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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)

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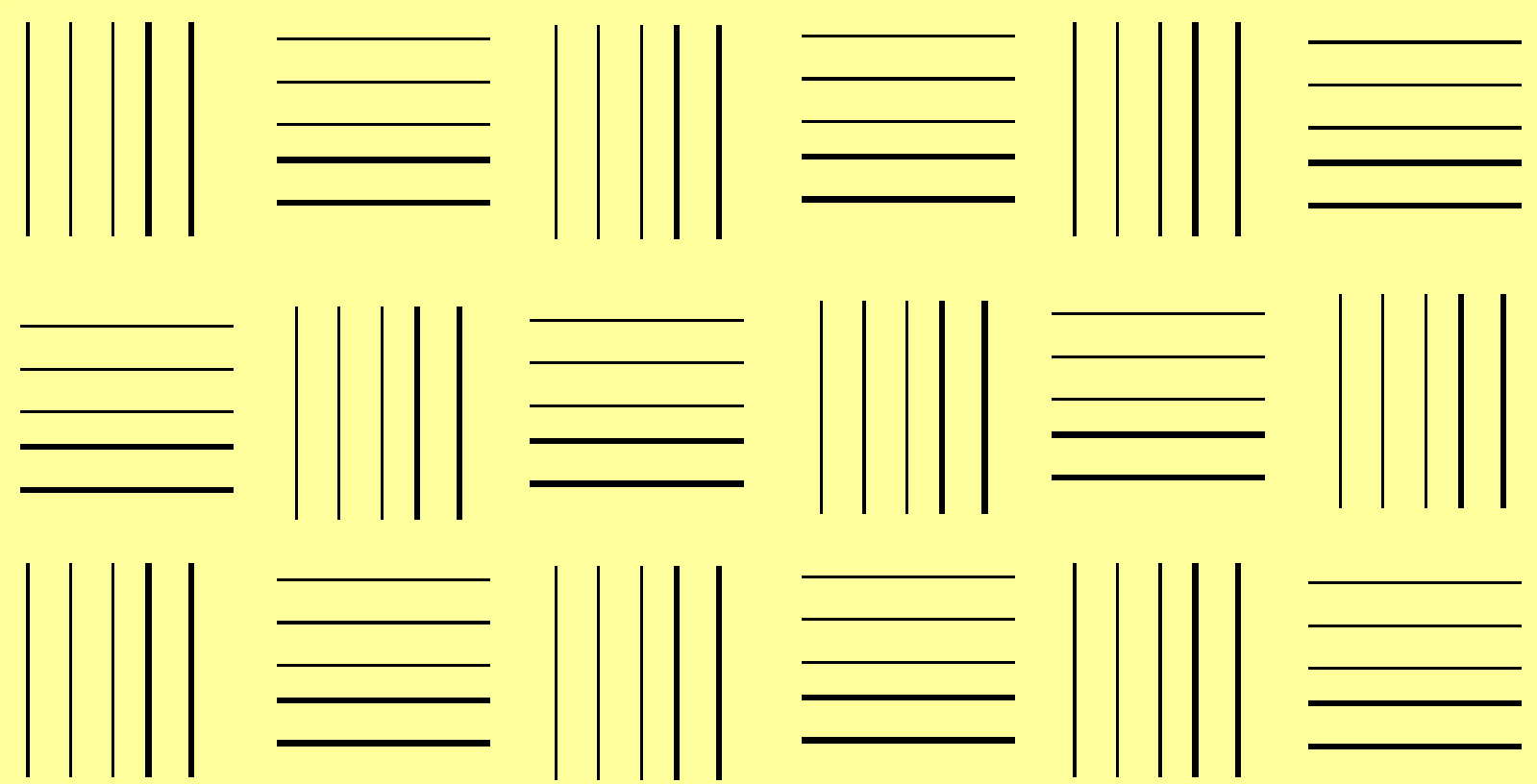
Test Image



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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

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Model 2315

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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

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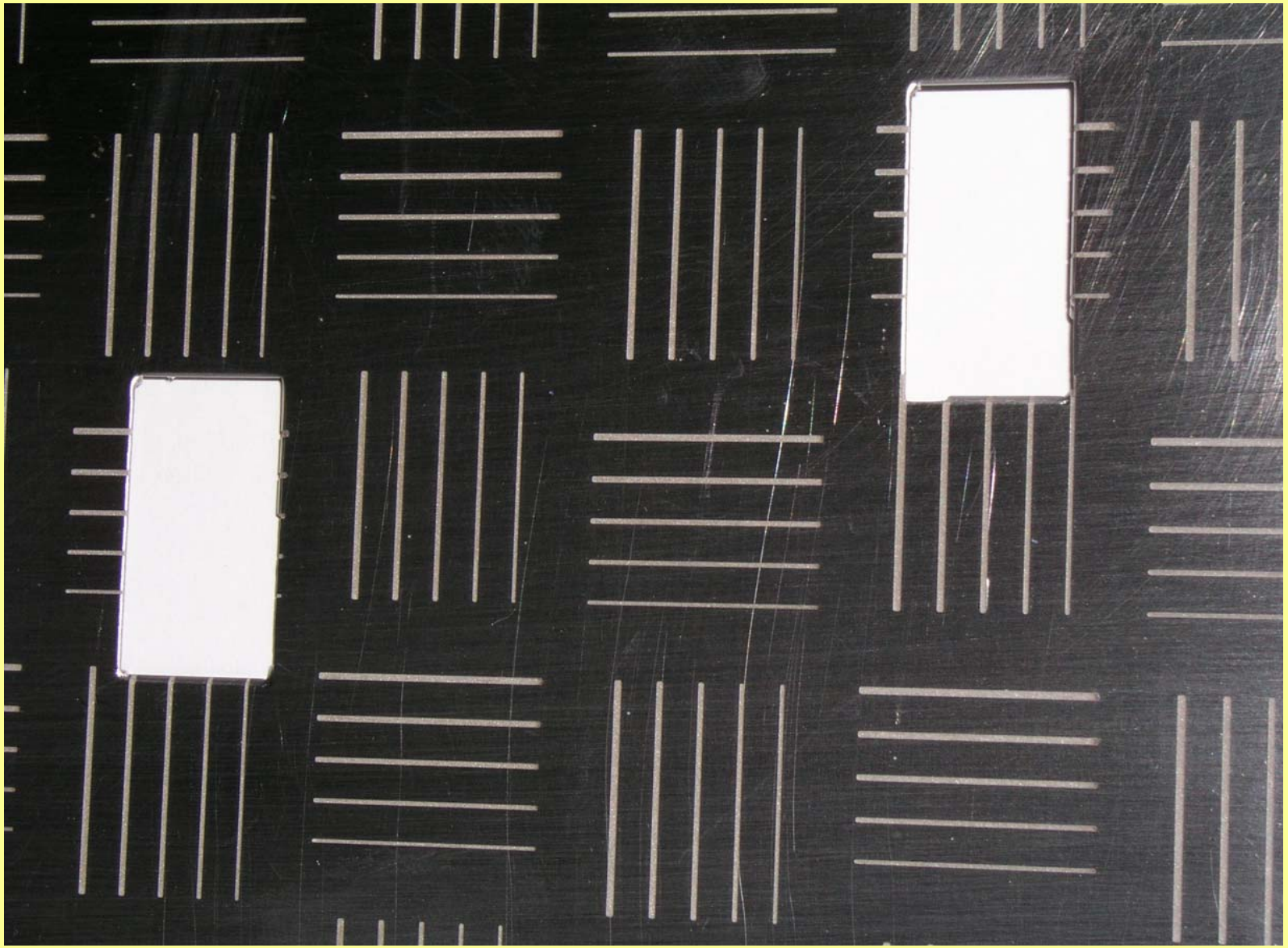

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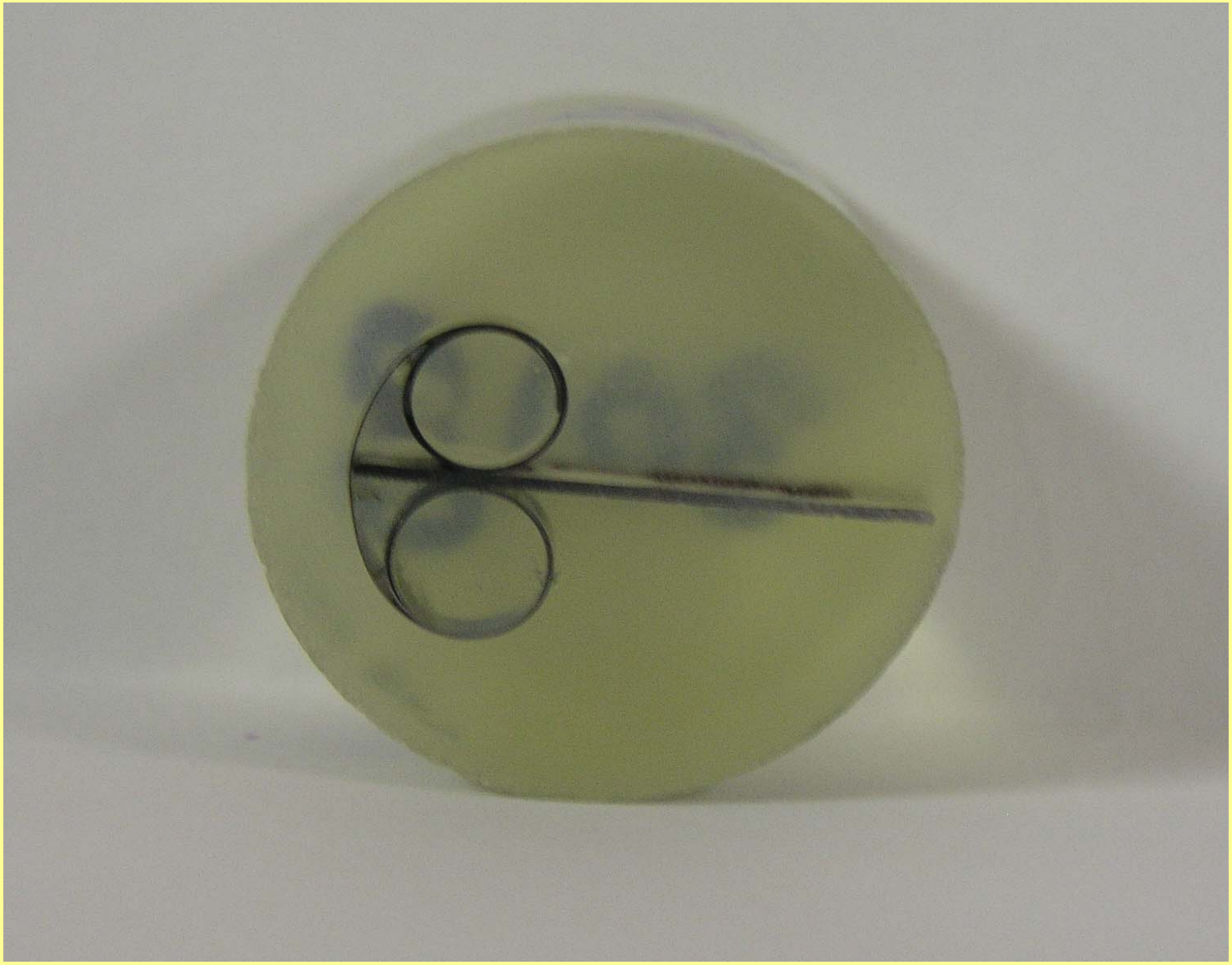

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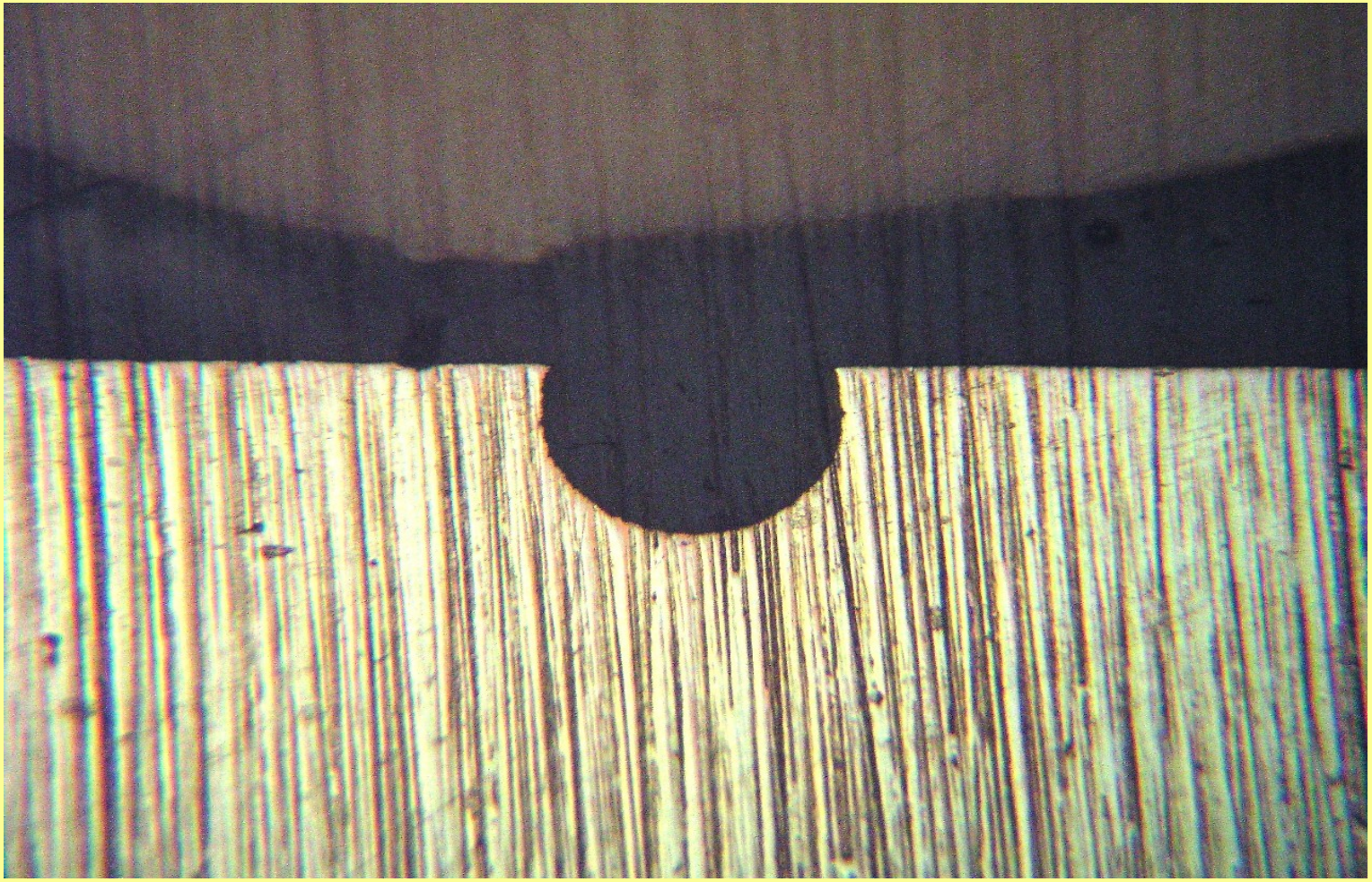
5.0-mil (127µ) line
410 Stainless Steel



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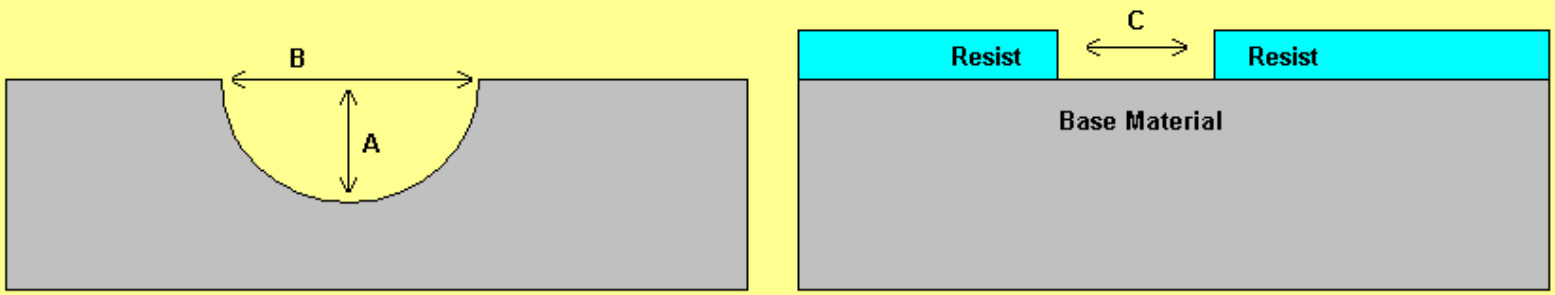
Calculations from Measurements

Etch Rate = A/4



Undercut Ratio = A/(B-C/2)

100/UR = % Undercut

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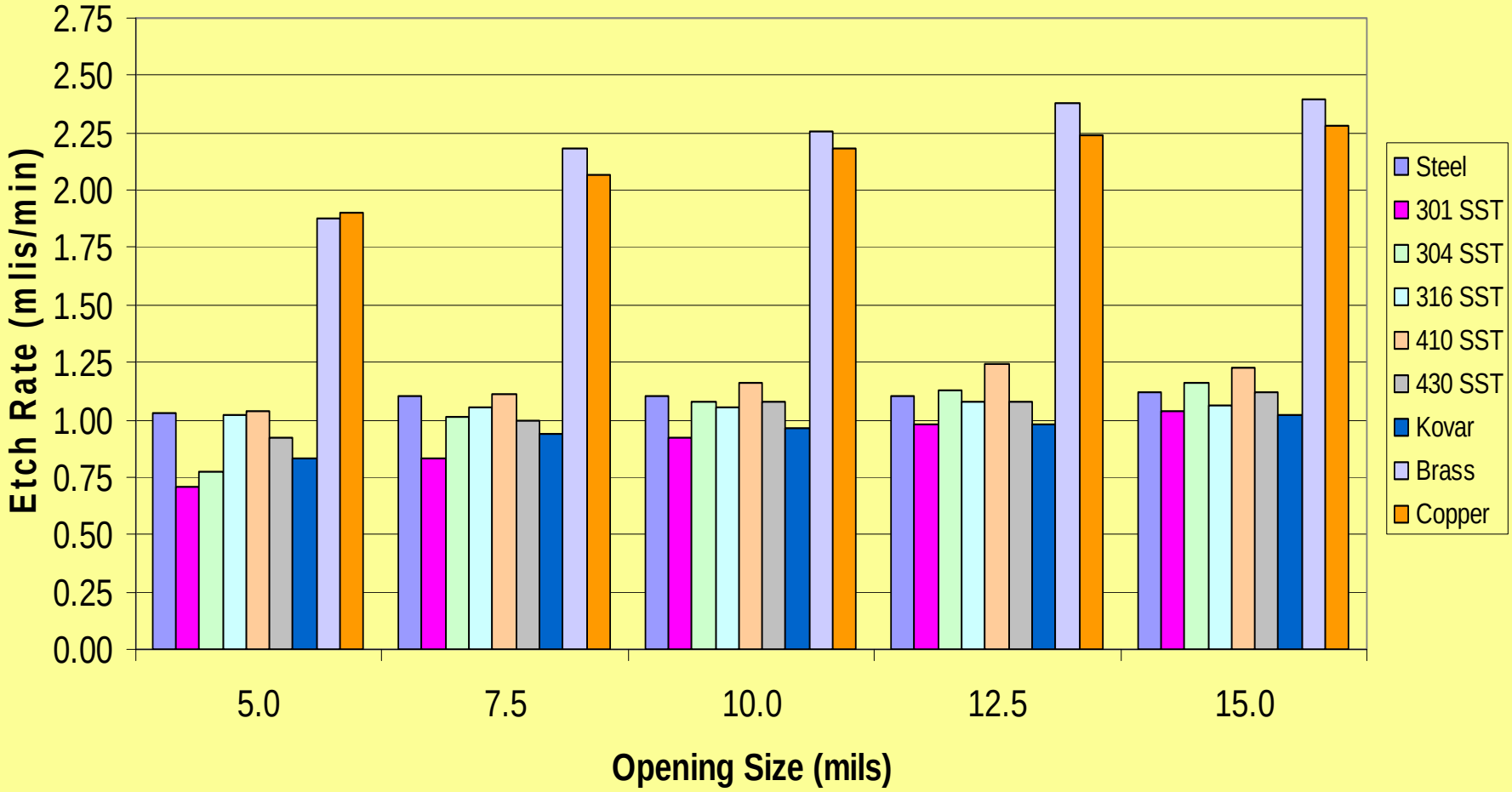
Top Spray Etch Rate (mils/min)
130ºF



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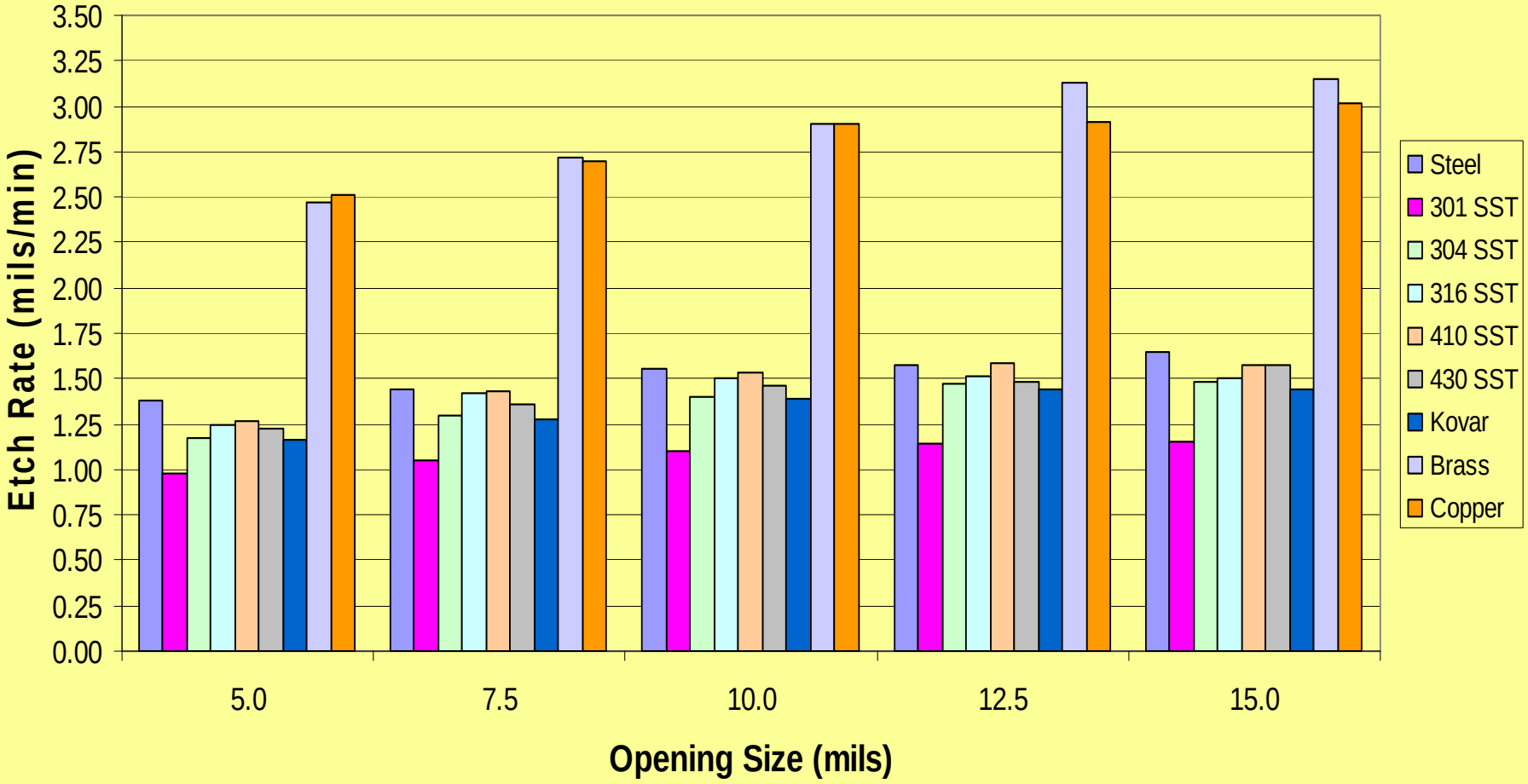
Top Spray Etch Rate (mils/min)
160ºF



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Etch Rate Increase – Top Spray

	Top Etch Rate Increase from 130F to 160F					
	Opening Size - Mils					Average
Material	5.0-mils	7.5-mils	10.0-mils	12.5-mils	15.0-mils	Increase
Steel	33.1%	30.2%	39.9%	47.3%	46.7%	39.4%
301 SST	38.1%	26.7%	20.0%	16.5%	11.4%	22.5%
304 SST	51.8%	29.3%	29.9%	30.3%	27.6%	33.8%
316 SST	22.3%	35.7%	43.2%	39.6%	41.1%	36.4%
410 SST	22.3%	28.7%	32.0%	28.7%	28.1%	28.0%
430 SST	33.5%	35.3%	35.4%	37.2%	40.5%	36.4%
Kovar	38.7%	36.4%	45.1%	46.4%	41.9%	41.7%
Brass	31.7%	25.0%	28.4%	31.2%	31.3%	29.5%
Copper	32.4%	30.4%	33.3%	29.9%	32.6%	31.7%

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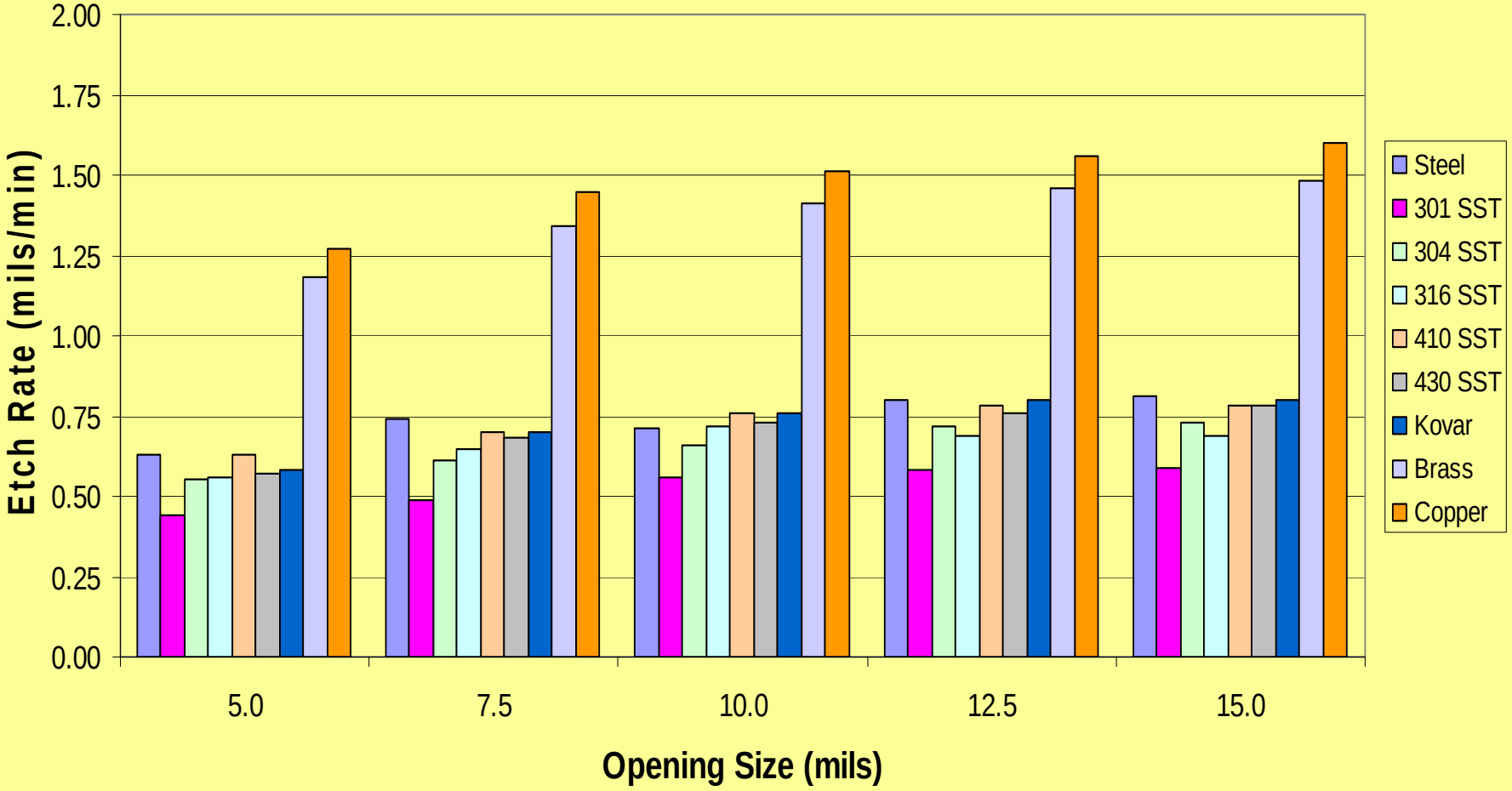
Bottom Spray Etch Rate (mils/min)
130ºF



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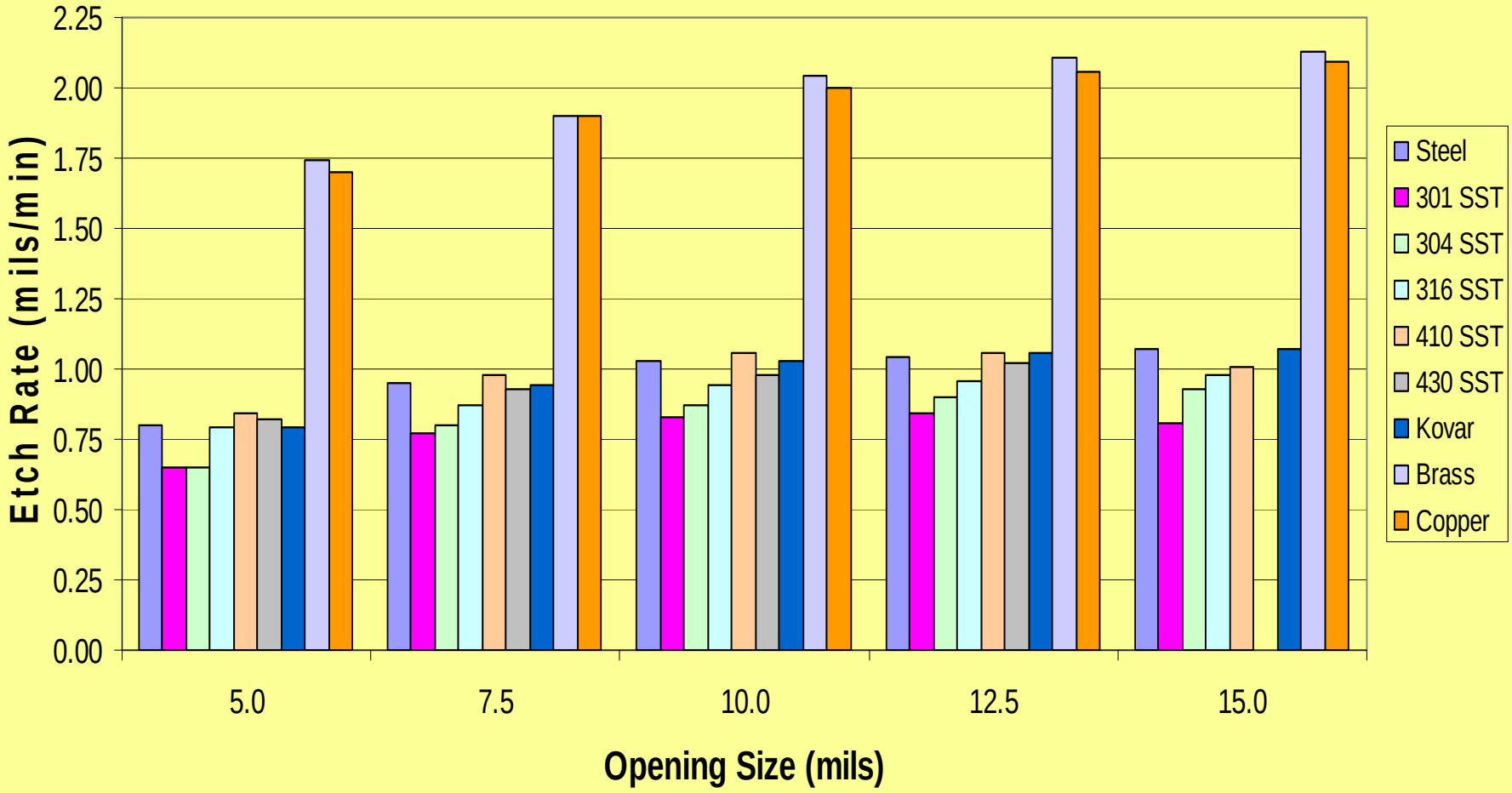
Bottom Spray Etch Rate (mils/min)
160ºF



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Etch Rate Increase – Bottom Spray

	Bottom Etch Rate Increase from 130F to 160F					
	Opening Size - Mils					Average
Material	5.0-mils	7.5-mils	10.0-mils	12.5-mils	15.0-mils	Increase
Steel	27.5%	27.7%	45.0%	29.4%	31.9%	32.3%
301SST	48.2%	58.1%	49.3%	45.6%	37.3%	47.7%
304SST	19.4%	30.1%	32.1%	25.8%	28.1%	27.1%
316SST	39.9%	34.5%	31.9%	40.0%	44.8%	38.2%
410SST	34.6%	40.1%	38.1%	37.1%	29.3%	35.8%
430SST	43.4%	35.8%	34.4%	34.2%	30.7%	35.7%
Kovar	35.8%	34.1%	35.9%	33.2%	35.1%	34.8%
Brass	34.1%	31.0%	32.6%	32.3%	30.5%	32.1%
Copper	47.8%	42.1%	44.7%	45.1%	44.5%	44.8%

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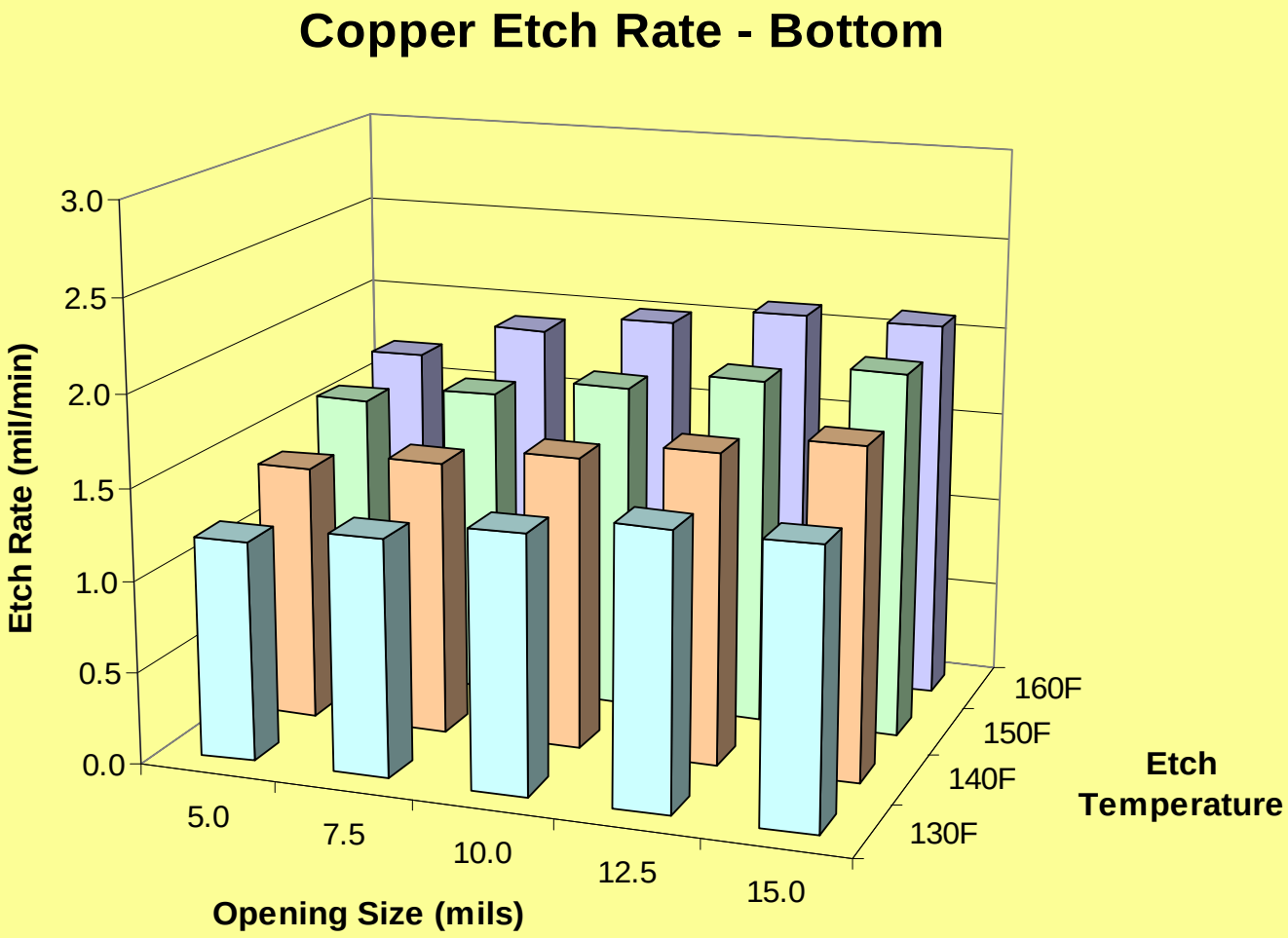
Typical Etching Trend



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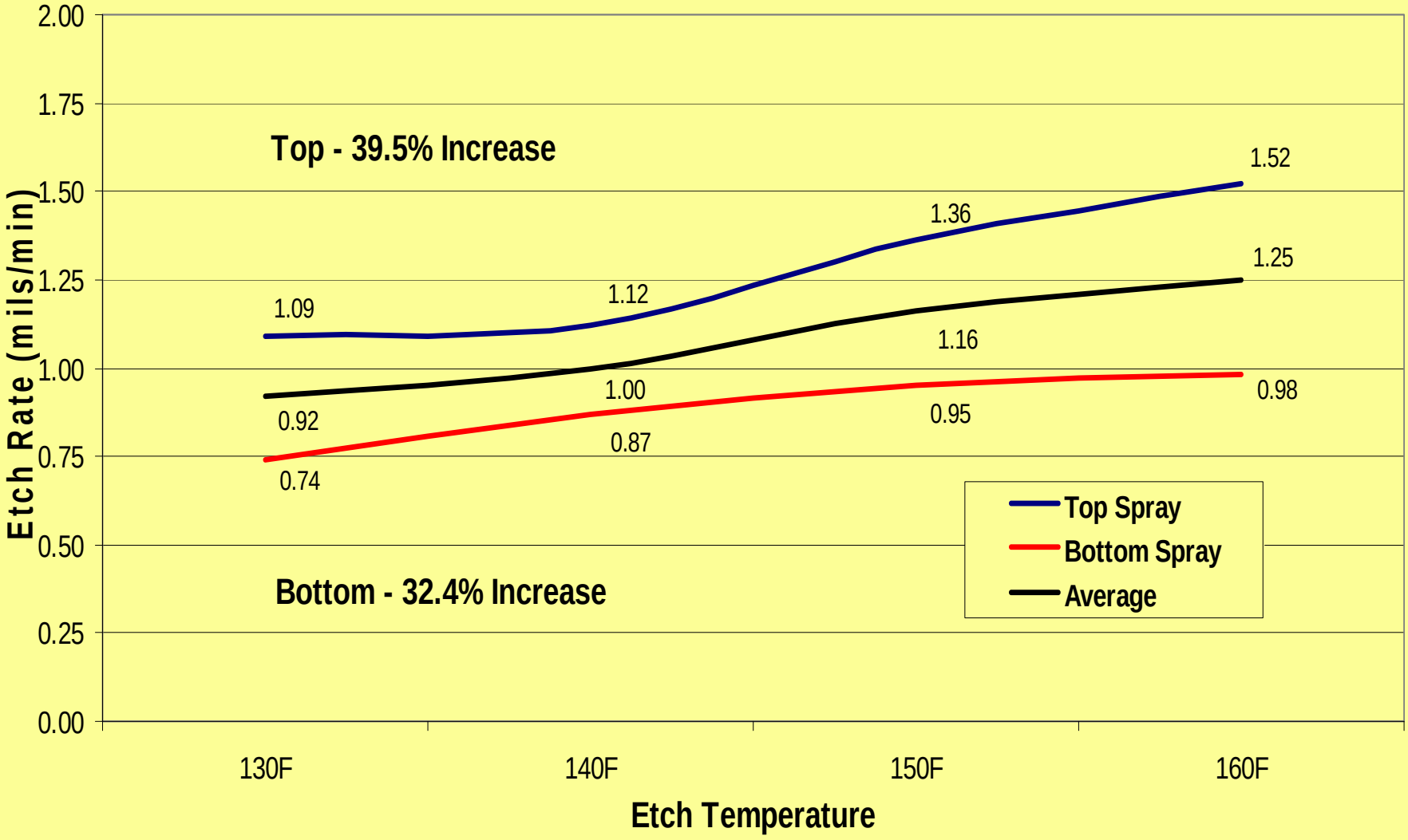
Steel Etch Rates
Average Increase - 36.0%, 0.11-mil/10ºF



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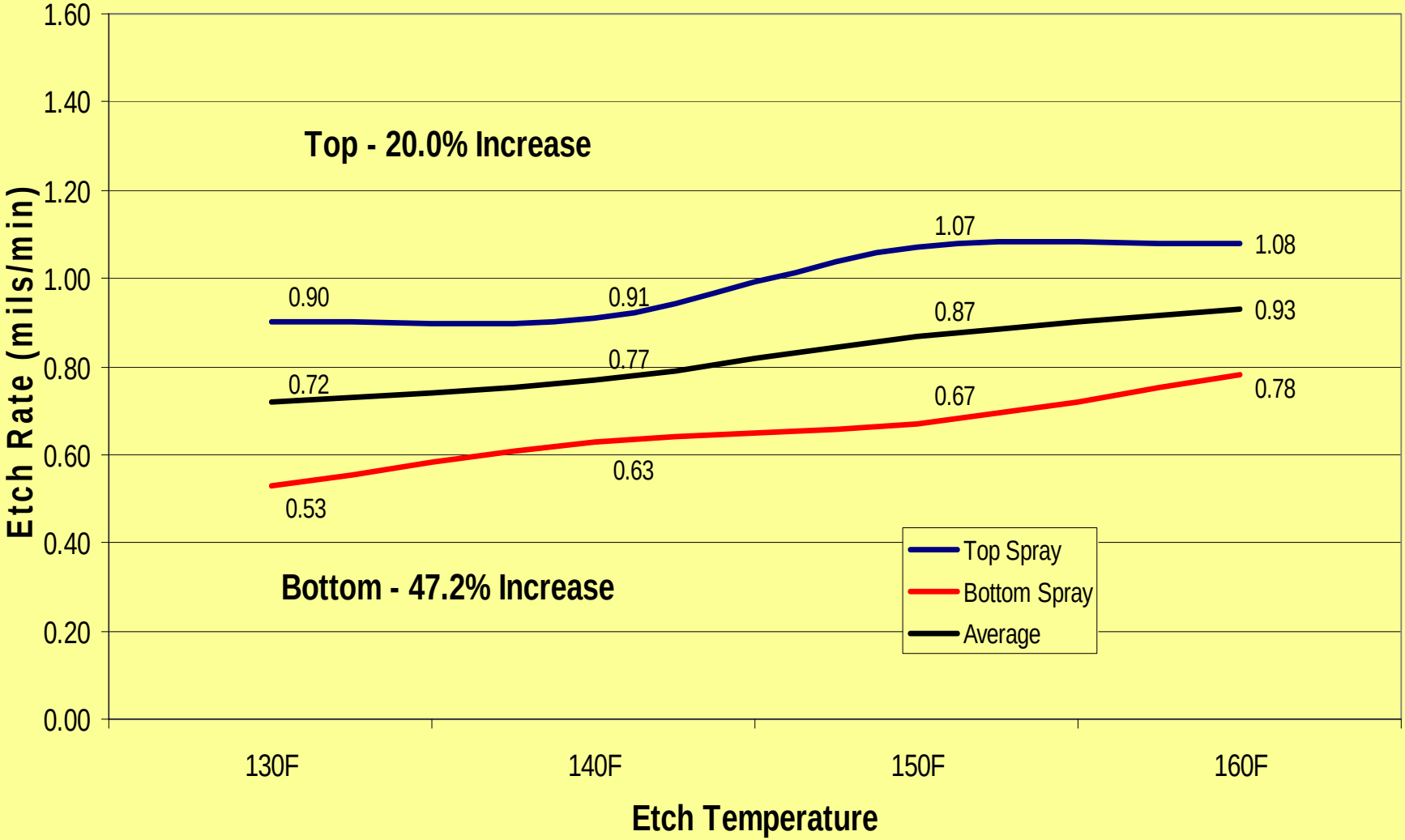
301 SST Etch Rates
Average Increase - 33.6%, 0.07-mil/10ºF



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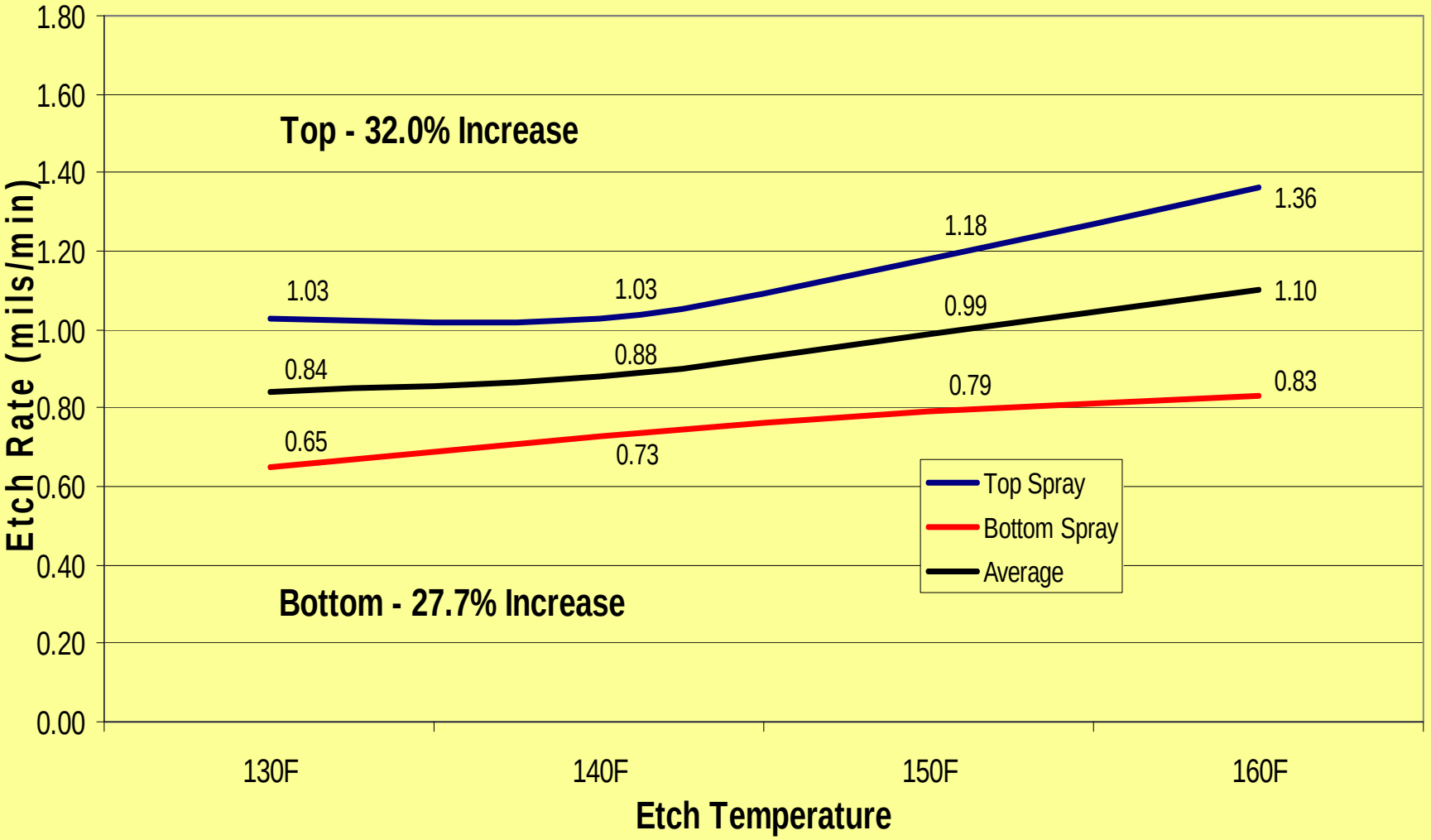
304 SST Etch Rates
Average Increase - 31.0%, 0.087-mil/10ºF



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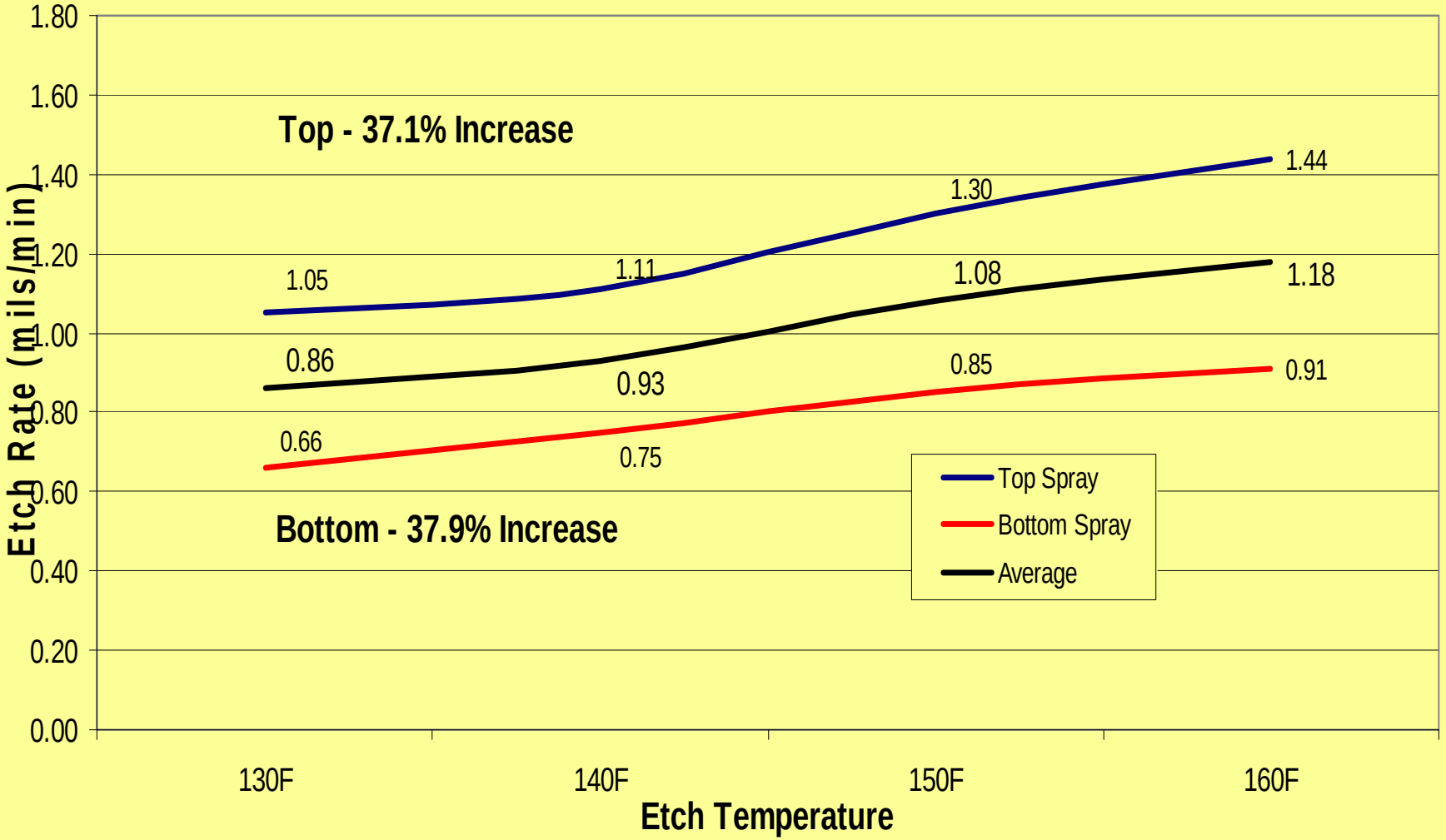
316 SST Etch Rates
Average Increase - 37.5%, 0.11-mil/10ºF



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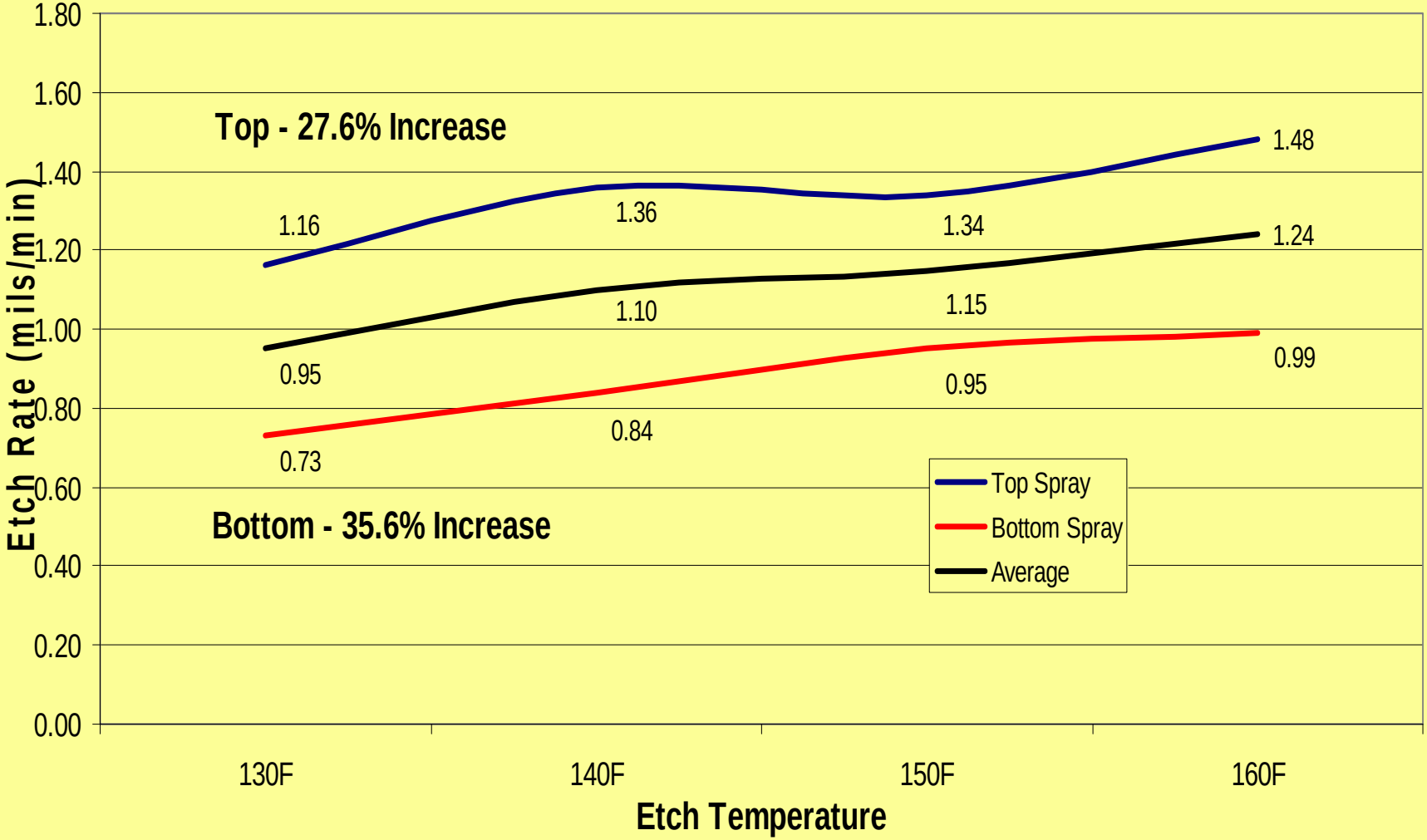
410 SST Etch Rates
Average Increase - 30.5%, 0.10-mil/10ºF



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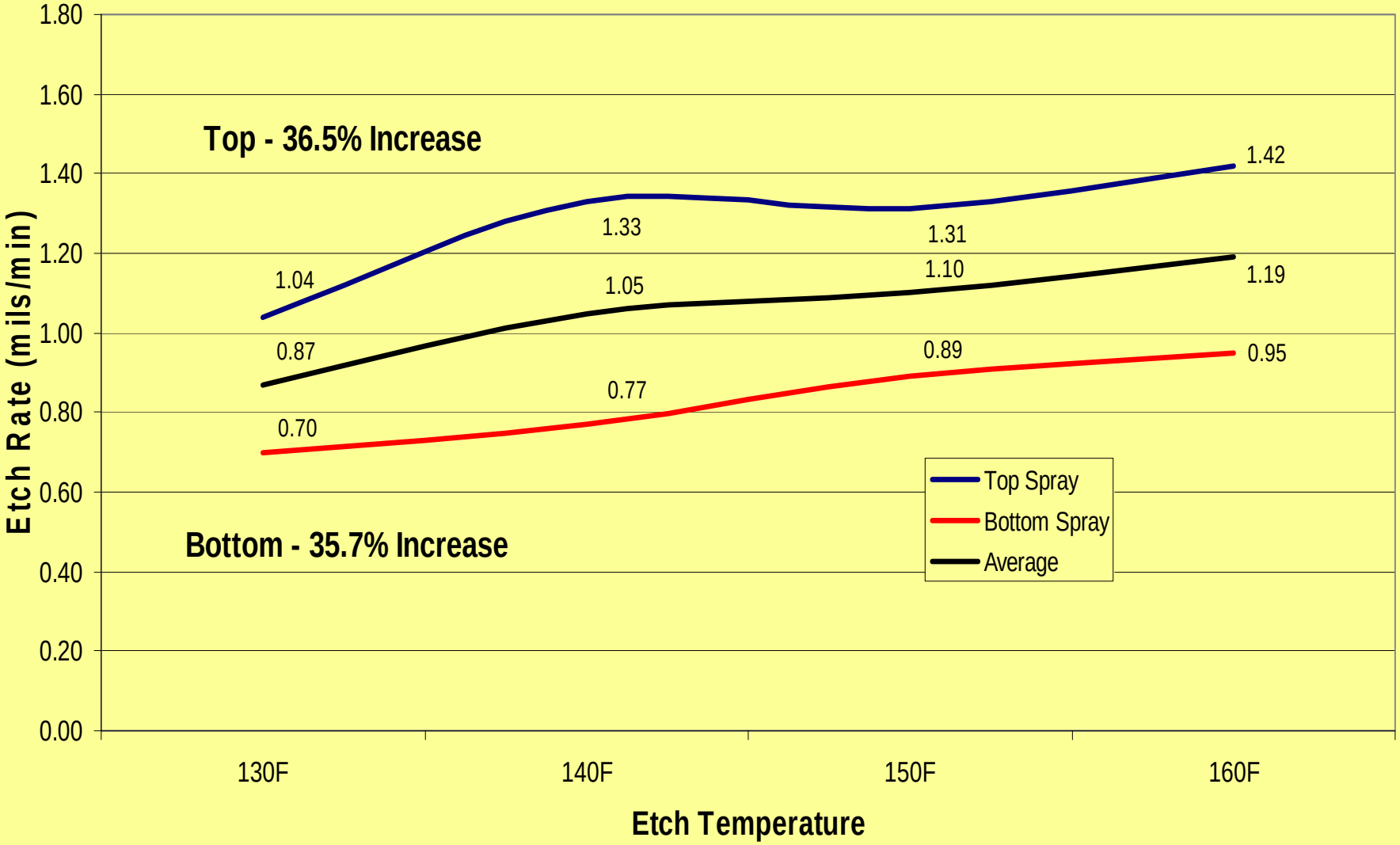
430 SST Etch Rates

Average Increase - 36.1%, 0.11-mil/10ºF



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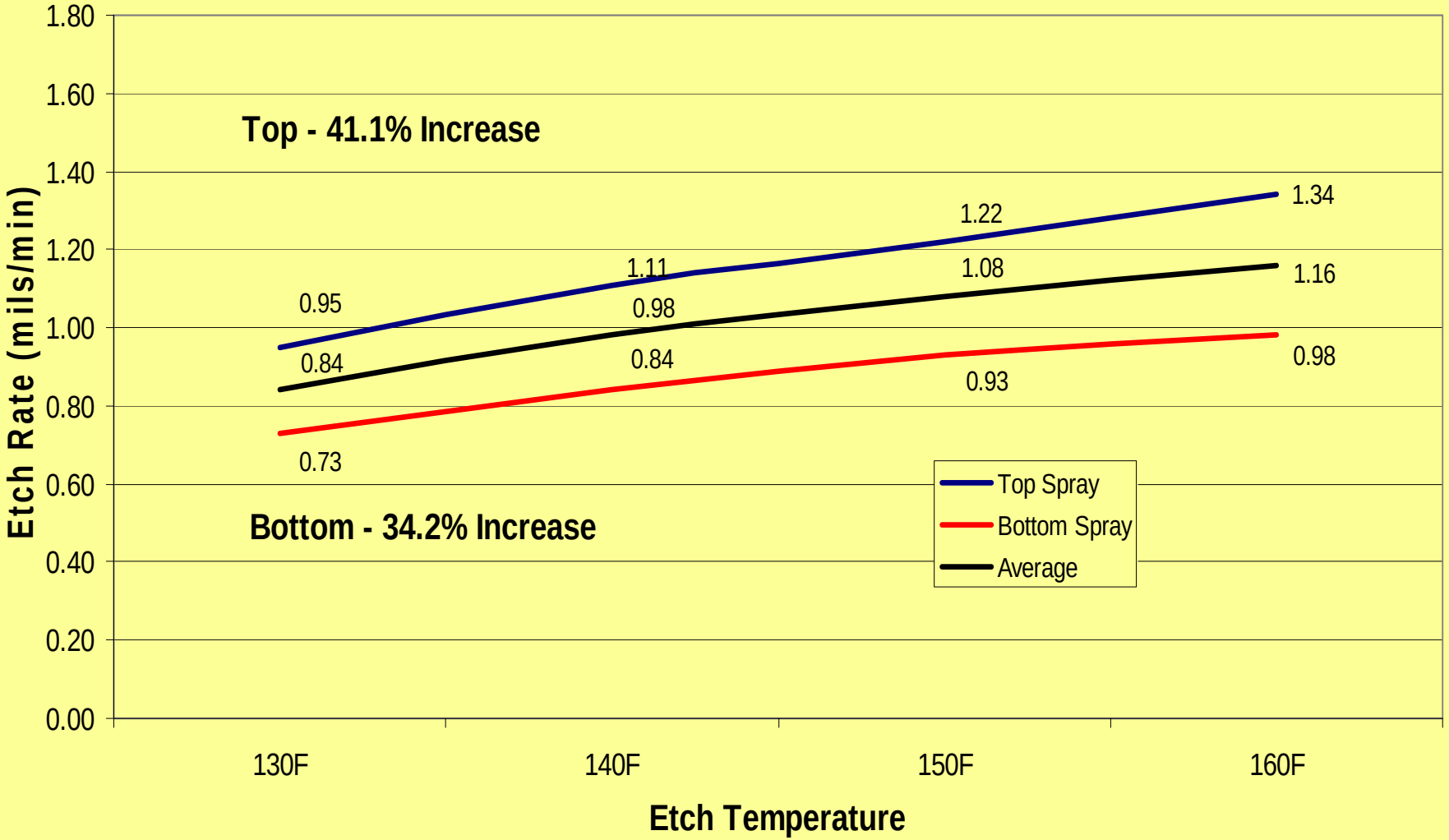
Kovar Etch Rates

Average Increase - 38.1%, 0.11-mil/10ºF



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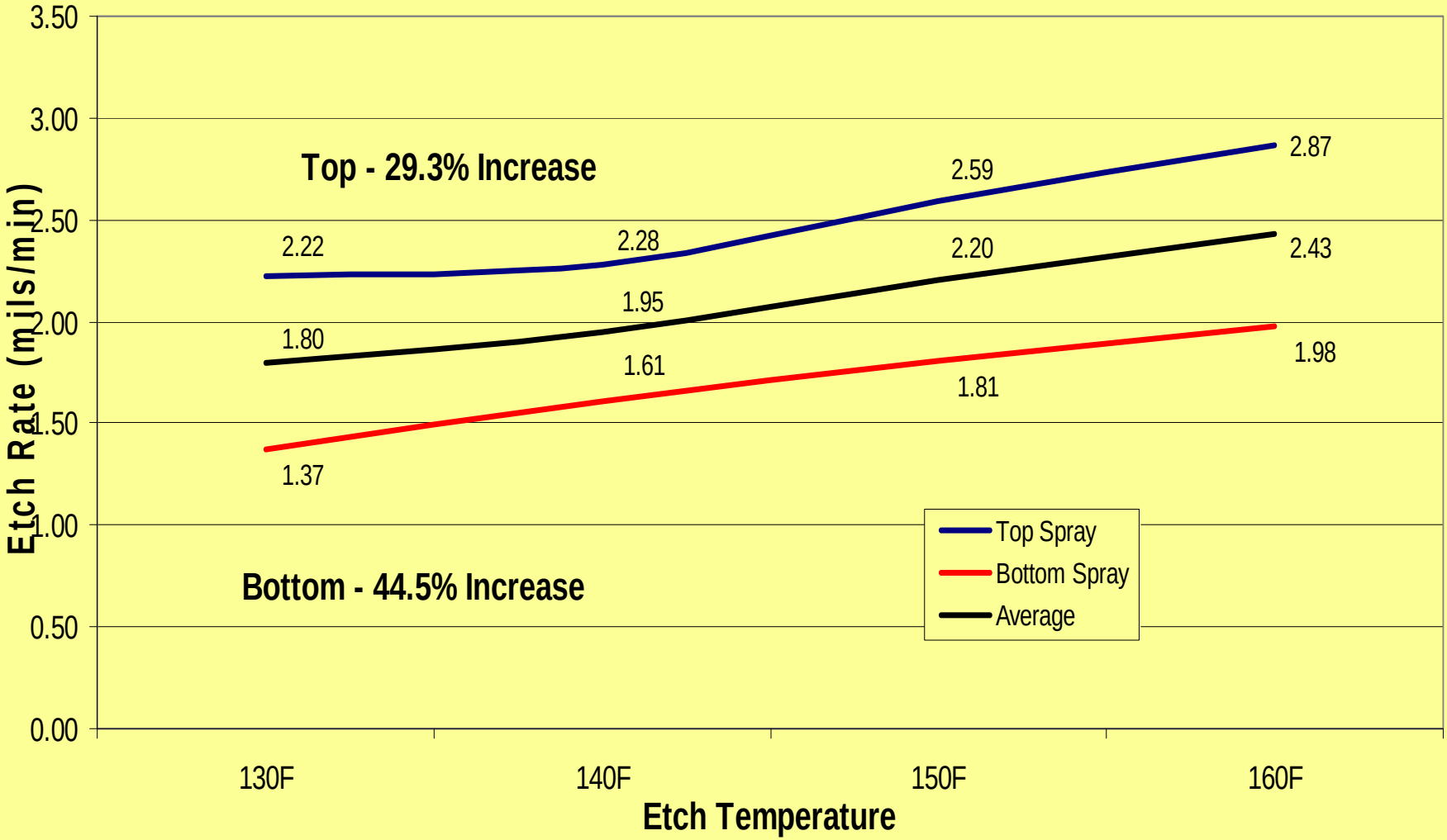
Brass Etch Rates

Average Increase - 35.0%, 0.21-mil/10ºF



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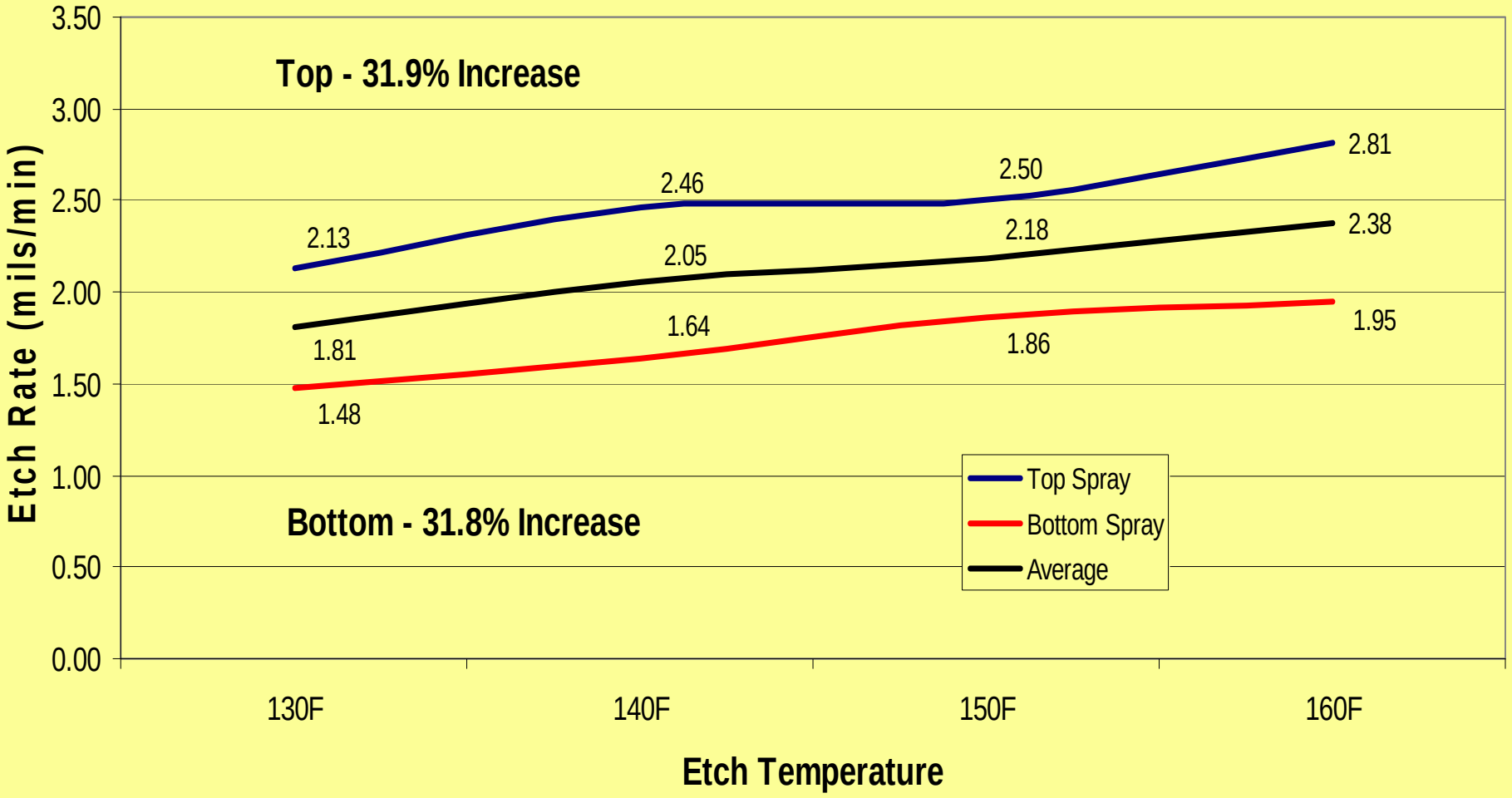
Copper Etch Rates
Average Increase - 31.9%, 0.19-mil/10ºF



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Undercut Ratios – Top Spray

Etch Temp	Pre-etch Opening	Undercut Comparison as a Ratio of the Vertical Etch								
		Steel	301 SST	304 SST	316 SST	410 SST	430 SST	Kovar	Brass	Copper
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**

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Undercut Ratios – Bottom Spray

Etch Temp	Pre-Etch Opening (u)	Undercut Comparison as a Ratio of the Vertical Etch						Kovar	Copper	Brass
		Steel	301SST	304SST	316SST	410SST	430SST			
130F	5.0-mil	2.8	1.2	1.4	1.5	2.3	1.9	1.4	2.7	2.8
	7.5-mil	2.9	1.4	1.6	1.6	2.6	2.1	1.7	3.2	3.0
	10.0-mil	3.6	1.3	1.8	1.9	3.0	2.4	1.7	3.4	3.1
	12.5-mil	2.7	1.4	2.0	2.0	3.0	2.5	1.8	3.4	3.1
	15.0-mil	2.8	1.4	1.8	1.8	3.0	2.3	1.7	3.2	3.1
Average Undercut Ratio		**3.0**	**1.3**	**1.7**	**1.8**	**2.8**	**2.2**	**1.7**	**3.2**	**3.0**
160F	5.0-mil	2.4	1.8	3.0	2.3	2.7	2.2	2.0	2.7	2.5
	7.5-mil	2.5	2.0	2.7	2.5	3.0	2.4	2.2	2.7	2.5
	10.0-mil	2.6	2.2	2.9	2.8	3.2	2.6	2.4	2.8	2.6
	12.5-mil	2.8	2.3	3.0	2.7	3.3	2.7	2.3	2.8	2.8
	15.0-mil	3.0	2.1	3.0	2.9	3.2	2.7	2.4	2.9	2.8
Average Undercut Ratio		**2.7**	**2.1**	**2.9**	**2.6**	**3.1**	**2.5**	**2.3**	**2.8**	**2.6**

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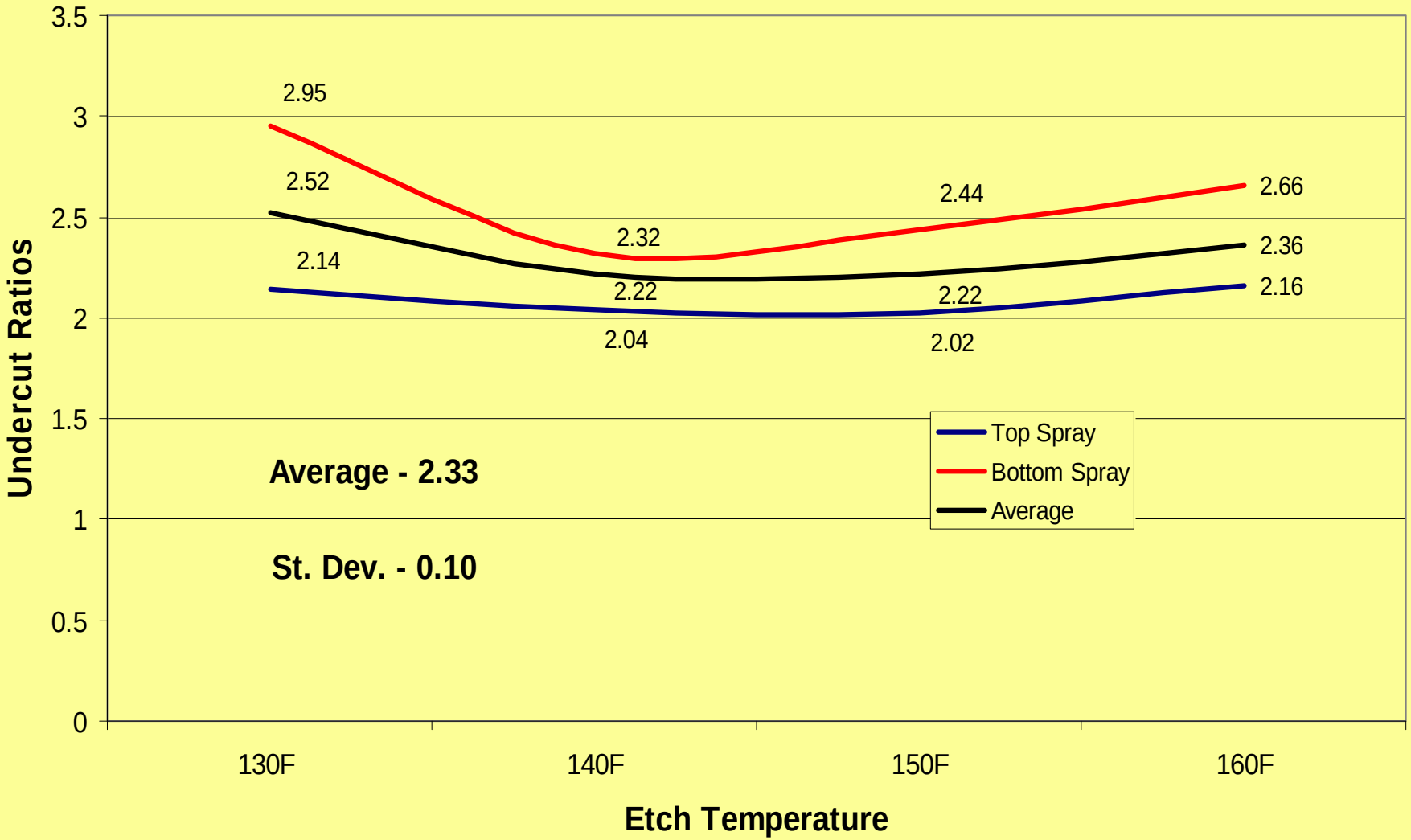
Steel Undercut Ratios



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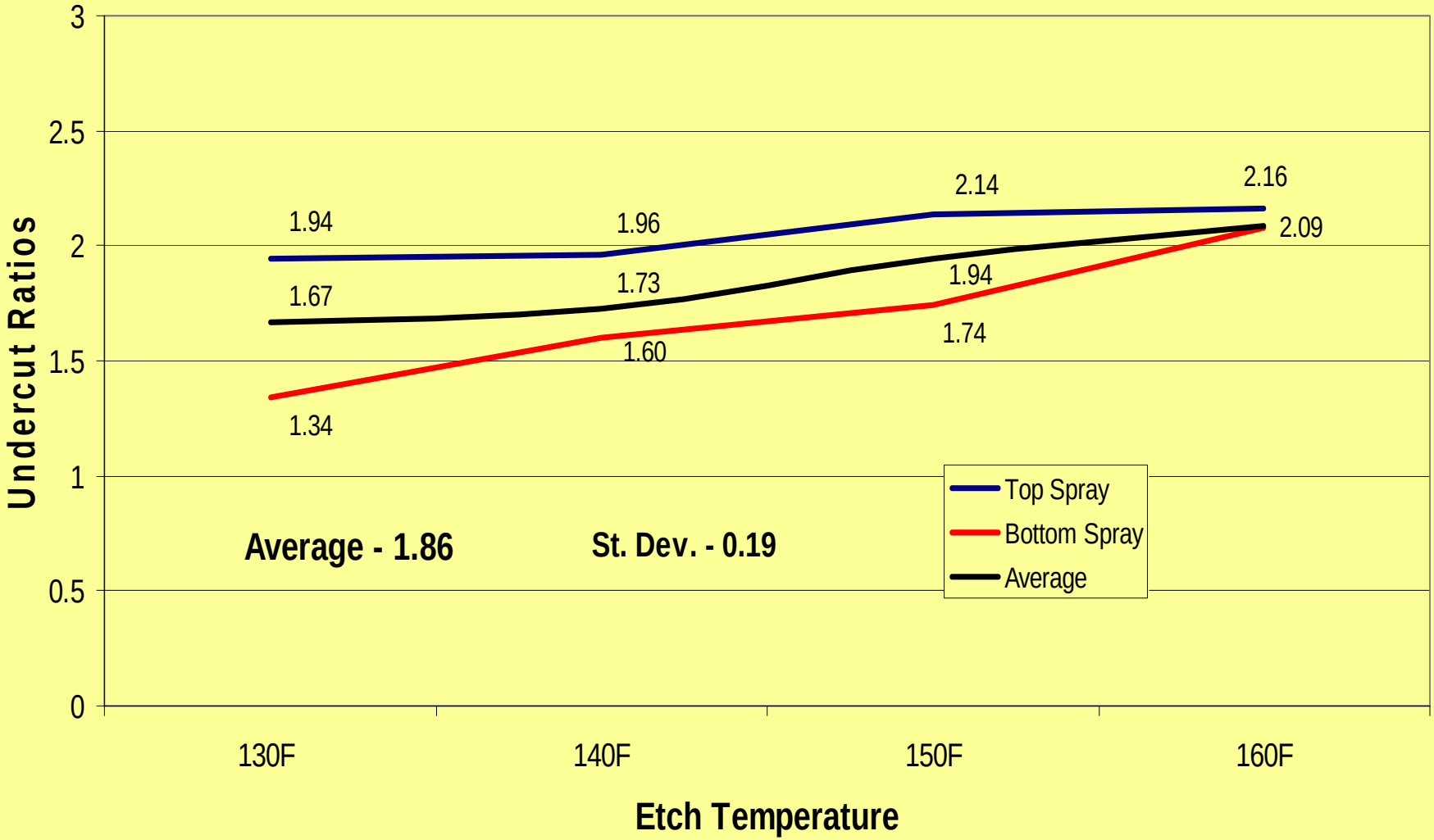
301 SST Undercut Ratios



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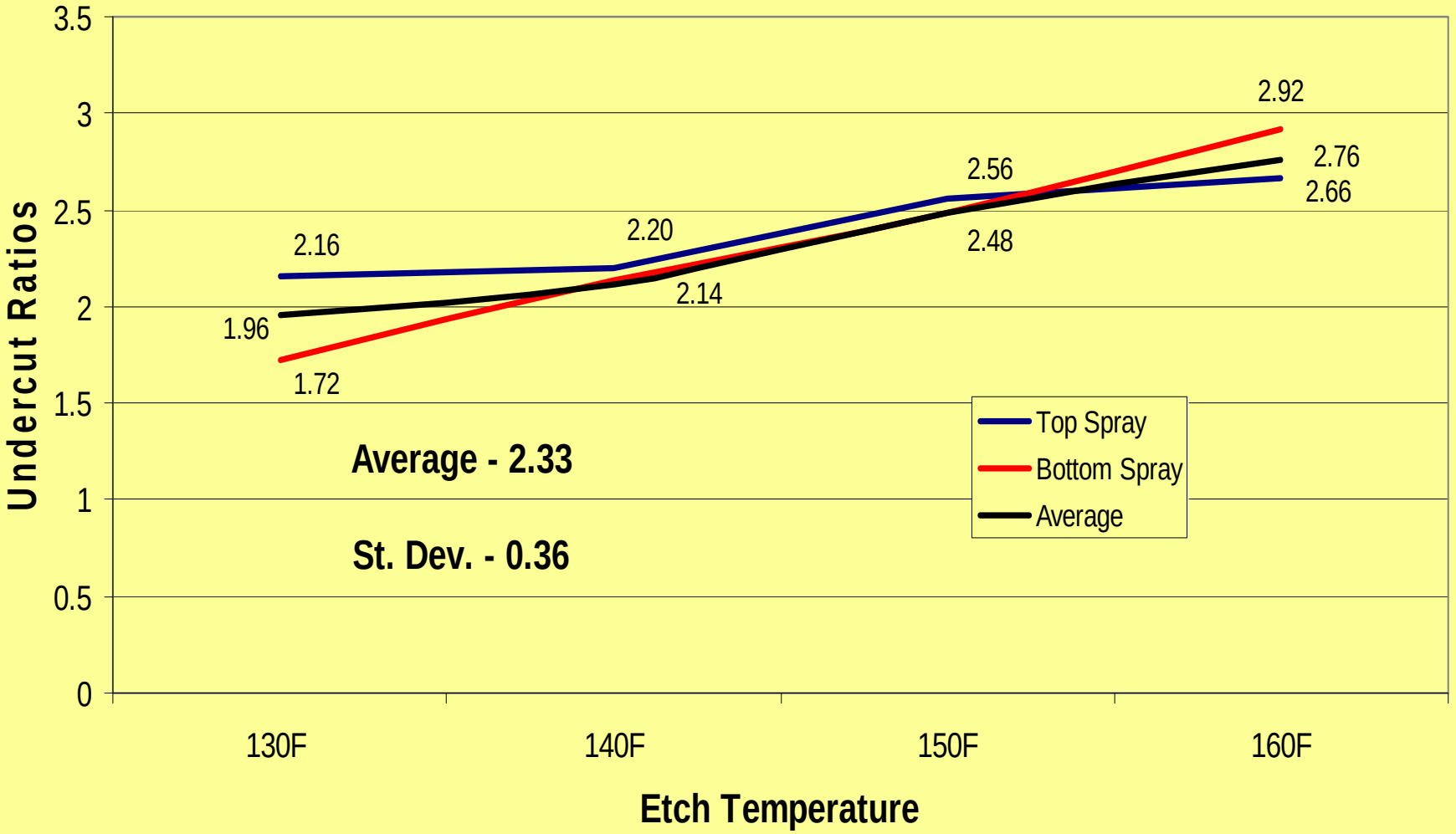
304 SST Undercut Ratios



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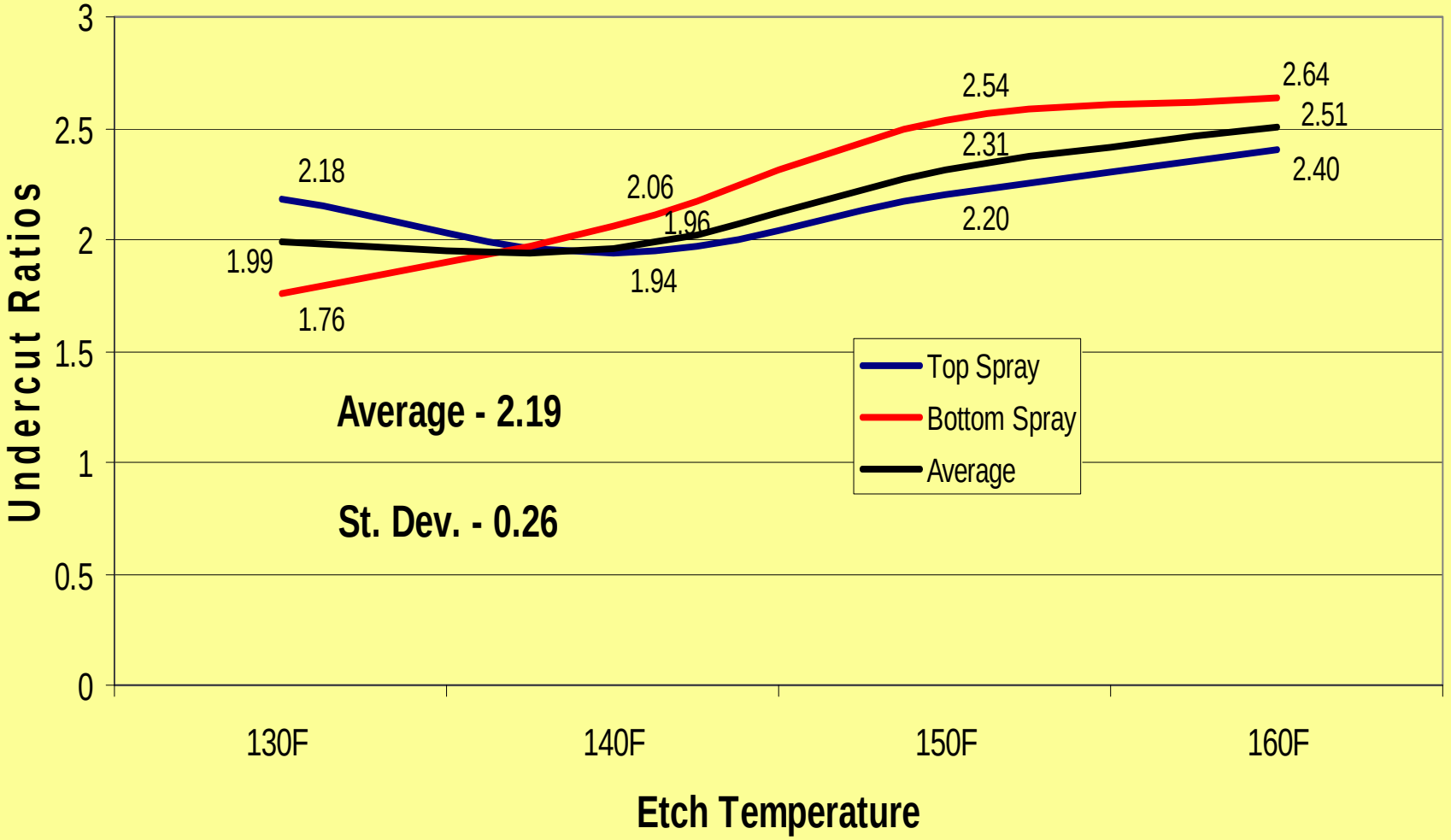
316 SST Undercut Ratios



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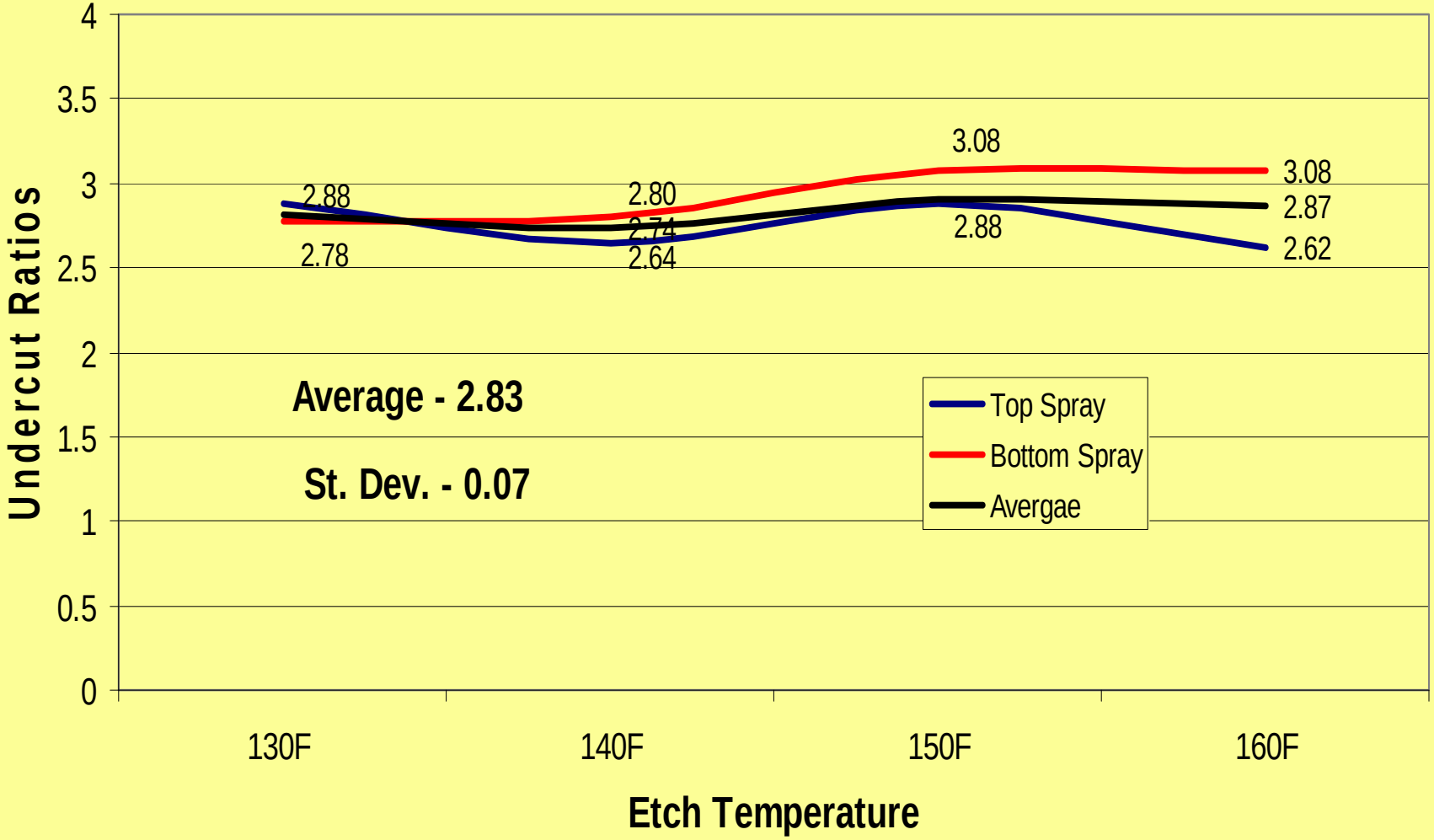
410 SST Undercut Ratios



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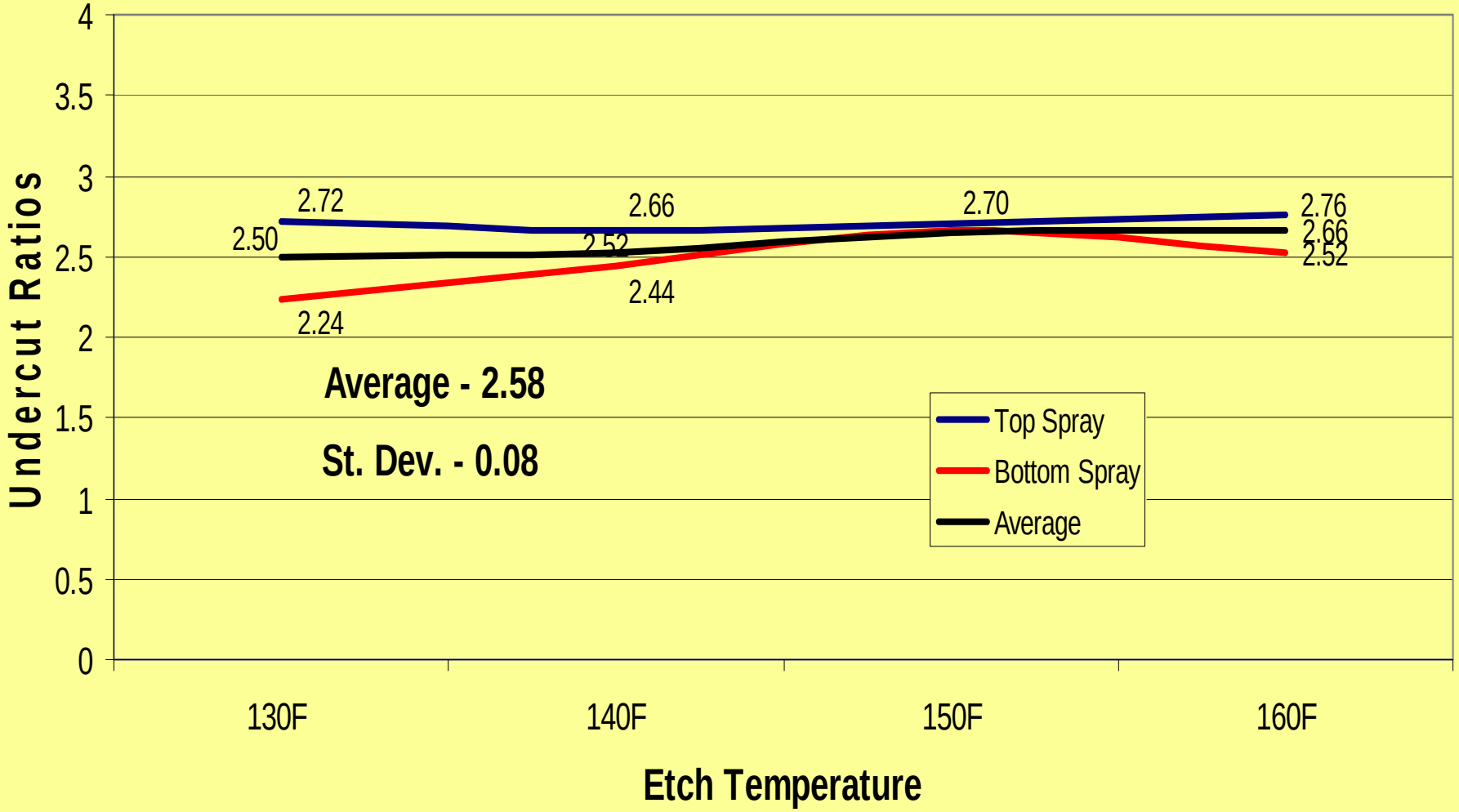
430 SST Undercut Ratios



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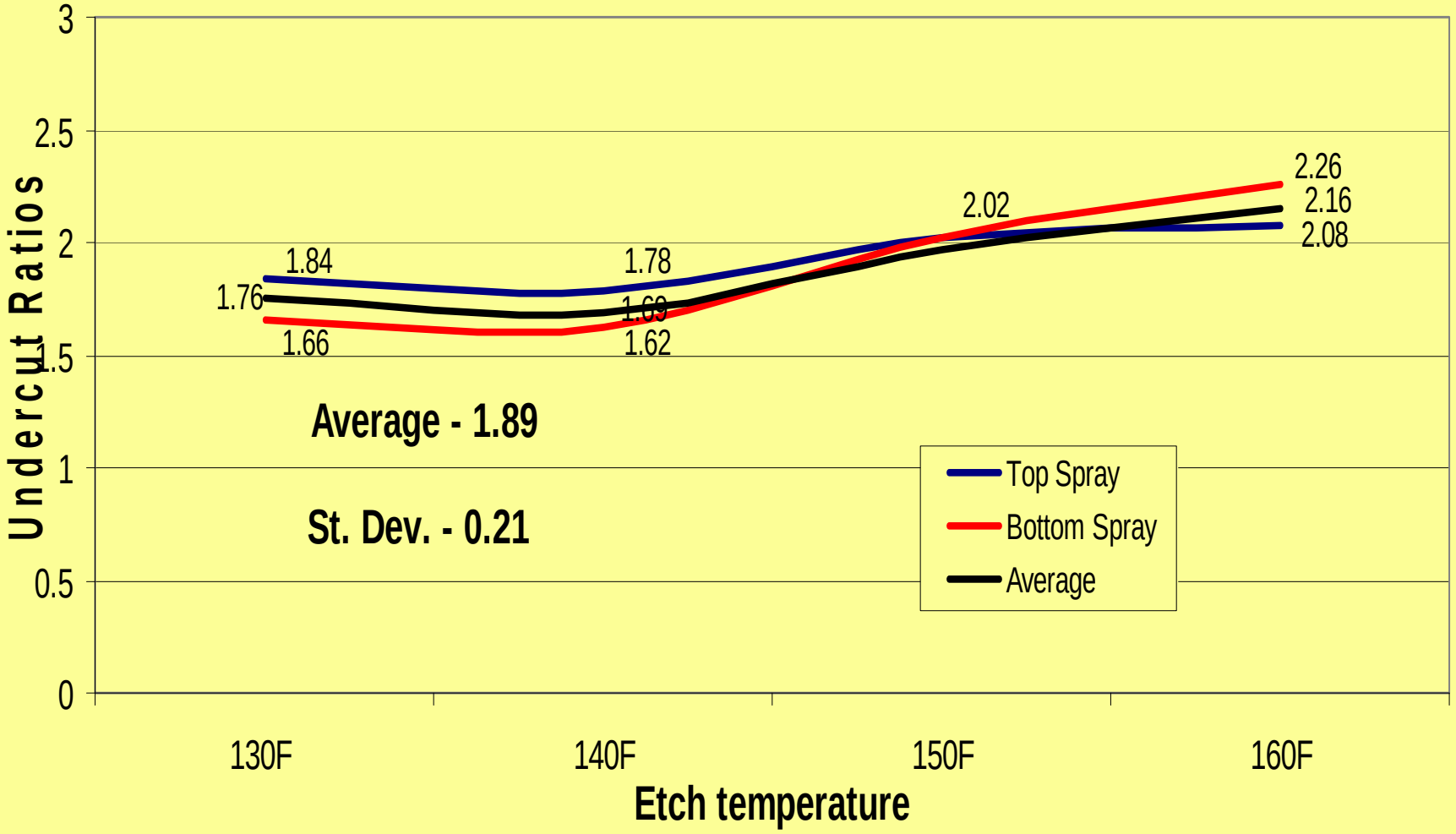
Kovar Undercut Ratios



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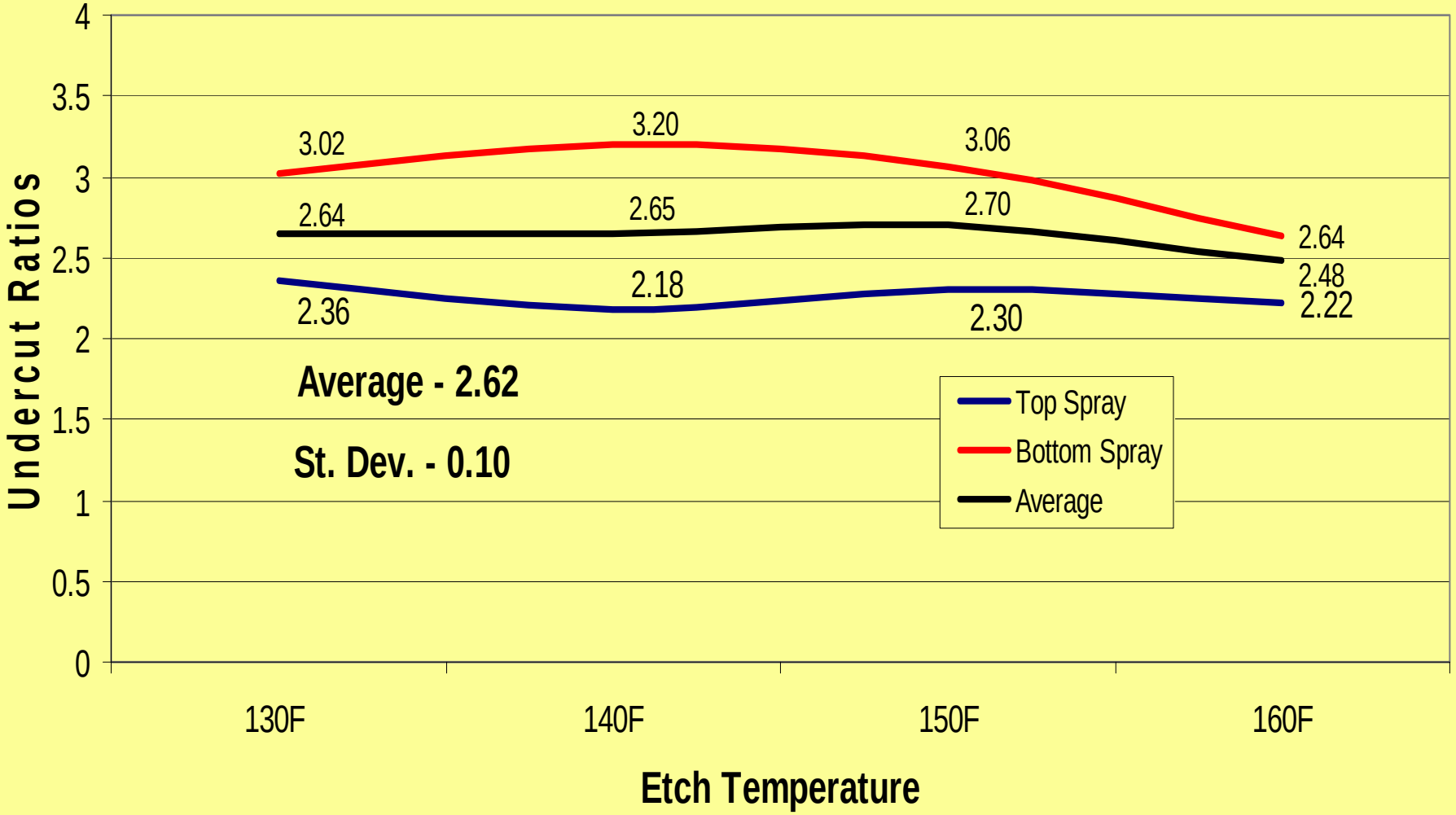
Brass Undercut Ratios



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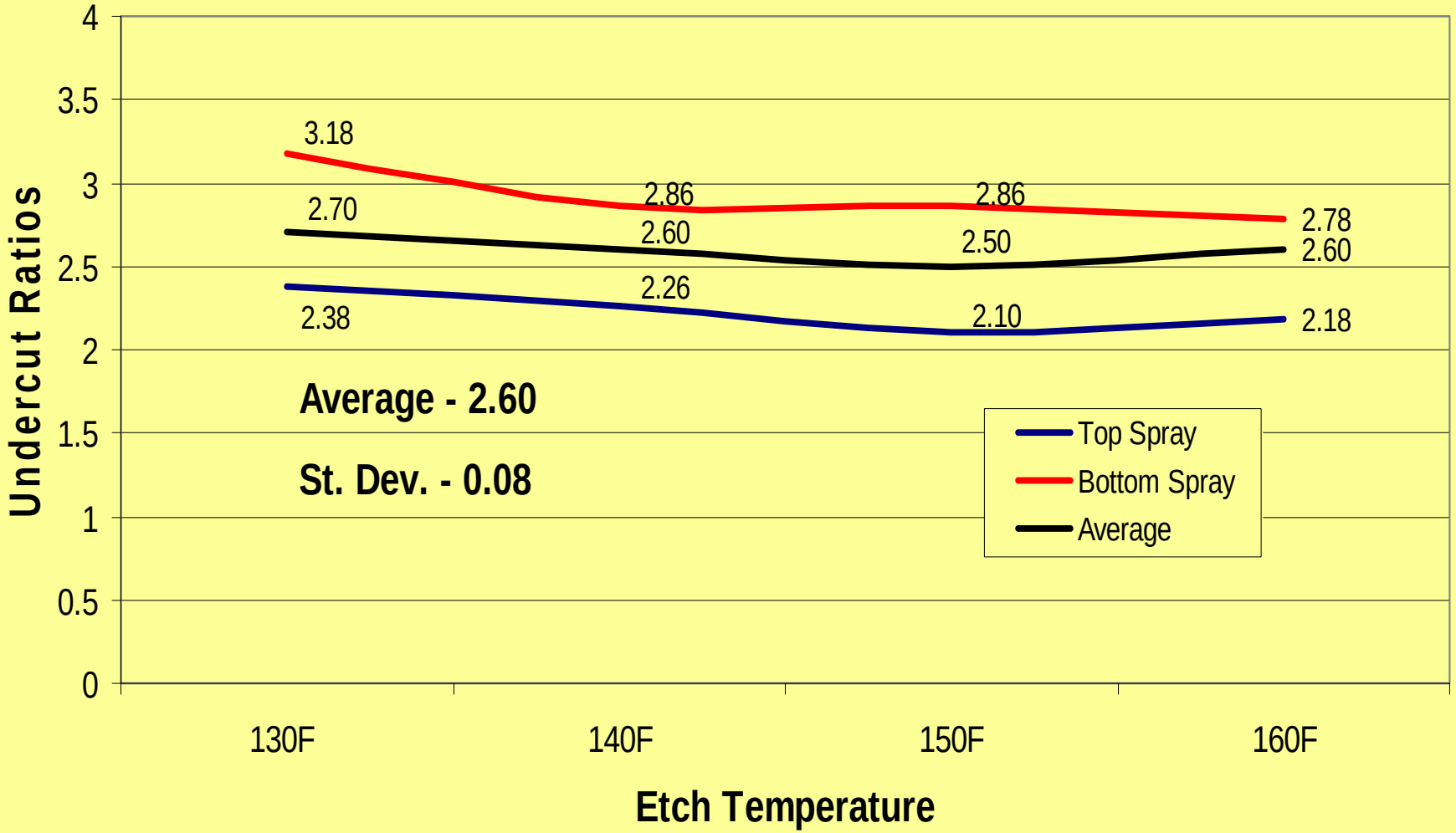
Copper Undercut Ratios



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

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Discussion

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

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High Temperature Ferric Chloride Etching

An Evaluation of the Process

Randy Markle

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