COA
CONTAINER COATINGS REPORT 2020

Container Owners Association
CONTAINER COATINGS REPORT 2020

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INTRODUCTION

This COA Container Coatings Report, compiled from information supplied by the Coatings Work Group, provides COA Members with a summary of coating technologies available for new container production in 2020 and beyond.

The Report provides information for use by COA Members, but does not provide recommendations.

The majority of dry cargo containers are built in China. Production lines are fast and efficient; in some cases, allowing a TAKT (time between consecutive units) of about three minutes at each work station. Container production in 2019 was estimated to be about 2.5 million TEU which required about 125 million litres of coating.

The initial switch in 2016 from established solvent-borne coatings to the use of alternative coating technologies was driven by environmental initiatives of the Chinese Government and the container industry. The objective was to reduce harmful emissions from VOCs (volatile organic compounds) which were emitted during the container production line coating process. The first stage of VOC reduction was achieved, but the ultimate aim is to practically eliminate harmful VOCs.

This report is focused on coating materials. Nevertheless, it is recognised that the performance of the coatings is dependent upon the skills and hard work of the personnel working on the line; applicators, technicians, inspectors and maintenance crews. The coating production line is an inherently arduous environment. New technologies allow the reduction of harmful emissions and improve working conditions. Embracing technology that advances the health and safety of personnel, is an obligation of all parties.
Waterborne coatings

Waterborne coating technology was widely chosen as the means to meet the objective of environmental controls and maintaining service performance equivalent to solvent-borne coatings.

The conversion to waterborne coatings required a substantial capital investment by container manufacturers. The investment included extending the line stations by adding heating, ventilation and dehumidification.

Energy consumption to provide the necessary additional production line heat, ventilation and dehumidification coating stations and paint kitchens, is up to 60% higher than when using solvent-borne coatings. Line speeds were reduced, on some lines by up to 30%, to provide additional drying time. These factors increased the overall cost of the container.

The waterborne coating material is a small proportion of the total increased cost of container production compared to the investment in production facilities. Nevertheless, coating manufacturers invested considerable resources both to develop the coatings and for specialists to work with the container manufacturers, to design the process and commission the coatings onto the production line.

The process change that took place during 2016 generally proceeded smoothly and, nowadays, waterborne coatings are the industry norm for standard dry cargo containers.

Solvent borne

Coatings materials supplied to the container industry made little change over the years due to the line-layout of the container factories, being mostly locked to the “traditional” 3-coat exterior and 2 coat interior systems.

Solvent coatings comprise a mix of coating and solvent, enabling the material to be conveyed (sprayed) - with solvent being a “carrier” from the pot to the container. Solvent-borne paints were previously used for a reason: they are more forgiving in the application process and provide operational flexibility to the container production process.

Waterborne coatings use a mixture of water and reduced solvent as a carrier. Waterborne coatings application parameters are more demanding of the manufacturing process.

Greater expertise and technology are required to efficiently apply waterborne coating.

Owners cautious

Container owners, manufacturers and coating suppliers were initially cautious of the use of waterborne coatings. Some expressed doubt as to the suitability of the coating, especially when applied in North China during the winter months, when temperatures can be sub-zero.

Due to the complexity of the change to waterborne, it is not surprising that - in the initial phase - there were reports of defects such as sagging, cracking, bubbling and flash-rusting. Interior coating was in some cases problematic, due to the difficulty of consistently achieving the requisite air-flow inside the container to evenly dry the coating.

However, procedures were put in place to overcome these issues and owners and manufacturers became confident with waterborne coatings.

Although waterborne coatings are being successfully applied, the ongoing quest is to seek greater efficiencies and lower VOC's - and that is driving the development of alternative technologies.

Waterborne VOC's

Waterborne coatings contain solvents, sometimes even more than the old “traditional” solvent-borne coatings, but the solvents are water reduceable at the container factory. Both solvents and water content need to be ventilated away from the container for the coating to dry, before the next coat is applied.

Whereas “waterborne” coatings reduce VOC's to tolerable levels, it is necessary to consider the overall total VOC (Volatile Organic Compound) released by the complete coating system. The coating industry is therefore looking to achieve lower VOC levels and is developing what is known in the industry as “Low VOC Coatings” and “High Solids Coatings”.
Material loss

In addition to the need for environmental limits on VOC’s and the health and safety of operatives undertaking the application procedures, the coating industry is seeking to minimise the economic and environmental loss of coating material resulting from overspray. It is estimated that 30-40% of the liquid coating is lost between the pot and the standard dry freight container. When the probable higher-than-specified film thickness in areas where it is difficult to apply an even coating is included, the total loss could be 50-60%.

Surface preparation

Together with the development of alternative technology coatings, container manufacturers are required to maintain high quality steel plate pre-treatment, control the production rhythm and the drying conditions. This requires robust quality control processes at all key links of coating application.

In some plants, there is a gap between the industry’s production restraints and the inherent precise application requirements of waterborne coatings.

Alternative technologies

Whereas waterborne coatings have been generally successfully introduced to the container industry, coating manufacturers are still seeking to develop additional technologies which are adaptable to the existing production lines and provide even lower VOCs.

Alternative technology coatings technology, that might be considered new to the container industry, is nevertheless of established and proven performance in other industries.

The expertise of the coating companies is employed refining and adapting the application of the coating to the conditions of the container production lines.

Alternative technology mostly concerns the technology to convey the coating from the pot to the container. The ingredients of a coating (i.e. binders, pigments and additives) are much the same. The difference is whether the ingredients are mixed with liquids such as solvents or water as a means to apply the coating. Depending upon the liquids, the coating requires different pumps and spray equipment, different ovens and drying time.

As with the transition to waterborne coatings, alternative technologies will require a holistic approach to the necessary changes to the production line process together with the support of container owners.

It is necessary to make further progress to reduce the environmental impact of container coatings and the economic loss through overspray. This may be through development of existing processes or evaluating alternative technologies.

Alternative coating systems under development and implementation include:

a. Waterborne
b. High-solids
c. One-coat
d. Electro-coat
e. Powder
2. COA MEMBER COATING MANUFACTURERS

Manufacturers of container coatings are active and essential participants in the container industry. They continue to research and develop coating technologies, ensure the production of coatings to meet the demand and provide expert technical support to the container production lines.

Approximately 95% of the world-wide shipping container production plants are located in China.

The coatings industry is estimated to supply approximately 50 million litres of coating materials for each one million TEU of manufactured containers.

Container production in 2019 was estimated at about 2.5 million TEU requiring 125 million litres of coating - representing an approximate supplied coating material value of about $625m.

COA member coating manufacturers supply the vast majority of coatings to the container industry:

**Coating manufacturers**
- Baojun New Material
- Chugoku Marine Paints
- Cosco Kansai Paint
- Guangzhou Jointas Chemical
- Hempel
- Jiangsu Dowill Paints
- KCC
- Mega Coatings
- PPG
- Sherwin Williams
- V.ABC Group

**Resin manufacturer**
- DSM Coating Resins
3. ALTERNATIVE TECHNOLOGY COATINGS

The days are past when all container production lines applied much the same solvent-based paints and could switch between coating specifications and suppliers with relative ease according to the container owner’s preference.

Switching from one alternative coating technology to another is problematic because the coatings are finely developed formulations with specific application requirements.

**Standardisation**

The production of a standard ISO dry freight container is not “standard” in every technical detail. Buyers and manufacturers specify slightly different structural profiles, fittings and coatings. These designs need to be considered in the precise settings of the automatic coating application.

The change to another coating might require a coating production line re-conditioning operation. Additional equipment may be required and the production line speed may need to be adjusted.

**Robotic production transition**

Container production line processes are in transition from labour intensive container assembly lines to highly technical and robotic work flows.

The introduction of robotic production equipment necessitates further standardisation in designs and materials. Coating suppliers develop coating technologies that are best suited to the new processes and the governmental environmental initiatives.

For the transition to be successful, coating manufacturers are required to be engaged with the container manufacturer and - through a “holistic” approach - achieve the benefits of alternative technology coatings.

Coating manufacturers continue to research and develop advanced technologies. The objective is to maintain the longevity of the corrosion protection performance and to achieve efficiency to the application process, along with the reduction of environmentally harmful vapours given off during the coating application.

**Waterborne VOC’s**

Waterborne systems significantly reduce VOC’s and meet existing limitations. Manufacturers and legislative authorities seek further reductions and aim to almost eliminate the VOC solvent content altogether. This is achieved by both adjusting waterborne formulations and at the same time evaluating alternative coatings.

Along with continuous work to improve and stabilise the application of waterborne coatings, manufacturers are developing new technologies that co-exist with the continued application of waterborne coating as is best suited to the prevailing conditions at each container manufacturing plant.

As with existing coatings, alternative technologies provide the performance required to protect the container during its service life. It is not the case that one system is necessarily better than the other in that respect; but that, adapted to the conditions of an individual container production line process and in consideration of economic performance, the alternative technology may be compatible to the overall objectives.

This report summarises progress to the following technologies:
- Waterborne
- High-solid
- One coat
- Electro-coat
- Powder
- Reefer coatings
3.1 WATERBORNE

**Summary**

Waterborne coatings are nowadays widely used in current container production. Although therefore not strictly alternative technology, developments in the coating - both through research and evaluation of empirical data - recognises the advancement in technology and rightful inclusion in this report.

Water-borne coatings are based on emulsifying the binder, pigments, and additives with water and solvent which act as the means to convey the coating from the pot to the container. The solvent content is significantly reduced compared to traditional solvent based coatings.

The polymer resins traditionally used as binders in solvent paints continue to be used in waterborne paints e.g. epoxy, acrylic, vinyl, alkyd and urethanes.

**Low VOC**

The driving force for the development of waterborne coatings has been environmental legislation that requires the lowering of volatile organic components (VOC’s). This effectively meant the phasing out of traditional high VOC solvent coatings from container production lines.

Legislation to reducing VOC's to a lower level are to be introduced, which means further development of waterborne coating for its continued use.

**Systems**

To achieve the necessary corrosion protection, container coating systems are specified with an epoxy zinc-rich primer, which provides a high degree of cathodic anti-corrosive protection performance.

Zinc-rich primer provides high strength adhesion and toughness of the middle coat enabling smooth transition and integration between coatings.

The layers of the coating systems are necessary to ensure a cohesive protective film. Discontinuities in the surface coating sometimes referred to as “holidays” (minute pinholes in the coating film) are practically unavoidable under the fast speed required in a mass production coating line. An impervious coating is achieved by the overlapping primer, mid-coat and top-coat.

Although the application of waterborne coatings is nowadays established on container production lines, manufacturers continue to fine-tune both the process and the materials to improve performance and workability.

The container interior coating application has been particularly challenging due to issues of airflow and drying time i.e. the need to rapidly extract the water content to prevent flash rusting.

Due to the efforts by coatings suppliers and container manufacturers, waterborne coatings are successfully applied and remain an alternative technology.

**Why waterborne?**

- Protection is at least the equivalent to that of traditional solvent-based paints.
- Appearance is good, available with different colors and gloss.
- Environmentally friendly, low VOCs. No benzene, heavy metals and other harmful substances achieving an overall 85% VOC reduction.
- Environmental laws and regulations compliant.
- Health & Safety protection of workers’ health by reducing harmful substances. Low fetid smell.
- Storage and transportation safety: Reduced risk storage and transportation by eliminating most of the highly flammable solvent content to lower the flash point.

**Why not?**

- Capital and operational cost of drying process.
- Critical control of conditions, humidity, temperature and airflow rate.
- Relatively high consumption of water treatment reagent.
- Coating temperature maintained above freezing (preferably +10degC) during transport and storage.
- Loss due to overspray and above specification thickness because existing layers of the coating are not dissolved but add more thickness when applied in same location due to spraying unevenness.

**Note:**

*The summary of attributes is not exclusive to a particular coating technology. Other coatings may share attributes. Coatings should be considered together with the conditions of an individual container production line process.*
Above: Interior coating by manual spray

Below: Container moving from the paint booth after the application of the coating. The paint booth pit allows for coating the underside.
Table 1: Waterborne new development (post 2019)

The table is provided as an example of coating data. Individual coating suppliers provide varying specifications to align with the precise formula developed by their company. Thus, whereas the data may be used as an example, for any detailed assessment, contact the coating supplier.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Zinc, talc, epoxy emulsion, polyamide, water, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pot life</td>
<td>Epoxy zinc primer: 5h@25°C</td>
</tr>
<tr>
<td></td>
<td>Epoxy mid-coat/interior topcoat: 5h@25°C</td>
</tr>
<tr>
<td>VOC emission</td>
<td>Compliant</td>
</tr>
<tr>
<td>Delivery method</td>
<td>Conventional high-pressure pump &amp; airless spraying equipment.</td>
</tr>
<tr>
<td>Compatibility other coatings</td>
<td>Compatible water-borne paint products.</td>
</tr>
<tr>
<td>Material efficiency</td>
<td>Consumption rate similar to solvent-based paints.</td>
</tr>
<tr>
<td>Drying and curing</td>
<td>Epoxy zinc primer:</td>
</tr>
<tr>
<td></td>
<td>Temp: 50-60°C*12min., Airflow: ≥1.5m/s,</td>
</tr>
<tr>
<td></td>
<td>Humidity: ≤40%.</td>
</tr>
<tr>
<td></td>
<td>Epoxy mid-coat &amp; interior topcoat:</td>
</tr>
<tr>
<td></td>
<td>Temp: 50-65°C*15min., Airflow: ≥1.5m/s,</td>
</tr>
<tr>
<td></td>
<td>Humidity: ≤40%.</td>
</tr>
<tr>
<td></td>
<td>Acrylic topcoat:</td>
</tr>
<tr>
<td></td>
<td>Temp: 75-85°C*25min., Airflow: ≥1.5m/s,</td>
</tr>
<tr>
<td></td>
<td>Humidity: ≤30%.</td>
</tr>
<tr>
<td>Durability tests</td>
<td>Degree of blistering: 10 (ASTM D714-09)</td>
</tr>
<tr>
<td></td>
<td>Degree of rusting: 10 (ASTM D610-08)</td>
</tr>
<tr>
<td></td>
<td>Undercutting: 3mm (Ext.), 5mm (Int.)</td>
</tr>
<tr>
<td></td>
<td>Adhesion:5B (ASTM D3359-09)</td>
</tr>
<tr>
<td></td>
<td>Impact resistance: 50 inch*lbs (Int.&amp;Ext., Forward) (ASTM D2794)</td>
</tr>
<tr>
<td></td>
<td>Abrasion resistance (for interior):47.7mg (ASTM D4060)</td>
</tr>
<tr>
<td>Cost-delta</td>
<td>About 20% higher than traditional solvent-based coatings.</td>
</tr>
<tr>
<td>Performance</td>
<td>Material of coating film are basically the same as those of traditional solvent-based paint.</td>
</tr>
<tr>
<td>Non-container segments use</td>
<td>Successfully used in many other industries</td>
</tr>
<tr>
<td>Repair procedures</td>
<td>Solvent-based paint may be used for repair</td>
</tr>
<tr>
<td></td>
<td>Waterborne may be used if the repair yard has good drying conditions.</td>
</tr>
</tbody>
</table>
3.2 HIGH-SOLID COATINGS

Summary

High-solids epoxy formulations contain solvents, but due to the high ratio of solids to solvent, the coating achieves VOC (volatile organic compounds) environmental compliance.

High-solid coatings supplied to the container industry contain at least 65% of solid components, i.e., binders, pigments, and additives mixed with solvents that serve as a means to convey the coating onto the container. Conventional solvent coatings might initially contain 50% solids but thinning reduces the solids to about 25%.

Ultra-high solid coatings can contain 80-90% of solid material by volume.

Viscosity

The viscosity of high-solids coating is 3-4 times higher than in conventional solvent-borne coatings and may reach 10,000 cP (centipoise).

The viscosity may be reduced, for the purpose of applying the coating, by chemical modification or by heating the material 40-66°C (104-150°F). For this reason, high solids are also referred to as high-solid, high-temperature coatings.

Spraying equipment

To apply the coating at this high viscosity requires investment in special two-component high-pressure spraying equipment that is able to pump the very stiff liquid coating.

Ultra-high solid coatings are best applied by two-component spray equipment, additionally fitted with individual heaters (30-60degC) on both the base and curing agent, running individual supply lines out to the spray guns as far as possible.

The coating is applied in a single coat and is fast drying, which facilitates an increased production line speed.

Heating

The heating of the individual coating components works as the “diluent” instead of diluting with solvents.

The challenge can be to achieve a low enough dry film thickness (DFT) to be competitive with the lower solid options. However, when considering the reduction in heat and ventilation, high-solids may provide economic benefit.

Mixing

Most ultra-high solids coatings have a short pot life which provides a benefit to the drying process, but requires production line planning to efficiently use mixed coatings and clear spray lines. Mixing techniques have been developed that largely overcome the short pot life.

Mixing of the coating is undertaken automatically during the spraying. When the robots stop spraying, the base and curing agent will circulate unmixed material back to the feeding tanks, thereby eliminating any considerations of the otherwise short pot-life after mixing.

Flash rust

Flash rust, a condition that is associated with waterborne coatings, is caused by the water content. Interior surfaces are vulnerable due to the difficulty achieving an even air flow to dry the coating and eliminate the rust. The condition is kept under control by precise drying procedures. Flash rust is non-existent in high-solid coatings because of the absence of any water content, the cause of flash rust.

High-solids are therefore relatively straightforward to apply on interior surfaces.

Drying ovens

High-solid coatings do not require, to the same extent as waterborne coatings, high capacity force drying ovens. As a result, high-solids coatings have the benefit of reducing drying oven energy consumption.
Furthermore, the coating is suitable for production lines not fully equipped with ovens of the type and capacity required for waterborne.

**Re-coating**

The re-coating interval is limited to 3 to 48 hrs which reduces the options should any post production remedial work be required. This mainly applies when a two-component primer is overcoated with a one component topcoat.

**Appearance and UV**

Although the available colours and shades are suitable for most owners, high-solid coatings do not have the wide range of shade choices or level of gloss stability compared with waterborne. However, it is possible to top coat with a waterborne of the required precise shade.

High-solid coatings are not fully UV (ultra violet light) stable. Where this is a critical factor for owners, the coating may require a waterborne exterior top coat to prevent colour fade.

High-solid epoxy coatings might chalk, fade or possibly yellow as a result of the curing agent used. High-solid Polyurea and Poly-siloxane coatings provide better colour stability.

**Cost delta**

The overall cost is competitive with other systems provided that the application is efficiently controlled.

High solid coatings have a greater cost per litre compared with waterborne but the coating reaches almost twice the surface area. The applied coating wet film is more or less equal to dry film thickness.

The cost of energy to drive the ovens and ventilation capacity as required for high-solids is reduced compared with waterborne.

The overall volume of supplied high-solid coating is reduced as no solvent/water is included. This reduces transport and storage costs.

High solids and ultra-high solids comprise 2-components + 1 exterior acrylic topcoat i.e. 3 drums. A waterborne system comprising 3 coat exterior and 2 coats interior is supplied in 9 different drums.

**Why high-solids?**

- Low VOC within the regulatory requirement, similar or better than water-borne paints.
- Compatible with production lines not fully equipped with force drying oven capacity required for waterborne.
- One coat application option.
- Cross-linking reaction density between the molecules (when cured to specification), is larger than that of the traditional solvent-borne epoxy paint and water-borne epoxy paint. The compactness and shielding effect of the coating film are stronger, and the corrosion resistance is better.
- Tolerable small variations to the quality of steel plate pre-treatment, production rhythm.
- Good appearance and fewer coating defects.
- Flexibility and toughness.
- Short pot life enables fast drying and reduced energy for heat/ventilation.
- Flash rust risk to interior surface eliminated by absence of water content.
- For transport purposes, high-solids formulations are not classified as dangerous goods (which increases transport and insurance costs).

**Why not?**

- Capital cost of specially designed spraying equipment.
- Relatively new experience in the container industry (but established in other sectors).
- Limited recoating interval.
- Susceptible to chalk and fade in UV light.
- Short pot life requires purpose design spray equipment.
- Ultra-high solids products can be difficult to apply in low (thin) thicknesses.

**Note:**

The summary of attributes is not exclusive to a particular coating technology. Other coatings may share attributes. Coatings should be considered together with the conditions of an individual container production line process.
Above: Application of the top coat
### Table 2: High-solid

The table is provided as an example of coating data. Individual coating suppliers provide varying specifications to align with the precise formula developed by their company. Thus, whereas the data may be used as an example, for any detailed assessment, contact the coating supplier.

<table>
<thead>
<tr>
<th><strong>Composition</strong></th>
<th>Talc, epoxy resin, polyamide, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pot life</strong></td>
<td>Pot life: Ultra-low VOCs paints: 2h@25°C</td>
</tr>
<tr>
<td><strong>VOC emission</strong></td>
<td>VOCs: Ultra-low VOCs paints: 50g/L</td>
</tr>
<tr>
<td><strong>Delivery method</strong></td>
<td>High-pressure pump &amp; airless spraying equipment.</td>
</tr>
<tr>
<td><strong>Material efficiency</strong></td>
<td>Consumption rate is lower than that of water-borne paints.</td>
</tr>
<tr>
<td><strong>Drying and curing</strong></td>
<td>Ultra-low VOCs paints: Normal temp: 10-40°C. Airflow: No special requirements Humidity: 40-85%. Reduced drying times enables increased production line speed</td>
</tr>
<tr>
<td><strong>Durability tests</strong></td>
<td>Degree of blistering: 10 (ASTM D714-09) Degree of rusting: 10 (ASTM D610-08) Undercutting: 1.8mm (Int.) Adhesion:5B (ASTM D3359-09) Impact resistance: 50 inch*lbs (Int. Forward) (ASTM D2794) Abrasion resistance (for interior):40.8mg (ASTM D4060)</td>
</tr>
<tr>
<td><strong>Cost-delta</strong></td>
<td>About 15-20% higher than the “Exterior and interior WBP system”.</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Physical and chemical properties of the Ultra-low VOCs coating film comparable to water-borne paint.</td>
</tr>
<tr>
<td><strong>Non-container segments use</strong></td>
<td>Construction machinery, road and rail</td>
</tr>
<tr>
<td><strong>Repair procedures</strong></td>
<td>Solvent-based paint, established standard procedures subject to National VOC legislation Waterborne may be used if the repair yard has good drying conditions.</td>
</tr>
</tbody>
</table>
3.3 ONE-COAT SYSTEM

Outline

The one-coat paint system has been developed primarily to provide an alternative technology to increase production line efficiency. A number of one-coat systems have been available for many years and reported to provide acceptable protection performance. Whereas there has been reported success, the system is vulnerable to discontinuities in the one coat, such as the so-called “holidays” (minute pinholes in the coating film). This can be overcome with technique but is a factor to consider under the fast speeds required of a mass production coating line.

Pre-assembly zinc primer

The container is coated with a pre-assembly zinc shop primer that provides protection as part of the “one-coat” system. However, some of this shop primer is burnt off in the assembly welding process. Since there is no post assembly primer coat as is applied as part of a conventional system, the corrosion protection is reliant on the top “one-coat”.

In the two or three coat systems that are mostly applied in the container industry, an impervious coating is more readily achieved by the traditional overlapping coats of primer, mid-coat and top-coat.

One-coat polyurea

The polyurea coating is a very fast drying/curing technology, which apart from being high-solid can be applied in one coat. Polyurea has to be applied by dual feed airless spray equipment as pot-life is normally between 5-20min and is therefore not possible to handle with a normal airless pump.

By utilizing the dual feed pump, the applicator minimises waste because mixing takes place as close as possible to the spray gun. The heaters fitted to the dual feed pump will function as the “solvent” liquifying the otherwise rather heavy components.

The polyurea coating will cure within 10-15min @ 30°C only, meaning that oven heating will only be required during the cold seasons.

The technology is used for reefers and tanks but it would work equally well on dry freight containers. It can be applied directly to surfaces of bare corten-steel, zinc shop primed steel, hot zinc metalized steel, stainless steel and aluminium i.e. all container surfaces. Polyurea provides good gloss and colour retention

The cost delta with other coatings is a high price per litre, but there are savings in application and reduced material loss which when considered, equalise the cost.

One spray pass, two coats

Trials are underway for an alternative technology one-coat system. It could perhaps be better described as a “one-spray pass, two-coat system” since two coats are applied at the same time using special dedicated dual spraying equipment.

The alternative technology comprises two coats formed of an Alkene Amine Polymer coat and an Alicyclic Alkenamide Urea (AAU) which is a film-forming polymerisation material. Performance tests are underway.

The one-spray pass system is said to provide production efficiency by replacing the conventional systems of separate primer, mid coat and top coat.

As with all other coating systems, up to 10um of zinc-based shop-primer is applied to the component parts of the container prior to assembly and forms part of the coating system that is designed to provide ongoing corrosion protection.

Why?

Environmental – Low VOC emission
Energy consumption – Lower than waterborne
Production line efficiency
Corrosion resistance
Appearance quality – High gloss, fewer pinholes, bubbles

Note:
The summary of attributes is not exclusive to a particular coating technology. Other coatings may share attributes. Coatings should be considered together with the conditions of an individual container production line process.
### Table 3: One spray pass, two coats

The table is provided as an example of coating data. Individual coating suppliers provide varying specifications to align with the precise formula developed by their company. Thus, whereas the data may be used as an example, for any detailed assessment, contact the coating supplier.

| Composition            | Alkene Amine Polymer 40um  
|                       | Alicyclic Alkanamide Urea 40um |
| Pot life              | Pot life 30-120 mins          |
| VOC emission          | VOC <30g/litre                |
| Delivery method       | Dedicated spraying equipment to apply the two-component coating system. |
| Drying and curing     | Curing 50-70C, >60mins        
|                       | Allows increased production line speed |
| Durability tests      | Chemical resistance – water 500hr 500 hr adhesion)  
|                       | Alkali 48hr (96hr adhesion), Acid 48hr (96 hr adhesion)  
|                       | Durability – neutral salt spar - >1200hr, unilateral rust at scratches <2mm |
| Availability          | Trials underway               |
| Cost-delta            | Similar to waterborne coating |
| Repair procedures     | Solvent paints, established procedures subject to national VOC legislation |
3.4 E-COAT PROCESS
(ELECTRO-COATING PROCESS)

Outline

Electro-coating is an electrochemical coating process, otherwise referred to as cathodic dip coating (CDC).

The entire container is immersed in a series of 60ft “baths” from pre-treatment to the final coating. The coating bath is filled with water-thinned paint.

A direct current is then passed through the paint. The container is the cathode and is charged negatively. The paint solids are positively charged and are attracted to the cathode (the container) and a coating is formed.

d. Drying
The container is “baked” in an oven for 20 minutes at about 190degC to cure and cross-link the coating film to maximize its performance.

Capital investment

The process requires a significant capital investment but the ongoing process is automated and efficient in both material usage and labour and is said to provide a payback on investment.

It is a proven coating process used in applications such as the coating of car and truck bodies, heavy duty equipment and marine engines.

Why?

- Container immersion ensures complete and uniform coverage interior and exterior
- “Difficult-to-reach” areas are coated
- Excellent coating material efficiency of 95%
- Automated process, therefore labour efficient
- Compliant with environmental laws and regulations
- Health & Safety compliance: protects workers’ health by reducing harmful substances
- Transportation and storage reduced risk due to low content of flammable solvent

Why not?

- Capital investment
- Energy costs
- Commitment to one system

Note:
The summary of attributes is not exclusive to a particular coating technology. Other coatings may share attributes. Coatings should be considered together with the conditions of an individual container production line process.
**Table 4: E-coat (dipped)**

**e-coat process (electro-coating process)**

The table is provided as an example of coating data. Individual coating suppliers provide varying specifications to align with the precise formula developed by their company. Thus, whereas the data may be used as an example, for any detailed assessment, contact the coating supplier.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Epoxy water matrix and Powder TGIC Topcoat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pot life</td>
<td>Pot life- N/A</td>
</tr>
<tr>
<td>VOC emission</td>
<td>VOC-80 grams/litre</td>
</tr>
<tr>
<td>Delivery method</td>
<td>Electro-deposition Tank designed for complete container immersion</td>
</tr>
<tr>
<td>Material efficiency</td>
<td>Material efficiency 95%</td>
</tr>
<tr>
<td>Drying and curing</td>
<td>180°C for 20 minutes PMT</td>
</tr>
<tr>
<td></td>
<td>Not impacted by humidity</td>
</tr>
<tr>
<td>Tests</td>
<td>IICL Performance Requirements score of 90+</td>
</tr>
<tr>
<td></td>
<td>FDA – Dry Food Contact Approval</td>
</tr>
<tr>
<td>Availability</td>
<td>Global - technology in existence since 1963</td>
</tr>
<tr>
<td>Cost-delta v waterborne</td>
<td>Reduced operating costs and increasing savings with volume</td>
</tr>
<tr>
<td>Application speed</td>
<td>Compatible with production line</td>
</tr>
<tr>
<td>Non-container segments use</td>
<td>Transportation (Truck, cars, construction, agriculture etc) and appliances</td>
</tr>
<tr>
<td>Repair procedures</td>
<td>Solvent based paints, established procedure subject to national VOC legislation</td>
</tr>
</tbody>
</table>
3.5 POWDER COATINGS

Outline

Container manufacturers investigating alternative technologies are considering powder coating systems. The coating is proven in other industries but requires capital investment to trial on a container production line.

The powder coating process is the electrostatic application of a paint in its dry powder form.

The powder contains all of the ingredients of “wet” paint but without the wet substances and VOC’s and, as such, meets environmental legislation.

The sprayed powder is charged with static electricity causing it to be attracted to an earthed surface of the container.

After coating the container is placed in a high temperature 180degC oven. The powder-coated surface melts and flows into cured smooth coating where the resins in the powder mixture cross link and provide a protective coating.

The electrostatic process enables in one pass 60-80 microns to be applied in an even film over the corrugated container surface. It provides for efficient use of materials because the electrostatic powder is attracted to - and adheres to – the container. Any overspray powder that might occur can be recovered for re-use, providing an estimated 98% material efficiency.

Like any coating process, the surface preparation is crucial. The container requires to be blast cleaned and degreased as is required for wet coatings.

Powder coatings are used widely in other industries such as indoor appliances, automotive components and heavy equipment such as farm machinery and transport chassis. In the container industry, reefer container machinery frames are powder coated.

Why?

- VOC: zero or near zero volatile organic compounds
- One coat of the required thickness without running or sagging.
- Ready to use: no stirring, mixing or thinning spray lines straight from the powder delivery crate
- No waste – over-sprayed powder recoverable
- Low fire risk saving on transport and storage
- Reduced health hazard to operators

Why not?

- New to container industry
- Start-up costs high
- Difficult to touch up
- Requires baking
- UV non-resistant

Note:

*The summary of attributes is not exclusive to a particular coating technology. Other coatings may share attributes. Coatings should be considered together with the conditions of an individual container production line process.*
4. REEFER CONTAINERS

Outline

Reefer container coatings were exempt from the first phase of the initiative to reduce VOC’s but are scheduled to transition to low VOC coatings at the beginning of 2021.

Reluctance to change

Owners are hesitant to change established coatings that have provided a satisfactory performance. However, there is of course an awareness of the necessary environment changes that must take place.

In readiness, most reefer container manufacturers and coating suppliers are conducting reefer production line trials jointly with owners to optimise the application of low VOC coating systems.

Waterborne

Waterborne and other low VOC coating systems are proven by use in the dry freight container. The trials and process changes are to adapt to the differences in the reefer production lines.

The systems are not identical to dry freight containers. The topcoat can be the same, but special primers are required to coat the zinc metalized frame and muffler grade side panels.

However, the experience with low VOC systems on the dry freight lines is of benefit to enable a smooth transition to VOC coatings.

Reefer construction

Reefer construction designs vary by factory and owner specification. As with the trend in dry freight, greater production efficiency is achieved through the introduction of automated systems which require standardised designs and processes.

Currently, most reefer steel end frames and side rails are hot zinc metalized prior to assembly - although at least one manufacturer applies the hot zinc after assembly. Alternatively, some manufacturers apply zinc rich epoxy primer to the frames.

Side walls may be of natural aluminium or muffler grade stainless steel recessed corrugated side walls.

After assembly of the container zinc rich epoxy primer is applied to the frame followed by a binder or mid-coat and top coat to the complete container. Solvent borne coatings are predominantly used pending the transition to low VOC’s

Reefers differ to standard steel dry-containers

Coatings for reefers differ to dry-container production because of reefer construction materials.

- Corten-steel frame pre-assembly hot zinc metalized coating.
- Muffler grade stainless steel side panels and doors
- Aluminium reefer side panels and doors option.
- Corrosion resistance of side walls is of a lower priority compared with dry-containers
- Adhesion of the coating to the substrate is factor not generally an issue with dry-containers
- Appearance and cleanliness requirement

As a result of the construction materials:

- Stainless steel and aluminium surfaces require coatings formulated to provide superior adhesive powers
- Frames that are hot zinc coating require top coats formulated to prevent popping (solvent entrapped blisters).
- Top coat weathering resistance and gloss retention to facilitate ease of cleaning and appearance
- Coating components with different systems requires added stages to the production line.

It has been a common specification to hot-zinc metalize the frame and apply a solvent-borne acrylic topcoat on the body and a polyurethane topcoat on the doors which provides a clean and shiny appearance.

Pre-assembly hot zinc metallization is an effective process to prevent corrosion. However, it is disadvantaged when considering health and safety of workers and the environment limitations although this could be mitigated by investment in advanced automated sealed systems.

Appearance

The avoidance of rust stains emanating from damaged steel rails and thereby spoiling the container appearance is said to be one of the drivers for the reliance on pre-assembly hot metalized frame components.
Polyurethane or an epoxy top coat is sometimes applied as this is one of the coating systems that provides a high level of appearance.

**Alternative coatings**

Low VOC coatings for reefer containers are specially formulated, and matched to the reefer production line process and materials. As such do not entirely replicate the systems applied to dry freight.

Some of the coating formulation principles used in the solvent borne coatings are not available in the waterborne resin material archive, but more and more resins are coming to the market. They need to be thoroughly tested and proven before introduction to the reefer production line.

**High-solids**

There are several ultra-high solids and low VOC alternatives that are proven in in other industries. The main challenge for reefer containers however, is that only minimal surface preparation is possible on the very thin reefer steel walls.

High-solids are not best suited to applying the low specified film thicknesses. Increased film thickness which is beneficial but it also adds cost.

Polyurea is one of the high-solid coatings. It is fast drying and can be applied in one coat to all surfaces i.e. hot zinc metalized steel, zinc shop primed steel, stainless steel and aluminium.

The challenge with high-solids is to prove initially higher pot price would reflect in a reduced production line process cost and reduced service life maintenance.

The challenge is to prove that a higher value system would reflect in a reduced maintenance cost over the years to come.

It is necessary to build experience of high-solid coatings in the reefer environment but that could also be said to apply to waterborne systems.

Low VOC coating systems to be applied to reefers are entirely the same materials and process as applied to dry freight containers, but the experience with the use of the systems on dry freight provides an advantage that should enable a smooth transition.

**Waterborne PU top coats**

It is feasible to use water-borne polyurethane paints instead of solvent-based polyurethane paints in theory and practice, but further development requires practical trials on the container production line.

Some manufacturers are planning to initially apply water-borne polyurethane to reefer door panels. A full switch (i.e. both doors and side walls) from solvent-borne and waterborne polyurethane could result in a considerably higher cost.

**Why waterborne**

Nb. Alternative low VOC systems may provide similar benefits

- Corrosion protection of hot zinc frame: equivalent to that of solvent-based paints.
- Adhesion to muffler grade panels.
- Appearance: materials such as polyurethane, polyurea, poly-siloxane and acrylics provide good weathering resistance, gloss retention, chemical resistance and appearance.
- Epoxy zinc primer: In the event of impact damage to the container frame, zinc provides a cathodic protection to help to minimize corrosion.
- Environment friendly: low VOCs content, low air pollution. No benzene, heavy metals and other harmful substances.
- Reduce up to 90% of VOC emission
- Environmental laws and regulations: meet the requirements of governmental legislation
- Health & Safety: Protects painting workers’ health by reducing harmful substances
- Storage and transportation safety: Reduced risk paint by eliminating most of the highly flammable solvent content.
- Storage and transport temperature risk: Waterborne coatings should be transported and stored at temperatures above freezing point and preferably +10C.

**Note:**

The summary of attributes is not exclusive to a particular coating technology. Other coatings may share attributes. Coatings should be considered together with the conditions of an individual container production line process.
Left: Reefer top coat commencing the oven drying process

Below: Cross hatch adhesion test – The coating is cut through its thickness with a special tool. This allows an adhesion to be measured by assessing the resistance to the separation of the coating from the substrate.
Table 5: Reefer waterborne

The table is provided as an example of coating data. Individual coating suppliers provide varying specifications to align with the precise formula developed by their company. Thus, whereas the data may be used as an example, for any detailed assessment, contact the coating supplier.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Zinc, talc, epoxy emulsion, polyamide, water, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pot life</td>
<td>Pot life: Epoxy zinc primer: 5h@25°C</td>
</tr>
<tr>
<td></td>
<td>Epoxy primer: 5h@25°C</td>
</tr>
<tr>
<td>VOC emission</td>
<td>Epoxy zinc primer: 81g/L</td>
</tr>
<tr>
<td></td>
<td>Epoxy primer: 56 g/L</td>
</tr>
<tr>
<td></td>
<td>Acrylic topcoat: 36g/L</td>
</tr>
<tr>
<td></td>
<td>Polyurethane topcoat: 88 g/L</td>
</tr>
<tr>
<td>Delivery method</td>
<td>Conventional conveying pump equipment. &amp; high-pressure airless spraying equipment.</td>
</tr>
<tr>
<td>Compatibility for different coatings</td>
<td>Spraying and conveying equipment can be compatible with different water-borne paint products.</td>
</tr>
<tr>
<td>Material efficiency</td>
<td>The consumption rate is basically the same as that of solvent - based paints.</td>
</tr>
<tr>
<td>Production line speed</td>
<td>Close to that solvent-based coating</td>
</tr>
<tr>
<td>Drying and curing</td>
<td>Epoxy zinc primer:</td>
</tr>
<tr>
<td></td>
<td>Temp: 50-60°C*12min.,</td>
</tr>
<tr>
<td></td>
<td>Airflow: ≥1.5m/s,</td>
</tr>
<tr>
<td></td>
<td>Humidity: ≤40%.</td>
</tr>
<tr>
<td></td>
<td>Epoxy primer:</td>
</tr>
<tr>
<td></td>
<td>Temp: 50-65°C*20min.,</td>
</tr>
<tr>
<td></td>
<td>Airflow: ≥1.5m/s,</td>
</tr>
<tr>
<td></td>
<td>Humidity: ≤40%.</td>
</tr>
<tr>
<td></td>
<td>Acrylic topcoat:</td>
</tr>
<tr>
<td></td>
<td>Temp: 55-65°C*30min.,</td>
</tr>
<tr>
<td></td>
<td>Airflow: ≥1.5m/s,</td>
</tr>
<tr>
<td></td>
<td>Humidity: ≤30%.</td>
</tr>
<tr>
<td></td>
<td>Polyurethane topcoat:</td>
</tr>
<tr>
<td></td>
<td>Temp: 65-85°C*25min.,</td>
</tr>
<tr>
<td></td>
<td>Airflow: ≥1.5m/s,</td>
</tr>
<tr>
<td></td>
<td>Humidity: ≤30%.</td>
</tr>
<tr>
<td>Durability tests</td>
<td>Degree of blistering: 10 (ASTM D714-09)</td>
</tr>
<tr>
<td></td>
<td>Degree of rusting: 10 (ASTM D610-08)</td>
</tr>
<tr>
<td></td>
<td>Undercutting: 0.3mm (Ext.), 5mm (Int.)</td>
</tr>
<tr>
<td></td>
<td>Adhesion:5B (ASTM D3359-09)</td>
</tr>
<tr>
<td></td>
<td>Impact resistance: 80 inch*lbs (Ext., Forward) (ASTM D2794)</td>
</tr>
<tr>
<td>Availability</td>
<td>Available to meet demand</td>
</tr>
<tr>
<td>Cost-delta</td>
<td>10-15%</td>
</tr>
<tr>
<td>Repair procedures</td>
<td>Solvent-based paint, established procedures subject to National VOC legislation</td>
</tr>
</tbody>
</table>
This Report has been prepared by the Container Owners Association

The COA is an international association established to represent the interests of owners of freight containers. The principle aims of the COA are to provide technical guidance, promote common standards and encourage the safe use of containers.

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