California HARDCOATING

White Paper

Starting a Low-Cost Hard Coating Operation

William Lewis, PhD

http://www.cahardcoating.com
Tel: +1 619-498-0098
E-mail: wlewis@cahardcoating.com

Introduction

This paper is intended to provide an overview of the business and technical considerations of starting up an in-house hard coating operation. The audience for this paper includes business managers and engineers from a variety of manufacturing businesses, such as consumer electronics, optics, medical equipment, plumbing fixtures, and automotive parts. Injection molders may also be interested in offering the added value of hard coating parts.

An in-house coating operation can be justified through new revenue, elimination of toll-coating fees, faster turnaround, greater control of quality, and a shorter supply chain. But until recently, the six- to seven-figure investment required to start a coating operation has been a barrier keeping many companies from bringing a hard coating operation in-house.

California Hardcoating's Perma-New™ abrasion- and scratch-resistant coatings significantly lower this barrier by eliminating the need for many costly environmental controls. Furthermore, through its years of experience in advising companies on how to start up and improve their coating operations, California Hardcoating has developed many practical ways to "bootstrap" a new coating operation through straightforward build-your-own plans.

With California Hardcoating's unique approach to hard coating, the investment required to start up a small-scale, in-house coating operation can be reduced by a factor of ten. In a few cases, a new coating operation has been started for as little as $25,000. In most cases, however, start-up costs fall in the range of $50,000 to $100,000. Often, a new operation can begin coating parts in a few months. An in-house coating operation can produce a very high ROI and often breaks even in less than one year.

Hard coating Overview

The term "hard coating" has different meanings based on industry. In this context, hard coating means to apply a very thin—about 5 micron deep—coating to a substrate material such as polycarbonate, acrylic or polished metal in order to protect it from abrasion and scratching as well as from chemical damage.

Generically, hard coatings are sol-gels of silica and resin nanoparticles that are applied in liquid form and then cured to a glass-like hard finish. Hard coatings can be applied in a number of manners, including flowing, dipping, spraying and spinning. Curing typically involves heating the coated materials at relatively low temperatures for 1–4 hours or by exposing the coated surface to UV light for several minutes. Although UV curing is often preferred because of the short cure time, heat-cured formulations produce a much harder finish and stronger adhesion. Furthermore, they are the only alternative where uniform exposure of UV light is difficult to achieve.

The cost of starting up a coating operation is based largely on the need for stringent environmental controls. Because coatings are only a few microns in thickness, small dust particles and other contaminants can appear as highly visible imperfections in the coated surface. It is necessary, therefore, to clean the substrate material prior to coating and to filter the air in the area where coating is performed

Technical Factors

Environmental

Air filtration

The coating must be applied in a dust-free environment and kept there until it is tack-free and ready for heat curing (usually about 5 minutes, including drain-down time). After the coated items have

dried, they can be moved to a non-filtered area. Because UV curing is performed while the solution is still wet, curing must be performed in a clean environment.

.Non-transparent parts typically do not require as high a standard of air particle removal as transparent sheet-like products. Optical devices, including lenses, require the most attention to making the air free of micron-sized particles.

As a guideline, suspended particles greater than 0.5 microns in size should be filtered to fewer than 100 particles per cubic foot. This can be accomplished through an easily constructed clean-air coating booth. A coating booth can be constructed using commercial self-powered HEPA (High Efficiency, Particle, Air filters) blowing downward, with plastic film as walls, extending down to within about 6–12 inches from the floor. Two of these filter/blower units, 2x4 feet each, can be used to make a 2x8 foot coating booth, which is practical for all but very large sheet coating. In addition, a static-neutralizing blower, blow-off nozzle, or grid (attached to the HEPA filter) is also needed as most plastics become easily charged with static electricity which attracts particles.

Humidity & Temperature

To prevent hazing of the wet coating film, many hard coatings require a major investment in dehumidification equipment to maintain relative humidity in the coating area below 30%.. Perma-New™ coatings largely avoid this expense, however, as they are formulated to tolerate R.H as high as 75% without hazing.

Coatings are subject to gelling as they age and as temperature increases. To avoid this and to extend the pot life of the coating solution, refrigeration is often required. Even with refrigeration, some coatings on the market have a pot life of only a few days before they begin to gel and must be replaced. In comparison, Perma-New coatings are stable at room temperatures and typically have a storage life as long as 6 months. They can be refrigerated or frozen to extend shelf life even further.

Coating Solutions

Hard coating solutions are often formulated to address specific requirements, such as UV curing, type of substrate or application methods. When selecting a coating, the following factors should be considered:

- Substrate material
- Whether the coating requires a primer to achieve adhesion
- Whether the coated part will be thermoformed
- Antifogging and other coatings
- Curing method
- Flow characteristics
- Coverage
- Transportation and storage
- Health and Safety

Substrate Materials

Although there are many kinds of substrates that can be potentially hard coated, the most common materials are polycarbonate, acrylic, CR-39 and other plastics. Various polished metals such as stainless steel and aluminum are also frequently coated. Hard coatings can also be applied over other coatings such as anti-reflection coatings.

Variations in coating results can occur based on the quality, purity and finish of the substrate. Sometimes, adjustments in the coatings solid content and other ingredients can positively affect the outcome. Before committing to a particular coating, it is important to perform tests on the actual material to be coated.

Primer coatings

To achieve acceptable adhesion, many obsolescent hard coatings require primer coatings, adding to cost. Because Perma-New coatings are based on leading edge technology, they achieve excellent adhesion on most plastics without the need for a primer. Exceptions are metals which often require a primer coating.

Curing methods

Virtually all commercially available hard coatings require either heating or UV curing to achieve hardness. The advantages of UV curable hard coats are their short curing time and lower costs. Their disadvantages are less resistance to abrasion and scratching as well as shorter life of the applied coating. Although coatings are designed to last a number of years, UV cured coatings typically wear off after approximately three years. On the other hand, heat cured coatings are typically much more scratch resistant and, depending on usage, will often last for ten or more years. The primary disadvantage to heat cured coatings is the curing time and the cost of ovens. Because of their shape or size, some items can only be heat cured.

Thermoforming characteristics

Although hard coatings are glass-like and tend to not stretch, some coatings are designed to allow a modest degree of bending (stretching) of the coated piece. This can sometimes involve a tradeoff in hardness and adhesion. Perma-New coatings can be thermoformed and, with special techniques, some coated materials can be bent to a 5 inch radius.

Flow characteristics

When choosing a coating, it is important to evaluate how the coating flows. Some coatings are more susceptible to leaving drips, “orange peel”, and other cosmetic defects. Sometimes this can be ameliorated by adjusting the percentage of solids in the coating solution or by selecting an alternative application technique.

Coverage

The thickness of a coating and the amount of surface area that can be coated per unit volume of coating is determined by the amount of “solids” contained in the coating. Some coatings contain as few as 20% solids whereas others contain solids of 35% or more. As a rule, higher solid content will result in greater coating thickness and coverage. Perma-New coatings are available in differing solid contents and can be adjusted through the addition or subtraction of solvents.

As coating runoff is recycled through repeated applications, solvents evaporate and need to be added to maintain a consistent solid percentage.

Like paint, coverage varies by the thickness of the coating. Typical coverage for Perma-New coatings with 33% solids is approximately 2000 square feet (200 square meters) per US gallon.

Transportation and storage

Careful attention to the transportation and storage of hard coatings is often necessary, as many use flammable solvents and must be treated as hazardous materials. Material Safety Data Sheets (MSDS) are available and should be consulted when planning facilities, applying for permits and transporting coating materials.

As mentioned above. Perma-New coatings can be stored and transported at room temperatures. Compared to less technically advanced coatings, Perma-New™ coatings are very stable at room temperature and have a greatly reduced tendency to form small gel particles during storage and use.

Health and Safety

In addition to flammability, consideration must also be given to the toxicity of a coating. You should consult the particular coatings MSDS when selecting a coating and when planning for the health and safety of workers.

Although masks, gloves and eye protection are always a good practice, no special re-breathing equipment, clothing or special fire suppression equipment are required when applying Perma-New coatings.

Coating Process

Cleaning

Dust and other foreign matter must be eliminated from the coating, and from the surface to be coated. Depending on the shape of the parts to be coated, cleaning prior to coating can be as simple as wiping with solvent, using a lint-free wiper. Complex shapes can be cleaned with high-pressure sprayers on in ultrasonic cleaning tanks, as needed.

To remove particles and gel particles, the coating is normally filtered during use by re-circulating with a positive-displacement type pump, through a polypropylene filter with 1 micron or smaller pore sizes. Filter media is readily available and inexpensive.

The coating that drains off the coated parts is caught in a rough or basin and re-circulated through the pump, with occasional addition of alcohol solvent to make up for evaporation.

Applying coatings

Coatings can be applied in four different ways. The application technique is largely driven by the size and shape of the item to be coated.

- *Dip coating* is used for two-sided application, especially with large quantities of relatively small parts. With dipping it is harder to control the coating thickness and is prone to wastage.

- *Spin coating* is especially suited for single-sided application on round parts (disks or lenses).

- *Spray coating* is often used for high production volume, single sided application on relatively small parts, or for very complex-shaped parts. Spray coated parts are especially susceptible to “orange peel” defects that result from surface tension on the spray droplets

- *Flow coating* is the recommended coating application process as it is inherently simple, requires almost no equipment, and has the advantage over dip and spray coating in allowing the use of the coating solution to "wash down" the part even after pre-cleaning, to maximize the cosmetic quality (absence of inclusions such as dust and lint) of the coating. The part to

be coated is flooded or washed-down with the coating solution. The viscosity and volatility of the coating are easily adjusted so that after the excess coating solution drains off (1-2 minutes), the proper coating becomes sufficiently dry so that it is tack-free to airborne dust, and can be cured in an ordinary forced-air oven.

Drying & Curing

As mentioned above, UV-curable coatings are cured while still wet, whereas heat-curable coatings must first dry to a tack-free state before curing. Once dried, there is no requirement to immediately cure a coated item. During the drying process, the coated items must remain in a dust-free environment to avoid cosmetic defects from particle contamination.

Curing temperatures for plastics are generally just below their melting points. For acrylics curing temperatures should fall in the range of 165–185° F (74–85° C) and for polycarbonates 250–265°F (121–129°C). Although Polycarbonate can be cured at a lower temperature, it must be primed to ensure adhesion. Careful attention must be paid to ensuring a constant and uniform curing temperature and air flow.

The coating reaches most of its ultimate hardness in the first hour of curing, and will become fully hardened over a period of weeks at room temperature. If the coating cure time is extended to four hours, ultimate hardness is reached in the oven.

The need for an expensive, industrial oven can be avoided when curing coated acrylics or primed polycarbonate as the cure temperature is so low that the cure can be carried out in a "hot box" made of commonly available rigid-foam insulation panels such as those used in home construction. A variety of inexpensive types of heating units can be used to warm the box and circulate air. To cure unprimed polycarbonate requires a more sophisticated oven than the hot box described above. Such ovens can be purchased, or constructed. BTU capacity of an oven or hot-box should match the type and quantity of substrate that is going to be coated at the same time.

Summary

At one time the investment required to start up a hard coating operation were well outside the reach of most small and mid-sized companies. As a result, they had to outsource coating to expensive toll-coaters, giving up control over schedule and quality. With modern hard coatings such as Perma-New, it is now possible for many companies to bring hard coating in-house with levels of investment 1/10 of that required in the past.

Although there are many technical aspects that must be evaluated when considering the feasibility of an in-house coating operation, California Hardcoating Consulting Services offers technical advice and training customized to your specific project. For more information on how to start up your own coating operation or to learn more about Perma-New hard coatings, point your Web browser to http://www.cahardcoating.com or send an E-mail to info@cahardcoating.com.