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White Paper

Closed-Loop Nozzle Management

Networked data acquisition reduces process risks in SMT manufacturing

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In SMT manufacturing, placement nozzles have a direct impact on process stability and assembly quality. The smallest deviations or contaminations can lead to faulty placements, scrap, and rising production costs. Even in small factories, thousands of nozzles place millions of components each day, and their cleanliness and integrity determine the quality of each placement step.

Conventional maintenance and cleaning strategies quickly reach their limits in this environment. Interval-based maintenance and sampling don't provide a reliable overview of nozzle health, and data from machines as well as from cleaning and maintenance operations is often collected in isolated silos. As a result, damaged or contaminated nozzles can easily re-enter the process – either on the same or another machine or even on other lines.

Closed-loop nozzle management provides a solution because nozzles are clearly identified, monitored and checked in a data-driven manner throughout their entire life cycle. Processes become more transparent, process quality improves, fault rates decline, and unscheduled downtimes are minimized. Maintenance is carried out as needed, based on actual usage and recorded parameters.

As the only direct physical interface with the component, the nozzle plays a critical role for the quality of the pickup and placement process.

An underestimated factor in SMT manufacturing

In SMT manufacturing, the smallest components often have the greatest impact on process stability and product quality. One crucial factor that is often underestimated: the nozzle is the only element in the entire process that comes into direct physical contact with the component. While cameras, placement heads, feeders and control systems govern and monitor the process, the nozzle – as the direct interface between machine and component – determines the quality of the pickup and placement steps.

Even the slightest deviations or contaminations can lead to faults. Nozzles are deployed thousands of times every day to pick up components and place them onto the circuit boards. Inadequately monitored nozzles affect the line's performance and drive up production costs.

As the only element in direct contact with the component, they are a central process element in which mechanical, physical and process-related factors interact. They are therefore not passive tools but active process resources whose condition has a direct impact on overall equipment effectiveness (OEE), yield, and throughput.

Nozzles must ensure maximum precision for super-small components as well as stable processes for large and heavy components.

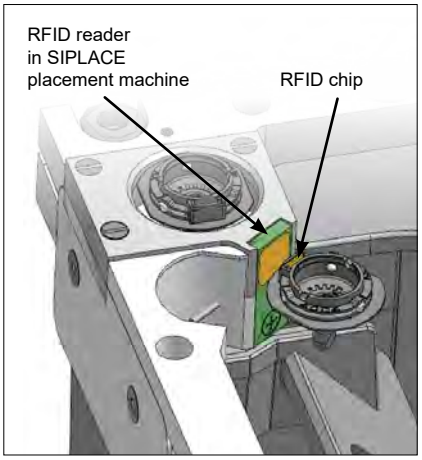
Sophisticated components make nozzles a decisive process factor

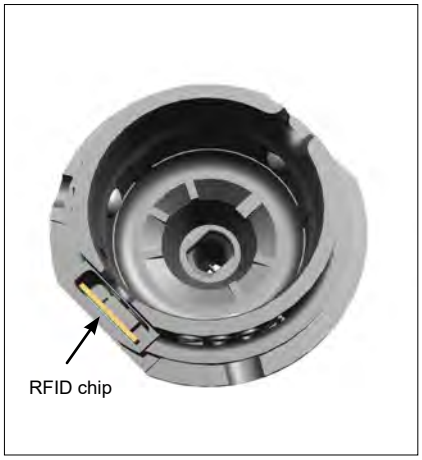
As components become ever smaller, they also become more susceptible to handling risks caused by placement nozzles. Small and super-small components such as 016008M chips require high-precision nozzles where even the slightest contamination or wear can raise the risk of placement faults significantly. At the same time, high-performance and AI components such as ball grid arrays (BGAs) become larger and heavier, placing greater demands on process stability and reliability. Correspondingly, they require robust nozzles that must function reliably.

This increases the bandwidth of requirements. Nozzles must operate with maximum precision for the smallest components while ensuring process stability with large and heavy components. This in turn raises the risk of production interruptions and quality deviations and reinforces the need for continuous monitoring and data analyses throughout the nozzles' entire life cycle.

Accordingly, production managers need a system that monitors nozzles in real time in order to identify risks at an early stage. Sporadic checks are no longer sufficient since dirty or damaged nozzles pose a significant process risk. Even low pickup fault rates can add up to noticeable quality shortfalls in high-volume operations. Each individual nozzle affects a multitude of placement operations, scaling their effects accordingly. In most cases, placement faults caused by impaired nozzles can no longer be fully corrected in subsequent process steps.

For the above reasons, the proactive management of the nozzle life cycle becomes a strategic necessity for a stable and efficient SMT production. Only through clear nozzle identification, continuous condition monitoring and centralized analytics can it be ensured that each nozzle is qualified for production use.





Nozzles are identified via RFID chips in the nozzles and RFID readers in the SIPLACE placement machines.

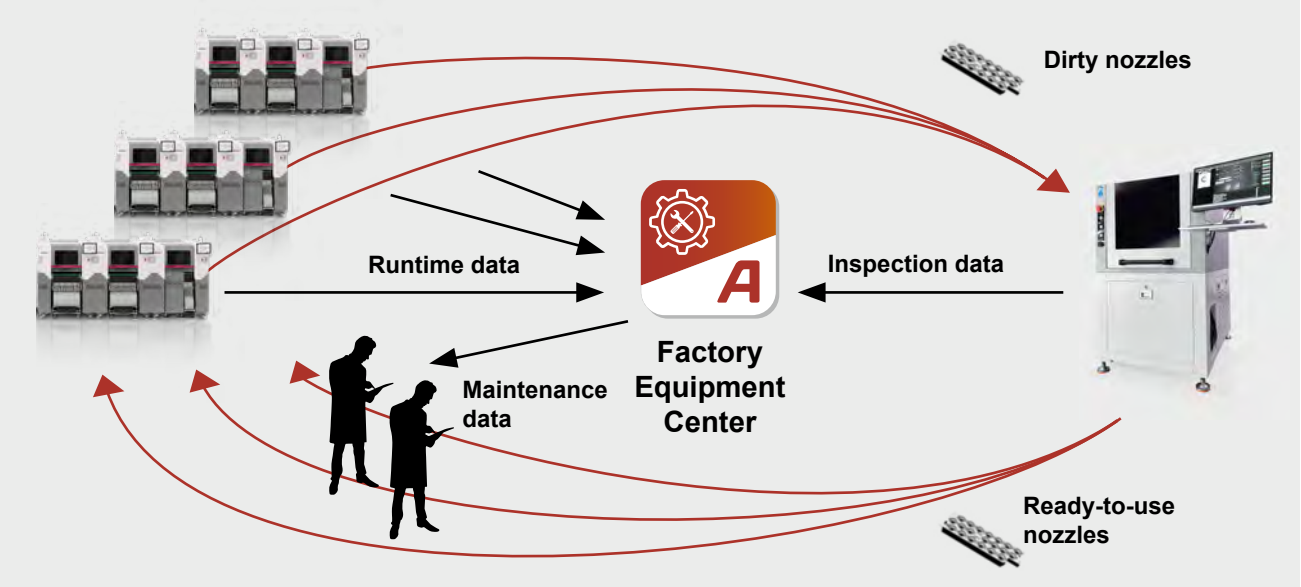
Closed-loop nozzle management – a new approach

A closed control loop reduces process risks, increases the process reliability, and makes data-driven maintenance decisions possible. It integrates all relevant information over the nozzle's entire life cycle: deployment in the machine, data acquisition, cleaning, status checks, and system-wide release or blocking.

The data-driven approach increases the process stability and sustainably reduces fault rates and unscheduled downtimes. The system uniquely identifies each nozzle and continuously monitors its performance. It detects anomalies automatically and can enable or block the nozzle for future operations.

This approach shifts maintenance from reactive to condition-based. Maintenance is performed only when needed, based on actual nozzle use and recorded parameters such as vacuum performance, fault rates, or cleaning cycles.

As a cleaning and inspection device, the automated Smart Nozzle Station is an integral part of a comprehensive closed-loop nozzle management system.



All operating data is transmitted to the central Factory Equipment Center, where it is analyzed.

The five elements of closed-loop nozzle management

Successful closed-loop nozzle management is based on five core elements that systematically minimize risks:

1. **Unique nozzle identification** – Transparently assigns each nozzle to a specific machine and a specific process. Each smart nozzle is assigned a unique ID that is used to track its life cycle from deployments to cleanings to enablings.

2. **Data collection during the entire placement process** – Real-time monitoring reduces the risk of failures and quality deviations. The placement machine logs every pickup fault, every vacuum reading, and all relevant process and quality parameters.

3. **Centralized maintenance management** – Maintenance is data-driven and proactive. Historical data, trend analyses and status information are brought together in a central system.

4. **Integrates cleaning and condition testing** – More process stability thanks to properly tested nozzles. The nozzles get cleaned and checked for damage away from the machine with the results being transmitted to the central system.

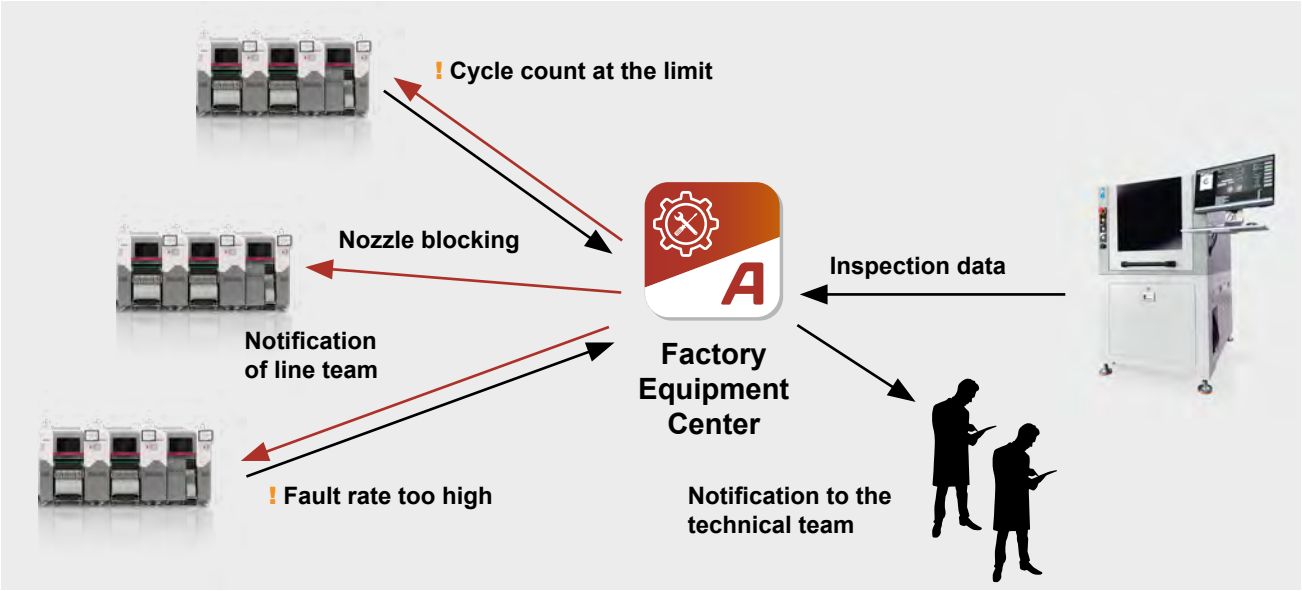
5. **System-wide release and blocking logic** – To minimize risks, defective nozzles are fully blocked from operation. The system determines which nozzles may return to operation and which remain blocked.

Benefits of data-driven nozzle monitoring

The data-driven closed-loop control approach reduces process risks, raises the product quality, and increases the system availability. Continuous status monitoring and centralized analyses ensure that only nozzles meeting the user's quality and performance standards get deployed. Nozzles which exhibit anomalies are automatically blocked or marked for maintenance.

Maintenance and cleaning processes are controlled, downtimes minimized, and operating costs sustainably reduced. Fixed maintenance intervals are replaced by condition-based maintenance. Data on pickup cycles, vacuum readings and cleaning cycles makes it possible to take targeted action.

Management gets transparency on process and system performance in real time. The central maintenance system aggregates all relevant nozzle data, provides statistics on usage, fault rates and cleaning histories, and enables informed decision-making.



Nozzles exhibiting anomalies are automatically blocked or marked for maintenance.

Smart nozzles & Factory Equipment Center

ASMPT offers a system that fully implements the closed-loop control principle – transparently, systematically, and data-driven. Each smart nozzle receives a unique nozzle ID and gets continuously monitored in SIPLACE placement machines. All operating data is transmitted to Factory Equipment Center, where it is analyzed.

This ensures that only qualified nozzles are deployed, process risks are minimized, and stable production flows are safeguarded. With the Smart Nozzle Station, nozzles can be cleaned and inspected away from the placement machine. The results are fed into the central system, nozzles are automatically released or blocked, and their status is continuously monitored.

Operators can see at all times where individual nozzles are located, how many placement processes they have executed, their maintenance status, their faults and fault rates, when their last check was performed, and whether they are currently being blocked.

Companies benefit from a seamless, data-driven control loop that reduces downtime, improves the production quality, and makes processes more transparent. The combination of smart nozzles, SIPLACE placement machines, the Smart Nozzle Station and Factory Equipment Center forms a truly closed life cycle for each nozzle that includes the tracking of each nozzle's usage, cleanings, fault frequency and maintenance requirements.

Conclusion

For the first time, the systematic integration of machine, cleaning and maintenance operations creates a fully data-driven closed-loop control system that significantly reduces the risks of nozzle faults in SMT production. ASMPT provides the technical implementation of this approach – smart nozzles, centralized data acquisition and automated release processes – and makes the closed-loop control system available for every factory.

Take advantage of ASMPT's extensive know-how

Talk with us and set up an appointment in one of our SMT Centers of Competence to develop a custom-tailored solution with our SMT specialists.

ASMPT provides its customers and partners with its decades of expertise in five Centers of Competence worldwide, one of which is located in Munich. All of them are staffed with experienced engineers who have access to full-featured SMT lines. Particularly with regard to print process simulation, this enables requirements to be met quickly and reliably and processes and procedures for new product launches, production and inspection to be optimized.

Together with ASMPT specialists you can evaluate, test and develop applications on site.

The ASMPT SMT Center of Competence also offers individual demos.

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