METAL FINISHERS

TECHNICAL SUPPLEMENT

COMPANION TO THE METAL FINISHERS GUIDE TO REDUCING ENERGY COSTS

A PUBLICATION OF THE
ENERGY CENTER OF WISCONSIN

ENERGY CENTER
OF WISCONSIN
We show you how

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Metal Finisher's Technical Supplement

Companion to the Metal Finisher's Guide to Reducing Energy Cost

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Prepared by

ENERGY CENTER
OF WISCONSIN
We show you how

595 Science Drive
Madison, WI 53711-1076
Phone: 608.238.4601
Fax: 608.238.8733
Email: ecw@ecw.org
www.ecw.org

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Chicago, Illinois
773.254.2406
www.sclweb.com
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We also thank the following review committee members for helping develop this guide:

Jack Annis	University of Wisconsin-Extension, Solid and Hazardous Waste Education Center
Leon Engler	Wisconsin Public Service Corporation
Brian Gilbert	American Finishing Resources
Jeff Hettmann	Ultra Plating
Kelly Huss	Astro Industries
Jill Osterholz	Alliant Energy
Julie Thorsen	Wisconsin Electric Power Company
Annette Weissbach	Wisconsin Department of Natural Resources

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How to Use this Supplement

This reference provides technical information to support the energy-saving techniques, or actions, described in the Energy Center of Wisconsin's *Metal Finisher's Guide to Reducing Energy Costs*. The information in this supplement is grouped by plant system and areas of energy consumption, and is meant to provide guidance for those who already have some technical expertise in system design and maintenance.

Selected resources for more information and assistance appear at the end of each section; see the *Metal Finisher's Guide* for a complete listing of resources.

Tank Ventilation Requirements

Ventilation design is covered in detail in ANSI (American National Standards Institute) Z9.1-1991. OSHA 29CFR, 1910.94 was replaced by this ANSI standard in 1998 and should no longer be used for ventilation guidance. Here we explain how to use the information in ANSI Z9.1 with a few examples.

Determining the Hazard Potential Rating and the Gas, Mist, Evaporation Rating

Each ventilated process tank must be evaluated to determine whether it should be ventilated and if so, what the exhaust rate should be. To do this, refer to ANSI Z9.1-1991 standard (Tables B.3-B.5, page 24) and obtain the "Hazard Class" for the chemicals in the process tank. Hazard class information can also be found in *Industrial Ventilation: Manual of Recommended Practice*. If these sources do not list your process, see "Determining Your Hazard Class" below.

For example, hexavalent chromium plating has a hazard potential class rating of "A." A sulfamate nickel-plating tank would have a hazard potential class rating of "B."

Next, obtain the Gas, Vapor, or Misting rating from Table 2 of ANSI Z9.1 (partially reproduced in the table below) or from *Industrial Ventilation* mentioned above. See "Determining Your Hazard Class" for information on obtaining this rating for other processes.

Table 1: Misting/Gassing/Evaporation Rating

Misting/Gassing/Evaporation Rating

Rate	Temp °F	Degrees Below Below Boiling °F	Relative Evaporation	Gassing
1	>200	0-20	Fast	High
2	150-200	21-50	Medium	Medium
3	94-149	51-100	Slow	Low
4	<94	>100	Nil	Nil

As shown in the table above, a rating of 1 is assigned to a process that operates above 200° F, or is 0-20° F below the boiling point, or has a fast evaporation rating, or has a high level of gassing (mist formation due to gas bubbles).

In our previous example, the chromium plating process has a rate of gas or mist evolution that is "High," yielding a gassing rate of 1. The nickel-plating process (sulfate process, using soluble anodes) has a gassing rating of "nil," which yields a rating of 4.

According to ANSI Z9.1, the above rating needs to be modified for certain equipment such as vapor degreasers. A modern, well-operated vapor degreaser can be given a gas, vapor, mist rating of 4. A vapor degreaser operated in “average” conditions is rated 3, while a poorly operated degreaser may be assigned a rating of 2 or 1.

Determining Hazard Classes

If Table B.3 of ANSI Z9.1 does not list the process for which you need a Hazard Class, use the following method to calculate the class.

Gather this information:

1. Permissible Exposure Limits” (PELs) or Threshold Limit Values (TLVs) of the major pollutants and hazardous ingredients in the process tank. PELs for common air contaminants can be found in OSHA (29CFR 1910.100). TLVs are published by the American Conference of Governmental Industrial Hygienists (ACGIH) in a booklet titled *2000 TLVs® and BEIs®*. If OSHA and ACGIH disagree on the PEL/TLV value applicable to a pollutant, the OSHA value supersedes the ACGIH value. The supplier of the chemical products or the MSDS (Material Safety Data Sheet) for the product may also have PELs and TLVs.

2. Boiling point of the process solution, in ° F. This typically is found in the MSDS. In most metal finishing tanks it is near enough to 212° F that this value can be used.

3. The flash point of the process chemical, which can also be found in the MSDS. This value is normally greater than 212° F for all water-based processing solutions.

4. Relative evaporation rate. This is a rating of how fast the liquid in the process evaporates. Data can be found in the *Electroplating Engineering Handbook* (Table 1 in Chapter 28 of Edition 4) and *Industrial & Engineering Chemistry*, Vol. 27, page 1169. Fast = 0-3 hours for complete evaporation, Medium = 3-12 hours. Slow = 0-50 hours, and Nil. = >50 hours. You may also find this data in the MSDS.

5. Gassing or misting rating for the process. If the resources mentioned above do not list your process, contact your chemical supplier or consultant/professional engineer for a professional estimate of the gassing rate.

Next, consult Table 1 in ANSI Z9.1 (reproduced below) to determine the Hazard Potential. The hazard potential is a rating based on the PEL or TLV for either gas, vapor or mist, depending on which is emitted by the process. The rating is also dependent upon the flash point, but this rarely is an issue for metal finishing processes.

Table 2: Hazard Potential (courtesy of ANSI Z9.1)

Hazard Potential	PEL/TLV		Flash Point (° F)
	Gas/Vapor, ppm	Mist mg/m3	
A	0-1	0-0.1	----
B	1.1-100	0.11-1.0	<100
C	101-500	1.1-10	100-200
D	>500	>10	>200

For example, hexavalent chromium plating has a hazard potential class rating of “A,” due to toxicity (OSHA PEL for chromic acid mist is 0.1 mg/M3). A sulfamate nickel-plating tank would have a hazard potential class rating of “B,” due to a PEL of 1.0 mg/M3 for soluble nickel mist.

Determining Ventilation Control Velocity

With the Hazard Potential Rating and the Gas, Mist, Evaporation Rating, you can determine the ventilation control velocity.

Table 3: Determining the Required Control Velocity

Determining The Required Control Velocity

Hazard Class	Control Velocity For Lateral Exhaust ft./min.
A1, A2	150
A3, B1, B2, C1	100
B3, C2, D1	75
A4, C3, D2	50
B4, C3, D2	General Room Ventilation

In our example, the Hazard Class rating for chromium plating is A1, while the nickel plating process has a rating of B4. Using Table 3 of ANSI Z9.1 (partially reproduced above) we can obtain the control velocity in feet per minute required for each plating tank.

The specified control velocity of a combination of hazard “A” and gassing rate “1,” is 150 ft/min for a lateral exhaust hood in an undisturbed location. You would need to increase this value if you have cross drafts around the plating tank or if the loading dock door is nearby. Note that the control velocity is not the ventilation rate (cfm)—it is the speed at which air must be moving at the opening of the hood in order to capture emitted fumes and mist.

For the B4 process (nickel plating, soluble anodes, no air agitation), general room ventilation is considered sufficient. Therefore if you are ventilating such a tank, you are wasting energy.

The above procedure should be applied to each ventilated process tank to confirm that ventilation is necessary and that it meets ventilation requirements.

Determining the Required Ventilation Rate

To determine the ventilation rate (cfm) required for a process tank, first divide the width of the tank by the length. For example, a tank that is 2 ft. wide and 4 ft. long would have a ratio of 0.5. Based on this ratio and the control velocity, look up the cfm per square foot exhaust rate required in Table 4 of ANSI Z9.1. Below is a portion of Table 4 showing requirements for a tank against a wall with a hood along one side.

Table 4: Determining the Required Ventilation Rate

Determining The Ventilation Rate

Tank With Lateral Exhaust Hood Against Wall Or Baffled					
Control Velocity,	Ventilation Rate, cfm per ft^2 For The Following Aspect (W/L) Ratios:				
fpm	0-0.09	0.1-0.24	0.25-0.49	0.5-0.99	1.0-2.0
50	50	60	75	90	100
75	75	90	110	130	150
100	100	125	150	175	200
150	150	190	225	250	250

In our example the required control velocity was 150 fpm. With a width-to-length ratio of 0.5, Table 4 of ANSI Z9.1 requires 250 cfm per square foot of tank surface area if the tank were up against a wall. The total exhaust rate for a 2 x 4 foot tank against a wall would then be 2000 cfm. If the tank is exhausted at a rate higher than this, energy is wasted. Table 4 also addresses free-standing tanks and tanks exhausted from two sides.

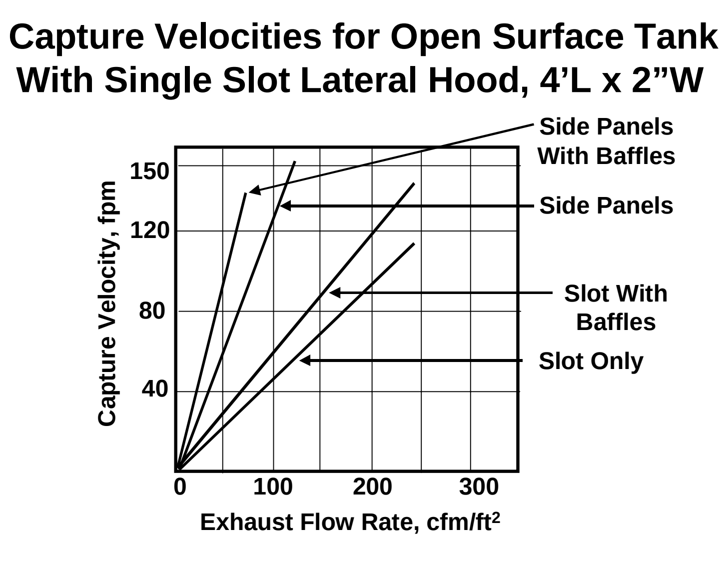
Reducing the Required Ventilation

Exhaust Hood Design

You can equip exhaust hoods with baffles and side panels to reduce exhaust requirements. A good ventilation design manual and ANSI Z9.1 will provide more detail than can be presented here.

According to the figure below from ANSI Z9.1, a tank two feet wide and four feet long takes about 250cfm/ft^2 to achieve a capture velocity of 150 fpm, with a lateral slot exhaust hood (with baffle), while the same capture velocity can be achieved with about 125 cfm/ft^2 if the exhaust hood has side panels. This reduces the air exhausted by 25/150, or 16.7 % with equivalent energy savings.

Figure 1: Open Surface Tank Velocities



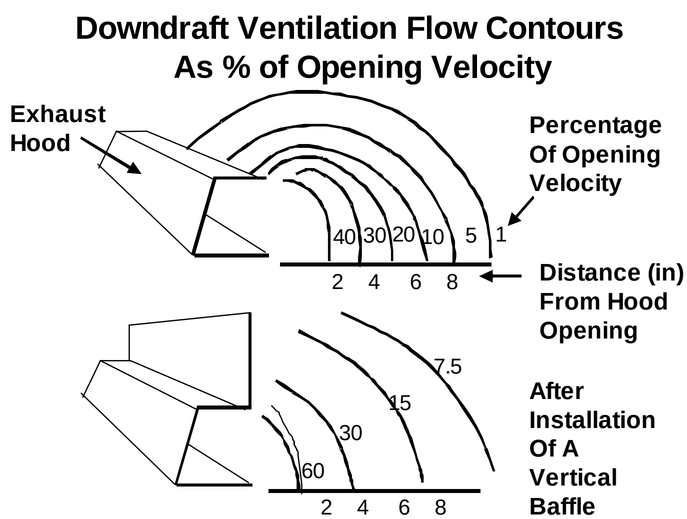
Adding or extending side panels can also improve the efficiency of an exhaust system by reducing cross drafts. The side panels should be extended as far out from the exhaust hood as possible.

Reduced ventilation rates save energy. Another reason to avoid high ventilation rates is that too high of an exhaust rate can "vacuum" out mist particles that ordinarily might fall back into the solution.

Downdraft Ventilation Systems

Vertical baffles installed on the tops of downdraft ventilation ducts will save energy by maximizing capture velocities. The vertical baffle also reduces air draw over the top lip of the hood. The height of this baffle should approach the width of the tank if ventilation is only from one side. In some cases this is not possible due to the travel of work over the tank.

Figure 2: Downdraft Ventilation Flow Contours



Cross draft velocities at exhausted tanks should not be greater than 75 ft/min (0.4 m/sec) to avoid excessive fugitive emissions and disruption of mist capture by the exhaust hood. On long tanks, the pull hood/plenum should be divided so that exhaust air is evenly drawn in along the length of the hood. The capture efficiency can be measured using tracer gas or smoke testing.

Push/Pull Systems

Push/pull exhaust systems are often used on tanks more than three feet wide. These systems use a high-pressure, low-volume spray of air to "push" contaminants to the exhaust hood. Push systems effectively reduce the "width" of the tank by two to three feet, so the exhaust rate can be reduced by about 50 %. Double pull or four-side pull can also be used.

The push air is supplied by a low-pressure blower or by a compressor system. Compressor systems have a tendency to spew oil along with the air, so they are not recommended for processes sensitive to oil contamination (see elsewhere in this document for information on compressed air).

Push/pull systems are not effective on tanks with a lot of hardware between the push duct and the pull duct. Hard chromium plating operations often employ auxiliary anodes, cables, clamps, additional copper bus, etc., which can interfere with air flow. Because push air is delivered at high velocity, it tends to cause high-speed collisions between the mist and the hardware on top of the tank, causing a high amount of fugitive emissions.

Consult ventilation handbooks and ANSI Z9.1 for information on designing push-pull systems.

Mist Suppressants, Foam Blankets, and Floating Poly Balls

Adding an effective, stable mist suppressant to a solution that normally produces a mist (such as a hard chromium plating solution) can significantly reduce associated energy costs by either reducing or eliminating the required ventilation. The Metal Finishing Association of Southern California determined the following reductions in emissions with the activities shown:

Table 5: Emission Reduction

Action	Emission Reduction
Eliminate air agitation	5.6%
Use floating poly balls	87%
Use foam blankets/wetting agents	93-98%
Keep solution clean & chemically stable	20-40%

Mist suppressants are available for use in most metal finishing processes, but tend to be expensive. Studies have shown you can use mist suppressants without affecting the quality of the finished product in most cases, but experimentation and verification is important. Some anodizers using chromic acid, for example, have reported an adverse effect on salt spray performance of the anodic coating produced, while others have had no problems.

Foam blankets are much less expensive but tend to trap hydrogen gas, creating loud explosions when a spark sets off the hydrogen in the foam.

Optimizing Make-up Air Systems

If you operate exhaust hoods over process tanks you must also supply make-up air to replace exhaust air. Make-up air creates either a positive or negative pressure in the building, depending on whether make-up air volume is greater or less than the exhaust air. ANSI Z9.1 specifies that the make-up air must be 90 to 110 percent of the exhaust air, but if the facility exhausts toxic emissions, the make-up air cannot exceed 100% of the exhaust (this prevents untreated toxins from being emitted). Therefore most metal finishing facilities should have a slight negative air pressure in the building so that when you open an exterior door, the pressure inside the building pulls on the door to resist your effort. If the opposite is true, an adjustment in the air make-up rate may be required.

Because make-up air must be heated in winter, keeping make-up air to minimum allowable amounts can bring about significant energy cost savings.

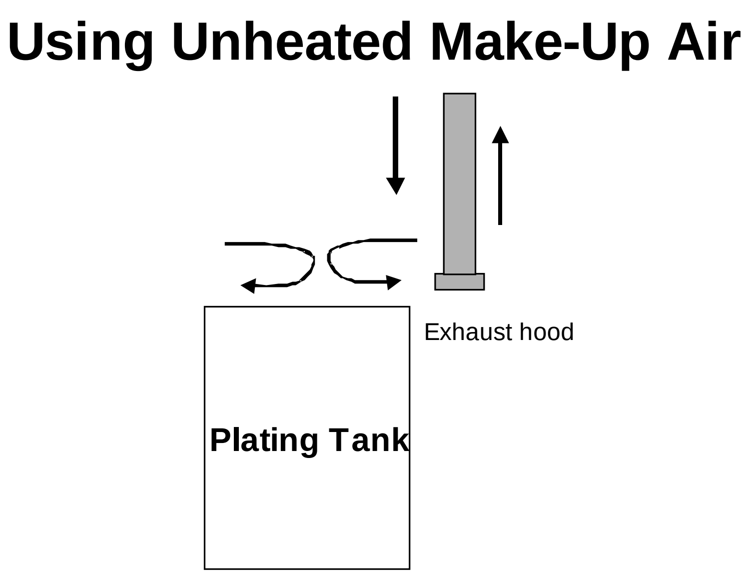
A comparison of the make-up air to the exhaust air should be made initially for a new facility and must be regularly verified according to ANSI Z9.1. We recommend verification annually and whenever system modifications are made. Keep records of your calculations and measurements.

Using Unheated Make-up Air

Sometimes unheated outside air can be directed over the working tank to make up for exhaust air, resulting in significant energy savings.

One possible system is diagrammed below. The company operates several hard chromium plating tanks that are ventilated using a hood that surrounds the top of the circular tanks. The duct supplies unheated outside air for the exhaust duct to draw out, reducing the amount of make-up air that needs to be conditioned. The hard chromium plating solution typically requires cooling, so unheated supply air lowers cooling requirements as well.

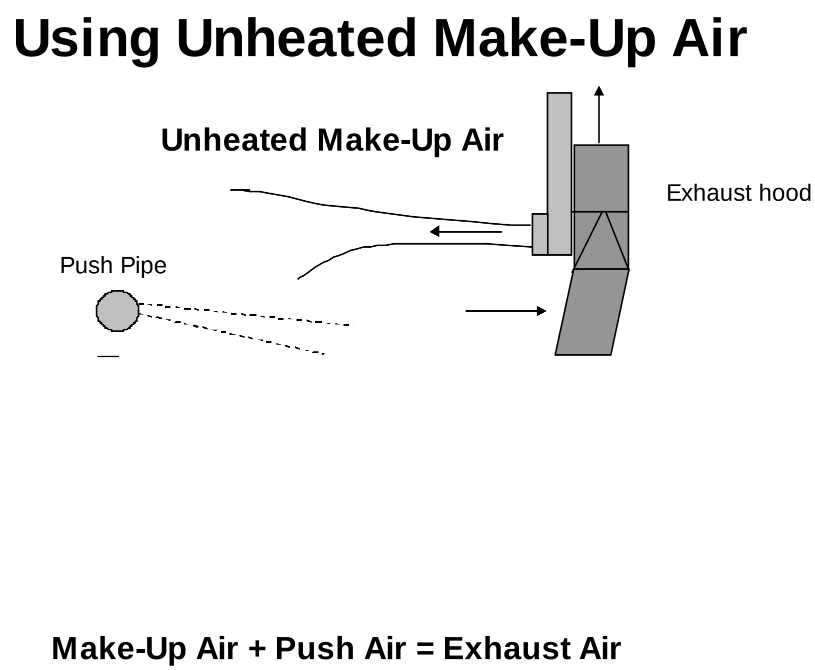
Figure 3: Using Unheated Make-Up Air



With heated tanks unheated make-up air may increase energy requirements for tank heating. However, the system may be more efficient in capturing emissions, allowing for a reduced exhaust rate and overall energy savings.

You can also use unheated make-up air for lateral exhaust hoods such that an unheated supply duct is piggy-backed over the pull duct, as shown below. Rather than exhaust conditioned air, the pull duct exhausts primarily unconditioned air. A fan and damper allow for adjustment of the make-up air system. The combination of push air and supply air from the make-up system creates an effective “air-cover” that can allow for reduced exhaust rates without compromising ambient air quality.

Figure 4: Using Unheated Make-Up Air



Optimizing Ventilation and Makeup Systems

Once you have calculated minimum required ventilation rates, you’ll need to optimize the system. One way to do this is to use dampers in each exhaust branch duct to set the proper flow rates, rechecking all flow rates after each round of adjustments. This will save energy by reducing the amount of required make-up air, but it could result in wasted fan power. If fans are working harder than they need to, you can reduce energy costs significantly by slowing or replacing oversized fans. In general, dampers should be used to trim ventilation rates no more than 15 percent.

You can also design a damperless system by changing the duct diameter and fittings to provide the correct air flows. Details on this “balanced system design” can be found in *Industrial Ventilation: Manual of Recommended Practices.*

Other ways to minimize the energy use in ventilation systems include:

- **Use energy efficient fans**
  Because of the high exhaust and make-up rates required in metal finishing plants, energy-efficient fans can have fast paybacks. One way of making fans more efficient is to replace standard motors with high efficiency motors, discussed later in this section.

- **Use efficient dampers**
  Variable inlet vanes are more efficient than parallel blades or butterfly dampers.

- **Use adjustable speed drives and multispeed motors**
  When air flow rates vary, variable speed drives or multispeed fan motors will save energy (see later in this section).

- **Avoid sharp turns in ductwork and intakes**
  Intakes should have inlet bells to prevent turbulent (and inefficient) intake into the system. Sharp duct bends should be avoided because they increase turbulence, noise, and energy cost.

- **Maintenance**
  Regular maintenance is vital to keep ventilation and exhaust systems working efficiently. Your plant should have a program to check for dirty filters, coils, or silencers; dirty or broken dampers; worn or dirty fan blades; and air leaks.

- **Heat Reclaim**
  In some situations, heat exchangers can be used to pre-warm outside air with heat from the exhaust air. Where the outside air intake and exhaust are not close enough to allow this, a heat pipe can be used to transfer the heat. One difficulty that may arise is corrosive exhaust gasses.

Motors and Variable Speed Drives

The Energy Policy Act of 1992 (effective 1997) requires that all new motors between one and 200 hp must meet minimum efficiency standards. Improved design and manufacturing processes and better materials have reduced motor energy consumption, typically improving efficiency by two to 10 percent.

When buying a new motor or replacing a failed motor, you should evaluate whether a minimum-efficiency or premium-efficiency motor will give you the best return, considering first costs and long-term operating costs. Often your motor supplier can help you with these calculations.

A properly rewound motor is typically one to two percent less efficient than when it was new. Rewinding may be appropriate for motors with intermittent, infrequent operation, but often motors with high runtimes should be replaced with high-efficiency motors. *Motor Challenge* materials can help you determine the most economical course of action.

Motors should be sized to operate with about a 75 percent load factor. A motor operating at either a much higher or much lower load factor could be a source of significant unnecessary energy cost and should be evaluated for replacement by a properly-sized motor. The Motor Challenge fact sheet, *Replacing an Oversized and Under-loaded Electric Motor,* can help with the evaluation. See also *Correct Sizing of Motors*. Motor full-load speed should match the desired operating speed for centrifugal devices (pumps and fans) without throttling with dampers or valves. When the desired operating speeds vary considerably, adjustable speed drives may be appropriate (see below).

When motors fail, they often must be replaced or rewound quickly. It is wise to have a replacement/repair plan in place. If you have already calculated which motor you should buy, you can quickly make a decision that may save operating costs for many years. If the replacement motor you want will not be easily available, you may want to buy a backup before failure.

Adjustable Speed Drives and MultiStep Motors

Full output is often not required of fans, pumps and similar equipment, however the motors that drive these devices run constantly at the same speed. Dampers, valves, and other devices can be used to throttle the output, but as Pacific Gas & Electric Company notes, it's "like driving a car by flooring the accelerator and controlling speed by using the brake!"

Adjustable speed drives and multistep motors can be used to modulate equipment speed far more efficiently. These options are most likely to be cost-effective in applications that have a high number of annual run hours.

An adjustable speed drive (ASD) adjusts the voltage and frequency of the AC current supplied to the motor to adjust the motor speed. This saves energy and often reduces maintenance costs. Recent improvements in reliability and decreases in cost have made ASDs more popular. You should not use ASDs for motors that need to run at or near full speed.

Power factor may be an issue with some ASDs, so consult your utility representative for advice. Multistep motors are designed to run at more than one speed. These motors may be more cost-effective than adding an ASD, but may not provide as great an energy savings. On the other hand, if only fixed motor speeds are required, multistep motors may be more efficient than ASDs.

Selected Resources

Table 6: Ventilation Selected Resources

2000 TLVs® and BEIs® American Conference of Governmental Industrial Hygienists 1330 Kemper Meadow Dr., Suite 600 Cincinnati, OH 45240 513.742.2020 www.acgih.org	**ANSI Z9.1** American National Standards Institute 1819 L Street, NW Washington, DC 20036 202.293.8020 www.ansi.org
Correct Sizing of Motors Pacific Gas & Electric Company. www.pge.com/customer_services/business/energy/smart/pdf/sizing.pdf	***Industrial Ventilation: A Manual of Recommended Practices*** Publication 2092 of the American Conference of Governmental Industrial Hygienists. 1330 Kemper Meadow Dr., Suite 600 Cincinnati, OH 45240 513.742.2020 www.acgih.org
Electroplating Engineering Handbook 1984. Edited by Lawrence J. Durney. Published by Van Nostrand Reinhold, New York, New York, USA. ISBN 0-442-22002-2, Library of Congress card number 84-3548.	***Motor Challenge Program, U.S. Department of Energy*** This program provides both Internet and printed material on the advantages of energy efficient motors, how to interpret ratings, how to calculate when energy efficient motors make sense financially and how to optimize motor-driven systems. The free MotorMaster software compares specific motors, calculates savings, and keeps maintenance records. Fact sheets, including *Replacing an Oversized and Under-loaded Electric Motor*, are also available. These resources are available through the Office of Industrial Technology, Best Practices web site. www.oit.doe.gov/bestpractices/ 800.862.2086.
Industrial & Engineering Chemistry, Vol 27 By A. K. Doolittle.	

See the *Metal Finisher's Guide* for more resources.

Air-Conditioning

Here are some ways to reduce air-conditioning costs.

Window Units

Window air conditioners cool small office areas. The National Appliance Energy Conservation Act minimum efficiency standards of 1990 requires that new window air-conditioners be much more efficient than older units. Instead of nursing along an old unit, it may be more economical to buy a new unit. A kilowatt-hour meter, sometimes available from your electric utility or library, can show you how much it's costing you to run your air conditioner. The appliance rating tags on new air conditioners can help you predict your costs with a new unit.

Reducing cooling loads by installing more efficient lighting, insulating or shading walls and windows, and turning off unnecessary equipment will also reduce your air-conditioning costs.

Packaged Units

Packaged air-conditioners are large units that can cool small areas of a plant. New units are much more efficient than old ones, so replacing an ailing unit is often economical. Regular maintenance, such as cleaning filters and condensers, will help all units perform better. Some studies report between 11% and 42% efficiency improvements with professional tune-ups.

Reducing cooling loads, as described above, is also important in areas cooled by packaged units. Installing a set-back thermostat to turn the unit down or off when the area is not occupied will save money. In moderate climates, economizer cycles should be considered. Economizer cycles use fresh, unconditioned outdoor air when the outdoor temperature is relatively cool.

Industrial-Size Air-Conditioning Systems

Optimizing industrial-size air-conditioning systems is beyond the scope of this guide, although we can outline some energy saving opportunities associated with large cooling systems.

Designing New Systems for Efficiency

New air-conditioning systems should be designed for efficiency. A few ways to do this are:

- Use a number of smaller chillers and air conditioning units that can be individually turned on or off as the demand dictates.
- Use separate circulation systems that can similarly be turned off and on individually.
- Use economizers in moderate climates. These use outside air for conditioning and air make-up without running the refrigeration system.

High-Efficiency Chillers

High efficiency chillers use as little as 0.50 kilowatts per ton (kW/ton), compared to 0.65-0.8 kW/ton for less-efficient chillers. High efficiency chillers should be considered when replacing an older chiller or installing a new system.

Chiller components include an electric motor, compressor, condenser, evaporator, expansion device, and controls. Each of these units may have a higher efficiency replacement that could be used when a replacement is needed. Making these types of substitutions, however, requires expert advice because of component interaction.

Converting existing chillers to alternative refrigerants to eliminate CFCs often lowers their efficiency. Total replacement may be a more energy effective alternative. See the *Cool $ense Network* for more information.

HVAC System Maintenance

Proper maintenance prevents ensures air balance, good indoor air quality, and lowers energy consumption by improving the efficiency of heat transfer. Routine activities include:

- Steam clean evaporator coils and air handlers regularly, according to manufacturer guidelines.
- Change filters according to manufacturer recommendations.
- Check air balance frequently. Metal finishing facilities should have a slight negative pressure.
- Check all air ducts for damage and infiltration.
- Verify ventilation rates on all process tanks with exhaust hoods.
- Verify proper refrigerant level/pressure on all air conditioning equipment and refrigerated chillers monthly.

Improving Existing Chillers

The following are some possible ways to improve the energy efficiency of an existing chiller system:

- If chiller water is required many hours each year and the outdoor temperature is often below 55° F, consider installing a free-cooling device. This will allow the cooling tower to be used to cool water instead of the evaporator.
- Consider using high-efficiency pumps and motors. Adjustable-speed drives may be appropriate when loads vary considerably.
- Consider lowering the condenser temperature to improve chiller efficiency. You should consult an expert because each system will have a minimum condenser temperature.
- Raise the chilled water temperature, if possible. You will need to verify that the system can still provide adequate humidity and temperature control.
- Use high-efficiency transmissions and motors in cooling towers when repairs must be made.

Space Heating

Space-heating is responsible for about 57% of the heat energy use of a metal finishing plant that plates small pieces. Optimizing the ventilation system (see previous chapter) is the first step in improving space-heating efficiency. Other measures include:

- If heat is provided by the steam system, explore ways to optimize the steam system (see next chapter). Also consider installing valves and vacuum breakers to cut off the flow of steam to unit heaters when the thermostat turns off the unit heater fan.
- In high-bay buildings, bring warm air down from the ceiling with ceiling fans. These fans should not be run during warm weather or during unoccupied periods.

- Consider gas-fired radiant heaters to “spot-heat” areas. This can be particularly energy efficient in areas that have large amounts of entering air, such as a loading dock or garage bay. At least one metal finishing plant uses radiant heat when temperatures must be maintained very accurately.

Selected Resources

Table 7: Heating and Cooling Resources

Cool $ense Network Energy efficient chiller projects (replacements, retrofits, and expansions). http://ateam.lbl.gov/coolsense	***Energy Answers: Low-Intensity Infrared Space Heating*** Wisconsin Public Service Corporation. www.wpsc.wpsr.com/business/No8.pdf
Guide to Reducing Energy Use in Commercial HVAC Systems Pacific Gas & Electric Company’s Smarter Energy Business Purchasing Guide. www.pge.com/customer_services/business/energy/smart/pdf/phvac.pdf	***Packaged and Unitary AC Systems*** PG&E’s Smarter Energy Business Purchasing Guide. www.pge.com/customer_services/business/energy/smart/html/hvac_guide.html

See the *Metal Finisher’s Guide* for more resources.

Steam Generation and Distribution

Boilers

Large boiler systems operate at 75 to 85 percent efficiency while new condensing gas-fired boilers have efficiencies above 92 percent. If you are replacing old boiler equipment, look at the advantages of multiple boiler systems and high-efficiency boiler models.

You can increase the efficiency of an existing boiler through proper operation and maintenance procedures and by adding energy saving devices.

Operation and Maintenance

Operation and maintenance can reduce boiler energy use by five to 10 percent. Here are a few tips:

Fire Side Maintenance

- *Maintain proper air-to-fuel ratio*. This ensures complete and efficient combustion. Delivering more air than is necessary for complete combustion increases the production of nitrogen, which absorbs heat and carries it out the stack. Not enough air results in incomplete combustion, forming carbon monoxide (CO), which releases one-third as much heat as the carbon dioxide formed by complete combustion.

- *Distribute fuel and air uniformly throughout the main combustion zone*. In multiple-burner gas boilers, nonuniform combustion can result if the fuel and air are not distributed evenly. One misadjusted or malfunctioning burner can result in higher CO levels. Raising the excess air levels (to counter the higher CO) for the whole boiler will cause the other burners to operate at unnecessarily high oxygen levels and reduce the boiler efficiency.

- Maintain clean heat transfer surfaces

Water or Steam Side Maintenance

- *Maintain acceptably low levels for total dissolved solids (TDS).* Water that contains a high level of TDS must be drained from the boiler to reduce scale formation which impedes heat transfer. This practice (blowdown) results in energy loss as hot water is drained from the boiler. Blowdown should not be done unnecessarily. Water treatment can reduce scale formation. You should have a plant protocol for water treatment. If your system is complex, an automatic treatment system may be cost effective.

- *Lower boiler steam pressure when the process permits.* Reducing steam pressure can reduce fuel consumption and stack temperatures.

- *Insulate boiler and boiler piping.* Add and/or repair insulation to reduce heat loss through boiler walls and piping (see also next chapter).

Energy Saving Devices

Various devices can be added to existing boilers to increase their efficiency.

- *Economizer*: a heat exchanger installed in the exhaust stack to transfer some of the heat in the stack gases to preheat water going into the boiler.

- *Air preheater*: a device that transfers heat from hot stack gas to air that is mixed with fuel for combustion.

- *Turbulators:* twisted pieces of metal placed in the tubes of fire-tube boilers to make hot gases travel more slowly and turbulently. This results in better heat transfer to the water.

- *Oxygen trim controls*: a system to monitor oxygen in the stack gas and adjust air intake to the burners for optimum efficiency.

Case Study: Savings from improving boiler operation efficiency

After an Energy, Environment, and Manufacturing assessment, a plating services company with a facility of 150,000 square feet was projected to realize cost savings of $7026 per year and energy savings of 23,188 CCF per year by taking two steps to improve their boiler operation efficiency:

- Adjusting the air-fuel ratio
  By obtaining the optimum air-fuel ratio, the boiler efficiency could reach 83.1% (up from 73.9%) and the company could achieve energy savings of 19,000 CCF per year and cost savings of $5757 per year. To implement this measure, the air-fuel ratio should be checked bimonthly and the boiler inspected for exterior cracks or holes through which excess air might enter the system. The cost to implement this measure was estimated to be $995 ($300 for an experienced boiler contractor and $695 for a flue-gas testing device) and would result in a simple payback of two months.

- Insulating feed water tank
  Insulating the boiler feed water tank reduces heat losses and boiler operating costs. By insulating the sides of the tank, the company could achieve energy savings of 1622 CCF per year. Installing an insulated cover on the tank saves another 2566 CCF per year. Energy savings for installing both types of insulation would be 4188 CCF per year with annual cost savings of $1269. The cost to implement this measure was estimated to be $1,260 (the cost of the insulation and the labor to install it) and would result in a simple payback of 12 months.

Table 8: Energy Savings and Payback

Action	Energy Savings	Cost Savings	Implementation Cost	Payback
Air-Fuel Ratio	19,000 CCF/yr	$5757/yr	$995	2 months
Insulation	4188 CCF/yr	$1269/yr	$1260	12 months
Total	**23,188 CCF/yr**	**$7026/yr**	**$2255**	**4 months**

Steam Traps

Steam traps—the automatic valves used to remove condensate, air, and other noncondensable gases from your steam distribution system—are prone to failure if they are not regularly maintained. Condensate that is not removed from the steam distribution system reduces the heat transfer efficiency in heat exchangers. Air and other noncondensable gases that are not removed can cause corrosion or act as an insulator and hinder heat transfer. Finally, as much as 20 percent of the steam leaving a central boiler plant can be lost through leaking steam traps.

To ensure that your steam traps are functioning correctly you should check them routinely. Number and map all traps to facilitate testing and record-keeping; train maintenance and operational staff in trap testing techniques. The Council of Industrial Boiler Owners has the following recommendations for correct steam trap operation:

- Give priority to the repair or maintenance of failed traps. Regular and timely maintenance procedures can reduce trap failures to three to five percent or less. A failed open trap can result in steam losses of 50-100 lb/hr.

- Install atmospheric vents on traps in closed systems so that trap operation can be checked visually.

- Select the proper trap design for the specific application. In certain applications, inverted bucket traps may be preferred to thermostatic and/or thermodynamic traps.

- Test traps regularly. The most foolproof method for testing traps is observation, so it is important to be able to observe the discharge from the traps through the header.

- Properly size traps for the expected condensate load. Improper sizing can cause steam losses, freezing, and mechanical failures.

- Properly design the condensate collection system to minimize frozen and/or premature trap failures. Condensate piping should be sized to accommodate 10 percent of the traps failing to open.

Heated Process Tanks and Piping

Metal finishing processes usually involve several tanks containing water-based chemical solutions operated at elevated temperature. Tanks are typically heated using steam or electricity and are subject to heat losses through the open tops of the tanks and through the tank walls.

In terms of operating cost, heating tanks with steam is almost always cheaper than heating with electricity. Small shops sometimes choose electric heating because first costs are lower. Larger shops with more tanks to heat usually choose steam heating. If you need to replace your tank heating systems, or if you are designing a new shop, have an expert calculate the long-term costs of electric vs. steam heating.

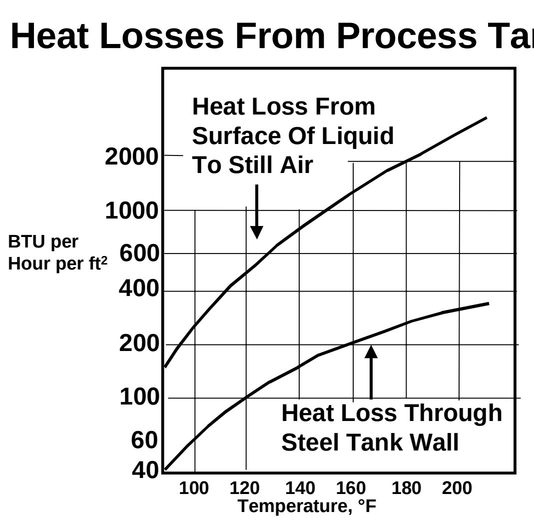
To ensure heating efficiency and prevent heat losses in and from tanks, you should:

- Reduce scaling using commercially available boiler treatment systems
- Reduce cross drafts
- Cover tanks when possible with either rigid or floating covers
- Consider automated covers
- Insulate tanks and pipes where economical

Estimating Heat Loss

Electroplating engineering guides such as *Electroplating Engineering Handbook* can provide you with tools—such as the graph below—to help you estimate heat loss. For example, we will calculate heat loss from a hot water rinse operated at 140° F. The tank is uninsulated, unventilated, and measures 3' x 4' x 3.5' deep.

Figure 5: Heat Losses from Process Tanks



According to the graph, the tank loses 150 BTU per hour per square foot through the tank walls. Wall area is 49 square feet, so the tank loses are 7350 BTU/hr, or 58,800 BTU per eight-hour day. The tank also loses 800 BTU per hour per square foot from the liquid surface. With 12 ft^2 of surface area, the losses are 9600 BTU/hr, or 76,800 BTU per eight-hour day.

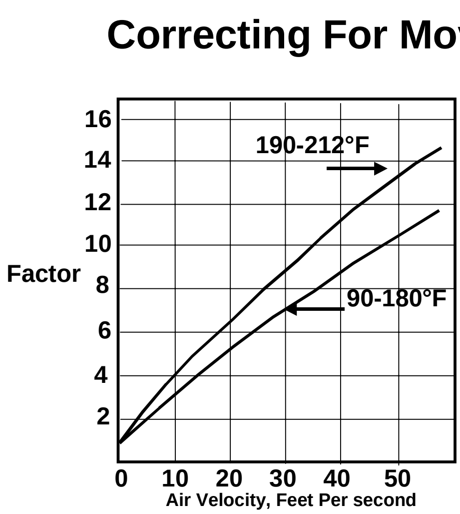
The tank is therefore losing about 136,000 BTU per day. At 100,000 BTU per therm and $0.10/therm energy costs, losses costing $0.14 per day, or about $36 per year. Air moving across the surface of the tank will increase these numbers, as we'll see below.

Although in cold weather the heat losses through tank sides may reduce a building's space heating costs, heat from the liquid surface is usually carried outside by ventilation and lost. In warm weather, heat losses increase air-conditioning costs.

Correcting Heat Loss Estimates for Cross Drafts and Ventilated Tanks

Heat losses calculated from the previous chart must be adjusted upward if the tank is exhausted or located in an area with cross drafts or a steady stream of moving air. Using a vane device (shown below), you can measure the air velocity over a tank by taking an average of at least five measurements. The chart below, taken from the *Electroplating Engineering Handbook*, yields a correction factor. Multiply the previously determined heat loss by this factor to obtain a corrected estimate.

Figure 6: Correcting for Moving Air



Vane Device For Measuring Air Velocity, fps

For the previous example, if the air velocity averages 20 feet per second the correction factor is five and the actual heat loss from the surface of the tank is 4000 BTU/hour- ft^2 or 384,000 BTU per eight-hour day. This is about $0.38 per day or $99 per year. The significantly higher energy losses are a major reason for eliminating cross drafts as much as possible and ensuring that ventilation rates do not exceed designed values.

Tank Covers

Most of the thermal losses from hot metal finishing processes result from heat loss from the open tops of hot tanks.

Figure 7: Rigid Covers

Rigid Covers

It is often difficult to use a tank cover without interfering with work flow. During idle periods a simple plastic cover can significantly reduce thermal losses and save energy. Shown below are tanks that are operated sporadically and have enclosures including a lid to allow for reduced ventilation rates during idle times. A typical cover of this type can cost about $800-1200 depending on materials used, while less complicated covers may only cost $100. If, in our example above, the tank was heated 24 hours/day the annual cost of the heat loss from the surface of the tank would be close to $300/year, making a cover an obvious consideration.

Figure 8: Floating Media

Floating Covers

Floating polypropylene media may be appropriate for tanks with less idle time. A covering of polypropylene disks three to four layers deep act as a floating cover and can cut energy losses by up to 50%. The floating media can also reduce mist emissions (see chapter on ventilation) by about 87%. Floating media should not be used in process tanks that are highly sensitive to organic contamination, as they tend to accumulate oil and grease on the surface. Periodic cleaning of the floating media in an alkaline soak cleaner is recommended.

The floating media shown above is less apt to fly out of the tank due to the flat shape. Avoid hollow or spherical media because they tend to pop out of the tank and get trapped in crevices and fixtures.

In an EEM-TRP assessment of one metal finishing plant, floating media on four soak cleaner tanks were expected to save about 15,627 CCF/year or $5530/year. The cost of implementation, including the balls, labor, and dams on two of the tanks (to allow the racks to dip in and out of the tanks without trapping balls) was expected to be $4360. This results in a payback time of nine months.

Automated Tank Covers

Many large metal finishing facilities use automated tank cover systems which allow for reduced ventilation rates, smaller scrubbers, and less personnel exposure to fugitive tank emissions.

Ken Hankinson of KCH Services, Inc. reported on the following design:

- Tanks are automatically covered except when it is necessary to lower or remove work from the tank. Because some fumes will escape from the edges of the cover, about 10-25% of the normal full ventilation rate is used.

- The exhaust rate automatically switches to full flow rate when the tank covers open.

- Automatic relief dampers keep the velocity of the air through the fume control device constant.

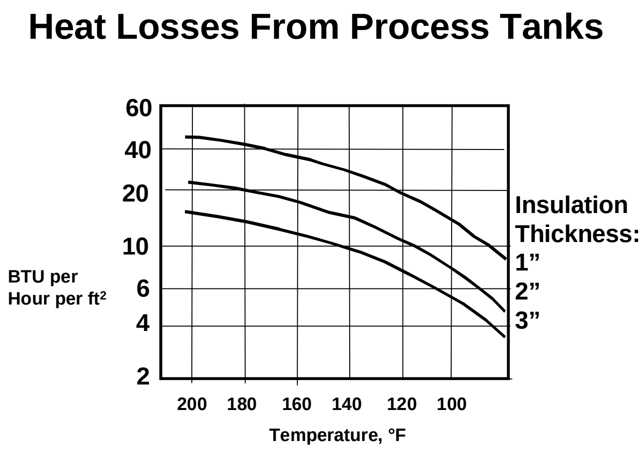
- When the total exhaust rate is calculated, it is assumed that all covers are closed except for the one on the tank with the highest ventilation rate, assuming there is only one hoist. If there are two hoists, then the two tanks with the highest ventilation rates are assumed open.

- The facility was able to reduce the ventilation rate by 60 percent, saving $48,000 per year assuming $0.06 per kWh. They also saved an additional $4000 by reducing the scrubber size.

Insulating Tanks

In the previous example we estimated a total thermal loss of about 58,800 BTU per eight-hour day from the sides of a small hot water tank operating in still air at 140° F. The graph below (adapted from the *Electroplating Engineering Handbook*) can be used to determine if insulating this tank is worthwhile and how much insulation is required.

Figure 9: Heat Losses from Process Tanks

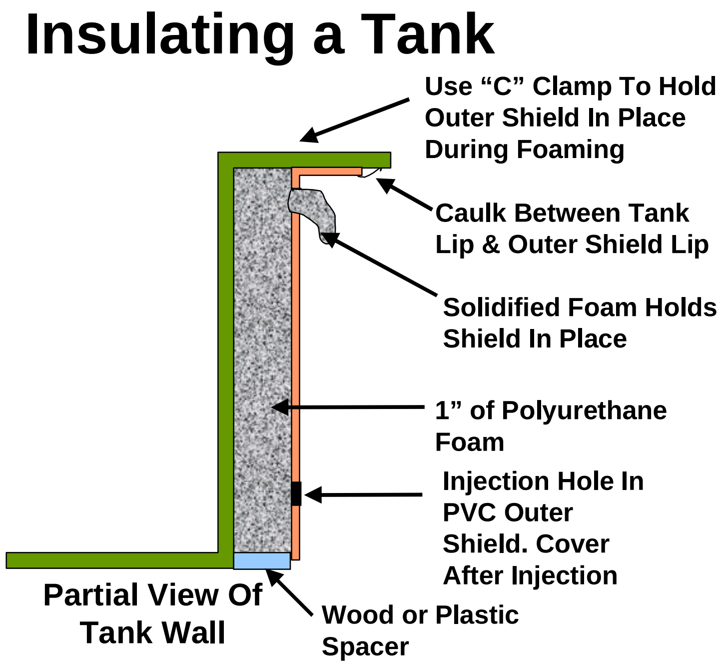


One inch of insulation reduces the heat loss through the tank walls from 800 BTU per hour per square foot down to about 30. Two inches would bring it to 16.5, and three inches would bring it to 11. Because most (96%) of the reduction comes from the first inch, making insulation beyond one inch of thickness is not economical.

Materials and labor to insulate the tank costs about $500. In our example from above, the payback would be unacceptably long, although the payback is significantly shorter for hotter and larger tanks.

A major consideration in insulating metal finishing tanks is eliminating moisture between the tank wall and the insulation. Moisture will corrode the tank wall very quickly and wet insulation loses much of its efficacy. Shown below is one way to insulate tanks. A rigid PVC outer shield is mounted with “C” clamps as shown. This protects the insulation from impact and shields against moisture. A wood or plastic spacer glued to the bottom holds the foam and the bottom of the outer shield in place. Additional spacers may be required on larger tanks. The insulation is injected into the cavity between the tank wall and the PVC outer shield, using the lower injection holes, until the foam comes out of the upper holes. Once the foam has solidified the “C” clamps can be removed along with the wooden spacer at the bottom. A caulk bead between the lip of the tank and the lip of the outer PVC shield prevents moisture and splashes from entering the crevice between the insulation and outer PVC shield.

Figure 10: Insulating a Tank



Other Tank Insulation Concerns

If combustible fluids are absorbed by wicking-type insulations (fiberglass, mineral wool, etc.) an auto-ignition fire can result.

Chloride stress corrosion of austenitic stainless steel can occur when chlorides (from contaminated insulation or outside sources) are concentrated on stainless steel surfaces at or above 60° C (140° F).

Calcium silicate, cellular glass, glass fiber, and mineral wool behave differently in a fire, with some materials accelerating a fire by wicking action. Further, the exterior moisture shield employed is usually rigid PVC, which is combustible. Noncombustible materials available but usually prohibitively expensive.

Insulation Material Choices

Thermal insulation is produced from many materials or combinations of materials in various forms, sizes, shapes, and thicknesses. Polyurethane's insulation capacity is superior to others by a wide margin over the temperatures normally used in metal finishing processes. For this reason, foam injection or spray application of polyurethane foam is the usually best method for insulating metal finishing tanks.

Heat Losses from Pipes

The most commonly insulated equipment (aside from hot tanks) in a metal finishing facility is steam piping. You can insulate piping with a variety of materials, but the most common is readily available preformed fiberglass insulation with a plastic or aluminum outer vapor barrier.

Piping Insulation-Economics and Profits describes the economics of insulating pipe and presents data (reproduced below) to help determine if insulating a given pipe is economical given energy costs, insulation thickness, pipe size, and pipe temperature. One chooses the right pipe size and determines if the pipe is at or above the temperature shown for any entry under a given column for energy cost. If there is no entry or the temperature is higher than that of the pipe under consideration, then insulating that pipe may be uneconomical. Because the data were generated in 1982, some assumptions (interest rates at 15%, inflation at 10% per year) are a bit high, but the data can still be useful in making an initial estimate of whether insulating is justified.

Table 9:Insulating Pipes

Insulating Pipes

		Minimum Pipe Temperature, °F							
	Insulation	Energy Cost, $/million BTU							
Pipe Size	Thickness	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00
¾”	1.5”	950	600	550	400	350	300	250	250
	2.0”				1100	1000	900	800	750
	3.0”								1200
2”	1.5”	1050	700	500	450	400	350	300	300
	2.0”			1050	850	750	700	600	600
	3.0”				1200	1050	950	850	800
6”	1.5”	600	350	300	250	250	200	200	200
	2.0”		1100	850	700	600	550	500	500
	3.0”			1150	1000	850	750	700	600

Table 10: Heated Process Tanks and Piping Selected Resources

Selected Resources

Electroplating Engineering Handbook 1984. Edited by Lawrence J. Durney. Published by Van Nostrand Reinhold, New York, New York, USA. ISBN 0-442-22002-2, Library of Congress card number 84-3548.	***Piping Insulation-Economics and Profits*** By F. L. Rubin. In *Practical Considerations in Piping Analysis*, ASME Symposium, vol. 69, 1982, pp. 27-46.

See the *Metal Finisher’s Guide* for more resources.

Lighting

Lighting accounts for a little over 11 percent of electricity consumption in metal finishing facilities. Lighting efficiency improvements can not only reduce energy costs but also provide better lighting, resulting in improved productivity and better quality control.

Increasing the Efficiency of Full-sized Fluorescent Lamps and Fixtures

Many metal finishing facilities are older buildings with full-sized fluorescent systems (lamp diameter of an inch or more). Newer fluorescent lighting systems are more efficient. Ways to increase efficiency include reducing overlighting, upgrading lamps and ballasts, improving fixture efficiency, and using better lighting control strategies.

Reduce Overlighting

The Illuminating Engineering Society of North America has established lighting-level recommendations based on the type of activity and characteristics of the task being performed. The suggested levels for metal plating activities are 200-300-500 lux or 20-30-50 footcandles. In spaces that have too much electric lighting, you can remove lamps (converting 3- or 4-lamp fixtures to 1-, 2-, or 3-lamp fixtures) or retrofit the system with lower output lamp-ballast systems. Any reduction in light output should take into consideration the resulting light quality, light distribution, surface brightness, and glare.

Reducing overlighting is an excellent approach to making your fluorescent lighting system more efficient as long as the quality and distribution of light is not compromised. These retrofits generally provide large energy savings within a short payback period and also reduce the cost of lamp and ballast replacement.

Upgrade lamps and ballasts

The most common older fluorescent systems are T-12 lamps with magnetic ballasts. The National Appliance Energy Conservation Act Amendment of 1988 banned the manufacture and import of the standard magnetic ballast used with these older fluorescent systems. Additionally, the Energy Policy Act of 1992 prescribes minimum lumens per watt and color rendering standards for most types of fluorescent lamps. Choices for upgrading the lamps and ballasts of these older systems include:

- **Electronic ballasts**
  Electronic ballasts rely on semiconductors to produce the high-frequency alternating current used by the lamp. They operate lamps more efficiently and can drive more lamps per ballast than conventional ballasts. They are also less affected by temperature and voltage variations, have low harmonic distortion, and eliminate visual flicker.

- **Hybrid ballasts**
  These ballasts use a combination of magnetic and solid-state technology. They can power either T-8 or T-12 lamps and offer some of the same efficiencies as electronic ballasts at lower cost.

- **T-8 lamps and electronic ballasts**
  T-8 lamps have a smaller diameter than the standard T-12s. They fit the same sockets, but require special ballasts. They provide better color rendering and are less costly, on a life-cycle cost basis, than T-12s.

Improve fixture efficiency

Fluorescent lighting fixture components include the housing, a lens or louver system, and possibly a reflector. The fixture distributes the light throughout the space and affects visual comfort. You can make improvements to your fixtures by retrofitting the reflectors and/or changing the diffusers, lenses, and louvers.

- **Reflectors**
  Reflectors are metal sheets designed to widen or narrow the light distribution from conventional fluorescent fixtures. They can decrease the internal losses of the fixture and frequently are used in conjunction with delamping (removing lamps).

- **Diffusers, lenses, and louvers**
  Diffusers are thin plastic sheets that cover recessed fluorescent fixtures. They are translucent sheets that disperse light equally in all directions and are extremely inefficient because of the amount of light they absorb.

  Lenses are also plastic sheets that cover the fixture but they redirect light rather than diffuse it and are much more efficient.

  Louvers are designed to control glare by using curved reflective surfaces that direct light downward while preventing a direct view of the lamp. Parabolic louvers are the most common type and fixtures with well-designed parabolic louvers are optically efficient. Because of this efficiency you may be able to use fewer fixtures and reduce your energy costs. Parabolic louvers however, can create a "dark ceiling" effect that makes the space seem gloomy.

Apply appropriate control strategies

Once the correct lighting levels have been established and other strategies for improving the efficiency of the fixtures and lamps and ballasts have been accomplished, you can apply various mechanisms to control whether the lights are on or off and what level of light they are providing. These controls include:

- Timers that switch lamps off when the room is expected to be vacant
- Localized switches installed near workstations so that the occupant can control the lighting
- Occupancy sensors that switch lamps off when the room is not occupied
- Photoelectric sensors that switch lamps on and off or adjust the lamp brightness based on the amount of daylight entering the room

Other Lighting Systems

Metal finishing facilities with ceilings 20 feet or higher may be candidates for high-intensity discharge (HID) lighting systems such as metal halide and high-pressure sodium lamps or the new high-intensity fluorescent systems. HIDs have the following characteristics:

- relatively long life (5000 to 24,000+ hours)
- relatively high lumen output per watt
- relatively small size

However, HIDs require from two to six minutes to warm up to full brilliance. A power interruption or a large enough voltage drop will extinguish the lamp and it then can take from five to 15 minutes to come back on. Lamp color characteristics are also an issue with both high-pressure sodium and metal halide lamps.

Case Study: Upgrading A Lighting System

After an Energy, Environment, and Manufacturing assessment, a plating services company with a 100,000-square-foot facility was projected to save $6591 per year and 96,724 kWh per year by taking three steps to upgrade their lighting system:

- **Install dusk to dawn sensor in an outdoor storage area**
  By connecting two 400 watt metal halide fixtures in an outdoor storage area to the existing dusk to dawn sensors controlling the facility's perimeter lighting, the company could not save 4100 kWh/year, or $303/year. The estimated cost of this measure was $200, resulting in a simple payback of eight months.

- **Replace standard lamps with high efficiency lamps**
  By replacing existing fluorescent lighting and incandescent lamps with high efficiency lamps, the company could save 81,273 kWh/year, or $5449/year. The estimated cost of this measure was $12037 (including labor), resulting in a simple payback of 26 months.

- **Install high-frequency electronic ballasts**
  By replacing standard magnetic ballasts as they fail with high frequency electronic ballasts, the company could save 11,351 kWh/year, or $839/year. The estimated cost of this measure was $1729 (the cost difference between the standard ballasts and the high frequency ballasts), resulting in an average simple payback per ballast of 25 months.

Table 11: Energy Costs, Savings, and Payback

Action	Energy Savings	Cost Savings	Implementation Cost	Payback
Dusk-Dawn Sensor	4100 kWh/yr	$303/yr	$200	8 months
Lamp Replacement	81,273 kWh/yr	$5449/yr	$12,037	26 months
Electronic Ballasts	11,351 kWh/yr	$839/yr	$1729	25 months
Total	**96,724 kWh/yr**	**$6591/yr**	**$13,966**	**25 months**

From "EEM-TRP Assessment Report, Volume 1: Metal Finishing," The Energy, Environment and Manufacturing Technology Reinvestment Project, 1996.

Table 12: Lighting Selected Resources

Selected Resources

EEM-TRP Assessment Report: Volume 1, Metal Finishing
The Energy, Environment, and Manufacturing Technology Reinvestment Project, June 20, 1996.
Energy and Environment Center Industrial Technology Institute
Ann Arbor, Michigan 48106.

See the *Metal Finisher's Guide* for more resources.

Compressed Air Generation, Distribution, and Use

Compressed air is used for push-pull ventilation systems, operating hydraulic equipment, and agitating process tanks. Plants in many industries have found that they can reduce costs and increase efficiency by optimizing their compressed air system.

The *Compressed Air Challenge* suggests this seven-step action plan for creating an energy efficient compressed air system:

1. Develop a basic block diagram of your system.
2. Measure a baseline kW, pressures, and leak load and calculate energy use and cost.
3. Work with a specialist to implement an appropriate compressor control strategy.
4. Once controls are adjusted, remeasure to get more accurate readings of kW and pressures, and to determine leak load. Recalculate energy use and costs.
5. Walk through to check for obvious preventative maintenance items and other opportunities to reduce costs and improve performance.
6. Identify and fix leaks and correct inappropriate uses—know costs, remeasure and adjust controls as above.
7. Evaluate steps 1-6, begin implementation of an awareness and continuous improvement program, and report results to management.

Compressor Control Strategy

Improving compressor control saves energy. Often other compressed air system improvements such as repairing leaks won't bring about savings until compressor control is adequate. Compressed Air Challenge has a fact sheet (#6) on compressed air controls. Some of the key points are:

- When multiple compressors are on, all but one should be running full load.

- New control methods allow for more precise pressure control. Often this allows system pressure set points to be lowered. In general, every two PSI of pressure increases energy consumption by approximately one percent. (If only a few pieces of equipment require higher pressures, it may be cost-effective to buy a small dedicated compressor or booster for that equipment and reduce the larger system pressure.)

- Compressor controls vary considerably in complexity. The control system should be matched carefully to the compressed air system needs.

- Storage is often an important aspect of optimal compressed air system control. Fluctuating air needs and peak demand periods can be met with less energy when well-designed storage is incorporated.

Preventative Maintenance

Compressed Air Challenge Fact Sheet #5 suggests the following basic maintenance checklist. All of these items should be done, at minimum, at the intervals recommended by the equipment manufacturer:

Inspect and clean or replace inlet filter cartridges.

Check and clean out drain traps.

Inspect compressor lubricant level daily and top-off or replace. Change lubricant filter according to manufacturer specifications.

Change air lubricant separator (in lubricant-injected rotary screw compressors) according to manufacturer specifications or when pressure drop exceeds 10 PSID, whichever is first.

- Use compressor and electric motor lubricants recommended by the manufacturer.
- Check belts for wear and check and adjust tension.
- Verify that operating temperatures match specifications.
- Replace particulate and lubricate removal elements on air line filters when pressure drop exceeds two or three PSID. This should be done at least once per year, regardless of pressure drop.
- For water-cooled systems, check water quality, flow, and temperature. Clean or replace filters and heat exchangers according to manufacturer's specifications.
- Check for leaks in joints, fittings, clamps, valves, hoses, disconnects, regulators, filters, lubricators, gauge connections and end-use equipment.
- Check for compressor and motor lubricant leaks.

Leaks

Fact Sheet #7 from the Compressed Air Challenge states that up to 20-30% of a compressed air system's output may be wasted by leaks. Plants with a plan to reduce leaks may reduce this waste to 10% or less. Compressed air leaks not only waste energy, they also cause production and maintenance problems.

An ultrasonic acoustic detector is the best tool for detecting leaks. A simpler, but more time-consuming method is to apply a soapy water solution where a leak is suspected. The soapy water will blow bubbles at the leaky spot.

The table below estimates costs for compressor leaks of varying sizes assuming 8000 operating hours per year and operating cost of $0.15/1000 cubic feet of air.

Figure 11: Leaks

Leak Size	Leak Rate 110 psi	Cost	Leak Rate 100 psi	Cost
1/16"	4.3 cfm	$312	3.9 cfm	$286
1/8"	17.4 cfm	$1,249	15.9 cfm	$1,142
1/4"	69.4 cfm	$4,997	63.5 cfm	$4,569
3/8"	156.2 cfm	$11,243	142.8 cfm	$10,281
1/2"	277.6 cfm	$19,988	253.9 cfm	$18,277

Figure courtesy Wisconsin Public Service Corporation

Other Measures

- Replace undersized air piping to reduce pressure losses. A larger diameter pipe will produce a lower local pressure at a leak, reducing air losses.

- Recover heat from compressors. A well-designed heat recovery system can recover over 50 percent of the compression heat energy, and recovery rates of 80-90 percent are common when heating air from air-cooled rotary screw compressors. The waste heat can be used for process use, space heating, make-up air heating, boiler makeup water preheating, or water heating. A 50-horsepower air compressor rejects approximately 126,000 Btu per hour. Compressed Air Challenge Fact Sheet #10: *Heat Recovery with Compressed Air Systems* gives more detail.

- Consider piping in outside air for the compressors. Most mechanical rooms are hot, and cooler air increases the efficiency of the air compressor. The EEM-TRP study estimated a payback of less than four months in one plant.

- Use synthetic lubricants. This reduces friction and heat and saves four to eight percent of the compressor motor drive energy.

- Section off the compressed air system with valves if some areas don't require compressed air when others do. For example, the maintenance area may not always need compressed air. This helps reduce the loss of air due to leaks.

- Consider motor efficiency when buying a new compressor. Compressors with variable speed drives are available and may be cost-effective when loads vary.

- Use air knives where appropriate. An air knife uses a small amount of compressed air to pull in a larger amount of surrounding air. This produces a high-flow, high-velocity stream of air for drying and cooling. Replacing air nozzles with air knives can save 70% of the required compressed air. The EEM-TRP study estimated a four month payback in one plant.

- Consider whether tasks currently using compressed air could be accomplished in some other way. For example, could electric propeller mixers be used instead of compressed-air propeller mixers? Could air agitation be done with blower air instead of compressed air?

Case Studies

EEM-TRP Assessment Report Volume 1: Metal Finishing gives a number of examples of improving compressed air systems in metal finishing plants. Annual energy savings estimates for measures with reasonable payback times ranged from $2490 to $54,061, with estimated implementation costs of $624 to $8516. The estimated average simple payback was four months. In one plant with 75-HP and 40-HP screw compressors, for example, the following measures were recommended:

- **Reduce nonproductive air use**
  By repairing leaks, sectioning off the plant, and installing automatic shutoffs of equipment that would otherwise use compressed air constantly, the facility could save an estimated 22,769 kWh/year ($1683 per year). The estimated implementation cost (with labor) was $1500, giving a payback of 11 months.

- **Use outside air for compressor's intake**
  This measure was estimated to cost $500, including labor. Energy savings were expected to be $21,575 kWh/year, with costs savings of $1594 per year, for a simple payback of four months.
- **Use synthetic lubricants**
  By switching from natural oil for lubrication to synthetic lubricants, the plant was expected to save

9100 kWh/year ($673 per year). The cost for this measure is the cost difference between the two types of oils, or $333 per year. The simple payback was six months.

Table 13: Energy Savings and Payback

Action	Energy Savings	Cost Savings	Implementation Cost	Payback
Reduce nonproductive air use	22,769 kWh/yr	$1683/yr	$1500	11 months
Use outside air	21,575 kWh/yr	$1594/yr	$500	4 months
Use synthetic lubricants	9110 kWh/yr	$673/yr	$333	6 months
Total	**53,454 kWh/yr**	**$3950/yr**	**$2333**	**7 months**

Table 14: Compressed Air Selected Resources

Selected Resources

Compressed Air Specialist Locator Service If you need help finding a compressed air system specialist in Wisconsin, contact the Energy Center of Wisconsin at 608.238.4601, industrial@ecw.org.	***EEM-TRP Assessment Report: Volume 1, Metal Finishing*** The Energy, Environment, and Manufacturing Technology Reinvestment Project, June 20, 1996. Energy and Environment Center Industrial Technology Institute Ann Arbor, Michigan 48106.
Energy Answers Compressor fact sheet from Wisconsin Public Service Corporation www.wpsc.wpsr.com/business/No27.pdf	**National Compressed Air Challenge** This collaborative provides information on optimizing compressed air systems through printed, on-line, and training materials, including fact sheets and *Improving Compressed Air System Performance: A Sourcebook for Industry*. 800.862.2086 www.knowpressure.org

See the *Metal Finisher's Guide* for more resources.

Rectifiers, Busses and Cables

Improving Rectifier Efficiency

Rectifiers supply DC current for electrocleaning, electroplating, electro-acid-descaling, electro-activation, anodizing, e-coating, electro-polishing, and many other operations. In some plants, particularly hard chrome shops, rectifiers are a major energy consumer.

You can reduce rectifier energy consumption with the following measures:

- Measure current rectifier efficiency and replace the least efficient rectifiers first when the need arises.
- Replace fan-cooled rectifiers with convection-cooled rectifiers, if possible, as fans consume about three percent of a rectifier's input power and tend to blow corrosives through the electronics.
- Operate rectifiers at the high end of the operating voltage, as they are considerably more efficient at higher voltages. For example, according to *Electroplating Engineering Handbook*, an air-cooled rectifier operating at 12 volts and producing 1000 amperes is about 87% efficient, while a 24 volt rectifier is 91.7% efficient producing the same current.

New Rectifier Purchases

When purchasing a new rectifier you should consider both the cooling type (see section below) and the interior circuitry. Both will have a significant impact on energy consumption.

Circuit Types

Rectifier circuits can contribute to the overall efficiency of the rectifier by producing a potential as close to pure DC as possible (low ripple). Three common circuit types are available:

- *Single-phase bridge circuits* are in almost all single-phase rectifiers and offer moderate energy efficiency at relatively low cost. They have a significantly lower efficiency when operated at lower voltages, so they should be sized to operate near the top of their voltage range. The rectifying diode arrangement produces 48% ripple (AC over DC), which must be further "smoothed" by installation of filter circuitry.
- *Three-phase half-wave circuits* have much higher theoretical conversion efficiency than single-phase bridge circuits (about 96%). The ripple is about 18%, so additional circuitry for ripple reduction is necessary.
- *Three phase bridge circuits* have a theoretical conversion efficiency of almost 99%, with an actual expected overall efficiency of 82%-92%. The transformer utilization factor is very high and the percent of ripple is only 4.5%. This is one of the most efficient circuit types available.

Cooling Types

Rectifiers can be cooled by forced air, convection, or water. Rectifier cooling is an important energy conservation variable that should be taken into consideration in a new facility and in a long-term replacement program.

Convection-Cooled

Normally convection-cooled units are limited to a maximum of 1000 amperes, but they corrode less in poor quality air. At least one plater has selected 12,000-ampere convection-cooled units because of the anticipated power savings (no fan and more efficient diodes).

Water-Cooled

Water-cooled rectifiers tend to be the most efficient because the temperature of the rectifying devices can be accurately maintained; but they are also the most expensive to purchase and maintain. They are the most effective energy conservation devices only if the heated water exiting from the units can be used elsewhere in the plant. Water-cooled rectifiers tend to last longer because they can be sealed from the atmosphere, protecting the unit from corrosives and because the temperature of the diodes or silicon controlled rectifiers can be controlled to the level that is most energy efficient. These types of rectifiers transfer heat through heat exchangers, water tubes, and water-filled diode heat sinks to water that is piped through the housing of the rectifier.

Water-cooled units include the standard air-cooled type in which air is passed through a water-cooled heat exchanger, similar to a unit heater. The second type is direct liquid cooling, in which diodes or thyristors are mounted directly onto a water-cooled heat sink. The liquid (water or antifreeze) is then cooled through a water-to-liquid heat exchanger. Always calculate heat exchanger energy consumption when considering a water-cooled unit over an air-cooled unit.

Rectifier Maintenance

A rigorous maintenance program will reduce energy consumption in rectifiers by keeping temperature-sensitive components cool. Perform the following maintenance on a monthly basis:

Clean intake/output screens of fan and convection-cooled units

Check all electrical connections for corrosion or loose connections and clean or tighten them if they are corroded or loose.

Verify that all diodes are firmly connected to their sockets. One loose diode can dramatically reduce rectifier efficiency and cause rectifier failure.

Inspect all moving parts such as the fan/bearing, brushes in autotransformers, and tap contacts in tap switch rectifiers. Lubricate/replace/repair as necessary.

Check potentiometers on automatic control systems for smooth resistance from zero to full output.

Electrical Conductor Efficiency

Copper and aluminum are commonly used for connecting rectifiers to processing tanks. Copper is the most commonly used due to its high conductivity. Poorly sized connectors and bad connections can increase the amount of electricity wasted as heat.

Sizing Copper Busses

Current conductors should be of adequate length and cross section to avoid voltage drops which cause energy losses. This must be balanced against the increase in installed cost as the cross section and length of a conductor is increased. The following equation (see Electroplating Engineering Handbook) gives the optimum length of a copper bus run, taking into account the amortized cost of the copper and the energy losses:

$$\text{Minimum Total Annual Cost (\$)} = 2.772\,(CB/N)^{1/2}\,(IL)$$

Where

C= Cost of power ($/kWh)
B = Installed cost of bus
N = Years of amortization
I = Operating Amperes
L= Length of bus (feet)

Another equation calculates the maximum bus run for a specific voltage drop:

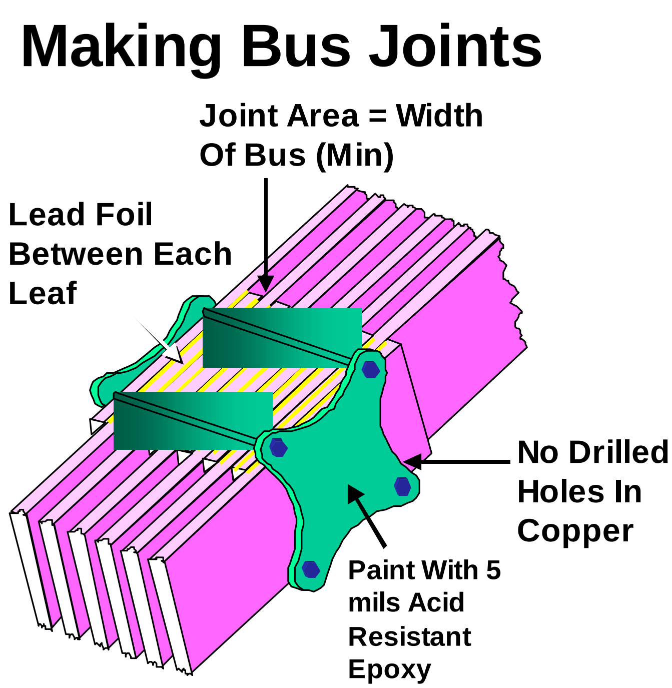
$$\text{Cross Sectional Area of Conductor (in.}^2\text{)} = 9.03 \text{ X } 10\text{-}6 \text{ LI/V}$$

where L, I are defined above and V is the maximum voltage drop desired.

For example, if the maximum voltage drop desired is 0.2 volts for a nine volt rectifier delivering 10,000 amperes through a conductor that has a total cross sectional area of 10 square inches, the maximum length of the bus would be 22.15 feet total (cathode plus anode). The rectifier should therefore not be farther away from the tank than about 10 feet.

Copper can carry about 1000 amperes of current for each inch of cross sectional area. For large currents, 1/4” x 1” bus is typically used and stacked with air gaps, as shown in the illustration below, for cooling purposes. Aluminum bus can also be used, but about 62% additional cross section is required due to the lower conductivity of aluminum. Cables are also used, typically when the total maximum current delivered by the rectifier is less than 5000 amperes. The insulation on the cables does not dissipate heat as well as bare copper, and this may be a problem at the higher amperages.

Figure 12: Making Bus Joints



Properly connecting copper bus at joints is critical to delivering power to the plating tank efficiently. One way to do this is to bolt together 1/4" x 4" copper using zinc plated steel bolts and washers. Simply placing one bar over the next and bolting the "sandwich" creates a poorly conductive joint air gaps between the bars.
The zinc plated bolts can set up a galvanic corrosion cell that will eventually undermine this joint. A bus joint that is too hot to keep a bare hand on is operating inefficiently.

According to *Electroplating Engineering Handbook* bus bar clamps are more practical than bolts when a large number of bars are to be joined. Two types of clamps give satisfactory service: the curved back clamp and the spring washer clamp.

The curved back clamp has convex faces that will be parallel when the bolts are drawn down to the rated capacities of the clamp. The spring washer clamp is more popular in the electrochemical industry. Large Belleville washers of rated capacity are incorporated as part of the clamps to distribute the bolting pressure evenly. When they are totally compressed, sufficient clamping pressure has been applied. Welded or brazed connections are also used in permanent installations.

For high amperage applications (2000 amperes or more), the best method of producing a bus joint involves placing a sheet of lead (0.008-0.01" thick) between each of the faces of the bars to be joined. The lead deforms to fill the air cavity created as the bus bars are bolted together, producing a solid, uniform electrical contact. The minimum contact area between bus bars that are to be joined should be the width of a bar, and a frame should be used to apply the joining pressure uniformly. Avoid drilling holes into the bars, as this reduces the amount of conductive metal at the joint and creates ridges that make intimate contact between bars difficult. If drilling must be done, be sure to sand or file each drilled hole flat.

Efficient Aluminum Bus Joints

The installed cost of aluminum bus is about half that of copper bus. Use Alcoa No. 2 Electrical Joint Compound to make connections with aluminum bus (EEH) to avoid power losses. It removes aluminum oxide without attacking the base metal. Apply to the joint area, and then abrade with a wire brush or abrasive cloth. Assembled the joint without removing the compound. If the joint is opened, follow the same procedure in making it up again. Use aluminum or steel bolts. With aluminum bolts use flat washers. Because the coefficient expansion of aluminum is considerably greater than that of steel, use Belleville washers with steel bolts to compensate for differential expansion. As the number of bolts is increased from one to four, joint resistance is decreased. There is no advantage to using more than four bolts and in some cases additional bolts increase resistance because you lose contact area.

When joining aluminum and copper or any other metal, coat all parts with joint compound before assembly. It is essential to exclude moisture and electrolyte from the joint. After bolting remove excess compound and clean and prime the surface with a zinc-chromate primer (MIL-P-6879A). Finally paint the entire area with five mils of epoxy paint.

Aluminum bus works well over hot acid zinc baths and cyanide plating baths. For the work rods in a still plating tank, for instance, copper may be preferred because it is easier to maintain a good contact with the rack.

Cables

Flexible cable has a number of advantages over solid copper bus: easy connections, flexing around obstacles, eliminating joints, color coding, and lower installed cost.

A major disadvantage is that cables tend to heat up due to their insulation, making them impractical for currents greater than 5000 amperes. Because cables come in fixed sizes, one often must use more cable than necessary. For example, if the current requirement to a given tank is 1200 amp maximum, three 500

MCM cables in parallel would be required for both the positive and negative conductors. The three cables could carry 1500 amperes so the excess installed capacity is wasted.

According to *Electroplating Engineering Handbook* a 500 MCM copper cable has a resistance of about 0.025 ohm/1000 ft at its operating temperature. When carrying 500 amps the voltage drop is 1.25 volts/100 ft. For most installations this voltage drop is the maximum allowable from the current source to the tank; therefore if the distance is greater than 50 ft, you'll need to put two or more conductors in parallel to limit the voltage drop.

Anode/Cathode Rods

Anode rods on electroplating tanks are commonly made of round or square copper bar stock, although bars of rectangular cross section are also used. On anodizing tanks, aluminum bus and rods are used because copper is a serious contaminant for these solutions. However, titanium clad copper is available and has superior conductivity properties over aluminum in anodizing applications.

Anode/cathode rods must have sufficient cross section to support the weight of the anodes and parts and to carry the current. For copper, the 1000 amperes per square inch of cross section typically provides a rod strong enough to carry a typical load, given support in a sufficient number of places.

Saddles

Saddles make good contact between round and square flight bars and barrel contacts. They are designed to apply both sliding abrasion and pressure contact during insertion of the rod into the saddle, due to the "V" shape of the opening. Saddles are typically made from a phosphorized bronze alloy, which withstands the repetitive impact of insertion and withdrawal of flight bars and barrel contact rods, but is lower in conductivity than copper.

Saddles must be properly insulated to avoid stray currents in tanks made from metals such as steel and stainless steel. Stray currents waste electricity and interfere with most electroplating processes. Some saddles are bolted to the tank with insulated bushings, an insulated pad, and insulating washer. Alternatively, fiberglass bolts and nuts can be used in some lower strength applications.

Connections between the rectifier bus and the tank rods and saddles must be secure enough to prevent joint overheating and high voltage drops.

Maintaining Good Connections

Maintaining electrical connections between the rectifier and the tank hardware is critical to energy efficiency. Water-based chemical solutions conduct electricity and will produce stray currents if allowed to contact or soak through insulators. Many chemical processing solutions are corrosive, which can create resistance at joints, poor current distribution, and improper anode conditions. A rigorous maintenance program will reduce energy consumption by eliminating needless resistance and reducing the reject frequency.

Because copper can contaminate many plating solutions, clean copper-based conductors in such a way that does not introduce copper into the process. Avoid scrubbing the tank hardware and flushing the remains into the process tank.

Copper can be purchased clad with titanium for situations where the solution is very sensitive to copper contamination. A less expensive option is to cover the copper with plastic tape, PVC sheet, or plastic tubing to prevent corrosion of the copper and copper joints.

Table 15: Electric Power Supply Selected Resources

Selected Resources

Electroplating Engineering Handbook Edited by Lawrence J. Durney. Published by Van Nostrand Reinhold, New York, New York, USA. 1984. ISBN 0-442-22002-2, Library of Congress card number 84-3548.

See the *Metal Finisher's Guide* for more resources.

Ultraviolet Curing

Systems that cure coatings directly with ultraviolet radiation have energy, environmental, and productivity benefits. An Industrial New Technology Fact Sheet on *Ultraviolet Curing* is available from the Energy Center of Wisconsin.

Membrane Filtration

Membrane filtration removes materials from wastewater. Microfiltration, ultrafiltration, and reverse osmosis are membrane filtration systems that remove different-sized particles and use less energy than conventional systems. An Industrial New Technology Fact Sheet on *Membrane Filtration* is available from the Energy Center of Wisconsin.

Zinc

The relatively low operating temperature of most zinc plating solutions does not allow for recovery of drag-out and often requires cooling. High-temperature potassium chloride plating solutions have been developed to answer these operational problems.

Being able to operate an acid zinc solution at higher temperatures increases its conductivity and therefore reduces power consumption. The tendency for burning is reduced and so it is possible to run a higher current density. This leads to an improved plating speed, especially in barrel lines.

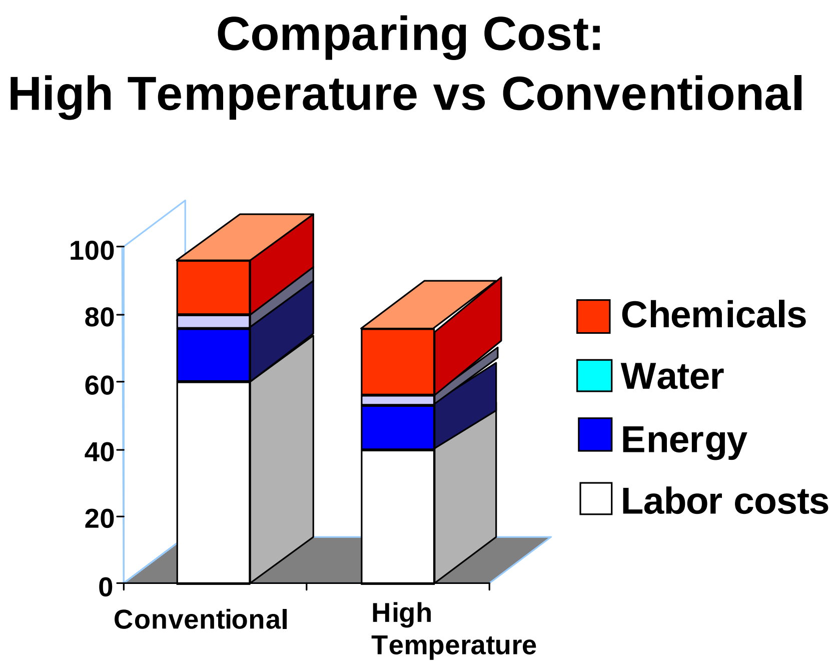
Barrel lines usually run already at about eight to nine volts. Increasing this voltage destroys the titanium baskets used for the anodes. Users of the new high temperature potassium process can operate their solutions at a higher current while maintaining the same voltage because of the better conductivity.

In some cases the plating speed after a conversion from a conventional acid zinc plating solution to a high temperature potassium solution increased so much that a job normally taking three shifts could be accomplished in two, which naturally energy from shorter operating times.

The disadvantage of the high-temperature potassium zinc process is the relatively high cost of additives, although productivity and energy savings may offset these costs.

The figure below compares costs created by conventional and high temperature potassium zinc plating solutions. Running a potassium chloride solution at increased temperatures creates chemical consumption rates 30% higher than those solutions operated at lower temperatures. The increase in consumption rate of additives leads to an overall chemical cost increase of only 1.5-2% over lower temperature potassium chloride solutions. If a cooling tower is required for zinc plating, high-temperature potassium zinc plating can reduce energy consumption by as much as 20 percent.

Figure 13: High Temperature Vs. Conventional



Cleaners

Almost all soak cleaners and electrocleaners contain metasilicates, sodium hydroxide, and phosphates. In cleaners containing silicates and sodium hydroxide, it is important to maintain a 2.5:1 ratio of sodium hydroxide to silicate. If the solution is allowed to go below this ratio, a hard crust forms over heating coils and tank walls, creating an insulating barrier that wastes energy.

Phosphates precipitate calcium from hard water, forming sludge and crusts over tank, heater, and other appliance surfaces. This is less of a problem if you use softened water to make up cleaners.

Electrocleaners contain sodium hydroxide for conductivity. Maintain this ingredient at the high end of the concentration range and monitor analytically to maintain solution energy efficiency.

Because cleaners typically operate at elevated temperature, these tanks are candidates for insulation. Low temperature substitute solutions may also be available.

Hexavalent Chromium Plating Solutions

A conventional chromium plating solution containing one oz/gal (7500 ppm) of total metallic impurities can be expected to deliver a plating efficiency of around 9-10%, while the same solution containing 0.5 oz/gal (3500 ppm) can deliver 12-14% efficiency. This translates into a 20-40% reduction in energy consumption and a corresponding reduction in mist generation. Design new plating tanks to use continuous purification (removal) of metallic impurities. Consider ion exchange, membrane purification, or porous pot technologies for purification of chromium plating solutions.

High levels of trivalent chromium increase gas emissions by reducing plating efficiency. If the new plating tank will be used with low anode/cathode ratios (less than 2:1), consider designing continuous electrolysis into the system to oxidize trivalent back to hexavalent.

The cathode efficiency of any chromium plating solution is closely tied to the ratio between the chromic acid and the sulfate content (typically 100:1 for a conventional solution and 200:1 for a mixed catalyst solution). Cathode efficiency is also closely tied to chromic acid concentration. For example, a conventional plating solution is about 20% less efficient at 50 oz/gal than at three oz/gal of chromic acid. Frequent analysis and adjustment of this ratio will optimize plating efficiency. You can estimate plating solution efficiency using a hull cell.

Purification Of Hexavalent Chromium Plating Solutions By Electrolysis

Adding a porous pot or membrane to the electrolyzing cell can make an ion exchange system significantly more effective. By placing the cathode in a porous pot containing plating solution or dilute chromic acid, it is possible to collect most of the foreign cation contaminants in the catholyte. A substantial amount of the Cr 3+ concentration will be oxidized to Cr 6+ if the anode area is large and the solution temperature is maintained at 57 to 63° C (135 to 145° F) in the cell. The catholyte may be removed periodically and the waste treated by the same methods used for the cation-exchange regenerant acid. For small plating installations, a porous-pot electrolysis system may provide economical purification because of its relatively low cost and small space requirements. In larger systems, it may be justified by reducing the capital investment required for a complete setup. The energy and labor costs are relatively high compared to ion exchange, but may be justified by the low cost of the equipment.

A typical porous pot is mounted on a reversible two bus bar plating rack, or on conventional plating tank bus bars. Two outside electrodes (anodes) are placed in close proximity to the walls of ceramic pot having a pore size of one micron or less. Inside the pot is the single cathode, made from lead mesh. When starting the purification, the inside of the pot should be filled with plating solution, or ideally, with 10-15 oz/gal of fresh chromic solution without catalyst. Metallic impurities will gradually collect inside of the pot and reoxidation of hexavalent chromium will begin on the outside anodes. The liquid level inside the pot will have a tendency to rise about two inches and will become hotter than the rest of the solution. The operating voltage is six to nine volts depending on solution conductivity.

As the purification and reoxidation proceeds there will be a gradual decrease of the current (amperage) as the cathode becomes coated with a layer of insoluble metallic salts and hydroxides. When the amperage becomes low it is time to remove the cathode, wire brush off the sludge, and start again. Removing the cathode and reassembly takes five to 10 minutes. Heavy contaminated baths will need initial frequent brushing of the cathode until equilibrium is reached. After that, one or two cathode cleanups per week is typically required for a small operation.

The porous pot is usually located at the end of the plating tank and is run continuously with the production or placed in an auxiliary tank. Solution from inside the pot should be waste treated along with the cathode sludge.

Typical operational conditions are:

1. Anode current density 20 ASF.
2. Cathode C.D. greater than 100 ASF.
3. Temperature as high as practical.

Case Study Of Hexavalent Chromium Solution Electrolysis

A plater operating 1300 gal (5000 L) of chromium solution keeps his nickel metal concentration in the Cr bath down to 4-6 g/L (0.6-0.7 oz/gal) with eight porous-pot cells. He applies 1200 A to the cells 24 hr/day. At nine volts, the power consumption is approximately 55,000 kWh per year. At $0.04/kWh the energy cost is $2200 per year. If his solution efficiency is improved by 40%, (assuming operating current at 5000 amperes, nine volts, 24 hours per day, 210 days per year) the energy cost is about $1320, for a savings of $888 per year.

Anode Maintenance For Hexavalent Chromium Plating

If the trivalent chromium content of a chromium plating solution exceeds about 3.5%, the solution efficiency drops, ventilation rates must be increased, and energy consumption goes up. Proper control and maintenance of the anodes maintains the trivalent chromium concentration below 3.5%.

Anodes should be operated at 100-175 amps/ft^2. Check this periodically with a tong meter. A 1.5" round anode can carry approximately 150 amperes, while a two-inch round anode can carry 250 amperes, depending on hook size and the length of the anode. Visually inspect the anodes frequently. They should have a chocolate brown coating; orange tells you the anode is not functioning properly. Remove these, clean them, and return them to the tank, making sure they have the correct current density and a good connection between the hook and anode rod.

Periodically check for extra heavy or irregular buildup of lead peroxide (chocolate brown color) or lead chromate (orange color) to prevent problems in current distribution. Heavily worked solutions and those with closely conforming anodes require periodic cleaning of anodes. Acid dipping, alkaline soaking, and scratch brushing, plus electrolytic reduction techniques, are useful to remove the lead chromate, which acts as an insulator. Most lead anodes tend to form insoluble chromate or fluoride when left in chromium plating solutions without applied current. The anodes then must be "energized" with full tank voltage for a period of several minutes to possibly an hour before they are fully reactivated and conductive. Remove anodes from the solution if they will remain idle for a long time.

Cyanide Based Plating Solutions

Cyanide plating solutions typically contain an ingredient that improves and maintains solution conductivity. In full-strength solutions, this ingredient is usually sodium or potassium hydroxide. It is therefore important to maintain the concentration of these conductive ingredients at the high end of the concentration window to minimize energy consumption and improve solution efficiency. Frequent analysis may be required to ensure proper concentrations.

In some strike solutions (notably those used on zinc die castings) the solution may not contain significant amounts of free sodium hydroxide. In those solutions the sodium carbonate provides the bulk of the conductivity and it should be maintained at about 4-8 oz/gal (30-60 g/L).

When the sodium or potassium carbonate increases above about 12-14 oz/gal (90-105 g/L) the resistivity of the solution increases dramatically and the plating process requires excess power (wattage) to deliver the same amount of work. Carbonates must therefore be regularly removed to maintain solution efficiency and to save energy.

In some solutions the ratio between the cyanide and metal contents must be controlled to optimize energy efficiency. For example, in a cyanide zinc solution the total cyanide divided by the zinc metal should be 2.0 for optimum efficiency. At a ratio of 2.8, the efficiency drops about 50%. This drop in efficiency may be beneficial, however, in certain cases where high throwing power is desired. When high throwing power is not required, use the lower ratio.

Removing Carbonates from Cyanide Plating Solutions

Most platers use freezing (exposure to about 30° F for several hours) to remove sodium carbonate and precipitation to remove potassium carbonate. Precipitation can also be used to remove sodium carbonate.

The precipitation method can be complicated in that adding precipitating compound almost always adds something you don't want. If you add calcium hydroxide, for example, you'll increase the hydroxide content of the plating solution and must readjust the other ingredients to maintain correct ratios. If you add calcium oxide, this increases the hydroxide as well. If you add calcium cyanide, this increases the free cyanide content.

Another problem is precipitation compounds are not highly soluble in either water or in the plating solution. If you try to dissolve the compound and then add it to the plating solution, you end up diluting the plating solution far beyond normal concentrations.

Lastly, precipitated carbonate is quite voluminous, even if only a small fraction of the original carbonate concentration is removed. In many cases barium nitrate works best as a precipitate, as it does not affect the conductivity of the plating solution and it can be added as a solid, avoiding the dilution effect mentioned above. (Warning! Verify any treatment you intend to use in the laboratory and get adequate advice, as improper treatment can result in an inoperative solution and a large volume of cyanide waste). Here are tips to remember when treating with barium nitrate:

- To precipitate 1 oz/gal of potassium carbonate using barium nitrate it takes about 2 oz/gal of barium nitrate.
- Crush the barium nitrate into a fine powder and add it as a solid to the solution, using a high level of agitation. The reaction time should be at least four hours, preferably overnight.
- The treatment produces a large amount of barium carbonate sludge. It can be settled in 4-8 hours or pressure filtered. The treatment can then be repeated to lower the carbonates further. However, at 8-10 oz/gal the carbonates should not hinder plating.
- The treatment does not affect the concentration of the other ingredients in the plating solution and can be repeated if necessary to lower the carbonate further.

Avoiding Carbonate Buildup

To prevent the rapid buildup of carbonates:

- Operate at as low a hydroxide concentration as possible while keeping the hydroxide high enough to maintain solution efficiency.
- Keep the tank covered when not in use; simply covering the tank can reduce buildup by 10 percent.
- Don't air agitate or propeller agitate a cyanide plating solution because this produces up to one ounce per gallon of carbonates per week of operating in a high speed plating process. Recirculating pump agitation (eductors can be used) reduces the carbonate buildup rate by two thirds.

- Maintain anode current density below the maximum for the process and maintain the anode area.
- Operate the plating solution at as low a temperature as possible. You can reduce carbonate generation by 50 percent by dropping the temperature from 180 to 160° F.

Noncyanide Zinc Plating Solutions

Chloride zinc plating solutions are highly energy efficient and typically have a 98-99% energy utilization rating. Consider them a lower energy substitution process for competing zinc plating processes. The high conductivity of these solutions stems from the chloride content, which should be maintained and controlled at the high end of the concentration range to maximize efficiency.

Alkaline noncyanide zinc plating solutions derive their conductivity from the sodium hydroxide content, and this ingredient should therefore be maintained and carefully controlled. These solutions also produce carbonates, so the previous discussion about carbonates applies here as well.

Acid Copper Plating Solutions

Acid copper plating solutions typically operate at 99-100% efficiency, so ingredient changes have an insignificant impact on energy consumption. Solution conductivity is related to the sulfuric acid content, but all such solutions contain a high concentration of sulfuric acid. Low sulfuric acid content reduces the solution efficiency and causes misting and bad odors.

Energy conservation options for these processes are limited to replacing air agitation systems with recirculating systems to reduce or eliminate the need for ventilation. However, in some installations this may require cooling coils to maintain temperature.

Nickel Plating Solutions

Decorative plating solutions contain organic addition agents that modify the growth of the deposit to yield fully bright, semibright, or satin-like surfaces. A normally operated Watts nickel plating solution is about 95% cathode current efficient. The small amount of hydrogen generated by the remaining five percent of the applied current causes the pH of the solution to slowly rise.

Nickel sulfamate plating solutions have a low level of conductivity, and therefore typically must be operated at low current densities to avoid plating problems. You can significantly increase solution efficiency and energy efficiency by adding a small concentration of nickel or magnesium chloride (1-2 oz/gal). This will increase tensile stress which must then be compensated by using a stress reducing additive (usually a saccharin based compound).

Chloride will increase tensile stress, so the optimum concentration is dependent on the acceptable stress levels. Also consider operating conditions and their effect on anode efficiency (current density, for example) when selecting a chloride concentration. Chloride is usually added as nickel chloride, or magnesium chloride. Magnesium chloride is considered to have a lesser impact on stress than nickel chloride.

Anodizing Solutions

Sulfuric acid anodizing solutions are relatively energy efficient and cannot be significantly improved by changing ingredient concentration. The main ingredient providing solution conductivity is sulfuric acid, which is typically in plentiful supply.

Dissolved aluminum should be controlled below five g/L (approximately 0.6 oz/gal) to maintain optimum solution efficiency. Aluminum can be continuously removed by ion exchange technology.

Electroless Nickel Solutions

- The energy consumed by any electroless process is unrelated to the process ingredients because the process operates without DC current. These solutions typically operate at elevated temperatures, however, and therefore you can cut energy consumption by:
- Insulating tanks operating at temperatures over 140° F. Typical electroless nickel processes operate at temperatures close to 200° F, making them ideal candidates for insulation.
- Eliminating air agitation, if possible, to allow for reduced ventilation rates.
- Using a cover system to minimize heat losses during idle periods.
- Reducing the solution temperature to about 140° F or lower during idle periods. Besides saving energy, a solution held at operating temperature when not in use results in abnormal consumption of the reducing agent as a result of oxidation. This condition also leads to a low plating rate and short solution life, resulting from excessive buildup of byproduct sodium phosphite.

Ambient temperature alkaline solutions are used for plating plastic and other temperature-sensitive materials. These solutions generally use little or no energy.

Tin Plating Solutions

Tin plating solutions based upon sulfuric acid, fluoboric acid, and methane sulfonic acid operate at high efficiency and offer few energy saving options. Tin-lead plating solutions based upon methane sulfonic acid and fluoboric acid are similarly poor candidates for energy saving as these solutions are highly efficient and operate at room temperature. Consider using these solutions as substitutes for the alkaline stannate process because they use less power.

The alkaline stannate tin plating process operates at very high temperatures and contains carbonates, which reduces current efficiency and increases power requirements. Insulation might be a worthwhile investment for this process.

The prime ingredient providing solution conductivity is sodium or potassium hydroxide, which should be carefully maintained and controlled. Control carbonates as described for cyanide-based solutions.

Phosphating Solutions

Phosphating is normally performed in spray systems (washers) and in immersion systems. High-temperature or low-temperature cleaners can be used. Temperatures in the standard cleaners are maintained at 43 to 71° C (110 to 160° F) and these are candidates for insulation.

Low-temperature systems that clean and phosphate at 49° C (120° F) or lower are commercially available. Effective low temperature cleaners have been developed that deliver a water-break-free surface on steel in 40 to 60 seconds.

Consider insulating hot process tanks in phosphating lines.

With spray phosphating systems, you can reduce operating temperature of process solutions if you simultaneously increase the number of sprays and/or the spray pressure.

Black Oxide Processes

Insulate black oxide process tanks; losses through the walls and from the surface of the very hot 240-305° F solution can be significant.

Using floating media to cut energy losses from the surface of the solution during processing is not appropriate because the media cannot withstand the hot caustic environment and presents a safety hazard if media pops out of the process tank. You should optimizing the ventilation system because most of the entire vapor from the process is water—so these tanks are often ventilated at rates higher than necessary.

Lower temperature processes are commercially available, but the number of alloys that can be blackened may be limited. Consider them as potential energy saving substitutes for hotter processes.

ENERGY CENTER
OF WISCONSIN
We show you how

595 SCIENCE DRIVE
MADISON, WI 53711
PHONE: (608) 238-4601
FAX: (608) 238-8733
EMAIL: ECW@ECW.ORG
WWW.ECW.ORG

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