COLOR & GLASS WORLD

THIS ISSUE

Cool Buildings with Ferro Architectural Glass Colors

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FOREWORD

DYNAMIC INNOVATION

On behalf of my Performance Colors and Glass (PCG) team, welcome to the Spring 2018 edition of Color and Glass World, our global newsletter that aims to keep you informed about the latest activities from the world of Ferro.

2017 proved to be an exciting year for Ferro, as we continue to position ourselves as a leading supplier of functional coatings and color solutions for a broad range of industries and applications. Ferro’s transformation has exceeded our targets set in 2013, and we have successfully invested in higher value growth opportunities. PCG has expanded its addressable markets in high value segments with six acquisitions made since 2014: Vetriglas (forehearth coloration), TherMark (laser marking), Ferer (Turkey and Middle East region expansion), Pinturas Benicarlo (organic coatings and inks), ESL (specialty materials for electronic applications), and Dip-Tech (digital printing on glass).

Our value creation strategy is now into Phase IV which we call “DYNAMIC INNOVATION AND OPTIMISATION”. We operate a custom-tailored, research, development and service driven, specialty business model with a “heavy customer touch”. Our goal is to be an innovative technology leader in our target markets, whilst introducing new technology platforms such as digital printing, through our Dip-Tech acquisition, and organic chemistry-based “green” products and technologies.

We want to have a balanced portfolio of organic and inorganic growth. For example in 2017, significantly more than 10% of PCG sales came from new products developed in the last three years; our NPD list inside this edition gives a summary of some of the major new product lines introduced during this time. Additionally, alongside this organic growth, we are continuing to develop a robust pipeline of acquisition targets in adjacent markets.

I am excited by our Dip-Tech acquisition which puts us at the forefront in the development of this disruptive technology. Dip-Tech is the global leader in technology and market position for digital printing on glass with its printers, ceramic inks, graphic software and services, and this acquisition will strengthen our leadership position in decoration, industrial and automotive glass markets. Described inside are examples of digital projects using Dip-Tech printing machines and inks that are helping to revolutionise the decoration of architectural and automotive glass. We will be joining forces with our new Dip-Tech colleagues at the glasstec 2018 show in Dusseldorf, Germany in October, where we will have further opportunities to showcase our combined technologies and talent. International trade shows such as glasstec, Ceramitec, GlassBuild and China Glass provide a perfect platform for us to share our ongoing product innovation and improvement efforts, and to introduce our latest acquisitions to the Ferro family. Included in this edition is a preview of the products for ceramic markets that we will be showcasing at the upcoming Ceramitec show in Munich, Germany.

Also featured inside the Spring edition is our use of “Cool pigments” in architectural glass colors, together with our collaboration with the French company Duralex, to introduce our latest forehearth color products.

As always, I hope you will find our stories interesting and informative. If you would like to learn more about any of the products featured, please feel free to contact a member of the PCG sales or technical teams in your region.

A key element of our PCG Vision 2020 includes the value we place on collaboration and partnership with our customers. When our customers succeed, we succeed. Thank you for your continued support.

Dieter Binder
Vice President, Performance Colors and Glass
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NEW FOREHEARTH COLORS FOR FRENCH ICON DURALEX

Duralex is a specialist in the design and production of tempered glass tableware since 1945. Duralex’s reputation is based on the quality of its product and its unique material, tempered glass, the strength of which inspired the brand name taken from the Latin motto “Dura Lex Sed Lex” (The law is tough but it is the law).

The first tableware item sold by Duralex, the Gigogne tumbler, was launched in 1946. Over the years, it has seamlessly passed from school canteens to the Museum of Decorative Arts, Paris and the MoMA store at the famous Museum of Modern Art, New York. The Picardie tumbler has become emblematic of French style and its easily identifiable curved shape has often been cast in feature films like the James Bond classic Skyfall. Both of these Duralex product lines are still manufactured today, and recognized as iconic designs.

The Duralex brand was originally registered in 1945 by Saint-Gobain, a pioneer in tempered glass technology, who expanded the brand internationally until the 1990’s when they decided to cede Duralex to concentrate on their core business. In 2008, Duralex was taken over by a group of managing shareholders and today, the Duralex brand embodies everyday glassware through modern tableware items in contemporary designs, and confidently graces all tables worldwide.

It is the tempering process that makes Duralex so tough. Glass that has been heated to around 650°C is suddenly cooled by cold air ventilation. This treatment creates controlled stress in the glass that improves its resistance to mechanical stress and thermal shock. Duralex glass is 2.5 times stronger than annealed glass. It is the same safety, tempered glass technology that is used to make automotive glass which, in the event of an impact or accident, shatters into thousands of non-cutting pieces.

During the last 10 years, Duralex made significant investments in production, branding, design and product innovation. Several new color lines have been introduced, some of which include Ferro forehearth colouring technology.

Ferro pioneered forehearth coloration in the 1970’s as a cost-effective alternative to traditional coloration in the glass tank. Changeover times between colors are reduced from days to hours, and the technology also introduces the possibility to produce special colors that would not usually be considered for production in the tank. Originally developed for the cosmetic glass bottle market, our technology is now also successfully commercialised for tableware, beverage bottles, and building glass.

During 2017, we co-operated closely with Duralex to develop a customized nickel-free grey forehearth colorant. Traditionally, smoky grey glass colors have been produced using nickel and cobalt compounds. However, nickel is now classified as hazardous, and replacing nickel in order to re-create these colors represents a significant technical challenge. Our new nickel-free...
forehearth color technology is the result of an important development program completed by our global R&D group.

Our French forehearth service engineers worked closely with Duralex’s production and technical teams to tailor our basic technology to create a specific color match that fits the Duralex glass formulation and production process. Extensive laboratory and production trials were necessary to color match and refine the forehearth conditions required to optimise the color tone and glass quality. The final products sold by Duralex use our nickel-free grey pearl concentrate – manufactured at our plant in Saint-Dizier, France - which has the added advantage of being free-flowing and dust-free in the customer’s mixing process.

M. Gérard Dansette, Duralex Industrial Director comments: “Ferro and Duralex have developed a strong mutual trust and co-operation during this project. Ferro’s local technical team was on hand to support and guide us every step of the way from concept to commercialisation. They advised us about the design and selection of our new forehearth equipment, and helped us to set up the precise working conditions in the coloring process, in order to create the exact color tone and glass quality required for our final products.”

Through such strong customer co-operation and partnerships, combined with our innovative approach to product development, our goal is to bring success to our customers. We are proud to be associated with the Duralex brand, and we will work continuously with all our customers around the globe, to help bring your brands to life.

PREMIUM PRODUCTS FOR PREMIUM VODKAS

In 2016, we announced our partnership with Cabro Chemicals and Coatings, based in Arezzo, Italy, to market their line of precious metal preparations (PMP) for premium glass and ceramics to selected regions and countries around the world.

Founded in 1987, Cabro S.p.A is a chemical company specializing in producing, treating and recovering precious metals such as Au, Ag, Pt, Pd, Rh, Ru and Ir. Cabro offers a complete portfolio of products for ceramic and glass decoration. Every line contains products based on gold, platinum and lusters. All of them can be applied through different methods (brush, direct screen-printing, decals etc.), at various temperatures (550-1200°C), and on a number of surfaces (tiles, earthenware, porcelain, bone china, flat and hollow glass, etc.). Over the past 30 years, Cabro have become known for its innovation and development of reliable, quality products, and for providing customised solutions in a demanding market. Such shared philosophies are proving to be a good fit as we develop our commercial relationship together.

An early example of our success has been the marketing of PMP’s for the decoration of premium vodka bottles in Russia.

Since 2005, Ferro has marketed products for the Russian glass market through our local offices in Saint Petersburg, which in 2009 became our wholly owned legal entity Ferro Specialty Materials LLC. This has enabled us to build a close co-operation with the market in Russia through operating a local commercial and technical service, backed with local warehousing and additional expert support from our Frankfurt technicians in Germany. Consequently, when we concluded our deal with Cabro, we were immediately able to combine forces and following comprehensive testing programs, the Russian glass industry was able to introduce Cabro’s line of thermoplastic gold and platinum printing pastes for their premium vodka bottles.

For more information about Cabro products, please talk to Ferro Specialty Materials LLC, our technical and commercial teams in Frankfurt, Germany, or contact your local Ferro representative.
To date, the growth in digital for glass printing has been mainly centred on architectural, appliance and decorative glass. In areas such as building facades, curtain walls, balustrades, shower walls, kitchen backsplashes and even art pieces, the advantages of digital printing, such as cost-effectiveness, fast set-up, flexibility, multi-color and one-of-a-kind printing have become well recognised.

But what about transportation glass? Can digital glass printing add value also for the production of cars, buses, trains, boats and aircraft?

OEM automotive glass manufacturers have typically chosen screen printing as their primary production process due to the speed, high print quality and low cost per piece achievable over long production runs. Of course, compared to the decoration of building and interior glass, the considerations for automotive glass manufacturers are typically less about creative freedom and more about print quality, precision, speed and OEM vehicle standards.

However, increasingly, auto-glass printers are recognising the inherent advantages that digital printing can deliver, and Dip-Tech is continuing to play its part in the development of this market.

Digital printing offers significant workflow advantages compared to traditional screen printing. Graphics for frames, logos, fine details and patterns are designed in digital format and processed with RIP software. They are then converted to printing models and jetted onto flat glass surfaces using drop-on-demand printing technology. Because digital print is file-based, there is less hardware involved, minimum machine
setup, reduced labor costs, and a simplified production line. No screens mean no post-print cleaning, and no need for storage. The digital option delivers simplified workflow, fast set up and increased flexibility. Especially for the smaller production runs required in the replacement glass and specialty transportation markets, this can offer significant cost reduction opportunities.

For example, with its improved productivity, Oran Safety Glass, a large Israeli glass processor, has found that digital technology is better suited for the quick set-up and flexibility required by the automotive aftermarket sector, while significantly reducing labor. Oran’s VP and CFO David Yogev notes, “With the digital printer, one operator can control the entire operation of the machine, setting up the windshield and the printing process with a computer. Basically the machine then operates itself until the glass comes out at the other end of the dryer.”

Pierpaolo Bazzacco, Technical Director at Veneto Vetro, Italy, has experienced similar results. “In our segment of the automotive market - nautical and cruise ships – 1 to 5 pieces are generally ordered at a time. Traditional screen printing is not flexible enough and the cost goes too high with all the setup involved. Digital printing is much more flexible for setting up the machine, which means that production is much faster for this type of order and we get far more glass printed each day.”

Because it’s file-based, digital printing easily accommodates customization and variable data printing – for branding options such as logos, serial numbers, and text – as demanded by the automotive industry. Every single piece of glass can be printed with a different serial number in a single run, with no additional setup. Additionally, digital printing is uniquely capable of printing multiple jobs – of different shapes and sizes – at the same time, on the same machine, in one pass.

This ease of customization can be a major advantage and opportunity for the autoglass segment, allowing glass part designs to be changed quickly, easily and cheaply. Furthermore, variable information lends itself to product traceability, and digital printing also allows for the immediate creation of a prototype, with almost no investment.

As for quality, by its very nature, digital printing is able to deliver exceptional accuracy, including edge-to-edge printing, precise registration (particularly relevant for two-sided printing), high resolution (down to the smallest fonts and ultra-fine details), and with Ferro/Dip-Tech glass enamel inks, proven durability.

Today, especially with advances in higher speed, cost-effective printers, the digital opportunities are becoming more and more recognised by automotive glass manufacturers. Until recently, digital printing solutions for the automotive industry were essentially adaptations of the printers used for architectural and interior design applications. Dip-Tech’s N Era-V printer is the first digital glass printer developed specifically for the automotive industry, and is the most advanced digital ceramic printing solution for automotive and repeatable patterns.

The machine integrates technology from screen printing, including an in-line automatic indexing system that is able to automatically index and register non-systematic glass shapes, with no manual operation required. It offers turbo-charged throughput, superb quality and a competitive ROI compared to screen printing in larger batches. N Era-V can print fully opaque automotive black bands at up to 300 sqm/hour, enabling a windshield to be printed in less than 40 seconds, and single-color fine details and logos at 120 sqm/hour.

Together with Ferro’s proven technology and experience in providing black obscuration glass enamels and silver pastes, we believe that the combined forces of Ferro and Dip-Tech are well positioned to drive the new opportunities that digital printing offers for the automotive glass market.

However, the choice between screen printing and digital printing is not a zero-sum game. Both offer excellent quality. Each has its benefits, and there is room for both, even within the same production floor. Screen printing has many advantages, particularly for the long runs of glass parts required by OEM manufacturers, while digital printing offers a robust additional technology, providing more flexibility, customization and responsiveness. Used in tandem, glass processors can shift between the formats according to need, to better utilise screen capacity and maximise ROI.

As your one-stop shop, Ferro/Dip-Tech can provide the solution you require to add value to your products.
COOL BUILDINGS WITH FERRO ARCHITECTURAL GLASS COLORS

Ferro’s System 140 range of lead-free flat glass enamel colors are recognised as an industry standard for the decoration of architectural, appliance and furniture glass. Typically, this series of colors can be applied by either screen printing or roll coating and over the years, they have been used to adorn the glass on many famous buildings around the world.

Now, this range of colors has been extended with innovative new products which will deliver a combination of both decorative advantage and functionality, for the glass processor as well as the end user.

Based on increasing demand for energy efficiency, we have developed our ‘Cool Colors’, as an extension of our System 140. At the wavelength of the light visible for human eyes (380-780 nm), such ‘Cool Colors’ provide the reflection and absorption of conventional enamels. However, in the IR spectrum of light (> 780 nm) – which means the heat radiation – these enamels provide a high reflectance.

Due to the IR reflection of ‘Cool Colors’ a better energy efficiency class can be achieved when using these colors in architectural facades. Additionally, such functionality can also provide benefits for appliances such as oven doors in kitchens, due to the heat energy being reflected back into the oven rather than absorbed by the glass.

In addition to these positive results for the facade construction, appliance manufacturers and end users, glass processors can also see advantages from reduced IR absorption. The lower heat gain of a black band printed with a ‘Cool Color’ reduces the effect that the glass bends up like a bowl during the firing process. Therefore the risk of glass damage, as well as damage to the heaters inside the roller furnace can be minimized.

Reflection over wavelength for standard black 14 4011 vs. cool black TDF9556A

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Reflection over wavelength for standard black 14 4011 vs. cool black TDF9556A

<table>
<thead>
<tr>
<th>Wellenlänge nm</th>
<th>% Reflexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>5</td>
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<tr>
<td>750</td>
<td>10</td>
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<tr>
<td>1000</td>
<td>15</td>
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<td>1250</td>
<td>20</td>
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<tr>
<td>1500</td>
<td>25</td>
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<tr>
<td>1750</td>
<td>30</td>
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<tr>
<td>2000</td>
<td>35</td>
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<tr>
<td>2250</td>
<td>40</td>
</tr>
<tr>
<td>2500</td>
<td>45</td>
</tr>
</tbody>
</table>

source: Ferro GmbH
## NEW PRODUCTS INTRODUCED BY FERRO IN THE LAST THREE YEARS

### FLAT GLASS

<table>
<thead>
<tr>
<th>System TEA (True Edge Application)</th>
<th>Architectural</th>
<th>TEA allows structural glazing with glass enamels at the edge of PVD-coated glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>LustRelex coating</td>
<td>Appliance and Architectural</td>
<td>Almost invisible coating to enhance durability of glass and ceramic glass surfaces</td>
</tr>
<tr>
<td>Cool Color coatings</td>
<td>Architectural and Appliance</td>
<td>Enamels with IR-reflecting properties for cool surface and energy saving</td>
</tr>
<tr>
<td>High Opaque/High Durability Black</td>
<td>Appliance</td>
<td>Bismuth-free, cost-efficient, passes appliance chemical durability and foodstuffs testing</td>
</tr>
</tbody>
</table>

### AUTOGLASS

<table>
<thead>
<tr>
<th>High resistant conductive silver inks</th>
<th>Laminated/Tempered Glass</th>
<th>Especially designed to pass 20 cycles of P1200 ageing test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductive silver inks for lead-free soldering</td>
<td>Laminated/Tempered Glass</td>
<td>Especially designed for the use in leadfree soldering process</td>
</tr>
<tr>
<td>High resistant black enamels</td>
<td>Tempered Glass</td>
<td>Excellent antistick and silver hiding properties, deep black color, passes 140 hours H₂SO₄ Toyota test</td>
</tr>
<tr>
<td>Black inks for Laser Transfer Printing (LTP)</td>
<td>Digital printing</td>
<td>Exclusively for use with LPKF LTP printers. Printing of fine line conductive tracks, bus bars, antennae</td>
</tr>
<tr>
<td>Conductive silver inks</td>
<td>Digital printing</td>
<td>Exclusively for use with LPKF LTP printers. Printing of edge bands, logos, serialisation</td>
</tr>
<tr>
<td>High resistant press bend enamels</td>
<td>Laminated windshields</td>
<td>Benchmark products for application on laminated glasses in press bend technology, passing 72 hour H₂SO₄ Toyota test</td>
</tr>
</tbody>
</table>

### CONTAINER GLASS

<table>
<thead>
<tr>
<th>VNS series Metallic-effect colors</th>
<th>Beverage bottles/Cosmetic bottles/Giftware Tumblers/Tableware</th>
<th>Special effect metallic shades with good scuff resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic HTP neon inks</td>
<td>Beverage bottles/Cosmetic bottles/Giftware Tumblers/Tableware</td>
<td>Intensive neon color shades with good dishwasher resistance</td>
</tr>
<tr>
<td>Fluorescent effect forehearth colors</td>
<td>Beverage/Cosmetic bottles/Tableware</td>
<td>Feeder frits or pearls to create fluorescence under UVA and Laser</td>
</tr>
<tr>
<td>Chrome pearl forehearth colors</td>
<td>Beverage/Cosmetic bottles/Tableware</td>
<td>Environmentally friendly, allows to achieve a yellow shade (Cr6+) in compliance with REACH</td>
</tr>
</tbody>
</table>

### CERAMIC DINNERWARE

<table>
<thead>
<tr>
<th>New Colors for Inglaze series Sky100</th>
<th>Decoration</th>
<th>Lead content &lt; 100ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Colors for Onglaze series Samba100</td>
<td>Decoration</td>
<td>Lead content &lt; 100ppm</td>
</tr>
<tr>
<td>Starlight100 Metallic colors for high temperature fast-firing</td>
<td>Dinnerware</td>
<td>Lead content &lt; 100ppm</td>
</tr>
<tr>
<td>Carnival100 onglaze colors</td>
<td>Dinnerware</td>
<td>Lead content &lt; 100ppm</td>
</tr>
</tbody>
</table>

### INDUSTRIAL

<table>
<thead>
<tr>
<th>ZTH/ZTL rings</th>
<th>Process Temperature Control</th>
<th>Working range 560-660°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTH/UTL rings</td>
<td>Process Temperature Control</td>
<td>Working range 660-900°C</td>
</tr>
<tr>
<td>Ultrafine filler Glasses for Dental</td>
<td>Dental Composites</td>
<td>0,4-0,7µ to get higher filling grades in dental composites</td>
</tr>
<tr>
<td>Phosphate glasses</td>
<td>Dental</td>
<td>Dental cements</td>
</tr>
</tbody>
</table>

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GLASSPRINT CONFERENCE REVIEW

Ferro presented at the seventh GlassPrint conference and exhibition in Düsseldorf, Germany on 29-30 November 2017.

GlassPrint is the main event dedicated to glass decoration, involving the most influential representatives in this important sector. Experts and industry representatives presented the latest trends and innovations in digital and screen printing technologies for the decoration of flat and hollow glass.

The conference was attended by more than 200 delegates from 28 different countries, not only from throughout Europe but also from South America, India, Israel, Japan, Korea, South Africa, Taiwan and USA.

Alexandra Cordes, Ferro’s European Technical Service Manager for Container Glass gave a presentation entitled ‘The Value of Glass Decoration’. The paper introduced established and new decoration techniques and decoration materials, covered EHS issues and focused on ideas about how to add value to glass through decoration.

Manfred Klingert, European Sales Manager for Container Glass said: “GlassPrint provides an ideal forum to present our innovative products, and to help us network and develop relationships with customers and other visitors.”

CERAMITEC 2018 PREVIEW: FOCUS ON DIGITAL PRINTING

This year, our Performance Colors and Glass business will exhibit at two of the major international trade fairs centred on the ceramic and glass industries. We will be in Düsseldorf, Germany for the glasstec glass industry show later in the year in October, and from April 10th-13th, we will welcome visitors to Ceramitec, the ceramic industry’s hotspot, which takes place in Munich, Germany. Regarded as the leading international trade fair within the ceramics industry, Ceramitec represents the entire value chain with all key players and innovation leaders.

Ceramitec is the key event for Ferro’s dinnerware and industrial specialties businesses. This year, we will focus on our activities with digital printing. Ferro pioneered the digital decoration of ceramic substrates in the early years of the millenium, initially for floor and wall tiles. This form of decoration has helped to revolutionise the industry and has now become the dominant decoration technology for ceramic tiles. Recently, Ferro extended its digital activities to flat and automotive glass and in 2017 acquired Dip-Tech, the pioneer and leading supplier of digital print machines and inks for glass, whose activities in automotive are featured inside this edition.

Now the focus is on the digital decoration of glazed but unfired dinnerware, and on roof tiles. For example, for roof tiles applications, the new technology allows us to create in ceramics, perfect imitations of wooden shingles. Such ceramic shingle effects have the advantage to be much more weather resistant than the wooden originals. For digital printing on dinnerware, Ferro offers a 7-color process based on the CerDeChrom color management technology, which allows dinnerware producers to achieve best possible color separations by themselves.

We look forward to welcoming customers to our booth to view examples of our digital printing developments and to share the exciting possibilities this can offer for your business. Please visit us in Hall A6, booth 423/522.
FERRO TODAY

Ferro Corporation is a leading global supplier of technology-based functional coatings and color solutions. Ferro supplies functional coatings for glass, metal, ceramic and other substrates, and color solutions in the form of specialty pigments and colorants for a broad range of industries and applications.

Ferro products are sold into the building and construction, automotive, appliances, electronics, household furnishings, and industrial products markets.

Headquartered in Mayfield Heights, Ohio, USA, the Company has approximately 5,680 associates globally and reported 2017 sales of $1.4 billion.

Our associates work in 30 countries, speak more than 17 languages and bring a wealth of knowledge and cultural perspective to our offices, laboratories and plant facilities every day. While we learn and benefit from the unique experiences that arise from our diversity, we also share a common set of core values and operating philosophies. We believe that our long term success will be determined by who we are and how we act.

Our core values apply equally to all interactions with customers, suppliers and colleagues:

• **Customer Focus:** Our customers are why we exist; we want to build trusting relationships that make customers successful.

• **Accountability for Performance:** We work to achieve the highest performance standards, to create value for customers and shareholders.

• **Innovative Thinking:** We seek new ideas for technologies and business processes, and are always striving to improve and serve our customers better.

• **Teamwork and Collaboration:** we are committed to a work environment of trust and respect, working together to consistently deliver value to customers and shareholders.

Where innovation delivers performance.
Where innovation delivers performance

For outstanding color and coating technologies – both decorative and functional, Ferro are global market leaders.

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