BRAUN[SM]
INTERTEC

Final Research Award Report

Alternatives to the Use of Cyanide
Solutions in Electroplating

Prepared For

Minnesota Office of Waste Management

Project Number CMJX-92-0113
July 31, 1992

Braun Intertec Environmental, Inc.

Engineers and Scientists Serving the Built and Natural Environments

Acknowledgements

Braun Intertec personnel involved in the research award included:

Barb Loida, Environmental Engineer
Paula Connell, Environmental Engineer
Laurie Kania, Environmental Scientist
Stephen Riner, Supervisor, Environmental Management Services
Laura Dingels, Marketing Analyst

This project would not have been completed without the help of:

Linda Stewart, Chemical Process Engineer, Peerless Chain Company
Diane Amell, Chemical Engineer, Minnesota Office of Waste Management
Andrea Wieland, Editor, Minnesota Technical Assistance Program
Gregory Dant, Technical Director, Superior Plating, Inc.
Roger Murnane, Director of Environmental Services, NICO Products
Robyn Anderson, Chemist, Dugas-Bowers Plating
Jim Platt, Minnesota Metal Finishers
Nicholas Corriere, Industrial Chemical & Equipment Company
Joel Schurke, WRITAR
Rich Bosshardt, Engineer, Minnesota Technical Assistance Program
Dr. Darcy Hughes, Sandia National Laboratories
Ronald Stoltz, Sandia National Laboratories
Chuck Stimetz, Kansas City Allied-Signal
Bob Carter, Supervising Engineer, Waste Reduction Resource Center
Paul Pagel, Engineer, Minnesota Technical Assistance Program
Bob Pohlman, Metropolitan Waste Control Commission
Mary Kimlinger, Minnesota Pollution Control Agency
American Electroplaters and Surface Finishers Society

And, special thanks to all 33 companies that participated in the telephone survey.

Table of Contents

Appendices

A: Alternative Solution Summary

B: Telephone Survey

C: Summary Table of Individual Responses

D: Peerless Case Study Outline

A. Introduction

A.1. Objectives

Braun Intertec Environmental, Inc. (Braun Intertec) received authorization from Diane Amell of the Minnesota Office of Waste Management (OWM) on April 7, 1992 to begin work on the research project described in State of Minnesota Contractual Service Agreement number 99650-90751. The objectives of the research award are to identify alternatives to the use of cyanide-based solutions in the electroplating industry, quantify the extent of implementation of these alternatives, investigate the further potential for reducing cyanide plating emissions and wastes at the source, identify barriers to the implementation of pollution prevention techniques, and propose strategies for overcoming these barriers.

This report serves to complete Task 7, the submission of the final report as required in the state contract and outlined below in Section A.2. of this report.

A.2. Scope of Services

The services provided for this project consist of the following:

Task 1 Investigation and assessment of available alternatives for different cyanide-based electroplating solutions.

Task 2 Conduct a telephone survey of 35 Minnesota firms currently using cyanide-based electroplating solutions.

Task 3 Develop an in-depth case study of the conversion process Peerless Chain Company of Winona, Minnesota went through in switching to an alkaline zinc plating solution.

Task 4 Develop three case studies of firms which have implemented or attempted to implement rinsing modifications to reduce dragout from their plating baths.

Task 5 Submission of an interim report to OWM, summarizing the work performed to date, the results of Task 1 and 2, and the status of Tasks 3 and 4.

Task 6 Submission of a draft final report to OWM by July 15, 1992.

Task 7 Submission of a final report to OWM by July 31, 1992.

B. Alternatives Information

B.1. Information Sources

A number of sources were contacted for information on alternative solutions and dragout reduction rinsing modifications. Sources contacted included: Minnesota Technical Assistance Program (MnTAP), American Electroplaters and Surface Finishers Society, Sandia National Laboratories, Industrial Chemical Supply, and Jim Platt with the Minnesota Metal Finishers.

B.2. Alternative Solutions

Cyanide-based solutions are widely used for plating of zinc, copper, cadmium, silver, gold, brass and nickel. Although cyanide solutions are highly toxic, they are also very effective at keeping metals in solution during the plating process. Plating with cyanide solutions is a well-known technology that has been in use since the 1850s. The destruction of the cyanide-containing wastewater solutions is also relatively easy to accomplish prior to discharge to the sewer. The use of cyanide technology contains an inherent liability due to the potential environmental and public health impacts of a major release. In addition, a general fear of toxics and an inherent distrust of industry by the public also exists. All of these factors provides impetus for companies to evaluate alternatives. As regulations and waste treatment and disposal costs continue to increase, more platers are seeking to switch to non-cyanide plating solutions.

Information on alternative solutions to cyanide-plating baths obtained is summarized below and in a table format in Appendix A. Alternative solutions are readily available for zinc, and to some extent, for copper. Information on alternative solutions for silver, cadmium, nickel, and gold is also presented.

B.2.a. Alternatives for Zinc. The most common alternatives of non-cyanide zinc plating solutions are those of alkaline zinc and acid (chloride) zinc. Other alternatives include acid sulfate, fluoroborate, or neutral baths or the use of mechanical plating.

Among the advantages of alkaline zinc solutions are the following:

- Excellent coverage of low-current density areas.
- Bright deposits (although the deposits may not level surface irregularities).
- Throwing power (ability of a solution to plate to a uniform thickness over a wide range of currents) similar to zinc cyanide baths.
- Conversion to alkaline zinc solutions can be performed as a gradual phasing in of non-cyanide solutions into existing baths.
- Ability to use existing plating equipment.
- Chemical costs for alkaline zinc solutions are similar to zinc cyanide solutions.
- Elimination of the cyanide destruction pretreatment costs.
- For zinc platers performing work on carbon steel, the exemption of pretreatment sludges from classification as a F006 hazardous waste, provided no cyanide is used in the process and no residual cyanide remains in the sludge.
- Faster deposition of zinc, which may result in higher production rates.

Disadvantages to alkaline systems include:

- Loss of the intrinsic cleaning ability of cyanide.
- Cast iron and carbonitrided steel parts are not as readily plated with alkaline zinc solutions.
- Alkaline zinc solutions generally require filtration.

Acid zinc solutions are also gaining acceptance as an alternative to zinc cyanide plating baths. Many of the advantages listed above also apply to acid zinc solutions. The relative advantages of the acid zinc solutions over alkaline zinc solutions are:

- Faster speed of deposition than alkaline solutions.
- Bright deposits, which level surface irregularities that may exist on the parts.
- Ability to readily plate on cast iron and carbonitrided steel.
- Parts are less prone to blistering after plating.
- Less sensitivity to make-up water.
- Ability to better accept chromate sealers.

Several disadvantages to acid solutions also exist. These disadvantages include:

- Corrosive nature of the solutions which may require equipment modifications (i.e. relining of tanks and floors) and result in higher maintenance cost.
- Need for new filtration and cooling systems.
- Complete elimination of the present cyanide solutions and replacement with the acid bath is required.
- In low-current-density areas coverage and throwing power can be poor.
- Make-up water may require treatment for the removal of iron.
- Ammonia systems require ammonia removal prior to pretreatment.

Mechanical plating is another non-cyanide alternative to zinc cyanide plating. Mechanical plating is a process that applies a zinc powder onto a part in a rotating tumbling barrel. Glass beads (or other tumbling media) and promoter chemicals provide a hammering effect that beats a zinc coating onto the parts. Mechanical plating is generally preferred over alkaline and acid solutions in cases where a thickness greater than 0.5 mils is required. Mechanical plating can also produces a uniform deposit and result in reduced waste treatment costs.

B.2.b. Alternatives for Copper. Conversion to a non-cyanide copper process may only be considered in cases where the existing equipment can be modified. The two primary alternatives to cyanide copper are acid sulfate and pyrophosphate solutions. Alkaline copper plating has also been developed, as well as a copper fluoroborate solution which is similar to acid copper but is more expensive and difficult to control. Other cyanide-free solutions that have been developed, but have not to date been commercially successful include copper fluorosilicate, amine-complexed copper, alkane sulfonate complexed copper, and alkaline organophosphonate complexed copper solutions.

Acid sulfate was introduced in the 1950s and has great acceptance in all phases of decorative plating applications, including jewelry, steel, zinc diecast plating, and plating of plastics. Advantages of the acid sulfate baths include:

- Superior leveling and brightness.
- Relatively easy and inexpensive effluent treatment.
- Relatively inexpensive solution make-up cost.
- High plating current densities and high line speeds are possible.
- Only bright copper is used in the plating of plastics. Acid copper overcomes the linear expansion coefficient differences of plastic and subsequent deposits of nickel and chrome. Results tend to be better when the parts are subjected to thermal cycling. Superior leveling of acid copper solutions also helps to hide flaws in the plastic surface.

The disadvantages of acid sulfate are:

- The bath is corrosive to plating equipment.

- Solution does not easily lend itself to dragout recovery.

- Solution has poor macro-throwing power.

- Solution may attack base metals, thus requiring heavy strikes on the parts. Strikes are thin layers of a coating (e.g. copper or nickel) that are applied to the part on which the final desired coating is applied. A copper cyanide strike is needed for aluminum, steel and zinc diecasting prior to acid copper plating.

- Solution additives may contain dyestuffs which must be electrocleaned off the copper surface.

- Additional cooling equipment may be needed.

- Acid-resistant ventilation systems for removing acid mist may also be necessary.

Pyrophosphate copper was developed in the early 1960s and has been in use extensively outside United States for copper plating. Use in the United States began to emerge in the late 1970s and early 1980s. One opinion expressed to us for the delay of the use of this solution in the United States is that it can be readily produced from commonly available bulk chemicals. The main informational source that platers rely on are plating solution vendors, who have not been promoting this do-it-yourself alternative. Another factor is that it takes longer to plate with copper pyrophosphate than copper cyanide which can drastically increases production time. Lastly, copper cyanide solutions are more forgiving than non-cyanide alternatives. As such, they require less maintenance and controls to provide adequate coatings.

Copper pyrophosphate is primarily used as a striker solution. Advantages of this solution include:

- Excellent throwing power of the solution.
- Solution does not attack base metals.
- Solution is not corrosive to equipment.
- Dragout recovery is possible.
- Effluent pretreatment is easy.
- Subsequent plated metal adhesion is excellent.
- Anode bags are not needed.
- High deposition of metals.

The disadvantages of pyrophosphate are:

- High initial solution make-up costs.

- Solution is slightly more sensitive to organic contaminants than cyanide or acid solutions.

- Longer plating time is sometimes required.

- Steel and zinc diecasts require a copper cyanide strike prior to plating with a copper pyrophosphate.

- Formulations may contain significant amounts of ammonia which may present environmental and waste treatment problems.

- Solution life is limited.

Alkaline copper plating systems can produce fine-grained, ductile, adherent deposits. Alkaline baths have been used on steel and brass substrates as well white metal, zinc diecast and zincated aluminum surfaces. Advantages include good throwing and covering power. However, these solutions do not offer the inherent surface cleaning abilities of cyanide, and therefore the process must be evaluated to determine whether additional cleaning or more process controls are needed.

Copper fluoroborate systems have also been developed. They are similar to copper sulfate solutions, but can accommodate higher line speeds and are more soluble than sulfuric acid. They can also be more expensive to operate and difficult to control.

Prior to the early 1980s, cyanide copper was the state-of-the-art technique for the striker coatings for zinc diecasts that were subsequently nickel plated. Plating of zinc die cast materials directly with electroless nickel can eliminate the need for copper cyanide strike. Advantages of electroless nickel include:

- Elimination of the need for cyanide.
- Improved coverage capability.
- Improved corrosion protection of the zinc diecasts.
- Lower reject rates.
- Plating of more complex geometries.

One disadvantage to electroless nickel is that the plating process becomes more complex with the extra care that must be taken in plating.

B.2.c. Alternatives for Silver. Most non-cyanide silver plating solutions are based on ammonium, halide, amino or thio complexes with silver in a combination with a variety of conductivity salts and brightening additives.

RCA obtained a patent for silver iodide plating in 1977. It was very stable and easy to operate. However, the solution was found to be unsuitable for electronics and decorative coatings due to its light sensitivity and the initial electrolyte costs. Silver iodide was also found to be toxic and would most likely complicate waste treatment requirements.

In 1968, IBM obtained a patent for a bath that uses silver ammonium complexes. This solution's optimum performance was found to be in the pH range of 11.0 to 12.5. At this pH level, the bath generates ammonium hydroxide, which poses worker health and safety problems.

Schering AG obtained a patent in 1976 for a bath using silver thiosulfate complex. At one time, it was advertised extensively, but the bath was apparently withdrawn from the market.

The most serious problem was the readiness for thiosulfate ions to be oxidized. In lower current density areas, the deposits could also be discolored.

A new silver plating bath with no free cyanide was developed especially for high-speed plating in the electronics industry. This solution can also be formulated for standard systems. Silver coatings from the no-free-cyanide bath have good contact properties, and are less susceptible to tarnishing than those from conventional alkaline cyanide silver baths. The no-free-cyanide solution is easy to maintain and requires less complicated waste treatment procedures. Silver can be precipitated as AgCN and reused. The neutral pH and no-free-cyanide properties cause the system to be free-rinsing (less likely to leave residuals on parts).

Work has also been done with a silver methanesulfonate-potassium iodide bath to study the effects of additives. It was possible to produce a deposit with a fine grain structure and appearance which was comparable to or better than conventional cyanide bath. However, this work was not performed on a commercial scale.

B.2.d. Alternatives for Cadmium. Since cadmium itself is toxic, finding alternatives to cadmium cyanide solutions does not eliminate concerns with the use of toxic substances. Alternatives to cadmium cyanide include cadmium chloride, cadmium sulfate, cadmium fluoroborate and cadmium perchlorate. The cadmium sulfate process has been used to produce thick (0.02 inches) deposits with good adhesion and density. One company which has installed cadmium sulfate plating lines found that the solution is working well for them, but they did experience problems with metal buildup on the cadmium electrolyte. Research of other electrodeposited alloys and plating with zinc-nickel coatings as a substitute for cadmium is also occurring. FMC Corporation has successfully used zinc-nickel as a replacement for cadmium in their San Jose - Ground Systems Division Plant.

B.2.e. Alternatives for Gold. Cyanide is present in some gold baths, particularly in the electronics industry. One alternative, sulfite-based gold, has been available for 15 years. The sulfite solutions are chemically less stable and thus require more effort at monitoring and conditioning the bath chemistry. The solution's stability is a function of frequency of use. If solution use is infrequent, the baths may need to be stored in air-tight containers to prevent the chemical oxidization. The solutions have excellent throwing power and can plate complex shapes. The United States Department of Energy (DOE) has performed work in evaluating cyanide solutions with sulfite solutions for the electronics industry. All of the measured properties of gold films from the sulfite baths were similar to those of films from cyanide baths. Sulfite gold chemistry was also compared with acid cobalt-hardened (no-free cyanide) gold chemistry. According to Chuck Stimetz, Kansas City, Allied-Signal Company, the cobalt hardened gold solutions can produce gold deposits up to 99.97 percent purity which is in the 99.9 - 99.99 percent acceptable purity range of sulfite gold. The cobalt-hardened gold also performs better in heavy slide wear applications. Its disadvantages center around the brittleness of its deposits which can crack under thermal applications such as soldering. The sulfite has been found to be solderable.

DOE was also evaluating soft gold for thermal compression bonding and as a conducting lubricant in rotary switches, as well as evaluating high purity mid-hardness commercial gold for use in microelectronics. DOE felt that more work needed to be completed before cyanide could be replaced for thick gold applications.

B.3. Rinsing Modification Information Summary

Adequate rinsing is a critical step within the plating process. In preparing a part for consecutive plating steps within a process, parts must be rinsed to stop chemical reactions and prevent cross contamination of subsequent plating tanks. Poor rinsing may result in the staining, spotting, blistering or peeling of the parts. Therefore, it is critical that rinsing processes also be examined in pursuing pollution prevention alternatives within the electroplating industry. In addition, for plating operations in which non-cyanide alternative solutions do not exist or lack necessary performance levels, one means of reducing their wastes is through alternative rinsing practices.

The goals of alternative rinsing practices are two-fold. One goal is to control the dragout of solutions from the baths, while the second is to minimize water consumption. Section B.3.a and B.3.b. of this report details the dragout control and water conservation measures currently available. Note that some of the options listed only apply to rack type plating operations as indicated below. Alternative rinsing practices will only succeed if the rinsing systems are properly designed, operated and maintained.

B.3.a. Dragout Control. Dragout can be minimized through the following options:

- Decreasing the withdrawal rate of the parts from the solution tanks is believed to reduce dragout since surface tension exerted by the plating bath is greater than that of the part. This results in the solution being pulled off the part and back into the tank. A less scientific reason for decreasing the withdrawal rate on automated lines is to increase the drain time without the appearance of slowing down the process. Some plating line operators may feel that the function of equipment is to move the parts quickely through the plating line and be unwilling to allow the hoist to idle over a tank to drain parts.

- Increasing the drip time over the solution tank can greatly reduce dragout. For manual systems drain bars and racks need to be added to encourage the operators to allow the parts to hang over the tanks and drain. In barrel plating it may be possible to allow the barrel to rotate over the tank for drainage, but this practice can result in some scratching and pitting on the parts.

- Racking parts correctly can avoid cupping solution in the cavities of parts which thereby increases dragout. For barrel lines it may be possible to increase the mesh size of the barrels to allow better drainage.

- Parts can also be shaken, vibrated, or passed through an air knife to remove dragout. If any of these dragout removal processes are employed, the system must be designed to capture and return dragout to the solution tank so that it is not lost to the floor or rinse tanks. Some of these dragout technologies may work on barrel type plating, but again the possibility of scratching or pitting the parts does exist.

- Drain boards angled between tanks will also serve to capture dragout and funnel the dragout back into the solution tank.

- Wetting agents will also decrease the surface tension in a solution tank and reduce the adherence of the solution to a part as it is withdrawn.

- Higher temperature baths also decrease the viscosity of the solution thereby reducing the adherence of a solution to parts.

B.3.b. Water Conservation. Water conservation measures include:

- The use of flow restricters on flowing rinses. A flow restricter is a device which is placed in the incoming water line to limit the flow rate of water entering a tank.

- The use of flow control valves which allows uniform individual tank water usage rates to be set.

- The use of air or water agitation within the tank to ensure homogenous rinse waters and adequate rinsing on all areas of the parts.

- The use of conductivity controllers to ensure that the rinse waters are fully utilized before new water is added to the rinse tanks.

- The use of dead rinses immediately after the plating baths to capture dragout; these are then reused as makeup water in the plating baths.

- The use of counter-current rinsing system. These systems usually consist of three rinse tanks connected in series. New water only enters the final, cleanest rinse. A discharge to the pretreatment system only occurs from the initial rinse tank. The overflow from the final rinse overflows into the secondary rinse, while the secondary rinse water flows into the initial rinse tank. Although this may intuitively appear as the wrong procedure in setting up rinse tanks, a properly designed counter-current rinse system allows the rinsing capacity of the water to be maximized and the overall usage of water to be minimized. A counter-current rinsing system also allows the heavy metals in the rinse water effluent to be concentrated which maximizes the performance of most types of pretreatment systems.

- The use of fog or spray rinsing to limit the amount of water used to rinse parts. It may be possible to limit the volume of water used to the rate of bath evaporation. This would allow the reuse of the spray rinse waters as plating bath make-up water. Spray and fog rinsing technologies are limited to rack type plating operations.

- The use of reactive rinses which allows for the reuse of rinse waters in compatible rinses. For example, the reuse of nickel rinse waters in an acid dip tank rinse. Again, this maximizes the rinsing capacity of the water. Note that if contamination occurs in the downstream rinse there is a risk that the contaminants will be transported upstream resulting in the contamination of the upstream rinse and the plating solution, as well as poor plating quality.

- Lastly, the use of purified water or softened water in the rinse tanks to ensure adequate rinsing and reduce the generation of sludge in precipitation type pretreatment systems.

C. Telephone Survey

C.1. Survey Information

The survey was designed to assess the status of pollution prevention efforts, the perceived pollution prevention barriers and incentives, and pollution prevention assistance desired within the electroplating industry in Minnesota.

A number of people were involved with drafting the survey to ensure the information collected was pertinent to the needs of OWM. Braun Intertec staff involved included Laura Dingels, Laurie Kania, Barb Loida, Theresa Savoie, and Steve Riner. In addition, individuals at other organizations were asked to review and comment on various drafts of the survey. These people included Andrea Wieland (MnTAP), Jim Platt (Minnesota Metal Finishers), Diane Amell (OWM), Joel Schurke (WRITAR), and Linda Stewart (Peerless Chain Company). The survey was revised several times based on the comments received and the results from testing the draft surveys. A copy of the final telephone survey can be found in Appendix B.

Lists of potential survey contacts were collected from the Metropolitan Waste Control Commission, the Minnesota Pollution Control Agency, the Minnesota Metal Finishers Association, the Upper Midwest Branch of the American Electroplaters and Surface Finishers Society, and the Western Lake Superior Sanitary District. These lists were screened to target electroplaters which were believed to be using cyanide solutions and to eliminate duplicates. A total of 62 contacts were identified, which included both job and captive shops. Four companies were further eliminated from the screened lists when current telephone numbers were not found in the Minnesota Business Directory or through directory assistance.

C.2. Survey Results

The calling portion of the survey was conducted by Laurie Kania between May 4 and May 18, 1992. A total of 58 companies were contacted. On average, each survey took approximately 10 to 15 minutes to complete. Table 1 below lists the type of survey respondents by number and percentage.

Table 1 - Survey Contacts

Type	Number	Percentage
Cyanide Users	33	57%
Non-Cyanide Users	9	15%
Non-Electroplaters	10	17%
Respondents Declined Participation	1	2%
* Miscellaneous	5	9%
Total	58	100%

* These companies were found to be duplicates on lists through name changes and ownership transfers or the contacts could not be reached within the timeframe of the survey.

Participation in the survey was excellent. Only one company contacted refused to participate. The relative size of the companies varied from 3 to 750 employees, with the majority of the companies having less than 50 employees. The responses appeared to equally represent electroplaters in both the Twin Cities Metropolitan Area and Greater Minnesota. Sixty percent of the contacts were within the seven county metropolitan area and 40 percent were from Greater Minnesota. Only companies currently using cyanide solutions were asked to complete the entire survey. Of the 33 cyanide users that completed the entire survey, only 4 were captive shops (meaning that plating was performed only on internal company parts). The other 29 companies were job shops. Table 2 below shows the range of solutions which the respondents use. Many respondents indicated that they were plating with more than a single form of cyanide-based plating solutions.

Table 2 - Solutions Plated

Type of Plating	Brass	Cadmium	Copper	Gold	Nickel	Silver	Zinc	Strippers
Number of Responses	4	5	12	12	2	8	12	3

A table summarizing the individual telephone survey results can be found in Appendix C. In order to encourage the electroplating companies to participate in the survey, an agreement to hold their names in confidence was given. Therefore, the summary information included in this report does not include any information that would allow an individual company to be identified. The information has been presented as near to the actual conversations (with a minimum of paraphrasing) so that the content and tone of the companies' responses were preserved.

C.3. Survey Trends

The survey responses show that electroplaters are aware of alternative non-cyanide solutions and alternative rinsing practices. Few of the respondents indicated that they had not performed at least some research in either of these areas. The factors most often cited as motivating their company to examine alternatives were stricter environmental regulations, higher waste management costs, higher disposal costs, and proven measurable cost savings. The barrier most often cited for not implementing more pollution prevention measures was the high capital costs in converting to the alternatives, which cannot be passed along to their customers. One other barrier cited quite often was a lack of acceptance of the alternatives by their customers.

The zinc and copper electroplaters seemed to have the most possible alternatives available. The respondents using brass, cadmium, gold, nickel, and silver cyanide solutions indicated that few if any feasible non-cyanide alternative solutions existed. Generally, these responses agree with the information gathered through our initial research for alternative solutions.

Most of the zinc electroplaters have conducted pilot studies with alternative solutions or partially replaced their zinc cyanide solutions with non-cyanide solutions. Five of the companies contacted have entirely converted to alkaline zinc solutions. All of the zinc platers expressed concern with post blistering and yellowing of parts which can occur long after the part has been plated. Another technical barrier expressed regarding alternative zinc solutions was the poor performance of the solutions in plating to a thickness of over 0.5 mils. Only one plater indicated that they have been able to plate greater than 0.5 mils without any problems.

Most of the copper cyanide platers have at least researched alternatives. Some were in the process of running pilot studies during the survey. A few had actually converted to non-cyanide solutions, but feel limited by the alternatives since they do not perform on a wide range of base metals, as well as the copper cyanide solutions.

A lot of frustration was expressed by the platers using gold cyanide solutions. Many felt that alternative non-cyanide solutions which would work in their shops simply did not exist. One plater stated that they found gold sulfite solutions to be unstable and that gold chloride solutions worked well only as thin films, such as striker solutions. This plater has also researched silver chloride solutions and has found them to be extremely photo sensitive resulting in the solutions plating out in the tanks. This problem with the silver chloride solution was overcome by the addition of chelating agents to the bath.

Only one cadmium plater indicated that their company had found an alternative non-cyanide process. Their shop switched to a zinc dichromate process. In addition, one brass plater found a non-cyanide solution that they believe will work satisfactorily, but they have not switched.

The majority of respondents have incorporated some rinsing modifications, such as the use of dead or counter-current rinses, and the use of flow restricters into their plating lines. The reuse of rinse waters and treated water from a pretreatment system also appears to be a trend that some platers are researching and pursuing.

C.4. Assistance Requested from OWM

When asked what type of assistance they would like to receive from OWM, most replies centered on the OWM facilitating and fostering a better relationship with industry. Some respondents expressed concern that OWM was not being patient enough with industry and recognizing good faith efforts on their part or providing enough positive reinforcement. Others felt that the OWM needed more input from industry. Some also suggested that staff visit more facilities to get a better understanding of their manufacturing processes and the operational limitations they face.

Respondents also expressed a strong need for a more streamlined and uniform approach to environmental regulations within the state. Some of this response is centered on the fact that a great deal of confusion exists in Minnesota on what each role the various environmental agencies within the state play and the duplication of some agencies' efforts. Others indicated that, although OWM and MnTAP state that their organizations are not regulatory in nature, they are still reluctant to work with OWM or MnTAP. They are concerned that some information given to OWM or MnTAP could be passed along to the regulatory agencies resulting in enforcement actions, or that this type of information may be used to develop additional regulations that will make it harder for them to operate their manufacturing processes.

In addition, responses such as requests for non-biased reliable source of current information may indicate that confusion between the roles of OWM and MnTAP or the lack of awareness of the MnTAP program exists. An effort to educate Minnesota industries on the functions and services of both programs may alleviate this confusion.

Respondents also requested;

- Tax reduction incentives be made available for companies implementing pollution prevention measures.
- A seminar specifically focusing on concerns of the electroplating industry and expressed support for past locally accessible pollution prevention seminars.
- Need to focus change at the end user (consumer) level to get alternatives accepted and create a market for products plated with non-cyanide solutions.
- Need to continue to perform and sponsor research activities.

D. Case Studies

The case studies were developed to serve as an educational tool in documenting the experiences of plating shops in examining alternative non-cyanide based solutions and modifying their rinsing practices. Companies which participated in the case studies included Peerless Chain Company of Winona, Minnesota, Superior Plating, Inc. of Minneapolis, Minnesota, NICO Products of Minneapolis, Minnesota, and Dugas-Bowers Plating of Fridley, Minnesota.

An outline for the Peerless Case Study was developed with the assistance of Peerless Chain, OWM, MnTAP and WRITAR. A copy of the Peerless Case Study Outline can be found in Appendix D. The outline questions were modified and addressed by the other case study companies. MnTAP and OWM personnel also assisted in reviewing the case studies. Note that these case studies are presented in a format that will allow them to be transformed into fact sheets and separate documents for distribution.

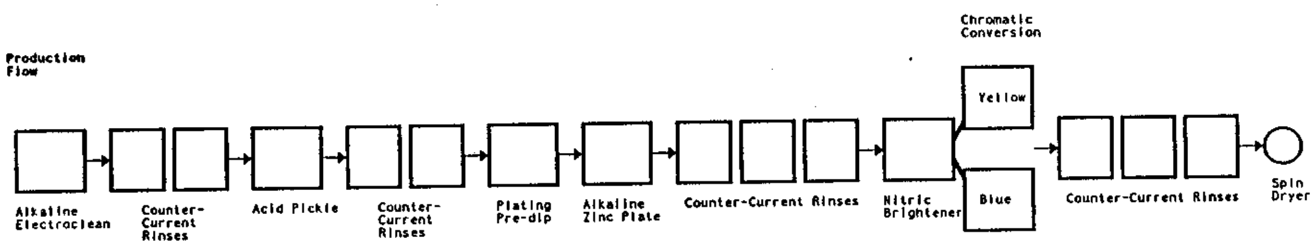
D.1. Peerless Case Study

The Peerless Chain Company of Winona, Minnesota produces automotive, commercial and industrial chain as well as wire forms for a national market. Manufacturing operations at Peerless include wire forming, heat treating, mechanical plating, electroplating, assembly, and packaging. In 1991, Peerless successfully switched from the use of cyanide zinc solutions in their electroplating operations to alkaline zinc solutions. This case study has been developed with the purpose of providing information to other electroplaters considering the use of non-cyanide solutions.

Background Information

Peerless processes approximately 30 million pounds of carbon steel and 25 thousand pounds of stainless steel yearly. Their electroplating operations consist of three barrel lines and a continuous chain plater. The barrel lines are primarily used for the plating of wire forms and chain assemblies. Peerless formerly operated their barrel lines using a 1-ounce cyanide per gallon of water solution and the continuous chain plater using a 3-ounce cyanide per gallon of water solution. A schematic of Peerless's current barrel plating lines as shown in the figure on the following page.

Peerless Barrel Plating



The continuous chain plater is one of Peerless's most vital operations. Unlike barrel or rack type plating where a group of parts are plated on a batch basis, the continuous chain plater allows chain to be strung through a conveying system and plated on a continuous basis. At the end of a process run, chain remains in the conveying system which is then lifted out of the processing tanks until the next run. The continuous chain line layout is similar to the barrel lines except that an alkaline soak bath is used in place of the alkaline electrocleaning process and all rinses are a single fog type.

Peerless first tested an alkaline zinc solution in 1980. Excessive levels of yellowing and post blistering were experienced. The defective parts were caught before they left the facility, but resulted in high volume of rework. Based on these results, Peerless abandoned the idea of converting to alkaline zinc solutions and continued to use zinc cyanide solutions. Higher pretreatment costs, controls, hazardous waste disposal fees, worker safety concerns, and community safety concerns associated with the use of cyanide-based solutions led Peerless to re-examine non-cyanide solutions in 1990. The effort to explore alternative solutions was led by Linda Stewart, Chemical Process Engineer. Initial annual cost savings of $50,000 were estimated with the elimination of the cyanide destruction pretreatment system.

As a result of the poor performance of the alkaline zinc solutions in 1980, Peerless initially focused on acid zinc solutions. However, acid zinc solutions would have required major modifications estimated at $600,000 to the existing plating lines. Based on this estimate, Peerless chose to re-examine alkaline zinc solutions which could be used in the existing plating lines with few modifications.

Personnel Involvement

The evaluation of alternatives and the conversion to non-cyanide solutions was actively supported by top management at Peerless. This support was critical since skepticism regarding the viability of alkaline zinc solutions existed. The support from management also fostered cooperation between the Engineering Department, which was involved with researching alternatives, and the Manufacturing Department, which operates the plating lines.

A considerable amount of time and patience were required to establish a sense of trust between not only among personnel from each department but among members of management and the operators. The initial resistance to alkaline zinc solutions gradually shifted to one of support to at least experiment with the alternative solutions. The line operators were not directly involved in the initial research but were involved with the selection of trial solutions, the conversion of the barrel lines in 1990, and the conversion of the continuous chain plater in 1991.

Information Collection

Peerless contacted many sources in locating information on alternative solutions. These sources included vendors of electroplating chemistry and equipment, the American Electroplaters and Surface Finishers Association, and other metal finishers operating similar plating lines. Personnel at Peerless also stated that they found useful information at environmental seminars which specifically focused on metal finishing operations. The majority of the information that Peerless found came from vendors since they knew what alternatives were available and what non-cyanide solutions platers with similar operations had successfully implemented.

Vendor claims were screened by contacting the references provided. A number of plating firms were visited by Peerless personnel. Also Peerless was allowed to run their parts through another facility's lines to determine if the type of alkaline zinc solution used could adequately plate Peerless's parts. Articles focusing on zinc cyanide alternatives were also used to screen vendor claims as well as convince Peerless staff that improvements in alkaline zinc solutions had occurred since 1980.

Pilot Studies/Barrel Line Conversion

By the spring of 1990, Peerless identified three alkaline zinc solutions to test in their barrel plating lines. The alternative solutions were judged on their performance and their respective capital/maintenance costs. In July 1990, the zinc cyanide bath in line 1 was removed and replaced with a MacDermit alkaline zinc solution. The MacDermit solution in line 1 and the zinc cyanide solution were run side by side for a 6-month trial period. One problem which became readily apparent was the loss of the intrinsic cleaning ability of the cyanide, which is capable of binding up iron and chelating other metal water ions. To compensate for this loss, an alkaline electrocleaning process and muriatic acid cleaning tank were added to line 1. Post blistering and yellowing were also experienced with the MacDermit solution since this solution was overly efficient at depositing zinc onto the parts. Peerless switched to a trivalent chrome to remedy yellowing problems and decided to test a second alkaline zinc solution in line 2.

In January 1991, the zinc cyanide solution in line 2 was removed and replaced with a McGean-Rohco solution. The MacDermit and MacGean-Rohco solutions were run on a side by side comparison basis for two months. Post blistering and yellowing problems were not experienced with the McGean-Rohco solution. A third solution, W. D. Forbes, was brought in for testing in March, 1991. Through the use of Forbes ForGlow brightens, the MacDermit solution was converted into a ForGlow alkaline zinc solution. The McGean-Rohco and ForGlow solutions were then run for several weeks on a side by side basis. Peerless chose to convert the barrel lines and continuous chain plater to the McGean-Rohco solution, since they felt its overall performance worked best for their plating needs.[1]

Continuous Chain Plater Conversion

An employee involvement team was formed for the conversion of the continuous chain plater. The team consisted of the quality assurance manager, quality assurance technician, plating foreman, 3 plating line operators, and was led by the chemical process engineer. Since the continuous chain plater is one of the most vital operations at Peerless, it could not be down longer then the two week annual maintenance period. The employee involvement team was formed to ensure that the conversion process was smoothly orchestrated. The team began meeting weekly on May 1, 1991. When the conversion process was started the team met

[1] Peerless had favorable remarks about each vendor they worked with and each solution they tried. They stressed that their results should not be used by other platers to eliminate potential solutions for trial in their plating operations. Each vendor supplied Peerless with on-site technical start-up support and were available to supply additional technical support on an on-call basis. The vendors also supplied the initial baths on a no-cost basis for the pilot studies, as well as operator training and free analysis of the baths.

daily for 14 days. At times, meetings were held on each shift to ensure that necessary information was communicated to all personnel involved with the conversion process.

Management support for the conversion of the continuous plater was critical. Authorization to spend $5,000 to upgrade chemical feed lines was granted. Major overhaul of the continuous plater was also moved up two years which included upgrading the alkaline soak tank to compensate for the loss of the intrinsic cleaning capability of cyanide.

Reduction and Cost Savings
Alkaline zinc has performed consistently for Peerless and has been easy to maintain. Line speeds or plating specifications were not changed with the use of the alkaline zinc solutions. Peerless typically plates to a 0.2 mil thickness of zinc and their specifications have never called for coatings over 0.5 mils. They feel that they could plate up to 0.5 mils with the alkaline zinc solutions, but above 0.5 mils would experience post blistering problems. Peerless is still operating the McGean-Rohco bath installed in 1991 and has not experienced any contamination problems with their solutions which would result in the need to purge and replace the bath. However, the conversion did require Peerless to pursue a more objective approach in operating and maintaining their plating lines.

Statistical process controls have been developed and implemented for the plating processes. Before the conversion to alkaline zinc solutions, single component brighteners were added on every shift and as needed as determined by the operators based on the appearance of the finished parts. Brightener components are now added based on the ampere hours the individual line has been running. Process control chemical analysis formerly performed on a weekly basis are now performed daily. The plating foreman has been trained and now performs some of the wet chemistry in the laboratory, which has allowed the chemical process engineer to pursue other pollution prevention projects at the facility.

A water conditioner is also now added to the plating tank at the same time the caustic is added to ensure that the parts are adequately cleaned prior to plating. This conditioner exhibits the same chelating effect of cyanide in binding up undesired water ions. These changes have resulted in more frequent, smaller additions to the lines, which has resulted in better management of the use of chemicals at the facility.

Customer acceptance of the alternative solutions was critical in the decision to convert to the alkaline zinc solutions. No further post blistering and yellowing has been experienced since the initial pilot studies. An acceptance criteria chart for finished appearance has been developed. This chart consists of a peg board on which parts plated with cyanide solutions having the desired appearance are located. Operators use these parts for visual comparison with parts plating with the alkaline zinc solutions.

Peerless has eliminated the need for their cyanide destruction system. This has resulted in a yearly cost savings of $21,000 for chemicals (sodium hypochlorite and chlorine), and $3,200 for maintenance. Peerless has also reduced their hazardous waste disposal costs for their F006 pretreatment sludge by $60,000 a year. Trace residual levels of cyanide (about 80 ppm) are still present in the sludge, but Peerless is in the process of cleaning and purging all cyanide residuals from their plant. Peerless is working with the MPCA on an exemption to listing of their pretreatment sludge as a F006 hazardous waste once all residual levels of cyanide are completely removed from the system. An exemption from the F006 listing does exist for plating operations which plate zinc on carbon steel. In converting to alkaline zinc baths, Peerless was also able to convert their chrome sealers to a trivalent form. If exemption is granted, Peerless will be able to manage their pretreatment sludge as an industrial solid waste.

The number of personnel hours spent on this project has not been calculated. The chemical process engineer estimates that prior to April 1990 she spent a total of 40 hours on the project. Between April and August 1990 the project was a half-time position. After August of 1990, the project was 10 percent of her job and will soon be phased out when the plating line foreman takes over trouble shooting the system's problems.

Peerless has not found any significant cost differences between the alkaline zinc and cyanide zinc solutions. They also feel that the time spent on maintaining the solutions are similar. They indicated that the use of alkaline zinc solutions has allowed them to gain better control of their plating lines.

Peerless is now in the process of adding filtration equipment onto their pretreatment system which will allow them to reuse treated water back in the plating process. The reuse of treated water has been estimated to reduce Peerless's water consumption by 10 million gallons a year and reduce annual sewer costs by $12,000.

Tips for Other Platers

The successful conversion to alkaline zinc from cyanide zinc solutions for the plating of steel parts is possible. Cyanide solutions in general are fairly forgiving. They have an intrinsic cleaning capability and are relatively easy to maintain. Companies that are not willing to compensate for the loss of the intrinsic cleaning capability of cyanide or perform the additional process controls will not be successful in their use of alkaline zinc solutions.

Peerless noticed the loss of the intrinsic cleaning capability of the cyanide in their first pilot study. They added an alkaline electrocleaning and acid cleaner to their barrel lines and upgraded their alkaline soak tank on their continuous chain plater. The additional cleaning requirements need to be evaluated to prior to the conversion, to avoid any potential problems.

Peerless also found that the alkaline non-cyanide zinc solutions required more controlled conditioning of the baths to maintain their integrity. This involved the implementation of statistical process controls. This removed a lot of guesswork from the plating process since operators now have guidelines of when brighteners and other plating components need to added. The implementation of process controls should be viewed as an empowerment mechanism rather than a means of control. The expertise of the operators is still utilized, with the process controls providing confirmation of what they think is happening to the system. The training and performance of analysis by the plating foreman speeds up the transfer of information to the line operators.

The successful conversion also requires that management actively supports the project and bridges any potential barriers that may arise. Operator involvement is also critical for feasible alternatives to be located and the alternatives to be accepted. Lastly, one key factor is also the willingness to keep examining alternatives when the first one which is explored is found not to be feasible.

D.2. Superior Plating Rinsing Case Study

The Superior Plating, Inc. of Minneapolis, Minnesota, is one of the largest job plating shops in the midwest. Since the mid-1980s, Superior has reduced their water usage from 1 million gallons per day to 300,000 gallons per day or 70 percent. Through the reuse of pretreatment effluent Superior has further reduced their water usage by 14 percent. This case study has been developed with the purpose of providing information to other electroplaters considering alternative rinsing techniques.

Background

Superior has been in business since 1918, and at its current location for more than 30 years. Superior has the ability to plate nickel, electroless nickel, decorative chrome, hard chrome, cadmium, sulphonated nickel, silver, gold, zinc, zinc cobalt, rhodium, tin, tin/lead, copper, brass, black oxide, and dry film lubricants. Superior also performs phosphatizing and hard coat anodizing. They employ 144 people and operate 5 to 7 days a week on three shifts. The majority of their plating lines are automated.

Twenty percent of the water used at Superior is municipal. A portion of this water is deionized and used as make-up water for solutions. The remaining 80 percent of the water used at the facility is supplied by a 300-foot private well.

Water Reduction and Reuse

In the mid-1980s, Superior installed a hydroxide precipitation pretreatment system in an effort to comply with the electroplating and metal finishing wastewater pretreatment standards. Before the pretreatment system was installed, Superior was using one million gallons of water per day in their plating operations. In designing the pretreatment system, Superior chose to limit the capacity of the pretreatment system to 500,000 gallons of water per day. This decision was made to contain the size and operational costs of the pretreatment system. To reduce water consumption, Superior installed flow restricters in all rinse tanks, extended drip times over solution and rinse tanks, and installed shut off controls for water feed lines.

The flow restricters used are homemade devices. A cap was installed on the end of each water supply pipe feeding the rinse tanks. A small single hole was then drilled in each cap. An extra benefit found after installing the flow restricters was an increase in available water pressure throughout the plant. All automated lines were also reprogrammed to allow for a minimum drip time of 5 seconds after parts are removed from each solution and rinse tank. Some drip times were extended up to 30 seconds. In addition, Superior installed shut off controls on all their lines which allows the water to quickly be turned on and off as needed. Through these changes, Superior was able to reduce their average daily water usage to 300,000 gallons.

In an effort to further reduce sewer disposal costs, Superior began reusing effluent from their pretreatment system in non-critical rinses in December 1989. Non-critical rinse areas include pre-plate cleaning and primary rinses on the zinc automated plating line. Laboratory pilot studies were conducted before reuse to assure operators that cycling used water back into the plating processes would not adversely affect the plated finishes. These studies were conducted over a week-long period within Superior's laboratory. The tests involved setting up worst case scenarios of overdosing filtered pretreatment effluent with defoamers, polymers and treatment chemicals and measuring the impact that these waters had on the rinsing quality of test panels. When the pilot studies indicated that the rinsing quality was not affected, one plating line was modified for the reuse of pretreatment effluent. This line was then run with reused water for a 2-month period. When no adverse effects were found, a sand filter was added to provide more polished pretreatment effluent and other lines were then modified to utilize the reuse of pretreament effluent. Superior reuses on average approximately 39,500 gallons of water daily or 13 percent of their pretreatment effluent.

Within the last several months, Superior has also been experimenting with reuse of pretreatment effluent as solution make-up water. They are currently evaluating the performance on one line. Superior is concerned that residual salts may affect the life and quality of the bath but have not experienced any significant problems. One benefit Superior has found with the use of pretreatment effluent is that the water is softer than both the city and well water they are currently using. The use of pretreatment effluent is saving Superior an additional 2,000 gallons of water per day or roughly 1 percent of their overall usage. If test results continue to be favorable, Superior may expand the reuse of pretreatment effluent as make-up water for other plating lines.

Personnel Involvement

The idea to make the initial rinsing modifications and reuse the pretreated effluent came from the managers. Management personnel involved included the plant manager, production manager, company president and the technical director. The initial rinsing modifications were resisted by the line operators, who feared that a reduced water flow would not provide adequate rinsing and would lead to an increase in the rejection rate. Management persuaded operators to at least test the modifications. Operators supported the modifications when it was found that they were not adversely affecting the quality of the finishes. An outside consulting firm was used by Superior to sample and analyze the pretreatment effluents and assist in estimating the costs of the sand filter.

Management also invested time in performing the laboratory pilot studies when the initial idea of reusing the pretreatment effluent was introduced. Results of these studies assured line operators that the finishes would not be adversely affected.

Other Pollution Prevention Projects

In July and August of 1991, Superior also implemented measures to reduce emissions of solvents from their degreasing operations. In a 6-week period, they reduced their emissions by 35 percent through improving the vapor degreasing housekeeping practices and providing operators with training on the correct cleaning procedures. Housekeeping practices included:

- Ensuring that the degreasers were turned off on weekends and other periods when they are not in use.
- Constructing covers for the degreasers and covering the units when they are not in use.

Superior is also examining the replacement of the copper cyanide, zinc cyanide and cyanide descaling solutions. They have switched all their cyanide solution to low concentration solutions and have found that they are saving on solution base metals, are getting better rinsing and are having an easier time in reusing the pretreatment effluent. They are currently running non-cyanide descaler on one line and have reduced cyanide usage by approximately 24,500 pounds a year. Superior has met a lot of customer resistance to the use of non-cyanide zinc solutions. Most of this resistance centers on customer fears of post blistering of the parts in storage. Superior is also concerned with the loss of the intrinsic cleaning ability of the cyanide. Their production space is limited and the addition of extra cleaning tanks to the individual plating lines may be difficult.

Tips for Other Platers

Relatively simple rinsing modifications (i.e. use of flow restricters, increase in dragout time or the use of shut off controls) can result in significant reductions in water usage. For Superior the reduction was nearly 700,000 gallons of water per day or 70 percent of its previous usage.

Superior has also demonstrated that the reuse of pretreatment effluent is also possible. They have been successful in utilizing pretreatment effluent in non-critical rinses and as make-up solution water on one plating line.

A key to the successful efforts at Superior is the support the projects received from management and the line operators. Management at Superior took the time necessary to gain the support of the line operators for the changes and to perform the initial laboratory pilot studies on the reuse of the pretreatment effluent.

D.3. NICO Products Case Study

NICO Products of Minneapolis, Minnesota is an electroplating job shop. Rinsing technologies utilized by NICO include countercurrent, dead, and spray rinses. NICO has also experimented in reusing pretreatment effluent in their chrome plating operations. This case study has been developed for the purpose of providing information to other electroplaters considering alternative rinsing techniques.

Background Information

NICO has been in business for 20 years and has been at its present location since 1981. They employ 80 people and operate on three shifts.

NICO primarily plates using rack lines, but they also perform barrel plating. Hand line plating capabilities include nickel, chrome, tin, cadmium, passivate, brass and zinc. They also operate three automated zinc plating lines.

Water Reduction and Reuse

NICO has used countercurrent rinsing since plating operations began. Dual or triple countercurrent rinses are utilized after dead rinses. NICO feels that countercurrent rinsing provides better rinsing and has incorporated countercurrent rinsing into all of its plating lines. Roger Murnane, Director of Environmental Services, feels that most large platers are taking advantage of the better rinsing capability of multiple countercurrent rinses rather than using single flowing rinses. One drawback of countercurrent rinsing is the additional space necessary to accommodate the extra tanks. For shops with limited floor space the space issue may pose a significant barrier.

NICO has also installed spray rinses on the automated zinc plating lines to improve removal of caustics and cleaning of seams, crevices and holes which tend to retain solution. Spraying is performed on hoists above the tanks, prior to countercurrent rinsing. One problem encountered with spray rinses is the potential for water to be sprayed around the shop. Side shields have been installed around the hoist's spraying system to direct the drainage of spray water back into the rinse tanks.

Dead rinses are also used by NICO following the solution tank. Dead rinse water is reused for bath makeup water in lines with heated baths. In cases where dead rinse water cannot be reused, the water is shipped to Metro Recovery Systems (MRS) for treatment and disposal on a periodic basis. NICO anticipates that dead rinses in the zinc lines will be eliminated when the cyanide zinc solutions are converted to alkaline non-cyanide zinc solutions. The dead rinse tank space will be used for additional cleaning tanks if they are necessary to compensate for the loss of the intrinsic cleaning capability of cyanide.

NICO has performed a water usage study to determine the flow rate through rinse tanks around the plant. Water usage was measured in various rinses using a stop watch and bucket. Nico found that water usage in some areas ranged from two to three gallons per minute (gpm). Through the use of flow restricters, NICO reduced water usage in each rinse to one gpm or less. One problem NICO experienced with the use of restricters is that in situations where water demand exceeds the supply rate (i.e. changing of plating solutions), the operators must use hoses to provide the additional water. Overall, NICO feels that the benefits of using the restricters outweighs their disadvantages. They also feel that the restricters have considerably reduced their water consumption.

NICO has also examined the reuse of pretreatment effluent from their MRS (ion exchange) pretreatment system. This system operates with both anion and cation resins, which results in water that is essentially deionized. NICO reused this water in their chromium line but discontinued reuse when line operators felt that the water was not providing adequate rinsing. NICO may try reusing the pretreatment effluent in non-critical cleaning rinses in the future.

NICO feels that they have gone as far as they can with reducing their water usage. In addition, they feel it is not possible to plate with a closed loop system because a high risk of ruining parts due to poor water quality exists. This could result in a high reject rate whose costs exceed those of the water, pretreatment and sewer cost savings.

Other Pollution Prevention Projects
The large hand zinc line has been converted to alkaline non-cyanide zinc. NICO intends to convert the automatic zinc lines to alkaline non-cyanide zinc within the year. They have also tried a prototype alkaline non-cyanide copper solution. Although NICO has experienced some problems with the alkaline non-cyanide copper solution, they plan to switch to a non-cyanide solution within the next several years. This will eliminate the majority of cyanide used by NICO.

NICO will be changing all of the chromium plating tanks from hexavalent to trivalent chromium. Currently, many of the chromates they are using are trivalent chromium. NICO has found that their trivalent solutions last longer, which allows them to replace solutions once every 2 to 3 weeks instead of twice a day.

Lastly, NICO is exploring alternatives to the trichloroethylene now used for degreasing. MnTap is assisting NICO in researching alternative solvents.

Tips for Other Platers
NICO has incorporated many types of rinsing into its plating operations including countercurrent, dead and spray rinses. These changes have reduced NICO's water consumption while maintaining quality finishes. NICO demonstrated how a relatively simple water study may allow the water usage in the individual rinses to be calculated. These flow rates can then be used to identify areas where water consumption could be reduced. Reuse of water as a means to further reduce water consumption is also possible.

NICO personnel stressed the need for platers to allow ample space for the use of countercurrent and dead rinses. They have found that countercurrent rinsing performs much better than single rinses.

NICO personnel also stated that a balance between the use of automatic lines and manual plating lines needs to be established. Manual lines can produce less dragout than automatic lines if the operators are properly trained and the equipment and process is set up correctly. This leads to the next tip: have a stable work force. It is important to train the employees properly, to have experienced personnel and high employee retention. This will result in quality work and a reduction in the wastes associated with performing plating finishes.

NICO is also working on other areas of its processes to identify waste reduction opportunities and to reduce the impact of environmental regulations on its operations. However, when changes are made, it is important to remember that the quality of the product must be maintained. The production of rejects which must stripped and replated can quickly offset any benefits gained by the changes.

D.4. Dugas-Bowers Plating Case Study

Dugas-Bowers Plating of Fridley, Minnesota, is a electroplating job shop which has been in business for 8 years. They have incorporated the use of dead, counter current and spray rinses into their plating lines. Dugas Bowers also has the capability to easily modify their rinses for any given job to ensure that rinsing quality is maintained and water usage remains low (3,000 to 5,000 gallons per day). This case study has been developed to provide information to other electroplaters considering alternative rinsing practices.

Background Information

Dugas-Bowers plates both alkaline non-cyanide zinc and cyanide zinc on two separate plating lines. They have twelve employees and operate on three shifts 5 to 6 days per week. The smaller, older line is manually operated and is used for plating cyanide zinc. The automated line was installed 2 years ago and is used for plating alkaline non-cyanide zinc. Dugas-Bowers also uses yellow, black and clear chrome sealers.

Water Reduction and Reuse

Originally, plating lines were operated with flowing rinses. In an effort to conserve bath solution, reduce water usage, minimize pretreatment costs and provide quality rinsing, Dugas-Bowers began experimenting with alternative rinsing techniques in 1990.

Dead rinses were first installed in 1985 to recover the initial dragout from the plating baths. The dragout is fed back into the heated plating tanks as make-up water. Spray rinses were later added to the plating lines in 1990 since the spray rinses work well in cleaning any holes which may exist on the parts. The spray rinses on the automated line are equipped with trigger switches that automatically turn the spray system on and off when parts are spray rinsed. The manual line is equipped with foot pedals that allow the operator to turn the spray system on and off as needed. Dugas-Bowers has designed their plating lines to be flexible so that the rinses can be modified to provide the most effective and water efficient rinsing of any parts received. Line speeds have not been affected by any of the rinsing changes implemented.

Other Pollution Prevention Projects
With the use of the alkaline non-cyanide zinc Dugas-Bowers has been able to replace hexavalent chrome sealers with trivalent sealers. Occasionally hexavalent chrome is run on the manual line as requested by customers, but this seldom occurs.

Dugas-Bowers has also eliminated vapor degreasing operations at their facility.

Tips for Other Platers
Dugas-Bowers has successfully limited their water consumption through the use of dead, spray and counter current rinses. They encourage other platers to build some flexibility into their plating lines to allow the layout of the rinsing tanks to be modified to provide the most effective rinsing while minimizing water consumption.

E. Summary and Conclusions

The majority of information uncovered in our literature search for alternative non-cyanide electroplating solutions search revealed that the most promising alternatives currently exist for zinc and copper solutions. Non-cyanide replacements for zinc solutions include alkaline zinc and acid zinc. Alkaline zinc is favored by many platers since it is far less corrosive to equipment and can be incorporated into existing lines without major modifications. However, the alkaline zinc can be more prone to post blistering especially at coatings greater than 0.5 mils. Companies or clients that have experienced any post blistering problems in the past may be more reluctant to accept non-cyanide alternatives.

Non-cyanide replacements for copper include acid sulfate copper, pyrophosphate copper, alkaline copper, copper fluoroborate and electroless nickel. Acid sulfate copper solutions are highly corrosive and hard on plating equipment. This solution may also attack base metals, thus requiring the application of strike coatings on the parts. Pyrophosphate copper solution requires longer plating time and has a limited life. Alkaline copper worked well on a number of base metals including zinc diecasts but may require additional cleaning and process control.

The copper fluoroborate and electroless nickel plating processes may be more expensive and difficult to control.

Information for alternative solutions for silver, gold, and cadmium solutions was also located. Alternative gold and silver solutions appear to require more research in stabilizing these solutions and defining their applications before they can be widely used as replacement solutions.

It is important to note that an overall concern exists for all alternative non-cyanide solutions discussed in this report. This concern centers on the additional cleaning that may be required when the intrinsic cleaning capability of cyanide is lost. Companies with limited space may find it difficult to convert to non-cyanide solutions due to a lack of space for additional cleaning. Peerless Chain demonstrated that the loss of the cleaning capability of cyanide can be compensated for by carefully planning and implementing of alternative solutions. They also point out that the alternatives can also serve as an opportunity to take more control over the plating operations.

For companies which cannot convert to non-cyanide solutions, alternative rinsing practices can greatly reduce the generation of cyanide-laden wastewaters at their facility. Alternative rinsing practices center on the concepts of dragout control and water conservation. Case studies developed as part of this research project document significant savings of water through the use of flow restricters, counter current rinsing, spray rinsing and water reuse.

Of the 33 electroplating firms using cyanide based solutions that participated in our telephone survey, the majority were plating zinc, copper, gold or silver cyanide. Their input confirmed the information revealed in the information search and case studies.

The survey was also used as an opportunity for the platers to state what assistance they would like to see from the OWM. The most frequent response was one of OWM facilitating and fostering a better relationship with industry. They felt that more patience was needed on the part of the OWM in implementing pollution prevention opportunities and that more positive recognition of their good faith efforts was needed. Some respondents also expressed the need for the OWM to get more input from industry to understand their operational limitations.

Many respondents also indicated that a more uniform and streamlined approach to environmental regulations in the state was necessary. A great deal of confusion exists in Minnesota on what role the various environmental agencies within the state play and the duplication of some agencies efforts. Respondents were generally aware that OWM and MnTAP are not regulatory in nature, but some companies expressed reluctant to work with either organization. They were concerned about information given to a state agency or program could be passed along to the regulatory agencies resulting in enforcement actions, or that the information may be used to develop additional regulations that will make it harder for them to operate their manufacturing processes. Responses such as requesting a non-biased reliable source of current information may indicate that confusion over the roles of OWM and MnTAP or the lack of awareness of the MnTAP program exists. An effort to educate Minnesota industries on the functions and services of both programs, as well as their relationships to regulatory agencies, may alleviate these concerns and confusion.

Respondents also requested tax reduction incentives for companies implementing pollution prevention measures, seminars specifically focusing on concerns of the electroplating industry, a focusing of education efforts for change at the end user (consumer) level, assistance in creating a market for products plated with non-cyanide solutions and the continuation of OWM performing and sponsoring research activities.

References

Aleksinas, Michael, "Direct Plating of Zinc Die Casts with Electroless Nickel", Sur/Fin 85, Session K.

Banham, John, 1986, "Meeting the Need for Pure Water in Plating", *Finishing*, Volume 10, Number 7.

Dargis, Raymond G., April 1988, "Zinc Plating - Entrenchments and Trends", *Products Finishing*.

Dowd, Patrick M., May 1985, "Conserving Water and Segregating Waste Streams", *Plating and Surface Finishing*.

Durney, Lawrence J., *Electroplating Engineering Handbook*, Van Nostrand Reinhold Company, 4th Edition, New York, pages 691-709.

Electrochemical Products, Inc., April 1992, Technical Data Sheet "Non-Cyanide Alkaline Copper Plating".

Finishers' Management, June/July 1989, "Cyanide-to-Noncyanide Switch: How Bowers Mfg. Planned for Success".

Frank, James M., R.O. Hull, "New Improvements in Decorative Copper Plating", Symposium 78, Decorative Plating.

Hall, E.P., D.J. Lizdas, and E.E. Auerbach, February 1979, "Recovery Techniques in Electroplating", *Plating and Surface Finishing*.

Hradil, Edward F., "Cyanide and Non-Cyanide Silver Electroplating", Sur/Fin 84, Session R.

Hughes D.A., November 11, 1991, Memo "Gold Electroplating Facilities within the DOE Complex".

Hughes, D.A., W. Worobey, W.D. Bonivert, and R.D. Mikkola, February 1992, "Replacement of Cyanide Containing Electroplating Solutions within the DOE Weapons Complex", submitted to *the International Journal of Environmentally Conscious Manufacturing*.

Humphreys, Paul G., May 1989, "New Line Plates Non-Cyanide Cadmium", *Products Finishing*.

Hunt, Gary E., and Richard W. Walters, June 1984, "Cost-Effective Waste Management for Metal Finishing Facilities: Selected Case Studies", *39th Purdue Industrial Waste Conference.*

Kessler, R., "Alkaline Non-Cyanide Zinc Plating", *Proceedings of the Symposium 77.*

Kondo, Tetsuya, Seishi Masaki, Hiroyuki Inoue, and Koji Yamakawa, October 1991, "Silver Plating from Silver Methanesulfonate-Potassium Iodide Bath," *Metal Finishing.*

Krumbein, S.J., L.B. Lerner, A.H. Reed, "A New Silver Plating Bath Containing No Free Cyanide for Electronic Applications", Sur/Fin 80, Session F.

Kushner, Joseph B., January 1955, "Rinsing Techniques", *Metal Finishing.*

Martinez, F.E. November 22, 1991, Memo "Plating Experience at SNL Albuquerque Using Gold Sulfite Chemistries".

McGeorge, Marilyn, April 1988, "Enviroscope: Agony and Ecstasy of Process Change", *Plating and Surface Finishing.*

Mohler, J.B., July 1985, "Rinsing Economy", *Metal Finishing.*

North Carolina Pollution Prevention Pays Program, *Pollution Prevention Tips Fact Sheet* "Dragout Management for Electroplaters".

Pagel, Paul, June 1990, "Waste Reduction at a Printed Circuit Board Manufacturing Facility Using Modified Rinsing Technologies", Clean Technologies Conference.

Poll, Gerard H. Jr, April 1987, "The Case for Alkaline Non-Cyanide Zinc", *Products Finishing.*

Poll, Gerard H. Jr., April 1988, "Zinc Plating/88", *Products Finishing.*

Roy, Clarence H., December 1973, "The Effect of Water Conservation on Quality Plating", *Plating.*

Tomaszewski, L.C., Robert A. Tremmel, "New Alkaline Copper Process: A Novel Alternative to Cyanide Copper", Sur/Fin 85, Session D.

Tweed, Rexford E., July 1968, "Rinsing Practices", *Metal Finishing.*

Vaidya, N., John McCormack, "High Speed Electroless Copper Plating at Room Temperature", Sur/Fin 79, Session R.

Walker, Charles A., and John A. Tallmadge, May 1959, "Metal Finishing Waste Reduction", *Chemical Engineering Progress*, Volume 55, Number 5.

Appendix A

Alternative Solution Summary

Alternative Solution	Advantages	Disadvantages	Outlook for Solution
Alkaline Zinc	• Good coverage in low-current density areas. • Bright deposits. • Throwing power similar to cyanide solutions. • Use of existing tanks. • Allows for gradual phase-out of cyanide solutions. • Chemical costs similar to cyanide solutions.	• Loss of intrinsic cleaning ability of cyanide. • Harder to plate on cast iron and carbonitrided steel. • Generally require additional filtration.	• Promising for plating under 0.5 mils. Firms using solution must compensate for loss of intrinsic cleaning ability of cyanide and control post-blistering problems.
Acid Zinc	• Faster deposition speed than alkaline zinc solutions. • Yield bright deposits that level surface irregularities. • Plate readily on cost iron and carbonitrided steel. • Less prone to post blistering than alkaline zinc solutions. • Less sensitive to make-up water than alkaline zinc solutions. • Better able to accept chromate sealers than alkaline zinc solutions.	• Loss of intrinsic cleaning ability of cyanide. • Corrosive nature of solutions may require modifications to plating equipment. • Higher maintenance costs. • Additional cooling and filtration equipment may be necessary. • Cannot be gradually phased-in. • Poor throwing power in low-current density areas. • Make-up water may require iron removal.	• Promising for firms willing to provide the necessary modifications and investments in their lines.
Acid Sulfate Copper	• Superior leveling and brightness. • Pretreatment is relatively easy and inexpensive. • Make-up costs are inexpensive. • High plating current densities are possible. • High line speeds are possible. • Only bright copper works well on plastic.	• Corrosivity of both is hard on plating equipment. • Hard to recover dragout. • Poor macro-throwing power. • Solution may attack base metal (strike coatings may be necessary). • Additional cooling equipment may be necessary. • Acid-resistant ventilation systems may be necessary.	• Promising - been around since 1950s and accepted in a wide variety of plating applications.

Alternative Solution	Advantages	Disadvantages	Outlook for Solution
Pyrophosphate Copper	• Excellent throwing power. • Does not attack base metal or plating • Anode bags are not needed. • High deposition of metals.	• High initial solution costs. • May require longer plating times. • problems. • Life of solution is limited.	• Promising - provided the loss of the intrinsic cleaning ability of cyanide is compensated for ... ower to plating time
Alkaline Copper	• Works well on steel, brass, white metal, zinc diecast and zincated aluminum surfaces. • Good throwing power. • Good coverage power.	• Additional cleaning and process controls may be necessary.	• Less promising - more difficult and expensive to operate.
Copper Fluoroborate	• Can accommodate higher line speeds. • More soluble than sulfuric acid.	• May be more expensive to operate and difficult to control.	• Less promising - more difficult and expensive to operate.
Electroless Nickel	• Eliminates need for a copper strike on zinc parts. • Improved coverage capability. • Improved corrosion protection of zinc substrates. • Lower reject rates.	• Plating process much more complex.	• Limited application - tested as alternation to copper/nickel plating on zinc diecasts.
* Ammonium Silver		• Bath generates ammonium hydroxide which poses an exposure concern for line operators.	• Not promising due to worker health and safety concerns.
Halide Silver	• Very stable and easy to operate.	• Light sensitive solution. • Initial cost high for electronic and decorative applications. • Solution is toxic.	• Limited application - since solution is fairly unstable.
Methanesulfonate-Potassium Iodide Silver	• Yields fine grained structured deposits similar to cyanide solutions.	• Not yet developed on a commercial scale.	• Only tested on laboratory scale. No tests in commercial setting have been performed.

* Little or no additional information on these solutions was available at the time of this research project.

Alternative Solution	Advantages	Disadvantages	Outlook for Solution
* Amino or Thio-Complex Silver		• Readiness of thiosulfate ions to be oxidized. • Low current density area may be discolored.	• Not promising. At one time widely marketed but has been withdrawn.
No Free Cyanide Silver	• Developed specifically for electronics industry. • Good contact properties. • Less susceptible to tarnishing. • Silver can be precipitated as AgCN and reused. • Neutral pH and no free cyanide allows for free rinsing.		• Limited test application. Developed for high speed electronics plating.
* Cadmium Chloride			• Cadmium not promising. Plating likely to be phased out due to toxicity of cadmium.
Cadmium Sulfate	• Can produce deposits up to 0.02 inches with good adhesion and density properties.		• Not promising. Cadmium plating likely to be phased out due to toxicity of cadmium.
* Cadmium Fluoroborate			• Not promising. Cadmium plating likely to be phased out due to toxicity of cadmium.
* Cadmium Perchlorate			• Not promising. Cadmium plating likely to be phased out due to toxicity of cadmium.
Gold Sulfite	• Excellent throwing power. • Can plate on complex parts. • Performs as well as gold cyanide solutions.	• Solutions are less stable, therefore require more monitoring and conditioning.	• For electronic application more research is required.
* Cobalt Hardened (No Free Cyanide) Gold	• Works well slide wear applications.	• Deposits are brittle and thermal shock may cause cracking.	• For electronic application more research is required.

* Little or no additional information on these solutions was available at the time of this research project.

Summary of Individual Telephone Survey Results

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
1	Job	Zinc	Steel	Sulfites, Alkalines, Acids	Reusing dead rinses as makeup water for solution tanks. Also replaced flowing rinses with spray rinses.	Using a zinc alkaline solution in addition to zinc cyanide. Working well but for customer specifications cannot completely eliminate zinc cyanide.	High capital costs.	Proven measurable cost savings and success stories from other businesses.	Elimination of vapor degreaser.	Start helping industry.
2	Job	Cadmium, Copper, Zinc	Steel and other parts that customers request be plated.	Sulfites, Alkalines, Acids	Using counter-current rinses, and have investigated spray rinses.	Replaced most of zinc cyanide with zinc alkaline. Are using half or less strength baths.	High capital costs, and potential loss of competitiveness within industry.	Stricter environmental regulations.	Preparing a pollution prevention plan.	Foster more cooperation. Keep industry more informed of reg. info. and research.
3	Job	Brass, Cadmium, Copper, Silver, Zinc	Steel, Copper, Zinc Diecast, Aluminum, Brass, Beryllium Copper	Gold Sulfite, Alkaline Copper, Alkaline Zinc, Acid Zinc	Reusing 15% of treated water from pretreatment system.	Using non-cyanide copper. Does not work on diecasts. Tried non-cyanide zinc solution on steels 2.5 years ago, experienced some post blistering. Currently, evaluating other alkaline zinc solutions for steel.	High capital costs, lack of proven technologies, lack of customer acceptance of alternatives, some solutions more expensive to run.	Stricter environmental regulations, company image.	Replacement of plating lines.	MnTAP has good materials, and OWM has been fairly helpful.
4	Job	Brass, Copper, Zinc	Steel, Brass, Stainless Steel	Sulfites, Alkalines, Acids	Using dead rinses and siphon breakers. Also, are keeping water valves partially closed.	Researched neutral based cadmium solutions. Using a alkaline, and chloride zinc solutions, and an acid cadmium solution. Can plate with alkaline zinc >0.5 mills with some post blistering and yellowing.	Feel they have gone as far as they can. No developments in the areas of non-cyanide copper and brass for their particular uses.	Proven measurable cost savings, stricter environmental regulations, and consultant foresight.	Switched from powder to liquid cleaners to reduce generation of sludge.	Be patient and listen. Feels industry is making good faith efforts to reduce their wastes.
5	Job	Potassium Gold	Copper, Nickel, Brass	None	Using dead rinses and plating out gold for recovery. Investigating spray rinses and other rinsing techniques.	Researched alternative potassium gold solutions. None found.	No alternatives available for the current processing techniques.	Disposal and operational costs.	None	Conduct more technical research.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
6	Job	Zinc	Steel	Alkalines, Acids	Using some closed loop rinses.	Tried non cyanide zinc solutions. Could not plate >0.5 mills without extremely clean parts. Also, experienced some post blistering. Heard that non-cyanide solutions exist which can plate up to 1 mill without post blistering.	Primarily start up costs, and the fact that costs can not be passed on to customers.	Proven measurable costs, stricter environmental regulations, tech. support to recover chrome and zinc through reverse osmosis, and company image.	Recovery of zinc.	Don't know.
7	Job	Cadmium, Copper, Sodium Stripper, Zinc	Steel, Brass	Sulfites, Alkalines, Acids	Using dead rinses and counter-current rinses. Tried spray rinses but were not successful.	Tried alkaline baths but experienced post blistering. Did not pursue further.	Rejects, costs, customers non-acceptance of alternatives.	Proven measurable cost savings, and stricter environmental regulations.	Modifying vapor degreasing operations.	Keep local seminars going.
8	Job	Copper	Copper, Zinc, Precious Metals	Sulfites, Alkalines, Acids	Using counter-current and cascading rinses.	Researching alternatives.	Costs, and regulatory agencies who amend promulgated rules after industry has designed and installed equipment to comply with promulgated rules (hard to redesign or modify for amended rules).	Proven measurable cost savings, worker health and safety issues.	Many	Work closer with facilities and trade associations. Equal regulation and enforcement across the industry.
9	Job	Nickel, Zinc	Steel, Zinc Diecasts, Aluminum	Alkalines, Acids	Using counter-current rinses. Has reduced water consumption from 1981 by 60 -70 %. Also, working on a system to reuse water.	Tried alkaline and acid nickel strippers. The strippers sometimes attacked the base metals. Researched non-cyanide copper, but found that they were not well enough developed.	Start up costs, and fact that these costs cannot be passed on to customers.	Proven measurable cost savings, technical support they have received.	Many	Keep working with facilities.
10	Job	Aluminum Cyanide · Stripper	Aluminum	Sulfites, Alkalines, Acids	Using overflow rinses with agitators.	Replaced cadmium cyanide solution with a zinc dichromate. Will soon be using a zinc cobalt solution.	Education	Genuine concern about the environment and economics.	Many	Return responses promptly.
11	Job	Potassium Copper, Potassium Gold, Nickel	Copper, Nickel	Sulfites, Alkalines, Acids	Using feedback water from dead rinses and counter current rinses.	Researched alternatives, but due to low volume of cyanide plating performed have not pursued. Most cyanide plating operations have been sold.	Large capital investments, no tax breaks, and some waste reduction techniques fall into waste treatment category which generator cannot perform.	Proven measurable cost savings and technical assistance/support.	Many	Get more input from facilities.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
12	Job	Copper	Copper Laminate	Carbon Black	Using flow restricters, dead rinses and cascading rinses.	Researching a carbon black product acceptable for military work.	Meeting military specifications.	Proven measurable cost savings, and stricter environmental regulations.	Always looking at alternatives.	Better facilitation of information transfer, especially new information.
13	Captive	Gold	Nickel	None	Using new system designed with spray rinses, gold recovery, and shut off valves.	Researched alternatives but none were found to be available. Only 2-3 vendors for the circuit board industry.	Lack of available alternatives. Lack of acceptance of potential alternatives by customers.	Vendor recommended, came with equipment purchased.	Reduce number of empty containers must manage.	Focus at the end user level (customers). Pursue financial incentives.
14	Job	Copper, Gold, Silver	Steel, Beryllium Copper	Sulfites, Alkalines, Chlorides	Using flow restricters, tank fill valves, dead rinses, and counter-current rinses.	In-house staff have researched substitutes for silver, and gold cyanide. Found that silver chloride was too photo sensitive and would plate out in tanks. This problem could be solved by adding a chelating agent but could only plate thin films. Will perform silver chloride plating at customers request. Gold sulfite was found to be too unstable. Gold chloride works as a stricter solution.	Financial, reliability of solutions and stability of the regulations.	MRS fees	Many	Help provide a stable regulatory environment.
15	Job	New circuit shop that will be installing a cyanide based plating system in 3 months.	----	None	None	None	----	----	Have not investigated alternatives.	----
16	Job	Zinc	Steel	Acids, Chlorides	None	None	Costs	Proven measurable cost savings.	Some	Tax Breaks
17	Job	Gold	Nickel	None	Using flow restricters and on/off switches for rinse tanks. Also, reusing rinse water.	None	Cost savings are not understood by management.	Proven measurable cost savings and stricter environmental regulations.	Some	Have people available to answer and return calls.
18	Job	Zinc	Steel, Aluminum	None that work well.	Using dead rinses.	None	Finding alternatives that work.	Proven measurable cost savings, stricter environmental regulations, and paper work "red tape".	Some	Stop creating paperwork.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
19	Job	Gold	Copper, Nickel	None	Using counter-current rinses.	None	None	Cost of waste treatment.	—	Facilitate the sharing of knowledge.
20	Job	Silver, Zinc	Brass, Beryllium Copper	Alkalines	Examined alternative rinsing technologies.	None	Costs	Proven measurable cost savings.	Are looking at various operations.	Work more with facilities.
21	Job	Brass, Copper, Silver	Steel, Zinc Diecast, White Metal, Brass	"Damn Few"	Using counter-current rinses for the last 30 years.	Testing non-cyanide copper solutions. 2 years ago, tried non-cyanide silver, which did not work well. Have not found a non-cyanide brass solution for flash brass.	Taxes, and foreign competition that have no environmental controls.	Stricter environmental regulations, high disposal costs, and regulatory threats.	—	Become an active spokesperson for businesses in Mn.
22	Job	Brass, Copper, Sodium Stripper, Zinc	Steel, Brass, Copper	Sulfites, Alkalines, Acids	Using dead rinses.	Tested some non-cyanide brass solutions. Found to work satisfactorily.	None	Stricter environmental regulations.	Alternative cleaners.	Provide seminars regarding the hazards of chemicals used and wastes generated in the plating industry.
23	Job	Copper, Gold, Silver	Steel, Brass, Copper	Sulfites, Alkalines, Acids	Using an evaporator and dead rinses.	Researched non-cyanide gold and copper solutions. Currently, testing non-cyanide copper solutions.	Long time it takes to dispose of wastes (chrome sludge). Also, technical problems of reintroducing contaminants into the plating baths.	Potential to reduce wastewater compliance issues by reducing water usage below 10,000 gallon/day. Would allow company to fall into the pretreatment limitations for electroplaters, which are less stringent.	Have decreased TCE usage in half.	Doesn't feel OWM can help due to conflicting political interest groups.
24	Job	Gold	Copper/Nickel Based Parts	Some Gold Citrate Solutions	Reusing some water from pretreatment system for rinsing. Also, doing other measures which are confidential.	Researched non-cyanide gold solutions, but technology not far enough along yet.	High capital costs. Also, feel that they have gone as they can with the existing technology.	Proven measurable cost savings, stricter environmental regulations and technical assistance/support.	Looking at replacing degreasing operations.	Agencies will tell you when you are in violation, but will not tell you how to correct the violations.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
25	Job	Copper, Gold, Silver	Steel, Aluminum, Brass, Copper Alloys, Diecast	Alkalines, Acids	None	Researching non-cyanide silver. Installed an acid sulfate based copper solution, which they have been able to plate >0.5 mills. Plan by next year to only have one cyanide bath for gold.	Lack of knowledge of environmental regulations. Hard to convince people that a reduction in waste management issues can result in savings.	Worker safety issues, company image and would like to eliminate the need for their waste treatment system.	Converted to aqueous based cleaners.	Have an accessible resource of information for small companies with limited knowledge resource base.
26	Captive	None currently, switched recently to non-cyanide copper solution.	Steel	Sulfites, Alkalines, Acids	None but feel they are limited by space.	Switching from cyanide copper stick solution to an alkaline stick.	None	Stricter environmental regulations, worker safety issues, and environmental problems.	Systems as tight as they can get them.	Be less adversarial and more receptive.
27	Job	Silver	Copper, Pewter, Lead, Brass Alloy	None	None. "Current system works," and are meeting discharge limits.	None	None	Nothing	None and are not planning to focus on in the future.	None
28	Job	Gold, Silver	Copper, Brass	Sulfites, Alkalines, Acids	Using dead rinses and counter-current rinses for the past three years.	Converted to alkaline zinc solution three years ago.	None	Economics	Are examining other areas.	None
29	Job	Cadmium, Zinc	Steel	Sulfites, Alkalines, Acids	Using counter-current rinses, and flow meters. Working on reuse, but have had limited success.	Tested alkaline zinc and cadmium solutions but were unable to meet customer specifications.	Have not found non-cyanide solutions that will meet customer specifications.	Stricter environmental regulations, and paper work "red tape".	Many	Too many regulatory agencies to report to. Need for a single regulatory agency.
30	Job	Copper	Steel, Zinc Diecast, Brass	Alkaline Copper	Using flow restricters, flow controllers, and shut off valves which has reduced water usage by 2/3.	Following the progress of non-cyanide copper (alkaline) solutions which are being tested in another facility. If found to work, will also be testing.	Costs and technical issues of determining the most cost effective alternatives.	Small fine issued by the MWCC.	Are investigating several areas.	State a course and help develop markets for recycling. Need more information on reuse of rinse waters.
31	Captive	Gold	Gold	None	Reusing some treated waters. Also are using flow restricters and ion sensors.	Have spoken with suppliers but high pH compatibility problems with alternative solutions.	Technical issues, and a learning curve that involves risk.	Company image and costs.	—	Help pool experiences while protecting proprietary information and make information available.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
32	Captive	Gold	Nickel	None	Examining alternative rinsing methods.	None	Layout of plant would need to be redesigned before they could implement modifications.	Proven measurable cost savings and stricter environmental regulations.	—	Visit facilities to see operations to get picture of actual working conditions.
33	Job	Cadmium Titanium	Steel	None	Using a double dead rinse.	None	Meeting customer specifications	Customer modifying specifications.	None	Come up with a solid waste bath filter that is reusable or recyclable.

Peerless Case Study Outline

Intro: Background information on what Peerless produces and their manufacturing operations.

Information to include quality requirements, solution maintenance, rinsing practices...

A. Issues that prompted Peerless to consider alternative non-cyanide plating solutions.

What motivated the company to look at alternatives? (Worker Safety Issues, Pretreatment Costs...)

What factors do you see that are motivating metal finishers to examine alternatives?

Where did the idea of considering alternatives originate from?

What were or are your colleagues within the electroplating industry doing?

B. Management support in examining alternatives.

What level of support was needed from management for this project?

Whose approval was needed to pursue this project, and what information was needed to convince management to change?

C. Employee participation and support in examining alternatives.

Were line operators involved in suggesting alternatives?

Was a pollution prevention team formed to study possible alternatives?

D. Steps taken in identifying alternatives.

How was information on alternatives found? (Vendors, Seminars, Trade Associations...)

How was vendor information/claims screened?

What type and level of assistance did vendors supply?

What other assistance was received (other than from vendors)?

Were other zinc electroplaters contacted for information?

E. Feasibility Analysis

1. Technical

How were pilot studies designed and implemented?

How were alternative solutions selected? (Selection Criteria)

What problems were found with potential substitutes, and experienced in the pilot studies or implementation phase of the project?

Who conducted the technical analysis?

2. Economic

Documentation of cost savings (solutions, waste treatment...).

Documentation of costs (capital expenditures).

Quantification on staff time spent on project.

F. Implementation and evaluation of alternative solutions.

What problems were found with potential substitutes, and experienced in the pilot studies or implementation phase of the project?

How were alternatives accepted by the line operators? (Was additional training provided...)

How does the zinc alkaline solution life compare to that of zinc cyanide?

Were line speeds affected by the switch to alkaline zinc?

How are the zinc alkaline solutions maintained and how does this compare with the zinc cyanide solutions?

How were products accepted by customers after the zinc plating lines were converted (quality issues such as thickness, appearance...)?

G. Future pollution prevention opportunities that Peerless will be pursuing.

What other processes or chemicals currently operating or being used at your facility are being targeted for elimination by environmental agencies or for environmental concerns (i.e. CFCs, Worker Health Safety Issues, Product Safety...)?

H. Summary

Emphasis on how Peerless results apply to other facilities (key details, suggestions on modifications, pitfalls to watch out for, educational needs...).

Appendix A

Alternative Solution Summary

Alternative Solution	Advantages	Disadvantages	Outlook for Solution
Alkaline Zinc	• Good coverage in low-current density areas. • Bright deposits. • Throwing power similar to cyanide solutions. • Use of existing tanks. • Allows for gradual phase-out of cyanide solutions. • Chemical costs similar to cyanide solutions.	• Loss of intrinsic cleaning ability of cyanide. • Harder to plate on cast iron and carbonitrided steel. • Generally require additional filtration.	• Promising for plating under 0.5 mils. Firms using solution must compensate for loss of intrinsic cleaning ability of cyanide and control post-blistering problems.
Acid Zinc	• Faster deposition speed than alkaline zinc solutions. • Yield bright deposits that level surface irregularities. • Plate readily on cost iron and carbonitrided steel. • Less prone to post blistering than alkaline zinc solutions. • Less sensitive to make-up water than alkaline zinc solutions. • Better able to accept chromate sealers than alkaline zinc solutions.	• Loss of intrinsic cleaning ability of cyanide. • Corrosive nature of solutions may require modifications to plating equipment. • Higher maintenance costs. • Additional cooling and filtration equipment may be necessary. • Cannot be gradually phased-in. • Poor throwing power in low-current density areas. • Make-up water may require iron removal.	• Promising for firms willing to provide the necessary modifications and investments in their lines.
Acid Sulfate Copper	• Superior leveling and brightness. • Pretreatment is relatively easy and inexpensive. • Make-up costs are inexpensive. • High plating current densities are possible. • High line speeds are possible. • Only bright copper works well on plastic.	• Corrosivity of both is hard on plating equipment. • Hard to recover dragout. • Poor macro-throwing power. • Solution may attack base metal (strike coatings may be necessary). • Additional cooling equipment may be necessary. • Acid-resistant ventilation systems may be necessary.	• Promising - been around since 1950s and accepted in a wide variety of plating applications.

Alternative Solution	Advantages	Disadvantages	Outlook for Solution
Pyrophosphate Copper	• Excellent throwing power. • Does not attack base metal or plating equipment. • Dragout recovery is possible. • Pretreatment is relatively easy. • Excellent subsequent plating adhesion. • Anode bags are not needed. • High deposition of metals.	• High initial solution costs. • May require longer plating times. • Steel and zinc parts require copper-cyanide strike. • May contain significant amounts of ammonia that may pose pretreatment problems. • Life of solution is limited.	• Promising - provided the loss of the intrinsic cleaning ability of cyanide is compensated for and production speed can be lower to compensate for the longer plating time required.
Alkaline Copper	• Works well on steel, brass, white metal, zinc diecast and zincated aluminum surfaces. • Good throwing power. • Good coverage power.	• Additional cleaning and process controls may be necessary.	• Less promising - more difficult and expensive to operate.
Copper Fluoroborate	• Can accommodate higher line speeds. • More soluble than sulfuric acid.	• May be more expensive to operate and difficult to control.	• Less promising - more difficult and expensive to operate.
Electroless Nickel	• Eliminates need for a copper strike on zinc parts. • Improved coverage capability. • Improved corrosion protection of zinc substrates. • Lower reject rates.	• Plating process much more complex.	• Limited application - tested as alternation to copper/nickel plating on zinc diecasts.
* Ammonium Silver		• Bath generates ammonium hydroxide which poses an exposure concern for line operators.	• Not promising due to worker health and safety concerns.
Halide Silver	• Very stable and easy to operate.	• Light sensitive solution. • Initial cost high for electronic and decorative applications. • Solution is toxic.	• Limited application - since solution is fairly unstable.
Methanesulfonate-Potassium Iodide Silver	• Yields fine grained structured deposits similar to cyanide solutions.	• Not yet developed on a commercial scale.	• Only tested on laboratory scale. No tests in commercial setting have been performed.

* Little or no additional information on these solutions was available at the time of this research project.

Alternative Solution	Advantages	Disadvantages	Outlook for Solution
* Amino or Thio-Complex Silver		• Readiness of thiosulfate ions to be oxidized. • Low current density area may be discolored.	• Not promising. At one time widely marketed but has been withdrawn.
No Free Cyanide Silver	• Developed specifically for electronics industry. • Good contact properties. • Less susceptible to tarnishing. • Silver can be precipitated as AgCN and reused. • Neutral pH and no free cyanide allows for free rinsing.		• Limited test application. Developed for high speed electronics plating.
* Cadmium Chloride			• Cadmium not promising. Plating likely to be phased out due to toxicity of cadmium.
Cadmium Sulfate	• Can produce deposits up to 0.02 inches with good adhesion and density properties.		• Not promising. Cadmium plating likely to be phased out due to toxicity of cadmium.
* Cadmium Fluoroborate			• Not promising. Cadmium plating likely to be phased out due to toxicity of cadmium.
* Cadmium Perchlorate			• Not promising. Cadmium plating likely to be phased out due to toxicity of cadmium.
Gold Sulfite	• Excellent throwing power. • Can plate on complex parts. • Performs as well as gold cyanide solutions.	• Solutions are less stable, therefore require more monitoring and conditioning.	• For electronic application more research is required.
* Cobalt Hardened (No Free Cyanide) Gold	• Works well slide wear applications.	• Deposits are brittle and thermal shock may cause cracking.	• For electronic application more research is required.

* Little or no additional information on these solutions was available at the time of this research project.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
1	Job	Zinc	Steel	Sulfites, Alkalines, Acids	Reusing dead rinses as makeup water for solution tanks. Also replaced flowing rinses with spray rinses.	Using a zinc alkaline solution in addition to zinc cyanide. Working well but for customer specifications cannot completely eliminate zinc cyanide.	High capital costs.	Proven measurable cost savings and success stories from other businesses.	Elimination of vapor degreaser.	Start helping industry.
2	Job	Cadmium, Copper, Zinc	Steel and other parts that customers request be plated.	Sulfites, Alkalines, Acids	Using counter-current rinses, and have investigated spray rinses.	Replaced most of zinc cyanide with zinc alkaline. Are using half or less strength baths.	High capital costs, and potential loss of competitiveness within industry.	Stricter environmental regulations.	Preparing a pollution prevention plan.	Foster more cooperation. Keep industry more informed of reg. info. and research.
3	Job	Brass, Cadmium, Copper, Silver, Zinc	Steel, Copper, Zinc Diecast, Aluminum, Brass, Beryllium Copper	Gold Sulfite, Alkaline Copper, Alkaline Zinc, Acid Zinc	Reusing 15% of treated water from pretreatment system.	Using non-cyanide copper. Does not work on diecasts. Tried non-cyanide zinc solution on steels 2.5 years ago, experienced some post blistering. Currently, evaluating other alkaline zinc solutions for steel.	High capital costs, lack of proven technologies, lack of customer acceptance of alternatives, some solutions more expensive to run.	Stricter environmental regulations, company image.	Replacement of plating lines.	MnTAP has good materials, and OWM has been fairly helpful.
4	Job	Brass, Copper, Zinc	Steel, Brass, Stainless Steel	Sulfites, Alkalines, Acids	Using dead rinses and siphon breakers. Also, are keeping water valves partially closed.	Researched neutral based cadmium solutions. Using a alkaline, and chloride zinc solutions, and an acid cadmium solution. Can plate with alkaline zinc >0.5 mills with some post blistering and yellowing.	Feel they have gone as far as they can. No developments in the areas of non-cyanide copper and brass for their particular uses.	Proven measurable cost savings, stricter environmental regulations, and consultant foresight.	Switched from powder to liquid cleaners to reduce generation of sludge.	Be patient and listen. Feels industry is making good faith efforts to reduce their wastes.
5	Job	Potassium Gold	Copper, Nickel, Brass	None	Using dead rinses and plating out gold for recovery. Investigating spray rinses and other rinsing techniques.	Researched alternative potassium gold solutions. None found.	No alternatives available for the current processing techniques.	Disposal and operational costs.	None	Conduct more technical research.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
6	Job	Zinc	Steel	Alkalines, Acids	Using some closed loop rinses.	Tried non cyanide zinc solutions. Could not plate >0.5 mills without extremely clean parts. Also, experienced some post blistering. Heard that non-cyanide solutions exist which can plate up to 1 mill without post blistering.	Primarily start up costs, and the fact that costs can not be passed on to customers.	Proven measurable costs, stricter environmental regulations, tech. support to recover chrome and zinc through reverse osmosis, and company image.	Recovery of zinc.	Don't know.
7	Job	Cadmium, Copper, Sodium Stripper, Zinc	Steel, Brass	Sulfites, Alkalines, Acids	Using dead rinses and counter-current rinses. Tried spray rinses but were not successful.	Tried alkaline baths but experienced post blistering. Did not pursue further.	Rejects, costs, customers non-acceptance of alternatives.	Proven measurable cost savings, and stricter environmental regulations.	Modifying vapor degreasing operations.	Keep local seminars going.
8	Job	Copper	Copper, Zinc, Precious Metals	Sulfites, Alkalines, Acids	Using counter-current and cascading rinses.	Researching alternatives.	Costs, and regulatory agencies who amend promulgated rules after industry has designed and installed equipment to comply with promulgated rules (hard to redesign or modify for amended rules).	Proven measurable cost savings, worker health and safety issues.	Many	Work closer with facilities and trade associations. Equal regulation and enforcement across the industry.
9	Job	Nickel, Zinc	Steel, Zinc Diecasts, Aluminum	Alkalines, Acids	Using counter-current rinses. Has reduced water consumption from 1981 by 60 -70 %. Also, working on a system to reuse water.	Tried alkaline and acid nickel strippers. The strippers sometimes attacked the base metals. Researched non-cyanide copper, but found that they were not well enough developed.	Start up costs, and fact that these costs cannot be passed on to customers.	Proven measurable cost savings, technical support they have received.	Many	Keep working with facilities.
10	Job	Aluminum Cyanide · Stripper	Aluminum	Sulfites, Alkalines, Acids	Using overflow rinses with agitators.	Replaced cadmium cyanide solution with a zinc dichromate. Will soon be using a zinc cobalt solution.	Education	Genuine concern about the environment and economics.	Many	Return responses promptly.
11	Job	Potassium Copper, Potassium Gold, Nickel	Copper, Nickel	Sulfites, Alkalines, Acids	Using feedback water from dead rinses and counter current rinses.	Researched alternatives, but due to low volume of cyanide plating performed have not pursued. Most cyanide plating operations have been sold.	Large capital investments, no tax breaks, and some waste reduction techniques fall into waste treatment category which generator cannot perform.	Proven measurable cost savings and technical assistance/support.	Many	Get more input from facilities.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
12	Job	Copper	Copper Laminate	Carbon Black	Using flow restricters, dead rinses and cascading rinses.	Researching a carbon black product acceptable for military work.	Meeting military specifications.	Proven measurable cost savings, and stricter environmental regulations.	Always looking at alternatives.	Better facilitation of information transfer, especially new information.
13	Captive	Gold	Nickel	None	Using new system designed with spray rinses, gold recovery, and shut off valves.	Researched alternatives but none were found to be available. Only 2-3 vendors for the circuit board industry.	Lack of available alternatives. Lack of acceptance of potential alternatives by customers.	Vendor recommended, came with equipment purchased.	Reduce number of empty containers must manage.	Focus at the end user level (customers). Pursue financial incentives.
14	Job	Copper, Gold, Silver	Steel, Beryllium Copper	Sulfites, Alkalines, Chlorides	Using flow restricters, tank fill valves, dead rinses, and counter-current rinses.	In-house staff have researched substitutes for silver, and gold cyanide. Found that silver chloride was too photo sensitive and would plate out in tanks. This problem could be solved by adding a chelating agent but could only plate thin films. Will perform silver chloride plating at customers request. Gold sulfite was found to be too unstable. Gold chloride works as a stricter solution.	Financial, reliability of solutions and stability of the regulations.	MRS fees	Many	Help provide a stable regulatory environment.
15	Job	New circuit shop that will be installing a cyanide based plating system in 3 months.	-----	None	None	None	-----	-----	Have not investigated alternatives.	-----
16	Job	Zinc	Steel	Acids, Chlorides	None	None	Costs	Proven measurable cost savings.	Some	Tax Breaks
17	Job	Gold	Nickel	None	Using flow restricters and on/off switches for rinse tanks. Also, reusing rinse water.	None	Cost savings are not understood by management.	Proven measurable cost savings and stricter environmental regulations.	Some	Have people available to answer and return calls.
18	Job	Zinc	Steel, Aluminum	None that work well.	Using dead rinses.	None	Finding alternatives that work.	Proven measurable cost savings, stricter environmental regulations, and paper work "red tape".	Some	Stop creating paperwork.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
19	Job	Gold	Copper, Nickel	None	Using counter-current rinses.	None	None	Cost of waste treatment.	—	Facilitate the sharing of knowledge.
20	Job	Silver, Zinc	Brass, Beryllium Copper	Alkalines	Examined alternative rinsing technologies.	None	Costs	Proven measurable cost savings.	Are looking at various operations.	Work more with facilities.
21	Job	Brass, Copper, Silver	Steel, Zinc Diecast, White Metal, Brass	"Damn Few"	Using counter-current rinses for the last 30 years.	Testing non-cyanide copper solutions. 2 years ago, tried non-cyanide silver, which did not work well. Have not found a non-cyanide brass solution for flash brass.	Taxes, and foreign competition that have no environmental controls.	Stricter environmental regulations, high disposal costs, and regulatory threats.	—	Become an active spokesperson for businesses in Mn.
22	Job	Brass, Copper, Sodium Stripper, Zinc	Steel, Brass, Copper	Sulfites, Alkalines, Acids	Using dead rinses.	Tested some non-cyanide brass solutions. Found to work satisfactorily.	None	Stricter environmental regulations.	Alternative cleaners.	Provide seminars regarding the hazards of chemicals used and wastes generated in the plating industry.
23	Job	Copper, Gold, Silver	Steel, Brass, Copper	Sulfites, Alkalines, Acids	Using an evaporator and dead rinses.	Researched non-cyanide gold and copper solutions. Currently, testing non-cyanide copper solutions.	Long time it takes to dispose of wastes (chrome sludge). Also, technical problems of reintroducing contaminants into the plating baths.	Potential to reduce wastewater compliance issues by reducing water usage below 10,000 gallon/day. Would allow company to fall into the pretreatment limitations for electroplaters, which are less stringent.	Have decreased TCE usage in half.	Doesn't feel OWM can help due to conflicting political interest groups.
24	Job	Gold	Copper/Nickel Based Parts	Some Gold Citrate Solutions	Reusing some water from pretreatment system for rinsing. Also, doing other measures which are confidential.	Researched non-cyanide gold solutions, but technology not far enough along yet.	High capital costs. Also, feel that they have gone as they can with the existing technology.	Proven measurable cost savings, stricter environmental regulations and technical assistance/support.	Looking at replacing degreasing operations.	Agencies will tell you when you are in violation, but will not tell you how to correct the violations.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
25	Job	Copper, Gold, Silver	Steel, Aluminum, Brass, Copper Alloys, Diecast	Alkalines, Acids	None	Researching non-cyanide silver. Installed an acid sulfate based copper solution, which they have been able to plate >0.5 mills. Plan by next year to only have one cyanide bath for gold.	Lack of knowledge of environmental regulations. Hard to convince people that a reduction in waste management issues can result in savings.	Worker safety issues, company image and would like to eliminate the need for their waste treatment system.	Converted to aqueous based cleaners.	Have an accessible resource of information for small companies with limited knowledge resource base.
26	Captive	None currently, switched recently to non-cyanide copper solution.	Steel	Sulfites, Alkalines, Acids	None but feel they are limited by space.	Switching from cyanide copper stick solution to an alkaline stick.	None	Stricter environmental regulations, worker safety issues, and environmental problems.	Systems as tight as they can get them.	Be less adversarial and more receptive.
27	Job	Silver	Copper, Pewter, Lead, Brass Alloy	None	None. "Current system works," and are meeting discharge limits.	None	None	Nothing	None and are not planning to focus on in the future.	None
28	Job	Gold, Silver	Copper, Brass	Sulfites, Alkalines, Acids	Using dead rinses and counter-current rinses for the past three years.	Converted to alkaline zinc solution three years ago.	None	Economics	Are examining other areas.	None
29	Job	Cadmium, Zinc	Steel	Sulfites, Alkalines, Acids	Using counter-current rinses, and flow meters. Working on reuse, but have had limited success.	Tested alkaline zinc and cadmium solutions but were unable to meet customer specifications.	Have not found non-cyanide solutions that will meet customer specifications.	Stricter environmental regulations, and paper work "red tape".	Many	Too many regulatory agencies to report to. Need for a single regulatory agency.
30	Job	Copper	Steel, Zinc Diecast, Brass	Alkaline Copper	Using flow restricters, flow controllers, and shut off valves which has reduced water usage by 2/3.	Following the progress of non-cyanide copper (alkaline) solutions which are being tested in another facility. If found to work, will also be testing.	Costs and technical issues of determining the most cost effective alternatives.	Small fine issued by the MWCC.	Are investigating several areas.	State a course and help develop markets for recycling. Need more information on reuse of rinse waters.
31	Captive	Gold	Gold	None	Reusing some treated waters. Also are using flow restricters and ion sensors.	Have spoken with suppliers but high pH compatibility problems with alternative solutions.	Technical issues, and a learning curve that involves risk.	Company image and costs.	----	Help pool experiences while protecting proprietary information and make information available.

Contact	Shop Type	Cyanide Solutions Plated	Base Metals	Known Alternative Solutions	Rinsing Modifications	Pollution Prevention Options Examined	Industry Barriers	Issues Would or Have Prompted You to Examine Alternatives	Future Pollution Prevention Targets	Advice to OWM in Assisting Industry With Pollution Prevention
32	Captive	Gold	Nickel	None	Examining alternative rinsing methods.	None	Layout of plant would need to be redesigned before they could implement modifications.	Proven measurable cost savings and stricter environmental regulations.	—	Visit facilities to see operations to get picture of actual working conditions.
33	Job	Cadmium Titanium	Steel	None	Using a double dead rinse.	None	Meeting customer specifications	Customer modifying specifications.	None	Come up with a solid waste bath filter that is reusable or recyclable.

Peerless Case Study Outline

Intro: Background information on what Peerless produces and their manufacturing operations.

Information to include quality requirements, solution maintenance, rinsing practices...

A. Issues that prompted Peerless to consider alternative non-cyanide plating solutions.

What motivated the company to look at alternatives? (Worker Safety Issues, Pretreatment Costs...)

What factors do you see that are motivating metal finishers to examine alternatives?

Where did the idea of considering alternatives originate from?

What were or are your colleagues within the electroplating industry doing?

B. Management support in examining alternatives.

What level of support was needed from management for this project?

Whose approval was needed to pursue this project, and what information was needed to convince management to change?

C. Employee participation and support in examining alternatives.

Were line operators involved in suggesting alternatives?

Was a pollution prevention team formed to study possible alternatives?

D. Steps taken in identifying alternatives.

How was information on alternatives found? (Vendors, Seminars, Trade Associations...)

How was vendor information/claims screened?

What type and level of assistance did vendors supply?

What other assistance was received (other than from vendors)?

Were other zinc electroplaters contacted for information?

E. Feasibility Analysis

1. Technical

How were pilot studies designed and implemented?

How were alternative solutions selected? (Selection Criteria)

What problems were found with potential substitutes, and experienced in the pilot studies or implementation phase of the project?

Who conducted the technical analysis?

2. Economic

Documentation of cost savings (solutions, waste treatment...).

Documentation of costs (capital expenditures).

Quantification on staff time spent on project.

F. Implementation and evaluation of alternative solutions.

What problems were found with potential substitutes, and experienced in the pilot studies or implementation phase of the project?

How were alternatives accepted by the line operators? (Was additional training provided...)

How does the zinc alkaline solution life compare to that of zinc cyanide?

Were line speeds affected by the switch to alkaline zinc?

How are the zinc alkaline solutions maintained and how does this compare with the zinc cyanide solutions?

How were products accepted by customers after the zinc plating lines were converted (quality issues such as thickness, appearance...)?

G. Future pollution prevention opportunities that Peerless will be pursuing.

What other processes or chemicals currently operating or being used at your facility are being targeted for elimination by environmental agencies or for environmental concerns (i.e. CFCs, Worker Health Safety Issues, Product Safety...)?

H. Summary

Emphasis on how Peerless results apply to other facilities (key details, suggestions on modifications, pitfalls to watch out for, educational needs...).