Porcelain Enamel Application Technology

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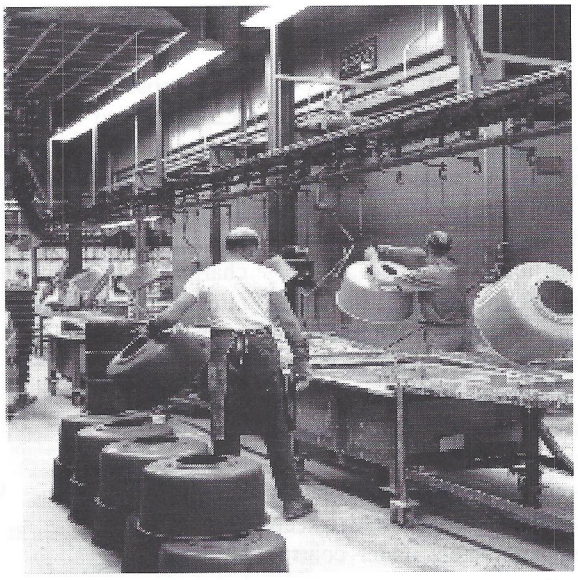
Introduction

The history of Porcelain Enamels goes back many centuries and started with the decoration of art by the old Egyptians, of which we may find fine examples at several museums around the world.
Industrial enameling was founded in Bohemia around 1830, and still today, porcelain enamel is used as a high quality coating for a broad range of products, such as major domestic appliances, sanitary ware, cook-ware and hot water tanks.
In this article, I will review the characteristics and benefits of some enamel application methods, which are actually used for the production of flatware and/or hollow-shaped products.

Dipping

This method, which is be used for a variety of non-visible products, consists of immersing the ware in a tank of enamel slip and with drawing the ware with a constant speed.
The required productivity and wages determine the optimum level of automation.
The obtained coating is characterized by the existence of so-called drainmarks.



The Dipping Process

Slushing

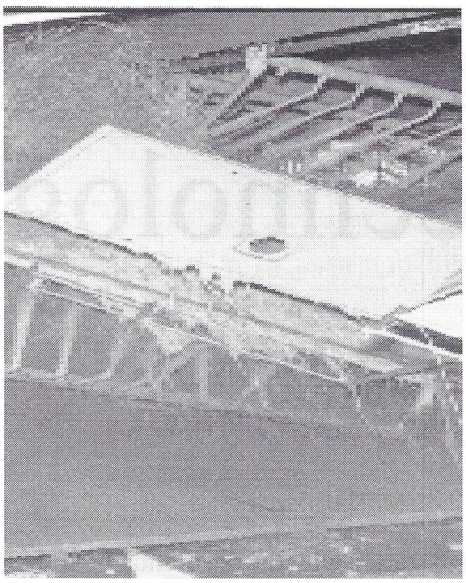
Slushing is mainly used for coating steel holloware.
The item to be coated is held in the operator's hand or by tongs and is swung or spun about to smooth out the enamel and remove the excess liquid.
Considerable production rates can be achieved with this system, although a good amount of skills is required.

Flow coating

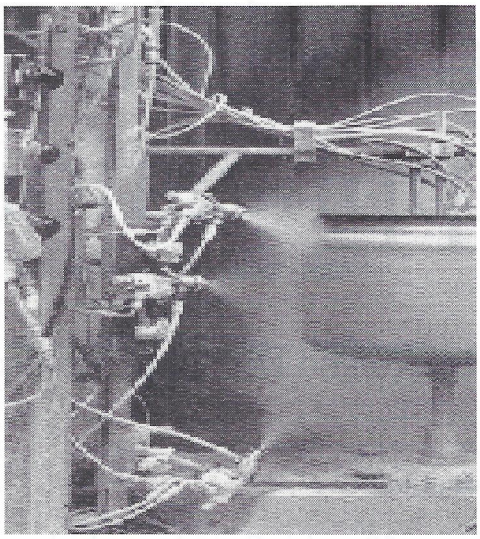
Flowcoating is frequently used for cooker panels, baking ovens, cookware and boilers and can be defined as the picking up of enamel by some means and delivering it to the ware in a high volume, low velocity pattern to uniformly flow the enamel over the ware.
As the ware proceeds through the machine, spraynozzles are directed so that the total coverage of the ware is obtained.
Advantage of this method versus dipping is the selective application of enamel at one side of the product.
However, products applied with enamel by means of flow coating have in most cases visible drain marks.

Vacuum application (for boilers)

Thanks to the under-pressure, which is created by sucking away the air



Flow Coating



Air Spraying

inside a hot water tank, the enamel slip is pressed into the tank.
When the vacuum effect is released the excess enamel slip will flow down from the vessel.

Electro-deposition

Electro-deposition is achieved by the suspension in water of enamel particles, which are negatively charged due to physical interaction with the surrounding liquid.
By applying an electric field the particles move toward the working piece, while the liquid moves to the opposite direction, resulting in the deposition of a rigid enamel layer with a low water content.
Since this method features a dynamic process, specialists are required to keep all process parameters under control and constant.

Air spraying

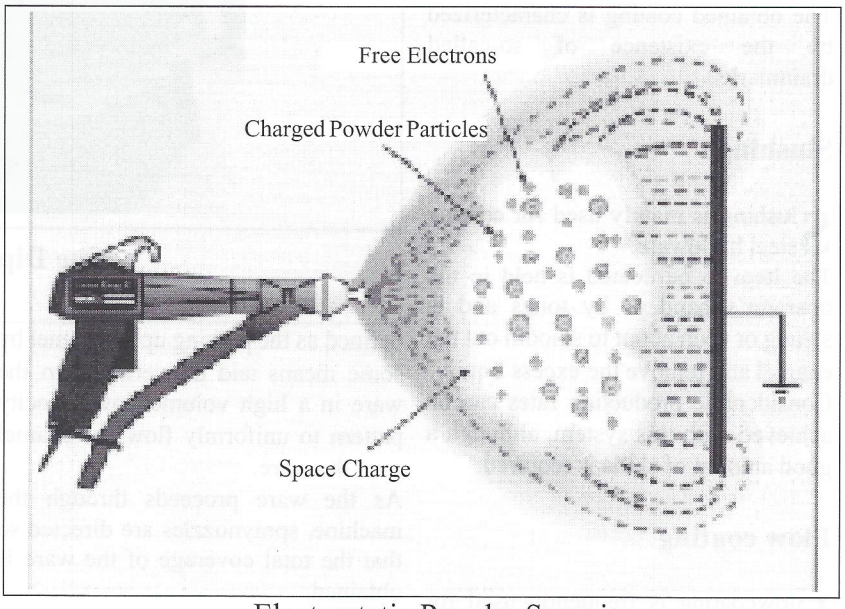
Manual spraying of wet enamel is mostly used for production of visible parts and was very fashionable till some decades ago.
Increasing labor cost resulted in the introduction of automated systems, which however tends to have low transfer efficiency c.q. poor enamel utilization.
Today the automatic air spraying method is mainly used for the production of sanitary ware and the manual spraying is done for small series of difficult parts.

Electrostatic wet spraying

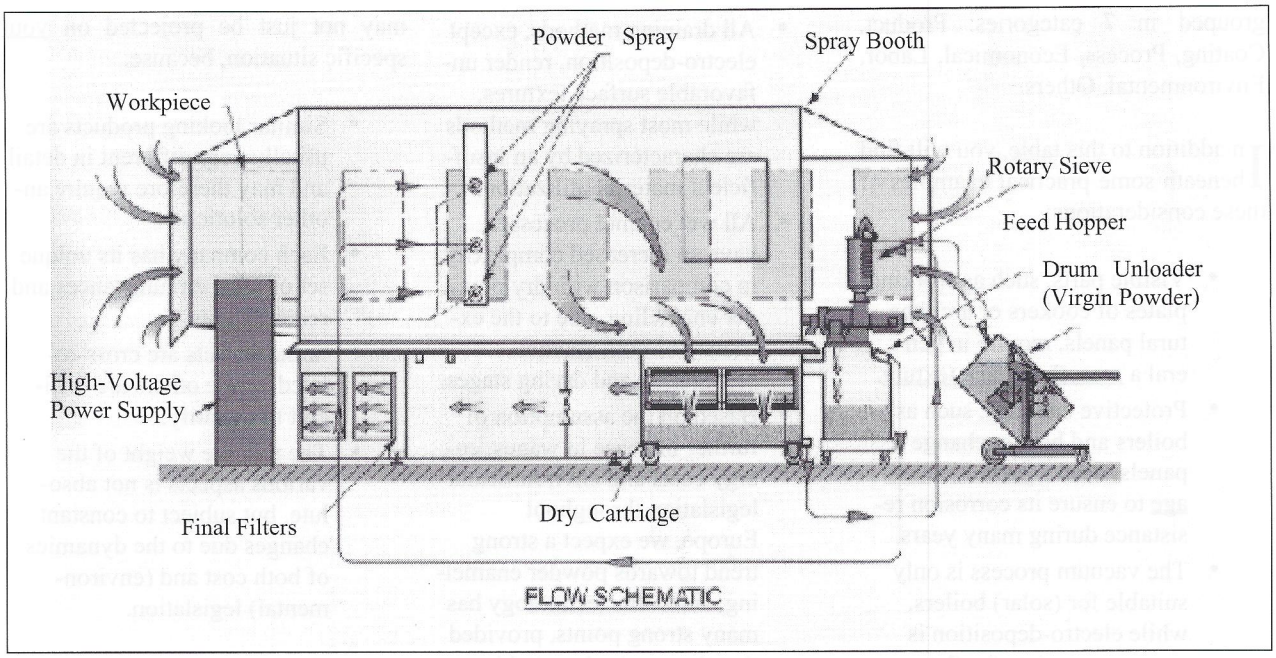
Electrostatic wet spraying has been introduced around 1960 to overcome the low transfer efficiency of above-mentioned automatic spraying.
This method is based on the principle that the enamel slip is high negatively charged and the sprayed particles are attracted to the grounded ware at the application conveyor.
Special attention should be paid to safety aspects, given the risky combination of wet enamels and high tensions.

Electrostatic powder spraying

The introduction of electrostatic dry powder spraying in the '70s reduced the complexity of the enameling process considerably, since it doesn't require in-house enamel preparation nor drying and has almost perfect material utilization.



Electrostatic Powder Spraying



Electrostatic powder spraying, which technology is also rapidly expanding in the paint industry, is based on the attraction and repulsion of electrically charged bodies.
The powder enamel particles are fluidized in a so-called hopper and led along an electrode system, which is maintained at a high electrostatic voltage and that produces an abundance of charged air particles.
The charged air particles then charge the powder particles by ion bombardment.
These charged powder particles are then attracted to the grounded ware at the application conveyor.
Overspray enamel is collected inside the powder booth and automatically recycled to the hopper.

All above indicated application methods have in common, that they are all based on either draining or spraying enamel on the surface of a metal substrate.
The selection of the right application method is of utmost importance for your company, since this may not only effect the appearance and functional properties of your products, but also define the structure of your (future) production cost and last-but-not-least your ability to remain competitive.
There are a great number of aspects, which you should take in consideration while reviewing your actual enamel application or selecting a new one. In the first table you will find an outline of all major aspects, which are

CATEGORY	CRITERIA
Product	* Product shape
Coating	* Enamel type * Enamel process * Aesthetic aspects * Protective aspects
Process	* Complexity * Reproducibility * Flexibility * Tolerances * Information
Economical	* Capital investment * Operating cost * Maintenance cost
Labor	* Required skills * Labor conditions * Availability of skilled labor
Environmental	* Quantity of waste * Quality of waste
Others	* Required space * Level of automation * Level of integration * Image

grouped in 7 categories: Product, Coating, Process, Economical, Labor, Environmental, Others.

In addition to this table, you will find beneath some practical examples of these considerations:

- Visible parts, such as working plates of cookers or architectural panels, require in general a smooth surface texture.
- Protective coatings, such as boilers and heat-exchange panels, need a perfect coverage to ensure its corrosion resistance during many years.
- The vacuum process is only suitable for (solar) boilers, while electro-deposition is more appropriate for flatware.
- Modern enamel processes, such as two coats / one fire, provide the best results while applying the enamel within strict thickness tolerances and in consequence demands for application methods with a good layer thickness control, even layer thickness distribution and reproducibility.
- The required productivity, the availability and cost of skilled labor and the reproducibility of the process/quality usually determine the appropriate level of automation.
- With regard to rapidly increasing international environmental legislation, enamel processes and application methods should also be evaluated upon its material transfer efficiency, potential waste generation and energy consumption.

For your guidance, we have also made a comparison of the various aspects between the different application methods, which you will find in the second table.
Based on this comparison and observations during visits to modern enameling plants, we may come to the following conclusions:

- All draining methods, except electro-deposition, render unfavorable surface textures, while most spraying methods are characterized by an insufficient material utilization.
- All wet enamel processes have an increased complexity in comparison with dry powder enameling, due to the existence of both enamel preparation and drying stages.
- Based on the assumption of further increase in wages, energy costs and environmental legislation throughout Europe, we expect a strong trend towards powder enameling, since this technology has many strong points, provided that the required capital investment is balanced by sufficient productivity.

However, please acknowledge that above-mentioned conclusions may not just be projected on your specific situation, because:

- Similar looking products are usually very different in detail and may therefore require another solution.
- Each company has its unique set of local circumstances and requirements.
- Some aspects are cross-related, while others are difficult to quantify.
- The relative weight of the various aspects is not absolute, but subject to constant changes due to the dynamics of both cost and (environmental) legislation.

Therefore we would like to conclude this article with the recommendation to seek professional assistance for the appraisal of your existing application and/or feasibility study before the implementation of a new technology.

Application Method	Surface texture	Layer-Thickness Distribution	Productivity	Simplicity	Automation	Capital investment	Maintenance	Transfer efficiency	Material efficiency	Flexibility
Manual Dipping	-	-	+	=	-	+	+	+	=	+
Automatic Dipping	-	=	+	+	+	=	=	+	=	-
Slushing	-	-	-	=	-	+	+	+	+	+
Flowcoating	-	=	+	+	+	=	=	+	+	=
Vacuum	-	-	-	=	=	-	-	+	+	=
Electrodeposition	+	+	+	-	+	-	-	+	+	-
Manual spraying	+	=	-	=	-	+	+	=	=	+
Automatic spraying	+	=	+	+	+	=	=	-	-	=
Electrostatic wet spraying	+	+	+	=	+	-	=	+	=	=
Electrostatic powder spraying	+	+	+	+	+	-	=	+	+	+