Part A 1

Application Technology, General Information

In order to achieve optimum results in screen printing, it is very important to take note of the material properties and ambient conditions (temperature and atmospheric humidity).

The following advice is thus designed to briefly explain the essential technical parameters of the individual products and show the significance these parameters have on the final result.

In this respect emphasis has deliberately been placed on providing a clear outline and dispensing with more extensive definitions.

This media guide deals almost exclusively, therefore, with the properties and processing of printing media and covercoats.

After the prepress stage – pattern processing, lithography, printing mould production – the following production stages are of importance for making ceramic decals:

A 1.1 Composition of Ceramic Decals

Ceramic decals consist of ceramic colors, printing media for pasting these colors, and covercoats which are used to overprint the decorative decals and thus turn them into a ceramic decal.

Ceramic inks:

FERRO supplies tailor-made color selections for all fields of applying ceramic decals to glass, porcelain, ceramic and enamel, which develop optimum properties in terms of shade and resistance for the application in question.
The importance of the technical parameters of ceramic color (grain size distribution, specific gravity and dispersibility) is described in more detail on the pages which follow.

Printing media:

The printing properties, as well as combustibility and depolymerization of the printing media are decisive for being able to use the decorative decals produced with such media without any difficulties. Due to the vast number of potential applications and almost perfect reproduction of decorative patterns, the range of printing media is extremely varied. From the large number of thixotropic and flowing printing media it is thus possible to select the ideal product for the intended application.
There is no one medium that is equally suitable for all applications. Owing to the different properties of thixotropic and flowing printing media, selection must be appropriate to the application in question.
The printing medium 80 820, which displays a sufficiently low degree of thixotropy, is suitable for both surface printing and – with certain restrictions – for halftone screen printing. This advantage has been known and has been field-proven over several years.
80 820 thus largely fulfils the demands made of a universal printing medium.

Covercoats:

Covercoats are made of thermoplastics, and for this reason the working temperature is of great importance when using the covercoat. Taking account of the thermoplasticity, it is evident that covercoats with a greater flexibility are required in countries with annual average temperatures of below 10 °C than in countries where the annual average temperatures are well above 20 °C. When a minimum dry film thickness of 22-25 µm is required, very careful consideration must be given beforehand to selecting the covercoat best suited to the task on hand. FERRO also offers appropriate products for all fields of application in this case, products which can be worked at temperatures of between 18 and 30 °C.
However, as even this wide range cannot satisfy all the conditions that may arise, there will be occasional situations which require the

need for auxiliary materials such as plasticizers for the film or anti-blocking agents.

From the advice given on the technical parameters it is already apparent how important the selection of material is for the flexibility, as well as combustibility and depolymerization of the ceramic decal. The individual parameters are explained below.

A 1.2 Printing Paste Production

Pasting ratio: Ratio of color powder to printing medium. We recommend, for example, 100:60; in this case the paste is made up of 100 parts powder and 60 parts printing medium. If the mixing ratio recommended by FERRO is fallen below (i.e. lower medium content), firing defects in the form of pinholes almost always occur. If this ratio is exceeded (i.e. higher medium content), the ceramic decals may stick together in a block due to the surface being too sticky.
We have, therefore, drawn up pasting ratio tables for the individual color selections. Our technical service will be pleased to provide the tables. Here you can find the recommended optimum pasting ratio, taking account of the physical properties of the individual color. If the printing paste viscosity you obtain when observing the recommended pasting ratio is too high, you can, in most cases, achieve the printing viscosity desired by adding 1 % of the dispersing agent 80 604.

Printing paste viscosity: The ideal printing paste viscosity is the one which achieves the fastest printing speed, the most detailed print and the best color constancy during production run-on for a specific task with a printing paste. This viscosity can vary considerably and mainly depends on the task concerned. Examples of very different degrees of viscosity and flow properties of the printing pastes are:

4-color-set decals	> 4,500 mPa*s at 200 1/s
glass colors	> 2,500 mPa*s at 200 1/s
intensive color banding	> 5,500 mPa*s at 200 1/s

Spec. gravity of color powder: Ceramic colors are made up of pigments and fluxes (frits). Although the specific gravity of the pigments differs, depending on the metal compound used, the specific gravity of the ceramic color is determined to a very large extent by the flux used. The specific gravity of fluxes containing lead is higher than that of lead-free frits. For this reason the volume of a lead-free color is considerably greater than the volume of the same quantity by weight of a color containing lead. For a lead-free type of color more printing medium is thus required to achieve the same paste viscosity as for a similar color that contains lead.

Later on in this chapter we have introduced the term color powder volume concentration (CPVC) and described the relation between color powder volume (CPV) and the ideal pasting ratio.

A 1.2 Printing Paste Production

Grain size distribution:

Finely ground ceramic colors are required for ceramic screen printing.
The more finely a color is ground, the larger its specific surface; and the opposite also applies, of course, that the coarser the color, the smaller its specific surface.
Since a printing medium should coat all particles, this means that a fine color requires more printing medium than a coarse color for all particles to be moistened. FERRO has paid particular attention in this respect when developing ceramic colors. Certain colors, however, cannot be ground too finely for physical reasons, as the color intensity and firing properties then deteriorate considerably. These include the Cd/Se colors and inclusion pigment products.
FERRO colors can be used for the finest of printing screens.

The type of grinding employed when producing ceramic colors affects the dispersibility of the color powder.

Dispersibility:

Dispersibility is determined by the production technique used and the physical properties of the color. Due to the variety of colors and fluxes employed, not all colors display equally good dispersing qualities.
FERRO has taken account of this fact when developing its printing media, and for this reason many of them compensate the innately poor dispersion properties of certain colors.
In addition, dispersing agents (80 604) are offered, with which dispersion can be further improved.

A 1.2 The Effect of the NVP Content of Printing Media on the Firing Properties of Decorative Decals

General Information:

Ferro as a producer of ceramic colors and media has endeavored to establish a connection between the nvp value and the firing result of ceramic screen printing pastes.

When compiling all the empirical figures, reproducible correlations are obtained between the nvp values, the specific gravity of the color powders and the mixing ratio of color powder with printing medium and the firing results.

The term nvp stands for the non-volatile part of the printing paste, also named solid part. In media, these are typically the binder and the plasticizer.
Each printing paste needs a minimum amount of medium or rather nvp depending on the used color powder. Only with a sufficient amount of medium the color powder can be covered and completely coated after drying, without entrapped air. Firing defects should hereby be avoided.
Depending on the density of the color powder, the volume of the varies, and therefore some powders need more medium, others less.
Additionally, the nvp content of the media can be different.

In due consideration of all contents and volumes, the pasting ratio for each color powder and each medium can be calculated and should not be undercut.
We have calculated the optimum pasting ratios for all common color selections and listed them in the tables in section B3.

In the following we present the definitions of the terms and the basis of calculation.

Definition of nvp:

According to DIN 53216, the term nvp is understood to be the proportional mass content that remains after evaporation of solvents. In the product data sheets, this value is given as nvp %.

Definition of nvpv:

The nvpv is the volume of the non-volatile contents. Because the density of these contents is almost always 1, the mass and the volume are almost identical.

Definition of CPV:

The CPV is the color powder volume, i.e. mass in relation to density.

Definition of CPVC:

In order to prepare appropriate pasting ratio recommendations for the current range of colors, we introduced the term color powder volume concentration (CPVC) as a new technical parameter for ceramic screen printing.

The color powder volume concentration is the proportional quotient from the color powder volume CPV and the sum of the color powder volume CPV and the binding agent volume nvpv.

In other words, the CPVC is the ratio of the color powder volume and the total volume of non-volatile contents.
This viewpoint is referring to the volume of the used materials and not to the weight (mass) and is crucial for the firing quality.
In the pasting ration tables (B 3), this is already taken into account.

The pasting ratio tables base upon a maximum CPVC of 53% to 55%, which was defined by our experience.

Please be aware that even when following the recommendations given here, a guarantee for the firing result cannot be given. The pasting ratios should only be a basic orientation.

In the following, two calculation examples are given:

- Calculation of the CPVP of the mixture 77 1234 with medium 80 820
- Calculation of the pasting ratio of the mixture 77 1234 with medium 80 820

Arithmetic examples: The Sunshine color 77 1234 is pasted at a ratio of 100g : 60 g by weight with printing medium 80 820.
How great is the CPVC of this mixture?

CPVC formula:

$$CPVC\ \% = \frac{CPV \times 100}{CPV + nvpv}$$

1st step: Calculating the CPV of 100 g color 77 1234
Specific gravity (ρ) of 77 1234 = 4.05 g/cm³

$$CPV = \frac{Mass}{\rho}$$

$$CPV = \frac{100\ g}{4.05\ g/cm^3}$$

CPV = 24.70 cm³

2nd step: Calculating the nvpv from 60 g printing medium 80 820
npv of 80820 = 45 %
Specific gravity (ρ) of nvp 80 820 = 1.00 g/cm³

$$nvpv = \frac{60\ g \times 45}{100 \times 1.00\ g/cm^3}$$

nvpv = 27.00 cm³

3rd step: Calculating the CPVC % of the paste from 100g 77 1234 + 60 g 80 820

$$CPVC\ \% = \frac{CPV \times 100}{CPV + nvpv}$$

CPV = 24.70 cm³

nvpv = 27.00 cm³

$$CPVC\ \% = \frac{24.70\ cm^3 \times 100}{24.70\ cm^3 + 27.00\ cm^3}$$

$$CPVC\ \% = \frac{2470\ cm^3}{51.70\ cm^3}$$

CPVC = 47.80 %

Arithmetic examples:

The Summerday color 77 1634 is to be pasted in terms of weight with printing medium 80 820 so that the finished printing paste has a CPVC of 53 %.
How many grams printing medium 80 820 (M) must I add to 100 g color 77 1634, in order to obtain the desired CPVC of 53 %?

CPVC formula:

$$\text{CPVC } \% = \frac{\text{CPV x 100}}{\text{CPV + nvpv}}$$

1st step:

Calculating the CPV of 100 g color 77 1634
Specific gravity (ρ) of 77 1634 = 2.64 g/cm³

$$\text{CPV} = \frac{\text{Mass}}{\rho}$$

$$\text{CPV} = \frac{100\text{ g}}{2.64\text{ g/cm}^3}$$

CPV = 37.88 cm³

2nd step:

Calculating the printing medium quantity **M** of 80 820 for 100 g color 77 1634, in order to obtain a CPVC of 53 %.

M = (100:nvp) x [(CPVx100:CPV) -CPV]

CPV = 24.70 cm³
CPVC = 53 %
nvp = 45 %

M = (100:45) x [(37.88 cm³ x 100:53) – 37.88 cm³]

M = 2.22 x (71.47 –37.88 cm³)

M = 2.22 x 33.59 cm³

M = 74.60 cm³

or **74.60 g** , as the specific gravity of the printing medium amounts in practice to 1.00 g/cm³.

A 1.3 Printing Paste Processing

When processing the printing paste, i.e. printing, the following parameters are important:

Printing paste rheology: This concerns the flow behaviour required of the print-ready color paste to achieve a certain printing quality and productivity. Printing media with a high to medium thixotropy, e.g. 80 810, are required to produce halftone screen décors.

Flowing printing media or those with a low thixotropy, e.g. 80 820 or NR. 221, are used for surface décors.

Type of squeegee and holder: The type of squeegee and holder used play a decisive part in obtaining an optimum print and constant production run-on.
In the field of ceramic decals it is well known that reproducible halftone decals cannot be obtained with a 65 ° Shore squeegee, which protrudes 3 cm from the holder.

This also applies to a lesser extent to surface and line decals.
When printing, the squeegee should be supported on the back in the direction of printing by a spring steel of 0.5 to 0.8 mm. This prevents the squeegee from bending toward the direction of printing, and the printing quality is thus considerably improved. This effect is increased further by using a triplex squeegee (inside 95° Shore, outside on both sides 65° Shore). The advantage of this method can also be recognized in practice by the fact that swelling of the protruding squeegee is significantly reduced thanks to the protective device, and the original initial hardness of the squeegee diminishes only very slowly when printing. This method of holding the squeegee can be used for almost any type of squeegee. If these findings are relied upon entirely, the best solution is to use the RKS-squeegee.

Screen type: The screens mostly used today for producing ceramic decals are steel and polyester screens. The advantages and disadvantages of the two types are not dealt with here. In daily practice, however, some features are very important and are mentioned for this reason.
The mesh opening of steel screens that are as fine as polyester is larger, which means that it is possible to print a greater volume of ink. Another outstanding advantage of steel screens is that there is virtually no static charging when printing with squeegees made of polyurethane or other plastics.

Electrostatic charging can become a problem when using polyester screens and certain printing media.
Please pay particular attention, therefore, to the technical advice given in the product data sheets on our printing media.

A 1.3 Printing Paste Processing

Ceramic decal drying:

The drying of the decal depends on the following:
the type of dryer used (wicket dryer or multi-shelf dryer); the speed at which the printing medium used dries; coat thickness of the decal; number of color layers on top of one another.
Every printer would like to have a printing medium that dries as quickly as possible on the one hand, but nevertheless keeps the screen constantly open and ensures perfect color constancy during production run-on.
This demand cannot be fulfilled by printing media that contain solvents. The more slowly a printing medium dries, the better the screen remains open and the color constant during production run-on. Such a medium can only be used, however, for thin layers of color and with halftone screen printing. Even the most efficient wicket dryers would be unable to produce a satisfactory result for thick layers of color. On the basis of the task on hand, very careful attention should be paid to such matters, therefore, when selecting the printing medium.

Production run-on constancy:

The connection between drying speed and color constancy during production run-on has already been explained above.
In general the following rule applies:
The more slowly a printing medium dries, the better the color constancy during production run-on.

Overprinting:

The more printing medium contained in the printed color which is to be overprinted, the better it can be overprinted. Due to the high proportion of printing medium, the surface of the decal is not as porous and its absorbency is thus reduced. The solvents in the overprint color are therefore absorbed more slowly by the printed color and the overprinting properties are thus improved.

Printing Covercoats on Decorative Decals

When printing covercoats the following parameters are important:

Rheology of covercoat:

This concerns the flow behavior required of the print-ready covercoat to achieve a certain printing quality and productivity. A distinction is made between flowing (83 450) and thixotropic (L 406/THIX) covercoats. In the case of wicket dryers with a horizontal pre-drying zone, both flowing and thixotropic covercoats can be used. If there is no predrying zone available, we recommend using only thixotropic covercoats, to prevent the covercoat from running and forming beads. This advice applies to coatings with a dry film thickness of 22-25 µm.

Initiated dissolution of the ceramic decals:

Covercoats strongly initiate dissolution of the decals produced with **thixotropic or flowing color pastes**. If a flowing covercoat is used on a decal made of flowing color pastes and no pre-drying takes place, the coat can run due to the vertical position of the decal in wicket dryers. The decal that has been dissolved also starts to run, causing the decorative decals to become completely indistinct. Every experienced printer knows this scenario.
In order to avoid this problem, either a thixotropic covercoat or a thixotropic printing medium should thus be used for making ceramic decals.
Running can only be prevented entirely, however, with the combination **"thixotropic printing medium and thixotropic covercoat".**

Temperature when printing:

Covercoats should always be processed at room temperatures of 18-30 °C. If covercoats are used at a temperature of below 18 °C, the following problems may occur:
1. Cobwebbing of the covercoat when printing
2. Insufficient thickness of dried coat. Failure to achieve the recommended coat thickness of approx. 23 µm.

As covercoats are frequently supplied in 180-kg drums, the process of equalizing the temperature may take several days, depending on the storage temperature of the covercoat. To be on the safe side, it is best to measure the temperature of the covercoat before starting to print. Inexpensive and accurate measuring equipment is available from specialized stores for this purpose.

Reversible solubility:

All resins contained in screen printing media and covercoats can be dissolved again, even if they have been thoroughly dried. A finished decal can thus be fully dissolved with, for example, thinners or screen cleaners. This property is called reversible solubility.

Dissolution is not only brought about by liquid solvents. A certain amount of solvent vapour is sufficient to make the decals very tacky. In poorly ventilated printing shops this problem often occurs, and most of the time it is incorrectly attributed to poor drying of the covercoat.

A 1.4 Coating the Printed Decorative Decals

Drying:

The solvent composition of almost all covercoats today, as far as the drying speed is concerned, is comparable.
The main differences lie in the choice of the lacquer resins, plasticizers, auxiliary materials and degree of thixotropy. How the covercoat dries depends almost exclusively, therefore, on the method with which the covercoat solvents are removed from the printed coat. The so-called wicket dryers – or dryers with a continuous flow of air – take on a prominent position in this respect. The air in these dryers is conducted in such a way that a type of counter-current drying is achieved. I.e. the solvent concentration is intentionally kept at a high level in the first part of these dryers, to avoid premature film formation. Final drying does not take place until the third and last stage by feeding in fresh air. Even when drying is carried out according to the process described here, 0.8 to 1.6 % of solvents remain in the "dry film". These residual solvents have an additional plasticizing effect on the covercoat. The covercoat does not obtain its final properties until the residual solvents have evaporated completely. The time between fresh decals and the final stage is called shelf life.
Fresh decals are thus considerably more ductile than older ceramic decals

Covercoat elongation:

The ductility of all covercoats developed by FERRO has been measured on solvent-free dry films. The ductility of these films is thus determined by the quantity of plasticizer added. An additional plasticization of the films, dependent entirely on the degree of drying, comes about, however, as a result of the solvent quantities remaining in fresh decals as described under the section on drying. We have no means of influencing these parameters. We advise printers, therefore, to dry the fresh decals at 35 °C for 48 hours as a test, so that the remaining solvents evaporate and an idea of the properties of the completely dried film can be obtained.

Dry film thickness:

FERRO recommends a dry film thickness of 22-25 µm for almost all cases involving the application of ceramic decals. The dry film thickness should be increased to 32-35 µm for décors with thick layers of color and for collector plates. In order to achieve this film thickness, however, thixotropic covercoats such as L 406/THIX must always be employed if wicket dryers without a horizontal pre-drying zone are used.

Storage of Decals:

Due to its sensitivity to humidity, ceramic decals should be stored at a temperature of approx. room temperature of 15-25 ° C and preferably at 50-65% humidity.