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# Flat Glass Enamel Decoration Systems

## Main Markets

Ferro's flat glass colors are specially formulated for decoration of glass during the tempering process. Our products are designed for

- **domestic appliance glass** – oven doors, control panels, refrigerator and freezer shelves, microwave doors.....
- **architectural glass** – spandrel panels, shower screens, advertising, internal glass doors and partitions
- **glass furniture** – tabletops, kitchen cabinets, wall cupboard doors, display cabinets....

## Global Product Systems

Ferro has rationalised its color ranges to create a number of Global Product Systems.

***The market trend and our recommendation is toward the increasing use of our new generation lead-free systems.***

The basic components and final colors from these ranges are made at our principle manufacturing sites around the world and controlled according to standard Ferro processes and specifications. In this way, we control quality standards to the exacting requirements specified by our customers and the final end user markets.

## Lead-Free Technology

Ferro has worked for a number of years researching heavy-metal free enamels for flat glass. The current generation of products, which benefit from recent technology advances, are lead-free and cadmium-free and are designed to:

- satisfy the needs of glass manufacturers and decorators arising from the latest legislation for Health & Safety in the workplace
- satisfy the needs of the end markets – especially building and appliance glass - arising from the latest legislation for environmental protection
- 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 heavy metal-free enamels.

Our Innovation 2006 program has resulted in our new hi-durable s1de ONE enamels for first surface application, delivering a new range of exciting special effects to the architect.

## Lead-Free Guarantees

- **Our System 140 and s1de ONE glass enamels are designed to be heavy-metal free, which means that they do not contain intentional additions of Pb, Cd, CrVI and Hg. They are provided with the following guarantees:**
  - **Pb, CrVI, Hg: max. content 1000 ppm;**
  - **Cd max content 100 ppm**
- **System 140 and s1de ONE are also lithium-free**

## Ferro's Decoration Systems for Flat Glass

- **System 140 Lead-Free Colors**

- Intermixable lead-free, cadmium-free, lithium-free colors, including etch & metallic-effects

- **System 140 Plus**

- **System 140 + cadmium-containing red and yellow colors**

(System 140 Plus is an extended lead-free range, introduced by request for customers specifying bright shades, containing cadmium. A big advantage of System 140 Plus is that our Cd-containing colors are fully intermixable with our Cd-free colors, in any proportions.)

Ferro's basic color ranges are designed to provide our customers with the flexibility they need to satisfy their individual processing and market requirements.

Where customers prefer to make their own "in-house" color matchings, we recommend our inter-mixable color systems. These comprise standardised colors that are fully inter-mixable, to achieve the widest possible color range.

The base Systems consist of white, black and several chromatic enamels, all of which are formulated with strict controls to minimise color drift, resulting in superior lot-to-lot consistency.

***Many of the markets we serve are moving to our lead-free System 140 colors for environmental reasons and because of existing or impending Governmental regulation.***

***As an additional value-added service, we are now offering a computerised Datacolor matching system for our System 140, which includes a full package of software, with colorimetric data for the standards and many color matchings. (See examples below)***

For customers who prefer us to make their color matchings for them, our local technical service teams offer the additional option of custom-color matching.

- **s/de ONE Lead-free Hi - Durable Colors**

- Intermixable lead-free colors and special effects for Surface 1

This new color range is specially developed for Surface 1 application and all **s/de ONE** colors have extremely high chemical and weathering resistance, compared with traditional flat glass enamels. This allows them to be used for first surface applications in most situations, where the decoration is applied to exterior surfaces directly exposed to the elements.

These resistant colors can also be used to produce interesting designs for kitchen work surfaces.

Compared to conventional flat glass enamels applied on Surface 2 and viewed through the glass, **s/de ONE** enamels provide architects with a much wider range of design possibilities and special effects. Durable colors replicating effects such as wood, stone and metal are now within reach for the architectural designer.

Most importantly **s/de ONE** enables the creation of different surface textures, e.g. matt and semi-matt, in combination with the natural transparency of glass.

- **LustReflex Hi-reflective coatings**

- Screen-printable semi-mirror coatings

LustReflex is a hard, chemically durable partially transparent mirror coating which is screen-printable and roller-coatable and provides a cost-effective alternative to similar coatings applied by PVD ('sputter') or CVD.

By its very nature, LustReflex allows the application of mirror patterns in combination with other colors and designs.

LustReflex can be used in glass design for appliance, architectural and furniture markets and works well in combination with System 140.

## Mixability and Color Shades

### 1. System 140 Intermixable Product Range

	Product Reference	Color Shade	
<b>Opaque colors</b>	11 4000	Light Green	
	11 4001	Green	
	11 4002	Blue-green	
	12 4000	Dark blue	
	12 4002	Royal blue	
	13 4002	Yellow	
	13 4003	Lemon Yellow	
	14 4001	Black	
	15 4001	Dark Grey	
	16 4000	Chocolate Brown	
	17 4000	Red –brown	
	19 4002	White	
<b>Intensive Colors</b>	14 4011	High Opaque Black	
	19 4011	High Opaque White	
<b>Transparent</b>	10 4001	Colorless	
<b>White Imitation Etch</b>	19 4020	Standard Etch	Use 90-48 (90T)
	19 4021*	Special etch	Screen for etches
<b>Metallic effect colors</b>	13 4030	Gold	
	15 4030	Sterling silver	48-70(48T) screen
	16 4030	Bronze	recommended
	17 4030	Red	for 'metallics'
	19 4030	Silver	

(\* 19 4021 etch has optimum light diffusion; easy-to-clean surface; stable firing condition)

- System 140 colors are free of added lead, cadmium and lithium.
- They are intermixable in all proportions.
- White 19 4002 is recommended as a mixing white.

With our intermixable lead-free colors, a minimum number of standards can create the widest range of color shades. In all cases, we always recommend that our standards and mixes are test fired before committing them to production scale-up.

System 140 delivers a range of colors with optimum opacity and gloss after firing. Intermixing with transparent flux 10 4001 can create more gloss and increases in translucency (lower opacity).

We urge caution when creating translucent mixes and/or using our Cd-containing colors from System 140 Plus, and always recommend full testing and firing under production conditions, with full-sized glass, prior to final approval.

Processing parameters - e.g .applied film layer thickness, drying and furnace set-up conditions ( glass loading, atmosphere, firing position) - can each influence the color shade after firing. Especially Cd-containing colors are sensitive to kiln set-up.

Color tone is also influenced by the surface treatment of the glass. For float glass, decorating on the Sn-side (tin bath side) results in a different color shade than on the air-side of the glass.

**In combination with our latest water-friendly medium systems, Ferro System 140 represents the state-of-the-art in environmentally-friendly decoration of flat glass, for architectural, appliance and furniture glass.....**

## 2. s1de ONE Intermixable Product Range

	Product Reference	Color Shade		
<b>Opaque colors</b>	11 4100	Light Green		
	11 4101	Green		
	12 4100	Dark blue		
	12 4101	Royal blue		
	13 4100	Yellow		
	13 4101	Ochre		
	14 4100	Black		
	15 4100	Grey		
	16 4100	Chocolate Brown		
	17 4100	Red –brown		
	19 4100	White		
	<b>Imitation Etch</b>	19 4120	Etch – use 90-48(90T) screen	
	<b>Special effects</b>	13 4130	Gold	
15 4130		Aluminium	48-70(48T) screen	
16 4130		Bronze	recommended	
19 4130		Silver	for 'special effects'	

By using combinations of the standard intermixable colors, our s1de ONE colors can be used to re-create interesting special effects, most notably wood, stone and metal effects like aluminium.

All the colors have been tested according with the norms for exterior exposure of architectural glass. Test results are available from our technical service teams.

## 3. System 140 Recommended Mixtures

**Using our unique Datacolor computer color matching system, we have built a comprehensive portfolio of mixings based on the intermixable System 140 lead-free colors.**

**Matchings for some important RAL and NCS shades are included in the following pages.**

The mixing recommendations for the referenced RAL and NCS numbers are indicative based on laboratory experimentation. We recommend that the mixed shades be tested under customer specific conditions of application and firing.

Actual results will depend on production conditions. The tests have been made on different glass thicknesses (4mm, 6mm, 8mm).

- RAL Shades

RAL-Nr	4 mm	6 mm	8 mm	P 1	%	P 2	%	P 3	%	P 4	%	Comment
1000		X		13 4002	54,0	19 4002	44,0	17 4000	2,0			Green beige *)
1001		X		13 4002	52,0	19 4002	43,5	17 4000	4,5			Beige
1002		X		13 4002	64,2	19 4002	31,0	17 4000	4,8			Sand yellow
1011	X			13 4002	75,0	17 4000	11,0	14 4001	1,0	19 4002	3,00	Brown beige
1011		X		13 4002	72,8	17 4000	17,5	11 4000	9,7			Brown beige
1013		X		19 4002	98,0	17 4000	1,0	13 4003	1,0			Oyster white
1014		X		13 4003	56,3	19 4002	40,8	17 4000	2,9			Ivory *)
1015		X		17 4000	1,0	13 4003	18,0	19 4002	81,0			Light ivory
1019		X		19 4002	47,2	13 4002	42,7	17 4000	8,4	14 4001	1,70	Grey beige *)
1020		X		13 4002	73,9	19 4002	20,4	17 4000	3,9	14 4001	2,00	Olive yellow *)
1024		X		13 4002	76,4	13 4003	17,5	17 4000	6,1			Ochre yellow *)
1035		X		15 4030	60,0	13 4030	40,0					Oyster beige
3009		X		17 4000	77,0	12 4002	23,0					Oxide red *)
5000		X		12 4002	73,0	19 4002	15,0	17 4000	12,0			Violet blue
5001	X			12 4002	50,0	12 4000	40,0	14 4001	10,0			Green blue
5003		X		12 4002	84,8	14 4001	15,2					Saphirblau *)
5005	X			12 4002	90,0	12 4000	9,0	17 4000	1,0			Signal blue
5007	X			19 4002	28,0	14 4001	9,0	12 4002	63,0			Brilliant blue
5007		X		12 4002	75,8	19 4002	15,1	14 4001	9,1			Brilliant blue
5008	X			12 4002	67,0	14 4001	28,0	19 4002	5,0			Grey blue
5008		X		14 4001	55,9	12 4002	29,5	19 4002	8,4	11 4002	7,40	Grey blue
5009	X			12 4002	48,0	12 4000	38,0	14 4001	9,0	19 4002	5,00	Azure blue
5009		X		12 4002	68,8	11 4002	12,3	19 4002	11,7	14 4001	7,20	Azure blue
5010		X		12 4002	94,0	19 4002	3,0	14 4001	3,0			Gentian blue
5010			X	12 4002	93,0	14 4001	3,0	19 4002	4,0			Gentian blue
5011				12 4002	80,0	14 4001	20,0					Steel blue
5012	X			12 4002	70,0	19 4002	27,0	13 4002	3,0			Light blue
5014		X		12 4002	57,0	19 4002	33,0	17 4000	10,0			Pigeon blue
5015		X		12 4002	78,5	19 4002	14,5	11 4002	7,0			Heaven blue
5017	X			12 4002	55,0	12 4000	40,0	14 4001	5,0			Traffic blue
5018	X			19 4002	40,0	11 4002	50,0	13 4003	10,0			Turquoise blue
5019	X			12 4002	85,0	12 4000	10,0	14 4001	5,0			Capri blue
5020		X		11 4002	49,0	14 4001	30,0	12 4002	21,0			Ocean blue
5021		X		11 4002	50,0	12 4002	27,4	13 4003	22,6			Water blue
5023	X			12 4002	75,0	19 4002	20,0	17 4000	5,0			Distant blue
5024	X			19 4002	76,0	12 4002	24,0					Pastel blue

RAL-Nr	4 mm	6 mm	8 mm	P 1	%	P 2	%	P 3	%	P 4	%	Comment
6000		X		11 4000	52,7	11 4002	36,9	19 4002	10,5			Patina green
6001		X		11 4001	64,4	11 4000	19,0	13 4002	16,6			Emerald
6002		X		11 4001	48,0	11 4000	38,0	13 4002	14,0			Leave green *)
6003		X		11 4000	40,6	11 4001	37,1	17 4000	21,7	14 4001	0,7	Olive green
6004	X			11 4002	57,0	11 4000	22,0	14 4001	19,0			Blue green
6004		X		11 4002	57,0	11 4000	23,0	14 4001	20,0			Blue green
6005		X		14 4001	35,0	11 4001	45,0	11 4000	20,0			Moos green
6006	X			11 4001	50,0	16 4000	30,0	14 4001	20,0			Grey olive
6006		X		14 4001	60,6	13 4002	32,5	17 4000	6,9			Grey olive
6007	X			11 4001	60,0	14 4001	20,0	16 4000	20,0			Bottle green
6007		X		11 4000	60,0	14 4001	25,0	16 4000	15,0			Bottle green
6009	X			11 4001	30,0	11 4000	25,0	14 4001	45,0			Fir green
6011		X		13 4002	72,1	11 4002	10,9	19 4002	10,4	14 4001	6,6	Reseda green
6012	X			11 4001	30,0	11 4000	20,0	14 4001	50,0			Black green
6013		X		13 4002	47,6	19 4002	24,3	11 4000	16,7	16 4000	11,4	Reed green
6014	X			11 4001	40,0	16 4000	40,0	14 4001	20,0			Yellow olive
6015	X			11 4001	35,0	16 4000	35,0	14 4001	30,0			Black olive
6015			X	11 4001	30,0	16 4000	38,0	14 4001	26,0	11 4002	6,0	Black olive
6016		X		11 4001	73,7	11 4002	26,3					Turquoise green
6017		X		11 4000	65,0	13 4002	35,0					Mai green
6018	X			11 4000	50,0	13 4003	50,0					Yellow green
6019	X			19 4002	80,0	11 4001	12,0	13 4003	8,0			White green
6019		X		19 4002	80,0	11 4001	12,0	13 4003	8,0			White green
6020	X			11 4000	70,0	14 4001	30,0					Chrome green
6021		X		19 4002	54,4	13 4003	25,0	11 4000	19,6	14 4001	1,0	Pale green
6022	X			11 4001	35,0	16 4000	45,0	14 4001	20,0			Brown olive
6024	X			11 4001	90,0	13 4003	10,0					Traffic green
6025	X			13 4003	48,0	11 4000	47,0	14 4001	5,0			Fern green
6026	X			11 4002	35,0	11 4001	60,0	14 4001	5,0			Opal green
6027	X			19 4002	72,0	11 4002	23,0	13 4003	5,0			Light green
6028		X		11 4001	74,5	14 4001	22,0	19 4002	3,5			Pine green
6029		X		11 4001	100,0							Mint green
6032	X			11 4001	100,0							Signal green
6033	X			11 4001	50,0	19 4002	30,0	12 4000	20,0			Mint turquoise
6034	X			19 4002	76,0	11 4002	23,0	14 4001	1,0			Pastel turquoise
6034		X		19 4002	90,0	11 4002	10,0					Pastel turquoise
7000	X			14 4001	20,0	19 4002	80,0					Squirrel grey
7000		X		19 4002	78,1	14 4001	12,5	12 4002	8,9	17 4000	1,3	Squirrel grey
7001	X			19 4002	82,0	14 4001	14,0	17 4000	2,0	12 4002	2,0	Silver grey
7001		X		19 4002	81,0	12 4002	10,0	17 4000	5,0	14 4001	4,0	Silver grey
7002		X		13 4002	45,8	19 4002	31,5	16 4000	13,7	11 4000	9,3	Olive grey
7003		X		13 4002	48,7	19 4002	24,5	14 4001	19,6	17 4000	7,2	Moss grey
7004	X			19 4002	85,0	14 4001	7,0	17 4000	5,0	12 4002	3,0	Signal grey
7004		X		19 4002	88,8	14 4001	5,8	17 4000	4,6	13 4002	0,8	Signal grey
7005		X		19 4002	50,6	13 4002	22,4	14 4001	20,0	16 4000	7,0	Mouse grey
7006		X		13 4002	36,7	19 4002	28,9	16 4000	26,3	11 4000	8,1	Beige grey
7008		X		13 4002	64,0	17 4000	21,4	11 4000	14,6			Khaki grey
7009	X			19 4002	20,0	16 4000	35,0	11 4001	45,0			Green grey
7009		X		11 4000	36,8	19 4002	26,4	14 4001	23,2	17 4000	13,6	Green grey

RAL-Nr	4 mm	6 mm	8 mm	P 1	%	P 2	%	P 3	%	P 4	%	Comment
7010	X			14 4001	35,0	19 4002	30,0	11 4000	15,0	16 4000	20,0	Tarpaulin grey
7010		X		11 4001	36,7	19 4002	26,7	16 4000	23,1	14 4001	13,6	Tarpaulin grey
7011		X		19 4002	40,6	14 4001	33,1	16 4000	14,4	11 4002	11,8	Iron grey
7012	X			19 4002	50,0	14 4001	30,0	11 4000	10,0	16 4000	10,0	Basalt grey
7012		X		19 4002	35,0	16 4000	28,1	11 4002	25,4	14 4001	11,5	Basalt grey
7013		X		13 4002	40,9	14 4001	35,2	17 4000	13,3	19 4002	10,6	Brown grey
7015	X			14 4001	46,0	19 4002	34,0	16 4000	20,0			Slate grey
7015		X		14 4001	42,0	19 4002	35,0	16 4000	23,0			Slate grey
7016	X			14 4001	80,0	19 4002	10,0	12 4002	10,0			Anthracite grey
7016		X		14 4001	77,9	19 4002	16,8	11 4000	3,7	17 4000	1,6	Anthracite grey
7021		X		14 4001	90,0	19 4002	10,0					Black grey
7022	X			11 4001	25,0	16 4000	30,0	14 4001	20,0	19 4002	25,0	Umbra grey
7023		X		11 4000	15,0	16 4000	15,0	19 4002	70,0			Concrete grey
7024	X			14 4001	63,0	19 4002	22,0	12 4002	13,0	17 4000	2,0	Graphite grey
7024		X		14 4001	42,8	19 4002	21,1	12 4002	19,6	16 4000	16,5	Graphite grey
7026	X			14 4001	75,0	19 4002	15,0	11 4000	10,0			Granite grey
7030		X		19 4002	60,0	13 4002	26,0	17 4000	7,0	14 4001	7,0	Stone grey
7031	X			14 4001	45,0	19 4002	55,0					Blue grey
7031		X		19 4002	45,3	14 4001	32,8	13 4002	11,3	12 4002	10,5	Blue grey
7032		X		19 4002	84,0	13 4002	10,0	16 4000	5,0	14 4001	1,0	Pebble grey
7033		X		19 4002	44,4	13 4002	40,2	14 4001	13,1	16 4000	2,3	Cement grey
7034		X		19 4002	43,4	13 4002	42,8	16 4000	8,3	11 4000	5,5	Yellow grey
7035	X			19 4002	98,0	14 4001	1,0	16 4000	1,0			Light grey
7035		X		19 4011	97,0	16 4000	2,0	11 4000	1,0			Light grey
7036		X		19 4002	82,0	14 4001	9,0	17 4000	9,0			Platinum grey
7037		X		19 4002	70,0	14 4001	10,0	17 4000	10,0	12 4002	10,0	Dusty grey
7038	X			19 4002	95,0	14 4001	2,0	16 4000	2,0	11 4000	1,0	Agate grey
7039	X			19 4002	26,0	16 4000	40,0	11 4001	34,0			Quartz grey
7040	X			19 4002	81,0	12 4002	8,0	14 4001	5,0	17 4000	6,0	Window grey
7040		X		14 4001	7,0	19 4002	76,0	17 4000	7,0	12 4002	10,0	Window grey
7042	X			19 4002	85,0	14 4001	10,0	16 4000	5,0			Traffic grey A
7043	X			14 4001	30,0	19 4002	25,0	16 4000	25,0	11 4001	20,0	Traffic grey B
7044	X			19 4002	96,0	16 4000	3,0	11 4000	1,0			Silk grey
7044		X		19 4002	90,0	16 4000	5,0	13 4002	5,0			Silk grey
7045		X		19 4002	70,0	12 4002	15,0	17 4000	10,0	14 4001	5,0	Tele grey 1
7046		X		19 4002	77,3	14 4001	17,3	17 4000	3,1	12 4002	2,3	Tele grey 2
7047		X		19 4011	99,0	17 4000	1,0					Tele grey 4
7048		X		15 4030	65,0	19 4030	20,0	16 4030	15,0			Pearl mouse grey
8000		X		13 4002	73,0	17 4000	15,2	11 4000	11,8			Green brown
8001		X		13 4002	74,2	17 4000	17,7	11 4000	8,1			Ochre brown
8002	X			16 4000	50,0	13 4003	35,0	17 4000	15,0			Signal brown
8004		X		17 4000	60,0	13 4002	40,0					Copper brown
8007		X		17 4000	53,2	11 4000	26,8	13 4002	20,0			Deer brown
8008		X		13 4002	41,4	17 4000	38,6	11 4000	20,0			Olive brown
8011		X		16 4000	82,0	17 4000	8,0	13 4002	10,0			Nutbrown
8014		X		16 4000	63,0	11 4000	35,0	14 4001	2,0			Sepia brown
8016	X			16 4000	100,0							Mahogany brown

RAL-Nr	4 mm	6 mm	8 mm	P 1	%	P 2	%	P 3	%	P 4	%	Comment
8017	X			16 4000	85,0	14 4001	15,0					Chocolate brown
8019	X			16 4000	36,0	14 4001	54,0	11 4001	10,0			Grey brown
8019		X		16 4000	45,0	14 4001	40,0	19 4002	10,0	17 4000	5,0	Grey brown
8024		X		17 4000	44,5	13 4003	27,3	11 4000	20,0	13 4002	8,2	Beige brown
8025	X			16 4000	48,0	13 4003	47,0	19 4002	5,0			Pale brown
8028		X		17 4000	40,6	14 4001	33,2	13 4002	26,3			Terra brown
9001		X		19 4002	98,0	17 4000	1,0	13 4002	1,0			Creme white
9002		X		19 4002	99,0	16 4000	1,0					Grey brown
9002		X		19 4011	96,5	13 4003	3,0	17 4000	0,5			Grey brown **)
9003				19 4011	100,0							Signal white
9004	X			14 4001	100,0							Signal black
9006	X			19 4030	96,0	14 4001	3,0	17 4030	1,0			White aluminium
9006		X		19 4030	96,0	17 4030	3,0	14 4001	1,0			White aluminium
9007	X			19 4030	80,0	14 4001	12,0	17 4030	8,0			Grey aluminium
9007			X	19 4030	81,0	14 4001	11,0	17 4030	8,0			Grey aluminium
9010	X			19 4002	98,0	13 4003	2,0					Pure white
9010		X		19 4002	100,0							Pure white
9011		X		14 4001	96,0	19 4002	4,0					Graphite black
9016		X		19 4011	100							Traffic white*)
9018	X			19 4002	99,0	16 4000	0,5	14 4001	0,5			Papyrus white

\* approximate match

\*\* matched on white glass

### - NCS Shades

NCS Ref.	4 mm	6 mm	8 mm	P 1	%	P 2	%	P 3	%	P 4	%	Comment
0010-B70G		X		19 4011	98,0	11 4002	1	11 4001	1			
0020-B70G		X		19 4002	97,0	11 4002	3					
1020-B70G		X		19 4002	95,0	11 4001	4,0	11 4002	1,0			
2500-N		X		19 4002	92,0	12 4002	5,0	17 4000	3,0			
4010-B70G			X	19 4002	71,0	11 4001	15,0	14 4001	11,0	16 4000	3,0	
5000-N		X		19 4001	70,0	14 4001	10,0	17 4000	12,0	12 4002	8,0	
5005-R80B		X		19 4002	68,0	14 4001	10,0	17 4000	12,0	12 4002	10,0	
7010-R70B		X		12 4002	62,0	19 4002	10,0	17 4000	18,0	14 4001	10,0	
7020-B30G		X		11 4002	47,0	11 4000	13,0	14 4001	40,0			
8005-B20G			X	14 4001	77,0	19 4002	13,0	12 4002	10,0			
8010-B70G		X		11 4001	25,0	11 4000	10,0	14 4001	50,0	11 4002	15,0	
S 0502-B		X		19 4002	99,0	13 4002	1,0					White Glass *
S 0502-G		X		19 4002	98,0	13 4002	2,0					White Glass *
S 0510-B30G		X		19 4002	89,0	11 4002	2,00					
S 0510-B50G		X		19 4002	99,0	11 4002	1,0					
S 0510-G10Y		X		19 4002	96,0	11 4001	4,0					
S 0520-Y												**
S 0520-G80Y		X		19 4002	65,0	13 4002	35,0					White Glass
S 0530-G30Y		X		19 4002	69,3	13 4003	29,2	114002	1,5			
S 0530-Y												**
S 0530-Y50R												**
S 0540-Y40R												**
S 0560-Y30R												**

NCS Ref.	4 mm	6 mm	8 mm	P 1	%	P 2	%	P 3	%	P 4	%	Comment
S 0565-G10Y												**
S 1002-G		X		19 4002	98,0	13 4002	2,0					White Glass
S 1005-R80B		X		19 4002	99,0	14 4001	1,0					
S 1005-Y40R												**
S 1010-B50G		X		19 4002	99,0	11 4002	1,0					
S 1010-B90G		X		19 4002	99,0	11 4000	1,0					
S 1020-B90G		X		19 4002	95,0	11 4001	5,0					
S 1010-G90Y		X		19 4002	80,0	13 4002	20,0					White Glass
S 1020-B		X		19 4002	96,0	12 4000	3,0	12 4002	1,0			
S 1020-Y		X		19 4002	53,4	13 4003	46,0	17 4000	0,6			White Glass
S 1030-B		X		19 4002	90,0	12 4002	10,0					
S 1050-B70G												**
S 1080-Y30R												**
S 1080-Y90R												**
S 1505-G10		X		19 4002	96,0	16 4000	2,0	13 4002	2,0			
S 1540-Y20R												**
S 1575-R10B												**
S 2005-R80B		X		19 4002	97,0	14 4001	3,0					White Glass
S 2005-R80B		X		19 4002	96,0	16 4000	2,0	14 4001	2,0			*
S 2005-G20Y		X		19 4002	97,8	11 4000	1,0	13 4002	1,2			
S 2010-B10G		X		19 4002	96,0	14 4001	3,0	12 4000	1,0			
S 2010-B90G		X		19 4002	93,4	13 4003	4,6	11 4002	2,0			
S 2010-G10Y		X		19 4002	91,9	13 4003	7,0	11 4002	1,1			
S 2010-R80B		X		19 4002	91,9	14 4001	4,3	17 4000	1,7			
S 2010-R80B		X		19 4002	95,0	14 4001	3,0	12 4002	2,0			
S 2020-B		X		19 4002	91,3	12 4000	7,7	14 4001	1,0			
S 2020-B30G		X		19 4002	91,0	11 4002	9,0					
S 2020-G30Y		X		19 4002	65,0	13 4003	32,0	11 4002	2,0	14 4001	1,0	
S 2020-G10Y		X		19 4002	82,0	11 4000	18,0					
S 2030-B		X		19 4002	80,0	12 4002	20,0					
S 2030-R90B		X		19 4002	74,6	12 4002	23,6	11 4002	1,8			
S 2040-G30Y		X		13 4003	87,9	19 4002	6,1	11 4002	6,0			
S 2040-G50Y		X		13 4003	47,4	13 4002	30,1	11 4000	12,6	19 4002	9,8	*
S 2040-Y20R												**
S 2050-B70G		X		13 4003	52,4	11 4002	40,5	12 4002	7,1			*
S 2050-B80G		X		13 4003	56,6	11 4002	20,6	12 4002	22,8			*
S 2050-B90G		X		13 4003	66,7	11 4002	40,5	12 4002	1,3			*
S 2060-Y70R												**
S 2065-R20B												**
S 2070-Y60R												**
S 2070-Y70R												**
S 2555-B60G		X		13 4003	40,0	12 4002	25,2	11 4002	34,8			*

NCS Ref.	4 mm	6 mm	8 mm	P 1	%	P 2	%	P 3	%	P 4	%	Comment
S 3005-G20Y		X		19 4002	92,7	11 4000	4,7	14 4001	1,0	11 4002	0,5	
S 3005-R80B		X		19 4002	92,4	12 4002	6,1	17 4000	1,4			*
S 3010-G10Y		X		19 4002	88,7	11 4000	10,6	14 4001	0,4	11 4002	0,3	
S 3010-Y10R		X		19 4002	62,7	13 4002	33,8	17 4000	3,3	14 4001	0,2	
S 3020-B90G		X		19 4002	65,4	13 4003	20,4	11 4002	13,4	16 4000	0,8	
S 3030-G10Y		X		13 4003	56,4	19 4002	28,9	11 4002	14,7			
S 3550-R												**
S 3060-Y90R												**
S 4000-N		X		19 4002	85,0	16 4000	5,5	14 4001	5,0	11 4001	4,5	White Glass *
S 4005-G20Y		X		19 4002	84,4	11 4000	7,7	11 4002	4,1	17 4000	3,8	*
S 4010-B10G		X		19 4002	84,7	14 4001	11,6	11 4002	2,9	12 4002	0,7	*
S 4020-B70G		X		19 4002	45,0	11 4002	30,1	13 4003	21,6	16 4000	3,3	
S 4020-Y80R		X		19 4002	50,4	17 4000	28,5	13 4002	21,1			
S 4040-B30G		X		11 4002	72,9	19 4002	23,3	11 4001	3,8			*
S 4050-R80B		X		12 4002	92,0	19 4002	5,0	14 4001	3,0			White Glass *
S 4500-N		X		19 4002	84,0	14 4001	5,5	11 4001	4,5	16 4000	6,0	White Glass *
S 4550-G10Y		X		11 4001	88,0	11 4000	12,0					
S 4550-R80B												**
S 5005-R50B		X		19 4002	69,0	17 4000	12,0	12 4002	12,0	14 4001	7,0	*
S 5005-R80B		X		19 4002	74,5	17 4000	4,1	12 4002	6,0	14 4001	15,4	*
S 5010-G70Y		X		19 4002	38,2	13 4002	35,3	11 4000	17,4	16 4000	9,1	
S 5020-B70G		X		11 4002	43,0	19 4002	31,8	11 4000	19,4	16 4000	5,8	
S 5020-R90B		X		12 4002	46,7	19 4002	34,8	14 4001	18,5			White Glass
S 5040-G70Y		X		13 4002	76,4	11 4000	18,3	17 4000	6,3			*
S 6010-G30Y		X		13 4003	43,6	14 4001	24,7	19 4002	21,2	11 4001	10,5	
S 6020-B		X		12 4002	51,6	11 4002	13,5	14 4001	16,7	19 4002	18,2	*
S 6030-R												**
S 6030-R70B												**
S 7000 N		X		19 4002	37,7	14 4001	35,3	13 4002	12,5	17 4000	14,5	
S 7020-R												**
S 7500 N		X		14 4001	42,9	19 4002	28,2	17 4000	15,3	11 4000	13,6	
S 8000-N		X		14 4001	49,6	16 4000	27,4	11 4000	11,7	19 4002	11,4	
S 8005-G20Y		X		14 4001	56,8	11 4000	39,5	17 4000	3,7			*
S 8010-R10B												**
S 8502-R		X		15 4000	50,0	14 4001	50,0					

\* approximate match

\*\* not possible to create a good match

## Basic Properties of the Systems

### 1. Thermal Expansion Coefficient

Linear coefficient of thermal expansion for each of our systems is in the range  $80-95 \cdot 10^{-7} \text{K}^{-1}$  (50 - 300 °C), dependant on factors such as pigment type and content.

The expansion of all our flat glass systems is designed to provide a good fit with the properties of float glass. If applied onto glass with low thermal expansion coefficients ( $< 60 \cdot 10^{-7} \text{K}^{-1}$ ), the colors will tend to crack.

### 2. Firing Temperature

Our colors are specially formulated for typical glass tempering cycles, with furnace temperatures set at 650 - 720 °C and with a total cycle time of 40 secs. per mm. of glass thickness.

This results in typical glass temperatures of 600 - 660 °C.

Typically for lead-frees, furnace temperatures are set at 670 - 710 °C (glass temps. 620 - 660 °C), whereas for lead-containing, set temperatures are more typically 650 - 720 °C (glass temps. 600 - 660 °C).

An oxidising atmosphere is recommended.

The colors are glossy after firing and resistant to the usual atmospheric conditions.

Under typical glass tempering cycles – fast heating and high temperatures for a short time – dense and glossy color surfaces are obtained.

However, if the firing is too fast, gas bubbles and pinholes may appear in the fired color surface. This will result in paler shades and the surface will become less scratch resistant and less durable.

To eliminate this defect, principally there are the following possibilities:

- Improve the drying of the enamel layer before firing, to optimise medium burn-off
- Increase the heat work during firing (increase firing temperature and/or the fire time)
- Reduce the firing temperature of the glass enamels with addition of transparent flux

### 3. Chemical, Weathering and Mechanical Durability

There are many tests available to judge the chemical and mechanical resistance of glass enamels and their evaluation and interpretation is a very complex issue.

The test results will depend, not only on the chemical formulation of the enamel, but also on the type of glass, the layer thickness of the enamel and the firing cycle used. The type and Concentration of the chemical agent used to simulate the effect of the environmental attack will of course also significantly effect the degree of resistance observed.

The International flat glass market has adopted a series of standardised tests to qualify and quantify the atmospheric attack on fired ceramic enamel systems.

Following these standards, representative selections of our colors from each basic system have been subjected to the following tests:

To evaluate weathering resistance, the following tests have been done:

- Weathering test according to ANSI Z.26.1 test 16 [literature ref.1]
- Condensation water test atmospheres, as DIN 50017 (increased temp. of 52 °C) [2]
- Temperature change test, -40 °C to +90 °C, 5 cycles
- Moist air sulphur dioxide 'Kesternich Test', to ISO 6988 (DIN 50018 – SFW 2,0S) [3]
- Abrasion resistance test, according ANSI Z 26.1 test 17 and test 18 [4,9,10]
- Water leachability, as per DIN 38 414 Part 4 [5]
- 10% citric acid test, ASTM C724-91 [12,13]
- 3.5% HCl test, ASTM C724-91 [12,13]
- Sulphide resistance test – Na<sub>2</sub>S in acetic acid, ASTM C777-93
- 0.1N H<sub>2</sub>SO<sub>4</sub>, 2hrs [12,13]
- 0.1N NaOH, 2hrs [14]

To evaluate mechanical resistance, especially relevant for spandrel glass panels:

- Mechanical strength according to DIN 18516, Part 4 [6]
- Bending test as per DIN 52 292, part 1 [7]
- Ball drop test, to DIN 52 338 [8]

#### • **Weathering and Mechanical Resistance Test Data**

Results from Intermixable System 140 are shown in the attached tables.

Summarising the chemical tests, a slight visual attack is evident on the enamel side of the glass for both leaded and lead-free systems. However, this does not classify the colors as 'non-resistant'.

When evaluating the colors through the glass, which corresponds to the standard exposure e.g. for tempered spandrel panels, all of the tested colors from our systems are fully resistant.

The resistance data indicated in this brochure is intended as a guide only, and we always recommend checking in customer's specific conditions of application and firing, prior to use.

Glass enamels with a rough surface (e.g. metallic colors) are more vulnerable to dirt and difficult to clean. However, the metallic colors included in System 140 can typically be cleaned with solvents, after exposure to dirt.

For domestic appliance glass, furniture glass and glass for general internal use, glass decorated on either Surface 1 or 2 can generally be used.

However, we do not typically recommend the use of System 140 decorated glass for outside use, where the glass enamel is exposed directly on the external surface.

For these first surface (Surface 1) architectural applications, we have specially developed our *s/de ONE* range.

We recommend checking with our technical experts for specific advice on application and use. Refer also Appendix 1 – Test Procedures

+ = no attack; o = some attack; - = not resistant

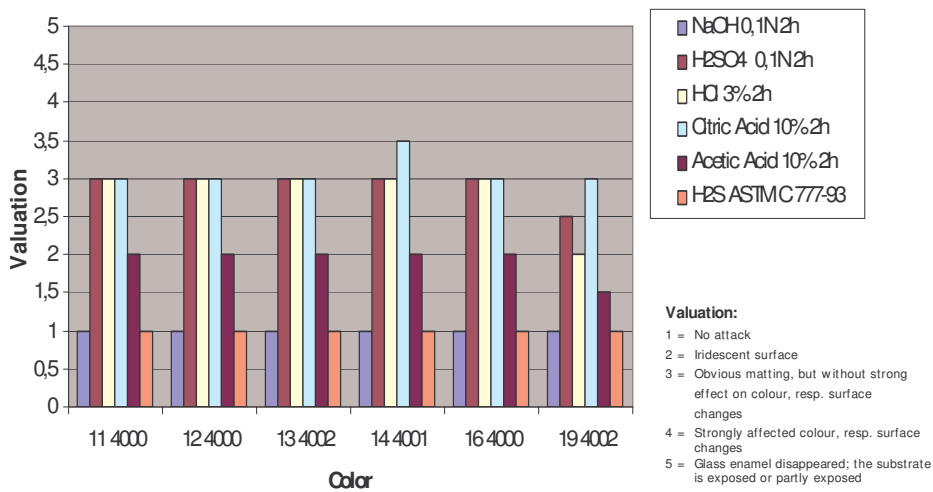
Test and Standard	Purpose	System 140 result
Condensation Water Test. DIN 50017 KK	Resistance to humidity /corrosion. High temp. (52 °C) used c.f. standard DIN 50017	<b>Evaluation through glass:</b> +: 114000,124000, 134002,144001, 174000, 194002, 194011, 194020, 154030, 154000 o : ----- - : ----- <b>Evaluation on enamel:</b> +: 154000, 144001,154030, 194020 o : 114000, 124000, 134002, 174000, 194002, 194011 - : -----
Weathering Test. ANSI Z26.1 Test 16	UV-Radiation exposure with temp. change, by Xenon-lamp Illumination	<b>Evaluation through glass:</b> +:114000, 134002,144001, 174000, 194002, 194011, 194020, 154030 o : ----- - : ----- <b>Evaluation on enamel:</b> +: 154030, 194020 o : 114000, 144001, 134002, 174000, 194002, 194011 - : -----
Temperature Change Test	Exposure to extremes of temp. change	<b>Evaluation through glass:</b> +: 114000, 134002,144001, 174000, 194002, 194011, 194020, 154030 o : ----- - : ----- <b>Evaluation on enamel:</b> +: 114000, 134002,144001, 174000, 194002, 194011, 194020, 154030 o : ----- - : -----
Taber Abrasion Test ANSI Z26.1 Test 17,18; DIN 53 754	Resistance to abrasion	The fired enamel layer is extremely abrasion resistant; rollers selected for this test simulate the durability against motor vehicle or pedestrian traffic. For architectural application, the durability is guaranteed for the air-side of the glass
Bending Strength DIN 18 516,4 DIN 52 292,1 DIN 52 303,1	Glass Breakage analysis	DIN 18 516 specifies a bending strength for decorated tempered glass of min. 75N/mm <sup>2</sup> Typical test result as per DIN 52 292, part 1: 144001=117, 174000=121, 194002=123 194020=147N/mm <sup>2</sup> Typical result as per DIN 52 303, part1: 144001=125Mpa, 154000=127MPa
Ball Drop Test DIN 52 338	Impact Resistance	Typical test result according DIN 52 238: 144001=84.6cm (min. value as per norm DIN 52 238=60cm.)

Test and Standard	Purpose	System 140 result
Chemical Durability – appliance/ furniture glass DIN 12 166	Resistance to acids and alkalis in commercial cleaners	10% citric acid, 2 hrs, 20 °C – attack scale 2.5-3.5 3% HCl, 2hrs, 20 °C – attack scale 2-3 0.1N H <sub>2</sub> SO <sub>4</sub> , 2hrs, 20 °C – attack scale 2.5-3 0.1N NaOH, 2hrs, 20 °C – attack scale 2.5-5
Sulphide Resistance ASTM C777-93	Resistance To attack by H <sub>2</sub> S atmosphere	All colors from the standard range have been evaluated and show no visible sign of attack
Leachability by water DIN 38 414 S4	Potential to pollute/ effects of exposure when stored	The following elements have been analysed: Pb, Cd, Cr, Fe, Cu, Ni, Zn, V, Mo, Co, Ba, Sn.  Result : < 0.1mg/l

- **Chemical Durability Test Data**

Results from the Intermixable System 140 are shown in the below table. Tests were made to evaluate the resistance of this System to alkali, sulphide and acids – hydrochloric, sulphuric, acetic and citric. In all case, the chemical durability was measured at level 3 or better, at least as good as leaded products for flat glass.

### Chemical Resistance



## Methods of Use & Recommendations

Our colors from all systems are developed and controlled for the following application processes:

- Direct screen printing
- Roller coating
- Curtain-coating
- Spraying

### 1. Availability

Colors are available either as powders or ready prepared in a medium suitable for one of the above application processes. Mediums suitable for all applications can also be provided separately (see mediums section).

### 2. Storage and Shelf Life

Color powders must be stored in dry conditions, in sealed tins. 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 12 months after the production date.

### 3. General Processing Conditions

The viscosity of the enamel pastes is strongly influenced by the ambient temperature in the processing shop and therefore the paste temperature itself. Any change in paste viscosity will effect the applied thickness which in turn influences color opacity and color shade.

To ensure prints of consistent quality, opacity and color shade, it is recommended to control the ambient temperature of the printing room and to maintain the printing machine parameters as constant as possible.

### 4. Screen Printing Pastes

For mixing with our color powders, we recommend our screen printing mediums 80 392, 80 1022, 80 1026, 80 858 or 80 840 (see also Mediums section). Recommended mixing ratio is 100 parts by weight of color powder : 30 - 45 parts of medium, followed by triple roll milling. If necessary, pastes can be thinned by adding the relevant oil, and stirring, to the required printing viscosity.

Alternatively, screen-printing pastes can be supplied ready prepared in either oil-based or water-mixable medium systems. Typical dispersions of our pastes are <20 microns.

Our pastes are supplied as a concentrate with a high viscosity; pastes should be let down with our recommended medium or thinner, to reach the printing viscosity required for the particular glass part or job. For direct screen printing on flat glass, mesh sizes from 36 T to 90 T are widely used with our products.

Due to the required thin layers required for the decoration of white imitation etch, we recommend etch application by screen printing. The best effects and surface quality are achieved using a 90 T screen. If coarser screens are used – e.g. 48 T (or coarser), noticeable differences in color shade can occur due to the increased layer thickness.

## 5. Spraying

For this application, powders should be dispersed in a liquid medium and it is important to create good wetting of the particles without additional grinding. High speed mixers are recommended, followed by fine sieving and then adjustment to the required spray viscosity with water.

We recommend the following spray compositions for lead-frees:

100 parts powder color: 42.5 parts de-mineralised water: 6.5 parts spray medium 80 1023.

If further needed, the spray suspensions can be thinned with water to the required viscosity.

We typically recommend a spray viscosity of 20 - 30 secs as measured with Ford No.4 cup, dependant on application and use.

Wet spray colors can also be supplied ready prepared in water-based medium.

## 6. Roller-coating

The most common machines used are the Bürkle and Giardina machines and we have created color systems suitable for each type, which we normally supply ready prepared.

The structuring roller of the Burkle / Giardina machine produces an even color application with low groove structure. The layer thickness is determined by the structure of the application roller. The machines can be used continuously by pumping color paste to the application roller.

### • Roller Coating Application by Burkle and Giardina Machines

Application	Roller Coater
<p><b><u>Technique</u></b></p> <p>Type of Roller</p> <p>Direction of application</p> <p>Filling amount</p> <p>Filling</p>	<p>Various structured rolls</p> <p>Regular – same direction as glass transport Dependant on the width of the roll c.2 - 10 kg color paste; In continuous mode c. 40 kg</p> <p>Manual or by pump</p>
<p><b><u>Handling</u></b></p> <p>Cleaning</p> <p>Time</p>	<p>Manual, with water or automatically by repumping</p> <p>c. 30 mins</p>
<p><b><u>Application</u></b></p> <p>Thickness of the wet color layer</p> <p>Surface</p> <p>Medium options</p> <p>Viscosity Guideline</p>	<p>Dependant on the structure of the application roll, from 30 - 150 <math>\mu</math> – e.g. 16 grades /inch <math>\Rightarrow</math> c. 110 - 130 <math>\mu</math> 48 grades /inch <math>\Rightarrow</math> c. 30 - 35 <math>\mu</math></p> <p>smooth surface, dependant on the color paste viscosity and the structure of the application roll</p> <p><b>lead-free:</b> 80 1022, thinned with 80 868 (for opaque effect) and thinned with 80 1022 or 80 8005 (for translucent)</p> <p>80 - 120 secs at working temperature, measured with 6 mm cup, DIN 53 211</p>

## 7. Curtain Coating

Leaded systems are available either as water-based or oil-based systems; lead-frees are available in water-friendly medium system 80 1029. (See also mediums). If necessary, the dispersion can be adjusted with water to reach the desired application viscosity. It is recommended to stir the systems thoroughly before use.

Optimal mixing ratio for lead-frees is 100 parts powder: 40 parts demin.water: 10 parts medium 80 1029.

When preparing suspensions from our powders, for an ideal removal of agglomerates, the suspension should be sieved directly after preparation using a vibratory sieve (70 µ ideal).

To ensure optimal wetting of the color powder, we recommend that the suspension be allowed to stand for 24 hours before use.

- **Curtain Coating Application Recommendations**

<b>Technique</b>	
Filling amount	70 kg suspension, depending on the width of the casting basin
Filling	Casting basin filled by pump system
<b>Handling</b>	
Cleaning	<ul style="list-style-type: none"> <li>• With water automatically during repumping when using water-mixable system</li> <li>• With thinner 80890 for oil-based system</li> </ul>
Time	c. 20 mins
<b>Application</b>	
Thickness of the wet color layer	Dependant on the opening and the speed of the conveyor belt Avge thickness of the wet layer: 150 - 200 µ; 300 - 400g suspension/m <sup>2</sup>
Surface	Smooth
Medium options	<ul style="list-style-type: none"> <li>• <b>Lead-frees</b> – 80 1029 water-friendly</li> </ul>
Viscosity	35 - 40 secs, at working temperature, measured with a 4 mm cup – DIN 53 211

## 8. Comparison of Application Techniques for Flat Glass Decoration

	Spraying	Screen-printing	Roller-coating	Curtain coating
<b>Enamel quantity</b>	very small amount possible	amount depends on the screen size	depending on the width of the roll, c. 2 - 10 kg	c. 60 - 70 kg for a typical run
<b>Loss of enamel</b>	approx. 30% (recycling of the overspray is possible)	small	depending on the machine, approx. 1 - 2 kg	depending on the machine, c.1 - 2 kg
<b>Surface</b>	even - in thin layers possibly tends to show clouds	even (screen mesh marks visible)	with a structured roll, the structure will be visible	smooth surface
<b>Thickness</b>	variable	depending on the screen and opacity, several printings may be needed	variable – depends on the structure of the application roll	variable
<b>Unwanted decoration of the edge</b>	high, sometimes the reverse side	no, but printing to the edges can be a problem	no	only front edge
<b>Exhaust-system</b>	required	not required	not required	not required
<b>Size</b>	unlimited	depending on the screen size or screen printing machine	depending on the roller size	depending on the length of the casting basin
<b>Cleaning of the tools</b>	simply with water	depending on the screen size, for big screens an automatic cleaning machine is recommended – Depending on the used medium, with either organic solvents or water	simply with water	simply with water
<b>Drying</b>	Air-drying possible	depending on medium used	Dryer required	depending on system

## 9. Recommended test methods to check correct firing of enamels

### Determination of scratch resistance

Reason for testing:	Underfired enamels show a residual porosity, indicated by low scratch resistance.
Test method:	Scratch durability measured with ERICHSEN PENCIL; visual judgement
Target:	Minimum durability is 16N. No damage of enamel surface, no scratch-marks should be visible through the glass.
Standard:	According with ISO 1518

### Gloss measurement

Reason for testing:	Gloss measurement compared to standard enamel indicates if firing process was sufficient.
Test method:	Gloss determination with Reflectometer TRI-Gloss, measuring geometry 60° and 80°
Target:	Keep within specification measured against reference standards.
Standard:	DIN 67 530; AST D 523 – 78, ISO 2813

### Determination of porosity

Reason for testing:	Evidence of no open porosity of the fired enamel. Humidity should not migrate into the enamel layer to attack the sealing.
Test method:	40% Isopropanol/water mixture dropped onto enamel surface.
Target:	Liquid must not soak through the layer. No “wet spot-effect” should be visible through the glass side.
Standard:	No reference

## Decoration Medium Systems

### Ferro's Standard Range

Ferro has developed special medium systems designed for each method of decoration. In particular, due to their differing rheological behaviour compared to leaded systems, we have developed several medium formulations that are specially designed for our new generation lead-free products. For environmental reasons, our R&D efforts are increasingly focussed on user-friendly water-mixable systems.

Our medium systems are divided into 3 main classes:

- **Water-friendly**
  - contains components which can be thinned with water
  - processing equipment can be cleaned with water
  - low odour
- **Water-based**
  - contains water as the main solvent
  - processing equipment can be cleaned with water
- **Oil-based**
  - can neither be diluted nor thinned with water
  - processing equipment cleaned with organic solvent

- **Direct Screen Printing**

Product number	Product Description	Notes
80 1022	Medium <b>water soluble</b>	low odour, slow drying time
80 1026	Medium <b>water soluble</b>	low odour, very slow drying time
80 868	Thinner <b>water soluble</b>	slow drying time
80 890	Thinner <b>water soluble</b>	medium drying time
80 858	Medium <b>water soluble</b>	low odour, very slow drying time
80 840	Medium <b>water soluble</b>	low odour, medium drying time
80 392	Medium <b>oil based</b>	medium drying time
80 064	Thinner <b>oil based</b>	slow drying time

Top 4 Lines are our standard products used for screenprinting.

We have a wide range of suitable screen-print medium systems for IR drying for application on flat glass. More detailed information is available on request.

- **Roller Coating**

Product number	Product Description	Notes
80 1022	Medium <b>water soluble</b>	low odour, slow drying time
80 1026	Medium <b>water soluble</b>	low odour, very slow drying time
80 868	Thinner <b>water soluble</b>	slow drying time
80 8005	Thinner <b>water soluble</b>	slow drying time, smooth surface

- **Spray Application**

Product number	Product designation	Notes
80 1023	Spraying Medium <b>water based</b> + water	colour preparation with medium and water by using a high speed stirrer  the suspension has to be sieved and adjusted to the required viscosity with water.

- **Curtain Coating**

Product number	Product designation	Notes
80 1029	Slip coating medium <b>water based</b>	colour preparation with a pearl mill or with a high speed stirrer  - dilute with water.

Oil-based and Water-friendly-systems need to be triple-roll milled.  
Water-based systems can be prepared by high-speed mixing, or pearl milling.

# Appendix 1: Weathering Resistance of Ceramic Glass Colors – Test Procedures

## Condensation water test atmospheres

### **Purpose and range of application:**

The test of the specimen is being carried out in a condensation cabinet with a constant atmosphere. The tests are designed to see the behaviour of the samples in humid ambient atmospheres and to pinpoint any defects of the protection of the specimen against corrosion. The exposure under these conditions does not allow to evaluate directly over the life circle of the tested pieces under real conditions [2].

### **Test conditions:**

Condensation water test atmospheres promote the condensation of atmospheric humidity on the surface of the specimen of which the temperatures are lower than the temperature of the saturated air in the test room due to the radiation onto the chamber walls or to the cooling of the sample.

The air temperature of the test room reads 52°C in contrast to the standard (DIN 50 017 = 40°C).

The relative humidity of the air in the test room is approx. 100 % covering the samples.

The period of exposure is 21 days with intermediate evaluations after 7 and 14 days.

### *Climatic testing procedure:*

The humidity of the air is achieved by a floor trough which is heated and filled with clean water (distilled or de-ionised water). The test room is tempered by heating the water in the floor trough. To avoid evaporation the water temperature should not exceed 60 °C.

The climatic chamber shall work at an environmental temperature of 18 °C to 28 °C and a relative atmospheric humidity of up to max. 75 %. For comparative investigations the ambient temperature in the installation room should amount to the standard temperature of  $(23 \pm 2)$  °C according to DIN 50 013. A reduction of the ambient temperature leads to an increase in the amount of condensation water.

For an intermediate evaluation the samples will be taken out of the climatic chamber without disconnecting the heating and will be incorporated immediately after evaluation.

## Weathering test

### **Purpose and range of application:**

The weathering test according to ANSI Z 26.1 Test 16 simulates the exposure on the specimen by radiation, temperature and the change of temperatures [1].

### **Procedure / test conditions:**

The exposure on the specimen is done in an enclosed testing apparatus. The period of the test is 1000 hours with an intermediate evaluation after 500 hours. The apparatus shall be operated 5 days of each week according to a schedule consisting of ten 2-hour-cycles (20 hours) per day. Each 2-hour-cycle shall be divided into periods during which the test panel shall be exposed to light without water spray for 102 minutes and to light with water spray for 18 minutes. The test panels shall remain undisturbed in the apparatus during the 2 days when the apparatus is not operating.

The radiation of the samples is made by a Xenon-lamp with an intensity of 0,35 W/m<sup>2</sup> at a wave length of 340 nm.

The temperature within the apparatus shall be controlled by the circulation of sufficient air to produce a black panel temperature of 60°C to 66°C (145°F ± 5°F) when measured by a standard black painted panel with a suitable thermometer embedded in the surface. This panel shall be mounted in the test panel rack and readings shall be taken in a position where the water spray is not striking the panel and at the point where maximum heat is developed due to light exposure.

The water shall strike the test panels in the form of a fine spray under a pressure of 172 - 207 kPa (25 - 30 psi) at the nozzle, and in sufficient volume to wet the panel immediately upon impact.

The water has to be absolutely free of impurities. The pH-value of the water shall be between 6.0 and 8.0. The temperature of the water entering the nozzle shall be between 10°C and 21°C (60°F ± 10°F).

## Temperature change test

### **Purpose and range of application:**

This test exposes the specimen by extreme differences of temperature. By this the normal exposure due to the change of temperature under normal circumstances over a longer period is simulated in a short period of time.

### **Procedure / test conditions:**

The specimen are being submitted to 5 cycles of exposure. The change of temperature per cycle is between -40 °C and +90 °C at a speed of the change in temperature of 1 K/min. The extreme temperatures (-40 °C and +90 °C) are maintained for approx. 10 hours.

## Abrasion Resistance tests

### **Purpose and range of application:**

The purpose of this test is to determine whether the surface has a certain minimum resistance to abrasion. The abrasion is the unwanted change of surface due to dissolving of small particles by mechanical exposure. The taber abraser test is a world-wide recognised method to test the durability which is described in ANSI Z26.1 test 17 and test 18 aswell in DIN 53 754 [9, 10].

### **Procedure / test conditions:**

The specimen is located on a facing abrading rotating wheel. On this wheel two abrasion rolls are fixed staggered on the side to the rotation diameter. It results a cross shear on a circuit which produces a defined abrasion. For the inspection of plastic surfaces rubberrolls with special abrasion disks are mainly used (DIN 53 754). However the herewith achieved abrasion is not sufficient for the judgement of glass enamel surfaces. Nevertheless there are some abrasion roll types available which can be used for the simulation of different practical exposure.

However, the trials for the abrasion resistance test with the taber abraser show that the exposure to select should be much higher than for non treated floatglass as the fired enamel layer is extremely abrasion resistant. In order to enable us to make a selection between the glass enamels the tests have to be done with strongly abrasive ceramic friction rollers H18 or with resilient rollers CS-17 at 1000 p exposure. The CS-17 elastic rollers simulate the durability on the motorway or by pedestrians. They show the highest abrasion effect of all resilient rolls. The usage of H18 rollers is only possible with absolutely flat samples and simulates a rough intensive abrasion.

While using the glass enamels for architectural glass with a decorative character this durability test will not be necessary. For the expected application it can be already stated after the first trials that the durability is guaranteed in any case.

## Determination of Bending Strength

### **Purpose and range of application:**

In DIN 18 516 part 4 it is determined that for spandrel panels, tempered security glass with special technological properties has to be used. The coating of the surface of the glass e. g. by enamels for the alteration of the technological properties of the glass is explicitly allowed. DIN 18 516 stipulates for toughened glass decorated with glass enamels a bending strength of at least 75 N/mm<sup>2</sup> if the decoration is directly on the glass surface and the tensile stress field (pressure area). The bending strength is the applied tensile stress which leads to breakage of the glass [6].

According to DIN 18 516 part 4 the bending strength of tempered security glass has to be found according to DIN 52 303 part 1. During this bending test according to the four knife-edge principle (DIN 52303, part 1) also the edges of the sample are subject to maximum exposure. Due to the frequently occurring very small damages of the edges this test often causes breakages which comes from the edge. The evaluation of the bending strength according to DIN 52 303 part 1 provides us as a result a value which describes the technological property of the tested glass as a whole. The quality of the edges and of the decorated glass colour have an influence on the result [12].

The coaxial double ring bending test according to DIN 52 292 part 1 serves us among others for the determination of the bending strength of any technically existing glasses with any existing surfaces in form of flat sheets. The coaxial double ring bending test according to DIN 52 292 part 1 is so special because just a circular limited piece of the glass sample is subject to maximum exposure but not the edges of the glass. DIN 52 292 part 1 is therefore adequate for the evaluation of the influence of the glass surface, respectively of the decorated glass colour, on the bending strength of the tempered security glass excluding any influences of damaged edges [7].

**Procedure / test conditions:**

A circular or square plane-parallel specimen resting on a support ring ( $r_2$ ) shall be loaded via a load ring ( $r_1$  with  $r_1 < r_2$ ) arranged concentrically relative to the support ring. For limited loads there is in the central region of the convexly bent sample a tensile stress field extending in all directions and adequately uniform for test purposes, the area of this field being bounded by the load ring.

Outside the load ring the radial and tangential stress in the sample decreases towards the edge so that there the risk of failure is small. By increasing the load, the tensile stress in the middle of the sample is raised at a constant rate until failure occurs the expected point of the failure being the most severely stressed surface region below the load ring.

For the evaluation should be considered only the samples for which the point of failure lies in the region bounded by the load ring contact circle. In order to determine the failure location the sample will be covered with an adhesive film on the side facing the load ring. At least 10 samples of a kind suitable for evaluation shall be taken.

Mean values of the bending strength of samples of similar type, determined as described in DIN 52 303 Part 1 are likely to be lower by a factor of 1.1 to 2.4. This is partly due to the size of the area and partly to a different type of loading (biaxial stressing in the coaxial double ring bending test uniaxial stressing when testing as specified in DIN 52 303 Part 1). For comparing the two methods, it is also necessary in the statistical evaluation to eliminate the fractures frequently originating from the edge when the test as specified in DIN 52 303 Part 1 is carried out [11].

### Sulphur dioxide test with general condensation of moisture, Kesternich test

**Purpose and range of application:**

The Kesternich test is a corrosion test. Moist air containing sulphur dioxide quickly produces easily visible corrosion of many metals in a form of resembling that occurring in industrial environments. This norm specifies a method for assessing the resistance of glass enamels to condensed moisture containing sulphur dioxide [3].

**Procedure / test conditions:**

Test cabinets of a preferred capacity  $300 \pm 10$  litre with a door capable of being closed hermetically are used. The specimens are placed in the cabinet. The distance between the specimens shall be not less than 20 mm, the distance between the specimens and the walls or roof of the test cabinet shall not be less than 100 mm. The distance between the lower edges of the samples and the surface of the water in the base of the test cabinet shall not be less than 200 mm. Arrange the specimen so that any moisture condensing on any of them or on their support does not fall onto other specimen placed at lower levels. Introduce  $2 \pm 0,2$  litres of distilled water having a conductivity of  $500 \mu\text{S/m}$  or less, into the base of the test cabinet. Introduce 2,0 litres of sulphur dioxide into the test cabinet through the inlet pipe in contrast to the standard (ISO 6988 0,2 litres sulphur dioxide). Raise the temperature on the heater to  $40 \pm 3 \text{ }^\circ\text{C}$  in about 1,5 hours. Maintain heating under control, so as to keep the temperature inside the test cabinet at  $40 \pm 3 \text{ }^\circ\text{C}$  for the specified period of 24 hours. One test cycle is 24 hours. The test lasts 10 cycles. For a test of continuous exposure in the test cabinet for longer than 24 hours, replace the water and the sulphur dioxide after each 24 hours period of test with minimum disturbance to the test samples.

The evaluation of the results is done by visual assessment of the samples after exposure through the glass and directly onto the glass enamel.

## Determination of leachability by water

### **Purpose and range of application:**

Determination of decorated glasses by type and mass is intended to provide information as to what adverse effects or risks to rivers and lakes can occur when the glasses are stored or dumped in such a manner that they may come into contact with water. The method can however produce values that cannot be obtained under conditions of dumping or only over long intervals of time. The harm caused by the decorated glass dumped, or intended to be dumped, cannot be determined solely on the basis of analytical values of the eluate [5].

### **Procedure / test conditions:**

The specimens are leached with water under defined conditions. Then the undissolved components are separated by filtration. The concentrations of the components to be determined are then measured in the same filtrate using the methods of water analysis. Normally the decorated glasses have to be analysed in the state in which they are dumped. Therefore the decorated glass will be examined in broken form. The weight of the samples is 100 grs. The leaching time shall be 24 hours at room temperature. Eluate the specimen with 1 litre of water by diluting the sample in a closeable flask and shake it during the eluation time so that the sample remains constantly in motion. After the leaching period has elapsed separate the undissolved residue by filtration or centrifugation. Measure the pH-value and the electrical conductivity of the filtrate or centrifugate.

## Chemical Durability

### **Purpose and range of application:**

Chemical durability tests differ between the acid and alkaline resistance.

Acid resistance follows work instructions QS-AA / KF-GSAT 016 / 000 of Ferro. The test methods follow the example of DIN 12 116 and DIN EN 122. This test specifies a method for assessing the durability of the glass enamel against several acids which are used in commercial cleaners [12,13].

Alkaline resistance follows work instructions QS-AA / KF-GSAT 040 / 000 of Ferro. The test methods follow the example of DIN 51 035 and DIN EN 122. This test specifies a method for assessing the durability of the glass enamel against soda based commercial cleaners [14].

### **Procedure / test conditions:**

Acid resistance - The sample is exposed during 2 hours at room temperature with the following acids:

- a) 10 weight % citric acid in demineralized water
- b) 3 weight % hydrochloric acid in demineralized water
- c) 0,1 N sulphuric acid

Alkaline resistance - The sample is exposed during 2 hours with 0.1 N soda base.

The evaluation of the test results is done by visual assessment of the exposed colour layer in comparison to the untreated colour layer. As a result the following classification is done:

- 5 glass enamel disappeared, the glass substrate is exposed or partly exposed
- 4 strongly affected colour resp. surface changes, not scratch resistant
- 3 obvious matting without strong effect on colour resp. surface changes
- 2 Iridescent surface or just noticeable loss of gloss
- 1 no attack

## Sulphide Resistance Test Method

### **Purpose and range of application:**

ASTM C777-93 is designed to simulate the attack by a hydrogen sulphide atmosphere

### **Procedure / test conditions:**

According with ASTM C777-93, test results are determined by visual observation.

## Ball drop test on glass

### **Purpose and range of application:**

The ball drop test specified in this standard serves to test the behaviour of toughened glass under impact of a hard object of small compact mass.

### **Procedure / test conditions:**

The specimen is fixed into a hold-release device. The sample size is 600 x 600 mm with a thickness of 8 mm. In the centre of the sample a square area of 200 x 200 mm is fully decorated with a glass enamel. The impact ball is made of roller bearing steel in a diameter of 63,50 mm and a weight of about 1030 grs. The drop height is the distance between bottom edge of the impact ball and top surface of the sample. The impactor hold-release device is a device for holding and releasing the impactor which allows setting the drop height to 5 m within the required tolerance. It does not impart any momentum to the impactor when dropped, so that the latter is only accelerated by the force of the gravity and drops perpendicular. The test temperature shall be  $23 \pm 2$  °C [8].

As a result it is determined the drop height at which the glass is just not broken under the impact of the ball (1,03 kg). In this norm the minimum value is considered to be 600 mm in average. This represents an impact energy of 6 Nm which is normally not exceeded in buildings.

## Appendix 2:

### Decoration Equipment – Manufacturers' References

#### Screen Printing

- **Thieme GmbH & Co.KG**  
Robert Bosch Strasse 1  
D-79331 Teningen
- **Fleischle Siebdruckmaschinen GmbH**  
Fleiner Str. 5  
D-74336 Brackenheim

#### Roller Coating

- **Maschinenfabrik Bürkle**  
Stuttgarter Str. 123 - 125  
D-72250 Freudenstadt
- **Giardina Officine Aeromeccaniche S.p.A.**  
Via V. Necchi 63  
I-22060 Figino Serenza (CO)

#### Automatic Spraying Machinery

- **BEFRA, Bersch & Fratscher GmbH**  
Seeligenstätter Strasse  
D-63791 Karlstein am Main
- **Venjakob, Maschinenbau GmbH & Co.**  
Augsburger Str. 4 - 6  
D-33353 Rheda-Wiedenbrück
- **Krautzberger GmbH**  
Stockbornstr. 13  
D-65333 Eltville

#### Curtain Coating Machines

- **Maschinenfabrik Bürkle**  
Stuttgarter Str. 6  
D-41334 Nettetal
- **Hymmen GmbH**  
Theodor - Hymmen - Straße 3  
D-33613 Bielefeld

## Appendix 2 ...cont:

### Ancillary Equipment – Manufacturers' References

#### Driers

- **TESOMA GmbH**  
Gottfried-Schenker-Strasse 17  
D-09244 Lichtenau
- **GTB Gesellschaft für  
Trocknung & Beschichtung mbH**  
In den Schafwiesen 19  
D-71720 Oberstenfeld
- **Svecia Siebdruck GmbH**  
Mühlbach 11  
D-90552 Röthenbach / Pegnitz
- **Klöpfer Maschinentechnik GmbH & Co**  
Niedersachsenweg 110  
D-44143 Dortmund

#### Exhaust Systems

- **GWE Lufttechnik**  
Wiechmannsallee 3  
D-27798 Hude

#### Colour Measurement Systems

- **Datacolor AG**  
Brandbachstrasse 10  
CH-8305 Dietlikon / Zurich

#### Sewage Technology

- **Enviro-Chemie GmbH**  
In der Leppsteinswiesen 9  
D- 64380 Rossdorf

## Appendix 3: Literature References

- [1] ANSI Z26.1 - 1990, Test 16: American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Code. Weathering, Test 16. 1990. SAE International
- [2] DIN 50 017: Kondenswasser Prüfklimat. Oktober 1982. Beuth Verlag GmbH, Berlin
- [3] EN ISO 6988 (Ersatz für DIN 50 018 : 1988-06): Metallische und andere anorganische Überzüge. Prüfung mit Schwefeldioxid unter allgemeiner Feuchtigkeitskondensation. 1995-01. Beuth Verlag GmbH, Berlin
- [4] Operating Instructions for Taber Models 5130 & 5150, Digital Abrasers with LED Readouts. Taber Industries, North Tonawanda, NY 14120, 1994
- [5] DIN 38 414, Teil 3: Schlamm und Sedimente (Gruppe S), Bestimmung der Eluierbarkeit mit Wasser (S4). Oktober 1984. Beuth Verlag GmbH, Berlin
- [6] DIN 18 516, Teil 4: Außenwandbekleidung, hinterlüftet. Einscheiben Sicherheitsglas. Anforderung, Bemessung, Prüfung. Feb. 1990. Beuth Verlag GmbH, Berlin
- [7] DIN 52 292, Teil 1: Bestimmung der Biegefestigkeit. Doppelringbiegeversuch an plattenförmigen Proben mit kleinen Prüfflächen, April 1984. Beuth Verlag GmbH, Berlin
- [8] DIN 52 338: Kugelfallversuch an Glas für bauliche Anlagen. Aug. 1977. Beuth Verlag GmbH, Berlin
- [9] ANSI Z26.1 - 1990, Test 17 und Test 18: American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Code. Abrasion Resistance, Test 17. Abrasion Resistance, Test 18 (Safety Glass). 1990. SAE International
- [10] DIN 53 754: Bestimmung des Abriebs nach dem Reibradverfahren. Jun 1977. Beuth Verlag GmbH, Berlin
- [11] DIN 52 303: Bestimmung der Biegefestigkeit. März 1983. Beuth Verlag GmbH, Berlin
- [12] DIN EN 122: Bestimmung der chemischen Beständigkeit. Glasierte Fliesen und Platten. Okt 1991. Beuth Verlag GmbH, Berlin
- [13] DIN 12 116: Bestimmung der Säurebeständigkeit und Einteilung der Gläser in Säureklassen. Mai 1976. Beuth Verlag GmbH, Berlin
- [14] DIN 51 035: Bestimmung der Resistenz von eingebrannten Aufglasurfarben und Dekoren gegenüber alkalischen Reinigungsmitteln. Beuth Verlag GmbH, Berlin

## The Complete Ferro Package for the Glass World

Ferro offers a full range of products and services for flat and automotive glass, adding value to our customer's final glass products the world over. Our technical service experts and local sales office personnel will be pleased to advise on any aspect of your individual requirements.

### Flat Glass

A full line of intermixable or custom-matched products for all market segments, including building glass, appliance glass and glass furniture.

### Automotive Glass

A comprehensive range of lead-free, cadmium-free black obscuration band systems for:

- **Tempered glass side-lites or back-lites**  
Materials specially formulated to suit all types of glass tempering, ranging from gravity-bend, to DBO4 –type furnaces, to deep-bend processing.  
High opacity systems.  
Anti-stick systems.  
Silver-hiding systems.  
High durability systems.  
Systems designed to satisfy the exacting specifications of the major automobile manufacturers.
- **Laminated glass windshields and side-lites**  
Materials designed for gravity bend and press bend furnaces, which provide high opacity black bands, and anti-stick properties when needed. Also products for Surface 2 application.

### Automotive Silver Pastes

Designed to be fully compatible with our black obscuration pastes, our silver paste line allows us to offer a full package of products for automotive glass producers. We offer several standard silver contents, allowing the user to tailor properties of individual parts. A full line of lead-free silver pastes is now available. Also, check out our latest developments in silver pastes for fine-line printing, which are increasingly adopted by the major car manufacturers.

### Functional Coatings

A whole new range of exciting applications is being created with our easy-printable functional coatings, designed as a flexible, high added value alternative to traditional CVD and PVD processes. Potential applications include building, medical, lighting, optical, solar panels...  
One such coating is our super-hydrophobic LotusEffect to provide clean glass surfaces.  
The coatings are technically sophisticated but easy to apply using normal glass processing equipment.

### LustReflex Decorative Reflective Coatings

LustReflex is an exciting new brand of super-reflective decorative coatings, which are easy to apply by screen printing, also over large print areas, and are highly scratch resistant.  
An enormous variety of decorative, mirror-like coatings can be created using conventional screen-print and tempering operations. They can be overprinted or combined with an additional print on the reverse side of the glass to increase the range of decorative effect possibilities.

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