A properly designed and implemented autom- system directly impacts cleaning efficiency while maximizing overall manufacturing objectives.

Making the Move Toward Automationation of Open-Top Cleaning Lines

BY JONATHAN ARIES

The argument for automation is simple: efficiency. Good automation maximizes throughput and utilization of human and material resources. The most successful automated cleaning operations also consider overall plant operations before and after product cleaning.

Vapor degreasers were traditionally considered isolated islands removed from the production environment. Degreasers utilizing traditional halogenated solvents were automated where worker exposure to noxious fumes were a concern. As the cost of CFCs increased, automation was justified for the conservation of resources.

The current broad spectrum of cleaning chemistries present increasing processing complexities which even further rely on the merits of automation. No longer incidental to production, cleaning is now often a production bottleneck.

Most new cleaning requirements involve more steps with longer times at each station, concerns for dilution of chemistry and attenuating waste treatment costs, potential damage to parts from over-exposure, concerns for efficient drying, and special handling of parts to ensure penetration of process steps in small spaces.

The objectives of a successful automation system can be grouped into two categories:

- Those directly related to cleaning efficiency — quality control, throughput, process control/abilities; and
- Those maximizing overall manufacturing objectives — integration of the cleaning operation with production, worker safety, and conservation of cleaning materials.

Quality Control

Obviously, for any chemistry to be effective, cleaning regimes must be followed to avoid rejection of parts due to inadequate cleaning, inadequate drying, or from over-exposure to aggressive chemistries.

One advantage of sophisticated automation is that it affords greater flexibility in processing various parts with the same equipment. Plus, depending on manufacturing packaging, throughput can be impressive even in relation to in-line *systems*.

Throughput

As the number of cleaning stations are consolidated due to the cost of equipment changeover and integration of cleaning operations into total prod production environments, throughput — described in terms of payloads per hour or minutes per payload — is becoming i increasingly important.

Beyond the quality control concern for over - or under-treating parts, wasting time is no longer tolerable. The objective is to maximize through put by eliminating bottlenecks; i.e., minimize the delta between en processing time and automation cycle time. Improving throughput is a function of **controlling distance and speed.**

Obviously, tanklines should, be as compact as practical for both length and height. After establishing the physical envelope, look to how well speed can be controlled and if breaking up the travel distance provides significant advantage.

Throughput strategies are best explored in terms of the three levels of processing sophistication: serial, parallel, and automatic prioritization.

Serial Throughput

With a serial approach, one payload is processed at a time according to its recipe — the specific order of processing from loading into the system through unloading, including the sequence of tanks with dwell time in each and accompanying drain-off time.

During this progression of steps, additional input or output (I/ O) instructions may be called out, such as turning on air knives during withdrawal from a certain tank, waiting for confirmation that the unload station is clear, etc.

Throughput for each payload = cumulative dwell and drain-off times + automation cycle time. The only way to affect throughput is to decrease cycle time. Since serial applications arc typically for low production rates, very short tanklines, or other special conditions, the best approach to marginally improve performance is to increase operating speeds.

Parallel Throughput

A parallel approach allows for simultaneous processing of payloads according to the longest delay within a recipe. This is most easily conceptualized as a tank line with load and unload stations at opposite ends and all stations between being full. When the payload at the final station unloads, the automation works its way “upstream” until a new payload loads into the system and the cycle repeals.

Also considered here are hybrid serial/parallel recipes where a station with aggressive chemistry (or oxidation of parts) requires critical removal and placement of a payload in an adjoining rinse tank. These multiple steps are described as a "serial segment" within a parallel process.

Throughput for each payload = longest dwell and drain-off time (serial segment) for any payload in the system + marginal automation cycle time.

While a considerable improvement over serial processing, simple parallel processing presents two limitations. The most significant is that throughput is limited by the longest dwell time for any payload in the system.

The best operations with parallel processing group together payloads having identical recipes. When switching from one recipe to another having significantly different dwell times, it may be best to simply clear the line before proceeding with the next group. With some applications having dissimilar recipes this can result in several hours of lost productivity.

A second uncommon limitation of simple parallel processing is that all recipes must be sequential — the progression of tank steps is a one-way street. This is occasionally a concern with re-work or when the tankline requirements are uncertain.

Depending on the application, throughput can be enhanced either by increasing operating speeds, through use of a "walking beam" or gang fixture on a single head which will move more than one payload at a time, or with multiple heads moving with varying degrees of independence.

Automatic Prioritization

Also referred to as "dynamic" or "random" loading in the plating industry, automatic prioritization allows for simultaneous processing of payloads regardless of recipe requirements. Tank stations are defined as to the criticalness of over-exposure or delay between any two stations.

Each payload is processed with maximum efficiency, respecting the priority of payloads previously placed into the system. While it may appear that the system is merely in parallel processing, it is a significant advantage to the user who is switching between recipes regularly, even with each payload.

This type of processing permits "leapfrogging" of one payload ahead of another when possible, as well as nonsequential recipes. *Throughput for each payload = automation cycle time + marginal dwell and drain-off time.*

To take full advantage of the flexibility of this more sophisticated processing, automatic prioritization typically utilizes one or more heads carrying single payloads. Higher operating speeds will have a dramatic improvement on cycle times, particularly if horizontal speeds increase when the automation is not carrying a payload. Multiple heads are advantageous under two conditions:

- When overall travel length (for either axis) creates long travel distances where the head carries no payload. Multiple heads "break up" operating zones, and each head performs efficiently.
- When a particular processing step requires time that is disproportionate to the rest of "a balanced tankline." This can occur where a slow-pull operation requires a head

to extract a payload at a fraction of its speed rating or where a "serial segment" bottlenecks the system.

While there should be no limit to the number of heads along a tankline, first consider increasing speeds within safe operating tolerances. An additional head will not significantly improve throughput where the limitation is the automation cycle time for reloading the same station.

Process Control/Abilities

Automation in its simplest forms (serial processing) allows for the simplest control, continuously progressing payloads through a series of positions while turning on and off switches for sonics, air knives, etc.

Automation with a moderate level of sophistication (parallel processing with some speed control) approaches the advantages of an experienced operator making adjustments in speeds.

Even more powerful automation (full speed control and automatic prioritization) can do much more than should be attempted with human labor: for example, simultaneous processing of divergent recipes, slow-pull drying or coating operations, and multi-axis manipulation of complex parts or process steps.

Integration with Tank Lines

The wide variety in cleaning tank systems corresponds to the broad range of chemical approaches to cleaning precision parts. Each approach calls for a change in automation requirements.

As described in "Components of Automation," pages 20-21, automation systems are composed of three main components: mechanical superstructure, drive system, and control package — all of which must work well with each cleaning equipment approach.

For vapor tanks — chlorofluorocarbon (CFC), hydrochlorofluorocarbon (HCFC), perfluorinated hydrocarbon (PFC), and alcohol-based systems — the mechanical automation superstructure must accommodate the deep sumps resulting from the freeboard over the vapor zones.

Where ceiling heights do not allow clearance approximately equal to the height of the tanks, an "I-beam or cable" mechanical system or motion multiplier may be appropriate. Though they're made to entirely avoid self-shedding, these instruments remain a consideration with cleanroom applications.

Aqueous, semi-aqueous, and water-miscible systems typically require longer cycle times for payload recipes (though not necessarily impacting throughput), more horizontal travel, and increased interaction with discrete tank functions. Both alcohol and semi-aqueous systems require spark suppression; all require tank monitoring and interaction with the automation.

Automation systems traditionally activated only process-dependent I/0 and perhaps conveyors at either end of the tankline. There is no reason, however, to limit the control package. With unlimited potential to expand the automation's I/O capability, anything with a sensor can be integrated: tank heaters and pumps, fill pumps and drains, tanks additives (such as those monitored by pH), etc.

In addition, automation is increasingly needed to interact with its own discrete features such as full-barrel rotation both in and above tanks, specific manipulation of parts such as tubing with multiple bends, or re-orientation of parts for tunnel dryers. All of these interaction forms can be accomplished in the con 01 package software and associated hardware.

Conservation of Resources

As cleaning operations have become more expensive, maximizing utilization of resources and minimizing associated waste treatment expenses take on greater importance. With most vapor degreasrs, the objective is to disturb

Pointers for Automation Planning

The most important consideration in choosing an automation system is anticipating current and future needs. Some designs are modular and can be expanded if the tankline configuration changes. Based on anticipated uses, choose the type of mechanical superstructure, drive system, control package, and operator interface that will best meet facility needs.

Some tips for designing any cleaning system for automation:

✔ Locate the load and unload stations at opposite ends of the tankline when possible. This will reduce the amount of "dead time" in parallel processing. Consider multiple heads, walking beams, or increased operating speeds where long traverses will significantly decrease throughput.

✔ Ensure that baskets and fixtures are rigid so that pick-up points will not become misaligned from operator handling. Closed-loop automation should operate within a range of 0.05" to 0.25" repeatability, far in excess of typical needs.

If the deflections in the mating of fixtures to end-effectors is out of tolerance due to the fixtures becoming bent out of shape, system accuracy becomes irrelevant. Whenever possible, design for a level three- or four-point handling design with tight registration to the end-effector connected to the automation.

A defined plane will improve registration, reduce deflection caused by the payload, and eliminate fixture swing from unevenly loaded baskets. Heavy or unevenly loaded baskets might also warrant nesting the payloads, typically with angled tubing at the bottom of each tank.

✔ Look for ways to improve safety in the operation, both in the automation system itself and with worker encounters. Depending on the environment, these measures may include light curtains, barriers, warning beacons, horns, etc. With tanklines over 10 feet in length, consider a remote pendant.

✔ When designing service to the tankline, consider the impact of vented hoods and plumbing fixtures, to avoid conflicts when servicing the tanks or installing the automation.

the vapor blanket as little as possible.

This is an ideal application for automation in that controlling the speed of penetration and removal of payloads from the vapor blanket, along with sealing the tank system to the maximum degree possible, will minimize losses. Fully enclosed systems are typically automated, though some vacuum batch systems are not designed for automation.

For aqueous and semi-aqueous systems, the objective is not so much keeping the chemistry from escaping the tank system, but minimizing dilution of chemistry as the payload moves from one tank to the next. Automation cycles should be balanced to move payloads as quickly as possible for increased throughput, but still provide adequate time allowances for drain-off above each wet station.

The savings in waste treatment from minimizing dilution may justify slightly reduced throughput. This is also particularly important where a slight increase in drain-off time can save considerable energy and delay at the dryer, which is often the bottleneck in throughput.

Overall Plant Integration

One of the advantages of current cleaning equipment changeovers is that the process is now being incorporated with overall plant operations.

Some facilities are standardized with

specific Programmable Logic Controllers (PLCs). extensions of which can make the cleaning operation seamless. There are, however, numerous advantages to controllers that avoid the ladder logic commonly associated with PLCs.

Even if the facility has a significant PLC investment, a pre-programmed embedded PC controller's flexibility, expandability, and enhanced interface to outside functions and the operator typically outweigh the advantage of PLC standardization. An embedded PC control system can provide the full production tracking and documentation afforded with a facility-wide PLC system.

A common argument for utilizing a PLC is that major modifications can be made in-house. However, pre-programmed embedded PCs are easier to adapt and support, in that they are more flexible to begin with and custom features can be added without affecting other software.

Where there is not a facility-wide investment in a particular PLC, the only argument for not utilizing a PC controller is cost savings, if any, for tanklines where minimal changes in recipes and operation are anticipated.

While today's choice of PLC vs. pre-programmed PC can be philosophical, the future of automation is in operating systems that are supported with high-level PC language.

Safety Provisions

Concern for worker exposure to noxious chemicals is a function of the particular chemicals in use and projected duration of contact for the operator or other employees.

Accordingly, automation may present a clear benefit or not. The main area where automation always benefits production objectives is in physical material handling throughout the cleaning operation.

The physical strain and potential injury associated with the heavier payloads now being placed in cleaning systems can be much more effectively managed via automation. While larger systems may seem the most obvious to automate, the cost of automating even a small system is a fraction of the expense of one serious back injury or the cumulative affect of numerous employees with work restrictions.

If a primary objective of automation is to enhance safely, it is important that the automation system be designed to safely integrate into the facility environment. Safety-minded design should include:

- End-of-Travel sensors which disconnect power to the relevant motor in the event of travel beyond specified limits, with hard-stops.
- E-STOPS at all operator interfaces, wired in series so that additional E-STOP can be brought in from additional remote locations to meet site-specific needs.
- Provisions to stop motion if system travel is temporarily obstructed *and if* the payload's travel is blocked even if the mechanical system is not.
- Proper electrical insulation and grounding.
- Audible and visual cues for changes in equipment status.
- Adequate remote controls if the system is of sufficient length to warrant.

The most important resources within any facility are its employees. Automation has two direct benefits: safety and efficiency. Every facility needs to maximize the contribution of every employee.

Automation, even in its simplest form, c eliminate operator error and ultimate y out-produce the most skilled and motivated operator. Carefully considered automation will derive the most value from tanklines and a significant improvement in facility operations. ❑

About the Author

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