POLLUTION PREVENTION

AT AN AGING MIDWESTERN MANUFACTURING FACILITY

This report describes the results of an Industrial Pollution Prevention Project (IP3) demonstration project in Nebraska. The goal of the project was to demonstrate the adoption of pollution prevention (P2) practices by a rural and aging manufacturing facility.

INTRODUCTION

The manufacturing facility is located in a predominantly agricultural area. The plant site is a 100 acre area on which several buildings are located -- the largest of which is the manufacturing facility (805,000 square feet). The facility produces fabricated metal products for farm and industrial uses including structural steel members and plates, farm gates, fencing, and livestock watering tanks, in addition to a wide variety of structural bolts, fasteners, etc. Because of the nature of its manufacturing, the facility is licensed as a hazardous waste generator and is permitted under the RCRA and NPDES systems.

In its various manufacturing processes, the facility performs many operations including electroplating, conversion coating, cleaning, machining, grinding, impact deformation, shearing, welding, sand blasting, hot-dip coating, painting, assembly and testing. Many of these processes result in the production of a variety of pollutants that have to be disposed of in some fashion depending on their nature. For example, the electroplating line results in the production of acids and rinse water containing zinc and chromium, and the hot-dip galvanizing process results in the production of acids and rinse water containing zinc, lead, and iron, which must be treated as a hazardous substance containing heavy metals. The painting processes result in the production of used industrial cleaners, acids, solvents, and chemicals used in the cleaning and degreasing of metal components.

All process wastewaters produced at this facility are treated in accordance with stipulations of the discharge permit. The wastewater is treated by lime and polymer addition and pH adjustment before discharge. In the past, waste disposal at this facility has resulted in potential problems to both surface and ground water resources in the area. The waste disposal systems at the facility constitute a major expense. The management at the facility recognized that the economic viability of the facility depended on reducing pollution control expenses and lowering or eliminating the burden of regulation the company must endure.

P2 OPPORTUNITY ASSESSMENT

A work plan for the P2 assessment program was developed identifying several tasks, including:

1. Development of a detailed assessment and evaluation of current practices and characterization of all wastes produced by the facility.

2. Identification and delineation of all possible P2 opportunities.

3. Economic and technical evaluation of all waste prevention and minimization alternatives including short-term as well as long-term impacts of these alternatives.

4. Development of recommendations to be made to the management of the manufacturing facility for P2 implementation that would be based on economic priority in terms of greatest benefit and shortest pay-back periods.

5. Providing technical assistance, where appropriate, during the process of implementation of the recommended alternatives.

6. Review of the results and impacts after implementation of the recommendations.

In developing the work plan, a multi-media approach was emphasized in developing pollution prevention and minimization strategies affecting all operations and processes. The waste stream evaluation process conducted at the facility followed procedures outlined by the U.S. Environmental Protection Agency (see References section at the end of this report: U.S. EPA, 1990; 1992; 1993).

In conducting the P2 opportunity assessment, emphasis became focused on finding those areas where the impact on reducing the total pollutant load produced by this facility could be the greatest. Those areas were the electroplating, hot-dip galvanizing and the painting lines as well as the tube-mill production area. Because these areas produced the bulk of the wastes with the greatest toxicity and hazard, it was judged that improvements in these areas would produce the greatest impacts.

The Electroplating Systems

The manufacturing facility operates both an automated line and a manual electroplating line. These lines are used to deposit a thin zinc film onto small items such as bolts, fasteners and nuts, which are then used in the construction of larger plant products such as farm buildings. The automatic electroplating line is a barrel system which plates about 65 kgs (145 lbs) of work per load. The barrels are moved by a conveyor chain.

The automated electroplating line processes an average of 65 kgs (145 lbs) of work pieces per barrel. There are 36 stations on the line, with an approximate cycle time of 3.5 minutes at each station (about two hours per barrel). The work is first cleaned in a soak cleaner and an electrocleaning solution. It is then rinsed, pickled in a hydrochloric acid bath, and rinsed again before going into a chloride-zinc electroplating bath. After residing in the plating bath for about an hour and ten minutes (20 stations), the work is rinsed. A light yellow chromate finish is added. A short rinse (20 seconds) follows the chromating process after which the work is dried at 65°C (150°F). The electroplating solution is circulated through a filter to remove impurities. Particles removed by the filter are rinsed into the treatment system. The total rinse water use in the automatic electroplating line at this facility was estimated at 166 liters per minute (20 gpm) during 8 hours of operation daily.

The manual process is more operator intensive, which requires hand moving of barrels from station to station. The barrels are bigger, but the average load of work per barrel is also 65 kgs (145 lbs). This line is used more often than the automated line, especially when small quantities need to be plated. The work is cleaned in a soak cleaning bath (no electrocleaning) for about 15 minutes. It is then rinsed, pickled in hydrochloric acid, and rinsed again before being placed in the chloride-zinc electroplating tank (stainless steel pieces are dipped in nitric acid, instead of hydrochloric acid). The work pieces are plated for an average of 1 to 1.5 hours before being removed from the tank. A short rinse precedes the chromate coating; which can be clear or yellow, depending on customer preference. After a final short rinse, the pieces are placed on a table to air dry. A more detailed analysis of these electroplating lines is given by Parr (1994).

Pollution Prevention Opportunities in the Electroplating Systems

House Keeping Practices. To obtain better product quality and assure that the lower flow rates will not compromise rinsing efficiency, it was recommended that housekeeping practices be changed. There needed to be a thorough cleaning of the electroplating area including all tanks (inside and out), floor, and all equipment related to the electroplating process. A system needed to be established for recording when maintenance is done, tanks are emptied, chemicals are added, and testing on tank parameters is performed (e.g. pH, temperature, chemical concentration).

Rinse Water Use. The suggested process changes were designed to reduce waste of both rinse water and electroplating chemicals. To achieve these reductions, improved cleanliness and more careful chemistry control were required. It was recommended that the rinse rates be reduced to decrease the amount of wastewater being discharged to the treatment plant. For both the automated and manual electroplating lines, reactive rinsing was recommended in order to decrease water use from the rinses following the acid dip (pickling) and alkali cleaning processes (Tsai and Nixon, 1989; Hunt, 1988). Water from the rinse after pickling would no longer go down the drain, but would instead flow to the rinse tanks following alkali cleaning. Rinse water flow calculations showed that for these two processes, the required flow on each line could be as low as 8 liters per minute (2 gpm) (Durney, 1984).

At this plant, it was found that the effluent from the rinsing step after the acid dip could be directed to the rinse tanks after the cleaning process. This change would save a total of about 76 m^3 (20,000 gal.) of water per day resulting in a cost savings of about $150 per day in waste treatment, sludge disposal, and water costs. Counter-current tanks similar to those on the automated line (after the cleaning and acid dip processes) would be needed on the manual line to incorporate this change. The cost of these counter-current tanks was estimated at $1,000.

It was recommended that the rinse processes after the electroplating tanks on both the automatic and manual lines be changed to counter-current with a rinse flow rate of 20 liters per minute (5.3 gpm) each. About 24 m^3 (6,400 gal.) of water per day can be saved, resulting in a cost reduction of $50 per day. The cost associated with these changes was estimated at $1,000 for the counter-current tank system.

Electroplating Chemistry. The testing of chemical and operating parameters in the tanks needed to be done on a daily basis for several variables. Electroplating tank variables included pH and temperature in addition to the concentrations of cleaners, acid dips, zinc metal, boric acid, total chlorides, and the wetting agent. Chromating tank variables included pH, temperature, and chromate concentration.

Other Changes. Other recommended changes that were needed to improve the process included increasing the temperature of the cleaning tanks on the automatic line from 71°C to 93°C (160°F to 200°F). It was noted that a certain amount of grease originating at the machining steps of bolt production was accumulating in the automatic electroplating line's cleaning tanks. Grease skimming from the top of the cleaning tanks needed to be improved to remove more of the grease and oil before it carries over into the downstream processes. The filtering system on the electroplating tanks needed to be repaired, as it was inoperative. Once the filtering system is repaired (on both lines), it should be possible to determine if these systems are adequate to maintain contaminants at proper low levels. In fact, it was recommended that a new filtering system be installed.

It was noted that anode bags should be used to keep contaminants and dirt from the zinc balls out of the electroplating solution. Also, a drain board needed to be installed over the drip tank after the chromate rinse (on the auto line) to direct all dragout back into the rinse tank.

By using a trivalent chrome conversion coating process instead of the hexavalent chrome process that was being used, the facility should reduce the toxicity of the waste produced. Lower treatment costs would be realized since hexavalent chrome must be chemically reduced to its trivalent form, which is less expensive to treat, before sending it to waste treatment plant. The potential disadvantages of these changes would be: a slight reduction in corrosion protection, the need for closer monitoring and testing of the process, and that trivalent chrome coats are only available in a bright blue color instead of the customary light yellow.

To recapture some of the chemical dragout from the electroplating and chromating, it was recommended that still rinse tanks be used after these processes. It is estimated that about 50% of the chemical lost to dragout can be recaptured by this method (Hunt, 1988). It was also recommended that air agitation be used in the tanks to increase rinsing efficiency.

The electroplating process should be supplied with as clean a water as possible. It was noted that the facility had a reverse osmosis (RO) purification unit which was not in use, so it was recommended that the RO unit be used to supply water to the electroplating, chromating, and still rinse tanks. This change would remove potential contaminants in tap water including total dissolved solids (TDS) and hardness, thereby increasing process efficiency.

The barrel withdrawal rates were measured at 5.2 m/min (17 ft/min) in the automated line and 8.2 m/min (27 ft/min) in the manual line. According to Foecke (1993), the maximum rate of withdrawal should be about 2.4 m/min (8 ft/min). This change would help decrease the amount of dragout from each tank resulting in decreased chemical usage.

It was also recommended that the hang time of the barrels over the tanks be increased by pausing longer before moving to next station. The barrel hang time on the auto line was 23 seconds. There was still significant dripping from the barrels after this time period. The hang time over tanks on the manual line varied according to operator discretion. For the most part, hang time was observed to be minimal, and dragout was consequently significant.

Results of Implemented Changes in The Electroplating Systems

Recommended changes to the automatic electroplating line were presented to the facility. To date, four recommendations have been implemented, the results of which are summarized in this section.

The first recommendation to be implemented was to clean the outside and inside of all the tanks on the plating line and remove bottom sludge that had developed. In particular, the bath contents of the electroplating tank were pumped into a temporary holding tank and the bottom sludge was shoveled into eight 55-gallon drums for disposal (this sludge is not listed as hazardous under RCRA regulations). The liquid portion of the plating bath was then pumped back into the plating tank and additional chemicals and water were added to restore them to normal levels.

Another recommendation that was implemented was regular testing of the cleaning, acid dip, electroplating, and chromating processes to maintain chemical concentrations at their optimum levels.

The third implemented recommendation was the hiring of an employee with suitable chemistry background to perform operational control testing (among other duties including the galvanizing system chemistry, as discussed below) and report results back to the plating operator so that any required chemical additions can be made. The results of this testing are being documented, and chemical additions are now being made on a regular basis.

The fourth implemented recommendation was the reducing of all rinse flows. Flow control devices have been installed on the rinses after the alkaline cleaning and acid dip processes to maintain flow rates at the recommended levels. The two systems have not been connected together as was recommended. The flow rate for the two rinses after electroplating also have been reduced, although neither a countercurrent system nor flow control devices have been installed. The new rates have not been measured, and it has also not been determined if they are being maintained at a consistent level. According to the plating operator, the valves controlling flow are not turned on as far as in the past. The flows still appear to be above recommended levels (as judged by visual observation), but until flow control valves are installed or some other way of producing a consistent flow is devised, the current method will be continued.

The implemented changes also have resulted in significant product quality increases as evidenced by the results of the 5% neutral salt spray testing (as per ASTM B-117) done on bolts plated on the automated line before and after the changes were initiated. These results are presented in Table 1 below, and show a 1,000% increase in white rust protection and a 550% increase in red rust protection.

Table 1. Results of 5% neutral salt spray tests

Parameter	Pre-Change Results	Post-Change Results	Typical Values
Hours to White Rust	16	168	96 - 250
Hours to Red Rust	48	264	200 - 350

In conclusion, the facility has been very encouraged by these positive results. Also, from a waste prevention and minimization perspective, the implemented changes have been effective. The reduction in rinse flows will no doubt lead to less wastewater needing to be treated at the waste treatment plant. The cleaning of tanks, removal of sludge, and use of oil absorbent pads on the cleaning baths should help reduce the drag-out of dirt, grease, and other contaminants to downstream processes. This will help to increase bath life which will result in fewer bath dumps and reduced chemical use. The costs associated with these implemented changes have been modest.

The Galvanizing System

The galvanizing process at the facility is a five-step procedure consisting of pickling, rinsing, prefluxing, galvanizing, and final rinsing. The pickling step prepares work for galvanizing by removing oxides from the steel surface using a 10% sulfuric acid solution at a temperature of 70°C (158°F). The work pieces are dipped in the pickling acid for varying lengths of time, and then taken away to be rinsed.

After pickling, work pieces are rinsed to remove the acid. The preferred rinsing method is to dip work pieces in the rinse tank, which is filled with unheated municipal water. The rinse water is agitated by moving the work pieces back and forth in the rinse tank.

After the first rinsing, work pieces are placed in the preflux tank, which is a crucial step in the "dry kettle" galvanizing process. The work is coated with flux chemicals ($ZnCl_2$ and NH_3Cl) prior to entering the zinc kettle. The preflux tank is kept at 70°C. Normally, the preflux solution should be allowed to dry thoroughly before proceeding with galvanizing.

Galvanizing is accomplished by immersing steel in a tank filled with molten zinc for 2 to 3 minutes. Livestock fencing, the majority of the steel galvanized at this plant, uses the wet kettle galvanizing method. This means that a flux layer is floated on top of the galvanizing kettle. A flux layer covers the kettle, and work pieces pass through it as they enter and leave the kettle. For galvanizing other materials such as building components, the kettle flux layer is skimmed to the side and not used.

The work pieces are cooled by rinsing them in a second rinse booth located next to the galvanizing kettle. This final rinse is needed to cool the work to below 200°C (390°F), which stops the possible growth of a brittle zinc-steel alloy layer. Cooling also makes it easier for operators to handle the work pieces. A detailed analysis of the galvanizing system at this facility is given by Montag (1993).

Pollution Prevention Opportunities in the Galvanizing Process

Pollution prevention efforts in the galvanizing area were concentrated on reducing the volume and metal content of rinse water since this is the principal medium through which metal is lost. Volume reductions can be accomplished by installing additional galvanizing equipment. Metal content reductions are possible by either discontinuing use of the kettle flux, or switching to a different kettle flux.

Rinse Water Use. The galvanizing system at this plant initially used about 265 m^3 of rinse water per day. Flow through the first rinse booth was measured during the waste stream assessment period at 1,200 liters per minute. Freshly galvanized pieces are cooled in the second rinse booth. Flow through this booth nowadays is estimated at approximately 1,200 liters per minute, a reduction in flow which is due to recent modifications after the assessment was completed. The rinse booths operate only when there are materials to be rinsed being carried through them.

Rinsing in a rinse tank, instead of a rinse booth, after galvanizing is the most important step in decreasing galvanizing water use. Use of rinse tanks after pickling is also important. The rinse booths could be replaced by rinse tanks linked in a counter-current flow arrangement. The benefit of such a system is that it allows water to be reused several times before it is discharged to the drain, in addition to the fact that work pieces are always rinsed using the cleanest water as they leave the process line.

A rinse test was conducted to verify the usefulness of the rinse tank concept. This test successfully demonstrated the feasibility of continuous-flow rinsing. Based on the results of the rinse test, a continuous rinse water flow rate of 24 liters per minute (6.3 gal/min) will remove pickling acid adequately for two rinse tanks in series. This flow rate will adequately cool the work, preventing the water temperature from rising high enough as to pose a worker safety problem. The proposed system would use about 35 m^3 of water (or less) per day. This represents a savings of about 83%. One of the changes resulting from the study was the replacement of the spray orifices (nozzles) in the rinse booths by water-saving (low-flow) ones. This change resulted in an immediate reduction in the water use by 60% and resulted in savings in water use and waste treatment costs of about $250 per day.

The cost of the proposed galvanizing equipment changes is estimated at about $70,000, and ventilation system improvements required to remove pickling solution vapors from the proposed pickling tank location would cost $25,000. Due to the expense of the suggested galvanizing changes, phased installation was recommended. The estimated payback period on the suggested modifications is about 10 months.

Galvanizing Chemistry. Fencing currently is being fluxed twice: once in the preflux tank, and a second time as it enters the kettle. For galvanizing of objects other than fence panels (such as building parts), the kettle flux is skimmed to the side and is not used. The kettle flux is 98% $ZnCl_2$ and contains a small amount of KCl. Kettle flux adds significantly to the metal content of galvanizing rinse water, so discontinuing the use of kettle flux would enhance pollution prevention.

Prefluxing is crucial in dry kettle galvanizing. To obtain good fluxing, proper concentrations of $ZnCl_2$ and NH_4Cl must be maintained, and iron and sulfate concentrations must be minimized. Frequent sampling is required.

In the preflux chemistry, two terms (i.e., degrees Baumé (°Be), and Ammonium Chloride Number (ACN)) are important to the operation of the system. The °Be is a unit of density which is directly related to the $ZnCl_2$ concentration. Optimum density ranges from 12 to 15 °Be (1.09 g/mL to 1.12 g/mL), measured at 20°C. The ACN of a preflux is the ratio of the NH_4Cl concentration divided by the concentration of all other components in solution. An optimum ACN value is difficult to ascertain. In U.S. practice, recommended values range from 1.17, used by most galvanizers, to 1.8 recommended by Cook (1982). Sjoukes (1990), a galvanizing expert from the Netherlands, recommends ACN values of 1.75 to 2.5.

The plant currently collects samples of the preflux solution for detailed analysis, including ACN, three or four times a year. More frequent ACN determinations (at least monthly) are needed for galvanizing strictly by the "dry kettle" method. This becomes more important if the kettle flux continues to be used after installing the recommended counter-current flow rinse system. This is because zinc chloride will be dragged into the preflux from the post-pickling rinse.

In-house testing was recommended for faster data acquisition. It was also recommended that a chemist be hired to perform chemical testing on a continuous basis. The same chemist would conduct tests associated with the electroplating lines, as pointed out above.

Additionally, a recommendation was made to the facility to switch from the zinc chloride preflux to a mixture of mostly ammonium chloride and some zinc chloride, or ammonium chloride alone. This recommendation was based on the work of Sjoukes (1990). This would probably produce better results by enhancing product quality, since the proposed counter-current flow system (with fresh water being added at the final rinse tank) would not complicate preflux chemistry.

Another problem associated the galvanizing operation was a layer of oil floating on the surface of the acid bath. This was not surprising since there was no cleaning stage prior to pickling. The oil problem could be minimized by installing a skimmer system to remove the oil layer periodically. A better alternative is to reduce the amount of oil being left on the work pieces during fabricating by careful monitoring of oil usage during that step.

The Painting System

The painting operation at the facility is a sequential system consisting of washing, etching, oven drying, spray painting, and oven curing. The paints used at the facility are of the traditional solvent-based variety which contain volatile organic compounds (VOC's). In 1992, the painting operation was estimated to have emitted about 37,500 kg (82,500 lbs) of xylene, and 11,000 kg (24,200 lbs) of toluene. Xylene and toluene are defined as hazardous under the 1990 Clean Air Act (CAA), and will be regulated strictly in the near future. Reducing emissions of these VOC's should receive a high priority.

Two major types of paint are in use at the plant. One is a solvent-based paint, which is used for painting gates, and the other is a silicone polyester paint used for painting building panels. In 1992, 74% of paint used by the automatic paint line was used in painting farm gates. In addition, large quantities of a mixture of several aromatic solvents are used for purposes such as cleaning paint supply piping. About 2,200 liters (580 gallons) of this solvent are consumed each month. A detailed analysis of the painting system at this facility is given by Montag (1993).

<u>Painting Alternatives.</u> The only practical way to significantly reduce VOC emissions is to change paint materials. There are several possible materials and alternative painting methods to consider. One choice is to use water-based paint for gates, which accounts for over 74% of the plant's paint use. If water-based paints are applied electrostatically, a high transfer efficiency can be obtained. Installation of new spray equipment is the only facility change that will be required, and therefore, the investment should be relatively small. Consequently, testing of water-based painting alternatives was recommended for immediate consideration.

Another method to reduce VOC emissions from painting gates, and also to eliminate chromic acid etching of galvanized building panels, is to switch to an autophoretic painting process. This process involves dipping metal to be painted into tanks filled with paint. Immersion is required because the coating is deposited by a chemical reaction between the paint and the metal which takes several minutes to occur. The autophoretic process resembles electrocoating, except that no electric current is required. Metal painted by this process reportedly has withstood salt spray tests of up to 3,000 hours without coating failure (Anonymous, 1992). The paint reportedly exhibits a high degree of hardness and good resistance to chalking from ultraviolet light exposure. An autophoretic system to coat gates was estimated to cost about $300,000. A detailed analysis of this painting method would be required. A serious drawback of this painting method is that color varies with the dissolved iron concentration in the paint, which increases slowly due to contact of the paint with the steel being painted. Another drawback is the fact that a separate paint tank is needed for each desired color.

A third alternative for painting is to consider the use of powder coating. Agricultural gates are ideally suited for powder coating because they are made in only two colors. Transfer efficiency is not an issue in this method because overspray is captured and blended with fresh powder for reuse. Powder coating would entirely eliminate volatile organics from the paints used for farm gates. An industrial supply contractor estimated that powder coating could be added to the existing paint line at this plant for as little as about $40,000. However, installation costs were estimated to be much higher than this estimate because the automatic paint line is quite old, and therefore must be replaced entirely. A new paint line was estimated to cost about $200,000.

Pollution prevention in the painting area at this plant will not be offset by significant savings in terms of reduced waste disposal costs at the present time. However, the Clean Air Act requirements will soon demand that action be taken. Estimates of the installation costs for various painting alternatives are shown in Table 2. As a result of this study, the plant has experimented with water-based paints as well as a powder coating system. The facility has requested bids to construct a powder coating system.

Table 2. Summary of costs of painting alternatives at the plant

OPTION	COST
Water-based Spray Painting	$25,000
Autophoretic Coating	$300,000
Powder coating	$200,000

The Tubing Manufacture System

A tube mill is used at the manufacturing facility to form metal pipe from coils of sheet steel. The plant makes the tubing for all its gates, and for sale to other companies. The major tube mill components include the coil unwinder, the feeder, the initial cold rolls, the welder, the re-galvanizer, the final cold rolls, the metering cutter, and the coolant distribution system.

A water-based fluid coolant is used by plant for lubrication and cooling of the tube mill. About 800 liters (210 gallons) of coolant per month are consumed at a cost of about $800. The coolant flows from its application points into sumps below the components. The sumps, in turn, drain by gravity to a large collection tank. The collection tank contains an oil removal system, consisting of a plastic tube pulled through the liquid coolant. Floating oil adheres to the polyethylene tube, and is removed by a scraper. The oil removal system is not able to remove oil fast enough.

The oil in the coolant originates from grease leaking out of the tube mill gearboxes. Over the years, oil and grease leaks have covered the tube mill and the surrounding area. Grease combines with the metal filings created when excess metal is scraped off the fresh welds, and together they make a black substance that fills the bottom of the sumps in about a month. The mill is occasionally shut down while operators scoop out all the grease. About two-thirds of the coolant is lost each time the sumps are cleaned, and this is the only time coolant is discharged from the system. A detailed analysis of the tube mill system at this facility is given by Montag (1993).

<u>Recommended Tube Mill Changes.</u> Recommendations for the tube mill area at this plant are mostly concerned with changes which would minimize grease contamination of the coolant. The old oil removal system needs to be replaced and an efficient oil removal system, which should allow the coolant to be used for several times its current life. A suitable new oil removal unit was estimated to cost less than $2,500. The payback period was estimated at less than six months assuming that the coolant's useable life is only doubled. Beyond that, the actual payback period could be even shorter.

There is also a problem with the coolant turning rancid. Coolant rancidity usually is controlled by adding one of several possible biocides. If rancidity problems continue after an improved oil removal system is installed, a new biocide may be needed.

It should be possible to prevent gearbox leakage, or at least reduce leakage from falling into the sumps through regular maintenance. Also, preventing metal filings from falling into the sump below the weld scraper would keep them from combining with the grease. It was strongly recommend that the entire area be shutdown for a short period of time for a thorough cleaning. This would vastly improve the operation of the system. The cleaning should include all equipment, floor grates, and the return trough.

SUMMARY AND CONCLUSIONS

In this report, the preliminary results of an extensive pollution prevention program at a metals fabricating and finishing facility are reported. The plant is a large, fairly aged, facility located in the midwestern United States. The principal operations involved at this facility include electroplating, conversion coating, cleaning, machining, grinding, impact deformation, shearing, welding, sand blasting, hot-dip galvanizing, painting, assembly and testing of various metallic components that are being made. The discussion in this report has centered on the principal operations that produce the bulk of the wastes at this facility including electroplating, galvanizing, painting, and tube manufacturing. Additional information regarding the manufacturing facility and its processes can be found in Dahab and Montag (1993), Dahab et al. (1994), Montag (1993) and Parr (1994). (See the references at the end of this report.)

This project has entailed an extensive and systematic waste stream assessment and evaluation. The operations and processes at this facility result in the production of large quantities of wastewater with significant concentrations of metals that require expensive treatment. One of the major constraints in making recommendations was the fact that the facility was fairly old and not very profitable. Consequently, all of the recommendations for process and operational modifications resulting from the P2 opportunity assessment had to meet critical economic payback periods.

The pollution prevention recommendations in the electroplating system, to date, have contributed to significant reductions in the amount of wastewater that needs to treated as well as a significant increase in the product quality. The product quality increase is clearly demonstrated by the 550 % and 1000 % increase in the level of protection against white and red rust, respectively, in the neutral salt spray tests conducted on the products before and after project implementation. The plant management has been quite pleased by these results since numerous claims have been made against the facility because of corroded fasteners.

The principal modification to the galvanizing process centered on dramatic reductions in the amount of wastewater produced in this process while improving product quality. As indicated, it was apparent that rinse water use could be reduced by as much as 83 percent of what the process was using prior to the waste stream assessment. One of the changes resulting from the study was the replacement of the spray nozzles in the rinse booths by water-saving (low-flow) ones. This change resulted in an immediate reduction in the water use by 60% and resulted in savings in water use and waste treatment costs of about $250 per day. The process modifications were estimated to have a payback period of about 10 months. Product quality should improve with the suggested improvements in process chemistry.

Pollution prevention in the painting line was concentrated on reducing VOC emissions which soon will be regulated under the Clean Air Act of 1990. The costs of proposed modifications probably could not be justified in terms of savings due simply to reduced waste. Installation expenses will have to be recovered through adjustments in the pricing of products. However, the modifications are well justified in terms of expected regulatory requirements.

The tube mill system was associated with excessive coolant loss as well as rancidity. The proposed changes were expected to significantly reduce coolant loss with an estimated payback of less than six months by installing a better oil and grease removal system. As it turned out, the facility was able to install a suitable oil removal system for a fraction of the estimate made during waste stream assessment.

EPILOGUE

The P2 Opportunity Assessment for the facility conducted in this project also produced longer-term recommendations in addition to the recommendations reported here (see the Recommendations Reports in the Appendices to this report). The facility will continue over the coming months and years to adopt additional recommendations from the assessment.

For example, subsequent to the implemented changes described above, the company has <u>also</u>:

(1) added a new sludge containment area, which conforms to modern RCRA standards (compared to the past when they simply piled up sludge outside until it was hauled away);

(2) revised their wastewater treatment plant system by installing a new sludge filter press to produce much drier sludge than before;

(3) with the hiring of the new chemist (as recommended), the facility continues to optimize the process lines in both the electroplating and galvanizing lines; and

(4) as of May 1995, the company indicated that they were well on their way in revamping the painting lines including the possible purchase of a new power coating system.

In conclusion, implementing pollution prevention and improving facility performance and profitability will be an ongoing work at this manufacturing site in Nebraska.

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APPENDICES

The Appendices include the following:

- The interim and final reports on recommendations for implementing P2, which were submitted to Behlen Manufacturing Company officials.

- Abstracts and tables of contents of two lengthy and highly technical reports on the project and the technologies considered in the project. (These two reports are referenced at the end of the above report as Montag, D. (1993) and Parr, J. (1994) and are available in their entirety as Masters of Science Theses from the University of Nebraska-Lincoln libraries.)

- An article from the November 1994 issue of Environmental Solutions. (Reprinted by permission of Advanstar Communications Inc.)

INDUSTRIAL POLLUTION PREVENTION PILOT PROJECT

An Interim Report

Submitted to the

Behlen Manufacturing
Columbus, Nebraska

Submitted by

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James Lund, EPA Washington, Project Managers

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INTRODUCTION

Work began in early 1992 on an industrial pollution prevention pilot project for Behlen Manufacturing Company of Columbus, Nebraska. The project, which is partially funded by the U.S. EPA, is part of an effort by the University of Nebraska-Lincoln to establish a pollution prevention and waste minimization program throughout Nebraska.

Behlen Mfg. Co. produces fabricated metal parts for farm and industrial uses. The areas of electroplating, galvanizing, painting, tubing manufacture, and water use are being studied for ways to prevent pollution.

This report begins with a section on electroplating, and then covers galvanizing, painting, tubing manufacture, water use, and the waste treatment plant. Each of the sections describes the process and then gives preliminary recommendations for minimizing waste production and/or improving product quality.

SECTION 1 - ELECTROPLATING

Behlen currently operates both automated and manual electro- plating lines. These lines electroplate zinc onto small items such as nuts and bolts which are then used in the construction of larger products such as fabricated metal farm buildings. A diagram of each line is included in the appendix section of this document.

Automated Electroplating Process Description

The automated electroplating line processes an average of 140 pounds of work per barrel. There are 40 stations on the line, with an approximate cycle time of 3.5 minutes per station (about 2 hours and twenty minutes total run time per barrel). This includes a 23 second hang time over the tank to allow solution to drip off the barrel before going to the next station. The barrels rotate while in the tank to help keep the work and solution well mixed.

Stations 1 and 2 (tanks 1 and 2 -- 200 gallons each) are filled with a soak cleaner called Metex S 1651 (8 to 12 ounces per gallon of water) and are maintained at a temperature of 150 to 170°F. According to the product information sheet, Metex S 1651 has a biodegradable surfactant which aids in the removal of dirt and oils from the surface of the work, and it works in hard water. The cleaner contains 12% sodium hydroxide, which acts to remove oil from work pieces through a saponification reaction. The sodium hydroxide also breaks down organic compounds and dissolves amphoteric metals.

Stations 3 and 4 (tank 3 -- 400 gallons) involve a cleaning process known as electrocleaning. Electrocleaning works by applying a positive charge to the work and a negative charge to plates hung at the edge of the tank. Rust, burrs, and smut are repelled from the parts, and are attracted to the negatively charged plates. The chemical used in this tank is Metex E 1726 (8 to 12 ounces per gallon of water). The tank temperature is maintained at 150 to 170°F. Metex E 1726 is 50% sodium hydroxide, and helps to removes oils missed by the soak cleaner tanks.

The contents of the cleaning tanks (soak cleaner and electrocleaner) are discharged to the waste treatment system about every one to four months. The tanks are dumped if either the chemical addition indicated by daily testing equals the chemicals needed to mix a new batch, or if the operator judges that the tank is dirty and should be changed.

NOTE: The first eight tanks of the plating line (this includes cleaning, rinsing, and hydrochloric acid pickling) are all emptied at the same time.

Stations 5 and 6 (tanks 4 and 5 -- 200 gallons each) involve rinsing the work with ambient temperature water to remove loosened dirt and oils, and cleaning solution dragout. Flow through the rinse tanks is counter-current (fresh water flows into tank 5 overflows into tank 4, and then overflows out to waste treatment system) and about 15 gallons per minute is used. The rinse tanks are cleaned when they are emptied, and any accumulation of metal sludge is rinsed into the waste treatment system.

After rinsing, the barrels continue through the process to stations 7 and 8 (tank 6 -- 400 gallons) where the work is pickled in hydrochloric acid. HCl acts to remove alkalinity and the thin film of oxide or tarnish that develops on pieces due to the previous cleaning processes. The tank contains about 12% hydrochloric acid at room temperature. Vapor rising from the tank due to the pickling process enters a hood and is exhausted outdoors.

Stations 9 and 10 (tanks 7 and 8 -- 200 gallons each) involve rinsing the pieces with ambient temperature water to remove all remaining contaminants prior to the electroplating process. Flow through the two rinse tanks is counter-current at a rate of about 12 gallons per minute.

The ninth tank (stations 11 through 30) is the electroplating tank, which holds 5,500 gallons of solution. Work stays in the tank for 20 stations (about 70 minutes). The electroplating solution contains zinc, potassium chloride, sodium chloride, boric acid, a leveling agent, a wetting agent, and a brightener at a pH of about 5. A monthly check of the solution is done (by the John Schneider Company) to see if any chemical additions are needed. Balls of zinc are held in titanium baskets along the side of the tank. A potential difference of 8 volts is applied between the zinc balls and the work pieces (the zinc being positively charged and the work negative). About 1,000 amps of current is drawn by this process. The current acts to dissolve and then deposit zinc from the balls onto the work in the barrel.

The electroplating solution is circulated through a filter to remove impurities, and a heat exchanger helps to cool tank contents to room temperature. The filter is cleaned in the hydrochloric acid tank on the manual electroplating line and rinsed in the rinse tank following the HCl tank (also on the manual line).

Stations 31 and 32 (tanks 10 and 11 -- 200 gallons each) involve rinsing the pieces with water to remove chemicals and loose zinc particles incurred during the electroplating process.
Rinse water flow in each tank is approximately 9 gallons per minute. The waste water drains to the waste treatment plant.

Tank 12 (station 33) is a drip tank where the barrel hangs above the tank to allow dragout from the rinse tanks to drip off. The waste water drains to the treatment plant.

Station 34 (tank 13 -- 200 gallons) involves a yellow chromate conversion coating process. Tank contents include chromic acid, formic acid, carboxylic acid, and nitric acid at a temperature of 80 F. The barrel is dipped into the tank for only 40 seconds during which time a yellow chromate coating of about one half micron thickness is deposited on the work. The barrel rotates about 20% of the time while in the tank compared to continuous rotation at the other stations (this is to prevent the chromate coating from being knocked off). The chromate tank is disposed of every three days, and prior to entering the waste treatment system, the chromium VI is reduced to chromium III with sodium bisulfite and sulfuric acid. Fumes from the chromate tank and the chromate rinse tank are collected by exhaust hoods and directed outdoors.

Station 35 (tank 14 -- 200 gallons) is a static rinse tank in which the barrel is dipped to remove excess chromic acid solution. This rinse tank is emptied daily. Prior to emptying, the rinse tank's contents must be treated with sodium bisulfite and sulfuric acid.

Station 36 (tank 15 -- 200 gallons) is a drip tank to allow dragout from the rinse tank to drip off (tank contents must be neutralized with sodium bisulfite and sulfuric acid before emptying to waste treatment plant).

Following the drip tank, tanks 16 and 17 (stations 37 and 38) are drying areas.

150°F air is blown through the barrels to speed drying of the work inside.

At stations 39 and 40, the pieces are allowed to cool before being removed from the barrel. At this point, the empty barrels have come full circle and are ready to be filled with a new load of work to be electroplated.

Automatic Electroplating Recommendations

1. Operation of the soak cleaner tanks can be improved in several ways:

   Temperature should be increased from the current 150 to 170°F to the temperature recommended by the soak cleaner manufacturer (200 to 205°F). Tank temperature and concentration should be monitored daily. This will improve the effectiveness of the cleaner.

   Fresh water use can be decreased by using water from rinse tank #4 as makeup for the soak cleaner and electrocleaner tanks.

   Filtration could prevent sludge build-up in the bottom of the soak cleaner tanks. Raising the temperature and filtering tank contents should improve product cleanliness and increase tank life.

   A grease skimmer and trap should be used to remove grease and oil from the surface of the tank solution to minimize carryover to downstream tanks.

2. Electrocleaning recommendations are similar to those for the soak cleaners and include:

   Increasing temperature to 200°F, using a grease skimmer and trap, monitoring temperature and concentration daily, filtering solution, and using water from tank #4 as makeup.

3. Recommendations for the rinsing process after both cleaning and pickling are as follows:

   The flow of rinse water through rinse tanks 4, 5, 7, and 8 can be reduced. As before, fresh water should enter tank #8, but at a reduced rate of about 0.6 gallons per minute (gpm) (flow control valves to maintain specific flow rates are about 35 dollars -- not installed). The flow is directed counter current into tank #7. Water overflowing from tank #7 would be directed to tank #5, and then countercurrent to tank #4. Rinse water flow can be cut from a total of 27 gpm to about 0.6 gpm, a savings of 26.4 gpm. Since it costs about 0.275 cents to treat a gallon of waste (based on Behlen estimates), 35 dollars per day could be saved. Also, the acid rinsed from the pieces in tank 7 will help to neutralize alkalinity from the cleaning tanks (stations 1 through 4) thus increasing the effectiveness of rinse tanks 5 and 4.

NOTE: All rinse water flow estimates are based on the use of deionized water and standard conditions. Flow estimates will increase if tap water is used and current housekeeping conditions prevail.

A 50 gallon tank could be used to store water overflowing from rinse tank #4. This water could be used as makeup for tanks #1, #2, and #3.

4. The hydrochloric acid tank pH should be checked daily to increase tank effectiveness.

5. Operation of the electroplating process can be improved in the following ways:

   Electroplating tank chemistry should be checked daily. Chlorides, zinc, temperature, and pH should be tested.

   The electroplating solution should be filtered more rapidly to aid in the removal of impurities. A typical plating tank filtration system filters 2 bath volumes per hour.

   Air agitation would facilitate better mixing of electroplating tank contents. This will improve plating results.

   The use of anode bags would decrease bath contamination from insoluble anode material.

   Perform regular maintenance on rectifiers, filter system, and barrel and tank anodes to optimize plating performance.

6. The following changes are recommended for the rinsing and chromating following the electroplating process:

   Eliminate the drip tank prior to chromating (tank 12). By eliminating the drip tank, tanks #11 and #12 can be used as counter-current rinses with a flow rate of about 0.3 gallons per minute (gpm). Tank #10 could then be used as a static rinse (no flow), and the water from this tank could be used as make-up for the electroplating tank. Air agitation of this still rinse tank would improve rinsing efficiency if the plating solution is highly contaminated. This set of changes should decrease rinse water use from the current level of 17 gpm (combined flow rate for tanks 10 and 11 now) to 0.3 gpm. This would result in a water savings of about 8,016 gallons per day, or $22 per day in waste treatment cost savings. As previously stated, flow control valves for specific flow rates are available for about 35 dollars.

NOTE - There is adequate space on the line to move the chromate tank down one space (to tank 14) if a drip tank is desired prior to chromating.

Substituting trivalent chromium for hexavalent chromium should be considered. This could help remove a hazardous waste from the process. Chromate tank concentration and temperature should be monitored daily.

7. Changes to the process after chromating are as follows:

A static rinse tank should be used after chromating. A float and pump system can be used to withdraw water from the rinse tank to use as makeup for the chromate tank.

A drain board should be installed over the drip tank so that solution falling over the tank is directed back to the rinse tank.

Manual Electroplating Process Description

The manual electroplating line is more labor intensive than the automated line. The barrels are hooked onto a chain conveyor system and the operator physically moves the barrels from station to station using the conveyor system. The barrels are bigger than those used on the automated line, but the average load of work is still about 140 pounds. The barrels rotate while in the tanks to promote mixing.

There is no electrocleaning process on this line. Also, a nitric acid tank is available for pickling stainless steel pieces (this doesn't occur often), and a yellow or clear chromate finish may be added after the zinc electroplating process (depending on customer preference).

Station 1 (tank 1 -- 600 gallons) is the soak cleaning station. The tank can accommodate three barrels at one time. The barrels are left in the soak cleaner solution (Metex S 1651) for about 15 minutes. The process is heated to about 200 F and as stated in the automated section, acts to remove dirt and oil from the work in the barrel.

Stations 2 and 3 (tanks 2 and 3 -- 100 gallons) are fresh water rinse stations. The barrels are dipped into either tank 2 or tank 3 for a period of about 30 seconds to remove dragout from the soak cleaning tank. The flow rate through the tanks is 2 gallons per minute for tank 2, and 7 gallons per minute for tank 3. The barrels hang over the tank for about 5 seconds and then move to the next station (HCl pickling).

Station 4 (tank 4 -- 200 gallons) is hydrochloric Acid pickling. The barrel is dipped into this tank for about 10 minutes to remove oxides, tarnish, and alkalinity. This tank is also used to clean the filter from the electroplating tank pump on the automated line. Tanks 1, 2, 3, and 4 are emptied at the same time, usually about once every 3 months.

Station 5 is a rinse tank (tank 5 -- 100 gallons) used to capture dragout from the hydrochloric acid tank. The flow rate through this tank is about 7.5 gallons per minute. The barrel is dipped into this tank for one complete rotation and then removed (about 10 seconds). This tank is also used to rinse off barrels after being dipped in the nitric acid tank (station 6), and to rinse the filter from the automated electroplating tank.

Station 6 (tank 6 -- 100 gallons) is the nitric acid tank which is used to pickle stainless steel parts. This tank is not used very often and is covered with a heavy piece of plastic between uses.

Station 7 (tank 7 -- 900 gallons) is the electroplating tank. The chemicals used are the same as for the automated electroplating tank. There is no filtering system on this tank, and the tank solution is checked monthly to determine if chemical additions are needed. Barrels are dipped into the tank for a period of between 45 minutes to 1.5 hours (depends on customer specifications). The electroplating of zinc onto the work pieces is similar to that described for the automated line.

Station 8 (Tank 9 -- 100 gallons) is a rinse tank with a flow rate of about 6 gallons per minute. The barrel must be lifted over tank 8 (clear chromate tank) to get to this rinse tank (the chromate tank is covered with a heavy plastic sheet during this time). This rinse tank is only used to rinse barrels coming from the electroplating tank.

Station 9 (tank 8 -- 100 gallons) is the clear chromate tank. This solution is similar to the yellow chromate finish described on the automated line except that it leaves a clear finish on the pieces instead of a yellow finish. This clear finish is used if preferred by the customer. The barrel is dipped into the tank for a period of about 3/4 to 1 full rotation (about 10 seconds. It is then allowed to hang over the tank until most of the dragout has dripped back into the tank. The barrel is then rinsed in tank 11 for about 20 seconds and then taken to the drying tables (station 12) where the work is removed and allowed to dry.

The chromate tank is emptied about once every 6 months. The hexavalent chromium (Cr VI) is neutralized to trivalent chromium (Cr III) with sodium bisulfite and sulfuric acid before emptying to the waste treatment system.

Station 10 (tank 10 -- 100 gallons) is the yellow chromate station. It is similar to the yellow chromate tank described on the automated line (including temperature of about 80 F). The barrel is dipped into the tank for about 1 full rotation (about 10 seconds) and then allowed to hang over the tank until most of the solution dragout has dripped back into the tank. This yellow chromate finish is used as per customer preference. The contents are treated as previously described before being emptied to the waste treatment system (tank is emptied about once every 4 months).

Station 11 (tank 11 -- 100 gallons) is a rinse station used after a barrel has been dipped into the yellow or clear chromate tanks. The barrel is dipped into the tank for about 20 seconds (2 full rotations) and then allowed to hang above until most of dragout has dripped off. This is a still rinse tank (flow is not continuous) and is emptied about once a month (chromates are neutralized before emptying to the waste treatment plant.

Station 12 is a drying area where finished pieces are taken out of the barrel and allowed to air dry.

Manual Electroplating Recommendations

1. All recommendations for the soak cleaning tank are similar to those made for the auto line including:

   installation of a grease skimmer and trap, daily monitoring of solution temperature (already at 200 degrees Fahrenheit) and concentration, solution filtration to remove sludge build-up, and use of rinse water from tank #2 to make up for evaporation and dragout losses.

2. Changes recommended for the process after cleaning and before electroplating (tanks 2, 3, 4, 5, and 6) are as follows:

   By moving the nitric acid tank next to the hydrochloric acid tank (tank 5) and using one of the empty tanks at the end of this side of the line (tank 7) (see figure in appendix for the manual line), it is possible to create two counter current systems that would be similar to those on the automated line. The fresh water flow would originate in tank #7 at 0.6 gpm (using flow control valves) and then be allowed to gravity flow to tanks #6, #3, and finally #2 where it could be collected in a 50 gallon tank and used for make-up in the soak cleaner tank. This would result in a savings of about 16 gpm (the current 16.5 gpm versus 0.6 for the proposed method) and a waste treatment savings of about 21 dollars per day.

   Daily testing of the hydrochloric acid tank concentration and pH would optimize pickling results.

NOTE: The use of disposable filters on all filtration systems (especially the Auto electroplating tank) will eliminate the use of the hydrochloric acid tank for filter cleaning as is currently done. This will result in extending the bath life and better results in the plating process that follows.

3. Recommendations for the electroplating tank are similar to those made for the auto electroplating tank:

   Daily monitoring of solution pH, temperature, total chloride and zinc levels, installation of an efficient filtering system to remove impurities and dirt (no filter currently on this tank), air agitation, use of anode bags, and regular maintenance of the rectifiers, filters, and anodes.

4. Changes proposed for rinsing after electroplating include:

   A system similar to that proposed for the auto line should be considered with a still rinse immediately after the electroplating tank and 2 counter current tanks following with a flow of 0.3 gpm (using flow control nozzles). The still rinse could be used for make-up into the electroplating tank and the rinse tank following the still rinse could be used for make-up into the still rinse (as needed).

   NOTE: This change would entail moving the clear and yellow chromate tanks next to each other. Secure lids would prevent contamination of one tank while the other was being used.

5. Changes to the chromating process and rinsing after are as follows:

   The use of trivalent chrome instead of hexavalent chrome must be considered.

   As stated above, secure lids on each of the chromate tanks (clear and yellow) would prevent contamination when barrels pass over the tanks.

   The use of one static rinse tank (no flow) followed by a drip area consisting of a drain board (to drain rinse dragout back into the rinse tank) would be the desirable method.

Recommendations for both Auto and Manual Electroplating Lines

1. Housekeeping:

Conduct a thorough clean-up of the electroplating area, including tanks and floor. The dirt, grease and grime that has built up around and in the tanks has a detrimental effect on product quality. The placement of lids over the tanks when not in use might be beneficial.

All tanks should be checked for leaks and other potential hazards.

Establish strict routines for:

1) regular maintenance of the electroplating area including the equipment used (e.g. rectifiers, pumps, heaters, barrels, and barrel anodes)

2) tank emptying and cleaning

3) chemical additions to tanks (in between emptying)

4) regular testing of tank contents (in the case of the soak cleaner, electrocleaner, electroplating, and chromate tanks) to make sure they are operating at optimum conditions

NOTE: All of the above should be incorporated into a written procedures manual for each line.

2. Hire a chemist to monitor and direct the operation of each line:

The current operator can run the line but he has no knowledge of the chemistry involved in the electroplating process. A person with a thorough understanding of how cleaning, rinsing, and plating work would help create a more efficient and cost effective electroplating operation.

3. Use of deionized water in all process and rinse tanks:

The current water used (from the Columbus Municipal supply) has extremely high values for hardness (300 mg/l as $CaCO_3$), alkalinity (304 mg/l as $CaCO_3$), and TDS (total dissolved solids) (440 mg/l). Deionized water would make chemical processes (e.g. cleaning and electroplating) more effective and would help in the rinsing process as well. It would also extend the life of the baths which would result in less chemical use. This should lead to a higher quality product while decreasing water usage.

4. Slower withdrawal rates for barrels from the tank solution:

Current rates are 17 ft/min. for the automated line and 27 ft/min. for the manual line. According to the literature, the maximum rate for withdrawal should be about 8 ft/min. This change would help decrease the amount of dragout from each tank resulting in decreased chemical usage.

5. Increase barrel hang time over the tank to decrease dragout into the next tank:

   The current hang time on the auto line is 23 seconds. There is still significant dripping from the barrels after this time period. The hang time over tanks on the manual line varies with operator discretion. For the most part it is minimal or non-existent, and dragout is visually significant. A study must be done to see how increasing the hang time affects the dragout rate from the barrels.

   NOTE: It will be necessary to see how increased hang time affects the amount of water used per barrel in the rinsing process (since rinse tanks are continuous flow).

6. Decrease flow rates used in the rinse tanks:

   Combined rinse tank flow rates for both the auto and manual lines are 64.5 gallons per minute (gpm). This adds up to a rinse water usage of about 31,000 gallons per day (based on an 8 hour work day) which must be treated at the waste treatment plant at an average cost of 0.275 cents per gallon (85 dollars per day or 22,150 dollars per year).

   Average rinse water rates seen in the literature are 10 gpm for single continuous flow tanks and 0.3 gpm for counter current flow rinses using 2 tanks (e.g. rinse tanks after electrocleaning and acid tanks on the auto line). Counter current flow using 2 tanks can contribute significantly to a reduction in water use. Currently the rinse system uses between 2 and 15 gallons per minute per tank, with the two counter current systems (after the soak and electrocleaner tanks, and the acid tank) using 15 and 12 gpm respectively.

   Note: It may be necessary to delay implementation of this recommendation until after deionized water is used which will improve the effectiveness of the rinsing process.

Section 2 - Galvanizing

Galvanizing is a five step process consisting of pickling, rinsing, prefluxing, galvanizing, and final rinsing. The next few paragraphs describe galvanizing in greater detail.

Pickling

Pickling prepares work for galvanizing by removing oxides from the steel surface. The pickling tank is maintained at a temperature of 155 to 160 degrees fahrenheit. It holds a 10% (by weight) sulfuric acid bath, which is inhibited with Rodine 85. The work pieces are dipped in the pickling acid for varying lengths of time, and then taken away to be rinsed.

Pickling time is very important because, while the time must be sufficiently long to remove oxides, excessive pickling can dissolve the base steel. The "proper" time depends on how much mill-scale is present, and is chosen based on operator experience. Fencing is pickled for 5 to 10 minutes.

Pickling consumes 17,000 pounds of 66 degree Baume sulfuric acid each month. Some of the acid is lost by evaporation and drag-out, but most of the acid used is hauled away as hazardous waste. The pickling tank is emptied once every five weeks, due to the slow rate of pickling when the acid becomes spent. Envirite Corporation of Harvey, Illinois hauls away the used pickling acid, and recycles it. Envirite charges Behlen $5,500 each time the pickling tank is emptied.

Behlen has purchased a sulfuric acid recovery system to recycle the acid bath contents. The acid recovery system is installed and operating. It precipitates iron sulfate and zinc sulfate by cooling the pickling solution. Operating principles of the system are explained in an attached summary, which was published by the manufacturer.

The pickling tank contains a small amount of Rodine 85, an inhibitor. Inhibitors are chemicals which minimize acid attack on the base metal during pickling. Page 9 of Pickling of Steels (Mulcahy, 1973) explains inhibitor action.

Rodine 85 is composed of 40-50% substituted triazine, 1-5% thiourea, 1-10% hydrochloric acid, <1% formaldehyde and <1% ortho toluidine. 1.5 gallons of Rodine 85 are added to each fresh tank of acid, and a total 60 gallons of Rodine 85 are used each year. The recovery system does not remove inhibitor, so less inhibitor will be used in the future.

Rinsing

After pickling, the work is rinsed with city water to remove all pickling acid. The preferred rinsing method is to dip work pieces in the rinse tank, which is filled with unheated city water. The rinse water is agitated by moving the crane back and forth while the work is submerged. When pickling is finished, the work is withdrawn, and held over the rinse tank to allow excess water to drip off before going to the preflux tank. The steel surface must not be allowed to dry completely, or oxidation will result.

As could be expected, contaminants build up in the rinse tank. A recent analysis of rinse tank water indicated that it contains 297 mg/l total iron and 473 mg/l total zinc. In order to prevent excessive buildup of chemicals in the rinse water, 2000 gallons from the rinse tank are emptied to the waste treatment plant each week.

Alternate rinse

The rinse booth located between the pickling tank and the rinse tank can be used as a substitute for the rinse bath. Operators say the rinse tank water is too dirty, so the rinse booth is almost always used (fencing is rinsed for about 17 seconds). The booth drains directly to the treatment plant without storing water for further use. Flow rate through the rinse booth was recently measured by David Montag at 300 gallons per minute.

Prefluxing

After the first rinsing comes prefluxing, which is a crucial step in the dry kettle galvanizing process. The work is coated with flux chemicals prior to entering the zinc kettle. The preflux tank is kept at 160 degrees fahrenheit, and is filled with water containing zinc chloride and ammonium chloride. Work pieces are dipped in the preflux tank and withdrawn. The preflux solution should be allowed to dry thoroughly before proceeding with galvanizing.

Behlen uses 1,006 pounds per month of zinc ammonium chloride mixture ($ZnCl_2 \cdot 2NH_4Cl$ with 56 wt% $ZnCl_2$ and 44 wt% NH_4Cl), and about 482 pounds per month of additional ammonium chloride is used.

To obtain good fluxing, proper concentrations of zinc chloride and ammonium chloride must be maintained, and iron and sulfate concentrations must be minimized. Frequent sampling is required for good chemistry control. Preflux sampling and sample frequencies are described below.

Two of the terms used in preflux chemistry may be unfamiliar to the reader. These terms are degrees Baumé (°Be), and Ammonium Chloride Number (ACN). °Be is a unit of density, and any density expressed in °Be can be converted to other, more familiar, units. A density conversion table is included in the appendix.

The preflux density depends almost entirely on $ZnCl_2$ concentration. The desired density range is about 12 to 15 °Be (1.09 g/ml to 1.12 g/ml) measured at 70 to 75°F.

The ACN of a preflux is a ratio of the NH_4Cl concentration divided by the concentration of all other components in the solution. Opinions about the best ACN differ: Mineral Research Corporation recommends 1.17, Dr. T.H. Cook recommends 1.4 to 1.8, and Sjoukes recommends 1.75 to 2.5.

Mr. Richard Robak, the galvanizing team leader, draws all preflux samples. Density is checked daily, and iron and sulfate samples are drawn every 3 to 4 days. Behlen's maximum specification for iron is 1%, and the max for sulfate is 1.5 to 2%. Every three or four months, Mr. Robak sends a preflux sample to Mineral Research Development Corp. of Charlotte, N.C.. Mineral Research performs a detailed analysis, including ACN determination.

A detailed preflux analysis was performed on a sample drawn on 6/16/92. The density was 15.99 degrees Baumé, and the ACN was 0.92. This means that Behlen's flux has more zinc chloride than necessary and too little ammonium chloride. A low concentration of ammonium chloride in the preflux causes poor fluxing for dry galvanizing (Cook, 1982; Sjoukes, 1990). The low ACN indicated by Behlen's most recent preflux sample analysis should be corrected immediately. A letter from Mr. Mark Keffer of Mineral Research to Mr. Dick Robak of Behlen recommends adding more ammonium chloride to Behlen's preflux. Mr. Keffer's letter is included in the appendix. Other suggested chemistry changes are given at the end of the galvanizing section.

Galvanizing

Galvanizing is accomplished by immersing steel in a tank filled with molten zinc for 2 to 3 minutes. Livestock fencing, the majority of the steel being galvanized, uses the wet kettle galvanizing method. This means that a flux layer floats on top of the galvanizing kettle. A flux layer covers the kettle, and work pieces pass through the layer when entering and leaving the kettle. For galvanizing other than fence panels, such as building parts, the kettle flux layer is skimmed to the side and not used.

The flux used by Behlen is called Preact, and is supplied by Mineral Research Corporation. Preact is 98% zinc chloride, and contains a small amount of potassium chloride. Behlen uses 16,300 pounds of Preact flux per month. Fencing galvanized without using the kettle flux always comes out covered with sharp zinc "icicles". Since the icicles could cut farm animals, the smoother finish obtained by using a kettle flux is considered necessary.

POLLUTION PREVENTION

AT AN AGING MIDWESTERN MANUFACTURING FACILITY

This report describes the results of an Industrial Pollution Prevention Project (IP3) demonstration project in Nebraska. The goal of the project was to demonstrate the adoption of pollution prevention (P2) practices by a rural and aging manufacturing facility.

INTRODUCTION

The manufacturing facility is located in a predominantly agricultural area. The plant site is a 100 acre area on which several buildings are located -- the largest of which is the manufacturing facility (805,000 square feet). The facility produces fabricated metal products for farm and industrial uses including structural steel members and plates, farm gates, fencing, and livestock watering tanks, in addition to a wide variety of structural bolts, fasteners, etc. Because of the nature of its manufacturing, the facility is licensed as a hazardous waste generator and is permitted under the RCRA and NPDES systems.

In its various manufacturing processes, the facility performs many operations including electroplating, conversion coating, cleaning, machining, grinding, impact deformation, shearing, welding, sand blasting, hot-dip coating, painting, assembly and testing. Many of these processes result in the production of a variety of pollutants that have to be disposed of in some fashion depending on their nature. For example, the electroplating line results in the production of acids and rinse water containing zinc and chromium, and the hot-dip galvanizing process results in the production of acids and rinse water containing zinc, lead, and iron, which must be treated as a hazardous substance containing heavy metals. The painting processes result in the production of used industrial cleaners, acids, solvents, and chemicals used in the cleaning and degreasing of metal components.

All process wastewaters produced at this facility are treated in accordance with stipulations of the discharge permit. The wastewater is treated by lime and polymer addition and pH adjustment before discharge. In the past, waste disposal at this facility has resulted in potential problems to both surface and ground water resources in the area. The waste disposal systems at the facility constitute a major expense. The management at the facility recognized that the economic viability of the facility depended on reducing pollution control expenses and lowering or eliminating the burden of regulation the company must endure.

P2 OPPORTUNITY ASSESSMENT

A work plan for the P2 assessment program was developed identifying several tasks, including:

1. Development of a detailed assessment and evaluation of current practices and characterization of all wastes produced by the facility.

2. Identification and delineation of all possible P2 opportunities.

3. Economic and technical evaluation of all waste prevention and minimization alternatives including short-term as well as long-term impacts of these alternatives.

4. Development of recommendations to be made to the management of the manufacturing facility for P2 implementation that would be based on economic priority in terms of greatest benefit and shortest pay-back periods.

5. Providing technical assistance, where appropriate, during the process of implementation of the recommended alternatives.

6. Review of the results and impacts after implementation of the recommendations.

In developing the work plan, a multi-media approach was emphasized in developing pollution prevention and minimization strategies affecting all operations and processes.
The waste stream evaluation process conducted at the facility followed procedures outlined by the U.S. Environmental Protection Agency (see References section at the end of this report: U.S. EPA, 1990; 1992; 1993).

In conducting the P2 opportunity assessment, emphasis became focused on finding those areas where the impact on reducing the total pollutant load produced by this facility could be the greatest. Those areas were the electroplating, hot-dip galvanizing and the painting lines as well as the tube-mill production area. Because these areas produced the bulk of the wastes with the greatest toxicity and hazard, it was judged that improvements in these areas would produce the greatest impacts.

The Electroplating Systems

The manufacturing facility operates both an automated line and a manual electroplating line. These lines are used to deposit a thin zinc film onto small items such as bolts, fasteners and nuts, which are then used in the construction of larger plant products such as farm buildings. The automatic electroplating line is a barrel system which plates about 65 kgs (145 lbs) of work per load. The barrels are moved by a conveyor chain.

The automated electroplating line processes an average of 65 kgs (145 lbs) of work pieces per barrel. There are 36 stations on the line, with an approximate cycle time of 3.5 minutes at each station (about two hours per barrel). The work is first cleaned in a soak cleaner and an electrocleaning solution. It is then rinsed, pickled in a hydrochloric acid bath, and rinsed again before going into a chloride-zinc electroplating bath. After residing in the plating bath for about an hour and ten minutes (20 stations), the work is rinsed. A light yellow chromate finish is added. A short rinse (20 seconds) follows the chromating process after which the work is dried at 65°C (150°F). The electroplating solution is circulated through a filter to remove impurities. Particles removed by the filter are rinsed into the treatment system. The total rinse water use in the automatic electroplating line at this facility was estimated at 166 liters per minute (20 gpm) during 8 hours of operation daily.

The manual process is more operator intensive, which requires hand moving of barrels from station to station. The barrels are bigger, but the average load of work per barrel is also 65 kgs (145 lbs). This line is used more often than the automated line, especially when small quantities need to be plated. The work is cleaned in a soak cleaning bath (no electrocleaning) for about 15 minutes. It is then rinsed, pickled in hydrochloric acid, and rinsed again before being placed in the chloride-zinc electroplating tank (stainless steel pieces are dipped in nitric acid, instead of hydrochloric acid). The work pieces are plated for an average of 1 to 1.5 hours before being removed from the tank. A short rinse precedes the chromate coating; which can be clear or yellow, depending on customer preference. After a final short rinse, the pieces are placed on a table to air dry. A more detailed analysis of these electroplating lines is given by Parr (1994).

Pollution Prevention Opportunities in the Electroplating Systems

House Keeping Practices. To obtain better product quality and assure that the lower flow rates will not compromise rinsing efficiency, it was recommended that housekeeping practices be changed. There needed to be a thorough cleaning of the electroplating area including all tanks (inside and out), floor, and all equipment related to the electroplating process. A system needed to be established for recording when maintenance is done, tanks are emptied, chemicals are added, and testing on tank parameters is performed (e.g. pH, temperature, chemical concentration).

Rinse Water Use. The suggested process changes were designed to reduce waste of both rinse water and electroplating chemicals. To achieve these reductions, improved cleanliness and more careful chemistry control were required. It was recommended that the rinse rates be reduced to decrease the amount of wastewater being discharged to the treatment plant. For both the automated and manual electroplating lines, reactive rinsing was recommended in order to decrease water use from the rinses following the acid dip (pickling) and alkali cleaning processes (Tsai and Nixon, 1989; Hunt, 1988). Water from the rinse after pickling would no longer go down the drain, but would instead flow to the rinse tanks following alkali cleaning. Rinse water flow calculations showed that for these two processes, the required flow on each line could be as low as 8 liters per minute (2 gpm) (Durney, 1984).

At this plant, it was found that the effluent from the rinsing step after the acid dip could be directed to the rinse tanks after the cleaning process. This change would save a total of about 76 m^3 (20,000 gal.) of water per day resulting in a cost savings of about $150 per day in waste treatment, sludge disposal, and water costs. Counter-current tanks similar to those on the automated line (after the cleaning and acid dip processes) would be needed on the manual line to incorporate this change. The cost of these counter-current tanks was estimated at $1,000.

It was recommended that the rinse processes after the electroplating tanks on both the automatic and manual lines be changed to counter-current with a rinse flow rate of 20 liters per minute (5.3 gpm) each. About 24 m^3 (6,400 gal.) of water per day can be saved, resulting in a cost reduction of $50 per day. The cost associated with these changes was estimated at $1,000 for the counter-current tank system.

Electroplating Chemistry. The testing of chemical and operating parameters in the tanks needed to be done on a daily basis for several variables. Electroplating tank variables included pH and temperature in addition to the concentrations of cleaners, acid dips, zinc metal, boric acid, total chlorides, and the wetting agent. Chromating tank variables included pH, temperature, and chromate concentration.

Other Changes. Other recommended changes that were needed to improve the process included increasing the temperature of the cleaning tanks on the automatic line from 71°C to 93°C (160°F to 200°F). It was noted that a certain amount of grease originating at the machining steps of bolt production was accumulating in the automatic electroplating line's cleaning tanks. Grease skimming from the top of the cleaning tanks needed to be improved to remove more of the grease and oil before it carries over into the downstream processes. The filtering system on the electroplating tanks needed to be repaired, as it was inoperative. Once the filtering system is repaired (on both lines), it should be possible to determine if these systems are adequate to maintain contaminants at proper low levels. In fact, it was recommended that a new filtering system be installed.

It was noted that anode bags should be used to keep contaminants and dirt from the zinc balls out of the electroplating solution. Also, a drain board needed to be installed over the drip tank after the chromate rinse (on the auto line) to direct all dragout back into the rinse tank.

By using a trivalent chrome conversion coating process instead of the hexavalent chrome process that was being used, the facility should reduce the toxicity of the waste produced. Lower treatment costs would be realized since hexavalent chrome must be chemically reduced to its trivalent form, which is less expensive to treat, before sending it to waste treatment plant. The potential disadvantages of these changes would be: a slight reduction in corrosion protection, the need for closer monitoring and testing of the process, and that trivalent chrome coats are only available in a bright blue color instead of the customary light yellow.

To recapture some of the chemical dragout from the electroplating and chromating, it was recommended that still rinse tanks be used after these processes. It is estimated that about 50% of the chemical lost to dragout can be recaptured by this method (Hunt, 1988). It was also recommended that air agitation be used in the tanks to increase rinsing efficiency.

The electroplating process should be supplied with as clean a water as possible. It was noted that the facility had a reverse osmosis (RO) purification unit which was not in use, so it was recommended that the RO unit be used to supply water to the electroplating, chromating, and still rinse tanks. This change would remove potential contaminants in tap water including total dissolved solids (TDS) and hardness, thereby increasing process efficiency.

The barrel withdrawal rates were measured at 5.2 m/min (17 ft/min) in the automated line and 8.2 m/min (27 ft/min) in the manual line. According to Foecke (1993), the maximum rate of withdrawal should be about 2.4 m/min (8 ft/min). This change would help decrease the amount of dragout from each tank resulting in decreased chemical usage.

It was also recommended that the hang time of the barrels over the tanks be increased by pausing longer before moving to next station. The barrel hang time on the auto line was 23 seconds. There was still significant dripping from the barrels after this time period. The hang time over tanks on the manual line varied according to operator discretion. For the most part, hang time was observed to be minimal, and dragout was consequently significant.

Results of Implemented Changes in The Electroplating Systems

Recommended changes to the automatic electroplating line were presented to the facility. To date, four recommendations have been implemented, the results of which are summarized in this section.

The first recommendation to be implemented was to clean the outside and inside of all the tanks on the plating line and remove bottom sludge that had developed. In particular, the bath contents of the electroplating tank were pumped into a temporary holding tank and the bottom sludge was shoveled into eight 55-gallon drums for disposal (this sludge is not listed as hazardous under RCRA regulations). The liquid portion of the plating bath was then pumped back into the plating tank and additional chemicals and water were added to restore them to normal levels.

Another recommendation that was implemented was regular testing of the cleaning, acid dip, electroplating, and chromating processes to maintain chemical concentrations at their optimum levels.

The third implemented recommendation was the hiring of an employee with suitable chemistry background to perform operational control testing (among other duties including the galvanizing system chemistry, as discussed below) and report results back to the plating operator so that any required chemical additions can be made. The results of this testing are being documented, and chemical additions are now being made on a regular basis.

The fourth implemented recommendation was the reducing of all rinse flows. Flow control devices have been installed on the rinses after the alkaline cleaning and acid dip processes to maintain flow rates at the recommended levels. The two systems have not been connected together as was recommended. The flow rate for the two rinses after electroplating also have been reduced, although neither a countercurrent system nor flow control devices have been installed. The new rates have not been measured, and it has also not been determined if they are being maintained at a consistent level. According to the plating operator, the valves controlling flow are not turned on as far as in the past. The flows still appear to be above recommended levels (as judged by visual observation), but until flow control valves are installed or some other way of producing a consistent flow is devised, the current method will be continued.

The implemented changes also have resulted in significant product quality increases as evidenced by the results of the 5% neutral salt spray testing (as per ASTM B-117) done on bolts plated on the automated line before and after the changes were initiated. These results are presented in Table 1 below, and show a 1,000% increase in white rust protection and a 550% increase in red rust protection.

Table 1. Results of 5% neutral salt spray tests

Parameter	Pre-Change Results	Post-Change Results	Typical Values
Hours to White Rust	16	168	96 - 250
Hours to Red Rust	48	264	200 - 350

In conclusion, the facility has been very encouraged by these positive results. Also, from a waste prevention and minimization perspective, the implemented changes have been effective. The reduction in rinse flows will no doubt lead to less wastewater needing to be treated at the waste treatment plant. The cleaning of tanks, removal of sludge, and use of oil absorbent pads on the cleaning baths should help reduce the drag-out of dirt, grease, and other contaminants to downstream processes. This will help to increase bath life which will result in fewer bath dumps and reduced chemical use. The costs associated with these implemented changes have been modest.

The Galvanizing System

The galvanizing process at the facility is a five-step procedure consisting of pickling, rinsing, prefluxing, galvanizing, and final rinsing. The pickling step prepares work for galvanizing by removing oxides from the steel surface using a 10% sulfuric acid solution at a temperature of 70°C (158°F). The work pieces are dipped in the pickling acid for varying lengths of time, and then taken away to be rinsed.

After pickling, work pieces are rinsed to remove the acid. The preferred rinsing method is to dip work pieces in the rinse tank, which is filled with unheated municipal water. The rinse water is agitated by moving the work pieces back and forth in the rinse tank.

After the first rinsing, work pieces are placed in the preflux tank, which is a crucial step in the "dry kettle" galvanizing process. The work is coated with flux chemicals ($ZnCl_2$ and NH_3Cl) prior to entering the zinc kettle. The preflux tank is kept at 70°C. Normally, the preflux solution should be allowed to dry thoroughly before proceeding with galvanizing.

Galvanizing is accomplished by immersing steel in a tank filled with molten zinc for 2 to 3 minutes. Livestock fencing, the majority of the steel galvanized at this plant, uses the wet kettle galvanizing method. This means that a flux layer is floated on top of the galvanizing kettle. A flux layer covers the kettle, and work pieces pass through it as they enter and leave the kettle. For galvanizing other materials such as building components, the kettle flux layer is skimmed to the side and not used.

The work pieces are cooled by rinsing them in a second rinse booth located next to the galvanizing kettle. This final rinse is needed to cool the work to below 200°C (390°F), which stops the possible growth of a brittle zinc-steel alloy layer. Cooling also makes it easier for operators to handle the work pieces. A detailed analysis of the galvanizing system at this facility is given by Montag (1993).

Pollution Prevention Opportunities in the Galvanizing Process

Pollution prevention efforts in the galvanizing area were concentrated on reducing the volume and metal content of rinse water since this is the principal medium through which metal is lost. Volume reductions can be accomplished by installing additional galvanizing equipment. Metal content reductions are possible by either discontinuing use of the kettle flux, or switching to a different kettle flux.

Rinse Water Use. The galvanizing system at this plant initially used about 265 m^3 of rinse water per day. Flow through the first rinse booth was measured during the waste stream assessment period at 1,200 liters per minute. Freshly galvanized pieces are cooled in the second rinse booth. Flow through this booth nowadays is estimated at approximately 1,200 liters per minute, a reduction in flow which is due to recent modifications after the assessment was completed. The rinse booths operate only when there are materials to be rinsed being carried through them.

Rinsing in a rinse tank, instead of a rinse booth, after galvanizing is the most important step in decreasing galvanizing water use. Use of rinse tanks after pickling is also important. The rinse booths could be replaced by rinse tanks linked in a counter-current flow arrangement. The benefit of such a system is that it allows water to be reused several times before it is discharged to the drain, in addition to the fact that work pieces are always rinsed using the cleanest water as they leave the process line.

A rinse test was conducted to verify the usefulness of the rinse tank concept. This test successfully demonstrated the feasibility of continuous-flow rinsing. Based on the results of the rinse test, a continuous rinse water flow rate of 24 liters per minute (6.3 gal/min) will remove pickling acid adequately for two rinse tanks in series. This flow rate will adequately cool the work, preventing the water temperature from rising high enough as to pose a worker safety problem. The proposed system would use about 35 m^3 of water (or less) per day. This represents a savings of about 83%. One of the changes resulting from the study was the replacement of the spray orifices (nozzles) in the rinse booths by water-saving (low-flow) ones. This change resulted in an immediate reduction in the water use by 60% and resulted in savings in water use and waste treatment costs of about $250 per day.

The cost of the proposed galvanizing equipment changes is estimated at about $70,000, and ventilation system improvements required to remove pickling solution vapors from the proposed pickling tank location would cost $25,000. Due to the expense of the suggested galvanizing changes, phased installation was recommended. The estimated payback period on the suggested modifications is about 10 months.

Galvanizing Chemistry. Fencing currently is being fluxed twice: once in the preflux tank, and a second time as it enters the kettle. For galvanizing of objects other than fence panels (such as building parts), the kettle flux is skimmed to the side and is not used. The kettle flux is 98% $ZnCl_2$ and contains a small amount of KCl. Kettle flux adds significantly to the metal content of galvanizing rinse water, so discontinuing the use of kettle flux would enhance pollution prevention.

Prefluxing is crucial in dry kettle galvanizing. To obtain good fluxing, proper concentrations of $ZnCl_2$ and NH_4Cl must be maintained, and iron and sulfate concentrations must be minimized. Frequent sampling is required.

In the preflux chemistry, two terms (i.e., degrees Baumé (°Be), and Ammonium Chloride Number (ACN)) are important to the operation of the system. The °Be is a unit of density which is directly related to the $ZnCl_2$ concentration. Optimum density ranges from 12 to 15 °Be (1.09 g/mL to 1.12 g/mL), measured at 20°C. The ACN of a preflux is the ratio of the NH_4Cl concentration divided by the concentration of all other components in solution. An optimum ACN value is difficult to ascertain. In U.S. practice, recommended values range from 1.17, used by most galvanizers, to 1.8 recommended by Cook (1982). Sjoukes (1990), a galvanizing expert from the Netherlands, recommends ACN values of 1.75 to 2.5.

The plant currently collects samples of the preflux solution for detailed analysis, including ACN, three or four times a year. More frequent ACN determinations (at least monthly) are needed for galvanizing strictly by the "dry kettle" method. This becomes more important if the kettle flux continues to be used after installing the recommended counter-current flow rinse system. This is because zinc chloride will be dragged into the preflux from the post-pickling rinse.

In-house testing was recommended for faster data acquisition. It was also recommended that a chemist be hired to perform chemical testing on a continuous basis. The same chemist would conduct tests associated with the electroplating lines, as pointed out above.

Solutions

Pilot project adds polish to metal finisher's pollution prevention efforts

BY M.F. DAHAB AND JIM LUND

AN AGING MIDWESTERN MANUFACturing facility that produces fabricated metal products for farm and industrial uses was chosen as the site for an industrial pollution prevention and waste minimization pilot project. The project goal was to demonstrate that using appropriate management and operating procedures can reduce the total pollution produced by an industrial operation. The facility is a licensed hazardous waste generator.

The plant engages in a variety of pollution-generating activities, including electroplating, conversion coating, cleaning, machining, grinding, impact deformation, shearing, welding, sand blasting, hot-dip coating, painting, assembly and testing. The hot-dip galvanizing process results in production of rinsewater containing such heavy metals as zinc and iron. Painting processes generate used industrial cleaners, acids, solvents, and chemicals used in cleaning and degreasing metal components.

Process wastewaters are treated by adding lime and polymer, and adjusting pH before discharge. Past disposal practices at the facility had threatened area surface and groundwater. Waste disposal is a major operating expense.

Past disposal practices at the facility had threatened area surface and groundwater. Waste disposal is a major operating expense.

Procedures and methods. The wastestream evaluation followed Environmental Protection Agency guidance. A pollution prevention assessment work plan identified several tasks, including:

- Developing a detailed assessment and evaluation of current practices, and characterization of all wastes produced by the facility;
- Identifying possible pollution prevention and minimization opportunities;
- Evaluating economic and technical aspects of waste prevention and minimization alternatives, and their short- and long-term impacts;
- Developing recommendations to management for implementation based on greatest benefit and shortest payback periods;
- Providing technical assistance during implementation of recommended alternatives; and
- Reviewing the results and impacts on waste prevention after implementing the alternatives.

In developing the pilot project, emphasis was placed on areas in which the impact on reducing total pollutant load would be greatest — the electroplating, hot-dip galvanizing and painting lines, and tube-mill production areas. Strategy development stressed a multimedia approach to preventing and minimizing pollution.

Electroplating systems. The facility operates an automated and a manual electroplating line to deposit a thin zinc film onto such items as bolts, fasteners and nuts, which are used to construct larger plant products. The automatic line is a barrel system that plates about 145 pounds of work per load. Barrels are moved by a conveyor chain. An average of 145 pounds of pieces per barrel are processed by 36 stations on the line. The cycle takes about 3.5 minutes per station, or about two hours per barrel.

The work first is soaked in cleaner and an electrocleaning solution. It then is rinsed, pickled in a hydrochloric acid bath, and rinsed again before entering a chloride-zinc electroplating bath. After about an 70 minutes in the plating bath (20 stations), the work is rinsed, and a light yellow chromate finish is added. A short rinse (20 seconds) follows the chromating process, after which work is dried at 65 degrees Celsius.

The electroplating solution is circulated through a filter to remove impurities, which are rinsed into the treatment system. Total rinsewater use in the automatic electroplating line, which operates eight hours a day, was estimated at 166 liters per minute.

The manual process requires operators to move barrels from station to station. The barrels are bigger, but the average load of work per barrel is the same as in the automated process. The manual line is used more than the automated line, especially when plating small quantities. The work is cleaned in a soak cleaning bath (no electrocleaning) for about 15 minutes. It then is rinsed, pickled and re-rinsed before entering the chloride-zinc electroplating tank. (Stainless steel pieces are dipped in nitric acid instead of hydrochloric acid.) Pieces are plated 60 to 90 minutes before being removed. A short rinse precedes the chromate coating, which can be clear or yellow. After a final short rinse, pieces are placed on a table to dry.

To obtain better product quality and ensure that the lower flow rates would not compromise rinsing efficiency, housekeeping changes were recommended. These included a thorough cleaning of the electroplating area (tanks, floor and electroplating process equipment), and a maintenance recordkeeping system.

The suggestions, designed to reduce rinsewater and electroplating chemical waste, called for improved cleanliness and better chemistry control. Also recommended was reducing rinse rates to decrease the amount of wastewater discharged to the treatment plant. Reactive rinsing was recommended for both electroplating lines to decrease water use from the rinses following pickling and alkali cleaning. Pickling rinsewater no longer would go down the drain, but instead flow to rinse tanks following alkali cleaning.

Use of still rinse tanks following electroplating and chromating was recommended to recapture some of the chemical dragout from these processes.

Effluent from the rinsing step after the acid dip could be directed to the rinse tanks after the cleaning process, saving about 76 cubic meters of water and $150 per day in waste treatment, sludge disposal and water costs. Countercurrent tanks similar to those on the automated line would be needed on the manual line to incorporate this change, at a cost of about $1,000. It was recommended that rinse processes following electroplating on both lines be changed to countercurrent with a rinse flow rate of 20 liters per minute each. About 24 cubic meters of water a day can be saved, saving $50 per day.

Daily testing of chemical and operating parameters in the tanks needed to be performed for several variables. Electroplating tank variables included pH and temperature in addition to concentrations of cleaners, acid dips, zinc metal, boric acid, total chlorides and the wetting agent. Chromating tank variables included pH, temperature and chromate concentration.

Other recommended changes included increasing the temperature of automatic line cleaning tanks from 71 degrees Celsius to 93 degrees Celsius. Grease skimming needed improvement, because grease originating from the machining steps of bolt production accumulated in the automatic electroplating line's cleaning tanks. An inoperative filter system on the electroplating tanks also needed repairs. Once the repairs are made on both lines, it should be possible to determine whether the systems are adequate to maintain contaminants at low levels. Installing a new filtering system was recommended.

Anode bags were recommended to keep contaminants and dirt from the zinc balls out of the electroplating solution. Additionally, a drain board was needed over the drip tank following the chromate rinse on the automatic line to direct dragout back to the rinse tank. By changing to a trivalent-chrome-conversion coating process instead of the hexavalent chrome process, the facility should decrease the toxicity of the waste it produces. This would save on treatment costs, because hexavalent chrome must be reduced chemically to its trivalent form — which is less toxic and less expensive to treat — before it is sent to a treatment plant.

Some potential disadvantages of these changes are a slight reduction in corrosion protection, the necessity of closer process monitoring and testing, and the fact that trivalent chrome coats are available only in bright blue instead of the customary light yellow.

Use of still rinse tanks following electroplating and chromating was recommended to recapture some of the chemical dragout from these processes. This method should recapture about half of the chemical lost to dragout. It was also recommended that air agitation be used in the tanks to increase rinsing efficiency.

The water supplied to the electroplating process should be as clean as possible. It was recommended that the facility's reverse osmosis purification unit be used to supply water to the electroplating, chromating and still rinse tanks. This would remove potential contaminants in tap water, including total dissolved solids and hardness, before its use in the electroplating line, increasing process efficiency.

The barrel withdrawal rates were measured at 5.2 meters per minute in the automated line and 8.2 meters per minute in the manual line. The maximum withdrawal rate should be about 2.4 meters per minute. Changing this would decrease the amount of dragout from each tank, resulting in decreased chemical use.

It was also recommended that the hang time of barrels over the tanks be increased by pausing longer before moving to the next station. Although hang time on the automated line was 23 seconds, significant dripping from barrels occurred after this time. Hang time over tanks on the manual line varied. Generally, hang time was observed to be minimal, and dragout was significant.

Results of system changes. Several recommended changes to the automatic electroplating line were implemented. All tanks were cleaned, inside and outside, on the plating line, and accumulated bottom sludge was removed. The bath contents of the electroplating tank were pumped into a temporary holding tank, and nonhazardous bottom sludge was shoveled into eight 55-gallon drums for disposal. The liquid portion of the plating bath was pumped back into the plating tank, and additional chemicals and water were added to restore them to normal levels.

Other changes included:

- Regular testing of cleaning, acid dip, electroplating and chromating processes to maintain optimal-level chemical concentrations;
- Hiring a qualified individual to perform operational control testing and work with the plating operator to make required chemical additions; and
- Reducing rinse flows, and installing flow measurement and countercurrent rinsing.

Flow control devices have been installed on the rinses following the alkaline cleaning and acid-dip processes to maintain flow rates at recommended levels. The two systems have not been connected as recommended. Flow rates for the two rinses following electroplating also have been reduced. The new rates have not been measured, so it has not been determined whether they are being maintained consistently. The plating operator reports the valves that control flow are not opened as far as in the past. Besides decreasing the rinsewater flow rate, adding the countercurrent system to the manual line should increase the rinsewater's utility.

Product quality has been increased significantly, as evidenced by results of the 5 percent neutral salt spray testing performed on bolts plated on the automated line before and after the changes occurred. The results show a 1,000 percent increase in white rust protection and a 550 percent increase in red rust protection.

Tank cleaning, sludge removal and use of oil absorbent pads on the cleaning baths should reduce the dragout of dirt, grease and other contaminants to downstream processes.

From a waste prevention and minimization perspective, the changes have been effective. Reduction in rinse flows should lead to less wastewater for treatment at an onsite facility. Tank cleaning, sludge removal and use of oil absorbent pads on the cleaning baths should reduce the dragout of dirt, grease and other contaminants to downstream processes. This will increase bath life, resulting in fewer bath dumps and reduced chemical use. Costs of implementing these changes have been modest.

The galvanizing system. The facility's galvanizing process consists of pickling, rinsing, prefluxing, galvanizing and final rinsing. The pickling step prepares work for galvanizing by removing oxides from the steel surface using a 10 percent sulfuric acid solution at 70 degrees Celsius.

Work pieces are rinsed after pickling. The preferred method is to dip them in the rinse tank, which is filled with unheated municipal water. The rinsewater is agitated by moving the pieces back and forth in the tank. After the first rinsing, work pieces are placed in the preflux tank, a crucial step in the dry-kettle galvanizing process. Work is coated with flux chemicals before entering the zinc kettle. The preflux tank is maintained at 70 degrees Celsius. The preflux solution generally is allowed to dry thoroughly before galvanizing.

Galvanizing is accomplished by immersing steel in a tank filled with molten zinc for two to three minutes. Most steel galvanized at this plant uses the wet-kettle method. A flux layer is floated on top of the galvanizing kettle, and work pieces pass through it as they enter and leave the kettle. For galvanizing materials, such as building components, the kettle flux layer is skimmed to the side and not used. Work pieces are cooled by rinsing them in a second rinse booth next to the galvanizing kettle. This final rinse is needed to cool the work to below 200 degrees Celsius, which prevents growth of a brittle zinc-steel alloy layer. Cooling also allows operators to handle the pieces.

Galvanizing operations. Pollution prevention efforts in galvanizing were concentrated on reducing the volume and metal content of rinsewater, as this is the principal medium through which metal is lost. Volume reductions can be accomplished by installing additional galvanizing equipment. Metal content reductions are possible by discontinuing use of the kettle flux or switching to a different kettle flux.

The galvanizing system initially used about 265 cubic meters of rinsewater per day. Flow through the first rinse booth was measured during wastestream assessment at 1,200 liters per minute. Freshly galvanized pieces are cooled in the second rinse booth. Flow through this booth was estimated at about 1,200 liters per minute. The rinse booths operate only while materials to be rinsed are carried through them.

Rinsing in a tank instead of a booth is the most important step in decreasing galvanizing water use. Using rinse tanks after pickling also is important. It was recommended that rinse booths be replaced by rinse tanks linked in a countercurrent flow arrangement. This allows water to be reused several times before being discharged and ensures that work pieces are rinsed with clean water as they leave the process line.

A rinse test conducted to verify the usefulness of the rinse tank concept successfully demonstrated the feasibility of continuous-flow rinsing. Based on the results, a continuous rinsewater flow rate of 24 liters per minute removes pickling acid adequately for two rinse tanks in series. This flow rate cools the work, preventing the water temperature from rising high enough to pose a safety problem. The proposed system would use no more than 35 cubic meters of water per day, representing a savings of about 83 percent. As a result of the study, water-saving (low-flow) nozzles were installed in the rinse booths. This immediately reduced water use by 60 percent, yielding water and waste treatment savings of about $250 per day.

The proposed galvanizing equipment changes cost about $70,000. Ventilation system improvements to remove pickling solution vapors from the proposed pickling tank location would cost $25,000. Due to the expense, phased installation of suggested galvanizing changes was recommended. The payback period is estimated at about 10 months.

Livestock fencing is being fluxed twice — once in the preflux tank and again as it enters the kettle. For galvanizing objects other than fence panels, kettle flux is not used. The kettle flux is 98 percent zinc chloride and contains a small amount of potassium chloride. Kettle flux adds significantly to the metal content of galvanizing rinsewater, so that discontinuing its use would aid pollution prevention.

Prefluxing is crucial in dry-kettle galvanizing. To obtain good fluxing, proper concentrations of zinc chloride and ammonium chloride must be maintained, and iron and sulfate concentrations minimized. Frequent sampling is required.

Switching from zinc chloride preflux to a mixture of mostly ammonium chloride and some zinc chloride or ammonium chloride alone was recommended. This probably would enhance product quality, because the proposed countercurrent flow system (with fresh water being added at the final rinse tank) would not complicate preflux chemistry.

Another problem with the galvanizing operation was a layer of oil floating on the surface of the acid bath. The oil could be minimized by installing a skimmer to remove it periodically or to reduce oil use in the fabricating step.

The painting system. The painting operation at the facility consists of washing, etching, oven drying, spray painting and oven curing. The plant's painting operation in 1992 was estimated to have emitted about 37,500 kilograms of xylene and 11,000 kilograms of toluene. Reducing emissions of these volatile organic compounds should be a top priority.

Another suggestion was to switch to an autophoretic painting process to reduce VOC emissions and eliminate chromic-acid etching.

Two types of paint are used at the plant. A solvent-based paint is used for painting gates, and a silicone polyester paint is used for coating building panels. Seventy-four percent of the paint used in the automatic paint line in 1992 was used to paint farm gates. About 2,200 liters per month of a mixture of aromatic solvents are used for such purposes as cleaning paint-supply piping.

The only practical way to reduce VOC emissions significantly is to change paint materials. One alternative is to use water-based paint for the gates. If water-based paints are applied electrostatically, a high transfer efficiency can be obtained. The investment should be relatively small, because the only facility change required is installing new spray equipment. Immediate testing of water-based paints was recommended.

Another suggestion was to switch to an autophoretic painting process to reduce VOC emissions and eliminate chromic-acid etching. This involves dipping metal to be painted into tanks filled with paint. The coating is deposited *via* a chemical reaction between the paint and metal which requires several minutes of immersion. The autophoretic process resembles electrocoating but requires no electric current. Metal painted using this process reportedly has withstood salt spray tests up to 3,000 hours without coating failure. The paint reportedly exhibits a high degree of hardness and good resistance to chalking from ultraviolet light exposure.

The estimated cost of an autophoretic system to coat gates was $300,000. A serious drawback of this method is that color varies with the dissolved iron concentration in the paint, which increases slowly due to contact of the paint with the steel being painted. Another drawback is the fact that a separate paint tank is needed for each color.

Another alternative is powder coating. Agricultural gates are ideally suited for powder coating, because they are made in only two colors. Transfer efficiency is not an issue, because overspray is captured and blended with fresh powder for reuse, and VOCs are not emitted. An industrial supply contractor estimated that powder coating could be added to the existing paint line for about $40,000. However, installation costs probably would be higher, because the automatic paint line is old and should be replaced. A new paint line was estimated to cost about $200,000.

Pollution prevention in the painting area at this plant will not be offset by significant savings in disposal costs. However, the Clean Air Act will require that action be taken soon. As a result of this study, the plant has experimented with water-based paints and requested bids to construct a powder coating system.

Tubing manufacture system. A tube mill at the facility forms metal pipe from coils of sheet steel. The plant makes tubing for all its gates and also sells tubing to other companies. The major tube mill components include a coil unwinder, feeder, initial cold rolls, welder, re-galvanizer, final cold rolls, metering cutter and coolant distribution system. A water-based fluid coolant is used to lubricate and cool the tube mill.

About 800 liters of coolant per month are consumed at a cost of about $800. The coolant flows from application points into sumps below the components. The sumps drain by gravity to a large collection tank, which contains an oil removal system consisting of a plastic tube pulled through the liquid coolant. Floating oil adheres to the polyethylene tube and is removed by a scraper. However, the oil removal system is unable to remove oil quickly enough.

Oil in the coolant originates from grease leaking out of the tube mill gearboxes. Over the years, oil and grease leaks have covered the tube mill and the surrounding area. Grease combines with metal filings created when excess metal is scraped from fresh welds. Together, the grease and filings form a black substance that fills the bottom of the sumps in about a month. The mill occasionally is shut down while operators scoop out the grease. About two-thirds of the coolant is lost each time the sumps are cleaned, and this is the only time coolant is discharged from the system.

Recommendations for the tube mill focus on minimizing grease contamination of the coolant. The old oil-removal system should be replaced with a system that would allow coolant reuse. A suitable unit was estimated to cost less than $2,500. The payback period was estimated at less than six months, assuming the coolant's usable life is doubled. If coolant could be used longer, the payback period would be shorter.

The coolant also turns rancid. Coolant rancidity usually is controlled by adding a biocide. If rancidity problems continue after an improved oil removal system is installed, a different biocide may be needed. Gearbox leakage should be prevented or kept from falling into the sumps through regular maintenance. In addition, preventing metal filings from falling into the sump below the weld scraper would keep them from combining with the grease. It was recommend that the entire area be shut down for thorough cleaning, as this would vastly improve system operation. Cleaning should include equipment, floor grates and the return trough. ❑

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INDUSTRIAL POLLUTION PREVENTION PILOT PROJECT

A Summary Report

Introduction

This project is intended to develop an industrial pollution prevention and minimization pilot project in Nebraska. The goal of the project is to demonstrate that through proper management and operating practices, the total pollution produced by an industrial operation can effectively be reduced significantly. The net effect of this pollution prevention program is to improve the economic net-worth of the industry by lowering expenditures on pollution control measures as well as minimizing the burden of regulation imposed by the government. Behlen Manufacturing Company of Columbus, Nebraska, has agreed to be the demonstration site for this project.

Behlen Manufacturing is an employee-owned facility engaged largely in the production of fabricated metal products for farm and industrial uses. The facility is located in Columbus, NE in a predominantly rural area. The plant site is a 97 acre area on which several buildings are located. The largest of these buildings is a 805,000 square foot manufacturing facility and a 42,000 square foot office complex. Because of the nature of its manufacturing, Behlen is permitted under the RCRA and the NPDES systems.

In its various manufacturing processes, Behlen performs many operations including electroplating, conversion coating, cleaning, machining, grinding, impact deformation, shearing, welding, sand blasting, hot-dip coating, painting, assembly and testing. Many of these processes result in the production of a variety of pollutants (gaseous, solid, and liquid) that have to be disposed of in some fashion depending on their nature. For example, the hot-dip galvanizing process results in the production of rinse water which must be treated as a hazardous substance containing heavy metals (e.g. zinc and iron) in addition to being highly corrosive. The painting processes result in the production of used industrial cleaners, acids, hexavalent chromium, solvents, and chemicals used in the cleaning and de-greasing of metal components.

All process wastewaters produced at this facility are treated in accordance to stipulations under the NPDES permit. The wastewater is treated by lime and polymer addition and pH adjustment before discharge to the Loup Power Canal. In the past, waste disposal at this facility resulted in potential problems to both surface and ground water resources in the area. The waste disposal systems at Behlen undoubtedly constitute a major expense to this facility. The management at Behlen welcomes any improvement in its economic picture by reducing its pollution control expenses and lowering or eliminating the burden of regulation the company must endure.

Project Tasks

In developing the demonstration pilot project at Behlen, emphasis was placed on areas where the impact on reducing the total pollutant load produced by this facility was greatest. These areas are electroplating, hot-dip galvanizing, the painting line, and the tube-mill area. As pointed out above, these areas produce the bulk of the wastes with the greatest toxicity and hazard, and consequently any improvements in these areas should result in the greatest impacts. In developing a work plan, a multi-media approach was emphasized in developing pollution prevention and minimization strategies affecting all operations and processes at Behlen. The work plan consisted of several tasks. These tasks are summarized as follows:

1. A detailed assessment and evaluation of the current practices in the areas identified above along with a detailed characterization of all wastes (gaseous, liquid, and solid) produced at this facility.

2. Identification and delineation of all possible pollution prevention and minimization opportunities.

3. Economic and technical evaluation of all waste prevention and minimization alternatives including short as well as long term impacts of these alternatives.

4. Recommendation to Behlen Manufacturing for implementation based on economic priority in terms of greatest benefit and shortest pay-back periods.

5. Providing technical assistance, where appropriate, to Behlen during the process of implementation of the recommended alternatives.

6. Review of the results and impacts on waste prevention after the implementation of the alternatives.

7. Development of a demonstration program involving technical workshops, if appropriate, and informational materials such as capsule and summary reports for use by interested individuals and corporations.

8. Reporting of the study results to the U.S. EPA in generic terms for use by other industries with similar processes and operations.

This report provides a summary of all activities completed to date and essentially covers Tasks 1 through 4, as identified above. A detailed summary report will be provided to Behlen Manufacturing at the conclusion of this study.

Project Recommendations

The initial phases of this study were begun in early 1992 with a detailed waste stream assessment of all operations at Behlen Manufacturing. In this report, the recommendations presented to Behlen for consideration are discussed sequentially by process category, as indicated above.

Galvanizing

The galvanizing process at Behlen is a five step process consisting of pickling, rinsing, prefluxing, galvanizing, and final rinsing. Pollution prevention efforts in the galvanizing area should concentrate on reducing the volume and metal content of rinse water since this is the principal medium through which metal is lost. Volume reductions can be accomplished by installing additional galvanizing equipment. Metal content reductions are possible by either discontinuing use of the kettle flux, or switching to a different kettle flux.

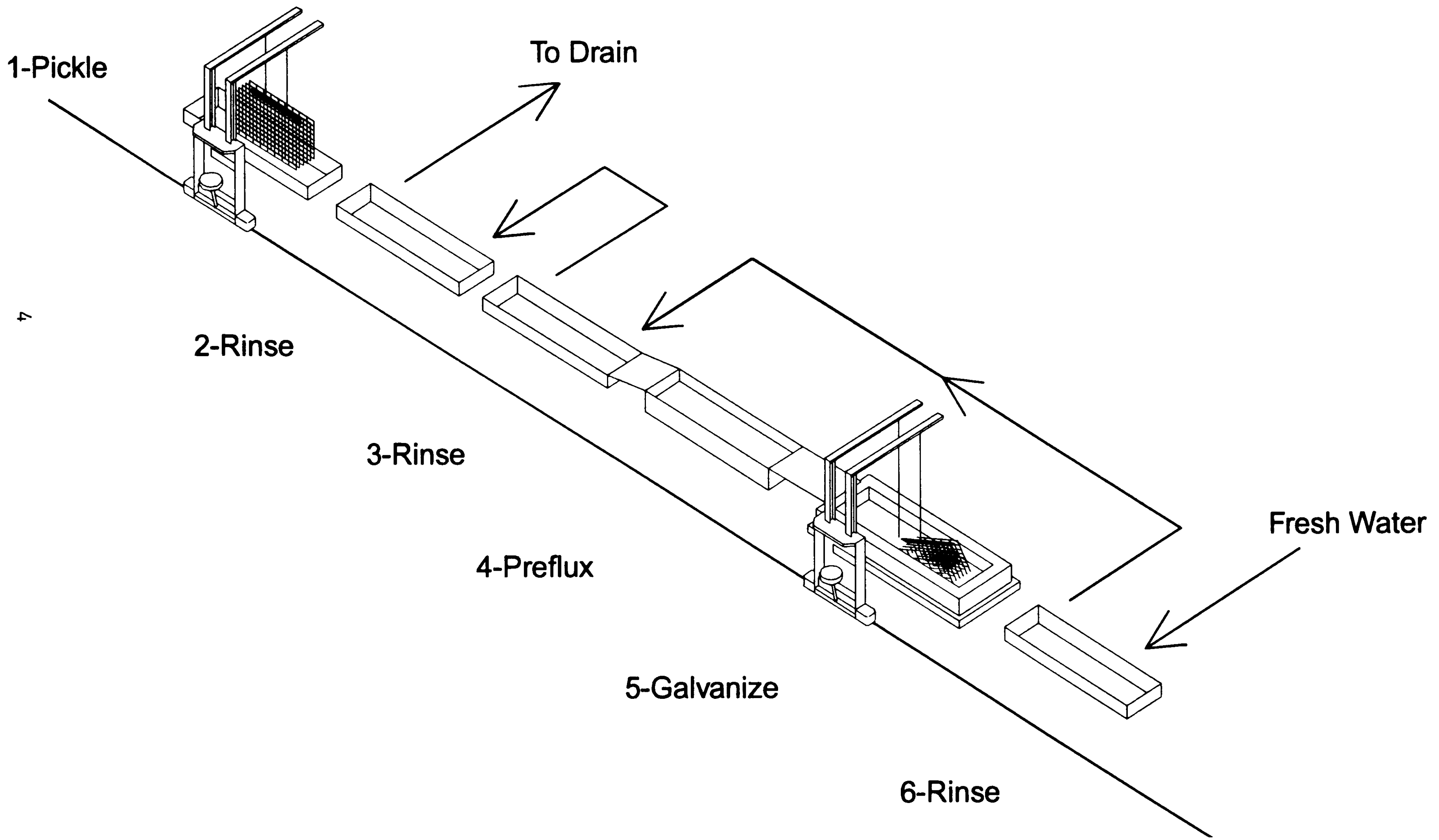
Rinse Water Use

The galvanizer uses about 55,000 gallons of rinse water per day. The rinse booth located between the acid tank and the rinse tank is used for spray rinsing after pickling. Flow through the booth was measured during the waste stream assessment period at 300 gallons per minute. Freshly galvanized pieces are cooled in the booth next to the galvanizing kettle. Flow through this booth these days is estimated at approximately 300 gallons per minute. The flow rate estimate for the second rinse booth has been reduced to reflect recent modifications after the assessment was completed.

Rinsing in a rinse tank (instead of a rinse booth) after galvanizing is the most important step in decreasing galvanizing water use. Use of rinse tanks after pickling is also important. As discussed at the March 19th meeting at Behlen, the rinse booths could be replaced by rinse tanks linked in a counter-current flow arrangement as shown in Figure 1. The benefit of such a system is that it allows water to be reused several times before it goes down the drain, in addition to the fact that work pieces are always rinsed using the cleanest water as they leave the process line.

A rinse test was conducted on April 1, 1993 which successfully demonstrated the feasibility of continuous-flow rinsing. Based on the results of the rinse test, a continuous rinse water flow rate of 7 gallons per minute will remove pickling acid adequately for two rinse tanks in series. A flow rate of 7 gpm flow will cool the work, preventing the water temperature from rising high enough as to pose a worker safety problem.

FIGURE 1 - PROPOSED COUNTER-CURRENT RINSE SYSTEM FOR THE GALVANIZER



The proposed system would use about 10,000 gallons per day. This represents a savings of about 45,000 gallons of water per day. The cost of these proposed galvanizing equipment changes is estimated at about $70,000, and ventilation system improvements required to remove pickling solution vapors from the proposed pickling tank location would cost $25,000. Due to the expense of the suggested galvanizing changes, phased installation is recommended. The final cooling tank could be added first and linked to the existing system as shown in Figure 2.; entitled Interim Solution. For a cost of about $17,000, the rinse tank at the West end of the line could be installed in a pit on the East end where the second rinse booth is now located. The costs and payback periods for the recommended galvanizing system and for the recommended interim solution are summarized in Table 1.

Table 1. Costs and pay-back periods for the recommended changes to the galvanizing line.

OPTION	COST	PAYBACK
Adding 3 rinse tanks as in Figure 1 - Proposed System	$95,000	10 months
Using the existing rinse tank in place of the second rinse booth as in Fig. 2	$17,000	3 months

Galvanizing Chemistry

Fencing currently is being fluxed twice: once in the preflux tank, and a second time as it enters the kettle. For galvanizing of objects other than fence panels (such as building parts), the kettle flux is skimmed to the side and is not used. The kettle flux is called Preact, and is supplied by Mineral Research Corporation. Preact is 98% zinc chloride, and contains a small amount of potassium chloride. Behlen uses 16,300 pounds of Preact each month, at a cost of about $8,500. Kettle flux adds significantly to the metal content of galvanizing rinse water, so discontinuing the use of kettle flux would enhance pollution prevention.

Prefluxing is crucial in dry kettle galvanizing. The preflux tank holds a solution of zinc chloride ($ZnCl_2$) and ammonium chloride (NH_4Cl). To obtain good fluxing, proper concentrations of $ZnCl_2$ and NH_4Cl must be maintained, and iron and sulfate concentrations must be minimized. Frequent sampling is required.

Two preflux chemistry terms which may be unfamiliar are degrees Baumé (°Be), and Ammonium Chloride Number (ACN). The °Be is a unit of density. Preflux density is directly related to the $ZnCl_2$ concentration. Optimum density ranges from 12 to 15 °Be (1.09 g/ml to 1.12 g/ml) as measured at 70 to 75°F. The ACN of a preflux is the ratio of the NH_4Cl concentration divided by the concentration of all other components in the solution. Opinions about the best ACN differ. For example, Mineral Research Corporation recommends 1.17 while Dr. T.H. Cook (America's most prominent galvanizing researcher) recommends 1.4 to 1.8, and F. Sjoukes (European galvanizing expert) recommends 1.75 to 2.5. Every three or four months, Mr. Dick Robak (of Behlen) sends a preflux sample to Mineral Research Development Corp. of Charlotte, N.C. Mineral Research performs a detailed analysis, including ACN. More frequent ACN determinations (about every 2 weeks) would be helpful in attempting to galvanize strictly by the "dry kettle" method.

If the kettle flux continues to be used after installing a counter flow rinse system, frequent preflux sampling will be needed in order to maintain a proper ACN. This is because zinc chloride will be dragged into the preflux from the post-pickling rinse. The magnitude of zinc chloride drag-in will be established when samples taken at Behlen during a June 16th rinse test are fully analyzed. Tony Raimondo Jr. (of Behlen) indicated that Mineral Research Development would probably be willing to analyze samples more frequently, and that they would still provide the service for free. Also, in-house preflux testing is possible. In his article: "Ammonium Chloride Control in Galvanizing Preflux," Cook (1982), Dr. T.H. Cook described a procedure for determining ammonium chloride concentration. The procedure is relatively simple, but it utilizes strong a strong acid and a strong base, and therefore, an experienced chemist should perform the test. It should be possible for either Mr. Will or Mr. Zobel (of Behlen) to conduct such a test.

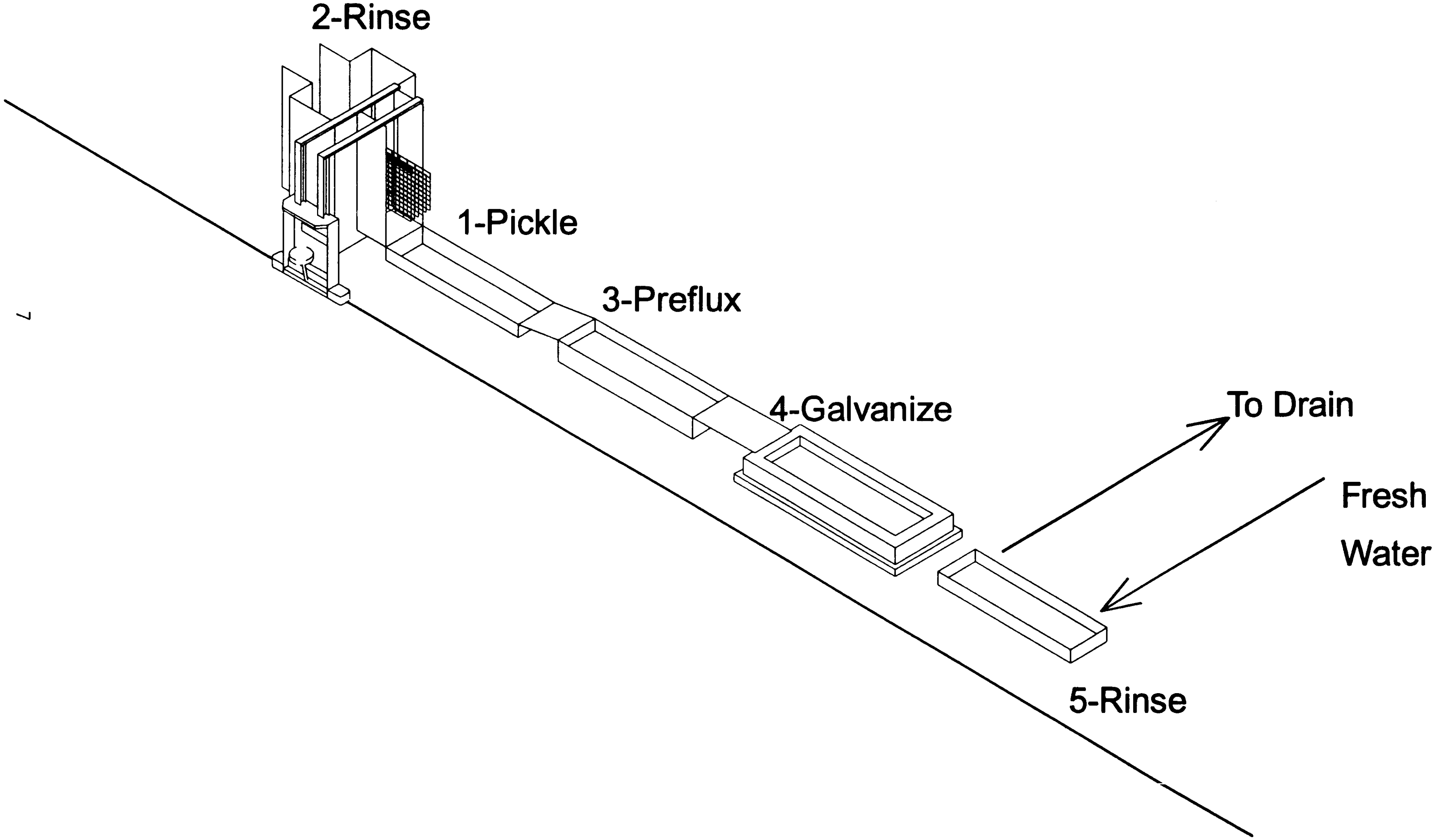
In addition, if a kettle flux must be maintained, it would be helpful to switch to one that is a mixture of zinc chloride and ammonium chloride, or even to pure ammonium chloride. Use of pure ammonium chloride kettle flux is described by F. Sjoukes in an article entitled: "Chemical Reactions in Fluxes for Hot Dip Galvanizing" (Sjoukes, 1990). A different kettle flux would probably give better results, and with different flux, the proposed counter flow system with fresh water being added to the final rinse tank would not complicate preflux chemistry.

Another problem associated the galvanizing operation is the oil floating on the surface of the acid bath. This is not surprising since there is no caustic cleaning stage prior to pickling. The oil problem could be minimized by installing a trough into which oil can be skimmed periodically. An attempt should be made to minimize oil on steel to be galvanized.

Painting

Painting is a sequential process consisting of washing, etching, oven drying, spray painting, and oven curing. The paints used at Behlen are of the traditional solvent based variety, and contain volatile organic compounds (VOC's). Last year the painting operation was estimated to have emitted about 82,000 pounds of xylene, and 23,000 pounds of toluene. Xylene and toluene are defined as hazardous by the 1990 Clean Air Act, and will be regulated strictly in the near future, so reducing emissions of these VOC's should receive a high priority.

FIGURE 2 - INTERIM SOLUTION FOR REDUCING GALVANIZING WATER USE



The two major types of paint in use at Behlen are Farmmaster paint, which is used for painting gates, and Pratt and Lambert silicone polyester paint, which is used for painting building panels. Last year (1992), 34,567 of the 47,312 gallons of paint consumed by the automatic paint line were used in painting gates. Additionally, large quantities of a solvent named "Vanblend 99" are used. This is a mixture of several aromatic solvents, and is used with Farmmaster paint for such purposes as line cleaning between colors. Approximately, 570 gallons of Vanblend 99 are consumed each month.

Painting Alternatives

The only practical way to significantly reduce VOC emissions is to change paint materials. There are several possible materials from which to choose.

One choice is to use water based paint for gates, which accounts for over 70% of Behlen's paint use. If water based paints are applied electrostatically, a high transfer efficiency can be obtained. New spraying equipment is all that would be required to make this change, and therefore, the investment should be minimal. George Werner has reservations about water based spray painting systems, so there are no plans to test such equipment.

With regard to painting, it is necessary that everyone concerned be kept aware of the importance of making progress toward reducing VOC emissions. Something really needs to be done about VOC's, and since using water based paint is the lowest cost solution, testing of water based painting alternatives should be conducted.

Another way to reduce VOC emissions from painting gates; and possibly to eliminate chromic acid etching of galvanized building panels; is to switch to an autophoretic painting process; an example of which is manufactured by Parker Amchem. This process involves dipping metal to be painted into tanks filled with paint. Immersion is required because the coating is deposited by a chemical reaction between the paint and the metal which takes several minutes to occur. The autophoretic process resembles electrocoating, except that no electric current is required. Metal painted by this process reportedly has withstood salt spray tests of up to 3,000 hours without coating failure. The paint exhibits a high degree of hardness, and good resistance to chalking from ultraviolet light exposure. An autophoretic system to coat gates would cost about $300,000. Parker Amchem has never built an autophoretic coating system large enough to coat building panels, so detailed analysis would be required to ensure that it is possible. Another difficulty is that the red and green vary somewhat in color. The variation is due to the changing iron content of the paint as corrosion products enter the paint and as makeup chemicals are added. Since each color requires a separate tank, and building panels come in several colors, the only color which would be practical for building panels probably is a clear coating which could be used as a base coat for pigmented paints. Since an autophoretic coating is a good primer, the top coat can be an inexpensive paint. Companies using this system have reported the cost of applying autophoretic paint to be about 3 cents per square foot. Parker

Amchem is willing to assist Behlen in planning an autophoretic coating system.

Agricultural gates are ideally suited to powder coating because they come in only two colors. Transfer efficiency is not an issue in powder coating because overspray is captured and blended with fresh powder for reuse. Powder coating gates would eliminate VOC's from about 70% of the current production. Industrial Finishing Systems, which is one of Behlen's long-time painting equipment suppliers, indicated that powder coating could be added to the existing paint line for as little as $40,000. Unfortunately, the real cost of a powder coating system would be much higher. This is because the automatic paint line is quite old, so powder coating should be installed on a new line. A new line would cost about $200,000. The pollution prevention measures in the painting area probably will not pay for themselves in terms of reduced current waste disposal costs, but Clean Air Act requirements will soon mandate that action be taken. Estimates of the installation costs for various painting alternatives are shown in Table 2.

Table 2. Estimated costs of painting alternatives.

OPTION	COST
Water Based Spray Painting	$25,000[a]
Autophoretic Coating	$300,000
Powder coating	$200,000

[a]Approximate; Industrial Finishing Systems is preparing a detailed estimate.

Tubing Manufacture

A water-based fluid coolant (Metkool 711) is used by Behlen for lubrication and cooling of the tube mill. About 195 gallons per month are consumed at a cost of about $800. The coolant flows from its application points into sumps below the components, and the sumps, in turn, drain by gravity to a large collection tank. The collection tank contains an oil removal system, consisting of a plastic (tygon) tube pulled through the liquid coolant. Floating oil adheres to the polyethylene tube, and is removed by a scraper. The oil removal system is not able to remove oil fast enough.

The oil in the coolant comes from grease leaking out of the gearboxes. In addition, oil and grease cover the tube mill and the surrounding area. Grease and metal filings from the scarfer combine to make a black substance that fills the bottom of the sumps in about a month. The mill is occasionally shut down while operators scoop out all the grease. About two-thirds of the coolant is lost each time the sumps are cleaned, and this is the only time coolant is discharged from the system.

Recommended Tube Mill Changes

Recommendations for the tube mill are mostly concerned with changes which would minimize grease contamination of the coolant:

The old oil removal system needs to be replaced. A suitable oil removal system can be furnished by Production Supplies Inc. An efficient oil removal system should allow the coolant to be used for several times its current life. The new oil removal unit only costs $2,500. Doubling the coolant's useable life would pay for a new oil removal system in 6 months. Beyond that, the actual pay-off period could be even shorter.

There is a problem with the coolant turning rancid. Coolant rancidity is usually controlled by adding one of several possible biocides. If rancidity problems continue after an improved oil removal system is installed, a new biocide may be needed.

It should be possible to prevent gearbox leakage, or at least reduce leakage from falling into the sumps through regular maintenance. Also, preventing metal filings from falling into the sump below the scraper which removes excess metal from the fresh weld, and thus keep them from combining with the grease.

We strongly recommend shutting down the entire area for a short period of time for a thorough cleaning. This would vastly the improve operation of the system. The cleaning should include all equipment, floor grates, and the return trough.

Automated and Manual Electroplating

Behlen Manufacturing currently operates both an automated and a manual electroplating line. The processes are shown in Figures 3 and 4. These lines are used to deposit (electroplate) a thin zinc film onto small items such as nuts and bolts, which are then used in the construction of larger plant products such as farm buildings.

The automated electroplating line processes an average of 140 pounds of work per barrel. There are 36 stations on the line, with an approximate cycle time of 3.5 minutes at each station (about two hours per barrel). The work is first cleaned in a soak cleaner and an electrocleaning solution. It is then rinsed, pickled in a hydrochloric acid bath, and rinsed again before going into a chloride-zinc electroplating bath. After being in the plating bath for about an hour and ten minutes (20 stations), the work is rinsed. A light yellow chromate finish is added. A short rinse (20 seconds) follows the chromating process after which the work is dried at 150 F.

The manual process is more operator intensive, which requires hand moving of barrels from station to station. The barrels are bigger but the average load of work per barrel is still 140 pounds. This line is used more often than the automated line, especially when small quantities need to be plated. The work is cleaned in a soak cleaning bath (no electrocleaning) for about 15 minutes. It is then rinsed, pickled in hydrochloric acid, and rinsed again before being placed in the chloride-zinc electroplating tank (stainless steel pieces are dipped in nitric acid, instead of hydrochloric acid -- this does not occur often). The work is plated for an average of 1 to 1.5 hours before being removed from the tank. A short rinse precedes the chromate coating; which can be clear or yellow, depending on customer preference. After a final short rinse the pieces are placed on a table to air dry.

Recommended Changes to the Electroplating Process:

Rinse rates should be reduced to decrease the amount of wastewater being discharged to the treatment plant. We believe that the rinse flow rate after the cleaning and acid dip processes on both, the automated and manual electroplating lines, can be reduced to as low as 2 gallons per minute (gpm). This value needs to be confirmed by actual rinse testing (as should the other rinse changes recommended). The effluent from rinsing after the acid dip should be directed to the rinse tanks after the cleaning process. This change would save a total of about 19,000 gallons of water per day resulting in a cost savings of about $150.00 per day for waste treatment, sludge disposal, and water costs. Counter-current tanks similar to those on the automated line (after the cleaning and acid dip processes) will be needed on the manual line to incorporate this change. The cost of these counter-current tanks is estimated at $1,000.00. The estimated cost of flow control nozzles to maintain the 2 gpm flow rate is about $45.00. A summary of costs associated with changes in the electroplating line are shown in Table 3.

The rinse process after the electroplating tank on both the automatic and manual lines should be changed to counter-current with a rinse flow of 5 gpm. About 6000 gallons of water per day can be saved resulting in a cost reduction of $50.00 per day. The costs associated with these changes are estimated at $1,000 for the counter-current tanks system and $45 for the flow control nozzle.

To obtain better product quality and assure that the lower flow rates will not compromise rinsing efficiency it is recommended that housekeeping practices be changed. There needs to be a thorough clean-up of the electroplating area including the tanks (inside and out), floor, and all equipment related to the electroplating process. Records should be kept to show when maintenance is done, tanks are emptied, chemicals are added, and testing on tank parameters is done (e.g. pH, temperature, chemical concentration). The testing of tank parameters should be done on a daily basis for such variables as temperature and concentration of the cleaners, concentration of the acid dips, zinc metal, boric acid, total chlorides, pH, and the wetting solution in the electroplating tanks as well as pH, temperature, and concentration of the chromate in the chromating tanks.

FIGURE 3 - OVERVIEW OF
AUTOMATIC ELECTROPLATING LINE

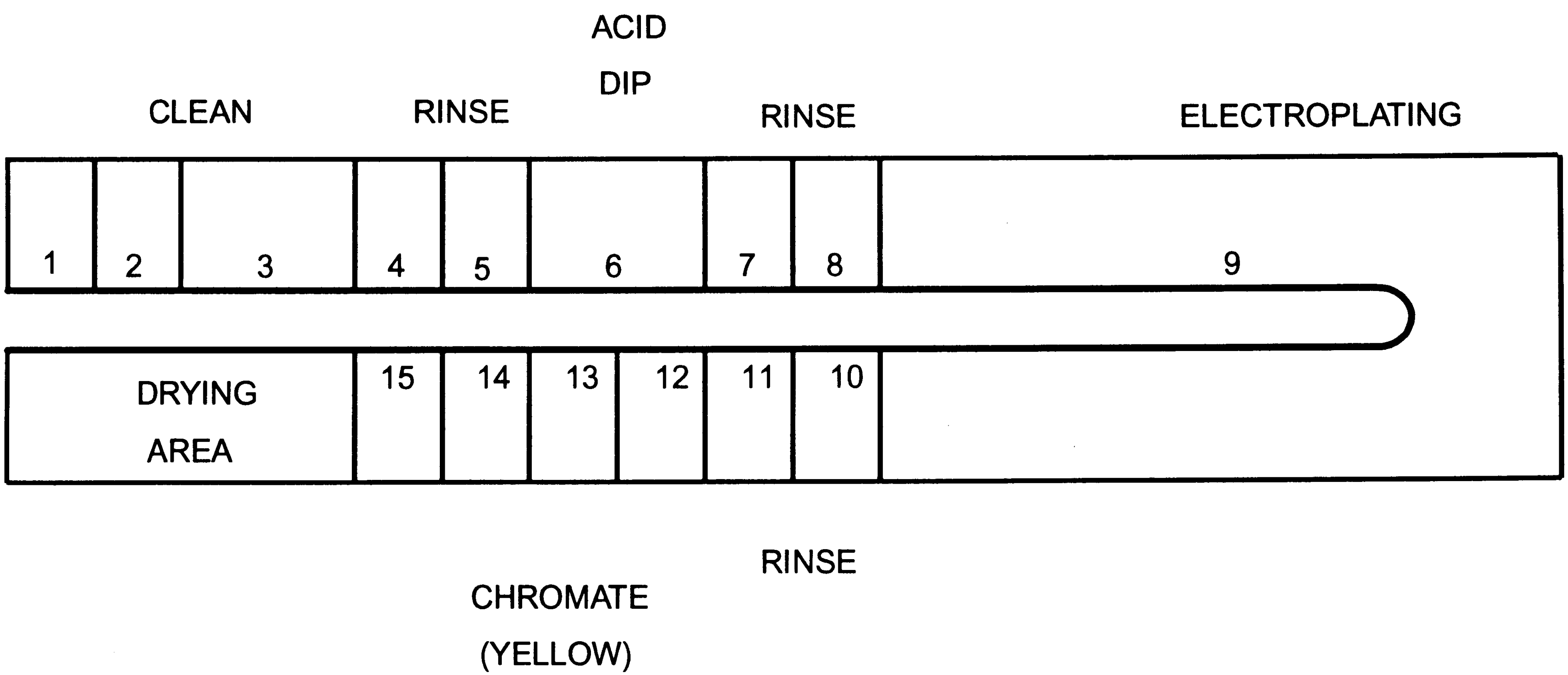
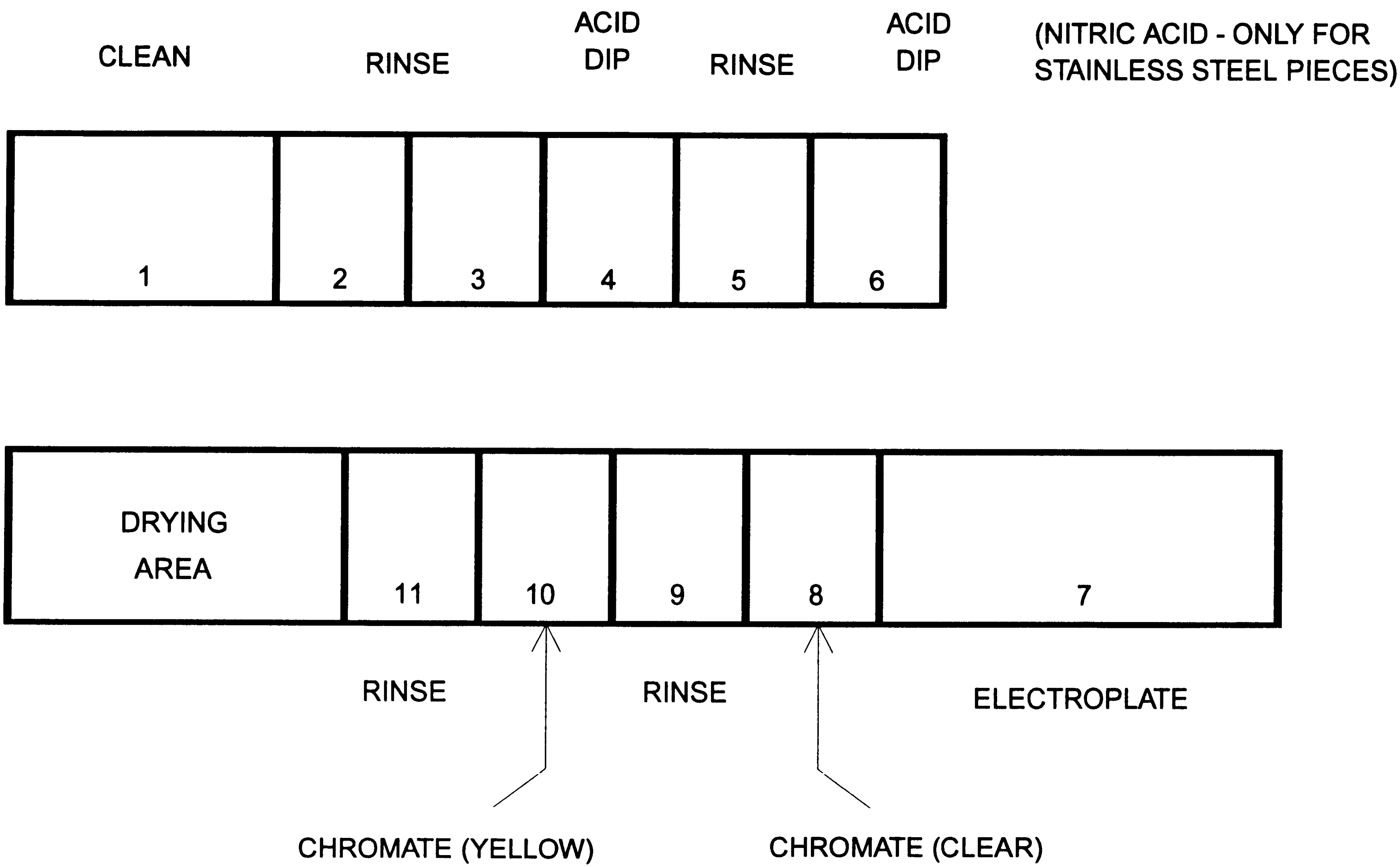


FIGURE 4 - OVERVIEW OF MANUAL ELECTROPLATING LINE



Other recommended housekeeping changes needed to improve the process include increasing the temperature of the cleaning tanks on the automatic line from 160°F to 180°F. Grease skimming from the top of the cleaning tanks must be improved to remove more of the grease and oil before it carries over into the downstream processes. The filtering system on the electroplating tanks needs to be repaired or improved. Once the current filtering system is repaired (on both lines), it will be possible to determine if this system is enough to maintain contaminants at proper levels. It is recommended that a new filtering system be installed if this is not the case. Anode bags should be used to keep contaminants and dirt in the titanium baskets (used to hold zinc balls) and out of the electroplating solution. Also, a drain board should be installed over the drip tank after the chromate rinse (on the auto line) to direct all dragout back into the rinse tank.

By using a trivalent chrome conversion coat process instead of the current hexavalent chrome process, Behlen could reduce the toxicity of a hazardous waste, lower treatment costs (hexavalent chrome must be chemically reduced to trivalent before sending it to waste treatment plant), and maintain overall costs at current levels. The disadvantages of these change would be a reduction in corrosion protection, the operator must monitor the process closely, and trivalent chrome coats are only available in a "bright blue" color.

To recapture some of the chemical dragout from the electroplating and chromating, it is recommended that still rinse tanks be used after these processes. It is estimated that about 50% of the chemical lost to dragout can be recaptured by this method. It is also recommended that air agitation be used in the tanks to increase rinsing efficiency.

Since Behlen has a reverse osmosis (RO) purification unit which is currently not in use, it is recommended that RO water be used to supply water to the electroplating, chromating, and still rinse tanks. This change would remove contaminants in tap water including total dissolved solids (TDS) and hardness thereby increasing process efficiency.

Current barrel withdrawal rates are 17 ft/min. for the automated line and 27 ft/min. for the manual line. According to information received from WRITAR (Waste Reduction Institute for Training and Applications Research), the maximum rate of withdrawal should be about 8 ft/min. This change would help decrease the amount of dragout from each tank resulting in decreased chemical usage.

It is also recommended that the hang time of the barrels over the tank (before moving to next station) be increased. The current barrel hang time on the auto line is 23 seconds. There is still significant dripping from the barrels after this time period. The hang time over tanks on the manual line varies with operator discretion. For the most part it is minimal or non-existent, and dragout is visually significant.

Acknowledgements

The project team acknowledges the valuable assistance received from all Behlen Manufacturing employees during this study. In particular, we would like to acknowledge Mr. Dick Goc, Mr. Tony Raimondo, Jr. and Rod Gering for their constant cooperation and assistance. This project is funded, in part, by the U.S. Environmental Protection Agency, and in part by the University of Nebraska-Lincoln Center for Infrastructure Research (CIR) under the Nebraska Research Initiative. The Project Officers for the U.S. EPA are Mr. James Lund, of the Office of Water, Washington, D.C., and Mr. Carl Blomgren, of EPA Region VII in Kansas City.

Table 3. Summary of costs and advantages of recommended changes in the electroplating lines.

CHANGE	COST	SAVINGS	Est. Payback Period
1) Lower Rinse Flow Rates a) auto line -- after cleaning and acid pickling, and after electroplating	$90 (two flow control valves) $50 (to hook up acid and cleaner rinses)	24,760 gpd see(1) $138/day in WTX (2), sludge disposal, and water costs	5 weeks
c) manual line -- after cleaning and acid pickling, and after electroplating	$3,000 (three counter current tank) see(3) $135 (three flow control valves)	7,680 gpd $59/day in WTX, sludge disposal, and water costs	2 months
2) Soak Cleaners and Electrocleaners a) increase temperature from 160°F to 180°F (auto line only)	$0.08/day + heat loss from tank and solution surface see(4)	less chemical dragout, cleaner work	
b) more efficient grease skimmer	$140 (not installed) for float valve system (also considering a squeegee system) see(4)	less organic contamination, cleaner work	
c) testing concentration of cleaning solution (daily)	test kit free from JSA (5)	more efficient process, cleaner work	
d) filtering solution (to remove dirt and metals)	see (4)	longer tank life	see (6)
3) HCl Acid Pickling a) testing concentration of acid (daily)	$20 (Baumé) density hydrometer) or $0.54/test (test kit from JSA)	more efficient process	
b) testing iron contamination	see (4)		see (6)
4) Electroplating a) testing: 1) iron contamination, pH and temperature, total chlorides, zinc, boric acid, and wetter	a total of only $7.30/week	more efficient process, better plating	see (6)
b) filtering tank solution 1) auto line	$7,212 for 2 filtering units - one on each end of tank (Serfilco Inc.)		
2) manual line	$3,607 one filter unit (Surfilco Inc.)	cleaner tank solution, better plating	see (7)
c) peroxide addition (daily)	minimal, see (4)	removal of iron contamination	see (6)
d) anode bags over titanium baskets	< $100, see (4)	capture contaminant metals and dirt	see (6)
5) Chromating a) testing: 1) pH, temp, and chromate concentration	no cost (time only)	more efficient process, better conversion coating	
b) replace hex-chrome with tri-chrome process	see (4)	less toxic process, less WTX and disposal costs	see (4)

(1) gpd = gallons per day
(2) WTX = waste treatment system
(3) estimate from Imperial Co., in process of obtaining other estimates
(4) In process of obtaining estimate
(5) JSA = John Schneider Company
(6) difficult to estimate, will result in a better product and more efficient process
(7) difficult to estimate, will result in better plating and less chemical use.

POLLUTION PREVENTION IN THE METAL FINISHING INDUSTRY

Mohamed F. Dahab
David L. Montag

ABSTRACT

The concept of pollution prevention has recently received much attention in the media. Minimizing harm to the environment by reducing the generation of pollution at its source is a logical approach to pollution problems. The University of Nebraska Lincoln (UNL) is encouraging Nebraska businesses to adopt pollution prevention.

One part of this effort has been a research project focused on industrial pollution prevention. During 1992 and 1993, a pollution prevention project was conducted at a large metal finishing company in Nebraska. The manufacturing processes studied were electroplating, galvanizing, painting, and tubing fabrication.

By examining the available literature and interviewing experts in the metal finishing industry, UNL researchers were able to identify several promising pollution prevention options. Tubing manufacture used a water based metalworking fluid that was susceptible to decomposition by anaerobic bacteria. The bacterial growth was encouraged by oil contamination from leaking gearboxes. This problem was minimized by replacing grease seals on the gearboxes and by installing an improved oil removal system to purify the coolant.

The paint used by the company contained volatile solvents, which evaporate as the paint dries and eventually contribute to smog (ozone pollution). Volatile organic compound emissions can be avoided by using coating materials other than traditional solvent based paint. Alternative materials studied were water based paint, autophoretic coatings, and powder coating. At the time of this writing, the company was seriously considering installing a powder coating line.

The galvanizing process produced large volumes of rinse water which was contaminated with sulfuric acid, and zinc, and which required expensive treatment prior to disposal. A test was conducted that successfully demonstrated that a counter current continuous flow rinse could reduce water use. Tests were also conducted to prove the feasibility of using a

continuous flow rinse to remove flux chemicals from the surface of freshly galvanized parts. These tests were unsuccessful. Testing was also conducted to change the process chemistry to avoid depositing a flux chemical film on the finished work. In this way, the need to rinse could be avoided. Unfortunately the chemistry changes resulted in unacceptable product quality, and the proposed rinsing system was not considered feasible. A rinse water flow reduction of about 21 percent was achieved, however, by installing new spray nozzles in the existing spray booths.

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Waste Minimization Opportunities For the Electroplating Industry: A Case Study

Mohamed F. Dahab
Gary Keefer
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ABSTRACT

Standard waste minimization and assessment methodologies were applied to an aging electroplating (manual and automated lines) facility that produced zinc plated nuts and bolts. The recommendations made and the results of implemented changes are reported in this thesis. In addition, an extensive literature review was performed concerning waste minimization opportunities for the electroplating process and includes sections on improving rinsing efficiency, housekeeping, drag-out reduction and/or return, material substitution, and recovery and recycling techniques.

The waste assessment involved documenting the electroplating processes and recommending changes that would reduce waste and increase product quality. The most profound change recommended dealt with the rinsing processes after the alkaline cleaning, acid dip, and zinc electroplating processes. The use of countercurrent rinses and reduced rinse flows were estimated to result in a savings of $209.00 per day in process wastewater treatment, sludge disposal, and water costs. Total cost for these

recommended changes is about $4,600.00 with an overall payback period of about 22 days.

Some of the recommended changes have been implemented and include: a thorough clean-up of the electroplating area including inside and outside the tanks; regularly testing chemical concentrations in the process tanks and making additions as needed; the hiring of a chemist to perform the testing and oversee all chemical processes on the lines; and reducing rinse flow rates. Since these changes have been in effect, product quality has improved, as documented by a 1000% increase in white rust protection, and a 550% increase in red rust protection.

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Pilot project adds polish to metal finisher's pollution prevention efforts

By M.F. Dahab and Jim Lund

An aging midwestern manufacturing facility that produces fabricated metal products for farm and industrial uses was chosen as the site for an industrial pollution prevention and waste minimization pilot project. The project goal was to demonstrate that using appropriate management and operating procedures can reduce the total pollution produced by an industrial operation. The facility is a licensed hazardous waste generator.

The plant engages in a variety of pollution-generating activities, including electroplating, conversion coating, cleaning, machining, grinding, impact deformation, shearing, welding, sand blasting, hot-dip coating, painting, assembly and testing. The hot-dip galvanizing process results in production of rinsewater containing such heavy metals as zinc and iron. Painting processes generate used industrial cleaners, acids, solvents, and chemicals used in cleaning and degreasing metal components.

Process wastewaters are treated by adding lime and polymer, and adjusting pH before discharge. Past disposal practices at the facility had threatened area surface and groundwater. Waste disposal is a major operating expense.

Past disposal practices at the facility had threatened area surface and groundwater. Waste disposal is a major operating expense.

Procedures and methods. The wastestream evaluation followed Environmental Protection Agency guidance. A pollution prevention assessment work plan identified several tasks, including:

- Developing a detailed assessment and evaluation of current practices, and characterization of all wastes produced by the facility;
- Identifying possible pollution prevention and minimization opportunities;
- Evaluating economic and technical aspects of waste prevention and minimization alternatives, and their short- and long-term impacts;
- Developing recommendations to management for implementation based on greatest benefit and shortest payback periods;
- Providing technical assistance during implementation of recommended alternatives; and
- Reviewing the results and impacts on waste prevention after implementing the alternatives.

In developing the pilot project, emphasis was placed on areas in which the impact on reducing total pollutant load would be greatest — the electroplating, hot-dip galvanizing and painting lines, and tube-mill production areas. Strategy development stressed a multimedia approach to preventing and minimizing pollution.

Electroplating systems. The facility operates an automated and a manual electroplating line to deposit a thin zinc film onto such items as bolts, fasteners and nuts, which are used to construct larger plant products. The automatic line is a barrel system that plates about 145 pounds of work per load. Barrels are moved by a conveyor chain. An average of 145 pounds of pieces per barrel are processed by 36 stations on the line. The cycle takes about 3.5 minutes per station, or about two hours per barrel.

The work first is soaked in cleaner and an electrocleaning solution. It then is rinsed, pickled in a hydrochloric acid bath, and rinsed again before entering a chloride-zinc electroplating bath. After about an 70 minutes in the plating bath (20 stations), the work is rinsed, and a light yellow chromate finish is added. A short rinse (20 seconds) follows the chromating process, after which work is dried at 65 degrees Celsius.

The electroplating solution is circulated through a filter to remove impurities, which are rinsed into the treatment system. Total rinsewater use in the automatic electroplating line, which operates eight hours a day, was estimated at 166 liters per minute.

The manual process requires operators to move barrels from station to station. The barrels are bigger, but the average load of work per barrel is the same as in the automated process. The manual line is used more than the automated line, especially when plating small quantities. The work is cleaned in a soak cleaning bath (no electrocleaning) for about 15 minutes. It then is rinsed, pickled and re-rinsed before entering the chloride-zinc electroplating tank. (Stainless steel pieces are dipped in nitric acid instead of hydrochloric acid.) Pieces are plated 60 to 90 minutes before being removed. A short rinse precedes the chromate coating, which can be clear or yellow. After a final short rinse, pieces are placed on a table to dry.

To obtain better product quality and ensure that the lower flow rates would not compromise rinsing efficiency, housekeeping changes were recommended. These included a thorough cleaning of the electroplating area (tanks, floor and electroplating process equipment), and a maintenance recordkeeping system.

The suggestions, designed to reduce rinsewater and electroplating chemical waste, called for improved cleanliness and better chemistry control. Also recommended was reducing rinse rates to decrease the amount of wastewater discharged to the treatment plant. Reactive rinsing was recommended for both electroplating lines to decrease water use from the rinses following pickling and alkali cleaning. Pickling rinsewater no longer would go down the drain, but instead flow to rinse tanks following alkali cleaning.

Use of still rinse tanks following electroplating and chromating was recommended to recapture some of the chemical dragout from these processes.

Effluent from the rinsing step after the acid dip could be directed to the rinse tanks after the cleaning process, saving about 76 cubic meters of water and $150 per day in waste treatment, sludge disposal and water costs. Countercurrent tanks similar to those on the automated line would be needed on the manual line to incorporate this change, at a cost of about $1,000. It was recommended that rinse processes following electroplating on both lines be changed to countercurrent with a rinse flow rate of 20 liters per minute each. About 24 cubic meters of water a day can be saved, saving $50 per day.

Daily testing of chemical and operating parameters in the tanks needed to be performed for several variables. Electroplating tank variables included pH and temperature in addition to concentrations of cleaners, acid dips, zinc metal, boric acid, total chlorides and the wetting agent. Chromating tank variables included pH, temperature and chromate concentration.

Other recommended changes included increasing the temperature of automatic line cleaning tanks from 71 degrees Celsius to 93 degrees Celsius. Grease skimming needed improvement, because grease originating from the machining steps of bolt production accumulated in the automatic electroplating line's cleaning tanks. An inoperative filter system on the electroplating tanks also needed repairs. Once the repairs are made on both lines, it should be possible to determine whether the systems are adequate to maintain contaminants at low levels. Installing a new filtering system was recommended.

Anode bags were recommended to keep contaminants and dirt from the zinc balls out of the electroplating solution. Additionally, a drain board was needed over the drip tank following the chromate rinse on the automatic line to direct dragout back to the rinse tank. By changing to a trivalent-chrome-conversion coating process instead of the hexavalent chrome process, the facility should decrease the toxicity of the waste it produces. This would save on treatment costs, because hexavalent chrome must be reduced chemically to its trivalent form — which is less toxic and less expensive to treat — before it is sent to a treatment plant.

Some potential disadvantages of these changes are a slight reduction in corrosion protection, the necessity of closer process monitoring and testing, and the fact that trivalent chrome coats are available only in bright blue instead of the customary light yellow.

Use of still rinse tanks following electroplating and chromating was recommended to recapture some of the chemical dragout from these processes. This method should recapture about half of the chemical lost to dragout. It was also recommended that air agitation be used in the tanks to increase rinsing efficiency.

The water supplied to the electroplating process should be as clean as possible. It was recommended that the facility's reverse osmosis purification unit be used to supply water to the electroplating, chromating and still rinse tanks. This would remove potential contaminants in tap water, including total dissolved solids and hardness, before its use in the electroplating line, increasing process efficiency.

The barrel withdrawal rates were measured at 5.2 meters per minute in the automated line and 8.2 meters per minute in the manual line. The maximum withdrawal rate should be about 2.4 meters per minute. Changing this would decrease the amount of dragout from each tank, resulting in decreased chemical use.

It was also recommended that the hang time of barrels over the tanks be increased by pausing longer before moving to the next station. Although hang time on the automated line was 23 seconds, significant dripping from barrels occurred after this time. Hang time over tanks on the manual line varied. Generally, hang time was observed to be minimal, and dragout was significant.

Results of system changes. Several recommended changes to the automatic electroplating line were implemented. All tanks were cleaned, inside and outside, on the plating line, and accumulated bottom sludge was removed. The bath contents of the electroplating tank were pumped into a temporary holding tank, and nonhazardous bottom sludge was shoveled into eight 55-gallon drums for disposal. The liquid portion of the plating bath was pumped back into the plating tank, and additional chemicals and water were added to restore them to normal levels.

Other changes included:

- Regular testing of cleaning, acid dip, electroplating and chromating processes to maintain optimal-level chemical concentrations;
- Hiring a qualified individual to perform operational control testing and work with the plating operator to make required chemical additions; and
- Reducing rinse flows, and installing flow measurement and countercurrent rinsing.

Flow control devices have been installed on the rinses following the alkaline cleaning and acid-dip processes to maintain flow rates at recommended levels. The two systems have not been connected as recommended. Flow rates for the two rinses following electroplating also have been reduced. The new rates have not been measured, so it has not been determined whether they are being maintained consistently. The plating operator reports the valves that control flow are not opened as far as in the past. Besides decreasing the rinsewater flow rate, adding the countercurrent system to the manual line should increase the rinsewater's utility.

Product quality has been increased significantly, as evidenced by results of the 5 percent neutral salt spray testing performed on bolts plated on the automated line before and after the changes occurred. The results show a 1,000 percent increase in white rust protection and a 550 percent increase in red rust protection.

Tank cleaning, sludge removal and use of oil absorbent pads on the cleaning baths should reduce the dragout of dirt, grease and other contaminants to downstream processes.

From a waste prevention and minimization perspective, the changes have been effective. Reduction in rinse flows should lead to less wastewater for treatment at an onsite facility. Tank cleaning, sludge removal and use of oil absorbent pads on the cleaning baths should reduce the dragout of dirt, grease and other contaminants to downstream processes. This will increase bath life, resulting in fewer bath dumps and reduced chemical use. Costs of implementing these changes have been modest.

The galvanizing system. The facility's galvanizing process consists of pickling, rinsing, prefluxing, galvanizing and final rinsing. The pickling step prepares work for galvanizing by removing oxides from the steel surface using a 10 percent sulfuric acid solution at 70 degrees Celsius.

Work pieces are rinsed after pickling. The preferred method is to dip them in the rinse tank, which is filled with unheated municipal water. The rinsewater is agitated by moving the pieces back and forth in the tank. After the first rinsing, work pieces are placed in the preflux tank, a crucial step in the dry-kettle galvanizing process. Work is coated with flux chemicals before entering the zinc kettle. The preflux tank is maintained at 70 degrees Celsius. The preflux solution generally is allowed to dry thoroughly before galvanizing.

Galvanizing is accomplished by immersing steel in a tank filled with molten zinc for two to three minutes. Most steel galvanized at this plant uses the wet-kettle method. A flux layer is floated on top of the galvanizing kettle, and work pieces pass through it as they enter and leave the kettle. For galvanizing materials, such as building components, the kettle flux layer is skimmed to the side and not used. Work pieces are cooled by rinsing them in a second rinse booth next to the galvanizing kettle. This final rinse is needed to cool the work to below 200 degrees Celsius, which prevents growth of a brittle zinc-steel alloy layer. Cooling also allows operators to handle the pieces.

Galvanizing operations. Pollution prevention efforts in galvanizing were concentrated on reducing the volume and metal content of rinsewater, as this is the principal medium through which metal is lost. Volume reductions can be accomplished by installing additional galvanizing equipment. Metal content reductions are possible by discontinuing use of the kettle flux or switching to a different kettle flux.

The galvanizing system initially used about 265 cubic meters of rinsewater per day. Flow through the first rinse booth was measured during wastestream assessment at 1,200 liters per minute. Freshly galvanized pieces are cooled in the second rinse booth. Flow through this booth was estimated at about 1,200 liters per minute. The rinse booths operate only while materials to be rinsed are carried through them.

Rinsing in a tank instead of a booth is the most important step in decreasing galvanizing water use. Using rinse tanks after pickling also is important. It was recommended that rinse booths be replaced by rinse tanks linked in a countercurrent flow arrangement. This allows water to be reused several times before being discharged and ensures that work pieces are rinsed with clean water as they leave the process line.

A rinse test conducted to verify the usefulness of the rinse tank concept successfully demonstrated the feasibility of continuous-flow rinsing. Based on the results, a continuous rinsewater flow rate of 24 liters per minute removes pickling acid adequately for two rinse tanks in series. This flow rate cools the work, preventing the water temperature from rising high enough to pose a safety problem. The proposed system would use no more than 35 cubic meters of water per day, representing a savings of about 83 percent. As a result of the study, water-saving (low-flow) nozzles were installed in the rinse booths. This immediately reduced water use by 60 percent, yielding water and waste treatment savings of about $250 per day.

The proposed galvanizing equipment changes cost about $70,000. Ventilation system improvements to remove pickling solution vapors from the proposed pickling tank location would cost $25,000. Due to the expense, phased installation of suggested galvanizing changes was recommended. The payback period is estimated at about 10 months.

Livestock fencing is being fluxed twice — once in the preflux tank and again as it enters the kettle. For galvanizing objects other than fence panels, kettle flux is not used. The kettle flux is 98 percent zinc chloride and contains a small amount of potassium chloride. Kettle flux adds significantly to the metal content of galvanizing rinsewater, so that discontinuing its use would aid pollution prevention.

Prefluxing is crucial in dry-kettle galvanizing. To obtain good fluxing, proper concentrations of zinc chloride and ammonium chloride must be maintained, and iron and sulfate concentrations minimized. Frequent sampling is required.

Switching from zinc chloride preflux to a mixture of mostly ammonium chloride and some zinc chloride or ammonium chloride alone was recommended. This probably would enhance product quality, because the proposed countercurrent flow system (with fresh water being added at the final rinse tank) would not complicate preflux chemistry.

Another problem with the galvanizing operation was a layer of oil floating on the surface of the acid bath. The oil could be minimized by installing a skimmer to remove it periodically or to reduce oil use in the fabricating step.

The painting system. The painting operation at the facility consists of washing, etching, oven drying, spray painting and oven curing. The plant's painting operation in 1992 was estimated to have emitted about 37,500 kilograms of xylene and 11,000 kilograms of toluene. Reducing emissions of these volatile organic compounds should be

Another suggestion was to switch to an autophoretic painting process to reduce VOC emissions and eliminate chromic-acid etching.

a top priority.

Two types of paint are used at the plant. A solvent-based paint is used for painting gates, and a silicone polyester paint is used for coating building panels. Seventy-four percent of the paint used in the automatic paint line in 1992 was used to paint farm gates. About 2,200 liters per month of a mixture of aromatic solvents are used for such purposes as cleaning paint-supply piping.

The only practical way to reduce VOC emissions significantly is to change paint materials. One alternative is to use water-based paint for the gates. If water-based paints are applied electrostatically, a high transfer efficiency can be obtained. The investment should be relatively small, because the only facility change required is installing new spray equipment. Immediate testing of water-based paints was recommended.

Another suggestion was to switch to an autophoretic painting process to reduce VOC emissions and eliminate chromic-acid etching. This involves dipping metal to be painted into tanks filled with paint. The coating is deposited *via* a chemical reaction between the paint and metal which requires several minutes of immersion. The autophoretic process resembles electrocoating but requires no electric current. Metal painted using this process reportedly has withstood salt spray tests up to 3,000 hours without coating failure. The paint reportedly exhibits a high degree of hardness and good resistance to chalking from ultraviolet light exposure.

The estimated cost of an autophoretic system to coat gates was $300,000. A serious drawback of this method is that color varies with the dissolved iron concentration in the paint, which increases slowly due to contact of the paint with the steel being painted. Another drawback is the fact that a separate paint tank is needed for each color.

Another alternative is powder coating. Agricultural gates are ideally suited for powder coating, because they are made in only two colors. Transfer efficiency is not an issue, because overspray is captured and blended with fresh powder for reuse, and VOCs are not emitted. An industrial supply contractor estimated that powder coating could be added to the existing paint line for about $40,000. However, installation costs probably would be higher, because the automatic paint line is old and should be replaced. A new paint line was estimated to cost about $200,000.

Pollution prevention in the painting area at this plant will not be offset by significant savings in disposal costs. However, the Clean Air Act will require that action be taken soon. As a result of this study, the plant has experimented with water-based paints and requested bids to construct a powder coating system.

Tubing manufacture system. A tube mill at the facility forms metal pipe from coils of sheet steel. The plant makes tubing for all its gates and also sells tubing to other companies. The major tube mill components include a coil unwinder, feeder, initial cold rolls, welder, re-galvanizer, final cold rolls, metering cutter and coolant distribution system. A water-based fluid coolant is used to lubricate and cool the tube mill.

About 800 liters of coolant per month are consumed at a cost of about $800. The coolant flows from application points into sumps below the components. The sumps drain by gravity to a large collection tank, which contains an oil removal system consisting of a plastic tube pulled through the liquid coolant. Floating oil adheres to the polyethylene tube and is removed by a scraper. However, the oil removal system is unable to remove oil quickly enough.

Oil in the coolant originates from grease leaking out of the tube mill gearboxes. Over the years, oil and grease leaks have covered the tube mill and the surrounding area. Grease combines with metal filings created when excess metal is scraped from fresh welds. Together, the grease and filings form a black substance that fills the bottom of the sumps in about a month. The mill occasionally is shut down while operators scoop out the grease. About two-thirds of the coolant is lost each time the sumps are cleaned, and this is the only time coolant is discharged from the system.

Recommendations for the tube mill focus on minimizing grease contamination of the coolant. The old oil-removal system should be replaced with a system that would allow coolant reuse. A suitable unit was estimated to cost less than $2,500. The payback period was estimated at less than six months, assuming the coolant's usable life is doubled. If coolant could be used longer, the payback period would be shorter.

The coolant also turns rancid. Coolant rancidity usually is controlled by adding a biocide. If rancidity problems continue after an improved oil removal system is installed, a different biocide may be needed. Gearbox leakage should be prevented or kept from falling into the sumps through regular maintenance. In addition, preventing metal filings from falling into the sump below the weld scraper would keep them from combining with the grease. It was recommend that the entire area be shut down for thorough cleaning, as this would vastly improve system operation. Cleaning should include equipment, floor grates and the return trough.

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