POWDER AND EXTRUSION COATINGS -
THE ROLE OF 100% SOLIDS TECHNOLOGY
IN PACKAGING COATINGS

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In recent years, there has been increased debate and speculation about the role 100% solids coatings will play in the future of the metal container industry. Almost universally among U.S. canmakers is the consensus that 100% solids materials such as powder and extrusion coatings, or even film lamination, will exist in some form. To what extent, and for what end uses are yet to be determined.

Coatings based on 100% solids have made limited in-roads into the metal container industry. Thermoplastic and thermosetting powder coatings have been used for over twenty years to protect the weld seam on 3pc containers. Also, film lamination has been promoted by such companies such as CMB (Alulite and Ferrolite), Toyo Seikan (TULC), Hokkai Can (Crystal Can), Rasselstein and Hoogovens, and their efforts have generated much interest. Thus far, cans produced using film laminated coil or sheets have seen limited commercial use in Europe and Asia due to their cost.

Many questions still remain unanswered. What will a metal container look like in the year 2,000 and beyond. Will the metal container survive, or be replaced by flexible or other forms of packaging? If the can does survive, how will it be coated?

Advances in new coating processes and polymer compositions will answer many of these questions. Extrusion coating and to a lesser degree powder coating offers new opportunities for the elimination of VOCs, improved quality, cost reduction, increased productivity, and container differentiation that have thus far been elusive. The technology exists to effectively eliminate all forms of solventborne and waterborne container coatings. The metal container and coatings industries are on the verge of what, in retrospect, may be perhaps the most prolific period of technological advancement in their history.

The following paper discusses the current capabilities and limitations of both powder and extrusion coatings, as well as provides a current "snap shot" of where each technology is in the commercialization stage. The paper also suggests a possible scenario of how each technology might fare, and provide a possible migration path to 100% solids coatings that the industry might follow in the coming years.
POWDER AND EXTRUSION COATINGS:
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

POWDER COATINGS
Powder coatings is not a new technology in the metal container industry. For over twenty years, powder has been successfully used to protect the weld seam on 3pc containers. There has been a growing interest during the last several years in the use of powders as an internal coating for 3pc containers and for repairing the score on easy-opening ends.

The interest in what is commonly called "360° spray" is a direct result of the introduction of Nordson Corporation's Tribomatic Powder Spray equipment. For the first time, an application unit was developed that made it possible to apply powder on the inside of a 3pc container. Nordson also has introduced a powder end repair machine based on the Tribomatic concept that uses special nozzles to concentrate powder to the score area, or score and rivet area of an easy-open end.

The most significant technical problem to be resolved in the commercial use of powder coating has always been, and still remains to be, its successful application. Early work in powder coating containers dates back to 1976 when W.R. Grace received a patent for an early application method. Development work also continued at several can manufacturers to develop an application method that would apply a uniform coating to a can's interior and continuous coil at high speed - quite a challenging prospect.

Equipment developments to date for 360° spray have been based on off-line application. Cans are conveyed to an application unit and sprayed at the speed of the unit, not the speed of the welder. This results in slower line speeds or necessitates an investment in additional powder application units to increase effective line speeds.

360° SPRAY
The use of powder coatings for 3pc containers has been looked at as both a means to eliminate VOCs in the coating process, and as a method to preserve the role of the 3pc can in food packaging. Powder coatings have also been looked at to provide better barrier resistance for aerosol cans (DME/water/alcohol) and paint cans and pails (emulsion paints, rust inhibitors). Despite the interest, several important technical limitations still plague the powder coating process.
Technical Limitations of Powder Coatings

- **Minimum Film Thickness**
The result of several years of laboratory experiments and tests reveal that a minimum film thickness of at least 12 microns, preferably 15 microns, is required to give acceptable pack performance. Pack tests performed by several US canmakers show similar results.

Although powder coated cans have generally failed under actual packs, certain areas of the can performed well. It was determined that in these areas of the can there was a sufficient film thickness to provide protection. Thus, both film weight and the resulting film thickness ultimately determine the performance of the can.

- **Uniform Spray Distribution**
With current application methods, powder coatings yield a dry film with poor relative uniformity. This necessitates having to increase film weights to compensate for thin areas. This phenomenon is illustrated by way of a topographical map (below) of the inside surface area of a 3pc can sprayed with an epoxy-phenolic powder.

*Figure 1*

**Surface Area Of Powder Coated 3pc Can**

Microns

Weld Margin
Ultra Fine Powders

Early attempts at commercializing powder coatings have centered on the use of what is commonly referred to as ultra fine powders. These powders are called so because of their rather large concentration of particles under 10 microns in size. The reason for wanting to pursue these powders were obvious; the smaller the particle size distribution of the powder, the lower the film weights that could be achieved.

Below is a chart depicting the particle size distribution of an ultra fine epoxy-phenolic powder both after production and after six hours of use. As the chart shows, over 50% of the powder particles are below 10 microns in size after production. After only six hours of use during a trial, the amount of "fines" increased to almost 60% of volume.

Several problems exist with the use of ultra fine powders that have largely been overlooked, but contributed to much of the early problems of powder coating containers.
POWDER AND EXTRUSION COATINGS:
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

Problems With Ultra-Fine Powders

1. Health Risk
Particles below 6 microns in size pose a potential health risk, as they cannot be seen in the air and will remain in nasal and lung passages when inhaled. Ultra fine powders are produced via a grinding method (jet milling) that generates large amounts of fines per volume of production, and thus cannot be economically avoided.

2. Application Problem
It is common knowledge in the general finishing industry that the presence of ultra fine particles in the coating process results in poor fluidizing, uneven air flow, clogging of spray nozzles and line fittings, greater variations in film thicknesses, and clogging of air filters - which in turn restricts air flow and powder flow.

3. Economics
Understanding that a minimum film thickness of 15 microns is required, it then becomes relevant to determine the most economical way to build a 15 micron film. An ultra fine powder can build a 15 micron film, but the manufacturing costs incurred to grind a resin compound to that fineness outweigh the cost savings associated with lowering film weights. Again, practical experience shows that film weights and resulting thicknesses cannot be lowered below 15 microns and still achieve acceptable pack performance.

The prospect of commercially spraying powder on the inside of 3pc food cans seems doubtful given off-line application, current application equipment, increasing commercial line speeds, and demands for low film weights. Further, there is currently a rather limited supply of FDA-approved resins, catalysts, additives and fillers available for formulating a greater variety of powder coatings - as in liquid coatings.

The situation is different, however, for the use of powder coatings for general line cans. There is a clear demand for more chemically-resistant coatings to meet the increased corrosiveness of products packed in these types of containers. Further, the relatively slow line speeds can feasibly support an off-line coating process. The general line market offers perhaps the greatest opportunity for the future use of powder coatings.
POWDER AND EXTRUSION COATINGS:
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

**EZO Open End Repair**
Tests conducted thus far for end repair are more encouraging. One pack test currently underway has shown above average performance versus a liquid coating standard. Weights in the range of 45 mgs. per 307 end can be achieved with mAs below 1, though controlling variation at this weight will be critical under commercial conditions.

The main issue holding back the commercial use of powder-repaired ends is the problems experienced by a few companies who conducted early evaluations. In all cases, these companies used ultra fine powders which contributed to many of the problems they experienced. Once these problems are overcome, powder end repair could find a role in the industry in the next one or two years.

**The Future Of Powder Coating**
Work is currently underway to incorporate the powder spray process into the welding unit. A device could be placed immediately after the weld arm that could conceivably apply powder to the inside of a container, while depositing an additional amount of powder along the weld seam. In effect, the sheet coating and seam protection processes would be eliminated in one step. The figure below depicts how the process might look.

*Figure 3*
POWDER AND EXTRUSION COATINGS: 
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

At last it may be possible to apply powder coatings at high speed and adequately protect the weld seam. The problem with off-line systems has been there is no way to ensure the precise indexing of the weld seam. By integrated powder application with the welding process, this problem is overcome. The position of the weld is known after welding and a specially designed spray nozzle can then deposit additional powder to the seam only.

Other companies are at work to incorporate a rotating electrostatic powder bell into the weld arm to coat small diameter cans, and especially large diameter cans such as one and five gallon pails. A rotating application device provides better dispersion of powder into air, and utilizes both centrifugal and electrostatic forces to build a film. An electrostatic bell could also be used in off-line systems engineered specifically for coating the inside of one and five gallon pails. Below is one such device.

Figure 4

The commercialization of powder coatings for uses other than side striping rests squarely with equipment suppliers or even perhaps a proactive canmaker. Powder types exist today (epoxy-polyester and epoxy-phenolic) which provide the required resistance for various types of food packs, such as vegetables, fruits, tomatoes, meats, and sauerkraut.
EXTRUSION COATING

No coatings technology has the greater potential to revolutionize the metal container industry than does extrusion coating. Long-term, extrusion could displace the packaging coatings industry, shift value-added from the can manufacturer to the substrate supplier, and change the very definition of substrate. All forms of liquid coatings and equipment, environmental compliance, and much of the pack testing process would be eliminated.

Extrusion coating is not a new coatings technology. The first commercial extrusion line dates to the late 1940s when St. Regis Paper produced some of the very first polyethylene coated paper stock for use in multiwall bags. Advances in the extrusion process have continued at quite a rapid pace during the last 50 years.

Below is an example of a modern high-speed extrusion/lamination line that is typically used to coat plastic films, paper and paperboard combinations.

Figure 5

These lines can produce coated paperboard at weights ranging from 7 to 80 g/m², widths up to 3 meters, and speeds to 600 meters/min. Extrusion coated stock is used to make snack food wrappers, meat packs, condiments, bag-in-box containers, and cartons.
POWDER AND EXTRUSION COATINGS:
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

Of course, there is a major technical difference between extrusion coating paperboard at high speeds and attempting to coat aluminum and steel. Differences in surface tension, the introduction of metallurgical properties, and metal surface coatings and pre-treatments influence adhesion of the polymer. Further, pre-heating of metal substrate, post-baking after polymer application and water quenching have shown to improve adhesion and advantageously effect the crystalline/amorphous structure of the molecular chains. Thus, material flexibility and formability characteristics can be dramatically influenced after application onto metal, unlike other substrate types.

Process Overview
A solid material in pellet form, such as thermoplastic or thermosetting resins, are first air dried and then fed into an extruder. Inside the extrusion barrel, a rotating screw forces the material towards the end of the barrel and in the process melts the composition until it is in a molten state. Once in a molten state, the polymer composition is fed through a slot die which allows the material to form a "curtain", which can then be positioned to flow onto a moving coil, sheet, or other parts of a coil line to optimize the process.

Figure 6
Process Overview - cont.

Figure 7 shows an example of how an extrusion coil coating line might be configured. A die head can be positioned to extrude a single-layer film directly onto coil, between the coil and nip roll, or onto the coil adjacent to a roll. Several companies in the industry are attempting to commercialize extrusion coating based on this basic premise.

Up to five layers can be extruded in a single step using a co-extrusion die head to form a composite coating with unique properties. A substrate layer could provide adhesion, the middle layers acting as "fillers", and a top layer being FDA material. Tests conducted on a co-extrusion pilot line have resulted in five layers of material being extruded onto various substrate types with a total thickness of only 12 microns.

Remaining work that is required to commercialize extrusion centers on advancing current die designs, and on optimizing the process. There is also a substantial need for FDA-approved compositions which are compatible with the extrusion process, provide the required product resistance, and have the flexibility to withstand fabrication.
POWDER AND EXTRUSION COATINGS:  
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

Much of the early process development work has used basic plastics, such as PET, polyethylene and polypropylene. These materials extrude extremely well and are helpful in the process development phase, but are largely too soft for use as a container coating and blush rather significantly after processing. Material development will undoubtedly play a critical role in determining the ultimate success of extrusion coating.

100% Solids Compositions
Several materials currently exist (some based on powder formulations) that represent good candidates for developing extrusion coatings. Slight modifications are required to remove additives which enhance the material's suitability to powder coating (which remove costs), and further cost reduction is gained by not incurring the cost of having to grind the material into powder form. Prices would be in the range of $1.50 to $3.00 lb for materials that have proven pack performance in the food and general line can market.

Polyesters
Semi-crystalline polyester modified with thermosetting compounds offer excellent product resistance to a variety of food and beverage packs. These materials are extremely flexible and can be successfully beaded, flanged, and drawn. End uses would include EZO ends with possibly no post-repairing, draw-redraw food cans, can blanks for 3pc food cans, and D&I and DWI bevcans if suitable ironing dies are developed.

<table>
<thead>
<tr>
<th>POLYESTER PRODUCT SUITABILITY</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Beverage Cans</td>
<td>beer, wine, juices, lemonade, tonic, cola</td>
</tr>
<tr>
<td>Food Cans</td>
<td>all vegetables, fruits, tomatoes, meats, fish, ready made dishes, seafood, soups, pickles, sauerkraut</td>
</tr>
<tr>
<td>Milk Cans</td>
<td>evaporated milk, cream, pudding, dry milk</td>
</tr>
<tr>
<td>Others</td>
<td>oils, fats, latex paints, &quot;mild solvents&quot;, alcohols</td>
</tr>
</tbody>
</table>
POWDER AND EXTRUSION COATINGS:
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

100% Solids Compositions - cont.

Polyesters - cont.

Recently an extrusion coating trial was conducted with a thermoplastic polyester applied at speeds in excess of 500 ft./min. The polyester was applied at an average thickness of 6 microns, had excellent substrate adhesion, and was free of pores.

Laboratory tests conducted on test panels showed the following:

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Duration</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Dow-Fax</td>
<td>15 minutes</td>
<td>No blushing</td>
</tr>
<tr>
<td>Water Pasteurization</td>
<td>30 min @ 180°F</td>
<td>No adhesion loss</td>
</tr>
<tr>
<td>Wet Feathering</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

Needless to say it was an extremely encouraging and, at this stage of development, rather successful trial of extrusion coating with a known material. Future development will continue to further advance the process and material.

Polypropylene

As a surface coating, polypropylene offers excellent chemical resistance and is beneficial from a processing perspective. Since natural polypropylene is so inert, it unfortunately shows little tendency to adhere to metal substrates. This characteristic makes it necessary to chemically modify the natural polypropylene (ex. acid groups) to affect good adhesion properties.

A polypropylene composition was tested for resistance against DME/water/alcohol for use in 3pc aerosol cans. The material successfully passed pack tests and will soon be tested for use in paint can rings and plugs and bodies. Additional modifications are being made to improve pencil hardness and blush resistance for use in bevcan ends and bodies, 2pc food cans, and EZO ends.
The Future Of The 3-Piece Can
A frequently asked question is whether the extrusion coating process could leave a margin to allow for welding, such as with Hokkia Can's Crystal Can. It is a daunting prospect for manufacturers of 3pc cans of having to invest in new 2pc canmaking equipment in order to become environmentally compliant using extrusion-coated coil. Several companies are fortunately working on two approaches to preserving the three-piece can:

Polymer Sheering
Equipment suppliers are currently working on machines to sheer polymer from coated substrate, either in sheet or coil form. Initial development work began to allow laminated substrate to be used in producing 3pc cans. Certainly this same approach can be used to sheer the polymer from extrusion-coated substrate. Initial trials have been conducted at high speeds with resulting blanks being successfully formed and welded.

Extrusion Sheet Coating
Development work is also underway to extrusion coat can blanks. Such a device could be placed before the welding unit to make one integral 3pc can blank coater, welding and powder stripe unit - thus achieving a VOC-free operation.
The Future of Film Lamination
At first glance, film lamination (ex. Ferrolite, TULC, Crystal Can) may seem to be a compatible technology with extrusion coating. After closer evaluation, the economics of film lamination and the overall process do not favor its long-term use.

Economics
In the extrusion film industry, a rule of thumb is it costs approximately twice the raw material cost to convert a pound of material to a film. Thus, it will cost about $1.15 to make a laminate film from one pound of packaging grade PET that has a raw material cost of $1.10 lb. Further cost information is below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM Cost</td>
<td>1.10/lb.</td>
</tr>
<tr>
<td>Conversion cost</td>
<td>1.15/lb.</td>
</tr>
<tr>
<td>Total cost</td>
<td>2.25/lb.</td>
</tr>
</tbody>
</table>

Yield

Cost per 1,000 sq/inch

$0.0405

Additional cost is then incurred by the substrate supplier to laminate the free film to a continuous coil or sheet - a cost that of course must be passed on the canmaker. On an applied cost basis only, the same $1.10 lb. PET material could be directly extruded onto a substrate at the same thickness with a cost of only $0.0198 per 1,000 sq. in.

In addition, pilot extrusion lines are running at speeds well in excess of those for film lamination. One can reasonably expect process-related costs to then be lower as well.

Thickness Limitations
Further, the economics of film lamination are most dependent on material cost not film thickness. The reason being there is a physical limitation to how thin a material can be formed into a free film while still maintaining oxygen and moisture barrier properties. Most film used to laminate substrate for the packaging industry is in the range of .75mm and 1.0mm thick. Driving down film cost long-term will have limited benefit.
POWDER AND EXTRUSION COATINGS:  
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

The Future of Film Lamination - cont.

Film Handling & Inventory
Handling also becomes an important issue as a free film is reduced in thickness. The process of film formation becomes more difficult to ensure that it is pore free. Although film of poor quality can easily be remelted and used to form new film, it must go through an additional film formation process which only adds cost.

Much of the advanced 100% solids compositions that could be used for extrusion or film lamination do not currently exist. Although the industry will be hopeful for a $1.00 lb universal material, it is going to take more polymer development and new methods of polymer modification to engineer a suitable material. The metal container industry will ultimately not pay for coated substrate that uses an inherently more expensive process, especially if it offers no measurable benefit versus direct extrusion coated stock.
POWDER AND EXTRUSION COATINGS:  
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

INDUSTRY TRANSFORMATION
As previously mentioned, extrusion coating is a technology that could fundamentally transform the entire value-chain of metal container manufacturing. This is most evident when considering a substrate producer integrating extrusion coating with substrate production to look for new opportunities for cost reduction and profit enhancement.

One of the most significant operational issues will then be how to cost-effectively coat tonnes of coils produced at mill speeds well in excess of likely extrusion coating line speeds. It would require a substantial investment in coating lines or a drop in mill productivity - both undesirable. If investment were to be shifted to intermediaries (coil coaters) or end converters, the cost to those industries in capital investment, training, and accessing extrusion know-how would be more extensive, perhaps even prohibitive.

Below offers what several supporting industries might look like if extrusion coating is commercialized:

■ Container Coatings Suppliers
The number of coating suppliers would be reduced to perhaps only three worldwide. In their place, perhaps five to ten years after extrusion is commercialized, could emerge the giants of 100% solids: Hoechst Celanese, DuPont, Shell, Ashland Chemical, etc.

■ Substrate Suppliers
Extrusion coating represents a tremendous opportunity for substrate suppliers to add value. By incorporating extrusion coating into the manufacturing process, and experimenting with ways to reduce substrate thickness and eliminate treatments and other coatings, their business would be to supply a totally new substrate. There would be a minimal differentiation between the substrate and the polymer used to coat it.

■ Coil Coating
If substrate suppliers are first or perhaps the only value-chain members to commercialize extrusion coating, they could possibly eliminate the role of coil coaters long-term. This is further magnified by the prospect that a universal coating could potentially be developed.
POWDER AND EXTRUSION COATINGS:  
THE ROLE OF 100% SOLIDS TECHNOLOGY IN PACKAGING COATINGS

Container Manufacturers  
The prevailing view of several canmakers is that can coating is a necessary evil, something they must do but prefer not to do. They are canmakers, process engineers, and container innovators - not painters.

Extrusion coating by substrate suppliers would eliminate the need for container coating. The cost savings to the industry - in the form of environmental compliance, elimination of liquid coatings and inventory management, plant rationalization, spray machines and maintenance, would far outweigh the additional cost of substrate and re-tooling.

BENEFITS OF EXTRUSION  
Extrusion coating will offer the canmaker more than just environmental benefits. The process may enable compositions based on high-molecular weight resins to become integral to the substrate. These types of resin compositions, after application and cooling, will reflow upon the application of heat. Such a system could prove advantageous to eliminating score repair on EZO ends, allow for plastisol curing without degrading the coating, and offer opportunities for improved decorating. Opportunities exist to formulate material that provides corrosion resistance and acts as a compound sealant for closures.

The following benefits would also be realized:

- improved container quality
- longer shelf life
- environmental compliance (and resolves vinyl issue)
- elimination of liquid coatings
- reduced health risk (and eliminating estrogen mimicking issue)
- differentiate metal packaging
- improved decorating appearance
CONCLUSION OF 100% SOLIDS
Of course no one knows for sure what the future of the container industry will hold. It is difficult to dispute, nonetheless, that many exciting coating technologies and processes are currently being pursued. The commercialization of one technology will not necessarily mean the immediate elimination of another technology. The stepwise progression from solvent borne to 100% solids is generally expected. However, if extrusion coating does indeed become commercially and economically viable, the concept of stepwise progression could be changed entirely.

Below suggests a possible timeframe for technology progression.

![Figure 7: Progression Of Coatings Technology](image)

Innovation will continue in the coatings industry to ensure that the metal container remains a viable form of packaging in the year 2000 and beyond. The partnership between process development and material development will be closer than ever before. The end result will be an improved form of packaging with an extended useful life and features that allow it to effective compete with other forms of packaging.