A Demonstration Project of Pollution Prevention in the Metal Finishing Industry

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Prepared for Presentation at
the National Conference on

Promoting Pollution Prevention by Voluntary Initiatives

Colonial Williamsburg, VA
June 1-3, 1994

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ABSTRACT

This paper describes the results of an industrial pollution prevention pilot project in Nebraska. The goal of the project is to demonstrate that through proper management and operating practices, that industrial pollution can effectively be reduced significantly. The net effect of this pollution prevention program is to improve the economic worth of the industry by lowering expenditures on pollution control measures as well as minimizing regulatory burdens. The industrial pollution prevention pilot program is taking place at an aging manufacturing facility that produces fabricated metal products for farm and industrial use including structural steel members and plates, farm gates, fencing, and livestock watering tanks, in addition to a wide variety of structural bolts, fasteners, and so on. During manufacturing, the facility performs many operations including electroplating, conversion coating, cleaning, machining, grinding, impact deformation, shearing, welding, sand blasting, hot-dip galvanizing, painting, assembly and testing. Many of these processes result in the production of hazardous pollutants that must be disposed of in some fashion. For example, the electroplating line results in the production of acids and rinse water containing zinc and chromium and the hot-dip galvanizing line results in the production of acids and rinse water containing zinc, lead and iron. The painting processes result in the production of used industrial acids, solvents, and chemicals used for cleaning and degreasing metal components.

By design, the initial recommended operational changes and process modifications to the plant to prevent or reduce waste were simple to implement, and their pay-back periods were fairly short. For example, modifications requiring minor structural changes in galvanizing resulted in reducing rinse water use by about 60 % thus leading to savings of about $250 per day in water consumption and waste treatment. Additional modifications requiring larger investments also were presented for implementation by the facility after initial modifications were completed.

INTRODUCTION

Pollution prevention encompasses all activities leading to the elimination of waste materials at the point of generation. Generally, within an industrial facility, pollution prevention programs constitute organized, comprehensive, and continual efforts to systematically reduce waste generation. By reducing the generation of wastes, industrial facilities can save money on

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raw material purchases, material handling fees, disposal fees, and other operating costs. In addition, potential environmental liabilities can be reduced and worker/public health and safety can be enhanced. Hazardous waste generators also can benefit from any improvements in the general quality of the environment as well as an enhanced public image resulting from their involvement in pollution prevention activities [U. S. EPA, 1990; 1992; 1993; University of Tennessee, 1990; Wentz, 1989].

The effort described in this paper was designed to develop an industrial pollution prevention and minimization pilot project. The goal of the project was to demonstrate that through proper management and operating practices, the total pollution produced by an industrial operation can be reduced significantly. The ultimate goal of this pollution prevention program was to improve the net worth of the industry by lowering expenditures on pollution control measures and minimizing the burden of government regulations. An aging industrial facility in the midwestern U.S. was identified as a suitable site for the implementation of the project.

The manufacturing facility is engaged largely in the production of fabricated metal products for farm and industrial uses. The facility is located in a predominantly agricultural area. The plant site is a 40-hectare (100 acre) area on which several buildings are located. The largest of these buildings is a 75,000 m^2 (about 19 acres) manufacturing facility and a 3,900 m^2 (1 acre) office complex. Because of the nature of its manufacturing, the facility is licensed as a hazardous waste generator.

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 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). The painting processes result in the production of used industrial cleaners, acids, solvents, and chemicals used in the cleaning and de-greasing 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 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.

PROCEDURES AND METHODS

The waste stream evaluation process followed procedures outlined by the U.S. Environmental Protection Agency (U.S. EPA, 1990; 1992; 1993). Accordingly, a work plan for the pollution prevention assessment program was developed. The work plan consisted of several tasks which are summarized as follows:

1. A detailed assessment and evaluation of current practices in the areas identified above along with a detailed characterization of all wastes produced by the 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 the management of the manufacturing facility for implementation 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 on waste prevention after implementation of the alternatives.

In developing the pilot project at the industrial facility, emphasis was placed on areas where the impact on reducing the total pollutant load produced by this facility is greatest. These areas are the electroplating, hot-dip galvanizing and the painting lines as well as the tube-mill production 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. This paper provides a summary of activities completed to date, and essentially covers the tasks identified above.

PLANT OPERATIONS

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 Activities in the Electroplating Systems

<u>House Keeping Practices.</u> 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).

<u>Rinse Water Use.</u> 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 the 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-l 17) 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 l,000% increase in white rust protection and a 550% increase in red rust protection.

The facility has been encouraged by these positive results and it is hoped that it will spur them to make further changes. From a waste prevention and minimization perspective, the implemented changes have been effective. The reduction in rinse flows will no doubt lead to less waste water 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.

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

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 ($ZnC1_2$ and NH_4Cl) 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^{o}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 Activities 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% $ZnC1_2$ 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 $ZnC1_2$ 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 (^{o}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 $ZnC1_2$ concentration. Optimum density ranges from 12 to 15 ^{o}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).

Painting Alternatives. 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).

Recommended Tube Mill Changes. 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 paper, 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 U.S. 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 paper centered on the principal divisions that produce the bulk of 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).

The study is an extensive and systematic waste stream assessment and evaluation. One of the major constraints was the fact the facility was fairly old and not very profitable. Consequently, all of the recommendations for process and operational modifications resulting from the waste stream assessment had to meet critical economic payback periods.

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. This treatment process involves lime and polymer addition followed by pH adjustment before discharge.

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 in waste reductions. Installation expenses will have to be recovered through adjustments in the pricing of products. 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.

ACKNOWLEDGEMENT AND CREDITS

This project was funded, in part, by the U.S. Environmental Protection Agency, and in part by the University of Nebraska-Lincoln Center for Infrastructure Research. At the time of the study, M. F. Dahab was Associate Professor in the Departments of Civil Engineering and Biological Systems Engineering, University of Nebraska, Lincoln, NE 68588-0531 and Jim Lund was Director of the Industrial Pollution Prevention Project (IP3), U.S. Environmental Protection Agency, Office of Water, Washington, D. C. 20460.

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