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Glass Coloration Made Easy: Adding Value to Glass

This article is based on presentation by P.J. Maitland, worldwide marketing manager, Glass, Ferro Corporation, made to the Society of Glass Technology, May, 1999. For more information, contact maitlandp@ferro.com

For years, glass was the preferred material of choice for the packaging industry worldwide. However, metal cans and then plastic and PET bottles eroded the market share traditionally held by glass. Even in the case of the automotive industry, as the market strives to increase fuel efficiency by reducing car weight, plastic windshields are being talked about as a real alternative to glass.

So, ladies and gentlemen, glass is being threatened from every angle, and everyone involved in glass is engaged in the search to add value and to make glass, as a material, more attractive than its competitive products.

In spite of its decline from its position as the number-one packaging material, glass can and does offer advantages to alternative package types, not least being its environmental-friendliness – recyclability – and its ability to cope with the latest waste packaging regulations. The industry has also been responding to the competitive threats, through developments in light-weighting and chemically strengthened glass.

Questions about how glass manufacturers could and should respond to current and future market needs were posed by Raul Hernandez, President of the World Packaging Organization, 1996-98, during his address to the 23rd AFGM Glass Conference in Thailand in October last year.

Among other key questions posed, he asked if "getting a bigger capacity furnace or high-speed forming machine is still consistent with today's niche marketing, where demands may be small and job changes frequent? How is glass challenging plastics' advantages in terms of relatively small volume runs, varied colors and unique shapes? Can glass be as flexible as plastic?"

"In terms of promoting the strengths of glass over other packaging materials, have we been equally assertive in addressing others' campaigns to promote their strengths and benefits? Why have we been silent in educating the market on the inherit packaging attributes of glass, which contribute to make it the ideal packaging?"

Finally, he asked "What can suppliers to the glass industry offer to contribute to unite with efforts to ensure the continuity and growth of this packaging material?"

In my presentation today, I am going to try to address some of the issues raised by Raul Hernandez and offer some possible solutions.

Forehearth Color (FHC) Technology

FHC technology involves the introduction, melting and dispersion of colorants into the forehearth – as opposed to the traditional method in the tank – and is designed to give the glass manufacturer more flexibility and cost effectiveness. Significantly smaller volume runs of colors can be made without prejudicing the economies of scale offered by producing in a large glass tank furnace.

It sounds easy and in principle it is, but the process variables require good control and the colors have to be carefully formulated in order to guarantee success. Compared to tank coloration, forehearth colors must be melted and dispersed in a short time at relatively lower temperatures.

A major technological breakthrough for this process came with Ferro's patented invention of specially formulated forehearth color concentrates (FHCC).

These are bonded mixtures of pigmenting materials and specially formulated glasses which are put together in a Ferro proprietary process to create granules of concentrated color. Significantly, as part of a comprehensive range of color possibilities, the invention of FHCC also allowed for the production of good quality green and green-tone glasses, containing high concentrations of chrome. Prior to this, the refractory nature of chromic oxide had made it very difficult to melt dark green glasses in the forehearth, without the formation of seeds and blisters. When using concentrates, it is also possible to reduce the amount of material added to the glass, which means less disturbance to the chemical and physical properties of the glass.

In addition to pioneering the original FHCC technology, Ferro has refined and developed this technology over many years. Not only has Ferro conducted its own model studies in the laboratory, but it has also worked closely with glass manufacturers, forehearth designers, builders and engineers in order to achieve the finished, high-quality colored products demanded by the market.

What Are the Potential Benefits of FHC Technology?

Production Flexibility: Glass manufacturers can change colors in response to customer demand without incurring the extreme costs of producing short runs of specialized colors in the glass tank.

Increased Productivity & Lower Costs: The high losses, both in glass and machine downtime, incurred during conversion of a large furnace from flint to colored glass and back again are minimized when coloring in the forehearth. The increased production efficiencies so achieved mean lower overall costs.

For example, on a glass tank with three forehearths, only 2.5 to three machine hours are generally lost going into color and no more than six to 10 hours coming out of color. To change the color of the entire tank may require up to 72 hours of downtime

going in and as much as 216 hours coming out of color. The stronger the color, the more severe the "downtime effect."

Lower Energy Costs: To minimize the downtime effect of color changes, some manufacturers have chosen to use small furnaces to produce colored glass. However, energy costs for smaller tanks can be up to double those for a large furnace. Hence, moving colored production back to larger furnaces, combined with coloring in the forehearth, can provide a major cost benefit.

Reduced Inventory: Since smaller lots of colored glassware can be produced as required, there is no need to produce and warehouse large quantities of colored glassware to meet future customer demand.

Lower Shipping Costs: In organizations with multiple plants, all colored glassware may be produced at one site to increase the company's plant efficiencies. Installing a flexible, cost-effective FHC system at each location can reduce or avoid unnecessarily high transportation costs.

The FHC Technology Process

From the hopper, concentrates are delivered in a controlled, measured fashion by way of vibrating conveyors to the feed tube, which then feeds the colorant into the forehearth. Cooling fan air directed through the feed tube prevents the forehearth color from overheating and also serves to help prevent blockage in the tube.

In a colorant system, the forehearth has an additional length, typically of 12 to 20 feet (3.6 to six meters) to allow for feeding, melting and blending of the color. The forehearth is equipped with banks of screw-type stirrers – usually made of zircon-mullite – which are positioned over its superstructure and are configured usually in banks of three or four, dependant on the forehearth design, pull and colors required.

Basic layouts have been determined following extensive laboratory modelling. However, it should be stressed that colorant feeder forehearths are designed to suit customer specifications, and it is very unusual to have two identical designs. Therefore, it is essential to work closely with the glass manufacturers and furnace designers to ensure the layouts are optimized as much as possible for each situation.

Typical colorant forehearth designs and stirrer configurations for a 26-inch (660 mm) and 36-inch (915 mm) channel width, with pulls of 40 tons per day and 100 tons per day respectively, are shown in the attached layouts. The first has four banks of three stirrers in each bank; the second five banks of four stirrers to homogenize the glass color. For pulls less than 40 tons per day, we would recommend three banks of three stirrers, which is our minimum stirring configuration. Stirrer life can be significantly enhanced using a proprietary ACT platinum coating.

Having entered onto the molten glass, the forehearth colors are formulated to melt as quickly as possible to minimize defects in the glass. The typical Ferro design has a shallower glass depth under the feed tube, which keeps the velocity of the glass up and helps to spread the concentrate over the surface of the glass. Stirrers are designed and set up to operate in a lifting thrust, and a screw-type design is recommended.

Introducing a New Forehearth Color

FHC technology is in use today all over the world, created both by converting already existing forehearths as well as installing from new.

When introducing a new colorant, it is critical to evaluate the key variables specific to the plant situation and job at hand. While models can be prepared under laboratory conditions to try to simulate real-world situations, the FHC theory must be confirmed with production trials. Many years of experience in providing FHC solutions, however, have proved to be of considerable benefit in ensuring successful trials. Ferro has built a massive global database, designed to minimize the time taken to prove the trials in plant situations. Not only must we be able to hit the color specifications provided but also to guarantee excellent glass quality.

From experience, these are the key issues:

- **Weigh system design:** The gravimetric method is preferred to volumetric, due to its accuracy and reliability; this system also generates less dust, and it is possible to position the weigh unit away from the forehearth in a more friendly environment. It is recommended to pulse small weights at frequent intervals to achieve the required feedrate.
- **Forehearth design:** Channel width; glass depth in the different zones; length of the preheat, melting and stirrer zones; forehearth shape.
- **Base glass analysis:** Batch composition; glass redox state.

- **FHCC formulation:** Customized to take account of the client's specific base glass, to give maximum chance to melt and degas and hence minimize the possibilities of seeds and blisters in the glass.
- Single ready-to-use (RTU) FHC or a blend of different color formulations.
- Position of feed entry and cooling air to spread FHC evenly over as wide an area as possible.
- **Pull rate:** Can be as low as four, as high as 120 tons per day.
- **Feed rate:** Typically from 0.2 up to 3%, depending on the application and type of product. Check consistent flow into the forehearth.
- Glass temperatures at feeding point, entry into and exit from stirrer section; typically from 1300 to 1220°C.
- Stirrer flight design and size.
- Stirrer configuration, total number, their position, distance between each other and the side walls, distance between banks and direction of rotation.
- Stirrer speed at each bank.

Careful formulation of the FHC, in conjunction with the other parameters, is essential to provide good melting and dispersion characteristics, ultimately producing good quality glass and color which truly add value for the glass producer and user.

Typical End Uses of Forehearth Color

Cosmetic Bottles: The relative short runs demanded by this market segment are perfect for FHC, and this was the first market segment to benefit from the relative economics of FHC. Most popular colors are blue, purple, grey, black and green.

Beverage Bottles: Drink manufacturers have recognized the potential added value offered by selecting colored glass bottles as the preferred package. Typical end use segments are mineral waters, wines, spirits and soft drinks with colors such as Bordeaux green, Georgia green, dead-leaf green, black, blue and smoke grey.

Tableware: Tabletop, ovenware, ornamental and promotional glass markets have all used FHC technology to add value to their products.

Architectural Glass: The latest segments to introduce FHCC are building blocks and rolled patterned glass, which are especially popular in Europe, the Middle East and Latin America.

Forehearth Coloring Possibilities

Generally speaking, almost all colors produced in the tank can be reproduced in the forehearth, using a combination of Co, Cr, Cu, Ni, Mn and other transition elements.

The following table is a typical illustration of coloring ions and color properties of some products manufactured in the forehearth, starting from oxidized tank flint:

Product	Coloring Ion		FHCC Feed Rate	DWL	%B	%P
Smoke Grey	BR-302A	Ni	0.4%	574	67.52	12.86
Ramlosa Blue	BI-242A	Co/Cu	0.8%	486	78.66	9.95
Clearly Canadian	LU-976-J	Co/Cu	0.5%	480	65.52	17.18
Bacardi Limon	PX-420-K	Ni/Co/Cr	0.25%	566	77.81	4.00
Dead-leaf Green	GN-176B	Mn/Cr	1.00%	562	90.30	5.09

Georgia green, cobalt blue, Perrier green, half white, Bacardi green, Bordeaux green, French antique green, emerald green, pink and black would be other popular container colors made using FHC technology.

The appended color curves show a comparison between some tank-produced colors and the same colors produced using FHC technology and illustrate clearly how closely this technology can reproduce the tank colors.

Untapping the Full Potential of Forehearth Coloration

While forehearth coloring traditionally centered on oxidized tank flint glass, the flexibility of this technology for the glass maker as well as the end market can also be illustrated by looking at the ability to convert one tank color to another.

For example, it is possible to convert reduced amber to black, light amber to dark amber, emerald green to Bordeaux (champagne) green and dead-leaf green to French antique green.

In the latter example, this produces a color tone demanded by the end market wineries, which would otherwise be difficult, if not impossible, to create starting from oxidized flint glass. The properties of the final FHC product are shown below, with the color curves illustrating the color shift appended. Clearly control of the tank color is important where a shift in the yellow component (from the reduced glass) or the green component (from iron chromite in the glass batch) will have a significant effect on the final color:

Product	Coloring Ion		FHCC Feed Rate	DWL	%B	%P
Antique Green	PX-422-C	Ni/Cr	0.55%	576	10.0	95.0

Forehearth coloring has also been used to convert a reduced champagne (Bordeaux) color produced in the tank to a specific color shade required by the wineries. The FHCC used was based on cobalt at a feed rate of 0.28%.

As another illustration of the flexibility of FHC, tank flint can be converted via the forehearth to UVA flint. As can be judged from the spectrographic curves, an appreciable amount of UVA transmission is blocked.

And What About the Future?

We believe that there remains some as yet untapped potential for FHC technology. For example, FHC could be used to create various shades of amber required by the market, starting from a reduced light amber base glass. This could be a more flexible and potentially more cost-effective route to produce shades of amber with color tones at each end of the standard amber spectrum, which today may have to be specially produced in large volume runs in the tank and held in stock. FHCCs have been developed for this application which are selenium-free and environment-friendly.

FHC reds are another added value potential, so far largely untapped because of the need to work with a specially formulated reduced base glass. However, the technology is proven and requires a partnership approach with interested parties to be successful.

Ferro is also investigating a method of producing opal glass in the forehearth.

Surface Decoration

Glass manufacturers are also turning toward decorating systems as a means to add value to their products.

One traditional method is the so-called ceramic ACL, which has come under pressure from increasingly stringent environmental regulations, such as CONEG, due to its traditional link with heavy metals, like lead and cadmium. The glasses used to bond these colors to glass were based on lead because of that element's natural fluxing action and its high refractive index leading to bright colors. The quality look of these colors traditionally placed these products at the premium sector of the market.

Considerable research has resulted today in glass colors technically free of added lead and cadmium, which have good aesthetic appeal and also have physical properties, which make them suitable for single-trip market segments.

Color ranges are available for cosmetics, single-trip beverages like wines, spirits, beers and soft drinks, promotional glass and decorative tableware. Check out Ferro's System 2020 colors. On the holloware front, there remains a need to improve the alkali resistance of the lead-frees for multi-trip bottle applications and for dishwasher- resistant tableware.

For flat glass, recent breakthrough technology has created a series of colors, which are bright and glossy and, with excellent acid resistance, conform to all the specifications required by the Appliance and Architectural Industries. Automotive glass decoration for windshields, backlites and body glass is also now largely based on lead-free technology. See Ferro's lead-free series for press-bend and sag-bend processes.

As an alternative approach for the packaging market, organic technology can be used to eliminate lead and, with this approach, strong reds free of cadmium can also be created.

Ferro's powder paint technology has helped to pioneer the application of powder coatings on glass, and this can be combined with organic screen print colors to expand the decoration possibilities for the glass market. In addition, powder coating is more environmentally friendly than wet paints because it is free of VOCs and production yields are also much greater, typically 95-98%. Most of the coating is deposited on the piece, not extracted to the stack. These days, a relatively small investment is required to set up a small powder plant for decoration of glass.

Another environmentally unfriendly process operated in the glass sector is acid etching, and R&D efforts have been made over the years to replace this with coatings. Lead-free ceramic coatings have been successfully produced to simulate acid-etch effects, although the appearance and feel is not as smooth as the "real thing." However, two new approaches are now available with not only the look, but also the handle of real HF-etched bottles. These could be especially interesting to the cosmetic industry. One is based on IMPACT powder coating, the other on a unique ceramic formulation which can be fired and decorated with conventional ceramic enamels.

Summary

Undoubtedly, glass has many properties that can differentiate it from its competition.

The glass industry must constantly strive to maximize these benefits and to find ways to add more value and more flexibility to its product. If, in so doing, we can also help to reduce costs, of course this would be a huge advantage.

Forehearth coloring technology is one possible solution proven and already available, which does provide not only added value but also increased flexibility and potentially lower costs.

Especially for the premium packaging market, this technology can be combined with the latest in lead-free ceramic decoration technology as a means to capitalize on the benefits of glass, not least its recycleability and its environmental friendliness.

Additionally, the use of organic powder coatings can contribute, especially in medium to lower range packaging and decorative glass segments, as a relatively low-cost, environmental-friendly decoration method.

Environmental-friendly alternatives are now also available which can make the replacement of HF etching a real possibility.

Combined with a strong effort from all involved in the wider marketing of the glass industry, all of these technologies can help, not only in the future protection of our industry but also in the fight back against competitive alternative materials, especially relating to the packaging market.