High Temperature Ferric Chloride Etching

An Evaluation of the Process

Randy Markle
Chemcut
Materials

- Carbon Steel 1020 – 0.2%C, 0.45%Mn, 0.25%Si
- 301 Stainless Steel – 17%Cr, 7%Ni, 0.15%C
- 304 Stainless Steel – 18.5%Cr, 9.5%Ni, 0.08%C
- 316 Stainless Steel – 17%Cr, 12%Ni, 2.25%Mo, 0.08%C
- 410 Stainless Steel – 12%Cr, 0.15%C
- 430 Stainless Steel – 17%Cr, 0.12%C
- Kovar – 29%Ni, 17%Co
- Brass – Alloy 260 (Cartridge Brass) – 70%Cu, 30%Zn
- Copper – Alloy 110 – 99.9%Cu (min)
Test Image
Process Steps

- Shear to size
  6” x 6” (15.2cm x 15.2cm)

- Degrease
  Solvent clean

- Clean
  Hand scrubbed & chemical dip

- Laminate
  Hot roll laminator, FX930

- Expose
  Tamarack 161B

- Develop
  Chemcut CC8000

- Etch
  Chemcut Model 2315

- Strip
  Chemcut CC8000

- Cross section
  Buehler equipment

- Measure
  Video-scope

- Calculations

- Graph & Analyze
Developing

- Chemcut CC8000 Developing System
- Atotech Imagine DS – 1.5% v/v
- Temperature – 85°F (29.4°C)
- Spray Pressure – 30psi (2.1 bar)
- Conveyor Speed – 72ipm (1.8 m/m)
- Dwell Time – 35 seconds
Model 2315
Etching Parameters

- Etching Solution – RCE Solution
- Specific Gravity – 42°Be (1.41)
- Free Acid - ~ 0.6%
- ORP - ~580mv
- Spray Pressure – 40psi (2.8 bar)
- Oscillation Rate – 30spm
- Conveyor Speed – 5.0ipm (12.7 cm/m)
- Etch Time – 4.0 minutes
Stripping

- Chemcut CC8000 Stripping System
- RD-56 from RD Chemicals – 10% solution
- Temperature – 130°F (54.4°C)
- Spray Pressure – 30psi (2.1 bar)
- Conveyor Speed – 18ipm (45.7 cm/m)
- Stripping Time – 2.0 minutes
5.0-mil (127µ) line
410 Stainless Steel
Calculations from Measurements

Etch Rate = \frac{A}{4}

Undercut Ratio = \frac{A}{(B-C/2)}

100/UR = \% Undercut
## Etch Rate Increase – Top Spray

<table>
<thead>
<tr>
<th>Material</th>
<th>5.0-mils</th>
<th>7.5-mils</th>
<th>10.0-mils</th>
<th>12.5-mils</th>
<th>15.0-mils</th>
<th>Average Increase</th>
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</thead>
<tbody>
<tr>
<td>Steel</td>
<td>33.1%</td>
<td>30.2%</td>
<td>39.9%</td>
<td>47.3%</td>
<td>46.7%</td>
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<tr>
<td>301 SST</td>
<td>38.1%</td>
<td>26.7%</td>
<td>20.0%</td>
<td>16.5%</td>
<td><strong>11.4%</strong></td>
<td>22.5%</td>
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<td>304 SST</td>
<td><strong>51.8%</strong></td>
<td>29.3%</td>
<td>29.9%</td>
<td>30.3%</td>
<td>27.6%</td>
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<tr>
<td>316 SST</td>
<td>22.3%</td>
<td>35.7%</td>
<td>43.2%</td>
<td>39.6%</td>
<td>41.1%</td>
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<td>410 SST</td>
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<td>28.7%</td>
<td>32.0%</td>
<td>28.7%</td>
<td>28.1%</td>
<td>28.0%</td>
</tr>
<tr>
<td>430 SST</td>
<td>33.5%</td>
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<td>40.5%</td>
<td>36.4%</td>
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<td>Kovar</td>
<td>38.7%</td>
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<td>45.1%</td>
<td>46.4%</td>
<td>41.9%</td>
<td>41.7%</td>
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<tr>
<td>Brass</td>
<td>31.7%</td>
<td>25.0%</td>
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<td>29.5%</td>
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<tr>
<td>Copper</td>
<td>32.4%</td>
<td>30.4%</td>
<td>33.3%</td>
<td>29.9%</td>
<td>32.6%</td>
<td>31.7%</td>
</tr>
</tbody>
</table>
Bottom Spray Etch Rate (mils/min)
130°F

Etch Rate (mils/min)

Opening Size (mils)
Bottom Spray Etch Rate (mils/min)

160ºF
## Etch Rate Increase – Bottom Spray

### Bottom Etch Rate Increase from 130F to 160F

<table>
<thead>
<tr>
<th>Material</th>
<th>Opening Size - Milss</th>
<th>Average Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.0-mils</td>
<td>7.5-mils</td>
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<td>Steel</td>
<td>27.5%</td>
<td>27.7%</td>
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<td>301SST</td>
<td>48.2%</td>
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<td>304SST</td>
<td>19.4%</td>
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<td>316SST</td>
<td>39.9%</td>
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<td>410SST</td>
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<td>430SST</td>
<td>43.4%</td>
<td>35.8%</td>
</tr>
<tr>
<td>Kovar</td>
<td>35.8%</td>
<td>34.1%</td>
</tr>
<tr>
<td>Brass</td>
<td>34.1%</td>
<td>31.0%</td>
</tr>
<tr>
<td>Copper</td>
<td>47.8%</td>
<td>42.1%</td>
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</tbody>
</table>
Typical Etching Trend

Copper Etch Rate - Bottom

- **Etch Rate (mil/min)**
- **Opening Size (mils)**
- **Etch Temperature**
Steel Etch Rates

Average Increase - 36.0%, 0.11-mil/10ºF

Top - 39.5% Increase
Bottom - 32.4% Increase
301 SST Etch Rates
Average Increase - 33.6%, 0.07-mil/10°F

Top - 20.0% Increase
Bottom - 47.2% Increase
304 SST Etch Rates
Average Increase - 31.0%, 0.087-mil/10°F

**Top - 32.0% Increase**

**Bottom - 27.7% Increase**

- **Top Spray**
  - 130°F: 1.03 mils/min
  - 140°F: 0.84 mils/min
  - 150°F: 0.65 mils/min
  - 160°F: 1.36 mils/min

- **Bottom Spray**
  - 130°F: 0.73 mils/min
  - 140°F: 0.88 mils/min
  - 150°F: 0.79 mils/min
  - 160°F: 0.83 mils/min

- **Average**
  - 130°F: 0.99 mils/min
  - 140°F: 1.03 mils/min
  - 150°F: 1.18 mils/min
  - 160°F: 1.10 mils/min
316 SST Etch Rates
Average Increase - 37.5%, 0.11-mil/10°F

Top - 37.1% Increase
Bottom - 37.9% Increase
410 SST Etch Rates
Average Increase - 30.5%, 0.10-mil/10°F

Top - 27.6% Increase
Bottom - 35.6% Increase
430 SST Etch Rates
Average Increase - 36.1%, 0.11-mil/10°F

Top - 36.5% Increase
Bottom - 35.7% Increase
Kovar Etch Rates

Average Increase - 38.1%, 0.11-mil/10°F

Top - 41.1% Increase
Bottom - 34.2% Increase
Brass Etch Rates
Average Increase - 35.0%, 0.21-mil/10°F

Top - 29.3% Increase
Bottom - 44.5% Increase
Copper Etch Rates

Average Increase - 31.9%, 0.19-mil/10°F

Top - 31.9% Increase

Bottom - 31.8% Increase
# Undercut Ratios – Top Spray

| Etch Temp | Pre-etch Opening | Undercut Comparison as a Ratio of the Vertical Etch | | Kovar | Brass | Copper |
|-----------|------------------|-----------------------------------------------|---|---|---|
|           |                  | Steel | 301 SST | 304 SST | 316 SST | 410 SST | 430 SST |       |       |       |
| 130F      | 5.0-mil          | 2.0   | 1.7     | 2.0     | 2.6     | 2.5     | 2.7     | 1.7   | 2.2   | 2.1   |
|           | 7.5-mil          | 2.1   | 1.9     | 2.0     | 2.1     | 2.8     | 2.6     | 1.8   | 2.3   | 2.3   |
|           | 10.0-mil         | 2.2   | 1.9     | 2.2     | 2.1     | 3.0     | 2.8     | 1.9   | 2.4   | 2.5   |
|           | 12.5-mil         | 2.2   | 2.1     | 2.3     | 2.1     | 3.2     | 2.8     | 1.9   | 2.4   | 2.5   |
|           | 15.0-mil         | 2.2   | 2.1     | 2.3     | 2.0     | 2.9     | 2.7     | 1.9   | 2.5   | 2.5   |
|           | Average Undercut Ratio | 2.14 | 1.94   | 2.16    | 2.18    | 2.88    | 2.72    | 1.84  | 2.36  | 2.38  |
| 160F      | 5.0-mil          | 2.2   | 2.1     | 2.2     | 2.1     | 2.6     | 2.4     | 1.9   | 2.0   | 2.1   |
|           | 7.5-mil          | 1.9   | 2.1     | 2.3     | 2.4     | 2.6     | 2.5     | 2.0   | 2.1   | 2.1   |
|           | 10.0-mil         | 2.0   | 2.1     | 2.4     | 2.5     | 2.7     | 2.9     | 2.1   | 2.1   | 2.2   |
|           | 12.5-mil         | 2.4   | 2.3     | 2.8     | 2.5     | 2.8     | 2.8     | 2.2   | 2.6   | 2.1   |
|           | 15.0-mil         | 2.3   | 2.2     | 2.4     | 2.5     | 2.4     | 3.2     | 2.2   | 2.3   | 2.4   |
|           | Average Undercut Ratio | 2.16 | 2.16   | 2.42    | 2.40    | 2.62    | 2.76    | 2.08  | 2.22  | 2.18  |
# Undercut Ratios – Bottom Spray

<table>
<thead>
<tr>
<th>Etch Temp</th>
<th>Pre-Etch Opening (u)</th>
<th>Steel</th>
<th>301SST</th>
<th>304SST</th>
<th>316SST</th>
<th>410SST</th>
<th>430SST</th>
<th>Kovar</th>
<th>Copper</th>
<th>Brass</th>
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<td>1.5</td>
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<td>7.5-mil</td>
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<td><strong>1.8</strong></td>
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<td><strong>Average Undercut Ratio</strong></td>
<td><strong>2.7</strong></td>
<td><strong>2.1</strong></td>
<td><strong>2.9</strong></td>
<td><strong>2.6</strong></td>
<td><strong>3.1</strong></td>
<td><strong>2.5</strong></td>
<td><strong>2.3</strong></td>
<td><strong>2.8</strong></td>
<td><strong>2.6</strong></td>
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</tbody>
</table>
Steel Undercut Ratios

Average - 2.33
St. Dev. - 0.10
301 SST Undercut Ratios

Etch Temperature vs Undercut Ratios

- Top Spray
- Bottom Spray
- Average

Average - 1.86  St. Dev. - 0.19
316 SST Undercut Ratios

- Top Spray
- Bottom Spray
- Average

Average - 2.19
St. Dev. - 0.26
410 SST Undercut Ratios

Average - 2.83
St. Dev. - 0.07
430 SST Undercut Ratios

**Average - 2.58**

**St. Dev. - 0.08**

- Top Spray
- Bottom Spray
- Average
Kovar Undercut Ratios

Etch temperature

Undercut Ratios

Average - 1.89
St. Dev. - 0.21

Top Spray
Bottom Spray
Average
Brass Undercut Ratios

Average - 2.62
St. Dev. - 0.10
Copper Undercut Ratios

Undercut Ratios

Average - 2.60
St. Dev. - 0.08

Etch Temperature

130F 140F 150F 160F

0 0.5 1 1.5 2 2.5 3 3.5 4

Top Spray
Bottom Spray
Average
Findings

- Etch rate increases with temperature increase
  - Steel alloys – 34.0% to 36.0%
    - ~0.1-mil for each 10º F
  - Copper alloys – 32.0% to 35.0%
    - ~0.2-mil for each 10º F

- No appreciable effect on undercut ratio
  - Steel alloys – 2.3 average
  - Copper alloys – 2.6 average
Discussion

- Footprint – Equal
- Throughput – 30% to 40% more
- Performance – Equal to PVC equipment
- Cost – More than PVC equipment
- Life expectancy – Could be less
High Temperature Ferric Chloride Etching

An Evaluation of the Process

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