

# NEW SURFACE ASPECTS OF ENAMELLED PRODUCTS



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## New Surface Aspects of Enamelled Products

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**Key words** 3-dimensional decoration, water print technique, metallic effects, metal-like effects, surface properties, cost comparison

This paper presents 2 different kinds of new surface aspects that are used for enamelled products.

In Part I of this paper, PEMCO's 3- dimensional decoration technique called ENAMERIS® is presented.

In Part II metallic and metal-like effects are described.

Part III is a summary of this presentation

### **Part I ENAMERIS®, 3-dimensional decoration**

Part I of this paper about new surface aspects of enamelled products describes a new technology to print designs with full surface coverage on complex 3-dimensional parts.

#### **Introduction**

Enamelled products mostly have a uniform, single-colour surface. Only on flat 2-dimensional pieces a full decorative or functional surface design is used. On more complex 3-dimensional pieces, a full surface design is not possible or at least very difficult to obtain.

For this kind of decoration, as state-of-the-art, the following existing technologies are mainly used:

- Screen paste technique for 2-dimensional parts
- Templates for 2-dimensional parts
- Sliding images for local decoration of 3-dimensional parts
- Stamp-printing technique for local decoration of 3-dimensional parts

The limitation of these existing technologies is that a full surface decoration of complex 3-dimensional parts is not possible or at least very difficult to obtain.

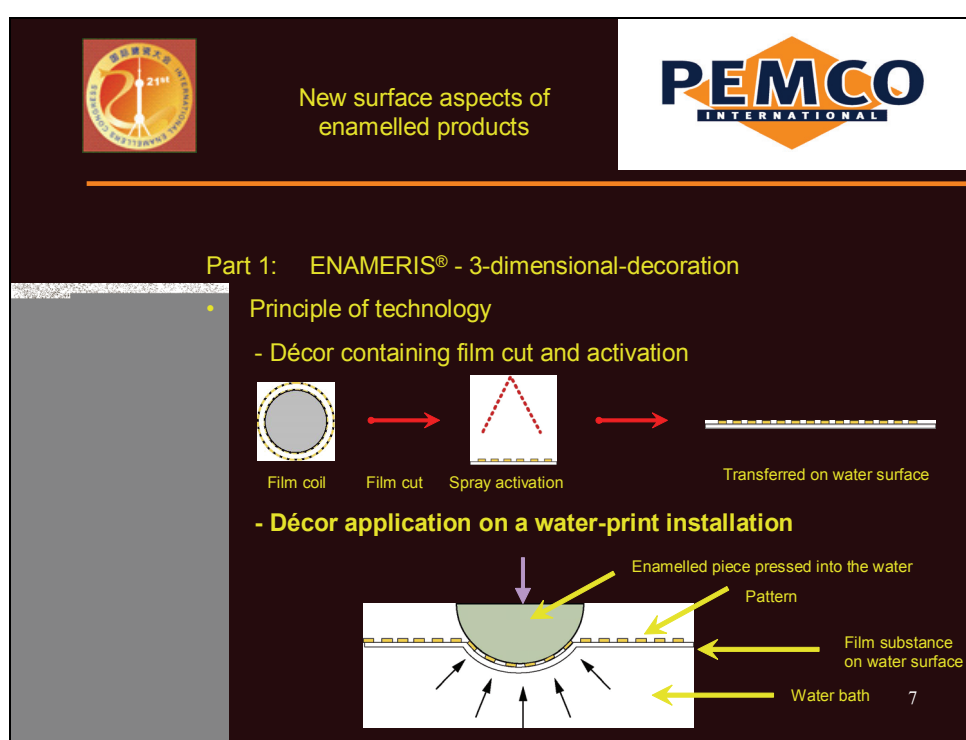
#### **Process**

Together with a specialized partner, who has the know-how and patents in the field of organic colour decoration, PEMCO has adapted a technology of 3-dimensional decoration to the field of enameled products, where this technology was not used before. This simple process of water print technique consists of the following 5 steps:

- Step 1: Cleaning of the pieces to be decorated
- Step 2: Cutting and activating the décor-containing film
- Step 3: Décor application on the surface of the enamelled piece by using a water-print installation

- Step 4: Rinsing and drying of the decorated products
- Step 5: Firing in the existing enamel furnace

A hydro-soluble film carrying the exclusive customer-tailored décor is supplied on coils. The size of the film needed for application is cut from the coil and by spraying a chemical activator is applied to enable the film substance to react with water. After the activation, the film is placed on the surface of the water-print installation and after a short time the activated film starts to react with the water in the sense that the hydro-soluble film substance goes into solution and the décor itself remains on the surface of the water. The piece to be decorated is now pressed into the water and just by the counter pressure of the water, the décor is fixed on the whole surface of the piece to be decorated.



### Know-how

The special know-how of this innovative process consists of the kind of hydro-soluble film substance, the special enamel colours used to print the décor on the film substance, the production of the decorated film, the process parameters during the application of the décor and the application installation itself.



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Part 1: ENAMERIS® - 3-dimensional-decoration

Know-how

1. Hydro soluble film substance
2. Special enamel colours
3. Production of decorated film
4. Process parameters
5. Installation






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### Properties

The properties of this kind of decoration are the following:

1. Full surface printing, decorative or functional, on complex 3-dimensional enamelled pieces
2. Whatever kind of pattern, photo, design can be used
3. All colours that are possible in enamel are also possible for this kind of decoration, using a 4-colour-printing device
4. All properties of the enamelled product are maintained, such as chemical resistance, scratch resistance and heat and light resistance, as special enamel colours are used and fired at approx. 780°C.

### Applications

This process was tested and introduced to a lot of different applications of enamelled products, like kitchen hobs, switch panels, pots and pans, pan supports, burner caps, bathroom sinks, ...



The ENAMERIS® process and the products are industrialized and the first installation using this process to decorate 3-dimensional enamelled pieces was built and is running in production in Italy at a job enameller.

## **Part II Metallic and metal-like effects**

Part II of this paper about new service aspects of enamelled products describes new types of metallic and metal-like effects.

### ***Introduction***

Looking on the market of consumer products, we can notice since several years an ongoing strong increase in the market share of stainless steel for these applications. The statistics of ISSF covering a 15 years period from 1990 to 2005, show an average increase for stainless steel production with approx. 6,4 % per year. For the period from 2005 to 2010, a further increase of approx. 5,1 % per year was forecasted. Also in applications where enamel is used, the growing market share of stainless steel products, for example at external parts of cookers, small kitchen appliances and kitchen sinks is a fact.

However, today metal-like effects have also become a real fashion trend. This means today fashion products like clothes, bags, shoes and this kind of products are increasingly showing metal-like effects.

Concerning enamelled products with metallic or metal-like effects the different existing technologies have all specific limitations, like partly low chemical resistance, partly no/few colouring possibilities and partly the need of special lower firing temperatures than those that can be used in existing furnaces for steel enamelling. PEMCO has developed processes that should overcome those mentioned restrictions.

### ***Process***

PEMCO has developed two different processes: one for metallic effects and one for metal-like effects.

For metallic effects we talk about enamels containing metallic pigments. To get the optimal result of the metallic effect and reach the target properties, PEMCO is using a 3-coat/2-fire system. In this case after applying the ground coat and the first firing, the second layer is applied containing a special transparent frit and standard colour oxides. The third layer applied wet-in-wet directly onto the second layer is applied as a very thin layer of about only 20-30 microns, containing the special metallic pigments. Also this layer contains a special transparent frit. The second and third layer are fired together in one single firing at 790-810°C under normal firing conditions.

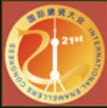
For the second kind of effect, metal-like enamels, PEMCO is using a 2 coat/2 fire system. The second layer is a special enamel frit, which is self-metallizing during firing. Firing is done at approx. 820°C under normal firing conditions.

### ***Know-how***


Concerning the metallic effects, the PEMCO know-how consists of the usage of the 3 coat/2 fire systems to improve the metallic effect and at the same time to reduce the metallic pigment cost, special frits with a good chemical resistance and a good development of the metallic colours and the usage of new types of metallic pigments.

Concerning the metal-like effects, the PEMCO know-how is based on the development of new frits with self-metallization under normal firing conditions.





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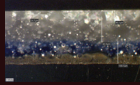


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Part 2: Metallic and metal-like effects

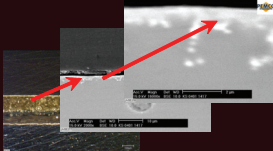
- Principle of technology
  - for metallic effects (metallic-pigment containing enamels):
 

2nd layer  
transparent + oxides



3rd thin layer transparent  
+ metallic-pigments  
steel, intermediate layer  
and ground coat
  - for metal-like effects:
 

cover coat  
ground coat



self-metalizing surface  
during firing

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### Properties and costs

As the metallic and metal-like effects of enamels are used in competition with stainless steel surfaces and partly aluminium surfaces, the technical properties of these 2 kinds of enamels were compared with the surface properties of stainless steel and aluminium. As for stainless steel and aluminium, no surface properties were available in public literature that could be compared with the surface properties of enamels, a standard stainless steel and aluminium used in the cooker industry was tested after standards used for enamel surfaces. By doing so, we can easily compare important properties of the enamelled surfaces with the competing metal surfaces.


For cold citric acid, as well as for water resistance, water vapour resistance and hot washing agent solutions, very similar values were found for the metal surfaces, as well for the metallic and metal-like enamels. A difference was observed concerning scratch resistance. Aluminium has a very soft surface and has practically no real scratch resistance. If the Mohs hardness of the surface is tested with the minerals, it is possible to demonstrate that also stainless steel is less hard and scratch-resistant than metallic enamels or metal-like enamels. Concerning hygienic properties, some years ago in Italy a study was done by putting different bacteria on stainless steel, aluminium and enamel surfaces. In all 3 cases bacteria were strongly reduced (germ reduction) but this effect is clearly stronger on enamelled surfaces compared to the metal surfaces of stainless steel and aluminium. Also the temperature resistance is higher for this kind of enamels than for aluminium or stainless steel, where at lower temperatures discoloration of the surface happens. Stainless steel and aluminium are looked on as being corrosion resistant, but this is not always the case. Under circumstances of humidity and halogens in the air, as at the seaside, local corrosion occurs, which is not the case for enameled products, if they are fully enameled and defect-free.

Also a very important aspect is cost. Everyone knows that during the last years the price of stainless steel and aluminium are strongly increased. This makes it of interest to look for alternative products which give similar surface aspects, like using metallic enamel or metal-look enamels. The cost calculation, which was done by Arcelor Mittal is considering the cost of the metal sheet or the metal substrate for enamelling, as well as the enamel costs and the process costs for enamelling with pre-

treatment, enamel application and firing. This calculation shows that these new enamels have a clearly lower cost per m<sup>2</sup> compared with aluminium and much lower compared with stainless steel.



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### Part 2: Metallic and metal-like effects

- Properties


		Stainless steel	Aluminium	Metallic-Enamel	Metal-like enamel
Cold citric acid	EN 14483-1 §9	A+	A+	A+	A+
Water resistance 48h	[g/m <sup>2</sup> ] EN 14483-2 §13	<1,6	<1,6	<1,6	<1,6
Vapour resistance 48h	[g/m <sup>2</sup> ] EN 14483-2 §13	<1,6	<1,6	<1,6	<1,6
Hot washing agent solution	[g/m <sup>2</sup> ] EN 14483-3 §9	<1,6	<1,6	<1,6	2,4
Scratch resistance	EN ISO 15694	≥ 10	1	≥ 10	≥ 10
Scratch hardness Mohs	EN 101	3	2	4	4
Hygiene ( germ reduction ) (*)	[%] Lit.	-87,5 / -91,7	-82,5 / -83,3	-98,3 / -99,8	-98,3 / -99,8
Temperature resistance		higher 300 °C discoloration	250°C	>400°C	>400°C
Corrosion resistance		corrosion initiated by flight rust, pitting by halogens	contact corrosion, pitting by chlorine and heavy metals	none	none

(\*) Lit.: Prof. F. Marelli: Comparative Bacteriological Studies, Medusa, DEU 2-2001 - Isolates: Staphylococcus Pyogenes/Escherichia Coli/Pseudomonas Mallei

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### Part 2: Metallic and metal-like effects

- Cost comparison

	Stainless steel	Aluminium	Metallic enamel	Metal-like enamel
Typ	1.4016 (brushed ) 0,8mm	1050 2,0mm	DC04EK 0,8mm	DC04EK 0,8mm
Metal price ( valid: 09/2007 )	2350 €/t	2710 €/t	590 €/t	590 €/t
Metal costs per m2	14,75 €	14,65 €	3,70 €	3,70 €
Enamel costs per m2 (incl. 20% overspray)	-	-	1,90 €	2,20 €
Process costs per m2 ( pretreatment/enamel application/firing )	- ( * )	-	7,15 € ( ■ , ● )	7,15 € ( ■ )
<b>Total costs ( ▲ )</b>	<b>14,75 €</b>	<b>14,65 €</b>	<b>12,75 €</b>	<b>13,05 €</b>

\* removal of protection foil not considered  
 ▲ costs for shaping not considered  
 ■ direct and non-direct costs, depreciations  
 ● process costs of 3rd layer not considered

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Another big advantage of this new kind of surface aspects for enamelled products by using metallic and metal-like effects is the possibility to colour the surface. For metallic effects developed by PEMCO using the 3 coat/2 fire process, it is easy to colour the second transparent layer and a relatively wide range of metallic colours becomes possible. Concerning the metal-like effects, as the



metallization is coming from the frit itself, these frits contain different metal oxides and because of this, these enamels have rather dark colours. This is the reason why also only dark colours are possible with the metal-like effect, like dark grey, dark blue, dark green, etc.

### **Applications**

These new self-metallizing frits are mainly developed for the hollowware and appliances industry, but could naturally also be used in other applications instead of stainless steel or aluminium.

### **Part III Summary**

The new kind of metallic and metal-like effect enamels have several advantages versus the metal surfaces:

- The possibility of producing easily different colours
- A very profound effect for the metallic effect colours, which is known from automotive paints
- The scratch resistance of the enamels
- The hygienic aspects of stronger germ reduction
- The cleanability of the metallic effect enamels, which is especially a problem for stainless steel, showing easily fingerprints on the surface which are difficult to remove
- The better temperature resistance of the enamels, as well as the better corrosion resistance
- Last but not least the cost advantages by using this kind of enamels instead of the metal surfaces.

Examples of potential application of metal and metal-like effects are cookers, kitchenware, pots and pans, sanitary ware, architectural panels, etc...

The new decoration process called ENAMERIS® helps to overcome the existing limitation in decoration of enamelled complex 3-dimensional pieces and opens new markets for enamelled products. New products can be created by offering much more possibilities to designers to create more attractive enameled products. The combination of a higher attractivity of the products by using the possibilities offered by this new ENAMERIS® decoration technology and the known advantageous technical properties of enameled products should enable additional market opportunities.

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