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Plaforization Process for Cleaning, Degreasing, and Phosphating

One-step pretreatment method provides economic, environmental, and safety benefits for operators.

Several industrial magazines[1–7] have previously focused their attention on the proprietary Plaforization process, a one-step system for cleaning, degreasing, and phosphating metal surfaces before painting. The Plaforization process is completely different from typical conventional water-based processes, and it offers a set of benefits and advantages to users:

- **It is a truly one-step process, with no rinse**
- **It uses no heat**
- **It creates no wastewater, sludge, or other contaminants**
- **It uses no water**
- **It reduces CO_2 emissions on the order of 90% in comparison with conventional processes**
- **Multiple types of metals can be treated, even simultaneously**
- **It is safe for the workplace because the products are not flammable, nor do they contain toxins or other harmful ingredients**

PROCESS BASICS

From a chemical point of view, Plaforization is very different from conventional, water-based processes for cleaning, degreasing, and phosphating. Its chemistry is based on a specialized set of organic high-boiling-point fluids and a very particular organic polymeric resin modified by phosphating groups.

The process is truly one step: no preliminary degreasing is required, and no rinsing is performed after the pretreatment step. Treatment time is about 60 seconds (only in a few special situations of stubborn soils is it necessary to increase the treatment time, but even then no more than 180 seconds) followed by a drip-off (normally the minimum is 5 minutes), and then an oven dry-off for 5–10 minutes at 275–300°F. (depending on the product used).

Application may be by dip or flowcoat, at ambient temperature, during which several different processes occur almost simultaneously:

- **Oily contaminants are dissolved[8] by the organic fluids, while solid particles such as powder, dust, fines, etc., are washed off and taken into the solution**
- **The metal surface is attacked by the phosphating acid part of the organic resin**
- **During fluid flash-off, the organic polymeric resin cross-links by creating a uniform organic polymer with a thickness of about one micron.**

This organic polymer provides excellent resistance against flash rust and also provides great adhesion with topcoats.

During fluid flash-off, the oily contaminants dissolved in the product are captured by the three-dimensional structure of the organic polymer without interfering in the interaction between the polymer itself and the topcoat. In fact, rather than being a waste product, the oils become a useful part of the process, acting as plasticizers in the resin.

As the product is used in the pretreatment, new fresh product is added to "top off" the level of chemical in the tank. This, of course, also adds "fresh organic resin" to the bath. So, on a continuous basis, the system is capable of absorbing up to 1.5 grams of oil per square meter of metal surface treated, a value at least three times larger than the standard quantity of oil on cold-rolled steel normally available in the market.

The insoluble solid particles are filtered out by a specific filtering system that is part of the equipment (normally filters are equipped with 50-/100-micron polypropylene bags). More detailed information[1,2] about the chemistry of this process

One-step organic phosphating (hypothetical customer)–126,000 ft² metal treated/mo	
– At 1,300 ft² coverage per gallon, uses 97 gal/mo	
– Specific gravity	0.945 g/cm³
– 1 gal B609	7.91 lb
– 97 gal chemical	763 lb
– Carbon percentage	53.95%
– Pounds of carbon	412
Same customer's heated conventional installation	
– Burner rating	1,500,000 BTUs
– Assume operation at 75% of capacity	
– 8 hr/day—monthly BTU use	187,500,000 BTUs/mo
– Volume of fuel	187,500 ft³
– Lb—16 lb/357 ft³ (methane)	8,403 lb.
– Percent carbon (methane)	75%
– Pounds of carbon	6,303

The first set of calculations estimate the consumption per month of Plaforization ECOPHOR chemicals for this hypothetical customer, and the resulting carbon emissions expressed in pounds. The second set of calculations takes the burner rating of the customer's existing conventional washer and determines the amount of carbon emitted from the combustion of heating fuel.

Table 1: Estimated Chemical Consumption and Carbon Emissions

*PAI-KOR S.r.l., is the inventor and manufacturer of Plaforization. Carpenter Chemicals, LC, based in Alexandria, Va., is a NAFTA distributor for Plaforization.

Figure 1: An aluminum metal sheet treated with ECOPHOR B/700 and then painted with epoxy polyester powder coating. After a cross-hatch adhesion test to verify the paint flexibility and resistance to bending and mechanical shock, the customer shot the panel with a .22-caliber bullet from 5 meters. You can see that the coating perfectly "follows" the hole left by the bullet.

Figure 2: Manual batch spraying equipment. Parts are hung and manually placed in the washer. The unit is equipped with three risers with nozzles, and the risers—rather than the parts—move during treatment to completely bathe all the part surfaces.

is available in previously published articles.[1–7]

RESULTS

The organic polyphosphate, despite its approximate one-micron thickness, provides excellent temporary protection against flash rust on uncoated parts for several weeks if stored indoors. Moreover, this organic polyphosphate uniformly coats the treated metal surface and is connected with the topcoat by a covalent chemical bond (powder coating or wet paint, solvent, or water-borne) applied in the subsequent finishing step. The result is a strong and continuous interaction between the organic polyphosphate and the topcoat over the entire treated surface.

Because the polyphosphate created by the Plaforization process is mainly organic, plastified by the oily contaminants, it has higher flexibility than the typical inorganic crystal of iron/zinc phosphate created by conventional processes. Therefore, painted surfaces treated by the Plaforization process have great resistance to mechanical shock, such as impact, bending, etc. (Fig. 1).

As far as corrosion resistance on steel is concerned, Plaforization normally provides at least the same results as an amorphous iron phosphate. When compared with microcrystalline zinc phosphate in laboratory testing, the results are typically lower, although in practice it should be noted that zinc phosphate is quite unstable, whereas Plaforization is extremely stable and gives the same results day after day.

On aluminum, in combination with Kynar coatings developed for high corrosion resistance, it has been possible to achieve the AAMA certification (4,000 hours of salt spray resistance). Using standard polyester powder coatings (even TGIC-free) on aluminum treated with Plaforization, it is possible to reach 1,000 hours of salt spray resistance. (A NAFTA customer using a TGIC polyester at a little more than 5 mils tested successfully to 3,500 hours of salt spray resistance.) Of course, these are general data and specific tests must be carried out to confirm results with particular topcoats at specific thicknesses.

ADVANTAGES OVER CONVENTIONAL PROCESSES

Simplicity. Plaforization users do not face two typical problems of conventional water-based cleaning and phosphating systems: continuous chemical analysis of each process stage, and continual equipment maintenance.

The Plaforization process is extremely stable because the ingredients in the bath are used up in proportion, the fines are constantly filtered out of the bath, and the oils are removed via absorption by the resin. Therefore, users have seldom need to do any tests or analysis. Just one sample every three months is sent to the PAI-KOR laboratory for a complete chemical analysis.

Eliminate Downtime. Plaforization users do not waste their time heating up tanks, emptying tanks for cleaning, removing sludge, dumping tanks and replacing chemicals, or cleaning nozzles or filters. Nor do they need to stop pretreating when the paint line operators take breaks or at the end of the day, because the treated parts do not flash rust.

Consistent Quality. By virtue of its simplicity, Plaforization users can forget reworking or repainting parts due to chemistry failure(s) in one or more stages of their washer, as they do when working with conventional systems

Multi-metal Process: With the same chemical product, users can treat steel, aluminum, galvanized steel (hot-dip galvanized or by galvanic deposition), cast iron, aluminum alloys, and even stainless steel.

Figure 3: Dual in-line flowcoat tunnels for multi-shift production. Each tunnel is equipped with its own tank and filtering system. Specific risers can be turned on or off—depending on conveyor speed—to allow for appropriate treatment time and to minimize chemical consumption.

Equipment for Every Process Need. Plaforization systems can be used by dipping or spray at low pressure (flow coating) in small, compact, and flexible equipment for limited production (Fig. 2), as well as in large automated tunnels (Fig. 3). Because of the compactness of the equipment, single-stage treatment, and the low air and liquid pressures, equipment costs are significantly reduced compared with conventional systems.

COSTS

The comparative economics of Plaforization and conventional, water-based processes have been previously analyzed in detail.[5] Regardless, it is important to point out here as well that the main advantage of the Plaforization system remains the absence of virtually all the variable costs typical of conventional process, such as heating of at least one stage of the process, wastewater treatment, sludge/mud disposal, downtime, and so on. Thus, although the specialty chemistry itself is more expensive than conventional chemicals, this cost is more than recouped in the elimination of almost all the conventional systems' variable costs.

In evaluating the economics of the Plaforization process, the higher the quantity of metal surface treated per day, the higher the effect of the cost of the chemicals for Plaforization user. There is a cross-over point (variable depending on the efficiency of the conventional process and the costs of natural gas, water, etc., at a given time) at which the conventional process is the more economical, and below that point Plaforization is more cost-effective. The North American distributor for Plaforization has recently developed[5] an return on investment (ROI) calculator that includes all the major costs and charges related to metal surface cleaning, degreasing, and phosphating with a conventional water-based process compared with Plaforization. This ROI calculator allows a user to make the comparison using his or her own numbers and to obtain an estimate of the savings as well.

ENVIRONMENTAL IMPACTS

There are several advantages for the environment derived from the use of Plaforization over conventional water-based systems:

- **Plaforization does not create any mud or sludge to be treated or discarded.**
- **Plaforization does not use water, so it does not pollute water or tax the water supply.**
- **The organic fluids are not flammable and are free of chlorine, aromatic compounds, halogenated substances, CFCs, and HCFCs.**
- **These organic fluids have been chosen specifically to provide the highest level of conformity to international and local environmental laws. The ECOPHOR/ Plaforization process is not even classified as a VOC under European Laws (1999/13/CE), and, although they are classified as VOCs in North America, they are so low-emitting as to be easily approved, generally without special permitting.**
- **These organic fluids have a very low vapor pressure (even lower than 0.01 KPa at 77°F), and thus the loss of product during application is minimized.**
- **The fluids, once evaporated into the atmosphere, are biodegraded quickly into carbon dioxide and water. It has been calculated that the total amount of CO_2 created through decomposition of these fluids used in the Plaforization process is roughly 10 times lower than the amount created by the natural gas combustion necessary to heat up the chemicals in one stage of a conventionalwasher to treat the same quantity of a metal surface (Table 1).**

HOW A NICHE PROCESS CONFORMS TO THE EVOLUTION OF TECHNOLOGY AND LAWS

Plaforization, as a technology, was first introduced into the European market in the late 1960s. The first generation of the product was based on chlorinated solvents such as trichloroethylene, 1,1,1-trichloroethane, and perchlorethylene.

The advantages provided by these solvents—at that time widely used in many industries—were the quick drying rate, the great degreasing power, and the non-flammability of the products. One of the biggest issues in Europe at that time was avoiding fire, and new laws came into force during this period to increase workplace protection.

The first product generation contained a rather large amount of phosphating acid salts (pH around 1), as well as zinc ions. Moreover, the process created a higher thickness of organic polyphosphate than later formulations, because the market demanded it. At that time, conventional phosphating quality was measured by the number of grams per square meter of phosphating salts coating the parts treated—even though, in fact, a high thickness made the coating more brittle, with consequent fragility issues in all coating processes.

The very first Plaforization customer was a sort of in-house "guinea pig," a company affiliated with PAI-KOR that manufactured seats for motorcycles and bicycles. This provided a good way for the inventor to verify the quality and limits of his own technology, so that he could further improve it before taking it to the wider market.

During last 40 years, the PAI-KOR R&D laboratory has been constantly working to develop new products to meet customers' increasingly elevated technical requirements (in order to meet new local and international legal requirements relating to the environment and workplace).

With this in mind, the second generation of products developed at the beginning of the 1980s contained no chlorinated solvents, because of new laws regulating and limiting their use in Europe. The second-generation technology had the following main improvements over the first generation:

- **It was free of chlorinated solvents, which were replaced by alcohols, acetates, and aromatics**

(these, too, were totally replaced a few years ago).
- **Acidity was reduced to increase compatibility with polyester powder coatings that had been introduced into the market in the meantime.**
- **Poly-phosphate thickness was lowered to reduce aesthetic defects caused by local overthickness in areas of accumulation.**

At the beginning of the 1990s, PAI-KOR developed the ECOPHOR process, using high-boiling-point organic fluids with strong degreasing power. Using more sophisticated equipment and a drying oven, the ECOPHOR process allows for the optimization of aesthetic results by making drip-off more efficient and even, and it greatly reduces solvent emissions into the atmosphere. A dedicated version of the ECOPHOR process, invented and patented by PAI-KOR, allows the vapor to be recovered by a special scrubber also developed by PAI-KOR.

While the first and second product generations were developed and sold first in Italy (during the late 1960s and 1970s) and then in Europe (during the 1980s), the development of the ECOPHOR process demonstrated that PAI-KOR, a family-owned company, could now provide alternative, innovative, and environmentally friendly solutions to the global market. (At present there are roughly 500 industrial plants running with Plaforization products in more than 25 countries.)

In fact, Plaforization products:
- **have been present in some European markets for more than 40 years;**
- **have been introduced to and used in North American markets; and**
- **have been distributed in Far East Asia since 2004, and between 2007–2008 new plants, sold by new distributors, have started up in Malaysia, Thailand, Turkey, and Northern Europe.**

USERS

Customers have chosen the Plaforization process because of its simplicity, flexibility, ability to meet varying manufacturing specifications, and, of course, the cost savings for small/medium production. It also complies with various national and European environmental and workplace safety laws. Among these users are:
- **A leading company in the manufacture of boilers and heating systems for both industrial and civil use, with several manufacturing sites in France (two of them are equipped with an ECOPHOR flowcoat tunnel).**
- **One of the largest manufacturers of display stands and shop-fitting and industrial storage equipment for specialized stores. The company has five manufacturing sites in Europe, and in three of them ECOPHOR is the process used to clean and phosphate parts before powder coating.**
- **A company that is part of an American Global 500 group, with a manufacturing plant in France. This company has been using Plaforization for more than 20 years. In fact, it built its own tank to treat electrical motor parts during the 1970s to use the chlorinated-based product. Since that time, it switched first to the non-chlorinated product and then to the non-chlorinated and non-aro matic generation. In 2002, the customer switched to the ECOPHOR process by adding a dry-off oven. Drip-off now takes place between the old tank and the oven itself.**

It is important to point out that all these changes were made without disposing of a single drop of chemicals, but just by adding the new-generation product to the old one: PAI-KOR has in its mission the "no-sludge" philosophy, so each generation is developed to be chemically compatible with the former.

In the NAFTA market, growth since product introduction in the year 2000 somewhat mimics PAI-KOR's early growth in the European market. The most difficult aspect of introduction of a new product, especially one so different from conventional processes, is to establish credibility.

In 2000, the first customer in the NAFTA region was a small user in Michigan with a dip process, and that company is still a loyal customer. From that point on, other small customers emerged as they found out they could talk with existing customers and convince them that the process actually does work as promised.

One early customer was a very large company, and it continues to successfully use the process. But a customer that size was the exception rather than the rule in the early days, largely because of the credibility factor.

More recent customers, however, include well-known companies in various fields—Global 500 and Fortune 500 companies—as well as smaller users. Industries include the military (MIL-TT-C-490), high-end office furniture, school furniture, point-of-sale displays, enclosures of various kinds (electrical enclosures, cabinets, etc.), motor starters, heating and ventilation equipment, compressors and filters, and various other industries.

CONCLUSIONS

This innovative one-step organic phosphating technology has been in use for more than 40 years, first in Italy, then in Europe, and now worldwide, with approximately 500 customers. These customers are the best testament possible to the viability of the technology, because they have been using the process through various improvements since the beginning, changing from earlier iterations to later innovations.

The process is economical for a wide variety of users because it eliminates virtually all of the variable costs associated with conventional water-based processes, such as natural gas, water, sludge, bath instability, down time, and labor associated with heavy maintenance requirements. The PAI-KOR laboratory continues its work on improving the product line and advancing the technology of organic phosphating, and the company and its distributors continue the work of making it available to an increasing global market.

NOTES

1. Carpenter S. One-step, zero-effluent organic phosphating. *Metal Finishing* 1999;97(9):56–60.
2. Carpenter S, Carpenter M. One-step, no-rinse cleaning and phosphating plaforization chemistry. *Metal Finishing* 2002;100(4):73–6.
3. Carpenter S, Carpenter M. One-step organic phosphating revisited. *Metal Finishing* 2003;101(9):30–1.
4. Carpenter S, Carpenter M. A one-step process for metal pretreatment: organic phosphating positioned as environmentally sound, user-friendly and inexpensive alternative to current systems. *Metal Finishing* 2006;104(2):37–41.
5. Carpenter M. One-step organic phosphating: how costs, features and benefits stack up against conventional pretreatment wash systems. *Metal Finishing* 2006;104(6):41–6.
6. Carpenter S, Carpenter, M. One-step metal pretreatment: a single-stage organic phosphating system is reducing the cost and environmental impact of pretreating metal substrates. *Finishing Today*; (July 2007).
7. Customer success stories: Carpenter Chemicals Plaforization solves problems in cleaning and adhesion. *Powder Coating* 2005(Mar.);16(3).
8. Ferraris E, Guidetti G. *Verniciatura Industriale*, 1976;103(9).

ABOUT THE AUTHORS

Dr. Gianluigi Guidetti *is the developer of the Plaforization process. He was schooled in Italy and Lausanne, Switzerland, and graduated with a PhD in chemical engineering from Milan Polytechnic. Dr. Guidetti's grandfather founded the Milan-headquartered PAI-KOR in 1924 and Gigi (as everybody calls Dr. Guidetti) spent his all career managing this family business, especially in his lab looking for new concepts and alternative solutions in metal pretreatment as well as in the wet paint industry.*

Carlo Guidetti *earned his degree in pure chemistry from Milan University. Guidetti, a member of the fourth generation of the Guidetti family involved in the business, has managed PAI-KOR international business development since he joined the company five years ago. He keeps at least one foot in the lab to guarantee the technical evolution and continuity of PAI-KOR know-how to meet the challenges of new global markets.*

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