

Pollution Prevention Opportunities for the Jessup Plater

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Executive Summary

During the summer of 2008, a Partners in Pollution Prevention (P3) intern from the University of Nebraska- Lincoln analyzed the resources used and wastes produced by EGS Appleton Electric in Columbus, Nebraska (NE) in order to identify pollution prevention (P2) opportunities. The primary benefits of implementing P2 opportunities include cost reductions from purchasing fewer raw materials and disposing of fewer wastes. EGS Appleton Electric has shown a commitment to pollution prevention so this project was a natural extension of that commitment.

The Columbus, NE Appleton plant receives parts from foundries and then grinds, machines, plates, powder coats, and assembles them. There are two platers that run in the plant: a rack plater and a barrel plater. This waste assessment focused on the P2 opportunities in the Jessup Rack Plater and gave the following results:

- 5.6 million gallons of water used and treated each year
- 0.11 gallons of plating bath chemicals dragged out per rack per tank totaling over 30,000 gallons dragged out of process baths per year
- 38,880 lbs (19.4 tons) of F006 hazardous waste produced per year from dragout

Several pollution prevention opportunities were identified to reduce these wastes as well as to reduce energy consumption associated with the process. These opportunities are summarized in Table 1 below.

Table 1. Summary of Pollution Prevention Opportunities for the Jessup Plater

Opportunities	Benefits
Dragout Reduction <ul style="list-style-type: none"> • Implement longer drain time • Implement slower workpiece withdrawal rate • Install drain boards • Optimize part placement • Optimize racks • Optimize chemical concentration • Install spray rinses • Install dragout tanks 	<ul style="list-style-type: none"> • Save \$21,800 / year in plating bath chemicals cost • Save \$12,200 / year in waste treatment and disposal costs • Reduce F006 listed hazardous waste by 13.5 tons / year • Reduce the amount of rinse water needed
Rinse Water Use Reduction <ul style="list-style-type: none"> • Install and maintain flow restrictors • Eliminate use of Tank 15A (Rinse) • Install solenoid valve and timer rinse control 	<ul style="list-style-type: none"> • Reduce rinse water use by 90 percent • Save 5 million gallons of water /year • Save over \$20,000 /year
Energy Use Reduction <ul style="list-style-type: none"> • Install air agitation switch • Make tank insulation improvements 	<ul style="list-style-type: none"> • Save over \$2,000 /year • Reduce greenhouse gas emissions by 48 metric tons /year • Reduce boiler workload
Material Reuse <ul style="list-style-type: none"> • Establish water filtration and reuse 	<ul style="list-style-type: none"> • Eliminate the need to purchase city water to use in plating rinses • Save 500,000 gallons of water /year • Save \$2,000 / year

Background and Waste Assessment

Business and Project Description

Ashley Baltes, a University of Nebraska- Lincoln Partners in Pollution Prevention intern, worked with EGS Appleton Electric in Columbus, Nebraska during the summer of 2008. The purpose of this work was to identify areas of potential pollution prevention improvement. This report will focus on ways to reduce the resources used and wastes generated by the Jessup Rack Plater. Included in this report is an assessment of resources used and wastes generated, analysis of current practices and processes, and possible pollution prevention opportunities.

Appleton Electric is one of the many quality electrical parts manufacturing brands of the EGS Electrical Group, a division of Emerson Industrial Automation. Appleton produces a variety of electrical installations for harsh conditions including; conduit bodies, junction boxes, light fixtures, liquidtight connectors, and couplings. These parts are used in challenging conditions all over the world.

The EGS Appleton plant in Columbus, NE receives parts from foundries and then grinds, machines, plates, powder coats, and assembles the final product. The Appleton plant employs about 350 people on three shifts for five days a week. They occasionally run on Saturdays and rarely on Sundays. The management at EGS Appleton in Columbus is dedicated to making pollution prevention (P2) a priority. Current P2 practices include; using destratification fans to reduce heating consumption, eliminating the use of hexavalent chromium, using a recyclable solvent, and recycling plastic wrap, scrap metal, aerosol cans, cardboard, paper, and plastic.

The following section details the resources used and wastes generated by the Jessup Plater in order to identify possible areas of even further pollution prevention.

Waste Assessment

As shown by their current pollution prevention practices, EGS is conscious of practicing pollution prevention and is therefore concerned with reducing resources used and wastes generated in everyday operations of the facility. The two major resources used during plating operation are water and plating bath chemicals. Table 2 shows the annual water use in the Jessup Plater, and Table 3 shows the total amount of chemicals used in plating operations, including both the rack and barrel platers. Appendix A shows the annual cost of plating chemicals. With minimal evaporation, it is assumed that all water that enters the rinse tanks flows to the facility's pretreatment center. The rinse tanks are completely emptied and refilled on a rotating eight week schedule. The used rinse water flows to the pretreatment center which treats 10 million gallons of water a year and produces about 9 tons of sludge a month. Waste from the Jessup Plater accounts for about 18 percent of this sludge: 38,880 lbs (19.4 tons) of sludge a year.

Table 2. Water Consumption in the Jessup Plater.

Water Consumption in the Jessup Plater

Tank	Flow (gpm)	Weekly Water Use (gal)	Annual Water Use (gal)
2	Manual*	537.0	26,850.0
3	2	12,384.0	619,200.0
4A	Manual*	448.0	22,400.0
4B	Manual*	448.0	22,400.0
5			
6	2	12,384.0	619,200.0
7A	Manual*	257.0	12,850.0
7B	Manual*	257.0	12,850.0
8			
9	5	30,960.0	1,548,000.0
10A	Manual*	484.0	24,200.0
10B	Manual*	484.0	24,200.0
11			
12			
13	5	30,960.0	1,548,000.0
14A	Manual*	257.0	12,850.0
15A	2	10,320.0	516,000.0
15B			
16	2	12,384.0	619,200.0
17	Manual*	257.0	12,850.0
Total		112,821.0	5,641,050.0

*Manual Water Use based on estimates by Doug Wiegand, Pretreatment Technician

Table 3. Chemicals Used in Plating Operations.

SOURCE:	PRODUCT NAME	CHEMICAL COMPOSITION	PART NUMBER	C.A.S. NUMBER	% COMPOSITION	QTY USED IN 07 *	UNIT	Price	UNIT	EST DAILY Usage **	CONCENTRATION
ZINC PLATING OPERATIONS:											
SOAK CLEAN	BIO VA	POTASSIUM HYDROXIDE HEXYLENE GLYCOL	59PPCH10034854	1310-58-3 107-41-5	10-20% 1-5%	935	gal	655.05	/55 gal	3,096	5-25%
ELECTROCLEANER	LC-B	SODIUM HYDROXIDE	59PPCH10034849	1310-73-2	46%	1,760	gal	248	/55gal	5,828	5-8%
	LEC-279	POTASSIUM PYROPHOSPHATE	59PPCH10034850	7320-34-5	30-40%	220	gal	585	/55gal	0,728	1-2%
ACID PICKLE		POTASSIUM HYDROXIDE		1310-58-3	1-5%						
		HYDROCHLORIC ACID	59PPCH10026402	7647-01-0	27-35%	see below		0.125	/lb		40-70%
		ACIDEX PAL	59PPCH10026403	7664-93-9	10-20%	0		261	/55 gal		20%
				7681-49-4	1-5%						
ZINC PLATE BATHS		SODIUM FLUORIDE	59PPCH10026397	7648-95-7	69%	0		39.6	/55 gal		
		ZINC CHLORIDE	59PPCH10037871			10	gal	32.5	/ql	0,033	
		ZYLITE ANTIFOAM									
		POTASSIUM CHLORIDE	59PPCH10032002	7447-40-7	100%	15,400	lbs.	0.315	/lb	50,993	17-21 oz/gal
		ZYLITE HT ADDITIVE	59PPCH10037870			770	gal	1075.3	/55 gal	2,550	3-6%
		ZYLITE HT BRIGHTENER	59PPCH10037869	109-59-1	20-30%	330	gal	887	/55 gal	1,093	
				122-67-6	5-10%						
		ZYLITE HT MB BRIGHTENER CH	59PPCH10037868			770	gal	674	/55 gal	2,550	
		ANOKLEEN	59PPCH10034853	1310-73-2	40-50%	0		2.75	/lb		
		ZINC BALLS	59PPCH10026404	7440-66-6	99.9%	52,800	lbs	1.36	/lb	174,834	4-5.5 oz/gal
		POTASSIUM PERMANGANATE	59PPCH10032445	7722-64-7	90-100%	0					
		HYDROGEN PEROXIDE (86% TECH)	59PPCH10026395	7732-18-5	30%-52%	1,000	lbs	0.405	/lb	3,311	
		BORIC ACID	59PPCH10037866	10043-35-3	>90%	4,700	lbs	0.636	/lb	15,563	1-7 oz/gal
		HYDROCHLORIC ACID	59PPCH10026402	7647-01-0	27-35%	see below		0.125	/lb		
RINSE/SEALER											
		BORIC ACID, COMPOUND WITH 2-AMINOETHANOL	59PPCH2201256	26038-87-9	1-5%	660	gal	1085	/55 gal	2,185	1-5%
		BORIC ACID, COMPOUND WITH 1-AMINO 2-PROPANOL		26038-90-4	1-5%						
		SUCCINIC ACID		110-15-6	1-5%						
CLEAR/BLUE CHROMATE	CORROTRIBLUE	NITRIC ACID	59PPCH10026407	7697-37-2	10-30%	1,760	gal	720.5	/55 gal	5,828	2-3%
		CHROMIUM HYDROXIDE SULFATE		12336-95-7	5-10%						
		COBALT SULFATE HEPTAHYDRATE		10026-24-1	1-5%						
		HYDROGEN FLUORIDE		7664-39-3	1-5%						

Table Compiled by Mike Sobota, Environmental Specialist.

One way that chemicals are removed from the plating baths is through dragout. Dragout is the water that is carried over from one tank to the next by the plating rack and parts. Dragout creates waste by placing chemicals in the rinse water system that are then converted into sludge. As shown by Appendix B, the average dragout is **0.11 gallons per rack per tank**. The cost per gallon of dragout is represented in Table 4 below. (Detailed calculations for Table 4 can be found in Appendix C.) Based on an average of 950 racks a week for 50 weeks a year, dragout costs over **\$31,000** a year in lost plating chemicals. (See Appendix D for detailed calculations.)

Table 4. Price per Gallon of Chemical Loses from Dragout

Tank Number	Description	Price per Gallon of Dragout
2	Soak Clean	\$1.19
4A and 4B	Electro Clean	\$0.45
7A	Weak Acid Pickle	\$0.95
7B	Strong Acid Pickle	\$0.66
10A and 10B	Zinc Plating Bath	\$2.69
14A	Chromate Bath	\$0.39
17	Rinse / Sealer	\$0.59

The following section details the process that uses these resources and generates waste.

Process Analysis

The process analyzed was plating operations in the Jessup Plater. Figure 1 shows a detailed diagram of tank layout and water flow in the plater. The parts are manually placed on racks and then wheeled into the part load/ unload station. Two automatic hosts take over the process from this point forward. The racks enter the tanks in numerical order and the time spent in each tank is provided in Appendix E. The racks only enter one tank at each numerical station. For example, a rack will enter either tank 4A or 4B; it will never enter both.

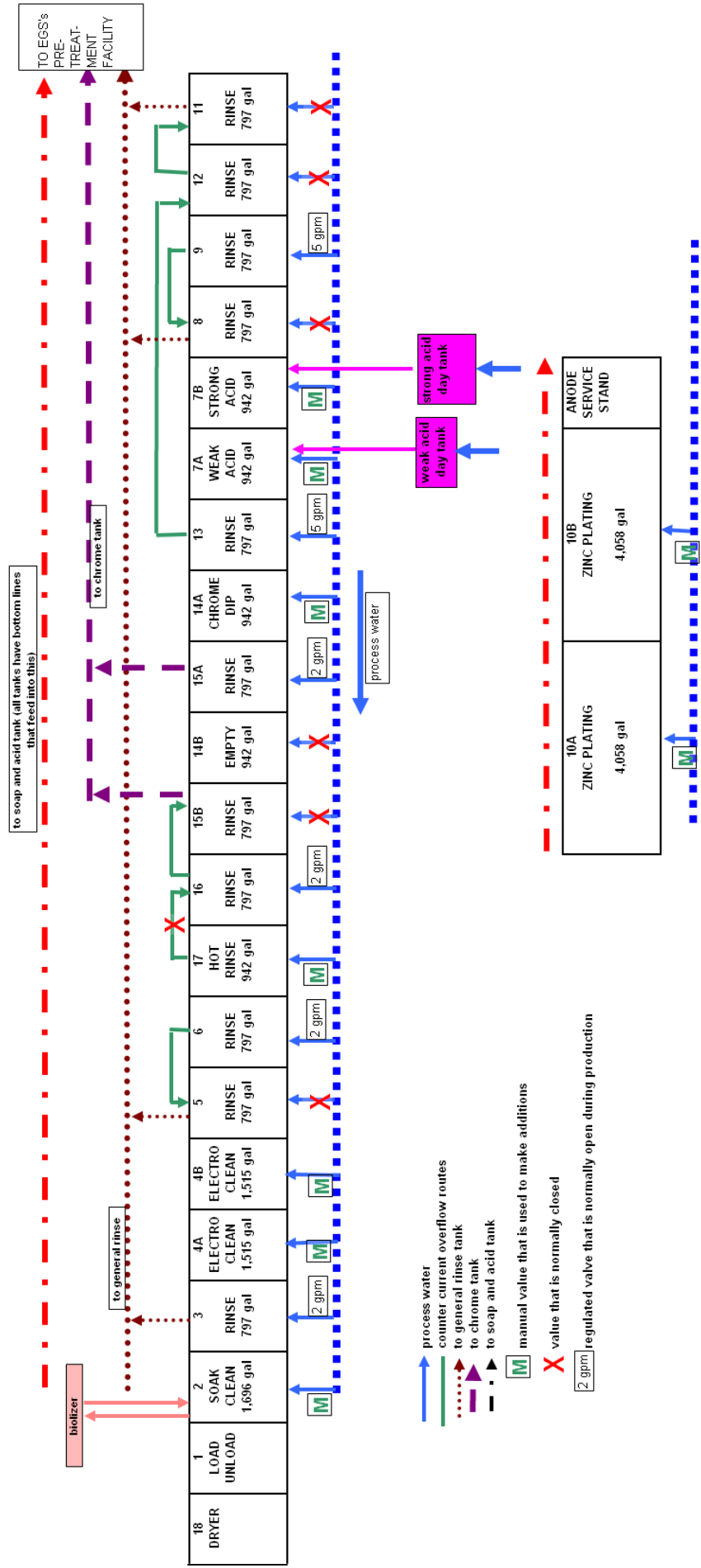


Figure 1. Jessup Plater Water Flow Diagram
 (Figure 1 used with slight modifications to the diagram produced by Ed Kinzer, Plant Environment Assistant.)

After analyzing the resources used, wastes produced, and process flow, potential pollution prevention opportunities were identified and are presented below.

P2 Opportunities

Information about several specific pollution prevention opportunities for the Jessup Rack Plater follows. These opportunities can be divided into four general categories of P2 suggestions: dragout reduction, rinse water use reduction, energy use reduction, and material reuse. Each suggestion will include a summary of current operations, suggested action, implementation cost, and a summary of benefits as appropriate.

Dragout Reduction

Dragout is the water that is carried over by the rack and parts as they move from one tank to the next in the plating line. Dragout water removes plating chemicals from the baths and places them into the rinse water system. The economic and environment problems of dragout are twofold. First, more chemicals must be added to the plating baths to make up for the chemicals lost to dragout, and second, the chemicals in the rinse water must be removed and disposed of properly. As shown earlier, the annual cost of dragout is over \$32,000 in lost plating chemicals. The following are suggestions on ways to minimize the amount of dragout in the Jessup Plater:

- **Implement Longer Drain Time**
Drain Time is the amount of time that the hoist holds the parts and rack over a tank after removal. Currently there is a 3 second drain time when the racks are withdrawn from process tanks. According to the Iowa DNR, increasing drain time from 3 seconds to 10 seconds will reduce dragout by up to 40 percent. Cutting dragout by 40 percent would result in an annual savings of over **\$12,000** in chemical costs and would also reduce the amount of necessary rinse water. Since productivity is also an important factor in determining drain time, the longer drain time could be implemented only over those tanks with the most expensive chemicals. Also, the hoist that removes racks from the zinc plating baths finishes its cycle before the other hoist so a longer drain time could be implemented over this tank with no loss in productivity. In addition to saving money on chemicals, treatment, and rinse water, reducing dragout will also reduce the amount of listed hazardous waste that must be disposed.
- **Implement Slower Work Piece Withdrawal Rate**
According to The Institute of Advanced Manufacturing Sciences, Inc., the work piece withdrawal rate is the most important factor for reducing dragout. The slower the pieces are withdrawn, the thinner the chemical film that forms on the piece. If productivity standards won't allow both of the first two suggestions to be implemented, the slower withdrawal rate should be implemented first.
- **Install Drain Boards**
There are currently drip boards between all of the tanks to prevent dragout from dripping on the floor when the rack is transferred from one tank to the next. These boards should be tilted back towards the process tanks so that the drips can drain

back into the correct tank reducing the amount of chemicals dragged out and rinse water needed.

- **Optimize Part Placement**

A simple solution to reduce dragout is to optimize the placement of parts on the plating rack. A good job is currently done of not hanging large parts vertically in line with one another so they are allowed to drip freely. Parts are also usually hung so water will be allowed to drain quickly and the part will not cup any water. The way that the LL and LR unilets are currently hung does cup some carryover in the bottom of the part. The unilets could be turned 180 degrees which will allow them to drain complete. (See Figure 2 below.) This simple change in procedure will save about **\$65** a year in dragout costs and will enable the use of less rinse water which will also result in lower costs as shown in Appendix F. Parts should also be placed on the rack at an angle when possible so dragout drips off one corner instead of an entire edge. Other racking solutions to problem parts should also be considered including racking individual parts differently and using different racks based on the part. An additional benefit of considering different racks is increased productivity by plating more parts per rack.



Current Hanging Practice. Water pools in the bottom of the part.



Alternative Hanging Practice. Water flows completely out of the part.

Figure 2. Part Placement of LR Unilet

- **Optimize Racks**
Another way to reduce dragout is to use racks specifically designed for parts. It would be highly impractical to have a different rack for every part because of the wide variety of parts processed by the facility, but racks can be produced for the parts that drag out the most water or can be used for several different parts. An additional advantage of new racks could be increased productivity by plating more parts per rack and producing fewer rejects.
- **Optimize Chemical Concentrations**
The concentration of plating chemicals in the bath has a direct effect on the amount of dragout. When the chemicals are at a higher concentration, the viscosity of the liquid increases so the amount of dragout also increases. To reduce the extent of this problem, plating baths should be run with the lowest possible chemical concentration while maintaining part quality. This level should be determined by gradually lowering the chemical concentration until quality suffers and then using the lowest concentration that produced good parts. A good estimate of the lowest possible chemical bath concentration can be determined by experimentation with a Hull Cell. Maintaining a lower chemical concentration will also have the added benefit of reducing the amount of chemicals lost per gallon of dragout saving new chemical purchase costs and waste treatment costs.
- **Install Spray Rinses**
Due to productivity constraints, installing spray rinses over the process baths may be the best solution to reducing dragout while maintaining the current tank timing schedule. Spray rinses spray a mist of water onto the rack and parts as they are withdrawn from the process bath. This rinse returns the plating chemicals to the bath. The primary concern with installing spray rinses is ensuring that the water added to the bath does not make the bath overflow. Based on a review of the installation of similar systems, it will cost an estimated \$1,500 per tank to install a spray rinse system. More information about spray rinses and a table with estimated evaporation rates of the process tanks is shown in Appendix G.
- **Install Dragout Tanks**
Dragout tanks are static rinse tanks directly after the plating baths. The water in these dragout tanks slowly builds up a concentration of plating chemicals and then is used as makeup water to the baths. An advantage to these systems is a capture and return rate of over 50 percent of chemicals lost to dragout. Disadvantages include having to use reverse osmosis water to makeup the static rinse and the tendency of the dragout tank to also concentrate and return impurities to the plating baths which may reduce plating bath life. There are empty tanks available on the Jessup plating line that could be converted into dragout tanks at a minimal cost.

Dragout is a problem not only because it removes chemicals from the process baths, but also because it introduces undesirable chemicals into the waste water treatment system. Reducing dragout with one or several of the above suggestions will reduce chemical costs, waste water treatment and disposal costs, and the amount of rinse water that is needed. If several of the above suggestions are combined, a 70 percent reduction in dragout may be possible. This reduction in dragout will reduce chemical costs by over

\$21,000 a year, the amount of rinse water that is needed, and sludge production by about **13.5 tons a year** for an additional savings of **\$12,200 a year** in waste treatment and disposal costs. (See Appendix H for calculation details.)

Reducing dragout is directly related to the amount of rinse water that is necessary. Rinse water use reduction P2 opportunities are presented in the following section.

Rinse Water Use Reduction

Rinse tanks follow every stage of the plating process as is seen in Figure 1, the Jessup Plater Water Flow Diagram. Rinsing is necessary to remove the contaminants from the parts and rack to prepare them for the next stage of the plating process. Rinses must be maintained in order to preserve part quality. As water becomes a more expensive commodity, it is important to use water more effectively. The following are ways to reduce water use while maintaining quality parts:

- **Install and Maintain Flow Restrictors**

There are currently six points in the Jessup plating line where fresh rinse water is constantly flowing into the system. As shown in Figure 1, these streams enter tanks 3, 6, 16, 15A, 13, and 9. The flow restrictors on tanks 3, 6, 16, and 15A allow 2 gallons per minute into the tanks while the restrictors on tanks 13 and 9 allow 5 gallons per minutes into the tanks. Switching the flow restrictors on tanks 13 and 9 from 5 gallons per minute to 2 gallons per minute would save EGS over **1.8 million gallons of water** a year which translates into a savings of over **\$7,400 a year** in water costs. (See Appendix I for details.)

Cost Analysis

Initial Investment: Two Pressure-Compensating Orifices from McMaster-Carr (catalog page 472)**\$70.32**

Current Annual Costs: The Columbus Water Usage Fee is \$1.32 for every 1,000 gallons of water and the Sanitary Sewer Usage Fee is \$2.70 for every 1,000 gallons of water as of October 2007. In total it costs \$4.02 for every 1,000 gallons of water that are obtained, used, and then disposed assuming minimal evaporation. Therefore, the total current costs of water entering rinse tanks 9 and 13 at 5 gallons per minute each is**\$12,446**

Future Annual Costs: Running the water input to tanks 9 and 13 at 2 gallons per minute will cost.....**\$4,978**

Potential Annual Savings:.....**\$7,468**

Payback Period:.....**3 days**

The orifices in flow restrictors can wear over time. It is suggested that the flow restrictors should be check at least bi-annually and replaced if wear is detected.

The price of a new flow restrictor is \$35.16. Even if every flow restrictor is replaced annually, the total cost would be \$211 which is less than 3 percent of the total annual savings of using flow restrictors.

- **Eliminate the Use of Tank 15A (Rinse)**

The current chrome rinse tank configuration is show below in Figure 3. Tank 15A is used as the first rinse tank after the chrome dip in tank 14A. There used to be two different chrome dips housed in tanks 14A and 14B. Tank 15B was used as the first rinse after the chrome dip in 14B. Tank 14B was eliminated when the use of hexavalent chromium ceased. Since 15B is counterflown with tank 16, it was not eliminated even though it hasn't been used since tank 14B was eliminated from the line. Instead of running rinse water through both tanks 15A and 15B, tank 15A should be eliminated and tank 15B should be used as the first rinse immediately following the chrome dip. 15B should be used instead of 15A because it is already set up in a counterflow with tank 16. The plating recipes should be reprogrammed to use tank 15B instead of tank 15A. This change would result in an annual savings of **620,000 gallons of water** and over **\$2,400 dollars a year**. (See Appendix J for detailed calculations.) Also, the implementation of the solenoid valve rinse water control option would become cheaper because the system would only have to be installed on five rinse water entry points instead of six.

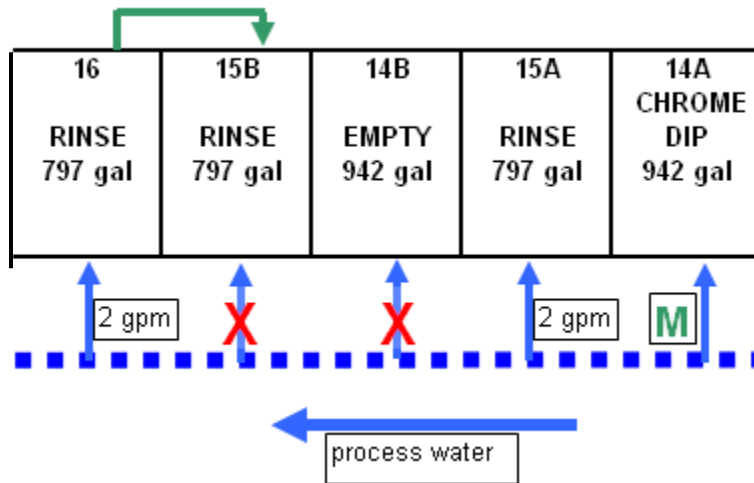


Figure 3. Chrome Rinse Tank Configuration

Cost Analysis

Initial Investment:.....minimal

Current Annual Costs: Water is \$4.02 for every 1,000 gallons that are obtained, used, and disposed. Currently water enters tank 15A at 2 gallons per minute and enters tank 15B through a counterflow with tank 16 at 2 gallons per minute for a total flow of 4 gallons per minute. The annual costs to run water to these tanks is**\$4,978**

Future Annual Costs: Running water through only tanks 16 and 15B in a counterflow for a total flow of 2 gallons per minute will cost.....**\$2,489**

Potential Annual Savings:.....**\$2,489**

- **Install Solenoid Valve and Timer Rinse Control**

A series of solenoid valves and a timer rinse control would offer a way to control the amount of rinse water entering the system based on the number of racks being processed. This setup would involve installing a solenoid valve on each of the six rinse input points on the plating line. The valves would then be wired into the plater's control computer and only opened after a rack enters the rinse tank. The valves can be programmed to remain open for a set period of time for each rack that enters the tank. A table of suggested rinse times for each tank based on the Hanson and Zabban (1959) method for calculating rinse flow rates is shown in Appendix K. Based on the suggested rinse times water use would be reduced by about **2.6 million gallons of water** a year.

Cost Analysis

Initial Investment: Five ¾" Brass Solenoid Valves from McMaster-Carr (catalog page 436).....**\$464.45**

Current Annual Cost: Assuming the elimination of Tank 15A and the installation of new flow restrictors, there is a total of 10 gallons per minutes flowing into the Jessup plater. At the rate of \$4.02 for every 1,000 gallons, the rinse water currently costs.....**\$12,446**

Future Annual Cost: The future cost of water usage with this system is dependent on the final time setting of the rinses. Based on the recommended time settings the water would cost.....**\$1,910**

Potential Annual Savings:.....**\$10,535**

Payback Period:.....**16 days**

More details about these calculations can be found in Appendix L.

If all of these suggestions- flow restrictors, timer rinse controls, and eliminating Tank 15A- are put into place, there will be an **over 90 percent reduction** in the amount of

rinse water used by the Jessup Plater for a total savings of **5 million gallons of water** and **over \$20,000 a year**. These changes are shown in Figure 4. In addition to the economic benefits, using and treating less water will improve EGS's reputation with the community as a leader in the conservation effort.

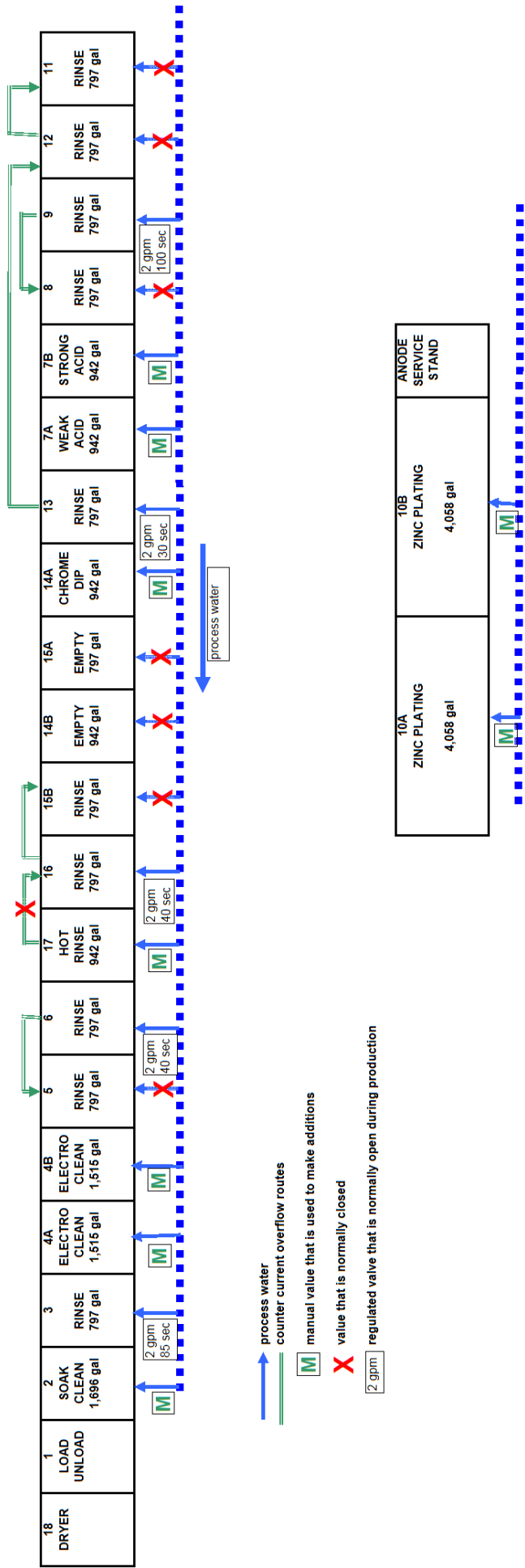


Figure 4. Proposed Jessup Plater Water Flow Diagram

In addition to reducing the amount of raw materials used, the amount of energy used can be reduced. Energy reduction suggestions are presented below.

Energy Use Reduction

Like water, energy is becoming a more expensive resource. The following suggestions offer simple solutions to reduce the amount of energy consumption in the Jessup Plater’s operation.

- **Install an Air Agitation On/ Off Switch**

Air agitation is used in the rinse tanks and process baths to provide more effective plating by mixing the contents of the tank. Currently, the air agitation is kept running 24 hours a day for the entire week so the motor that powers the Hoffmann blower is constantly running. A more energy efficient solution is to install an air agitation switch to turn off the air agitation during the weekends and downtime. One concern about turning the air agitation off was that the chemicals would settle in the plating baths over the weekends reducing the plating quality. To prevent a reduction in quality, the air agitation could be turned back on as prep work for plating begins to allow the baths time to mix before any parts are plated. Besides energy cost savings of over **\$2,000 a year**, an additional benefit of turning off the air agitation during plating down time is fewer airborne contaminants being introduced to the baths which could extend the bath life. Also, this reduction in electrical energy use will reduce greenhouse gas emissions by 48.4 metric tons a year, the equivalent of removing 9 passenger vehicles from the road. (See Appendix M for complete calculations.)

Cost Analysis

Current Annual Cost: Electricity to run the 20 hp motor for 24 hours a day, 7 days a week at the rate of \$0.0285 / kWh.....**\$3,713**

Future Annual Cost: Running the air agitation only when plating is taking place.....**\$1,542**

Potential Annual Savings:.....**\$2,171**

- **Make Insulation Improvements**

Several of the process baths are heated. Most of the tanks are well-insulated, but both the Soak Clean and Electro Clean tanks are hot to the touch. These tanks could be insulated better in order to reduce the amount of energy consumed to heat the tanks

The ultimate goal of any facility with pollution prevention in mind should be to progress towards zero discharges. One way to obtain this goal is to reuse resources in-house. Material reuse is explored in the following section.

Material Reuse

- **Establish Rinse Water Filtration and Reuse**

After water goes through EGS's pretreatment facility it is discharge to the POTW. Instead of discharging this water, some of it could be treated further and reused in the Jessup plating rinses. EGS just ordered a sand filter that will be used for this purpose. Discharged water will be further purified in the sand filter and then mixed with fresh process water to be used in the rinses. This process will cut the amount of fresh water used by the Jessup rinses in half. If all the other rinse water reduction opportunities are followed, the reuse of water will reduce the amount of fresh water used by an additional **250,000 gallons** of water and **\$1,000** a year.

An alternative to mixing the filtered water with fresh process water is further treating the filtered water with a reverse osmosis unit. This water can then be used as the feed for the Jessup rinse water without having to be mixed with fresh water. With this system, **no new city water** will ever have to be used for the Jessup Plater's rinses; all of the rinse water can be supplied by treated water already used once in the plant. This option will reduce city water use by **500,000 gallons** a year for an annual savings of **\$2,000**.

EGS Appleton Electric has shown a proven commitment to pollution prevention and implementing future improvements. The P2 opportunities presented in this report encourage a more efficient use of resources and result in a large financial savings. The dragout reduction, rinse water use reduction, energy use reduction, and material reuse suggestions above have the potential annual savings summarized below:

- Save **\$58,600** / year
- Reduce F006 listed hazardous waste production by **27,000 lb** (13.5 tons) / year
- Reduce water use by **5.5 million gallons** / year
- Reduce energy use by **130,000 kWh** a year

The P2 suggestions for the Jessup Rack Plater should be seriously considered and implemented as soon as possible to start reaping financial and environmental benefits.

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Appendix A. Annual Cost of Plating Chemicals

Annual Cost of Plating Chemicals						
Tank	Product	Part Number	Quantity Used (2007)	Unit	Cost	Annual Cost
Soak Clean	BIO VA	59PPCH10034854	935	gal	\$655.05	\$11,135.85
Electroclean	LC-B	59PPCH10034849	1,760	gal	\$248.00	\$7,936.00
	LEC-279	59PPCH10034850	220	gal	\$585.00	\$2,340.00
Acid Pickle	Hydrochloric Acid*	59PPCH10026402	120,000	lb	\$0.125	\$15,000.00
Zinc Plate Baths	Zylite Antifoam	59PPCH10037871	10	gal	\$32.50	\$325.00
	Potassium Chloride	59PPCH10032002	15,400	lb	\$0.315	\$4,851.00
	Zylite HT Additive	59PPCH10037870	770	gal	\$1,075.25	\$15,053.50
	Zylite HT Brightener	59PPCH10037869	330	gal	\$887.00	\$5,322.00
	Zylite HT MB Brightner CH	59PPCH1003786MB	770	gal	\$674.00	\$9,436.00
	Zinc Balls	59PPCH10026404	52,800	lb	\$1.36	\$71,808.00
	Hydrogen Peroxide	59PPCH10026395	1,000	lb	\$0.405	\$405.00
	Boric Acid	59PPCH10037866	4,700	lb	\$0.536	\$2,519.20
	Hydrochloric Acid*	59PPCH10026402	5,000	lb	\$0.125	\$625.00
Rinse/Sealer	Uniprep PP	59PPCH2201256	660	gal	\$1,085.00	\$13,020.00
Clear/ Blue Chromate	Corrottriblue	59PPCH10026407	1,760	gal	\$720.50	\$23,056.00
Total Cost						\$182,833

*Amount of Hydrochloric Acid used estimated based on total Hydrochloric Acid use throughout all plant processes.

Appendix B. Dragout Calculation Data

$$\text{Dragout}_{\text{volume}} = \frac{(\Delta \text{conductivity}_{\text{of}_{\text{rinse}_{\text{water}}}) (\text{volume}_{\text{rinse}_{\text{water}}})}{\text{conductivity}_{\text{of}_{\text{process}_{\text{water}}}}$$

Dragout Test: June 11, 2008

Tank	Initial Conductivity	Final Conductivity			# of racks	Dragout (gal / rack)	Dragout (cups / rack)	Dragout (mL / rack)
11	1,500	3,500		Zinc	35	0.10	1.61	380.79
12	580	590		Chrome	36	0.10	1.62	383.42
10A	440,000	460,000						
10B	460,000	460,000						
15A	740	880						
14A	31,200	30,000						

Dragout Test: June 18, 2008

Tank Conductivity Readings								
Tank	Initial Conductivity	Final Conductivity			# of racks	Dragout (gal / rack)	Dragout (cups / rack)	Dragout (mL / rack)
11	2,600	7,300		Zinc	84	0.11	1.70	402.26
12	1,100	1,300		Chrome	84	0.12	1.98	469.05668
10A	440,000	430,000						
10B	440,000	440,000						
15A	1,300	1,650						
14A	26,400	27,200						
	Average Dragout Per Rack							
		0.11						

Appendix C. Cost per Gallon of Dragout

Dragout Calculation

$$\frac{950 \text{ racks}}{\text{week}} \times \frac{1 \text{ week}}{5 \text{ days}} \times \frac{0.1 \text{ gal}_{-} \text{ dragout}}{\text{rack}} = 19 \text{ gal dragout / day}$$

Soak Clean:

- Bio va
*10 percent concentration

$$\frac{\$11.91}{\text{gal}_{-} \text{ product}} \times \frac{0.1 \text{ gal}_{-} \text{ product}}{\text{gal}_{-} \text{ dragout}} = \$1.19 / \text{gal dragout}$$

Total = \$1.19 / gal dragout

Electro Clean:

- LC-B
*6.5 percent concentration

$$\frac{\$248}{55 \text{ gal}_{-} \text{ product}} \times \frac{0.065 \text{ gal}_{-} \text{ product}}{\text{gal}_{-} \text{ dragout}} = \$0.293 / \text{gal dragout}$$

- LEC-279
*1.5 percent concentration

$$\frac{\$585}{55 \text{ gal}_{-} \text{ product}} \times \frac{0.015 \text{ gal}_{-} \text{ product}}{\text{gal}_{-} \text{ dragout}} = \$0.1595 / \text{gal dragout}$$

Total = \$0.45 / gal dragout

Weak Acid Pickle:

- Acidex Pal
*20 percent concentration

$$\frac{\$261}{55 \text{ gal}_{-} \text{ product}} \times \frac{0.20 \text{ gal}_{-} \text{ product}}{\text{gal}_{-} \text{ dragout}} = \$0.95 / \text{gal dragout}$$

Total = \$0.95 / gal dragout

Strong Acid Pickle

- Hydrochloric Acid
*55 percent concentration

$$\frac{0.55 \text{ gal_product}}{\text{gal_dragout}} \times \frac{\$0.125}{\text{lb}} \times \frac{9.66 \text{ lb}}{\text{gal_product}} = \$0.66 / \text{gal dragout}$$

Total = \$0.66 / gal dragout

Zinc Plating Bath

- Potassium Chloride
*19oz / gal

$$\frac{19 \text{ oz}}{\text{gal_dragout}} \times \frac{1 \text{ lb}}{16 \text{ oz}} \times \frac{\$0.315}{\text{lb}} = \$0.374 / \text{gal dragout}$$

- Zylite HT Additive
*4.5 percent concentration

$$\frac{\$1075.30}{55 \text{ gal_product}} \times \frac{0.045 \text{ gal_product}}{\text{gal_dragout}} = \$0.88 / \text{gal dragout}$$

- Zinc Balls
*5oz / gal

$$\frac{5 \text{ oz}}{\text{gal_dragout}} \times \frac{1 \text{ lb}}{16 \text{ oz}} \times \frac{\$1.36}{\text{lb}} = \$0.42 / \text{gal dragout}$$

- Boric Acid
*4oz / gal

$$\frac{4 \text{ oz}}{\text{gal_dragout}} \times \frac{1 \text{ lb}}{16 \text{ oz}} \times \frac{\$0.536}{\text{lb}} = \$0.134 / \text{gal dragout}$$

- Zylite Antifoam
*based on estimated daily usage

$$\frac{1}{2} \times \frac{0.033 \text{ gal_product}}{\text{day}} \times \frac{\$32.50}{\text{gal_product}} \times \frac{\text{day}}{19 \text{ gal_dragout}} = \$0.028 / \text{gal dragout}$$

- Zylite HT MB Brightener CH

*based on estimated daily usage

$$\frac{1}{2} \times \frac{2.550 \text{ gal}_{-} \text{ product}}{\text{day}} \times \frac{\$674}{55 \text{ gal}_{-} \text{ product}} \times \frac{\text{day}}{19 \text{ gal}_{-} \text{ dragout}} = \$0.82$$

- Hydrogen Peroxide
*based on estimated daily usage

$$\frac{1}{2} \times \frac{3.31 \text{ lb}}{\text{day}} \times \frac{\$0.405}{\text{lb}} \times \frac{\text{day}}{19 \text{ gal}_{-} \text{ dragout}} = \$0.035$$

Total = \$2.69 / gal dragout

Chrome Plating Bath

- CorroTriBlue
3 percent composition
$$\frac{\$720.50}{55 \text{ gal}_{-} \text{ product}} \times \frac{0.03 \text{ gal}_{-} \text{ product}}{\text{gal}_{-} \text{ dragout}} = \$0.393 / \text{gal dragout}$$

Total = \$0.39 / gal dragout

Rinse / Sealer

- Uniprep PP
3 percent composition
$$\frac{\$1,085}{55 \text{ gal}_{-} \text{ product}} \times \frac{0.03 \text{ gal}_{-} \text{ product}}{\text{gal}_{-} \text{ dragout}} = \$0.59 / \text{gal dragout}$$

Total = \$0.59 / gal dragout

Appendix D. Annual Cost of Dragout

$$\begin{aligned} \text{Total Dragout Cost per Rack (Strong Acid)} &= \frac{\$5.97}{\text{gallon}_{\text{dragout}}} \times \frac{0.11 \text{gal}_{\text{dragout}}}{\text{rack}} \\ &= \$0.6567 / \text{rack} \end{aligned}$$

$$\frac{950 \text{racks}}{\text{week}} \times \frac{50 \text{weeks}}{\text{year}} \times \frac{\$0.6567}{\text{rack}} = \mathbf{\$31,193 / \text{year}}$$

Appendix E. Rack Immersion Times

*Immersion times provided by Jessup Engineering, Inc.

Station Number	Process Station	Zinc with Acid Cycle (sec)	Zinc with no Acid Cycle (sec)	Up Drain Time (sec)
1	LOAD	253	253	
2	SOAK	550	550	3
3	R	251	251	
4	EC	205	205	3
5	R	157	157	
6	R	10	2	3
7A or 7B	ACID	180		3
8	R	63		
9	R	40	25	3
10	ZINC PLATE	1739	1739	3
11	R	40	40	
12	R	DIP	DIP	3
13	R	30	30	3
14A	CLEAR	60	60	3
15A	R	65	65	3
16	R	DIP	DIP	
17	HR	37	37	3
18	DRYER	387	387	

Appendix F. Dragout Reduction from Hanging Modification Estimates

Dragout Reduction From Hanging Modification					
Part Type	Parts per Month	Dragout per Part (gal)	Monthly Dragout (gal)	Annual Dragout (gal)	Annual Cost of Dragout (gal)
LL27	3,046	0.00050	1.52300	18.28	\$12.01
LR27	2,800	0.00050	1.40000	16.80	\$11.04
LL37	970	0.00050	0.48500	5.82	\$3.82
LR37	1,271	0.00092	1.16932	14.03	\$9.22
LL47	109	0.00100	0.10900	1.31	\$0.86
LR47	100	0.00100	0.10000	1.20	\$0.79
LL57	241	0.00172	0.41452	4.97	\$3.27
LR57	400	0.00172	0.68800	8.26	\$5.42
LL67	253	0.00555	1.40415	16.85	\$11.07
LR67	220	0.00555	1.22100	14.65	\$9.63
LL77	5	0.00700	0.03500	0.42	\$0.28
LR77	3	0.00700	0.02100	0.25	\$0.17
			8.56999	102.84	\$67.57

Appendix G. Spray Rinse Information

Tank	Process	Temperature (°F)	Evaporation Rate (gal/ sq. ft / hr)	Surface Area (sq. ft)	Evaporation (gal/ day)	Maximum Daily Racks	Maximum Flow per Rack (gal)
2	Soak Clean	113	0.03	38.4	27.6	200	0.14
4A	Electro Clean	121	0.04	33.8	32.4	200	0.16
4B	Electro Clean	121	0.04	33.8	32.4	200	0.16
7B	Acid	88	0.01	24.4	5.9	200	0.03
10A	Zinc Plate	95	0.02	105	50.4	100	0.50
10B	Zinc Plate	97	0.02	105	50.4	100	0.50
14A	Chrome	80	---	24.4	---	200	---
17	Hot Rinse	120	0.04	24.4	23.4	200	0.12

*Evaporation rates based on Electroplating Engineering Handbook, Durney, 1984.
 Direct measurement of bath makeup water will provide a more accurate indication of the maximum allowable flow per rack. The tanks should be monitored closely after spray rinses are installed to ensure that the tanks do not overflow.

$$\text{Flow per Rack} = (\# \text{ of nozzles}) * (\text{nozzle flow rate}) * (\text{time on per rack})$$

*Air Knives may be an alternative option for tanks with minimal evaporation where tank overflow is a concern.

Appendix H. Dragout Reduction Savings

Chemical Cost Savings

$$0.70 \times \frac{\$31,193}{\text{year}} = \mathbf{\$21,835 / \text{year}}$$

Sludge Reduction Savings

\$4,250 / load	transportation and fuel costs
\$162 / ton = \$1,620 / load	disposal costs
\$3,200 / load	treatment chemicals
<hr/>	
\$9,070 / load	total cost

$$13.5 \text{ tons} \times \frac{1 \text{ load}}{10 \text{ tons}} \times \frac{\$9,070}{\text{load}} = \mathbf{\$12,200 \text{ savings from sludge reduction}}$$

Appendix I. Flow Restrictor Calculations

Initial Investment:

Flow Regulators available from McMaster-Carr on catalog page 472.

$$2 \text{ regulators} \times \frac{\$35.16}{\text{regulator}} = \$70.32$$

Water Cost:

*Assuming negligible evaporation takes place in the rinse water tanks.

Columbus Water Rate as of 10/1/07:	\$1.32 / 1,000 gallons
Columbus Sanitary Sewer Rate as of 10/1/07:	\$2.70 / 1,000 gallons

Total Water Use and Disposal Rate: \$4.02 / 1,000 gallons

Current Water Use:

*Water is run continuously from 7:00 am on Monday through 3:00 pm on Friday for a total of 4.3 days a week.

$$2 \text{ regulators} \times \frac{5 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hour}} \times \frac{24 \text{ hour}}{\text{day}} \times \frac{4.3 \text{ days}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} = 3,096,000 \text{ gal / year}$$

$$\frac{3,096,000 \text{ gal}}{\text{year}} \times \frac{\$4.02}{1,000 \text{ gal}} = \$12,446 / \text{year}$$

Future Water Use:

$$2 \text{ regulators} \times \frac{2 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hour}} \times \frac{24 \text{ hour}}{\text{day}} \times \frac{4.3 \text{ days}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} = 1,238,400 \text{ gal / year}$$

$$\frac{1,238,400 \text{ gal}}{\text{year}} \times \frac{\$4.02}{1,000 \text{ gal}} = \$4,978 / \text{year}$$

Potential Savings:

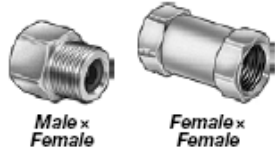
$$3,096,000 \text{ gal} - 1,238,400 \text{ gal} = 1,857,600 \text{ gal / year}$$

$$\$12,446 - \$4,978 = \$7,468 / \text{year}$$

Payback Period:

$$\frac{\$70.32}{\$7,468/\text{year}} = 0.00942 \text{ years} = \mathbf{3 \text{ days}}$$

Pressure-Compensating Orifices



Conserve drinking water and energy with these inline-mounted regulating control valves; they deliver consistent outlet flow over varying pressure conditions. The control mechanism is a flexible orifice that varies its effective area inversely to the applied pressure. Maximum inlet pressure is 200 psi. Temp. range is 40° to 180° F.

Brass Body—Seal is Buna-N, except for 1 and 2 gpm valves, which have an EPR (ethylene propylene rubber) seal.
Nickel-Plated Brass and Type 316 Stainless Steel Bodies— $\frac{3}{8}$ " orifices have an EPR seal, unless noted. $\frac{1}{2}$ ", $\frac{3}{4}$ ", and 1" orifices have a Buna-N seal, unless noted.

Zinc-Plated Steel Body—Seal is Buna-N, except for 1 and 2 gpm orifices, which have an EPR seal.

Connections: NPT male and NPT female. See table.

To Order: Please specify outlet flow from those listed.

Pipe Size	Available Outlet Flow, gpm	O'all Lg.	Each	Pipe Size	Available Outlet Flow, gpm	O'all Lg.	Each
Brass Body—Male Inlet x Female Outlet				Zinc-Plated Steel Body—Male Inlet x Male Outlet (Cont.)			
$\frac{3}{4}$ "	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1 $\frac{1}{2}$ "	8105K11 ... \$35.11	1 $\frac{1}{2}$ "	1, 2, 3, 5, 6, 8, 10, 15, 30	3"	8107K33 ... \$90.43
Nickel-Plated Brass Body—Female Inlet x Female Outlet				Type 316 Stainless Steel Body—Female Inlet x Female Outlet			
$\frac{3}{8}$ "	0.13, 0.19, 0.25, 0.35, 0.50, 0.75, 1	1 $\frac{3}{4}$ "	4762K41 ... 28.72	$\frac{3}{8}$ "	0.13, 0.19, 0.25, 0.35, 0.50, 0.75, 1	1 $\frac{3}{4}$ "	4762K51▲ 150.64
$\frac{1}{2}$ "	1, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6	1 $\frac{5}{8}$ "	4762K43● 32.34	$\frac{1}{2}$ "	1, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6	1 $\frac{5}{8}$ "	4762K53● 171.82
$\frac{3}{4}$ "	1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10	2 $\frac{1}{2}$ "	4762K45■ 35.16	$\frac{3}{4}$ "	1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10	2 $\frac{1}{2}$ "	4762K55■ 239.78
1"	1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 25, 30	2 $\frac{3}{4}$ "	4762K47■ 69.15	1"	1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 25, 30	2 $\frac{3}{4}$ "	4762K57■ 262.48
Zinc-Plated Steel Body—Male Inlet x Male Outlet							
1 $\frac{1}{4}$ "	1, 2, 3, 5, 6, 8, 10, 15, 30	3"	8107K31 ... 81.91				

● 1.5 gpm orifice has an EPR seal. ■ 1 and 2 gpm orifices have an EPR seal. ▲ 0.35 gpm orifice has a Buna-N seal.

Appendix J. Tank 15A Elimination Calculations

Water Cost:

*Assuming negligible evaporation takes place in the rinse water tanks.

Columbus Water Rate as of 10/1/07:	\$1.32 / 1,000 gallons
Columbus Sanitary Sewer Rate as of 10/1/07:	\$2.70 / 1,000 gallons

Total Water Use and Disposal Rate: \$4.02 / 1,000 gallons

Current Water Use:

$$2 \text{ regulators} \times \frac{2 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hour}} \times \frac{24 \text{ hour}}{\text{day}} \times \frac{4.3 \text{ days}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} = 1,238,400 \text{ gal / year}$$

$$\frac{1,238,400 \text{ gal}}{\text{year}} \times \frac{\$4.02}{1,000 \text{ gal}} = \$4,978 / \text{year}$$

Future Water Use:

$$1 \text{ regulator} \times \frac{2 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hour}} \times \frac{24 \text{ hour}}{\text{day}} \times \frac{4.3 \text{ days}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} = 619,200 \text{ gal / year}$$

$$\frac{619,200 \text{ gal}}{\text{year}} \times \frac{\$4.02}{1,000 \text{ gal}} = \$2,489 / \text{year}$$

Potential Savings:

$$1,238,400 \text{ gal} - 619,200 \text{ gal} = 619,200 \text{ gal / year}$$

$$\$4,978 - \$2,489 = \mathbf{\$2,489 / year}$$

Appendix K. Rinse Time Estimations

Tank	Rinse Time (sec)
3	85
6	40
16	40
13	35
9	100

*Calculations based on Hanson and Zabban (1959) and Mohler (1984)

$$Q = \frac{D}{t} \left(\frac{C_o}{C_r} \right)^{1/r}$$

Q = rate of fresh water flow (gal / min)

D = volume of dragout per rack (gal)

t = time between racks (min)

r = number of rinse tanks in series

C_o = concentration of solution being drug into rinse tank

C_r = maximum allowable concentration in rth rinse

Example: Zinc Plating Rinses based on conductivity measurements

$$Q = \frac{0.11 \text{ gal}}{5 \text{ min}} \left(\frac{460,000}{500} \right)^{1/3} = 0.21 \text{ gal / min or } 32 \text{ sec per rack @ } 2 \text{ gpm}$$

*These calculations are estimates. The actual amount of rinse water needed may need to be adjusted based on observations of part or bath quality.

Appendix L. Solenoid Valve Calculations

Initial Investment:

Solenoid Valves available from McMaster-Carr on catalog page 436.

$$5 \text{ valves} \times \frac{\$92.89}{\text{valve}} = \$464.45$$

*Labor will also have to be invested in installing and programming the new system.

Water Cost:

*Assuming negligible evaporation takes place in the rinse water tanks.

Columbus Water Rate as of 10/1/07:	\$1.32 / 1,000 gallons
Columbus Sanitary Sewer Rate as of 10/1/07:	\$2.70 / 1,000 gallons

Total Water Use and Disposal Rate: \$4.02 / 1,000 gallons

Current Water Use:

$$5 \text{ regulators} \times \frac{2 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hour}} \times \frac{24 \text{ hour}}{\text{day}} \times \frac{4.3 \text{ days}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} = 3,096,000 \text{ gal / year}$$

$$\frac{3,096,000 \text{ gal}}{\text{year}} \times \frac{\$4.02}{1,000 \text{ gal}} = \$12,446$$

Future Water Use:

$$\frac{950 \text{ racks}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} \times \frac{300 \text{ sec}}{\text{rack}} \times \frac{2 \text{ gal}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 475,000 \text{ gal / year}$$

$$\frac{475,000 \text{ gal}}{\text{year}} \times \frac{\$4.02}{1,000 \text{ gal}} = \$1,910 / \text{year}$$

Potential Savings:

$$3,096,000 \text{ gal / year} - 475,000 \text{ gal / year} = 2,621,000 \text{ gal / year}$$

$$\$12,446 - \$1,910 = \mathbf{\$10,535 / year}$$

Payback Period:

$$\frac{\$464.45}{\$10,535 / \text{year}} = 0.044 \text{ years} = \mathbf{16 \text{ days}}$$

Appendix M. Air Agitation Calculations

Hoffmann T Series Blower

Model: T2B05

20 hp motor

Current Annual Costs:

Energy Cost: \$0.0285 / kWh (as of March 2008)

$$20 \text{ hp} \times \frac{745.7 \text{ watt}}{\text{hp}} \times \frac{1 \text{ kW}}{1,000 \text{ watt}} \times \frac{\$0.0285}{\text{kWh}} \times \frac{52 \text{ weeks}}{\text{year}} \times \frac{7 \text{ days}}{\text{week}} \times \frac{24 \text{ hours}}{\text{day}} = \$3,713 / \text{year}$$

Potential Savings:

Turn off air agitation when plating is not running.

$$\text{Weekends: } \frac{52 \text{ weeks}}{\text{year}} \times \frac{2 \text{ days}}{\text{week}} \times \frac{24 \text{ hours}}{\text{day}} = 2,496 \text{ hours / year}$$

$$\text{Down Time: } \frac{52 \text{ weeks}}{\text{year}} \times \frac{5 \text{ days}}{\text{week}} \times \frac{10 \text{ hours}}{\text{day}} = 2,600 \text{ hours / year}$$

Total Time = 2,496 hours + 2,600 hours = 5,096 hours / year

$$20 \text{ hp} \times \frac{745.7 \text{ watt}}{\text{hp}} \times \frac{1 \text{ kW}}{1,000 \text{ watt}} \times \frac{\$0.0285}{\text{kWh}} \times \frac{5,096 \text{ hours}}{\text{year}} = \mathbf{\$2,172 / \text{year}}$$

Green House Gas Emissions Reduction:

$$20 \text{ hp} \times \frac{745.7 \text{ watt}}{\text{hp}} \times \frac{1 \text{ kW}}{1,000 \text{ watt}} \times \frac{5,096 \text{ hours}}{\text{year}} \times \frac{1.404 \text{ lbs } - \text{CO}_2}{\text{kWh}} \times \frac{\text{metric } - \text{lb}}{2,204.6 \text{ lb}} = 48.4 \text{ metric tons}$$

*CO₂ Region 7 Emissions Factor provided by The Cadmus Group, Inc. *Regional Electricity Emission Factors Final Report*

48.4 metric tons = 9 passenger vehicles

*Source: EPA's Greenhouse Gas Equivalencies Calculator