Metal Finishing Workshop for Captive and Job Shop Metal Finishers

Session 3: Water Use and Recovery
10:45am – 11:15am
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Overview

• Optimizing Rinse Water Use

• Water Recovery
  – Technologies
  – Rinse Water Requirements
  – Which Technologies make sense
  – Cost and Payback considerations
Typical Cleaning Steps

1. Alkaline cleaner, could include ultrasonics, agitation, or electrocleaning to assist the cleaning chemistry in contaminant removal. Contaminants are typically oil, dirt, buffing compound, fingerprints, etc.

2. Rinses (parts drag alkali into rinse water)

3. Acid etch, to remove light rust or oxides

4. Rinses (parts drag acid into rinse water)

5. Sometimes a repeat of the alkaline and acid steps including rinses
Typical Cleaning and Rinsing Layout

- Alkaline Electroclean
- Alkaline Rinse 1
- Alkaline Rinse 2
- Acid Dip
- Acid Rinse 1
- Acid Rinse 2

Parts and solution drag-out movement

Water use at 12 gpm

Water in at 3 gpm

Water out at 3 gpm
100 gallon tank, .05 gal. dragout, 100 gm/gallon in dragout

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Single Rinse Dilution Model

![Rinse model showing rinse flow vs. rinse tank concentration](image)

- 25 gpm
- 25 gpm repeat rinse
- 5 gpm
- 5 gpm repeat rinse
- 1 gpm
- 1 gpm repeat rinse

**Concentration of rinse water**

**Time in minutes**

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Single Rinse

• Conclusion: Based on the rate of dilution in even a small tank (100 gallons), it is very difficult to obtain good rinsing with a single rinse tank. Even relatively high flow rates of 5 gpm cannot keep up with the contamination loading from parts dragout.

• Therefore, there really needs to be a second rinse tank for critical rinsing.

• And......it becomes very important to determine your real rinse tank dynamics by measuring flow and conductivity/TDS.
Purpose of Rinsing

• First rinse tank
  – remove most of the previous tank’s chemicals from the part
  – Stop the chemical reaction from the previous tank

• Second rinse tank
  – Final rinse to remove additional chemicals and maximize part cleanliness
  – Minimize contamination of next chemical tank

If there was zero dragout of chemicals then there would be no need to rinse!!!
Optimized Cleaning and Rinsing Layout

Parts and solution drag-out movement

Alkaline Electroclean

Alkaline Rinse 1

Alkaline Rinse 2

Countercflow Rinse

Water out at 3 gpm

Water use at 3 gpm

Acid Dip

Acid Rinse 1

Countercflow Rinse

Reactive Rinse

Acid Rinse 2

Water in at 3 gpm

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Water Use in Finishing: Rinse Water

- Measure the flow rate on each rinse tank to determine the rinse water use
  - Needed: ruler, tape measure, stop watch, small pump and hose
  - Pump the tank down 1-2” inches
  - Measure the time it takes for the water level to move some convenient amount (1/2”, 1”, etc.)
  - Measure the surface area of the tank (length, width)
  - Length x width x change in water level = volume in cubic inches (231 cubic inches =1 gallon)
  - Gallons/measured time gives the flow rate
Monitoring the Rinse

- Rinse water contaminants (chemical solution dragout) are typically electrically conductive in solutions.
- As more solution gets dragged into a rinse tank the rinse conductivity goes up.
- As the rinse flow is increased the contamination level drops more rapidly due to dilution (and vice versa)

Note: Conductivity is directly related to total dissolved solids or TDS
Flow vs. Concentration

• Measuring contamination in rinse water
  – Chemical analysis (slow and expensive)
  – Solution conductivity: start with a beaker (create a curve), end with on-line rinse tank measurements

Conductivity/TDS meters cost from $140-$900
Flow Controls in Immersion Rinsing

- In-line flow restrictors: the hand operated valve has an aperture to restrict the flow to some maximum value at maximum valve opening.

- Conductivity controls: rinse valve opens and closes based on TDS value of rinse tank

From: www.freshwatersystems.com

From: Myron L Company, Controlstik Systems
Conductivity/TDS Controls

• Finding the best TDS set points (valve opens when water reaches maximum TDS set point, valve closes when water reaches minimum TDS set point)

• Measure the TDS with a meter in the critical rinse tanks. Knowing the existing flow rate also helps.
Immersion vs. Spray Rinsing

- 3 gpm continuous

100 gallon tank turnover rate is 33 minutes

- 3 gpm continuous

8 spray nozzles, each running 0.75 gpm
total water use per minute is 6 gpm
rinse for 2 minutes every 10 minutes

- averaged flow, 1.2 gpm

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Other options for spray rinsing

• If part geometry is difficult to rinse with fixed spray, if the line is a manual line then the operator can use a manual spray rinse to reach the hard-to-rinse areas of the parts
• If the chemistry is difficult to rinse with cold water, set up an in-line heater for the spray water supply or have a pre-heated supply tank
Available Water for Reuse

- **Rinse water**
  - Primary rinse water (high in TDS, variable pH)
  - Secondary rinse water (low in TDS, variable pH)

- **Treated waste water**
  - Very low in dissolved metals
  - Very high in TDS from neutralization and treatment
  - Consistent pH, typically slightly alkaline from metal precipitation process
  - Typically room temperature
  - May have some other residuals such as oils, soaps, or emulsifiers
Water Recovery Technologies

Rinse Water Requirements

For reuse as rinse water, water needs to be:

- low in TDS
- near neutral in pH to avoid possible contamination of the chemical tanks by rinse dragout
- Free of oils, soaps, etc.
- RO/DI, if necessary
Methods of Removing TDS

• Mixed bed resin columns (ion exchange) to remove both cations and anions (will not remove dissolved organics such as saccharin)

• Reverse Osmosis to remove all solids and solubles except for small amounts of NaCl (0.5 to 3% of the initial concentration)
Resin Columns (ion exchange)

cation exchange resin removes metal ions iron, magnesium, calcium, zinc, etc.

freshly regenerated resin bead

saturated resin bead

anion exchange resin removes negative ions chlorides, nitrates, phosphates, sulfates, etc.

freshly regenerated resin bead

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Advantages/disadvantages of Ion Exchange

**Advantages**
- Excellent ion removal
- Flow rate can be increased with a larger diameter column

**Disadvantages**
- Requires a carbon filter to remove organics
- Requires additional filtration to remove particulate and any resin bead particles
- Requires regular cylinder exchange or regular regeneration to maintain ion removal rate
Reverse Osmosis

**Figure 1.**
- Osmotic Flow
  - Salt Solution
  - Pure Water
  - Semipermeable Membrane
- Reverse Osmotic Flow
  - Salt Solution
  - Pure Water
  - Semipermeable Membrane

**Figure 2.**
- Water Flow
- Purified Water
- Feed Water In
- Membrane
- Unwanted Molecules
- Concentrate Stream
Advantages/disadvantages of RO

Advantages:
- Removes everything: ions*, bacteria, viruses, solids
- Relatively simple, low maintenance system

Disadvantages:
- Low temperature water produces lower pure water yields
- Higher TDS water produces lower pure water yields
- *Tend to leak small amounts of single charge ions (Na⁺, K⁺)
- Membrane can foul rapidly if suspended solids are high (may require pre-filtration with ultrafilter)
- Current technologies allow up to about 75% fresh water yields (typical yields ~50%)
RO-Temperature Relationship

- Higher water temperatures, over 77° F but no higher than 100F, will have water recovery yields greater than the rated yields.

**RO Efficiency vs. Water Temperature**
(data provided by SpectraPure)
### Different RO Membrane Types

<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>Cost Level</th>
<th>Water Flow</th>
<th>pH Range</th>
<th>Max. Temp.</th>
<th>Oxidation Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose Acetate</td>
<td>Low</td>
<td>Medium</td>
<td>pH range 4-8</td>
<td>Max. 95°F</td>
<td>Oxidation resistant</td>
</tr>
<tr>
<td>Composite (thin film composite, TFC)</td>
<td>High</td>
<td>High</td>
<td>pH range 2-11, Max. 113°F</td>
<td>Vulnerable to oxidizers (chlorine)</td>
<td></td>
</tr>
<tr>
<td>Aromatic Polyamide</td>
<td>Medium</td>
<td>Low</td>
<td>pH range 4-11</td>
<td>Max. 95°F</td>
<td>Oxidation resistant</td>
</tr>
</tbody>
</table>

In short, no perfect membrane material.
Water Cost vs. RO Equipment Cost

• Some cost comparisons from on-line prices (Watertiger, PureWaterExpress, Siemens)

• Rochester city water charges $5.22/1000 gallons ($2.67 water bill, $2.55 water treatment tax)

• New York City, $9.04/1000 gallons with sewer charges included
Water Cost Curves

- **NYC water cost per year**
- **Rochester water cost per year**

Gallons per year

- $0 - $250,000
- 4,000,000 - 26,000,000
Water Recovery Cost

• For an 8 hour operation, pure water storage and waste water storage is needed to obtain the best use of RO equipment (16 hours of off-shift filtration available).
• An RO system should be sized for less than the lows of daily water use.
• Be sure that the concentrate from the RO is still below the metals concentration limit for disposal.
Costs per year, either RO system or water cost

- Approx. cost ($CAD), Watertiger.net
- Approx. cost, PureWaterExpress.com
- Approx. cost, Siemens
- 50% NYC annual water cost
- 50% Rochester annual water cost

Gallons per year
Payback Considerations

- At the right place, both DI and RO systems can help recover water for either rinsing or makeup water.
- As water prices continue to rise, the payback for these systems gets better.
- In the previous RO example, NYC costs make an RO system pay for itself in approximately one year.
Questions/Discussion