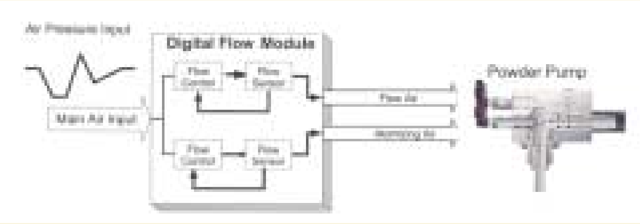

Figure 6. Closed-loop approach to airflow regulator design.

In closed-loop control, changes in the input are measured and converted into signals that change the process to produce a steady output.

This happens every time automotive cruise control is engaged. As the car travels up and down hills, the computer adjusts the engine to produce a constant speed. To do this manually would require continuous, tiny incremental adjustments. With the constantly varying changes in supply air, such adjustments to all guns are impossible. The latest digital flow modules make this constant monitoring and adjustment achievable and affordable.

Figure 7 illustrates the benefits of advanced, closed-loop flow control in actual production situations. In this test, a standard gun regulator is compared with a new digitally controlled regulator. The digital system uses the same sort of PID (proportional-integral-differential) algorithms found in other control schemes (like temperature controllers on ovens) to compensate quickly for any variations.

THE REAL ADVANTAGES OF SOPHISTICATED SOFTWARE

So far this discussion of advanced controls has focused on new hardware such as photoeye arrays and digital flow control modules. But software plays a significant role in the ability to optimize application efficiency as well.

Although graphic interfaces provide a "high tech" look to the system, the real dollars-and-cents payback results from the tasks computer control systems allow, rather than the "GUI" graphic user interface itself.

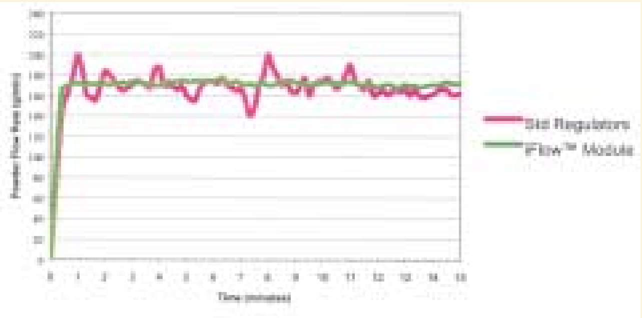

Figure 7. Benefits of advanced, closed-loop flow control in actual production situations.

FAST, REPEATABLE SETUPS

Computer-driven systems allow all parameters associated with a specific part style to be stored for instant recall. The electrostatic KV, µA settings, gun trigger timing, lead and lag values, powder flow control, flow and atomizing air settings for any number of individual guns can be stored and recalled instantly.

On large systems, the mere thought of making several adjustments to each spray gun is exhausting! Not only would this be impossible to accomplish in a fast moving environment, where literally dozens of adjustments would need to be made very quickly, but the opportunity for error becomes more likely as more changes are needed. This becomes a deterrent to making needed adjustments to a conventional system.

The field experiments in repeatability proved that if time were taken to make these adjustments, the accuracy and repeatability would be poor and result in lost profits.

Digital control literally offers one-step ability to reset a huge number of operating parameters to a predetermined recipe. Digital control also eliminates the wide swings in flow control values that waste vast amounts of powder.

New storage technology, like miniature, commercially available flash-memory cards, is now used to store recipes for convenience, low cost, and ease of use. The entire control system is now a centralized digital "dashboard" for the powder system operator making setup fast, convenient, and nearly transparent.

EXPANSION, SYSTEM TOOLS, AND TRAINING

Computer-based systems also make tasks, such as copying recipes or duplicating and editing parameters for a wide range of different parts, easier. The era of loose-leaf binders filled with setup sheets and pages of cryptic documentation is over. They have been replaced with icon-driven screens that make training easier, and eliminate language barriers and confusion. Documentation can present operators with exactly what they will see on the line, while digital control eliminates the variability of the human eye and hand. Also, control functionality can be enhanced as future needs arise by upgrading the software rather than buying new controllers.

CONNECTIVITY

When the software platform is chosen with connectivity in mind to interface the powder system to other systems, a whole new opportunity opens up.

Whether it's to export data to a quality control or SPC (statistical process control) system for ISO- or QS-9000 record-keeping, or to a plant LAN for sharing data, or even to interface the paint system to other upstream or downstream processes, DDE and ODBC protocols make leveraging the investment into a computer-based control system an easier task.

CONCLUSION

The evolution of powder technology has moved controls into a new, computer-driven, era. Digital devices using closed-loop technology now allow for more accurate, repeatable performance. Better flow control combined with automated gun triggering has a proven impact on increased profitability through increased application efficiency.

Computer software not only provides convenient, centralized control of large systems, it eliminates errors in setup and enables operators to optimize systems by a large number of adjustments quickly and easily through recipe-driven capabilities. All of this sophistication occurs unobtrusively, almost transparently, to the operator.

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Powder Coating System Controls for Today's Applications

by Ken Kreeger

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It has been said that the more a technology improves, the more transparent it becomes. Think of the complexity of the modern automobile, with a computer more powerful than the one aboard the Apollo 11 spaceship that took man to the moon. With no assistance from the driver, the engine management system accumulates real-time data from a number of sensors and adjusts the engine components accordingly. The result is better performance, higher reliability, and savings through improved fuel economy.

The same is true of control systems now available for the modern powder coating line. Powerful hardware and software combine invisibly to process information about the application and make the necessary adjustments to optimize powder delivery, better finish quality, longer system life, and improved savings.

High application efficiency is at the crux of any powder coating operation. It provides material cost savings, faster color change, reduced wear on system parts, better finish quality, and greater control of film thickness.

This paper examines the need for better powder system controls and some of the latest developments that make improved control possible in today's powder coating applications, where all kinds of different parts to be coated are loaded by everyday operators who can only do so much to control quality. And where parts wear out, booths take time to clean, and improvements can result in significant savings.

TESTING WHY CONTROLS ARE NECESSARY

Nordson Corp. conducted a field experiment to determine the actual performance of a conventional powder system where the operator manually adjusts the powder flow rate (see Fig. 1). In the experiment, operators were asked to reset a conventional powder regulator to a certain value. The value chosen (210 g/min) was the lowest powder flow rate that would achieve the required film thickness for a given part.

After the operator set the control, the actual flow rate was measured. The procedure was repeated 20 times. Results are depicted in Figure 2.

The data shows that under actual conditions, a manual regulator setting by a trained powder operator to 210 (g/min) results in an average flow rate of 238.6 (g/min).

The higher rate is due to a variety of factors: how well the operator can read the gauge, how finely he can adjust the regulator, and the accuracy of the gauge itself. Each of these factors compounds the problem of maintaining a consistent, optimum powder flow.

Figure 1. Manually adjusting traditional powder regulators has some inherent problems with accuracy and consistency.

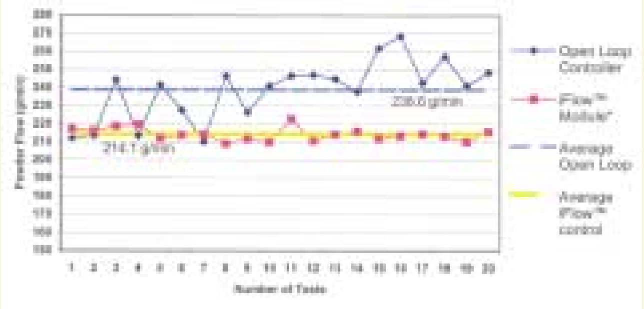

Figure 2. Manual (open loop) versus automated powder flow control.

The same chart shows the effect of state-of-the-art, closed-loop flow-control systems in which the electronic "invisible hand" takes over. In the same experiment, the Nordson iControl system produced an average flow rate of just 214.1 g/min.

Consider the cost of this inconsistency. At an average delivery of 238.6 g/min compared to 214.1 g/min with the iControl system, each 7½-hour shift sprayed nearly 37 extra pounds of powder per gun. On a typical 12-gun system, that would result in an extra 112,000 pounds of sprayed powder in a year.

INTO THIN AIR

Application efficiency of a system describes an actual coating production measurement. Unlike the commonly misused concept of transfer efficiency that describes the deposition rate when spraying a continuous, solid sheet of metal, application efficiency is the deposition rate when coating actual parts.

Since no recovery system is 100% efficient, whenever powder is sprayed some portion of that powder will not remain on the part and be wasted. This is the cost of application efficiency. Figure 3 illustrates the impact of application efficiency.

In actual production, when parts of varying shapes and sizes are hung on the paint line, openings and gaps between them are created (see Fig. 4).

Unless spray guns are triggered on/off to account for these gaps, a great deal of powder would be sprayed in the booth and not on the parts.

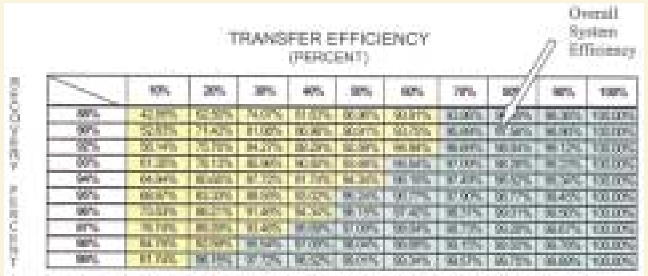

Figure 3. Impact of application efficiency.

Figure 4. Large gaps between and around parts of differing shapes and sizes are common.

Because application efficiency is so important to improved profitability, a popular feature of more sophisticated control systems is gun triggering. Triggering guns on/off prevents powder guns from spraying into thin air. Often this means shutting off some or all of the spray guns between parts, in the gaps within parts, or when parts of different shapes and sizes are mixed on the paint line (see Fig. 5).

An array of photocells with reflectors or light curtain can automatically detect the presence of each part, as well as its shape and size. The photoeye array can then signal ahead to the application equipment to ensure the needed guns are triggered at the appropriate time as parts pass in front of them. Again, the "invisible" eyes and hands of the system act transparently to adjust the spray guns for random loading of parts or gaps that commonly occur because an operator is busy doing something else.

What impact does gun triggering typically have?

To quantify the savings, Nordson performed another actual production experiment. The data in Table I summarizes results of trials conducted on a powder line with 12 automatic spray guns, with and without triggering. The system used a high-efficiency cyclone collector with 95% recovery efficiency and all settings other than gun triggering were kept identical.

Table I indicates that better flow control reduces total powder used. While triggering doesn't affect the amount of powder applied to parts, it greatly affects the total consumed (in this case 25% more). With the same cyclone reclaim efficiency, this means more wasted powder. And while the amount of wasted powder adds up, it's just a fraction of the excess powder that must be sprayed, pumped, and cleaned up. Excess powder produces wear and tear on the components and lots of added time wasted by plant personnel.

Table I. Powder Line Trial Results

	Manual Flow Without Triggering	*Closed Loop Without Triggering*	*With Closed Loop Triggering*
Powder applied	252,000	212,625	212,625
Powder consumed	275,400	232,368	174,276
Powder wasted	23,400	19,743	14,807
Cost of wasted powder ($2.10/lb)	$49,140	$41,462	$31,096

DIFFERENT STROKES FOR DIFFERENT FOLKS

If all parts to be coated were flat sheets of metal, it would be a lot easier to save money. Once the minimum film thickness required for the right cosmetic or performance properties had been determined, the regulators could be set and left alone. The guns would continue to lay down a consistent layer of powder as determined by line speed, powder flow rate, target distance of the gun, and electrostatic factors.

Figure 5. Photoeyes connect to the control system to trigger spray guns on/off.

But in actual production, parts have varying geometries like deep recesses, corners, and edges. Distance varies and electrostatic effects come into play and, if the powder flow rate is held constant, results in surfaces with varying amounts of powder. On a fixed flow rate system, this means either undercoating portions of the part or wasting powder on others by turning up the delivery rate.

The right solution lies in being able to tailor the process to the application using more sophisticated flow control. In another actual production test of the savings of digital, closed-loop flow control, Nordson documented that when a traditional powder line was set up to produce parts with a minimum film thickness of 2.0 mils, actual film thickness averaged 2.37 mils. The results are typical of most powder lines that sacrifice profitability every day because of equipment limitations.

THE UPS AND DOWNS OF FLOW CONTROL

So far we've discussed setting controls as though we operate in a stable world; however, in actual production, plant air that feeds powder equipment is constantly changing. As changes in inputs like the air delivery system occur, they produce unwanted results downstream. To smooth out the powder flow rate, these instantaneous changes must be measured and corresponding adjustments made.

Some attempts to compensate for changes in input factors have focused on trying to measure powder flow from the guns themselves. This approach is tempting because we care most about the actual powder delivery rate. But it is very expensive and technically difficult to measure the flow of powder. Techniques developed for measuring fluids (like liquid paint) don't work very well for powder that has been "fluidized" in air.

Some have attempted to measure powder flow indirectly, by measuring its characteristics, like the electric charge it possesses. This approach, though good in theory, becomes unreliable in actual production situations where different powders are used or when the humidity in the spray booth changes.

A practical solution lies in a "closed loop" approach to airflow regulator design (see Fig. 6.)