Converting to Waterbornes for Less Cost

Nordson Corporation, Industrial Coating Systems

Many waterbornes outperform the solvent-based paints they replace, but that is rarely the reason that manufacturers convert to waterbornes. More often, government regulations regarding VOC emissions are the motivating factor. Converting solvent-based coating lines to waterbornes can be the least costly way to comply with the regulations.

When manufacturers consider converting to waterbornes, they must factor in both the short-term (installation) and long-term (cost to paint each part) costs. They should also include a factor for intangible or unpredictable costs, such as a lost time injury to an operator.

Installation Cost

Installation cost is the expense to buy and install any new equipment required to use waterborne coating material. This cost increases quickly if the paint process changes and most of the paint line equipment, including atomizers, must be replaced. Fortunately, that is rarely the case. The process that works best in a particular application with a solvent-based coating will usually continue to be the best after converting the application to a waterborne coating. The dynamics of getting atomized material from the applicator to the part are similar whether the material contains mostly solvents or mostly water. This means that there is no single “best” atomizer for waterborne paints. Instead, the shape of the part being painted, the coverage required, and the production rate determine the best atomizer for the waterborne paint, just as they do for solvent-based paints.

To illustrate the importance of part configuration on atomizer selection, consider a simple boxlike part, open on one end, requiring paint on both the inside and outside surfaces. The outside of the box might best be painted with a “soft” spray using electrostatics to get good part coverage, high transfer efficiency, and good wrap. A rotary atomizer would be a good choice for the outside of the box.

The rotary atomizer and electrostatics would be a poor choice for the inside of the same box, however, because the “Faraday Cage” effect caused by the electrostatics and the walls of the box would keep most of the paint out of the box. A better choice for the inside of the box would be an airless spray atomizer. Airless spray uses the momentum of the paint particles to get the paint to the part, rather than electrostatic attraction.

The point is that a manufacturer who has spent much time perfecting his paint process for solvent-based paint should stay with that process when he converts to waterbornes – if he already has the latest technology, good equipment, and is getting good transfer efficiency.

Sometimes a particular waterborne coating formulation may need to be modified slightly to accommodate the atomizer. For example, an emulsion may separate when subject to severe centrifugal force on a spinning rotary atomizer cup.

Application Equipment

The cost of any new equipment required specifically for waterborne coating material can be reduced by using as much of the existing equipment as possible. This is especially important to the manufacturer who intends to stay with his existing process and already has good equipment. The problem with reusing equipment is its compatibility with waterbornes.

Waterbornes rush plain steel and sometimes attack aluminum. Piston pumps made of steel must be replaced with pumps made of 316 stainless. Paint piping systems are often made from stainless steel, even for solvent-based paint and can often be reused for waterbornes. Also, many atomizers contain 316 stainless or plastic parts and can be used for either solvent-based paints or waterbornes. Seals in atomizers and pumps may need to be changed, but there is no single “best” seal material for waterbornes because formulations vary so much. Seal materials used for solvent-based paint, such as ethylene propylene or nitrile, are also suitable for many waterbornes.

One caution about reusing equipment from a solvent-based paint line for waterbornes: a surprising amount of “dirt” from old coating material can appear in the new coating material for awhile, after converting to waterbornes. A few filters in the fluid lines can prevent a lot of downtime due to plugged nozzles and orifices.

As with the paint process and most of the equipment, the physical plant does not necessarily need to be changed to convert to waterbornes. Often, formulation of the waterborne paint can be adjusted a little to accommodate the facility. For example, drying time for a waterborne primer may need to be adjusted for the time available before the color coat is applied.

The Real Challenge for Waterborne Conversions

To summarize, the paint process, application equipment, and even the physical plant may not need to change much when waterbornes replace solvent-based paints. Much of the technology and expertise is the same, whatever the paint formulation. The real issue in converting to waterbornes is electrostatics.

Waterborne coating material conducts high-voltage electricity much more readily than solvent-based material. As a result, the coating material behaves like a wire and all wetted equipment gets charged by the electrostatics. Any equipment that contacts an electrical ground, such as a pipe or a damp concrete floor, provides an electrical pathway that drains off the electrostatics. This means that the electrostatics will not work in a waterborne system unless all wetted equipment is isolated from potential grounds.

Using Electrostatics with Waterbornes

There are three ways to avoid ground out the electrostatics in a waterborne system, as follows:

- Isolate the entire paint system from electrical grounds
- Isolate a small part of the wetted system with a voltage blocking device, or
- Indirectly charge paint particles away from any wetted equipment.
- Each scheme has advantages and disadvantages.

The advantage of fully isolating the entire paint system is that coating material can be directly charged with electrostatic voltage. If isolation is successful, the resulting transfer efficiency will be the highest possible for the specific application. The exact transfer efficiency that can be achieved in specific application depends on the part geometry, line speed, application equipment, and other factors, the same as it would with a solvent-based coating material.

To isolate a complete paint system, every pump, paint tank, pipe, atomizer, or other piece of equipment that contacts wet paint must be set on a plastic table, hung from a plastic rod, or stuffed in a PVC pipe sleeve. The problem is that it is almost impossible to consistently maintain good isolation in anything but the smallest paint system. Even dust on paint hoses on a humid day can provide an electrical pathway to ground out the electrostatics in a waterborne system. This means lower average TE and thousands of dollars in excess paint cost annually.

Besides being inefficient, isolated systems can be dangerous because they can store too much electrical energy. All the equipment that gets wetted with electrically charged paint, stores electrical energy, much like a giant capacitor. All that stored energy gets discharged if the system shorts out. If the system is big enough, and stores enough electrical energy, a painter can get injured if he short it our accidentally by touching a charged hose or atomizer.

It is impossible to draw a definite line that says, “A system this small is safe, and a system that big is dangerous.” Trying to define a safe electrical shock is like trying to define a safe height from which to fall. For example, a shock itself might only be annoying, but the victim might be so startled by it that he bumps his head or injures himself in another way. While a “safe” system with regard to storage of electrical energy may be a contradiction in terms, some guidance regarding the size of “probably unsafe” systems would be useful. Unfortunately, no regulations directly applicable to electrically charged waterborne paint systems are available.

By making some assumptions about the meager data that is published, extrapolating to the 70,000 to 100,000 volt range, and plugging the resulting voltage and capacitance values into the standard equation for storing electrical energy in a capacitor, the following equation can be developed:

$$\text{MAX. ENERGY} = 3.5 \text{ JOULES} = CV^2/2$$

WHERE: C = CAPACITANCE (FARADS)

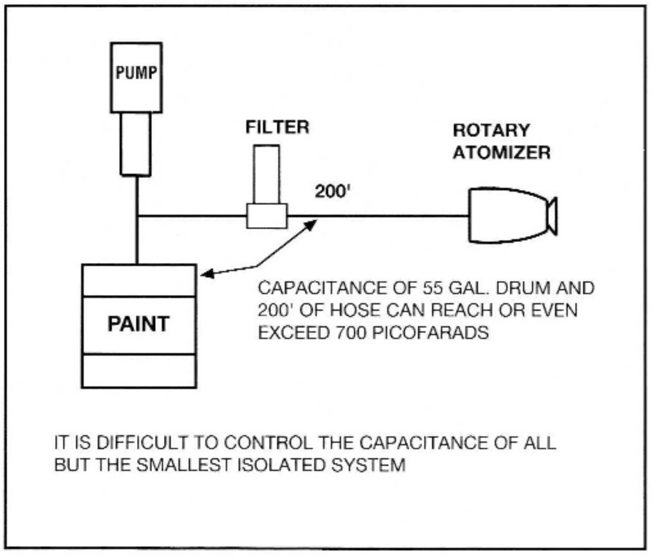
$$\text{REARRANGING: C MAX.} = 7/V^2$$

WHERE VOLTAGE IS THE MAXIMUM AVAILABLE FROM THE POWER PACK

This equation can be used as an indicator of the potential for a given isolated system to pose a serious shock hazard.

The capacitance of the system, as measured with a capacitance bridge or a suitable capacitance meter, must be less than the value of C MAX., if there is a possibility of accidental human contact that could result in an electrical shock. For example, if a 100,000 volt electrostatic paint system has a capacitance equal to, or greater than 700 picofarads, caging and interlocks should be considered for operator protection.

FIGURE 1



For comparison purposes, a single 55-gallon drum and 200 ‘ of 3/8 I.D. hose, all set 12” above the ground, can have between 450 and 900 picofarads of capacitance. This means that a typical paint system (Figure 1), which has much more hardware, would almost always exceed the maximum capacitance value and could store potentially dangerous levels of electrical energy.

Note that the voltage term is squared in the equation. This means that a given system at 100,000 volts will store four times the energy that it would at 50,000 volts. At the lower voltage not only will the system be safer, but also guns and cables will last much longer before breaking down electrically.

Still another compelling reason for lowering the voltage, is to maximize transfer efficiency. The maximum TE for most waterborne paints occurs between 40,000 and 60,000 volts. By comparison, the maximum TE for a less conductive solvent-based paint can be 90,000 volts or more.

Handguns present a special problem when a paint line is converted from solvent-based paints to waterbornes. An isolated electrostatic system for waterbornes can have multiple automatic atomizers, or it can have a single handgun. It cannot have both, nor can it have more than one handgun.

National Fire Prevention Association (NFPA) regulations dictate that the electrostatic voltage to any handgun must turn off when the trigger is released. Since all the atomizers in a waterborne system are connected electrically by their paint hoses, the voltage remains “on” to an idle handgun as long as it is “on” to any atomizer in the system. This means that a handgun cannot be used with electrostatics, if there are other atomizers in the system, and without electrostatics it is impossible to achieve the maximum transfer efficiency.

Indirect Charging

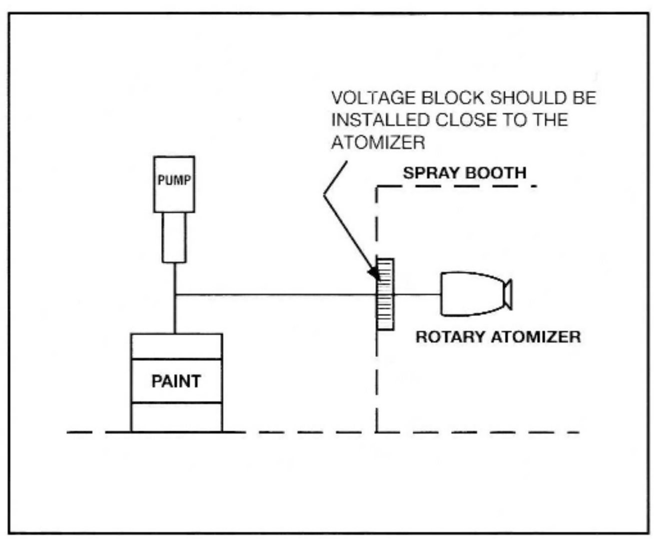
Isolated systems for waterbornes have serious disadvantages including high maintenance, electrical shock hazards, and limitations regarding handguns. One way to avoid these problems is to charge the paint particles after they leave the nozzle of the atomizer. This way the voltage never gets into the paint hoses so it cannot leak away to ground and there is no need to isolate the wetted equipment.

Remote or indirect charging of the atomized paint is done by positioning a high voltage electrode in the stream of atomized paint particles near the nozzle of the atomizer. The particles pick up a charge on their way to the part being painted. This improves the transfer efficiency significantly compared to non-electrostatic painting. Unfortunately, tests provide that the TE with indirect charged is less the TE that can be achieved by direct charging in any given application – that means using the same applicators, coating material, part shape, etc. The difference can be considerable, up to 25% reduction in TE in some cases.

Voltage-Block Systems

The best waterborne paint system should maximize the TE by directly charging the paint, as in an isolated system, but avoid the voltage leaks and safety problems associated with large isolated systems. This can be achieved by using a voltage block at each atomizer (Figure 2). Each atomizer then becomes a “mini” isolated system with no electrical connection to any other atomizer in the system.

FIGURE 2



These “mini” isolated systems do not have the problems found in large isolated systems because less hardware is charged with electrical energy. Capacitance is greatly reduced, making the system inherently safer. Safer systems mean easier access can be permitted to the insides of the spray booth. Often a simple guardrail and warning sign can replace elaborate caging and interlocks. With “mini” isolated systems, voltage leakage problems are minimized since only the atomizer and a short hose are charged, making it easy to keep the TE up to a high level.

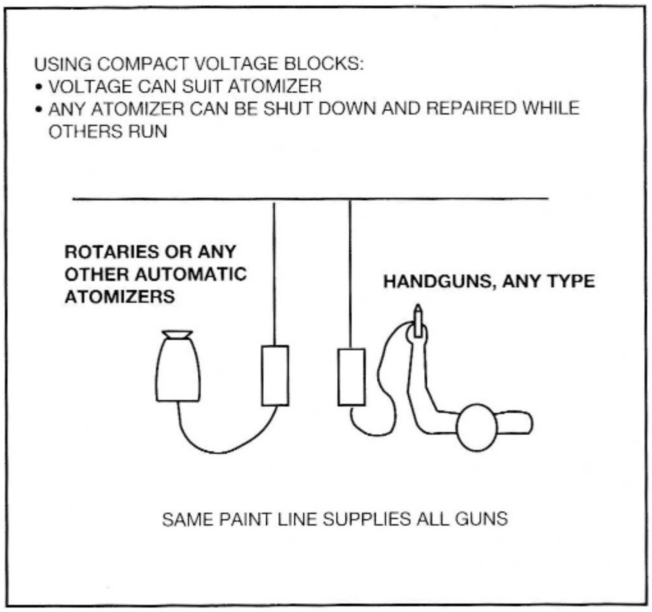
Voltage blocks are installed in the paint hoses as close to the atomizers as possible. They allow paint to flow from grounded pumps or paint kitchen to charged atomizers, yet block voltage from leaking back from the atomizers to the pumps or kitchen. This means that the hardware in the paint kitchen and distribution system requires no special treatment and can be virtually the same as for a conventional solvent-based system.

By isolating atomizers from each other, mini isolated systems have some unexpected advantages. First, the NFPA limitation concerning handguns no longer applies. Each handgun is independently isolated from every other handgun so the voltage to idled guns can be turned “off.”

Spraying waterbornes with a handgun and voltage block can be easier than spraying the old solvent-based paint with a handgun. With solvent-based paint, the paint is charged at the gun barrel so a high-voltage cable to the gun is required for most guns. Since waterborne paint conducts electricity, however, the paint can be directly charged at the voltage block and the cable to the gun can be eliminated, if desired. With the cable gone, the gun feels lighter and the hose bundle flexes more easily.

Even automatic atomizers like rotaries or discs require less maintenance if the paint is charged at the voltage block rather than at the atomizer, as it was when spraying solvent-based paint. This is because the high-voltage cable last longer when they do not get flexed repeatedly by the motion of the gun mover or robot.

FIGURE 3



A second unexpected advantage of making each atomizer into a mini isolated system is that every atomizer can operate at a different voltage, if desired. For example, TE tests might show that the rotary atomizers in a paint line run best at 60,000 volts, but the handguns used for touch-up operations run best at 45,000 volts. The handguns and the rotary atomizers can run at different voltages, yet all can be supplied form a common paint distribution system (Figure 3).

Finally, any atomizer in the system can be shut down and repaired or changed out, although the other atomizers are operating at high voltage because each atomizer is independently isolated.

FIGURE 4

COMMON METHODS FOR USING ELECTROSTATICS WITH WATERBORNES

	ISOLATED	REMOTE CHARGED	VOLTAGE BLOCKED
INSTALLATION COST	High	Moderate	Moderate
OPERATING COST	①Moderate	②High	Low
HUMAN COST	③High	Low	Low

① Good transfer efficiency when running well, but high maintenance cost to keep it running well.

② Lower transfer efficiency than the isolated system (when it is running well) or the voltage-blocked system.

③ Greater shock injury danger and less accessibility to the equipment due to caging requirements.

Conclusion

The best conversions from solvent-based paint to waterbornes result in the highest possible operating efficiency at low cost and with maximum operator safety. The operating cost, in terms of transfer efficiency should be about the same as that of a well-run solvent-based paint system. To achieve this, electrostatics must operate at peak efficiency. Installation cost can be minimized by reusing existing processes and equipment if compatible with the waterborne coating material.

In Figure 4, three common methods for using electrostatics with waterbornes for a typical plant are compared in terms of cost.

To summarize, the following are some application considerations when converting to waterbornes:

- Re-use the existing process and hardware if it is up-to-date and performing well for the existing solvent-based system. Change components where materials are not compatible with waterbornes.
- Turn each atomizer into a mini isolated system by installing a voltage block in the coating material hose, as close to the atomizer as possible. Directly charge the paint for maximum transfer efficiency.
- Lower the voltage to maximize transfer efficiency, extend equipment life, and reduce shock hazard.
- Take advantage of the fact that waterbornes conduct electricity. Remove the electrostatic cables from the atomizers and charge at the voltage blocks. Cables will last longer and the guns will move more easily.