow-out of the coating and to cross-link the system, which are two competing actions. Flow and levelling agents are utilized since 1960 to improve film properties [1,2] by preventing or eliminating surface defects in the cured film.

## **Background**

Coating defects are mostly caused by flow and induced flow evoked by surface tension gradients.

Powder coating after electrostatic application forms a heterogeneous layer on top of the substrate. Individual powder paint particles are surrounded by a layer of air and are in contact with other particles to build a loose packaging pattern. We can assume that the heat for the baking process approaches the solid powder coating layer first from the top. In the first stage

particles start to melt and coalescence. During the melting process entrapped air is released from the layer. After a certain time period the coating will get thermal energy through the substrate due to its thermal conductivity. Here deviations in the thickness of the metal panel could lead locally to different energy inputs. Finally the whole material is in the molten stage and forms a continuous film.

As the temperature is gradually increasing the viscosity will decrease until it reaches its lowest value. In general this melt viscosity is on a much higher level than for liquid coatings at application viscosity therefore much lesser wetting ability is achieved.

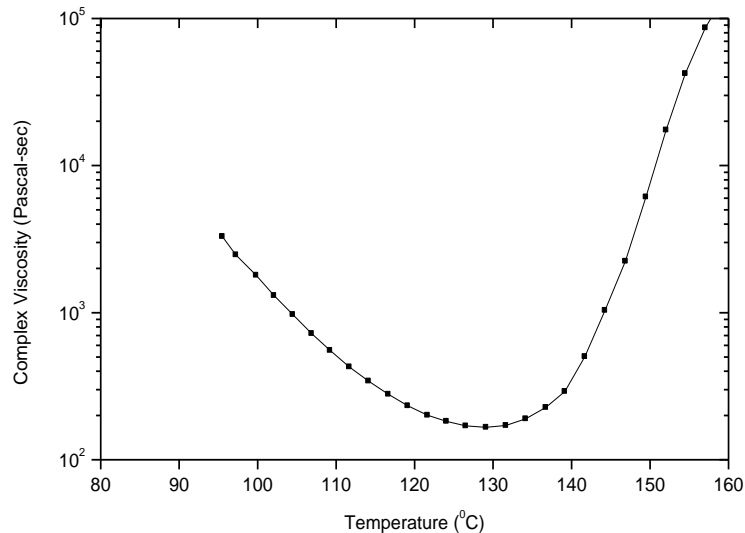


Fig. 1.: Melt Viscosity Profile of an Epoxy Powder Coating System

The melting process and the viscosity minimum value is greatly influenced by particle size and shape, film thickness, type of resin, the glass transition temperature, the coating formulation and the temperature profile.

Throughout the coating layer there will be temperature- and viscosity gradients in vertical and in horizontal direction that causes differentials in surface tension. These differentials induce a flow because the whole system is seeking to reach a stage of lowest free energy. This can be achieved if the surface tension across a panel at the interface powder coating/air is reaching its minimum. Therefore a flow from low surface tension areas onto high surface tension areas is induced.

Due to the competing curing reaction that increases sharply the viscosity of the coating material the system often will not have the chance to reach a stable equilibrium before the curing is overcompensating all other effects. This unbalanced situation gives raise to the formation of film defects.

Inert components that are able to reduce the melt viscosity and have influence upon surface tension are suitable to overcome and to control these undesired effects. The reduction of melt viscosity is a desired side effect, but the main impact of flow promoter is on the film formation stage.

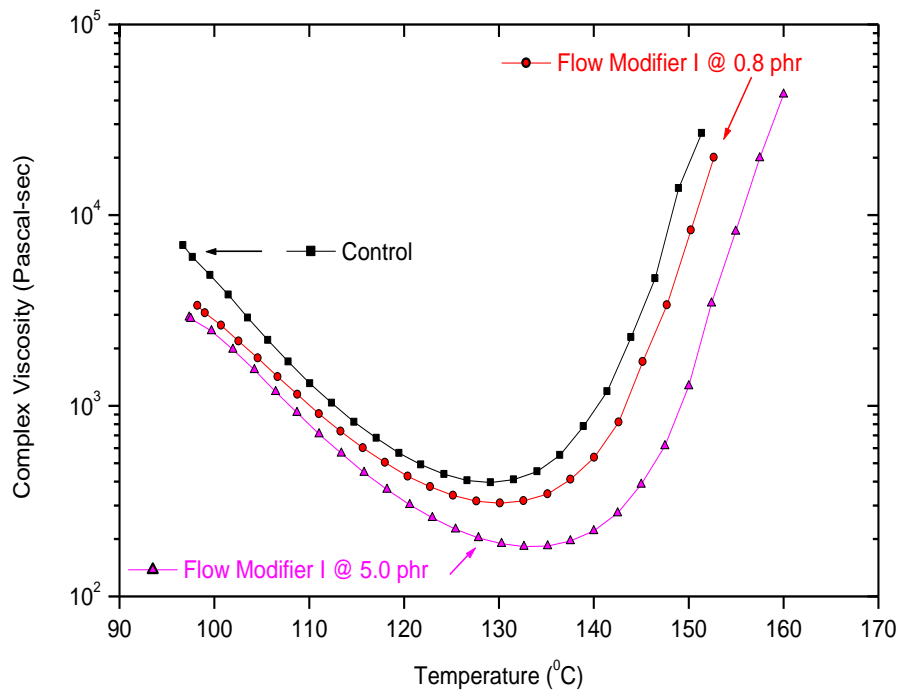


Fig. 2. : Melt Viscosity Depression by the Presence of Flow Modifier

The flow modifiers which are typically formulated into powder coatings are composed of a variety of chemistries [3]. The most common chemistries are the acrylic polymer types and silicone based compositions, which may also be used in combination. Fluorocarbon based additives are also found in powder coatings.

Flow promoter on the base of acrylic homo- or co-polymers are in use for all kind of chemistries that are common in powder coatings including epoxy-, hybrid-, polyester-TGIC and other alternative hardeners and acrylic systems.

Powder manufacturers use flow promoter in several forms, since the active compound is a liquid it is usual to combine them with a carrier for instance silica or a binder resin. This allows the additive to be processed as a solid together with other raw materials.

Since the absorption capability of binder resins is lower than for silica, the activity level differs and is for masterbatches around 15% whereas silica based additives achieve up to 70%.

The use of a silica carrier is common in US and Asia especially for outdoor formulations, whereas in Europe the use of so-called masterbatches- a combination of the additive with a binder resin like polyester or epoxy resin is more dominant. Epoxy-masterbatches are in use for hybrid systems in Asia as well.

Furthermore- especially in Japan- the technique to introduce the liquid additive direct into the pre-mix is established in parallel. This procedure avoids the presence of the “unwanted” carrier in the powder coating.

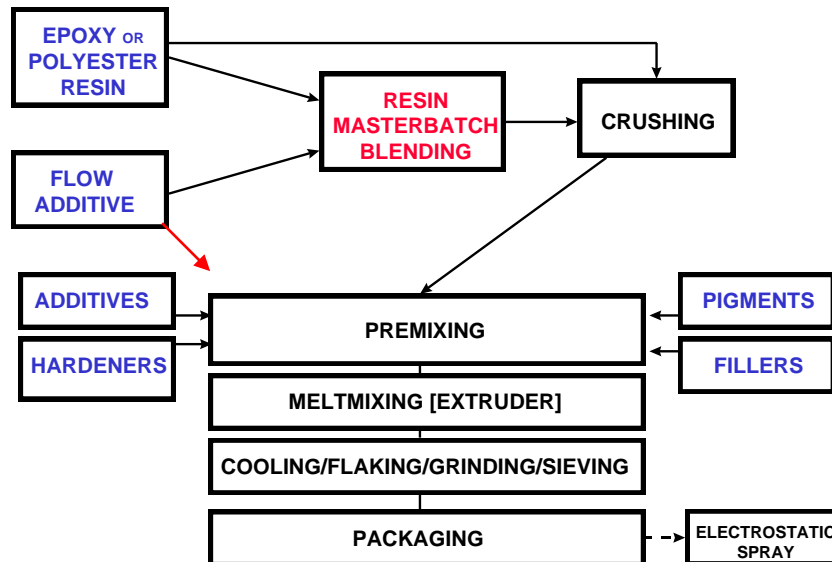


Fig. 3.: Powder Coating Processing with different Flow Modifier Addition

The targets for the development of a new flow promoter are manifold. The flow promoter needs to migrate to the surface to be capable to overcome surface defects. It should not significantly reduce the surface tension of the powder coating system to avoid cross contamination. Lastly a balance of performance between crater control and flow and levelling must be achieved.

The main important parameters for the design of such an active compounds are depicted in Figure 4.

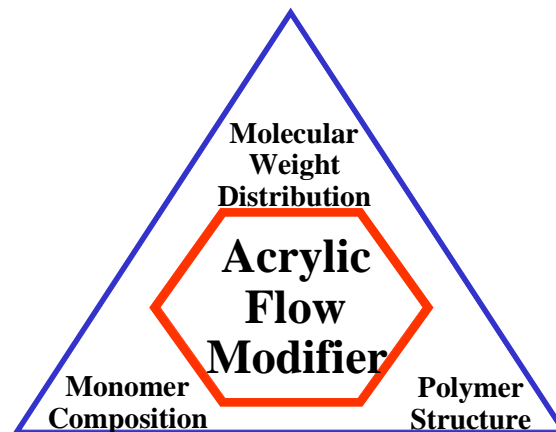


Fig. 4.: Design Parameters for Flow Modifier

The flow promoter should have positive impact on five items:

- Haze**
- Crater Control**
- Flow / Orange Peel**
- Gloss**
- Cross-Contamination**

## Haze

One key parameter is the molecular weight distribution that determines the compatibility with other binder resins and hardeners. Since a certain incompatibility is required to enable the acrylic co-polymer to migrate to the surface, haze can be an undesired side-problem. That is the reason, why common flow promoter for pigmented systems, not necessary are useful in clear coating systems or lead to haze problems in dark or black color shades..

As shown in Figure 5. the new flow promoter is optimized in this respect and is superior to established systems in the market.

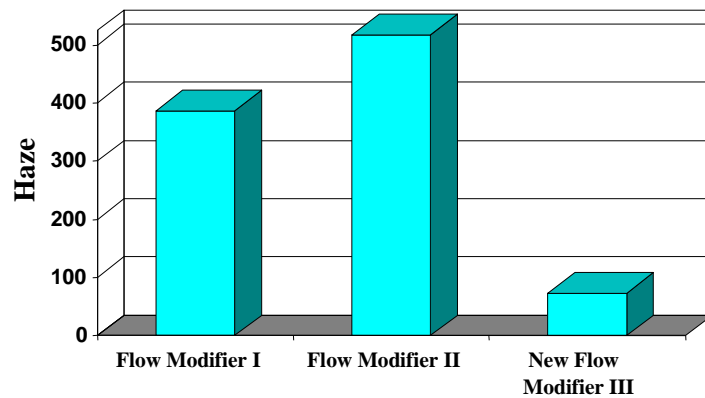


Fig. 5.: Haze Values of a black Hybrid Formulation prepared with different Flow Modifiers

## Crater Control

Crater formation in powder coatings is well known and typically result from contamination by a low surface tension material (Figure 6.).

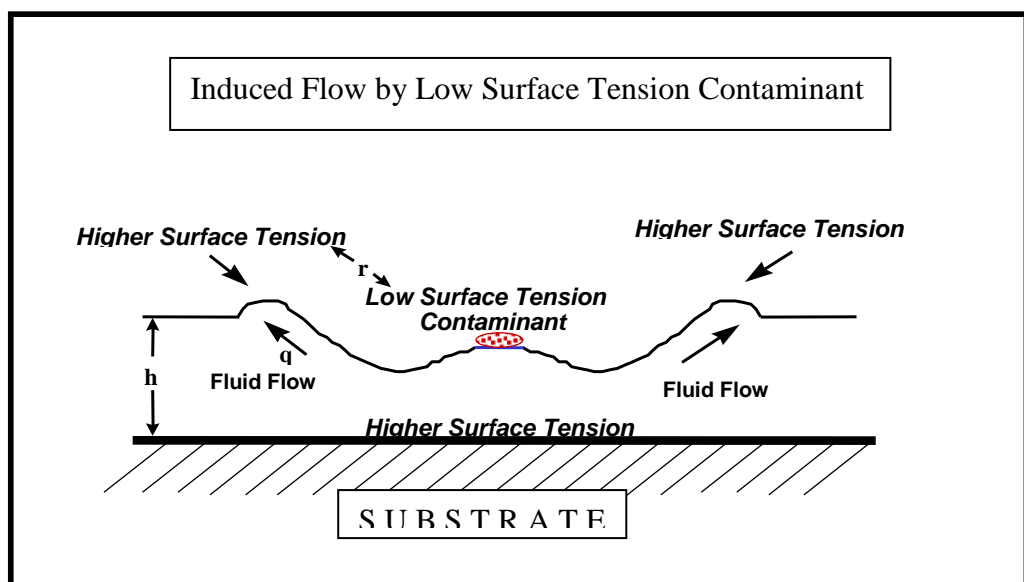


Fig. 6.: Induced Flow and Crater Formation by Contaminant

The phenomenon can be described mathematically by the Fink-Jensen equation [4]:

$$q = h^2 r / 2\mu$$

In this equation,  $q$  represents the flow of the powder coating material in the molten state,  $h$  is the thickness of the film,  $\mu$  is the melt viscosity and  $r$  is the surface tension gradient across the locale of the crater. To reduce the potential for crater problems, a lower  $q$  value, or flow, is desired.

Reduced flow will result when the surface tension gradient is minimized and/or the melt viscosity is increased. The film thickness is normally set as an application condition and cannot be changed freely.

Thus low surface tension additives such as surfactants, silicones or fluorinated compounds can significantly reduce the surface tension difference between the bulk of the powder coating and contaminants eliminating crater formation. The downside of using these surface-active agents is that these chemicals can also have negative effects on intercoat adhesion and recoat ability and potential orange peel problems.

Acrylic flow modifiers are able to reduce surface tension differentials as well, though to a lesser extent. A too big depression of surface tension of the bulk of the powder coating system is unwanted, because it has adverse effect on the flow and leveling.

Figure 7. shows how the surface tension of the new flow modifiers compares to the standard system. From this plot it can be seen, that the new system shows a lower surface tension at lower temperature levels thus being more effective in crater control, but at the typical curing temperature the level of the surface tension is quite similar. This explains the similar activity on the flow behavior in the second stage.

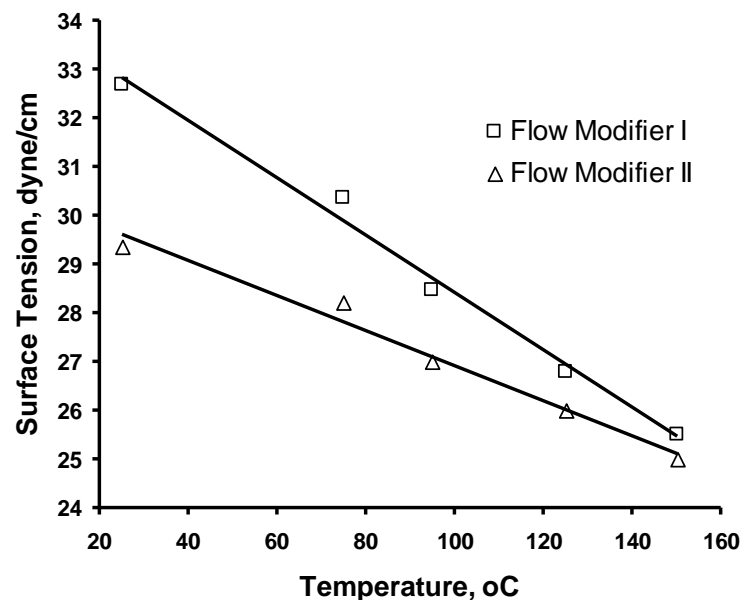


Fig. 7.: Temperature Dependence of Surface Tension for Acrylate Flow Modifiers

An example for the crater control is given in Figure 8. The new flow promoter improves crater control in a white hybrid formulation significantly.

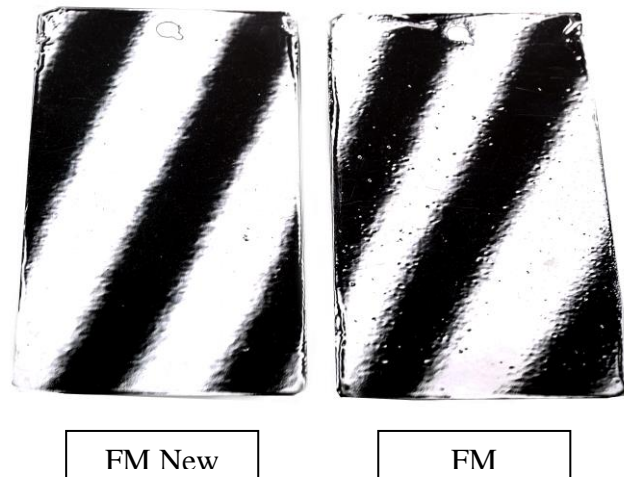


Fig. 8.: Crater Control by Flow Modifier

### Flow / Orange Peel

Orange peel in a powder coating is directly associated with leveling during the film formation stage. The situation is not different as for liquid coatings and the key parameters can be mathematically describe by the Orchard equation [5].

$$\ln \frac{a_0}{a_1} = \frac{5.3 \gamma h^3}{\lambda^4} \cdot \frac{dt}{\eta}$$

$a_0$  = initial amplitude

$a_1$  = amplitude at time t

$h$  = average coating thickness

$\gamma$  = surface tension

$\lambda$  = wave length ( atomization)

$\eta$  = viscosity

$t$  = time

The best flow / leveling is achieved, if the left term in the equation is increased. Only two parameters can be changed freely and are under the control of the coating formulator: the surface tension and the melt viscosity.

To get optimum flow the surface tension has to be increased or to be maintained on a certain level and the melt viscosity has to be decreased. These requirements are contradictory to what crater control requires.

The flow/leveling ability of a coating or the tendency for orange peel formation is measured by the so-called DOI = Distinctiveness of Image. Figure 9. shows a direct comparison of the standard with the new flow modifier system (Flow Modifier II). In most cases a high DOI value goes along with an increased values for gloss measured at an angle of 20° and 60°.



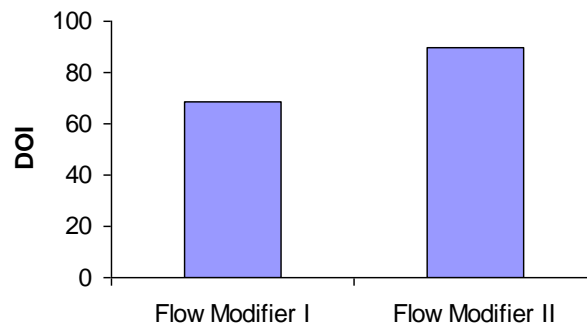


Fig. 9.: Improvement of DOI Value by new Flow Modifier II.

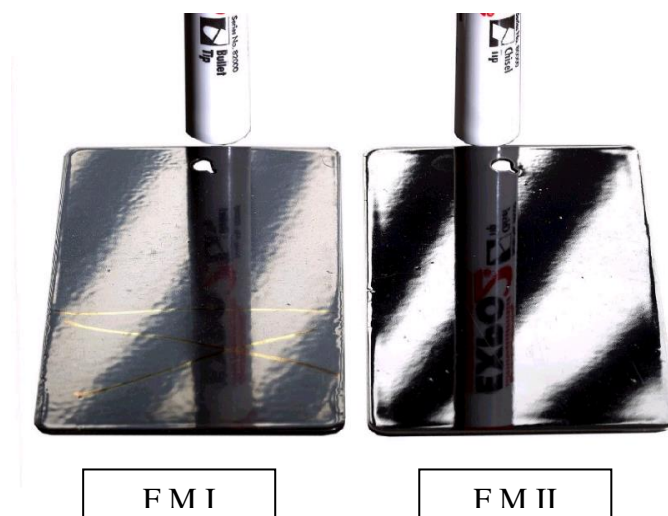


Fig. 10.: Photographic Demonstration of DOI Improvement by Flow Modifier II

### Cross Contamination

Cross contamination can be a serious problem in practice when finished powder coatings of different or slightly different composition are blended together. This problem can occur at OEM coatings when different production batches differ slightly, more often these problems appear at so-called job coaters where powder material of different origin is in use.

Cross contamination can result in surface defects or in an undesired down glossing. In general the powder coating with the lower surface tension contaminate the other one with higher surface tension. For a flow promoter it is important therefore to provide a broad compatibility.

In a test series white powder coating formulations were separately prepared on the base of a 95/5 polyester resin in combination with Primid XL 552 with different flow modifiers. Individual powder coatings were mixed in different ratios from 99.9 : 0.1 , 99:1, 90:10, 80: 20, 70: 30, 50:50, 30: 70, 20: 80, 10: 90, 99: 1, 99.9 : 0.1 to simulate all kind of blends that can occur under practical conditions. The degree of incompatibility can be followed up by measuring the gloss at 20 ° or by the DOI value.

Results of compatibility test of the new flow modifier system with a masterbatch based on a hydroxy-functional polyester carrier can be seen from Fig. 11. Comparisons with other silica based additives result in much less change in gloss and DOI.

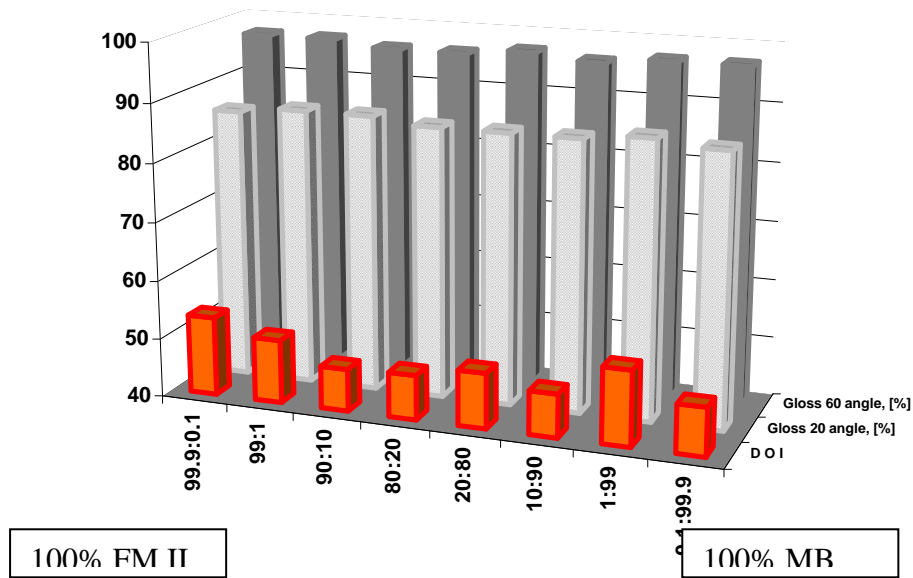


Fig. 11.: Gloss and DOI Values for Powder Coating Blends

## Conclusion

Melt viscosity and surface tension are the two key parameters in the film formation stage of powder coatings that have major impact on film quality. The new flow promoter shows an optimized balance between these two parameters and provides improvements in gloss, haze, DOI and crater control.

## References

1. Grolitzer, M.A. and Erickson, D. E., Journal of Coatings Technology, Vol. 67, No. 845, pp. 89-91 (Jun 1995).
2. Grolitzer, M. and Jacquin, J., Powder Coatings, p. 15-25 (Oct 1997).
3. Knauer, J. Coatings Magazine p. 50 (JUL-AUG 1998).
4. Fink-Jensen, P., Farbe und Lack, 68, 155, (1962).
5. Orchard, S. E., Appl. Sci. Res. A 11, p 451, 1962