System Design using Voltage-block Technology

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A well-run paint shop applying solvent-based paint and using good application equipment should be able to convert to waterbornes without significantly changing the operation if voltage blocks are used. These devices make it relatively easy to use electrostatics to obtain high transfer efficiency even with electrically conductive coating materials. Although design parameters for application systems for waterbornes using voltage blocks are not extraordinary, there are a few issues that should be considered.

System design using voltage blocks

Electrostatics improve transfer efficiency in coating applications where the material is first atomized into fine droplets or particles and then carried by air to the part being coated. Most coating applicators, such as spray guns, rotary atomizers and discs work this way. Without electrostatics, paint droplets that aren't aimed directly at the part miss it completely and are wasted. With electrostatics, however, much of the paint that would miss the part actually gets attracted back to it. The result is less paint waste and a better paint job.

Attraction forces between the paint droplets and the part being painted are caused by a difference in electrical polarity. The part is usually grounded by an earth ground, and the paint droplets are given a high-voltage negative electrical charge at the atomizer. The charged droplets are attracted to the nearest earth ground, where they seek to pick up a positive charge to balance the negative charge imparted at the atomizer. In a well-designed coating system, the nearest earth ground to the charged paint particles is the part itself, so the particles are attracted to it, even those particles that would have missed otherwise.

The difference in TE between parts coated using electrostatics and parts coated under identical conditions but without electrostatics is dramatic. It is not unusual to double the transfer efficiency in a given application by using electrostatics. This translates to thousands of dollars in paint savings annually even in modest coating lines employing only one or two atomizers. These savings easily justify the cost of electrostatic application equipment, in most cases.

The problem with electrostatics in waterborne coating application systems is that the coating material itself conducts electricity. This means that the electrical charge used for electrostatics finds an easier path to earth ground via the conductive paint hoses than via airborne paint particles. With electrostatics grounding out through conductive paint hoses, the transfer efficiency of the coating application system drops down to exactly the same as if no electrostatics were being used.

For electrostatics to work with waterbornes, all the equipment containing the conductive coating material must be isolated from earth grounds. Without a path to ground, the electrostatics charge the coating material and all the isolated equipment at high voltage. When the charged coating material gets atomized, the droplets contain the same charge and get attracted to the nearest earth ground, which is the part being coated.

Isolating waterborne systems

Waterborne systems are commonly isolated in one of three ways:

1. Complete isolation of all equipment that contacts wet coating material.
2. Isolating the charging electrode away from the wet coating material.
3. Isolating only the atomizer and its feed hose by using a voltage-blocking device.

To isolate a complete waterborne system every pump, tank, pipe, atomizer, or other piece of equipment that contacts wet coating material must be kept away from earth grounds. Equipment being isolated can be set on plastic tables, hung from plastic hangers, stuffed in plastic pipe sleeves, or simply suspended in the air far from any earth ground.

Experience with completely isolated waterborne systems has generally not been good, except for very small coating lines. When a large quantity of hardware, such as pumps, hoses, and atomizers is isolated and charged with high voltage, two problems develop: First, frequent and elusive electrical shorts occur. These defeat the electrostatics, and transfer efficiency is reduced.

Second, as the system size increases, so does its ability to capacitively store electrical energy. This energy is released when the system shorts out. If the short is caused by human contact, serious injury can result. If the short occurs through a hose wall or other piece of equipment, that equipment can get damaged.

Indirect charging systems avoid many of the problems of completely isolated systems by eliminating the need to charge system hardware with high voltage. With indirect charging, the high voltage for electrostatics never directly contacts the paint or any wetted hardware so the application equipment never gets charged. Instead, a high-voltage electrode is placed near the "cloud" of atomized droplets. The electrode causes a high-voltage field around the paint droplets, and the droplets take on an electrical charge. As with completely isolated systems, the negatively charged paint droplets are attracted to the grounded part being coated by the electrostatic forces.

Indirect charging eliminates the two major problems found in completely isolated systems: preventing accidental shorts and storing dangerous levels of electrical energy. The cost for eliminating these problems is lower transfer efficiency. Indirect charging results in transfer efficiencies that fall somewhere between "no" electrostatics and "good" electrostatics. In recent tests in an automobile plant, the transfer efficiency improved between 12% and 27% when otherwise identical application systems went from indirect to direct charging electrostatics.

Application systems with the lowest operating cost for waterbornes combine the advantages and avoid the disadvantages of both schemes – complete isolation and indirect charging. They allow direct charging of the paint, as in a completely isolated system. This results in the highest possible transfer efficiency for a given application. At the same time, they limit the amount of hardware that is charged with high voltage. This minimizes the problem of maintain isolation to avoid accidental shorts. It a lso minimizes the "capacitance" (or ability to store electrical energy) of the system, so it is safer for personnel and equipment.

Voltage-block equipment

The amount of hardware that gets charged in these systems is limited by a "voltage-blocking device" that prevents voltage from leaking to an earth ground via the conductive hardware in the system. Voltage-blocking devices can be envisioned as "one way" valves in the paint supply hoses. These "one way" valves allow paint to pass through from the pumps or paint kitchen to the atomizers, but prevent the high voltage from the electrostatics from leaking back from the atomizers and grounding out in the application equipment.

Voltage-blocking devices are installed directly in the paint supply hoses, as close to the atomizers as possible. This way only the atomizer and a short hose to the voltage block get charged with high voltage. Since the paint in the atomizer gets directly charged, transfer efficiency is maximized.

On the other hand, since only the atomizer and a short hose are charged, it is relatively easy to isolate this equipment to avoid accidental shorts. Furthermore, the electrical energy that can be stored capacitively in the equipment is limited, so shorts are much less likely to damage equipment or endanger an operator.

Waterborne systems operate like solvent-based paint systems they replace when voltage blocks are used. Equipment upstream of the voltage-blocking device, such as paint pumps and distribution systems, is essentially the same as for solvent-based paint. In fact, the only change necessary with this equipment to convert to waterbornes is replacement of parts that would corrode in contact with the coating material.

Likewise, atomizers and hoses that supply them can be essentially the same as used for solvent-based paint, with the following qualifications:

- They must be constructed of materials that will not corrode in contact with waterborne coating materials.
- Atomizers and hoses must either be completely isolated from earth grounds, or they much be designed to completely isolate the fluid tubes.

This is the starting place for a discussion of the design issues to consider for an application system for waterbornes.

Designing an application system for waterbornes

- Some design issues for a voltage-block system include:
- Isolating equipment between the voltage block and atomizer.
- Safety and operator access.
- Charging the paint with electrostatic voltage.
- Applications using both waterborne and solvent-based paints.
- Changing colors quickly and with minimal waste.

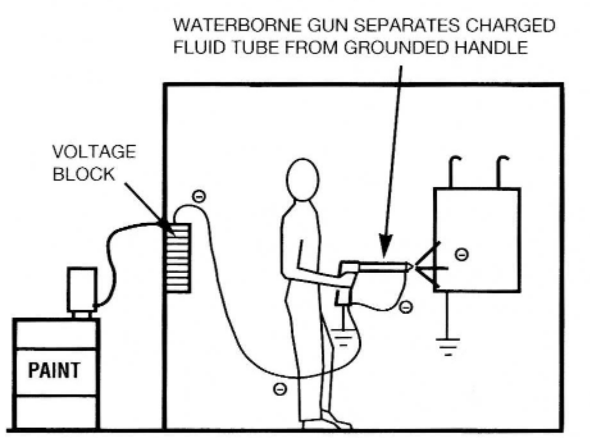
The hardware that gets charged in a voltage-blocked system must be isolated from earth grounds. Usually this hardware consists only of the atomizer and a short paint-supply hose between the voltage block and atomizer. This equipment must be isolated as completely and for the same reasons, as wetted hardware in a completely isolated system. In other words, there must not be a path to ground that can short out the electrostatics.

Equipment designed specifically for waterbornes and electrostatics can usually contact, or even be attached directly to grounded hardware. This equipment is designed to isolate the paint or fluid tube from the exterior of the hardware. With the paint tube isolated, paint within it can be charged with high voltage, but the voltage cannot leak back to the handle or hose covering. In fact the exterior of equipment designed specifically for applying waterbornes with electrostatics is often intentionally grounded to drain off any static charges that can accumulate on the surface. For example, handles of handguns used to apply waterbornes electrostatically, should be grounded so that the operators do not charge their bodies with electrical energy when they use the equipment.

A painter holding the grounded handle of a spray gun for waterbornes is grounded by means of the contact between his hand and the grounded gun handle (Fig 1). Thus, any static charge attracted to his body will drain away to ground before it can accumulate and become dangerous.

It is important to ground hand gun operators because everything in the spray booth, including the operator, picks up a static charge from the high-voltage used for electrostatics. That is why “indirect charging” electrodes can charge paint droplets in the air even though there is no direct contact with the paint stream. Any electrical energy that is not drained away from the operator by the grounded gun handle or some other means can accumulate. The electrical energy accumulated in the operator’s body this way will eventually short to ground and the sudden release of energy can cause a severe shock and possible injury to the operator.

FIGURE 1

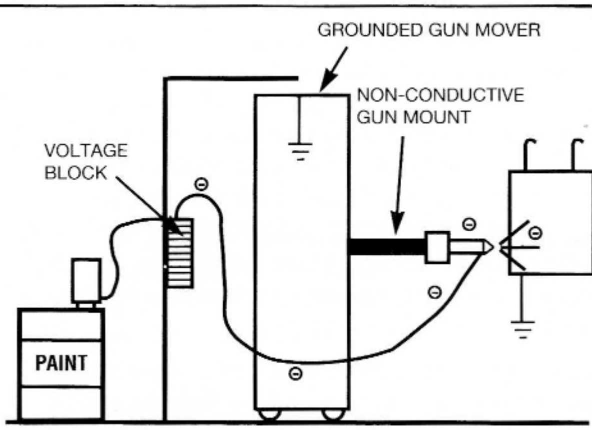


HANDGUN OPERATORS MUST BE GROUNDED THROUGH THE GUN HANDLE SO THEY DON’T PICK UP A STATIC CHARGE WHICH CAN SUDDENLY DISCHARGE TO GROUND SHOCKING THE OPERATOR.

This generally means that hand guns must be designed specifically for waterbornes or for dual use with either waterbornes or solvent-based paints. Two features that are mandatory for a waterborne handgun are:

1. The handle must be attached to an earth ground and designed to electrically connect the operator to that ground.
2. The paint tube in the gun must be isolated from the grounded handle, so that it can be charged with high voltage.

FIGURE 2



CONDUCTIVE ATOMIZERS FROM SOLVENT-BASED PAINT APPLICATIONS CAN OFTEN BE USED FOR WATERBORNES BY USING A PLASTIC MOUNTING IF THE ATOMIZER PARTS ARE COMPATIBLE WITH THE PAINT.

On the other hand, automatic atomizers like air spray guns, rotary atomizers, and discs can be the same or similar for waterbornes as for solvent-based paints, if the entire atomizer can be isolated from earth grounds (Fig 2). One way to isolate equipment like this is to mount it on plastic or some other material that won’t conduct high-voltage electricity. For example, rotary atomizers can be attached to grounded gun movers by means of a heavy PVC bar that electrically isolates the atomizer from the gun mover.

Once isolated, the entire atomizer can be charged with high voltage along with the paint in the atomizer’s fluid passages, but the voltage can’t leak past the mounting bar. Since the entire atomizer is charged with high voltage, any operators in the vicinity must be grounded to avoid charging their bodies with electrical energy. Conductive wrist or ankle straps connected to an earth ground can be used for this purpose.

Operator safety and caging

Two ways in which operators can get shocked by high-voltage electrostatics are:

1. Contact with a piece of equipment such as a paint hose, which is at high voltage.
2. Charging their bodies with static electricity and then discharging it to ground. (Grounding operators prevents shocks caused by accumulating a static charge in the body and then discharging it into a ground.)

Grounding, however, does not protect operators from external shocks, such as those caused by touching some electrically charged hardware. An operator who gets close enough to a charged automatic spray gun, for example, can draw a spark and get shocked whether or not he is grounded. The only way to avoid shocks from a piece of equipment at high voltage is to avoid contact. If the charged equipment has significant capacitance, it can store enough electrical energy to be dangerous, and the operators must be kept away by fences and caging to prevent accidental contact.

Completely isolated electrostatic waterborne systems can easily store enough electrical energy capacitively, to be dangerous. For this reason, most of these systems require caging and door interlocks to keep operators away when production is running. Voltage-blocked systems, however, limit the amount of hardware at high voltage. Less hardware means less capacitance, and that means that less electrical energy is stored in the system. For this reason, many voltage-blocked systems do not require elaborate caging for operator protection.

One of the design objectives of the system should be to minimize capacitance of the hardware between the voltage block and atomizer nozzle. Hoses should be as short as possible and placed far away from nearby grounds. In most cases, systems with several atomizers should be broken down into several "mini isolated systems," each with one atomizer and its own voltage block, as opposed to a single, voltage-blocked system encompassing several atomizers. Accessory system hardware l ike filters and regulators should be located on the grounded or "kitchen" side of the voltage block, rather than on the charged or "atomizer" side whenever possible.

Charging the system

A voltage-blocked waterborne system can be charged with high voltage for electrostatics at any point between the voltage block and the atomizer. Conductive paint will carry the charge to all the wetted equipment that is isolated by the voltage block.

Charging at the voltage block is best for most applications because the electrostatic power cable does not need to flex with the atomizer's movement. Instead, the cable need not move at all so it is less likely to be damaged. If the atomizer is a handgun, it will feel lighter and easier to handle if the cable is taken out of the gun and plugged into the voltage block.

In applications with several atomizers that are located close to one another, such as on a common gun mover, there can be a significant cost advantage to charging at the voltage block. Since the paint hose to each atomizer is also a "wire" for the electrostatic voltage, all the atomizers on the gun mover can be charged with a single power supply and cable, if the cable is plugged into the voltage block.

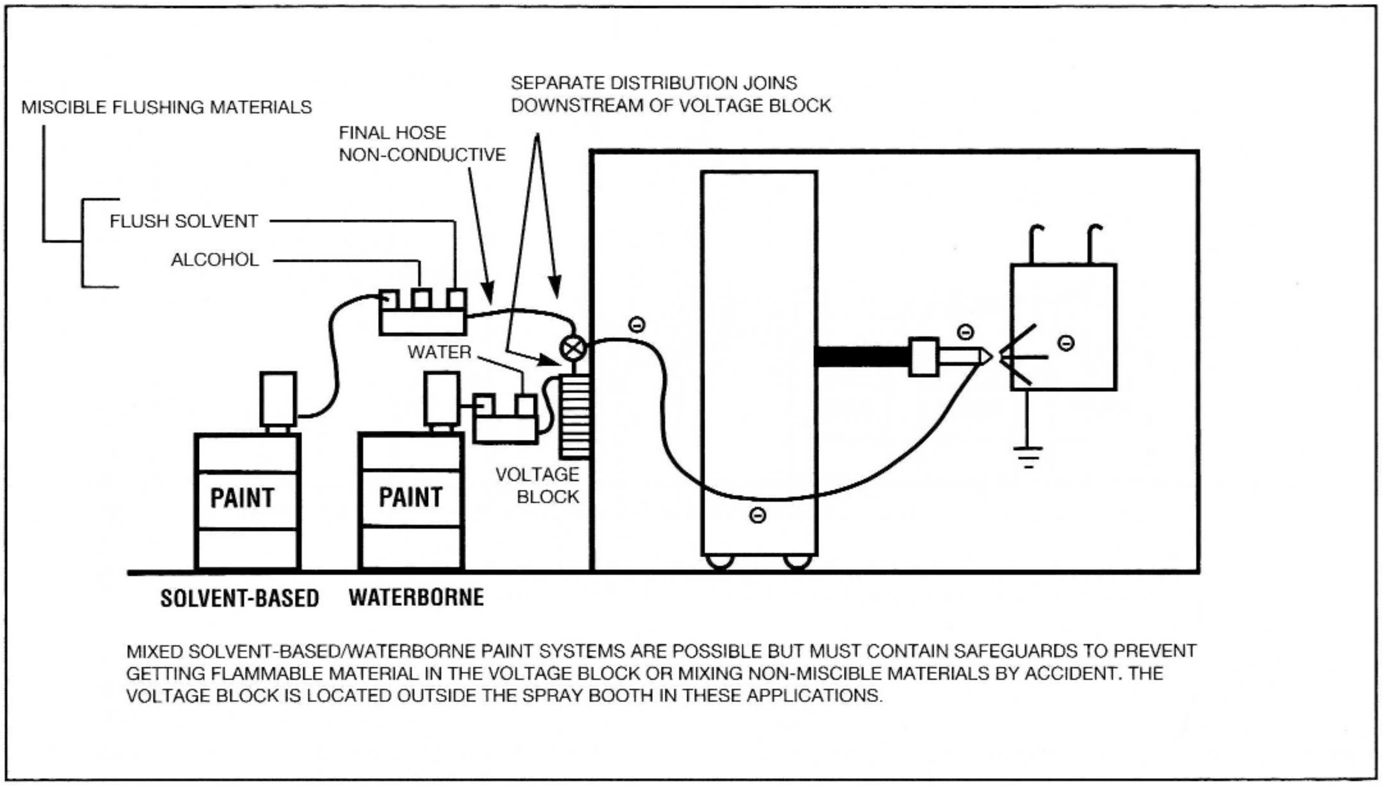
Mixed solvent-based/waterborne systems

The issues discussed to this point have dealt with installing and using a voltage block in a waterborne system. Design issues for mixed systems, containing both solvent-based paint and waterbornes, are more complex.

There are many mixed systems in use, particularly as companies change from solvent-based paints to waterbornes. Often companies make the change to waterbornes one color at a time, as they work with their formulators to get coatings approved for production. These companies often ask if they can run the solvent-based paint through the same equipment as the waterbornes. The answer is "not through the voltage block."

Some of the hardware inside the voltage-blocking device gets alternately charged and grounded, depending on whether it is filling from the kitchen, or dispensing to the atomizer. When a piece of charged hardware goes to ground, it discharges the static electricity accumulated when it was charged with high voltage. This generates a spark just before contact between grounded parts in the voltage block, and recently charged parts. That spark can carry enough energy to ignite flammable solvent-based paint. For that reason, flammable materials such as solvent or solvent-based paint cannot be permitted inside or near the voltage block.

FIGURE 3



It is possible, however, to design a voltage-blocked application system that uses both waterbornes and solvent-based paints (Fig 3). Here are some design guidelines:

Use a separate distribution system for each type of resin and tie the two together between the voltage block and atomizer. Then, it is less likely that solvent or solvent-based material will find its way into the voltage block by accident, which could create a fire hazard. It also minimizes the risk of a mess caused by mixing two materials that are not miscible.

A simple manual or automatic 3-way valve can be used at the tie-in point. The valve would connect the atomizer to either the waterborne line going to the voltage block, or to the solvent-based paint line to the kitchen.

Use non-conductive hoses or pipes for the last few feet on the solvent-based paint system, ending at the tie-in between the two systems. This will prevent voltage from leaking away through the pipes for the solvent-based paint, assuming that the paint itself is non-conductive. Consider an “air push” on the solvent-based paint system to blow out the paint if it is a little conductive.

Flush the system with materials that mix when switching from solvent-based paint to waterbornes or vice versa. A sequence to get from a waterborne to a solvent-based paint might be as follows: waterborne paint, water flush, alcohol rinse, solvent rinse, solvent-based paint. This sequence could be reversed when changing back to the waterborne material.

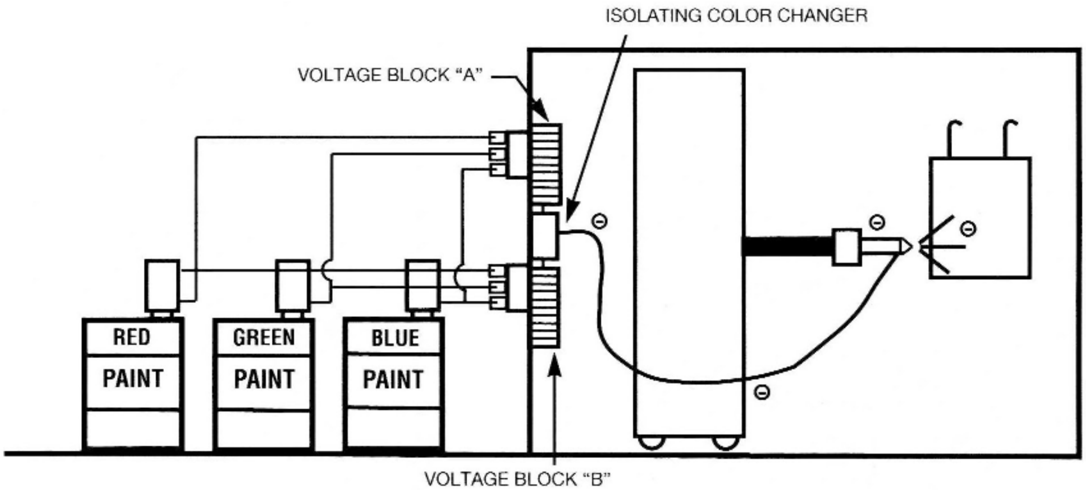
Color change

Manufacturers facing government regulations regarding VOC emissions have choices. They can switch from solvent-based paint to waterbornes, high solids, powder, supercritical fluid, etc. For many of them, the choice is wholly or partly driven by a need to change colors frequently and quickly. This requirement can give waterbornes the edge over the alternative processes, provided the system can be designed for fast color changes.

Voltage blocks can be cleaned easily for color changing. Nevertheless, a simple voltage-blocked system cannot be color-changed in the same short period required to change color through a color changer in a solvent-based paint system. In the l atter system, the only equipment that is flushed and cleaned is the color-change manifold, the hose to the atomizer, and the atomizer itself. This equipment flushes and cleans like a series of hose-like passages, and color changes of less than a minute are routine.

It is more difficult and time-consuming to clean and color change a waterborne system with a voltage block. The voltage-blocking device itself includes one or two piston pumps and one to four

FIGURE 4



"A-B" COLOR CHANGE SYSTEM. COLOR-CHANGE TIME IS COMPARABLE TO A SOLVENT-BASED PAINT SYSTEM. IDLE UNIT IS GROUNDED FOR UNRESTRICTED ACCESS TO MAINTAIN OR CLEAN.

quick connect fluid couplings, all of which need to be cleaned at color-change time. In addition, the voltage block may contain several ounces of the old color paint that will need to be purged out before the cleaning process can begin. A simple voltage-blocked waterborne system can require 5 to 10 minutes for color change.

A 5 to 10 minute color change is too slow for most manufacturing operations, particularly if the main reason for staying with a liquid coating is the need for fast color changes. Fortunately, there are ways to speed-up color-change time in a waterborne system using voltage blocks. Predictably, the faster schemes are more complicated and expensive. Here are three basic schemes for color changing through voltage blocks:

- Simple color change – color change time 5 to 10 minutes. This scheme doesn't require special or extra hardware specifically for changing color.

  The color change sequence is as follows: a. Purge old color, b. Flush unit with water, and c. Fill with new color.
- A-B system (Fig 4) – color change time under a minute. This scheme requires two parallel voltage blocks, "A: and "B". While "A" supplies paint to the atomizer, "B" can be cleaned and filled with the next color. At color-change time only the atomizer and its supply hose need to be flushed and cleaned, similar to the wet solvent-based paint systems are color changed through a color changer. As soon as the atomizer and its supply hose are clean, the "B" voltage block comes on-line and supplies the new color.

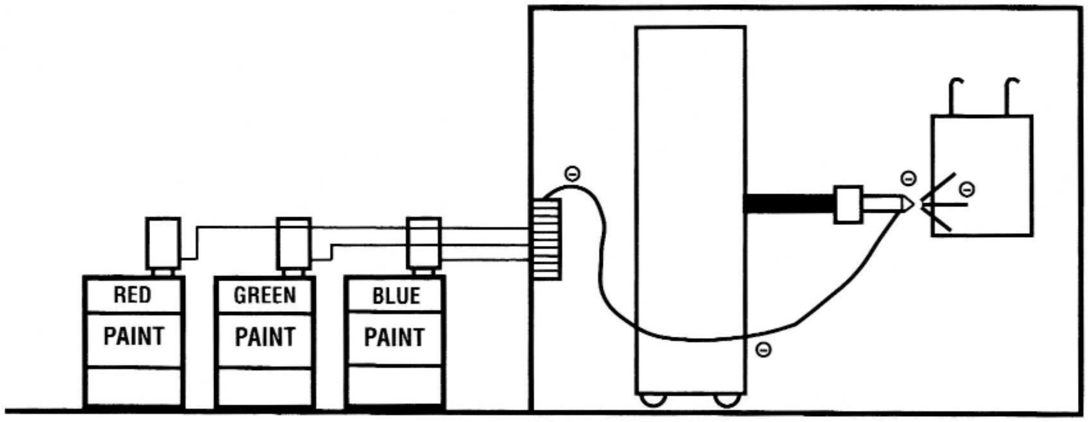
  The actual color time with the A-B system approaches that of a comparable solvent-based paint system. The idled voltage block containing the old color is cleaned and color changed, while production runs with the new color on the other voltage block.
- Dedicated color system (Fig 5) – color change time under a minute. This scheme dedicates a voltage-block module to each color. Modules are compact and six colors fit inside a single wall-mounted cabinet. No voltage-block hardware is ever flushed or color changed. Instead color changes are taken at a color changer, the same as in a solvent-based paint system.

The advantage of dedicated systems are that they replicate the solvent-based paint systems they replace. No more paint is wasted than would be lost in a comparable solvent-based paint system.

Conclusion

Before converting a solvent-based paint system to waterbornes, some fundamental design issues related to the conversion should be reviewed. An implicit goal in many conversions to waterbornes from solvent-based paint systems is to avoid disrupting "the way it's done now," particularly if the existing system has good equipment and is performing well. That goal is not out of reach since the existing process and much of the existing equipment can often be used for waterbornes with only minor changes to avoid corrosion problems.

FIGURE 5



DEDICATED COLOR-CHANGE SYSTEM HAS A VOLTAGE-BLOCK MODULE FOR EACH COLOR. PERFORMANCE IS SIMILAR TO SOLVENT-BASED PAINT SYSTEM WITH COLOR CHANGER. NO ADDITIONAL PAINT IS WASTED AT COLOR-CHANGE TIME.

The bigger question is how to maintain high transfer efficiency after the conversion. To get the best transfer efficiency from a waterborne system, electrostatics must operate at peak efficiency. This means directly charging the material with electrostatic voltage, but limiting the hardware that gets charged. Voltage-blocking devices confine high electrostatic voltage to only the atomizer and hoses to the atomizer. The system can now operate at the highest efficiency possible for the specific application. The voltage-blocked waterborne system will be as close to the solvent-based material system it replaces as is possible, with a coating material that conducts electricity.