Application of the Technology of Hot Enamel in Design

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Abstract. Enameling is a very ancient, well-known method of combining glass and metal, and at the same time it is a very young, rapidly developing and widely demanded type of art. This happened because with the development of science and, as a result, the improvement of enameling technology, the process became quite accessible and universal. The works made in the "durable" technology are becoming more wide-spread in the design of architecture, interior decoration and decorative applied art. The article gives the classification of enamels and the possibility of using various techniques in product design. The authors note role of enamels by Russian manufacturers in obtaining a spectrum of color combinations. The distinctive features of enameling techniques are revealed. Some types of defects while enameling, their causes and main ways of its elimination are discovered in the article.

1. Introduction
The wide interest to hot enamel has increased dramatically in recent years, not only among artists, but also in the work of designers and the work with utilitarian-technical, applied and functional objects with enamel coating. Despite the impressive and convincing history, artistic hot enamel is still in an active development process. The quality of work is primarily determined by the practical experience of the enameller, since the complex problems of the composition of enamels, burning and metal interaction with enamel, as well as many other technical issues, continue to improve. The enamel artists, working today with traditional enamels, also actively use hot technical enamels, that makes it possible to diversify the artistic expressiveness of modern created images and forms. Hot enamel by its nature exists only in a single copy. However, this type of art is exclusive.

The functional application of enamel in people's daily life has also expanded. This is not only enamelware or protective anti-corrosion coatings, but also a wide range of application of enamels in architecture, in space technologies and in special technologies. Today enamel coatings can be seen in the tunnel under the English Channel, at the stations of the Moscow Metro, on the International Space Station, in deep-water bathyscaphes, as well as in the interior design of public buildings and everyday life. Natural interest is in the use of enamel in the design. This is a whole cosmos of understanding traditions and innovations, decorative plastics and functional applications. The designer needs to solve many problems. Persistent search for own techniques, intuition and design flair will help to create original and highly artistic works.

2. Main Body
There are many techniques used by enamel artists and designers. To date, the scientific literature describes the features of modern manufacturing technology of enameled artworks, which are divided
into several types of enameling. It is necessary to consider the classification of enamels used in the design.

Cloisonné. The essence of this technology is in the fact that the enamel is applied to individual sections of the product, obtained by using partitions - metal strips or wires soldered to the metal surface. Due to the fact that certain sections have a small surface area, the enamel on them is clung quite firmly. This decorative method is accessible and understandable, but it requires perseverance and quality of work performing.

Champlevé enamel involves filling holes in the metal, gained by engraving or etching.

Stained glass or window enamel. The peculiarity of this enamel is based on the fact that the enamel works on the lumen in the previously prepared holes. It resembles stained glass window in miniature. It is a technically complex technology that requires practical experience, skill and handicraft from the enameller. The sphere of application, as a rule, is in jewelry.

Guilloche enamel. Drawing on the metal surface is created by stamping, guilloching, engraving, notching, etc. The recessed areas of the pattern are filled with enamel, and the protruding edges of the metal base are polished and form a contour. This method is used for producing rewards: orders, medals, as well as small jewelry items.

Graffiti. This term designates one of the ways of painting enamels. The essence of the method is in scratching the upper layer applied to the lower (annealed) layer and varying several colored subsequent layers. This type of enamel is well studied and used for "easel" enamels.

Painted enamel, obtained by the way of polishing, is achieved after applying and annealing thick layers of industrial enamel, polishing the surface of the product with abrasive bars. The use of this technique gives the opportunity to get sophisticated, beautiful pictural transitions. It is quite a laborious technique, requiring professionalism and developed imagination of the artist-designer. Sheets of copper and steel plates are used as the base material for this technique.

Enamel on chased relief. This is Medieval enamel, not completely supplanted by modern methods of enameling. Enamel on chased relief is more artistically enriched and universal. However, it is laborious and hardly applicable, but the interaction with the noble metal of the base is very harmonious.

Matt enamel. It is divided into two types: matt polishing and matt enamel as it is. The palette for such enamel is limited, but after annealing it opens great opportunities in textures, crackles, and obtaining shades.

Enamel of mixed technologies. In the search of new expressive forms from the design and technical point of view, enameling went beyond the classical methods. Natural and artificial materials (all types of metals, precious stones, mother-of-pearl, a turtle, ivory, enamel) are included in the design composition due to the great artistic merit without material value. This type of enamel allows the designer greater freedom in creativity without restricting his research.

Enamel with the effect of smudges. This type of technology resembles the application of glaze on ceramics and is widespread on volume objects: vessels, small forms of sculpture, small plastic. The easiest and most affordable way is enameling convex and three-dimensional planes. There are several techniques to technically make enamel more fluid. This technique is used as a form of decorative coating of works.

Mosaic enamel. In order to obtain a mosaic enamel, prepared beforehand chopped enamel pieces are used, as a rule, on a bronze plate. First, the selection of the palette and the module is carried out, then goes a mosaic composition on the tragacanth and annealing. This is a very effective, but rather complicated technique. Muffled and opaque enamels are used in this process.

Enamel of free color mixing. Unlike all other techniques with free mixing of enamels of different tones, the decision on the composition developed by the work cannot be determined before annealing. The process of obtaining takes place with an open muffle. This method opens up the possibility of obtaining intricate effects that are freely obtained on a brilliant enamel coating. This method opens up large spaces for creativity in design.
Enamel granulation. When the enamel balls are melted on the ground enamel, an effect similar to metallic granulation is created. Balls with a diameter of 0.2-4 mm are made from enamel grains. It is carried out on asbestos or charcoal, fused on a gas flame. Finished beads are placed on the ground enamel with a tragacanth or with the help of a fusible enamel powder.

Enamel granulation. According to its technology this method is similar to the previous one, only instead of enamel beads gold or silver beads are used. They are fixed and melted in the same way as enamel granulation. However, metal balls should not be more than 1.0-16 mm in diameter. After annealing, the fused balls are coated with transparent enamel. This method is time consuming, but it allows to get the original effects.

Painting with enamel paints. Fondon painting and ground enamel painting are distinguished. For this, colored enamel powder is applied directly on a metal base, on a foil coating or on a prepared layer of ground enamel without metal partitions. It is annealed so that the enamel melts and forms a dense coating resembling colored glass. This unique technique opens up a wide range of possibilities for an artist-designer in creating unique works.

In addition to these basic techniques, there are a lot of techniques which are used by Russian enamellers. The use of enamel in design is based on the quality and guaranteed durability of paints, its light resistance and their physical characteristics.

The second factor that attracts designers to hot enamel is its versatility, wide possibilities of creative self-realization and the novelty of the plastic solutions of the composition.

The scientific literature reveals information about the technical application of dye-stuff for the manufacture of products, but the process of obtaining a particular color on enamels is more experimental.

To obtain a decorative surface with desired properties, the designer must take into account the characteristics of paints (jewelry or technical enamel), material properties, and the capabilities of the equipment used (temperature) in the process of creating a work using the technique of hot enamel.

It should be kept in mind that enamels of different colors have different melting points and different coefficients of expansion (Table 1). In the other case it can lead to burning or cracking of the enamel coating. Introducing any pigment in the enamel makes it possible to change its physical properties, but this does not affect the intensity of the color range. That is why, the composition of enamels may vary.

| Enamel number | Color    | The temperature of annealing, C. |
|---------------|----------|---------------------------------|
| 13            | white    | 820-840 ° C                     |
| 63            | light-blue | 720-820 ° C                  |
| 34            | yellow   | 720-840 ° C                     |
| 5             | red      | 780-880 ° C                     |
| 134           | orange   | 760-840 ° C                     |
| 60            | green    | 740-840 ° C                     |
| 91/2          | blue     | 740-800 ° C                     |
| 32            | fondon   | 800-860 ° C                     |

Enamels of Russian manufacturers (Likino-Dulyovo and Cherepovets) can be simultaneously combined to develop and create artistic easel works for the environment and the interior design (Figure 1).
To eliminate conflicting color combinations, it is necessary to take into account possible defects during enameling and the main ways to eliminate it (Table 2).

**Table 2.** Some types of defect of enamel coating; causes and basic remedies.

| Defect type                  | Causes                                                                 | Remedies                  |
|------------------------------|------------------------------------------------------------------------|---------------------------|
| Blistering                   | A large amount of water in the enamel, poor quality copper preparation | Second annealing          |
| Uneven, rough surface        | Reduced annealing temperature                                          | Stripping, second annealing |
| Absence of shine             | The original enamel formulation is broken.                             | Mechanical polishing      |
| Lagging of enamel from copper| Poor degreased copper, low annealing temperature                       | Stripping, enameling, annealing |

It should be noted that when applying paint to copper, the thickness of the paint layer should be taken into account. So, for example, in order to obtain a crazing, first Dulevo enamel is applied (not less than 1 mm thickness) and burned at a temperature of 740 °C. Then liquid technical enamel is applied to the finished surface and, after complete drying, is put in a muffle furnace. Due to the difference in melting temperature, a decorative crackle effect (artificial aging) is obtained.

### 3. Conclusion

To obtain a decorative effect and expand the color palette you need:
- observe different levels of melting point of the applied enamels for a specific type of product;
- take into account the purity of the paint composition from different manufacturers; comply with the formulation of the composition of artistic paints;
- the ability to lay at the same time jewelry and technical enamel, taking into account the thickness of the paint layer.

A variety of hot enamel techniques, an insistent search for one’s own techniques, intuition and design flair contribute to the creation of original and highly artistic works.

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