

# CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

# CONTROLLED

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Notebook NO. 695

Issued to Kuang-Tsan Kenneth Chiang *K.T. Chiang*

On February 8 2005

Department Corrosion Science & Process Engineering

Returned April 14 2009

Project number : 06002.01.322

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| $\text{NaHCO}_3 + \text{NaCl} + \text{KCl} + \text{NaOH}$ | 185  |

Continue from Notebook 615

**Initial Scientific Notebook Entry for Corrosion Resistant Material  
Potentiostatic Tests, Potentiodynamic Tests, Slow Strain Rate Tests**

**Title:** Potentiostatic tests, polarization tests, slow strain rate tests.

**Test Performed by:** Kuang-Tsan Kenneth Chiang

**Objective:** Study the effect of Bicarbonate [ $\text{HCO}_3^-$ ], Carbonate [ $\text{CO}_3^{2-}$ ]  
Nitrate [ $\text{NO}_3^-$ ] to Chloride [ $\text{Cl}^-$ ] concentration ratio in simulated groundwater  
on stress corrosion cracking susceptibility of mill-annealed Alloy 22 and  
Alloy 22 weldments.

**Equipment:** EG&G Versastat Serial Number 20104. EG&G Model 352  
corrosion software. NEC 586 computer. Keithley Electrometer Model 614  
SN 55538 or equivalent. ASTM G-5 Polarization Cell. Large 2 L glass cells  
with Teflon tops. Electrochemical Impedance Spectroscopy system  
including Solaritron 1260 FRA and Solaritron 1287 Potentiostat. ESC 440  
multichannel potentiostats with National Instruments Labview data  
acquisition software or Strawberry Tree data acquisition software.

**Materials:** Mill-annealed Alloy 22, gas metal-arc welded Alloy 22, gas  
tungsten-arc welded Alloy 22

**Specimen Specifications:** Cylindrical CPP specimens 1.195"x.250" and  
slow strain rate specimens.

**Measurement Parameters:** Current and Potential as described in TOP-008.  
Temperature of solution  $\pm 2^\circ\text{C}$ .

**Required Level of Accuracy:** Potentials  $\pm 5\text{mV}$ . Current less than 0.1  
microamp.

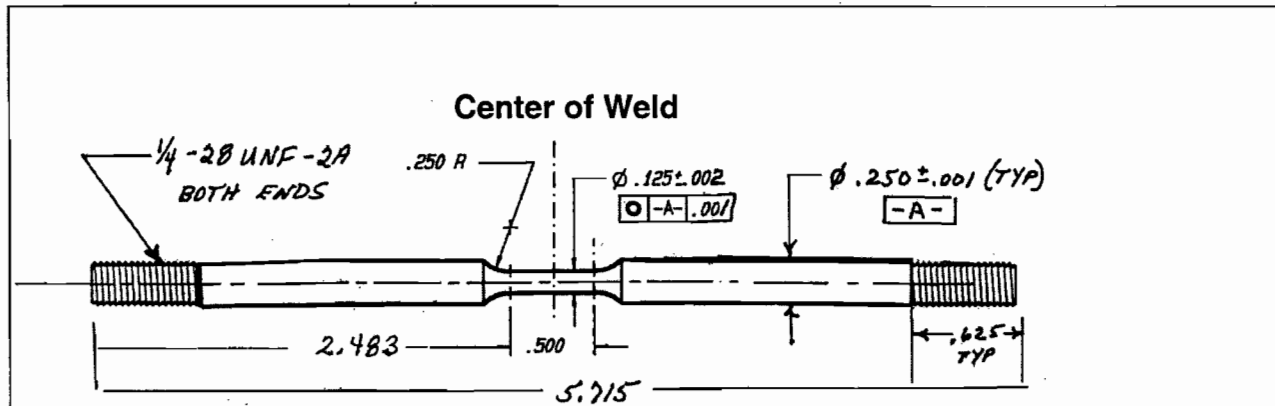
**Uncertainty and Source of Error:** Current density calculated as current  
divided by sample area. Actual current density of corroding areas is not  
determined. Resolution limit of data acquisition systems may limit accuracy  
of passive current density measurements.

Revised Initial Entry on P. 70.

K. T. Chiang  
2/8/05

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SwRI DRAWING # 20-06002-01-321-001



NOTE: 1. DO NOT UNDERCUT RADII  
 2. USE LOW STRESS MACHINING PROCEDURE

All dimensions in inches

| PART NO. | QTY REQ. | MATERIAL                              | CODE IDENT NO. | PART OR IDENTIFYING INC. | NOMENCLATURE OR DESCRIPTION |                              |
|----------|----------|---------------------------------------|----------------|--------------------------|-----------------------------|------------------------------|
|          |          |                                       |                |                          | PARTS LIST                  |                              |
|          |          | WELDED<br>0.5 THICK PLATE<br>SUPPLIED |                |                          |                             | SOUTHWEST RESEARCH INSTITUTE |
|          |          | FINISH<br>16 RMS                      |                |                          |                             | SLOW STRAIN RATE SPECIMEN    |
|          |          |                                       |                |                          |                             | DRAWING NO.<br>20-3704-042-2 |
|          |          |                                       |                |                          |                             | SCALE 2 = 1                  |
|          |          |                                       |                |                          |                             | SHEET                        |

K. T. Chiang  
2/5/05

K. T. Chiang 1/13/05  
 Initiator: K. Chiang Date

V. Jain 1/13/05  
 Reviewer: V. Jain Date

R. Brient 1/14/05  
 QA Approval: R. Brient Date



## Welded Alloy 22 Slow Strain Rate Test Specimens

## GMAW

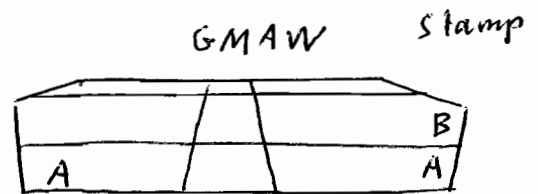
Plate # 6 and # 2

Total 8 bars

Heat 2277-3-3292

filler WN 813/XX 1977 BG 11

|           |     |   |                        |
|-----------|-----|---|------------------------|
| Sample ID | 10A | } | Group 1 As welded      |
|           | 11A |   |                        |
|           | 12A |   |                        |
|           | 13A |   |                        |
|           | 14A | } | Group 3, 1125°C-20 min |
|           | 15A |   |                        |
|           | 16A |   |                        |
|           | 17A |   |                        |



## GTAW

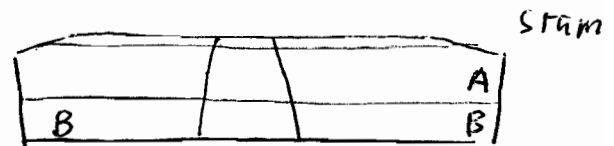
Plate # 7 and # 4

Total 7 bars

Heat 2277-3-3292

filler WN 813/XX 1977 BG 11

|           |     |   |  |
|-----------|-----|---|--|
| Sample ID | 10B | } | Group 2 As welded - 10A and 10B air test                 |
|           | 11B |   |  |
|           | 12B |   |  |
|           | 13B |   |  |
|           | 14B | } | Group 4 for waterjet cut, annealing<br>1125°C for 20 min |
|           | 15B |   |  |
|           | 16B |   |  |

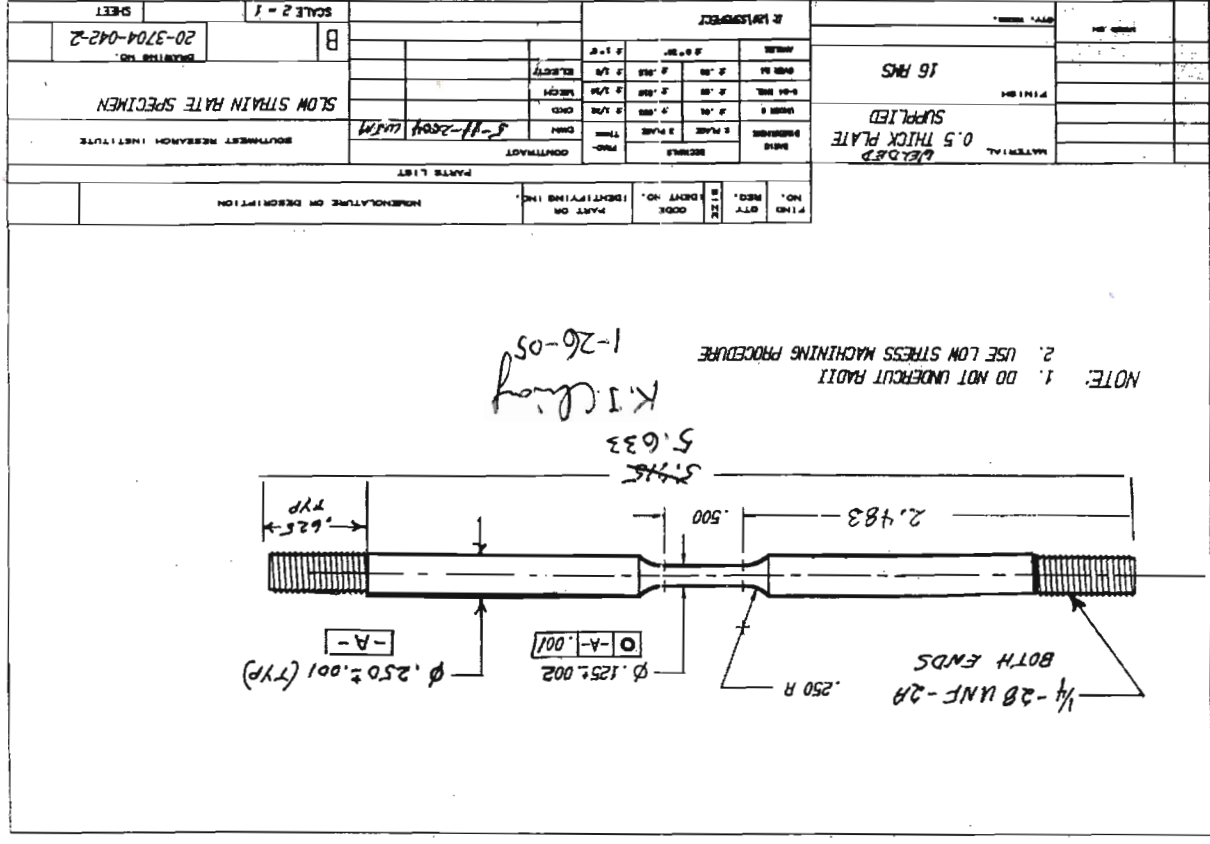


K. T. Chua  
3/16/05

Group 1 GMAW As welded

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SWRI DRAWING # 20-06002-01-321-001



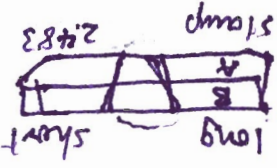
| FINI | QTY | REQ. | SIZE | CODE | IDENTIFYING INFO. | PART OR IDENTIFYING INFO. | NUMERICAL OR DESCRIPTION |
|------|-----|------|------|------|-------------------|---------------------------|--------------------------|
|      |     |      |      |      |                   |                           |                          |

| DATE | REVISION | BY | CHKD | APP. CONTRACT |
|------|----------|----|------|---------------|
|      |          |    |      |               |


  

| FINI | QTY | REQ. | SIZE | CODE | IDENTIFYING INFO. | PART OR IDENTIFYING INFO. | NUMERICAL OR DESCRIPTION |
|------|-----|------|------|------|-------------------|---------------------------|--------------------------|
|      |     |      |      |      |                   |                           |                          |

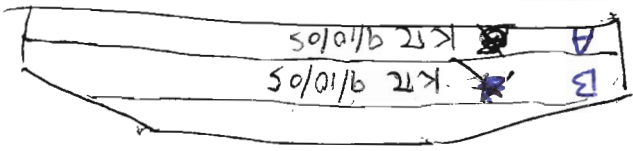


Procedure: **IOS • W1821**  
 Project # \_\_\_\_\_  
 TOTAL PCS. INSPECTED \_\_\_\_\_  
 TOTAL PCS. ACCEPTED \_\_\_\_\_  
 TOTAL PCS. REJECTED \_\_\_\_\_  
 "NR #": IF REJECTS \_\_\_\_\_

LOCATION: **CC31 M5**  
 J.C. # **80879**  
 EQUIPMENT: **HQ 002150**  
**Inv. 002151**  
**Mic. 009976**  
**TM Data 002176**

INSPECTOR:   
 DATE: **FEB - 8 2005**

"M A" And Gage Area have same RUNOUT between Centers

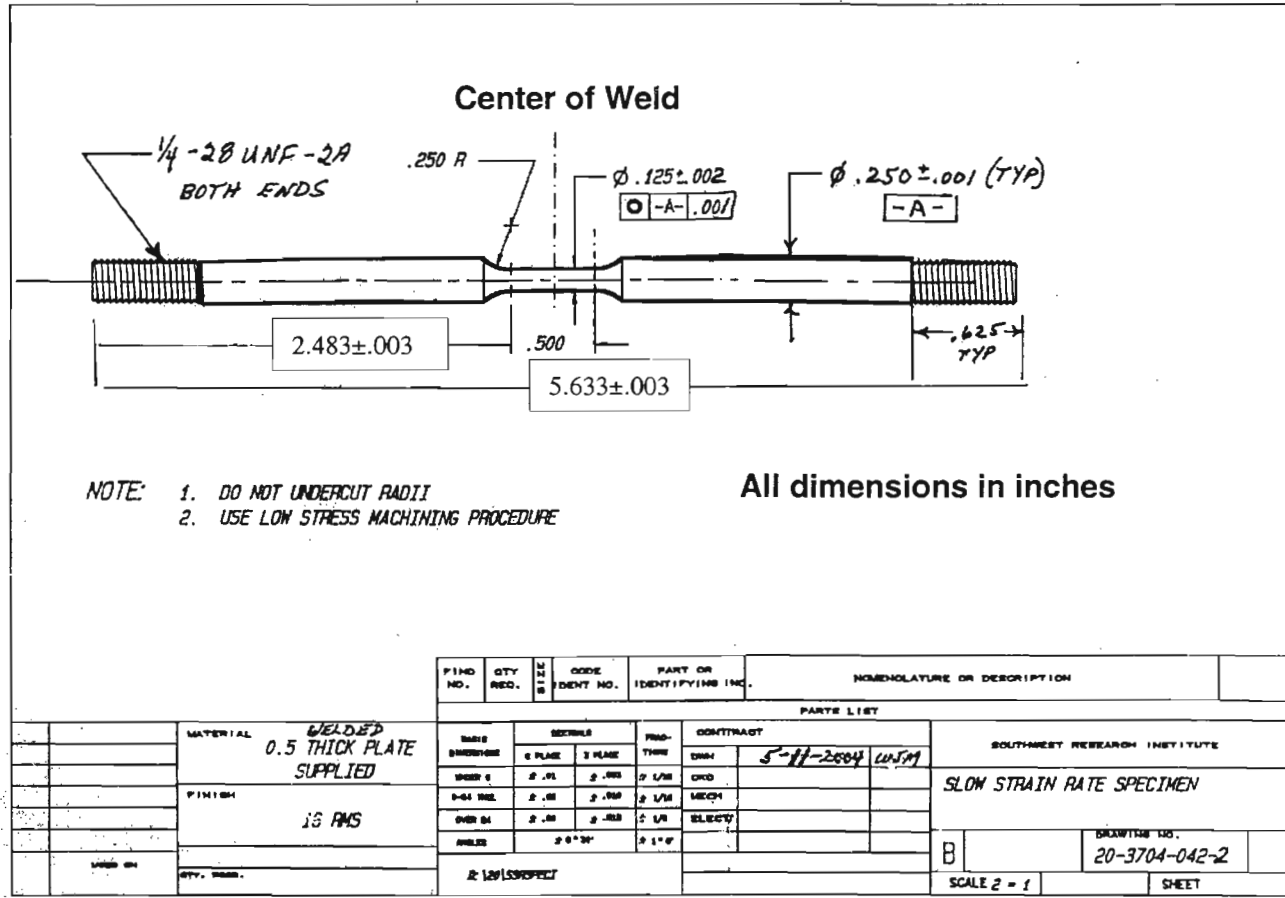


K.T. Chiang 3/16/05

Group 2 GTAW As Welded

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SwRI DRAWING # 20-06002-01-322-001



Procedure: 105-01-821  
Project #  
TOTAL PCS. INSPECTED  
TOTAL PCS. ACCEPTED  
TOTAL PCS. REJECTED  
"NR #": IF REJECTS

INSPECTOR

J.C. # 80911  
LOCATION CC31MS

CC31MS

Equip part #  
Comp # 002155 Date 1-18-06  
M/c 009716 Date 1-18-06  
Tid Cage 002176 11-19-07

DATE MAR - 8 2005

K. T. Chiang 2/23/05  
Initiator: K. Chiang Date

V. Jain 2/23/05  
Reviewer: V. Jain Date

R. Brient 2/23/05  
QA Approval: R. Brient Date

Group 3 GMAW Welded + 1125°C 20min Anneal 10 Pieces 13/14/15/16/17

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SwRI DRAWING # 20-06002-01-322-001

Procedure: I05-101-821  
Project # \_\_\_\_\_  
TOTAL PCS. INSPECTED \_\_\_\_\_  
TOTAL PCS. ACCEPTED \_\_\_\_\_  
TOTAL PCS. REJECTED \_\_\_\_\_  
"NR #" IF REJECTS \_\_\_\_\_

INSPECTOR

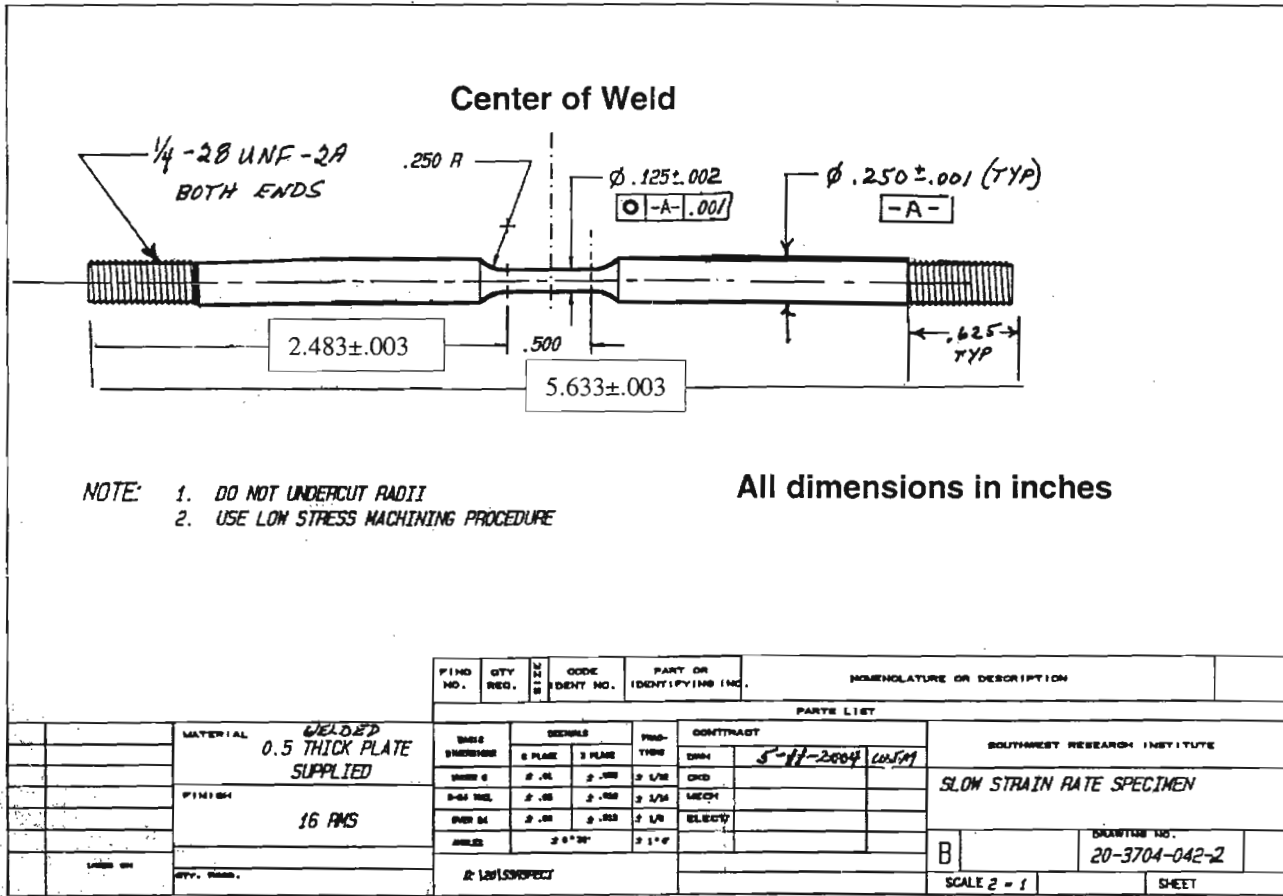


LOCATION: J.C. # 8107  
OC31 MS.

EQUIPMENT: MCRMELEP 00997L Date 1-13-06  
M1 G99E 002176 Date 11-19-07  
Comparator 002158 Date 1-18-06

DATE: MAR 24 2008

K. Chiang 3/24/08

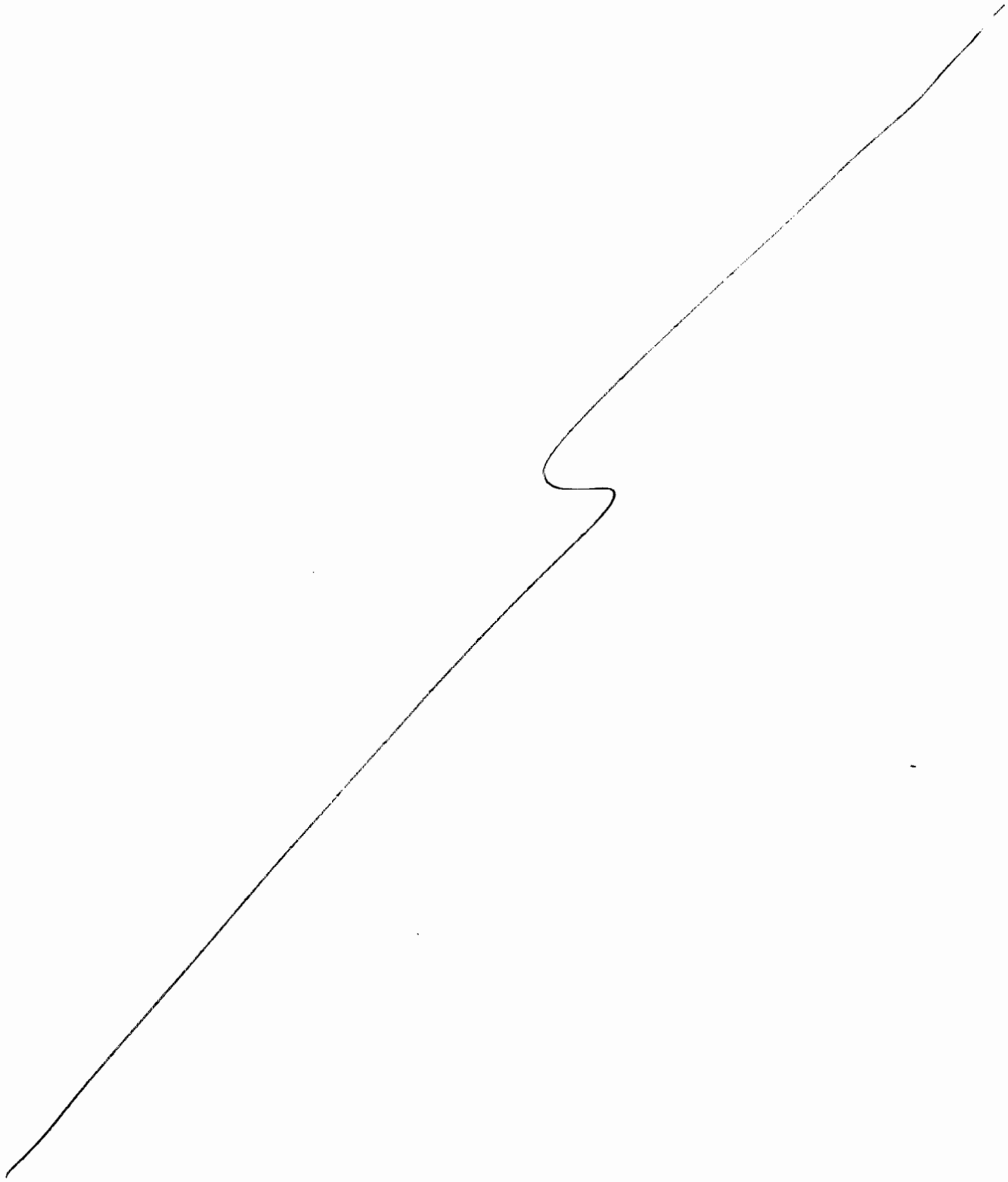


K. Chiang 2/23/05  
Initiator: K. Chiang Date

V. Jain 2/23/05  
Reviewer: V. Jain Date

R. Brient 2/23/05  
QA Approval: R. Brient Date

Group 4 GTAW Weided + 1125°C 20min Anneal



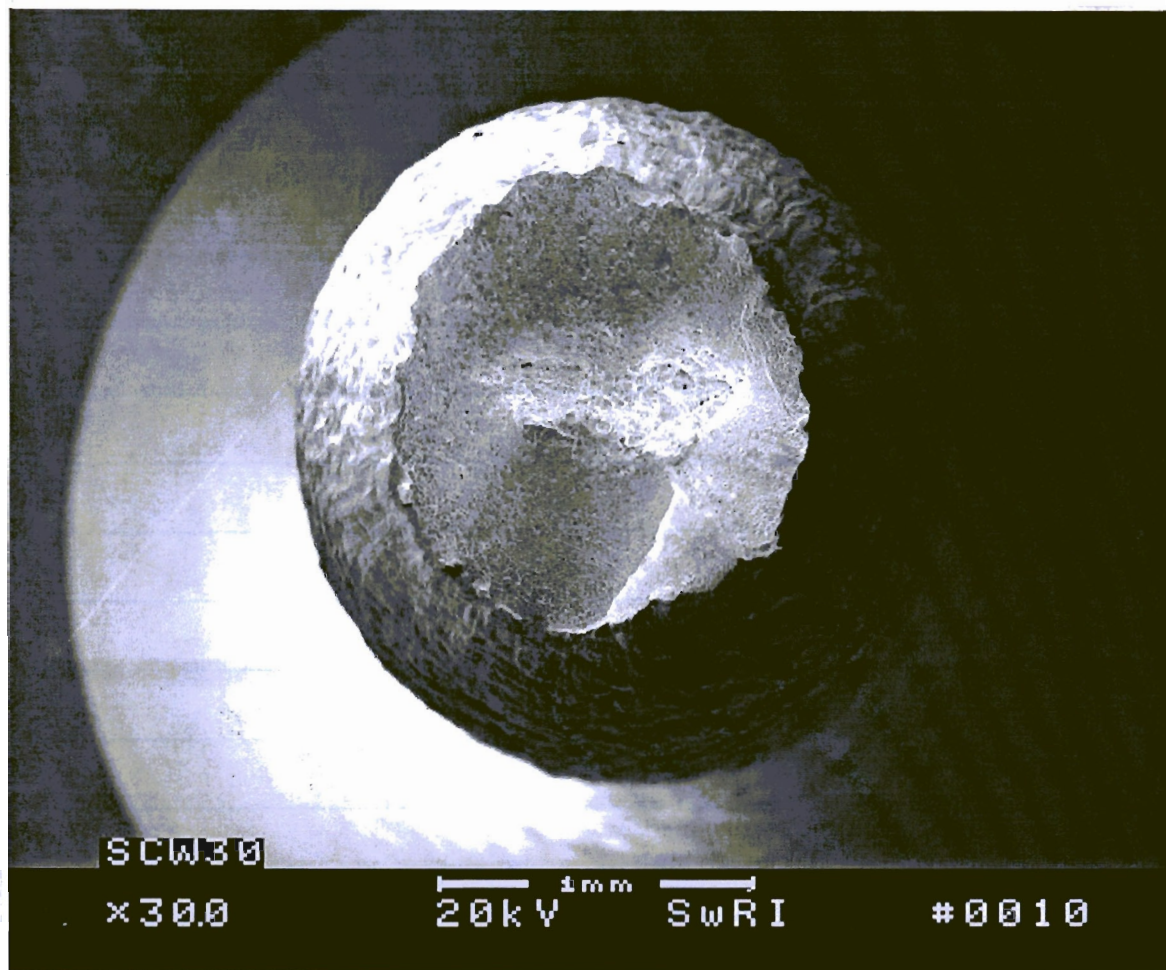
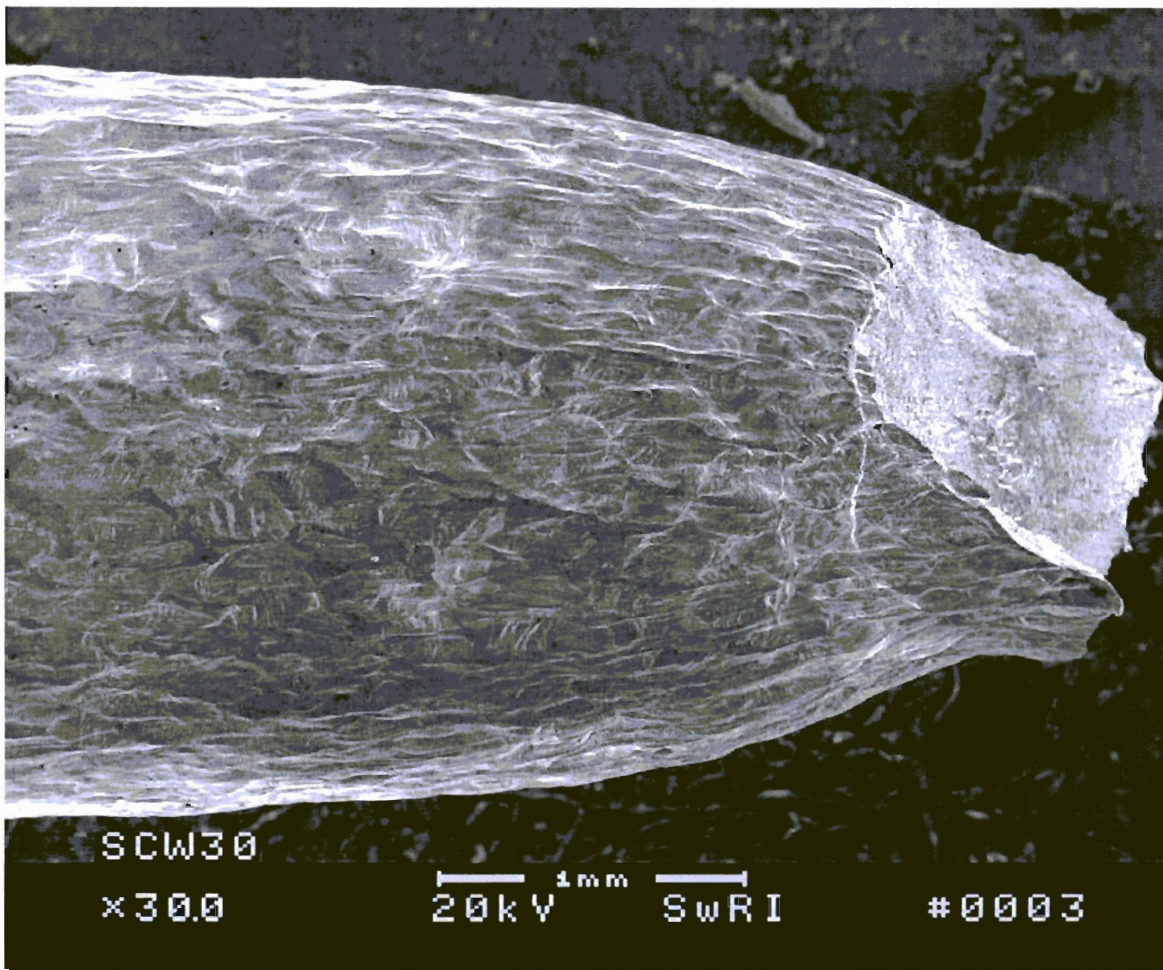
K.S. Ching 3/24/05

| Slow Strain Rate Testing of MA Alloy 22 |  |            |           |          |          |                  |          |       |         |      |  |
|---|--|------------|-----------|----------|----------|------------------|----------|-------|---------|------|--|
| Test ID                                 | Solution Composition   | pH Initial | pH Adj'd  | pH Final | Eapp(mV) | Max Stress (Mpa) | TTF(hrs) | RA(%) | % Elong | SCC? |  |
| SSRMA22_SCW28<br><i>400 mV</i>          | 0.5M NaCl; 7.1M KCl <i>7.6M</i><br>0.38M NaNO3; NaCO3 as<br>in SCW | 7.87       | not adj'd | 9.36     | 400      | 560              | 39       | 55.9  | 44.4    | Y    |  |
| SSRMA22_SCW29<br><i>400 mV</i>          | same as *28 except 3.3M KCl<br><i>3.8M Cl</i>                      | 7.41       | not adj'd | 9.44     | 400      | 590              | 50       | 50    | 55      | Y    |  |
| SSRMA22_SCW30                           | same as *26 except no HCO3   |            | not adj'd |          | 400*     | 787              | 79       | 76.9  | 87.6    | N    |  |
| SSRMA22_SCW31                           | SCW  | 7.73       | 8.31      | 9.03     | 200      | 730              | 74       | 77    | 85.2    | N    |  |
| SSRMA22_SCW32                           | SCW <i>GMAW "A"</i>  | 7.73       | 8.31      | 8.85     | 400      | 674              | 38       | 65.9  | 41.6    | N    |  |
| SSRMA22_SCW33<br><i>400 mV</i>          | 1.05M NaHCO3; 0.5M NaCl<br>0.19M NaOH; 1.5M KCl                    | 8.58       | not adj'd | 9.81     | 400      | 652              | 33       | 30    | 36.6    | Y    |  |
| SSRMA22_SCW34                           | AIR - GMAW #12A  | N/A        | N/A       | N/A      | N/A      | 725              | 36       | 56.9  | 38.8    | N/A  |  |
| SSRMA22_SCW35                           | AIR - GMAW #12B  | N/A        | N/A       | N/A      | N/A      | 753              | 45       | 48.2  | 50.4    | N/A  |  |

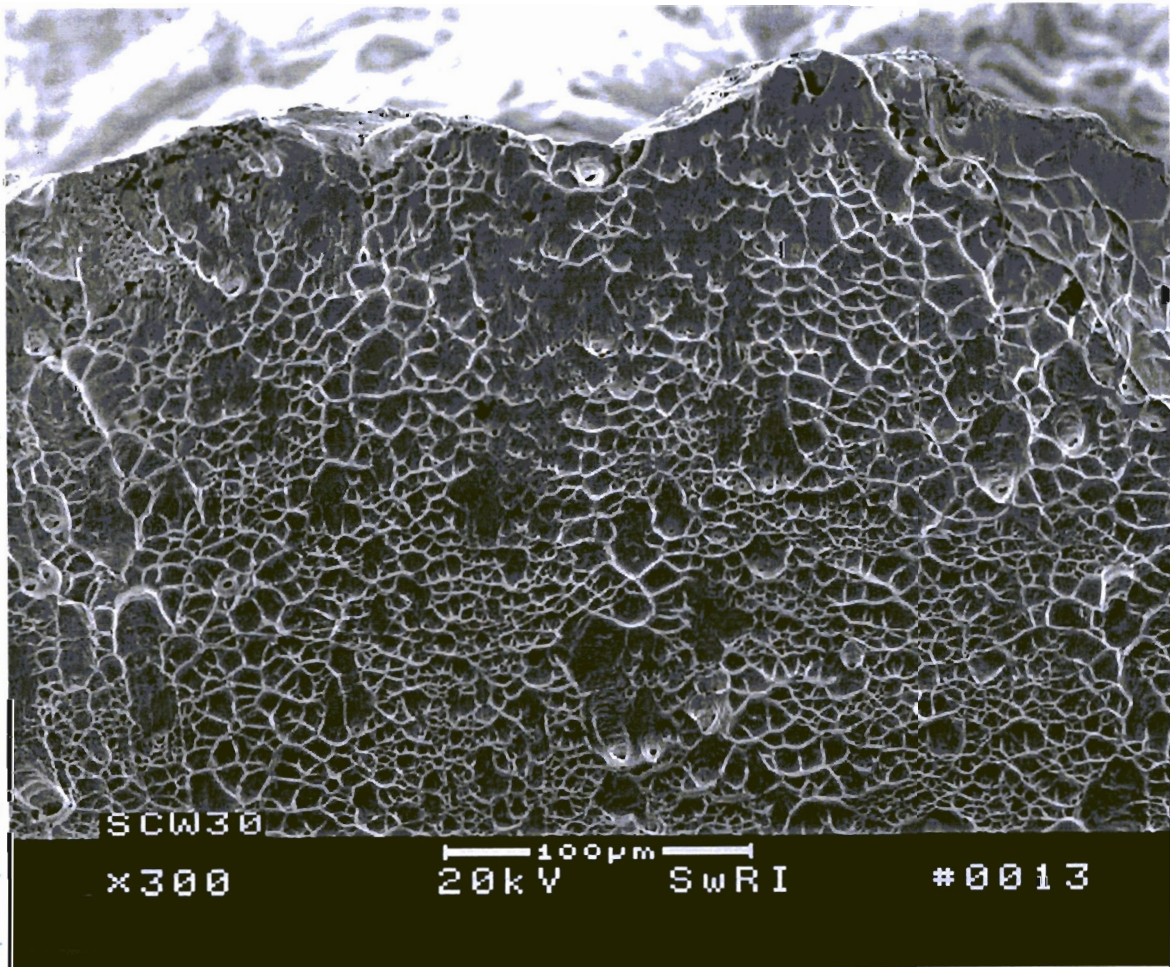
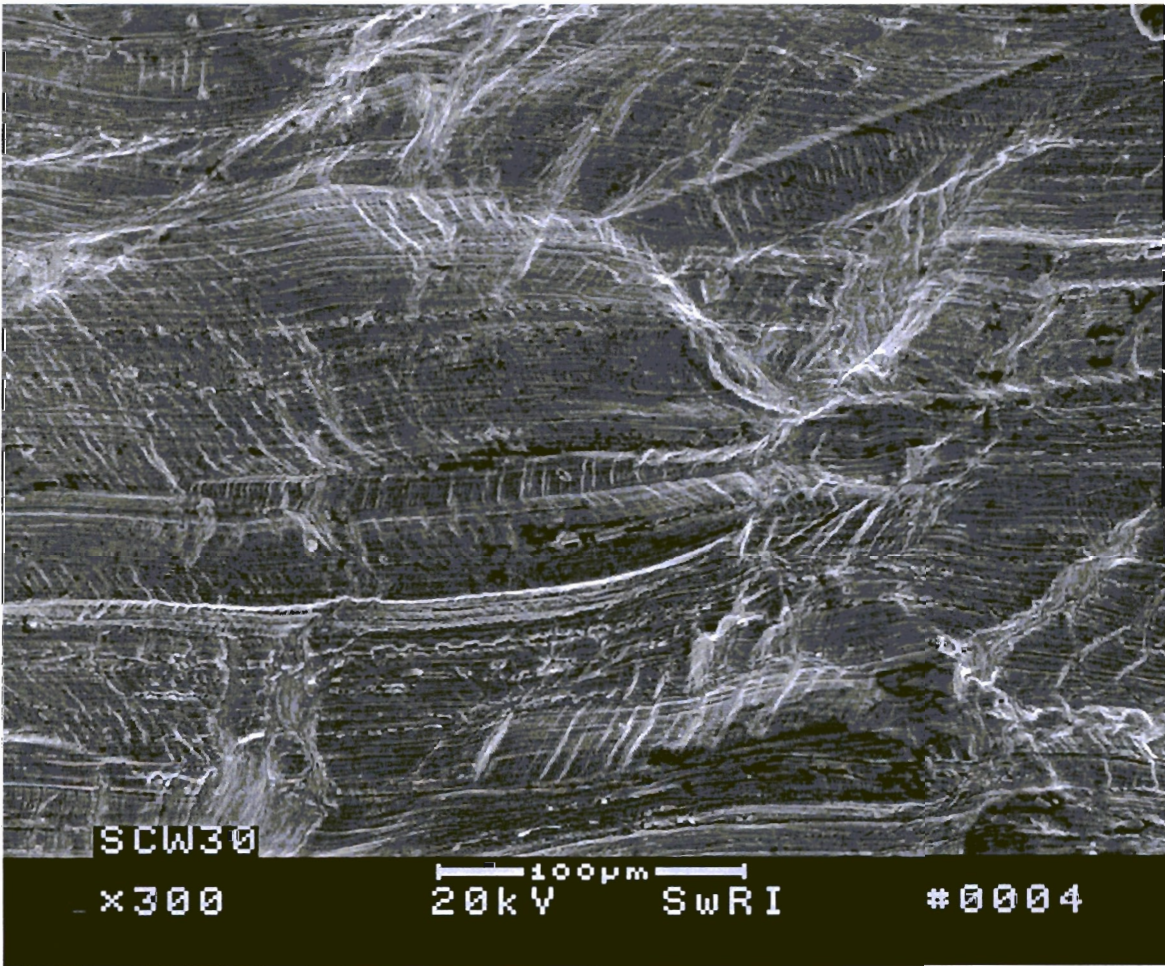
*K-1. Cluening 3/24/05*

*Summary of  
Slow Strain Rate Test Data*

SCW26 except  
NO  $\text{HCO}_3^-$

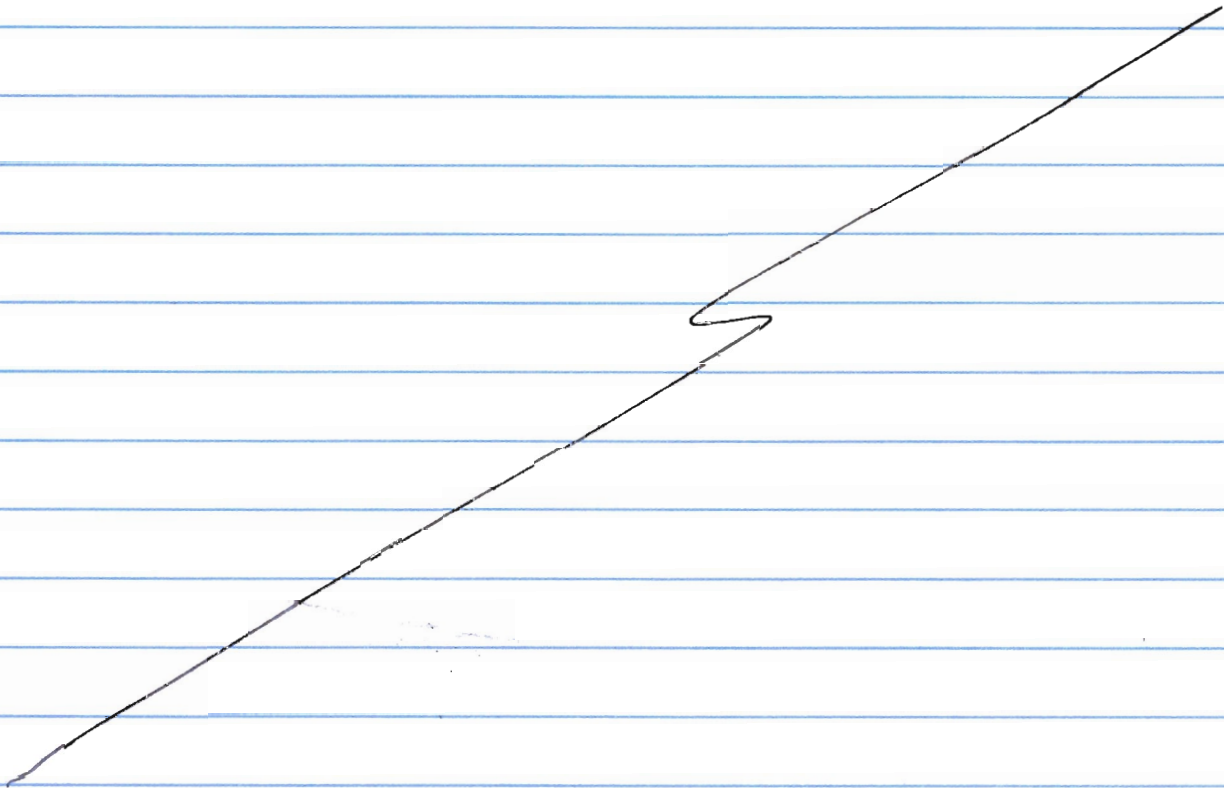
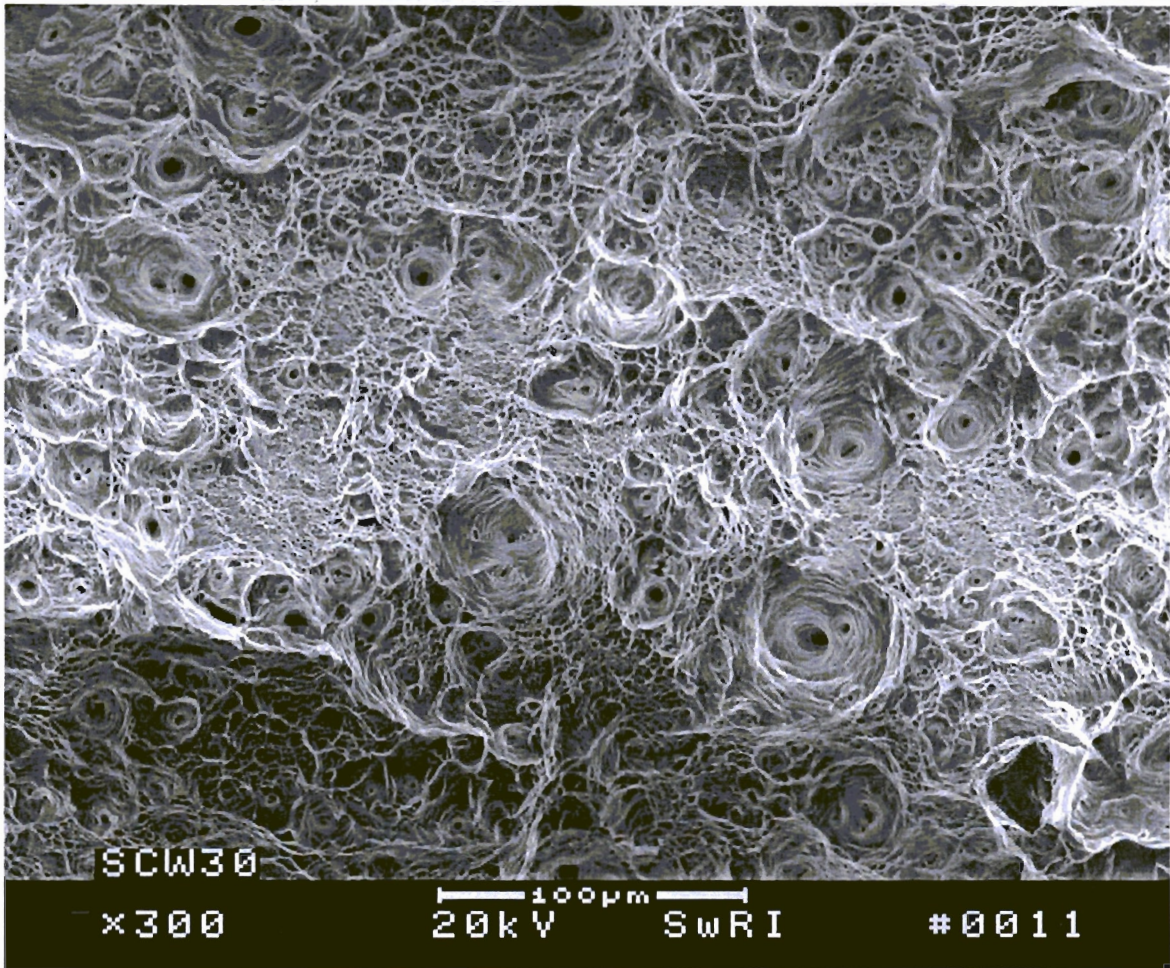


K.T. Ching 3/24/05

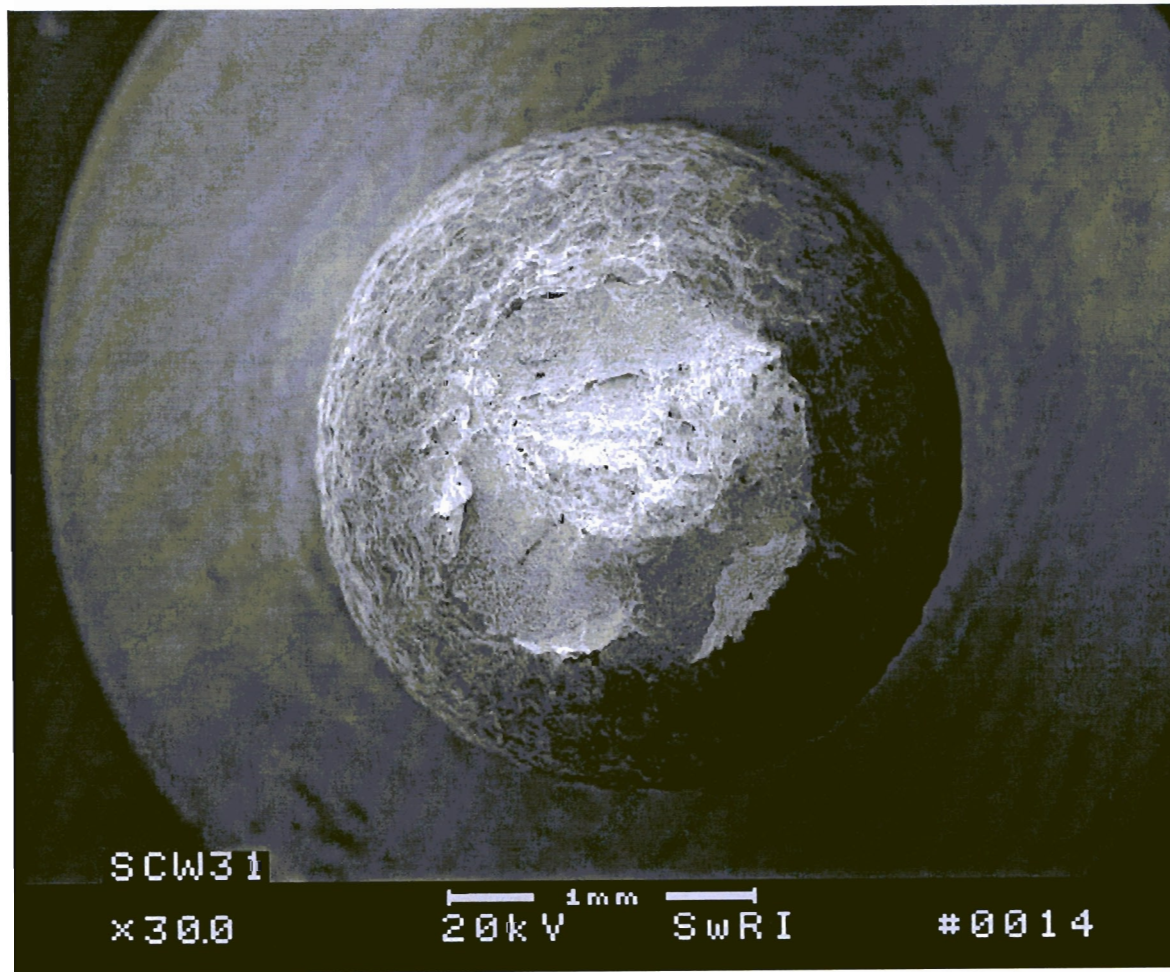
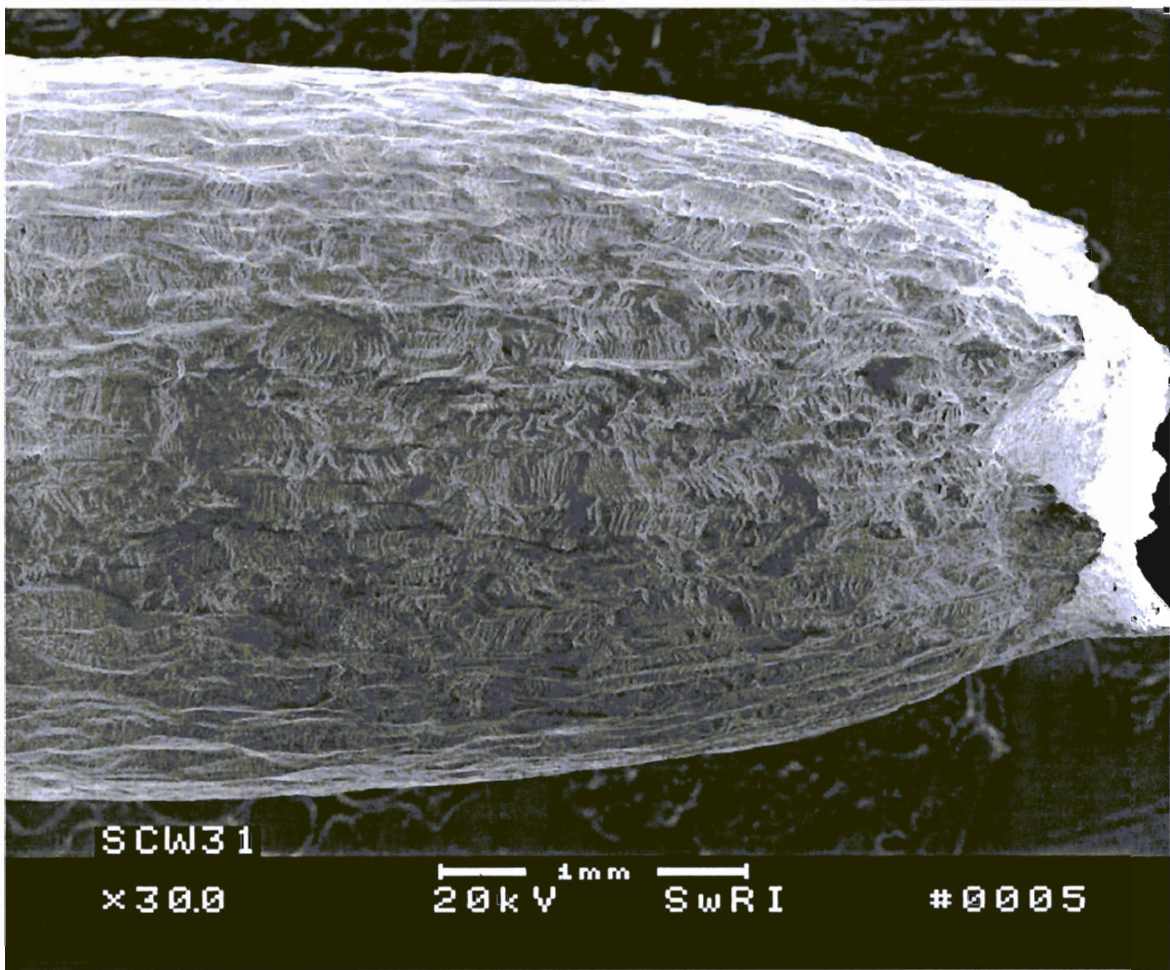


K. T. Ching 3/24/05

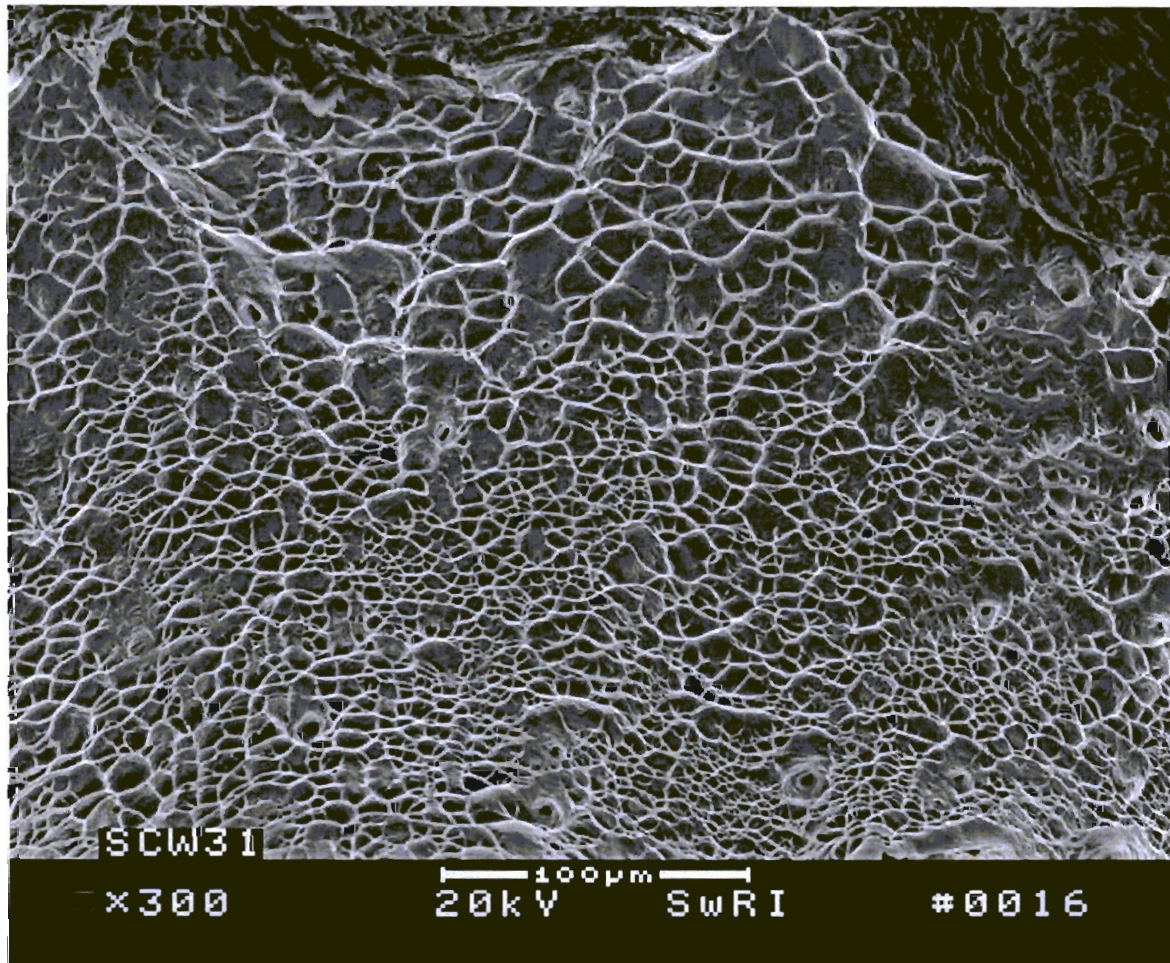
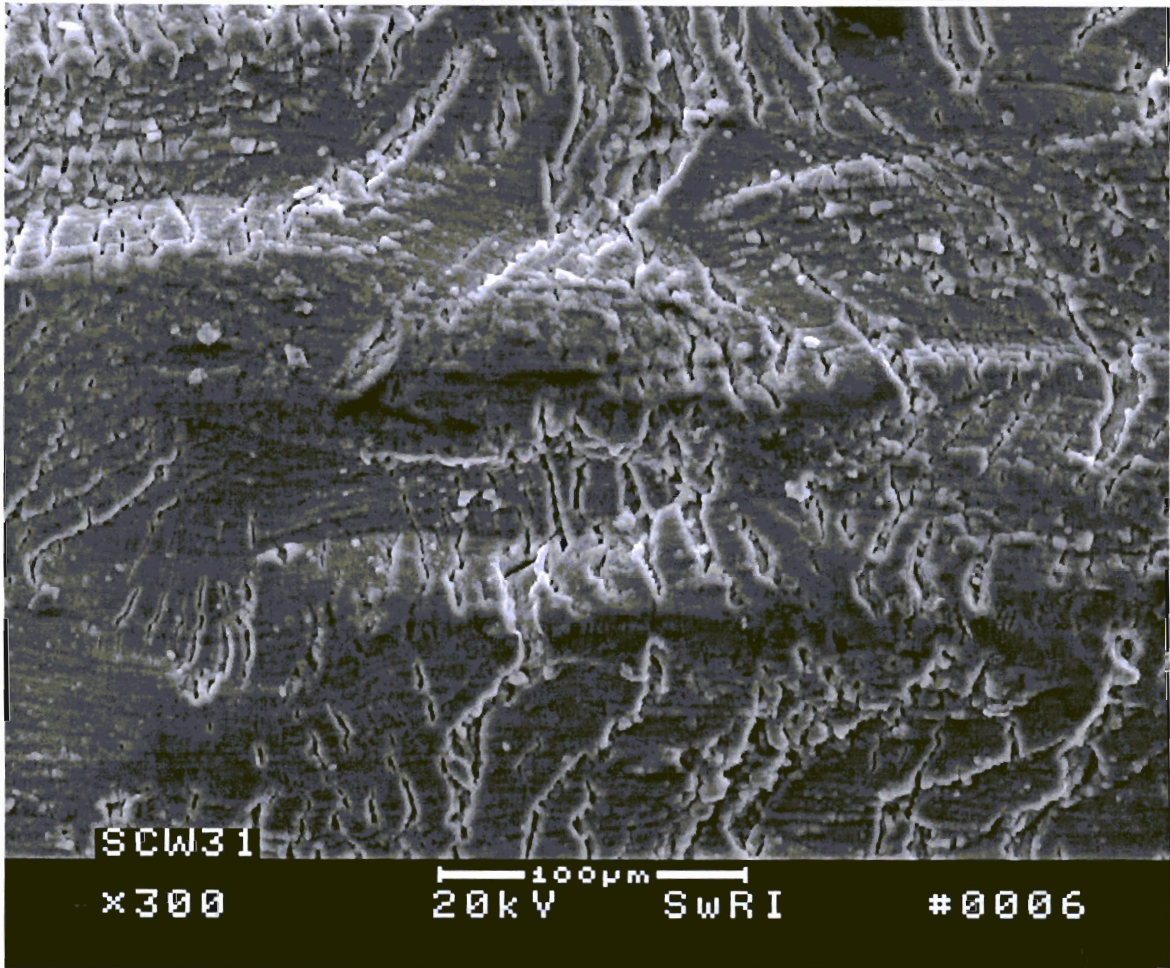




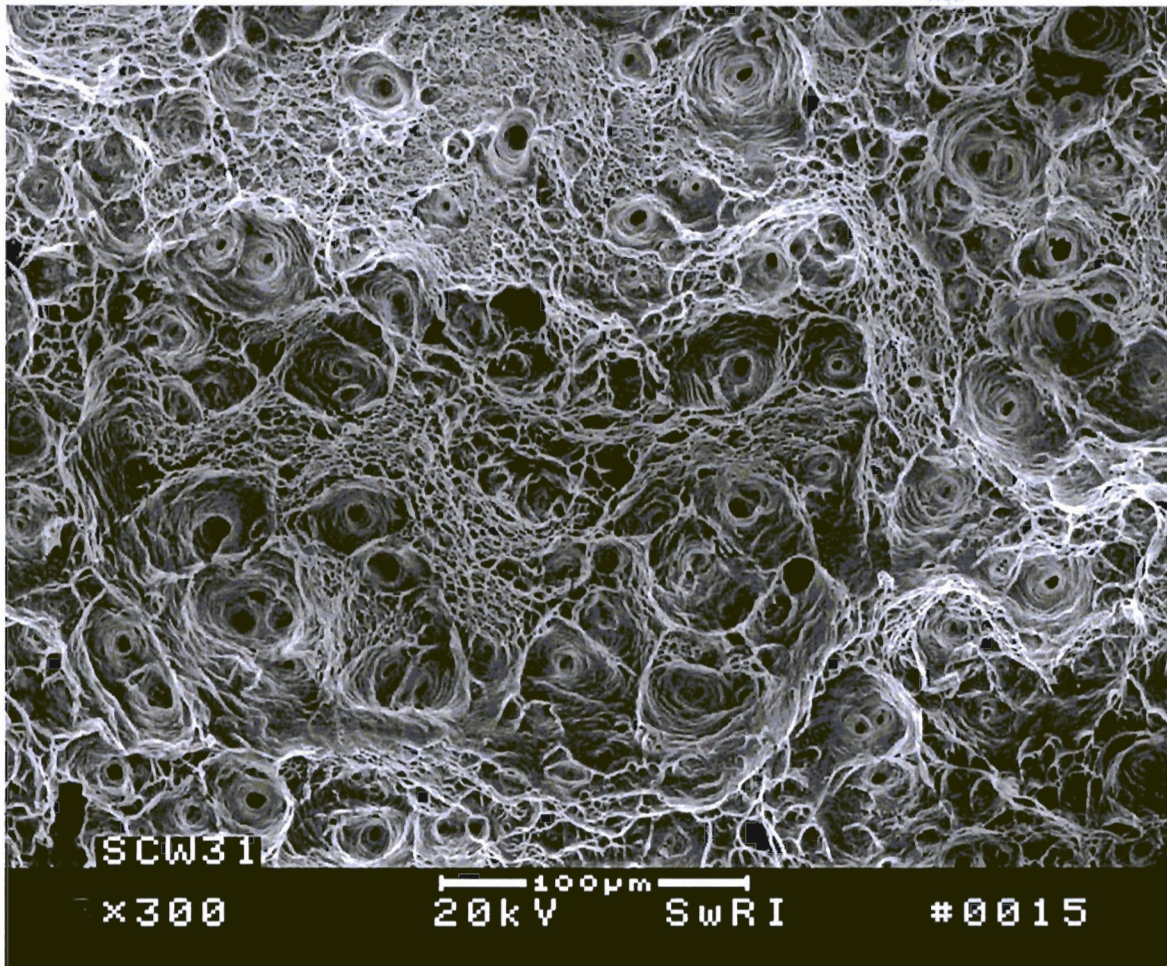
K.T. Chiao 3/24/05



K. J. Ching 3/24/05

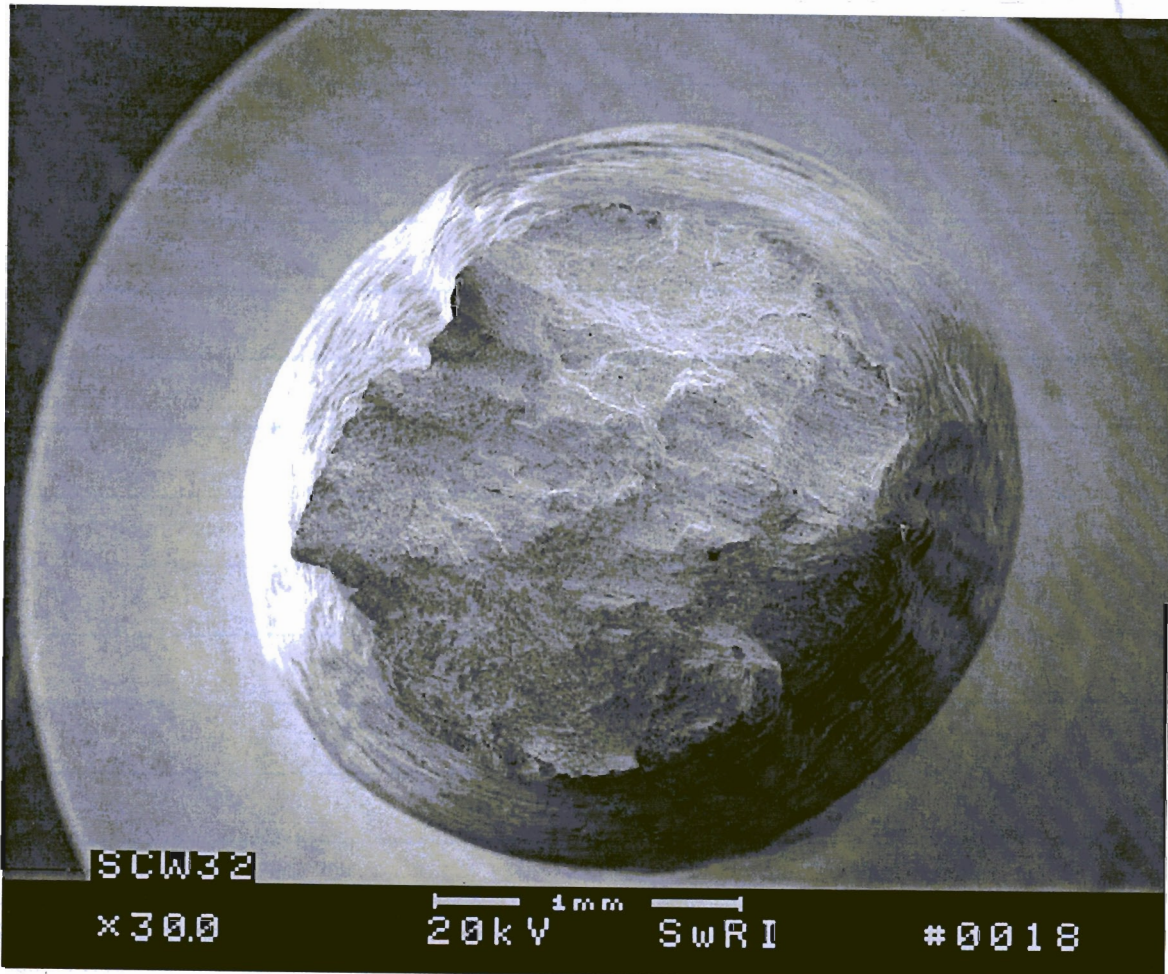
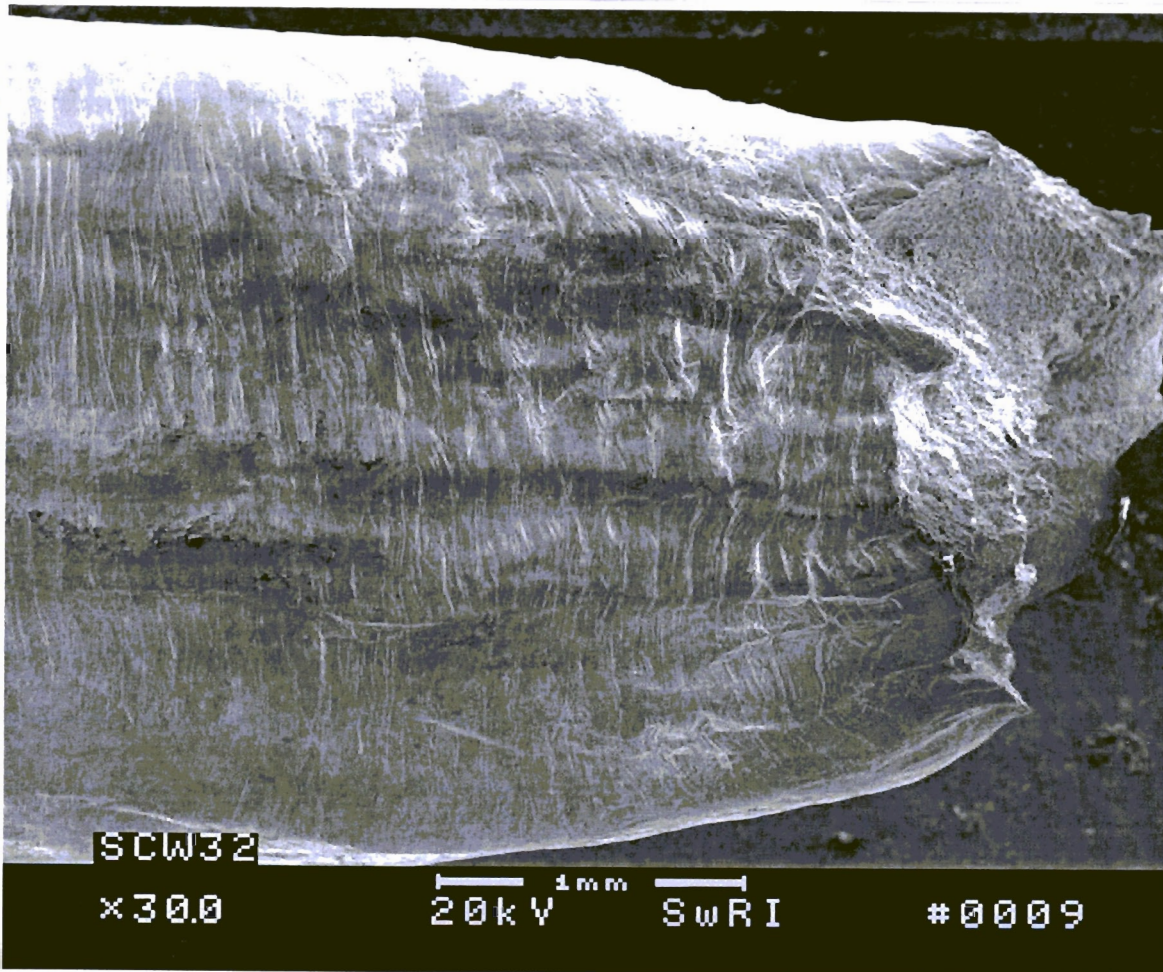


K. J. Chiang 3/24/05

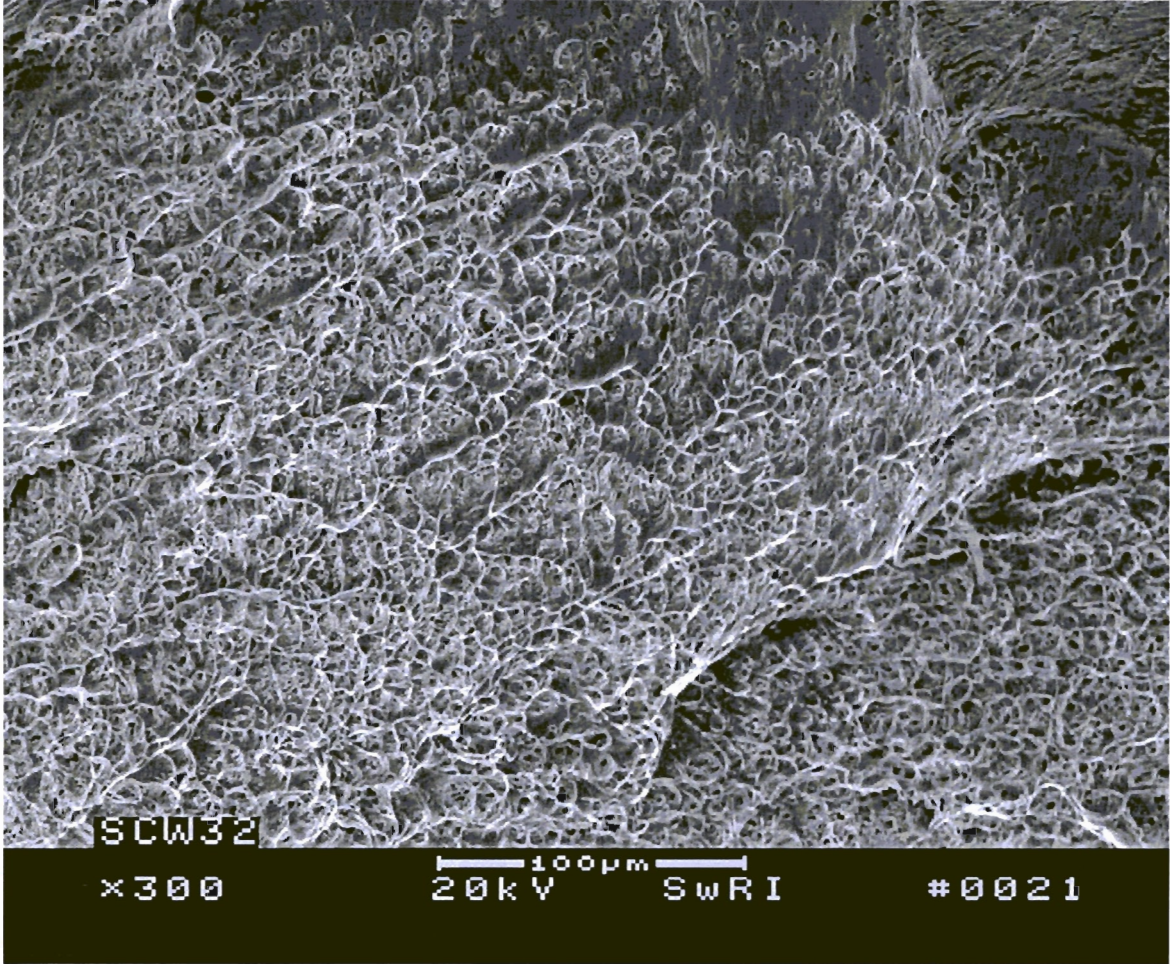
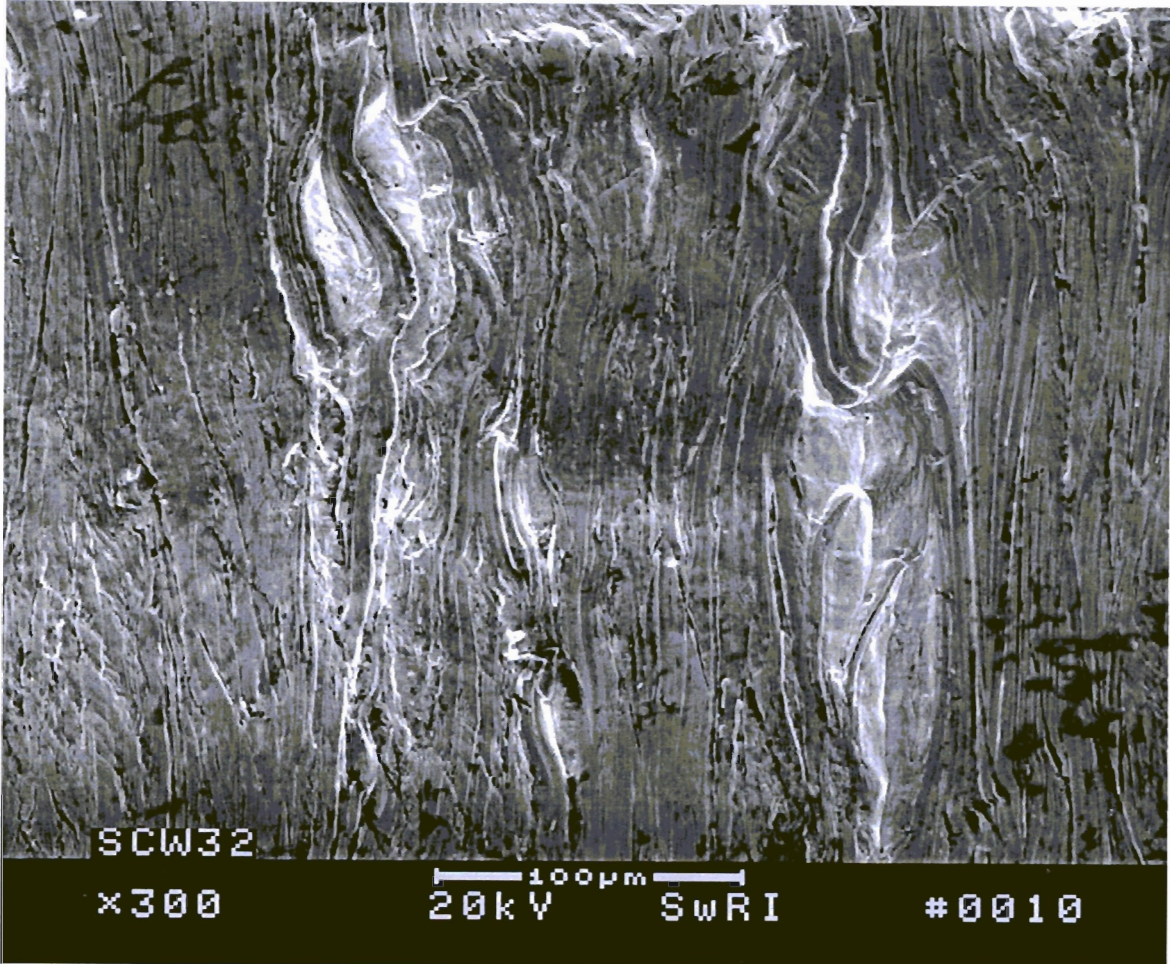


K. T. Chiang 3/24/05

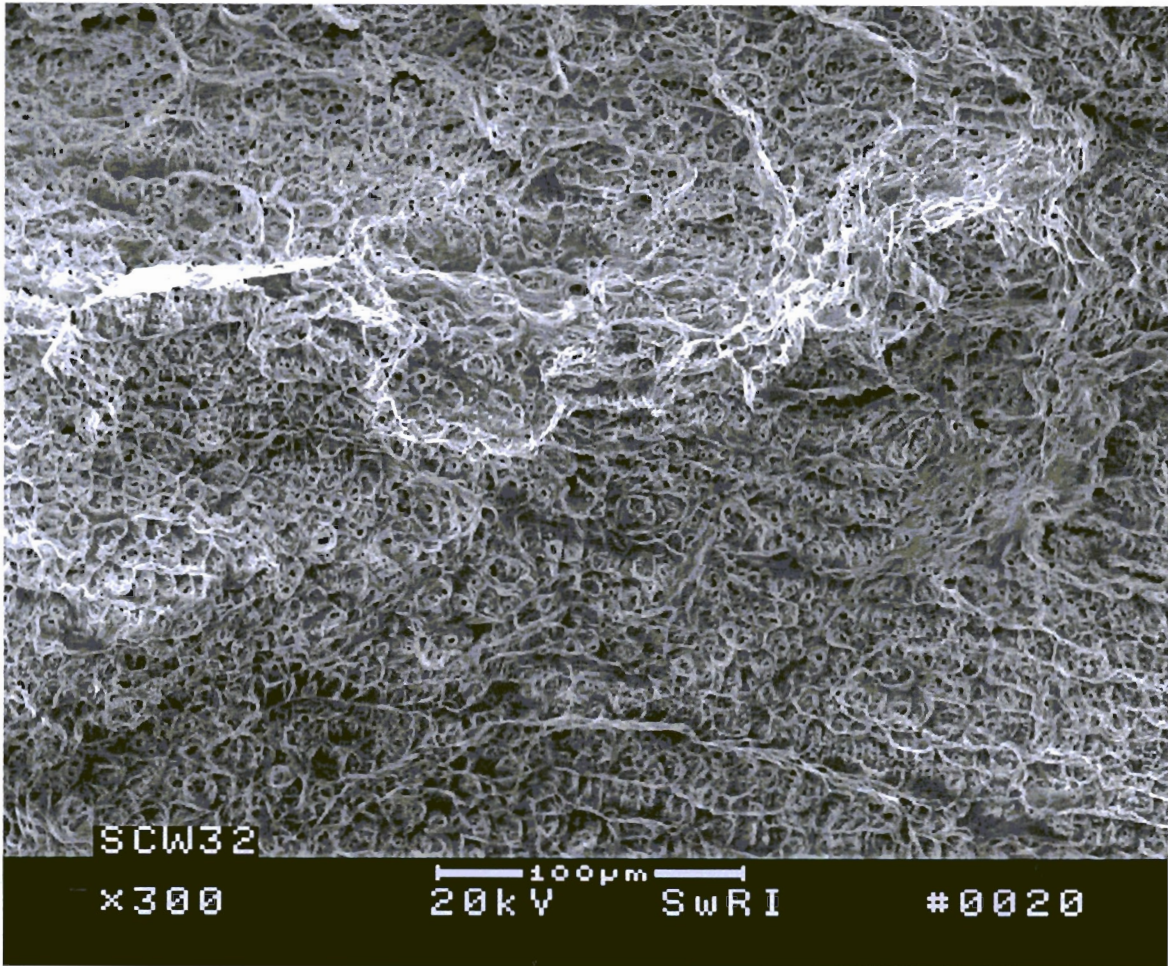
GMAW "A"  
SCW



K. J. Chiao 3/24/05



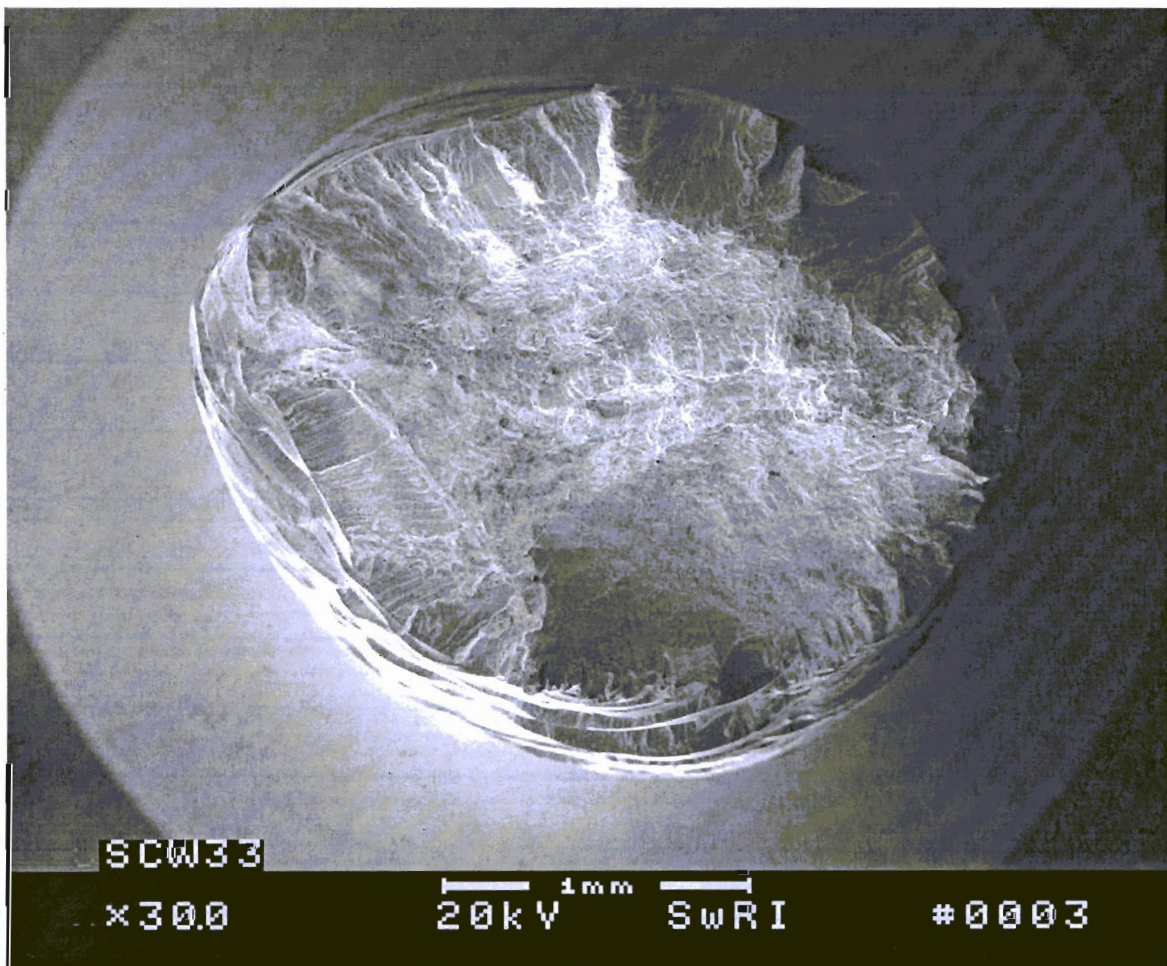
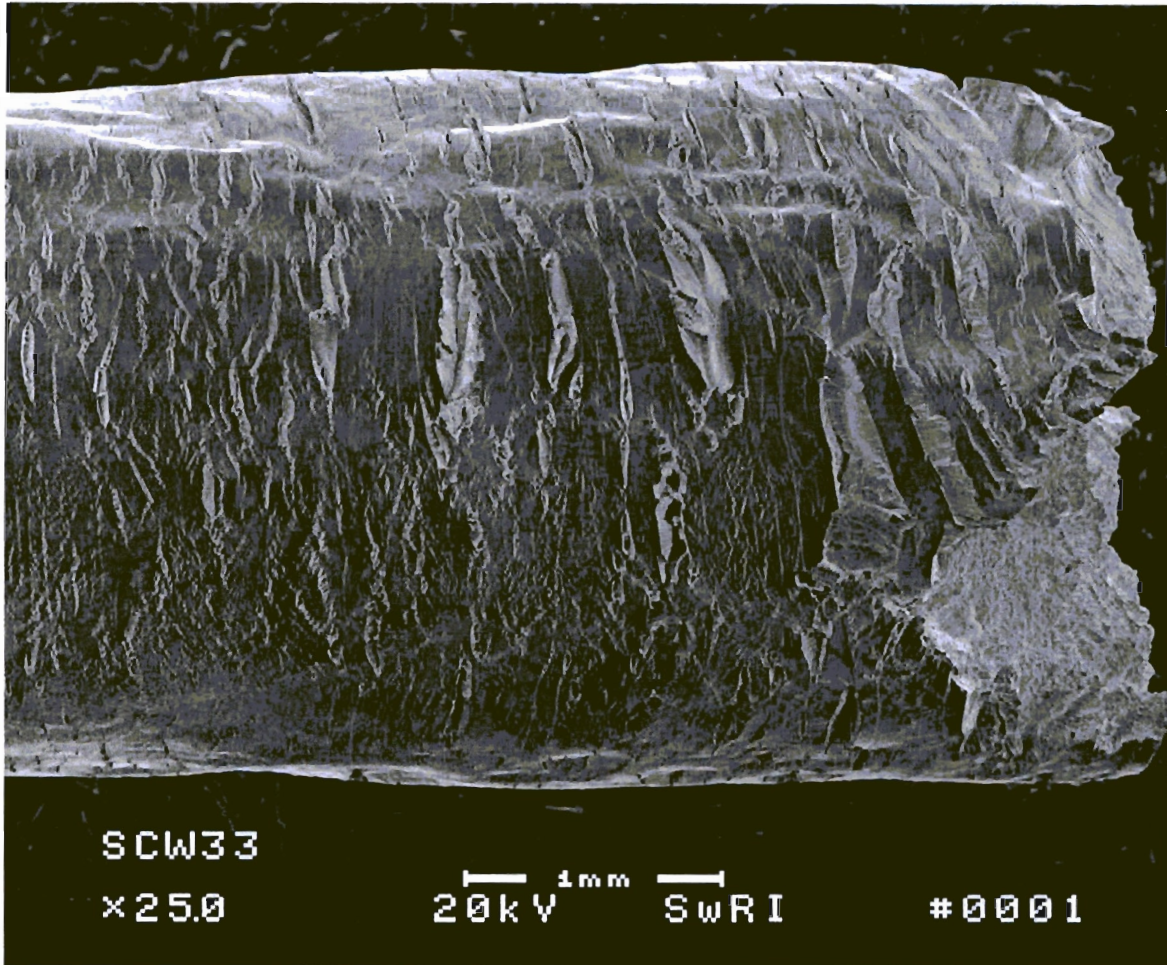
K. T. Chiang 3/24/05



Small dimples

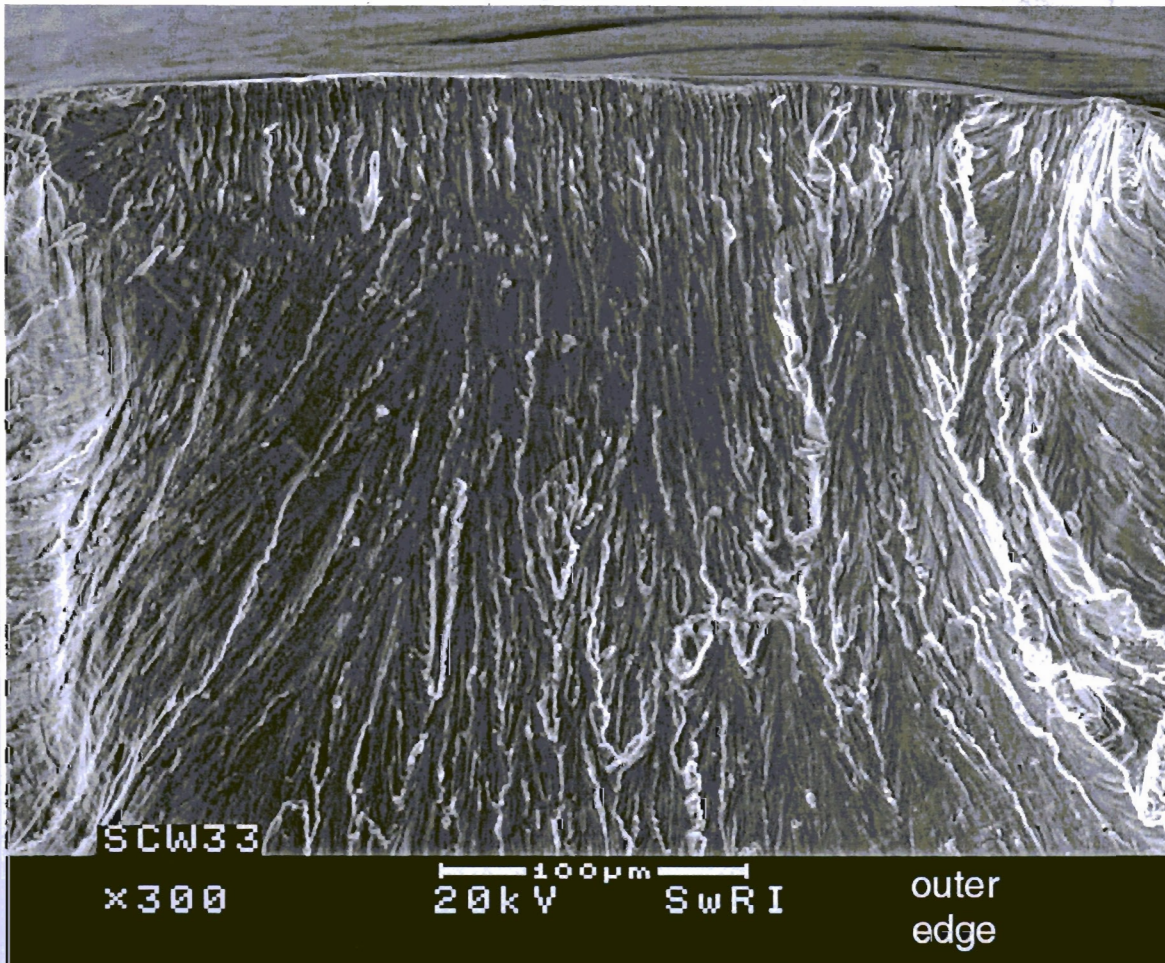
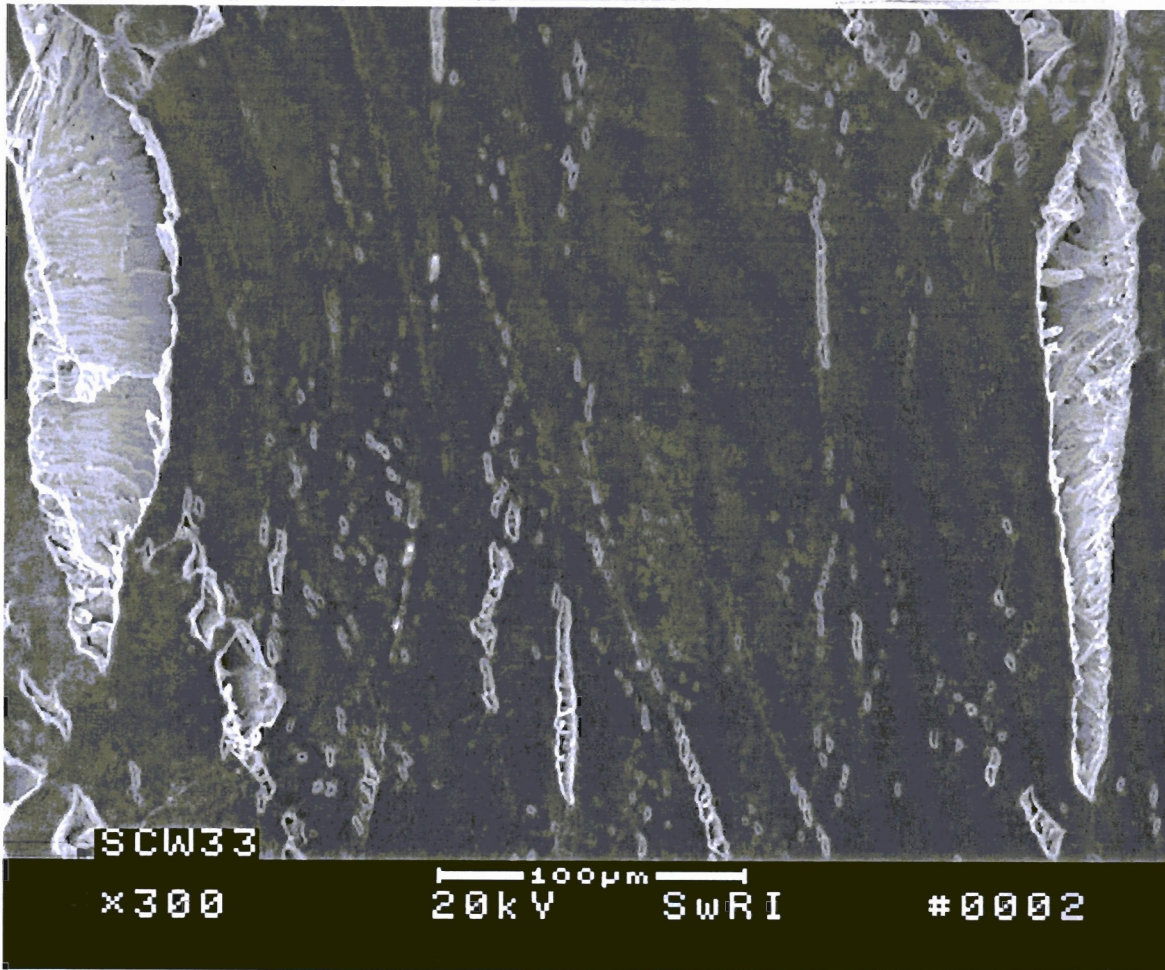
K.T. Chiang 3/24/05

22



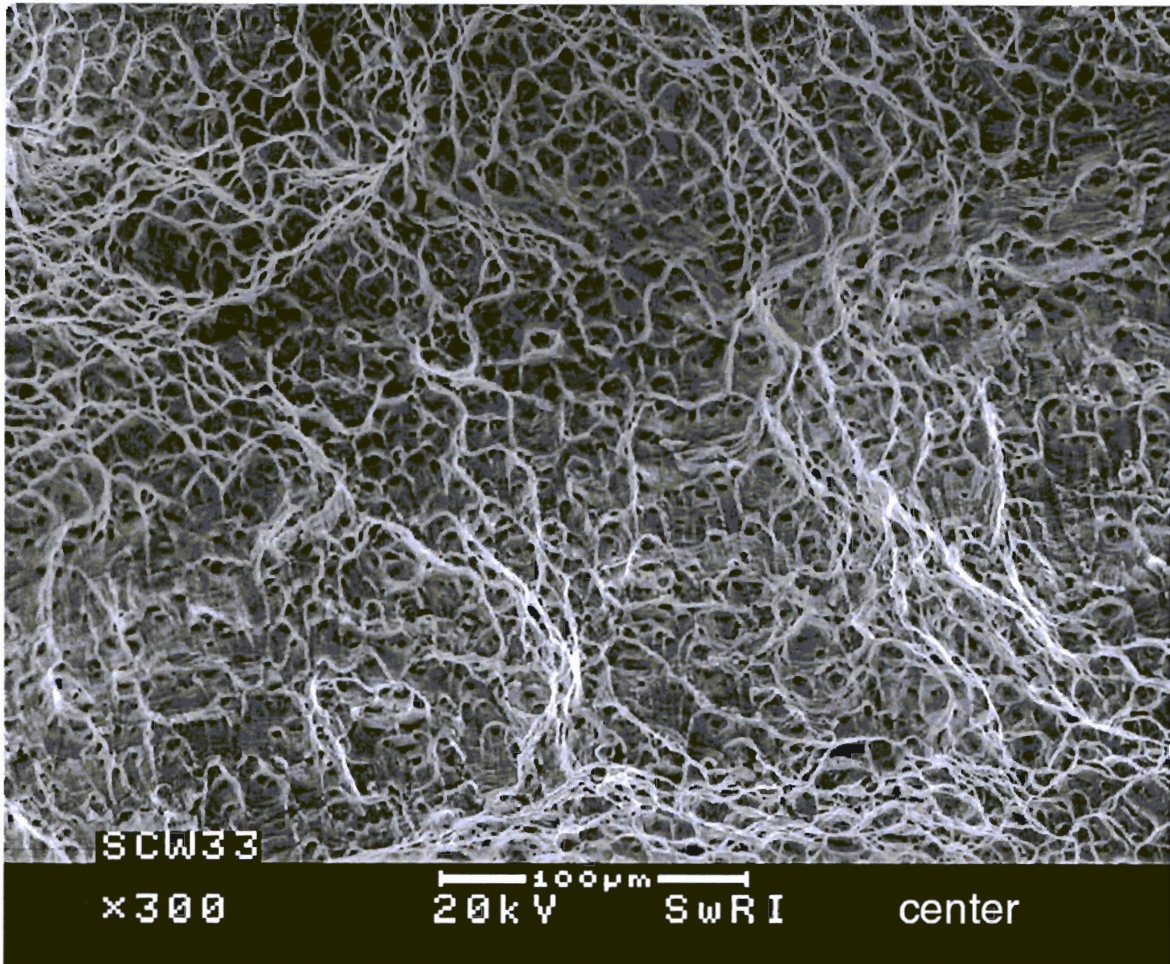
K. T. Chiu 3/24/05





Lined area for notes.

K. J. Ching 3/24/05



K.T. Ching 3/24/05

prepare specimens for annealing

|     |           |      |
|-----|-----------|------|
| 14C | as welded | GTAW |
| 14B | as welded | GTAW |

|   |     |                   |      |
|---|-----|-------------------|------|
| ✓ | 15C | welded + Annealed | GTAW |
|   | 15B | welded + Annealed | GTAW |

weld

|   |                   |      |     |
|---|-------------------|------|-----|
| ✓ | welded + Annealed | GTAW | 16C |
|   | weld + Annealed   | GTAW | 16B |

|   |     |           |      |
|---|-----|-----------|------|
| ✓ | 10B | As-welded | GMAW |
|   | 10A | As-welded | GMAW |

|   |     |                   |                 |
|---|-----|-------------------|-----------------|
| ✓ | 16B | welded + Annealed | <del>GMAW</del> |
|   | 16A | welded + Annealed | <del>GMAW</del> |

✓ samples provided to Y.M. Pan for microstructure analysis.

K.J. Chiang 3/28/05

## THERMALLY AGED PROCEDURE

Quantity/Specimens = GTAW 14 B+C - GTAW 15 B+C - GTAW 16 B+C  
 Side cuts 15 B+C                      Side cuts 16 B+C  
 HT# 2277-3-3292      WWS13/XX19778611

OVEN= Linobreg SN# 909172 Model # 51333

OVEN SETPOINT= 1137°C

OVEN TEMPERATURE= 1128.4°C

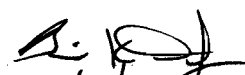
Measurement taken with OMEGA MICROPROCESSOR THERMOMETER                      MODEL# MH22  
 SN# T-94140                      CAL= 11/4/04                      DUE= 5/4/05

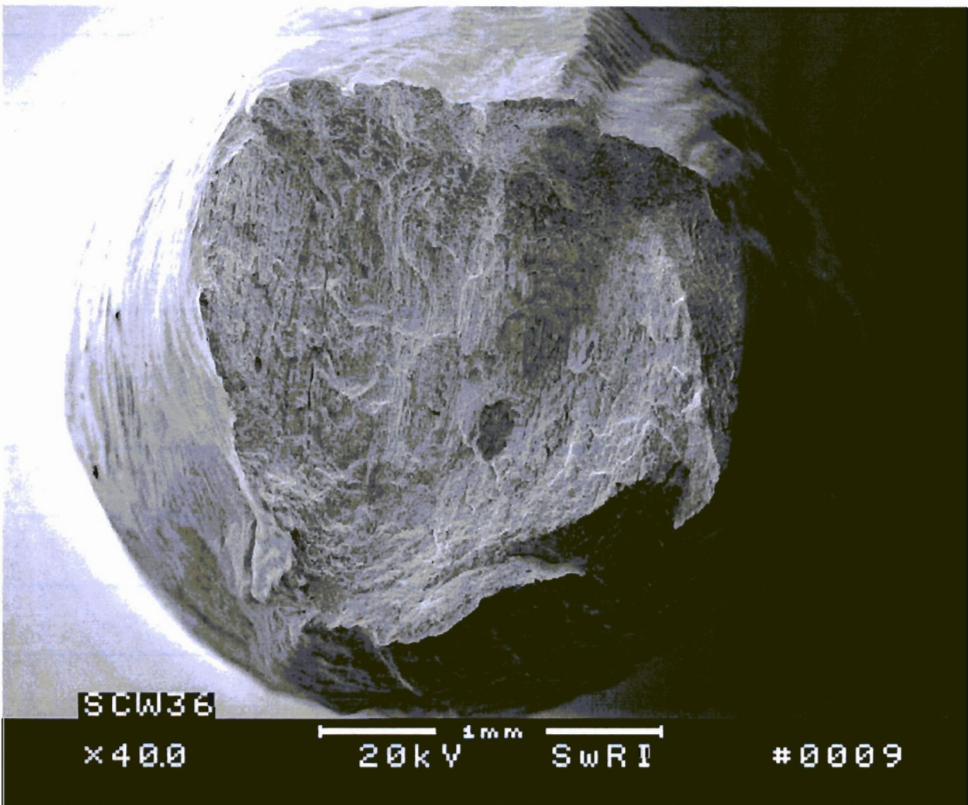
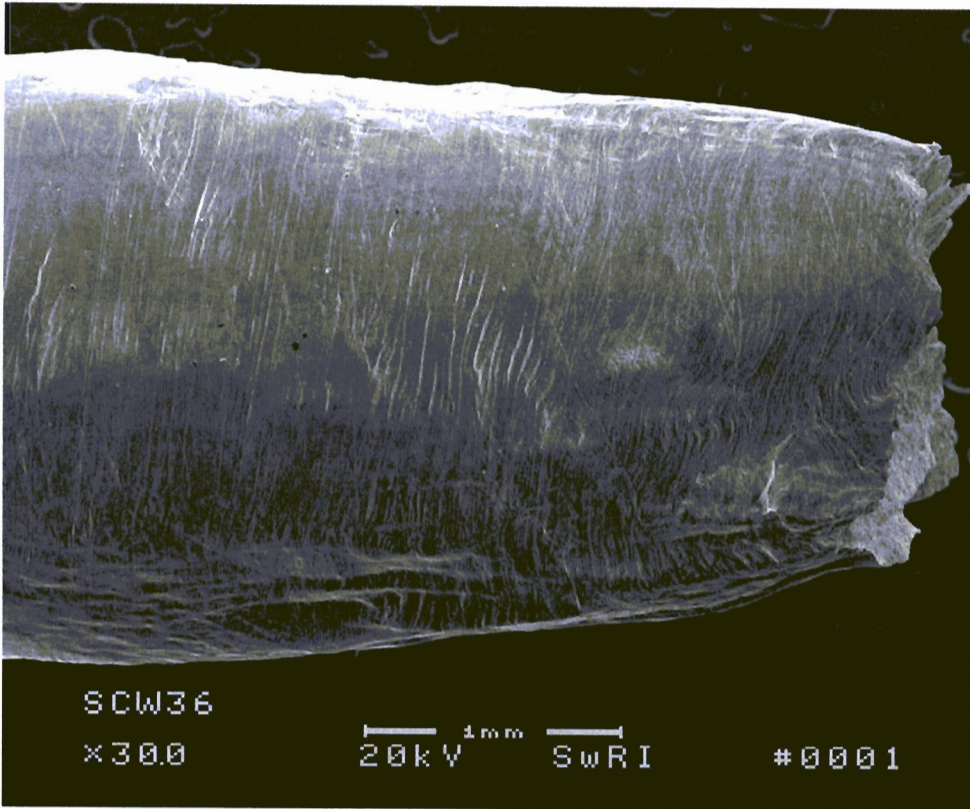
Thermocouple=                      SN# 326                      Cal = 2/2/05                      Due = 8/2/05

AMOUNT OF TIME = 20 mins @ Temp

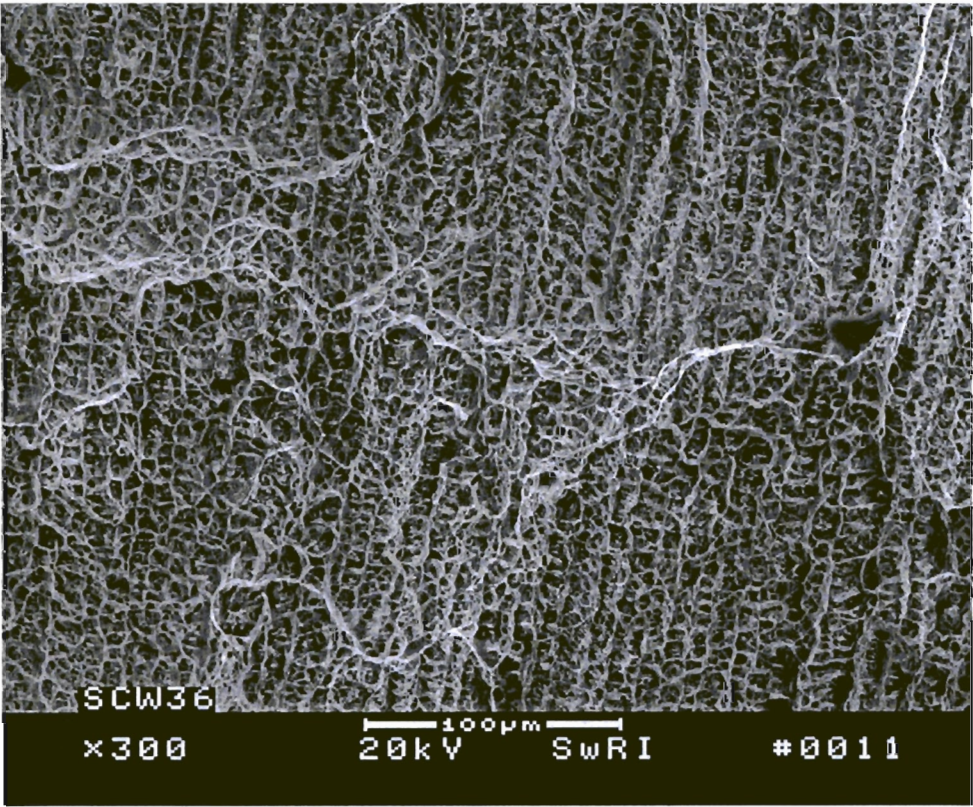
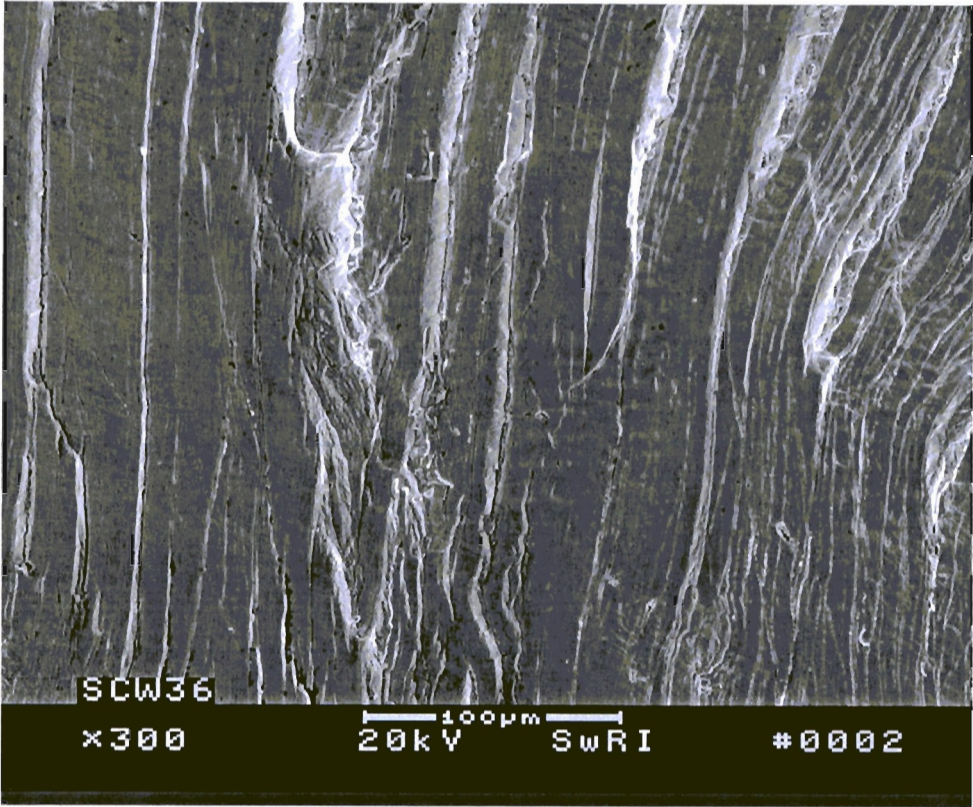
DETAILS= Main GTAW 14-15-16  
 oven placement @ 10:17 Reach Temp set point @ 10:23  
 started timer for 20 mins - water quench

GTAW 15-16 side cuts  
 oven placement @ 10:49 reaches temp set point @ 10:52  
 started timer for 20 mins - water quench

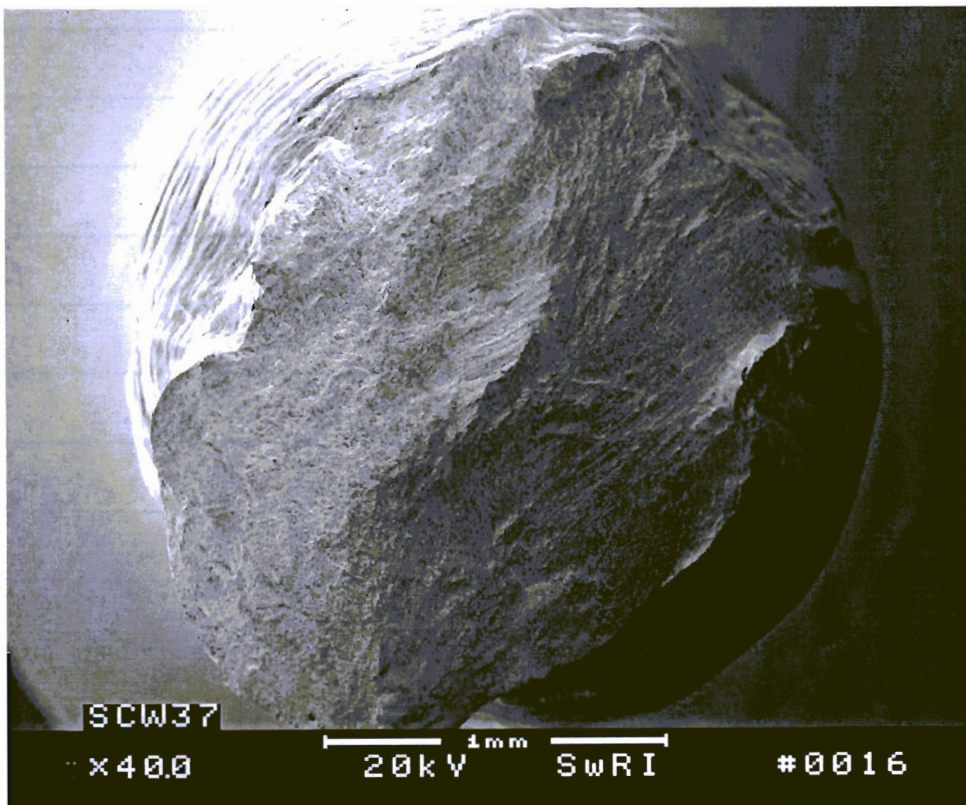
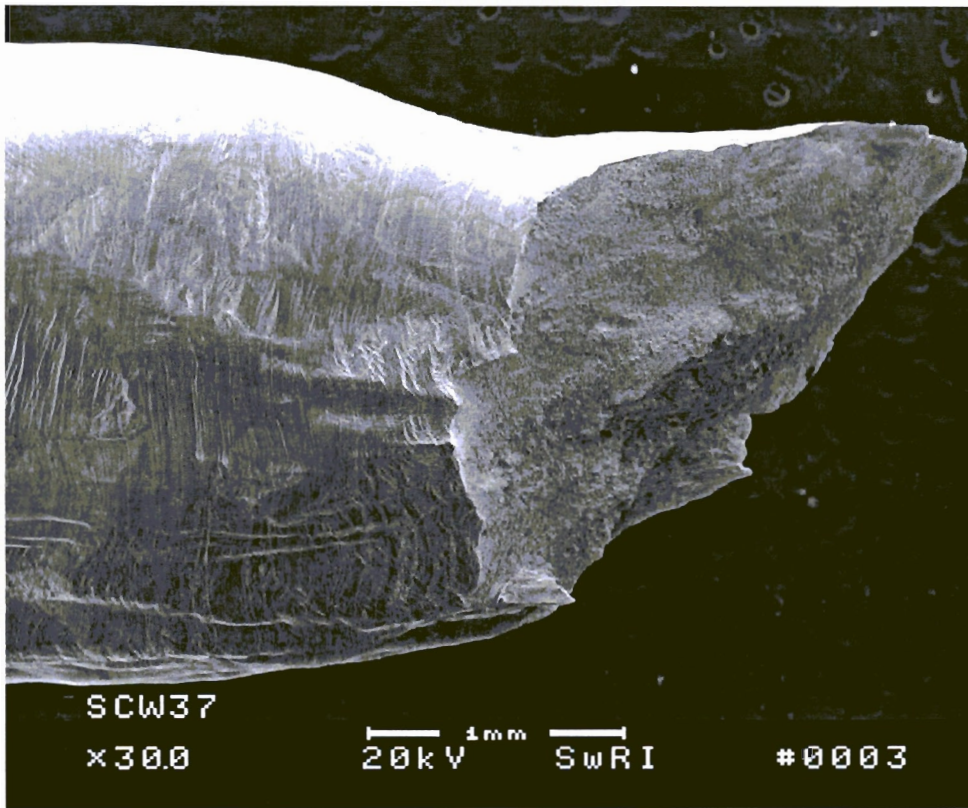
  
 3/29/05



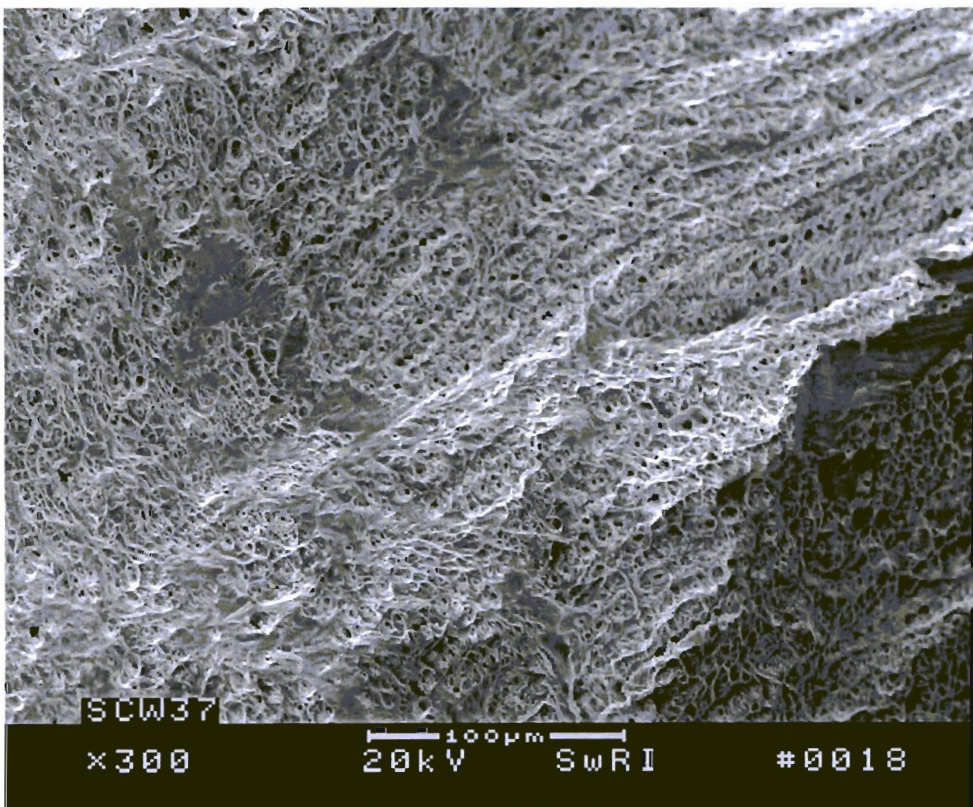
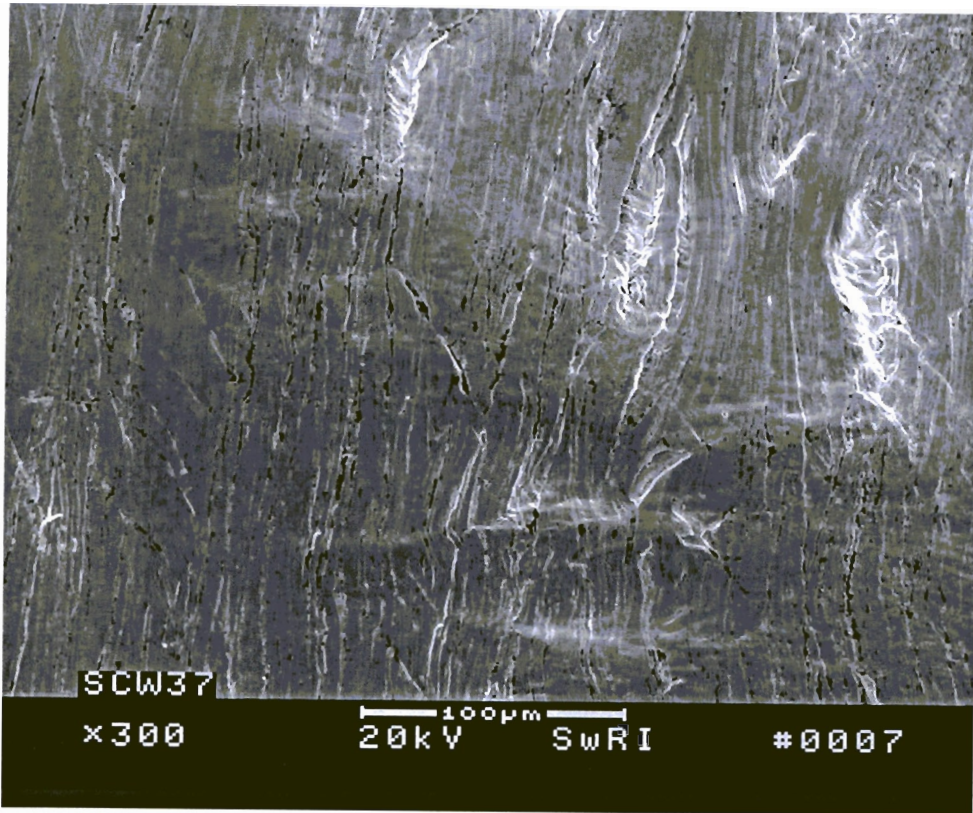
*K. J. Chiang 3/31/05*



*K. J. Chiang*  
3/31/05

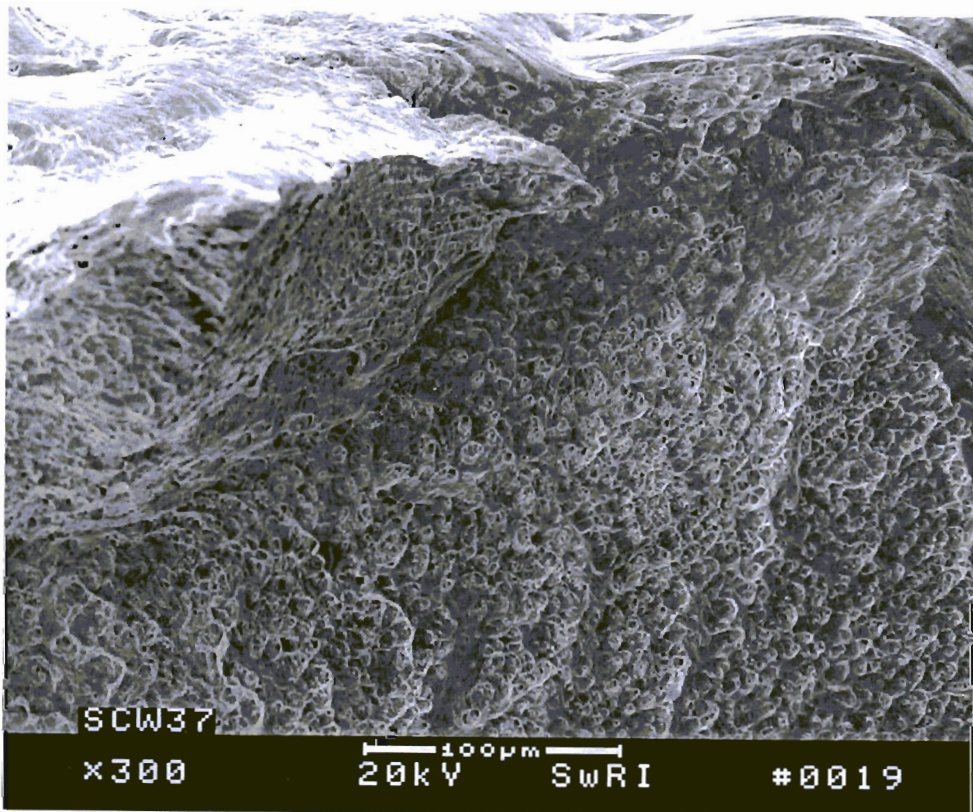
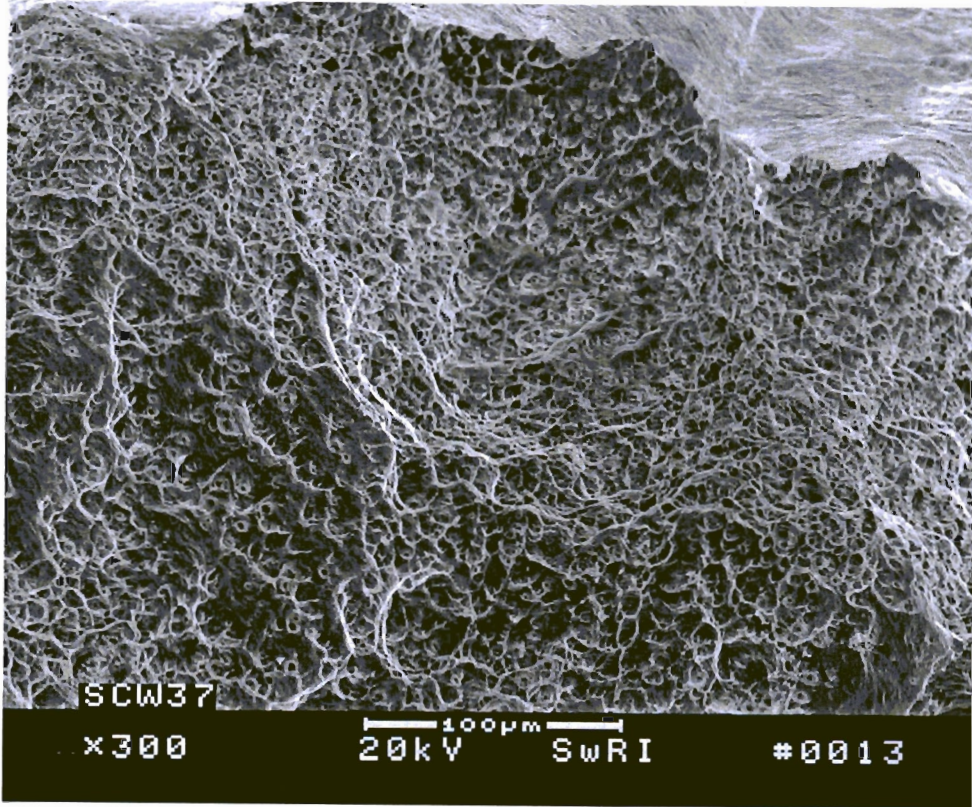


*K. T. Chiang*  
3/31/05



K. T. Chiang 3/31/05





K. J. Ching 3/31/05

Continue from Notebook No. 615

SLOW STRAIN RATE TEST

Objective: see page #5

CMAA #14A

Specimen: MA Alloy 22 SwRI Drawing # 20-03704-042-001 webes

Solution: x 1 liter

~~Heat #2277-8-3266~~  
2277-3-3292 UN813/XY177 BG11

BK0  
6/27/06

|  | LOT #'S |   |
|--|---------|---|
| 6.482 g KCl                              | 005613  | 96.284 g NaHCO <sub>3</sub> 028924      |
| 5.431 g NaCl                             | 042771  | 3.093 g NaF 991555                      |
| 8.752 g NaNO <sub>3</sub>                | 020809  | pH 7.79 $\xrightarrow{\text{adj}}$ 8.69 |
| 20.701 g Na <sub>2</sub> SO <sub>4</sub> | 035431  |   |

Reagents measured with

Model: OHAUS

SN: 2883

Cal: 14 JAN 05

Due: 14 JUL 05

Counter Electrode: Pt foil Reference Electrode: Ag/AgCl 4/3M KCl  
in bronze

Gas: N<sub>2</sub> (99.999) Ecorr:

\* Applied: +415mV Potentiostat: ESC 440-2 SN: 9209138

Specimen Visual:

no visible cracking  
looks more like ductile failure

$$\epsilon^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$$

\* temp correction (+15mV) @ 95°C

5/10 6/27/06

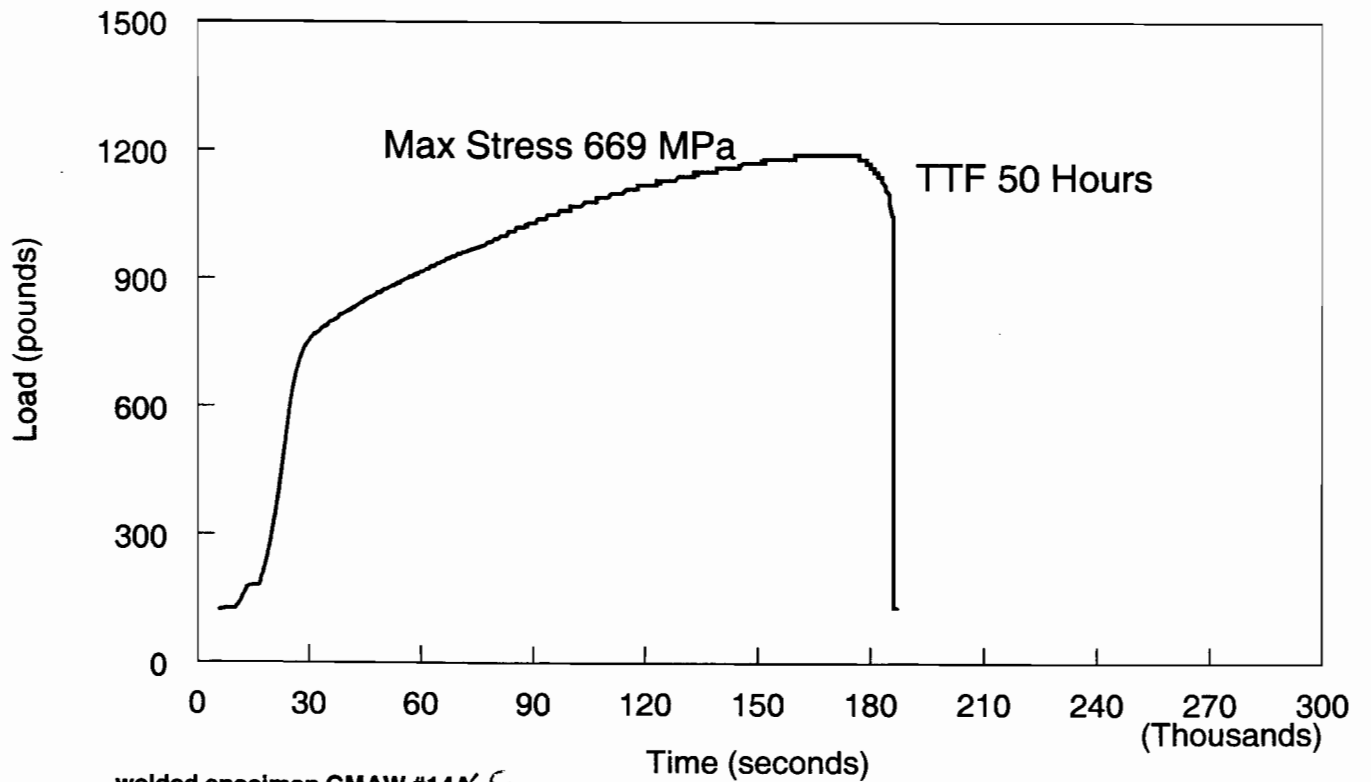
Test SSRMA22 SCW41

K. J. Ching 4/11/05

# Slow Strain Rate Test

SCW

Test SSRMA22\_SCW41

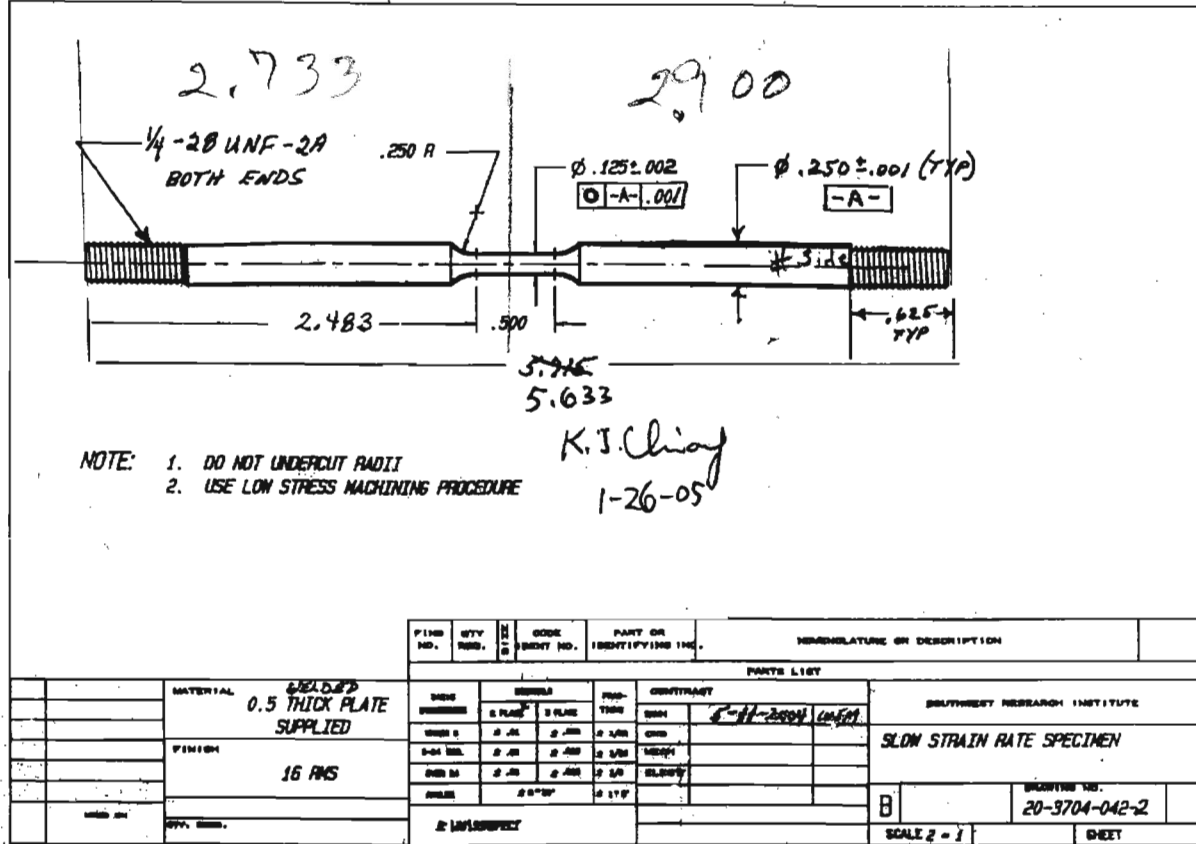
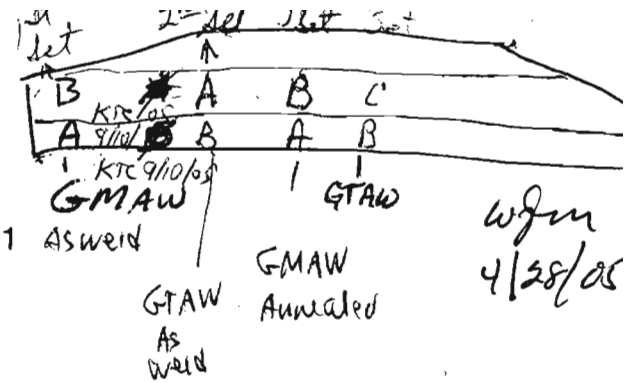


welded specimen GMAW #14A<sup>C</sup>  
aged at 1125°C for 20 minutes *KTC 4/11/05*

*K. J. Chiang 4/11/05*

Ken Chiang  
 SwRI-CNWRA  
 Phone: (210) 522-2308  
 Fax: (210) 522-5184  
 e-mail: Kchiang@swri.org

SwRI DRAWING # 20-06002-01-321-001



Procedure: 193-wt-821  
 Project # \_\_\_\_\_  
 TOTAL PCS. INSPECTED \_\_\_\_\_  
 TOTAL PCS. ACCEPTED \_\_\_\_\_  
 TOTAL PCS. REJECTED \_\_\_\_\_  
 "NR #" IF REJECTS \_\_\_\_\_

INSPECTOR

LOCATION CC31 MS  
 J.C. # 31173

EQUIPMENT  
 Shimadzu 005081 Mx 4-13-05  
 Ltd Gage 002174 Dm 11-19-02  
 Compax 005 D02158 1-18-06

DATE APR 25 2005

K.I. Chiang 4/27/05

| FILE NO.                        | QTY REQ. | REV. | CODE                         | PART OR IDENTIFYING INFO. | QUANTITY OR DESCRIPTION |
|---------------------------------|----------|------|------------------------------|---------------------------|-------------------------|
| PARTS LIST                      |          |      |                              |                           |                         |
| MATERIAL                        |          |      | SOUTHWEST RESEARCH INSTITUTE |                           |                         |
| WELDED 0.5 THICK PLATE SUPPLIED |          |      | SLOW STRAIN RATE SPECIMEN    |                           |                         |
| FINISH                          |          |      | DRAWING NO.                  |                           |                         |
| 16 RMS                          |          |      | 20-3704-042-2                |                           |                         |
| APP. DIMS.                      |          |      | SCALE 2 = 1                  |                           |                         |
| INSPECT                         |          |      | SHEET                        |                           |                         |

Initiator: K. Chiang Date

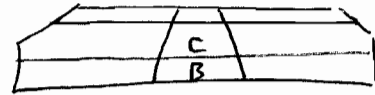
Reviewer: V. Jain Date

QA Approval: R. Brient Date

GTAW weld + 1125°C-20min annealed

14B, 14C 15B, 15C 16B, 16C

GTAW



| Weld | Sample | HT                  | Test  |
|------|--------|---------------------|---|
| GTAW | 14B    | weld + 1125°C/20min | Air - Ambient   |
|      | 14C    | weld + 1125°C/20min | Air - Ambient   |
| GTAW | 15B    | weld + 1125°C/20min | SCW   |
| GTAW | 15C    | weld + 1125°C/20min | 1.05M NaHCO <sub>3</sub> , 0.5M NaCl<br>0.19M NaOH 1.5M KCl |

K. J. Chiong  
4/28/05

SLOW STRAIN RATE TEST

Objective: see page #5 *5/4/05* *ND* *SM* *CTAW #14A*

Specimen: MA Alloy 22 SwRI Drawing # 20-03704-042-001 *06002-01-321-001*

Solution: *Heat 2278-8-3266*  
*2277-3-3292* *WN813/XY1977 B611* *8/0* *6/27/04*  
*thermally aged @ 1125°C / 20 min*

*test run in ambient air*

|                        |                      |      |
|------------------------|----------------------|------|
| Reagents measured with | Model:               | SN:  |
|                        | Cal:                 | Due: |
| Counter Electrode:     | Reference Electrode: |      |
| Gas:                   | Ecorr:               |      |
| Applied:               | Potentiostat:        | SN:  |
| Specimen Visual:       |                      |      |

*looks like ductile fracture*

$$e^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$$

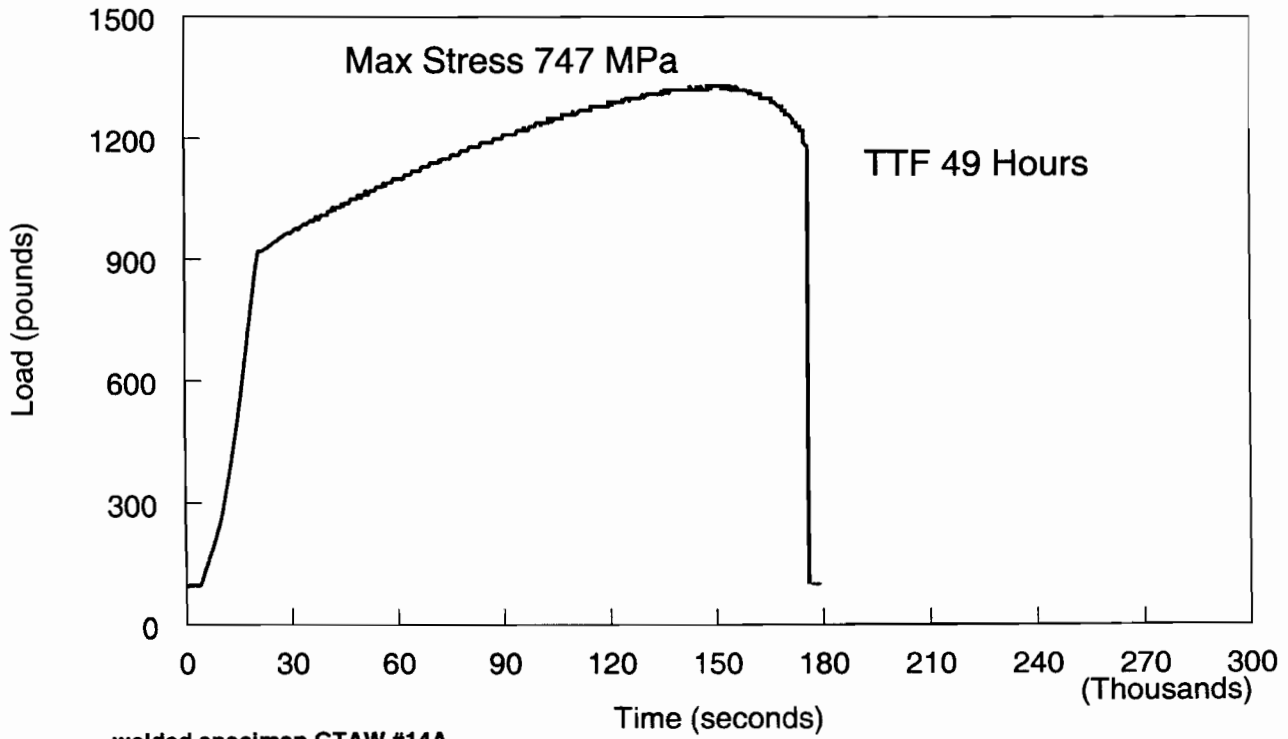
Test SSRMA22-SCW42 *3/0* *01/27/06*

*Walter J. Macroski*  
*5/4/05*

# Slow Strain Rate Test

Ambient Air

Test SSRMA22\_SCW42



welded specimen GTAW #14A  
aged at 1125°C for 20 minutes

*Walter J. Machoricki*  
5/4/05

SLOW STRAIN RATE TEST

5/4/05  
WJM

Objective: see page #5

Specimen: MA Alloy 22 SwRI Drawing # 20-03704-042-001 ~~06002-01-321-001~~ GTAW ueloco

Heat ~~2578-8-5262~~ 2277-3-3292 WJN813 / XJ977 0611  
BKO 6/27/06

Solution:

thermally aged @ 1125°C / 20 min

run in ambient air

Reagents measured with

Model:

SN:

Cal:

Due:

Counter Electrode:

Reference Electrode: *WJM*

Gas:

Ecorr:

Applied:

Potentiostat:

SN:

Specimen Visual:

looks like ductile fracture

$$\epsilon^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$$

5/4/05 Test SSRMA 22 SCW43

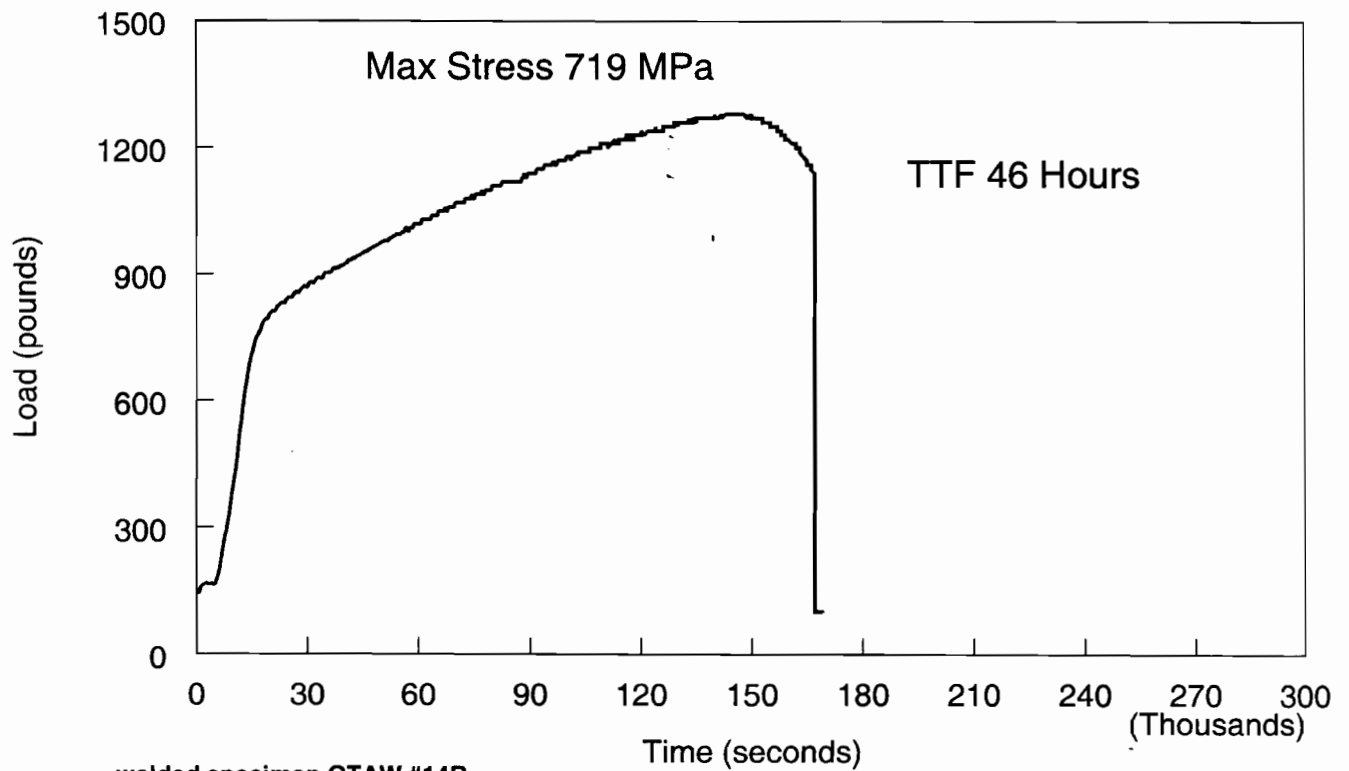
Walter J. Machowski  
5/4/05



# Slow Strain Rate Test

Ambient Air

Test SSRMA22\_SCW43



welded specimen GTAW #14B  
aged at 1125°C for 20 minutes

*Walter J. Meehan*  
5/4/05

SLOW STRAIN RATE TEST

Objective: see page #5

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001 GTAW welds  
 Solution: x 1/2 L *Neat* ~~2278-8-326-6~~ 2277-3-3292 WNS13/XP19770611 306/22/02

|                   |        |             |                                   |       |             |
|-------------------|--------|-------------|-----------------------------------|-------|-------------|
| KCl               | 3.24 g | LOT #005573 | Na <sub>2</sub> SO <sub>4</sub> g | 10.35 | LOT# 035461 |
| NaCl              | 2.72 g | LOT#050089  | NaHCO <sub>3</sub> g              | 48.17 | LOT# 044998 |
| NaNO <sub>3</sub> | 4.38 g | LOT#020809  | NaFg                              | 1.55  | LOT# 991559 |

Reagents measured with Model: OHAUS SN: 2883  
 Cal: 14 JAN 05 Due: 14 JUL 05  
 Counter Electrode: Pt *flag* Reference Electrode: Ag/AgCl w/3M KCl in house  
 Gas: N<sub>2</sub> (99.999) Ecorr: ?  
 \* Applied: +415 mV Potentiostat: ETC 440-2 SN: 9209138

Specimen Visual:

*looks like ductile fracture*

$$\epsilon^0 = 3.2 \times 10^{-6} s^{-1}$$

\* difference between RT and 95°C

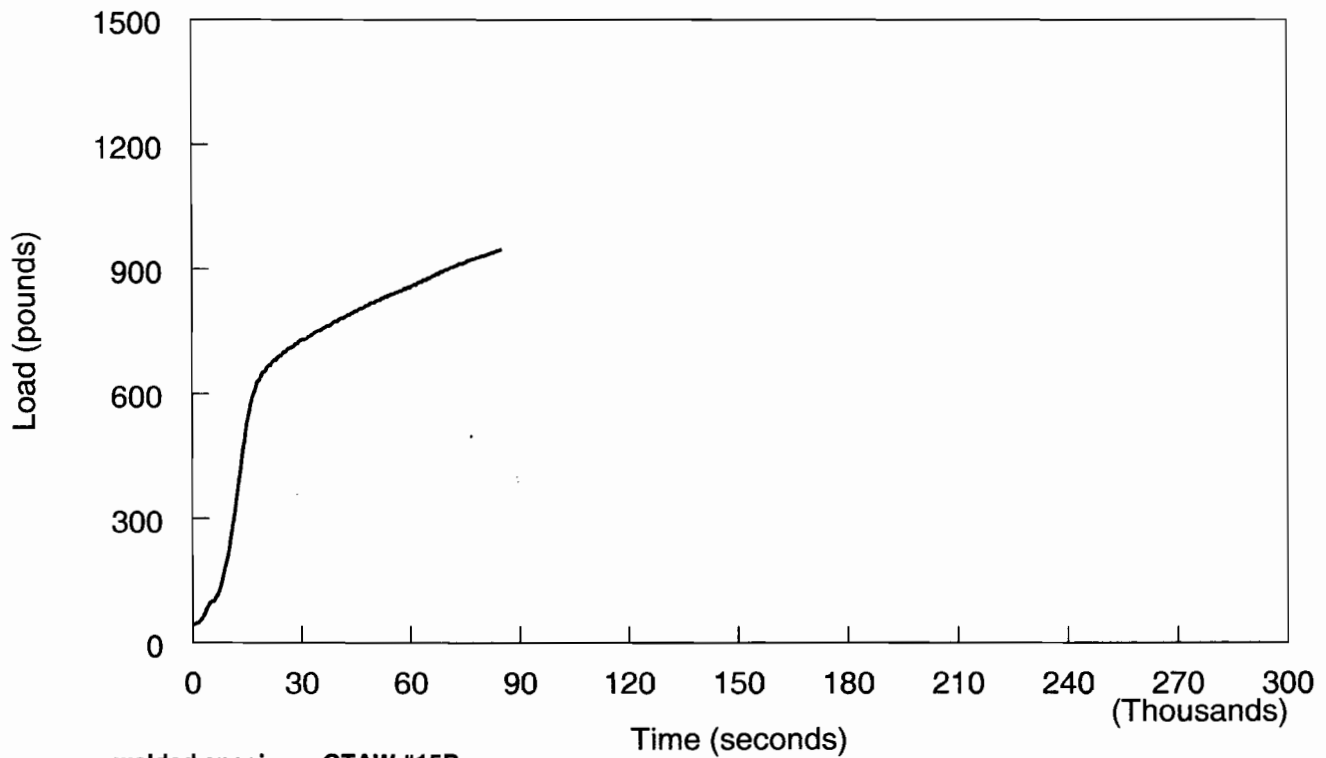
file: SSRMA22-SCW44

*Walter J. MacKosh*  
 5/9/05

# Slow Strain Rate Test

SCW

Test SSRMA22\_SCW44



welded specimen GTAW #15B  
aged at 1125°C for 20 minutes

*Computer glitch caused data to be overwritten  
and lost.*

*Walter J. Machowski  
5/9/05*

SLOW STRAIN RATE TEST

CTAW 15C

Objective: see page #5

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001 welded B19/02/06  
 Kent ~~2278-8-3266~~ 2277-3-3292 WNR13/XX19778011

Solution: ~ 1/2 liter

|                    |          |             |                   |       |
|--------------------|----------|-------------|-------------------|-------|
| NaCl               | 14.668 g | Lot #50089  | pH <sub>ini</sub> | 8.724 |
| NaHCO <sub>3</sub> | 44.04 g  | Lot #044998 | pH <sub>f</sub>   | 9.98  |
| NaOH               | 3.75 g   | Lot #897895 |                   |       |
| KCl                | 55.71 g  | Lot #005573 |                   |       |

Reagents measured with Model: OHAUS Cal: 14 JAN 05 SN: 2883 Due: 14 JUL 05

Counter Electrode: Pt flgc Reference Electrode: Ag/AgCl satm KCl in buret

Gas: N<sub>2</sub> (99.999%) Ecorr: -302 mV

Eapplied: -415 mV Potentiostat: ESC 440-2 SN: 9209138

Specimen Visual:

looks like ductile failure

spec temp w/ TC 008421 sent 327 cal 2/7/04-8/5/05

\* flake 179 DVM #010857 cal 5/4/05-5/11/06

\*\* connection @ 95°C (215 mV)

$$E^0 = 3.2 \times 10^{-6} \text{ S}^{-1}$$

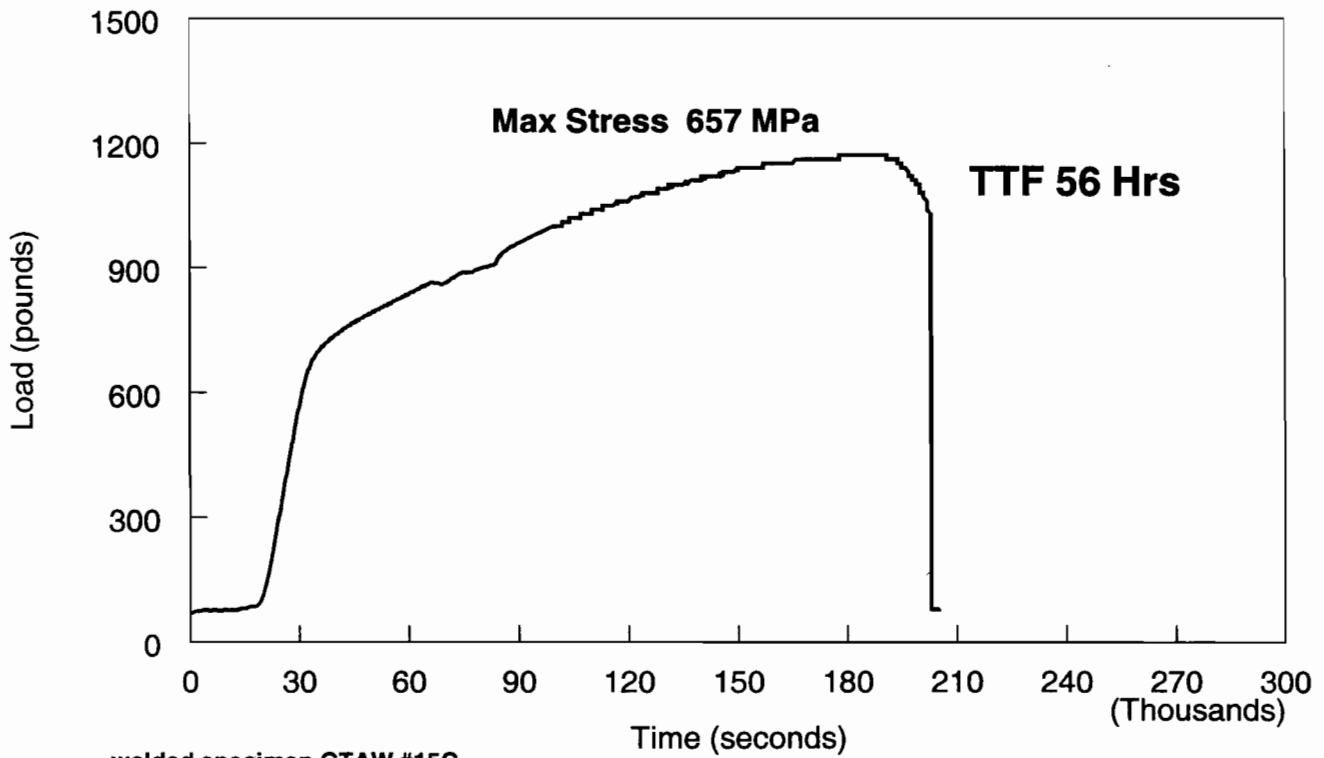
Test SSRMA 22 - SCW 45

Nathan J. Macorowski  
5/6/05

# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 0.19M NaOH; 1.5M KCl

Test SSRMA22\_SCW45



welded specimen GTAW #15C  
aged at 1125°C for 20 minutes

*Walter J. Markowski*  
5/9/05

## THERMALLY AGED PROCEDURE

Quantity/Specimens = (6) C-22 HT# 2277-3-3266 6" pre Cut for  
machining of slow strain Test Specimens - Long Rectangular Specimens

OVEN= Lindberg Model # 909172 SN# 51333

OVEN SETPOINT= 894°C


OVEN TEMPERATURE= 877.4°C

Measurement taken with OMEGA MICROPROCESSOR THERMOMETER MODEL# MH22  
SN# 7-94140 CAL= 5/12/05 DUE= 11/11/05

Thermocouple=  
SN# 330 Cal= 2/2/05 Due= 8/2/05

AMOUNT OF TIME = 30 min then Water Quenches

DETAILS= All Specimens placed Into Oven At the Same  
time Held for 30 min - lose of 6° from  
Door being open 4 min to reach Back up to  
Set Point Temperature - then water Quenches

  
5/13/04

K. T. Chiang  
5/20/05

Details of Equipment Calibration and Performance Verification.  
 SSRT Instrument Calibration for Slow Strain Rate Tests per QAP-019.

**Institute Calibration Laboratory Instruments Processed:**

Action Performed: CHECKIN Date: 5/19/2005

| Asset                                  | Charge Code    | Workorder | Model  | Manufacturer | Description  | Serial Number |
|--|----------------|-----------|--------|--------------|--------------|---------------|
| 011659                                 | 00751.006 1.20 | 303064334 | TYPE K | DURO-SENSE   | THERMOCOUPLE | 0003          |
| Total Number of Instruments Processed: |                | 1         |        |              |              |               |

MARCH 19, 2004

THE GAGE BLOCKS LISTED BELOW WERE MEASURED IN BUILDING #162 LOCATED ON SOUTHWEST RESEARCH INSTITUTE CAMPUS. THE TEMPERATURE WAS 70 DEGREES AND HUMIDITY OF 60 PERCENT. 0-1 DIGITAL MICROMETER (ASSET# 009976, SERIAL #2191790) WAS USED TO TAKE THE MEASUREMENTS AND HAS A CALIBRATION DUE DATE OF JAN. 15, 2005.

| GAGE BLOCK #    | DIMENSION MEASURED |
|-----------------|--------------------|
| 1/16 P&W X369A  | .0625              |
| 1/16 P&W X379A  | .0624              |
| .125 P&W Y242A  | .12505             |
| .250 P&W Y455A  | .2500              |
| .500 P&W Y694A  | .5001              |
| 1.000 P&W Y189B | 1.0000             |



WALTER L. SMITHSON  
 IQA Sr. INSPECTOR

*R. J. Ching*  
 6/15/06

**SOUTHWEST RESEARCH INSTITUTE  
CALIBRATION LABORATORY  
MEMORANDUM**

**To:** DARRYL WAGAR DIV18 B128

**From:** Walt Hill, Metrology Group Leader  
Institute Calibration Laboratory

**Subject:** Status of Calibration Supplier

**Manufacturer/Model:** MOREHOUSE 10,000 LBF

**Description:** PROVING RING

**Serial Number:** 3668C-709

**Asset Number:** 000748

**Work Order Number:** 444061883

**Date Calibrated:** December 30, 2004

**Supplier:** MOREHOUSE, YORK PA - A2LA - 717 843-0081

**Remarks:** Morehouse Report # 3668CL3004.

- Supplier is on the Approved Suppliers List (ASL).
- Supplier is not on the Approved Suppliers List.
- Calibration is ISO 17025 accredited.
- Calibration is not ISO 17025 accredited.
- There is no known supplier to meet ISO 17025 accreditation at this time.

Please notify the Institute Calibration Laboratory, extension 5215, of any discrepancies with the item or calibration documentation.

Attachment(s) 9

*K-T. Chiang*  
6/15/06



"As Returned"  
**Certificate of Calibration**

and Traceability to the

United States National Institute of Standards & Technology

MOREHOUSE INSTRUMENT CO.  
 SERIES 100: PROVING RING, SERIAL NO. 3668C  
 10,000 LBF CAPACITY, TENSION & COMPRESSION

The above identified instrument was calibrated in accordance with Section 7 of the American Society for Testing and Materials (ASTM) specification E74-02 entitled, "Standard Practice of Calibration of Force-Measuring Instruments...". We could not provide an "As Received" calibration due to the condition of the Proving Ring when it was returned to us. This calibration is in conformance with the requirements of Morehouse QAM Rev.7, dated 12/04/00, ISO/IEC 17025, and ANSI/NCSL Z540.1.

The result of this calibration as determined by statistical analysis according to Section 8 of ASTM E74-02, is as follows:

|              | Uncertainty | Resolution |
|--------------|-------------|------------|
| Tension:     | 1.57 Lbf    | 0.60 Lbf   |
| Compression: | 1.61 Lbf    | 0.58 Lbf   |

**This is within the Manufacturer's tolerance of 5.00 Lbf.**

Calibration data is correct for a temperature of 23 degrees C. For a temperature of t degrees C, the values of the calibration factor should be corrected for temperature using the following formula.

$$d_{23} = d_t - .00027 \times ((t-23) \times d_t)$$

Where:

- $d_{23}$  = deflection at a temperature of 23 degrees C.
- $d_t$  = deflection at a temperature of t degrees C.
- t = temperature, degrees Celsius.

This calibration is certified traceable to the United States National Institute of Standards & Technology according to the following documentation and calibration apparatus used:

Dead Weight Force Machine S/N M-4644 NIST Lab No. 822/255038-95

Uncertainty of Force Standard used to perform this calibration did not exceed +/- 0.002% of applied load

Calibrated By:



Date Calibrated:  
 February 16, 2004  
 Report No: 3668CB1604

MOREHOUSE INSTRUMENT COMPANY, INC.  
 FORCE CALIBRATION LABORATORY  
 1742 SIXTH AVENUE  
 YORK, PA 17403-2675 U.S.A.  
 PHONE: 717 / 843-0081  
 FAX: 717 / 846-4193  
 WEB: [www.morehouseinst.com](http://www.morehouseinst.com)

This Certificate shall not be reproduced except in full, without written approval from Morehouse Instrument Company, Inc.

*K. T. Chiang*  
 6/15/06

SOUTHWEST RESEARCH INSTITUTE

6220 Culebra Road  
San Antonio, TX. 78228

Program name: Date: 03/01/105 Time: 11:35 Page: 1  
Program Number: 0

Description Value Tolerance

DISTANCE Plane (Feature # 1) to Point (Feature # 2)  
DISTANCE 0.0625 1/16 P+W X369A

SOUTHWEST RESEARCH INSTITUTE

6220 Culebra Road  
San Antonio, TX. 78228

Program name: Date: 03/01/105 Time: 16:56 Page: 1  
Program Number: 0

Description Value Tolerance

DISTANCE Plane (Feature # 1) to Point (Feature # 2)  
DISTANCE 0.0625 1/16 P+W 379A

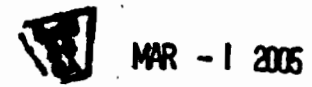
DISTANCE Plane (Feature # 1) to Point (Feature # 3)  
DISTANCE 0.1251 .125 P+W 4242A

DISTANCE Plane (Feature # 1) to Point (Feature # 4)  
DISTANCE 0.2500 .250 P+W 4455A

DISTANCE Plane (Feature # 1) to Point (Feature # 5)  
DISTANCE 0.5001 .500 P+W 694A

DISTANCE Plane (Feature # 1) to Point (Feature # 11)  
DISTANCE 1.0001 1.000 P+W Y189B

Bldg # 162  
Temp 70°  
Humidity 48%  
CMM 900900871 DUE 1-18-05



K-7. Chinas 6/15/06

Load Cell Calibration

Frame No. 1 Date: 4/4/2005  
 Load Cell S/N: 732329  
 Morehouse Proving Ring S/N: 3668C-709  
 Last Cal.: 12/30/2004 Next Cal: 12/30/2006

| Load | Moorehouse Ring | Adj. Moorehouse Ring Wts. | Meter  | Computer | Chart Table Wts. |
|------|-----------------|---------------------------|--------|----------|------------------|
| 0    | 4.0             | 0.0                       | 0.0    | -3.7     | 0                |
| 600  | 54.2            | 50.2                      | 599.7  | 594.7    | 593              |
| 1200 | 105.7           | 101.7                     | 1198.0 | 1194.6   | 1201.7           |
| 1800 | 155.7           | 151.7                     | 1791.4 | 1789.2   | 1794.2           |
| 2400 | 204.3           | 200.3                     | 2376.1 | 2376.2   | 2371.6           |
| 3000 | 252.3           | 248.3                     | 2951.4 | 2952.4   | 2943.2           |
| 3600 | 300.5           | 296.5                     | 3522.6 | 3524.1   | 3518.5           |
| 4200 | 348.0           | 344.0                     | 4091.0 | 4093.0   | 4086.9           |
| 4800 | 395.0           | 391.0                     | 4652.7 | 4655.7   | 4650.7           |
| 5000 | 425.0           | 421.0                     | 5010.7 | 4995.0   | 5011.3           |
| 4800 | 400.3           | 396.3                     | 4716.0 | 4719.0   | 4714.4           |
| 4200 | 361.0           | 357.0                     | 4237.3 | 4239.2   | 4242.7           |
| 3600 | 313.7           | 309.7                     | 3697.4 | 3699.2   | 3676.3           |
| 3000 | 264.0           | 260.0                     | 3081.6 | 3083.1   | 3082.7           |
| 2400 | 212.5           | 208.5                     | 2465.4 | 2465.4   | 2469.1           |
| 1800 | 160.6           | 156.6                     | 1849.4 | 1847.5   | 1852.3           |
| 1200 | 108.0           | 104.0                     | 1232.5 | 1229.5   | 1228.9           |
| 600  | 56.0            | 52.0                      | 615.1  | 610.1    | 614.2            |
| 0    | 4.0             | 0.0                       | 2.4    | 1.5      | 0.0              |

Load Cell Calibration

Frame No. 2 Date: 4/4/2005  
 Load Cell S/N: 732328%  
 Morehouse Proving Ring S/N: 3660C-709  
 Last Cal.: 12/30/2004 Next Cal: 12/30/2006

| Load | Moorehouse Ring | Adj. Moorehouse Ring Wts. | Meter  | Computer | Chart Table Wts. |
|------|-----------------|---------------------------|--------|----------|------------------|
| 0    | 4.0             | 4.0                       | 0.7    | 2.1      | 0                |
| 600  | 51.3            | 51.3                      | 563.2  | 562.1    | 558.6            |
| 1200 | 100.6           | 100.6                     | 1137.1 | 1136.5   | 1141.3           |
| 1800 | 148.4           | 148.4                     | 1711.4 | 1710.3   | 1707.6           |
| 2400 | 197.0           | 197.0                     | 2283.4 | 2282.4   | 2284.7           |
| 3000 | 245.0           | 245.0                     | 2856.1 | 2855.1   | 2856.1           |
| 3600 | 293.3           | 293.3                     | 3429   | 3427.2   | 3432.5           |
| 4200 | 340.0           | 340.0                     | 4001.2 | 3999.1   | 3991.1           |
| 4800 | 387.0           | 387.0                     | 4575.2 | 4572.3   | 4554.7           |
| 5000 | 420.0           | 420.0                     | 4958.8 | 4955.8   | 4951.1           |
| 4800 | 385.0           | 385.0                     | 4578.3 | 4575.3   | 4500.6           |
| 4200 | 339.9           | 339.9                     | 4007.3 | 4004.8   | 3870.2           |
| 3600 | 292.0           | 292.0                     | 3435.3 | 3433.5   | 3417             |
| 3000 | 243.3           | 243.3                     | 2862.6 | 2861.5   | 2835.9           |
| 2400 | 195.0           | 195.0                     | 2286   | 2288.6   | 2260.9           |
| 1800 | 148.0           | 148.0                     | 1718.5 | 1716     | 1702.8           |
| 1200 | 100.6           | 100.6                     | 1142.2 | 1140.7   | 1141.3           |
| 600  | 52.0            | 52.0                      | 567.3  | 561.6    | 566.9            |
| 0    | 4.0             | 4.0                       | 0      | 2        | 0                |

*K.T. Chief*  
 6/15/06

Load Cell Calibration

Frame No. 3 Date: 4/4/2005  
 Load Cell S/N: 789126  
 Morehouse Proving Ring S/N: 3668C-709  
 Last Cal.: 12/30/2004 Next Cal: 12/30/2006

| Load | Moorehouse Ring | Adj. Moorehouse Ring Wts. | Meter  | Computer | Chart Table Wts. |
|------|-----------------|---------------------------|--------|----------|------------------|
| 0    | 4.0             | 0                         | 0.0    | -2.0     | 0.0              |
| 600  | 53.3            | 49.3                      | 575.3  | 574.5    | 582.5            |
| 1200 | 103.6           | 99.6                      | 1157.8 | 1156.7   | 1176.8           |
| 1800 | 153.5           | 149.5                     | 1740.7 | 1739.3   | 1768.1           |
| 2400 | 200.1           | 196.1                     | 2322.7 | 2319.0   | 2321.6           |
| 3000 | 247.3           | 243.3                     | 2840.1 | 2839.4   | 2883.6           |
| 3600 | 287.3           | 283.3                     | 3304.5 | 3304.2   | 3360.8           |
| 4200 | 332.4           | 328.4                     | 3830.5 | 3830.4   | 3900.1           |
| 4800 | 355.6           | 351.6                     | 4102.2 | 4102.2   | 4178.0           |
| 5000 | 374.8           | 370.8                     | 4328.4 | 4328.9   | 4408.2           |
| 4800 | 367.6           | 363.6                     | 4244.2 | 4243.1   | 4321.9           |
| 4200 | 342.7           | 338.7                     | 3949.7 | 3949.9   | 4023.4           |
| 3600 | 302.0           | 298                       | 3481.8 | 3481.7   | 3536.5           |
| 3000 | 250.3           | 246.3                     | 2910.0 | 2909.1   | 2919.3           |
| 2400 | 203.8           | 199.8                     | 2327.2 | 2325.6   | 2365.6           |
| 1800 | 153.3           | 149.3                     | 1743.7 | 1742.8   | 1765.7           |
| 1200 | 103.4           | 99.4                      | 1161.6 | 1160.6   | 1174.4           |
| 600  | 53.5            | 49.5                      | 577.9  | 577.0    | 584.6            |
| 0    | 4.0             | 0                         | -0.9   | -1.5     | 0.0              |

Load Cell Calibration

Frame No. 4 Date: 4/4/2005  
 Load Cell S/N: 789127  
 Morehouse Proving Ring S/N: 3668C-709  
 Last Cal.: 12/30/2004 Next Cal: 12/30/2006

| Load | Moorehouse Ring | Adj. Moorehouse Ring Wts. | Meter  | Computer | Chart Table Wts. |
|------|-----------------|---------------------------|--------|----------|------------------|
| 0    | 4               | 0.0                       | 0.4    | 0.2      | 0.0              |
| 600  | 48.3            | 44.3                      | 532.6  | 531.6    | 523.2            |
| 1200 | 96.5            | 92.5                      | 1091.6 | 1090.6   | 1092.8           |
| 1800 | 143.0           | 139.0                     | 1640.7 | 1639.7   | 1643.5           |
| 2400 | 188.3           | 184.3                     | 2184.9 | 2182.4   | 2181.3           |
| 3000 | 234.5           | 230.5                     | 2727.5 | 2726.4   | 2731.0           |
| 3600 | 279.5           | 275.5                     | 3265.1 | 3268.1   | 3267.7           |
| 4200 | 324.0           | 320.0                     | 3803.3 | 3802.6   | 3799.6           |
| 4800 | 367.0           | 363.0                     | 4332.4 | 4331.6   | 4314.7           |
| 5000 | 396.2           | 392.2                     | 4672.2 | 4671.3   | 4665.1           |
| 4800 | 370.5           | 366.5                     | 4389.4 | 4389.3   | 4356.7           |
| 4200 | 336.4           | 332.4                     | 3944.0 | 3943.0   | 3948.0           |
| 3600 | 298.4           | 294.4                     | 3480.5 | 3479.3   | 3493.4           |
| 3000 | 252.6           | 248.6                     | 2945.2 | 2944.7   | 2946.7           |
| 2400 | 202.4           | 198.4                     | 2349.0 | 2347.0   | 2349.0           |
| 1800 | 149.0           | 145.0                     | 1758.0 | 1761.1   | 1714.7           |
| 1200 | 102.0           | 98.0                      | 1158.0 | 1156.5   | 1157.9           |
| 600  | 51.5            | 47.5                      | 561.3  | 560.4    | 561.0            |
| 0    | 4.0             | 0.0                       | 2.3    | 1.6      | 0.0              |

*K. J. Chiao*  
 6/15/06

Ken Chiang  
 SwRI-CNWRA  
 Phone: (210) 522-2308  
 Fax: (210) 522-5184  
 e-mail: Kchiang@swri.org

Procedure: 105-wi-821  
 Project # \_\_\_\_\_  
 TOTAL PCS. INSPECTED 12  
 TOTAL PCS. ACCEPTED 12  
 TOTAL PCS. REJECTED 0  
 "NR #" IF REJECTS NA

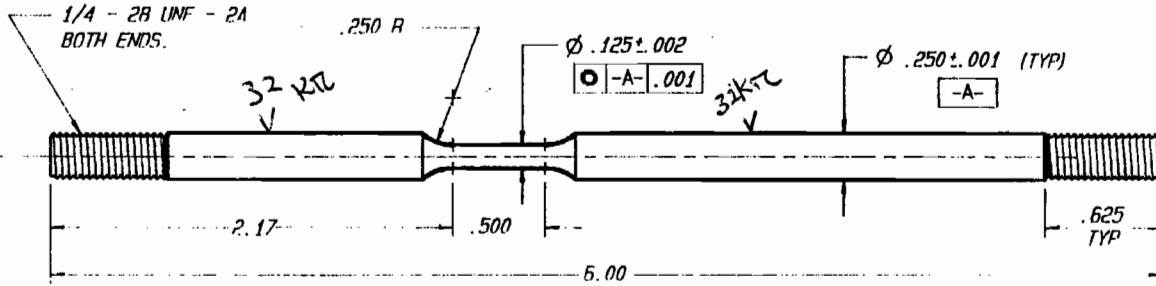
LOCATION CC31 MS  
 EQUIPMENT Mic 009976 Due 1-13-06  
 The Gauge 002176 Due 11-19-07  
 Comp. 002185 Due 1-18-06

INSPECTOR

DATE MAY 25 2005

No SPECIAL OPERATIONS

SwRI DRAWING # 20-03704-042-001



NOTE: 1. DO NOT UNDERCUT RADIIT  
 2. USE LOW STRESS MACHINING PROCEDURE

Procedure: 105-wi-821  
 Project # \_\_\_\_\_  
 TOTAL PCS. INSPECTED 6  
 TOTAL PCS. ACCEPTED 6  
 TOTAL PCS. REJECTED 0  
 "NR #" IF REJECTS NA  
 Thoroughly Inspected  
 S706  
 30 minutes  
 1/25/05  
 DATE JAN - 7 2005  
 LOCATION CC31 MS  
 J.C. # 813414  
 EQUIPMENT Mic 009976 Due 1-13-06  
 The Gauge 002176 Due 11-19-07  
 Comp. 002185 Due 1-18-06

| FIND NO.                          | QTY REQ. | UNIT | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | CONTRACT                     |           |         | DRAWING NO. | SHEET |
|-----------------------------------|----------|------|----------------|-------------------------|-----------------------------|------------------------------|-----------|---------|-------------|-------|
|                                   |          |      |                |                         |                             | DMN                          | 4-10-1992 | A. NMGY |             |       |
| PARTS LIST                        |          |      |                |                         |                             | SOUTHWEST RESEARCH INSTITUTE |           |         |             |       |
| MATERIAL                          |          |      |                |                         |                             | SLOW STRAIN RATE SPECIMEN    |           |         |             |       |
| FINISH                            |          |      |                |                         |                             | DRAWINGS NO. 20-3704-042-1   |           |         |             |       |
| MATERIAL 0.5 THICK PLATE SUPPLIED |          |      |                |                         |                             | SCALE 2 = 1                  |           |         |             |       |
| FINISH 16 RMS                     |          |      |                |                         |                             | SHEET                        |           |         |             |       |
| MATERIAL 16 RMS                   |          |      |                |                         |                             | SCALE 2 = 1                  |           |         |             |       |
| MATERIAL 16 RMS                   |          |      |                |                         |                             | SHEET                        |           |         |             |       |

K.J. Chiang 1-13-04  
 Initiator: K. Chiang Date

Parul Datta for V. Jain  
 Reviewer: V. Jain Date 1/13/04

Mark R. Shurtz  
 QA Approval: R. Brient Date

C-22 H# 2277-3-3266

SLOW STRAIN RATE TEST

Objective: see page #5

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution: *C-22 mill annealed* *not welded* HT#2277-3-3266 *8/27/06*

*ambient air*

|                        |                      |      |
|------------------------|----------------------|------|
| Reagents measured with | Model:               | SN:  |
|                        | Cal:                 | Due: |
| Counter Electrode:     | Reference Electrode: |      |
| Gas:                   | Ecorr:               |      |
| Applied:               | Potentiostat:        | SN:  |
| Specimen Visual:       |                      |      |

*ductile failure*

$\epsilon^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$

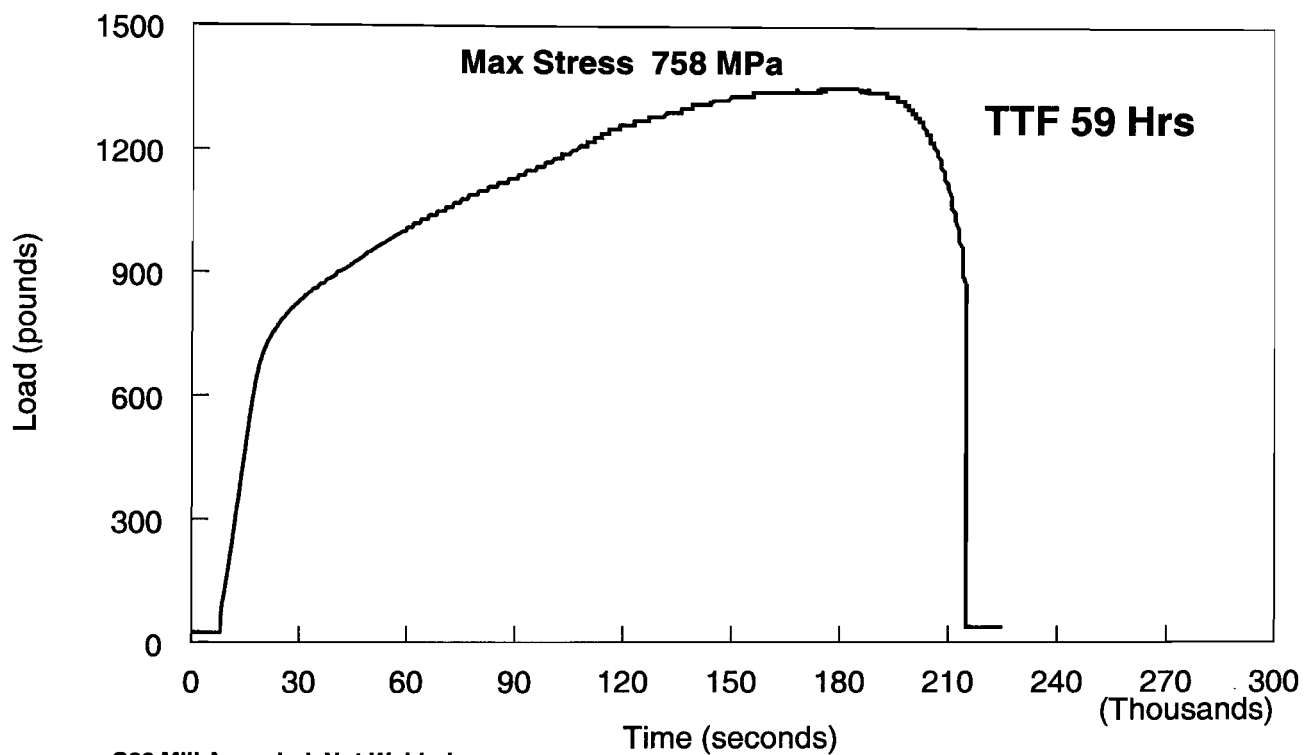
*8/27/06* Test SSRMA22-SCW46

*Walter J. Mackowski*  
*7/5/05*

# Slow Strain Rate Test

Ambient Air

Test SSRMA22\_SCW46



Walter J. Muehler  
7/5/05

SLOW STRAIN RATE TEST

Objective: see page #5

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution:

*C-22 mill annealed +  
thermally aged 870°C / 30 min  
HT # 2277-3-3266 See pg #44 8/27/06*

*ambient air*

Reagents measured with

Model:  
Cal:SN:  
Due:

Counter Electrode:

Reference Electrode:

Gas:

Ecorr:

Applied:

Potentiostat:

SN:

Specimen Visual:

*ductile failure*

$$\dot{\epsilon}^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$$

*8/27/06  
Test SSRMA22-SCW47*

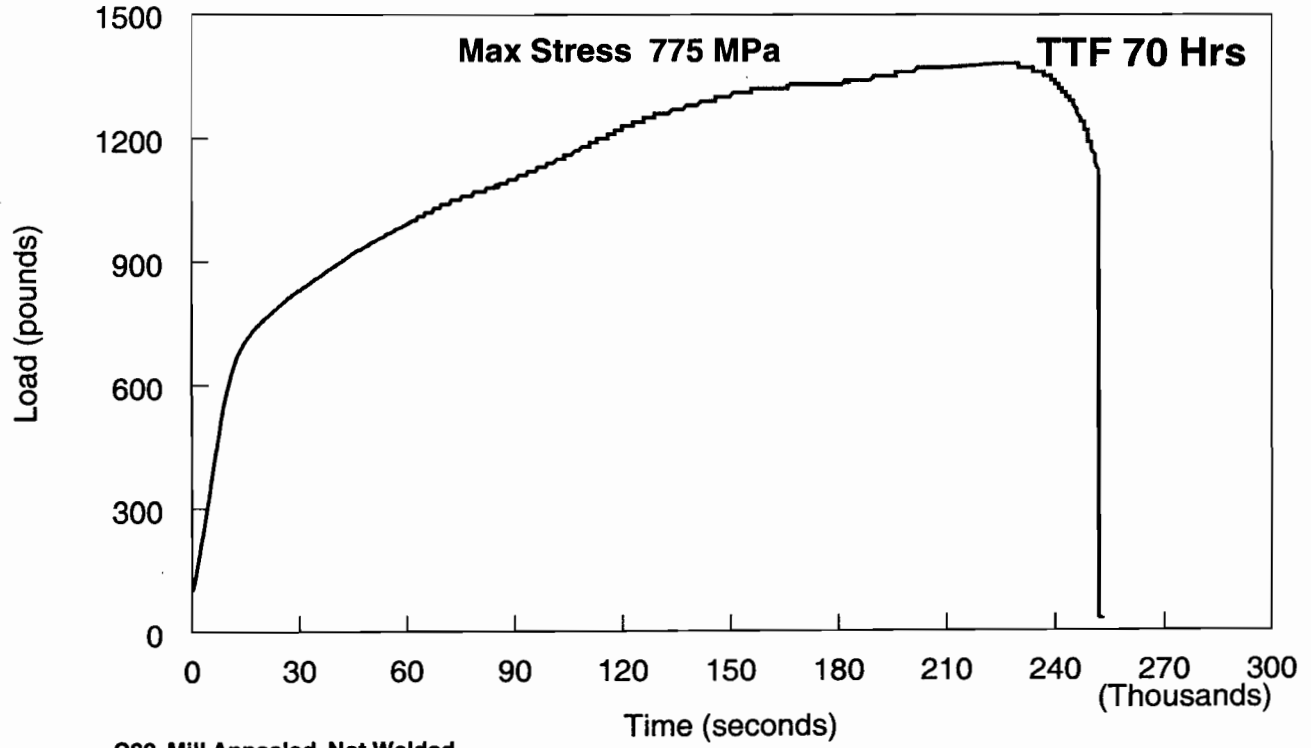
*Walter J. Macbrackie  
7/8/05*



# Slow Strain Rate Test

Ambient Air

Test SSRMA22\_SCW47



C22 Mill Annealed Not Welded  
Aged 870 C - 30 minutes

*Walter J. Macchiarli*  
7/8/05

SLOW STRAIN RATE TEST

Objective: see page #5

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution: *C-22 mill annealed - not  
HT# 2277-3-3266 810 6/27/00 welded*

1.05M NaHCO<sub>3</sub> 88.29g Lot # 041522 x 1 L  
 0.5M NaCl 29.30g Lot # 045904  
 1.5M KCl 111.78g Lot # 044597

pH<sub>i</sub> = 8.74      pH<sub>f</sub> = 10.30      0.19M NaOH 7.64g Lot # 033972

Reagents measured with Model: OHAUS SN: 2883  
 Cal: 14 JAN 05 Due: 14 JUL 05

Counter Electrode: Pt flag Reference Electrode: H<sub>2</sub>/AgCl w/3M KCl  
 in house

Gas: N<sub>2</sub> (99.999%)  
 Ecorr: -269mV

\* Applied: -415mV Potentiostat: ESC 440-2 SN: 920 9138

Specimen Visual:

*some cracking - looks like brittle failure*

\* connection @ 95°C (Δ15mV)  
 \*\* fluke 179 DVM SN 010857 cal 5/11/05 - 5/11/06

$\epsilon^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$       Temp 95°C T/C S/N 0003  
 cal 5/19/05 - 11/18/05

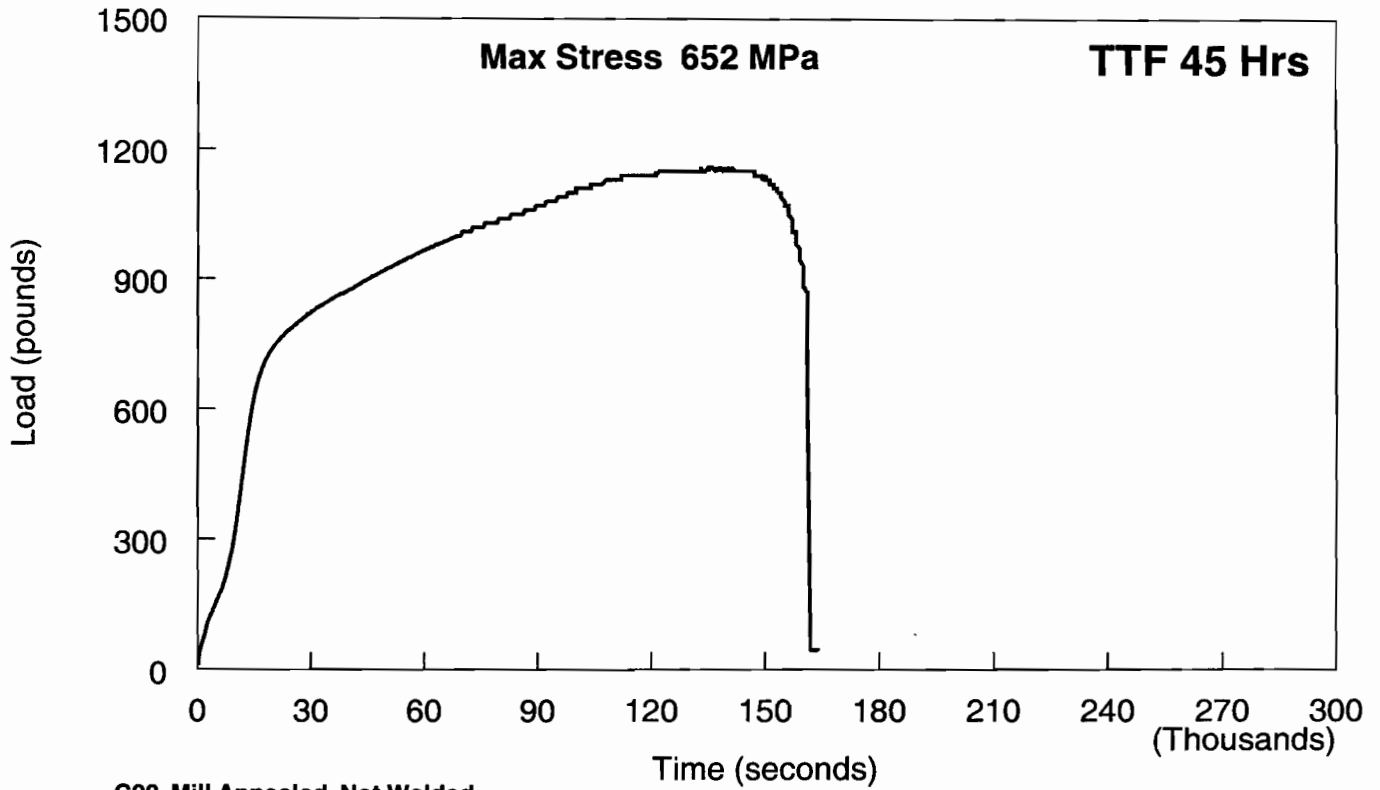
Test SSRMA22-SCW48 *810 6/27/00*

*Walter J. Mackowski  
 7/12/05*

# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 1.5M KCl; 0.19M NaOH

Test SSRMA22\_SCW48

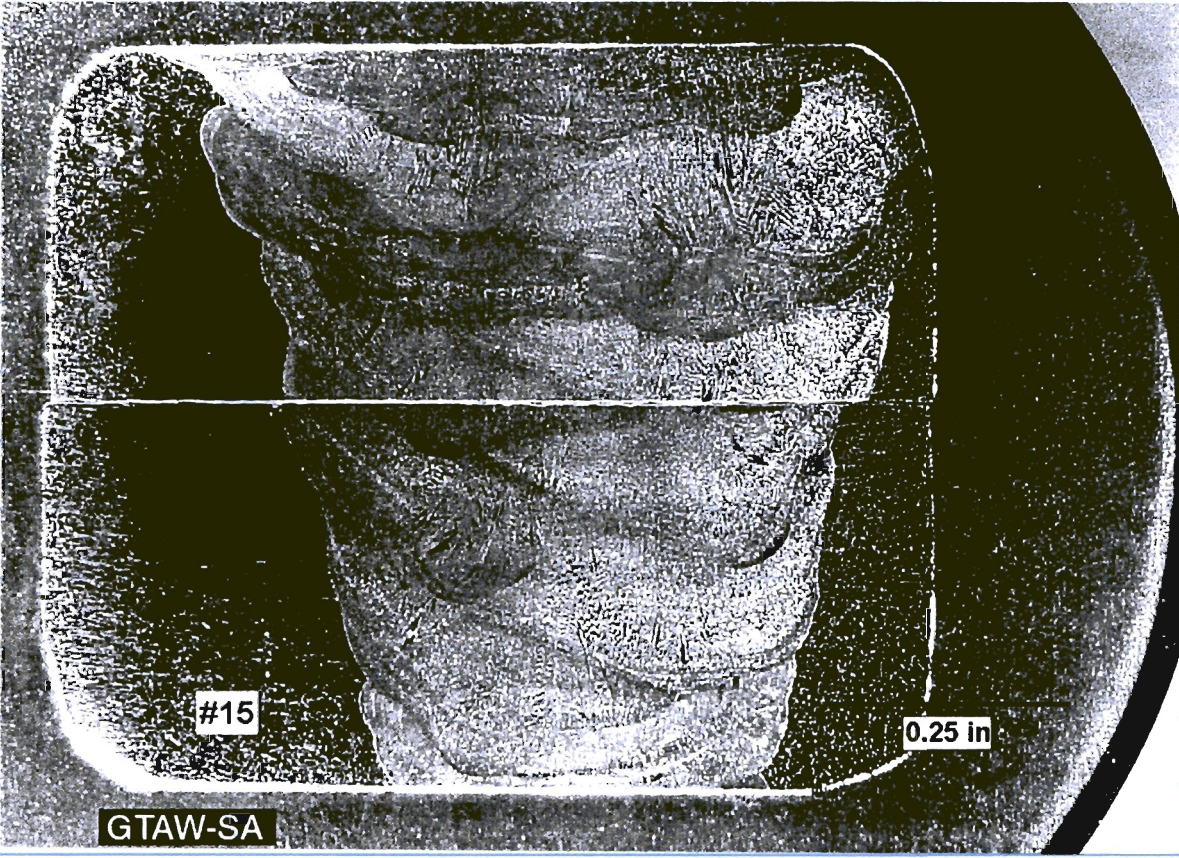
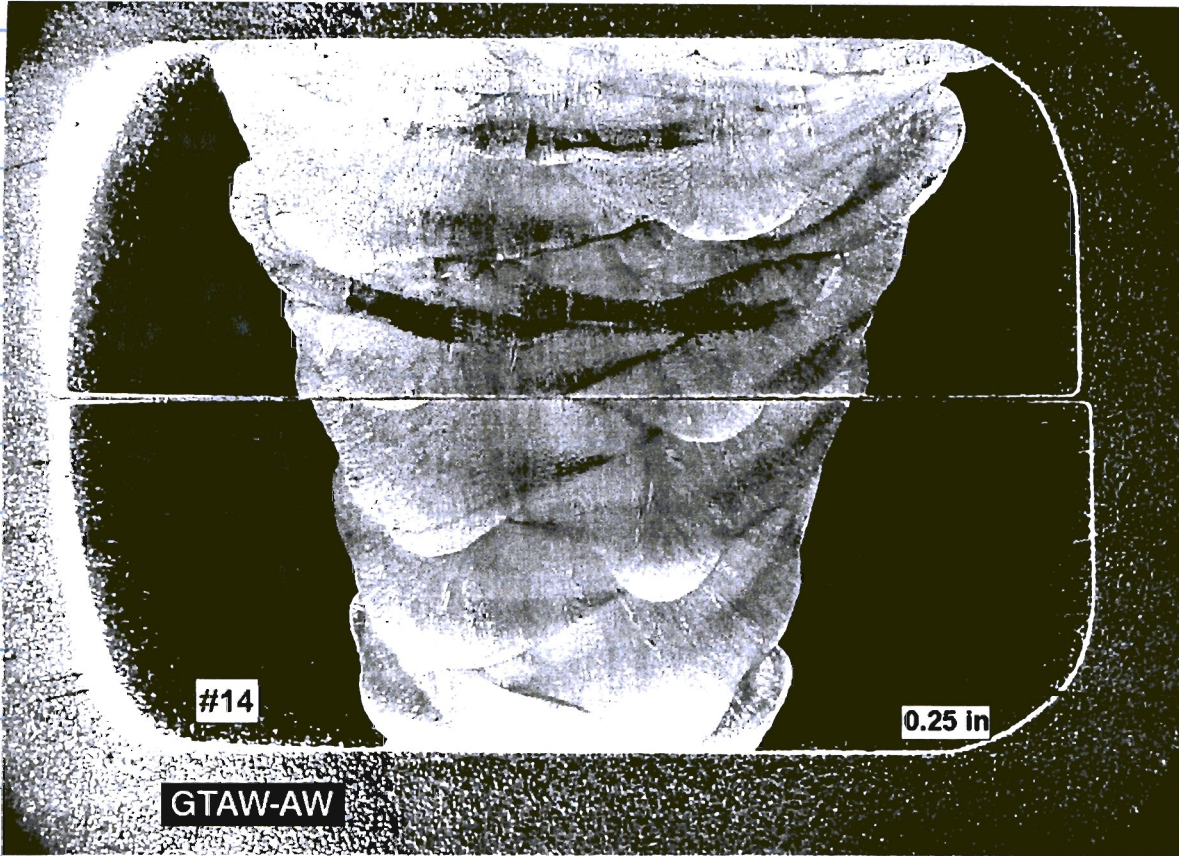


C22 Mill Annealed Not Welded

*Walter J. Machowski*  
7/12/05

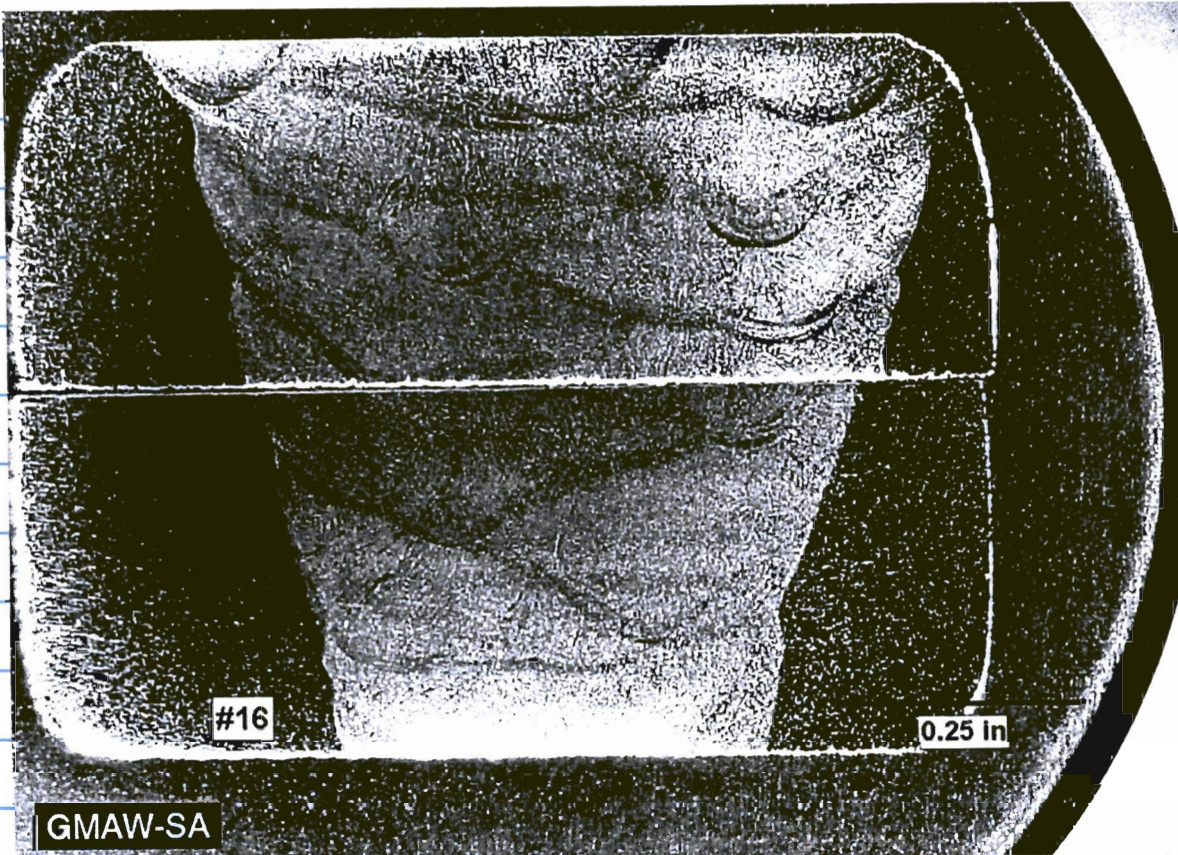
GTAW welded + 1125°C - 20min, ~~As~~welded Cross-sections

✓



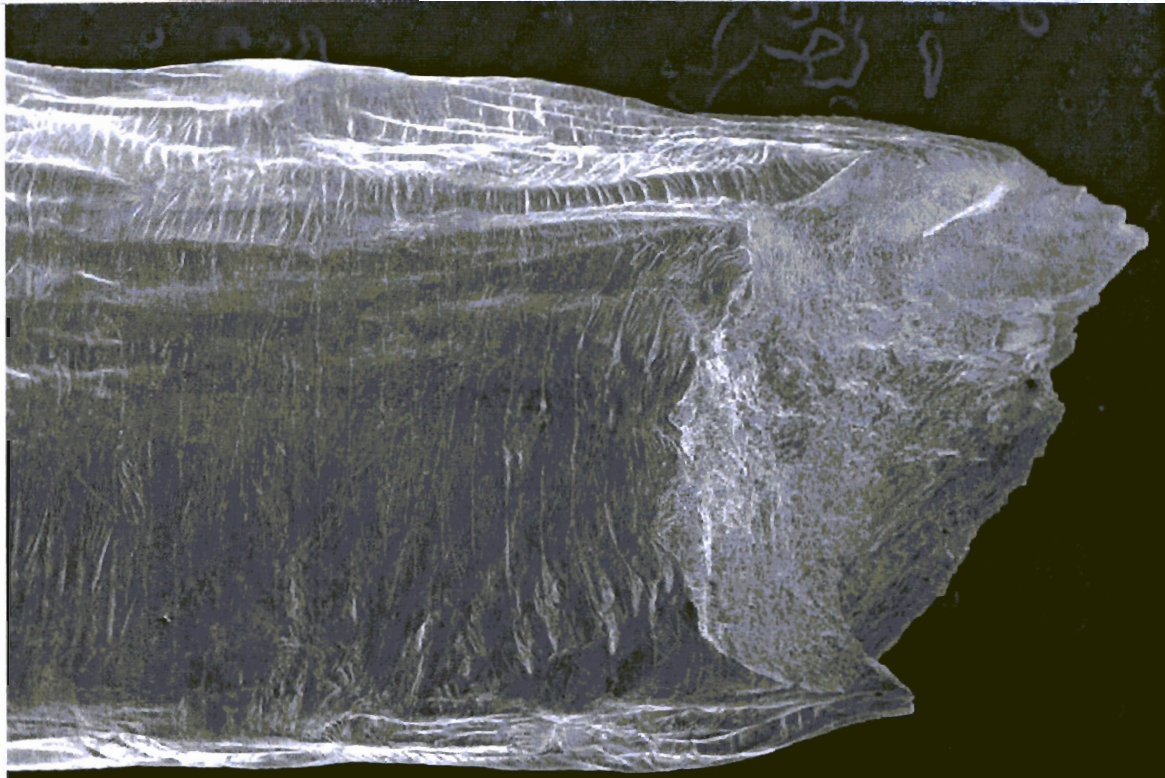
K.T. Chiang  
7/17/05

GMAW As welded, welded +1125°C-20min



K. J. Ching  
7/13/05

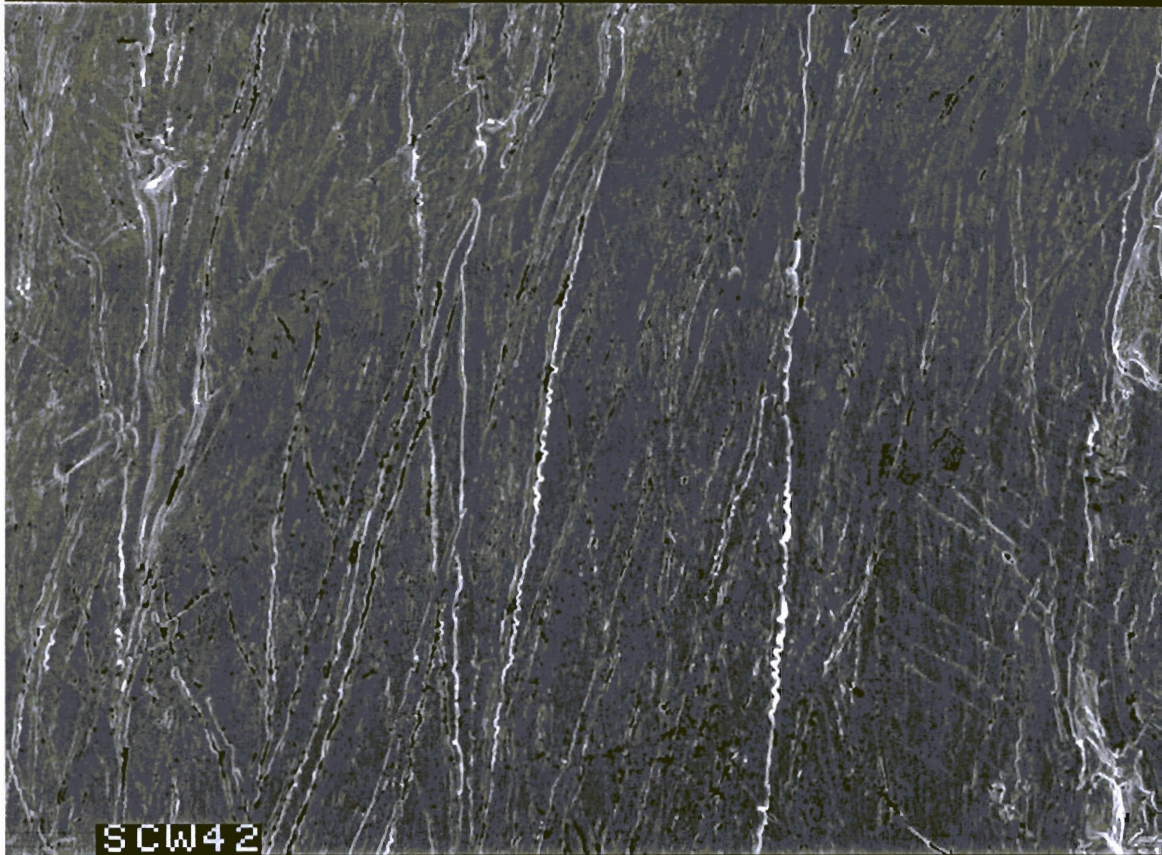
SCW42 GTAW welded + 1125°C - 20min AY GTAW 14 AC KRC 7/13/05



SCW42  
x300

1mm  
20kV SwRI

#0001



SCW42  
x300

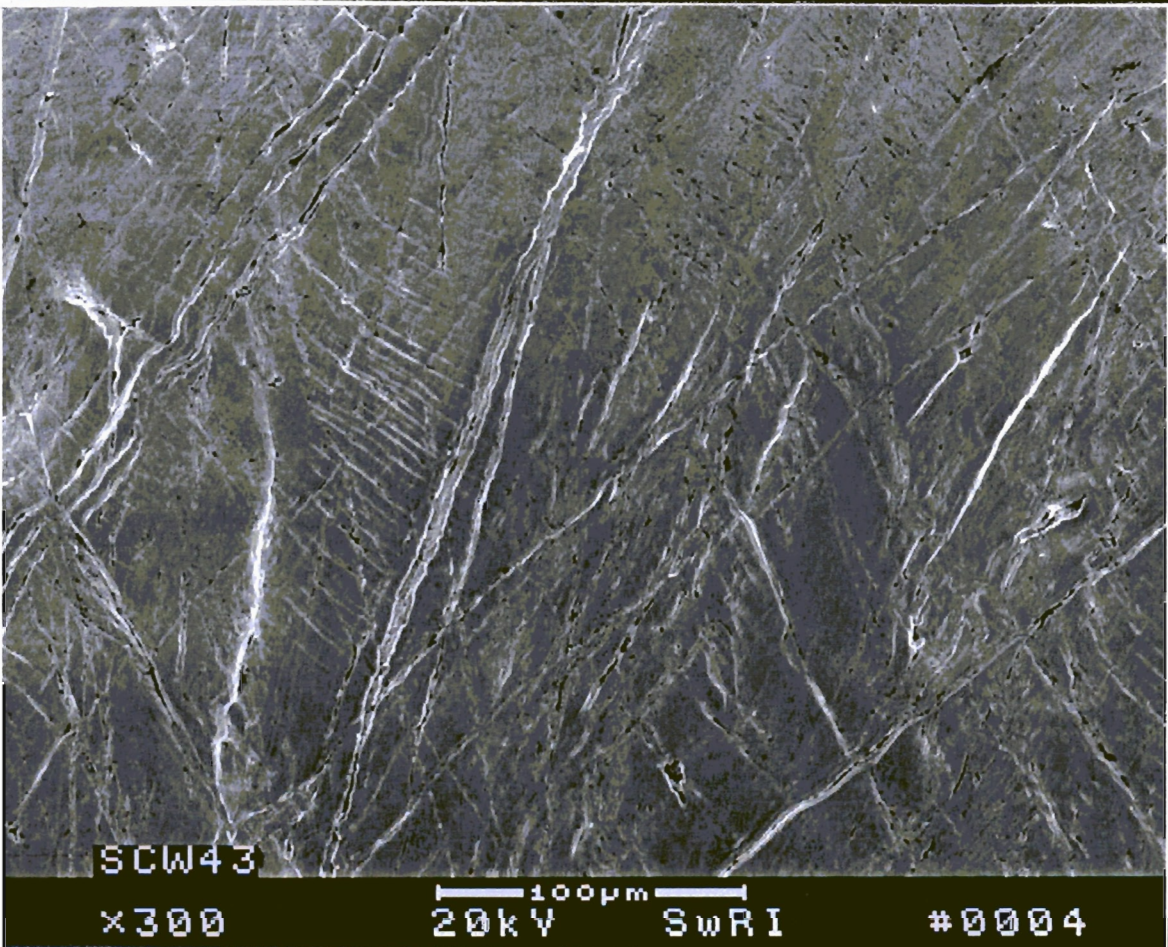
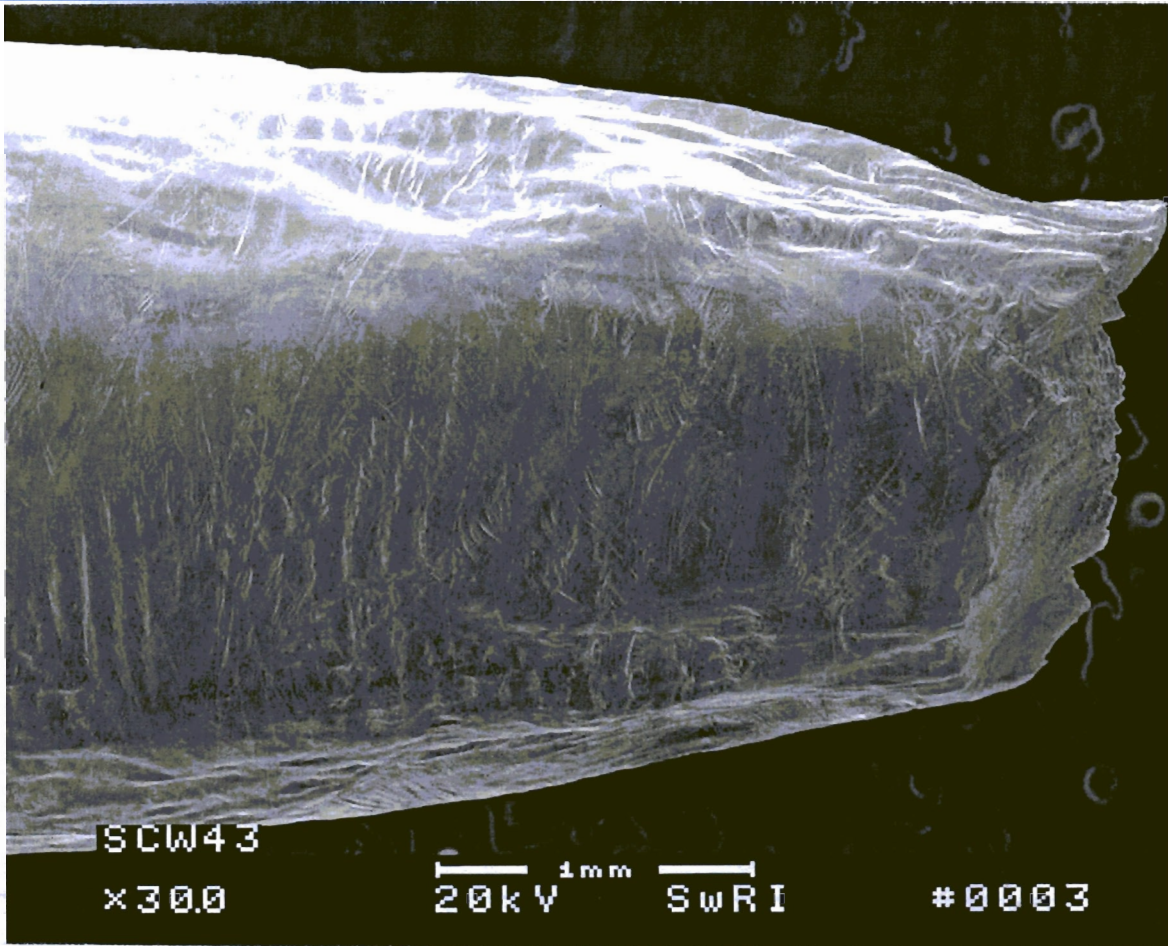
100µm  
20kV SwRI

#0002

K.J. Chng 7/13/05

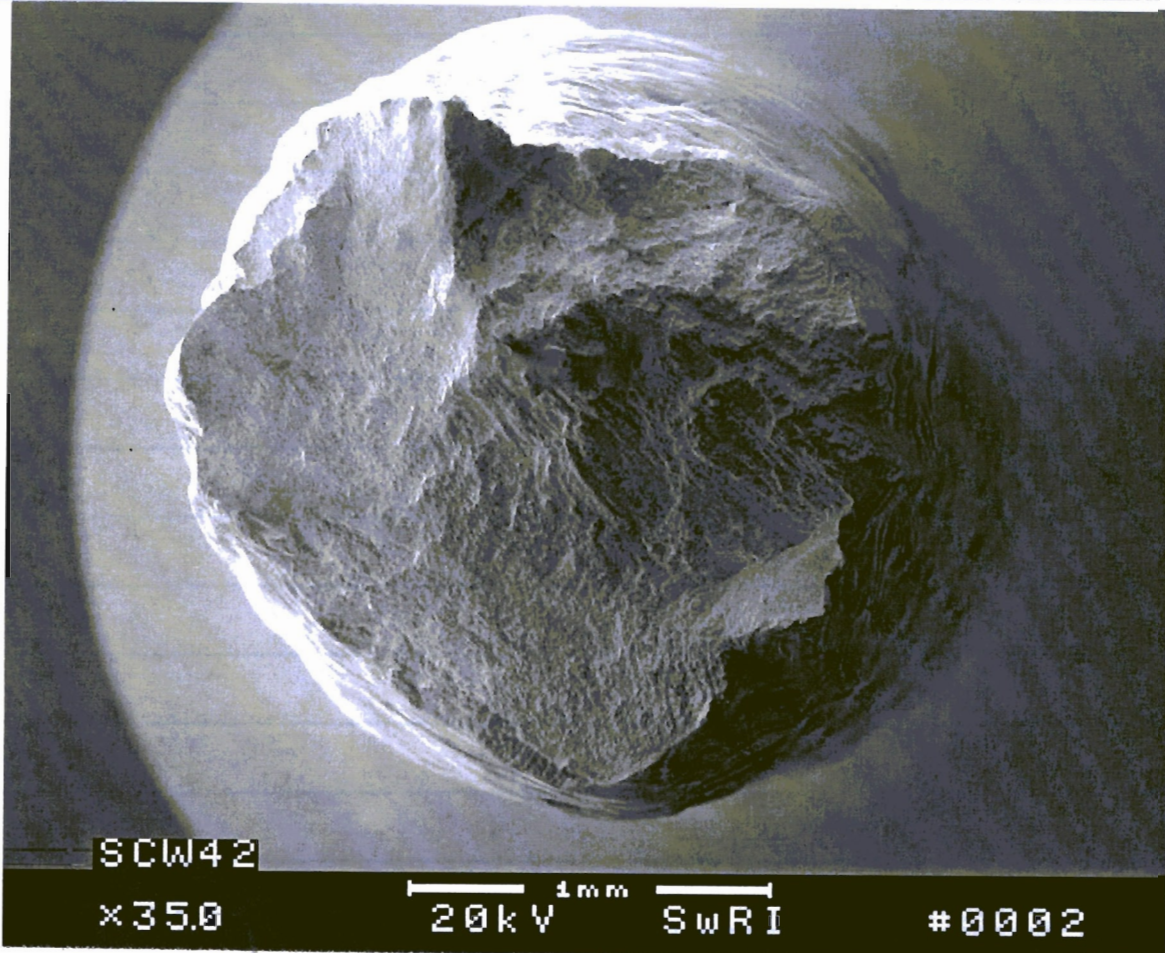
SCW 43 GTAW welded + 1125°C - 20 min

GTAW 14B



K. J. Chival 7/13/05

✓

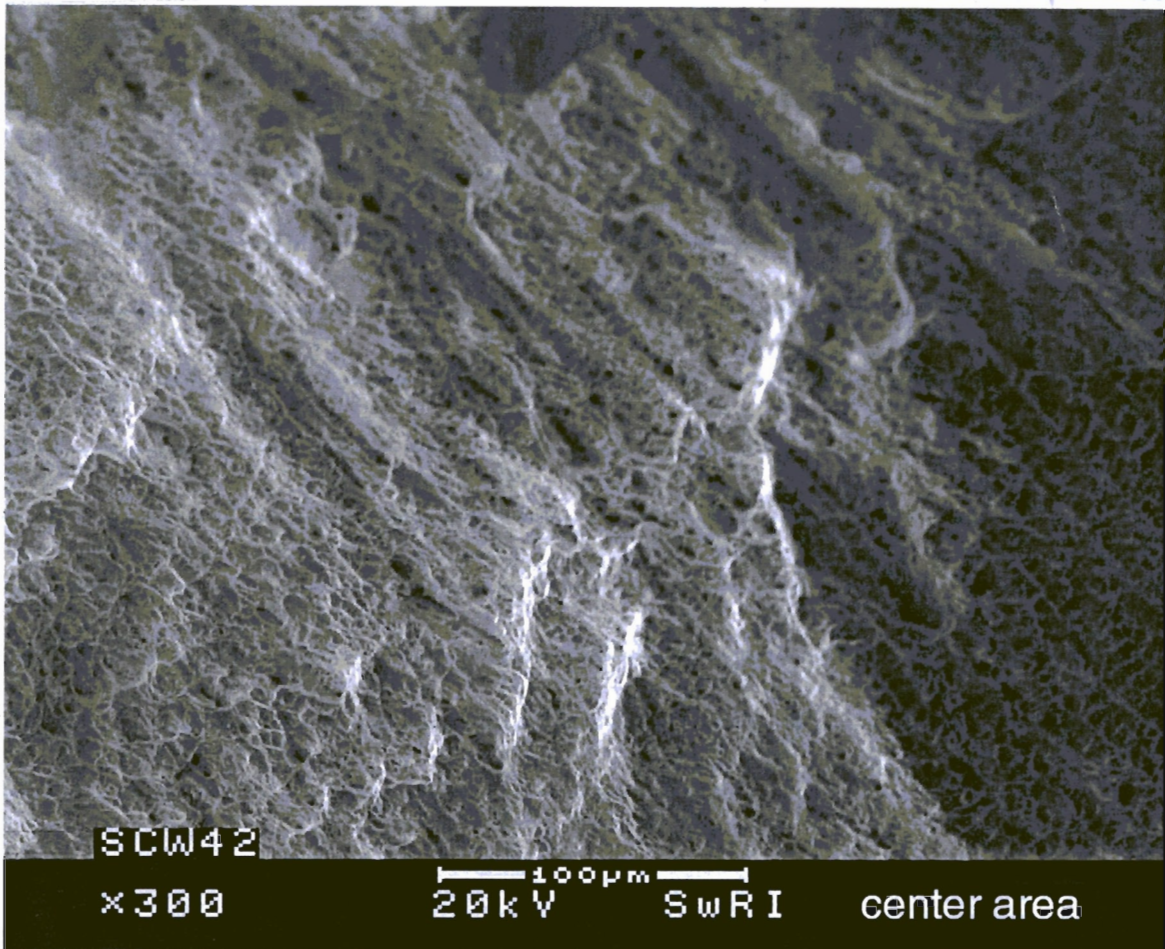


SCW42

x350

1mm  
20kV SwRI

#0002



SCW42

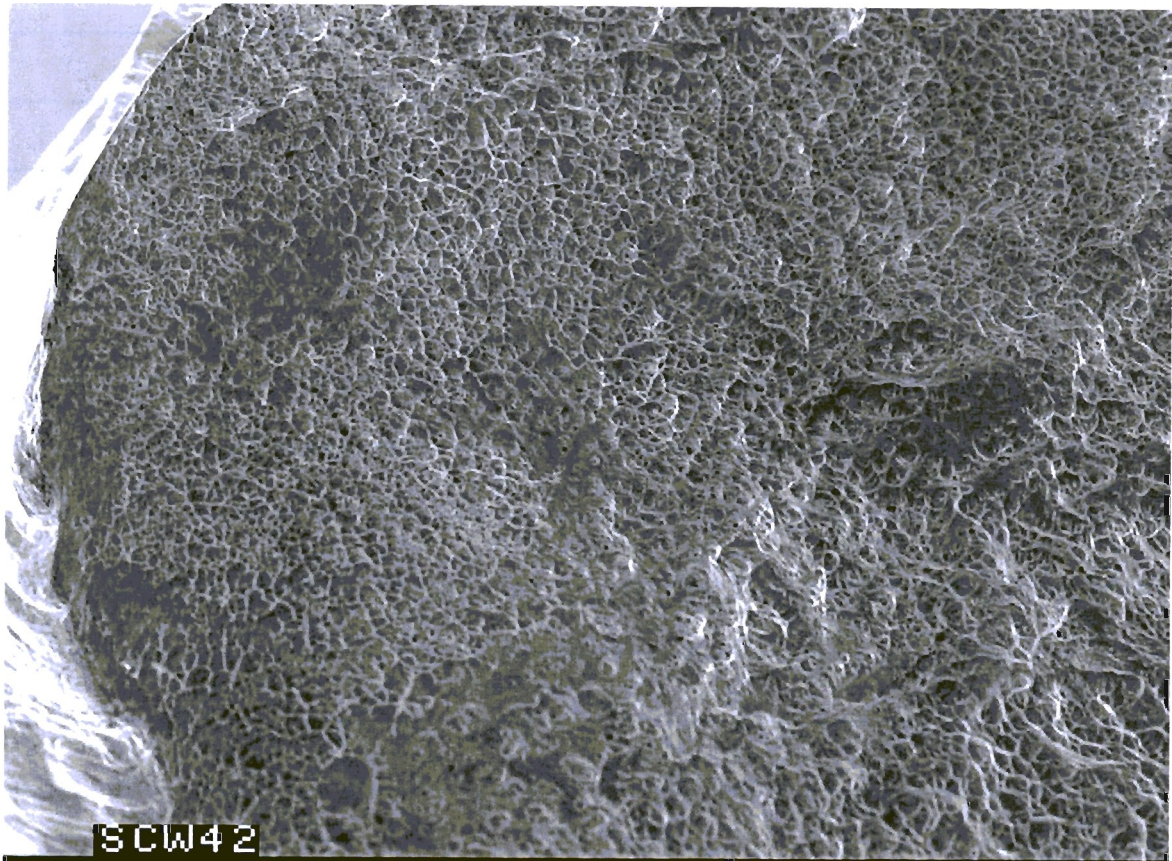
x300

100µm  
20kV SwRI

center area

K.A. Chip 7/13/05





SCW42

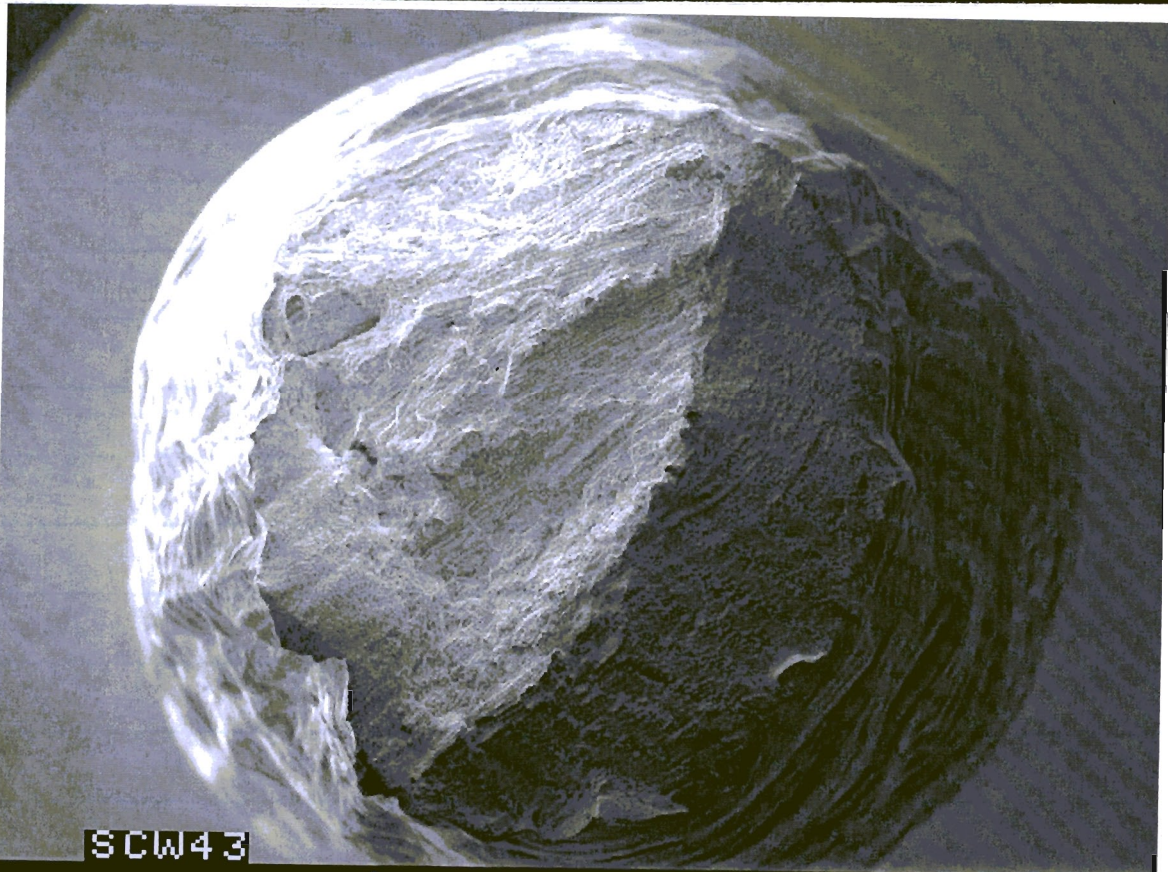
x300

100µm

20kV

SwRI

outer edge



SCW43

x400

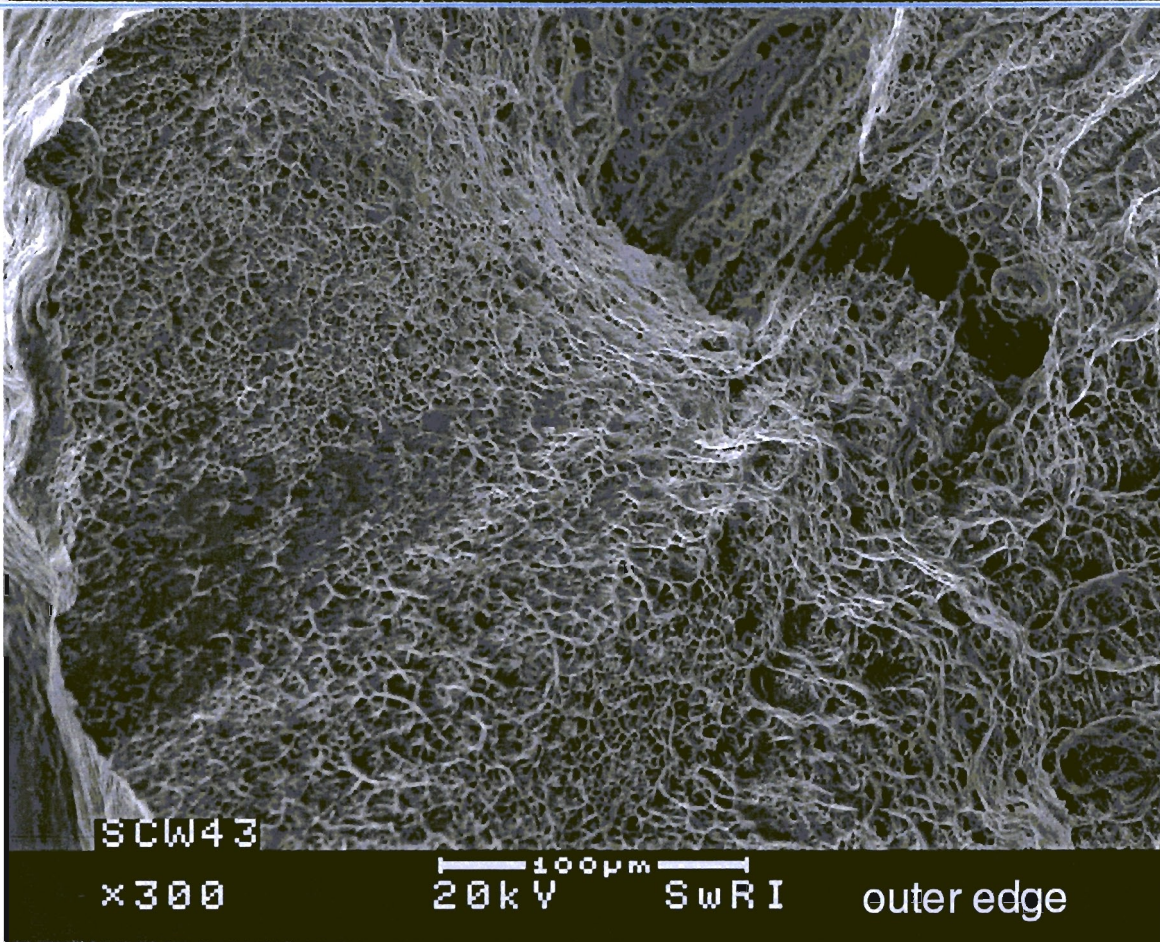
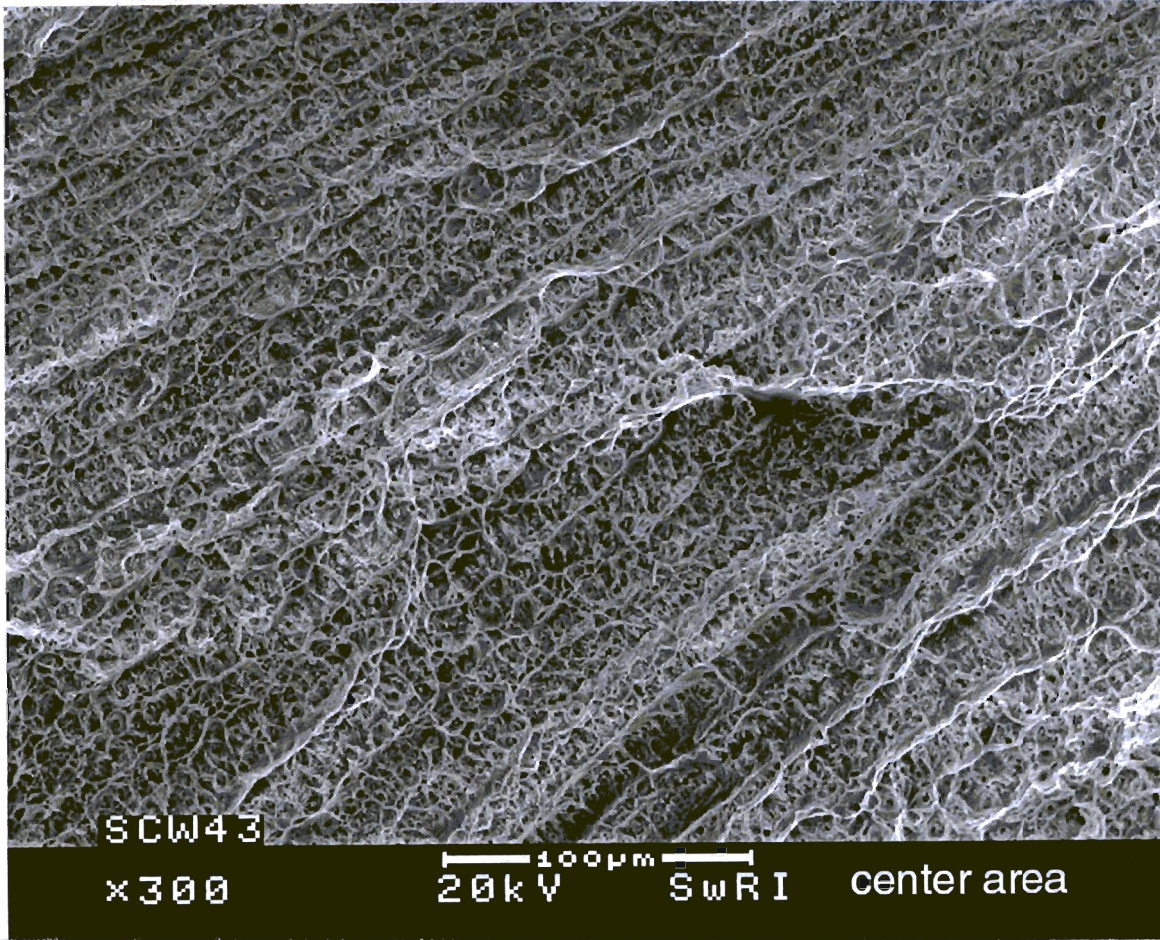
1mm

20kV

SwRI

#0005

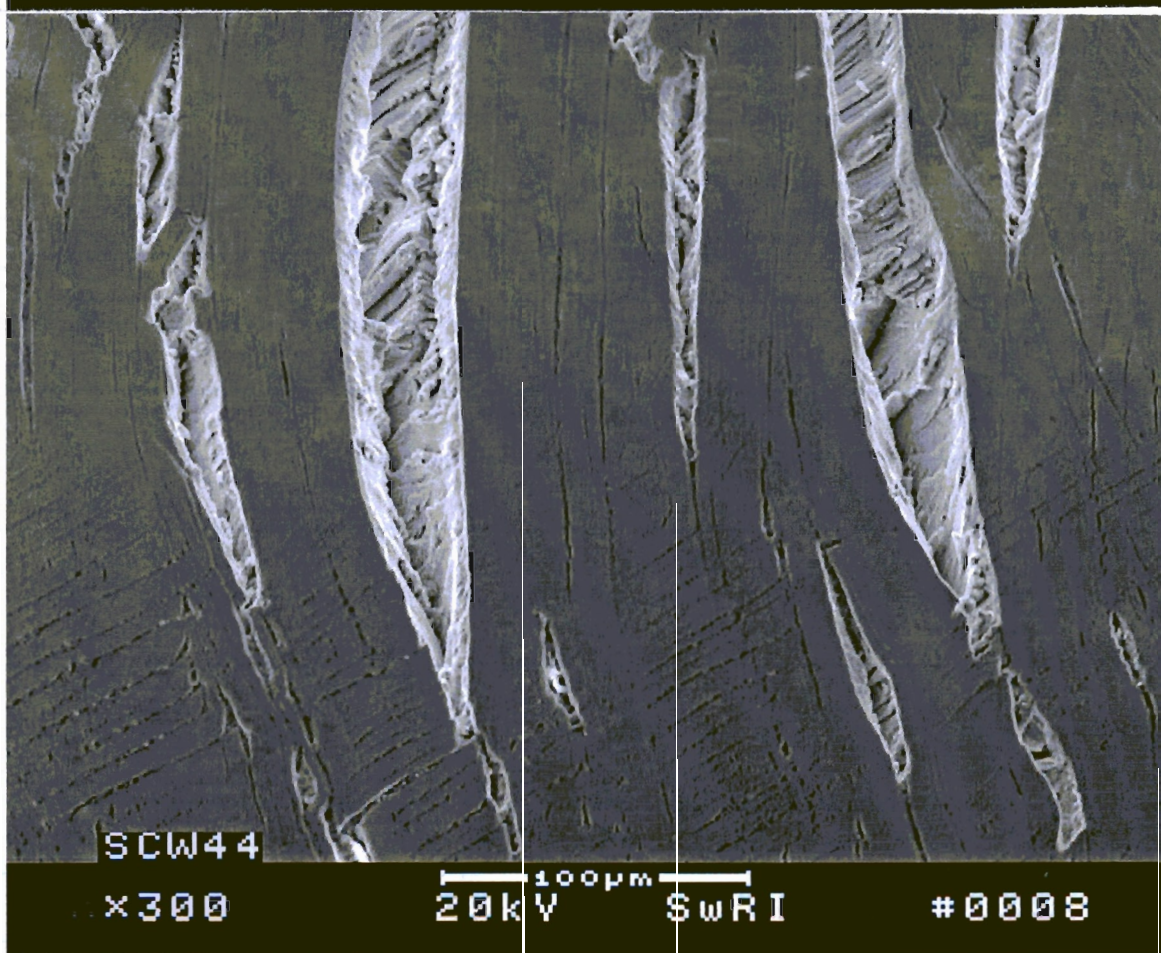
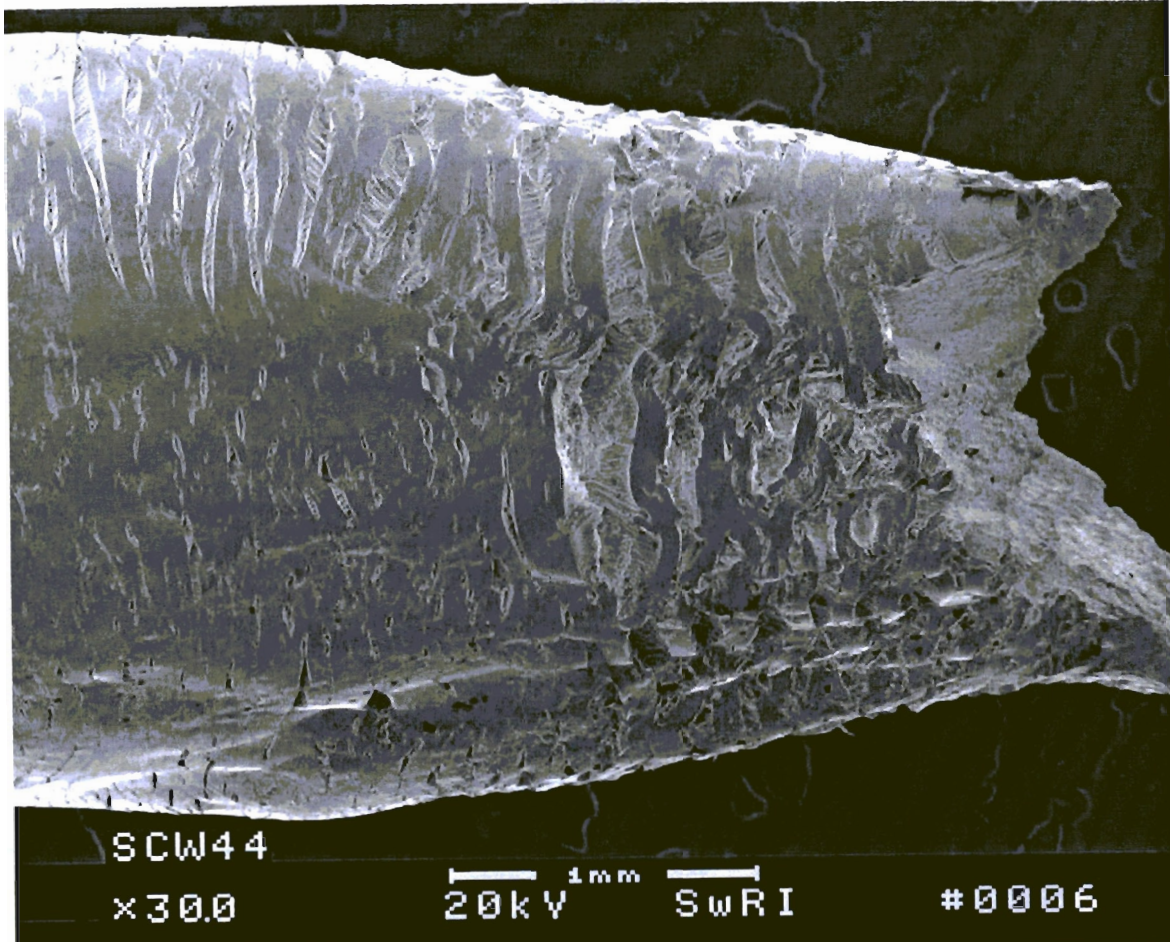
*K. J. Chiles*  
2/13/05



*K. T. Chien*  
7/13/05

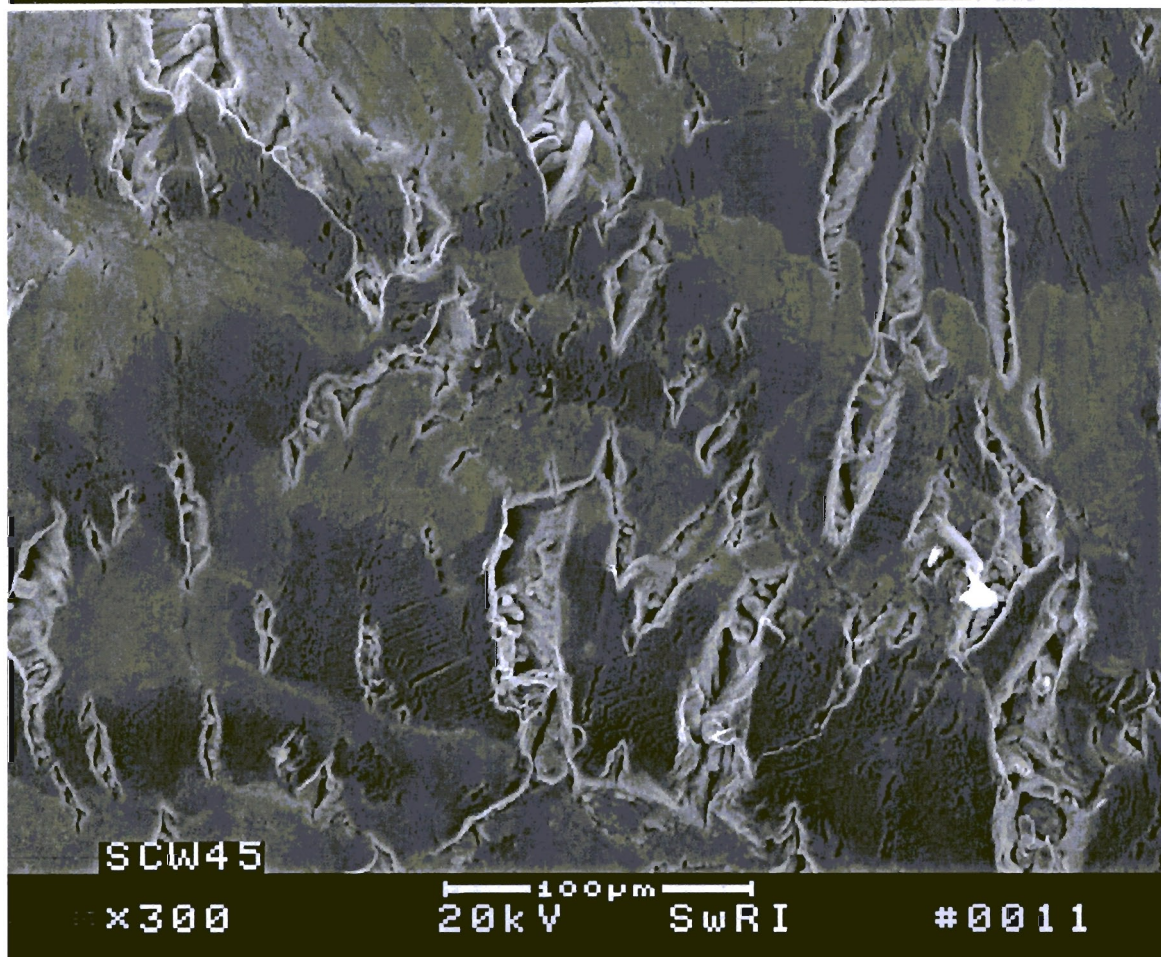
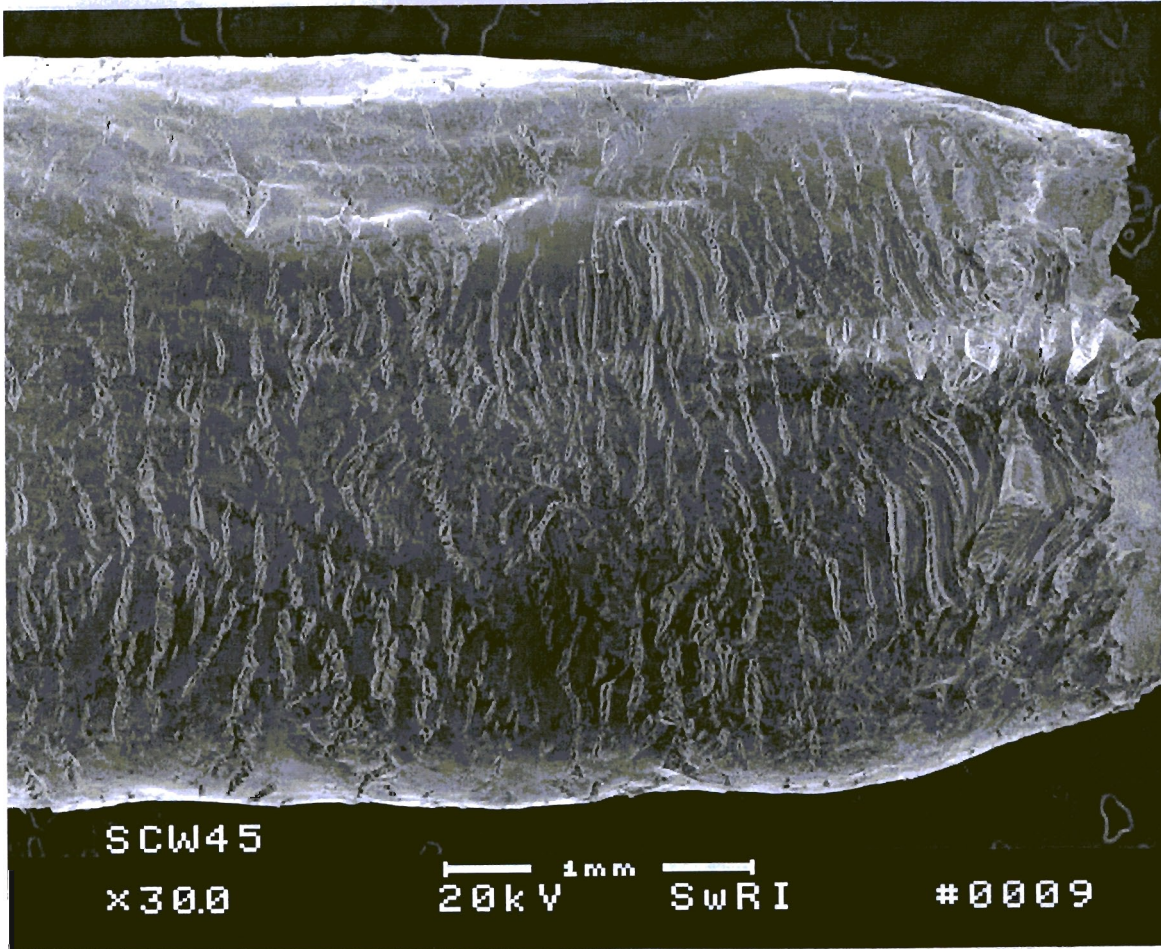
SCW44 welded GTAW 1125°C-20min, GTAW ISB

Test data  
Incomplete

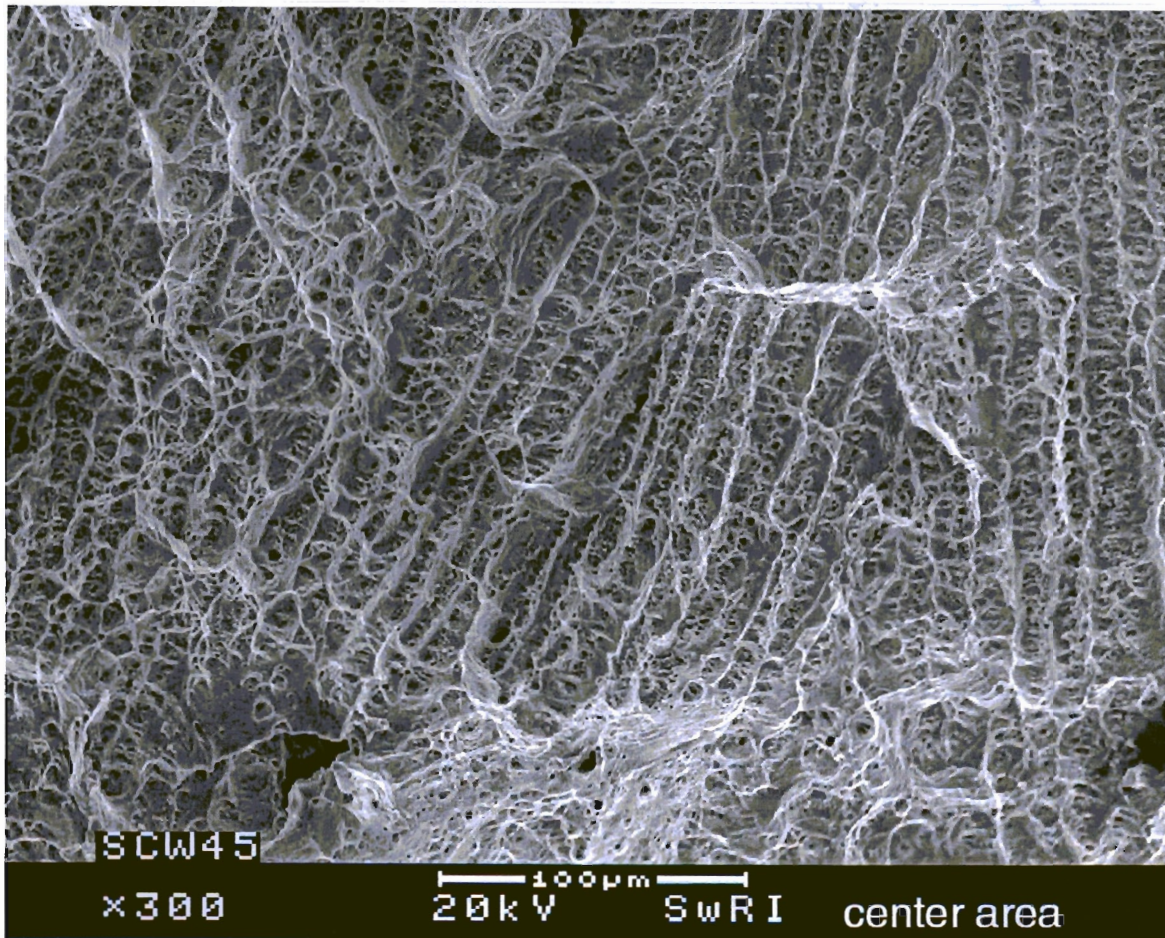
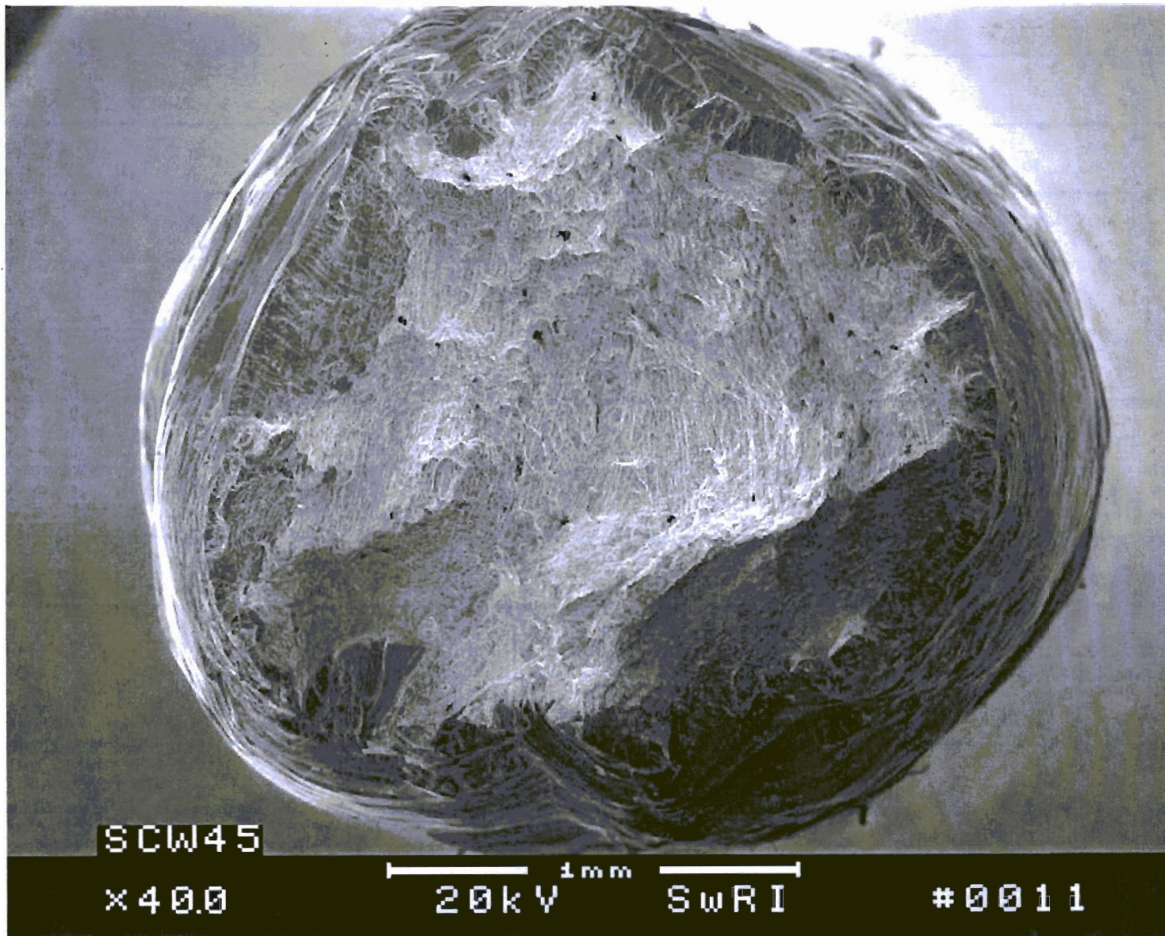


R. J. Chinn 5/15/08

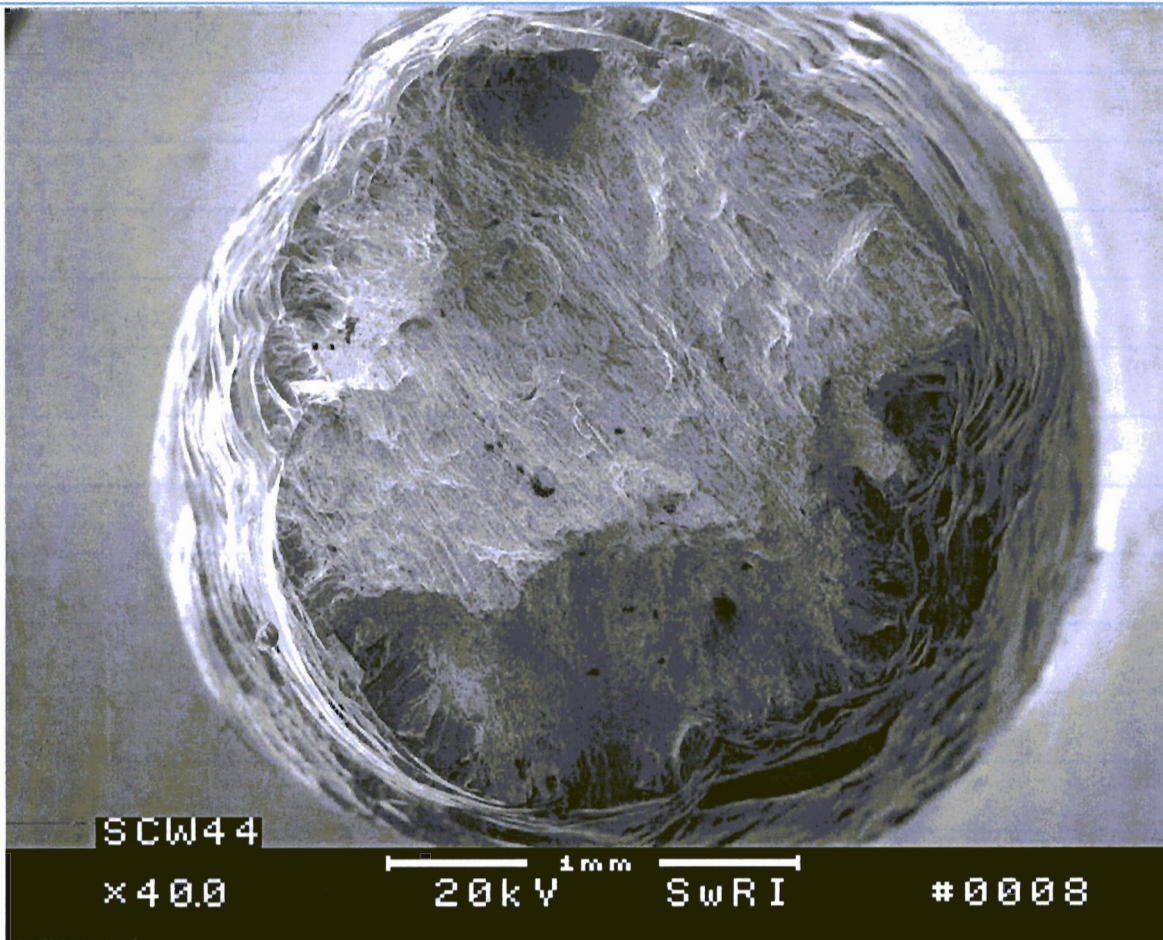
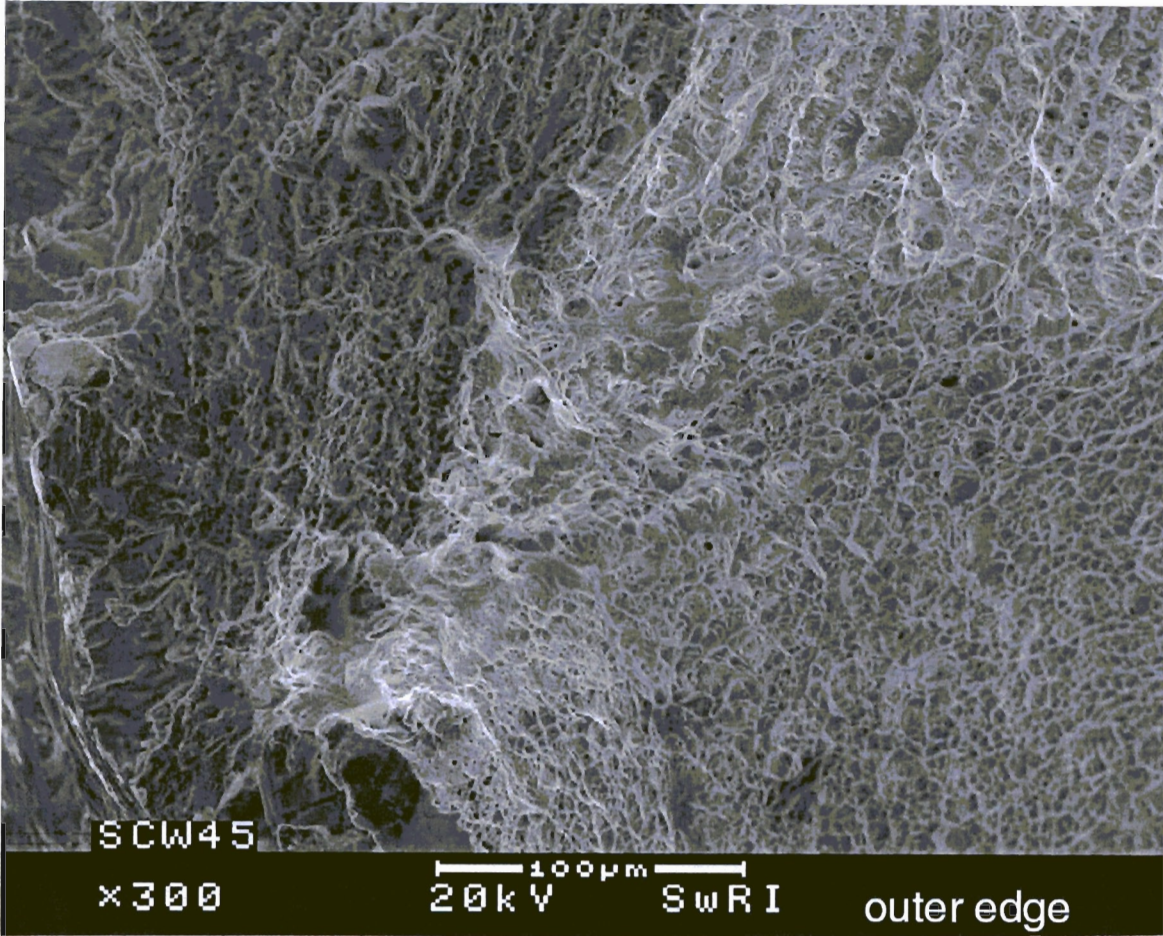
SCW45 in 2.0M Cl + NaHCO<sub>3</sub> as in SCW, GTAWISC Welded + Annealed  
1125°C - 20min



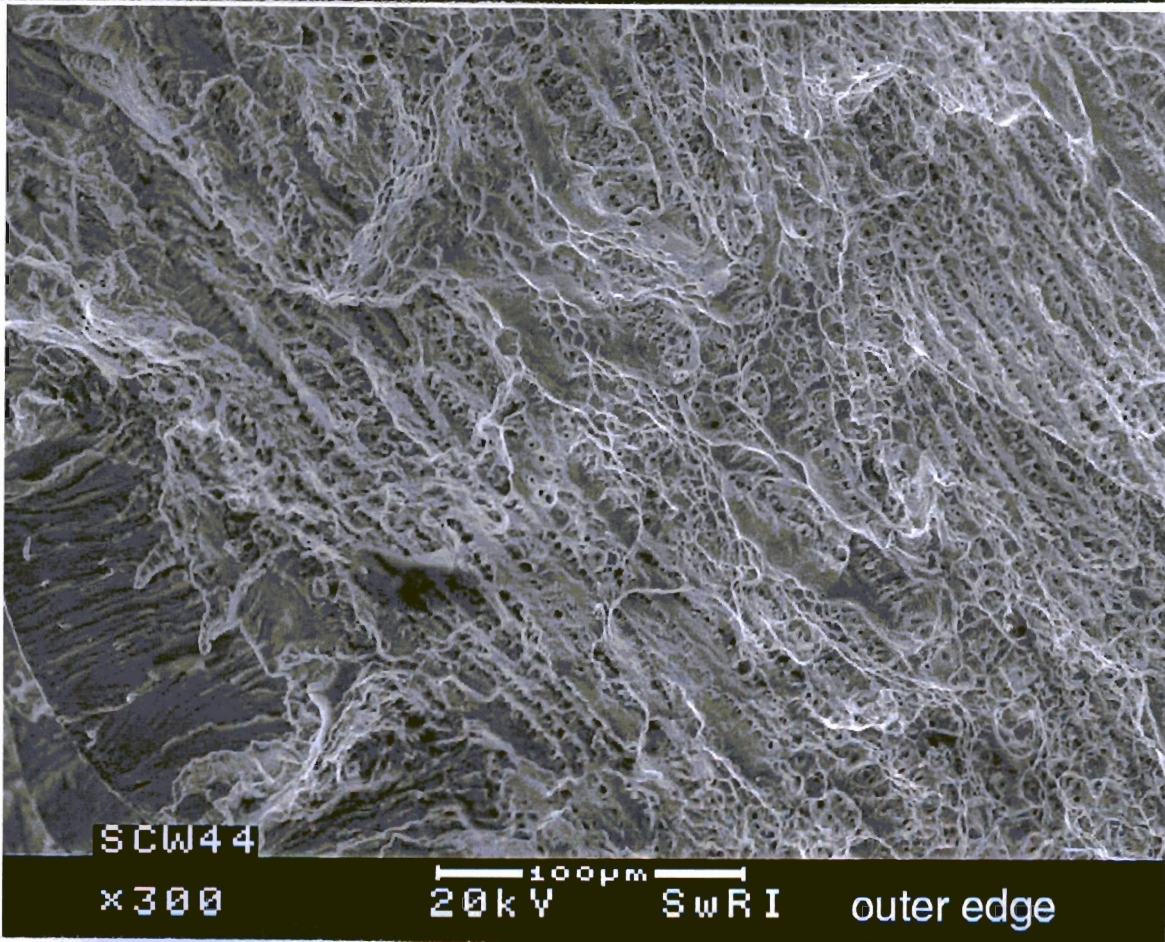
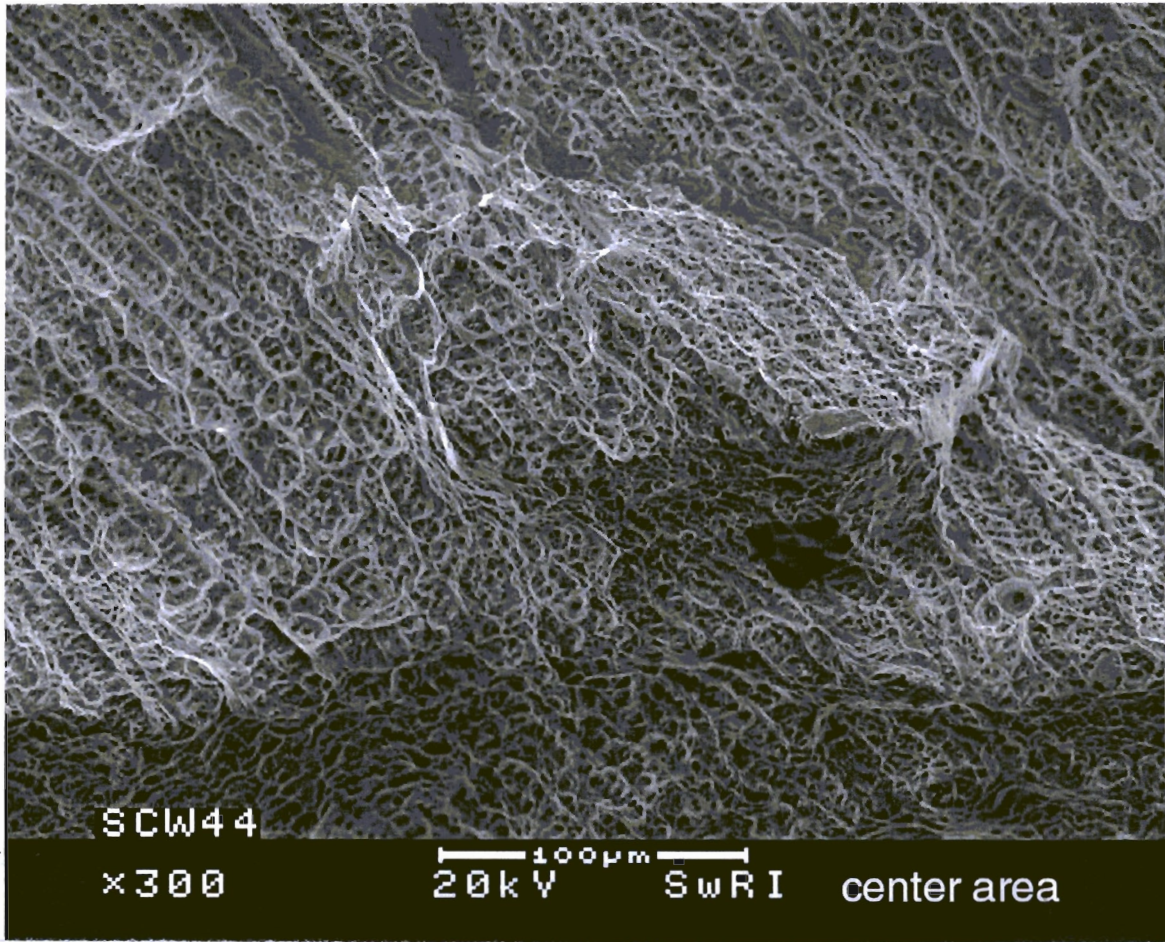
K. J. Ching 7/13/05



*K. T. Chiu 7/13/05*



*K. F. Chinn 7/13/05*



K. T. Chiu 7/13/05

**Initial Scientific Notebook Entry for Corrosion Resistant Material Potentiostatic Tests, Potentiodynamic Tests, Slow Strain Rate Tests**

**Title:** Potentiaostatic tests, polarization tests, slow strain rate tests (SSRT).

**Test Performed by:** Kuang-Tsan Kenneth Chiang, Walter Machowski, Brian Derby

**Objective:** Study the effect of Bicarbonate [ $\text{HCO}_3^-$ ], Carbonate [ $\text{CO}_3^{2-}$ ] Nitrate [ $\text{NO}_3^-$ ] to Chloride [ $\text{Cl}^-$ ] concentration ratio in simulated groundwater on stress corrosion cracking susceptibility of mill-annealed Alloy 22 and Alloy 22 weldments using slow strain rate tests.

**Equipment:** EG&G Versastat Serial Number 20104. EG&G Model 352 corrosion software. NEC 586 computer. Keithley Electrometer Model 614 SN 55538 or equivalent. ASTM G-5 Polarization Cell. The SSRT equipment and instrumentation in Div. 18 laboratory is classified as calibrate before use. The SSRT system includes B&B Motor Control Type MSH-54RL Motor, Ohio Gear Model D3 Gear Box, Sensotec LVDT Model VL7A, Bodine DC Motor Speed Control (SN L4904600), 440 multichannel potentiostats with National Instruments Labview data acquisition software 4.1. CNWRA Computer Property No. 2330. Calibration and due dates are provided in data sheets for each test.

**Materials:** Mill-annealed Alloy 22, gas metal-arc welded Alloy 22, gas tungsten-arc welded Alloy 22.

**Specimen Specifications:** Cylindrical CPP specimens 1.195"x.250" and slow strain rate specimens drawings 20-06002-01-321-001 and 20-06002-01-322-002. SSRT per ASTM G129 procedure.

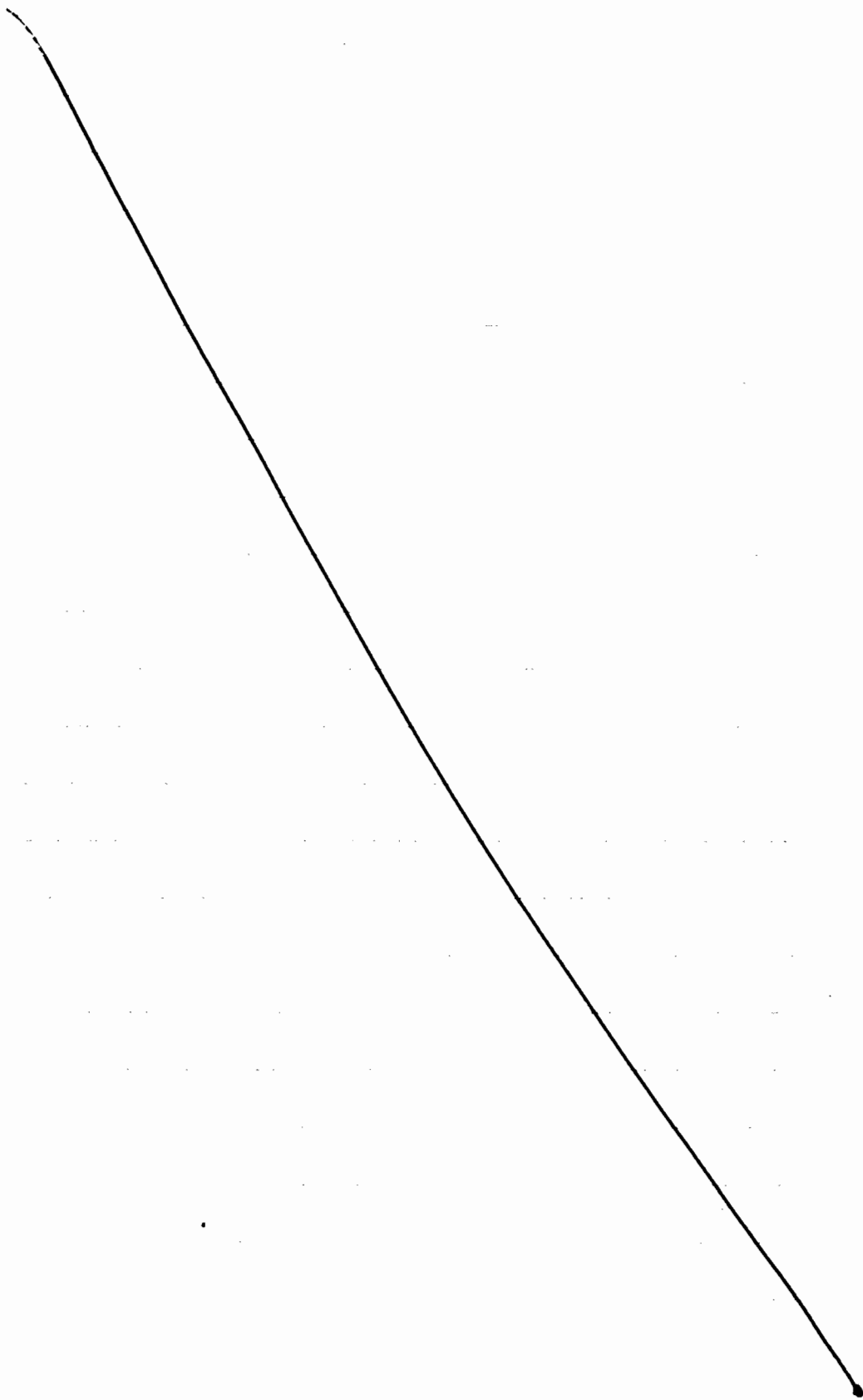
**Measurement Parameters:** Current and Potential as described in TOP-008. Temperature of solution  $\pm 2^\circ\text{C}$ .

**Required Level of Accuracy:** Potentials  $\pm 5\text{mV}$ . Current  $\pm 0.1$  microamps.

**Uncertainty and Source of Error:** Current density calculated as current divided by sample area. Actual current density of corroding areas is not determined. Resolution limit of data acquisition systems may limit accuracy of passive current density measurements.

*K. T. Chiang*  
7/20/05





Walter J. MacKowski  
7/15/05

SLOW STRAIN RATE TEST

Objective: see page #5 #70 *WJM 7/15/05*

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution: *C-22 mill annealed not melted then aged HT #2277-3-3246 <sup>870°/30 mi</sup> <sub>6/27/05</sub> Sec #44*  
*balance of solution on p. 5b*

Reagents measured with

Model:  
Cal:

SN:  
Due:

Counter Electrode: *Pt flag* Reference Electrode: *As/AsCl<sub>2</sub> a/3M KCl in house*

Gas: *N<sub>2</sub> (99.999%)* Ecorr: *-292 mV*

*\*\*\** Applied: *+415 mV* Potentiostat: *ESC 440-2* SN: *9209138*

Specimen Visual:

*some cracking - looks like brittle fracture*

*E° = 3.2 x 10<sup>-6</sup> s<sup>-1</sup> T = 95°C TC S/W 0003 cal 5/19/05 - 11/18/06*

*\* connection @ 95°C (415 mV)*

*\*\* fluke 179 S/W 010857 cal 5/11/05 - 5/11/06*

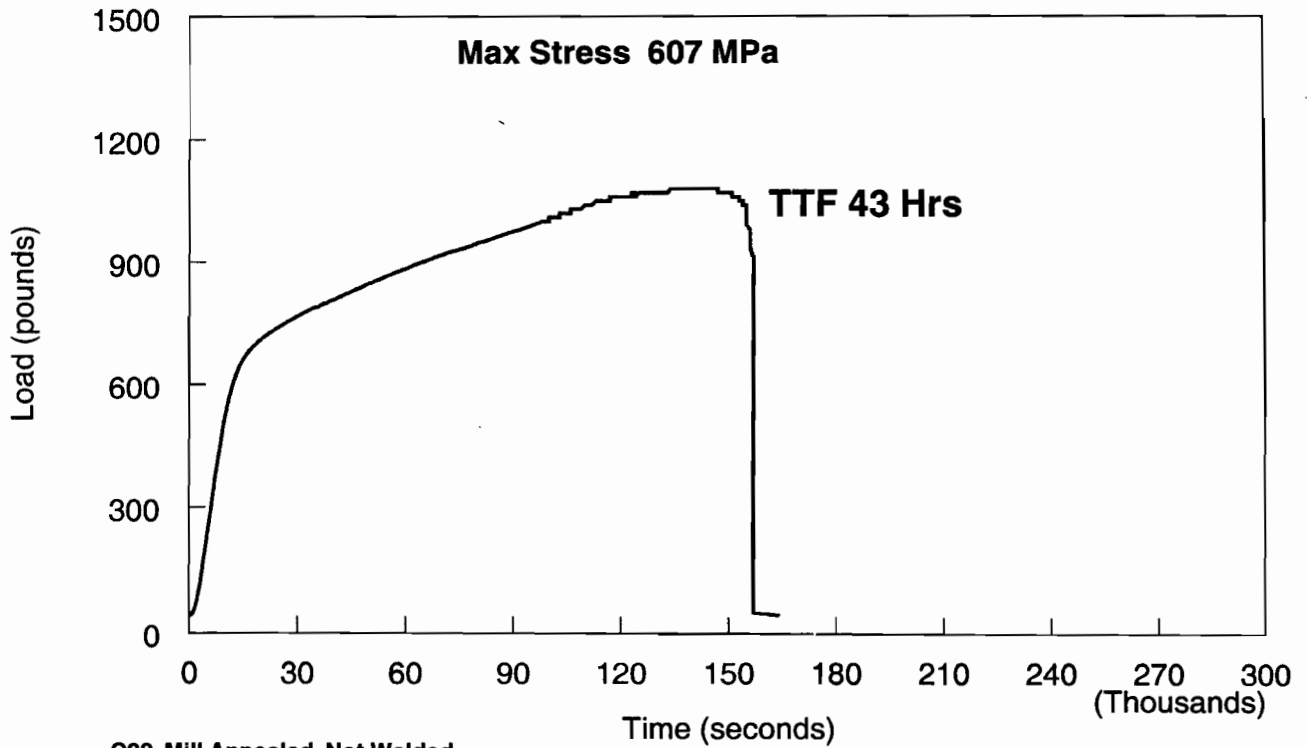
*Test SSRMA22-SCW 49 <sup>870°</sup> <sub>6/27/06</sub>*

*Walter J. MacKowski  
7/15/05*

# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 1.5M KCl; 0.19M NaOH

Test SSRMA22\_SCW49



C22 Mill Annealed Not Welded  
Themally Aged 870°C - 30 minutes

*Walter J. Machowski*  
7/15/05

SLOW STRAIN RATE TEST

Objective: see page #5 p. 70 wgm 8/12/05

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution: alloy 22 MA GTAW #15A aged 1125°C/20 min  
x 1/2 L HT# 2277-3-3292 WN8B/XX19778611 8/27/06

KCl 3.245g Lot# 044597 NaHCO<sub>3</sub> 48.21g Lot 041522  
NaCl 2.735g Lot# 051510 NaF 1.539g Lot 991559  
NaNO<sub>3</sub> 4.363g Lot# 020809 pH<sub>i</sub> 7.90 pH<sub>f</sub> 10.28  
Na<sub>2</sub>SO<sub>4</sub> 10.358g Lot 035451

Reagents measured with Model: JHAUS SN: 2883  
Cal: 7/12/05 Due: 1/12/06

Counter Electrode: Pt flag Reference Electrode: Ag/AgCl w/3M KCl in house

Gas: 99.999 N<sub>2</sub> Ecorr: \*\* -191mV

\*\* Applied: +415mV Potentiostat: ESC440-2 SN: 9209138

Specimen Visual:

some staining (very slight) some cracks visible, failure looks more brittle than ductile

T=95°C TC s/n 0003 cal 5/19/05 - 11/18/05 pH Orion EA940 s/n 2330

G<sup>0</sup> = 3.2 x 10<sup>-6</sup> s<sup>-1</sup> PHelectrode 13-650-296 s/n 14065196P

\* connection @ 95°C (Δ15mV) \*\* fluke 179 s/n 010857 cal 5/11/05 - 5/11/06

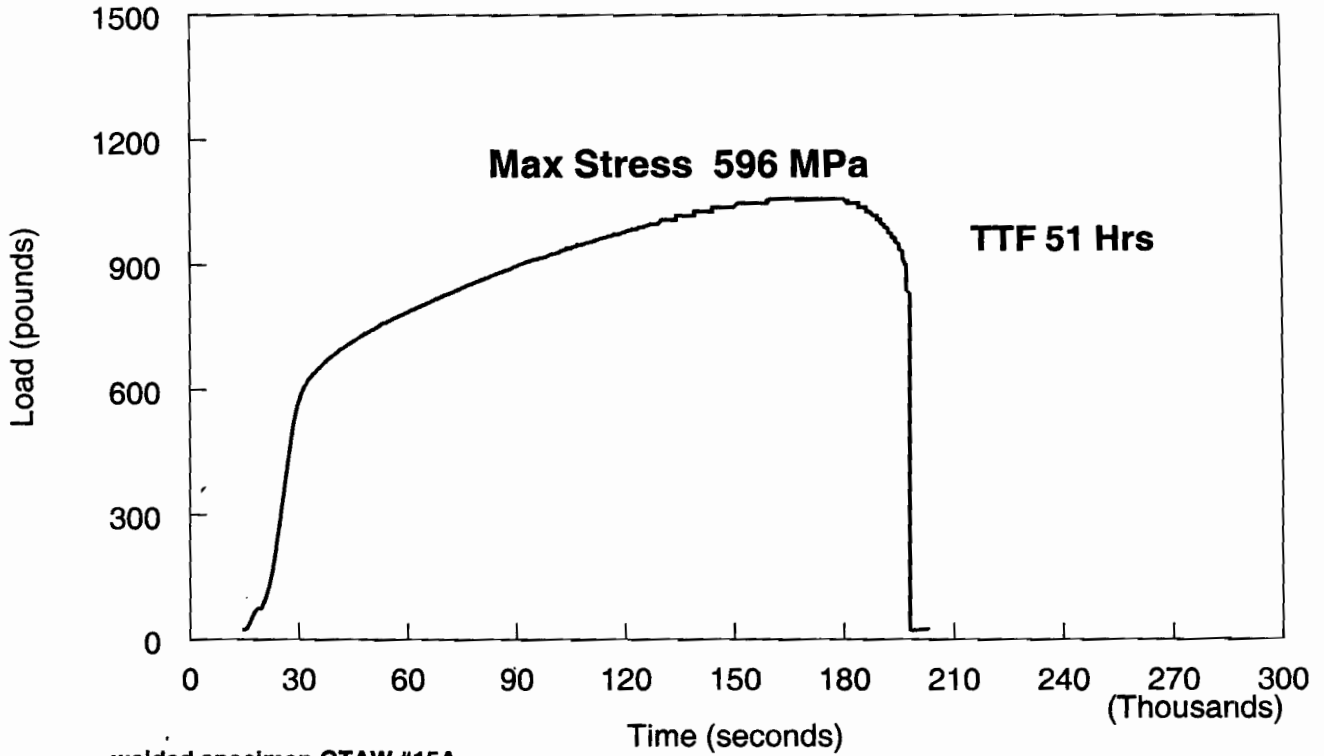
Test SSRMA 22-SCW50 8/27/06

B. D. J. 8/12/05

# Slow Strain Rate Test

SCW

Test SSRMA22\_SCW50



welded specimen GTAW #15A  
aged at 1125°C for 20 minutes

*Walter J. Michowski*  
8/12/05

SLOW STRAIN RATE TEST

Run @  
+300 mV

Objective: see page #5 #70 wgm 8/18/05

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution: x 1/2 L mill annealed not welded  
HT # 2277-3-3266 8/18/06

|                           |         |              |                       |
|---------------------------|---------|--------------|-----------------------|
| 1.05 M NaHCO <sub>3</sub> | 44.19 g | Lot # 041522 | pH <sub>i</sub> 8.71  |
| 0.5 M NaCl                | 14.71 g | Lot # 051510 |                       |
| 1.5 M KCl                 | 55.90 g | Lot # 044597 | pH <sub>f</sub> 10.21 |
| 0.19 M NaOH               | 3.88 g  | Lot # 033922 |                       |

|                        |               |              |
|------------------------|---------------|--------------|
| Reagents measured with | Model: OXPHUS | SN: 2883     |
|                        | Cal: 3/12/05  | Due: 1/12/06 |

Counter Electrode: Pt flg Reference Electrode: Ag/AgCl of 3M KCl in house

Gas: N<sub>2</sub> (99.999%) Ecorr: -150 mV

\* Applied: +300 mV Potentiostat: ZSC 440-2 SN: 9209138

Specimen Visual:

some cracks visible; could be brittle failure

$E^{\circ} = 3.2 \times 10^{-6} \text{ s}^{-1}$  T=95°C TC s/n 0003 cal 5/19/05 → 11/8/05

\* = connector @ 95°C (Δ15 mV)

\*\* fluke 179 s/n 010857 cal 5/11/05 - 5/11/06

pH meter Orion EA940 s/n 2330 pHelectrode

8/18/06

Test SSRMA 22 - SCW51

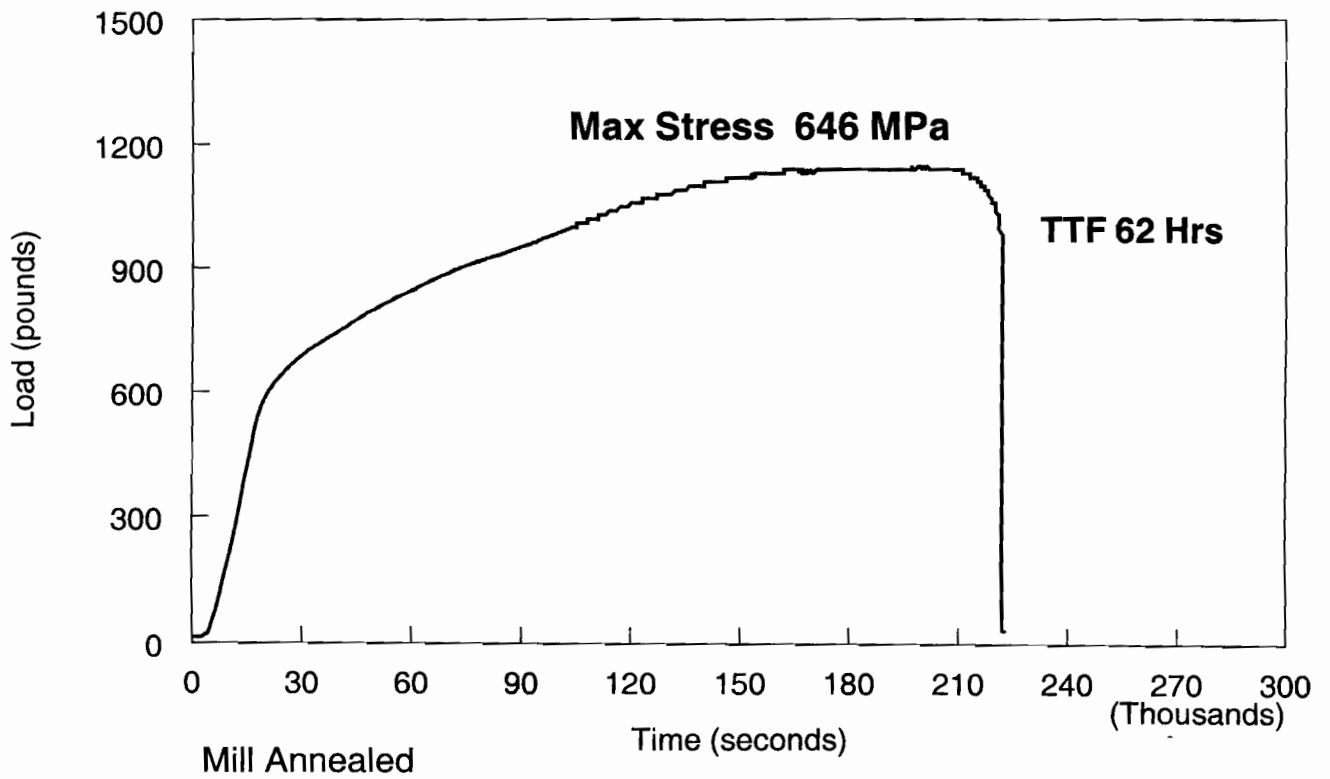
Walter J. MacKowski  
8/18/05

# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 1.5M KCl; 0.19M NaOH

+300mV

Test SSRMA22\_SCW51



*Walter J. Machowski*  
8/18/05

Run @ 75°C  
+400 mV

SLOW STRAIN RATE TEST

Objective: see page #5 #70 NYSM 8/23/05

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution: x 1/2 L  
mill annealed - not welded  
HT # 2277-3-3266 8/27/06

|                          |        |              |                      |
|--------------------------|--------|--------------|----------------------|
| 1.05M NaHCO <sub>3</sub> | 44.09g | Lot # 041522 | pH <sub>i</sub> 8.68 |
| 0.5M NaCl                | 14.65g | Lot # 051510 | pH <sub>f</sub> 9.23 |
| 0.19M NaOH               | 3.87g  | Lot # 033972 |                      |
| 1.5M KCl                 | 55.90g | Lot # 044597 |                      |

Reagents measured with Model: OXPHUS SN: 2883  
Cal: 7/12/05 Due: 1/12/06

Counter Electrode: Pt flag Reference Electrode: Ag/AgCl 0.1M KCl  
in house

Gas: N<sub>2</sub> (99.999%) Ecorr: -195 mV

\* Applied: +415 mV Potentiostat: ESC 440-2 SN: 9209138  
\*\*

Specimen Visual:

slight stain, some cracks visible  
looks like brittle failure

$i^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$  T=75°C TC S/N 0003  
cal 5/19/05 - 11/18/05

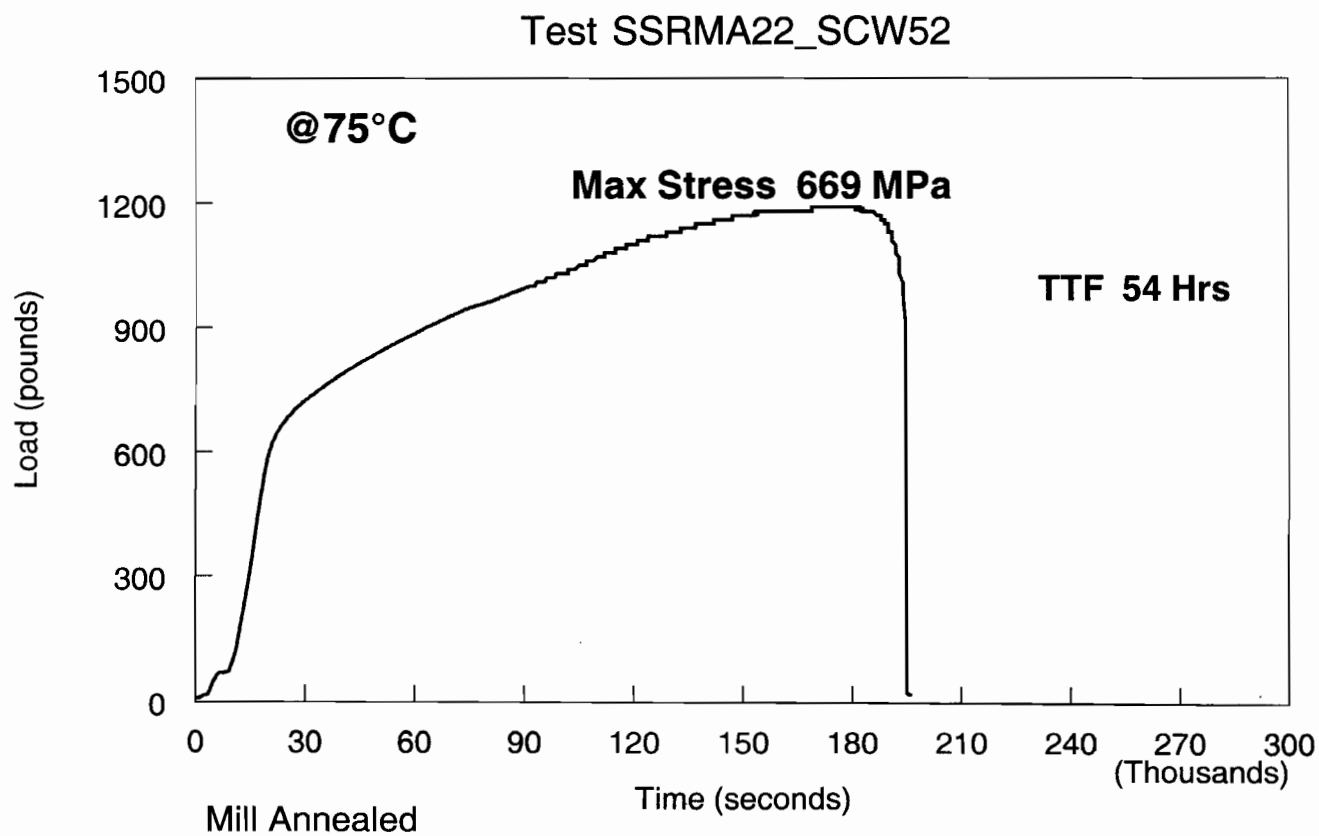
\* connection @ 95°C (Δ15 mV)  
\*\* fluke 179 S/N 010857 cal 5/10/05 - 5/11/06  
pH meter orion EA440 S/N 2330 pH electrode 13-620-296  
cal 7/25/05 - 7/25/06 S/N 14065196 P  
6/10/06 Test SS RA22 SCW52

Walter J. MacKowski  
8/23/05



# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 1.5M KCl; 0.19M NaOH



Walter J. Macchowski  
8/23/05

Run @ 55°C  
+400mV

SLOW STRAIN RATE TEST

Objective: see page #5 #70 wpm 8/29/05

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution: x 1/2 L  
mill annealed - not welded  
HT # 2277-3-3266 8/27/06

|                          |         |              |                 |      |
|--------------------------|---------|--------------|-----------------|------|
| 1.05M NaHCO <sub>3</sub> | 44.08 g | Lot # 041522 | pH <sub>i</sub> | 8.68 |
| 0.5M NaCl                | 14.63 g | Lot # 051510 | pH <sub>f</sub> | 9.31 |
| 0.19M NaOH               | 3.80 g  | Lot # 033972 |                 |      |
| 1.5M KCl                 | 55.98 g | Lot # 044597 |                 |      |

Reagents measured with Model: OHAUS SN: 2883  
Cal: 7/12/05 Due: 1/12/06

Counter Electrode: Pt flag Reference Electrode: Ag/AgCl 4/3M AgCl in house

Gas: N<sub>2</sub> (99.999%) \*Ecorr: -187mV

\*Eapplied: +415mV Potentiostat: ESC 440-2 SN: 9209138

Specimen Visual:  
some slight staining looks like ductile failure

$E^0 = 3.2 \times 10^{-6} \text{ s}^{-1}$  T=55°C TC s/n 0003 cal 5/14/05 → 11/8/05

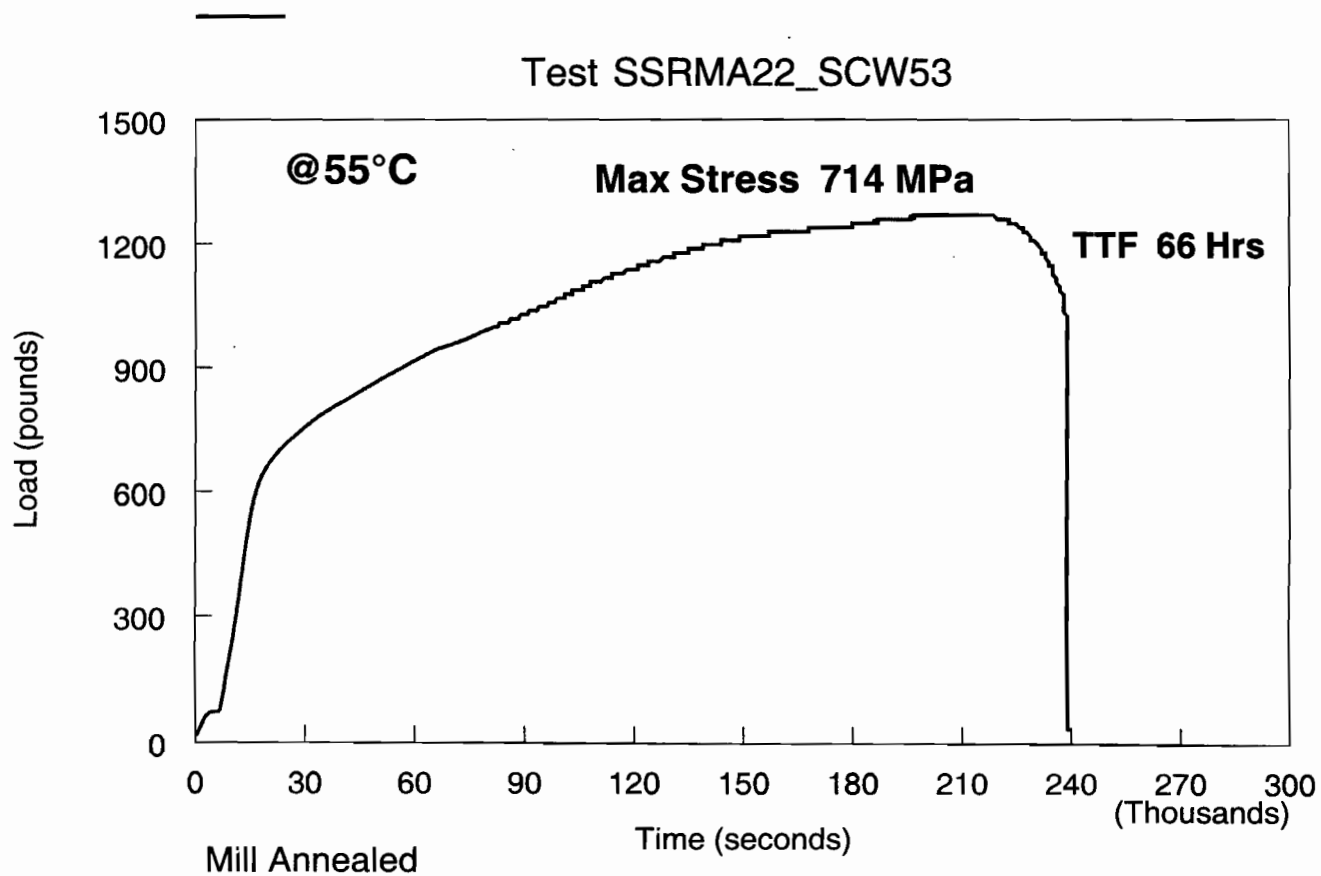
\* corrected for temp (Δ15mV)  
\*\* fluke 179 s/n 010857 cal 5/11/05 - 5/14/06  
pH meter ORION EA940 s/n 2330 cal 7/25/05 - 7/25/06  
pH electrode 13620-296 s/n 14065196P

5/27/06 Test SSRMA22 - SCWS3

Walter J. Machowski  
8/29/05

# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 1.5M KCl; 0.19M NaOH



*Walter J. Machowski*  
8/29/05

run @ RT  
+400mV

SLOW STRAIN RATE TEST

Objective: see page #5 #70 8/30/05

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

mill annealed - not welded  
HT # 2277-3-3266 8/27/06

Solution: x 1/2 L

|        |                    |         |              |                      |
|--------|--------------------|---------|--------------|----------------------|
| 1.05 M | NaHCO <sub>3</sub> | 44.35 g | Lot # 041522 | pH <sub>i</sub> 8.72 |
| 0.5 M  | NaCl               | 14.59 g | Lot # 051510 | pH <sub>f</sub> 9.15 |
| 0.19 M | NaOH               | 3.84 g  | Lot # 033972 |                      |
| 1.5 M  | KCl                | 55.49 g | Lot # 044597 |                      |

Reagents measured with Model: OXANS SN: 2883  
Cal: 7/12/05 Due: 1/12/06

Counter Electrode: Pt flag Reference Electrode: Ag/AgCl 1/3M KCl in buret

Gas: N<sub>2</sub> (99.999%) E<sub>corr</sub>: -214mV

\* Applied: +400mV Potentiostat: ESC 440-2 SN: 9209138

Specimen Visual:

some slight staining looks like ductile failure

$E^{\circ} = 3.2 \times 10^{-6} S^{-1}$

\* fluke 179 S/N 010857 cal 5/11/05 - 5/11/06

pH meter ORION EA 940 S/N 2330 cal 7/25/05 - 7/25/06

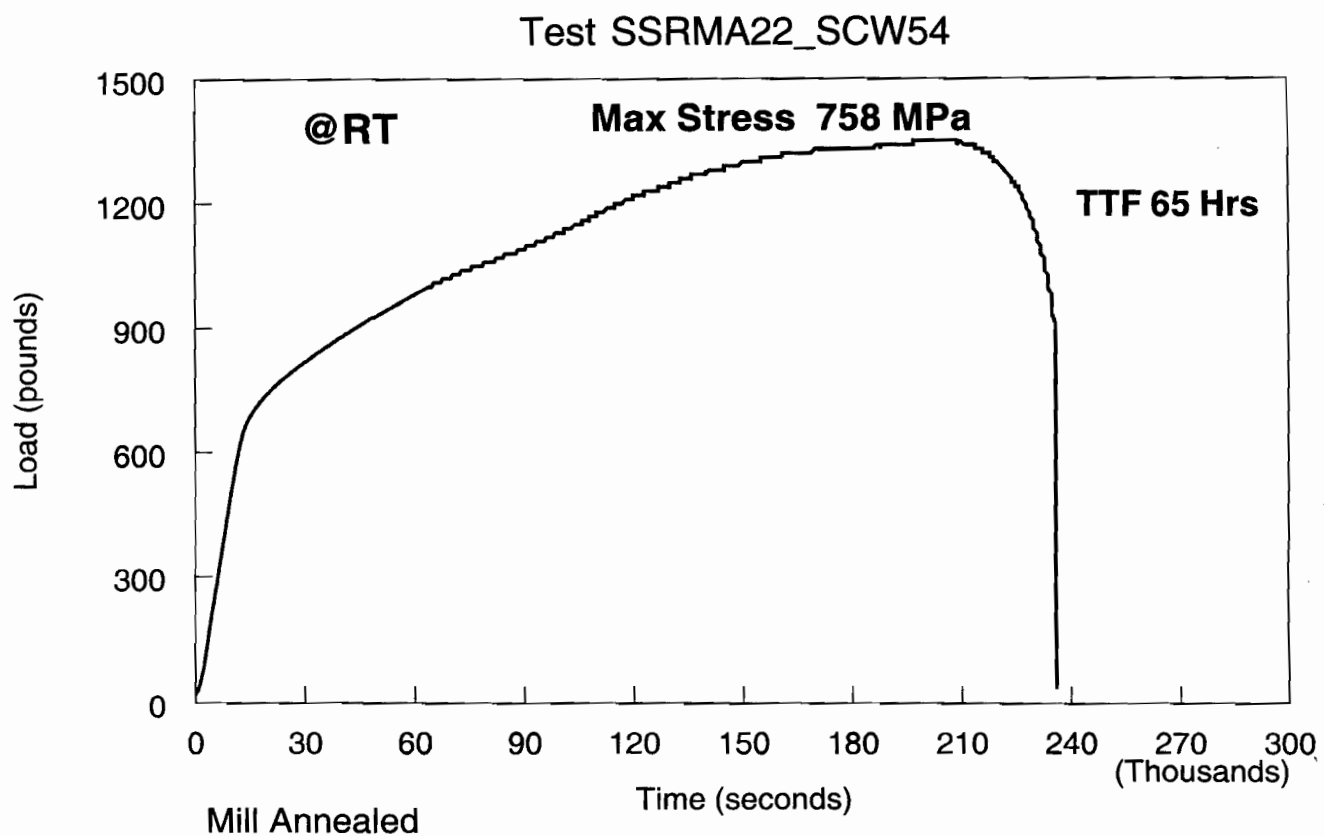
pH electrode 13-620-296 S/N 14065196P

8/27/06 Test SSRMA22-SCW54

Walter J. Macintosh  
8/30/05

# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 1.5M KCl; 0.19M NaOH



Walter J. Machowski  
8/30/05

@ +200mV

SLOW STRAIN RATE TEST

Objective: see page # ~~75~~ #70 *WJM 9/2/05*

Specimen: MA Alloy 22 SwRI Drawing # 20-06002-01-321-001

Solution:  $\approx \frac{1}{2}$  L *mill annealed - not welded*  
*HT # 2277-3-3266 8/27/06*

|                           |         |              |          |
|---------------------------|---------|--------------|----------|
| 1.05 M NaHCO <sub>3</sub> | 44.09 g | LIT # 050282 | pH: 8.68 |
| 0.5 M NaCl                | 14.63 g | LIT # 051510 | pH: 9.40 |
| 0.19 M NaOH               | 3.85 g  | LIT # 033972 |          |
| 1.5 M KCl                 | 55.91 g | LIT # 044597 |          |

Reagents measured with Model: *ORION* SN: 2883  
 Cal: *7/12/05* Due: *1/12/06*

Counter Electrode: *Pt flag* Reference Electrode: *Ag/AgCl w/3M KCl*  
*in house*

Gas: *N<sub>2</sub> (99.999%)* \*Ecorr: *-240mV*

\* Applied: *+200mV* Potentiostat: *ESC 440-2* SN: *9209138*

Specimen Visual:

*some staining (slight) looks like ductile failure*

$$E^{\circ} = 3.2 \times 10^{-6} \text{ s}^{-1}$$

\* fluke 179 S/N 010857 cal 5/1/05 - 5/11/06  
 pH meter ORION EA 940 S/N 2330 cal 7/25/05 - 7/25/06  
 pH electrode 13620-296 S/N 14065196 P  
*T=95° TC S/N 0003 5/19/05 - 11/18/05*

*6/27/06* Test SSRMA22 - SCW55

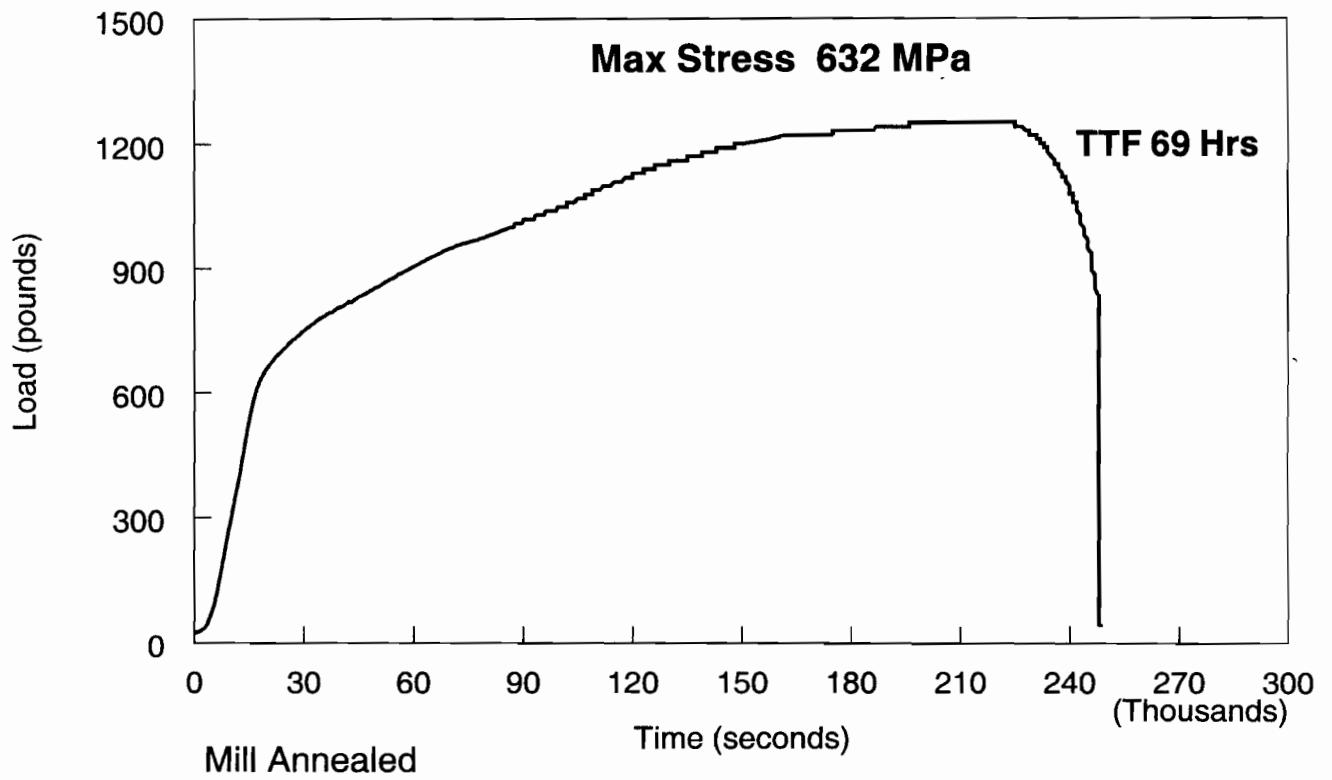
*Walter J. Machowicz*  
*9/2/05*

# Slow Strain Rate Test

1.05M NaHCO<sub>3</sub>; 0.5M NaCl; 1.5M KCl; 0.19M NaOH

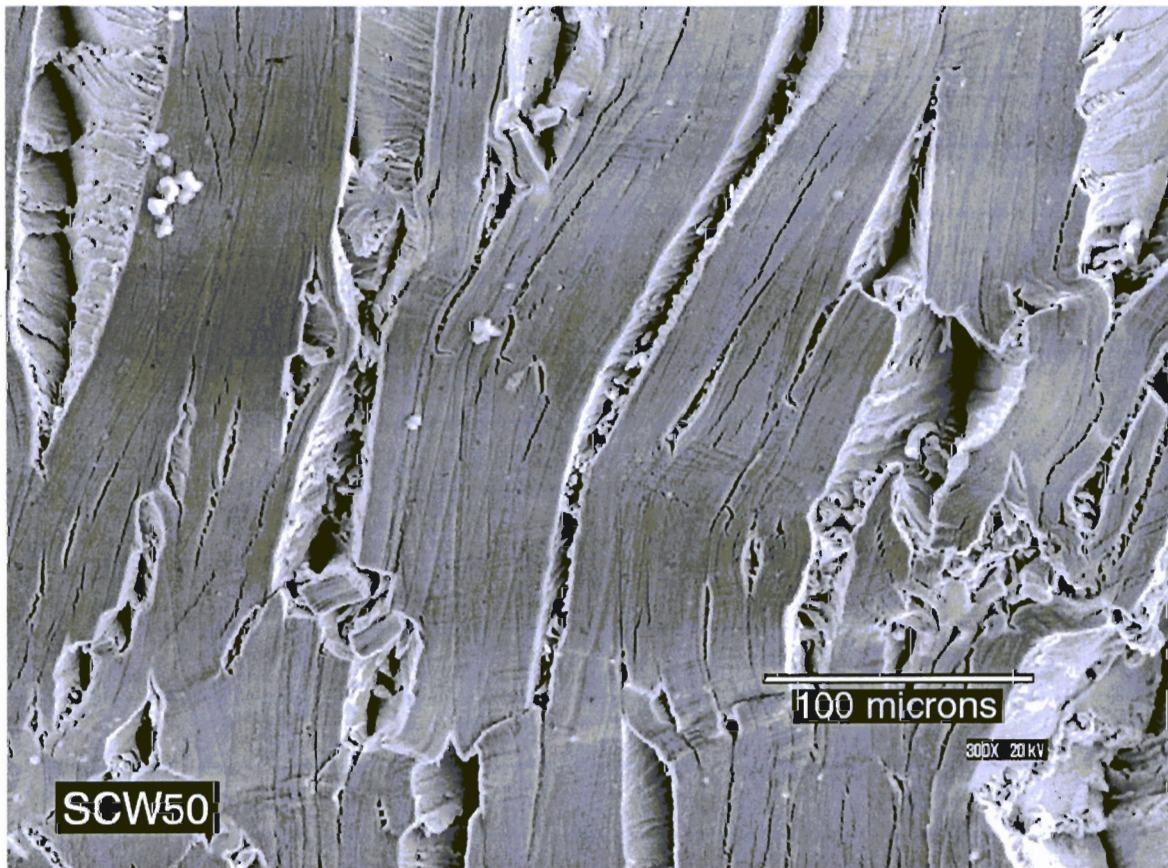
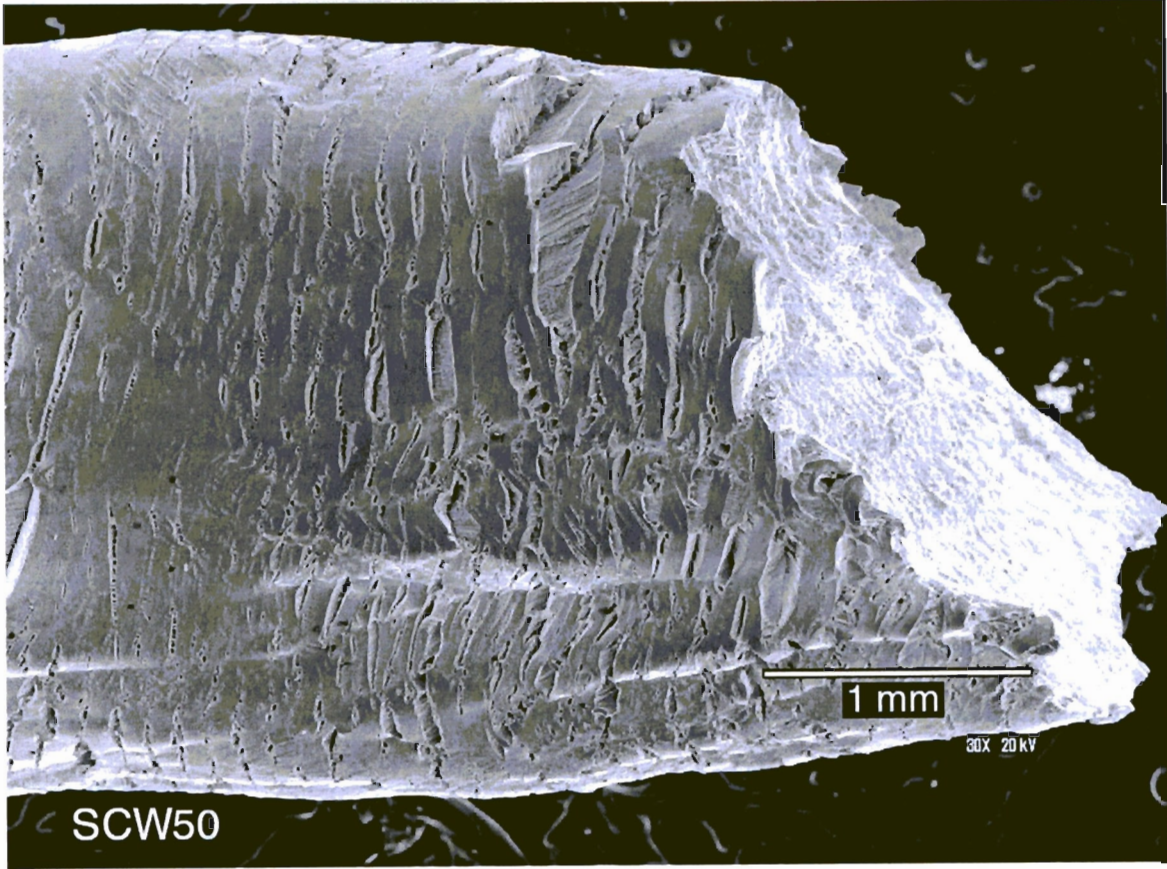
+200 mV

Test SSRMA22\_SCW55



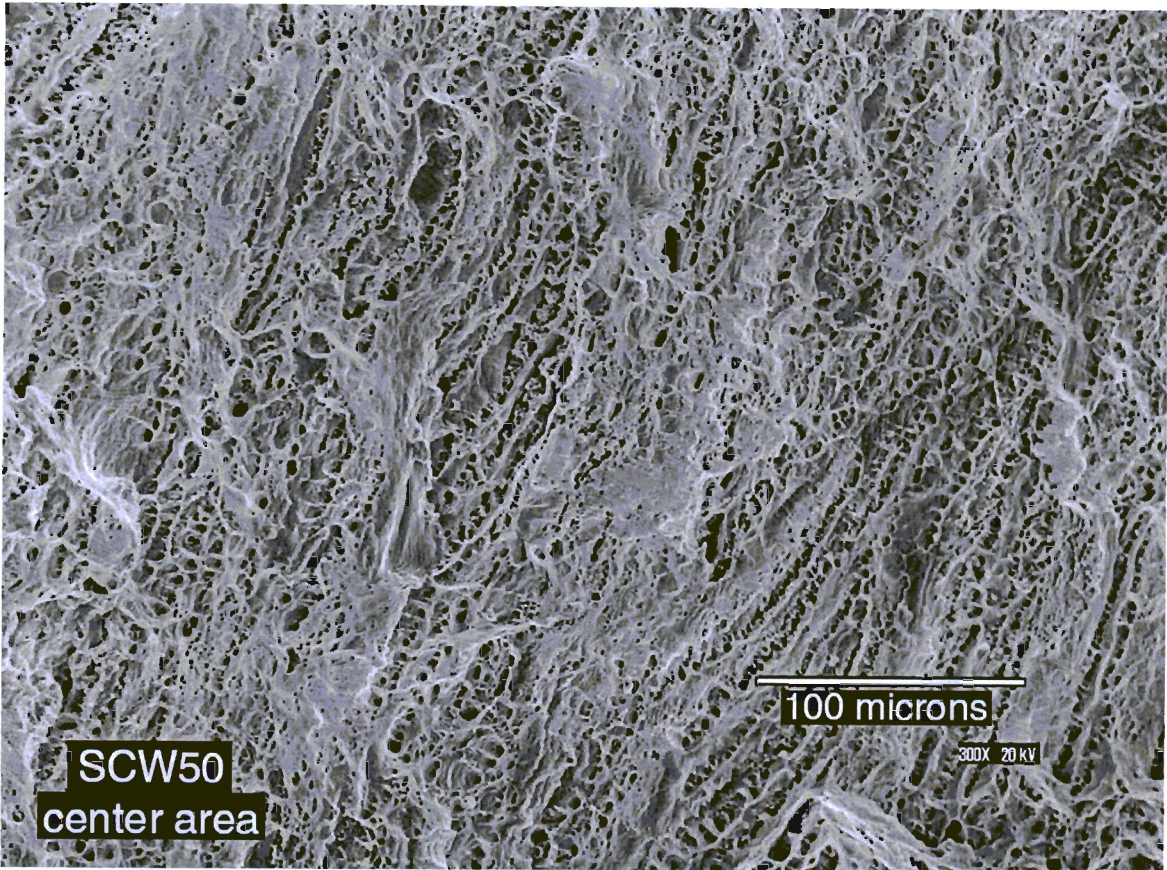
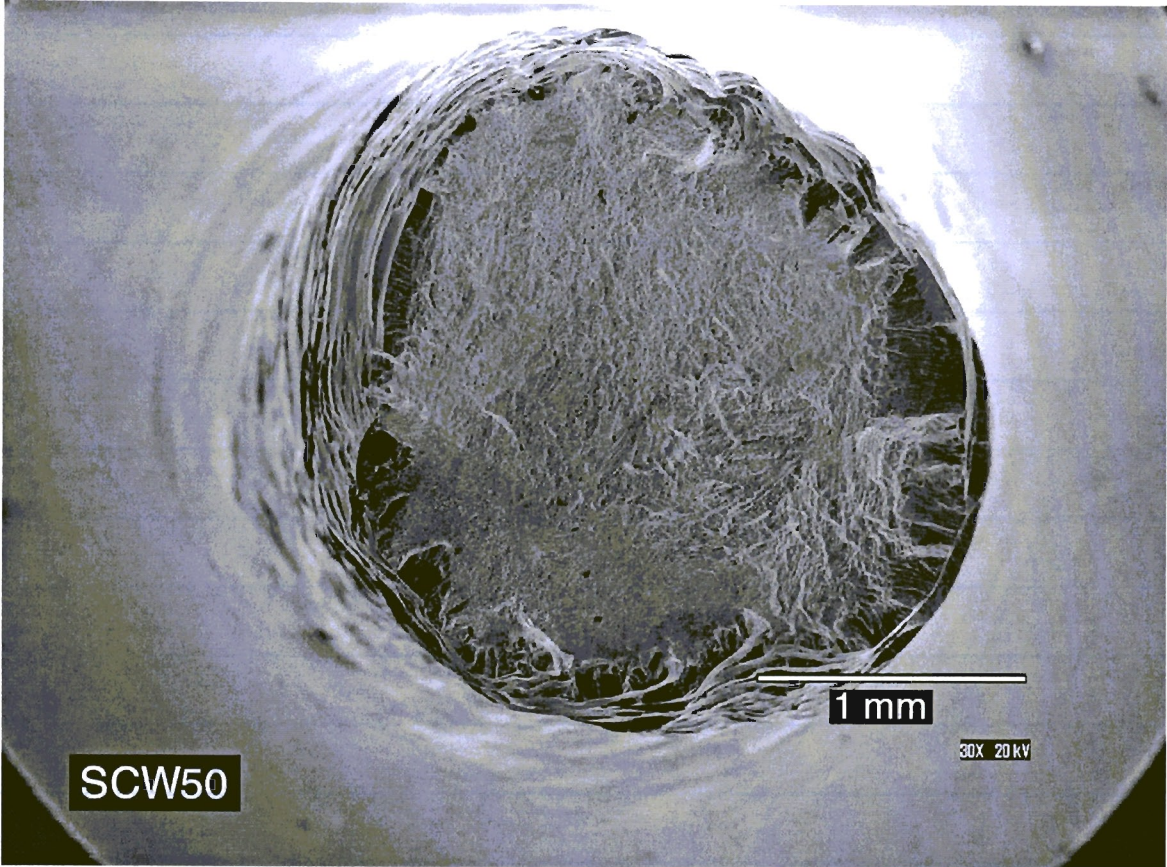
*Walter J. Macintosh*  
9/2/05

SCW50 SCW - GTAW #15A Thermally aged 1125°C/20min

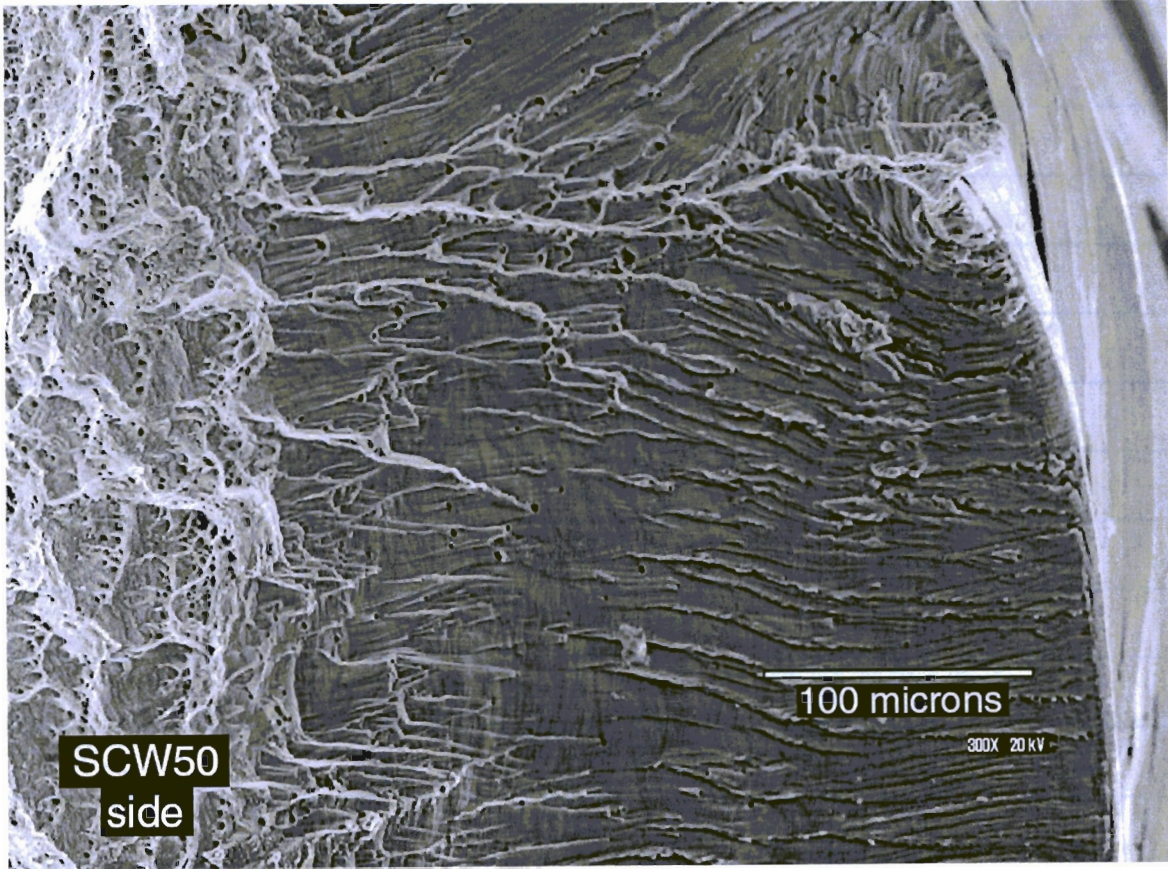


K.S. Chinn 9/8/05



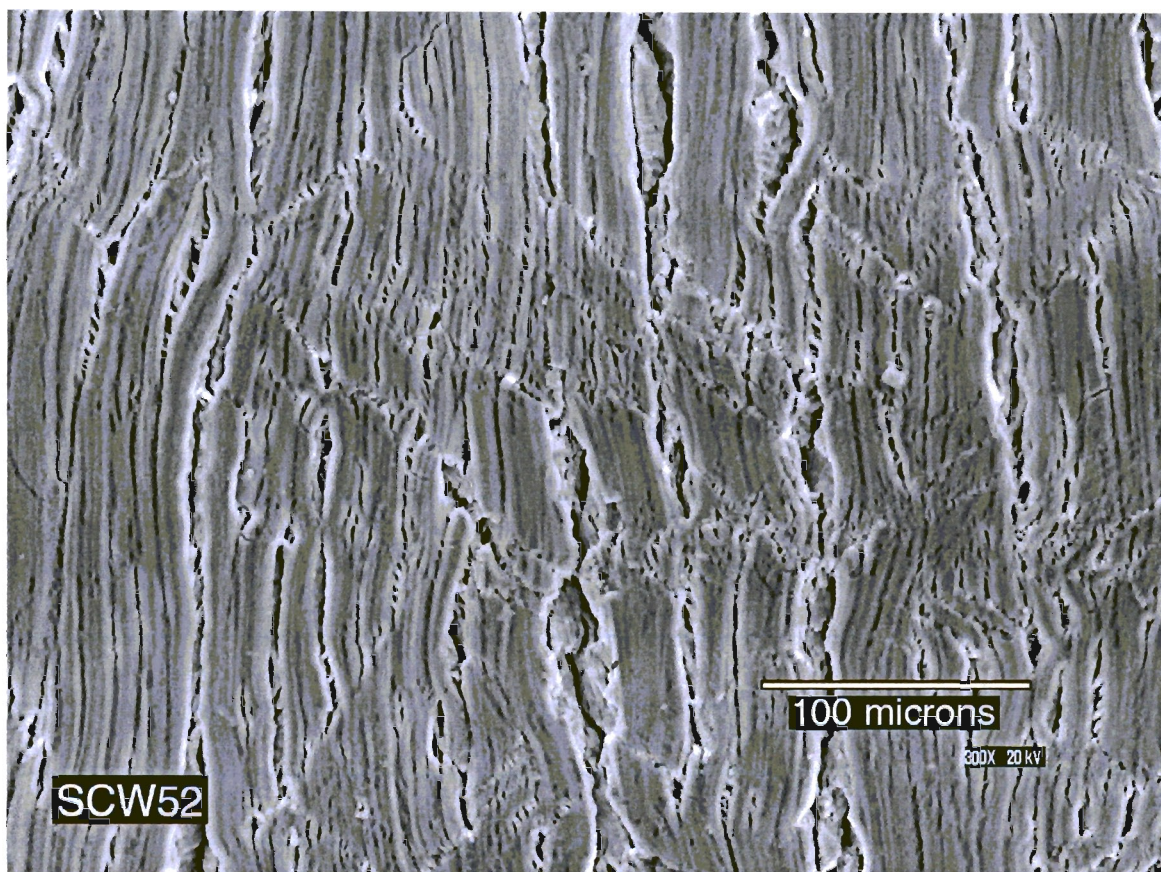
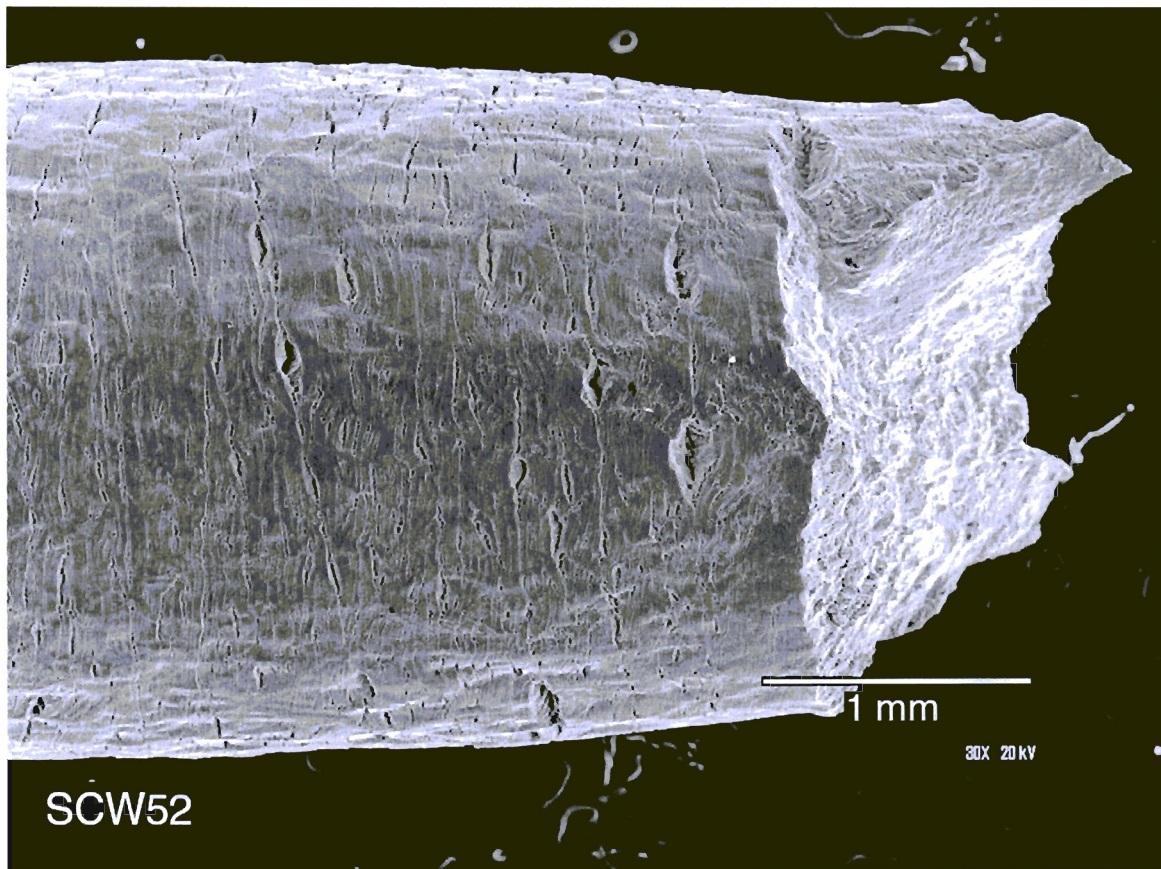


*K. J. Ching 9/8/05*

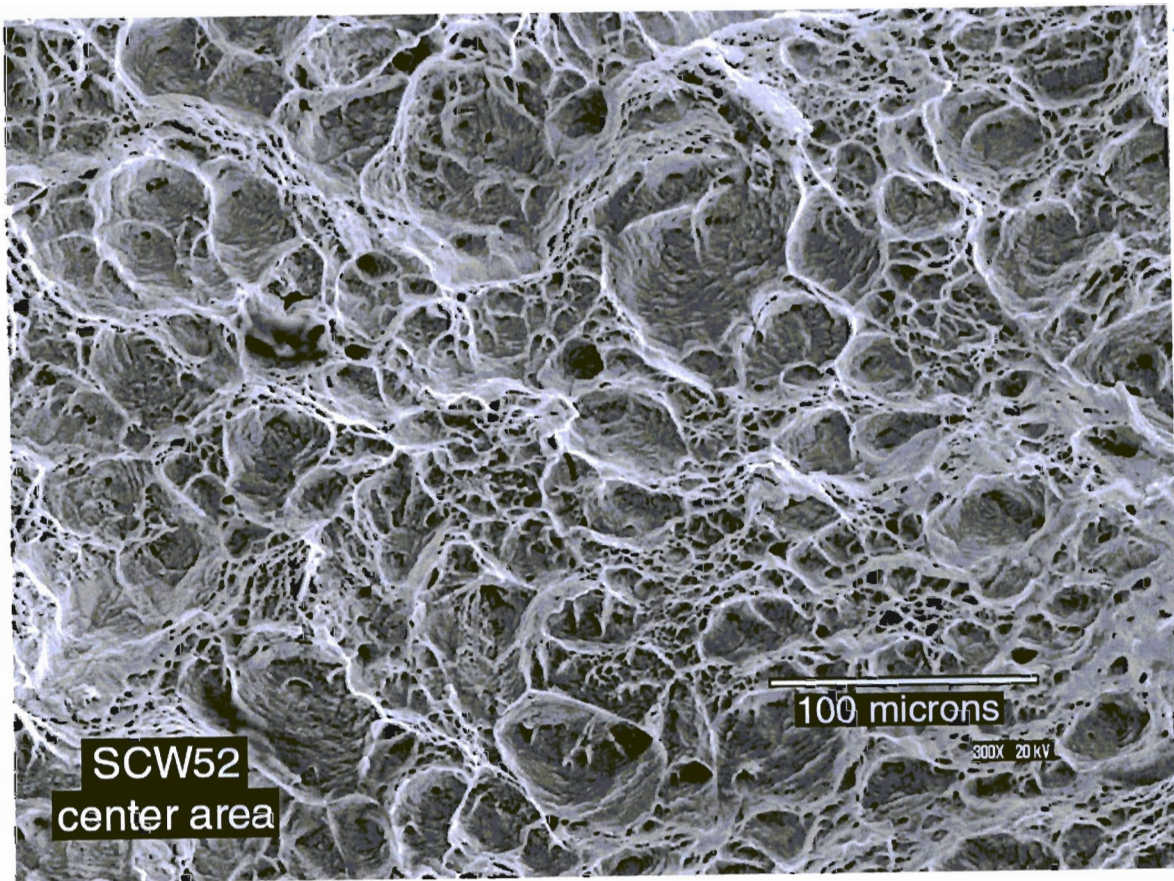
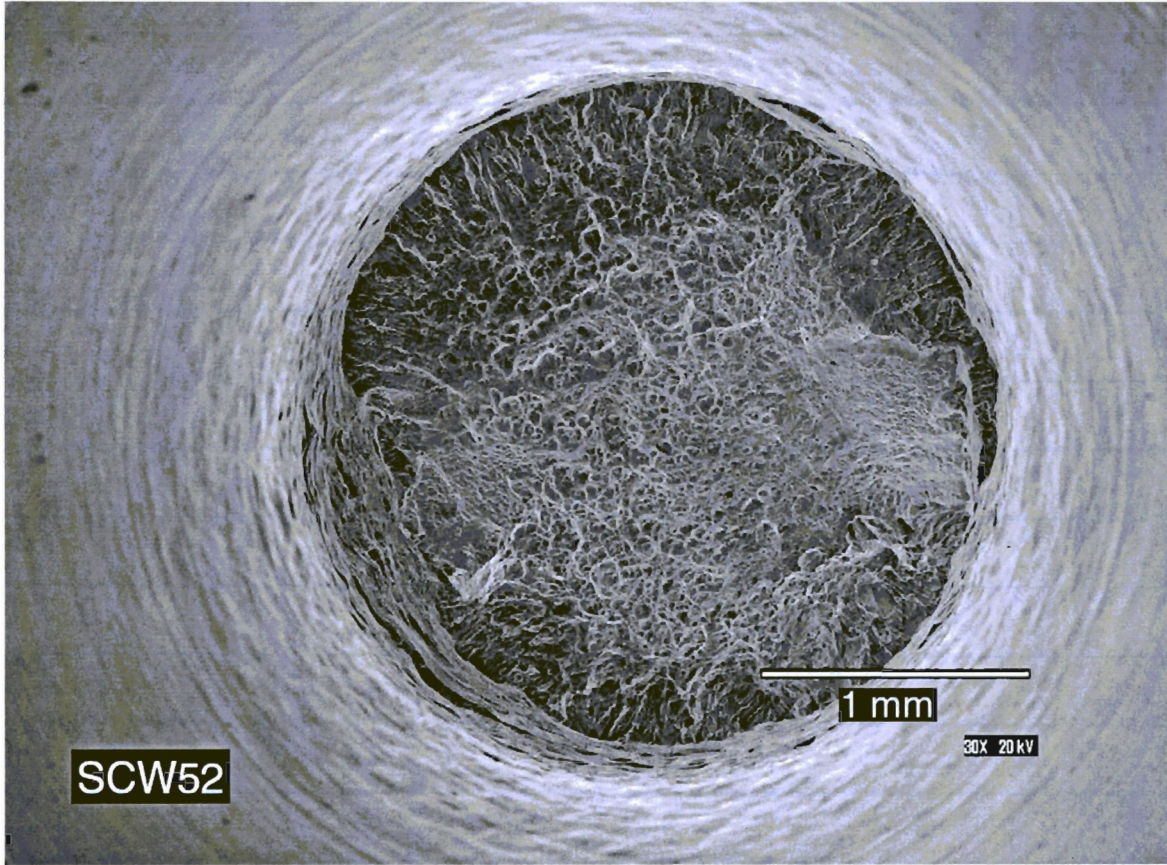


*K. J. Ching*  
9/8/05

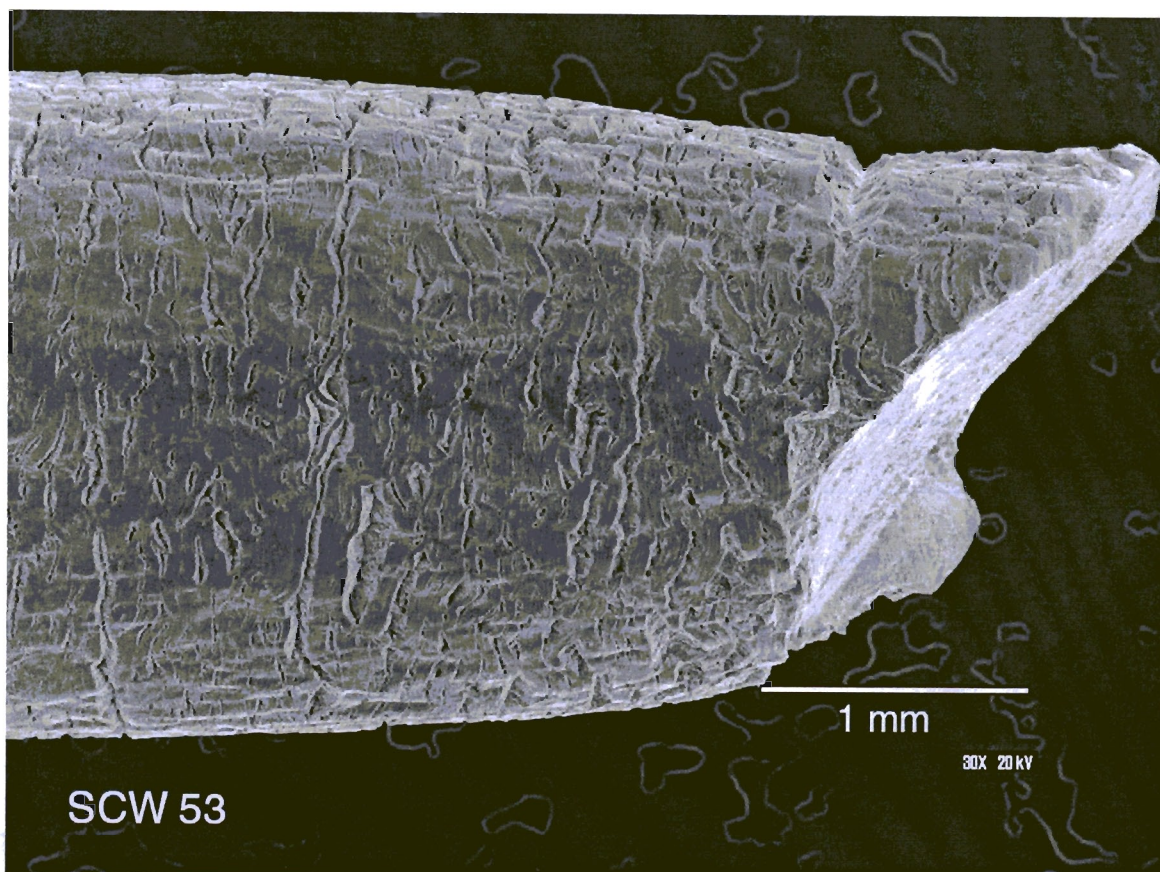
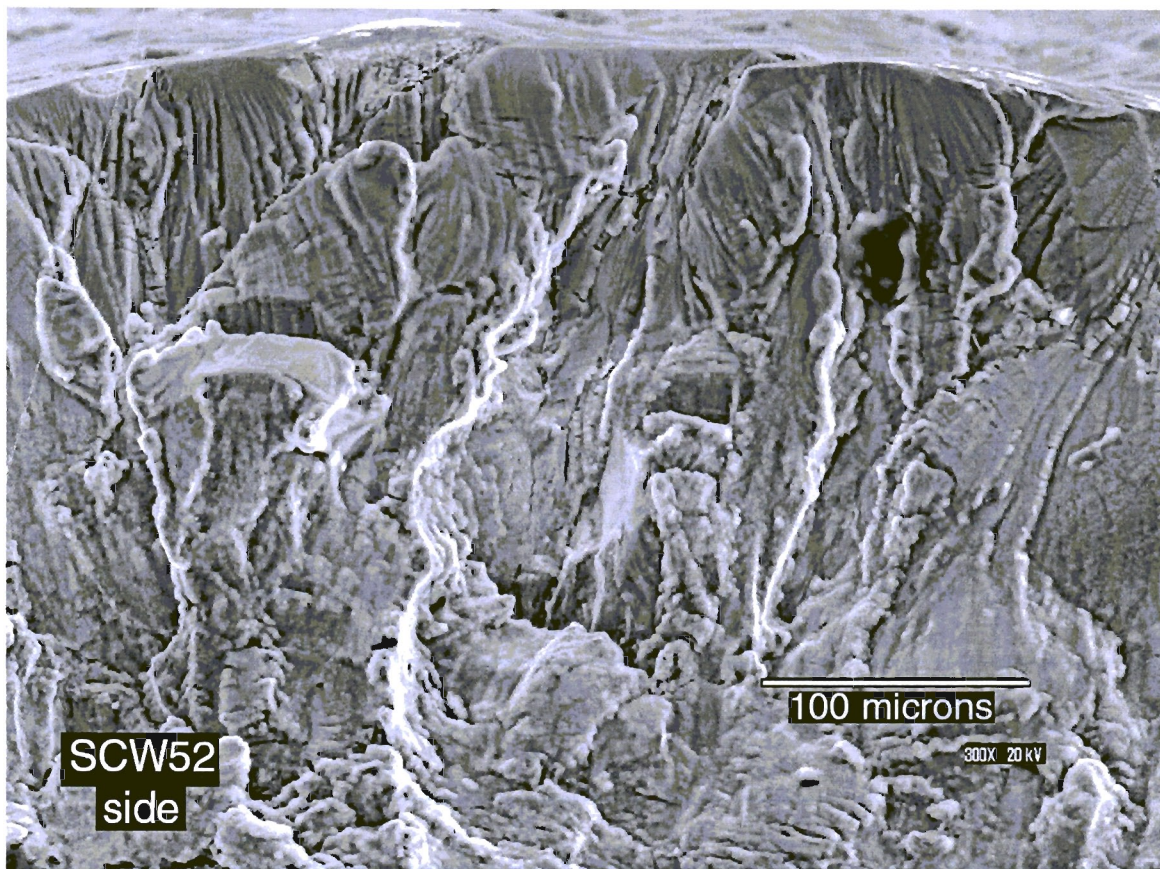
Effect of Solution Temperatures (75°C, 55°C, 22°C)



K.J. Chiof 9/8/05

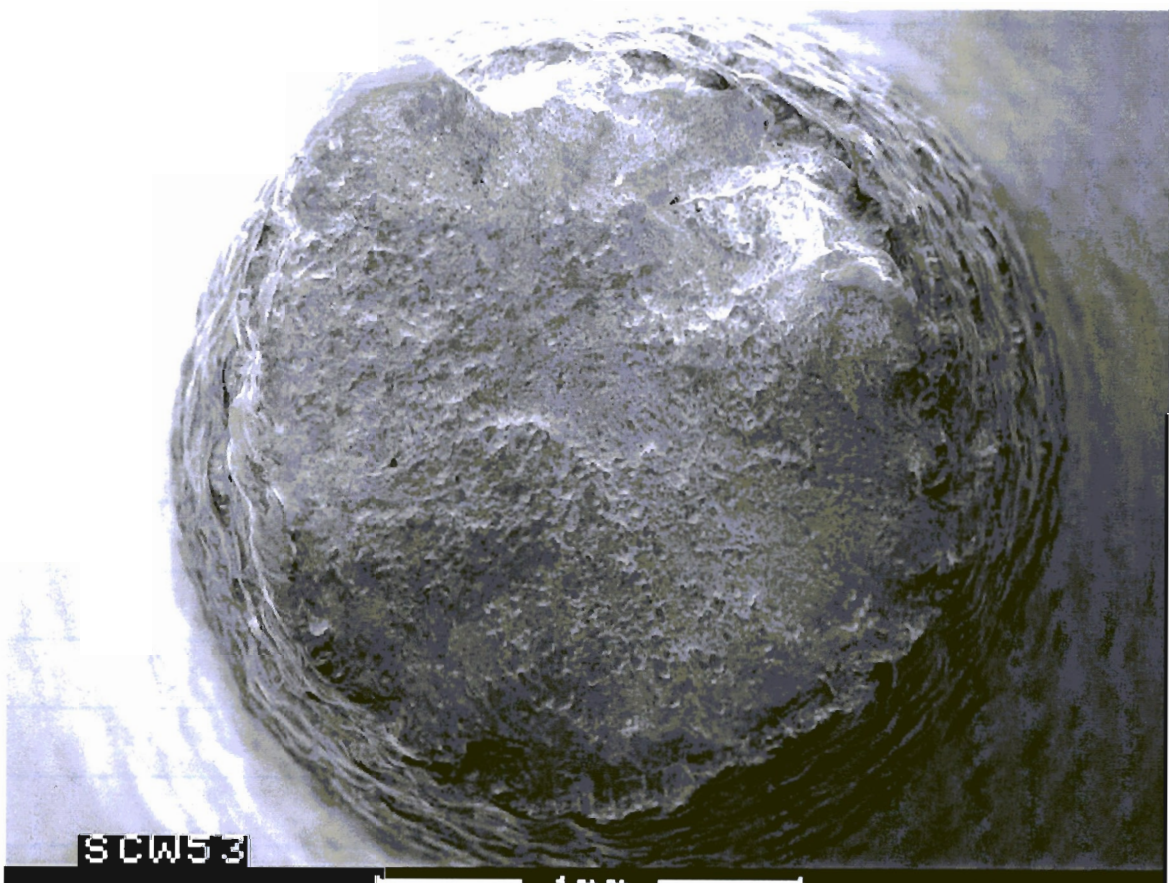
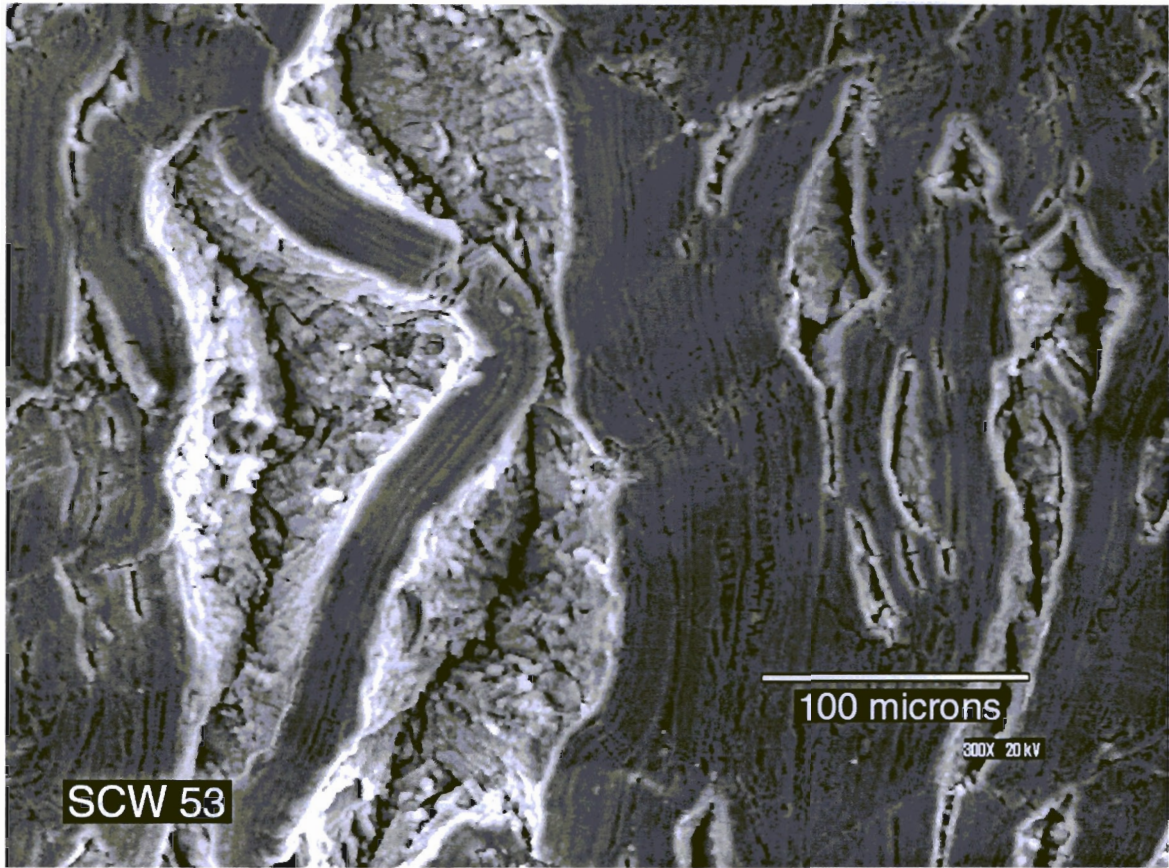


*K. J. Ching 9/8/05*

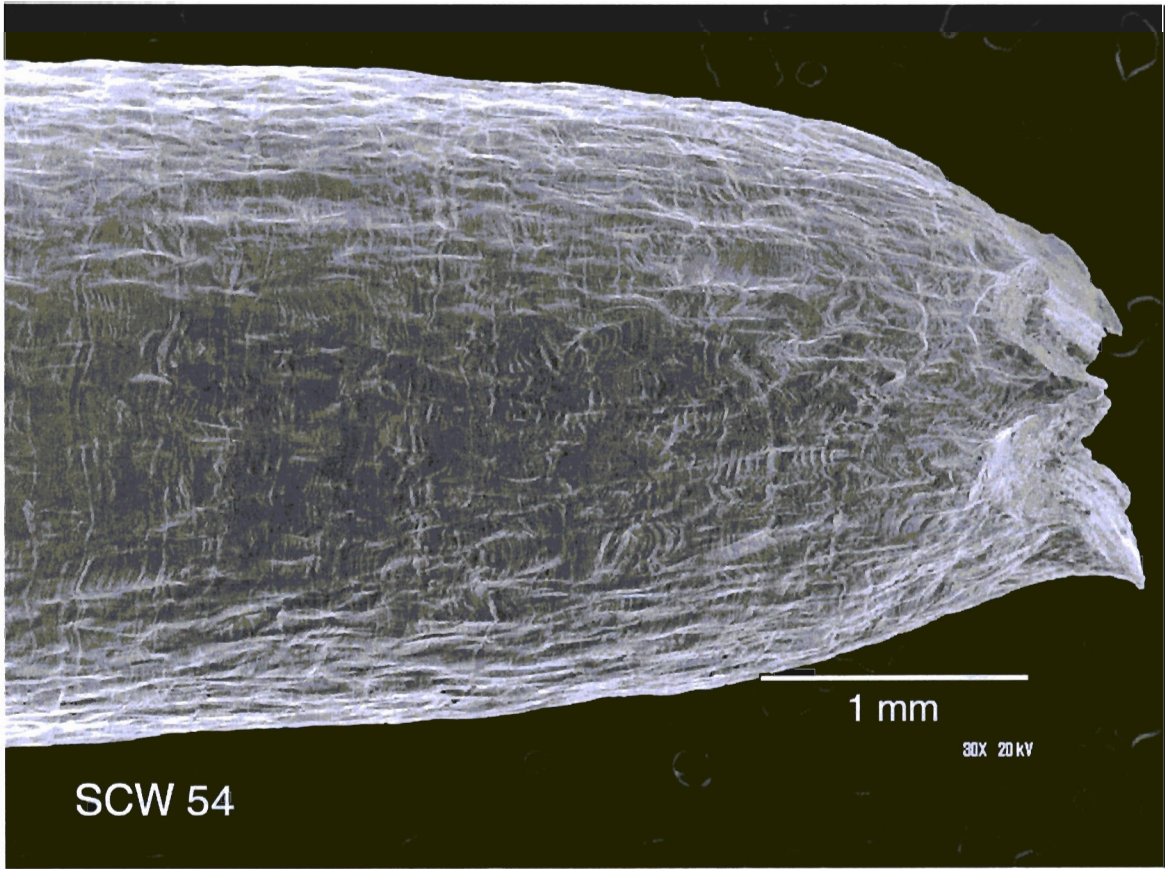


↓ 55°C  
shallow

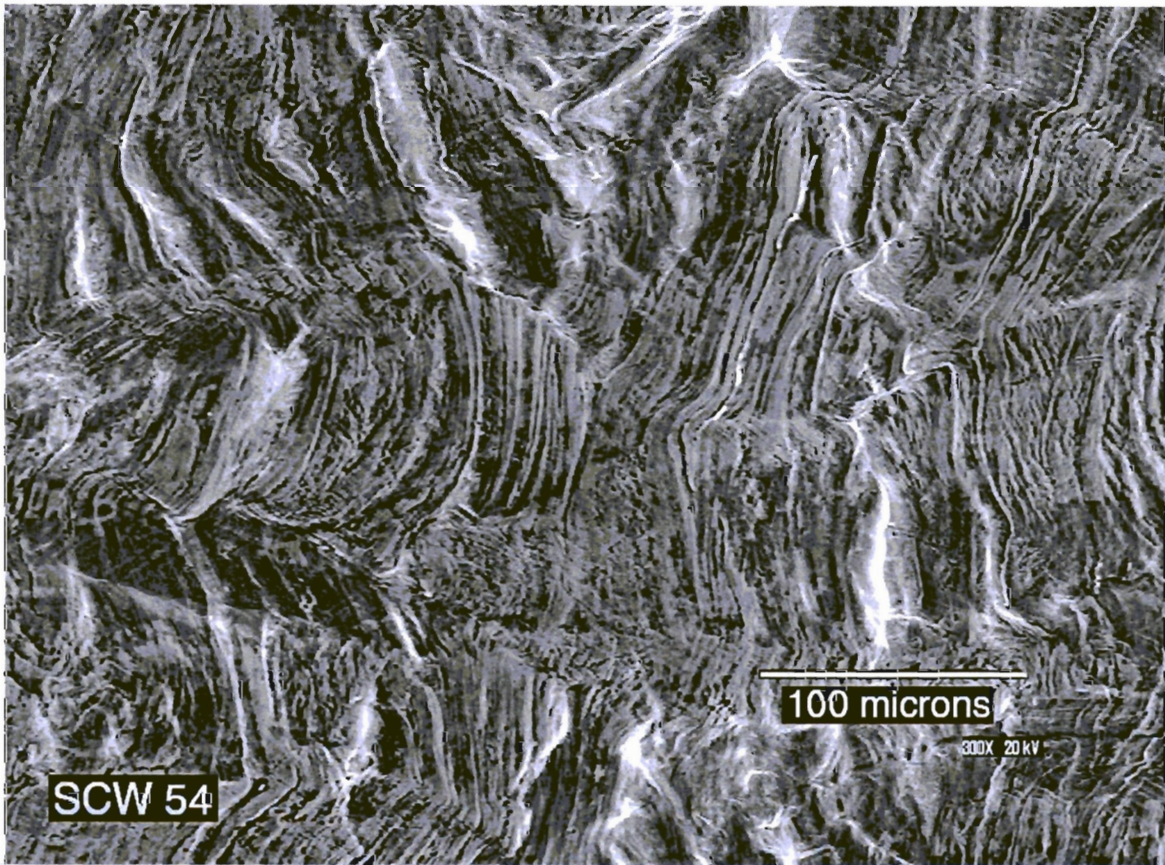
K. J. Chirif 9/8/05



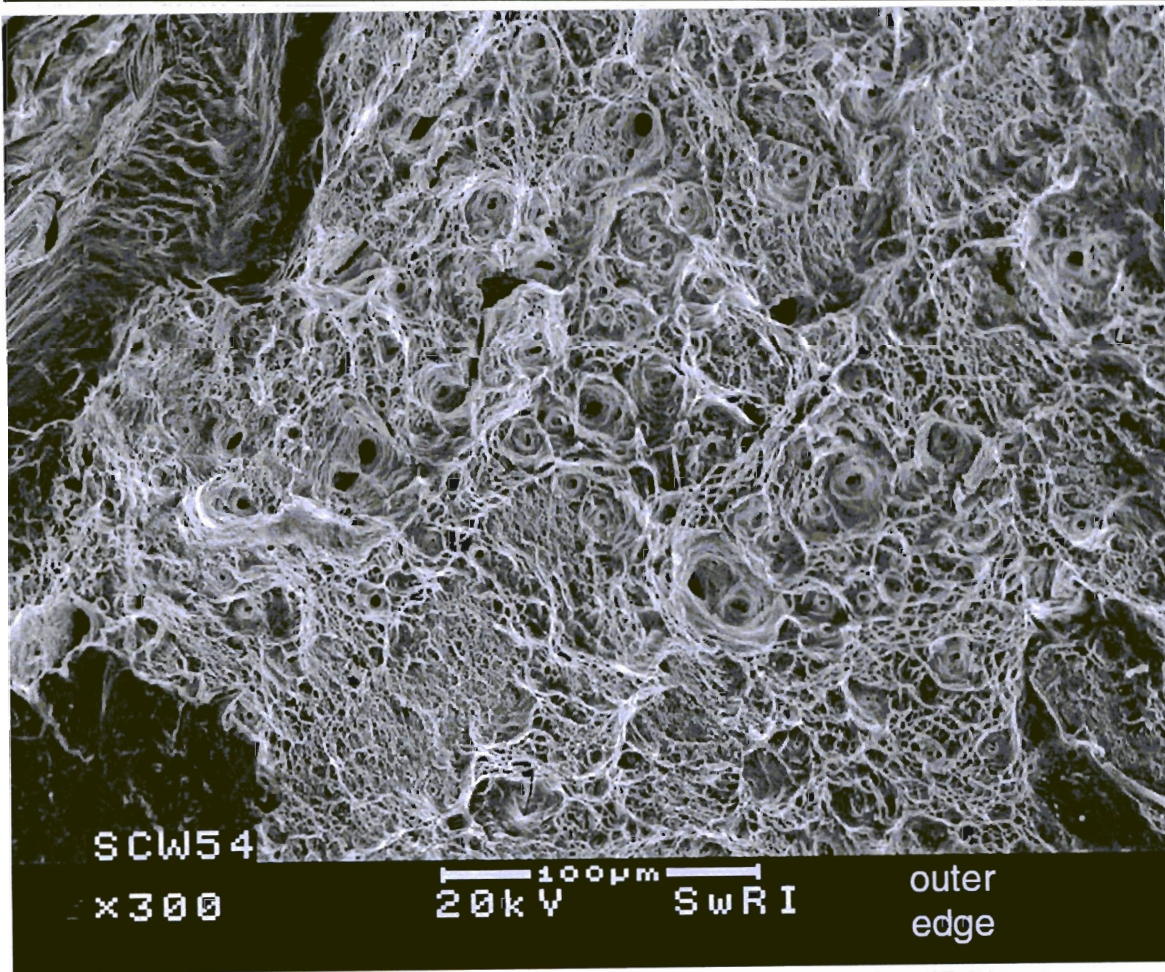
K. J. Chiang 9/8/05



25°C  
No SCC



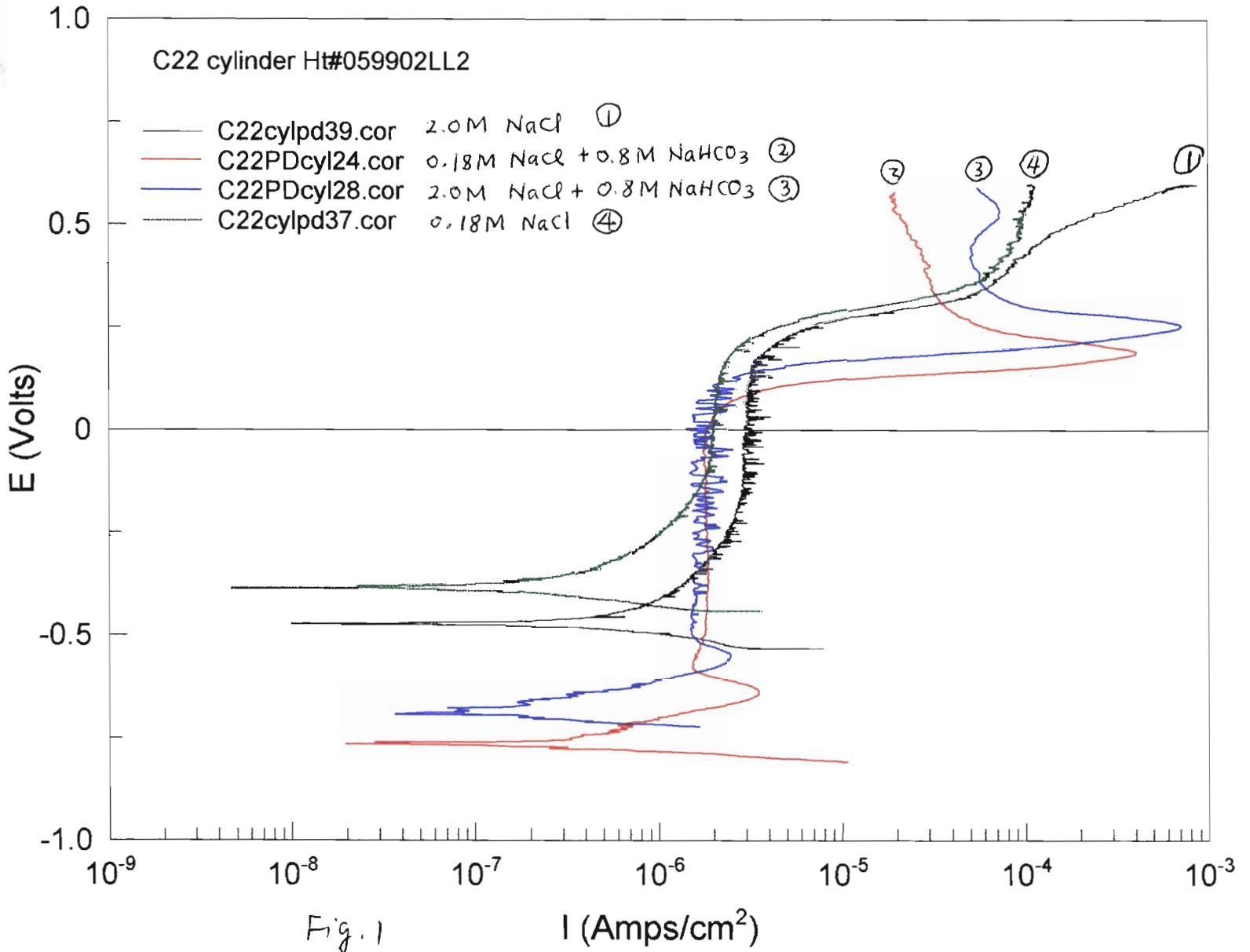
K. J. Ching  
a18105



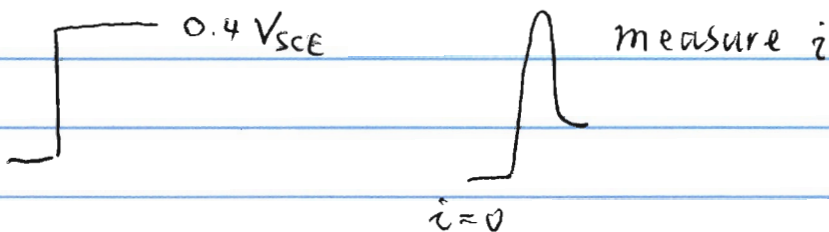
K. J. Chung  
9/8/05



Potentiodynamic Tests Ref. Notebook #713 p. 51



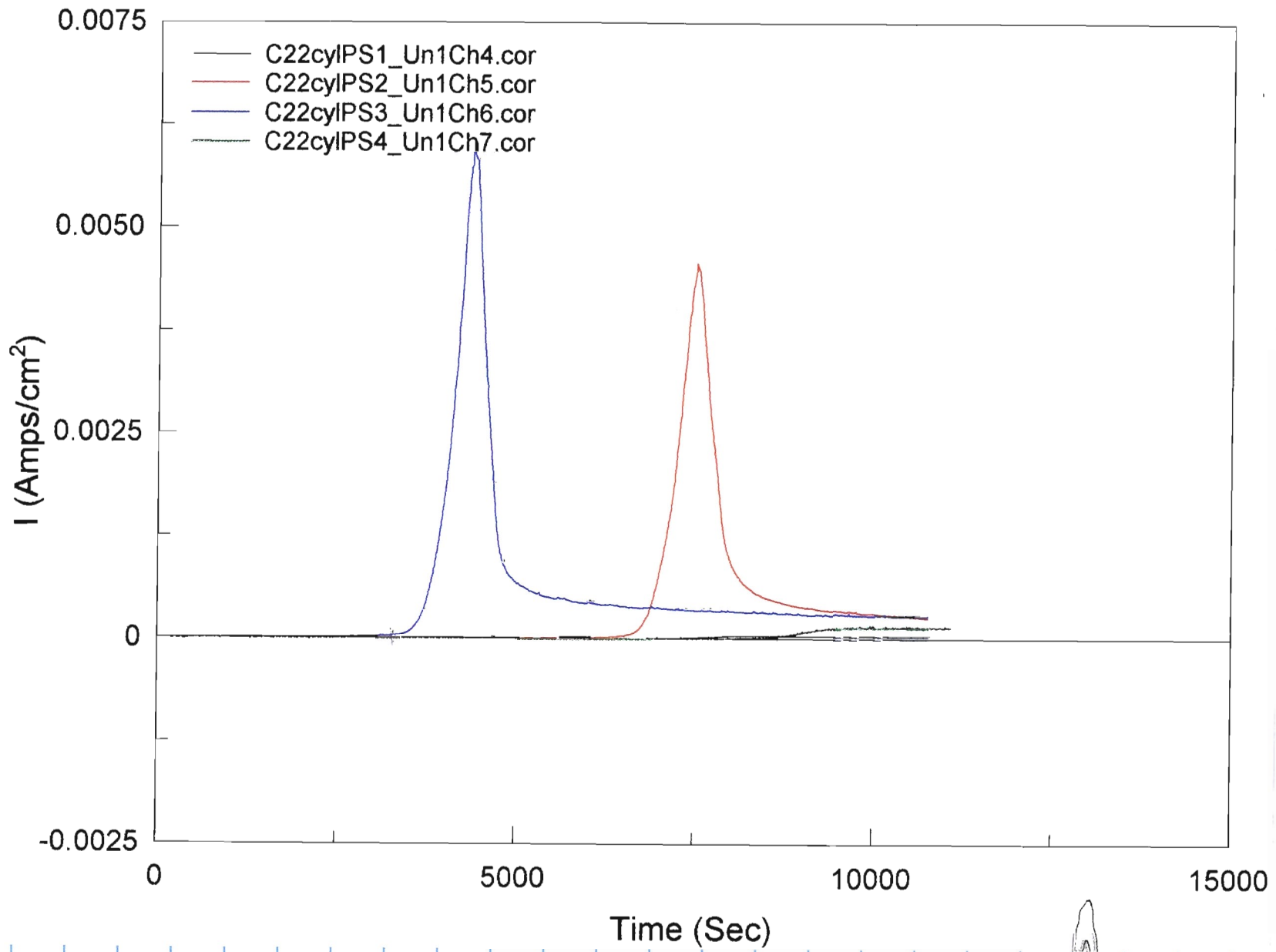
Conduct 4 potentiostatic tests at 0.4 V<sub>sce</sub> in solutions of Fig. 1



Potentiostatic test results see Notebook #713 pages 58-65

R. T. Ching a/8/05

From Notebook 713 page 65

R. T. Chien  
9/8/05