Automatic Bath Control Systems For Electroless Nickel Plating

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Automatic bath controllers have become necessary to satisfy the strict requirements imposed by many users of the electroless nickel coatings. They allow the bath to be maintained within close limits, providing optimum bath performance and deposit quality. They can also provide the records needed for today's quality control and SPC programs. Bath controllers offer many benefits for electroless nickel plating, even for the smallest plating operation.

This paper describes these benefits, and provides ideas on how control systems can improve the operation of a plating facility. It also describes the functions, installation and operation of controllers, and provides an overview of the different types of systems that are presently available.

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Benefits of Controllers

Automatic controllers provide many benefits for the operation of electroless nickel plating baths. Principal among these are improved bath performance and deposit quality. The plating rate of electroless nickel solutions is dependent upon the bath's concentration, pH and temperature. As they fall, so does the bath's plating rate. The rate is not consistent, but declines as the solution is used and increases when it is replenished. The more a solution is allowed to decline, before an addition is made, the lower will be its average plating rate. Conversely, if the bath's concentration and pH are maintained near their optimum, the average plating rate will also remain high.

With manual additions, a bath's activity may decline by 15 or even 20 percent, or its pH may drop by 0.2 or 0.3 units, before it is replenished, especially with high bath loading. However, with automatic control this cannot occur. The concentration and pH of the solution will be maintained within 1 or 2 percent of optimum. With many baths, this improved control can increase the bath's plating rate by as much as 20 percent. This is illustrated by Figures 1 and 2, which show how solution activity and plating rate are related.

Higher plating rates provide increased production rates, so more billable work is produced. Also, since many of a shop's overhead and labor costs are fixed, profits are increased. Likewise, instead of analyzing solutions or making additions, the operator is available to process more parts, further increasing production.

By making small frequent additions, automatic controllers also avoid shocking the bath with slugs of chemicals. Large additions increase the likelihood of salts precipitating, roughness and bath decomposition. Small additions also help reduce plate out on tank walls and components and further reduce chemical usage.

The quality of an electroless nickel deposit also can be degraded by improper bath operation. Fluctuating or a too high pH

Figure 1
Effect of Replenishment Frequency

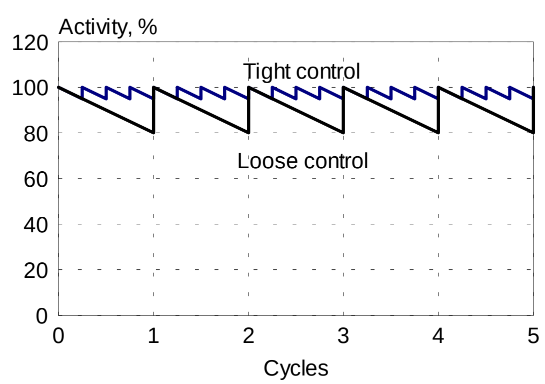
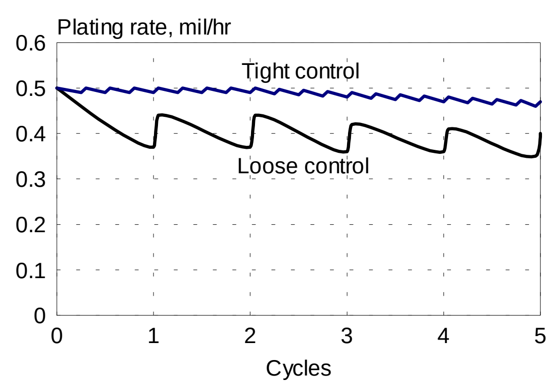


Figure 2
Effect of Replenishment Frequency



or bath activity will cause the deposit's phosphorus content, corrosion resistance, ductility and other functional properties to decline. Delaying replenishments can result in too little brightener or stabilizer in the solution, and in aesthetically unpleasing or rough deposits. An automatic controller provides a more consistent and higher quality product and fewer rejects. Reduced rejects mean less rework and reduced costs. They also result in more time to produce billable work, and in operators that are better used.

More important, improved quality produces more contented customers, who are less likely to seek other vendors. Improved quality reduces costs and increases profits, since repeat customers are less expensive to service and since less effort is needed to obtain sales.

The life of an electroless nickel solution also depends upon how well the bath is maintained. The efficiency of the reduction reaction declines as the bath grows out of balance, and reaction by-products, contaminants, and total acidity increase more rapidly. These conditions also increase the degradation of organic control agents, further reducing bath life, and sometimes resulting in solution decomposition. Automatic control avoids these problems by maintaining the solution at its optimum. It extends the bath's life and reduces the costs of making up new solutions, waste treating spent baths, and cleaning fouled tanks.

Some bath controllers also provide comprehensive records. Besides the solution's concentration and pH, these include bath temperature and age and the amount of chemicals used and remaining, These records can allow the plater to more accurately calculate the real costs of his operation, or even the true cost of a job. This allows better planning for the company, and better quotations for the customer.

With some controllers, these records can be transmitted to a personal computer and analyzed with SPC software. Since many companies require not only by their vendors, but also their vendor's vendors, to establish quality assurance and SPC programs, records permit the plater to compete for work that would not otherwise be available to him. Better records, with SPC, also allow developing problems to be recognized, before they become failures. They can also help convince the customer that his parts are receiving better care and that he is obtaining a higher quality product. Records, not only result in reduced costs, but also in increased business.

Types of Controllers

The use of automatic controllers in plating operations began in the late 1960's, primarily as a curiosity for many platers. These controllers were simple units with only the minimum of control ability. Since then, as electronics and software have improved, so have the intelligence of bath controllers, growing from "dumb" switches to sophisticated microprocessors with data logging and SPC capabilities.

Today, two types of controllers are commercially available for electroless nickel baths. Generically, these two types are called two-position controllers and integral controllers. They differ in the way that they respond to the bath's need for replenishment.

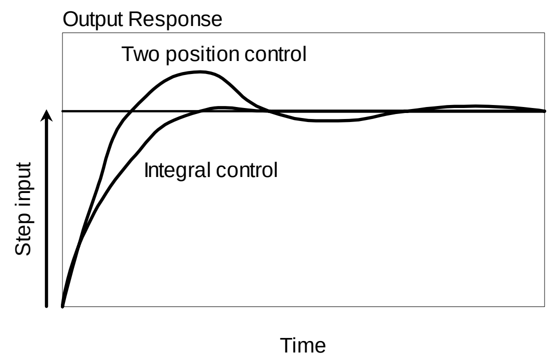
Two-position controllers are simple on-off units. When the bath's concentration or pH falls below the desired minimum level (the set-point), the controller turns on the replenishment or neutralizer pumps until the concentration or pH is increased above the set-point. With integral controllers, additions are made step-wise. When the controller analyzes that an addition is needed, it turns on the pump to add a small fixed amount of chemical. After this addition is complete and the solution has mixed, it analyzes the solution again to see if further additions are needed and repeats the process until the set-point is reached.

The difference between the two types of controllers is illustrated by Figure 3. The response of on-off controllers is undamped, so that there is a delay between when the set-point is exceeded and when the addition pump is stopped. Accordingly, the concentration of the bath typically overshoots the desired level. This action is usually followed by a lag as the concentration falls below the set point leading to the oscillating response shown in Figure 3.

Because integral controllers make step-wise additions, they are less likely to overshoot their set-point. Instead, their response asymptotically approaches the set-point as shown in Figure 3. Also because of their incremental additions, the response of integral controllers is typically slower than on-off units, especially if a large replenishment is required.

A second difference between these two controller types is the secondary functions usually available with integral type controllers. Because more powerful microprocessors and software are required to provide integral control, these controllers usually also have the capacity to provide other information that the operator may need. Typically, these controllers will record all of the concentration and pH readings it has made along with all of the actions it has taken. They can also track chemical usage, bath age, and the remaining supplies of chemicals and have alarms for high and low conditions. Some controllers will also measure and record the bath's operating temperature. Failsafe logic is built into the software of most controllers to prevent over replenishing the bath in case of equipment failure. The data collected by some controllers can also be printed or transmitted to a computer.

Figure 3
Output Response From Different



How Controllers Work

All electroless nickel bath controllers consist of four basic components:

- A sample recirculation and conditioning circuit,
- Sensors for nickel and pH and sometimes temperature,
- A microprocessor to operate the system, and
- Addition pumps for nickel and hypophosphite replenishers and neutralizer.

Figure 4

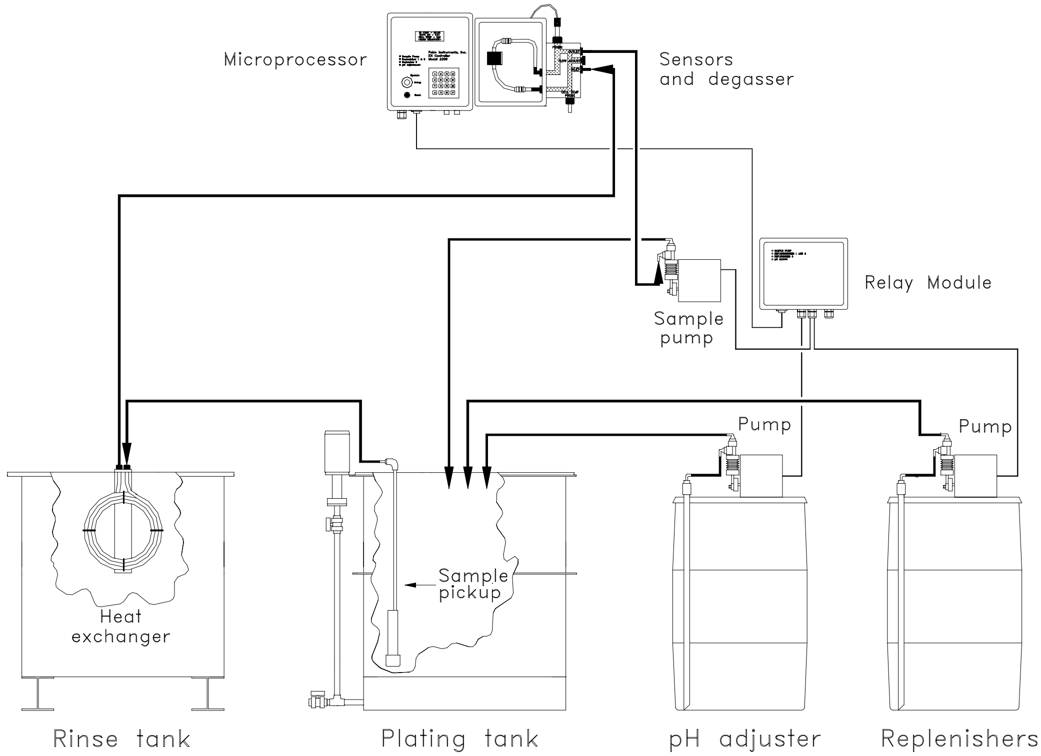


Figure 4 shows the layout of a typical controller with its different components.

The sample conditioning circuit includes a sample pickup tube, a cooler, a degassing device and the sample recirculation pump. Its purpose is to provide a cooled sample to the sensors that is free of hydrogen or air bubbles. The sample cooler can either be a plastic coil in a nearby rinse tank or a heat exchanger with its own source of cooling water. With either, the cooler should be sized to lower the temperature of the sample to 40°C or less to ensure that plating does not occur on the sensors or other components. The sample pickup tube should be designed to allow a minimum of gas bubbles to enter the circuit with the sample. Degassing is usually improved if the sampling pump is used to pull rather than push the sample through the circuit. A degassing device is the final part of the circuit. It separates the remaining gas from the sample before it enters the sensors. Without the degasser, the bubbles passing the colorimeter would cause fluctuating and inaccurate readings. Depending on the system design, the degasser can be as simple as a bypass passage in the sensor block, or as complex as an independent gravity separation vessel.

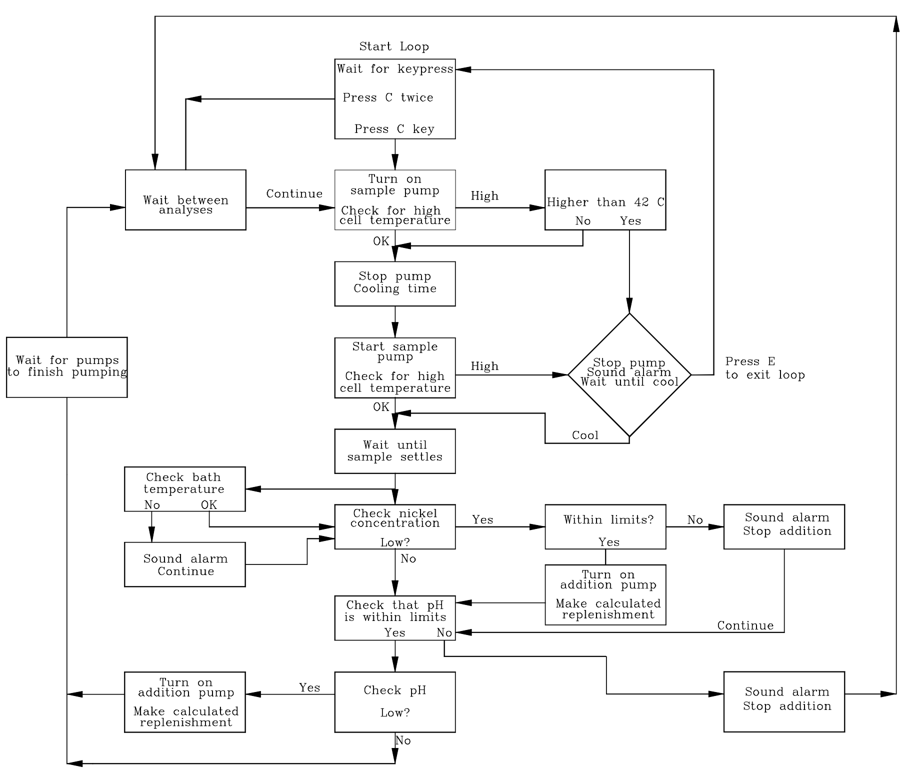
The sensors include a colorimeter to measure the nickel content of the solution, usually a combination electrode to measure the bath's pH, and sometimes a thermistor to monitor the temperature of the bath. In the colorimeter, the bath sample passes between typically a 650-nm light source and a photo-detector and the absorbance of the solution determined. The concentration of the solution is then calculated by comparing the measured absorbance with that of previous calibration standards. The bath's pH is determined by measuring the voltage between a pH-sensitive glass electrode and a reference, usually silver chloride. It is important that the sensor block is designed so that the pH electrode is always submerged and never allowed to dry. The pH electrode must also be calibrated versus standard pH buffers. Some controllers also measure the bath's operating temperature for record keeping purposes.

None of the controllers commercially available analyze the plating bath for sodium hypophosphite. Since modern plating solutions are designed to replenish the hypophosphite content of the bath in proportion to its nickel content, this feature is not needed. Also, no simple instrumental technique is available for hypophosphite. Instead, this component must be measured using a lengthy, auto-titration.

Besides operating the nickel, pH and temperature sensors, the microprocessor receives their measure of the bath's condition and decides what corrective action, if any, is needed. The logic flow chart for one controller's operating system is shown in Figure 5.

With this controller, the controller first pumps the sample from the tank to the

Figure 5
Logic Flow Diagram for an Integral Controller



cooler and stops the sample pump to allow the solution to cool to the proper temperature. Next, the controller pumps the cooled solution to the sensor block and colorimeter. Then, the controller stops the sample pump again to allow the solution to settle and degas.

Next, the controller measures the nickel concentration and pH of the solution and displays the results. If the bath's concentration and pH are low *and* within their accepted limits, the controller will turn on the appropriate pump for the time needed to make an integral addition. Then, after a delay to allow the bath to be completely mixed, it will obtain another sample and repeat the measurement to check that the solution's concentration and pH have returned to their normal level. If they are still low, it will repeat the process until the set point is reached. However, to safeguard against over replenishing the solution, if the bath's condition is higher or lower than its accepted range, the controller will sound an alarm, but take no other action. If an addition is not needed, the controller will wait for several minutes and then begin another sampling cycle.

When the controller begins making an addition, it also updates its internal record of the bath and its history. It increases the amount of replenisher and neutralizer used during the life of the bath and the bath's age, and it reduces the volume of chemicals remaining in the addition storage vessels. Set points, alarm levels, bath volume, concentration and age, and sampling and addition times are all adjustable. The user can change them to account for changes in bath chemistry or volume.

Typically, bellows type metering pumps are used for both the sampling and addition pumps with electroless nickel controllers. These pumps are accurate and reliable and require little maintenance. They are also available with flow rates suitable for most facilities. Other types of metering pumps, including diaphragm and peristaltic designs, have been tried in the past, but with less success.

Controller Installation

Installation of an electroless nickel controller is simple and straight forward. While the models commercially available are different, the way they are installed is similar. This installation is also illustrated by Figure 4.

Normally, the controller's sensors should be within about fifteen feet of the plating bath to reduce sampling time and increase the unit's accuracy. The controller can be at a greater distance from the tank, but its response will be slowed. It should be mounted on a nearby wall or structure, where it will be protected from traffic, steam, harmful vapors and potential damage, and where it can be easily reached for maintenance or calibration.

The sampling, replenisher and neutralizer pumps should also be as close to the plating tanks as possible to reduce hose lengths and the chance of their damage. The replenisher and neutralizer pumps are often mounted directly on top of their chemical supply drums.

The sample pickup tube should be placed in the plating tank at a location where it will not interfere with the work being processed and where there is good agitation. It should also be placed away from the air sparger, where a minimum of bubbles and particulate will be drawn in with the sample. A corner of the tank is usually the best location.

Flexible hoses are normally used to connect the components of the sampling circuit and to deliver the replenishers and neutralizer to the tank. These hoses are reliable and easy to install. Hard plumbing the components with PVC piping or rigid polyethylene tubing is also possible, but is more difficult and costly. Routing the hoses either under floor grating or overhead where they will be protected from kinks and mechanical damage is usually best. The hoses should be well attached to the tank and pumps so that they cannot come loose and spill solutions outside the tank. Adding replenishers and neutralizers either into the filter bag or into the circulation pump overflow hole is often preferred. These locations provide rapid mixing and capture any particles produced.

After the controller has been installed, it is only necessary to set it up for its application. Several steps are required to complete this process. The sample pumping and cooling times are measured, the sensor cell flow adjusted, the replenishment pumps calibrated, the bath's operating parameters added to the program, the set-point and alarm points added, and the pH probe and colorimeter calibrated. The unit is then ready for continued operation.

Daily Operation and Maintenance

Operating an electroless nickel controller requires little attention from the operator, but does not replace him. To ensure the continued accurate measurement of the bath's nickel content and pH, the colorimeter and pH electrode must be standardized periodically. For most applications, the sensors should be standardized at least daily. Usually, standardizing the sensors in the morning, while the bath is still heating and before the controller is set to automatic control mode, is most convenient. Standardization typically only requires about five minutes of the operators time.

As he is doing his other work, the operator should visually check all of the tubing, pickup tubes, pumps, connections, etc. to ensure that they are tight and leak free. He should also listen for out of control alarm conditions and check that the pumps are operating properly.

Finally, at the end of each shift or period of use, the plating solution should be cleaned from the tubing and sensor block. This action will protect the sampling circuit from plugging and prevent damage to the colorimeter and pH electrode. Cleaning is easily accomplished by removing the sample pickup tube from the bath, placing it into a bucket of deionized water, and pumping water through the sample circuit until it returns to the plating tank. Pumping nitric acid passivation solution through the sampling circuit is not advisable. This solution may oxidize and damage plastic components.

Electroless nickel controllers require little maintenance, other than periodic cleaning and calibration. Controller's electronic components are unlikely to fail, but can be broken by rough handling. A few of the controller's components do have a limited life and will require periodic replacement. These components are the colorimeter lamp, pH probe, and valves for the bellows pumps. The colorimeter lamp, like any other electric light, becomes dimmer over time and will eventually burn out. It should be replaced yearly. A pH electrode also loses sensitivity with time as the glass and reference junction become coated with salts and organic compounds. To reduce errors and to ensure accurate control, the pH electrode should be reconditioned, or the electrode replaced, every six months.

The check valves in both the sampling and addition pumps are made of rubber, which will lose some of its elastic properties over time. They also can become gummed with organic compounds. These changes can lead to bypassing and loss of pumping capacity. To guard against changes in flow rate and replenishment, the valves in all of the pumps should be replaced yearly. Other than these few items, little maintenance should be needed for an automatic electroless nickel controller.

Conclusion

Automatic bath controllers allow an electroless nickel bath to be maintained within close limits, providing optimum bath performance and deposit quality. They can also provide the records needed for today's quality control and SPC programs. Bath controllers offer many benefits for electroless nickel plating, for both large and small plating shops.