

## TECHNICAL INFORMATION

# CONTAINER GLASS ENAMEL DECORATION SYSTEMS

### Table of Contents

<b>P2</b>	<b>Container Glass Enamel Decoration Systems</b>	
	▪ Main markets	
	▪ Global Product Systems	
	▪ Lead-free Technology	
	▪ Lead-free Guarantees	
<b>P4</b>	<b>Summary of Ferro Decoration Systems</b>	
	▪ Lead-free systems	
	▪ Lead-containing systems	
<b>P5</b>	<b>System Test Specifications</b>	
	▪ Expansion	
	▪ Firing	
	▪ Durability	
<b>P6-8</b>	<b>Methods of Use and Recommendations</b>	
	▪ Powders	
	▪ Banding	
	▪ Brushing	
	▪ Spraying	
	▪ Cold Screening	
	▪ Thermoplastic screen printing	
	▪ Troubleshooting common printing faults	
	▪ Drying	
	▪ Firing	
<b>P9</b>	<b>Medium Systems</b>	
	▪ Recommended Ferro Mediums	
	▪ 4-Color Printing	
<b>P10-14</b>	<b>Lead-Free Systems Technical Data</b>	
	▪ Resistant Colors for Bottles.....	VNR System Plus
	▪ Semi-Resistant Colors for Bottles .....	GEMStone
	▪ Low-temperature Colors for Bottles.....	VN System
	▪ Tableware/Tumblers Decoration.....	NP2000 System
	▪ Decoration of Low Expansion Borosilicate.....	VPS System
<b>P15-19</b>	<b>Lead-Containing Systems Technical Data</b>	
	▪ Resistant Colors for Bottles.....	VR System
	▪ Resistant Colors for tableware/tumblers .....	VM System
	▪ Semi-resistant Colors for tableware/cosmetiC .....	VS System
	▪ Decoration of Low Expansion Borosilicate.....	PR System
	▪ Transparent Colors for lighting/ornamental-ware .....	T System
<b>P20</b>	<b>Ferro's complete package of Container Glass products</b>	

## *Container Glass Enamel Decoration Systems*

### Main Markets

Ferro's container glass products are formulated to meet the needs of our customers from all market segments

- Beverage bottles for single- and multi-trip use
- Cosmetic and Perfume bottles
- Glass tableware, stemware and tumblers
- Glass decorative and promotional ware
- Lighting
- Pharmaceutical, ampoules and laboratory glassware

### Global Product Systems

Ferro has rationalised its glass enamel product ranges to create a number of Global Product Systems. Colors from each of these systems are made at our principle manufacturing sites around the world to standard Ferro processes and specifications.

In this way, quality standards are controlled globally to the exacting requirements of our customers and the major brand names in the beverage, cosmetic and tableware market segments.

Each of our Global Product Systems contains a standard inter-mixable color palette. In addition a full custom color matching service, including special effect colors, is provided from our local service laboratories.

This allows us to offer a flexible and fast customer service, taking account of the individual application and firing conditions as well as the desired decorative effects, for each of the market segments we serve.

Alongside the creation of global systems, we have also created some global products, for example our VCB Series of approved, proprietary soft drink ACL's.

These colors are standardised global products, which are produced at each of our principle sites to meet global customer specifications.

### Lead-Free Technology

Ferro has worked for a number of years researching heavy-metal free enamels for container glass.

The current products, which benefit from recent technology advances, are intended to:

- satisfy the needs of glass decorators arising from legislation – eg CONEG and EC Packaging Directive EU/94/62/EC- which restricts the content of heavy metals in packaging and tableware products
- reinforce our commitment to the Chemical Industry's Responsible Care program, in relation to the health and safety of our own workforce and to the protection of the environment

Our R&D teams are working on continuous improvements in our technologies and final product systems to closely match the performance of the traditional lead-containing products, especially in terms of brightness and chemical durability.

These programs have already led to significant improvements in brightness and chemical durability for our lead-free enamels. We have recently launched 2 new ranges – our **VNR PLUS System** for multi-trip bottles has recently been approved for use by Coca-Cola and Pepsi-Cola; our **GEMStone** for single-trip bottles is an exciting new high-gloss, lower firing range allowing decorators to reduce cost and enhance product design.

The substitution of cadmium has still not been fully realised for the vibrant tones of reds and oranges. Therefore, some cadmium-containing colors are included in our systems, in case of need by the market.

## Heavy Metal - Free Guarantees

Our heavy metal-free systems are provided with the following guarantees for heavy metal content:

- **Chrome VI and mercury are not used in the manufacture of our heavy-metal free glass enamels**
- **Li content: max 30ppm in Systems VNR Plus & VNG, designed for bottles decoration (applies also to leaded system VR)**

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In addition, for our lead-free Systems designed for bottle decoration – VNR *Plus*, VNS and VN:

- **Pb content: max. 100ppm for lead-free enamels, containing cadmium-based pigments**
- **Pb+Cd content: max. 100ppm for lead-free and cadmium-free enamels**
- **In compliance with Packaging Directive EU/94/62/EC (June 2006 requirement)**

In addition, for all other lead-free container Systems:

- **Pb content: max. 600ppm for lead-free enamels, containing cadmium-based pigments**
- **Pb+Cd content: max. 600ppm for lead-free and cadmium-free enamels**

## Summary of Ferro Container Glass Decoration Color Systems

### ▪ Lead-Free Systems

Market Segment	Ferro System	Firing Temp. (°C)	Expansion (x 10 <sup>-7</sup> K <sup>-1</sup> )	Acid Resistance (1)	Alkali Resistance (2)
1-trip bottles	GEMStone	580-610	79	7	7
Multi-trip bottles	VNR PLUS	630-650	87	4	5
Cosmetic bottles	VN	580-600	91	7	7
Tableware/Tumblers	NP2000	580-630	75	5	5
Lighting	VN	580-600	91	7	7
Pharmaceutical (Borosilicate)	VPS	630-650	60	7	7

### ▪ Lead-Containing Systems

Market Segment	Ferro System	Firing Temp. (°C)	Expansion (x 10 <sup>-7</sup> K <sup>-1</sup> )	Acid Resistance (1)	Alkali Resistance (2)
1-trip bottles	VR	600-630	80	4	4
Multi-trip bottles	VR	600-630	80	4	4
Cosmetic bottles	VS	580-600	90	4	5
Tableware/Tumblers	VR	580-630	80	4	4
	VM	540-580	80	4	4
	VS	580-600	90	4	5
Lighting	VS	580-600	90	4	5
	31	540-580		7	7
Pharmaceutical (Borosilicate)	PR	600-630	57	4	4

(1) Test method QKB-9047 (10% citric acid, 15 min)

(2) Test method QKB-9045 (10% NaOH, 88°C, 4h)

Refer also to the additional technical data for each system, attached, plus the general recommendations on application techniques.

## System Test Specifications

### 1. Thermal Expansion Coefficient

Values quoted are measured between 50 – 300 °C (ramped at 4°C per min.), on the basic fluxes used in the systems concerned.

This is an indicative value, with a variation  $\pm 4$ , and dependant on factors such as pigment type and content.

### 2. Firing Temperature

The optimal range shown is based on laboratory control tests, established during conception of each system.

Under industrial conditions, the actual firing cycle can be influenced by factors such as the type of kiln, the ware loading and weight of the decorated articles.

We recommend setting the fire cycle with our systems on site, and our technicians will provide a full support to help achieve the optimal conditions.

### 3. Chemical Durability

There are many tests available to judge the chemical resistance of glass enamels. The test results will depend, not only on the chemical formulation of the enamel, but also on the nature of the article, the layer thickness of the enamel and the firing cycle used.

Also for dishwasher resistance testing, the final results are influenced by the article, machine set-up, and the detergent type.

To try to overcome these testing variations, Ferro has created its own control tests to evaluate chemical resistance, with a visual testing scale to compare one system with another.

- Acid resistance test method QKB-9047 – 10% citric acid, 15 min at room temperature.
- Alkali resistance test method QKB-9045 – 10% NaOH, 4 h at 88°C.

The visual testing scale is as follows:

- (1) No attack
- (2) Iridescence or visible stain on the exposed surface when viewed at a 45 angle but not apparent at angles <30.
- (3) Definite staining which does not blur reflected images and is visible at angles < 30.
- (4) Definite stain with gross color change or strongly iridescent surface visible at angles < 30 and which may blur reflected images
- (5) Surface dull or matt with chalking possible
- (6) Significant removal of enamel with pinholing evident
- (7) Complete removal of enamel in the exposed area

The values we show are averages obtained from different colors. White enamels from a particular system typically have more chemical resistance than non-whites from the same system.

Additionally, we control our products according to the following market-specific International test methods:

- EN 1388-2 – designed specifically for the glass tableware market  
Measurement of Cd & Pb released by exposure to 4% acetic acid at 22°C for 24 h, to simulate the effect of exposure to food contact.
- ASTM C777-84 – for the glass packaging market  
Measurement of attack of the glass enamel by H<sub>2</sub>S, to simulate the effects of exposure to sulphur attack, from the atmosphere or certain types of corrugated packaging.

### 4. Heavy metal content in packaging

Latest legislation requires decorators to declare the content of heavy metals in their decorated articles.

To support you, we can provide on request Safety Data for our lead-free systems, which indicate the levels of heavy-metals voluntarily introduced.

Based on the weight of enamel deposited on the article, we can calculate the quantity of heavy metals coming from our decoration system deposit, and relate that to the total weight of the packaging, according to EU Packaging Directive 94/62/CE.

## Methods of Use & Recommendations

Glass enamels are ground mixtures of fluxes - formulated according to the fusibility and expansion of the glass substrate to be decorated - and inorganic pigments, which produce a wide range of shades after firing. They can be blended with several types of medium system, depending on the final method of application eg direct screening, decal, banding, brushing, spraying.....

Our colors from all systems are usually provided in the following forms:

- powders, for use by decorators making their own pastes
- water-mixable screening pastes
- oil-based screening pastes – not mixable with water
- thermoplastic pastes (TP) for multi-color printing
- wet spray – both for conventional or wet electrostatic application

Mediums suitable for all applications can also be provided separately (see separate medium section).

## 1. Storage and Shelf Life

Color powders must be stored in dry conditions.

Medium and color paste systems should be stored in dry conditions and at temperatures not below 5°C (40°F) or above 35°C (95°F); the ideal storage temperature is 8-15°C (45-60°F). Partly used tins must be tightly sealed after use. Pastes must be stirred thoroughly before printing.

If stored as recommended, color pastes and medium are guaranteed with a minimum shelf life of 6 months after the production date.

## 2. Recommendations for converting powders to pastes

### 2.1. Cold Screen printing

Mix powder in the ratio of 100 parts color:20-30 parts of our recommended medium using a mixer, then process the paste through a triple-roll mill.

For indirect screen printing (decals), we recommend color : medium ratios of 100:50.

Finally thin with c. 5% of the recommended medium to adjust the final viscosity for printing.

### 2.2. Spraying

#### 2.2.1. Water-mixable system

Using a high speed stirrer or ball mill, mix at a color : medium ratio of 100 parts color: 20 parts medium. Then add 40 to 60 parts water to adjust the viscosity for final application. We recommend a spray viscosity of 25-30 s, as measured with a No.4 (4mm) Ford flow Cup.

#### 2.2.2. Oil-based system

Take our oil-based screening paste and add ethanol at a ratio of 35 parts ethanol: 100 parts paste. Then add ethanol to reach an application viscosity of 25-30 s, through a 4mm flow Cup.

Typically, spray guns with a 1mm nozzle are used, with spray pressures set at 2.5 to 5 bars (35- 75psi).

We recommend stirring the spray paste in the tank to avoid sedimentation or settling.

### 2.3. Banding/Lining

Use the same process as in 2.1.above, except that the final viscosity should be adjusted with 25-30% of our recommended medium, after roll milling. Test with a 6mm flow cup to reach a viscosity of 25-30 s.

### 2.4. Brushing

Typically, the powder is mixed with an oil-based medium and thinned with turpentine.

### 3. Wet Spray Enamel Recommendations

Our wet spray enamels are typically supplied as water-based systems. They are supplied ex factory at high viscosity, to be let down with water on site to the required spray viscosity for the job.  
We recommend 20-30 s, measured with a Ford No.4 (4mm) Cup.

### 4. Recommendations for Screen Printing

#### 4.1. Cold Screening

Our pastes can be supplied ready-to-use (RTU) or, more typically customers prefer to thin to a suitable printing viscosity on site. Recommended pasting ratios are 100 color: 20-30 medium. Printing viscosities in the range 18-23 Pa.s. (180-230 Poise.s.) are recommended.

Our RTU pastes are supplied with typical dispersions (as measured on a Hegman Gauge) of 15-25 microns. Either stainless steel screens – 150 to 304 meshes per inch (screen opening of 60-120 microns)...  
...or nylon or polyester screens – 123 to 304 meshes per inch (opening of 48-120 microns), may be used. Squeegees should be made of hard rubber and sanded enough to avoid printing streaks. Screens can be cleaned with a suitable solvent, generally ethanol, following the usual safety precautions.

#### 4.2. Thermoplastic (TP) ink recommendations

TP Inks, which are solid at room temperature, need heat applied to become printable. The molten enamel is screen-printed through a heated metal screen, which can be heated either electrically or with IR-lamps. Their main advantage is that each print-layer ‘freezes’ as it hits the colder glass, and therefore no drying is required between each successive print. This makes TP’s ideal for automatic multi-color printing machines.

##### 4.2.1 Storage

TP inks are supplied as solid flakes, ready-to-use, with typical Hegman dispersions of <20 microns. As they contain waxes with melt temperatures of around 50°C, they should be stored in sealed containers at room temperature, in a dry area protected from moisture & extremes of temperature.

##### 4.2.2 Pre-melting

TP inks perform best when pre-melted in temperature-controlled melting pots. We recommend melting at 65-75°C. Avoid overheating, signified by smoke emission, as this may change the properties and printing behavior of the ink.

##### 4.2.3 Screens

We recommend stainless steel screens, with mesh size 150-304 meshes per inch (screen opening of 60-120 microns), dependant on the type of job. For lead-free TP inks, coarser mesh sizes are recommended, compared to those typically used with lead-containing enamels. This ensures good deposit weight and optimum brightness of the fired glasses. Heated screens should be maintained at 70-90°C and overheating (emission of smoke) should be avoided (see 4.2.5)

##### 4.2.4 Coverage

1 –1.5 g. of TP will print a surface area of 100 cm<sup>2</sup>, dependant on the density of the product and the size of the screen.

##### 4.2.5. Thermal Decomposition of the medium

During the firing of our TP inks:

- at c.70°C, there is an endothermic reaction, signifying the melting of the medium
- at 180-320°C, we observe an exothermic reaction, which signals the combustion of the major components of the medium, mainly waxes and fatty alcohols.

- at 320-520°C, a small exothermic reaction takes place, corresponding to the highest melting components of the TP medium system.

It is absolutely necessary that all medium components are burned off before the vitrification of the glass enamel powder components. If not, there is a potential to create defects, such as craters, bubbles and pinholes.

Whilst our TP systems are formulated to minimise such defects, we always recommend to adjust the firing cycle up-to c. 500°C, but especially between 250-320°C, so that the medium has sufficient time to burn out completely.

#### 4.2.6. Trouble-Shooting Guide

The most commonly noticed defects are:

- [bad aspect of Cd-containing reds and yellows](#)

Cadmium pigments are very sensitive to kiln atmosphere. Oxidising atmospheres are necessary for the good color development of cadmium-containing reds and yellows.

In addition, we recommend to manage a good extraction of the combustion gases from the kiln, and to leave enough space between the decorated items in the kiln, for an improved air circulation.

- [‘back-lapping’](#)

This is an irregular deposit on one of the sides of the ACL label, which can occur if the glass enamel is too fluid during printing.

Solution is to decrease the temperature of the heated screen.

- [blistering](#)

This is created by the formation of bubbles in the body of, or craters at the surface of the glass enamel. The defect is caused by a bad evacuation of the gases formed from the combustion of the medium (see 2.2.5). There are several solutions:

- improve the extraction in the kiln
- decrease the speed of the kiln belt i.e. throughput
- increase temperature and/or speed of the pre-heat phase of the firing cycle
- [crawl](#)

This is where the glass enamel recedes from the glass surface, and is generally caused by oily deposits on the glass before decoration. Solution is to clean the glass before decoration.

- [drip-through](#)

In this defect, the glass enamel drips through the screen

Solution is to decrease the screen temperature, in order to increase slightly the TP ink viscosity.

- [tears](#)

This is where the glass enamel runs down the glass to form tears, and is often due to condensation of some of the waxes, onto cold items in the first zones of the kiln. Solutions are:

- improve the kiln extraction, especially in the first zones of the lehr
- increase the temperature in the pre-heat zone more rapidly
- increase the space between the decorated articles to improve the air circulation

## 5. Drying Recommendations

For oil-based pastes or wet spraying applications, the decoration must be dried prior to firing, if the ware is to be handled or is to be over-printed, or if the temperature at the kiln entrance exceeds 100°C.

Decorated ware can be dried either at room temperature or in a drier. Alternatively, a hot-air draft over the decorated ware will speed up the drying process.

Tunnel-type driers can be used and are usually powered by gas or electricity. An adequate flow of air in the tunnel must be maintained to assist evacuation of the fumes via the chimney.

The heat input and drier length should be designed such that the decorated ware is at c.40°C (100°F) at the exit.

## 6. Firing Recommendations

During the firing cycle, the organic components of the medium are burnt off and the enamel fuses to the glass surface to become a vitrified coating. Because of the presence of hydro-carbon organics in the kiln atmosphere, good ventilation must be maintained to minimise the possibilities of decoration defects.

Typical firing cycle profile:

- room temperature to peak temperature: 20-40 min.
- soak time at peak: 10-20 min.
- Cooling zone cycle will be adapted to the type of decorated glass.

This typical cycle can be modified dependant on the glass thickness, to achieve optimal results.  
With tempering glass cycles, the duration of the firing is reduced to a few minutes, dependant on the thickness of the glass.

## Medium Systems for Screen Printing

We offer 3 types of medium:

- Water-friendly mediums – these systems can be diluted with water; equipment can also cleaned with water
- Oil-based mediums – these products must be let-down with solvent, not water
- Thermoplastic mediums (TP) – used for hot screen printing

### Recommended Ferro Medium Systems

Application Method	Product Reference	Medium Type	Properties
<b>Direct screening</b>	MX 54	Oil-based	Medium drying rate
	MX 840	Water-friendly	Medium drying rate, low odour
	MX 44.62	TP	Mainly for Pb-products
	MX 57	TP	Mainly for Pb-frees
<b>Indirect screening (decals)</b>	80 820	Oil-based	Low thixotropy
	83 450	Covercoat	EGA-free
<b>Spraying</b>	80 1022	Water-based	Dilute with water
	80 1026	Water-based	Dilute with water/slow drying
<b>Banding</b>	MX54	Oil-based	Thin with ethanol
	MX21	Water-friendly	Dilute with water

## Four-Color Screen Print Process

This technique is becoming more and more popular for the creation of complex decorations on glass bottles, tumblers, plates, gift-ware and promotional ware.

4-color screen-printing is particularly interesting to create photographic images on beverage bottles and glass tumblers. Some of the largest drink manufacturers in the world have increased brand awareness and shelf value through the use of Ferro colors specially designed and processed for 4-color print.

The technique calls for three primary colors – cyan, yellow and red magenta, together with black. In addition a High Opacity Intense White is used as an underlayer to provide a raft of background opacity. Typically, the order of printing is white raft, magenta red, cyan, yellow and black.

We have developed special colors within our each of our major Product Systems to satisfy the essential requirements of this innovative printing technology. We also work closely with the screen print machine manufacturers to optimise the print quality and fired appearance of our colors.

Please refer to our technical service teams for detailed advice on application and screen printing technique.

## Lead-Free Systems Technical Data

### VNR System PLUS

*VNR System PLUS represents a significant improvement from our original lead-free VNR System, developed for the decoration of returnable bottles. Our new system combines a good gloss level, with a notable improvement in alkali resistance, a critical property for multi-trip bottles, which need to withstand caustic washing plant cycles. Furthermore, this System is fully compliant with Packaging Directive EU/94/62/EC (June 2006 requirement – max 100ppm heavy metals content). Proprietary colors listed below are fully approved for use by Coca-Cola and Pepsi-Cola.*

#### Main Market Use

These lead-free enamels are recommended for decoration of soda-lime glass packaging, more particularly multi-trip returnable bottles. They are the most durable of the lead-free systems we offer for packaging, and are also recommended for the decoration of proprietary soft drink labels offered by the major International drinks brands, such as those listed below.

#### Chemical Composition

Colors in this System do not contain voluntary additions of heavy metals – Pb, Cd, Hg and CrVI.

Exceptions are the cadmium-containing green, yellow, reds and oranges (marked \* below) which need to use cadmium pigments, to provide the color tones required by the market.

However, for glass decorated with these Cd colors over a relative small area, the heavy metal content of the article is in compliance with the total amounts specified under EU Packaging Directive 94/62/EC.

#### Intermixable Color Range

COLOR	REFERENCE	COLOR	REFERENCE
GREEN	VNR 1409 *	Coke Red 2000	VNR 7418 *
GREEN	VNR 1414 *	Sprite Blue	VNR 2416
COBALT BLUE	VNR 2403	Sprite Yellow	VNR 3417
BLUE	VNR 2419	Fanta Blue	VNR 2439
YELLOW	VNR 3414 *	Fanta Green	VNR 1412
YELLOW	VNR 3417	Fanta Orange	VNR 7419 *
BLACK	VNR 4403	White	VNR 9407
BROWN	VNR 6407	Pepsi red	VNR 7424 *
RED	VNR 7420 *	Pepsi blue	VNR 2417
ORANGE	VNR 7422	Montain Dew red	VNR 7424 *
WHITE	VNR 9407	Montain Dew green	VNR 1427
FLUX	VNR 401	Teem yellow	VNR 3434
AcE IMITATION ETCH	VNR 9316	Mirinda green	VNR 1415
		7UP Iron Red	VNR 7432

These colors are intermixable. We recommend performing preliminary tests before launching production with color mixtures from this System, especially for combinations of red or yellow cadmium-containing colors (marked \*) with any other colors.

Colors from different Systems should not be mixed.

Our technical service teams also offer a full custom-color matching service.

#### Expansion Coefficient (C.o.E.)

Avg C.o.E. measured on the basic frit System is  $87 (\pm 4) \cdot 10^{-7} K^{-1}$ . This system is suitable for most chemical compositions used in the production of soda-lime glass bottles.

For decorated bottles that have to withstand strong internal pressures or significant mechanical forces, it is recommended to perform preliminary trials, such as bursting pressure tests, to ensure compliance with the required standards.

#### Recommended Firing Conditions

From 630°C to 650°C (1165-1180°F) in a cycle of 1hr-1.5h or more, dependant on both the type of furnace and the volume of ware fired. We recommend an oxidising atmosphere to give optimal fired appearance and brightness. It is essential to maintain good ventilation, and an efficient extraction of the combustion gases and the products resulting from decomposition of the medium.

## *GEMStone colors*

*GEMStone - our new improved lead-free system for the decoration of single-trip bottles - replaces our VNS System. The new colors deliver high-gloss and can be fired at lower temperatures (typically c.20 °C) than traditional single-trip bottle colors. This means lower energy costs, lower maintenance cost for the decorating lehrs and potential higher throughput - with brighter colors!*

### Main Market Use

These lead-free enamels are recommended for decoration of soda-lime packaging, more particularly single-trip non- returnable bottles, where chemical durability is not an issue. **Furthermore, this System is fully compliant with Packaging Directive EU/94/62/EC (June 2006 requirement – max 100ppm heavy metals content).**

### Chemical Composition

Colors in this System do not contain voluntary additions of heavy metals – Pb, Cd, Hg and CrVI.

Exceptions are the cadmium-containing green, yellow, reds and oranges (marked \* below) which need to use cadmium pigments, to provide the color tones required by the market.

However, for glass decorated with these Cd colors over a relative small area, the heavy metal content of the article is in compliance with the total amounts specified under EU Packaging Directive 94/62/EC.

### Intermixable Color Range

COLOR	REFERENCE
GREEN	VNG 1900
GREEN	VNG 1901
GREEN	VNG 1943
BLUE	VNG 2900
BLUE	VNG 2920
YELLOW	VNG 3901*
YELLOW	VNG 3917
BLACK	VNG 4900
BROWN	VNG 6900
BROWN	VNG 6901
RED	VNG 7900*
RED	VNG 7907*
ORANGE	VNG 7934*
WHITE	VNG 9920
FLUX	VNG 900
AcE IMITATION ETCH	VNG 903

These colors are intermixable. We recommend performing preliminary tests before launching production with color mixtures from this System, especially for combinations of red or yellow cadmium-containing colors (marked \*) with any of the other colors.

*Colors from our different Systems (eg VNR with GEMStone) should not be mixed with each other.*

Our technical service teams also offer a full custom-color matching service.

### Expansion Coefficient (C.o.E.)

Avg C.o.E. measured on the basic frit System is  $79 (\pm 4) \cdot 10^{-7} K^{-1}$ . This system is suitable for most chemical compositions used in the production of soda-lime glass bottles.

For decorated bottles that have to withstand strong internal pressures or significant mechanical forces, it is recommended to perform preliminary trials, such as bursting pressure tests, to ensure compliance with the required standards.

### Recommended Firing Conditions

From 580°C to 610°C (1075-1130°F) in a cycle of 1hr-1.5h, with a soaking period of c.10 min.

The ideal temperature for an optimal fired surface appearance and brightness is c. 610°C(1130°F)

We recommend an oxidising atmosphere to give optimal fired appearance and brightness. It is essential to maintain good ventilation, and an efficient extraction of the combustion gases and the products resulting from decomposition of the medium.

## VN System

### Main Market Use

These lead-free enamels are recommended for decoration of cosmetic and perfume containers.

**Furthermore, this System is fully compliant with Packaging Directive EU/94/62/EC (June 2006 requirement – max 100ppm heavy metals content).**

### Chemical Composition

Colors in this System do not contain voluntary additions of heavy metals – Pb, Cd, Hg and CrVI.

Exceptions are the cadmium-containing green, yellow, reds and oranges (marked \* below) which need to use cadmium pigments, to provide the color tones required by the market.

However, for glass decorated with these Cd colors over a relative small area, the heavy metal content of the article is in compliance with the total amounts specified under EU Packaging Directive 94/62/EC.

### Intermixable Color Range

COLOR	REFERENCE
TURQUOISE	VN 1301
APPLE GREEN	VN 1306
BLUE	VN 2305
COBALT BLUE	VN 2301
YELLOW	VN 3301*
BLACK	VN 4300
DARK BROWN	VN 6301
DARK RED	VN 7301*
RED	VN 7300*
ORANGE	VN 7315*
WHITE	VN 9320
FLUX	VN 821
AcE IMITATION ETCH	VN 9321

These colors are intermixable. We recommend performing preliminary tests before launching production with color mixtures from this System, especially for combinations of red or yellow cadmium-containing colors (marked \*) with any of the other colors.

*Colors from our different Systems (eg VNR with VNS) should not be mixed with each other.*

Our technical service teams also offer a full custom-color matching service.

### Expansion Coefficient (C.o.E.)

Avg C.o.E. measured on the basic frit System is  $91 (\pm 4) \cdot 10^{-7} K^{-1}$ . This system is suitable for most chemical compositions used in the production of soda-lime glass bottles.

For decorated bottles that have to withstand strong internal pressures or significant mechanical forces, it is recommended to perform preliminary trials, such as bursting pressure tests, to ensure compliance with the required standards.

### Recommended Firing Conditions

From 580°C to 600°C (1075-1110°F) in a cycle of 1hr-1.5h, with a soaking period of c.10 min.

Enamels from this System will lose their gloss if fired above 600°C.

We recommend an oxidising atmosphere to give optimal fired appearance, gloss and brightness. It is essential to maintain good ventilation, and an efficient extraction of the combustion gases and the products resulting from decomposition of the medium.

## *NP2000 System*

### Main Market Use

These lead-free enamels are intended mainly for the decoration of glass tumblers and tableware. They represent a significant breakthrough in chemical durability for decorated glasses, which need to exhibit a high degree of dishwasher-resistance.

### Chemical Composition

Colors in this System do not contain voluntary additions of heavy metals – Pb, Cd, Hg and CrVI. Exceptions are the cadmium-containing green, yellow, reds and oranges (marked \* below) which need to use cadmium pigments, to provide the color tones required by the market. NP2000 System contains lithium and therefore, we do not recommend these colors for decoration of pressurised containers. Lithium can migrate into the body of the glass substrate during firing, which may cause a weakening of the glass.

### Intermixable Color

COLOR	REFERENCE
GREEN	NP 2023
GREEN	NP 2043
COBALT BLUE	NP 2016
BLUE	NP 2028
YELLOW	NP 2030 *
BLACK	NP 2003
BROWN	NP 2052 *
RED	NP 2008 *
RED	NP 2041 *
ORANGE	NP 2035 *
WHITE	NP 2022
FLUX	NP 751
AcE IMITATION ETCH	NP 2055

These colors are intermixable. We recommend performing preliminary tests before launching production with color mixtures from this System, especially for combinations of red or yellow cadmium-containing colors (marked \*) with any of the other colors.

Colors from different Systems should not be mixed.

Before starting production of a new decoration, we recommend to perform appropriate thermal and mechanical tests, to evaluate possible effects on weakening of the glass due to the presence of lithium.

### Expansion Coefficient (C.o.E.)

Avg C.o.E. measured on the basic frit System is  $75 (\pm 4) \cdot 10^{-7} K^{-1}$ . This system is suitable for most chemical compositions used in the production of soda-lime glass tableware.

For decorated bottles that have to withstand strong internal pressures or significant mechanical forces, it is recommended to perform preliminary trials, such as bursting pressure tests, to ensure compliance with the required standards.

### Recommended Firing Conditions

From 600°C to 630°C (1110-1165°F) in a cycle of 1hr to 1.5h., with a soaking period of c.10 min., dependant on both the type of furnace and volume of ware fired.

We recommend an oxidising atmosphere to give optimal fired appearance, gloss and brightness. It is essential to maintain good ventilation, and an efficient extraction of the combustion gases and the products resulting from decomposition of the medium.

## VPS System

### Main Market Use

These lead-free enamels are used for the decoration of low expansion glass, such as pharmaceutical glass, ampoules and laboratory boro-silicate glassware.

### Chemical Composition

Colors in this System do not contain voluntary additions of heavy metals – Pb, Cd, Hg and CrVI.

Exceptions are the cadmium-containing yellow, reds and oranges (marked \* below) which need to use cadmium pigments, to provide the color tones required by the market.

Colors in this System contain lithium.

The enamels are specially formulated for application onto borosilicate glass and they should be tested for suitability to the expansion of the glass to be decorated. The ‘fit’ of these enamels is also dependent on application weight and to avoid microcracking or fracture problems, they should not be applied too thickly.

### Intermixable Color Range

COLOR	REFERENCE
GREEN	VPS 1100
EMERALD GREEN	VPS 1101
ROYAL BLUE	VPS 2102
ULTRAMARINE BLUE	VPS 2101
LIGHT YELLOW	VPS 3133
DARK YELLOW	VPS 3130
BLACK	VPS 4100
BROWN	VPS 6100
DARK RED	VPS 7103*
ORANGE	VPS 7101*
WHITE	VPS 9102
TRANSPARENT FLUX	VPS 857

These colors are intermixable. We recommend performing preliminary tests before launching production with color mixtures from this System, especially for combinations of red or yellow cadmium-containing colors (marked \*) with any of the other colors.

Colors from different Systems should not be mixed.

Before starting production of a new decoration, we recommend to perform appropriate thermal and mechanical tests, to evaluate possible effects on weakening of the glass due to the presence of lithium.

### Expansion Coefficient (C.o.E.)

Avgc C.o.E. measured on the basic frit System is  $60 (\pm 4) \cdot 10^{-7} K^{-1}$ .

For decorated bottles that have to withstand strong internal pressures or significant mechanical forces, it is recommended to perform preliminary trials, such as bursting pressure tests, to ensure compliance with the required standards.

### Recommended Firing Conditions

From 600°C to 630°C (1110-1165°F) in a long cycle; from 630 to 700°C (1165-1290°F) in a short cycle. We recommend an oxidising atmosphere to give optimal fired appearance, gloss and brightness. It is essential to maintain good ventilation, and an efficient extraction of the combustion gases and the products resulting from decomposition of the medium.

## Lead-Containing Systems Technical Data

### VR System

#### Main Market Use

These enamels are recommended for decoration of soda-lime glass packaging, more particularly single-trip and multi-trip returnable bottles.

This System can also be used for special application as color-break enamels for pharmaceutical boro-silicate glass ampoules.

#### Chemical Composition

Colors in this System contain lead and cadmium.  
 We guarantee a lithium content of maximum 30ppm.

#### Intermixable Color Range

COLOR	REFERENCE	COLOR	REFERENCE
DARK GREEN	VR 99.59	BROWN	VR 280
GREEN	VR 231	RED	VR 270
BLUE	VR 209	DARK RED	VR 272
COBALT BLUE	VR 208	ORANGE	VR 261
YELLOW	VR 241	WHITE	VR 290
BLACK	VR 285	AcE IMITATION ETCH	VR 291

In both groups, cadmium-free and cadmium-containing enamels (marked\*), the colors are fully intermixable in any proportion.

However, we recommend making preliminary tests if mixing cadmium-free and cadmium-containing colors (\*), to check the color stability during firing.

*Colors from different Systems should not be mixed.*

Our technical service teams also offer a full custom-color matching service, including special decorative effects.

#### Expansion Coefficient (C.o.E.)

Average C.o.E. measured on the basic frit System is  $80 (\pm 4) \cdot 10^{-7} K^{-1}$ .

Exception is VR208 which has a C.o.E of  $85 (\pm 4) \cdot 10^{-7} K^{-1}$ .

#### Recommended Firing Conditions

600°C to 630°C (1110-1165°F) in a cycle of 1hr-1.5h or more, with a soaking period of c.10 min.

It is also possible to fire the VR System at a temperature of 600-700 °C (1165-1290 °F) in short cycles, such as used for pharmaceutical glass bottles.

#### Chemical Resistance

Norm EN 1388-2 (tests on the basic flux system in laboratory conditions)

- lead release is  $< 10 \text{mg/dm}^2$  of the decorated surface.
- Cadmium release is  $< 1.5 \text{mg/dm}^2$  of the decorated surface.
- See also the acid/alkali resistance test results in the product summary table.

## VM System

### Main Market Use

These enamels are designed specifically for decoration of tableware, including tumblers, plates, vases.....

### Chemical Composition

Colors in this System contain lead, cadmium and lithium.

### Intermixable Color Range

COLOR	REFERENCE
LIGHT BLUE	VM 1204
GREEN	VM 1223
DARK GREEN	VM 1231
COBALT BLUE	VM 1208
ROYAL BLUE	VM 1200
BLACK	VM 1285
YELLOW	VM 1241
BROWN	VM 1146
MEDIUM RED	VM 1370
ORANGE	VM 1261
AcE IMITATION ETCH	VM 250
WHITE	VM 1390

In both groups, cadmium-free and cadmium-containing enamels (marked\*), the colors are fully intermixable in any proportion.

However, we recommend making preliminary tests if mixing cadmium-free and cadmium-containing colors (\*), to check the color stability during firing.

*Colors from different Systems should not be mixed.*

Our technical service teams also offer a full custom-color matching service.

### Expansion Coefficient (C.o.E.)

Avg C.o.E. measured on the basic frit System is  $80 (\pm 4) \cdot 10^{-7} K^{-1}$ .

### Recommended Firing Conditions

540°C to 580°C (1000-1075°F) in a cycle of 1hr-1.5h or more, with a soaking period of c.10 m.

### Chemical Resistance

Norm EN 1388-2 (tests on the basic flux system in laboratory conditions)

- lead release is  $< 10 \text{mg/dm}^2$  of the decorated surface.
- Cadmium release is  $< 1.5 \text{mg/dm}^2$  of the decorated surface.
- See also the acid/alkali resistance test results in the product summary table.

## VS System

### Main Market Use

These enamels are intended mainly for the decoration of tumblers, but are also used for cosmetic and perfume bottles.

### Chemical Composition

Colors in this System contain lead and cadmium.

### Intermixable Color Range

COLOR	REFERENCE
DARK GREEN	VS 327
GREEN	VS 321
ROYAL BLUE	VS 300
COBALT BLUE	VS 302
YELLOW	VS 68.59
BLACK	VS 384
BROWN	VS 73.59
LIGHT RED	VS 370
DARK RED	VS 372
ORANGE	VS 361
WHITE	VS 390
AcE IMITATION ETCH	VS 391

These colors all contain lead and cadmium and are therefore intermixable in any proportion.

*Colors from different Systems should not be mixed.*

Our technical service teams also offer a full custom-color matching service, including special decorative effects.

### Expansion Coefficient (C.o.E.)

Avg C.o.E. measured on the basic frit System is  $90 (\pm 4) \cdot 10^{-7} \text{K}^{-1}$ .

Exception is cobalt-blue VS 302, which contains a Co-based flux and has a C.o.E. close to  $100 (\pm 4) \cdot 10^{-7} \text{K}^{-1}$ .

We do not recommend this system for multi-trip bottles, or bottles which have to withstand strong internal pressures.

### Recommended Firing Conditions

From 580°C to 600°C (1075-1110°F) in a cycle of 1hr-1.5h or more, with a soaking period of c.10 min.

### Chemical Resistance

Norm EN 1388-2 (tests on the basic flux system in laboratory conditions)

- lead release is  $< 25 \text{mg/dm}^2$  of the decorated surface.  
Exception is VR 302 cobalt blue, with a lead release of c.  $60 \text{mg/dm}^2$  of the decorated surface.
- Cadmium release is  $< 3 \text{mg/dm}^2$  of the decorated surface.
- See also the acid/alkali resistance test results in the product summary table

## *System 31*

### Main Market Use

These enamels are intended mainly for the decoration of lighting fixtures and ornamental hollow-ware, where chemical durability is not important.

### Chemical Composition

Colors in this System contain lead, but are lithium-free. There are also some gold-containing colors contained in this System.

### Intermixable Color Range

COLOR	REFERENCE
GREEN	11699
BOTTLE GREEN	11934
GREEN	11940
BLUE	12601
DARK BLUE	12603
SILVER YELLOW	73018
GOLDEN YELLOW	13142
PURPLE	77396*
VIOLET	78149*
RUBY	77436*
TRANSPARENT FLUX	10022

Colors marked \* are gold-containing colors and can be mixed with each other in any proportion, but are not recommended to be mixed with any of the other colors in this System

The non-gold colors are all intermixable with each other in any proportion.

Transparent flux 10022 can be blended with any of the colors to produce weaker color tones.

The color shade can also be influenced by the surface pre-treatment of the glass, dependant on the nature of any hollow-ware hot-end coating, such as tin or titanium.

Mixing charts are available, as a guide to the range of color shades achievable.

### Application

The unfired color layer should not exceed 20 microns, to avoid cracking during firing. Too thin layers may fire matt or very pale.

Highly effective designs can be achieved by applying a combination of transparent and opaque color layers (eg System VS) via spraying, screen-printing, brushing or stippling.

### Expansion Coefficient (C.o.E.)

These enamels have a high C.o.E., and therefore it is advisable to take special care when applying these colors. Enamels with a higher C.o.E. than the glass substrate to be decorated, can weaken the glass.

We recommend decorators make preliminary trials to check that the end results are in accordance with their requirements.

### Recommended Firing Conditions

From 540°C to 580°C (1000-1080°F), with the higher temperature recommended for optimal transparency. An addition of 20-30% flux 10022 will further reduce the firing temperature by some 20 °C.

### Chemical Resistance

Transparent colors have very limited resistance to acids, alkalis and atmospheric pollution. This limited resistance is characterised by gradual fading of the colors, or iridescence may appear.

## *PR System*

### Main Market Use

These low expansion enamels are specially designed for decoration of low expansion glasses, such as alkali boro-silicate glass.

### Chemical Composition

Colors in this System contain lead, cadmium and lithium

The enamels are specially formulated for application onto borosilicate glass and they should be tested for suitability to the expansion of the glass to be decorated. The 'fit' of these enamels is also dependent on application weight and to avoid microcracking or fracture problems, they should not be applied too thickly.

### Intermixable Color Range

COLOR	REFERENCE
GREEN	PR 106
BLUE GREEN	PR 109
ULTRAMARINE BLUE	PR 113
ROYAL BLUE	PR 108
YELLOW	PR 107
BLACK	PR 112
BROWN	PR 105
DARK BROWN	PR 103
ORANGE	PR 101
MEDIUM RED	PR 100
DARK RED	PR 118
WHITE	PR 104

These colors all contain lead and cadmium and are therefore intermixable in any proportion.

*Colors from different Systems should not be mixed.*

For decorated bottles that have to withstand strong internal pressures or significant mechanical forces, it is recommended to perform preliminary trials, such as bursting pressure tests, to ensure compliance with the required standards.

Our technical service teams can also offer a full custom-color matching service.

### Expansion Coefficient (C.o.E.)

Avg C.o.E. measured on the basic frit System is  $57 (\pm 4) \cdot 10^{-7} K^{-1}$ .

Exception is black PR 112, with a C.o.E. close to  $62 (\pm 4) \cdot 10^{-7} K^{-1}$ .

### Recommended Firing Conditions

From 600°C to 630°C (1110-1165°F) in a long cycle; from 630 to 700°C (1165-1290°F) in a short cycle.

### Chemical Resistance

Norm EN 1388-2 (tests on the basic flux system in laboratory conditions)

- lead release is  $< 10 \text{ mg/dm}^2$  of the decorated surface.
- Cadmium release is  $< 1 \text{ mg/dm}^2$  of the decorated surface.
- See also the acid/alkali resistance test results in the product summary table.

## The Complete Ferro Package for the Glass World

Ferro is unique amongst suppliers to the glass industry in offering a complete package of products for the container glass market worldwide.

In addition to the Container Glass Decoration enamels detailed here, we supply a complimentary range of other materials and services, which add value to our customer's glass and the final end use product.

Our technical service experts would be pleased to advise on any aspect of your requirements. Also please check out our detailed literature for:

### AcE Imitation Acid Etch

Our line of durable, abrasion resistant glass enamel coatings and inks, indistinguishable from the real thing.

### SpecTruLite Organic Coatings & Inks

New generation water-borne organic coatings, *complimented by our UV-cure, hot-melt and cold printing inks. Our colors are heavy metal-free and provide a rich range of vibrant color shades and special effects.*

### Precious Metal Preparations

A natural compliment to our decorating enamels, we can supply precious metal golds, palladium, platinum and silvers for application by automatic or semi-automatic screen printing, banding, brushing or decals. All our products are formulated to fit perfectly in combination with our decoration color palettes.

Our ranges are especially of interest for premium brand beverages and cosmetics, and for decoration of high quality tableware and giftware.

### Forehearth Color Technology

Ferro pioneered the development of forehearth coloration as a cost effective, flexible alternative to glass tank coloration.

Not only does this provide the glass manufacturer with the option of producing 'standard' tank colors in relatively short runs, but also allows for the production of specialist colors that would otherwise be extremely costly, or in some cases impossible to achieve in the tank.

### Cermark Laser Decoration

A recent innovation, Ferro is at the forefront in the development of laser decoration and I.D. marking of glass.

For containers, we have developed a line of specialist colors for application on cosmetic and beverage bottles, and tableware.

The innovation is providing exciting new opportunities for the decoration of glass.

This 'non-contact' technique creates complex designs, combined with instant firing, to produce a permanent durable decoration. The need for a secondary firing process is completely eliminated.

It is low maintenance, efficient, cost effective and extremely flexible, with the added capability to link to computer design and to print on complex geometrical surfaces.

## *One Glass World ..... One Color Solution ..... One Name.....*



**Fiches de sécurité** : nous tenons des fiches de sécurité à disposition pour chacun de nos produits, donnant toutes informations quant à leur utilisation en matière d'hygiène et de sécurité.

Nous communiquons en toute bonne foi nos connaissances et expériences concernant l'application de nos produits. Toutefois, ces renseignements techniques ne peuvent constituer que de simples indications qui n'engagent pas notre responsabilité. Ils ne dispensent pas les utilisateurs de la nécessité de vérifier la conformité de nos produits à leurs propres procédés, l'application, l'emploi et la transformation de ces produits échappant à nos possibilités de contrôle.

En outre, nous nous réservons le droit, dans le cadre du développement continu de nos produits, de procéder à des modifications techniques.

En cas de contestation sur la conformité d'un produit, notre responsabilité serait engagée dans les limites de l'article III de nos conditions générales de vente.

L'emploi de nos produits doit être limité aux usages pour lequel ils ont été créés et mis sur le marché ; nous mettons en garde nos clients sur des utilisations non prévues qui, en aucun cas, ne sauraient engager notre responsabilité.

Nos recommandations en matière d'hygiène et de sécurité ne dispensent pas les utilisateurs de déterminer par eux-mêmes les mesures adaptées aux conditions propres à leur exploitation que nous ne pouvons prévoir.

**Safety and handling** : the Material Safety Data Sheet should be read and understood before handling or using this product.

Information provided on the application of our products is based on our research and experience and is given to the best of our knowledge. These technical details are only indications and we can accept no responsibility for them, as they do not exempt end-users from making their own tests to determine the suitability of our products for their own purposes ; application, use and transformation of these products being beyond our control.

We also reserve the right to make technical modifications in the course of product developments.

Should a product be found not to conform to recognized standards, our liability shall be confined within the limits stipulated under clause III of our standard conditions of sale.

The use of our products must be limited to the uses for which they have been created and put on the market ; we warn our customers concerning uses for which they are not provided and for which there can be no liability from our part (whichever the case is).

Our recommendations regarding hygiene and security do not exempt the customer from evaluating these products by his own tests and in his own conditions, which cannot be foreseen.