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High Temperature Ferric Chloride Etching

An Evaluation of the Process

Randy Markle

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Materials

- 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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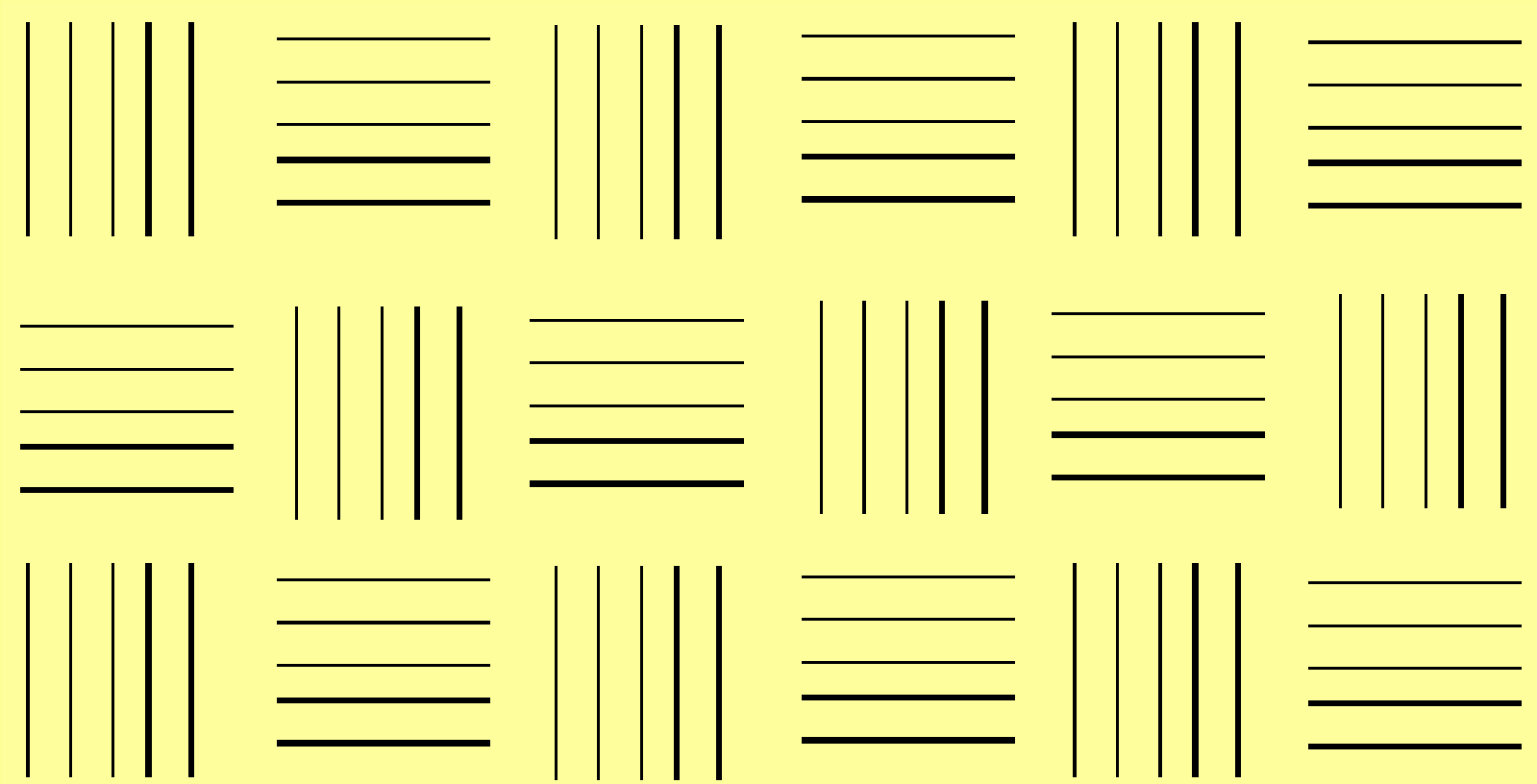
Test Image



Process Steps

- Shear to size
  15.2 x 15.2 cm (6” x 6”)
- 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 – 29.4°C (85°F)
- Spray Pressure – 2.1 bars (30psi)
- Conveyor Speed – 1.8 m/min (72ipm)
- Dwell Time – 35 seconds

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Model 2315

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Etching Parameters

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

Stripping

- Chemcut CC8000 Stripping System
- RD-56 from RD Chemicals – 10% solution
- Temperature – 54.4°C (130°F)
- Spray Pressure – 2.1 bars (30psi)
- Conveyor Speed – 45.7 cm/min (18ipm)
- Stripping Time – 2.0 minutes

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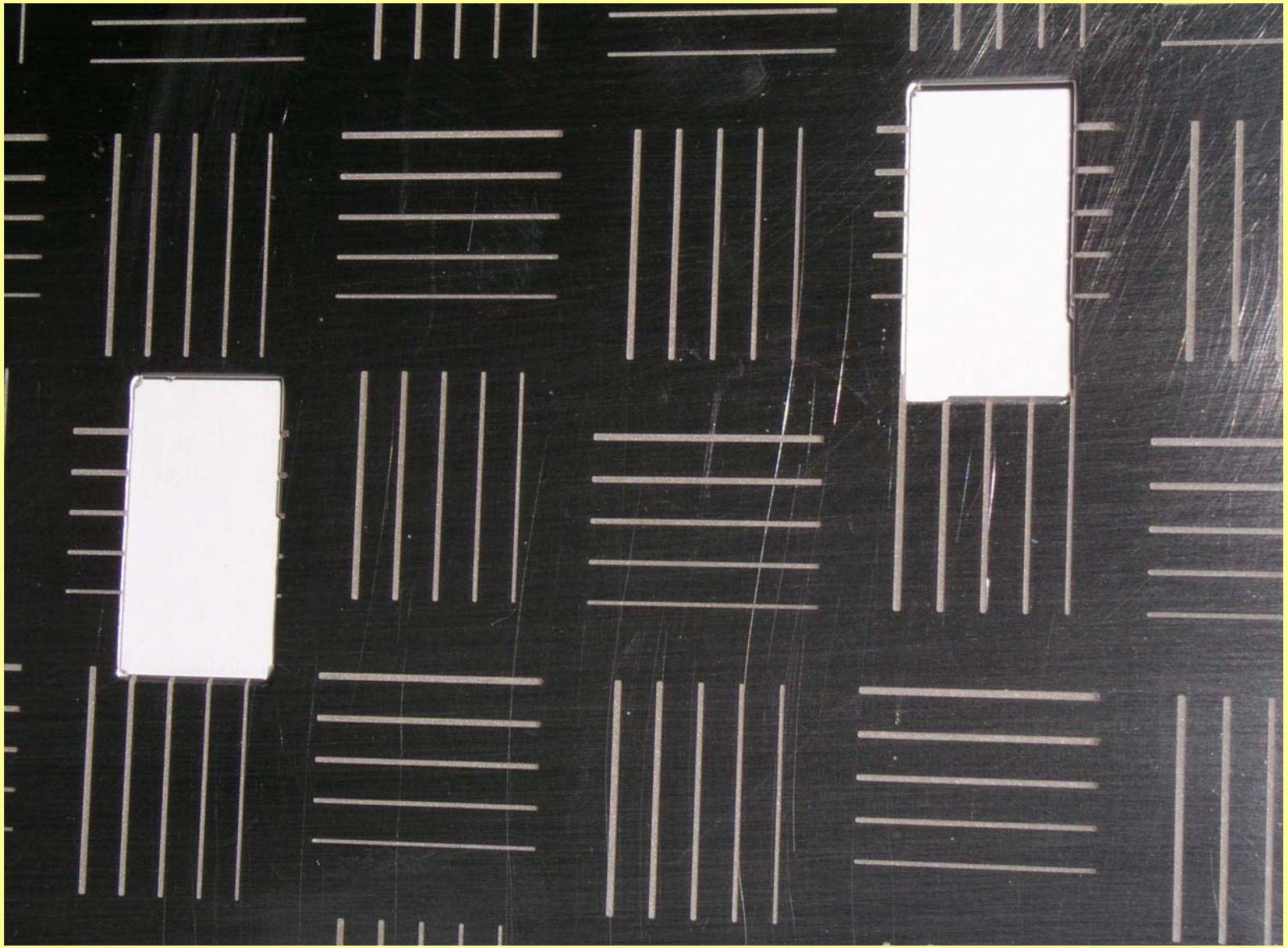

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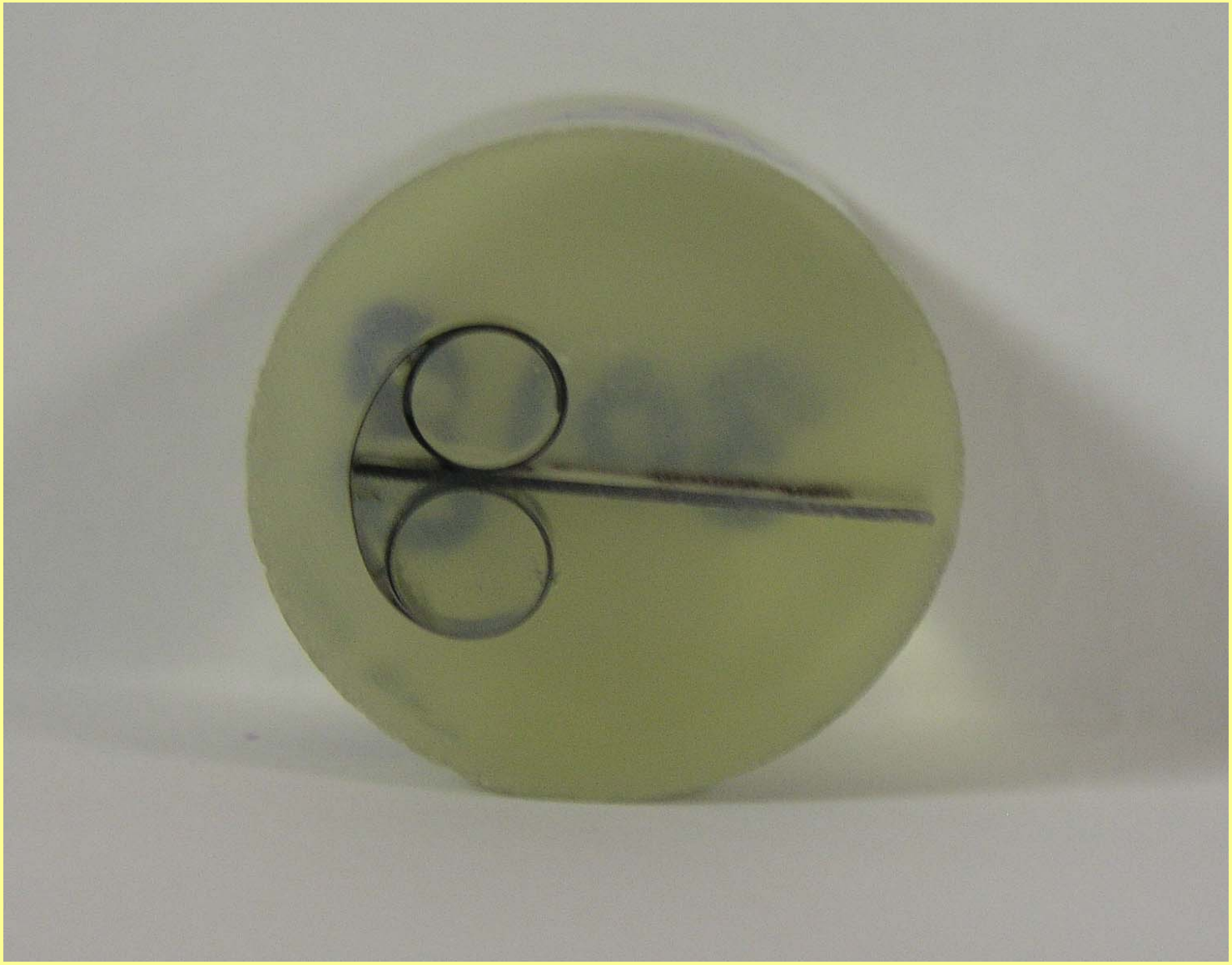

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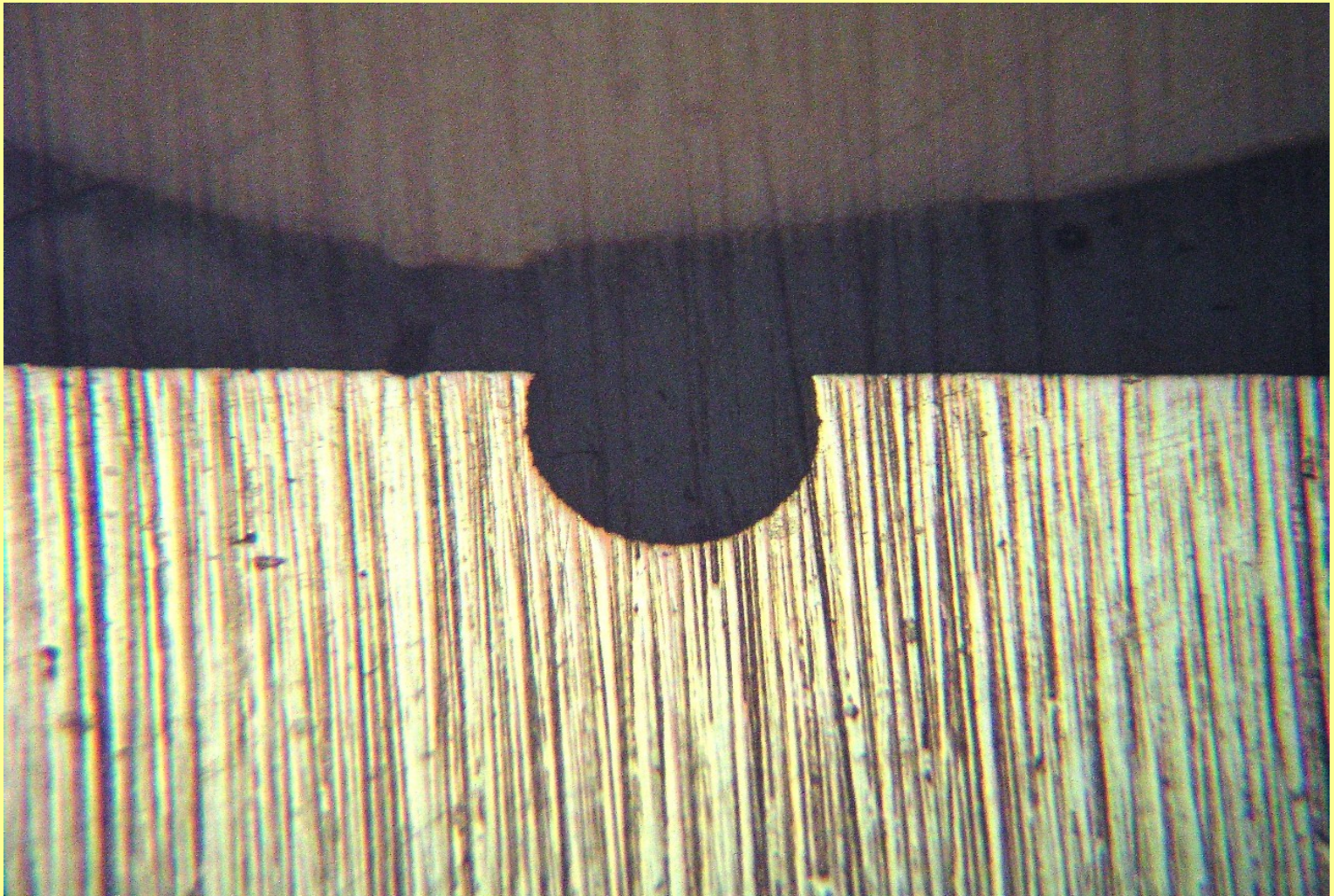
127µ (5.0-mil) line
410 Stainless Steel



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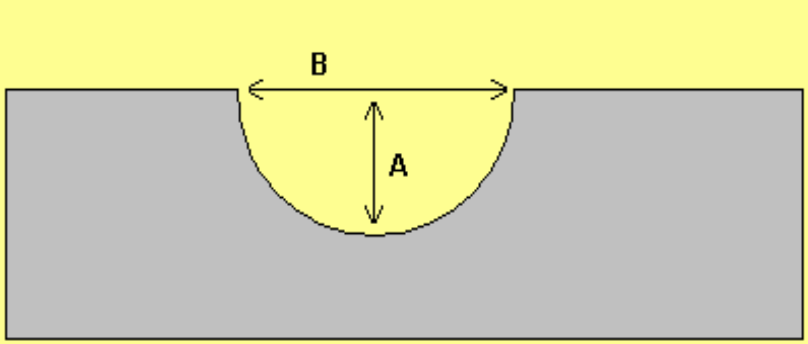
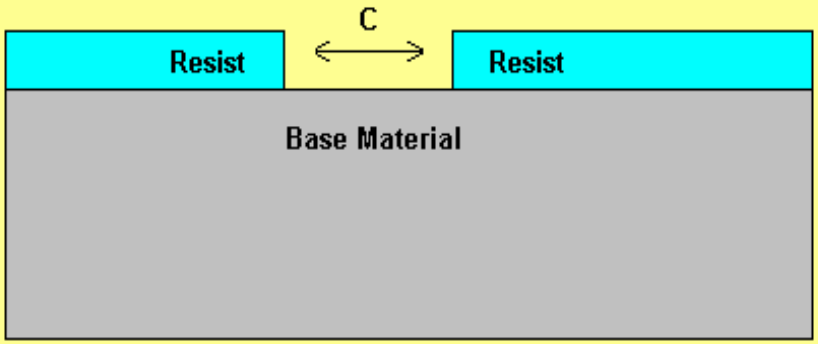
Calculations from Measurements

Etch Rate = A/Etch Time





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

100/UR = % Undercut

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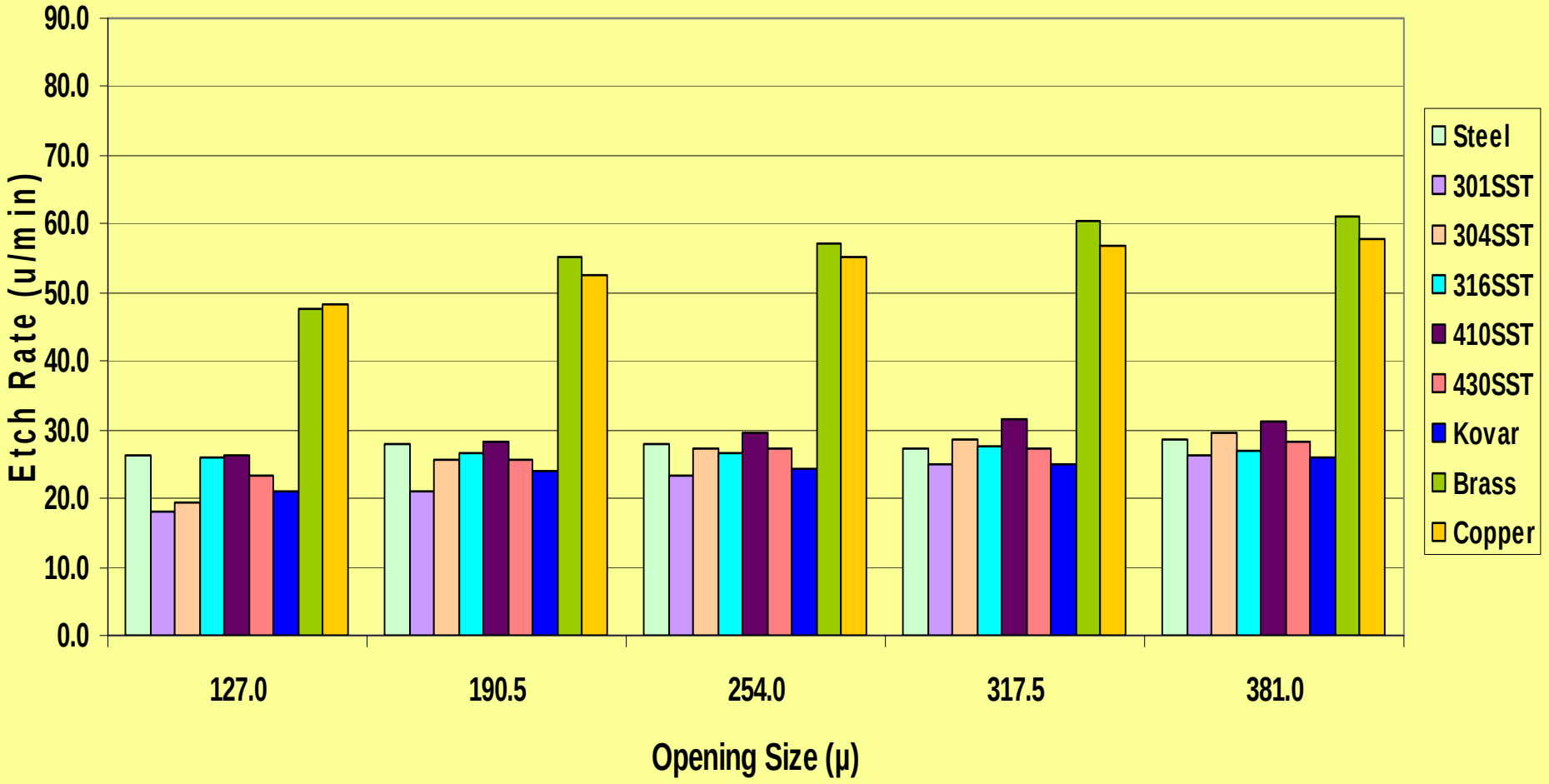
Top Etch Rate - 54.4ºC (130ºF)



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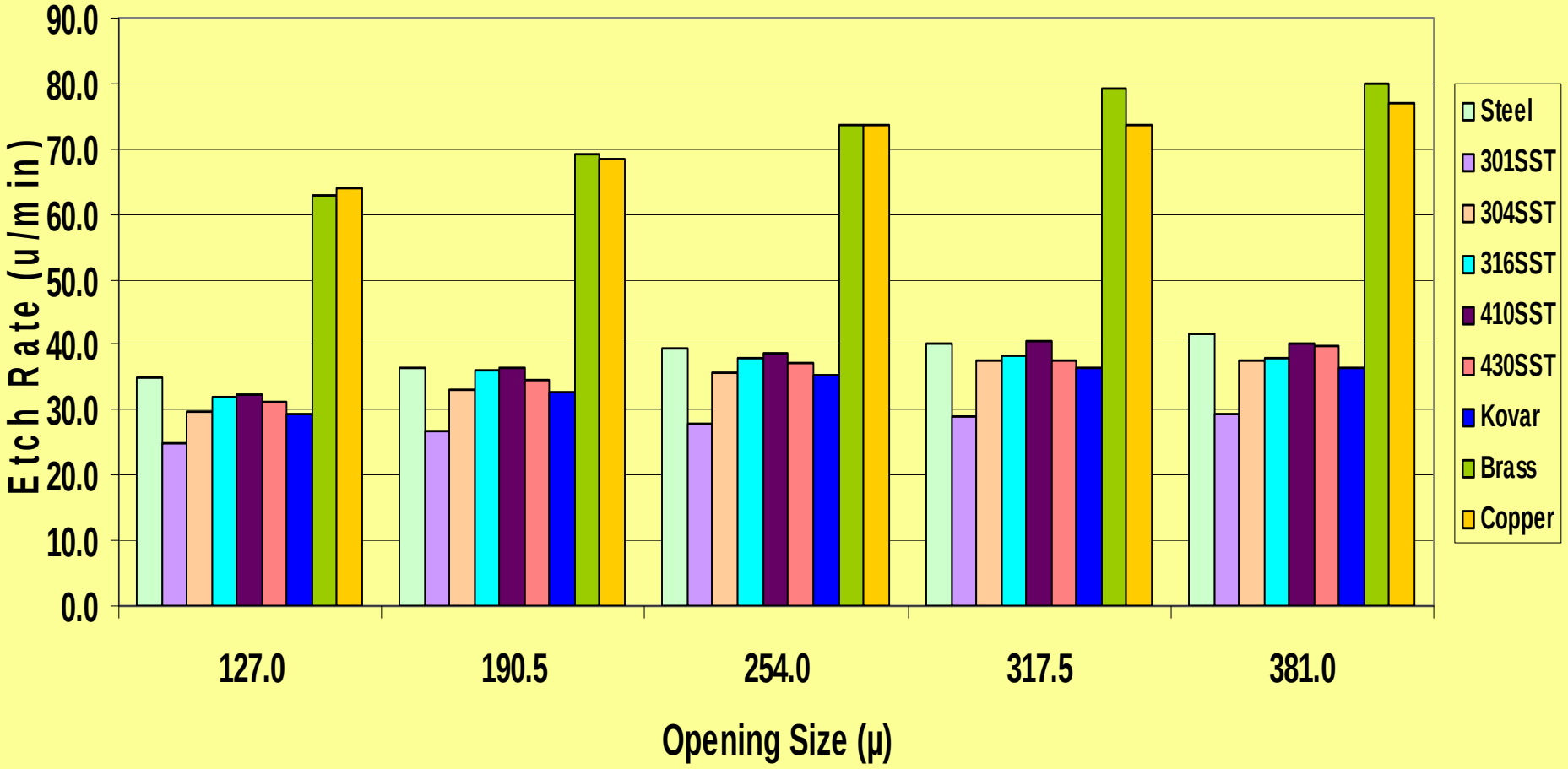
Top Etch Rate - 71.1ºC (160ºF)



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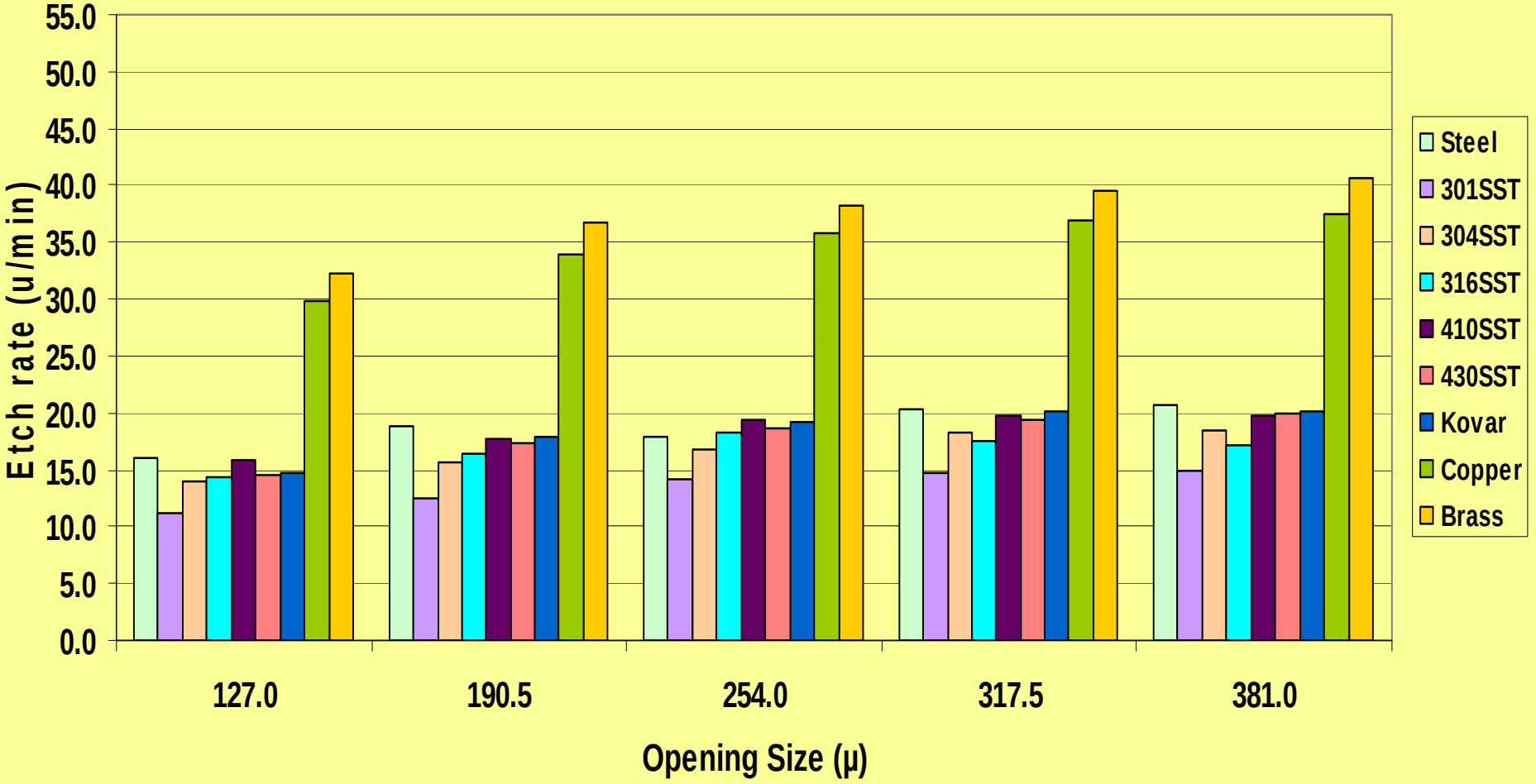
Bottom Etch Rate - 54.4ºC (130ºF)



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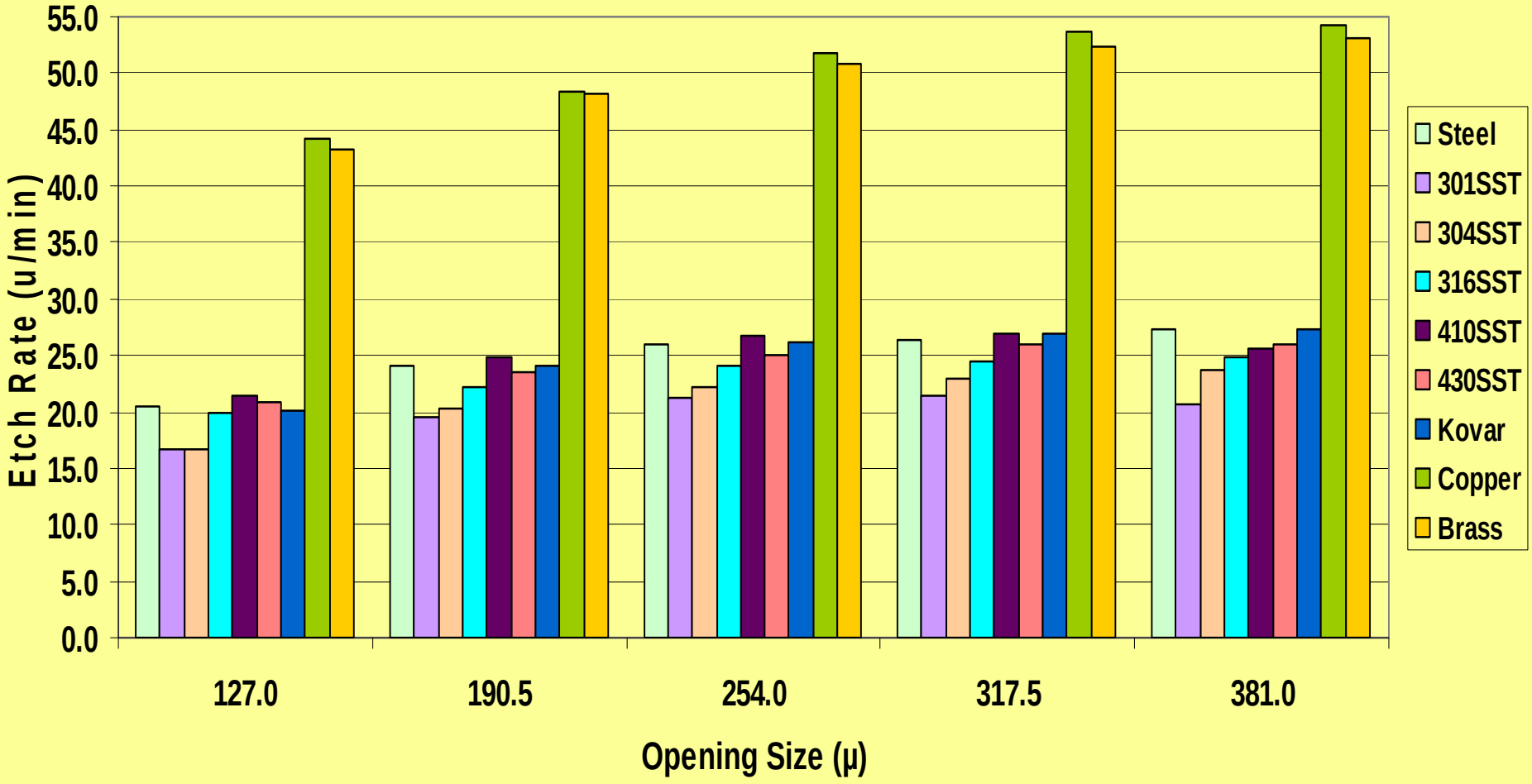
Bottom Etch Rate - 71.1ºC (160ºF)



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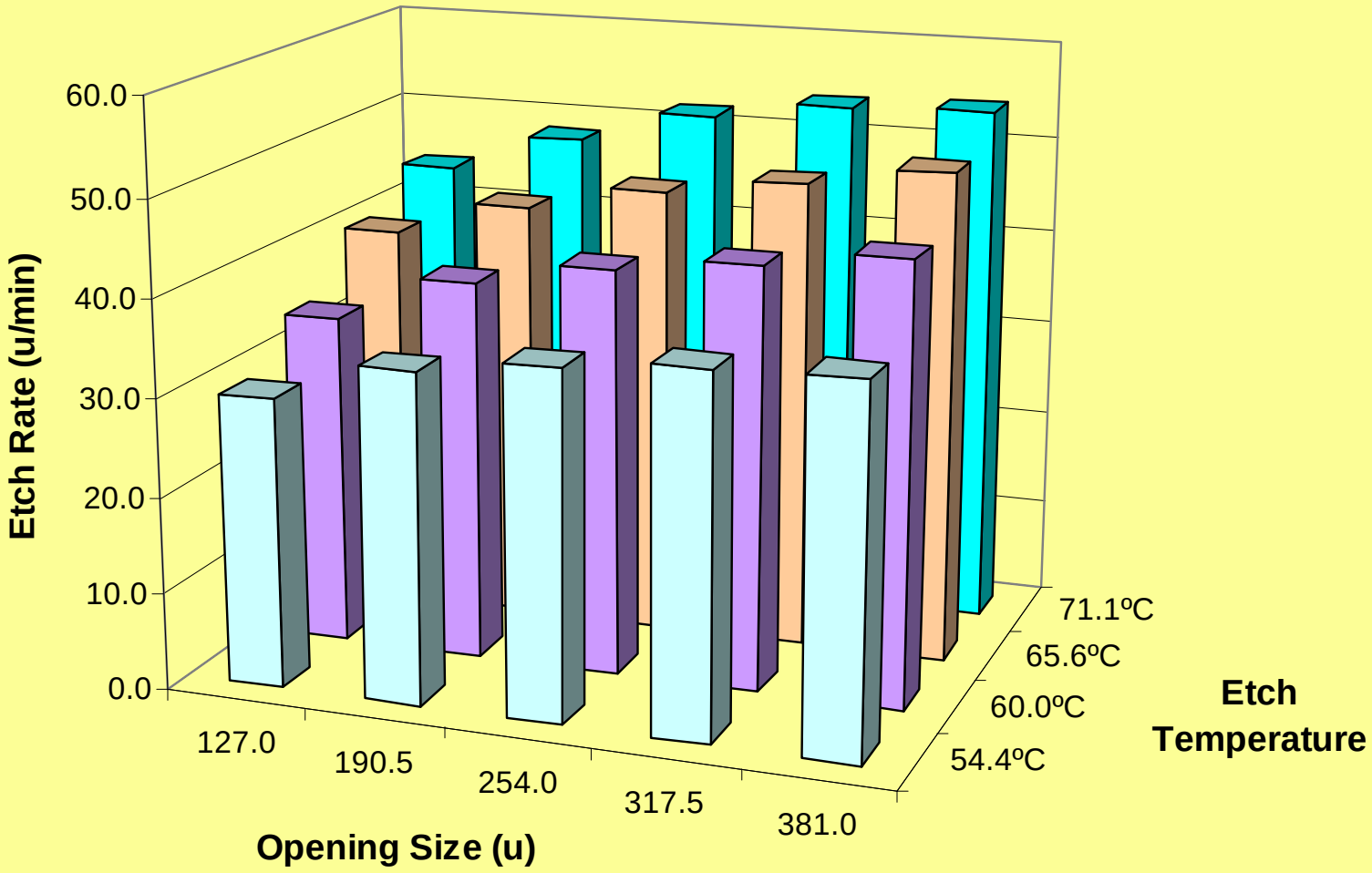
Copper - Bottom Etch Rate



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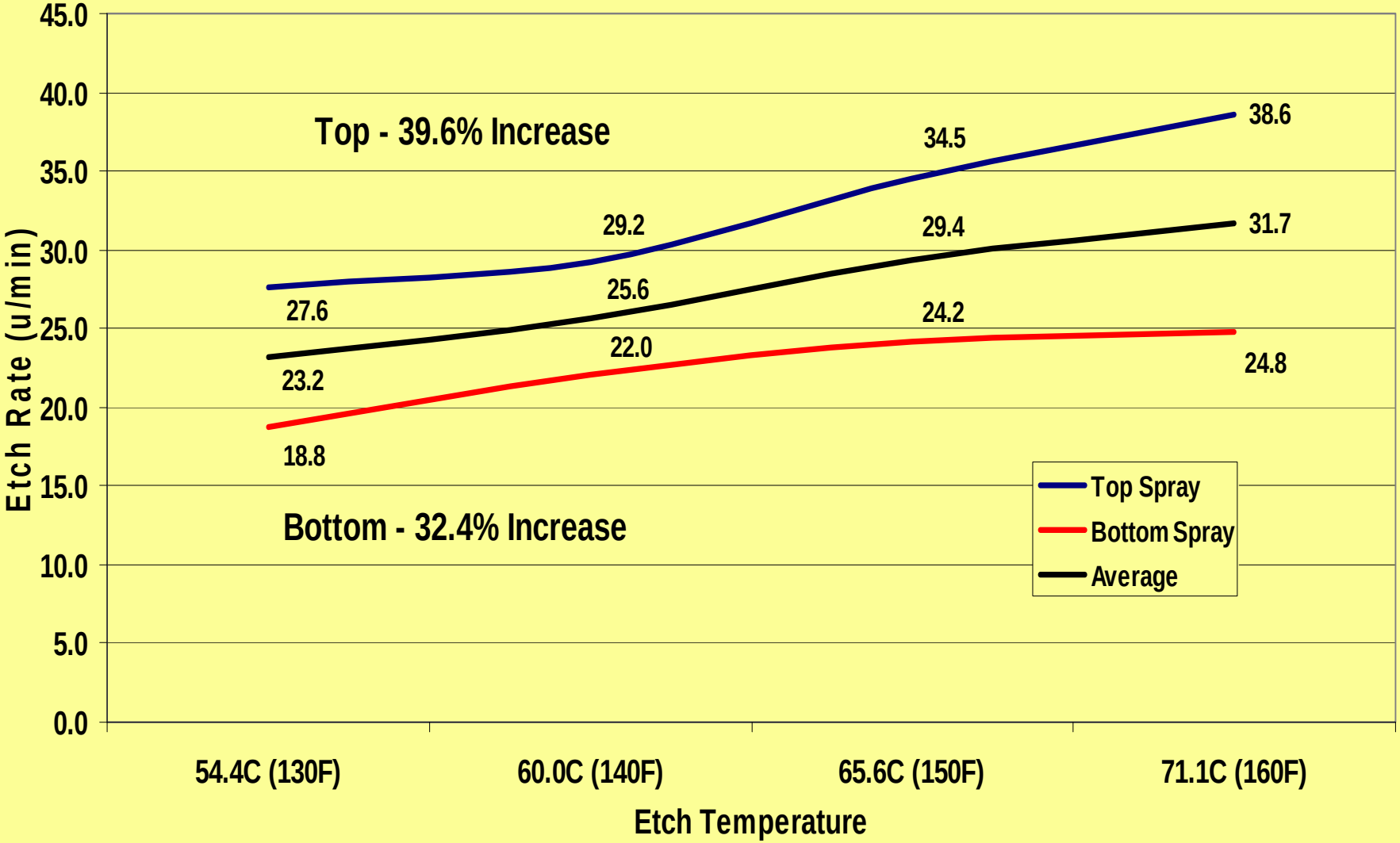
Steel Etch Rates

Average Increase - 36.0%, 0.55µ/1°C



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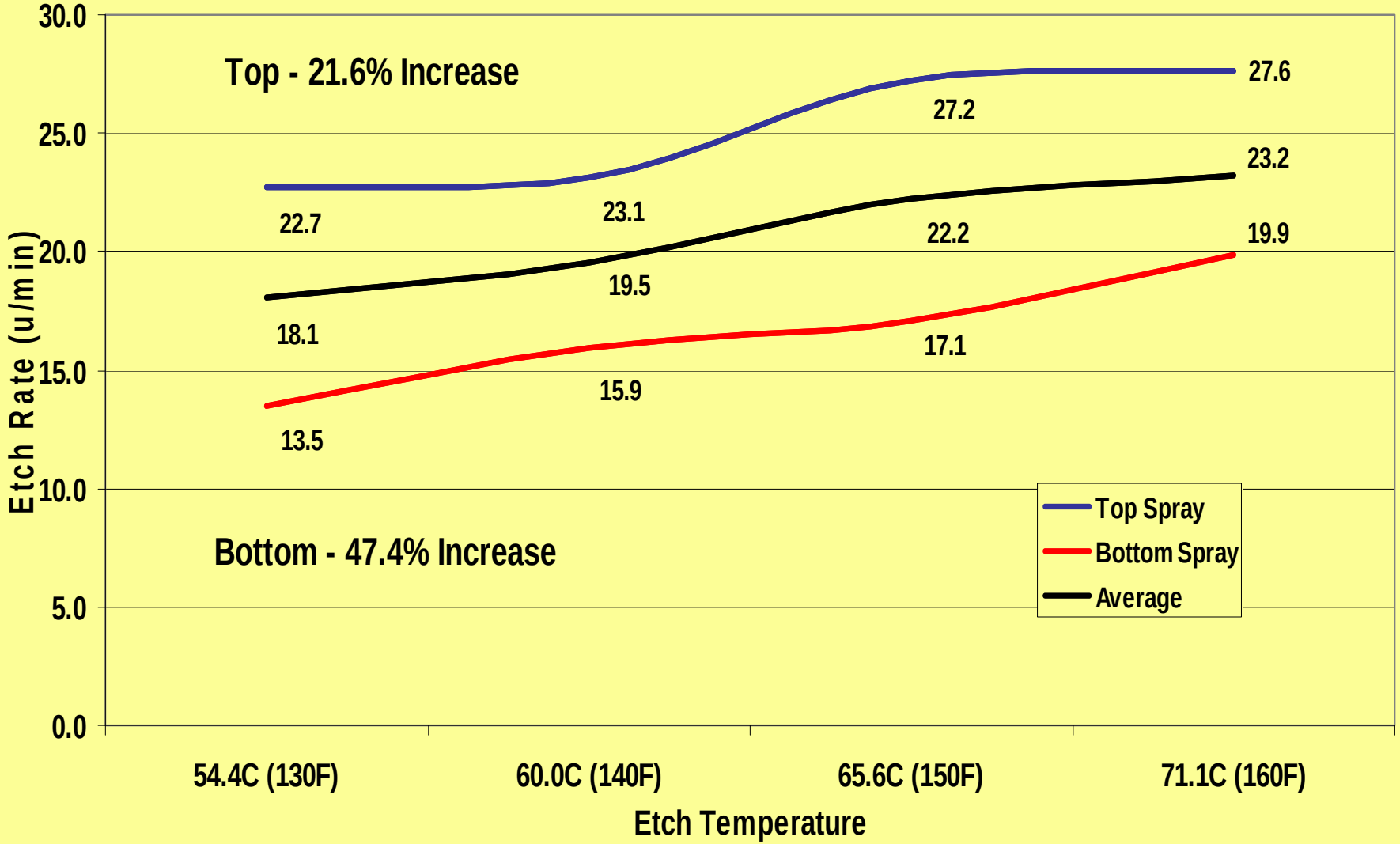
301 SST Etch Rates

Average Increase - 34.5%, 0.35µ/1°C



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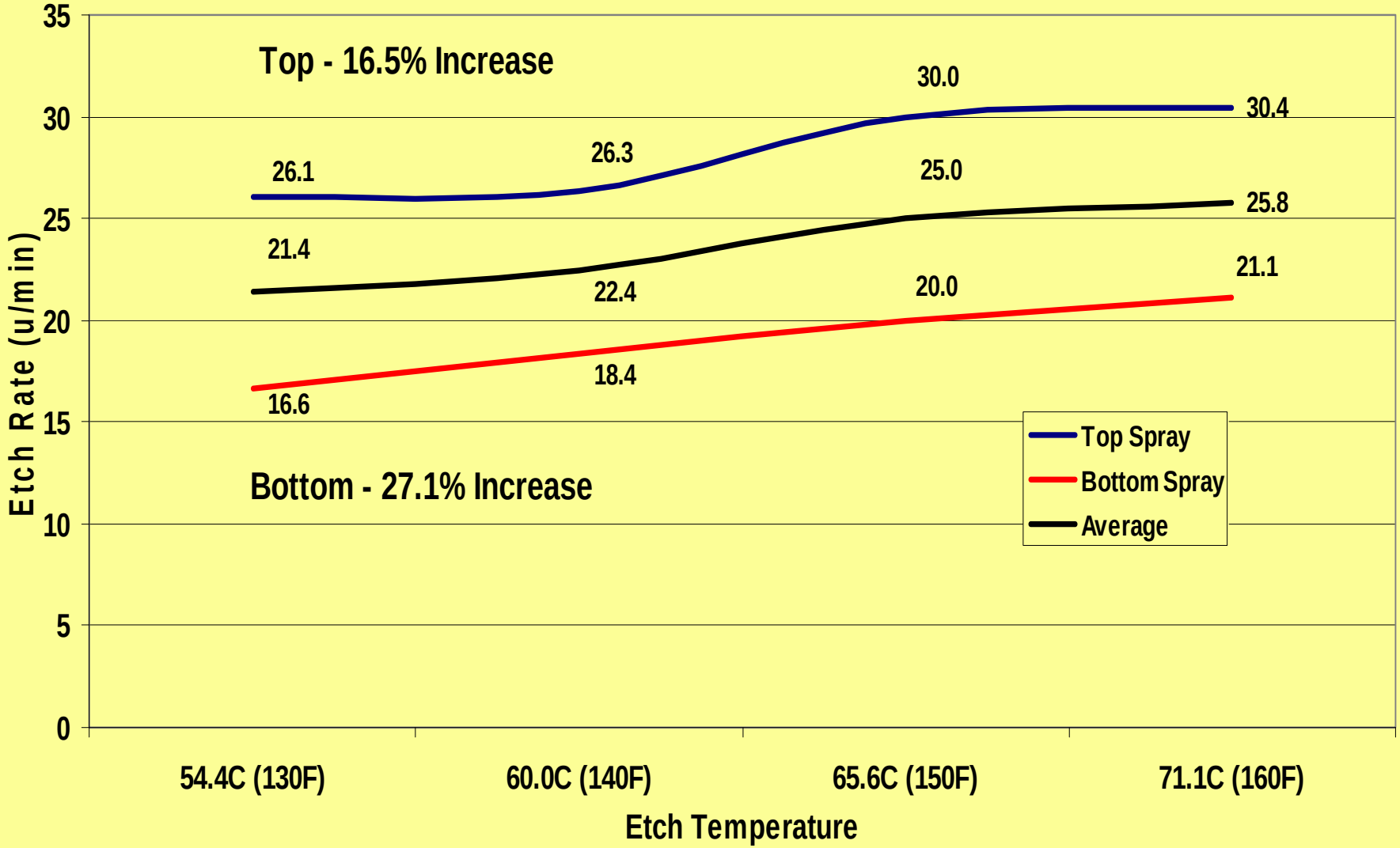
304 SST Etch Rates

Average Increase - 21.8%, 0.3µ/1°C



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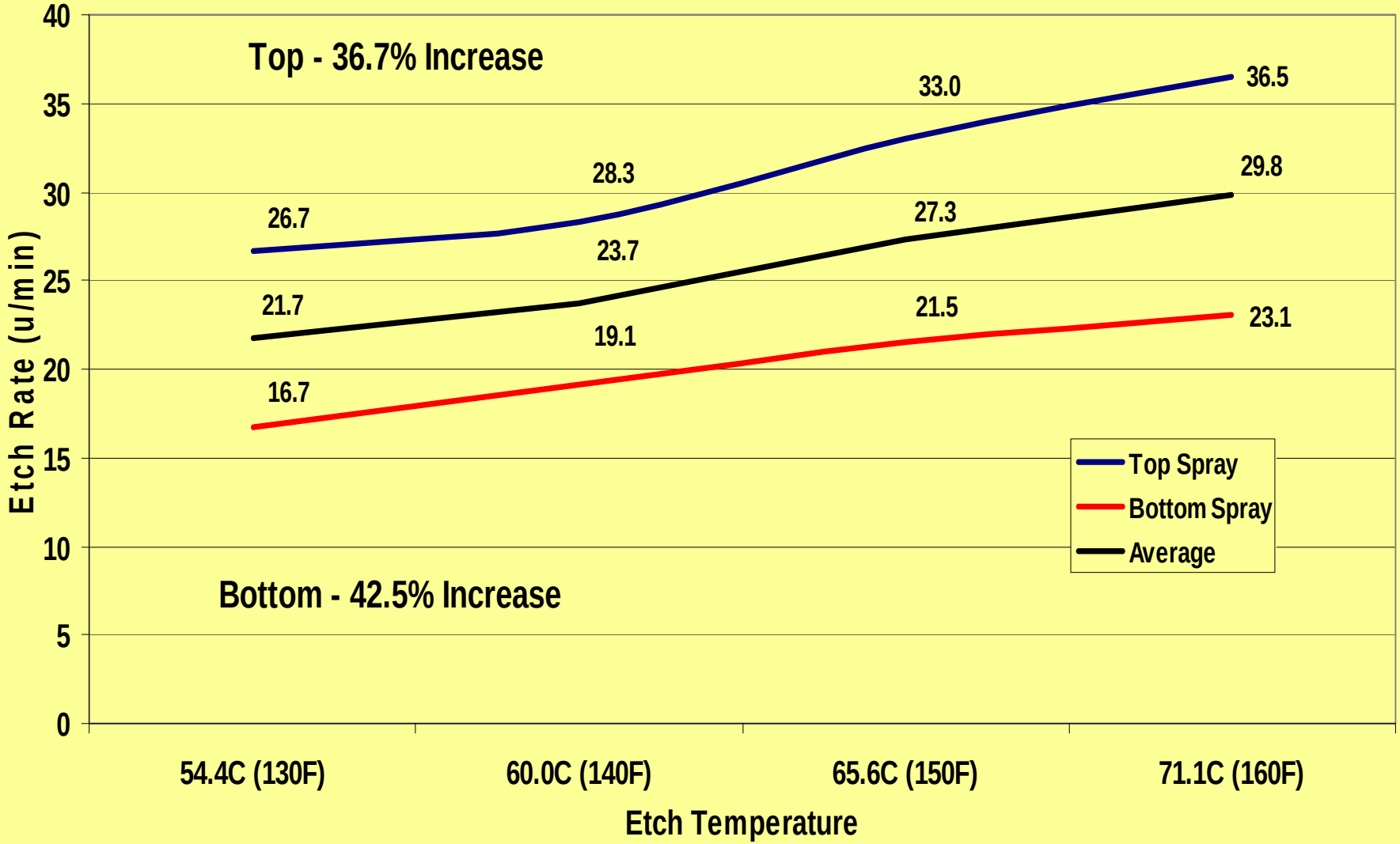
316 SST Etch Rates

Average Increase - 39.6%, 0.5µ/1ºC



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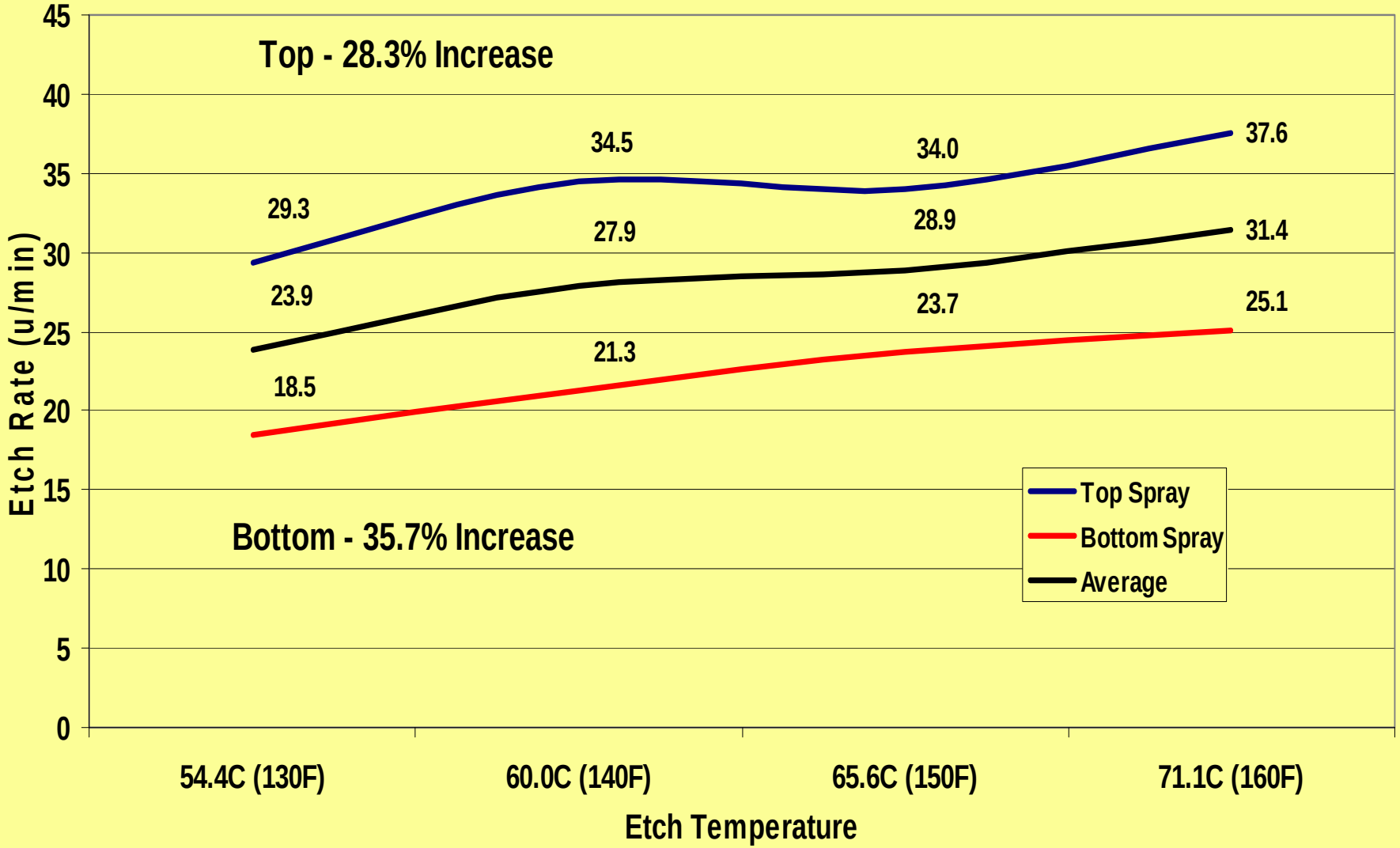
410 SST Etch Rates

Average Increase - 32.0%, 0.45µ/1°C



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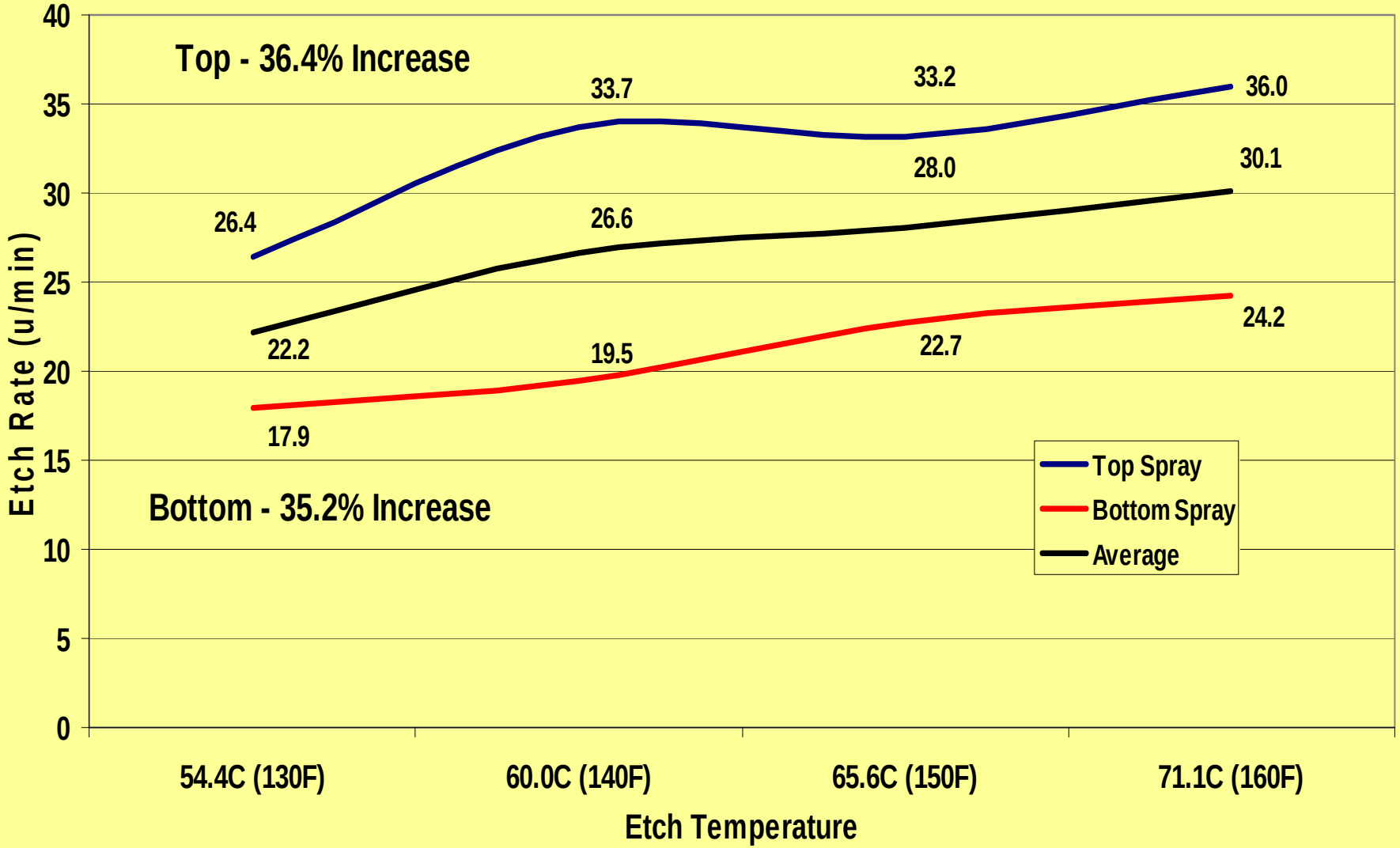
430 SST Etch Rates

Average Increase - 35.8%, 0.5µ/1ºC



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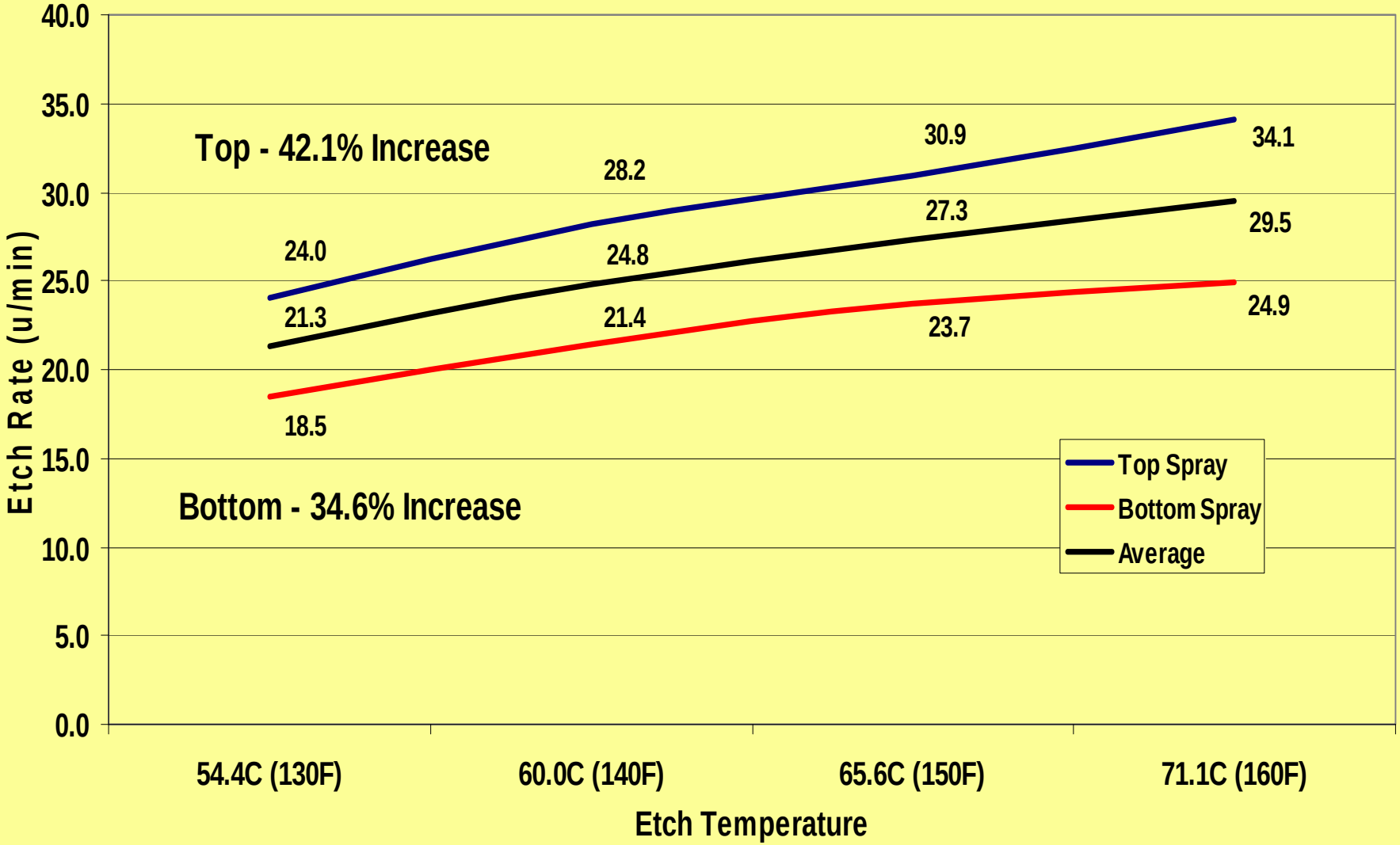
Kovar Etch Rates
Average Increase - 38.4%, 0.5µ/1°C



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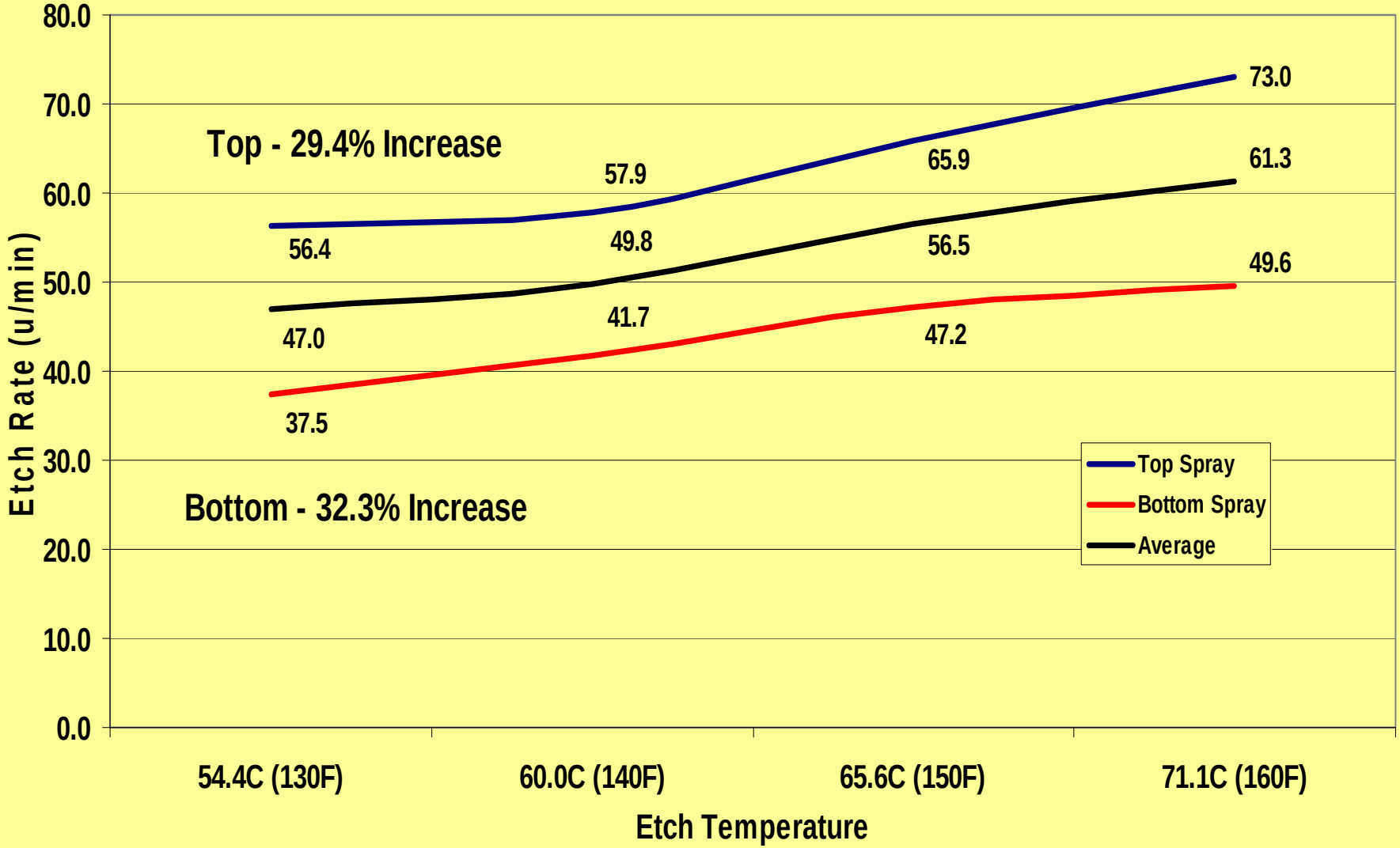
Brass Etch Rate

Average Increase - 30.9%, 0.85µ/1°C



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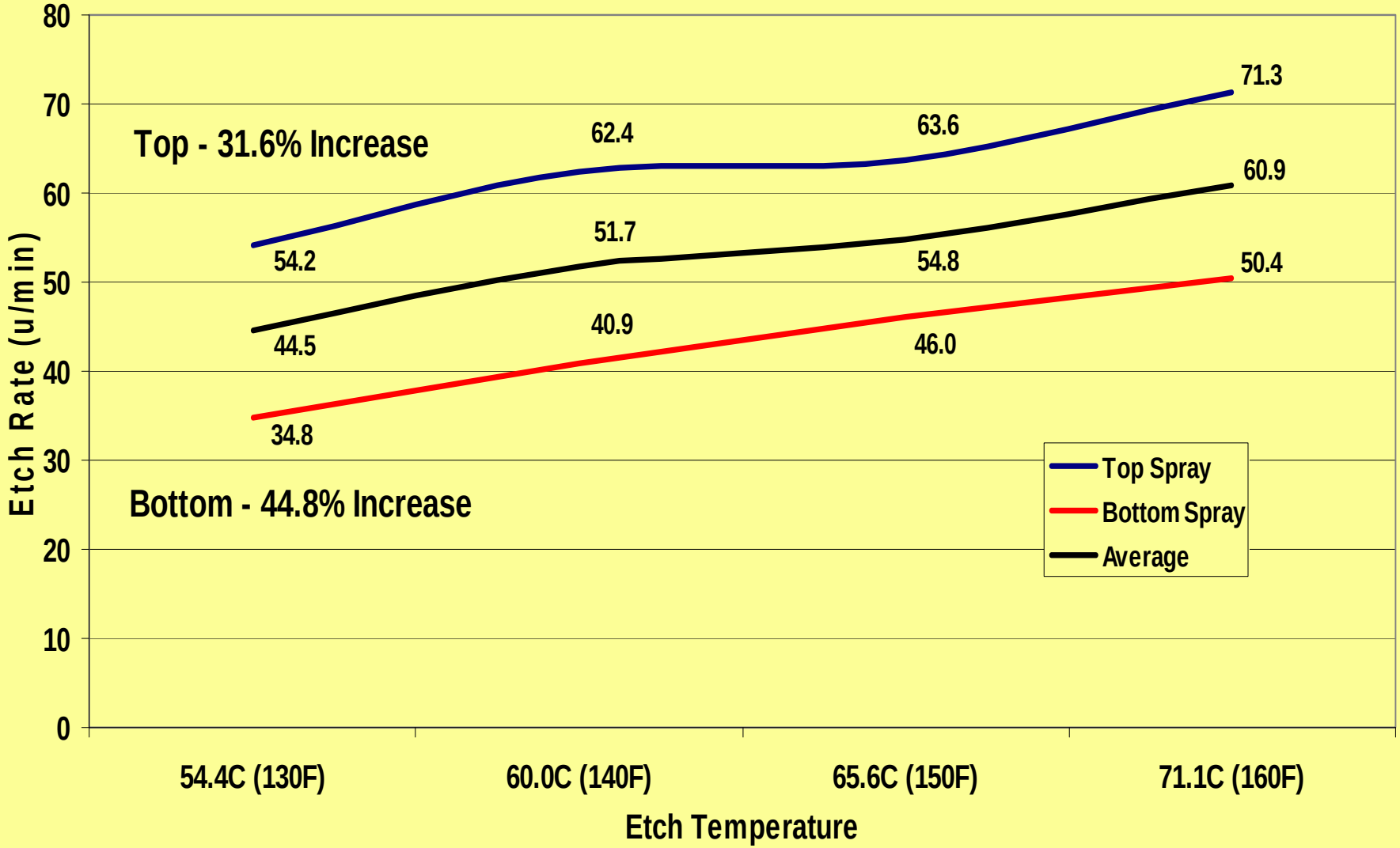
Copper Etch Rates

Average Increase - 38.2%, 0.95µ/1°C



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Top Spray

	Top - Etch Rate Increase from 54.4ºC to 71.1ºC					
		Opening Size in Microns				Average
Material	127u	190.5u	254u	317.5u	381u	Increase
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%

Bottom Spray

	Bottom - Etch Rate Increase from 54.4ºC to 71.1ºC					
		Opening Size in Microns				Average
Material	127u	190.5u	254u	317.5u	381u	Increase
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%

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Top Spray

	Top - Etch Rate Increase from 54.4ºC to 71.1ºC					
		Opening Size in Microns				Average
Material	127u	190.5u	254u	317.5u	381u	Increase
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%
Steel	33.1%	30.2%	39.9%	47.3%	46.7%	39.4%
Kovar	38.7%	36.4%	45.1%	46.4%	41.9%	41.7%

Bottom Spray

	Bottom - Etch Rate Increase from 54.4ºC to 71.1ºC					
		Opening Size in Microns				Average
Material	127u	190.5u	254u	317.5u	381u	Increase
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%
Steel	27.5%	27.7%	45.0%	29.4%	31.9%	32.3%
Kovar	35.8%	34.1%	35.9%	33.2%	35.1%	34.8%

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Top Spray

	Top - Etch Rate Increase from 54.4ºC to 71.1ºC					
		Opening Size in Microns				Average
Material	127u	190.5u	254u	317.5u	381u	Increase
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%

Bottom Spray

	Bottom - Etch Rate Increase from 54.4ºC to 71.1ºC					
		Opening Size in Microns				Average
Material	127u	190.5u	254u	317.5u	381u	Increase
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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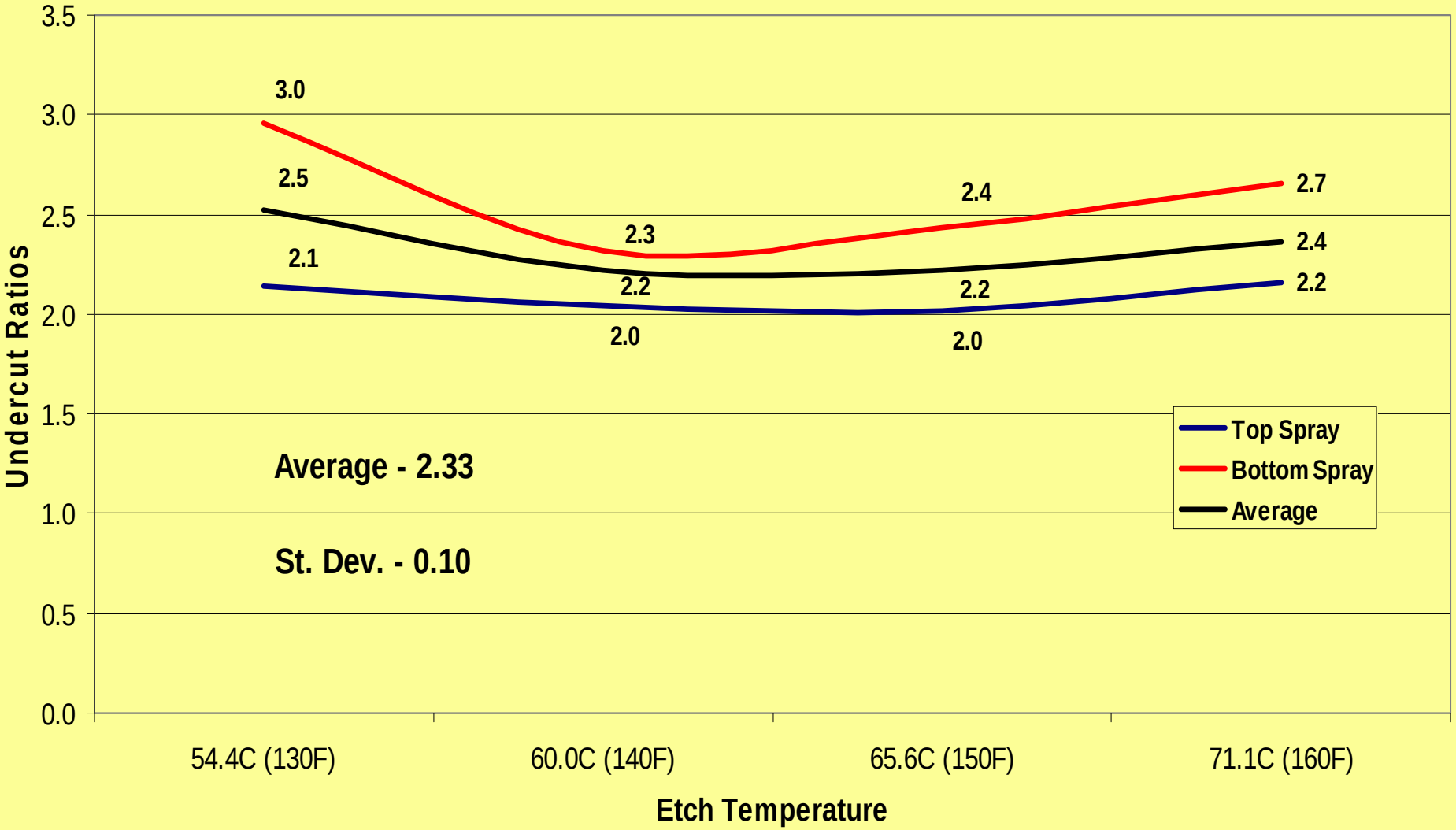
Steel Undercut Ratios



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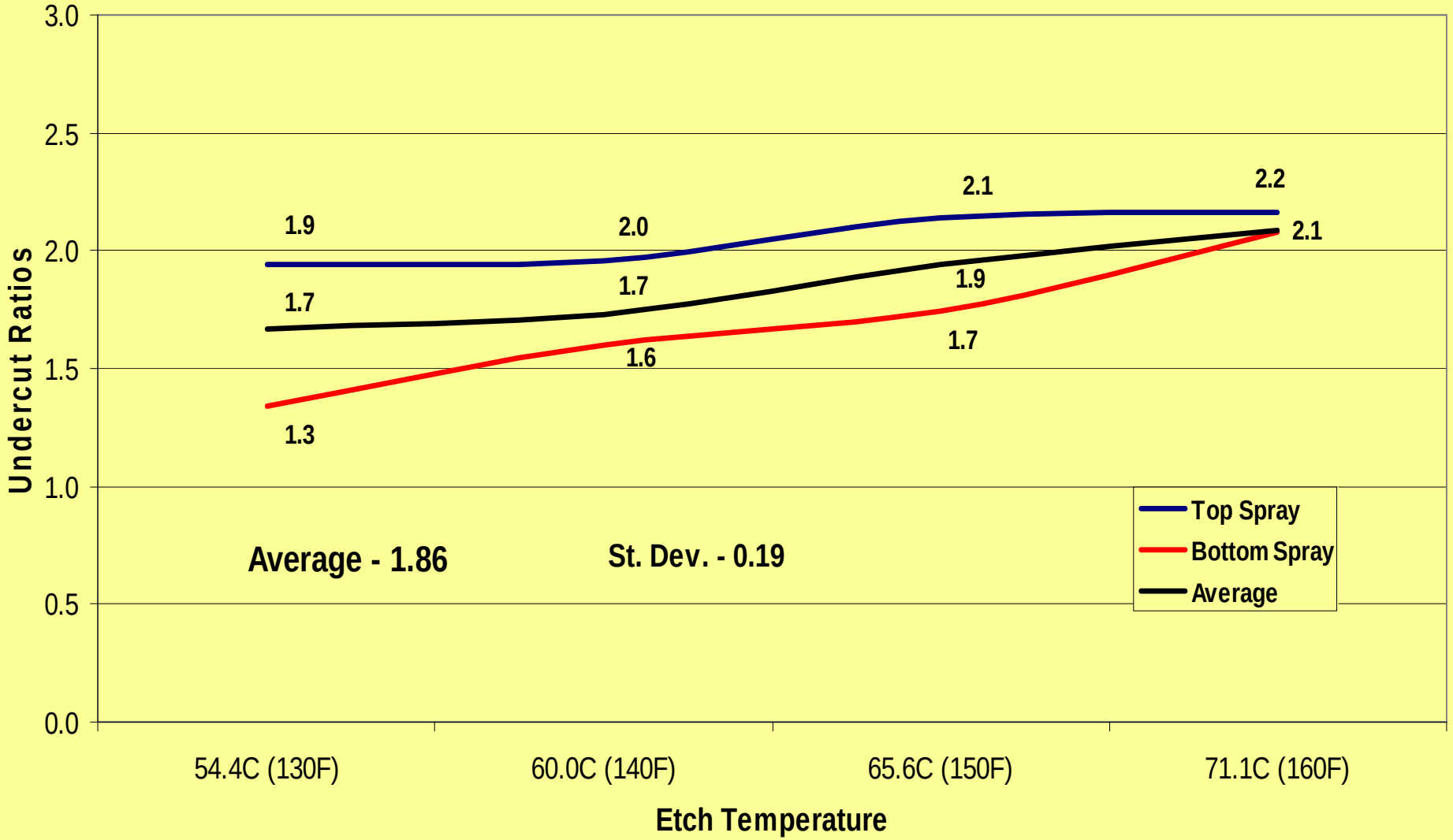
301 SST Undercut Ratios



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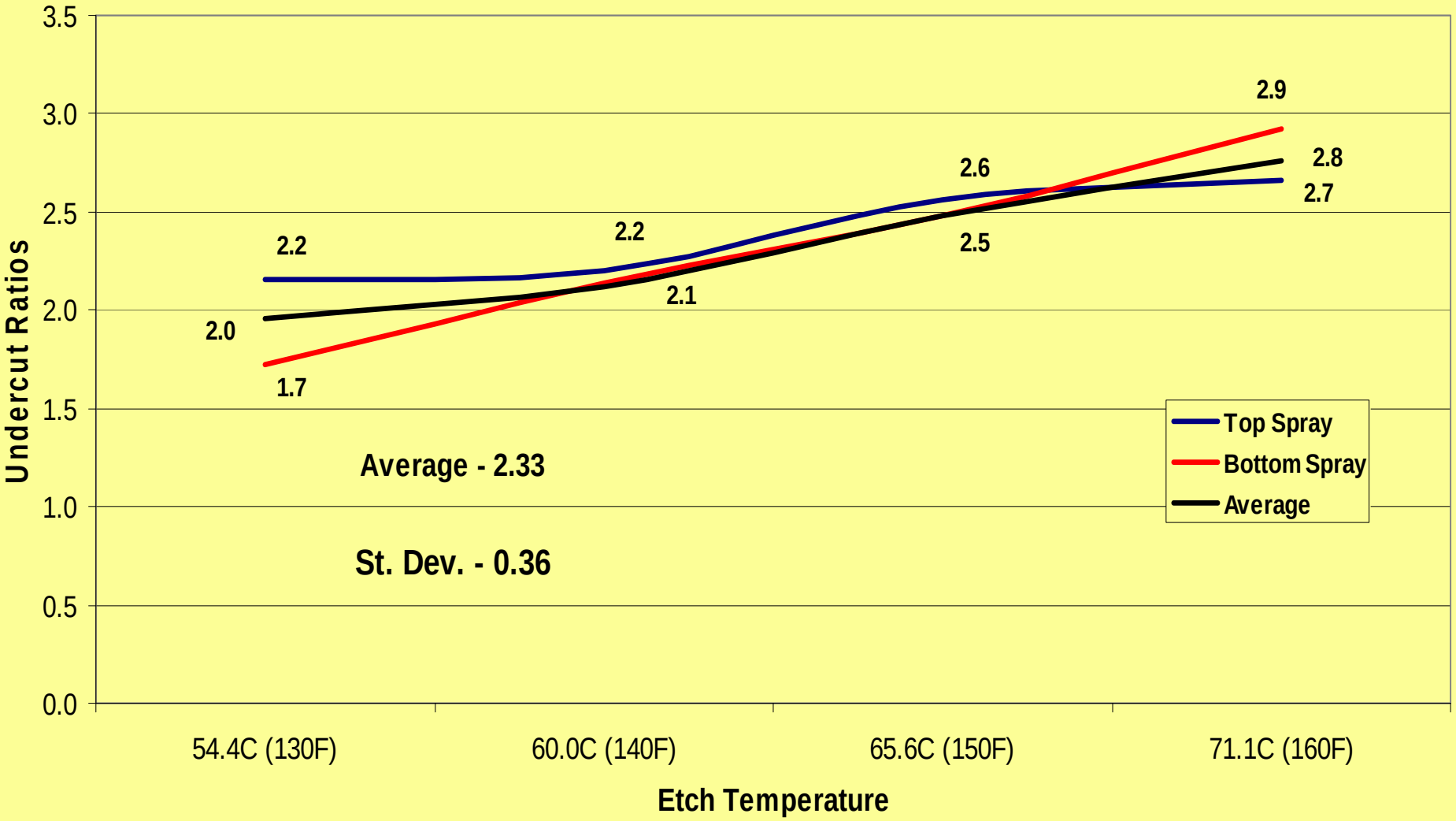
304 SST Undercut Ratios



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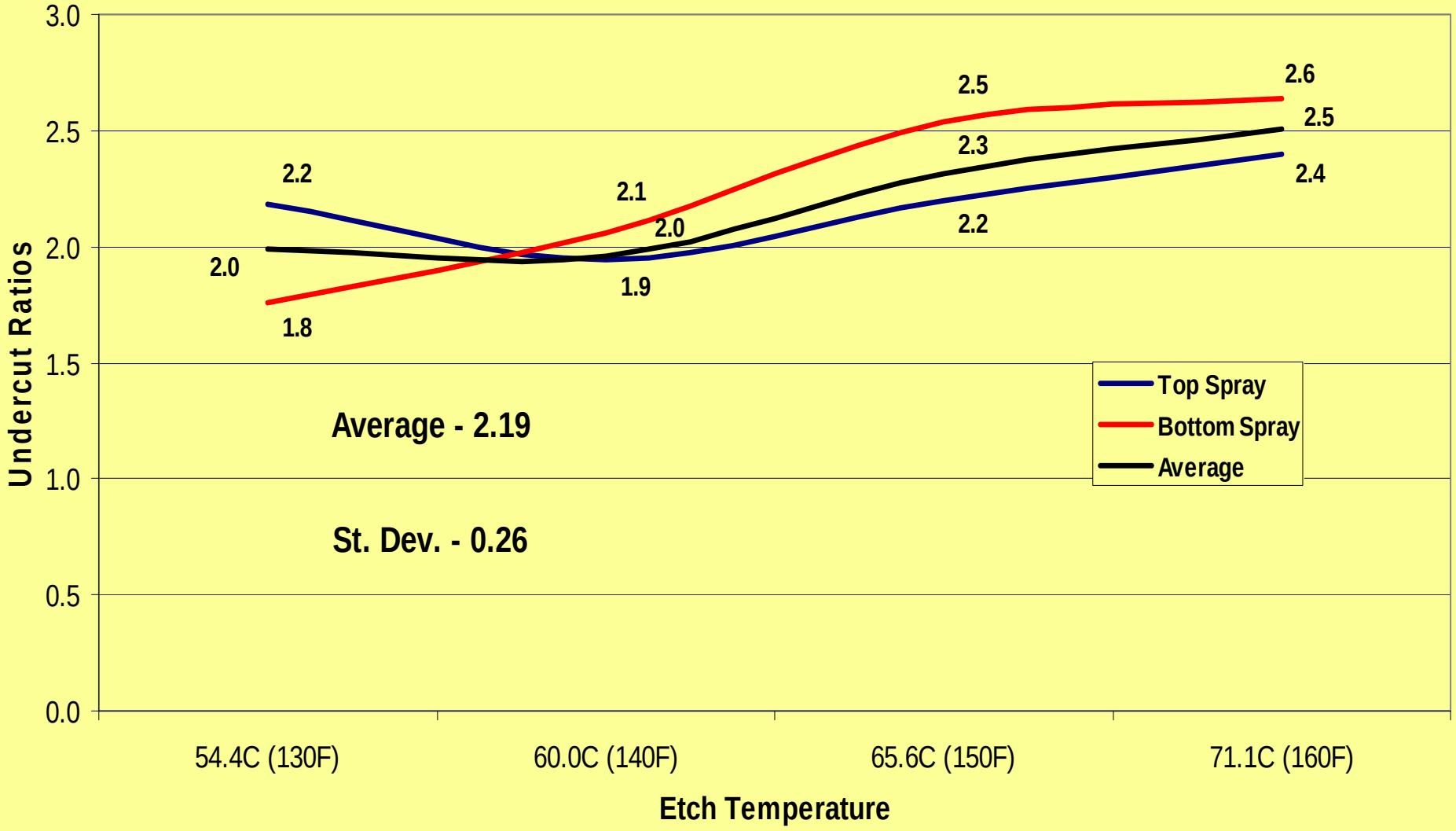
316 SST Undercut Ratios



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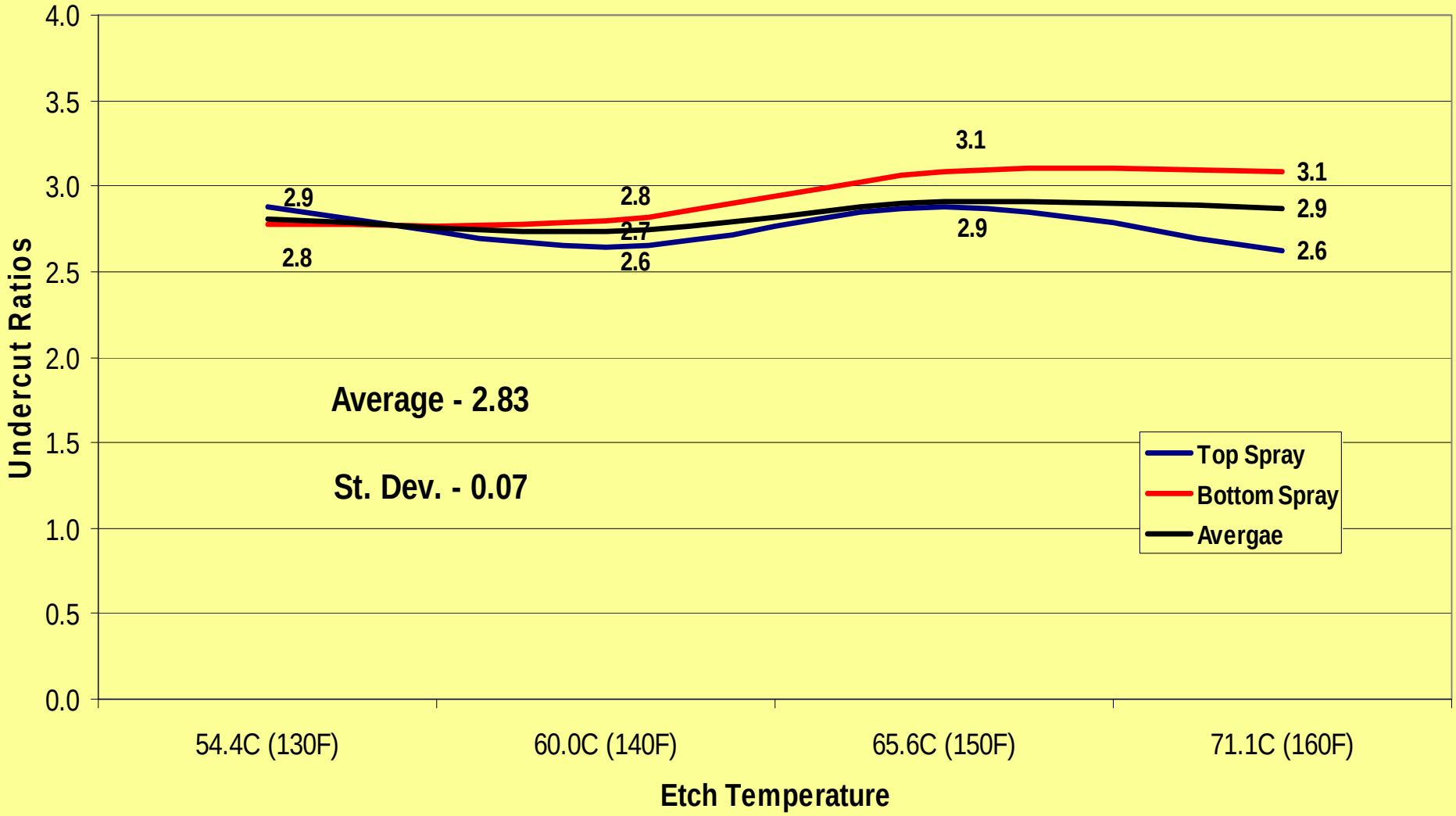
410 SST Undercut Ratios



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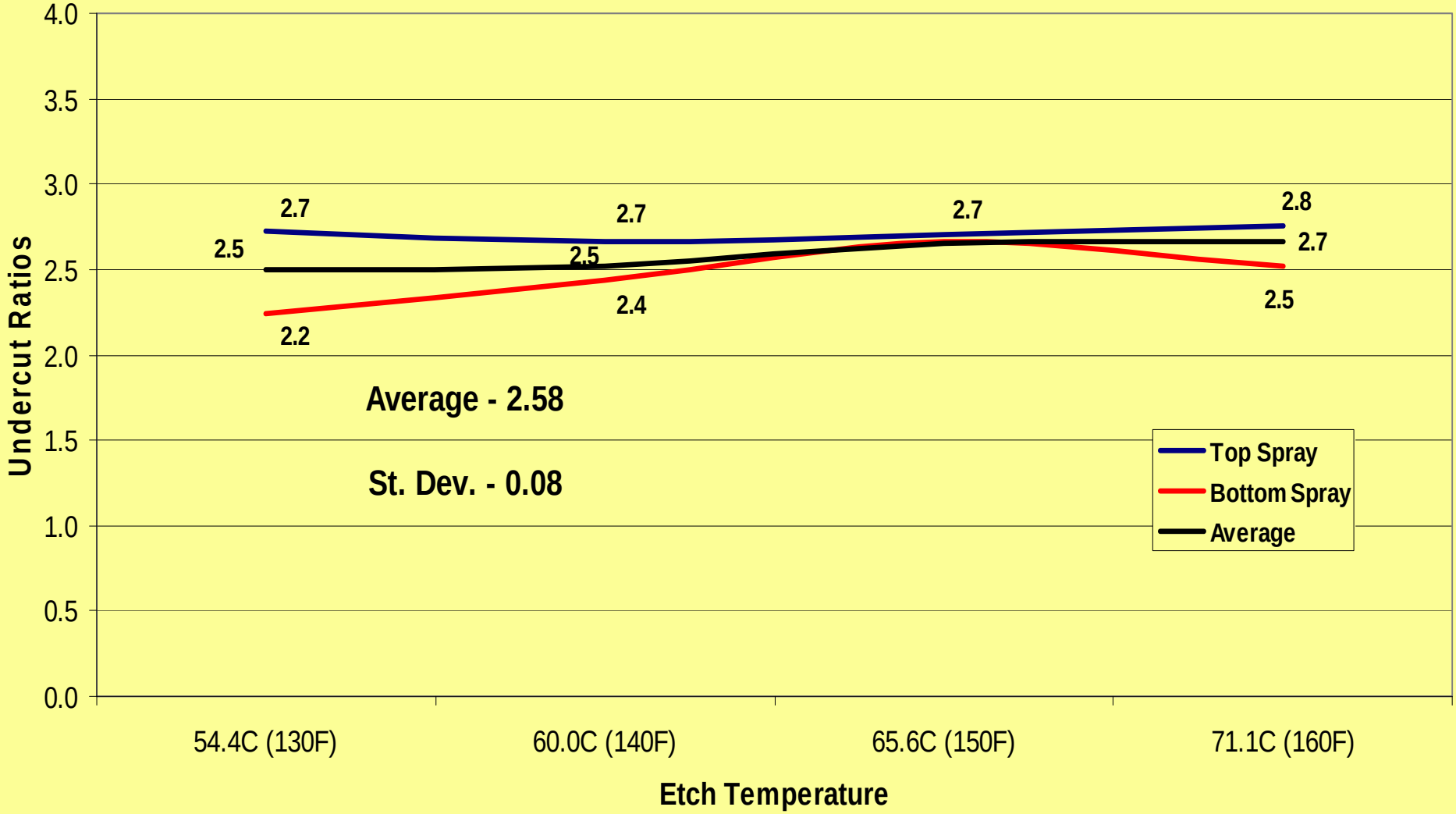
430 SST Undercut Ratios



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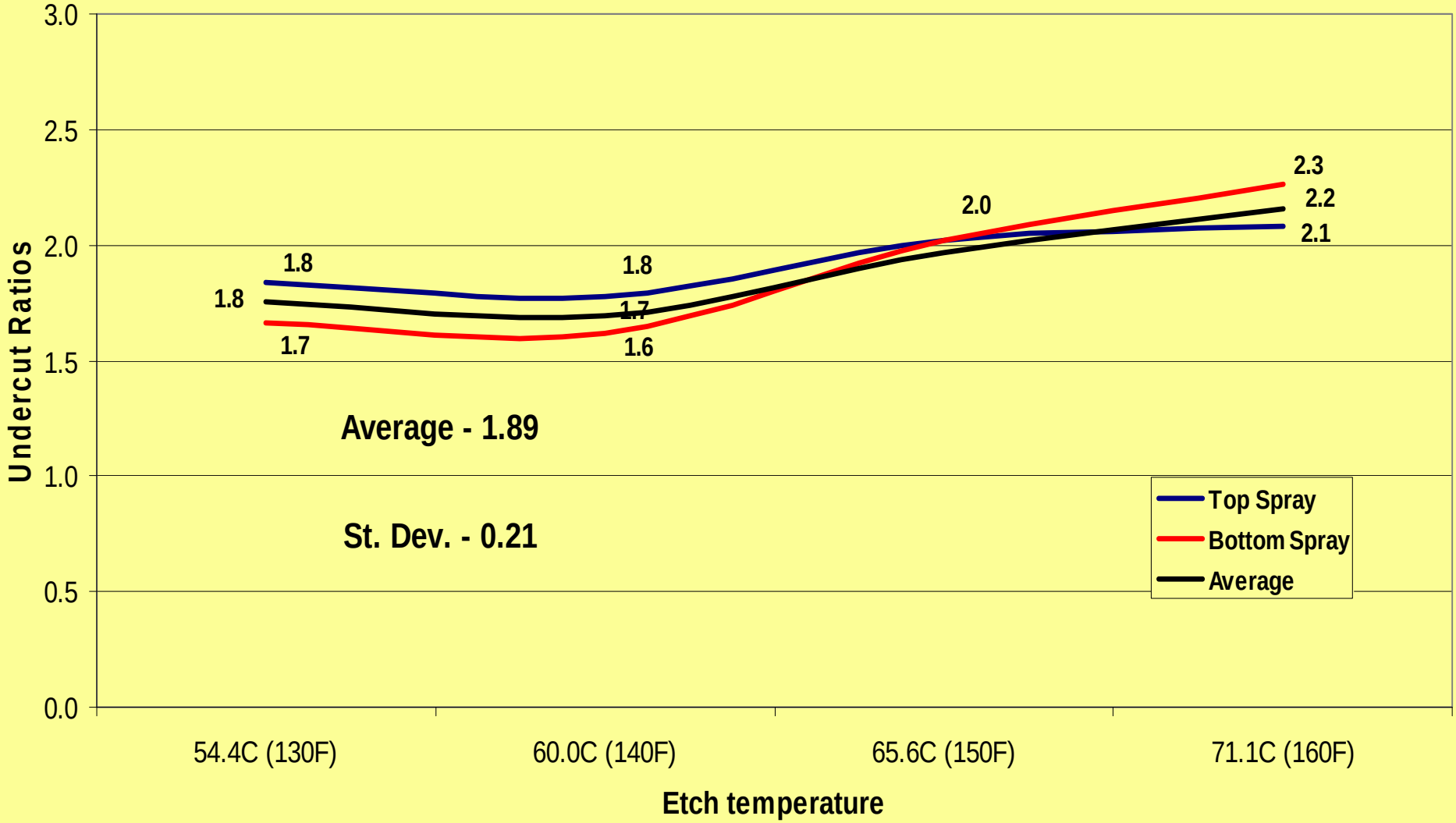
Kovar Undercut Ratios



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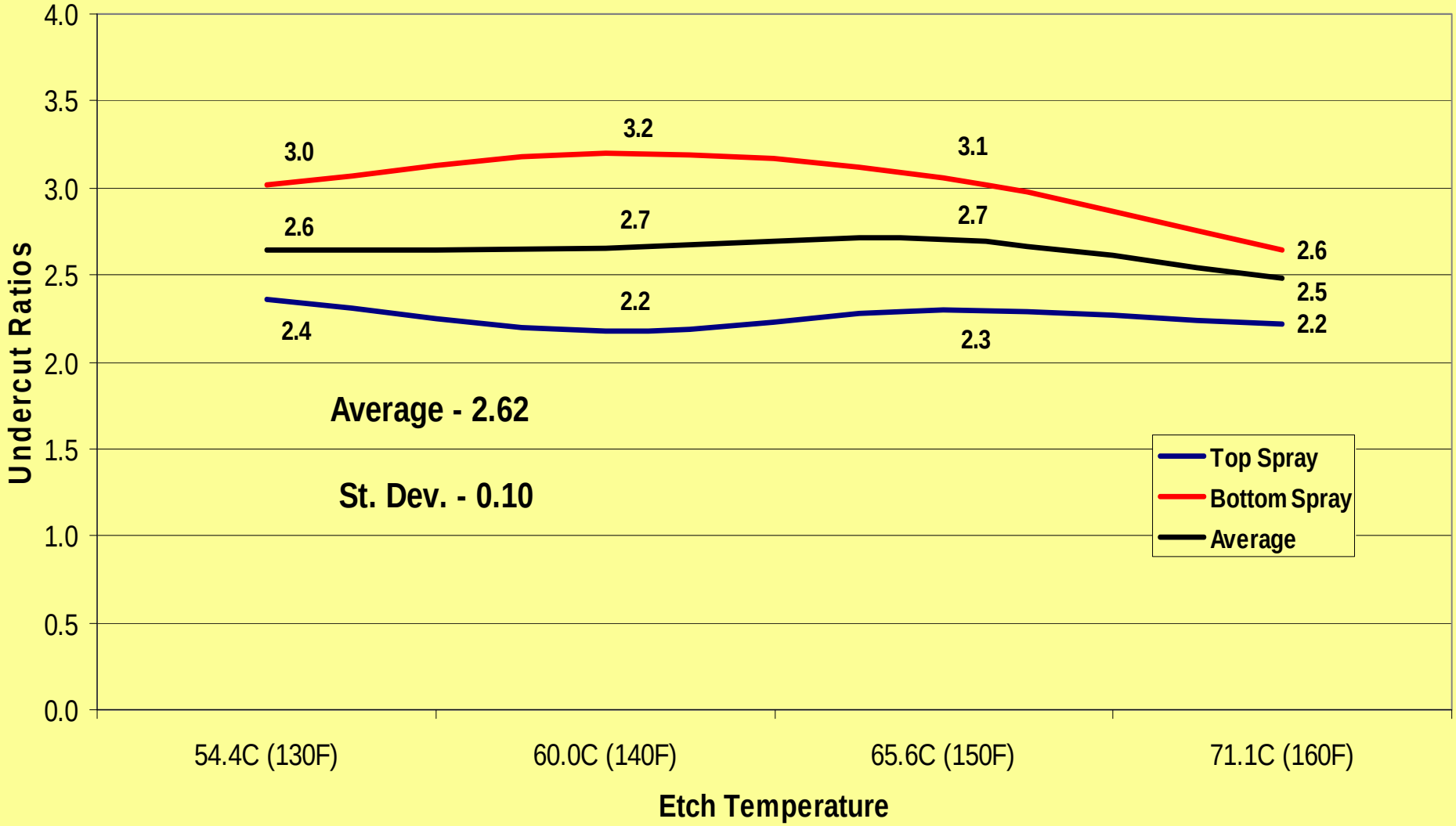
Brass Undercut Ratios



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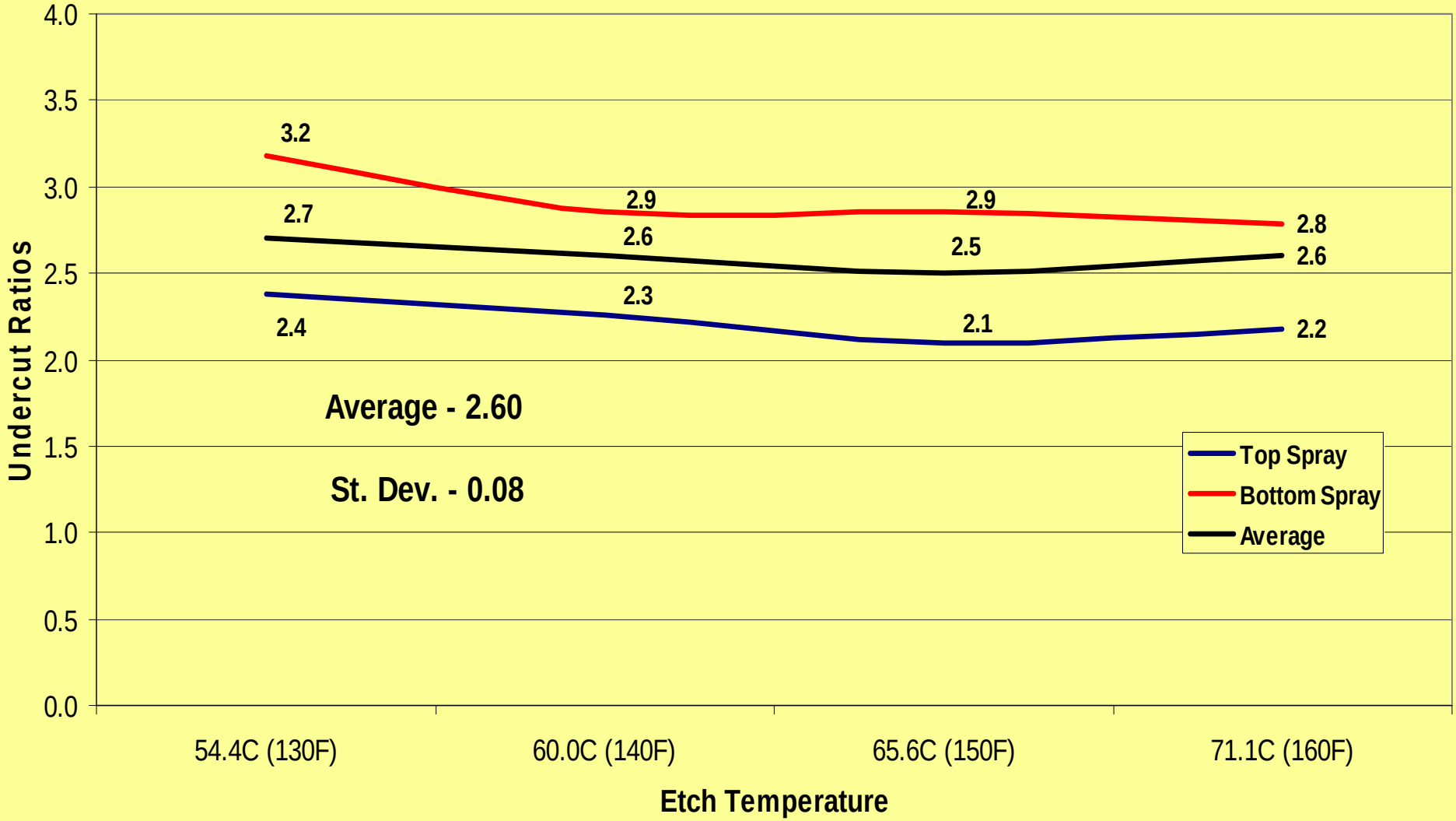
Copper Undercut Ratios



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Undercut Ratios – Top Spray

Etch Temp	Pre-etch Opening (µ)	Top Spray Undercut Comparison as a Ratio of the Vertical Etch								
		Steel	301 SST	304 SST	316 SST	410 SST	430 SST	Kovar	Brass	Copper
54.4ºC (130ºF)	127	2.0	1.7	2.0	2.6	2.5	2.7	1.7	2.2	2.1
	190.5	2.1	1.9	2.0	2.1	2.8	2.6	1.8	2.3	2.3
	254	2.2	1.9	2.2	2.1	3.0	2.8	1.9	2.4	2.5
	317.5	2.2	2.1	2.3	2.1	3.2	2.8	1.9	2.4	2.5
	381	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**
71.1ºC (160ºF)	127	2.2	2.1	2.2	2.1	2.6	2.4	1.9	2.0	2.1
	190.5	1.9	2.1	2.3	2.4	2.6	2.5	2.0	2.1	2.1
	254	2.0	2.1	2.4	2.5	2.7	2.9	2.1	2.1	2.2
	317.5	2.4	2.3	2.8	2.5	2.8	2.8	2.2	2.6	2.1
	381	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

Etch Temp	Pre-Etch Opening (µ)	Bottom Spray Undercut Comparison as a Ratio of the Vertical Etch								
		Steel	301SST	304SST	316SST	410SST	430SST	Kovar	Copper	Brass
54.4ºC (130ºF)	127.0	2.8	1.2	1.4	1.5	2.3	1.9	1.4	2.7	2.8
	190.5	2.9	1.4	1.6	1.6	2.6	2.1	1.7	3.2	3.0
	254.0	3.6	1.3	1.8	1.9	3.0	2.4	1.7	3.4	3.1
	317.5	2.7	1.4	2.0	2.0	3.0	2.5	1.8	3.4	3.1
	381.0	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**
71.1ºC (160ºF)	127.0	2.4	1.8	3.0	2.3	2.7	2.2	2.0	2.7	2.5
	190.5	2.5	2.0	2.7	2.5	3.0	2.4	2.2	2.7	2.5
	254.0	2.6	2.2	2.9	2.8	3.2	2.6	2.4	2.8	2.6
	317.5	2.8	2.3	3.0	2.7	3.3	2.7	2.3	2.8	2.8
	381.0	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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Findings

- Etch rate increases with temperature increase

  Steel alloys – 34.0% to 36.0%

  ~ 0.5µ for each 1º C

  Copper alloys – 30.6% to 38.5%

  ~ 0.9µ for each 1º C

- 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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An Evaluation of the Process

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