

# Search for weld pit formation mechanisms: Weld coupon EP

C Thompson, D Hicks, D Burk, R Schuessler  
N Dhanaraj, M Steinke, M Foley, D Ford, L Cooley  
Bill Starch – FSU  
Welders at AES, Roark, Pavac

 **Fermilab**



# Motivation, Objectives, Techniques

- What causes pits?
  - Material state? **Annealed** vs **cold worked** Nb
  - Weld defect? Test **welded** vs **no-weld** coupons
  - Something wrong during EP? **Temperature**, flow, **cathode area** were varied
- How do we assess surface quality?
  - Number of pits or defects
  - Gloss (GU)
  - Roughness
  - 400 GU = 0.5 nm Ra
- Techniques
  - Parallel plates in a bath, with flow thru a heat exchanger, 14 V, 50 mA/cm<sup>2</sup>
  - Scan coupon with flat-bed scanner, Analyze images (subjective)
  - Follow-up with profilometer
  - Compare vs EP parameters and “quality” measurements
- QC
  - Removal rate was proportional to current
  - Removal rate prop. to temp.
  - Our removal rate lower than JLab’s coupon EP

# Important results to take away

- For reasons we do not understand, a small cathode (1:20 area ratio) produced grain texture similar to what we see in cavities
  - Increasing temperature amplified this effect on one sample
  - 1:1 area ratio produces no grain contrast whatsoever
- Cold-working increases tendencies to form pits
  - But CW coupons are very glossy, too!
- Higher temperature increases tendencies to form pits
- Annealing decreases tendencies to form pits



# Annealed Coupons, 30°C



EP-11  
Pre-EP

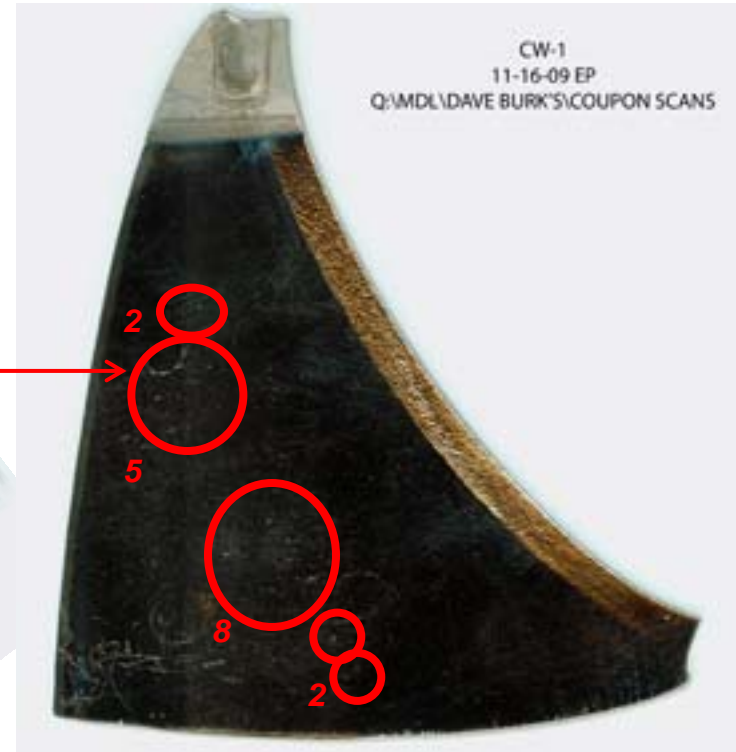
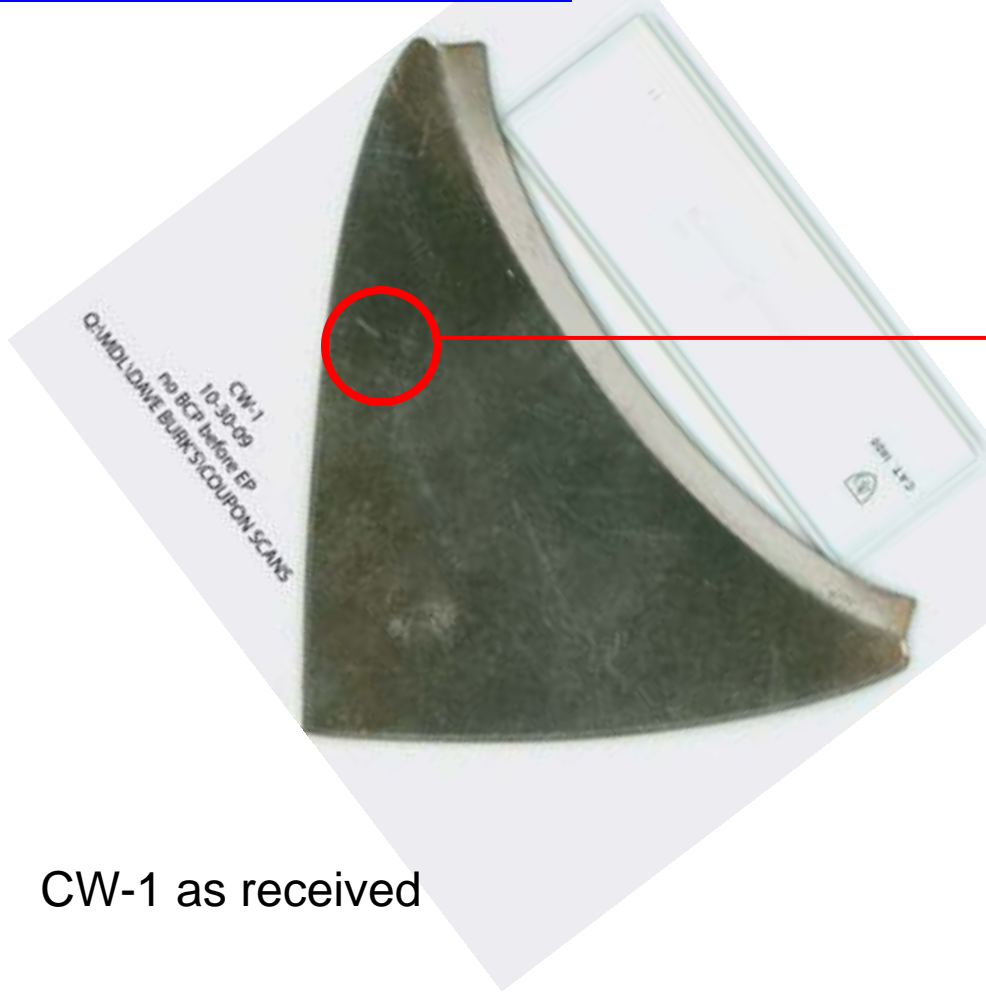


EP-11  
31 °C 303 min  
263  $\mu\text{m}$  removed  
410 GU  
20:1 anode:cath



EP-4 31 °C 120 min, 160  $\mu\text{m}$  removed  
456 GU 110 nm Ra  
4 pits / 50  $\text{cm}^2$   
1:1 anode:cath

# CW Coupons, 30°C



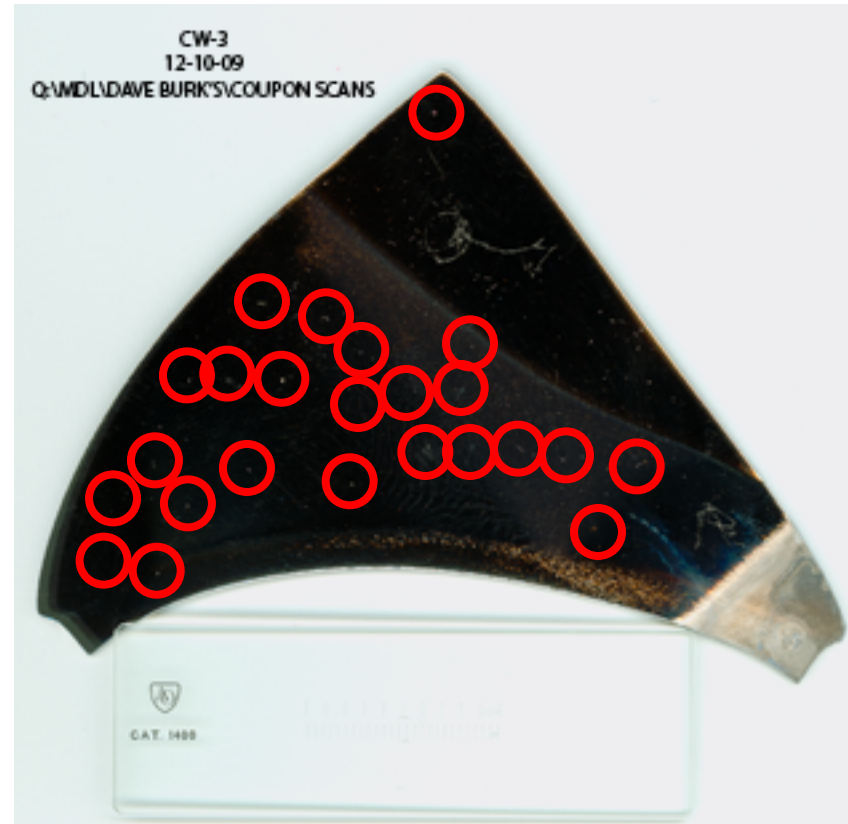
CW-1 EP  
29 °C  
298 min  
168 µm removed  
**466** GU  
73 nm Ra  
18 pits / **40** cm<sup>2</sup>

**Cold-worked coupons** RF SIDE and reduced to 72 dpi

## CW Coupons, 30°C



CW-2  
30 °C  
300 min  
193 µm removed  
**465** GU  
30 nm Ra  
**16** pits / **40** cm<sup>2</sup>



CW-3  
31 °C  
298 min  
189 µm removed  
**422** GU  
60 nm Ra  
**>20** pits / **40** cm<sup>2</sup>  
Some larger defects

**Cold-worked coupons** RF SIDE and reduced to 72 dpi



## CW Coupons

Pits being analyzed

30 °C  
1:1



WSC-46 EP RFside  
1-25-10

EP 30°C, 50 mA/cm<sup>2</sup>, 1 L/min, 1:1  
ratio of cathode to anode areas, 107  
µm removed, 353 GU

Note grain boundaries  
and clearly visible HAZ

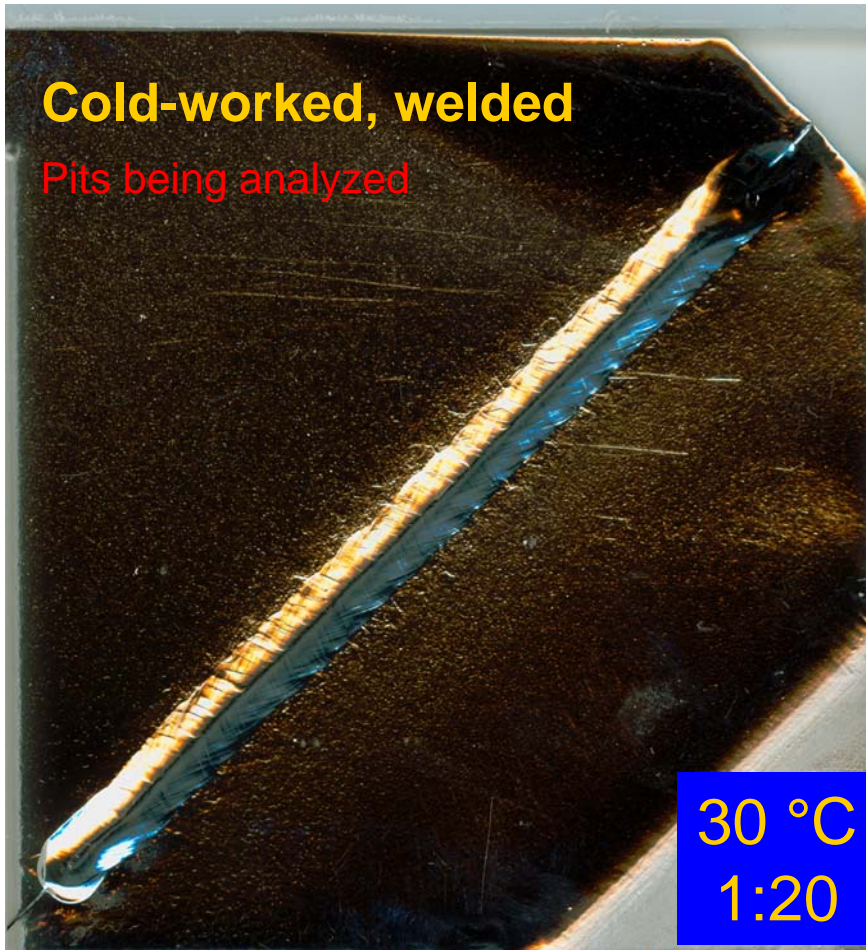
Pits being analyzed

50 °C  
1:20



EP 50°C, 50 mA/cm<sup>2</sup>, 1 L/min, 1:20  
ratio of cathode to anode areas, 110  
µm removed, 125 GU





**Cold-worked, welded**

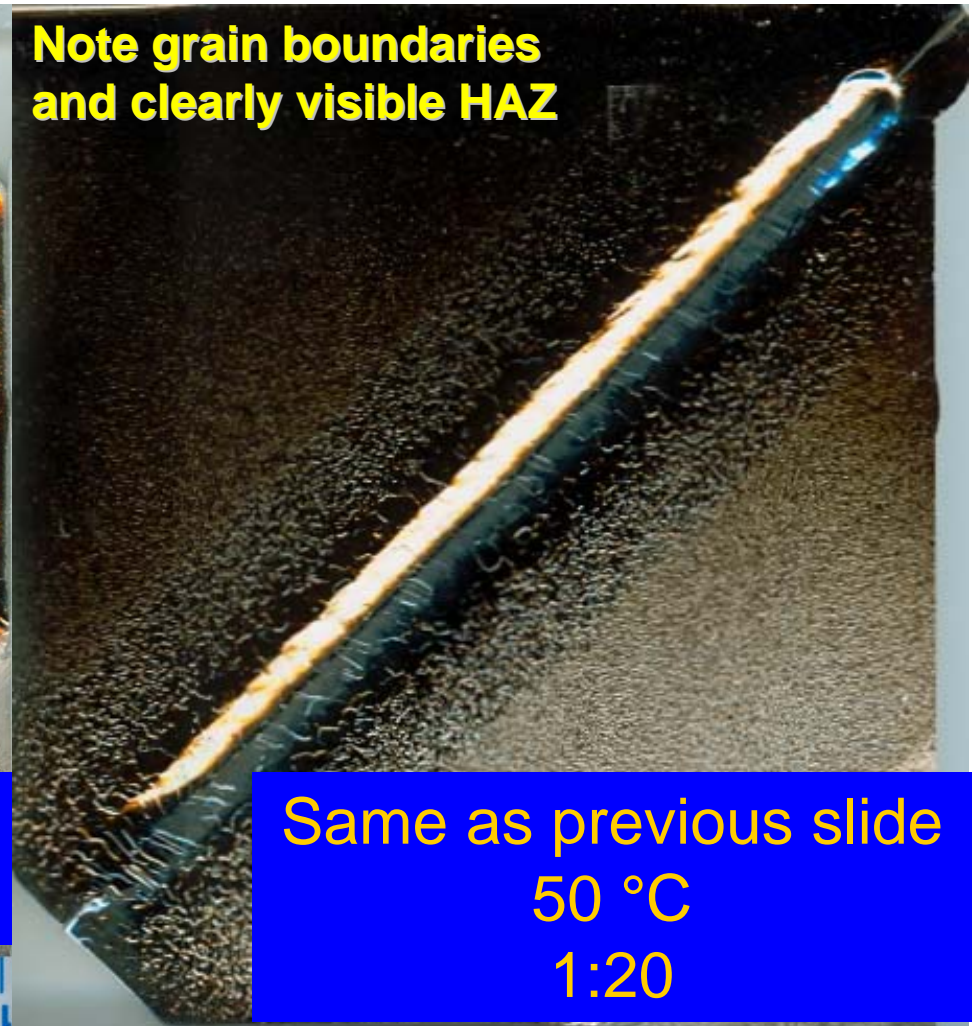
Pits being analyzed

30 °C  
1:20



WSC-49 EP RF SIDE  
2-15-10  
Q:\MDL\DAVE BURK'S\COUPONSCANS

EP **30°C**, 50 mA/cm<sup>2</sup>, 1 L/min, **1:20**  
ratio of cathode to anode areas, 140  
µm removed, 392 GU



**Note grain boundaries  
and clearly visible HAZ**

Same as previous slide  
50 °C  
1:20

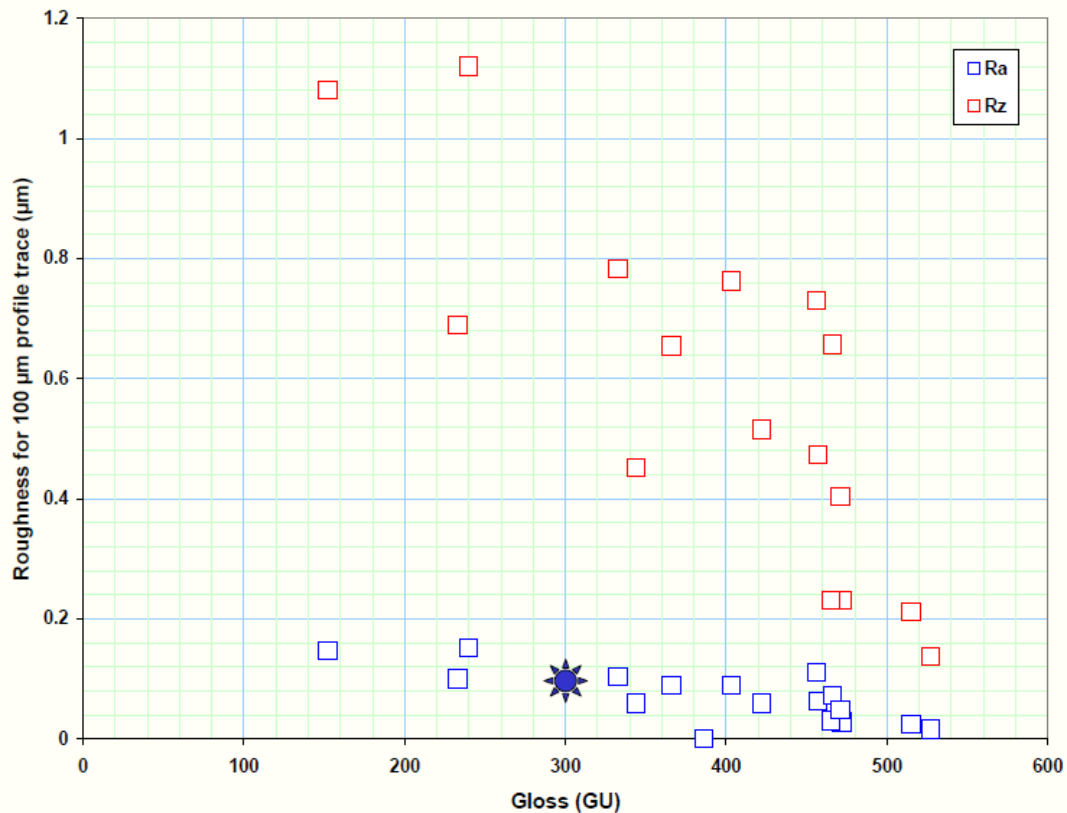


EP **50°C**, 50 mA/cm<sup>2</sup>, 1 L/min, **1:20**  
ratio of cathode to anode areas, 110  
µm removed, **125 GU**



# Reserve slides

## Coupon Roughness vs Gloss

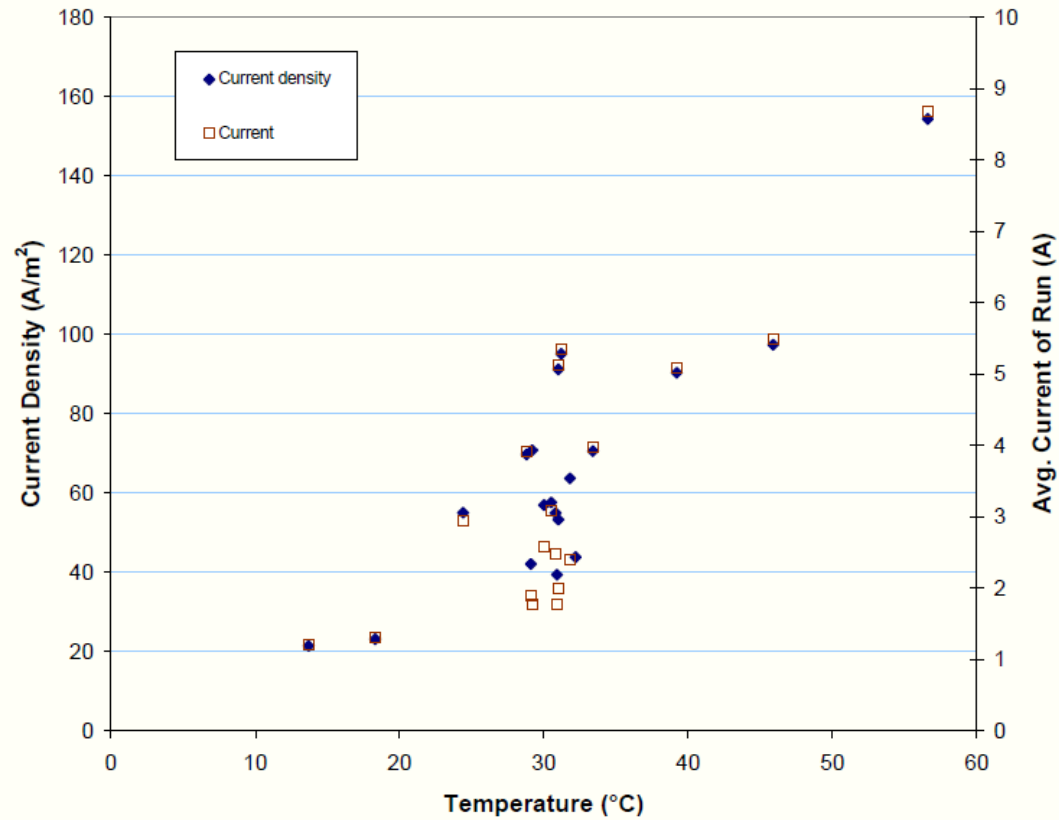


Trend suggests target of < 0.1 μm Ra corresponds to gloss of 300 GU or better

# EP Process Data



EP current vs Temp. at 14.5 to 15 V





# EP Process Data



Removal rate vs. temperature at target 14.5 V, 50 A/m<sup>2</sup>

