Leaks of any magnitude should not be tolerated. They cost valuable process time and impair quality. If records of performance have been kept and the checks made of the system, it is likely that part of the problem is in-leakage.

The leak detection method varies with the size of the leak. If the leak is large enough to prevent pumping below 1 torr, it should be audible. Close RV and shut off the roughing pump if the noise level is too high to hear the leak. If the leak allows pumping below 1 torr but not below 100 microns, cigarette smoke being pulled into the leak may locate it. Below 100 microns there are several choices.

At or below 100 microns the thermocouple gauges can be used. By spraying the suspect areas with acetone or Freon, one may detect a leak by watching for TC needle fluctuations. This method is not very sensitive and results are unpredictable. Halogen leak detectors are more sensitive but can only be used at atmospheric pressure. It would be necessary to put Freon in the system at a slight positive pressure to use this to sniff the points of possible leakage. Care must be taken to control the pressure to low positive levels, as some devices on the system may be designed for vacuum use only.

The most sensitive and versatile device for finding leaks is the mass spectrometer leak detector. This device is basically an ionization gauge tuned to read the partial pressure of helium. The conventional leak detector has a liquid nitrogen trap, diffusion pump, valves and mechanical pumps to maintain high vacuum at the sensing tube. The Varian PortaTest is simpler to apply as it has no liquid nitrogen trap and can be used without throttling if the pressure in the system is below 200 microns. It uses the mechanical pump of the system to maintain the necessary foreline pressure. Only 115 volt power and a supply of helium are needed to leak test the system.

By applying helium to the part, the point of leakage is found and can be sealed temporarily, using electrician’s putty or silicone putty until a permanent repair can be made. Do not use varnishes or glyptal, as they ultimately dry and crack and make further leak testing or repairs more difficult.

In leak testing a system, first isolate the various sections of the manifold to locate the portion of the system that has the leak, as noted above. Connect the leak detector to the system at AR-2 and proceed with the helium check. Probe the sections with helium in the order of probability of leakage:

1. All sliding seals, such as valve shaft seals
2. Rotating seals, such as fixture drive seals
3. Compression seals and threaded joints on vacuum gauges, plugs, etc.
4. Bellows shaft seals on valves
5. Flexible connectors in piping
6. Gasket and O-ring seals on valve discs, chamber doors, removable flanges.
7. Static gasket seals on sight ports, feedthroughs, manifolds.
8. Welds and braze joints.

The leak detector can also be used with a probe to find leaks if the part can be pressurized. The part is filled with helium and, using the probe which is itself a carefully calibrated leak, the part can be checked with the probe and the point of leakage determined.

The above suggestions represent a method of checking a system that is in use and has been performing satisfactorily. The rate of rise indicated by TC1 was not noted, as it varies substantially with the volume of the system, the type of product, the room humidity, etc. A normal rate of rise, if recorded, should be qualified for temperature, relative humidity, type of product, and with and without fixtures. The rate of rise is significant only when compared to a well qualified norm.

With a good set of records and a few checks one can establish an orderly program to restore the vacuum system to normal operation, and may even establish new normal reduced cycle times or improved product.

ELECTROLESS (Autocatalytic, Chemical) PLATING

by Jim Henry

Wear-Cote Int'l., Rock Island, IL

Electroless plating refers to the autocatalytic or chemical reduction of aqueous metal ions plated to a base substrate. The process differs from immersion plating in that deposition of the metal is autocatalytic or continuous.

The Electroless Bath:

Components of the electroless bath include an aqueous solution of metal ions, catalyst, reducing agent(s), complexing agent(s), and bath stabilizer(s) operating in a specific metal ion concentration, temperature and pH range.

Unlike conventional electroplating, no electrical current is required for deposition. The electroless bath provides a deposit which follows all contours of the substrate exactly, without building up at the edges and corners. A sharp edge receives the same thickness of deposit as a blind hole.

The base substrate being plated must be catalytic in nature. A properly prepared workpiece provides a catalyzed surface and, once introduced into the electroless solution, a uniform deposition begins. Minute amounts of the electroless metal (i.e., Ni, Cu) itself will catalyze the reaction, so the deposition is autocatalytic after the original surfaces are coated. Electroless deposition then continues, providing that the metal ion and reducing agent are replenished. If air or evolved gas, however, are trapped in a blind hole or downward facing cavity, this will prevent electroless deposition in those areas.

In electroless plating, metal ions are reduced to metal by the action of chemical reducing agents, which are simply electron donors. The metal ions are electron acceptors which react with electron donors. The catalyst is the substance (workpiece or metallic surface) which accelerates the electroless chemical reaction, allowing oxidation of the reducing agent.

The metal ion and reducer concentration must be monitored and controlled closely in order to maintain proper ratios and to maintain the overall chemical balance of the plating bath. The electroless plating deposition rate is controlled by temperature, pH and metal ion/reducer concentration. Each of the particular plating reactions has optimum ranges at which the bath should be operated (Table I). Complexing agent(s) act as a buffer to help control pH and maintain control over the “free” metal salt ions available to the solution, thus allowing solution stability. The stabilizer(s) act as catalytic inhibitors, retarding potential spontaneous decomposition of the electroless bath. Few stabilizers are used in excess of 10 PPM, because an electroless bath has a maximum tolerance to a given stabilizer. Excessive use of stabilization material(s) can result in depletion of plating rate, bath life and poor metallurgical deposit properties.

Trace impurities and organic contamination (i.e., degreasing solvents, oil residues, mold releases) in the plating bath will affect deposit properties and appearance. Foreign inorganic ions (i.e., heavy metals) can have an equal effect. Improper balance and control will cause deposit roughness, porosity, changes in final color, foreign inclusions and poor adhesion.
<table>
<thead>
<tr>
<th>Electroless Method</th>
<th>Temperature</th>
<th>pH</th>
<th>Deposition Rate/hr</th>
<th>Metal Salt(s)</th>
<th>Reducing Agent(s)</th>
<th>Compensating Agent(s)</th>
<th>Stabilizer(s)</th>
<th>pH Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Nickel</td>
<td>77°-93°C (170°-200°F)</td>
<td>4.4-5.2</td>
<td>12.7-25.4μm (0.5-1 mil)</td>
<td>Nickel sulfate, Nickel chloride</td>
<td>Sodium borohydride, Sodium hypophosphite, Dimethylamine borane (DMAB), Hydrazine</td>
<td>Citric acid, Sodium citrate, Succinic acid, Propionic acid, Glycolic acid, Sodium acetate</td>
<td>Fluoride compounds, Heavy metal salts, Thiourea, Thioorganic compounds (e.g., Mercaptoethanol, MBT), Oxy anions (e.g., iodate)</td>
<td>Ammonium hydroxide, Sulfuric acid</td>
</tr>
<tr>
<td>Alkaline Nickel</td>
<td>26°-55°C (79°-131°F)</td>
<td>8.5-14.0</td>
<td>10-12.7μm (0.4-0.5 mil)</td>
<td>Nickel sulfate, Nickel chloride</td>
<td>Sodium borohydride, Sodium hypophosphite, DMAB, Hydrazine, Diethylamine borane (DEAB)</td>
<td>Citric acid, Sodium citrate, Sodium acid, Lactic acid, Glycolic acid, Sodium acetate, Sodium pyrophosphate</td>
<td>Thiourea, Heavy metal salts, Thioorganic compounds, Triethanolamine, Thallium salts, Selenium salts</td>
<td>Ammonium hydroxide, Sulfuric acid, Caustic soda, Sodium hydroxide</td>
</tr>
<tr>
<td>Copper</td>
<td>26°-70°C (79°-158°F)</td>
<td>9.0-13.0</td>
<td>1-7.5μm (0.04-0.3 mil)</td>
<td>Copper sulfate, Copper acetate, Copper carbonate, Copper formate, Copper nitrate</td>
<td>Formiate, Formaldehyde, DMAB, Sodium hypophosphite, Hydrazine sulfate</td>
<td>Rochelle salt, EDTA, Ammonium hydroxide, Pyridine-2-sulfonic acid, Potassium ioximate</td>
<td>Thiodiglycolic acid, MBT, Thiourea, Sodium cyanide, Vanadium oxide, Potassium hydroxide</td>
<td>Hydrochloric acid, Sulfuric acid, Sodium hydroxide, Potassium hydroxide</td>
</tr>
</tbody>
</table>

(Continued on next page)
<table>
<thead>
<tr>
<th>Electroless Method</th>
<th>Temperature</th>
<th>pH</th>
<th>Deposition Rate/hr</th>
<th>Metal Salt(s)</th>
<th>Reducing Agent(s)</th>
<th>Complexing Agent(s)</th>
<th>Stabilizers</th>
<th>pH Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>65°F-88°F</td>
<td>10.0-13.0</td>
<td>2-5µm (0.08-0.2 mil)</td>
<td>Gold cyanide Gold chloride Potassium aurate</td>
<td>DMAB Sodium hypophosphate Potassium boroxydride Potassium cyanoboroxydride</td>
<td>Sodium phosphate Potassium citrate Sodium borate Potassium tetraborate EDTA</td>
<td>Alkali metal cyanide Alkali hydrogen fluoride Acetylacetone</td>
<td>Potassium hydroxide Phosphoric acid Sulfuric acid</td>
</tr>
<tr>
<td>Palladium</td>
<td>65°C-73°C</td>
<td>8.0-12.0</td>
<td>2-5µm (0.08-0.2 mil)</td>
<td>Palladium chloride Palladium bromide</td>
<td>Sodium hypophosphate Hydrazine DMAB Triethylamine borane</td>
<td>Ammonia Methylamine EDTA</td>
<td>Thiocyanate Thiourea</td>
<td>Ammonium hydroxide Hydrochloric acid</td>
</tr>
<tr>
<td>Cobalt</td>
<td>85°F-99°F</td>
<td>9.0-11.0</td>
<td>2.5-14µm (0.1-0.4 mil)</td>
<td>Cobalt chloride Cobalt sulfate</td>
<td>DMAB Sodium hypophosphate</td>
<td>Sodium citrate Citric acid Ammonium chloride Succinic acid</td>
<td>Urea Thiocyanate Ammonium hydroxide Sodium hydroxide</td>
<td></td>
</tr>
</tbody>
</table>
Electroless Nickel:

Electroless nickel baths may consist of four types:
1. Alkaline, nickel-phosphorus.
2. Acid, nickel-phosphorus.
3. Alkaline, nickel-boron.
4. Acid, nickel-boron.

The chemical reducing agent most commonly used is sodium hypophosphite, others include sodium borohydride, n-dimethylamine borane (DMAB), n-diethylamine borane (DEAB) and hydrazine.

Alkaline nickel-phosphorus deposits are generally reduced by sodium hypophosphate. These alkaline baths are formulated mostly at low temperatures for plating on plastics. Deposits provide good solderability for the electronics industry, and energy operating costs are reduced due to some solution's low operating temperatures, however, less corrosion protection, adhesion to steel and difficulty in processing aluminum due to high pH values are drawbacks.

A low temperature bath can produce hard as-deposited values of 700 VHN at 2% phosphorus. The phosphorus content can be varied by changing the operating temperature of the bath. One such bath consists of the following components:

- Nickel sulfate .......................... 30 g/L
- Sodium hypophosphate .................. 30 \(^\circ\)
- Sodium pyrophosphate .................. 60 \(^\circ\)
- Triethanolamine .......................... 100 ml/L
- pH ........................................ 10.0
- Temperature ................................ 30 to 35 °C (86 to 95 °F)

An example of a high-temperature, alkaline, electroless nickel-phosphorus bath is:

- Nickel sulfate .......................... 33 g/L
- Sodium citrate ............................ 84 \(^\circ\)
- Ammonium chloride ...................... 50 \(^\circ\)
- Sodium hypophosphate .................. 17 \(^\circ\)
- pH ........................................ 9.5
- Temperature .............................. 85 °C (185 °F)

Acid nickel-phosphorus deposits normally consist of 88 to 94% nickel and 6 to 12% phosphorus operating at 77 to 93 °C (171 to 200 °F) with a pH of 4.4-5.2. The re-

**"Handbook of Printed Circuit Manufacturing"**

by: R. H. Clark .......................... $57.95

This book is a primary, comprehensive reference for those engaged in the manufacture and sale of printed circuits. Each major operation such as screen printing, pattern plating, etc., is covered by its own chapter. Basic definitions are supplied, enabling it to serve for the training of personnel. Include postage and handling: $3.50 US, Canada & Mexico; $6.00 foreign (in NJ add 6% Sales Tax) Price subject to change. Payment in US funds.

**METAL FINISHING** Three University Plaza, Hackensack, NJ 07601 201 / 487-3700

**When it comes to purity . . .**

**You Take Control!**

**NICKEL SULFATE**

**NICKEL CHLORIDE**

**NICKEL CARBONATE**

**NICKEL SULFAMATE**

Americhem's comprehensive lot control system ensures consistency of raw materials. Purity is confirmed by computerized statement and chemical analysis with each order shipped. Americhem's Accelerated Customer Service program underscores our commitment to serving your needs promptly and efficiently.

**Americhem's Complete Line of Higher Purity Salts . . .**

- Nickel
- Sulfates
- Copper
- Chlorides
- Tin
- Carbonates
- Chromium
- Oxides
- Cadmium
- Specialties

Call 215-335-0990 for more information.
Reducing agent is commonly sodium hypophosphate. The pH of the solution is the controlling factor affecting the phosphorus content of the deposit. In general, the higher the pH, the lower the phosphorus content, resulting in deposit property changes. Lower phosphorus containing deposits (i.e., 6%) typically have less corrosion resistance than 9% alloys. Also, deposits containing phosphorus in excess of 8.0% are typically non-magnetic. When the pH drops below 4.0, subsequent nickel deposition virtually stops.

As-deposited nickel-phosphorus hardness is 500 to 600 VHN, while maximum values of 950 VHN or slightly more may be realized by post-heat-treatment of the coating at a temperature of 400°C (752°F) for one hour. The temperature is a dominant factor in determining the final deposit hardness. Careful consideration should be given to the choice of temperature so as not to affect structural changes of the base substrate. Additionally, low temperatures are used (116°C/240°F) to relieve any hydrogen embrittlement that may be produced from pretreatment cycles or subsequent electroless nickel deposition.

Post-baking of the deposit produces marked structural changes in hardness, wear and abrasion resistance. Depending upon the temperature, bath composition and phosphorus content, this post-treatment cycle will totally change the initial microcrystalline structure, resulting in nickel phosphides to be precipitated creating a very hard matrix. Complete precipitation of nickel phosphides does not occur at temperatures significantly below 400°C (752°F). In general, deposits with 9.0% phosphorus and above tend to produce lower as-deposited hardness values but give slightly higher hardness when post-heat-treated. The coating will discolor above 250°C (482°F) in an air atmosphere. Prevention of coating discoloration can be accomplished in a vacuum, inert or reducing atmosphere oven. Physical properties affected by the post-heat-treatment include increas-
ing magnetism, adhesion, tensile strength and electrical conductivity while decreasing ductility, electrical resistivity and corrosion resistance.

Thickness of the nickel-phosphorus deposit generally ranges from 2.5 to 250 µm (0.1 to 10.0 mils). Deposits less than 2.5 µm and greater than 625 µm are currently and successfully being preformed. Thickness measurements can be carried out with magnetic devices, micrometers, coulometry, beta backscatter and X-ray fluorescence.

The following is an example of an acid hypophosphate reduced bath:

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel sulfate</td>
<td>28 g/L</td>
</tr>
<tr>
<td>Sodium acetate</td>
<td>17</td>
</tr>
<tr>
<td>Sodium hypophosphate</td>
<td>34</td>
</tr>
<tr>
<td>Lead acetate</td>
<td>0.0015</td>
</tr>
<tr>
<td>pH</td>
<td>4.6</td>
</tr>
<tr>
<td>Temperature</td>
<td>82 to 88°C (180 to 190°F)</td>
</tr>
</tbody>
</table>

Alkaline nickel-boron solutions utilize the powerful reducing agent, sodium borohydride, to produce a deposit containing 5 to 6% boron and 94 to 95% nickel by weight. These highly alkaline solutions operate at a pH of 12.0 to 14.0 and temperatures of 90 to 95°C (195 to 205°F). These baths tend to be less stable because of their high alkalinity, and bath decomposition may occur if the pH falls below 12.0. As-deposited hardness values of 650 to 750 VHN are typical. After post-heat treatment at 400°C (752°F) for one hour, values of 1200 VHN can be produced. The melting point of borohydride reduced deposits is 1080°C (1975°F).

The following is an example of a sodium borohydride reduced electroless nickel bath:

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel chloride</td>
<td>31 g/L</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>42</td>
</tr>
<tr>
<td>Ethylenediamine, 98%</td>
<td>52</td>
</tr>
<tr>
<td>Sodium borohydride</td>
<td>1.2</td>
</tr>
<tr>
<td>Thallium nitrate</td>
<td>0.022</td>
</tr>
<tr>
<td>pH</td>
<td>14.0</td>
</tr>
<tr>
<td>Temperature</td>
<td>95 to 95°C (200 to 205°F)</td>
</tr>
</tbody>
</table>

Acid nickel-boron varies from 0.1 to 4% boron by weight depending on the bath formulation. The boron content of electroless nickel is reduced by either n-dimethylamine borane (DMAB) or n-diethylamine borane (DEAB). Bath parameters include a pH of 4.8 to 7.5 with an operating temperature range of 65 to 77°C (149 to 171°F). DMAB or DEAB reduced deposits have a very high melting temperature of 1350°C (2460°F). Baths containing less than 1% boron have excellent solderability and good ultrasonic (wire) bonding characteristics. A typical DMAB reduced bath contains:

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel sulfate</td>
<td>25 g/L</td>
</tr>
<tr>
<td>Sodium acetate</td>
<td>15</td>
</tr>
<tr>
<td>DMAB</td>
<td>4</td>
</tr>
<tr>
<td>Lead acetate</td>
<td>0.002</td>
</tr>
<tr>
<td>pH</td>
<td>5.9</td>
</tr>
<tr>
<td>Temperature</td>
<td>26°C (78°F)</td>
</tr>
</tbody>
</table>

470 Frelinghuysen Ave., Newark, N.J. 07114
201-242-4110
Electroless Copper:

Electroless copper deposits are generally applied before electroplating on plastics and other non-conductors providing a conductive base for subsequent plating. These include ABS, polystyrene, modified polyphenylene oxide, PVC, Noryl, polyethylene, polysulfone, structural foam, epoxy and ceramics. In such applications, usually a thin deposit (0.127 µm; 0.05 mil) is applied followed by an additional decorative or protective thickness of copper, nickel or gold deposited electrolytically or electrolessly. The electroless copper in such applications provides good life in corrosive atmospheric and/or environmental exposures.

Automotive, appliance, hardware parts, circuit boards, through-hole plating, EMI/RFI shielding of electronic devices and ceramics represent major markets for electroless copper. In through-hole plating of circuit boards, the use of electroless copper has eliminated the need for an electrodeposited flash and provides good electrical conductivity in these hard-to-reach areas.

In the pretreatment of circuit boards, the most common method involves an acidic aqueous solution of stannous chloride (SnCl₂) and palladium chloride (PdCl₂) immersion for subsequent deposition of the electroless copper. Many proprietary activators are available in which these solutions can be used separately or together at room temperature. Palladium drag-in to the electroless copper bath can cause solution decomposition instantly.

The pH of an electroless copper bath will greatly influence the brightness of the copper deposit. Usually a value above 12.0 is preferred. A dark deposit may indicate low bath alkalinity and contain cuprous oxide. The plating rate is equally influenced by pH. In formaldehyde-reduced baths an optimum value of 12.0 to 13.0 is generally best.

Electroless Gold:

There is a growing need in the electronic industry for selective plating to conserve plating costs and to allow the electronics engineer freedom for circuit design improve.

**"Thickness Testing of Electroplated & Related Coatings" (2 Vols.)**

ed. by: S. W. Baier ................................ $32.50

This is a lucid, intelligently organized and edited exposition of the principal methods of measuring the thickness of electrodeposited, electroless, hot dipped, conversion, vitreous enamel and anodic coatings. It is a practical, workmanlike treatment of the subject, and well worth the price.

Include postage and handling $3.50 US, Canada & Mexico; $6.00 foreign
(in NJ add 6% Sales Tax) Price subject to change.
Payment in US funds.

**METAL FINISHING**

Three University Plaza, Hackensack, NJ 07601 201 / 487-3700

---

Stability of the bath and pH are critical. A high pH value (14.0) results in poor solution stability and reduces the bath life. Below about 9.5, solution stability is good, however, deposition slows or ceases.

The best known reducing agent for electroless copper baths is formaldehyde. The complexing agent serves to complex the copper ion to prevent solution precipitation and has an effect on deposition rates plus quality of the deposit. These conventional baths are stable, have plating rates of 1 to 5 µm or 0.04 to 0.2 ml/hr, and operate in an alkaline solution (pH 10.0 to 13.0).

An example of a formaldehyde reduced electroless copper bath is:

- Copper sulfate .................................. 15 g/L
- Rochelle salt .................................. 40 g/L
- Formaldehyde (37%) .......................... 6 ml/L
- Vanadium oxide ................................. .001 g/L
- pH .............................................. 12.0
- Temperature .................................. 70-75°C (158-167°F)

Recent proprietary formulations allow for sodium hypophosphite reduced baths. These high speed (>10 µm/hr; >0.4 ml/hr) or heavy deposition baths generally operate at a lower pH without the use of formaldehyde. High speed baths generally are more expensive and exhibit less stability but have non-harmful formaldehyde vapors given off during subsequent solution make up, heating and deposition. These baths can deposit sufficient low stress copper eliminating the need of an electrolytic flash.

**Electroless Palladium**

- Pallamers Porefree barrier layer

**Electroless Nickel**

- Nickelmerse

---

**ELECTROLESS**

**GOLDS**

- Electroless Gold HR  
- Electroless Gold EH  
- Electroless Gold K

**IMMERSION GOLDS**

- Oromerse  
- Oromerse HR  
- Oromerse N

**ELECTROLESS PALLADIUM**

- PALLAMERSE ... Porefree barrier layer

**ELECTROLESS TIN**

- Stanomerse ... Immersion on printed circuit

**ELECTROLESS NICKELS**

- Nicklmerse

---

**Take the unknowns out of your electroless processes with automatic control and SPC.**

**Palm Commodities**

Your source for the only smart process controllers.

Also nickel chemicals, sodium hypophosphite, cleaners and equipment.

P.O. Box 17264  
Nashville, TN 37217  
615-333-2700  
FAX: 615-333-3232
ment. Many electronic components today are difficult to gold plate by electrolytic means. Thus, electroless gold is one such selective plating currently being used in the fabrication of semiconductor devices, connector tabs, chips and other metalized ceramics. Many commercially available electroless gold baths are produced by immersion plating techniques, however, there are a few true autocatalytic gold processes available with 99.99% purity.

Electroless gold can successfully be applied to Kovar, nickel, nickel alloys, electroless nickel, copper, copper alloys, electroless copper and metalized ceramics. Electroless gold can be deposited onto already present thin electrodeposited gold to give added strength.

The following is an example of an electroless gold bath:

- Gold chloride hydrochloride trihydrate: 0.01 moles/L
- Sodium potassium tartrate: 0.014 "
- Dimethyamine borane: 0.013 "
- Sodium cyanide: 400.0 mg/L
- pH (adjusted with NaOH): 13.0
- Temperature: 60°C (140°F)

Electroless Palladium:

Palladium deposits are ductile and ideal for contacts undergoing flexing (i.e., printed circuit board end-connectors and electronic switch contacts). Palladium has also been used as a less expensive replacement for gold providing tarnish resistance and solderability.

Using specific bath components, the deposit can be hard and bond to electroless nickel with a bond strength greater than the tensile strength of the palladium plate itself. The electroless nickel preplate can be either from a pyrophosphate or boron reduced bath.

The following is an example of an electroless palladium (hypophosphite reduced) bath:

- Palladium chloride: 10 g/L
- Rochelle salt: 19 "
- Ethylenediamine: 25.6 "
- Cool solution to 20°C (68°F) and then add sodium hypophosphite: 4.1 "
- pH (adjusted with HCl): 8.5
- Temperature: 68-73°C (155-165°F)

Electroless Cobalt:

Thin electroless cobalt deposits have had limited use in the electronics industry on magnetic memory discs and storage devices primarily for their magnetic properties.

The following is an example of an electroless cobalt bath:

- Cobalt chloride: 30 g/L
- Sodium hypophosphite: 20 "
- Sodium citrate: 35 "
- Ammonium chloride: 50 "
- pH: 9.5
- Temperature: 95°C (203°F)

Good News for Electroless Nickel Users

ADDPLATE™
WILL CUT YOUR CHEMICAL COSTS UP TO 50%

- Highly stable composition
- Easy to use and maintain
- Capable of ten or more metal turnovers
- Available in different surface finishes
- Reduces shipping costs

Inquiries on all aspects of electroless technology are welcomed.

Surface Technology, Inc.
P.O. Box 8585, Trenton, NJ 08650
609-259-0099

"Recovery and Refining of Precious Metals"
by: C.W. Ammen
$32.95

This book uses a very basic approach to introduce the subject of precious metal refining from primary and secondary sources. Working examples for recovery of clean scrap, silver from sterling silver scrap, and gold from "yellow gold" scrap are given, using step by step procedures. It is a practical guide to recovering, testing, extracting and refining precious metals.

Include postage and handling $3.50 US, Canada & Mexico; $6.00 foreign (in NJ add 6% Sales Tax)
Price subject to change.
Payment in US funds.

METAL FINISHING
Three University Plaza
Hackensack, NJ 07601
201 / 487-3700