POWDER ELECTROSTATIC CHARGE

XXI International Enamellers Congress

18 - 22 May 2008 Shanghai - China
1. Introduction
The adoption of electrostatic enamel powder coating has been one of the keys for obtaining an ecologic process maintaining the competitiveness in the enamel powder coating.

Starting from the first powder systems utilisations in 1975, users number all over the world increased year by year and consequently the technology has developed and got up to date.

The first industrial application in Italy go back to 1980 and from then on, the technical improvements of plants and products allowed to passing from direct applications of those years to the successive ones, with two coats and 1 fire, and later on, to the adoption of different enamel types and different colours application in the same booth.

The principles which the enamel powder coating is based on, are:

- Powder electrostatic charge
- Suction and recycle of powder that does not adhere to the piece

Practically the powder is sucked from a fluidised bed container, pneumatically sent to a gun that provides to charge it electrostatically; thanks to this effect, a powder percentage adheres to the piece. The enamel powder that does not adhere to the piece is recycled, mixed with virgin powder and utilised again. Then the pieces are transferred to curing oven.

1.1 Powder Electrostatic Charge
The powder particles, during the product manufacture, are coated with organic material to allow the electrostatic charge.

In the most cases, the electrostatic charge happens between the guns and the piece; the electrostatic generator produces a negative charge that charges the powder, reaches the piece and is attracted by it, that is electrically earthed by the hooks holder jig and the air conveyor.

The "Corona" charge, generally negative, is generated by an integrated cascade in the gun, that is therefore supplied with low pressure. The high voltage discharged by the electrode is driven from the electrostatic field lines to the nearest earth point.
The powder composition is a very important factor. The presence of too many fine particles does not allow a correct charge and takes, for example, to an excessive powder built-up in the piece corners. On the other hand, the presence of too many particles with big granulometry takes to a disproportional attraction charge with consequent irregular thickness.

Therefore, for a correct application, enamels must have an ideal granulometric curve. The electrons that do not attach to powder particles (free electrons) go by themselves in the air flow and, driven from the electrostatic field lines, reach the piece to be enamel coat (because it is earthed). The electrostatic charge can generate some problems and faults as the “Faraday Cage” or the “back ionization” phenomenon; these problems negatively influence the enamel powder coating result and, for this reason, a particular installing attention is necessary: but we will talk about it later on.

1.2 Suction and Recycle of Powder That does not Adhere to the Piece

The possibility to recycle integrally the enamel powder has granted the success of this technology, in terms of economy, as well. In effect, being possible to recover integrally the enamel powder that does not adhere to the piece, it results also easier to automate the application systems. The enamel powder recovery must be carried out in the quicker and more direct way, in order to reduce risks deriving from product high hygroscopicity. The enamel powder over-spray naturally contains both fine and bigger particles that must be recovered in the shortest possible time.

Booths have a suction system with filters that, causing a depression inside the booth, recovers the finest particles, whereas the bigger one fall down, on the booth bottom.

Particles with bigger dimension are transferred to the filter, where the recoveries are mixed with virgin powder, in order to use the most constant mix possible, under a granulometry point of view.

During enamel powder coating process, the enamel is applied, recovered and charged directly from the original packing; it is important to never forget all the critical application points that allow the achievement of good results, as well as the fact that the environment, where all these operation take place, must be protected even under an hygienic point of view.

2. Technical Plant Solutions

Now, we analyse, for each single component, the different stages of an enamel powder coating line:

1) Powder application
2) Suction, filtration and recycle
3) Virgin powder loading
4) Hooks cleaning booth
5) Air conditioning system

2.1 Powder Application

We start with the concept that the application must be performed trying to reduce the over-spray at the lowest possible level, because this over-spray must be recovered by suction system. It is easy to understand that, with a low quantity of over-spray, suction and recovery system will be less charged and, consequently, it will have a longer life and will be more efficient.

In order to optimise the application, it is opportune to:

1) Have always under control the electrostatic part of the system, checking with the appropriate instruments the effective electrostatic charge.  
2) Reduce the empty spaces in the chain. 
3) Adjust reciprocators stroke, always according to the pieces height that must be enamel coated. 
4) Do not spray enamel powder with prolonged absence of pieces.
The application optimisation has been improved thanks to the computerised control and check systems, able to automatically manage:

1) Reciprocators stroke according to the pieces height.
2) Automatic synchronism of reciprocators speed with the conveyor one.
3) Automatic adjusting of gun / piece distance
4) Output absence without piece
5) Hydrometric parameters and application temperature checking

### 2.2 Suction, Filtration and Recycle

To avoid enamel powder deteriorations, it is necessary to recover the over -spray in the most direct way possible.

The suction is effected by aspirating and filtering groups that separate powder from air. The suction must grant that no powder exits from booth free openings.

Filtering groups are constructed today using rigid filtering elements, able to assure a perfect filtration and in the meantime, to grant a long life to the filters themselves.

The filters with hoses used in the past, do not assure the outlet concentrations from the primary filter of rigid filters. In fact, the rigid filters grant a powder outlet < 3 mg/m³ allowing a longer life of the absolute filters mounted after the primary filter.

Obviously, the adoption this kind of filter is not the only indication of a good construction of a booth; the filtration speed is surely one of the most important indication.

A good filtration speed is normally considered around 0,7 / 0,8 m³ / m² / 1'.

### 2.3 Vorgin Powder Loading

The virgin powder loading often causes loss of powder, because some enamel powder is transferred from the original packaging (bags of 25 kg, drums of 250 kg or big-bag from 1000 kg) to the booth working container.

a) Manual loading from bags

We found it useless to underline that the bags manual loading is not recommended because, first of all, an enamel powder coating booth normally has high consumptions and for this reason, an excessive frequency of loading operations would be needed; then, this operation must be carried out manually.

b) Automatic loading from drums of 250 kg

This kind of virgin powder loading system has been lately used, but it has some disadvantages, above all concerning the hygiene of work.

The drum uncompleted emptying by suction units forces to effect some manual transfers of the remaining powder.

When the drum has to be replaced and the suction units have been removed, the most of the powder, previously deposited on them, falls down to earth, rendering practically impossible to have a clean environment around the drums.

Because of this, some times was necessary to insert these drums inside a box in depression.

c) Automatic loading from Big-Bag of 1000 kg

This is the most used system universally, since the start of enamel powder coating at industrial level; this system has several advantages compared to the two previous ones.
1) The operators intervention is reduced to a minimum, because this system autonomy is of 1000 kg.
2) The emptying is complete, because it happens thanks to gravity.
3) The powder is sent to the plant by means of pumps that take it from a fluidised container, assuring loading capacities and clean working environment.

The only inconvenient is the eventual replacement of the bag before it is completely empty.

2.4 Hooks Cleaning Booth
This equipment is necessary to remove the powder from the hooks pieces holders, after that the products is transferred into the curing line.

The powder is removed by means of different systems, such as blowing, beating system by pneumatic cylinder or pneumatic motor that beats repeatedly some small arms on pieces holders.

These hooks cleaning booths can be equipped with its own suction for avoiding that the powder goes into the environment : this powder can be transferred automatically to the application booth where it is completely reuse without the intervention of any operator.

2.5 Compressed Air Conditioning System
A characteristic of enamel powder is to be really sensitive to environment conditions and above all to air humidity.

In this diagram you can see how important features as “Adhesion” and “Back emission” deeply depend from the air water content.

You can clearly see that an average value of 7 gr/m³ could be particularly indicated for obtaining good results of “Adhesion” and “Back emission”.

The next diagram concerning relation between temperature /humidity (slide 11) shows in the yellow area the range which should be opportune to work in (i.e. 20° and 50%, or 28° and 30%).

But we cannot check the environment conditions; so, we have to modify temperature and humidity of compressed air that comes in contact with the enamel powder.

The compressed air conditioning system allows to check and adjust the compressed air temperature and humidity that feeds both guns and fluidised beds.

The air arriving from the factory net is first degreased, heated and humidified through an appropriate spraying nozzle. Then, the air passes throughout a cryogenic dehydrator where the humidity rate is set. In a second time the air arrive at another heater where it reaches the temperature wanted.

The use of this system allows to quickly perform the correction of the above mentioned parameters.

3. Application in Domestic Appliance
Now the main enamel powder coating uses will be analysed.

Approximately the 85% of the running plants concerns the enamelling of cookers parts that are in contact with high temperatures and approximately the 15% concerns the enamelling of boilers inside part.
3.1 **Enamel Powder Coating of Cookers**

The cookers parts that have to be enamelled are the following ones:

1. Inside flat parts (ground application)
2. Cavities (ground application)
3. Outside flat parts (white application)
4. Grids (ground application).

3.3.1 **Enamel powder coating of inside flat parts (ground application)**

This application normally is made on degreased sheet and usually concerns pieces that don't present big difficulties of application.

More than 95% of enamel powder application on flat parts is effected in automatic way by means of no. two reciprocators placed face to face with a guns number proportional to the working speed.

The areas of difficult penetration are coated with the utilisation of one or more fixed guns.

The plants with automatic ground application have usually a working speed from 2 to 7 m/min, allowing, in this way, high productivities.

The automation level of these plants can be really high: in fact it is possible to foresee installations that automatically effect the following functions:

**Synchronism with reciprocator / conveyor speed**

The reciprocator speed is automatically synchronised with the air conveyor speed, in order to obtain thicknesses uniformity even at chain speeds changing.

**Distance gun / piece**

The pieces to be enamelled on one face only are hanged back-to-back on hooks holders; on the contrary the pieces that must be enamelled on both faces will be hanged individually. Therefore, it is necessary to adjust the distance between gun / piece according to the two cases above mentioned.

In this case automation system allows, firstly, to identify if the pieces are hanged back-to-back or individually and therefore, to send a control to both reciprocators and fixed guns supports to let them placing in the right position.

**Stop of powder spraying**

Considered the high speed that normally characterised these plants, the powder total spraying is really high, so it is important to avoid powder spraying at pieces absence; if the gap is higher than 10÷15 seconds it is convenient to switch off the guns for avoiding to send to recovery system a too high quantity of powder. This stop is automatically effected.

**Fixed guns switch ON – OFF**

In order to avoid to continuously move fixed guns according to the different needs, on high speed installation a lot of fixed guns are installed in order to be able to switch on only the guns dedicated to the piece that it is enamelled.

This concept avoids also the possibility of an uncorrected positioning of guns.
3.1.2 Enamel powder coating of cavities (ground application)

The enamel powder coating of cavities is surely the most automated and specialised one. In fact, the geometric configuration of these pieces forces the use of precision robotics in order to apply enamel in the most uniform way possible.

The plants with medium / high productivity (80 ÷ 220 pieces/h), normally use 2/3 robots with 3 axis, where are mounted a certain number of guns; their number and position are determined by both productive capacity and difficulty in enamelling the piece.

The prerogative of our plants for cavities is to use particular gun heads, inclined of 135°, specially studied to facilitate the enamel powder penetration in cavity corners. The 3 axis robots allow to follow the pieces during the application and to effect different movements inside them (each movement has its own programmable speed). The high performances of our enamel powder coating booths for cavities allow us to have a reference list of approx. 30 running plants.

In any case, it exists a further economic option for enamel powder application on cavities, that can be considered in case of low productivity (approx. 20 ÷ 25 pieces/h). This option foresees the application by means of 1 or 2 guns mounted on one 6 axis robot. The application result is qualitatively good; the only limit of this technology is the low productivity.

Both systems are controlled by a PLC/PC able to store a very high number of programs, allowing therefore to enamel with the same plant also different types of cavities.

3.1.3 Enamel powder coating of external flat parts (white application)

Concerning white application of external flat parts, everything said about the ground application of internal parts remains valid. But it is important to say that white application can be performed through different cycles:

- **Direct application**
  This system supposes the utilisation of decarburized sheet metal and pre-treatment with pickling and nickel; it is less and less used because the ecological impact results to be really high due to pickling use.

- **2 Coats + 2 Fires**
  This process can use sheet metal that can be enamelled: it is about enamelling with white powder some pieces previously enamelled with ground and, then, fired. This system is usually applied in case of low productions, because the two firing are economically disadvantageous.

- **2 Coats + 1 Fire Powder on Powder**
  This process foresees the application of a very light film (35-50 microns) of ground powder and the immediate application of 100-120 microns of white powder; nowadays, due to several problems, this cycle has been almost left.

- **2 Coats + 1 Fire Powder on Wet**
  This is the enamel powder coating system with white actually used; the ground application is effected by wet enamel, dried (preferably with infrared oven) and therefore sent directly to the booth for white powder application. This cycle was born some years ago with the purpose of using common sheet metal that can be enamelled. At the present time it is preferable to use decarburized sheet metal in order to big quality problems.
3.1.4 Enamel powder coating of grids
The grids are powder enamelled with plants similar to the ones used for enamelling in ground. But there are two different application technologies that can be adopted according to several industrial reality of the different customers.

- **Application with horizontal grids**
  This kind of application is widely used: in fact grids producers usually produce for several different customers and, therefore, with grids of different designs.

  The horizontal application forces the grids firing in the same position, because it minimises any risk of distortion. The application is carried out using a series of fixed guns placed over and below the pieces going inside the booth.

- **Application with vertical grids**
  This kind of application is mostly used by cookers manufactures which, producing and designing the grids by themselves, can predispose their project in the way that they, also vertically hanged, don’t deform themselves.

  In this case the enamel powder application will be effected by means of reciprocators and the grids will be hanged back-to-back.

3.2 Enamel Powder Coating of Boilers
This technology has been introducing since approx. 15 years, but it is in the last 2-3 years that it shows a considerable increase.

Today, more than 25 plants are running for enamel powder coating of boilers.

The enamel powder coating of boilers concerns the enamelling of boilers inside part only, thank to one or more mono-axis robots that, through an extension mounted on the electrostatic guns, performs the adequate cycles inside the water heater.

This application happens with the still piece and the pieces will be transferred throughout the plant in stop and go mode; the transfer will be of 2, 3 or 4 pieces according to the plant productivity. When the chain stops, the pieces are blocked in the correct position by an appropriate locking device, in order to be sure the lance can enter the boilers opening.

The productivity average relevant to these plants is usually included within 30-140 pieces/hour, considering a volume average of 80 litres.

4. CASE HISTORY 1

**WHIRLPOOL – Italy, Plant of Cassinetta**
The plant of Cassinetta was the first to install, in the far 1980, the first enamel powder coating booth.

Therefore, Whirlpool has been a pioneer in enamel powder application and, starting from 2000, integrated its enamelling line with 2 changing colour booths (grey and black), one for panels and one for ovens. In 2003, arisen the need to integrate the production with pyrolytic enamelled kitchens, Whirlpool decided to install a booth equipped for both ovens and panels enamelling; by taking advantage of the previous changing colour booths, a three colour booth (black, pyrolytic and blue) was installed. In June 2007 a second ovens enamelling booth was installed, equipped for two colours (pyrolytic and grey).
The application is performed by n. 3 three axis robots which move 16 guns equipped with special nozzles; a series of fixed guns guarantees the perfect front frame coating.

Robots movement is managed by a main control board with PLC and workstation, which is able to control different working programs. Whirlpool works on this line (3 three axis robots equipped with single arm) ‘just in time’ with 4 different oven models.

The particular booth project, central suction channel, assures:
- perfect and homogeneous suction
- no powder stagnation inside the booth
- easy cleaning for a rapid (60 min.) changing colour

Aspiration is effected by 2 trolley filters (one for each colour), mounted on rails, in order to be positioned in the working area depending on the colour to be executed.

The powder recovered from the aspirating filter falls down, passing through a rotating sieve, in the below container. Powder pumps are mounted on a special support which allows the automatic cleaning at changing colour moment.

The first level technological characteristics of this innovative enamel powder coating booth has allowed to obtain the following results:
- Uninterrupted operation at 3 shift for 5,5 days per week
- 3 / 4 colour changes per week
- 210 pcs/h of production ‘just in time’, with a recoating percentage inferior to 0,5%.

5. CASE HYSTORY 2

**MTS – Italy, Plant of Genga**

The plant of Genga was one of the first which installed, in 1985, the first enamel powder coating booths for boilers.

Since the first experience, MTS mounted a powder enamelling installation as ‘direct on’: the first in Italy.

The enamel powder application in the last of 4 booths installed in Genga plant, is performed by n. 2 mono axis robots that move 8 guns equipped with extensions, that allow to enter inside the boiler; a series of fixed guns assured the application of a very light enamel coat on the external surface, in order to prevent the annoying formation of calamine.

Robots movement is managed by a main control board with PLC and workstation, which is able to control different working programs.

The aspiration is effected by 1 filter mounted near the booth. The powder recovered from the aspirating filter falls down, passing through a flat sieve, in the below container. Powder pumps are mounted directly on the container itself.

The first level technological characteristics of this innovative enamel powder coating booth has allowed to obtain the following results:
- Uninterrupted operation at 3 shift for 5 days per week
- 130 pcs/h production of boilers with diam. 410 mm and height 650 mm, with a recoating percentage inferior to 0,5%.
6. Conclusions
We tried to explain the several themes object of this short report easiest and most understandable way possible.

For further explanation, we are at your disposal in order to answer to your questions.

Thank you for your attention.