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Monitoring Aqueous Parts Cleaning

Abstract

In-situ particle monitoring of aqueous cleaning systems can help optimize and control aqueous cleaning processes, thereby increasing product yield and system productivity. Technological advances have allowed manufacturers to miniaturize their products, improving their performance and utility. Key to the miniaturization process is the requirement for clean parts and mechanical assemblies. Contamination on the surfaces of electronic parts and machinery can degrade the performance, production yield and life expectancy of a product. Therefore, many manufacturers have instituted cleaning procedures to ensure their component parts are clean and not likely to adversely effect the completed product. Growing awareness of environmental impact and increasing regulations are greatly curtailing the use of many cleaning solvents, increasing manufacturer's reliance on environmentally friendly water based cleaning processes. Although many different types of contamination are removed through aqueous cleaning processes, particulate contamination is often most critical and is easily monitored with the current technology of particle counters. Continuously monitoring particulate concentration in an aqueous part cleaner, provides a real-time indication of the amount of contamination remaining on a part.

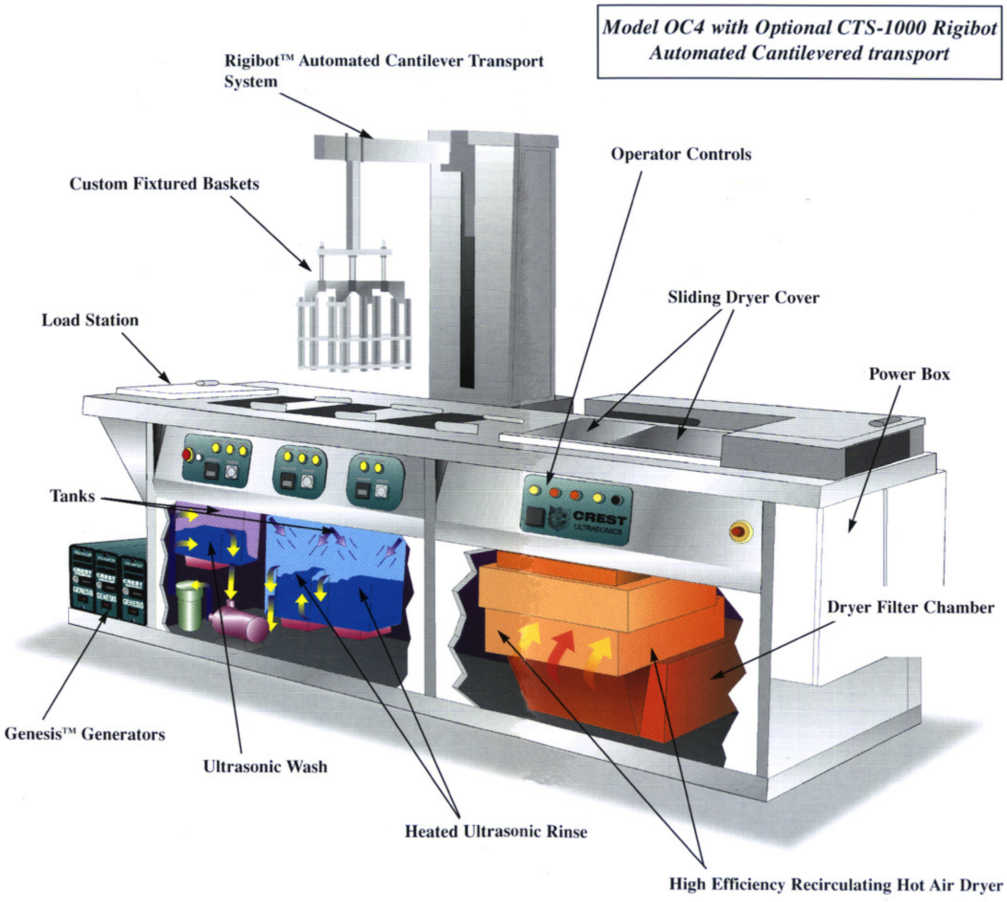

Figure 1: A Typical Aqueous Cleaner

A typical aqueous cleaner

Figure 1 shows a diagram of a typical aqueous cleaner used in the disk drive industry. The disk drive industry is a good test subject because of their extensive use of aqueous cleaning and their reliance on many varied mechanical parts and assemblies used in their products. In this particular cleaner, parts undergo a multi-step cleaning process. Parts are initially placed in a surfactant bath and subjected to ultrasonic waves, which form cavitation bubbles. The formation and collapse of the cavitation bubbles literally scrub the many facetted surfaces of the mechanical parts. After the surfactant bath, the parts are sprayed with clean DI water and placed in progressively cleaner DI rinse baths. The DI rinse baths subject the parts to more ultrasonic waves and a continuous flow of clean DI water. After the last DI rinse bath, the parts are dried and taken to the production line.

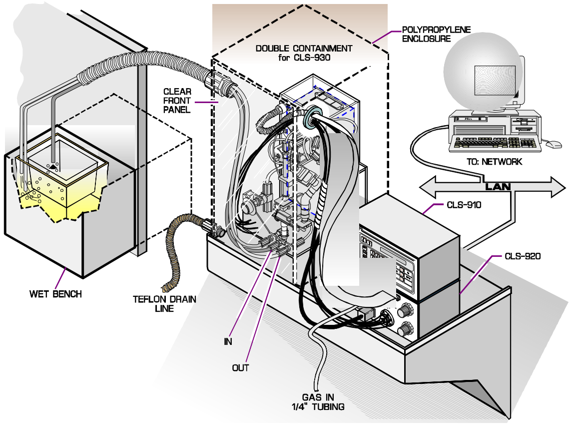

Figure 2: Compression Sampler

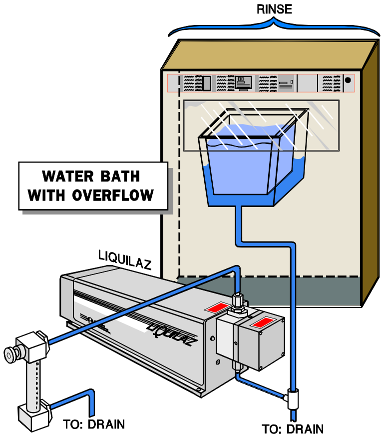

Figure 3: Inline Particle Counter

Installing a particle counter

The critical variable in the cleaning process is whether the parts are clean enough to use in product or not. The most cost effective way to determine out-going part cleanliness is by placing an in-situ particle counter in the final DI rinse bath. This particle counter will quantify the level of contamination remaining on the mechanical parts before they reach the assembly line. Particle counters can be integrated into the parts cleaner in several different ways. The approach illustrated in figure 2 uses a PMS CLS-900 compression sampler. The CLS-900 draws rinse water into the sampler under vacuum. Once proper fluid levels are reached the inlet valve closes and the chemical is pressurized to eliminate bubbles. After a user specified pressurization delay, the chemical flows through the particle counter at a constant pressure and flow rate. Non-recirculating DI rinse systems normally use CLS-900s for its ability to deliver fluid to the particle counter without any pumps or major plumbing modifications. If the rinse bath is recirculated or if the bath provides an isolated overflow return with sufficient head height, a less costly, continuous inline particle counter can be used. Figure 3 shows a LiQuilaz-S02 particle counter mounted in the drain line of a DI rinse bath. A Futurestar flow meter regulates fluid flow through the particle counter to 50 ml/min. Several different particle counters may be used in either system to match particle sizing requirements of the process being monitored.

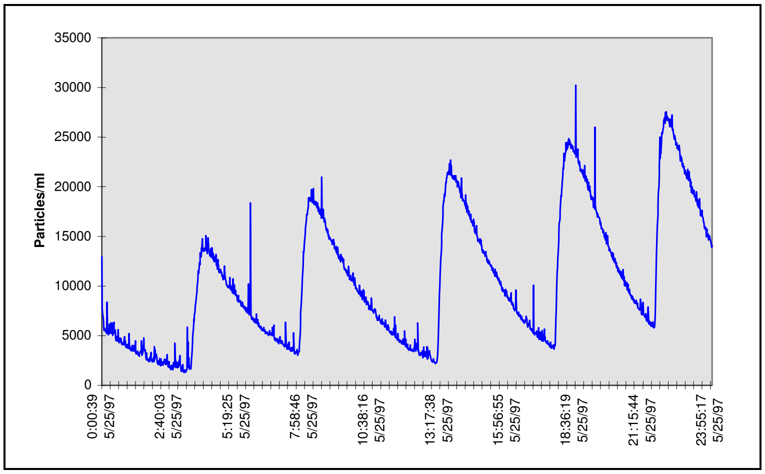

Figure 4: DI Water Filtration Failure

Parts cleaning signature

Figure 4 shows data gathered on a final rinse tank that identified cyclical particle contamination generated whenever new city water entered the DI plant. All aqueous cleaners rely on clean DI water to act as a rinse agent. This clean DI water is normally provided by a consolidated factory DI water filtration system. The aqueous cleaner is almost totally dependent on the cleanliness of the incoming DI water. If for any reason the DI rinse water becomes contaminated, its ability to clean parts is degraded. A DI water system failure can be gradual or as illustrated in figure 4 abrupt. Periodically, raw city water enters the facility's DI water plant to replace water used in cleaning. Normally, incoming city water enters a pre-filtration process before reaching the DI distribution system and production tools. In this system the pre-filtration process is not working normally. The gradual return to baseline observed in figure 4 was accomplished by the DI re-circulation filters.

With a normally functioning DI water system, the particle concentration in the final rinse bath is normally very low and consistent when product is not being run. When product enters the final rinse bath there is a corresponding increase in particle concentration. The magnitude of the particle concentration is a good indication of the particle contamination remaining on the part. Figure 5 shows a typical "at rest" baseline of particles in the rinse bath and the particle signature generated by parts cleaning.

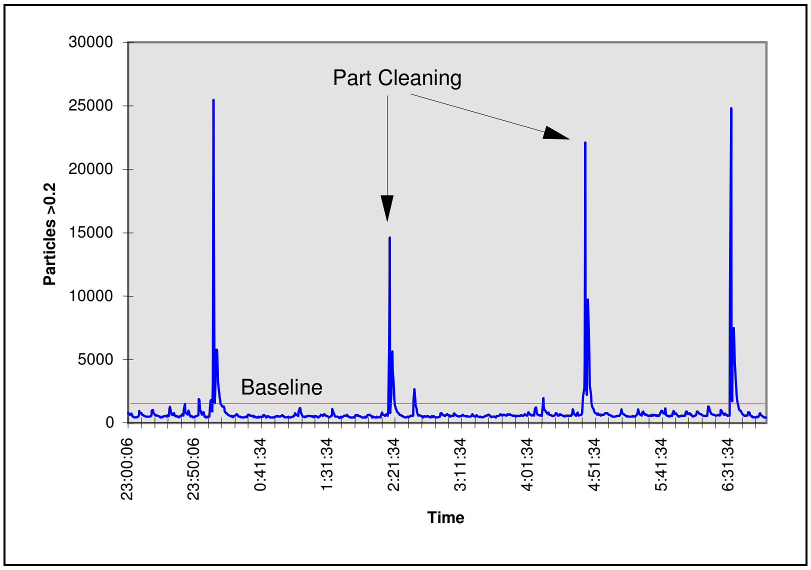

Figure 5: Normal Processing and Return to Baseline Levels

Evaluating the cleaning recipe

Many companies attempt to clean parts as fast as their system can handle them. Often the throughput of a cleaner is determined solely by the speed of the robotic delivery system, or on general guidelines given by the cleaner manufacturer. However, only a few aqueous cleaner manufacturer have the time, equipment and resources to determine optimal cleaning parameters for all the parts a given manufacturer may use. Ultimately, the tool user must determine what processing times, temperatures and settings produce the cleanest parts. Figure 6 shows what happens when parts are processed faster than the rinse bath can recover. Rather than the return to baseline seen in figure 5, the rapid processing produces a stair-step signature with a gradually increasing particle concentration. The stair-step signature should alert the tool user to modify their processing recipe.

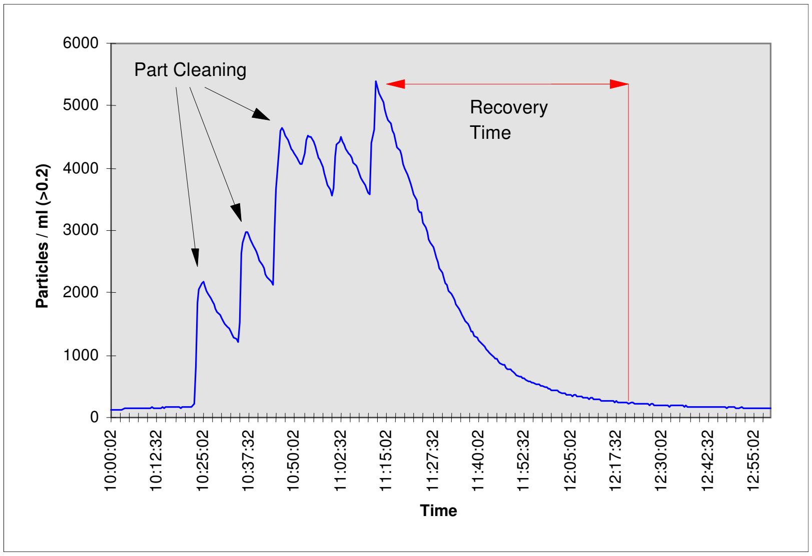

Figure 6: Effects of Cleaning Multiple Part Lots too Rapidly

As illustrated in figure 6, following each part lot processed, there is a consistent bath recovery rate. The time necessary to return the bath to normal baseline levels (recovery time) is a function of the flow rate of fresh DI water entering the bath and the level of contamination initially present. Using the observed recovery rate, an operator can determine the optimal processing frequency for a particular tool or type of part. Once an operator determines appropriate processing frequency, they can use the particle signature to optimize the cleaning process. Adjusting one or more of the following cleaning parameters can help tune the system to its best performance:

- Flow of DI water through rinse baths
- Ultrasonic intensity and duration
- Type and concentration of surfactant
- Temperature of wash and rinse baths
- Duration of wash and Rinse processes

Cleaning System Watchdog

Ideally, a particle monitoring system will provide a go / no-go flag for the system operator, indicating the system is ready to run additional product or whether the last part run is clean enough for production. To accomplish this, the tool user must evaluate the characteristics of their system over some time period. Specifically, enough data must be gathered to develop a clear value for the normal operational baseline and part cleaning signature of the cleaner (figure 5).

A simple way to determine a baseline (lower) control limit, is by calculating the average and standard deviation of the particle concentration excluding periods when parts are being cleaned. An analysis of the data presented in figure 5 results in the following statistics:

Average:	22.86 particles per ml

Standard Deviation: 4.34 particles per ml

To set a control limit at better than 95% confidence add 3 times the standard deviation to the average. Using this value (35.88) as an alarm limit, the particle monitoring system can indicate if the rinse bath is ready to process parts again.

It is often difficult to quantify if a high particle spike during part cleaning will result in a failed product, but it is strait forward to determine if the particle spike is within normal ranges. To determine the upper control limit for part cleanliness the same type of study described in the previous paragraph can be used. In this case, use the maximum particle concentration seen over many parts cleaning runs to determine the average and standard deviation. Over 20 parts cleaning runs (of similar part types and quantities) the following data was calculated:

Average:	2265.1 particles per ml
Standard Deviation:	221.9 particles per ml

To set a control limit at better than 95% confidence that a part is dirtier than normal add 3 times the standard deviation to the average. Using this value (2930.8) as an upper alarm limit, the particle monitoring system can indicate if the part is ready for production or if it requires further cleaning. Figure 7 illustrates when the particle monitoring system would generate a color coded alarm notification. In this case, the sensor status indication is green when the rinse bath is ready for product to run, and red if parts are too dirty.

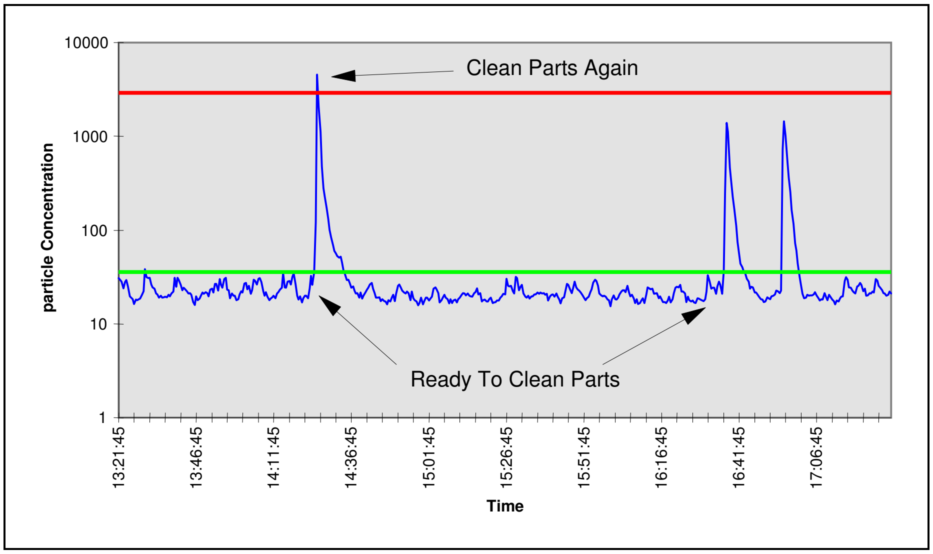

Figure 7: Parts Cleaning with Control Limits in Place

Summary

Continuously measuring particle concentration in an aqueous cleaner can identify problems caused by internal tool or external system failures. Monitoring changes in particle concentration and clean-up rates, allow operators to adjust process parameters, and tune a tool for maximum performance. Once the tool is operating at peak efficiency, the particle monitor provides statistical process control information to ensure the cleanliness of all parts cleaned. Exceedingly dirty parts can be identified and re-cleaned before they reach production, reducing the potential for dirty parts to impact product yields.

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