

Solving color acceptance problems in decorative paints

To improve compatibility of universal colorants in base paints

Key Benefits

- ❖ Effective reduction of rub-out issues
- ❖ Improvement of colorant acceptance by optimum compatibilization

Overview

The use of universal colorants for tinting purposes of aqueous as well as solventborne decorative paints can be quite difficult due to poor color acceptance. Optimal color acceptance has a vital bearing on the application properties and quality of tinted paints. Color acceptance is related to the composition of the colorant as well as the base paint.

Poor color acceptance results in performance problems such as poor color development, inhomogeneous film appearance, mottling, formation of Bénard cells etc.

A practical way to solve color acceptance problems is the application of specific additives to the base paints.

This article will show various examples of color acceptance failures and solutions to solve these shortcomings using NUOSPERSE® additives in aqueous and in solventborne decorative paints.

Introduction

Universal colorants are typically used as part of an in-plant, retail- or shop-tinting system. Tinting systems meet the requirement for optimizing the production of a wide range of paint colors. Such systems are widely used in the industry already in the 1950s and are widely used in many parts of the world. With modern tinting systems the paint industry can offer thousands of colors as close to the point of use as possible. As only a small range of base paints and colorants is needed, major savings in stockholding costs and better service can be achieved throughout the supply chain. Decorative universal colorants are used for tinting of both waterborne as well as solventborne paints.

The basic concept of a tinting system is that the selected color shade can be formulated just by mixing the colorants into the base paint, at a ratio according to the specific formulation. The accuracy of reaching the desired color shade is strongly related to the color acceptance.

Good color acceptance means that the color appears in a uniform homogeneous manner and at the expected strength (ref. 1, 2).

Colorant acceptance is related to the compatibility, distribution and stability of the colorant in the base paint. An essential precondition for excellent color acceptance is to make sure the colorant is compatible

with the base paint, to which it is being added.

Practical experience shows that this condition is only fulfilled if the base paint is adjusted in order to optimize the compatibility with the specific colorant line.

The following most characteristic color acceptance problems in relation to the application of universal colorants in decorative paints are most common:

1. Poor mechanical stability: the color gets weaker on mixing.
2. Slow color development, slowly improving on mixing
3. Poor color development in solventborne alkyds, mottled or streaked film appearance
4. Bénard cells, appearing as floating

NUOSPERSE® additives, offered by ELEMENTIS, have been used successfully to avoid color acceptance problems. Cause and cure of color acceptance problems is described more in detail in the next paragraphs.

Universal Colorants

Before going into detail of the color acceptance issue, let us first consider some general characteristics and compositions of universal colorants.

“Universal” refers to the applicability of the colorants in waterborne coatings as well as solventborne coatings. Universal Colorants are dispensable by gravimetric or volumetric dispensing machines and applicable to a color system. Universal colorants (“UC”) are composed of pigment dispersions in a liquid medium, comprising a mixture of dispersing agents, stabilizers, solvents and vehicles.

Typical examples of UC formulations for respectively an iron oxide yellow (P.Y. 42) as well as a phthalocyanine blue (P.B. 15:4) based colorant are shown in table 1. Main ingredients, next to the pigment and solvent, are the pigment dispersing agent and carrier (ref. 3, 4).

The dispersing agent serves to disperse and stabilize the pigment in the colorant medium as well as in the paint system after it been dispensed.

Table 1: Universal colorant compositions

| | Ingredient | Feature | P.Y. 42 colorant [%] | P.B. 15:4 colorant [%] |
|----|-----------------------|---------------------------|----------------------|------------------------|
| 1 | NUOSPERSE® FN 265 | Dispersant/Carrier | 4.0 | 10.0 |
| 2 | NUOSPERSE® FX 600 | Dispersant | 2.0 | — |
| 3 | NUOSPERSE® FA 196 | Dispersant/Compatibilizer | 6.0 | 4.0 |
| 4 | Water | — | 14.5 | 29.6 |
| 5 | Propylene glycol | Humectant | 15.0 | 15.0 |
| 6 | Bayferrox yellow 3910 | Pigment | 58.0 | — |
| 7 | Heliogen blue L 7101F | Pigment | — | 30.0 |
| 8 | RHEOLATE® FX 1070 | Stabilizer | 0.2 | — |
| 9 | Preservative A | Biocide | 0.1 | 0.2 |
| 10 | Defoamer | — | 0.2 | 0.2 |
| 11 | Total | | 100.0 | 100.0 |

The “carrier” functions as the dispersion medium for the pigment and works as an emulsifier for the colorant droplet during the dispensing process of the colorant into the base paint. As the composition of the base paint may vary from polar to non-polar medium compositions, the carrier should show excellent compatibility with both mediums. The compatibilizer optimizes the compatibility between the colorant and the base paint. Typically universal colorants, based on waterborne dispersions (like in table1) already contain some compatibilizer in order to improve the compatibility in non-aqueous paints (being obviously most critical). However, depending on the characteristics of both colorant as well as base paint, some further, more specific adjustments of the base paint, may be required.



Experimental part

In this experimental part various examples are presented of practical cases related to the correction of color acceptance problems of universal colorants in base paints. The examples discussed in detail are subdivided according to the appearance of the color acceptance problem.

Following appearance phenomena will be used:

1. The color gets weaker or stronger on mixing.
2. Slow color development, slowly improving on mixing
3. Poor color development, mottled or streaked film appearance, no improvement by mixing
4. Formation of Bénard cells, appearing as floating

The paints used are various commercially available paints, as is the case for most of the used colorants. Both waterborne as well as solventborne paints have been used. The colorants are universal colorants, most of them containing water as part of the solvent medium.

Test methods

The paints were tinted using several approaches. Unless described differently, the colorants were added to the base paint, mixed with a spatula and mixed using a dissolver or shaking machine e.g. "Skandex" or "Red Devil".

A widely accepted test for colorants being part of a "Point of Sale" tinting system is "the 2/10 minutes shaking test". After adding the colorant to the base, the paint is shaken for 2 and 10 minutes respectively. Subsequently draw-dawns and finger rub-up tests are made. Color acceptance is best if no color difference between the rubbed and non-rubbed area is noticed. The 2 minutes test is regarded as being the minimum mixing time typically used, whereas the 10 minutes test simulates conditions of over-mixing. Any difference in color acceptance performance between these two mixing conditions would indicate a risk in color reproducibility (color shade/film appearance being related to mixing time).

The rub-up test is carried out soon after application in the wet, already tacky paint layer. The paint is gently rubbed, breaking up the loosely flocculated pigment particles, which will be distributed evenly and approaching the optimum color development (ref. 5).

Note: It is very important to use the same shaker for this test than is used out in the market. The amount of sheer force that is added to the paint mixture can vary greatly between different models. Some problems will be more obvious, some less, depending on what shaker you are using. Important is that you can replicate what your the formulator is seeing.

The color differences between the rubbed and non-rubbed area are quantified by measuring the color strength of both areas and using the CIE Lab formula:

$$\Delta E \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

Color acceptance is adjusted, incorporating additives ("compatibilizers") to the base paint. The selection of the compatibilizer is made by adding approximately 1% additive (compatibilizers) to the base paint. Further optimization of the dosage of the compatibilizer is made either by addition to the base paint (in case of "trouble shooting") or by incorporating the compatibilizer in the paint recipe and adding the compatibilizing additive to the mill base prior to the milling process (see also paragraph 5).

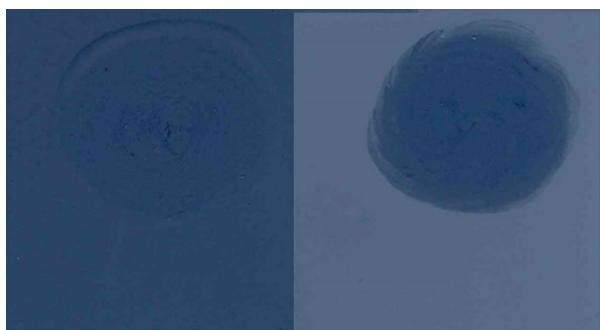
Results and discussion

Part 1: The color turns weaker or stronger on mixing; surfactant drift

Observations

After mixing the paint at first shows good color development. The paint loses its color strength however when energy is added to the system by stirring or shaking. The difference is striking when rub tests are done before and after shaking (figure 1).

**Figure 1: Left – rub up test on a freshly prepared colored paint after 2 minutes shaking
Right – same test after 10 minutes shaking**



After 10 minutes shaking the color strength is reduced. Rubbing up the paint will make the original color reappear in the rubbed up area.

This is probably the most frequently noticed color acceptance failure, certainly in case of color acceptance failures in waterborne paints.

Two paints have been tested; a styrene acrylic decorative paint, and a PVA latex wall paint.

The original latex base paint (table 2) shows no rub-up when the colorant is gently mixed into the paint base using a spatula. Using stronger mixing forces for a longer time (10 minutes) by means of shaking, a strong rub-up is noticed.

Table 2: For tinting system – manual mixing versus machine mixing

| Paint with 5% colorant | Universal colorant (UC) | ΔE , 2 min. shaking | ΔE , 10 min. shaking | Visual appearance after shaking |
|--|-------------------------|-----------------------------|------------------------------|---------------------------------|
| Styrene acrylic latex | Yellow oxide* | 0.1 | 3.3 | rub-up |
| Same, with 0.3% Anionic low Mw diester (NUOSPERSE® 2006) | — | 0.1 | 0.1 | O.K. |
| PVA latex wall paint | Organic yellow** | 4.0 | 4.6 | rub-up |
| Same, with 0.5% Anionic low Mw Sulpho compound (NUOSPERSE® FA 115) | — | 1.0 | 1.0 | O.K. |

* CPS ** Colortrend 990

Addition of a well chosen dispersant can solve the color acceptance issues.

Mechanism and solutions

In case of physical adsorption - as for most organic or organically treated pigments - some of the dispersing agent molecules will be desorbed and adsorb simultaneously. This is indicated as "surfactant drift".

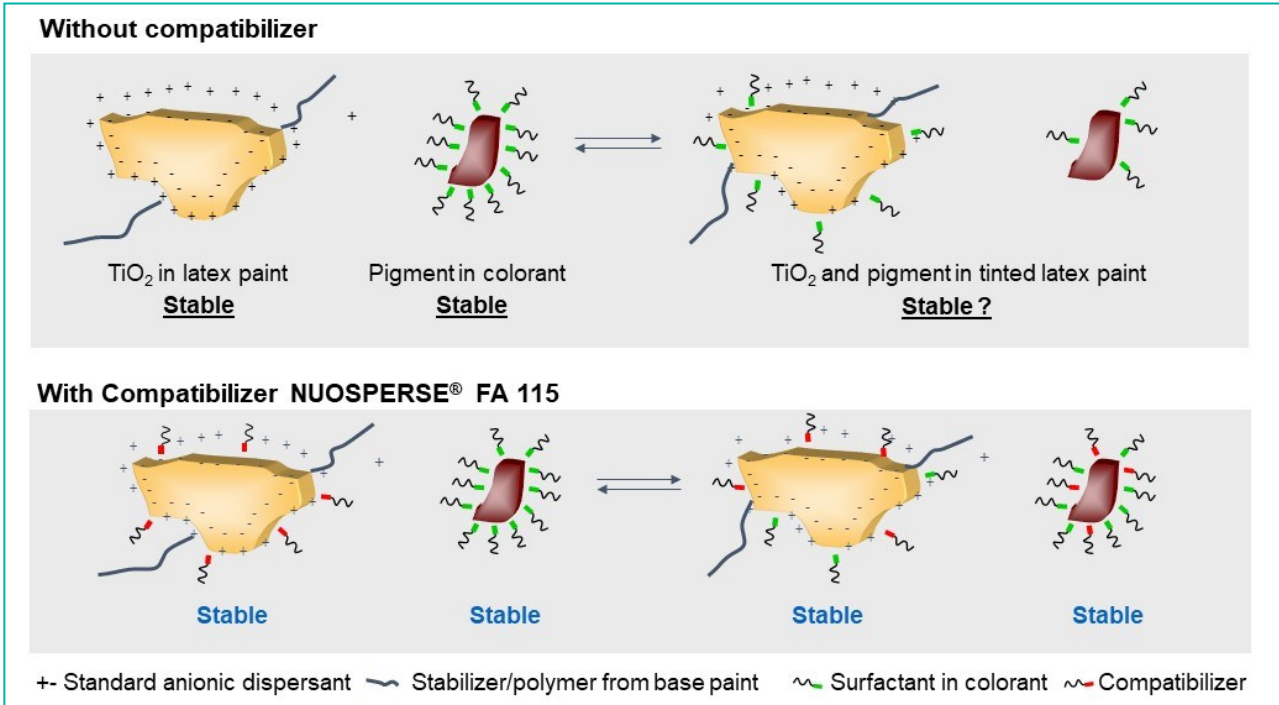
At longer mixing time - or increased mixing forces - the mobility of the particles in the system is increased. Under these conditions it is more likely that the desorbed dispersing agent is adsorbed onto a near pigment particle for which the total surface area is larger. For instance the pigment or extender from the base paint. As a consequence of this surfactant drift, the colorant pigment remains unprotected, tends to flocculate and will show poor color development (figure 2, top).

The solution to obtain acceptable color acceptance performance under standard as well as extended mixing conditions is the incorporation of a low molecular weight, multi-functional, dispersant in the base paint.

The speed of adsorption is inversely related to molecular weight of the dispersant. Low molecular weight dispersants like those mentioned in table 1, are instantly adsorbed onto the pigment surface, as soon as desorption from the original stabilizer takes place. The multi-functional nature of the NUOSPERSE® dispersants explain these products adsorb well onto a wide variety of pigment surfaces.

The demonstrated dependency of color acceptance on mixing conditions and the weakening of color strength at longer mixing times indicates loss of pigment stabilization over time. Most likely the dispersant on the colorant pigment is desorbed from the pigment surface onto the TiO₂ pigments in the base paints. The fact that adding small amount of anionic surfactant to the base paint solves the problem, enforces this theory. The surfactant will migrate onto the charged TiO₂ particles and occupy positions which otherwise could be taken by surfactants from the colorants (figure 2).

Figure 2: Surfactant drift in a water based paint - mechanism of flocculation (top) and solution



So the solution for the described lack in color development is to adapt the base paint to the used colorants. A practical way is to choose a dispersant showing fast and strong adsorption characteristics with a wide variety of pigment surfaces (from all colorants as well as base paints).

The dispersing agent of the colorant will have a reduced tendency to leave the pigment surface because the space on the TiO_2 pigments is already taken. Desorbed dispersing agent molecules from the colorant pigment surfaces will be replaced with the added dispersant thus preventing flocculation.

The use of multifunctional dispersants having different anchoring groups in the same molecule, is preferred. High molecular weight dispersants should be avoided because of their limited mobility in the system.

NUOSPERSE® FA 115 and NUOSPERSE® 2006 are the two preferred compatibilizers for waterborne paints. Both products demonstrate:

- Fast adsorption characteristics (so relatively low molecular weight)
- Multifunctional anchoring moieties (anionic)

Similar interactions between the colorant surfactants and pigments present in the base paint have been noticed in solventborne alkyd paints. In order to overcome surfactant drift in alkyds it is recommended to use an organic polyphosphate based additive like NUOSPERSE® FA 196 in the base paints. Other cases have shown good performances from NUOSPERSE® 2006, which is the second option.

Like with NUOSPERSE® FA 115 for waterborne systems, NUOSPERSE® FA 196 shows fast adsorption and multi-functional anchoring characteristics in non-aqueous systems.

NUOSPERSE® 2006 is best described as being an amphiphilic surfactant, with high surface activity, compatible in waterborne and non-aqueous systems.

Observations and solutions when the color turns stronger on mixing

In some case following phenomena is noticed: the color strength increases at longer mixing and a negative rub-up is noticed (lighter color of the rubbed area).

This appearance is a clear indication for flocculation of the white pigment from the base paint. The white pigment is not sufficiently protected. The applied stabilization system (dispersing agent) is ineffective to avoid flocculation during the mixing process. This problem is noticed for instance in alkyd base paints, without containing any dispersing agent as well as.

However, also in alkyd paints in which the TiO_2 pigment is stabilized with dispersing agents, that are weakly adsorbed onto the pigment. During the mixing process the dispersing agent is desorbed from the TiO_2 surface and moves for instance to the surface of the colorant-pigment or -extender.

The TiO_2 will be flocculated; rubbing will deflocculate the TiO_2 increasing the whiteness.

The problem occurs most often when iron oxide based colorant is added and is mainly noticed in solventborne paints.

It is solved using a dispersing agent in the base paints that is strongly attached to the TiO_2 surface. For this purpose NUOSPERSE® FA 601 is the preferred dispersing agent.

Following products are first choices:

For waterborne base paints:

- NUOSPERSE® FA 115
- NUOSPERSE® 2006

For solventborne base paints:

- NUOSPERSE® FA 196
- NUOSPERSE® 2006
- NUOSPERSE® FA 601

Part 2: Slow color development, slowly improving on mixing

Observations

The opposite to what has been described in the previous paragraph is found in the “D-base”, waterborne alkyd (figure 3). In this case the color develops gradually and full color development is obtained only after a long mixing time. Strong differences between the color shade obtained after 2 minutes shaking and 10 minutes are seen. Only the mixture shaken for 10 minutes shows no rub-up. This indicates homogeneous distribution of the pigments in the “new” mixture has been reached. The draw-down and rub test taken after 2 minutes shows a strong, positive rub. A similar example is given in table 3, but for a latex ED base (“Extra Deep”).

**Figure 3: Left – rub up test on a freshly prepared colored paint after 2 minutes shaking
Right: same test after 10 minutes haking**

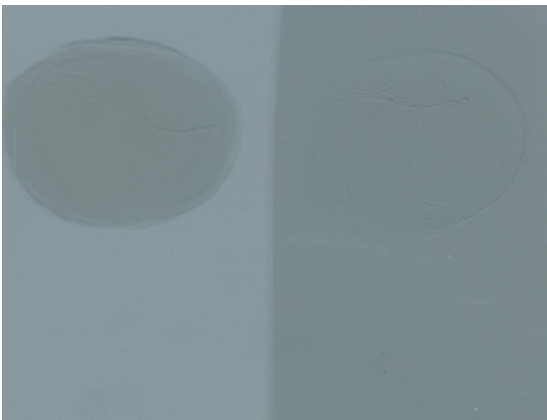


Table 3: Improvement of color development by adding a compatibilizer

| Paint with 5% colorant | Universal colorant (UC) | ΔE , after 2 min. shaking | ΔE , after 10 min. shaking |
|---------------------------|-------------------------|-----------------------------------|------------------------------------|
| Matt PVA latex | Violet | 2.4 | 0.7 |
| With 0.5 % compatibilizer | — | 0.7 | 0.6 |

Mechanisms and solutions

Strong dependency on mixing conditions should be avoided not only because the mix could be inhomogeneous but also as the reproducibility of the color shade could be affected.

This example of lack of color acceptance is often noticed in applying (waterborne) universal colorants in alkyd base paints as well as when applied in poor wetting latex paints.

The phenomenon is related to the poor (slow) emulsification of the colorant and the slow wetting of the colorant - pigment particles with the base paint.

When insufficient energy is applied during the incorporation of the colorant into the base paint color development may not be complete. Upon applying more energy (mixing) the color acceptance can be improved.

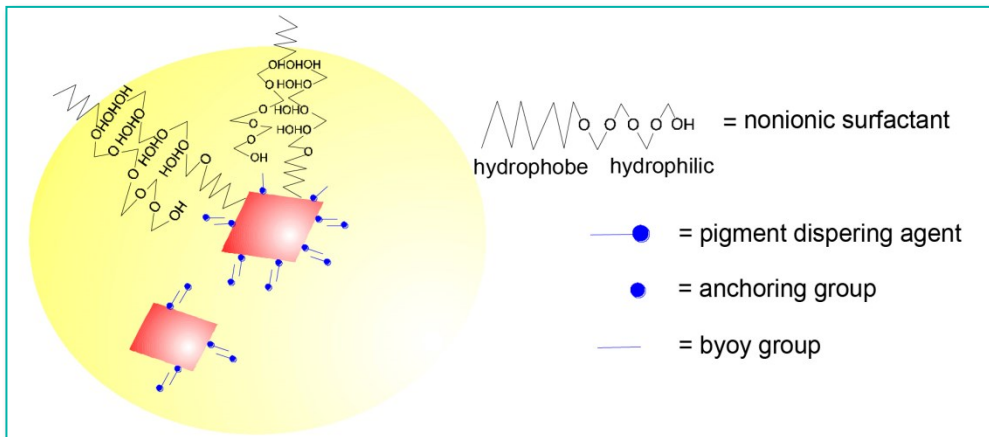
Causes are usually :

- The viscosity of the base paint is too high to ensure ideal distribution, or
- The HLB (hydrophilic-lipophilic balance) value of the base paint is not in line with the colorant (ref 7, page 4)

Mainly problems occur with colorants based on hydrophobic organic pigments or extenders (talcum). These pigments and extenders show low surface tension characteristics and adsorb high amounts of surfactants; little surfactant is left to act as emulsifier for the colorant. This again leads to the formation of relatively large droplets (having lower total surface area than smaller droplets) and slow dispersion speed.

The solution is to improve emulsification of the colorant and to improve wetting by reducing the interfacial tension between the liquid phase and the pigment surface. Surfactants that position themselves at the interface between colorant droplet and base paint are the most obvious choice .

Figure 4: Schematic model of a yellow colorant, dispensed in a solventborne white paint (NB: adjusted size scale). Amphiphilic functionality of the nonionic carrier (NUOSPERSE® FN 265, or similar nonionic surfactants). The hydrophobic part of the surfactant molecule is directed towards the interface colorant/non-polar paint medium.



Following products are first choices:

1. For waterborne base paints

A nonionic emulsifier with hydrophilic and hydrophobic groups adsorbs onto the pigments in the colorants while its tail will position itself at colorant - base paint interface (figure 4). An example would be NUOSPERSE® FN 265 or NUOSPERSE® 2006.

2. For solventborne base paints

- NUOSPERSE® 2006 : will bring faster wetting
- NUOSPERSE® FA 196 : will give better dispersion of the colorant pigment because it reduces colorant

Part 3: Poor color development in SB alkyds, mottled or streaked film appearance

Observations

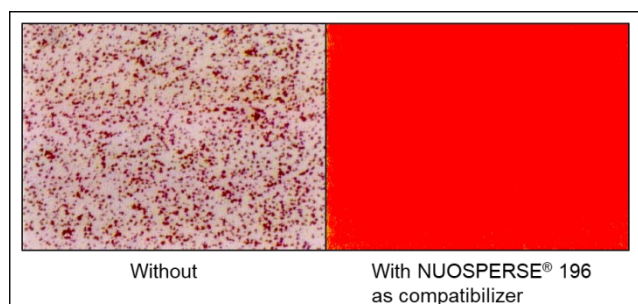
The case as presented in figure 5 demonstrates typical color development problems in SB base paints, mainly due to improper “emulsification” of the colorant into the base paint: very strong rub-up in the original paint.

The microscope picture of the dried paint film (figure 6, enlargement 220 times) gives more detailed information of what is happening at a smaller scale. It clearly shows large colored particles, homogeneously distributed through the coating layer.

**Figure 5: Left - improper emulsification of the colorant into the base paint
Right - problem solved by adding a polyphosphate emulsifier (NUOSPERSE® FA 196)**



Figure 6: Microscopic view on the effect of NUOSPERSE® FA 196 on colorant distribution in the alkyd ED Base (220*)



Mechanisms and solutions

This example of lack of color acceptance is typically seen in alkyd base paints, very rarely in waterborne systems. The problem is related to the incompatibility of the liquid phases of, on one hand the colorant (aqueous) and on the other the base paint (mineral spirits).

The mechanism is in fact similar to the “Slow color development” described in section part 2. The difference is that now we have a stable 2 phase system which will not become homogeneous by prolonged shaking. This stable 2 phase system only occurs in solventborne paint because of the different polarity of colorant and paint. This situation will not occur in waterborne base paints.

During the first steps of mixing the “aqueous” universal colorant in the non-aqueous base paint the ease of colorant emulsification into the base paint has to be considered. As the continuous phase of the colorant is polar (typically water/glycol) and the solventborne paint non-polar (mineral spirits) complete mixing requires high energy, which is beyond the capabilities of the paint shaker. Thus rather coarse emulsified colorant particles are being formed.

The emulsification properties of the colorant/base paint system should be sufficiently effective in order to reduce the colorant droplet upon further shaking and finely break these droplets completely. Once the droplets break, the pigment particles move from a polar medium into a non polar medium. The effectiveness of this is largely due to the amphiphilic surfactant characteristics of the dispersants on the colorant pigment.

(NUOSPERSE® FN 265) in the colorant formulation of table 1. This dispersant/carrier enables the change of the dispersion phase of the colorant pigment particle from the polar to non-polar phase.

Unfortunately this process is not always completed, resulting in poor color development. The most difficult step is the de-emulsification step, followed by the stabilization of the pigment in the new environment (alkyd base paint).

Based on the structure and distribution of the particles, it has been deduced these are being formed from emulsified colorant particles, during the drying stage of the coating layer (figure 7).

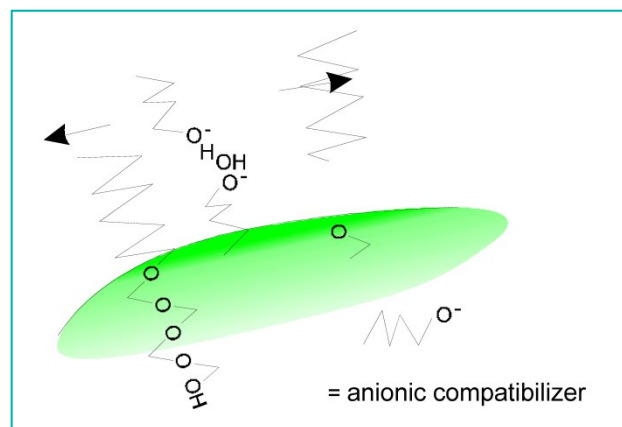
The colorant remains in the paint as a micro-emulsion, the demulsification process is not complete. Therefore colorant-pigment particles are still dispersed in the polar colorant medium, rather than in the non-polar medium of the paint. Various colored pigment particles are present in the same micro-emulsion particle.

During the drying stage the colored pigment particles tend to flocculate, resulting in the distribution as can be observed in figure 7.

In many cases best color development improvement is found using low molecular weight, rather hydrophilic anionic compatibilizers, which also have strong pigment stabilizing properties (figure 8).

At a first glance this may be quite surprising, as these compatibilizers tend to dissolve best in the water phase rather than in a non-polar phase like mineral spirits. The benefit is explained by the destabilizing effect of these polar surfactants on the colorant emulsion (ref. 6). The addition of these compatibilizers results in a reorientation and stretching of the polyethyleneglycol chain of the nonionic - carrier (NUOSPERSE® FN 265 in table 1), thus destabilizing the colorant droplet, still emulsified in the base paint. As a result of this destabilization of the emulsion, the continuous phase surrounding the pigment particle is changed from the polar to the non-polar phase (figure 8).

Figure 7: The effect of a hydrophilic anionic compatibilizer to a SB base paint. Destabilization of the interface of a green colorant in a white base paint



Following products are first choices:

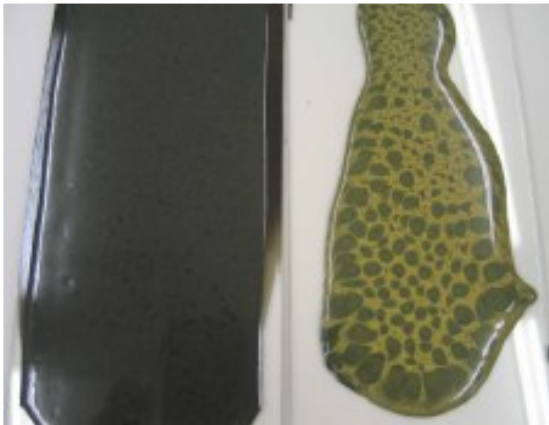
- NUOSPERSE® FA 196
- NUOSPERSE® 2006

Part 4: Bénard cells, appearing as floating

Observations

Floating appears in colored paints containing more than one pigment. During drying or storage one or more of the pigments separates from the others, producing an inhomogeneous surface appearance, in which hexagonal structures are visible. These structures are known as Bénard cells and are more visible if the paint dries slowly (thicker film).

**Figure 8: Left - formation of Bénard cells left in a 0.4 mm DFT film
Right - the same paint now in a 4 mm DFT film**



Mechanisms and solutions

These structures are known as Bénard cells and formed because of minor local differences in surface tension. During solvent separation a circular flow occurs in the drying film. From this flow pigment particles will be transferred and - typically smaller-sized, low specific gravity, hydrophobic-particles may be separated at the edges of the cell.

The pigment separation is strongly related to the difference in particle mobility. Following Stoke's Law (ref. 5, page 93) larger particles, with high specific gravity (like most inorganics) tend to settle faster rather than moving to the surface, compared to smaller, or low specific gravity particles (most organic pigments).

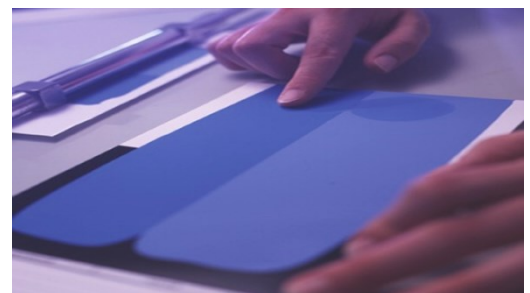
The circulating currents mentioned sweep smaller particles to the paint surface, where they are concentrated in the dead zones between various current centers, resulting in pigment floating and visible as Bénard cells.

The mobility of particles is affected by:

1. Particle size: the higher the size, the lower the mobility. Thus flocculation reduces mobility and increases the risk of separation from non-flocculated particles.
2. Viscosity of the liquid medium: increasing viscosity reduces particle speed and degree of separation during film formation.
3. Surface tension: reducing film surface tension reduces the risk of local surface tension gradients.

Color acceptance problems, related to the formation of Bénard cells are best attacked applying additives influencing the phenomenon as mentioned under 1 to 3. Often a combination is required. For instance a product that reduces pigment flocculation (NUOSPERSE® FA 196), reduces surface tension (NUOSPERSE® 2006) in conjunction with a product affecting viscosity (DAPRO® BEZ 75).

Color acceptance problems related to the formation of Bénard cells are mainly seen in solventborne paints, less in latex paints.



Products tested

A practical way to solve color acceptance problems is to start to define the problem: mix the colorant into the base paint, check the ease of distribution while hand-mixed, run the 2/10 minutes shaking test, followed by the finger rub-up test. Compare the results of these experiments with the mechanisms as described under part 1 to part 4 and apply the suggested NUOSPERSE® additives to the base paints. The recommendation is to start by selecting the best additive, adding 1% calculated on total weight of the base paint and post added to the base, thus saving time and avoiding separate milling.

In most cases this 1% will be a strong overdose, as typically just approx. 0.5% will be required, if the NUOSPERSE® is part of the base paint formulation and added to the mill base prior of the dispersion

process. In this case, the efficiency for using the NUOSPERSE® will be optimized and work as well to improve the milling.

The test with 1% NUOSPERSE® would then be followed with a ladder study, evaluating various dosages of the NUOSPERSE®, preferably added to the mill base.

Thus the following sequence is used:

1. Define problem
2. Choose 1 or 2 potential problem solvers
3. Add as post-add to base paint
4. Take 1% for start (overdose)
5. Test for rub after 2 minutes and 10 minutes
6. Reduce concentration for optimum solution

Conclusion

Color acceptance problems can be optimized using NUOSPERSE® color acceptance improvers in the base paints. Following table is applicable:

Table 4: Suggested solutions to color acceptance problems

| Shaker | | Problem | Add to base paint | |
|--------|--------------------|--|--|---|
| 2 min. | 10 min. | | Waterborne | Solventborne |
| OK | Rub | Surfactant drift | NUOSPERSE® FA 115 (NUOSPERSE® 2006) | NUOSPERSE® FA 196 (NUOSPERSE® 2006) |
| Rub | OK | Difference in tension surface bad wetting | NUOSPERSE® FA 115 (NUOSPERSE® 2006) | NUOSPERSE® 2006 (NUOSPERSE® FA 196) (NUOSPERSE® FN 265) |
| Rub | Rub still possible | Poor emulsification of WB colorant in SB paint | Not applicable | NUOSPERSE® FA 196 (NUOSPERSE® 2006) |
| — | — | Variable pigment mobility Bénard cells (visible in slow drying droplets) | Not applicable | NUOSPERSE® FA 196 (NUOSPERSE® 2006) (DAPRO® BEZ 75) |

However, the “trial and error” approach cannot completely be avoided in solving color development problems. Moreover, the specialists in the ELEMENTIS technology centers are well experienced in solving most difficult color acceptance issues.

Appendix

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