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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, advertising, internal glass doors and partitions
- **shower screens**....
- **glass furniture** – tabletops, display cabinets....

Global Product Systems

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

Whilst the market trend and our recommendation is toward increasing use of our new generation lead-free systems, our traditional lead-containing types are retained for those applications and markets where lead-free is not yet specified by our customers.

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 - 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.

Lead - Free Guarantees

Our heavy-metal free colors are provided with the following guarantees:

- **Pb+Cd: max. content 600ppm**
- **Chrome VI and mercury are not used in the manufacture of our heavy-metal free glass enamels**
- **System 140 is free of added lead, cadmium and lithium**

Ferro's Decoration Systems for Flat Glass

Lead-free, Cadmium-free, Lithium-free

- **System 140 – Inter-mixable Lead-free Colors, including metallic-effect colors**
- **System 140 Plus – System 140 + cadmium-containing reds**

(System 140 Plus is an extended range, introduced by request for customers specifying bright reds, containing cadmium. Cadmium-containing colors should not be mixed with cadmium-frees.)

Traditional Lead-containing

- **System 2034 – Inter-mixable Lead- and cadmium-containing colors**

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 within the designated Groups (see below), 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.

Mixability and Color Shades

1. System 140 Intermixable Product Range

| Group 1 | Product Reference | Color Shade | |
|------------------------|-------------------|-----------------------|-----------------|
| Opaque colors | 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 4000 | Dark Grey | |
| | 16 4000 | Chocolate Brown | |
| | 17 4000 | Red –brown | |
| | 17 4001 | Orange-red | |
| | 19 4002 | White | |
| | Special colors | 19 4011 | Opaque White |
| Transparent | 10 4001 | Colorless | |
| Group 2 | Product Reference | Color Shade | |
| White Imitation Etch | 19 4020 | Etch – use 90T screen | |
| Metallic effect colors | 13 4030 | Gold | |
| | 15 4030 | Sterling silver | 49T screen |
| | 16 4030 | Bronze | recommended |
| | 17 4030 | Red | for 'metallics' |
| | 19 4030 | Silver | |

System 140 colors are free of added lead, cadmium and lithium.

They are intermixable in all proportions, with the exception of opaque white 19 4011.

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 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 transparency (lower opacity).

Color tone is 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.

• System 140 Recommended Mixtures

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 | 4 mm | 6 mm | 8 mm | P 1 | % | P 2 | % | P 3 | % | P 4 | % | Notes |
|------|------|------|------|---------|-------|---------|-------|---------|-------|---------|----|----------------|
| 1011 | X | | | 13 4002 | 75,00 | 17 4000 | 11,00 | 14 4001 | 1,00 | 19 4002 | 3 | Brown beige |
| 1011 | | X | | 13 4002 | 72,80 | 17 4000 | 17,50 | 11 4000 | 9,70 | | | Brown beige |
| 1013 | | X | | 19 4002 | 98,00 | 17 4000 | 1,00 | 13 4003 | 1,00 | | | Oyster white |
| 1015 | | X | | 17 4000 | 1,00 | 13 4003 | 18,00 | 19 4002 | 81,00 | | | Light ivory |
| 5000 | | X | | 12 4002 | 73,00 | 19 4002 | 15,00 | 17 4000 | 12,00 | | | Violet blue |
| 5001 | X | | | 12 4002 | 50,00 | 12 4000 | 40,00 | 14 4001 | 10,00 | | | Green blue |
| 5005 | X | | | 12 4002 | 90,00 | 12 4000 | 9,00 | 17 4000 | 1,00 | | | Signal blue |
| 5007 | X | | | 19 4002 | 28,00 | 14 4001 | 9,00 | 12 4002 | 63,00 | | | Brilliant blue |
| 5007 | | X | | 12 4002 | 65,00 | 19 4002 | 30,00 | 17 4000 | 5,00 | | | Brilliant blue |
| 5008 | X | | | 12 4002 | 67,00 | 14 4001 | 28,00 | 19 4002 | 5,00 | | | Grey blue |
| 5008 | | X | | 14 4001 | 70,00 | 19 4001 | 15,00 | 12 4002 | 15,00 | | | Grey blue |
| 5009 | X | | | 12 4002 | 48,00 | 12 4000 | 38,00 | 14 4001 | 9,00 | 19 4002 | 5 | Azure blue |
| 5010 | | X | | 12 4002 | 94,00 | 19 4002 | 3,00 | 14 4001 | 3,00 | | | Gentian blue |
| 5010 | | | X | 12 4002 | 93,00 | 14 4001 | 3,00 | 19 4002 | 4,00 | | | Gentian blue |
| 5011 | | | | 12 4002 | 80,00 | 14 4001 | 20,00 | | | | | Steel blue |
| 5012 | X | | | 12 4002 | 70,00 | 19 4002 | 27,00 | 13 4002 | 3,00 | | | Light blue |
| 5014 | | X | | 12 4002 | 57,00 | 19 4002 | 33,00 | 17 4000 | 10,00 | | | Pigeon blue |
| 5017 | X | | | 12 4002 | 55,00 | 12 4000 | 40,00 | 14 4001 | 5,00 | | | Traffic blue |
| 5018 | X | | | 19 4002 | 40,00 | 11 4002 | 50,00 | 13 4003 | 10,00 | | | Turquoise blue |
| 5019 | X | | | 12 4002 | 85,00 | 12 4000 | 10,00 | 14 4001 | 5,00 | | | Capri blue |
| 5020 | | X | | 19 4002 | 49,00 | 14 4001 | 30,00 | 12 4002 | 21,00 | | | Ocean blue |
| 5023 | X | | | 12 4002 | 75,00 | 19 4002 | 20,00 | 17 4000 | 5,00 | | | Distant blue |
| 5024 | X | | | 19 4002 | 76,00 | 12 4002 | 24,00 | | | | | Pastel blue |
| 6000 | | | | 11 4001 | 77,00 | 19 4001 | 11,00 | 12 4000 | 9,00 | 14 4001 | 3, | Patina green |
| 6004 | X | | | 11 4002 | 57,00 | 11 4000 | 22,00 | 14 4001 | 19,00 | | | Blue green |
| 6004 | | X | | 11 4002 | 57,00 | 11 4000 | 23,00 | 14 4001 | 20,00 | | | Blue green |
| 6005 | | X | | 14 4001 | 35,00 | 11 4001 | 45,00 | 11 4000 | 20,00 | | | Moss green |
| 6006 | X | | | 11 4001 | 50,00 | 16 4000 | 30,00 | 14 4001 | 20,00 | | | Grey olive |
| 6007 | X | | | 11 4001 | 60,00 | 14 4001 | 20,00 | 16 4000 | 20,00 | | | Bottle green |

| RAL | 4 mm | 6 mm | 8 mm | P 1 | % | P 2 | % | P 3 | % | P 4 | % | Notes |
|------|------|------|------|---------|-------|---------|-------|---------|-------|---------|-----|------------------|
| 6009 | X | | | 11 4001 | 30,00 | 11 4000 | 25,00 | 14 4001 | 45,00 | | | Fir green |
| 6011 | | X | | 11 4000 | 48,00 | 13 4003 | 45,00 | 14 4001 | 7,00 | | | Reseda green |
| 6012 | X | | | 11 4001 | 30,00 | 11 4000 | 20,00 | 14 4001 | 50,00 | | | Black green |
| 6014 | X | | | 11 4001 | 40,00 | 16 4000 | 40,00 | 14 4001 | 20,00 | | | Yellow olive |
| 6015 | X | | | 11 4001 | 35,00 | 16 4000 | 35,00 | 14 4001 | 30,00 | | | Black olive |
| 6015 | | | X | 11 4001 | 30,00 | 16 4000 | 38,00 | 14 4001 | 26,00 | 11 4002 | 6 | Black olive |
| 6017 | | X | | 11 4000 | 65,00 | 13 4002 | 35,00 | | | | | May green |
| 6018 | X | | | 11 4000 | 50,00 | 13 4003 | 50,00 | | | | | Yellow green |
| 6019 | X | | | 19 4002 | 80,00 | 11 4001 | 12,00 | 13 4003 | 8,00 | | | Pastel green |
| 6019 | | X | | 19 4002 | 80,00 | 11 4001 | 12,00 | 13 4003 | 8,00 | | | Pastel green |
| 6020 | X | | | 11 4000 | 70,00 | 14 4001 | 30,00 | | | | | Chrome green |
| 6022 | X | | | 11 4001 | 35,00 | 16 4000 | 45,00 | 14 4001 | 20,00 | | | Drab Olive |
| 6024 | X | | | 11 4001 | 90,00 | 13 4003 | 10,00 | | | | | Traffic green |
| 6025 | X | | | 13 4003 | 48,00 | 11 4000 | 47,00 | 14 4001 | 5,00 | | | Fern green |
| 6026 | X | | | 11 4002 | 35,00 | 11 4001 | 60,00 | 14 4001 | 5,00 | | | Opal green |
| 6027 | X | | | 19 4002 | 72,00 | 11 4002 | 23,00 | 13 4003 | 5,00 | | | Light green |
| 6029 | | X | | 11 4001 | 100 | | | | | | | Mint green |
| 6032 | X | | | 11 4001 | 100 | | | | | | | Signal green |
| 6033 | X | | | 11 4001 | 50,00 | 19 4002 | 30,00 | 12 4000 | 20,00 | | | Mint turquoise |
| 6034 | X | | | 19 4002 | 76,00 | 11 4002 | 23,00 | 14 4001 | 1,00 | | | Pastel turquoise |
| 6034 | | X | | 19 4002 | 90,00 | 11 4002 | 10,00 | | | | | Pastel turquoise |
| 7000 | X | | | 14 4001 | 20,00 | 19 4002 | 80,00 | | | | | Squirrel grey |
| 7000 | | X | | 19 4002 | 67,00 | 12 4002 | 19,00 | 14 4001 | 7,00 | 17 4000 | 7 | Squirrel grey |
| 7001 | X | | | 19 4002 | 82,00 | 14 4001 | 14,00 | 17 4000 | 2,00 | 12 4002 | 2 | Silver grey |
| 7001 | | X | | 19 4001 | 70,00 | 12 4002 | 13,00 | 14 4001 | 10,00 | 17 4000 | 7 | Silver grey |
| 7003 | | X | | 13 4002 | 39,20 | 19 4002 | 38,30 | 14 4001 | 17,20 | 17 4000 | 5 | Moss grey |
| 7004 | X | | | 19 4002 | 85,00 | 14 4001 | 7,00 | 17 4000 | 5,00 | 12 4002 | 3 | Signal grey |
| 7004 | | X | | 19 4002 | 84,00 | 14 4001 | 10,00 | 17 4000 | 6,00 | | | Signal grey |
| 7005 | | X | | 19 4002 | 55,00 | 14 4001 | 17,00 | 11 4000 | 13,00 | 16 4000 | 15 | Mouse grey |
| 7009 | X | | | 19 4002 | 20,00 | 16 4000 | 35,00 | 11 4001 | 45,00 | | | Green grey |
| 7009 | | X | | 19 4002 | 20,00 | 16 4000 | 34,00 | 11 4001 | 43,00 | 14 4001 | 3,0 | Green grey |
| 7010 | X | | | 14 4001 | 35,00 | 19 4002 | 30,00 | 11 4000 | 15,00 | 16 4000 | 20 | Tarpaulin grey |
| 7011 | X | | | 15 4000 | 100 | | 0,00 | | | | | Iron grey |
| 7012 | X | | | 19 4002 | 50,00 | 14 4001 | 30,00 | 11 4000 | 10,00 | 16 4000 | 10 | Basalt grey |
| 7012 | | X | | 19 4002 | 50,00 | 14 4001 | 35,00 | 16 4000 | 15,00 | | | Basalt grey |
| 7015 | X | | | 14 4001 | 46,00 | 19 4002 | 34,00 | 16 4000 | 20,00 | | | Slate grey |
| 7015 | | X | | 14 4001 | 42,00 | 19 4002 | 35,00 | 16 4000 | 23,00 | | | Slate grey |
| 7016 | X | | | 14 4001 | 80,00 | 19 4002 | 10,00 | 12 4002 | 10,00 | | | Anthracite grey |
| 7016 | | X | | 14 4001 | 75,00 | 19 4002 | 15,00 | 12 4002 | 10,00 | | | Anthracite grey |
| 7021 | | X | | 14 4001 | 90,00 | 19 4002 | 10,00 | | | | | Black grey |
| 7022 | X | | | 11 4001 | 25,00 | 16 4000 | 30,00 | 14 4001 | 20,00 | 19 4002 | 25 | Umbr grey |
| 7023 | | X | | 11 4000 | 15,00 | 16 4000 | 15,00 | 19 4002 | 70,00 | | | Concrete grey |
| 7024 | X | | | 14 4001 | 63,00 | 19 4002 | 22,00 | 12 4002 | 13,00 | 17 4000 | 2,0 | Graphite grey |
| 7026 | X | | | 14 4001 | 75,00 | 19 4002 | 15,00 | 11 4000 | 10,00 | | | Granite grey |

| RAL | 4 mm | 6 mm | 8 mm | P 1 | % | P 2 | % | P 3 | % | P4 | % | Notes |
|------|------|------|------|---------|-------|---------|-------|---------|-------|---------|-----|------------------|
| 7030 | | X | | 19 4002 | 74,00 | 16 4000 | 13,00 | 13 4002 | 9,00 | 14 4001 | 4,0 | Stone grey |
| 7031 | X | | | 14 4001 | 45,00 | 19 4002 | 55,00 | | | | | Blue grey |
| 7032 | | X | | 19 4002 | 84,00 | 13 4002 | 10,00 | 16 4000 | 5,00 | 14 4001 | 1,0 | Pebble grey |
| 7036 | | X | | 19 4002 | 82,00 | 14 4001 | 9,00 | 17 4000 | 9,00 | | | Platinum grey |
| 7037 | | X | | 19 4002 | 70,00 | 14 4001 | 10,00 | 17 4000 | 10,00 | 12 4002 | 10 | Dusty grey |
| 7038 | X | | | 19 4002 | 95,00 | 14 4001 | 2,00 | 16 4000 | 2,00 | 11 4000 | 1,0 | Agate grey |
| 7039 | X | | | 19 4001 | 26,00 | 16 4000 | 40,00 | 11 4001 | 34,00 | | | Quartz grey |
| 7040 | X | | | 19 4002 | 81,00 | 12 4002 | 8,00 | 14 4001 | 5,00 | 17 4000 | 6,0 | Window grey |
| 7040 | | X | | 14 4001 | 7,00 | 19 4002 | 76,00 | 17 4000 | 7,00 | 12 4002 | 10 | Window grey |
| 7042 | X | | | 19 4002 | 85,00 | 14 4001 | 10,00 | 16 4000 | 5,00 | | | Traffic grey A |
| 7043 | X | | | 14 4001 | 30,00 | 19 4002 | 25,00 | 16 4000 | 25,00 | 11 4001 | 20 | Traffic grey B |
| 7044 | X | | | 19 4002 | 96,00 | 16 4000 | 3,00 | 11 4000 | 1,00 | | | Silk grey |
| 7045 | | X | | 19 4002 | 70,00 | 12 4002 | 15,00 | 17 4000 | 10,00 | 14 4001 | 5,0 | Telegrey 1 |
| 7046 | | X | | 19 4002 | 69,00 | 14 4001 | 28,00 | 17 4000 | 3,00 | | | Telegrey 2 |
| 7048 | | X | | 15 4030 | 65,00 | 19 4030 | 20,00 | 16 4030 | 15,00 | | | Pearl mouse grey |
| 8001 | | X | | 13 4002 | 74,20 | 17 4000 | 17,70 | 11 4000 | 8,10 | | | Ochre brown |
| 8002 | X | | | 16 4000 | 50,00 | 13 4003 | 35,00 | 17 4000 | 15,00 | | | Signal brown |
| 8004 | | X | | 17 4000 | 60,00 | 13 4002 | 40,00 | | | | | Copper brown |
| 8011 | | X | | 16 4000 | 82,00 | 17 4000 | 8,00 | 13 4002 | 10,00 | | | Nut brown |
| 8014 | | X | | 16 4000 | 63,00 | 11 4000 | 35,00 | 14 4001 | 2,00 | | | Sepia brown |
| 8016 | X | | | 16 4000 | 100,0 | | | | | | | Mahogany brown |
| 8017 | | | | 16 4000 | 85,00 | 14 4001 | 15,00 | | | | | Chocolate brown |
| 8019 | X | | | 16 4000 | 36,00 | 14 4001 | 54,00 | 11 4001 | 10,00 | | | Grey brown |
| 8019 | | X | | 16 4000 | 45,00 | 14 4001 | 42,00 | 19 4002 | 8,00 | 17 4000 | 5,0 | Grey brown |
| 8025 | X | | | 16 4000 | 48,00 | 13 4003 | 47,00 | 19 4002 | 5,00 | | | Pale brown |
| 9001 | | X | | 19 4002 | 98,00 | 17 4000 | 1,00 | 13 4002 | 1,00 | | | Cream |
| 9003 | | | | 19 4011 | 100,0 | | | | | | | Signal white |
| 9004 | X | | | 14 4001 | 100,0 | | | | | | | Signal black |
| 9006 | X | | | 19 4030 | 96,00 | 14 4001 | 3,00 | 17 4030 | 1,00 | | | White aluminium |
| 9006 | | X | | 19 4030 | 96,00 | 17 4030 | 3,00 | 14 4001 | 1,00 | | | White aluminium |
| 9007 | X | | | 19 4030 | 80,00 | 14 4001 | 12,00 | 17 4030 | 8,00 | | | Grey aluminium |
| 9007 | | | X | 19 4030 | 81,00 | 14 4001 | 11,00 | 17 4030 | 8,00 | | | Grey aluminium |
| 9010 | X | | | 19 4002 | 98,00 | 13 4003 | 2,00 | | | | | Pure white |
| 9011 | | X | | 14 4001 | 96,00 | 19 4002 | 4,00 | | | | | Graphite black |
| 9018 | X | | | 19 4002 | 99,00 | 16 4000 | 0,50 | 14 4001 | 0,50 | | | Papyrus white |

- NCS Shades

| NCS Ref. | 4 mm | 6 mm | 8 mm | P 1 | % | P 2 | % | P 3 | % | P 4 | % |
|-------------|------|------|------|---------|------|---------|------|---------|------|---------|------|
| 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 0510-B30G | | X | | 19 4002 | 89,0 | 11 4002 | 2,00 | | | | |
| S 0530-G30Y | | X | | 19 4002 | 69,3 | 13 4003 | 29,2 | 114002 | 1,5 | | |
| S 1005-R80B | | X | | 19 4002 | 99,0 | 14 4001 | 1,0 | | | | |
| 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 1030-B | | X | | 19 4002 | 90,0 | 12 4002 | 10,0 | | | | |
| S 1505-G10 | | X | | 19 4002 | 96,0 | 16 4000 | 2,0 | 13 4002 | 2,0 | | |
| S 2005-R80B | | X | | 19 4002 | 97,0 | 14 4001 | 3,0 | | | | |
| S 2010-B10G | | X | | 19 4002 | 96,0 | 14 4001 | 3,0 | 12 4000 | 1,0 | | |
| 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 3005-G20Y | | X | | 19 4002 | 92,7 | 11 4000 | 4,7 | 14 4001 | 1,0 | 11 4002 | 0,5 |
| 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 4020-Y80R | | X | | 19 4002 | 50,4 | 17 4000 | 28,5 | 13 4002 | 21,1 | | |
| S 4550-G10Y | | X | | 11 4001 | 88,0 | 11 4000 | 12,0 | | | | |
| S 5005-R50B | | X | | 19 4002 | 69,0 | 17 4000 | 12,0 | 12 4002 | 12,0 | 14 4001 | 7,0 |
| S 5020-B70G | | X | | 11 4002 | 43,0 | 194002 | 31,8 | 11 4000 | 19,4 | 164000 | 5,8 |
| S 6010-G30Y | | X | | 13 4003 | 43,6 | 14 4001 | 24,7 | 19 4002 | 21,2 | 11 4001 | 10,5 |
| S 7000 N | | X | | 19 4002 | 37,7 | 14 4001 | 35,3 | 13 4002 | 12,5 | 17 4000 | 14,5 |
| 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 8502-R | | X | | 15 4000 | 50,0 | 14 4001 | 50,0 | | | | |

2. System 2034 Intermixable Product Range

| Group 1 (Cd/Li-free) | Product Reference | Color Shade | |
|--------------------------|------------------------|-------------------------|--|
| Opaque colors | 11 715 | Dark Green | |
| | 12 714 | Royal Blue | |
| | 12 1016 | Dark Blue (contains Li) | |
| | 13 712 | Yolk | |
| | 14 710 | Black | |
| | 15 710 | Grey | |
| | 15 711 | Grey | |
| | 15 712 | Dark Grey | |
| | 16 712 | Red-Brown | |
| | 16 1153 | Chocolate Brown | |
| | 16 1154 | Light brown | |
| | 19 710 | White | |
| | Special colors | 19 219 | Opaque White (contains Li) – designed for oven doors |
| | | 77 499 | Purple – mixable with white |
| Group 2 (contains Cd/Li) | Product Reference | Color Shade | |
| | 11 711 | Yellow-green | |
| | 12 713 | Dark Blue | |
| | 13 710 | Bright Yellow | |
| | 14 711 | Black | |
| | 16 1155 | Red-brown | |
| | 17 710 | Dark Red | |
| | 17 711 | Orange-red | |
| | 17 715 | Orange-red | |
| | 17 718 | Orange-red | |
| | 19 169 | White | |
| | 19 712 | Mixing white | |
| | White Imitation Etch | 19 760 | Etch – use 90T screen |
| | | 19751 | Etch – use 90T screen |
| | Metallic-effect colors | 13 2160 | Green-gold |
| 15 4030 | | Red-gold | 49T screen |
| 16 4030 | | Silver | recommended |
| 17 4030 | | Bronze | for 'metallics' |
| | 19 4030 | Copper | |

System 2034 has evolved from the harmonisation of our former ranges Collection 34 and System2030; we have selected the best-of-the-best from each of these ranges.

System 2034 colors are split into 2 groups:

- Group 1 = lead containing/ cadmium-free/ lithium-free
- Group 2 = lead-containing/cadmium containing/ lithium containing

Colors within the same Group are intermixable. Exceptions are 11711 yellow-green, 12 713 blue and 16 1155 red brown which are not intermixable in all ratios with the other colors of Group 2.

It is not recommended to mix colors between the 2 Groups, as uncontrollable changes in shade could occur during firing

Color tone is 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.

- System 2034 Recommended Mixtures – RAL Shades**

The mix recommendations for the referenced RAL 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 | P 1 | % | P 2 | % | P 3 | % | P 4 | % | Notes |
|------------|------------|----------|------------|----------|------------|----------|------------|----------|--------------------------------------|
| 1000 | 19 710 | 77,00 | 16 1154 | 13,00 | 13 712 | 10,00 | | 0,00 | |
| 1001 | 19 710 | 65,00 | 13 712 | 26,00 | 16 712 | 9,00 | | 0,00 | |
| 1002 | 19 710 | 63,00 | 16 712 | 8,00 | 13 712 | 29,00 | | 0,00 | |
| 1004 | 13 710 | 96,00 | 17 710 | 4,00 | | 0,00 | | 0,00 | Cd containing |
| 1005 | 16 1154 | 10,00 | 13 712 | 90,00 | | 0,00 | | 0,00 | |
| 1006 | 13 710 | 95,00 | 16 1155 | 5,00 | | 0,00 | | 0,00 | Cd containing |
| 1007 | 13 710 | 95,00 | 16 1155 | 5,00 | | 0,00 | | 0,00 | Cd containing |
| 1013 | 19 219 | 95,00 | 16 1154 | 5,00 | | 0,00 | | 0,00 | |
| 1015 | 19 710 | 90,00 | 16 1154 | 10,00 | | 0,00 | | 0,00 | |
| 1017 | 19 712 | 92,00 | 13 710 | 5,00 | 17 715 | 3,00 | | 0,00 | Cd containing |
| 1018 | 13 712 | 100,00 | | 0,00 | | 0,00 | | 0,00 | standard range 2034 |
| 1021 | 13 710 | 100,00 | | 0,00 | | 0,00 | | 0,00 | standard range 2034 Cd containing |
| 1024 | 13 712 | 60,00 | 16 1154 | 40,00 | | 0,00 | | 0,00 | |
| 1028 | 13 710 | 90,00 | 17 715 | 10,00 | | 0,00 | | 0,00 | Cd containing |
| 1034 | 19 712 | 91,00 | 13 710 | 5,00 | 17 715 | 4,00 | | 0,00 | Cd containing |
| 2000 | 19 712 | 25,00 | 13 710 | 52,50 | 17 715 | 22,50 | | 0,00 | Cd containing |
| 2001 | 17 715 | 75,00 | 13 710 | 25,00 | | 0,00 | | 0,00 | Cd containing |
| 2002 | 17 711 | 100,00 | | 0,00 | | 0,00 | | 0,00 | standard 2034 Cd containing |
| 2003 | 19 712 | 52,00 | 17 715 | 33,00 | 13 710 | 15,00 | | 0,00 | Cd containing |
| 2004 | 17 715 | 75,00 | 13 710 | 25,00 | | 0,00 | | 0,00 | Cd containing |
| 2008 | 19 712 | 52,00 | 17 715 | 32,00 | 13 710 | 16,00 | | 0,00 | Cd containing |
| 2011 | 13 710 | 75,00 | 17 715 | 25,00 | | 0,00 | | 0,00 | Cd containing |
| 3002 | 17 710 | 100,00 | | 0,00 | | 0,00 | | 0,00 | standard range 2034 Cd containing |
| 3003 | 17 710 | 90,00 | 12 713 | 10,00 | | 0,00 | | 0,00 | Cd containing |
| 3005 | 17 710 | 92,00 | 14 711 | 8,00 | | 0,00 | | 0,00 | Cd containing |
| 3009 | 16 1155 | 100,00 | | 0,00 | | 0,00 | | 0,00 | standard range 2034 |
| 3011 | 17 710 | 90,00 | 12 713 | 10,00 | | 0,00 | | 0,00 | Cd containing |
| 3012 | 19 712 | 86,40 | 16 1155 | 9,10 | 13 710 | 4,50 | | 0,00 | Cd containing |
| 3031 | 17 710 | 90,00 | 19 712 | 7,00 | 14 711 | 3,00 | | 0,00 | Cd containing |
| 5000 | 12 1016 | 61,00 | 12 712 | 14,00 | 14 710 | 10,00 | 19 710 | 15,00 | |
| 5002 | 12 713 | 100,00 | | 0,00 | | 0,00 | | 0,00 | standard range 2034 Cd containing |

| RAL | P 1 | % | P 2 | % | P 3 | % | P 4 | % | Notes |
|------|---------|--------|---------|-------|---------|-------|---------|-------|--------------------------------------|
| 5011 | 12 1016 | 80,00 | 14 710 | 20,00 | | 0,00 | | 0,00 | |
| 5012 | 12 714 | 55,00 | 19 710 | 45,00 | | 0,00 | | 0,00 | |
| 5013 | 12 1016 | 90,00 | 14 710 | 10,00 | | 0,00 | | 0,00 | |
| 5014 | 12 1016 | 42,00 | 19 710 | 58,00 | | 0,00 | | 0,00 | |
| 5017 | 12 714 | 95,00 | 13 712 | 5,00 | | 0,00 | | 0,00 | |
| 5018 | 11 715 | 27,00 | 12 714 | 42,00 | 19 710 | 31,00 | | 0,00 | |
| 5019 | 12 714 | 90,00 | 13 712 | 10,00 | | 0,00 | | 0,00 | |
| 5020 | 12 713 | 80,00 | 11 711 | 20,00 | | 0,00 | | 0,00 | Cd containing |
| 5021 | 11 715 | 25,40 | 12 714 | 42,40 | 19 710 | 29,70 | 13 712 | 2,50 | |
| 5022 | 12 1016 | 100,00 | | 0,00 | | 0,00 | | 0,00 | Std. 34 System |
| 5023 | 19 710 | 60,00 | 12 714 | 36,00 | 14 710 | 4,00 | | 0,00 | |
| 6001 | 13 712 | 80,00 | 11 715 | 20,00 | | 0,00 | | 0,00 | |
| 6005 | 11 715 | 70,00 | 12 1016 | 30,00 | | 0,00 | | 0,00 | |
| 6008 | 11 715 | 50,00 | 16 712 | 30,00 | 14 710 | 20,00 | | 0,00 | |
| 6010 | 11 711 | 70,00 | 12 713 | 30,00 | | 0,00 | | 0,00 | Cd containing |
| 6014 | 11 715 | 45,00 | 16 712 | 40,00 | 14 710 | 15,00 | | 0,00 | |
| 6016 | 11 715 | 65,00 | 12 714 | 25,00 | 19 710 | 10,00 | | 0,00 | |
| 6017 | 11 715 | 55,00 | 13 712 | 45,00 | | 0,00 | | 0,00 | |
| 6024 | 11 715 | 70,00 | 19 710 | 30,00 | | 0,00 | | 0,00 | |
| 6033 | 19 710 | 29,40 | 13 712 | 32,30 | 12 714 | 38,30 | | 0,00 | |
| 7000 | 19 710 | 90,00 | 14 710 | 10,00 | | 0,00 | | 0,00 | |
| 7001 | 19 710 | 93,00 | 14 710 | 7,00 | | 0,00 | | 0,00 | |
| 7006 | 16 1154 | 36,00 | 15 710 | 54,00 | 16 712 | 8,00 | 14 710 | 2,00 | |
| 7008 | 16 1154 | 90,00 | 11 715 | 8,00 | 13 712 | 2,00 | | 0,00 | |
| 7011 | 14 710 | 15,00 | 15 710 | 77,00 | 16 712 | 8,00 | | 0,00 | |
| 7012 | 14 710 | 15,00 | 15 710 | 78,00 | 16 712 | 7,00 | | 0,00 | |
| 7015 | 19 710 | 60,00 | 16 1153 | 15,00 | 14 710 | 25,00 | | 0,00 | |
| 7016 | 14 710 | 50,00 | 19 710 | 45,00 | 11 715 | 5,00 | | 0,00 | |
| 7021 | 14 710 | 63,00 | 19 710 | 22,00 | 16 712 | 15,00 | | 0,00 | |
| 7022 | 16 712 | 20,00 | 14 710 | 30,00 | 19 710 | 30,00 | 13 712 | 20,00 | |
| 7023 | 15 710 | 63,40 | 13 712 | 6,30 | 14 710 | 5,00 | 16 1154 | 25,30 | |
| 7024 | 14 710 | 30,00 | 15 712 | 70,00 | | 0,00 | | 0,00 | ev.+5-10 % 16 712 or c.5% 16 1153 |
| 7031 | 15 712 | 100,00 | | | | | | | Std. 34 System |
| 7032 | 19 710 | 75,00 | 16 1154 | 7,00 | 15 710 | 18,00 | | 0,00 | |
| 7035 | 19 710 | 81,00 | 15 710 | 19,00 | | 0,00 | | 0,00 | |
| 7036 | 15 710 | 90,00 | 16 712 | 10,00 | | 0,00 | | 0,00 | |
| 7037 | 15 710 | 89,00 | 14 710 | 4,00 | 16 712 | 7,00 | | 0,00 | |
| 7038 | 15 710 | 80,00 | 19 710 | 20,00 | | 0,00 | | 0,00 | |
| 7042 | 15 710 | 95,00 | 14 710 | 2,00 | 16 712 | 3,00 | | 0,00 | |
| 7043 | 14 710 | 40,00 | 19 710 | 30,00 | 16 1154 | 30,00 | | 0,00 | |

Basic Properties of the Systems

1. Thermal Expansion Coefficient

Linear coefficient of thermal expansion for each of our systems is in the range $80\text{-}95 \cdot 10^{-7} \text{K}^{-1}$ ($50\text{-}300^\circ \text{C}$), 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 $650\text{-}720^\circ \text{C}$ and with a total cycle time of 40 secs. per mm. of glass thickness.

This results in typical glass temperatures of $600\text{-}660^\circ \text{C}$.

Typically for lead-free, furnace temperatures are set at $670\text{-}710^\circ \text{C}$ (glass temps. $620\text{-}660^\circ \text{C}$), and for lead-containing, set temperatures are more typically $650\text{-}720^\circ \text{C}$ (glass temps. $600\text{-}660^\circ \text{C}$).

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 $+90^\circ \text{C}$, 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_2S in acetic acid, ASTM C777-93
- 0.1N H_2SO_4 , 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 Systems 140 and 2034 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 decorated glass for outside use, where the glass enamel is exposed directly on the external surface.

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 | System 2034 result |
|---------------------------------------|--|---|--|
| Condensation Water Test. DIN 50017 KK | Resistance to humidity /corrosion. High temp. (52 °C) used c.f. standard DIN 50017 | Evaluation through glass: +: 114000, 124000, 134002, 144001, 174000, 194002, 194011, 194020, 154030, 154000 o : ----- - : ----- Evaluation on enamel: +: 154000, 144001, 154030, 194020 o : 114000, 124000, 134002, 174000, 194002, 194011 - : ----- | Evaluation through glass: +: 11715, 13710, 121016, 14710, 17710, 19710, 19751, 19760 o : ----- - : ----- Evaluation on enamel: +: 14710, 19751, 19760 o : 11715, 13710, 121016, 17710, 19710 - : ----- |
| Weathering Test. ANSI Z26.1 Test 16 | UV-Radiation exposure with temp. change, by Xenon-lamp illumination | Evaluation through glass: +: 114000, 134002, 144001, 174000, 194002, 194011, 194020, 154030 o : ----- - : ----- Evaluation on enamel: +: 154030, 194020 o : 114000, 144001, 134002, 174000, 194002, 194011 - : ----- | Evaluation through glass: +: 11715, 13710, 121016, 14710, 17710, 19710, 19751, 19760 o : ----- - : ----- Evaluation on enamel: +: 13710, 19751 o : 11715, 121016, 14710, 17710, 19710, 19760 - : ----- |
| Temperature Change Test | Exposure to extremes of temp. change | Evaluation through glass: +: 114000, 134002, 144001, 174000, 194002, 194011, 194020, 154030 o : ----- - : ----- Evaluation on enamel: +: 114000, 134002, 144001, 174000, 194002, 194011, 194020, 154030 o : ----- - : ----- | Evaluation through glass: +: 11715, 13710, 121016, 14710, 17710, 19710, 19751, 19760 o : ----- - : ----- Evaluation on enamel: +: 11715, 13710, 121016, 14710, 17710, 19710, 19751, 19760 o : ----- - : ----- |

| Test and Standard | Purpose | System 140 result | System 2034 result |
|---|--|---|--|
| 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 | 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 ² Typical test result as per DIN 52 292, part 1: 144001=117, 174000=121, 194002=123 194020=147N/mm ² Typical result as per DIN 52 303, part1: 144001=125Mpa, 154000=127MPa | DIN 18 516 specifies a bending strength for decorated tempered glass of min. 75N/mm ² Typical test result as per DIN 52 292, part 1: 14710=141N/mm ² |
| 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.) | |
| Exposure to moist air containing SO ₂ DIN 50018 SFW 2.0S - 'Kesternich' Test | Corrosion Resistance | Independent test laboratory MPA NRW Test Certificate 22 0449 0 97-01/ 04.06.97 Evaluation through glass: +: 134002, 144001, 164000, 194002 o : ----- - : ----- Evaluation on enamel: +: o : 134002, 144001, 164000, 194002 - : ----- Color variation before and after exposure test: 134002 ΔE=0.18, 144001 ΔE=0.08 164000 ΔE=0.11, 194002 ΔE=0.12 | Independent test laboratory MPA NRW Test Certificate 22 0449 0 97-01/ 04.06.97 Evaluation through glass: +: 11711, 13712, 14710, 19712 o : ----- - : ----- Evaluation on enamel: +: 19712, 11711 o : 13712, 14710 - : ----- Color variation before and after exposure test: 11711 ΔE=0.24, 13712 ΔE=0.29 14710 ΔE=0.11, 19712 ΔE=0.31 |
| 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 ₂ SO ₄ , 2hrs, 20 °C – attack scale 2.5-3 0.1N NaOH, 2hrs, 20 °C – attack scale 2.5-5 | 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 ₂ SO ₄ , 2hrs, 20 °C – attack scale 2.5-3.5 0.1N NaOH, 2hrs, 20 °C – attack scale 2.5-5 |
| Sulphide Resistance ASTM C777-93 | Resistance To attack by H ₂ 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 | The following elements have been analysed: Pb, Cd, Cr, Fe, Cu, Ni, Zn, V, Mo, Co, Ba, Sn. Result : < 0.1mg/l |

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 6 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 oils 80392, 801022, 801026, 80858 or 80840 (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 <20microns.

We recommend a printing viscosity of 15-30 Pa.s., dependant on the screen mesh size, with lower viscosity for finer mesh size. For direct screen printing on flat glass, mesh sizes from 36T to 90T 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 90T screen.

If coarser screens are used – e.g. 48T (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 801023.

For lead-containing:

100 parts powder color: 10 parts water: 30 Parts 80520 spray medium: 20 parts methylated spirits.

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 Union Tool and Burkle machines and we have created color systems suitable for each type, which we normally supply ready prepared.

The differences in application technique are summarised here, in particular:

1. The reverse operation of the Union Tool roller-coating machine produces a structured surface of the color layer. The layer thickness is controlled by the proportioning roller.
2. The structuring roller of the Burkle machine produces an even color application with low groove structure. The layer thickness is determined by the structure of the application roller.
3. The Burkle machine can be used continuously by pumping color paste to the application roller.

• Roller Coating Application by Union Tool and Burkle Machines

| Application | Union Tool | Burkle |
|----------------------------------|---|---|
| Technique | | |
| Type of Roller | Flat roll | Various structured rolls |
| Direction of application | Reverse | Regular – same direction as glass transport |
| Filling amount | Dependant on the width of the roll c.2-10kg color paste | Dependant on the width of the roll c.2-10kg color paste; In continuous mode c. 40kg |
| Filling | Manual addition | Manual or by pump |
| Handling | | |
| Cleaning | Manual, with water | Manual, with water or automatically by repumping |
| Time | c. 20mins | c. 30mins |
| Application | | |
| Thickness of the wet color layer | Max. 200 μ | Dependant on the structure of the application roll, from 30-150 μ – e.g. 16 grades /inch \Rightarrow c. 110-130 μ 48 grades /inch \Rightarrow c. 30-35 μ |
| Surface | Structured | smooth surface, dependant on the color paste viscosity and the structure of the application roll |
| Medium options | Leaded: 80858 water-friendly Lead-free: 80 1022 water-friendly | leaded: 80858, thinned with 80868 lead-free: 801022, thinned with 80868 (for opaque effect) and thinned with 801022 (for transparent) |
| Viscosity Guideline | 6 Pa.s. measured with cone and plate at working temperature, d= 200 | 80-120 secs at working temperature, measured with 6mm cup, DIN 53 211 |

7. Curtain Coating

Leaded systems are available either as water-based or oil-based systems; lead-frees are available in water-friendly medium system 801029. (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 801029. 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

| | |
|--|--|
| Technique Filling amount | 70kg suspension, depending on the width of the casting basin |
| Filling | Casting basin filled by pump system |
| Handling Cleaning | <ul style="list-style-type: none"> • With water automatically during repumping when using water-mixable system • With thinner 80890 for oil-based system |
| Time | c. 20 mins |
| Application 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 ² |
| Surface | Smooth |
| Medium options | <ul style="list-style-type: none"> • Lead-frees – 801029 water-friendly • Leaded – MEDIAMIX water-friendly (TOE8803a 90.7%/TOE8804a 9.3%) - oil-based 80960, 80890 thinner |
| Viscosity | 35-40 secs, at working temperature, measured with a 4mm cup – DIN 53 211 |

8. Comparison of Application Techniques for Flat Glass Decoration

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

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 Classification | Lead-free system | Thinner | Leaded system |
|---------------------------------|------------------|---------|---------------|
| Oil-based, medium drying time | 80392 | 80064 | 80392 |
| Oil-based, slow drying | | | 80599 |
| Water-friendly, medium drying | 801022 | } | |
| Water-friendly, slow drying | 801026, 80858 | }80868 | 80858 |
| Water-friendly, medium-fast dry | 80840 | }80890 | 80840 |

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.

• Spray Application

| Product Classification | Lead-free system | Leaded system |
|------------------------|------------------|-----------------------|
| Water-based | 801023 + water | 80520 + meths + water |

• Roller Coating

| Product Classification | Lead-free system | Leaded system |
|------------------------|--|---------------------------------|
| Water-friendly | 801022(medium dry); 80840 801026(slow-dry); 80858 | 80858, thin with 80898 or 80868 |

These systems can also be used for screen printing.
Colors should be prepared by triple-roll milling.

• Curtain Coating

| Product Classification | Lead-free system | Leaded system |
|--------------------------------|---------------------------|--|
| Oil-based, curtain-coat medium | | 80960, dilute with 80890 |
| Water-based medium | 801029, dilute with water | MEDIAMIX – dilute with water TOE8803a 90.7%/ TOE8804a 9.3% |

Oil-based 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 ± 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/m² 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 specimens 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 as well 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 rubber rolls 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 selected should be much higher than for non treated float glass, 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/mm², 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 ± 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 $\mu\text{S}/\text{m}$ 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 ± 3 °C in about 1,5 hours. Maintain heating under control, so as to keep the temperature inside the test cabinet at 40 ± 3 °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 elution 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 Ferro work instructions QS-AA / KF-GSAT 040 / 000. 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:

- 1 glass enamel disappeared, the glass substrate is free or partly free
- 2 strongly affected colour resp. surface changes, not scratch resistant
- 3 obvious matting without strong effect on colour resp. surface changes
- 4 Iridescent surface or just noticeable loss of gloss
- 5 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 ± 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

- **Europa-Siebdruck-Centrum**
Heldmannstr. 30
32108 Bad-Salzuflen, BRD
- **Maschinenbau Gerold GmbH & Co. KG**
Industriestraße 6
41334 Nettetal, BRD
- **Fleischle Siebdruckmaschinen GmbH**
Fleiner Str. 5
74336 Brackenheim, BRD
- **Svecia Siebdruck GmbH**
Mühlbach 11
90552 Röthenbach / Pegnitz, BRD

Roller Coating

- **Maschinenfabrik Bürkle**
Stuttgarter Str. 123 - 125
72250 Freudenstadt, BRD
- **Union Tool Corp.**
P.O. Box 935
Warsaw, IN 46581 - 0935, USA

Automatic Spraying Machinery

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

Curtain Coating Machines

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

Driers

- **Klöpper Maschinenteknik GmbH & Co.**
Niedersachsenweg 110
44143 Dortmund, BRD
- **Svecia Siebdruck GmbH**
Mühlbach 11
90552 Röthenbach / Pegnitz, BRD
- **GTB Gesellschaft für
Trocknung & Beschichtung mbH**
In den Schafwiesen 19
71720 Oberstenfeld
- **TESOMA Textil- und
Sondermaschinen GmbH**
Hauptstraße 2
09238 Auerswalde

Exhaust Systems

- **GWE Lufttechnik**
27798 Hude, BRD

Appendix 3: Literature References

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- [2] DIN 50 017: Kondenswasser Prüfkimate. 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 Feuchtigkeitkondensation. 1995-01. Beuth Verlag GmbH, Berlin
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- [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 eingebraunten Aufglasurfarben und Dekoren gegenüber alkalischen Reinigungsmitteln. Beuth Verlag GmbH, Berlin

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