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Scientific Notebook No. 149: Fracture Mechanics Wedge Open Loading Stress Corrosion Cracking Tests (02/21/1997 through 09/19/2000)

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INITIAL ENTRY FOR FRACTURE MECHANICS TESTS

The purpose of this series of experiments was to determine whether a potential below repassivation potential will lead to stress corrosion cracking (SCC) arrest. These tests are envisaged to complement the smooth sample tests (U-bend) in that the focus is on crack growth.

Modified wedge opening loading (WOL) specimens were used.

Initial Scientific notebook entry for Fracture Mechanics Wedge Open Loading Stress corrosion cracking tests.

Title: FM316L(#).

Tests Preformed by: Darrell S. Dunn and Gustavo A. Cragnolino.

Objectives: Determine the propagation rate for stress corrosion cracking of 316L SS as a function of applied potential in chloride containing environments.

Equipment: ESC multichannel potentiostat Serial Number 9209138. Strawberry tree data acquisition boards (16 channel, 16 bit A/D and 8 channel, 12 bit D/A) and workbench data acquisition software. IBM 486 computer. Teflon/glass reaction vessels or vessel meeting the requirements of TOP-008, Ultrasonic inspection unit with transducer mounted on crack length measurement caliper.

Materials: 316L Heat # P80746.

Specimen specifications: As shown in CNWRA-149 page 72-74

Measurement Parameters: Potentials verses saturated calomel electrode, current, crack length

Required level of accuracy: Potentials: $\pm$ 5mV; Current: 1.0×10^{-6} A: Crack length: 0.001" (0.025 mm)

Uncertainty and Sources of Error: Specimens only partially immersed during testing. Actual current density of corroding areas is not determined.

2/21/97

Procedure for conducting fracture mechanics wedge open loading stress corrosion cracking tests

1. Specimens machined by Metal samples (Munford, AL) according to specifications shown on pages 72-74.

2. Specimens were fatigued using a cyclic tensile load in order to initiate a sharp precrack. Precrack length was than measured and recorded.

3. Specimens were then loaded using loading wedges. Deflection of specimen or crack opening was monitored with clip gage attached to specimen.

4. Loaded specimens will be placed in test cells and immersed in solution. Potential of specimens will be monitored. Tests conducted at applied potentials will use Ti plated as counter electrodes. Potential and current data will be saved to disc as ASCII data files.

5. Specimens will be periodically removed from test cells in order to measure crack length. Crack length will by measured using both ultrasonic and microscopic inspection methods as described below:

Ultrasonic inspection. Specimen will be placed in measuring jig and secured in order to prevent movement of the specimen. A water based ultrasonic coupling agent will be applied to the edge of the specimen parallel to the orientation of the crack. The ultrasonic transducer, which is attached to a vernier caliper, will be held on the specimen by means of a spring. The transducer will be moved along the surface in order to find the location of the end of the crack. Crack length will be reported as the distance from the crack tip to the center of the loading bore (0.505" diameter).

Microscopic inspection Specimens will be placed either under a stereomicroscope or on an inverted metallurgical microscope and observed. A small scribed line may be used to note the location of the crack tip after each testing period. This method will provide information on whether the crack tip has advanced, however precise measurement of the crack length may not be possible using this method.

6. At the conclusion of the tests, specimens may be opened by applying a tensile load until the specimen breaks. The propagation of the crack over the course of the exposure will then be observed.

2/21/97

FM316L1.DAT

OBTAINING MEASURE CRACK GROWTH RATE AS A FUNCTION OF Cl^- LOAD & TEMPERATURE ON 316L

SPECIMEN 316L P80746 MACHINED BY METAL SAMPLES # 316L #2

LOAD 30 KSI $\sqrt{in}$
INITIAL CRACK LENGTH (ULTRASOUND)
INITIAL CRACK LENGTH (VISUAL)

SOLUTION 1000 ppm Cl^- AS NaCl
3.29813 g NaCl LOT 941616 +
0.41 ml 0.05 g/mL HCl LOT 945500
pH = 4.0 T = 95°C Hg THERMOMETER 183301

REFERENCE SCE FISHER 13-620-51 SN 9214080
COUNTER ELECTRODE Ti PLATES

POTENTIOSTAT ESC 440 #2 CHANNEL #5
DATA SAVED AS FM316L1.DAT

E_{CORR} -179 mV
E_{Ti} -294 mV RESISTOR 614
$E_{APPLIED}$ -150 mV_{SCE}

TEST STARTED 10:30 AM 6/8/95
TEST STOPPED ~~FOR~~ 6/9/95 FOR CRACK GROWTH 6/9/95
t = 87,800 sec
TEST RESTARTED 3:05 pm 6/9/95 t=0
DATA FILE FM316L1B.DAT
E_{CORR} AT RESTART -150 mV_{SCE} ~~DD~~ 6/12/95 WD 6/12/95
TEST STOPPED 3:10 pm 6/12/95 ~~t=6~~ ~~t=25976~~
t = 259700 s
pH AT END 7.983 MANY SMALL PITS ON SPECIMEN
6/12/95

Fm 316L2.DAT

OBJECTIVE SAME AS Fm 316L1.DAT p 9

SPECIMEN 316L P80746 MACHINED BY
METAL SAMPLES # 316L #7

LOAD 50 KSI $\sqrt{IN}$
INITIAL CRACK LENGTH (ULTRASOUND)
INITIAL CRACK LENGTH (VISUAL)

SOLUTION 1000 ppm Cl^- AS NaCl
3.30019 g NaCl LOT 941616
+0.41 mL OF 0.05 g/mL HCl LOT 945500
pH = 4.0 T=95°C Hg THERMOMETER 115749

REFERENCE SCE FISHER 13-620-51 SN 3106321
COUNTER ELECTRODE Ti PLATES

POTENTIOSTAT ESC 440 #2 CHANNEL #6
DATA SAVED AS Fm 316L2.DAT

E_{CORR} ~~-219mV~~ DD 6/8/95 -127mV
E_{Ti} -219mV
$E_{APPLIED}$ -120mV SCE

TEST STARTED 10:30 AM 6/8/95
TEST STOPPED 6/9/95 t = 87000 SEC FOR
CRACK GROWTH MEASUREMENT
TEST RESTARTED 3:05 pm 6/9/95 t=0
DATA FILE Fm 316L2B.DAT
E_{CORR} AT RESTART -145mV SCE
TEST STOPPED 3:10 pm t = 259700 s
END pH 7.542

6/12/95

Fm 316L3.DAT

OBJECTIVE SAME AS Fm 316L1.DAT

SPECIMEN 316L P80746 MACHINED BY
METAL SAMPLES # 316L 14

LOAD 30 KSI $\sqrt{IN}$
INITIAL CRACK LENGTH (ULTRASOUND)
INITIAL CRACK LENGTH (VISUAL)

SOLUTION 1000 ppm Cl^- AS NaCl
3.29183 g NaCl LOT 941616
+0.41 mL of 0.05 g/mL HCl LOT 945500
pH = 4.0 T=95°C Hg THERMOMETER 183301

REFERENCE SCE FISHER 13-620-51 SN 9214080
COUNTER ELECTRODE Ti PLATES

POTENTIOSTAT ESC 440 #2
DATA SAVED AS Fm 316L3.DAT

E_{CORR} -155mV
E_{Ti} -294mV
$E_{APPLIED}$ O.C. POTENTIAL MONITORED W/KEITHLEY 614
SN 467374
TEST STARTED 10:30 AM 6/8/95
TEST STOPPED FOR CRACK GROWTH MEASUREMENT
ON 6/9/95 t = 87000 SEC
TEST RESTARTED 3:05 pm 6/9/95 t=0
DATA FILE Fm 316L3B.DAT
E_{CORR} AT RESTART -155mV SCE
TEST STOPPED 3:10 pm 6/12/95 t = 659700 s
END pH ~~6.588~~ DD 6/12/95 7.983

6/12/95

Fm 316L 4.DAT

OBJECTIVE SAME AS Fm 316L 4.PAT

SPECIMEN 316L P80746 MACHINED BY METAL SAMPLES # 316L #4

LOAD 50 KSI $\sqrt{IN}$
INITIAL CRACK LENGTH (ULTRASOUND)
INITIAL CRACK LENGTH (VISUAL)

SOLUTION 1000 PPM Cl^- AS NaCl
3.30019 g NaCl LOT 941616 +
0.41 mL OF 0.05 g/mL HCl LOT 945500
pH = 4.0 T = 95°C H_2 INGERMOMETER 115749

REFERENCE SCE FISHER 13-620-51 SN 3106321
COUNTERELECTRODE Ti PLATES

POTENTIOSTAT ESC 440 #2 ~~CH~~ DO 6/8/95
DATA SAVED AS Fm 316L 4.DAT

E_{CORR} -97 mV
E_{Ti} -219 mV
$E_{APPLIED}$ O.C. POTENTIAL MONITORED W/ KEITHLEY
MODEL 617 SN 579628
TEST STARTED 10:30 AM 6/8/95
TEST STOPPED 6/9/95 t = 87000 SECONDS FOR.
CRACK GROWTH MEASUREMENT
TEST RESTARTED 3:05 pm 6/9/95 t = 0
DATA FILE Fm 316L 4B.DAT
E_{CORR} AT RESTART -130 mV SCE
TEST STOPPED 3:10 pm 6/12/95 t = 259700 SECONDS

6/12/95

Fm 316L 1 C.DAT

OBJECTIVE SAME AS Fm 316L 1.DAT P 9

SPECIMEN 316L #2 WOL SPECIMEN SAME AS Fm 316L 1.PAT

LOAD 30 KSI $\sqrt{IN}$
SOLUTION 1000 PPM Cl^- AS NaCl LOT 941616
3.29710 g NaCl LOT 941616 + 0.37 mL
0.05 g/mL HCl LOT 945500 + DI WATER TO 2000mL
START pH = 4.00 T = 95°C
REFERENCE FISHER SCE 13-620-51 SN 9214080
COUNTER ELECTRODES Ti PLATES
POTENTIOSTAT ESC 440 #2
DATA SAVED AS Fm 316L 1.DAT

E_{CORR} -64 mV
E_{Ti} -232 mV
$E_{APPLIED}$ -64 mV SCE
TEST STARTED 4:54 PM 6/13/95 t = 0
TEST STOPPED 1:02 pm 6/16/95 t = 245300 SECONDS
END pH 6.1588
VISUAL EXAMINATION AT 60 X SHOWS NO APPARENT CRACK GROWTH SCRIBE MARK PLACED AT END OF FATIGUE CRACK

6/16/95

FM 316L 2C.DAT

OBJECTIVE SAME AS FM 316L 1.DAT p 9
SPECIMEN 316L #7 WOL SAME AS FM 316L 2.DAT p 10

LOAD ~~3~~ QW 6/13/95 50 KSI $\sqrt{in}$
SOLUTION 1000 ppm Cl^- AS NaCl 3.30012 g
NaCl LOT 941616 + 0.31 mL OF 0.05 g/mL
NCl LOT 945500 + DI WATER TO 2000mL
START pH = 4.0
REFERENCE SCE FISHER 13-620-51 SN 3106321
POTENTIOSTAT ESC 440 #2 CHANNEL #6
DATA SAVED AS FM 316L 2C.DAT

E_{CORR} -78mV
E_{Ti} -232mV
$E_{APPLIED}$ -78mV
TEST STARTED 4:54 PM 6/13/95 t=0
TEST STOPPED 1:02 PM 6/16/95 t= 245300 SECONDS
END pH 6.386
VISUAL OBSERVATION AT 60x SHOWS NO INDICATION OF CRACK GROWTH SCRIBE MARK PLACED AT END OF PRECRACK

6/16/95

FM 316L 3C.DAT

OBJECTIVE SAME AS FM 316L 3C.DAT
SPECIMEN ~~316L #7~~ QW 6/13/95 WOL SPECIMEN SAME AS FM 316L 3.DAT p 11 SPECIMEN 316L #14

LOAD 30 KSI $\sqrt{in}$
SOLUTION SAME AS FM 316L 1C.DAT p 13
START pH = 4.0
REFERENCE SCE FISHER 13-620-51 SN 9214080

DATA SAVED AS FM 316L 3C.DAT

POTENTIAL MONITORED WITH KEITHLEY 614 SN 467374

E_{CORR} -72mV
E_{Ti} -232mV
$E_{APPLIED}$ O.C.
TEST STARTED 4:54 PM 6/13/95 t=0
TEST STOPPED 1:02 PM 6/16/95 t=245300 SECONDS
END pH 6.588
VISUAL OBSERVATION AT 60x SHOWS NO INDICATION OF CRACK GROWTH. SCRIBE MARK PLACED AT END OF PRECRACK

6/16/95

FM 316L 4C.DAT

OBJECTIVE SAME AS FM 316L 1.DAT p9

SPECIMEN SAME AS FM316L 4.DAT p 12
SPECIMEN 316L #4

LOAD 50 KSI $\sqrt{IN}$
SOLUTION SAME AS FM 316L 2C.DAT p 14
START pH = 4.0

REFERENCE SCE FISHER 13-620-51 SN 3106321
~~POT~~ DD 6/13/95
DATA SAVED AS Fm 316L 4C.DAT

POTENTIAL MONITORED WITH KEITHLEY 617 SN 578628

E_{corr} -55 mV
E_{Ti} -232 mV
$E_{applied}$ 0.C
TEST STARTED 4:54 PM 6/13/95 t=0
TEST STOPPED 6/16/95 1:02 PM t= 245300 SECONDS
END pH 6.386
VISUAL OBSERVATION AT 60X SHOWS NO
INDICATION OF CRACK GROWTH. DD 6/16/95
SCRIBE MARK PLACED AT END OF PRECRACK

6/16/95

FM 316L 5.DAT

OBJECTIVE SAME AS FM 316L 1.DAT p4

SPECIMEN 316L 6

LOAD 20 KSI $\sqrt{IN}$
SOLUTION 9.1 MOLAL LiCl 500 g LiCl LOT 94158FSA
+ 1.3 L DI WATER ADJUSTED TO PH 4
BY ADDITION OF HCl LOT 945500 T=95°C
START pH = 4.0
T=95°C N_2 THERMOMETER 115880
REFERENCE SCE FISHER SN 0169033
DATA SAVED AS FM 316L 9.DAT
CURRENT INCREASED (WRONG SIGN) IN THIS DATA FILE
POTENTIOSTAT GSC 440 #2 CHANNEL #2
E_{CORR} -341 mV
E_{Ti} -343 mV
E_{APP} -405 mV
TEST STARTED 12:03 PM 6/14/95
TEST STOPPED 9:27 AM 6/15/95 t= 77100 SECONDS

TEST RESTARTED IN SAME SOLUTION UNDER
SAME CONDITIONS 6/15/95
DATA FILE FM 316L 5B.DAT
E_{CORR} -344 mV
E_{Ti} -163 mV
$E_{APPLIED}$ 0.C.
TEST STARTED 3:04 PM 6/15/95
TEST STOPPED 11:21 PM 6/17/95 t=202700
END pH 2.226
VISUAL EXAMINATION SHOWED NO CRACK GROWTH
SCRIBE MARK PLACED AT END OF PRECRACK

6/18/95

Fm316L6.DAT

SPECIMEN 316L1 MODIFIED WOL MACHINED BY METAL SAMPLES

OBJECTING SAME AS Fm316L1.DAT

LOAD 20 KSI $\sqrt{in}$
SOLUTION SAME AS Fm316L5.DAT p 17
T-95°C Hg THERMOMETER 115880
START pH = 4.0
REFERENCE SCE FISHER 13-620-51 SN 0169033
DATA SAVED AS Fm316L6.DAT

E_{CORR} -341mV
E_{Pi} -343mV
$E_{APPLIED}$ O.C.
TEST STARTED 6/14/95 12:03pm t=0
TEST STOPPED 9:27 AM 6/15/95 t= 77100 SECONDS

TEST RESTARTED IN SAME SOLUTION UNDER SAME CONDITIONS 6/15/95
DATA FILE Fm316L6B.DAT
E_{CORR} -344 mV
E_{Ti} -163 mV
$E_{APPLIED}$ -400 mV
TEST STARTED 3:04 pm 6/15/95
TEST STOPPED 11:21 pm 6/17/95 t= 202700 SECONDS
END pH 2.226
VISUAL EXAMINATION SHOWED NO CRACK GROWTH
SCRIBE MARK PLACED AT END OF PRECRACK

6/19/95

Fm316L7.DAT

OBJECTING SAME AS Fm316L1.DAT

SPECIMEN 316L9 MODIFIED WOL MACHINED BY METAL SAMPLES

LOAD 30 KSI $\sqrt{in}$
SOLUTION 9.1 MOLAL LiCl 500g LiCl LOT 941585A
+ 1.3 L DI WATER pH ADJUSTED TO 4.0
BY ADDITION OF HCl LOT 945500
T=95°C Hg THERMOMETER 183305
START pH = 4.0
REFERENCE SCE FISHER 13-620-51 SN 3106345
DATA SAVED AS Fm316L7.DAT

POTENTIOSTAT ESC 440 #2 CHANNEL #3

E_{CORR} -355mV
E_{Ti} -353mV
$E_{APPLIED}$ -405mV
TEST STARTED 12:03 pm 6/14/95 t=0
TEST STOPPED 9:27 AM 6/15/95 t= 77100 SECONDS

TEST RESTARTED IN SAME SOLUTION UNDER SAME CONDITIONS 6/15/95
DATA FILE Fm316L7B.DAT
E_{CORR} -348mV
E_{Ti} -100mV
$E_{APPLIED}$ -400mV
TEST STARTED 3:04 pm 6/15/95
TEST STOPPED 11:21 pm 6/17/95 t= 202700 SECONDS
END pH 1.989
VISUAL OBSERVATION SHOWED NO CRACK GROWTH
SCRIBE MARK PLACED AT END OF PRECRACK

6/19/95

FM 316L 8.DAT

OBJECTIVE SAME AS FM316L1.DAT p 9

SPECIMEN 316L 8 MODIFIED WOL MACHINED BY METAL SAMPLES

LOAD ~~20 KSI √IN~~ 30 KSI √IN QD 6/14/95

SOLUTION 9.1 MOLAL LiCl SAME AS FM316L7.DAT p 19
T = 95°C N_2 THERMOMETER 183305
START pH = 4.0

REFERENCE SCE FISHER 13-620-51 SN ~~3106345~~ 3106345 QD 6/14/95

DATA SAVED AS FM 316L 8.DAT

E_{CORR} -353 mV
E_{Ti} -353 mV
$E_{APPLIED}$ O.C.
TEST STARTED 12:03 pm 6/14/95 t=0
TEST STOPPED 9:27 AM 6/15/95 t = 77100 SEC

TEST RESTARTED IN SAME SOLUTION UNDER SAME CONDITIONS 6/15/95
DATA FILE FM316L8B.DAT
E_{CORR} -345 mV
E_{Ti} -100 mV
$E_{APPLIED}$ O.C.
TEST STARTED 3:04 pm 6/15/95
TEST STOPPED 11:21 pm 6/17/95 t = 202700 SECONDS
END pH 1.989
VISUAL OBSERVATION SHOWED NO CRACK GROWTH
SCRIBE MARK PLACED AT END OF PRECRACK

6/19/95

FM316L1D.DAT

OBJECTIVE SAME AS FM 316L1.DAT p9

SPECIMEN 316L #2 MODIFIED WOL
LOAD 30 KSI √IN
SOLUTION 1000 PPM Cr AT pH 4.0 3.29831 g NaCl LOT 941616 0.31 mL 0.05 g/mL NCl LOT 945500 + DI WATER TO 2000 mL pH = 4.0 AT START
QD 6/14/95 ~~REFERENCE~~
REFERENCE SCE FISHER 13-620-51 SN 9214080
REMAINDER OF SETUP SAME AS FM 316L1.DAT p9
T = 95°C N_2 THERMOMETER 183301

E_{CORR} -80 mV
E_{Ti} -31 mV
$E_{APPLIED}$ -80 mV
TEST STARTED 7:23 pm 6/19/95
DATA FILE FM316L1D.DAT
TEST STOPPED 6/23/95 ~~5:23~~ QD 6/23/95 5:23 pm t = 338000 S
END pH 5.820

TEST RESTARTED IN FRESH SOLUTION 7/6/95
3.30102 g NaCl LOT 941616 + 0.34 mL 0.03 g/mL NCl LOT 945500 + DI WATER TO 2000 mL pH = 4.0
DATA FILE FM 316L1E.DAT
E_{CORR} -45 mV REFERENCE 614 SN 467374
E_{Ti} -55 mV
$E_{APPLIED}$ -45 mV
TEST STARTED 7/6/95 3:15 pm
TEST STOPPED 7/27/95 ~~3:~~ QD 7/27/95 4:15 pm
END pH 6.658
RUNTIME 1818011 SECONDS

8/30/95

FM316L2D.DAT

OBJECTIVE SAME AS FM316L1.DAT p9

SPECIMEN 316L #7

LOAD 50 KSI $\sqrt{IN}$

SOLUTION 1000 PPM Cl^- AS NaCl 3.29844 g NaCl
LOT 941616 + 0.37 mL 0.05 g/mL NCl LOT 945500
+ DI WATER TO 2000mL pH = 4.0 AT START
T = 95°C Ng THERMOMETER 115749
REFERENCE FISHER SCE 13-620-51 SN 3106321
REMAINDER OF SETUP SAME AS FM316L2.DAT p 10

E_{CORR} -87 mV
E_{Ti} -109mV
$E_{APPLIED}$ -87 mV
TEST STARTED 7:23 pm 6/14/95
DATA FILE FM316L2D.DAT
TEST STOPPED 6/23/95 5:23pm t= 338,000 s
END pH 6.191

TEST RESTARTED IN FRESH SOLUTION 7/6/95
3.30204 g NaCl LOT 941616 +0.36 mL OF
0.05 g/mL NCL LOT 945500 + DI WATER TO
2000mL pH = 4.0
DATA FILE FM316L2E.DAT
E_{CORR} -75mV REFINED 617
E_{Ti} -148 mV REFINED 617
$E_{APPLIED}$ -70 mV
TEST STARTED. 7/6/95 3:20 pm
TEST STOPPED 7/27/95 4:20 pm
END pH 6.764
t= 1817996 SECONDS

8/30/95

FM316L3D.DAT

OBJECTIVE SAME AS FM316L1.DAT p9

SPECIMEN 316L #14

LOAD 30 KSI $\sqrt{IN}$

SOLUTION SAME AS FM316L1D.DAT p 21
T = 95°C Ng THERMOMETER 183301
REFERENCE FISHER SCE 13-620-51 SN 9214080
E_{CORR} -108mV
E_{Ti} -31 mV
$E_{APPLIED}$ O.C.
TEST STARTED 7:23 pm 6/14/95
DATA FILE FM316L3D.DAT
TEST STOPPED 6/23/95 5:23 pm t= 338,000 s
END pH 5.820

TEST RESTARTED IN FRESH SOLUTION 7/6/95
SOLUTION SAME AS FM316L1E.DAT p 21
DATA FILE FM316L3E.DAT
E_{CORR} -88mV REFINED 614 SN 467374
E_{Ti} -55mV "
$E_{APPLIED}$ O.C.
TEST STARTED 7/6/95 3:15 pm
TEST STOPPED 7/27/95 4:15 pm
END pH 6.658
t= 1817996 SECONDS

8/30/95

FM 316L 4D. DAT

OBJECTIVE SAME AS FM 316L 1, DAT p9

SPECIMEN 316L #4

LOAD 50 KSI $\sqrt{in}$
SOLUTION SAME AS FM 316L 2D. DAT p 22
T = 95°C N_2 THERMOMETER 115749
REFERENCE FISHER 13-620-51 SN 3106321

E_{CORR} -110 mV
E_{TI} -109 mV
$E_{APPLIED}$ O.C.
TEST STARTED 7:23 pm 6/19/95
DATA FILE FM 316L 4D. DAT
TEST STOPPED 6/23/95 5:23 pm t = 338,000 s
END pH 6.191

TEST RESTARTED IN FRESH SOLUTION 7/6/95
SOLUTION SAME AS FM 316L 2E. DAT
DATA FILE FM 316L 4E. DAT
E_{CORR} -75 mV KEITHLEY 617
E_{TI} -175 mV KEITHLEY 617
$E_{APPLIED}$ O.C.
TEST STARTED 7/6/95 3:20 pm
TEST STOPPED 7/27/95 4:20 pm
END pH 6.764
t = 1818283 SECONDS

8/30/95

FM 316L 5C. DAT

OBJECTIVE SAME AS FM 316L 1, DAT p9

SPECIMEN 316L #6

LOAD 20 KSI $\sqrt{in}$
SOLUTION 9.1 MOLAR LiCl LOT 941585A
pH = 4.0 WITH ADDITION OF HCl LOT 945500
500g LiCl + 1.3 L DI WATER
T = 95°C N_2 THERMOMETER 183305
REFERENCE FISHER SCE 13-620-51 SN 0169033
REMAINDER OF SETUP SAME AS FM 316LS. DAT p 17

E_{CORR} -338 mV
E_{TI} -160 mV
$E_{APPLIED}$ -400 mV
TEST STARTED 7:16 Pm 6/19/95
DATA FILE FM 316L 5C. DAT
TEST STOPPED 6/23/95 5:16 pm t = 338,000 s
END pH 6.535
VISUAL OBSERVATION: NO CRACK GROWTH OF FATIGUE PRECRACK MANY PITS SOME WITH CRACK LIKE FEATURES SMALL CRACKS ABOVE SOLUTION VAPOR INTERFACE.

TEST RESTARTED IN FRESH SOLUTION 500g LiCl LOT 941585A + HCl LOT 945500 + 1.3 L DI WATER
pH = 4.0
DATA FILE FM 316L 5D. DAT
E_{CORR} -357 mV
E_{TI} -111 mV
$E_{APPLIED}$ -400 mV
TEST STARTED 7/6/95 3:00 pm
TEST STOPPED 7/13/95 3:00 pm
END pH 1.948
RUNTIME 604,800 SECONDS 7/13/95

Fm 316L 6C.DAT

OBJECTIVE SAME AS Fm 316L 1.DAT p9

SPECIMEN 316L1

LOAD 20 KSI √IN
SOLUTION 9.1 MOLAL LiCl 500g LiCl
LOT 941585A + 1.3 L DI WATER +
HCl LOT 945500 TO START pH = 4.0
T = 95°C Hg THERMOMETER 183305
REFERENCE FISHER SCE 13-620-51 SN 0169033
REMAINDER OF SETUP SAME AS FM 316L 6.DAT p18

E_{CORR} -337 mV
E_{Ti} -160mV
$E_{APPLIED}$ O.C.
TEST STARTED 7:16 PM 6/19/95
DATA FILE Fm 316L 6C.DAT
TEST STOPPED 6/23/95 5:1CPM t = 338,000s
END pH 6.535
VISUAL OBSERVATION BRANCHING OF PRE CRACK
BRANCHES EXTEND ACROSS WIDTH OF NOTCH AND
BEYOND SCRIBE MARK MANY SECONDARY CRACKS
ALL OVER SPECIMEN

TEST RESTARTED IN FRESH SOLUTION 7/6/95
SOLUTION SAME AS FM316L5D.DAT p25
E_{CORR} -343 mV
E_{Ti} -111 mV
$E_{APPLIED}$ O.C.
TEST STARTED 7/6/95 3:00PM
DATA FILE Fm 316L 6D.DAT
TEST STOPPED 7/13/95 3:00PM
END pH 1,918
RUNTIME 604,800 SECONDS

7/13/95

Fm 316L 7C.DAT

OBJECTIVE SAME AS Fm 316L 1.DAT p9

SPECIMEN 316L #9

LOAD 30 KSI √IN
SOLUTION 9.1 MOLAL LiCl 500 g LiCl
LOT 941585A + 1.3 L DI WATER + HCl
LOT 945500 TO pH = 4.0
T = 95°C Hg THERMOMETER 115880
REFERENCE FISHER SCE 13-620-51 SN 3106345
REMAINDER OF SETUP SAME AS FM316L7 p19

E_{CORR} -351 mV
E_{Ti} -136 mV
$E_{APPLIED}$ ~~0~~ DD 6/19/95 -400mV
TEST STARTED 7:16PM 6/19/95
DATA FILE FM 316L 7C.DAT
TEST STOPPED 6/23/95 5:16PM t = 338,000 s
END pH 1.837
VISUAL OBSERVATION NO CRACK GROWTH
SECONDARY CRACKS ABOVE SOLUTION VAPOR
INTERFACE

TEST RESTARTED IN FRESH SOLUTION OF 500g LiCl LOT
941585A + HCl LOT 945500 + 1.3 L DI WATER
pH = 4.0
E_{CORR} -345 mV
E_{Ti} -155mV
$E_{APPLIED}$ -400mV
TEST STARTED 7/6/95 3:00 PM
DATA FILE Fm 316L 7D.DAT
TEST STOPPED 7/13/95 3:00 PM
END pH 2.559
RUNTIME 604,800 SECONDS

7/13/95

FM 316L 8C.DAT

~~8~~ DD 6/18/95

OBJECTIVE SAME AS FM 316L1.DAT p 9

SPECIMEN 316L #8

LOAD ~~20 KSI √IN~~ DD 6/19/95 30 KSI √IN

SOLUTION SAME AS FM 316L 7C.DAT p 27
9.1 MOLAL LiCl AT pH 4.0
T = 95°C Hg THERMOMETER 115880

REFERENCE FISHER SCE 13-620-51 SN 3106345
REMAINDER OF SETUP SAME AS FM 316L8 p 20

E_{CORR} -339 mV
E_{Ti} -136 mV
$E_{APPLIED}$ O.C.
TEST STARTED 7:16 pm 6/19/95
DATA FILE FM 316L 8C.DAT.
TEST STOPPED 6/23/95 5:16 pm t = 338,000 SECONDS
END pH 1.837
VISUAL OBSERVATION BRANCHING CRACKS EXTENDING BEYOND SCRIBE MARK SECONDARY CRACKS ALL OVER SPECIMEN SOME PERPENDICULAR TO FATIGUE PRE CRACK.

TEST RESTARTED IN FRESH SOLUTION 7/6/95
SOLUTION: SAME AS FM 316L 7D.DAT p 27
DATA FILE FM 316L 8D.DAT
E_{CORR} -345 mV
E_{Ti} -155 mV
$E_{APPLIED}$ O.C.
TEST STARTED 7/6/95 3:00 pm
TEST STOPPED 7/13/95 3:00 pm
END pH 2.559
RUNTIME = 604,800 SECONDS

DD 7/13/95

CRACK GROWTH MEASURMENTS FOR 316L 2 (FM 316C1)

MEASURMENTS MADE ULTRASONICALLY UNLESS OTHERWISE NOTED.

CRACK LENGTH ± SDEV (IN)	EXPOSURE TIME (S)	POTENTIAL mV SCE	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASUREMENT DATE
0.601 ± 0.002	~~87,800~~ DD 9/21/04 0	6/27/95 —	—	ORIGINAL MEASUREMENT	6/7/95 BY TOM MASDEN
0.610 ± 0.005	~~259,700~~ DD 9/21/04 87,800	-170 TO -142 mV	-2×10^{-5} TO 7.9×10^{-5}	87,800	6/9/95 DD
0.608 ± 0.004	259,700	-150 mV TO -460 mV	-0.156 TO 0.471	347,500	6/13/95 DD
0.625 ± 0.013	245,300	-104 TO -69 mV	-3×10^{-6} TO 9×10^{-5}	592,800	6/16/95 DD
0.613 ± 0.004	338,000	~~-108~~ DD 6/27 -87 mV	-6×10^{-6} TO 7×10^{-5}	930,800	6/26/95 DD
0.613 ± 0.003	1818011	-45 mV TO -150 mV	1×10^{-5} 3×10^{-4}	2,748,811	7/28/95 DD
0.623 ± 0.005	2420401	-104 TO -203	-4×10^{-6} 2×10^{-4}	~~2 DD 8/29/95~~ 5169212	8/29/95 DD
0.610 ± 0.003	2409601			7,578,813	10/11/95 DD
0.582 ± 0.005	4936000	-160 mV		12,514,813	12/12/95 DD

DD 12/12/95

CRACK GROWTH MEASUREMENT FOR 316L 14 (FM 316L 3)

MEASUREMENTS MADE ULTRASONICALLY UNLESS OTHERWISE NOTED

CRACK LENGTH ± SDEV (IN)	EXPOSURE TIME (S)	POTENTIAL mV SCE	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASURE DATE
0.611 ± 0.008	—	—	—	ORIGINAL MEASUREMENT	6/7/95 DD
0.611 ± 0.006	87,800	O.C. -153 TO -87 mV	—	87,800	6/9/95 DD
0.615 ± 0.005	259,700	O.C. -219 TO -132 mV	—	347,500	6/13/95 DD
0.610 ± 0.005	245,300	O.C. -54 TO -216 mV	—	592,800	6/16/95 DD
0.610 ± 0.003	338,000	O.C. -174 TO -104 mV	—	930,800	6/26/95 DD
0.624 ± 0.002	1817996	O.C. -81 mV TO -175 mV	—	2,748,796	7/28/95 DD
0.614 ± 0.004	2420401	O.C. -80 mV TO -245 mV	—	~~5,169,197~~ 8/29/95 DD 5,169,197	8/28/95 DD
0.605 ± 0.005	2408401	O.C.	—	7,577,598	10/11/95 DD
0.619 ± 0.016	4936000	O.C.	—	12,513,598	12/12/95 DD

DD 12/12/95

CRACK GROWTH MEASUREMENT FOR 316L 7 (FM 316L 2)

MEASUREMENTS MADE ULTRASONICALLY UNLESS OTHERWISE NOTED.

CRACK LENGTH ± SDEV	EXPOSURE TIME (S)	POTENTIAL mV SCE	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASURE DATE
0.614 ± 0.005	—	—	—	ORIGINAL MEASUREMENT	6/7/95 BY TOM MASON
0.625 ± 0.005	87,000	-134 TO -122 mV	-5×10^{-5} TO 4×10^{-5} A	87,000	6/9/95 DD
0.636 ± 0.008	259,700	-176 TO -148 mV	-2×10^{-7} TO 8×10^{-5} A	346,700	6/13/95 DD
0.628 ± 0.021	245,300	-110 TO -78 mV	-7×10^{-7} A TO 1.2×10^{-4} A	592,000	6/16/95 DD
0.623 ± 0.006	338,000	-83 mV	-1.9×10^{-6} TO 1.4×10^{-4} A	930,000	6/26/95 DD
0.612 ± 0.011	1817996	-70 mV TO -140 mV	-2×10^{-6} 3×10^{-4} A	2,747,996	7/28/95 DD
0.607 ± 0.007	2420401	-100 mV TO -200 mV	2×10^{-6} 2×10^{-4}	5,168,397	8/29/95 DD
0.605 ± 0.005	2408401			7,576,798	10/11/95 DD
0.592 ± 0.006	4936000			12,512,798	~~12/18/95~~ DD 12/12/95

DD 12/12/95

CRACK GROWTH MEASUREMENTS FOR 316L4 (Fm316L4)

CRACK MEASUREMENTS MADE ULTRASONICALLY UNLESS OTHERWISE NOTED

CRACK LENGTH ± SDEV (IN)	EXPOSURE TIME (S)	POTENTIAL mVSCE	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASURE DATE
0.608± 0.004	—	—	—	ORIGINAL MEASUREMENT	6/7/95 DD
0.608± 0.010	87,000	O.C. - 126 TO -201 mV	—	87,000	6/9/95 DD
0.623± 0.010	259,700	O.C.	—	346,700	6/13/95 DD
0.612± 0.008	245 300	O.C. -71 TO -191 mV	—	592,000	6/16/95 DD
0.605± 0.002	338,000	O.C. -109 TO -203 mV	—	930,000	6/26/95 DD
0.601± 0.007	1818283	O.C - 62 TO -210	—	2,748,283	7/28/95 DD
0.597± 0.007	2420403	O.C. -110 TO -290	—	5,168,686	8/29/95 DD
0.603± 0.005	2408401			7,577,087	10/11/95 DD
0.588± 0.005	4936000			12,513,087	12/12/95

12/12/95

CRACK GROWTH MEASUREMENTS FOR 316L6 (Fm 316L5)

MEASUREMENTS MADE ULTRASONICALLY UNLESS DD 6/8/95 OTHERWISE NOTED ~~OPEN CIRCUIT 20 RSI VEN~~

CRACK LENGTH ± SDEV (IN)	EXPOSURE TIME (S)	POTENTIAL mVSCE	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASURE DATE
0.602± 0.003	—	—	—	ORIGINAL MEASUREMENT	6/8/95 BY TOM MADSEN
0.610± 0.009	77,100	-405mV	-10^{-3}	77,100	6/15/95 DD
0.611± 0.004	202,700	-405mV	-10^{-3}	279,800	6/19/95 DD
0.615± 0.004	338,000	-405mV TO -566mV	-10^{-3} TO 8×10^{-2}	617,800	6/26/95 DD
0.625 ± 0.002	604,800	-400 TO -600 mV		1,222,600	7/19/95 DD
0.621± 0.003	608400	-400mV	-1×10^{-4} TO -4.5×10^{-4}	1,831,000	7/28/95 DD
0.625± 0.002	1041601	-400mV	-2×10^{-4} TO 3×10^{-5}	2872601	8/28/95 DD
0.692± 0.006	596400	-400 mV		3469001	9/7/95 DD
0.614± 0.008	~~1637~~ 1636725 9/4/04	-400 mV		5,105,726	10/11/95 DD
0.577± 0.003	4933000	-400mV		10,038,726	12/12/95 DD

12/12/95

CRACK GROWTH MEASUREMENT FOR 316L1 (FM 316L6)

MEASUREMENT MADE ULTRASONICALLY UNLESS OTHERWISE NOTED. OPEN CIRCUIT ~~20 F~~ 20 KSI√IN DW 6/14/95

CRACK LENGTH ± SDEV (IN)	EXPOSURE TIME (S)	POTENTIAL mV SCE	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASURE DATE
587 ± 0.007	–		–	ORIGINAL MEASUREMENT	6/8/95 BY TOM MASDEN
0.614 ± 0.002	77,100	-342 TO -392 mV O.C.	–	77,100	6/15/95 DD
0.613 ± 0.005	202,700	O.C. -337 TO -386	–	279,800	6/19/95 DD
0.603 ± 0.007	338,000	O.C. -336 TO -580	–	617,800	6/26/95 DD
0.609 ± 0.003	604800	O.C. -343	–	1,222,600	7/19/95 DD
0.603 ± 0.004	608400	O.C. -337 mV	–	1,831,000	7/28/95 DD
0.611 ± 0.006	1041602	O.C -331 mV TO -338 mV	–	2,872,602	8/28/95 DD
0.628 ± 0.012	596402	OC.	–	3469004	9/7/95 DD
0.605 ± 0.003	1636713	OC	–	5,105,717	10/11/95 DD
SEE NOTE P 55 ← NOT POSSIBLE	4933000			10,038,717	12/12/95 DD

12/12/95

CRACK GROWTH MEASUREMENT FOR 316L9 (FM 316L7) (~~FM 316L8~~) DR 6/27/95

MEASUREMENT MADE ULTRASONICALLY UNLESS OTHERWISE NOTED

CRACK LENGTH ± SDEV (IN)	EXPOSURE TIME (S)	POTENTIAL mV SCE	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASURE DATE.
0.638 ± 0.005	–	–	–	ORIGINAL MEASUREMENT	6/8/95 BY TOM MASDEN
0.632 ± 0.004	77,100	-400 mV	-10^{-3}	77,100	6/15/95 DD
0.644 ± 0.004	202,700	-400 mV	-10^{-3}	279,800	6/19/95 DD
0.638 ± 0.009	338,000	-400 mV	-10^{-3}	617,800	6/26/95 DD
0.637 ± 0.004	604,800	-400 mV	-10^{-3}	1,222,600	7/19/95 DD
0.634 ± 0.004	608,400	-400 mV	-1×10^{-4} -5×10^{-4}	1,831,000	7/28/95 DD
0.632 ± 0.002	1041601	-400 mV	-1×10^{-4} -8×10^{-4}	2,872,600	8/28/95 DD
0.665 ± 0.004	596400	-400 mV		3469000	9/7/95 DD
0.637 ± 0.007	1636736	-400 mV		5,105,736	10/11/95 DD
0.599 ± 0.008	4933000	-400 mV		10,038,736	12/12/95 DD

12/12/95

CRACK GROWTH MEASUREMENTS FOR 316L8 (Fm 316L8)

MEASUREMENTS MADE ULTRASONICALLY UNLESS OTHERWISE NOTED OPEN CIRCUIT 30 KSI$\sqrt{IN}$

CRACK LENGTH ± SAG (IN)	EXPOSURE TIME (S)	POTENTIAL mV$_{SCE}$	CURRENT A	CUMULATIVE EXPOSURE TIME (S)	MEASURE DATE
0.616 ± 0.002	–	–	–	ORIGINAL MEASUREMENT	6/8/95 BY TOM MASON
0.631 ± 0.011	77,100	-335 TO -346 mV O.C.	–	77,100	6/15/95 DD
0.611 ± 0.005	202,700	-336 TO -349 mV O.C.	–	~~202,700~~ DD 6/19/95 279 800	6/19/95 DD
0.642 ± 0.005	338,000	-334 TO -346 mV O.C.	–	~~338,000~~ DD 6/26/95 617,800	6/26/95 DD
0.648 ± 0.005	604,800	-345 mV	–	1,222,600	7/19/95 DD
0.668 ± 0.015	608400	O.C. -335 TO -345	–	1831000	7/28/95 DD
0.654 ± 0.002	1041603	O.C. -345 TO -330	–	2872600	8/28/95 DD
0.643 ± 0.016	596400	O.C.	–	3469000	9/7/95 DD
0.630 ± 0.004	1636748	O.C.	–	5,105,748	10/11/95 DD
NOT POSSIBLE	4933000	O.C.		10,038,748	12/12/95

SEE NOTE p57

Darrell D 12/12/95

Fm 316L 5E, DAT

OBJECTIVE SAME AS Fm 316L1.DAT p9

SPECIMEN 316L #6
LOAD 20 KSI$\sqrt{IN}$
SOLUTION 9.1 MOLAL LiCl FRESH SOLUTION
500g LiCl LOT 941585A + 1.3L DI WATER + HCl LOT 945500 TO pH 4.0
T = 95°C Ng THERMOMETER 183305
REFERENCE FISHER SCE 13-620-51 SN 0165415
REMAINDER OF SETUP SAME AS Fm 316L5.DAT p17
E_{corr} -345 mV KEITHLEY 617 SN 537418
E_{Ti} -155 mV "
$E_{APPLIED}$ -400 mV
TEST STARTED 3:30 pm 7/26/95
TEST STOPPED 4:30 pm 7/27/95
END PN 1.776

TEST RESTARTED 7/31/95 USING FRESH SOLUTION PREPARED USING 500g LiCl LOT 951169A + 1.3L DI WATER, pH ADJUSTED TO pH 4.0 WITH HCl LOT 945500
OBJECTIVE AND SETUP SAME AS ABOVE

E_{corr} -340 mV KEITHLEY 617 SN 537418
E_{Ti} -97 mV KEITHLEY 617 SN 537418
$E_{APPLIED}$ -400 mV
TEST STARTED 7/31/95 3:10 pm
DATA FILE FM 316L 5F, DAT
t = 1041601 SECONDS
TEST STOPPED 8/12/95 3:20 pm

Darrell D 8/30/95

Fm 316L 6E.DAT

OBJECTIVE SAME AS Fm 316L 1.DAT p 9

SPECIMEN 316L #1
LOAD 20 KSI $\sqrt{in}$
SOLUTION 9.1 MOLAL LiCl SAME AS
Fm 316L 5E.DAT p 37
T = 95°C Ng THERMOMETER 183305
REFERENCE FISHER SCE 13-620-51 SN 0165415
REMAINDER OF SETUP SAME AS Fm 316L 6 p 18
E_{corr} -337 mV KEITHLEY 617 SN 537418
E_{Ti} -155mV "
$E_{APPLIED}$ O.C.
TEST STARTED 3:30 pm 7/20/95
NO DATA FILE RECORDED
TEST STOPPED 4:30 pm 7/27/95
END pH 1.776

TEST RESTARTED 7/31/95 USING FRESH SOLUTION
PREPARED USING 500g LiCl LOT 95116 9A
+1.3 L DI WATER ADJUSTED TO pH 4.0
USING HCl LOT 945500
SETUP AND OBJECTIVE SAME AS ABOVE

E_{corr} -340 mV KEITHLEY 617 SN 537418
E_{Ti} -97mV KEITHLEY 617 SN 537418
$E_{APPLIED}$ O.C.
TEST STARTED 7/31/95 3:10 pm
DATA FILE Fm 316L 6F.DAT
t = 1041602 SECONDS
TEST STOPPED 8/12/95 3:20 pm

8/30/95

Fm 316L 7E.DAT

OBJECTIVE SAME AS Fm 316L 1.DAT p 9

SPECIMEN ~~Fm 4D~~ 7/20/95 316L #9
LOAD 30 KSI $\sqrt{in}$

SOLUTION 9.1 MOLAL ~~LiCl~~ 4D 7/20/95 LiCl LOT 9415 85A
500 g ADDED TO 1.3 L DI WATER +
HCl LOT 945500 TO pH 4.0
T = 95°C Ng THERMOMETER 115880
REFERENCE FISHER SCE 13-620-51 SN 3106345
REMAINDER OF SETUP SAME AS Fm 316L 7 p 19
E_{corr} -346 mV KEITHLEY 617 SN 537418
E_{Ti} -218 mV "
$E_{APPLIED}$ -400 mV
TEST STARTED 330 pm 7/20/95
TEST STOPPED 4:30 pm 7/27/95 t = 608400 s
END pH 1.842

TEST RESTARTED 7/31/95 USING FRESH SOLUTION
PREPARED USING 500g LiCl LOT 95116 9A + 1.3 L
DI WATER ADJUSTED TO pH 4.0 USING HCl
LOT 945500
SETUP AND OBJECTIVE SAME AS ABOVE

E_{corr} -343 mV KEITHLEY 617 SN 537418
E_{Ti} -84mV KEITHLEY 617 SN 537418
$E_{APPLIED}$ -400mV
TEST STARTED 7/31/95 3:10 pm
DATA FILE Fm 316L 7F.DAT
TEST STOPPED 8/12/95 3:20 pm
t = 1041601 SECONDS

8/30/95

FM316L8E.DAT

OBJECTIVE SAME AS FM316L1.DAT p 9

SPECIMEN 316L #8
LOAD 30 KSI $\sqrt{IN}$
SOLUTION SAME AS FM316L7E.DAT p 39
T = 95°C Hg THERMOMETER 115880
9.1 MOLAL LiCl
REFERENCE FISHER SCE 13-620-51 SN 3106345
REMAINDER OF SETUP SAME AS FM316L8 p20
E_{CORR} -336mV KEITHLEY 617 SN 537418
E_{Ti} -218 mV "
$E_{APPLIED}$ O.C.
TEST STARTED 3:30 pm 7/20/95
TEST STOPPED 4:30 pm 7/27/95
END pH 1.842

TEST RESTARTED 7/31/95 USING FRESH SOLUTION
9.1 MOLAL LiCl PREPARED USING 500g
LiCl LOT 951169A + 1.3L DI WATER pH=4.0
SETUP AND OBJECTIVE SAME AS ABOVE
E_{CORR} -337mV KEITHLEY 617 SN 537418
E_{Ti} -84mV KEITHLEY 617 SN 537418
$E_{APPLIED}$ O.C.
TEST STARTED 7/31/95 3:10 pm
DATA FILE Fm 316L 8F.DAT
TEST STOPPED 9/27/95

9/27/95

FM 316L 1F.DAT.

OBJECTIVE ~~SAME AS~~ DD 7/31/95 SAME AS Fm316L1.DAT p9

SPECIMEN 316L #2 30 KSI $\sqrt{IN}$
SOLUTION 1000 ppm Cl⁻ AS NaCl 3.30482 g NaCl
LOT 941616 + DI WATER TO 1000 mL pH ADJUSTED
TO 4.0 USING HCl LOT 945500
T = 95°C Hg THERMOMETER 115858
REFERENCE FISHER SCE 13-620-51 SN 9214080
REMAINDER OF SETUP SAME AS p9
E_{CORR} -91 mV KEITHLEY 614 SN 467374
E_{Ti} -52mV KEITHLEY 614 SN 467374
$E_{APPLIED}$ -100 mV TO -200mV
TEST STARTED 7/31/95 3:20 pm
TEST STOPPED 8/29/95 3:20 pm
t = ~~2419200 SECONDS~~ DD 8/29/95 2420401 SECONDS
CURRENT 2×10^{-6} TO 1×10^{-4} A
DATA NOT RECORDED TO DISK AS SEPARATE
FILE. APPENDED TO FM316L1E.DAT

TEST RESTARTED 8/30/95 USING FRESH SOLUTION
1000 ppm Cl⁻ AS NaCl pH 4.0 BY ADDITION
OF HCl 3.30109 g NaCl LOT 941616 + 2000ml DI WATER
SETUP AND OBJECTIVE SAME AS ABOVE
E_{CORR} -197mV
E_{Ti} -191 mV
$E_{APPLIED}$ -190 mV
TEST STARTED 8/30/95 5:20 pm
DATA FILE Fm316L1G.DAT
TEST STOPPED 9/27/95 t = 2409601 s
END pH 7.96

9/27/95

FM 316L 2E.DAT

OBJECTIVE SAME AS FM 316L 1.DAT p9

SPECIMEN 316L #7 50 KSI √in

SOLUTION 1000 PPM Cl^- AS NaCl 3.30007 g NaCl
LOT 941616 + DI WATER TO 1000 mL
PH ADJUSTED TO 4.0 BY ADDITION OF
HCl LOT 945500
T = 95°C N_2 THERMOMETER 115749
REFERENCE FISHER 13-620-51 SN 3106321
REMAINDER OF SETUP SAME AS FM316L2.DAT p10

E_{CORR} -135mV KEITHLEY 614 SN 467374
E_{Ti} -144mV KEITHLEY 614 SN 467374
$E_{APPLIED}$ -130mV
TEST STARTED 7/31/95 3:20 pm
TEST STOPPED 8/29/95 3:20 pm
DATA APPENDED TO FM316L2E.DAT
t = 2420401 SECONDS

TEST RESTARTED 8/30/95 USING FRESH SOLUTION
1000 ppm Cl^- AS NaCl pH 4.0 BY ADDITION OF HCl
3.30217 g NaCl + 2000 mL DI WATER NaCl LOT # 941616
SETUP AND OBJECTIVE: SAME AS ABOVE
E_{CORR} -140 mV
E_{Ti} -129 mV
$E_{APPLIED}$ -140 mV
TEST STARTED 8/30/95 5:20 pm
DATA FILE FM 316L2F.DAT
TEST STOPPED 9/27/95 t = 2408401 s
END pH 7.72

9/27/95

QD 7/31/95

~~FM316L3E.DAT~~ FM 316L 3F.DAT

OBJECTIVE SAME AS FM 316L 1.DAT p9

SPECIMEN 316L #14 30 KSI √in

SOLUTION 1000 ppm Cl^- AS NaCl AT pH 4.0
~~T = 25~~ QD 7/31/95 T = 95°C
SAME AS FM 316L 1F.DAT p41

REFERENCE FISHER SCE 13-620-51 SN 9214080
REMAINDER OF SETUP SAME AS p11

E_{CORR} -33mV KEITHLEY 614 SN 467374
E_{Ti} -52mV KEITHLEY 614 SN 467374
$E_{APPLIED}$ O.C.
TEST STARTED 7/31/95 3:20 pm
TEST STOPPED 8/29/95 3:20 pm
t = 2420401
DATA APPENDED TO FM 316L3E.DAT FILE

TEST RESTARTED 8/30/95 USING FRESH SOLUTION
1000 ppm Cl^- AS NaCl pH 4.0 BY ADDITION OF HCl
3.30109 g NaCl LOT 941616 + DI WATER TO 2000 mL
SETUP AND OBJECTIVE: SAME AS ABOVE
E_{CORR} -162mV
E_{Ti} -191 mV
$E_{APPLIED}$ O.C.
TEST STARTED 8/30/95 5:20 pm
DATA FILE FM 316L3G.DAT
TEST STOPPED 9/27/95 t = 2408401 s
END pH 7.96

9/27/95

WD 7/31/95

~~FM316L4E.DAT~~ FM 316L4F.DAT

OBTECTIVE SAME AS FM316C1.DAT p 9

SPECIMEN 316L #4 50 KSI√IN

SOLUTION 1000 PPM Cl⁻ AS NaCl T=95°C pH=4.0
SAME AS FM316L2F.DAT p 42

REFERENCE FISHER SCE 13-620-51 SN 3106321
REMAINDER OF SETUP SAME AS p4

E_{CORR} -147 mV KEITHLEY 614 SN 467374
E_{Ti} -144 mV KEITHLEY 614 SN 467374
$E_{APPLIED}$ O.C.
TEST STARTED 7/31/95 3:20 pm
TEST STOPPED 8/29/95 3:20 pm
t = 2420401 SECONDS
DATA APPENDED TO FM316L4E.DAT FILE

TEST RESTARTED 8/30/95 USING FRESH SOLUTION
1000 ppm Cl⁻ AS NaCl pH 4.0 BY ADDITION OF HCl
3.30217 g NaCl LOT 941616 + 2000 mL DI WATER
SETUP AND OBTECTIVE: SAME AS ABOVE
E_{CORR} -106 mV
E_{Ti} -129 mV
$E_{APPLIED}$ O.C.
TEST STARTED 8/30/95 ~~5:00~~ WD 8/30/95 5:20 pm
DATA FILE FM316L4G.DAT
TEST STOPPED 9/27/95 t = 2408401
END pH 7.72

FM316L5G.DAT (316L #6 20 KSI√IN -400 mV 9.1M $LiCl$)

OBTECTIVE & SPECIMEN CONTINUED FROM p37
SETUP SAME AS p37
SOLUTION 9.1 MOLAL LiCl MADE USING 500 g
LiCl LOT 951169A + 1.3 L DI WATER pH = 4.0
BY ADDITION OF HCl T=95°C
E_{CORR} -334 mV
E_{Pt} -179 mV
$E_{APPLIED}$ -400 mV
TEST STARTED 8/30/95 5:10 pm
DATA FILE FM316L5G.DAT
TEST STOPPED 9/6/95 2:50 pm t = 596400 s

TEST RESTARTED USING SAME SOLUTION 9/8/95 3:40 pm
E_{CORR} -345 mV
E_{Ti} +117 mV
$E_{APPLIED}$ -400 mV
DATA FILE FM316L5N.DAT
TEST STOPPED 9/27/95 t = 1636725 s
END pH 2.52

9/27/95

FM316L6G.DAT (316L#1 ~~20 KSI√m~~ ~~30 KSI√m~~ DD 8/30/95 O.C. 9.1m LiCl)

OBJECTIVE, SPECIMEN, AND SETUP SAME AS p 38

SOLUTION 9.1 m LiCl pH 4.0 SAME AS p45

E_{CORR} -329mV
E_{Ti} -179mV
$E_{APPLIED}$ O.C.
TEST STARTED 8/30/95 5:10 pm
DATA FILE FM 316L6G.DAT
TEST STOPPED 9/6/95 2:50pm t= 596402s

TEST RESTARTED USING SAME SOLUTION 9/8/95 3:40 pm
E_{CORR} -341mV
E_{Ti} +117mV
$E_{APPLIED}$ O.C.
DATA FILE FM316L6H.DAT
TEST STOPPED 9/27/95 t= 1,636,713 s
END pH 2.52

Dwight D 9/27/95

FM316L7G.DAT (316L #9 30 KSI√m -400mV$_{SCE}$ 9.1m LiCl)

OBJECTIVE SPECIMEN AND SETUP SAME AS p 39
SOLUTION 9.1 m LiCl. 500g LiCl LOT 951169A
+1.3 L DI WATER. pH ADJUSTED TO 4.0
BY ADDITION OF HCl T=95°C
E_{CORR} -346mV
E_{Ti} -252mV
$E_{APPLIED}$ ~~-346 mV~~ DD 8/30/95 -400mV
TEST STARTED 8/30/95 5:10 pm
DATA FILE. FM316L7G.DAT
TEST STOPPED 9/6/95 2:50pm t= 596400 s

TEST RESTARTED USING SAME SOLUTION 9/8/95 3:40pm
E_{CORR} -342mV
E_{Ti} +89 mV
$E_{APPLIED}$ -400mV
DATA FILE ~~FM316L6~~ DD 9/8/95 FM316L7H.DAT
TEST STOPPED 9/27/95 t= 1636736 s
END pH 1.88

Dwight D 9/27/95

FM 316L8G.DAT (316L #8 30 RSEV 0.C. 9.1 m LiCl)

OBJECTIVE SPECIMEN AND SETUP SAME AS p40
SOLUTION 9.1 m LiCl SAME AS p47

E_{corr} -326mV
E_{Ti} -252mV
$E_{APPLIED}$ O.C.
TEST STARTED 8/30/95 5:10 pm
DATA FILE FM 316L8G.DAT
TEST STOPPED 9/6/95 2:50 pm t_2 596400 s

TEST RESTARTED USING FRESH SOLUTION 9/8/95 3:40 Pm
E_{corr} ~334mV
E_{Ti} +87mV
$E_{APPLIED}$ O.C.
DATA FILE FM316L8N.DAT
TEST STOPPED 9/27/95 ~~t=167~~ @ 9/07/95
END pH 1.88 t= 1636748 s

9/27/95

EBSER PLAN

Scientific notebook entry for Engineered Barrier System Experimental Research (EBSER).

EBSER TASKS:

1. Effect of Microorganisms on the Near Field Environment and the Corrosion of Waste Packages.
2. Effect of Waste Packages on the Near-Field Environment.
3. Long-Term Corrosion Tests for Prediction of Waste Package Performance.
4. Long-Term Stability and Embrittlement of Overpack Materials.
5. Stability of Multipurpose Canister Basket Materials.
6. Dissolution and Radionuclide Release From Spent Fuel and Vitrified Waste Form.
7. Reporting.

Tests Preformed by: Darrell S. Dunn, Peter Angell, Gustavo Cragnolino, and Narasi Sridhar.

EBSER Specific Objectives:

1. Develop and understanding of the processes affecting the near-field environment contacting the waste package in order to provide input to models and to confirm model predictions.

2. Address performance issues (corrosion, mechanical properties, radionuclide release rate) relevant to the current DOE ACD phase while retaining the flexibility to the methodologies developed to a variety of materials and design features

3. Conduct waste package experiments to scope and study the key parameters such as critical potentials, and fracture toughness affecting the long-term waste package performance.

4. Assess the adaquacy of the DOE data and methodologies used to support lisense application.

5. Provide information to support modeling activities related to waste package performance for Engineered Barrier Systems and Iterative Performance Assessment programs.

Detailed test objectives identified in initial entries or individual test entries.

TASK: All tests in this notebook form this page on were conducted as part of TASK 3, Long-Term Corrosion Tests for Prediction of Waste Package Performance, unless otherwise identified.

Equipment: Same as in IWPE program. Specific equipment lists provided in test initial entries or in individual test entries.

Materials: Alloy 825 heat HH4371FG, Alloy 825 heat HH8882F, 316L heat P80746. Other materials and heats to be added and identified prior to testing.

12/22/95

FM316L1H.DAT 316L #2 30 KSI√IN ANODIC

OBJECTIVE SAME AS P9

SOLUTION 1000 ppm Cl⁻ AS NaCl AT pH 4.0
3.29621 g NaCl LOT 941616 pH ADJUSTED
TO pH 4.0 BY ADDITION OF HCl LOT 945500
T=95°C Hg THERMOMETER 115749
REFERENCE FISHER 13-620-51 SN 9214080
E_{CORR} -148mV
E_{Ti} -8mV
$E_{APPLIED}$ -160mV
TEST SPECIMEN HAS REGIONS OF LOCALIZED
CORROSION AND CRACKING ABOVE SOLUTION VAPOR
INTERFACE AT START OF TEST

TITANIUM HARDWARE AND WIRE USED TO MAKE
ELECTRICAL CONTACT WITH SPECIMEN

TEST STARTED 10/12/95 12:00 PM
TEST STOPPED 12/8/95 2:00 PM
RUNTIME 4936000 SECONDS
END pH 7.718

12/22/95

FM316L2H.DAT 316L #7 50 KSI√IN ANODIC

OBJECTIVE SAME AS P9

SOLUTION 1000 ppm Cl⁻ AS NaCl pH 4.0
3.29633 g NaCl LOT 941616 pH ADJUSTED
TO 4.0 BY ADDITION OF HCl LOT 945500
T=95°C Hg THERMOMETER 115858
REFERENCE FISHER 13-620-51 SN 3106321
E_{CORR} -100mV
E_{Ti} -40mV
$E_{APPLIED}$ -130mV

TEST SPECIMEN HAS REGIONS OF LOCALIZED CORROSION
AND SCC ABOVE SOLUTION VAPOR INTERFACE
AT START OF TEST

TITANIUM HARDWARE AND WIRE USED TO MAKE
ELECTRICAL CONTACT WITH SPECIMEN

TEST STARTED 10/12/95 12:00PM
TEST STOPPED 12/8/95 2:00PM
RUNTIME 4936000 SECONDS
END pH 7.763

12/22/95

Fm 316L 3H.DAT 316L #14 30 KSI $\sqrt{in}$ O.C.

OBJECTIVE SAME AS p 9

SPECIMEN 316L #14 30 KSI $\sqrt{in}$

SOLUTION 1000 PPM Cl^- AS NaCl AT pH 4.0
T = 95°C
SAME AS FM 316L 1H P50

REFERENCE FISHER 13-620-51 SN 9214080

E_{corr} −92mV
E_{Ti} −8mV
$E_{applied}$ O.C.

TEST SPECIMEN HAS REGIONS OF LOCALIZED CORROSION ABOVE SOLUTION VAPOR INTERFACE

TITANIUM HARDWARE AND WIRE USED TO MAKE ELECTRICAL CONTACT WITH SPECIMEN

TEST STARTED. 10/12/95 12:00 pm
TEST STOPPED 12/8/95 2:00 pm
RUNTIME 4936000 SECONDS
END pH 7.718

12/22/95

Fm 316L 4H.DAT 50 KSI $\sqrt{in}$ O.C. 316L #4

OBJECTIVE SAME AS p 9

SPECIMEN 316L #4 50 KSI $\sqrt{in}$

SOLUTION 1000 PPM Cl^- AS NaCl AT pH 4.0
T = 95°C
SAME SOLUTION AS Fm 316L 2H p 51

REFERENCE FISHER 13-620-51 SN 3106321

E_{corr} −52 mV
E_{Ti} −40 mV
$E_{applied}$ O.C.

TEST SPECIMEN HAS REGIONS OF LOCALIZED CORROSION ABOVE SOLUTION VAPOR INTERFACE

TITANIUM HARDWARE AND WIRE USED TO MAKE ELECTRICAL CONTACT WITH SPECIMEN

TEST STARTED 10/12/95 12:00 pm
TEST STOPPED 12/8/95 2:00 pm
RUNTIME 4936000 SECONDS.
END pH 7.765

12/22/95

FM316L5I.DAT
~~FM316L5H~~ DD 10/12/95 316L #6 20 KSI√IN -400mV LiCl

OBJECTIVE SAME AS p9
SPECIMEN 316L #6 20 KSI√IN

SOLUTION 9.1 MOLAL LiCl AT pH 4.0
500g LiCl + 1.3L DI WATER
pH ADJUSTED TO 4.0 BY ADDITION
OF HCl LOT 945500
T=95°C Hg THERMOMETER 61771

E_{CORR} -326mV
E_{Ti} -51mV
$E_{APPLIED}$ ~~O.C.~~ DD 10/12/95 -400mV

LOCALIZED CORROSION ALREADY PRESENT ON SPECIMEN PRIOR TO START OF TEST ~~PITS~~ NO 10/12/95 BELOW SOLUTION VAPOR INTERFACE ARE MANY PITS ABOVE SOLUTION PITS AND CRACKS

TITANIUM HARDWARE AND WIRE USED TO MAKE ELECTRICAL CONTACT WITH SPECIMEN

REFERENCE FISHER 13-620-57 SN 8291050

TEST STARTED 10/12/95 12:30 pm
TEST STOPPED 12/8/95 2:00 Pm
RUNTIME 4933000 SECONDS
END pH 2.637

12/22/95

FM316L6I.DAT 316L #1 20 KSI√IN O.C. LiCl

OBJECTIVE SAME AS p8

SPECIMEN 316L #1 20 KSI√IN

SOLUTION 9.1 MOLAL LiCl pH 4.0 SAME AS p54

E_{CORR} -325mV
E_{Ti} -51mV
$E_{APPLIED}$ O.C.

LOCALIZED CORROSION ALREADY PRESENT ON SPECIMEN PRIOR TO START OF TEST. PITS AND CRACKS ABOVE AND BELOW SOLUTION VAPOR INTERFACE.

TITANIUM HARDWARE AND WIRE USED TO MAKE ELECTRICAL CONTACT WITH SPECIMEN.

REFERENCE FISHER 13-620-57 SN 8291050

TEST STARTED 10/12/95 ~~10~~ DD 10/12/95 12:30 pm
TEST STOPPED 12/8/95 2:00 pm
RUNTIME 4933000 SECONDS

CRACK LENGTH MEASUREMENT NOT POSSIBLE USING ULTRASONIC TECHNIQUE SURFACE CRACKS IN SPECIMEN ATTENUATED SIGNAL FROM CRACK.
END pH 2.637

12/22/95

Fm 316L 7I.DAT 316L #9 30 KSI√IN -400mV LiCl

OBJECTIVE SAME AS p9

SPECIMEN 316L #9 30 KSI√IN

SOLUTION 9.1 MOLAL LiCl AT pH 4.0
500 g LiCl + 1.3 L DI WATER
pH ADJUSTED TO 4.0 BY ADDITION
OF HCl LOT 945500
~~T = 95°C~~ DD 10/12/95 T = 95°C Hg THERMOMETER 115880

REFERENCE FISHER 13-620-51 SN 0165415

E_{CORR} −312mV
E_{Ti} −94mV
$E_{APPLIED}$ −400mV

LOCALIZED CORROSION (PITS, CRACKS) PRESENT ON SPECIMEN ABOVE SOLUTION VAPOR INTERFACE
BELOW SOLUTION VAPOR INTERFACE NO CRACKS OR PITS

TITANIUM HARDWARE USED TO MAKE ELECTRICAL CONTACT WITH SPECIMEN.

TEST STARTED 10/12/95 12:30 pm
TEST STOPPED 12/8/95 2:00 pm
RUNTIME 4933000 SECONDS
END pH = 2.713

12/22/95

Fm 316L 8I.DAT 316L #8 30 KSI√IN O.C. LiCl

OBJECTIVE SAME AS p9

SPECIMEN 316L #8 30 KSI√IN

SOLUTION 9.1 MOLAL LiCl AT pH 4.0
SAME AS p 56

REFERENCE FISHER 13-620-51 SN 0165415

E_{CORR} −324mV
E_{Ti} −94mV
$E_{APPLIED}$ O.C.

CRACK AND PITS PRESENT ON SPECIMEN ABOVE AND BELOW SOLUTION VAPOR INTERFACE PRIOR TO START OF TEST

TITANIUM HARDWARE AND WIRE USED TO MAKE ELECTRICAL CONTACT WITH SPECIMEN.

TEST STARTED 10/12/95 12:30 pm
TEST STOPPED 12/8/95 2:00 pm
RUNTIME. ~4933000 SECONDS

CRACK LENGTH MEASUREMENT NOT POSSIBLE USING ULTRASONIC TECHNIQUE. SURFACE CRACKS IN SPECIMEN ATTENUATED SIGNAL.
END pH: 2.713

12/22/95

FM316L1I.DAT 316L #2 30 KSI√IN ANODIC

OBJECTIVE SAME AS P9
SPECIMEN 316L #2 30 KSI√IN ANODIC
SOLUTION 1000 PPM Cl^- 10^{-2} M $Na_2S_2O_3$ pH 4.0
NaCl LOT 941616 3.29904 g NaCl
3.16455 g $Na_2S_2O_3$ LOT 923931A
pH TO 4.0 BY ADDITION OF HCl LOT 945500
TOTAL CHLORIDE CONCENTRATION = 1000 ppm VOLUME = 2000 mL
T = 95°C Hg THERMOMETER 115858
REFERENCE FISHER SCE 13-620-51 SN 9214080
COUNTER ELECTRODE ~~C~~ DD 1/5/96 Ti PLATES

Ti HARDWARE USED TO MAKE ELECTRICAL CONTACT BETWEEN SPECIMEN AND POTENTIOSTAT

SPECIMENS AND COUNTER ELECTRODE COMPLETELY IMMERSED IN SOLUTION

POTENTIOSTAT ESC 440 #2 CHANNEL #5

E_{CORR} −227 mV
E_{Ti} −49 mV KEITHLEY 617
$E_{APPLIED}$ −240 mV AT START THEN OPEN CIRCUIT

TEST STARTED 1/5/96 4:15 PM
TEST STOPPED 2/12/96

CRACK LENGTH AT START 0.582 ± 0.005
CRACK LENGTH AT END 0.657 ± 0.015
NO EXTERNAL INDICATION OF CRACK PROPAGATION.
SEE NOTE P 61
SOME NEW PITS OBSERVED ON SPECIMENS

DD 2/21/96

FM316L2I.DAT ~~316L~~ DD 1/5/96 316L #7 50 KSI√IN ANODIC

OBJECTIVE SAME AS P9
SPECIMEN 50 KSI√IN 316L #7 ANODIC
SOLUTION 1000 PPM Cl^- 0.01 M $S_2O_3^{2-}$ pH 4.0
2000 mL SOLUTION MADE AS FOLLOWS.
3.29812 g NaCl LOT 941616
3.16809 g $Na_2S_2O_3$ LOT 923931A
pH ADJUSTED TO 4.0 BY ADDITION OF HCl
LOT 945500 TOTAL CHLORIDE CONCENTRATION = 1000 PPM
T = 95°C Hg THERMOMETER 115749

REFERENCE FISHER SCE 13-620-51 SN 3106321

COUNTER ELECTRODE Ti PLATES

Ti HARDWARE USED TO MAKE ELECTRICAL CONNECTION FROM POTENTIOSTAT TO SPECIMEN

SPECIMENS AND COUNTER ELECTRODE COMPLETELY IMMERSED IN SOLUTION.

POTENTIOSTAT ESC 440 #2 CHANNEL #6

E_{CORR} −225 mV
E_{Ti} −41 mV
$E_{APPLIED}$ −240 mV AT START THEN OPEN CIRCUIT

TEST STARTED 1/5/96 4:15 PM
TEST STOPPED 2/12/96

CRACK LENGTH AT START 0.592 ± 0.006
CRACK LENGTH AT END 0.646 ± 0.005
NO EXTERNAL INDICATION OF CRACK PROPAGATION
SEE NOTE P 61
SOME NEW PITS OBSERVED ON SPECIMENS

DD 2/21/96

FM316L3I.DAT

OBJECTIVE SAME AS P9
SPECIMEN 316L #14 30 KSI √IN
SOLUTION SAME AS P58

REFERENCE FISHER SC6 13-620-51 SN 9214080

SPECIMEN COMPLETELY IMMERSED, Ti HARDWARE USED TO MAKE ELECTRICAL CONTACT TO SPECIMEN
SPECIMEN TESTED AT OPEN CIRCUIT DATA RECORDED MANUALLY AS SHOWN ~~BELOW~~ DD 2/21/96 ON PAGE 63
ECORR AT START -202mV
TEST STARTED 1/5/96 4:15 PM

ERROR LOGGING DATA FILE COMPUTER RE BOOTED AND TEST RESTARTED 1/8/96 8:30 AM NO DATA COLLECTED IN 230,000 s OF EXPOSURE.

TEST STOPPED 2/12/96

CRACK LENGTH AT START 0.619 ± 0.016
CRACK LENGTH AT END 0.645 ± 0.016
NO EXTERNAL INDICATION OF CRACK PROPAGATION.
SEE NOTE p61
SOME NEW PITS OBSERVED ON SPECIMEN

DD 2/21/96

Fm316L4I.DAT

OBJECTIVE SAME AS P9
SPECIMEN 316L #4 50 KSI √IN
SOLUTION SAME AS P 59

REFERENCE FISHER SC6 13-620-51 SN 3106321

SPECIMEN COMPLETELY IMMERSED Ti HARDWARE USED TO MAKE ELECTRICAL CONTACT TO SPECIMEN
SPECIMEN TESTED AT OPEN CIRCUIT DATA RECORDED ~~BELOW~~ DD 2/21/96 ON PAGE 63

ECORR AT START -212mV
TEST STARTED 1/5/96 ~~4~~ DD 1/5/96 4:15 PM

ERROR LOGGING DATA FILE COMPUTER RE BOOTED AND TEST RESTARTED 1/8/96 8:30 AM NO DATA COLLECTED IN 230,000 S OF EXPOSURE.

TEST STOPPED 2/12/96

CRACK LENGTH AT START 0.588 ± 0.005
CRACK LENGTH AT END 0.612 ± 0.005
NOTE: NO EXTERNAL INDICATION OF CRACK PROPAGATION.
ALL SPECIMENS TESTED IN 1000 PPM Cl^- + 0.01 M $S_2O_3^{2-}$
FM 316L 1I, FM 316L 2I, FM 316L 3I, FM 316L 4I
SHOWED NO EXTERNAL INDICATION OF CRACK PROPAGATION AS OBSERVED USING 70 x MAGNIFICATION. CRACK TIP LOCATION WAS PREVIOUSLY MARKED ON SIDE OF SPECIMEN IN SIDE GROOVE AND NO ADVANCE BEYOND CRACK TIP MARKING WAS OBSERVED. LONGER CRACK TIP MEASUREMENTS AFTER END OF TEST ARE LIKELY TO BE A RESULT OF SLIGHTLY DIFFERENT ALIGNMENT OF ULTRASONIC TRANSDUCER IN CALIPER JIG AS A RESULT OF ASSEMBLY & DISASSEMBLY IN ORDER TO TEST A VARIETY OF SPECIMENS.

DD 2/21/96

SSRTSS73

OBJECTIVE MEASURE CRACK GROWTH RATE

SPECIMEN 316L SS P80746 NOTCHED SOLUTION ANNEALED AT 1050°C FOR 10 min AND WATER QUENCHED

SOLUTION 9.1 MOLAR ~~LiCl~~ DD 2/16/96 LiCl
LOT 954236 PREPARED AS FOLLOWS
500g LiCl + 1.3 L DI WATER. SOLUTION ADJUSTED TO PH 4.0 BY ADDITION OF HCl LOT 956212
TOTAL CHLORIDE CONCENTRATION 9.1 MOLAR
T= 95°C Hg THERMOMETER 9243196
SOLUTION DEAERATED WITH 99.999% N_2

POTENTIOSTAT ~~ESC 440 #3~~ DD 2/16/96 ESC440#3 CHANNEL #1

REFERENCE FISHER SCE 13-620-51 SN 3106340

COUNTER ELECTRODE pt FLAG

E_{CORR} −358 mV
E_{pt} +214 mV
$E_{APPLIED}$ O.C.
TEST STARTED 2/16/96 8:30 AM
STRAINING STOPPED 28731 SECONDS 2/16/96 4:29 pm
LOAD = 624 LBS 0.025 IN ELONGATION
STRAINING RESTARTED 2/26/96 12:34 pm 878700 s
STRAINING STOPPED 888200 SECONDS LOAD = 802 LBS
ELONGATION = 0.033 IN 2/26/96
SPECIMEN FAILED 3/7/96
END pH 3.30

3/7/96

OPEN CIRCUIT POTENTIALS FM316L3I & FM316L4I

t SECONDS	DATE	FM316L3I (316L14)	FM316L4I (316L#4)
34,000	1/8/96	−120 mV	−148 mV
83628	1/9/96	−115	−116
115,600	1/9/96	−113	−114
183,000	1/10/96	−109	−117
256,000	1/11/96	−110	−113
290,000	1/11/96	−108	−108
344,000	1/12/96	−106	−107
467,000	1/13/96	−104	−103
569,120	1/14/96	−104	−101
636,000	1/15/96	−104	−100
723,000	1/16/96	−103	−99
910,600	1/18/96	−104	−94
1207,200	1/22/96	−107	−91
2,191,500	2/2/96	−101	−49
2,535,000	2/2/96	−137	−142
3,043,000	2/12/96	−177	−198.

TEST STOPPED 2/12/96

2/21/96

FM 316L 1J.DAT

OBJECTIVE SAMG #5 P9
SPECIMEN 316L #2 30 KSI√IN ANODIC
SOLUTION 1000 PPM Cl^- 10^{-2} M $S_2O_3^{2-}$ pH 4.0
3.29981 g NaCl LOT 951450
3.16773 g $Na_2S_2O_3$ LOT ~~8777E~~ 2/28/96 923931A
pH ADJUSTED TO 4.0 BY ADDITION OF
NCl LOT 945500 TOTAL CHLORIDE = 1000 PPM
VOLUME = 2000 mL T=95°C Hg THERMOMETER
115858
REFERENCE FISHER SCE 13-620-51 SN 3106345
COUNTER ELECTRODES Ti PLATES

Ti HARD WARE USED TO CONNECT SPECIMENS AND
COUNTER ELECTRODES TO POTENTIOSTAT

SPECIMENS COMPLETELY IMMERSED

POTENTIOSTAT ESC 440 #2 CHANNEL #5

E_{CORR} -121 mV
E_{Ti} -11 mV
$E_{APPLIED}$ -180 mV

TEST STARTED 2/28/96 3:50 PM
TEST STOPPED 4/13/96 2:00 PM
END pH 2.921

NO INDICATION OF CRACK GROWTH FROM
VISUAL OBSERVATION AT 100x

4/10/96

FM 316L 2J.DAT

OBJECTIVE SAMG #5 P9
SPECIMEN 316L #7 30 KSI√IN ANODIC
SOLUTION 1000 PPM Cl^- 10^{-2} M $S_2O_3^{2-}$ pH 4.0
3.29936 g NaCl LOT 951450
3.16623 g $Na_2S_2O_3$ LOT 923931A
pH ADJUSTED TO 4.0 BY ADDITION OF NCl
LOT 945500 TOTAL CHLORIDE CONCENTRATION = 1000 ppm
VOLUME = 2000 mL T=95°C Hg THERMOMETER 115749
REFERENCE FISHER SCE 13-620-51 SN 9214080
COUNTER ELECTRODES Ti PLATES

Ti HARDWARE USED TO CONNECT SPECIMENS AND
COUNTER ELECTRODES TO POTENTIOSTAT

SPECIMENS COMPLETELY IMMERSED

POTENTIOSTAT ESC 440 #2 CHANNEL #6

E_{CORR} -117 mV
E_{Ti} -18 mV
$E_{APPLIED}$ -180 mV

TEST STARTED 2/28/96 3:50 pm
TEST STOPPED 4/13/96 2:00 PM
END pH 3.294

NO OBSERVATION OF CRACK GROWTH FROM
VISUAL OBSERVATION AT 100x

4/10/96

FM 316L 3J.DAT

OBJECTIVE SAME AS P9
SPECIMEN 316L #14 30 KSI$\sqrt{IN}$
SOLUTION 1000 PPM Cl^- 10^{-2} M $S_2O_3^{2-}$ PH 4.0
SAME AS P 64
SPECIMEN SETUP SAME AS PAGE 64 EXCEPT
SPECIMEN NOT CONNECTED TO POTENTIOSTAT

E_{CORR} AT START −128mV
TEST STARTED. 2/28/96 3:50pm
TEST STOPPED 4/3/96 2:00pm t= 3017000 SECONDS
END pH 2.921

NO INDICATION OF CRACK GROWTH FROM
VISUAL OBSERVATION AT 100x

4/10/96

FM 316L 4J.DAT

OBJECTIVE SAME AS P9
SPECIMEN 316L #4 50 KSI$\sqrt{IN}$
SOLUTION 1000 PPM Cl^- + 10^{-2} M $S_2O_3^{2-}$ pH 4.0
SAME AS P 65
SPECIMEN SETUP SAME AS P65 EXCEPT SPECIMEN
NOT CONNECTED TO POTENTIOSTAT.

E_{CORR} AT START −119mV
TEST STARTED. 2/28/96 3:50pm
TEST STOPPED 4/3/96 2:00pm t= 3017000 SECONDS
END pH 3.294

NO INDICATION OF CRACK GROWTH FROM
VISUAL OBSERVATION AT 100x

4/10/96

OPEN CIRCUIT POTENTIALS. FM316L3 & FM316L4

TIME (SECOND)	FM316L3 (316L 14) 30 KSI√IN (mV)	FM316L4 (316L #4) 50 KSI√IN (mV)
80,400	-126	-131
164,300	-125	-132
277,587	-125	-130
574,500	-125	-129
609200	-125	-128
662400	-120	-124
694500	-119	-122
749100	-117	-121
777200	-117	-120
1008500	-115	-117
1031800	-114	-117
1096244	-114	-117
1126590	-113	-116
1201200	-114	-117
1265500	-114	-116
1298000	-112	-115
1357000	-112	-116
1386100	-111	-114
1613000	-105	-109
1648000	-100	-105
1698500	-101	-105
1799300	-96	-101
1816000	-94	-99
1873600	-92	-98
1959000	-91	-97
1990000	-89	-95
2239000	-77	-87
2322000	-77	-82
2401 1431	-164	-80

4/10/96

SSRT 5574

OBJECTIVE MEASURE CRACK GROWTH RATE

SPECIMEN 316L SS P80746 TENSILE 600 GRIT FINISH

SOLUTION 9.1 MOLAL LiCl LOT 954236
SAME AS P62
T = 95°C N_2 THERMOMETER 924396
SOLUTION DEAERATED WITH N_2 99.999%

POTENTIOSTAT ESC 440 #3 CHANNEL #1

REFERENCE FISHER SCE 13-620-51 SN 3106339

COUNTER ELECTRODE PT FOIL

E_{CORR} -342mV
E_{pt} +218mV
$E_{APPLIED}$ O.C.
TEST STARTED. 3/26/96 9:50 AM
INITIAL LOAD 60 LBS
STRAINING STOPPED 3/26/96 10:30 pm t = 45800 s
LOAD = 495 LBS ELONGATION = 0.042"
E_{CORR} = -0.355 V_{SCE}
ON SEVERAL DAYS BUBBLES WERE OBSERVED IN LUGGIN PROBE RESULTING IN LOW VALUE OF CORROSION POTENTIAL BEING RECORDED HOWEVER E_{CORR} WAS MOST LIKELY STABLE AT ABOUT -355mV
STRAINING RESTARTED 4/5/96 1:30 PM t = 877600 SECONDS
LOAD = 406 LBS E_{CORR} = ~~0.0~~ DR 4/5/96 -356mV
EXTENSION = 0.042"
STRAINING STOPPED 4/5/96 5:38 PM t = 892300 s
LOAD = 496 LBS E_{CORR} = -366 mV EXT = 0.056"

SSRTSS74

HEATER FOR SOLUTION TURNED OFF
AT t= 1459000 s 8:10 AM 4/12/96
LOAD= 412 LBS EXT= 0.056" E_{CORR} = -351mV
AT t= 1461000 SECONDS STRAINING RE STARTED
CELL WAS FLUSHED WITH DI WATER 5 TIMES
AND EMPTIED AND OPEN TO AIR

SPECIMEN FAILED: INITIAL CRACKS OPENED
UP AND SOME DUCTILE REGIONS

SPECIMEN CLEANED AND ANALYZED W/SEM

4/15/96

SSRTSS75

OBJECTIVE MEASURE CRACK GROWTH RATE

SPECIMEN TYPE 316L SS NOTCHED HEAT P80746
MACHINED AT METAL SAMPLES

SOLUTION 9.1 MOLAL LiCl LOT 954236
SAME AS PAGE 62
T= 95°C N2 THERMOMETER 9243196
SOLUTION DEAERATED W/N2

POTENTIOSTAT EGC 440 #3 CHANNEL #1

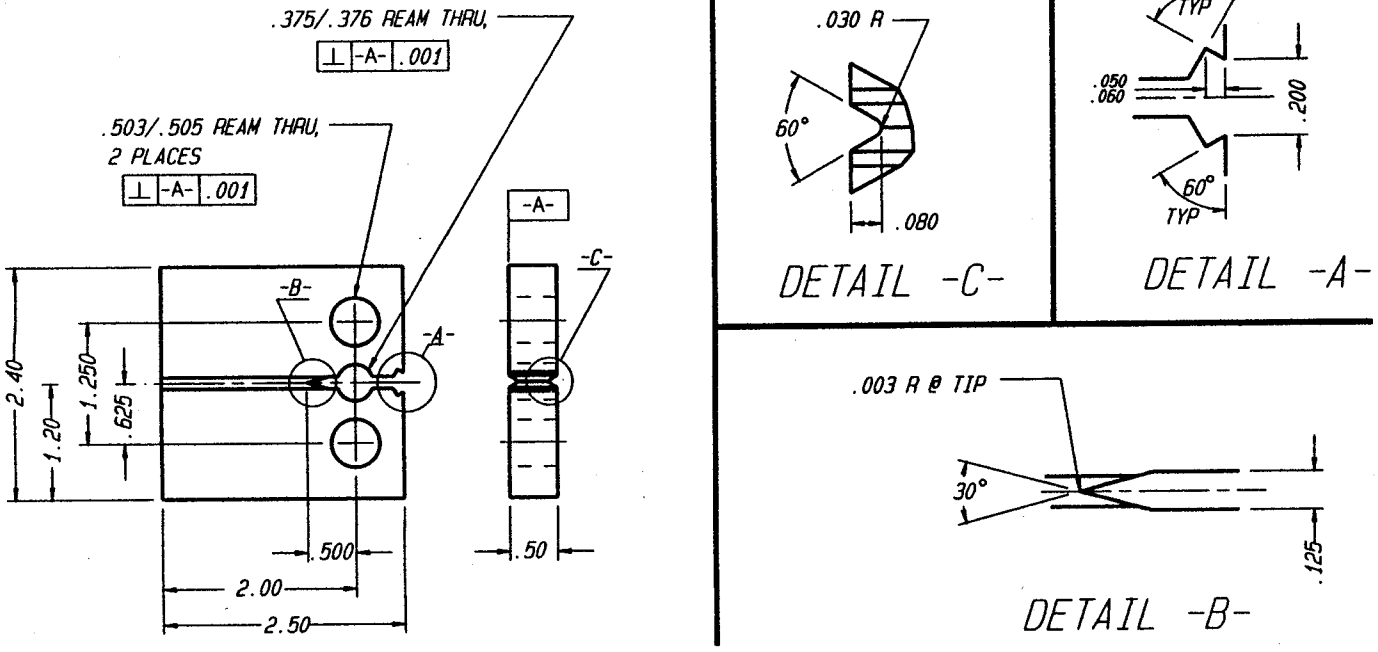
REFERENCE FISHER 13-620-51 SN 3106339

COUNTER ELECTRODE Pt FOIL

E_{CORR} -348mV
E_{pp} +90 mV
TEST STARTED 4/16/96
E APPLIED O.C.
INITIAL LOAD = 35 LBS
STRAINING STOPPED t= 8200 s LOAD = 150.9 LBS
ELONGATION = 0.002" E_{CORR} = -328mV
STRAINING RESTARTED TO LOAD OF 200 LBS AND
ELONGATION OF 0.003" THEN STOPPED
AT t= 2078300 s E_{CORR} = -338mV LOAD = 205 LBS
ELONGATION = 0.003"
APPLIED POTENTIAL OF -325mV AT t= 2078300 s
I = -10^{-6} TO $+10^{-6}$ A

11/15/96

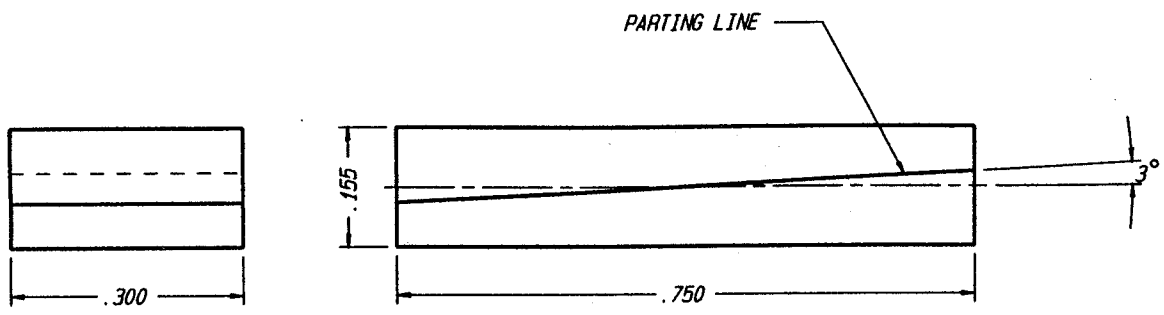
WOL Specimen Dimensions



FIND NO.	QTY REQ.	SIZE	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
					PARTS LIST

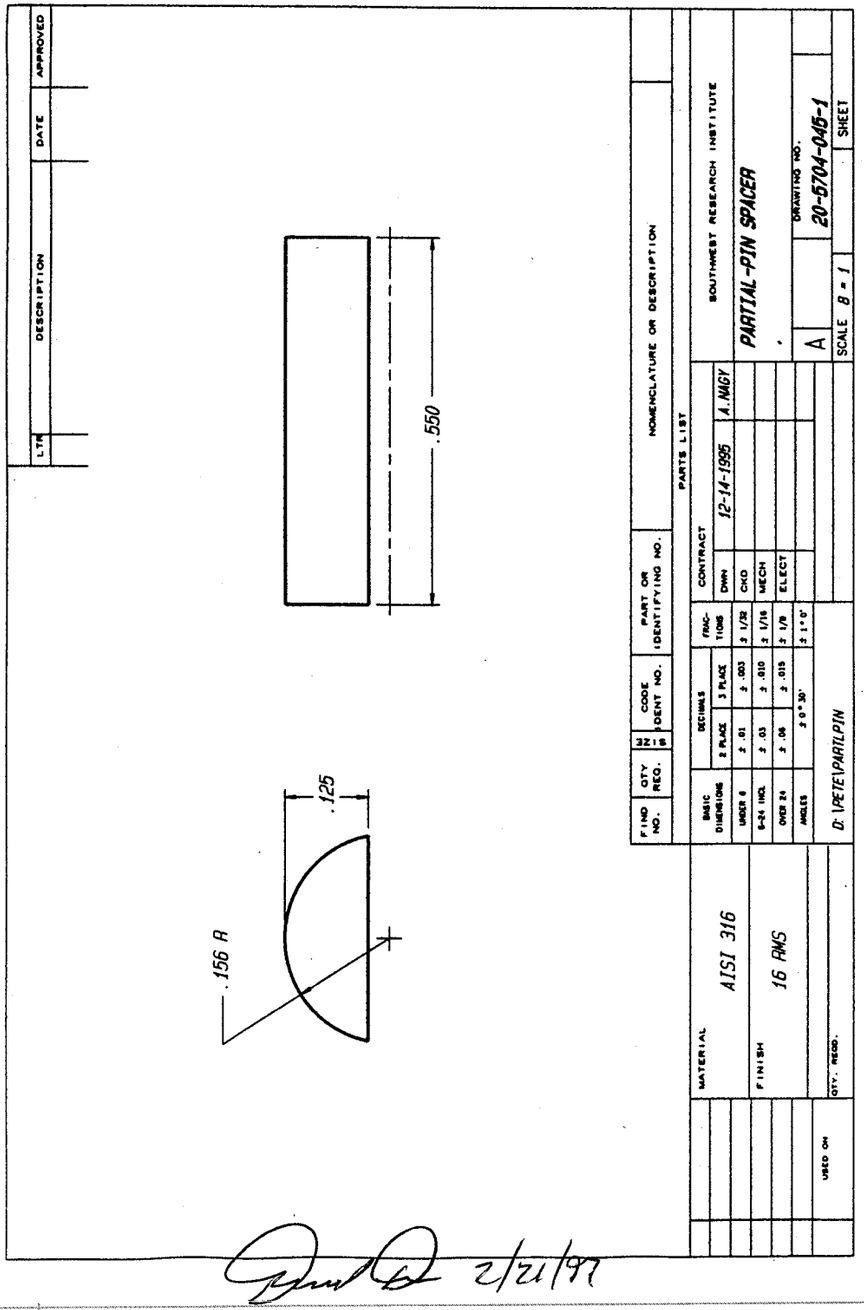
MATERIAL	BASIC DIMENSIONS	DECIMALS 2 PLACE	DECIMALS 3 PLACE	FRACTIONS	CONTRACT			SOUTHWEST RESEARCH INSTITUTE
	UNDER 6	± .01	± .001	± 1/32	DWN	2-7-1995	A.NAGY	1T PLAN C(T) SPECIMEN: W/4 THICK
FINISH ALL SURFACES 16 RMS	6-24 INCL	± .03	± .010	± 1/16	CKD			
	OVER 24	± .06	± .015	± 1/8	MECH			
	ANGLES	± 0° 30'		± 1° 0'	ELECT			DRAWING NO. 06-2795-1
USED ON	QTY. REQD.	D: \SPEC\1TW4SPC						SCALE 1 = 1 SHEET

LTR	DESCRIPTION	DATE	APPROVED



FIND NO.	QTY REQ.	SIZE	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
					PARTS LIST

MATERIAL AISI 316	BASIC DIMENSIONS	DECIMALS 2 PLACE	DECIMALS 3 PLACE	FRACTIONS	CONTRACT			SOUTHWEST RESEARCH INSTITUTE
	UNDER 6	± .01	± .003	± 1/32	DWN	12-14-1995	A.NAGY	LOADING WEDGE
FINISH 16 RMS	6-24 INCL	± .03	± .010	± 1/16	CKD			
	OVER 24	± .06	± .015	± 1/8	MECH			
	ANGLES	± 0° 30'		± 1° 0'	ELECT			A DRAWING NO. 20-5704-045-2
USED ON	QTY. REQD.	D: \PETE\LOADWEDG						SCALE 8 = 1 SHEET



2/21/97

Initial Scientific notebook entry for double cantilever beam stress corrosion cracking tests.

Title: DCB tests

Tests Preformed by: Darrell S. Dunn, Gustavo A. Cragnolino, Yi-Ming Pan.

Objectives: Determine the environmental conditions in which stress corrosion cracking occurs for 316L SS and Alloy C-22.

Equipment: ESC multichannel potentiostat, National Instruments data acquisition system (16 channel, 16 bit A/D, 12 bit D/A) and Labview data acquisition software. Net Force 586 computer. Teflon/glass reaction vessels or vessel meeting the requirements of TOP-008. Additional equipment will be added if needed.

830 4/15/98

Materials: Alloy C-22 Heat # 2277-6-3193 (Metal Samples lot # M~~380~~), Alloy C-22 Heat # 2277-7-3101 (Metal Samples lot # M 924), 316L Heat # P80746

Specimen specifications: DCB specimens Dimensions provided on page 76 - 77

Measurement Parameters: Potentials verses saturated calomel electrode, current density, crack length

Required level of accuracy: Potentials: $\pm$ 5mV, Current density: 1×10^{-7} A/cm^2, Crack length: 0.025 mm.

Uncertainty and Sources of Error: Crack may not propagate in a uniform manner. Crack length will be determined using ASTM standard procedures.

Yi Pan 4/15/98

DCB Specimen Dimensions

The information potentially subject to copyright protection was redacted from pages 76 and 77. The redacted material is proprietary drawings and property of Metal Samples Co. of double cantilever beam stress specimen dimensions.

DCB Specimens Order Statement

April 23, 1998

Mr. Benjamin J. Lackey
Metal Samples Company
P.O. Box 8
152 Metal Samples Road
Munford, AL 36268

Dear Ben:

Thank you for your quotation for preparing double cantilever beam specimens and loading wedges for both Hastelloy C22 and 316L stainless steel. The purchase order will be sent to you shortly.

As we discussed, the 316L SS specimens will be manufactured from the material supplied by SwRI. I am now sending you a 316L SS plate of 12" x 12" x ½" from which the specimens will be cut out. The heat number of this material is P80746. Please notice that the DCB specimens will be machined in such a way that the direction of crack growth is parallel to the direction of grain flow (longitudinal axis). This will also apply to the C22 DCB specimens. You can keep the remaining material at your place for our future purchase inquiry. If you have any questions, please contact Darrell Dunn at (210)522-6090 or myself at (210) 522-5259. Thank you.

Sincerely,

Yi-Ming Pan, Ph.D.
Consultant

Yi-Ming Pan 4/23/98

Alloy C22 Material Specifications

Customer: 01482 SOUTHWEST RESEARCH INSTITUTE
Your PO#:

227753177

Lot No. L380 Mill: HAYNES INTERNATIONAL Our Order Line No. 0
Description: HASTELLOY C22 .5" X 9.5" X 7"
Chemical Properties:

C:0.004	Co:1.500	Cr:21.400	Fe:4.900
Mn:0.150	Mo:13.410	Ni:BALANCE	P:0.010
S:0.007	Si:0.027	V:0.120	W:3.100

Physical Properties:
Tensile-PSI:106,000 (731 MPa) Elong-%:70
Yield-PSI:48,000 (331 MPa) Condition:ANLD
Hardness:HRB 89

2277 63193

Lot No. M830 Mill: HAYNES INT'L Our Order Line No. 0
Description: C22 .500"X12X22.75 1 PC
Chemical Properties:

C:0.003	Co:1.620	Cr:21.790	Fe:4.010
Mn:0.200	Mo:13.420	Ni:BALANCE	P:0.008
S:0.001	Si:0.024	V:0.130	W:2.970

Physical Properties:
Tensile-PSI:108,000 (745 MPa) Elong-%:68.0
Yield-PSI:54,000 (372 MPa) Condition:ANLD
Hardness:RB 90

227773101

Lot No. M926 Mill: HAYNES INT'L Our Order Line No. 0
Description: C22 1.00" x 6.25" x 12.00
Chemical Properties:

C:0.003	Co:0.370	Cr:21.570	Fe:5.170
Mn:0.260	Mo:13.390	Ni:BALANCE	P:0.011
S:0.002	Si:0.023	V:0.160	W:2.900

Physical Properties:
Tensile-PSI:107,000 (738 MPa) Elong-%:67.0
Yield-PSI:51,000 (352 MPa) Condition:ANLD
Hardness:RB 90

We certify that the Material Test Report is correct to the best of our knowledge and that the material supplied meets your required P.O. specifications.

THANK YOU, Quality Control Dept.

Metal Samples

ALABAMA LASER TECHNOLOGIES
"Innovations for laser manufacturing"

ALABAMA RESEARCH AND DEVELOPMENT

Yi-Ming Pan 5/8/98

B-1867-A CERTIFIED REPORT OF TESTS • RAPPORT D'ESSAIS CERTIFIE • WERKSZEUGNIS

HAYNES International

Haynes International, Inc.
1020 West Park Avenue
P.O. Box 9013
Kokomo, Indiana 46902-9013

INVOICE NO. / NO DE FACTURE / RECHNUNGS NR.	S.O. / BON DE SOUDE / B.D.	SUF	DATE ENTERED / DATE DE COMMANDE / BESTELLDATUM	CUSTOMER REFERENCE • REFERENCE CLIENT • KUNDENBESTELLDATEN	REPORT NO. / RAPPORT NO. / ZEUGNIS NR.	PAGE OF PAGES / PAGE DE PAGES / ANZAHL DER SEITEN
164161- 1- 1-0	00	00	960222	25895	960223714	1 1

SOLD TO • CLIENT • BESTELLERANSCHRIFT: 5681450

METAL SAMPLES CO INC
152 METAL SAMPLES RD
NUNFORD AL 36268

SHIP TO • DESTINATAIRE • LIEFERANSCHRIFT: 5681450

METAL SAMPLES COMPANY INC
152 METALS SAMPLES ROAD
NUNFORD AL 36268

PRODUCT DESCRIPTION • DESCRIPTION PRODUIT • MATERIAL BESCHREIBUNG

.5 x 9.5 x 7
HASTELLOY(R) C-22 (TM) ALLOY - PLATE

L380 / 2277-5-3177

SPECIFICATION • SPECIFICATION • SPEZIFIKATION	QUANTITY ORDERED / QUANTITE COMMANDEE / BESTELLMENGE	QUANTITY SHIPPED / QUANTITE EXPEDIEE / LIEFERMENGE
ASTM-B-575-94, ASME-SB-575-95 N06022	1 PC	1 PC

CHEMICAL ANALYSIS • ANALYSE CHIMIQUE • CHEMISCHE ANALYSE

HEAT NUMBER / NUMERO DE COULEE / CHARGE NR.	HEAT CODE	PCS	Al	B	C	Si	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	W	W						Si
2277S3177		1			004		1302140			440	15	1241	BAL	010	007			12	310						027

TENSILE TEST AT ROOM TEMPERATURE • ESSAI DE TRACTION A TEMP. AMBIANTE • ZUGVERSUCH BEI RAUM TEMP.						TENSILE TEST AT ELEVATED TEMPERATURE • ESSAI DE TRACTION A HTE. TEMP. • WARM ZUGVERSUCH						STRESS RUPTURE • ESSAI A CHARGE DE RUPTURE • ZEITSTANDVERSUCH					
YIELD / LIMITE D'ELASTICITE / STRECKGRENZE	ULTIMATE / RESISTANCE A LA RUPTURE / ZUGFESTIGKEIT	ELONG. / ALLONG. / DEHNUNG				YIELD / LIMITE D'ELASTICITE / STRECKGRENZE	ULTIMATE / RESISTANCE A LA RUPTURE / ZUGFESTIGKEIT	ELONG. / ALLONG. / DEHNUNG				TEST / ESSAI / VERSUCH	STRESS / CONTRAINTE / SPANNUNG	HOURS / HEURES / STUNDEN	ELONG. / ALLONG. / DEHNUNG		
PSI		PSI	2IN														
106000		48000	70		ANLD												

ANNEALED / RECUIT / GEGLUHT	AGED / DURCI / GEALTERT	GRAIN SIZE / GROSSEUR DE GRAIN / KORNGROSSE
RB 89		3.0

L380

MAT'L I.D. NO. L380 P.O. NO. 25895
SPEC. N06022 INITIAL MBS
C22

CERTIFIED BY • CERTIFIE PAR • BESCHEINIGT DURCH

James L. Ritledge 02-23-96

5/8/98

B-1867-A CERTIFIED REPORT OF TESTS • RAPPORT D'ESSAIS CERTIFIE • WERKSZEUGNIS

HAYNES International

Haynes International, Inc.
1020 West Park Avenue
P.O. Box 9013
Kokomo, Indiana 46902-9013

INVOICE NO. / NO DE FACTURE / RECHNUNGS NR.	S.O. / BON DE SOUDE / B.D.	SUF	DATE ENTERED / DATE DE COMMANDE / BESTELLDATUM	CUSTOMER REFERENCE • REFERENCE CLIENT • KUNDENBESTELLDATEN	REPORT NO. / RAPPORT NO. / ZEUGNIS NR.	PAGE OF PAGES / PAGE DE PAGES / ANZAHL DER SEITEN
124918- 1- 1-0	00	00	970919	35983	970930757	1 1

SOLD TO • CLIENT • BESTELLERANSCHRIFT: 5681450

ALABAMA SPECIALTY PRODUCTS INC
152 METAL SAMPLES RD
NUNFORD AL 36268

SHIP TO • DESTINATAIRE • LIEFERANSCHRIFT: 5681450

ALABAMA SPECIALTY PRODUCTS, INC.
152 METAL SAMPLES ROAD
NUNFORD AL 36268

PRODUCT DESCRIPTION • DESCRIPTION PRODUIT • MATERIAL BESCHREIBUNG

.5 x 11.8 x 22.75
HASTELLOY(R) C-22 (R) ALLOY - PLATE

M830 / 2277-6-3193

SPECIFICATION • SPECIFICATION • SPEZIFIKATION	QUANTITY ORDERED / QUANTITE COMMANDEE / BESTELLMENGE	QUANTITY SHIPPED / QUANTITE EXPEDIEE / LIEFERMENGE
ASTM-B-575-94, ASME-SB-575-95 N06022	1 PC	1 PC

CHEMICAL ANALYSIS • ANALYSE CHIMIQUE • CHEMISCHE ANALYSE

HEAT NUMBER / NUMERO DE COULEE / CHARGE NR.	HEAT CODE	PCS	Al	B	C	Si	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	V	W						Si
2277G3193		1			003		1623179			401	20	1342	BAL	008	001			13	397						024

TENSILE TEST AT ROOM TEMPERATURE • ESSAI DE TRACTION A TEMP. AMBIANTE • ZUGVERSUCH BEI RAUM TEMP.						TENSILE TEST AT ELEVATED TEMPERATURE • ESSAI DE TRACTION A HTE. TEMP. • WARM ZUGVERSUCH						STRESS RUPTURE • ESSAI A CHARGE DE RUPTURE • ZEITSTANDVERSUCH					
YIELD / LIMITE D'ELASTICITE / STRECKGRENZE	ULTIMATE / RESISTANCE A LA RUPTURE / ZUGFESTIGKEIT	ELONG. / ALLONG. / DEHNUNG				YIELD / LIMITE D'ELASTICITE / STRECKGRENZE	ULTIMATE / RESISTANCE A LA RUPTURE / ZUGFESTIGKEIT	ELONG. / ALLONG. / DEHNUNG				TEST / ESSAI / VERSUCH	STRESS / CONTRAINTE / SPANNUNG	HOURS / HEURES / STUNDEN	ELONG. / ALLONG. / DEHNUNG		
PSI		PSI	2IN														
108000		54000	68		ANLD												

ANNEALED / RECUIT / GEGLUHT	AGED / DURCI / GEALTERT	GRAIN SIZE / GROSSEUR DE GRAIN / KORNGROSSE
RB 90		3.5

MAT'L I.D. NO. M830 P.O. NO. 35983
SPEC. N06022 INITIAL JW

M830

CERTIFIED BY • CERTIFIE PAR • BESCHEINIGT DURCH

09-30-97

5/8/98

CERTIFIED REPORT OF TESTS • RAPPORT D'ESSAIS CERTIFIE • WERKSZEUGNIS

HAYNES International — Haynes International, Inc., 1020 West Park Avenue, P.O. Box 9013, Kokomo, Indiana 46902-9013

Invoice No.	B.O.	Suf.	Date Entered	Customer Reference	Report No.	Page of Pages
26753- 1- 1-0	00	00	971017	36061	971017466	1 1

Sold to: 5681450 LABAMA SPECIALTY PRODUCTS INC, 52 METAL SAMPLES RD, UNFORD AL 36368

Ship to: 5681450 ALABAMA SPECIALTY PRODUCTS, INC., 152 METAL SAMPLES ROAD, MUNFORD AL 36368

Product Description: 1 x 12 x 6 HASTELLOY(R) C-22 (R) ALLOY - PLATE

M924 / 2277-7-3101

Specification: TM-B-575-94, ASME-SB-575-95 N06022

Quantity Ordered: 1 PC — Quantity Shipped: 1 PC

Heat Number	Heat Code	PCS	Al	B	C	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	V	W
2277-9101		1			003	978157			517	261389		BAL	011	002			16	290

Tensile Test at Room Temperature (PSI)	PSI	%DIN	
107000	51000	670	ANLD

Annealed Hardness	Aged Hardness	Grain Size
B 90		3.0

M924

Certified by: James [signature] 10-17-97

M924 N06022 C22 36061

Yj Pan 5/8/98

Alloy C22 Chemical Composition Analysis

FORM FOR REQUESTING WORK FROM OTHER DIVISIONS

A. TO BE COMPLETED BY DIVISION 20 PERSONNEL

Requester: Darrell Dunn / Yiming Pan **Request Date:** June 19, 1998
Project No.: 20-1402-571 **Phone No.:** 6090 5259 (Yiming)
Description of Work Requested: Chemical composition analysis of Hastelloy C-22 materials from Lot # M830 and # M924. Elements to be analyzed include C, Mn, P, S, Si, Ni, Cr, Mo, Fe, W, Co, V. The specimens will be analyzed first using EDS technique at SwRI, and then by Kawin through wet method.

☐ Optical Microscopy ☒ SEM ☐ Hardness ☐ Profilometer ☐ Auger ☒ Other

QUALITY REQUIREMENTS: The work requested is governed by the CNWRA Quality Assurance Program which addresses requirements of 10CFR50, Appendix B. Personnel performing this work shall be qualified under the CNWRA QA program or equivalently under the SwRI Nuclear QA program. Test and analysis methods shall be documented by approved procedures or recognized, standard methods. Measuring and test equipment shall be calibrated and controlled according to CNWRA and SwRI Nuclear QA program requirements.

Sample Identification	Description
① C22-M830	Hastelloy C22 archive material from Lot # M830.
② C22-M924	Hastelloy C22 archive material from Lot # M924.

B. TO BE COMPLETED BY DIVISION PERFORMING WORK[1]

☐ Optical Microscopy ☐ SEM ☐ Hardness ☐ Profilometer ☐ Auger ☐ Other

Person Assigned: HAROLD SALDANA **Signature:** [signature]
Division: 06 **Date:** 6-23-98

Make, Model & Serial No. of Equipment Used (*attach list if necessary*): AMRAY Mod. 1645 T SEM ; Kevex Sigma KS3 EDS

Software Used (If any):

Standards Used (If any):

Photographic Negative Numbers (If Applicable):

[1] Please sign and date any hardcopy of analysis or list of photographs (The photographs themselves need not be signed). If error occurred during entry, do not erase or overwrite, but strikeout with single line, initial and date, and then reenter correct information.

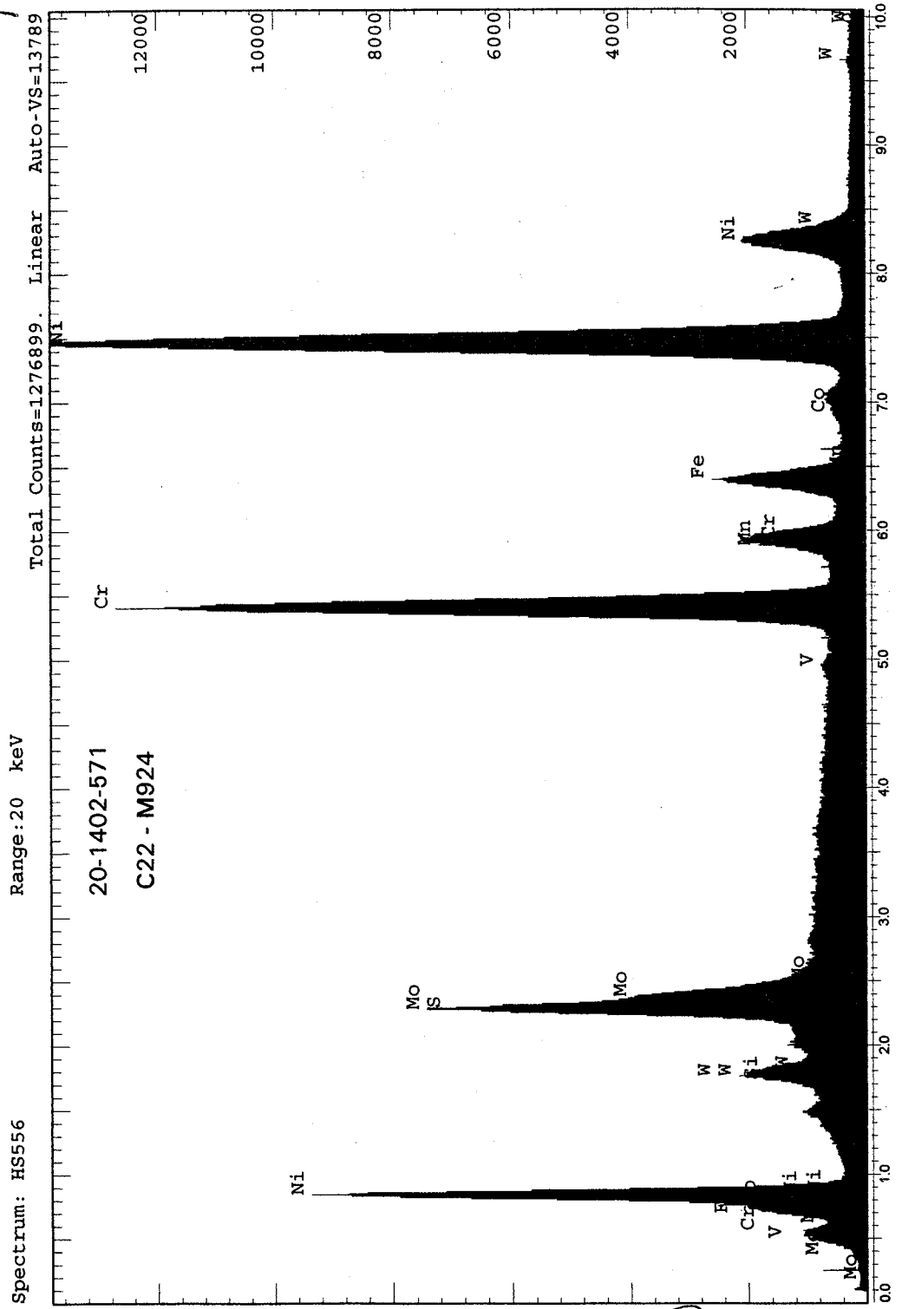
Yj Pan 6/19/98

GENERAL CONDITIONS

Result File	: HS556
File Version	: 1
Background Method	: Fit
Decon Method	: Gaussian
Decon ChiSquared	: 4.29
Analysis Date	: 23-JUN-98
Microscope	: SEM
Comments	: C22 - M924

Element	Line	Weight%	K-Ratio	Cnts/s	Atomic%
Si	Ka	0.00	0.0000	0.00	0.00
P	Ka	0.00	0.0000	0.00	0.00
S	Ka	0.00	0.0000	0.00	0.00
V	Ka	0.22	0.0021	5.55	0.26
Cr	Ka	21.73	0.2235	513.79	25.44
Mn	Ka	0.49	0.0052	10.37	0.55
Fe	Ka	5.06	0.0531	92.64	5.51
Co	Ka	0.42	0.0040	5.97	0.43
Ni	Ka	57.14	0.5639	713.46	59.25
Mo	La	11.90	0.0834	206.07	7.55
W	Ma	3.05	0.0165	33.56	1.01
Total		100.01			

MJP 6/24/98



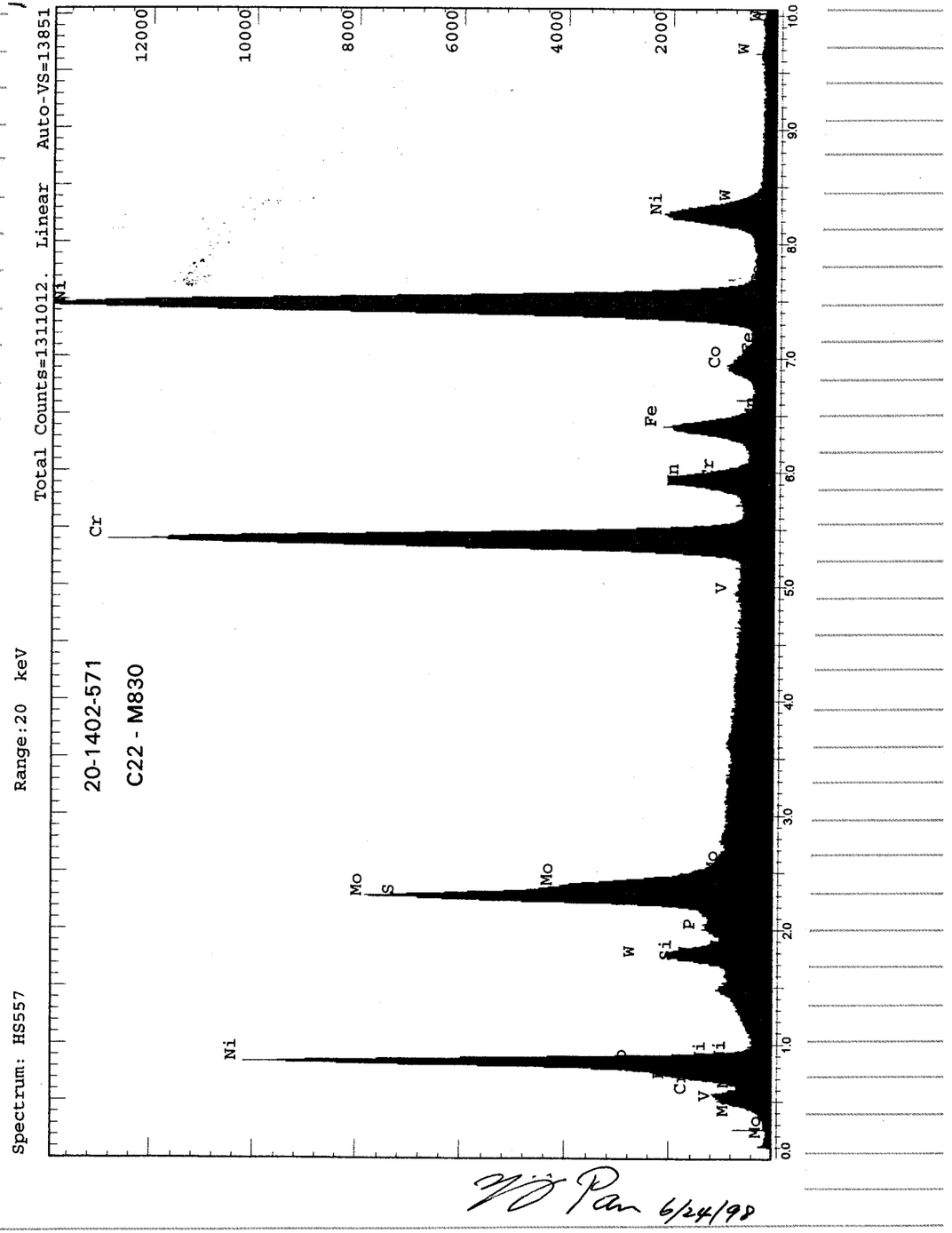
MJP 6/24/98

GENERAL CONDITIONS

Result File	: HS557
File Version	: 1
Background Method	: Fit
Decon Method	: Gaussian
Decon ChiSquared	: 3.94
Analysis Date	: 23-JUN-98
Microscope	: SEM
Comments	: C22 - M830

Element	Line	Weight%	K-Ratio	Cnts/s	Atomic%
Si	Ka	0.00	0.0000	0.00	0.00
P	Ka	0.00	0.0000	0.00	0.00
S	Ka	0.00	0.0000	0.00	0.00
V	Ka	0.17	0.0017	4.33	0.20
Cr	Ka	21.90	0.2254	520.32	25.66
Mn	Ka	0.27	0.0028	5.68	0.30
Fe	Ka	4.15	0.0436	76.33	4.53
Co	Ka	1.65	0.0159	23.83	1.71
Ni	Ka	56.78	0.5612	713.14	58.91
Mo	La	12.19	0.0856	212.45	7.74
W	Ma	2.90	0.0157	32.04	0.96
Total		100.01			

W Pan 6/24/98



W Pan 6/24/98

SOUTHWEST RESEARCH INST. 7010 P.O. NO: 50138
6220 CULEBRA RD
P.O. DRAWER 28510 DESCR: 06/24/98
SAN ANTONIO TX 78284 RELEASE#20511
HAROLD SALDANA
*** D R A F T *** REPORT DATE: 07/01/98

LAB NO: 0625-008 / 01 JOB NO: 06/26 #45

C22-M830

CHEMICAL ANALYSIS (WT %)

Si	.04	Mn	.22	C	.04
P	.025	S	.001	Ni	58.32
Cr	20.10	Mo	11.26	V	.13
Co	.30	Fe	3.52	W	2.90

TEST METHODS: ASTM E 663 ; ASTM E 1019 ; ICP ;

SOUTHWEST RESEARCH INST. 7010 P.O. NO: 50138
6220 CULEBRA RD
P.O. DRAWER 28510 DESCR: 06/24/98
SAN ANTONIO TX 78284 RELEASE#20511
HAROLD SALDANA
*** D R A F T *** REPORT DATE: 07/01/98

LAB NO: 0625-008 / 02 JOB NO: 06/26 #44

C22-M924

CHEMICAL ANALYSIS (WT %)

Si	.04	Mn	.28	C	.07
P	.021	S	.001	Ni	57.64
Cr	20.40	Mo	11.25	V	.14
Co	.39	Fe	4.40	W	2.30

TEST METHODS: ASTM E 663 ; ASTM E 1019 ; ICP ;

Yi Pan
6/26/98

DCB specimens Machining Correction

June 23, 1998

Mr. Dennis Pritchard
V.P., Sales and Marketing
Metal Samples Company
P.O. Box 8
152 Metal Samples Road
Munford, AL 36268

Dear Dennis:

As discussed with Ben Lackey of Metal Samples, I am sending you the DCB specimens from purchase order numbers 27724 & 28169 for side groove correction. Enclosed you will find a total of 14 DCB specimens: six each for Hastelloy C22 and 316L stainless steel from PO 27724 and two Hastelloy C22 specimens from PO 28169. Please notice that the labels of the C22 specimens from two different POs were duplicate. The two specimens from PO 28169 have been marked 7 & 8, respectively.

Our dimensional measurements indicate that both the width and depth of the side grooves do not fulfill the specifications in Drawing #IS 2706. Ben mentioned that Metal Samples has a standard QA inspection procedure and will correct the problems if the dimensions of the specimens are off specifications. Would you please send me the QA check results and let me know your correction plan. Please also provide me a quotation for machining of both knife edge and thread hole on the DCB specimens. The drawings are attached. Your comments on the additional machining work will be appreciated.

I can be reached through a telephone at (210)522-5259 or by fax at (210)522-5184. Thank you.

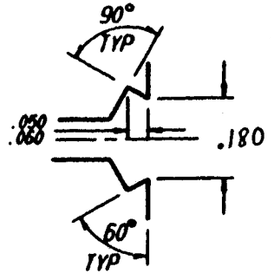
Sincerely,

Yi Pan

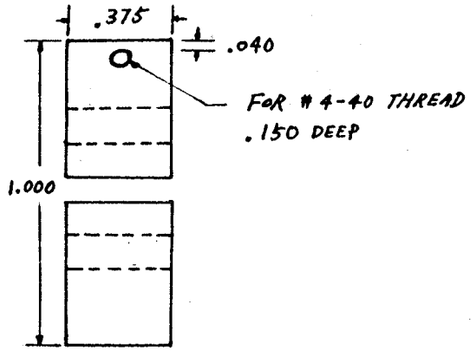
Yi-Ming Pan, Ph.D.
Consultant

Yi Pan
6/26/98

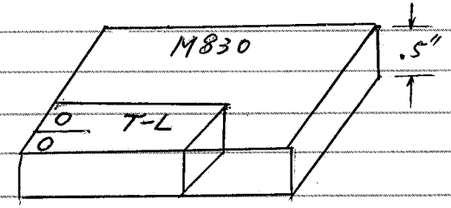
KNIFE EDGE

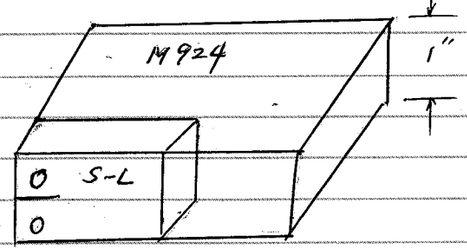


THREAD HOLE



SIDE VIEW
DCB SPECIMEN





Yi Pan 6/26/98

Yi Pan 7/1/98

Metal Samples Company
a division of Alabama Specialty Products, Inc.
152 Metal Samples Road
P.O. Box 8
Munford, Alabama
United States 36268
Tel: (256) 358-4202
Fax: (256) 358-4515
e-mail: benl@alspi.com
Internet: http://www.alspi.com

Fax Transmission from Ben Lackey

Recipient Yi-Ming Pan
Company Southwest Research Institute
Fax Number 1-210-522-5184
Subject Q.C. Disposition for DCB's
Date 6/26/98 **Number of Pages (including cover)** 2

Dear Yi-Ming,

Per our earlier conversations, and your correspondence with Dennis Pritchard, we have had our Q.A. group inspect the notch / side groove positions of your DCB specimens, as ordered on order #'s 27724 and 28169.

The Drawing # IS2706 calls out a positioning tolerance of 0.004" for the notch / side groove dimensions. Following, please find the results and disposition of the inspection of the samples.

In regard to the addition of the knife edges for a clip gauge and the threaded hole, Metal Samples Company will make these additions to this group of specimens at no additional charge.

If you have any questions, or concerns, please let us know.

Best Regards,

Benjamin J. Lackey
Metal Samples Company

Test Condition	Ser. No.		Position	Orientation	Disposition
30ksi√in/5%NaCl –	C22 - 1	M830	.007"	T-L	Remake specimen
30ksi√in/40% $MgCl_2$ –	C22 - 2	"	.005"	"	Remake specimen
Compliance –	C22 - 3	"	.0075"	"	Remake specimen
	C22 - 4	"	.004"	"	Remake specimen
	C22 - 5	"	.004"	"	Remake specimen
	C22 - 6	"	.004"	"	Remake specimen
30ksi√in/40% $MgCl_2$ –	C22 - 7	M924	.002"	S-L	No Work Required
	C22 - 8	"	.002"	S-L	No Work Required
23 ksi√in/5% NaCl –	316L - 1	P80746	.0037"	T-L	Remake specimen
23 ksi√in/44% $MgCl_2$ –	316L - 2	"	.0045"	"	Remake specimen
Compliance –	316L - 3	"	.003"	"	Rework specimen
	316L - 4	"	.003"	"	Rework specimen
-340 mV SCE –	316L - 5	"	.005"	"	Remake specimen
20 ksi√in/30% $MgCl_2$/0.C. –	316L - 6	"	.005"	"	Remake specimen

Yi Pan 7/1/98

Yi Pan 7/1/98

Bending Moment and K_{Iscc} Calculation of DCB SCC Specimen

Calculate the bending moment and k1scc of DCB SCC specimens given the load and crack length

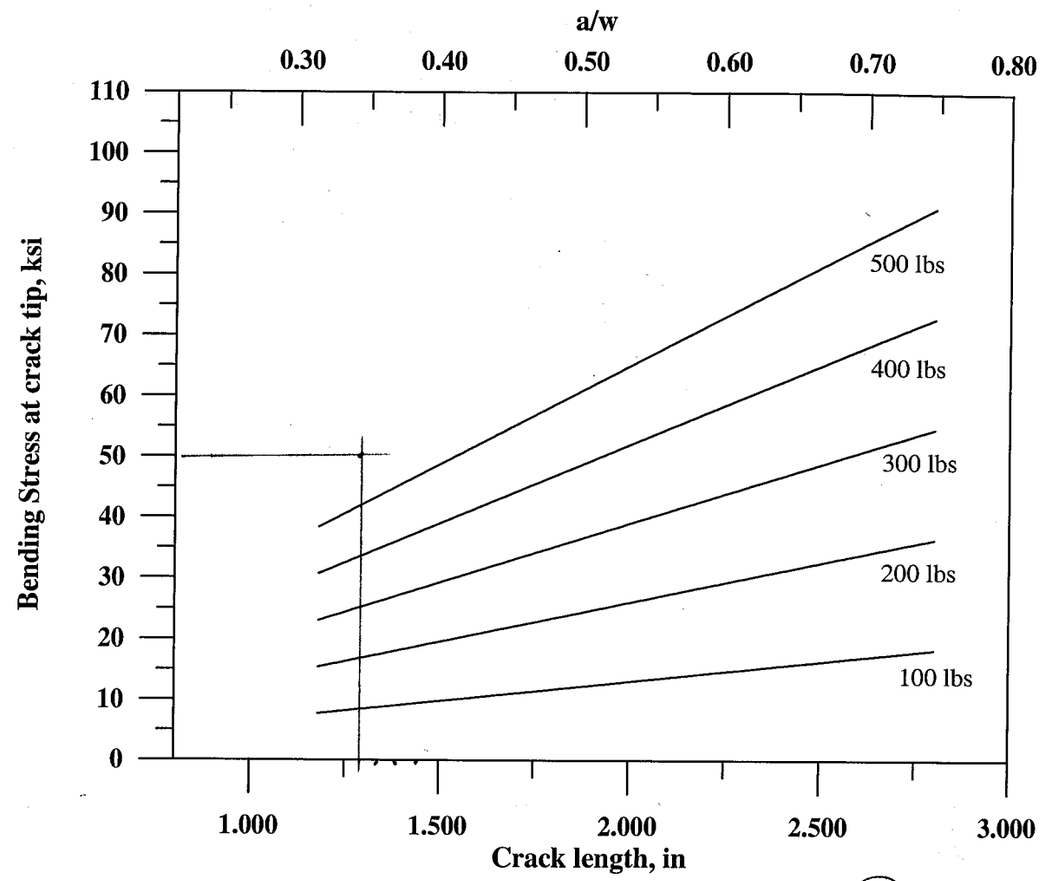
PARAMETERS

load=load in kips
a=precrack length (notch + fatigue crack), inches
hb=height of DCB beam, inches
b=specimen thickness, inches
h=specimen thickness at crack tip, inches
ba=web thickness, inches
w=loadline to end of specimen, inches
awratio=a/w
bendingstresscracktip=stress on DCB arms at tip of crack
bendingstressnotch=stress on DCB arms at end of notch
k1scc=ksi(in)^0.5
nl=notch length

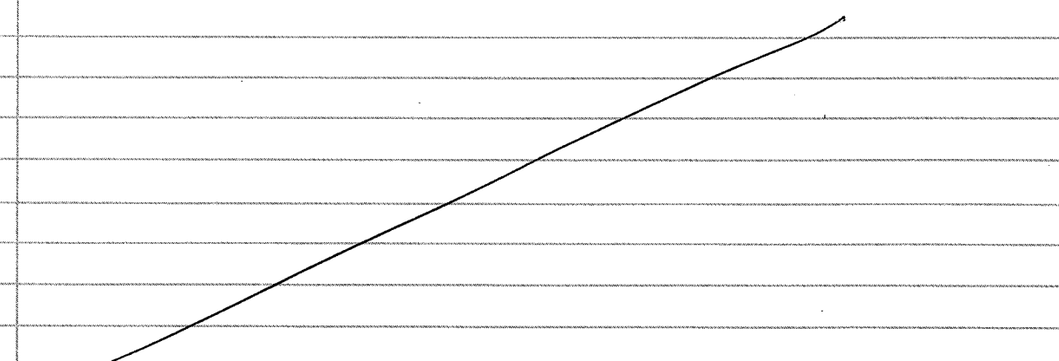
Input

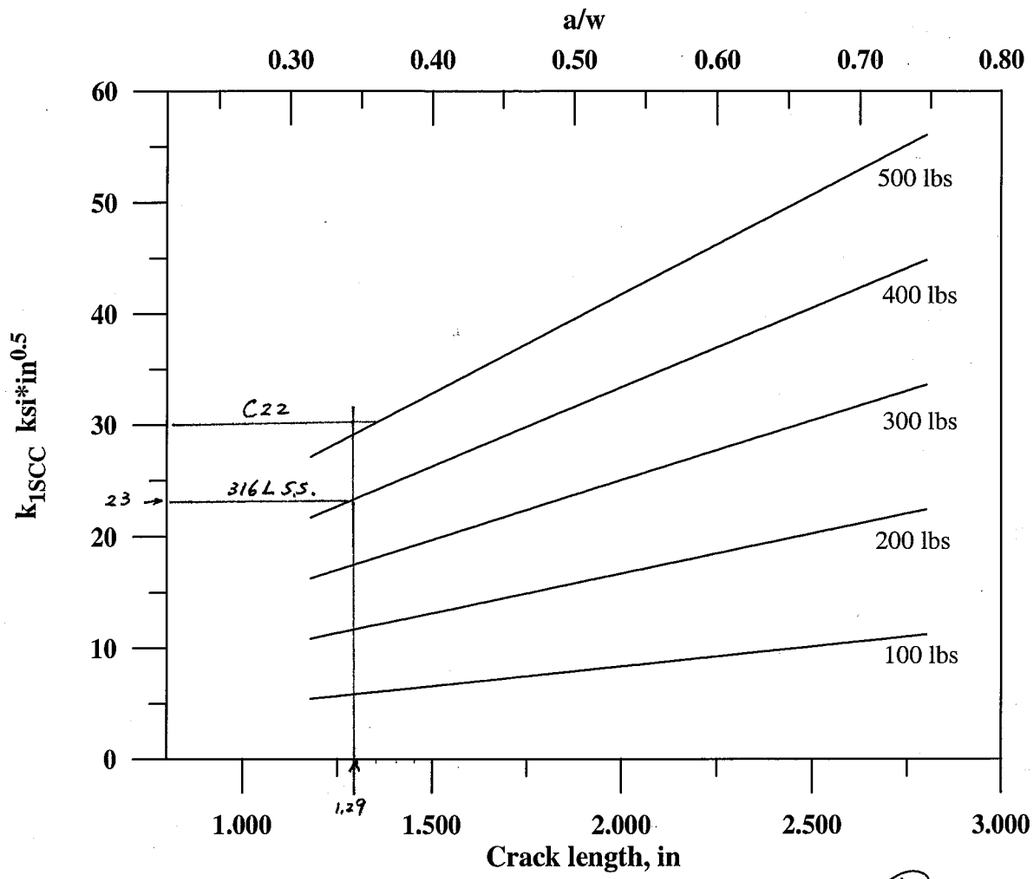
```
load=0.100;
hb=0.456;
b=0.375;
h=0.496;
ba=0.223;
w=3.75;
nl=1.1835;

Off[General::spell]
Off[General::spell1]
SetOptions[$Output, PageWidth->1000]

Print["hb(inches)"," ","b(inches)"," ","h(inches)"," ","ba(inches)"," ","w(inches)"," ","a(inches)","
","nl(inches)"," ","load(kips)"," ","bendingstresscracktip(ksi)"," ","bendingstressnotch(ksi)","
","a/w(inches/inches)"," ","k1scc(ksi(in)^0.5)"," ","written:10/16/98"," ","run:10/16/98"]

Do[
bendingstresscracktip=((load*a)*(h/2))/((1/12)b*h*h*h);

bendingstressnotch=((load*nl)*(hb/2))/((1/12)b*hb*hb*hb);

awratio=a/w;

k1scc=((load*a(3.4641+(2.38*h/a)))*(b/ba)^0.57735)/(b*h^1.5);

Print[FortranForm[hb],"  ",FortranForm[b],"  ",FortranForm[h],"  ",FortranForm[ba],"  ",FortranForm[w],"
",FortranForm[a],"  ",FortranForm[nl],"  ",FortranForm[load],"  ",FortranForm[bendingstresscracktip],"
",FortranForm[bendingstressnotch],"  ",FortranForm[awratio],"
",FortranForm[k1scc]],{a,1.180,2.800,0.010}]
```

Nij Pan 10/14/98

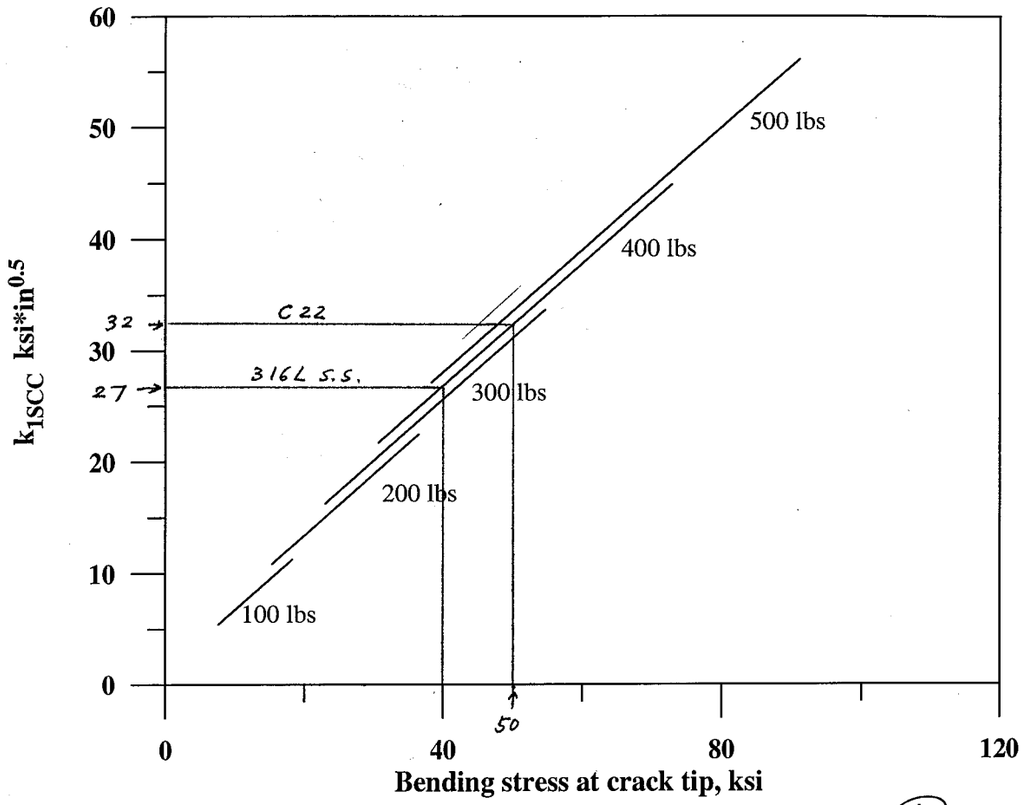


Nij Pan 10/14/98

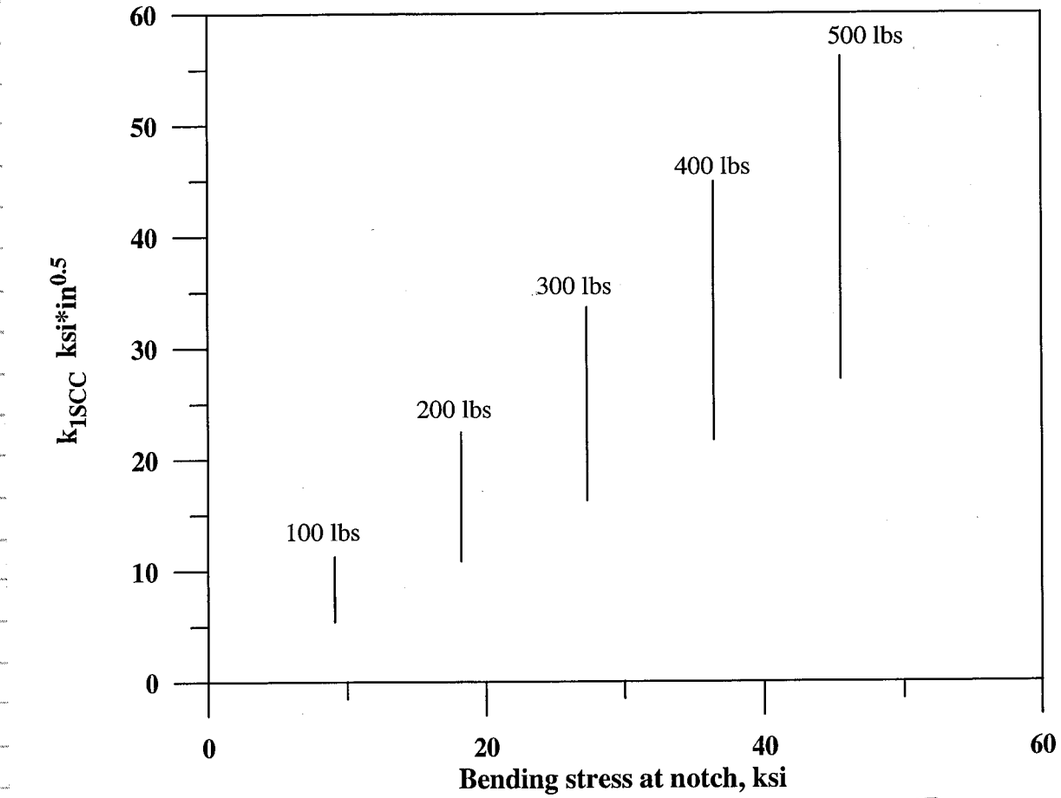




Yi Pan
10/14/98



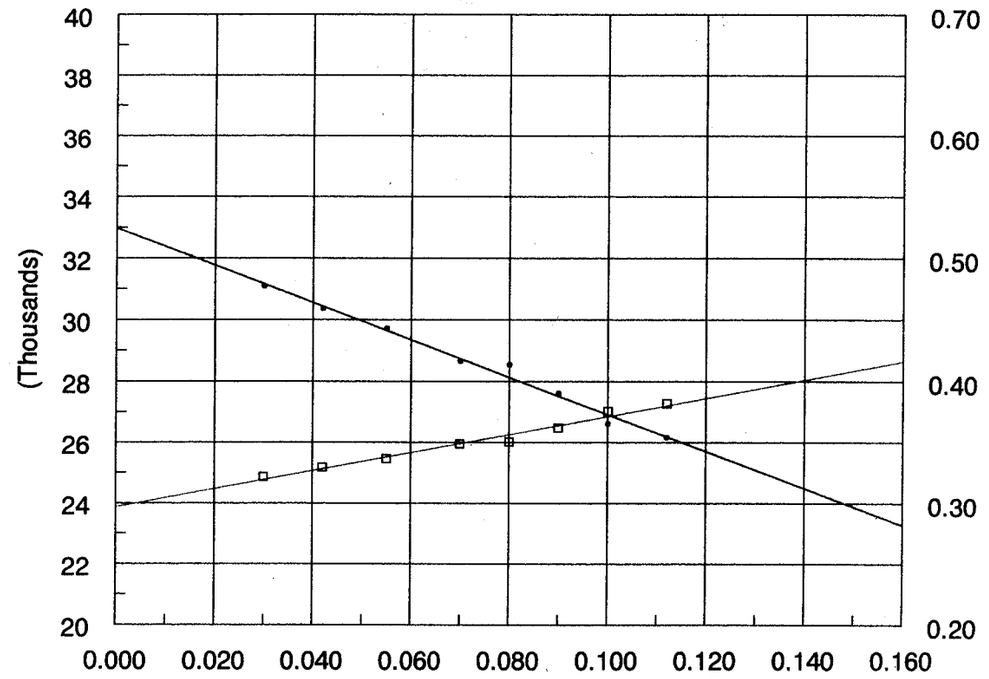
Yi Pan
10/14/98



load / mouth disp (lb/in)

10/14/98

Compliance Measurement of 316L3 DCB SCC specimen

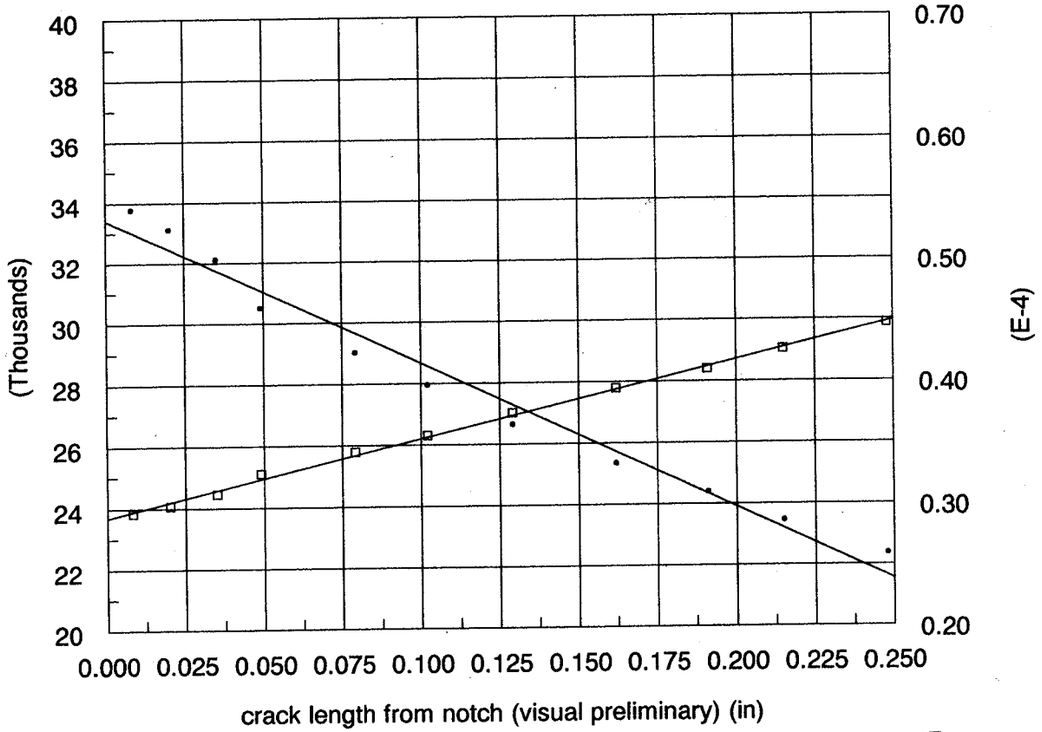


10/14/98

Compliance Measurment of C-22-3DCB SCC Specimen

C22-3

preliminary compliance as to crack length



Mi Pan
10/30/98

Precrack Length and Initial Loading of DCB SCC Specimens

Subject: Precrack length and initial loading of SCC DCB specimens

A. 316L Stainless Steel
The precrack length for 316L DCB specimens will be .110" +/- .005" (.105" to .115") and the initial wedge loading will be 400 lbs with a wedge thickness of .112". This gives a K_I value of about 23 ksi-in$^{1/2}$. (see page 94)*

B. Alloy C-22
The precrack length for C-22 DCB specimens will be the same as 316L. To achieve a high K_I value of 30 ksi-in$^{1/2}$, it requires an initial loading of about 510 lbs. (see page 94)*

It is understood that the wedge loading point will be varied as a result of the difference between the crack mouth opening displacement and the wedge thickness.

Mi Pan
11/11/98

*1) Crack length = notch length + precrack length
= 1.1835" + 0.110"
= 1.2935"

2) The yield strength for 316L S.S. is about 40 ksi, and 50 ksi for C22. Therefore, the maximum initial loading (K_I) for 316L S.S. without arm deformation is 27 ksi√in according to the calculation shown in page 95. the maximum initial loading for C22 is 32 ksi√in.

Mi Pan
11/11/98

Precrack Length Measurements of DCB SCC Specimens

Specimen No	Precrack Length (in)					
	SEM			Visual		
	Front	Rear	Ave.	Front	Rear	Ave.
316L - 1	.113	.121	.117	.113	.112	.1125
316L - 2	.112	.106	.109	.112	.100	.106
C22 - 1	.121	.100	.1105	.116	.100	.108
C22 - 2	.118	.109	.1135	.110	.106	.108

ZJ Par
11/18/98

316L DCB1 Stress Corrosion Cracking Test

Objective Measure SCC growth rate

Specimen 316L-1 Heat P80746 machined by Metal Samples
Precrack length 0.117" (SEM) / 0.1125" (Visual)

Load 23 ksi$\sqrt{in}$ (25 MPa$\sqrt{m}$)

Test Environment
Solution: 5 wt. % NaCl
105.20381 g NaCl Lot # 972274
pH = 2.734
Temp: T = 90°C Hg Thermometer C 96-649
Degerated with 99.999% N_2

Potentiostat ESC 440 #2 Channel # 1

Reference FISHER SCE 13-620-51 SN 9214080, 5% NaCl
Counter Electrode Pt Flag

Data File 316LDCB1 using Labview

Test Started	1:40 PM	11/17/98	
Test restarted +	8:50 a.m	11/20/98	Data File 316LDCB1b
Test Stopped	9:30 a.m	11/23/98	For visual and SEM examinations
Test Restarted	4:30 p.m	11/24/98	Data File 316LDCB1C
Test Stopped	8:20 a.m	12/9/98	For visual, SEM and NDE examinations.
Test Restarted	4:45 PM	12/10/98	Data File 316LDCB1d
Test stopped	2:50 p.m.	1/6/99	For visual and SEM examinations.
Test Restarted	12:25 pm	1/8/99	Data File 316LDCB1e
Test Restarted	8:30 am	1/11/99	Data File 316LDCB1f
Test Restarted	8:26 am	1/5/99	Data File 316LDCB1g
	LabView stopped at an accumulated time of 2,088,554 sec		
Test stopped	2:30 pm	1/10/99	No crack advance observed visually.

+ File 316dcb1 recorded a time period of 65.4 hrs. This suggests that the data acquisition system was off around 7:30 a.m. Nov. 20, 1998.

Test restarted 4:00 pm 1/11/99 Data File 316LDCB1h

< Continued P128 >

ZJ Par 2/11/99

C22DCB1 Stress Corrosion Cracking Test

Objective Measure SCC growth rate

Specimen C22-1 Heat 2277763193 machined by Metal Samples
Precrack length 0.1105" (SEM) / 0.108" (visual)

Load 30 ksi$\sqrt{in}$ (33 MPa$\sqrt{m}$)

Test Environment
Solution: 5 wt% NaCl
105.21198 g NaCl Lot # 972274
pH = 2.751
Temp.: T = 90°C Hg thermometer C 96-784
Deaerated with 99.999% N_2

Potentiostat ESC 440 #2 Channel #2

Reference FISHER SCE 13-620-51 SN 5087405, 5% NaCl

Counter Electrode Pt Flag

Data File C22DCB1 using LabView

Test Started 1:40 pm 11/17/98

Test Restarted	8:50 am	11/20/98	Data File C22DCB1b
Test stopped	9:30 am	11/23/98	For visual and SEM examination.
Test Restarted	4:30 pm	11/24/98	Data File C22DCB1C
Test Stopped	8:20 a.m	12/9/98	For visual and SEM examination.
Test Restarted	4:45 p.m	12/10/98	Data File C22DCB1d
Test stopped	2:50 p.m.	1/6/99	For visual and SEM examination.
Test Restarted	12:25 pm	1/8/99	Data File C22DCB1e
Test Restarted	8:30 am	1/11/99	Data File C22DCB1f
Test Restarted	8:26 am	2/5/99	Data File C22DCB1g
Test stopped	2:30 pm	2/10/99	No crack advance observed visually.
Test Restarted	4:00 pm	2/11/99	Data File C22DCB1h
Test Restarted	8:25 am	3/1/99	Data File C22DCB1i mp
Test stopped	2:30 pm	3/9/99	No crack advance observed visually
Test Restarted	5:15 pm	3/10/99	Data File C22DCB1j

(continued p151)

MP 3/10/99

316LDCB2 Stress Corrosion Cracking Test

Objective Measure SCC growth rate

Specimen 316L Heat P80746 machined by Metal Samples
Precrack length 0.109" (SEM) / 0.106" (visual)

Load 23 ksi$\sqrt{in}$

Test Environment
Solution: 40 wt.% $MgCl_2$
2500 g $MgCl_2$ Lot # 951190 + 250 ml H_2O
Temp.: T = 110°C Hg thermometer C 96-377

Potentiostat ESC 440 #2 Channel #3

Reference FISHER SCE 13-620-51 SN 3106339, 30% $MgCl_2$

Counter Electrode Pt Flag

Data File 316LDCB2 using LabView

Test Started 1:40 pm 11/17/98

Test Restarted	8:50 am	11/20/98	Data File 316LDCB2b
Test stopped	9:30 am	11/23/98	For visual and SEM examination.
Test Restarted	4:30 pm	11/24/98	Data File 316LDCB2C
Test Stopped	8:20 a.m	12/9/98	For visual and SEM examination

Loading wedge became loose and transverse cracks observed.
Test Finished.

MP 12/9/98

Note: Crack growth rate calculation
Test duration: 135.5 hrs
Crack advance: 1) visual 0.360" − 0.106" = 0.254"
2) SEM 0.298" − 0.112" = 0.186"
Crack growth rate: 1) visual $(0.254)(0.0254)/(135.5\times3600) = 1.32\times10^{-8}$ m/s
2) SEM $(0.186)(0.0254)/(135.5\times3600) = 9.69\times10^{-9}$ m/s

MP 12/14/98

C22 DCB 2 Stress Corrosion Cracking Test

Objective Measure SCC growth rate

Specimen C22-2 Heat 2277 63193 machined by Metal Samples
Precrack length 0.1135" (SEM) / 0.108" (visual)

Load 30 ksi √in

Test Environment
Solution: 40 wt % $MgCl_2$
2500 g $MgCl_2$ Lot # 951190 + 250 ml H_2O
Temp.: T = 110 °C Hg Thermometer C96-616

Potentiostat ESC 440 #2 Channel # 4

Reference FISHER SCE 13-620-51 SN 81 22003, 30% $MgCl_2$
Counter Electrode Pt Flag

Data File C22DCB2 using Labview

Test Started 1:40 pm 11/17/98
Test Restarted 8:50 am 11/20/98 Data File C22DCB2b
Test stopped 9:30 am 11/23/98 For visual and SEM examination.
Test Restarted 4:30 pm 11/24/98 Data File C22DCB2c
Test Stopped 8:20 am 12/9/98 For visual and SEM examination.
Test Restarted 4:45 pm 12/10/98 Data File C22DCB2d
Test Stopped 2:50 p.m. 1/6/99 For visual and SEM examination.
Test Restarted 12:25 pm 1/8/99 Data File C22DCB2e
Test Restarted 8:30 am 1/11/99 Data File C22DCB2f
Test Restarted 8:26 am 2/5/99 Data File C22DCB2g
Test Stopped 2:30 pm 2/10/99 No crack advance observed visually
Test Restarted 4:00 p.m 2/11/99 Data File C22DCB2h
Test Restarted 8:25 am 3/1/99 Data File C22DCB2i
Test Stopped 2:30 pm 3/9/99 No crack advance observed visually
Test Restarted 5:15 pm 3/10/99 Data File C22DCB2j

<Continued P152>

3/10/99

Crack Length Measurements After Disassembly on 11/23/98

1. Crack length measured by visual method using a Nikon OPTIPHOT-POL microscope at 100 x. The unit length of the exepiece scale is 10 μm.

Specimen No.	Front (unit / in)	Rear (unit / in)	Ave. (in)
316LDCB1	299 / .118	290 / .114	.116
316LDCB2	812 / .320	1015 / .400	.360
C22 DCB 1	303 / .119	257 / .101	.110
C22 DCB 2	290 / .114	274 / .108	.111

2. Crack length measured by SEM with a reference ruler having a .01" unit length. The measurements were done on the front side.

Specimen No.	Reference Ruler Unit length	Crack Length (mm / in)
316LDCB1	95.0 mm for 12 units	84.0 mm / .106"
316LDCB2	21.0 mm for 1 unit	625.0 mm / .298"
C22 DCB 1	99.0 mm for 12 units	89.2 mm / .108"
C22 DCB 2	107.0 mm for 13 units	88.5 mm / .107"

3. Crack length results after disassembly on 11/23/98.

Specimen No	Crack Length (in)					
	SEM[1]			Visual[2]		
	Front	Rear	Ave.	Front	Rear	Ave.
316L - 1	.106	--	--	.118	.114	.116
316L - 2	.298	--	--	.320	.400	.360
C22 - 1	.108	--	--	.119	.101	.110
C22 - 2	.107	--	--	.114	.108	.111

Note: 1. The SEM measurements were done on photographs with a reference ruler having a .01" unit length.
2. The visual measurements were done using an optical microscope at 100x with a unit length of 10 μm of the eyepiece scale.

11/30/98

Crack Length Measurements After Disassembly on 12/9/98

1. Crack length measured by visual method

Specimen No.	Crack Length	Remark
316LDCB1	no crack advance	–
316LDCB2	no crack advance	Wedge became loose; surface pits observed.
C22DCB1	no crack advance	–
C22DCB2	no crack advance	–

2. Crack length measured by SEM
No crack advance has been observed for all four DCB specimens. However, transverse cracks perpendicular to the groove have been observed in specimen 316L DCB2.

Yijing Pan
12/11/98

SEM Micrographs of Cracks of the DCB specimens Disassembly on 11/2/98

1. 316L DCB1

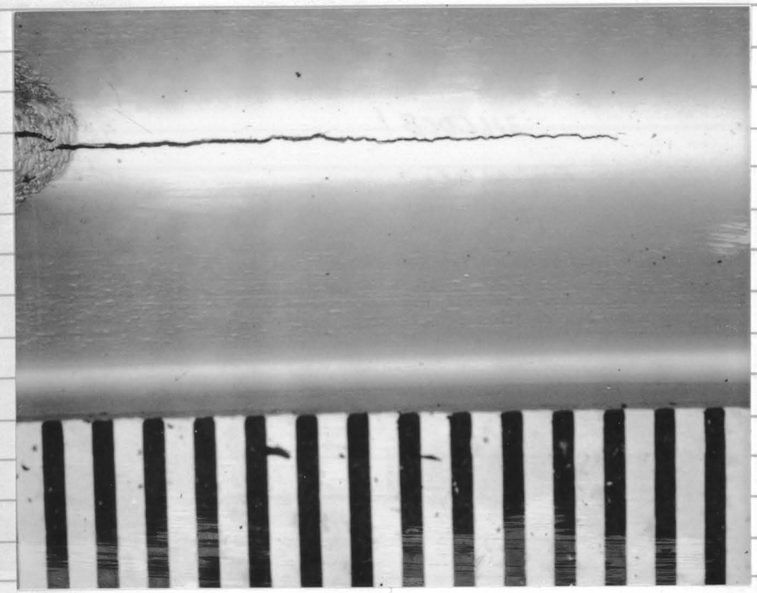


Photo No: 94602
266X

Photo No. 94597

Yijing Pan
12/11/98

2. 316LDCB2

Photo No: 94606

Yi Pan
12/11/98

3. C22DCB1

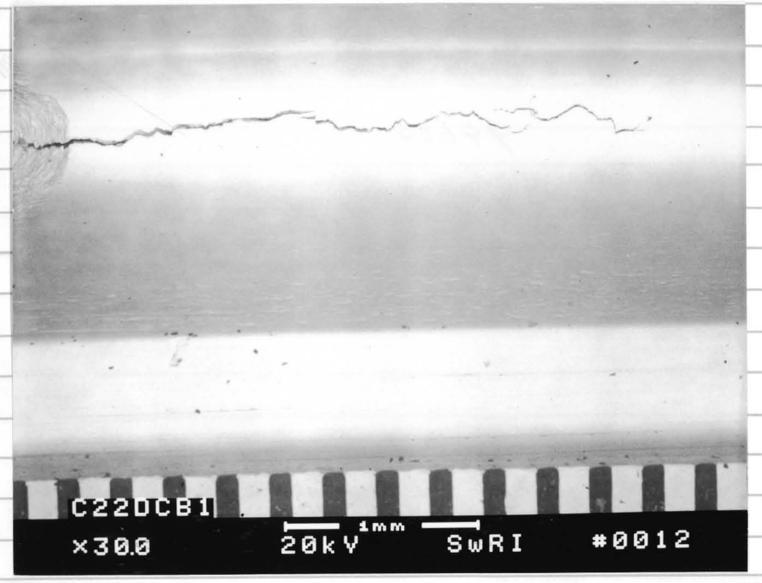


Photo No: 94603

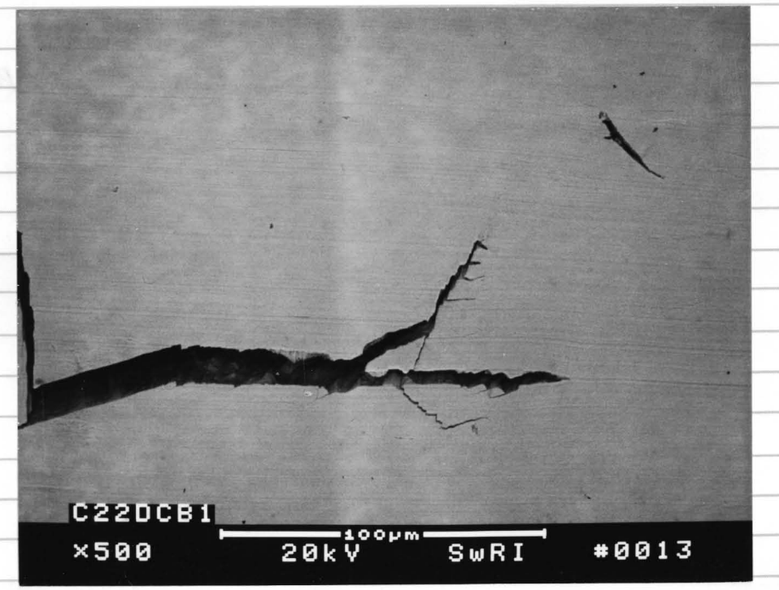


Photo No: 94605

Yi Pan
12/11/98

4. C22DCB2

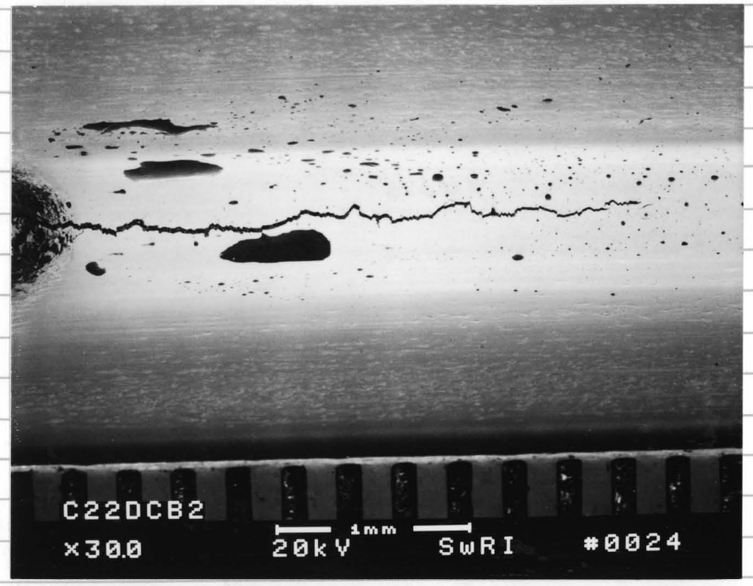


Photo No. 94615

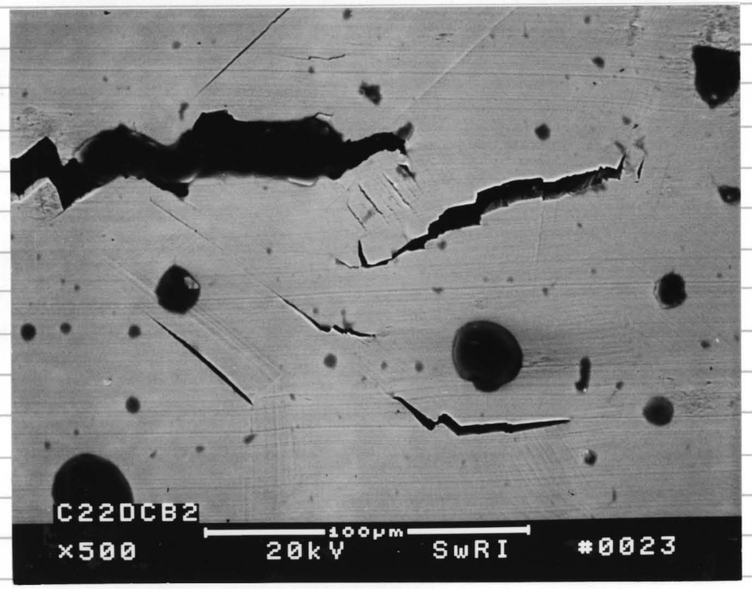


Photo No. 94614

12/11/98

SEM Micrographs of Cracks of the DCB Specimens Disassembly on 12/9/98

1. 316L DCB1

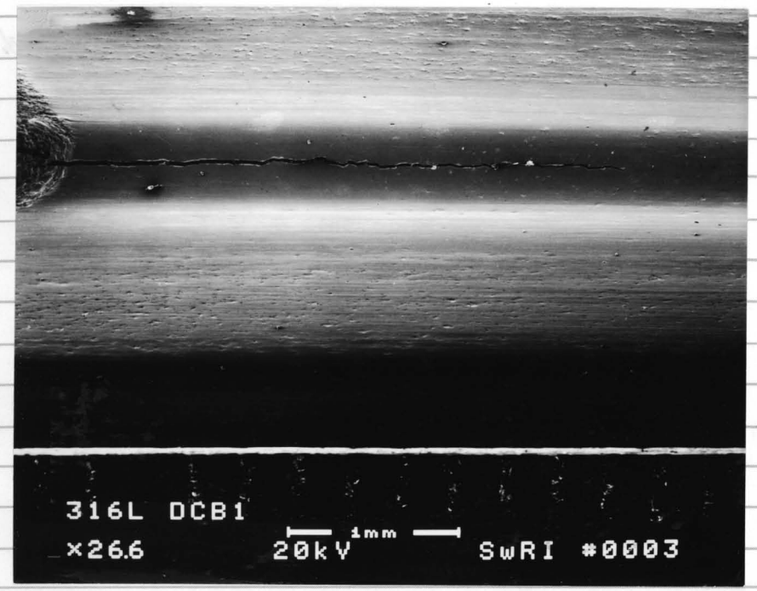


Photo No. 94851

photo No. 94852

12/14/98

2. 316L DCB2

Photo No. 94859

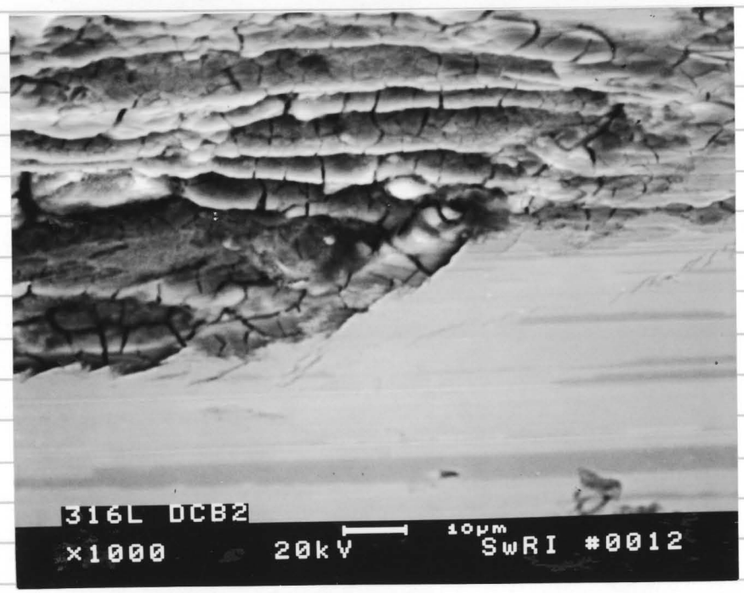


Photo No. 94860

12/14/98

3. C22 DCB1

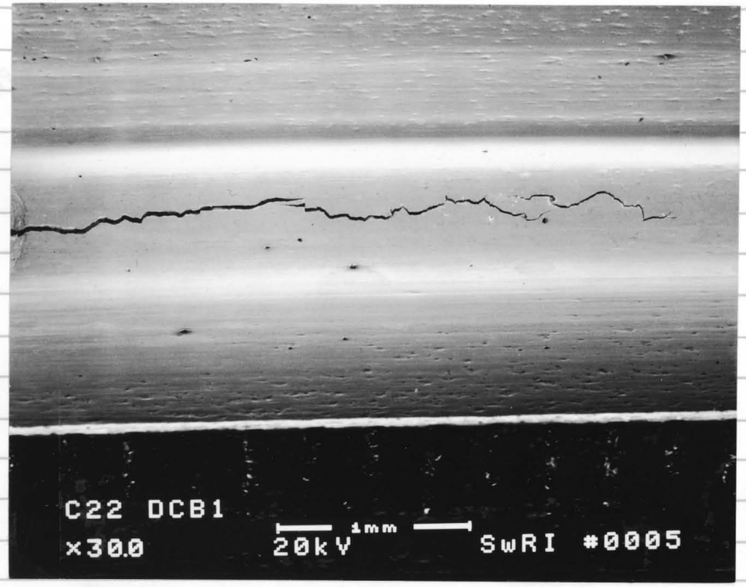


photo No. 94853

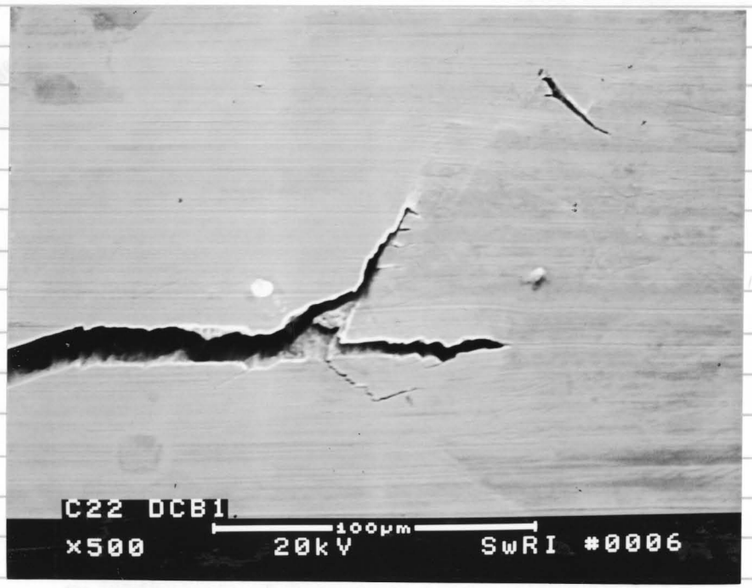


Photo No. 94854

12/14/98

4. C22DCB2

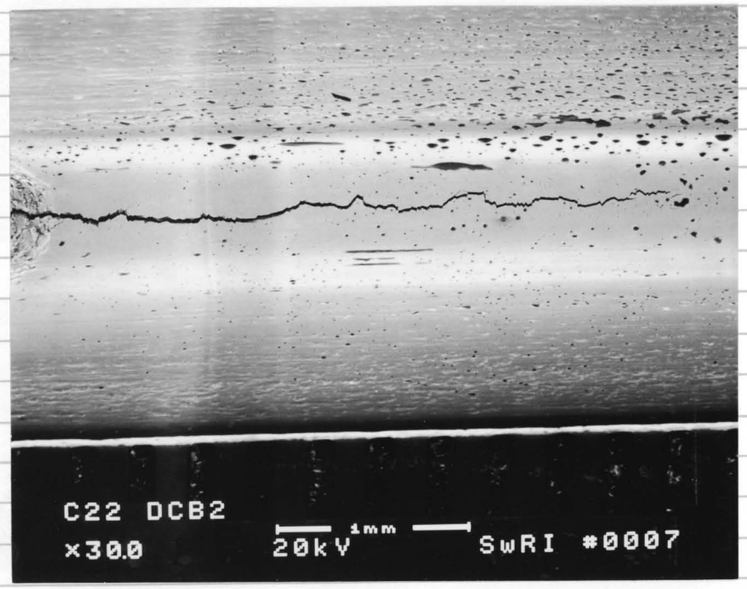


Photo No 94855

Photo No. 94856

12/14/98

5. 316LDCB2 — Transverse Cracks

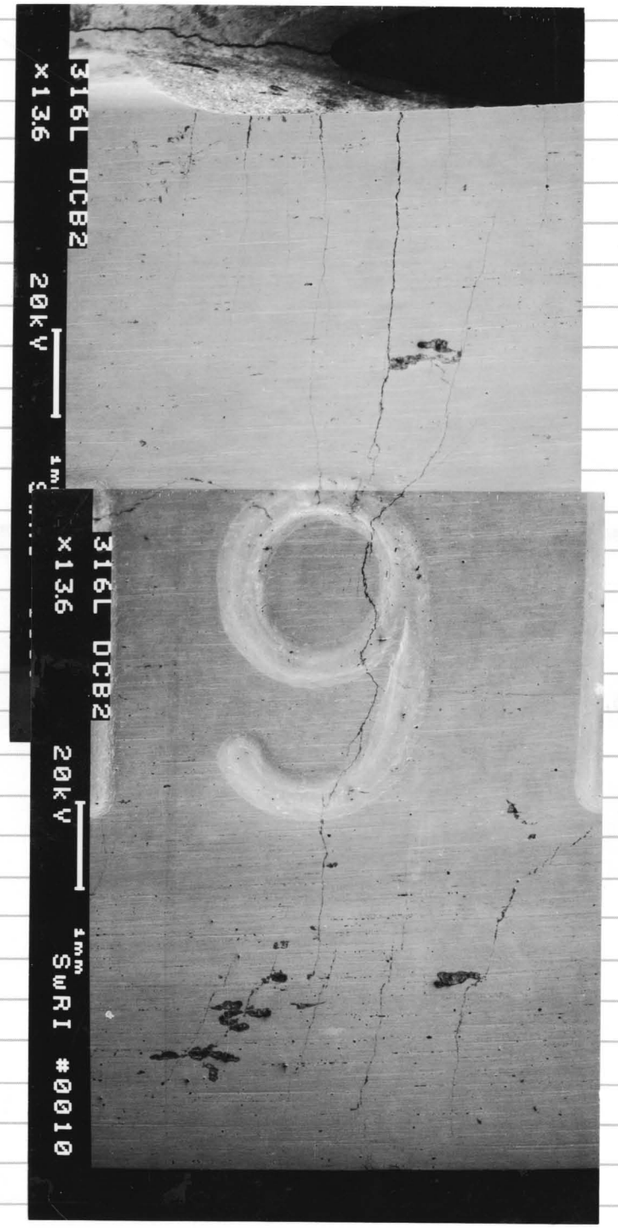


Photo No. 94857

Photo No. 94858

12/14/98

SEM Micrographs of the DCB Specimens Disassembly on 1/6/99

1. 316LDCB1

photo No: 95080

2. C22 DCB1

Photo No. 95081

1/8/99

3. C22DCB2

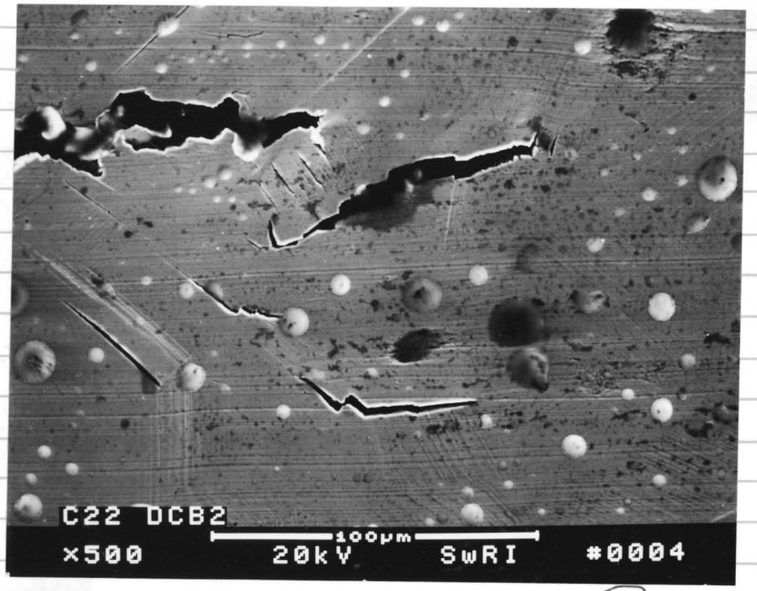
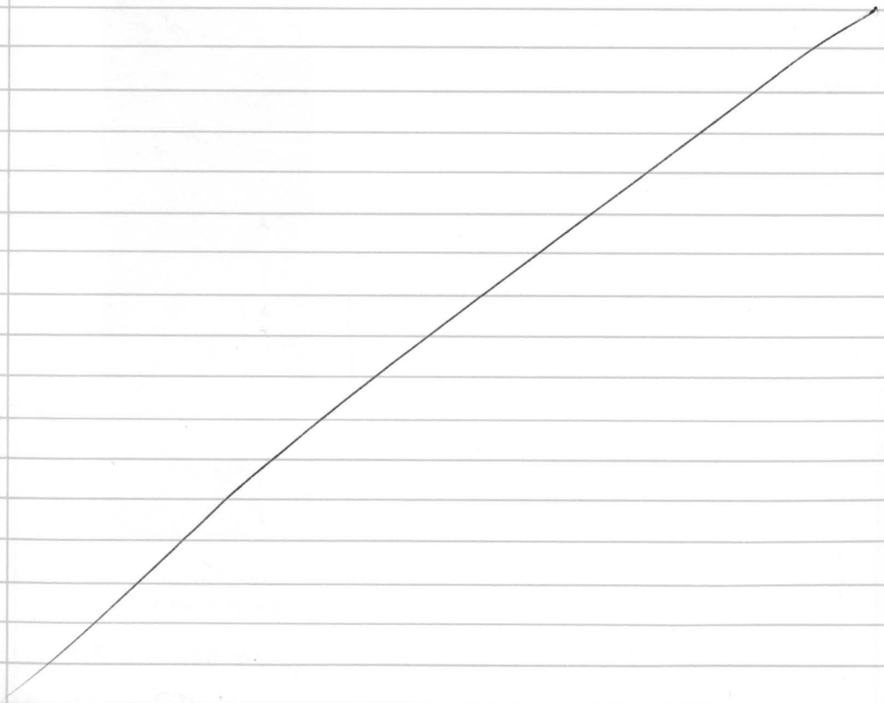


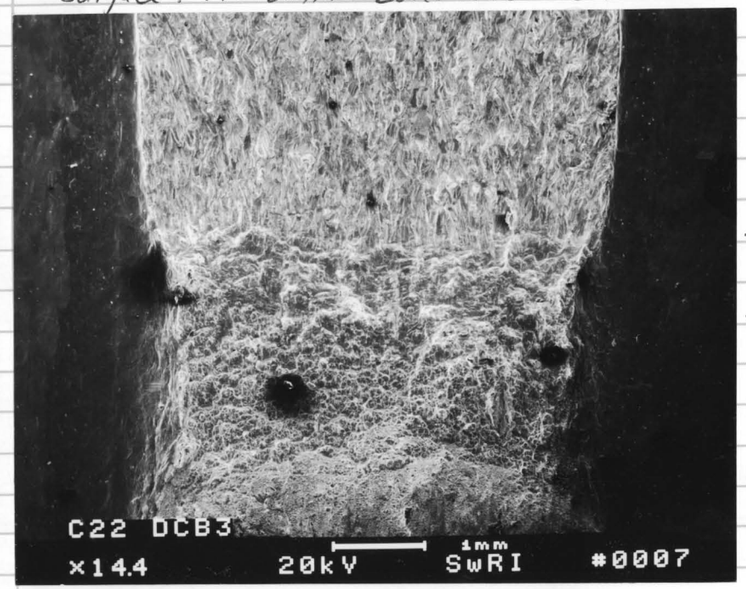
photo No: 95082

1/8/99



Fracture surface morphology of C22-3 DCB specimen

C22-3 DCB specimen was originally used for compliance calibration. The specimen was heat tinted and saw cut from back edge to near crack tip, and then broke open to reveal fracture surface. The distinct zones were observed and documented below.



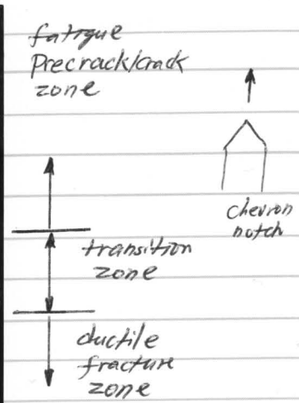


photo No: 95085

fatigue crack zone

transition zone

width = 1,320 μm or 0.052 in

ductile fracture zone

photo No: 95090

Yj Pa 1/11/99

1. Fatigue crack zone

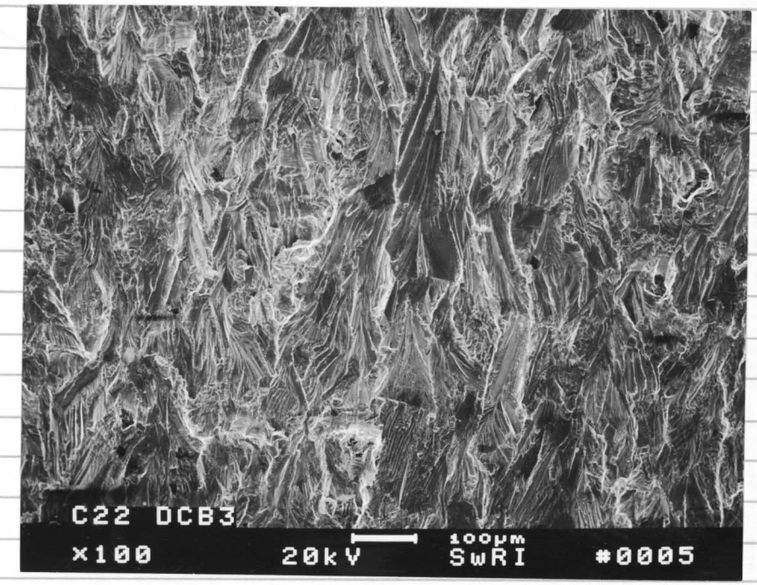


Photo No: 95083

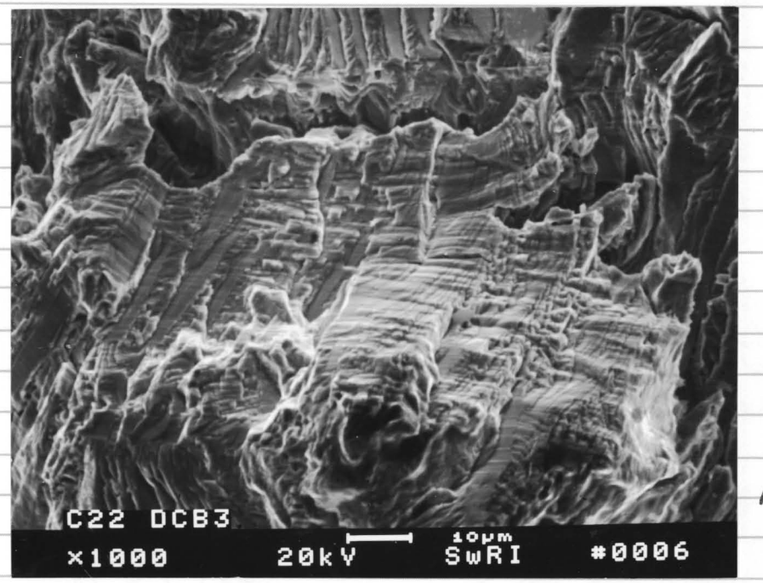


photo No: 95084

Yj Pa 1/11/99

2 Transition zone

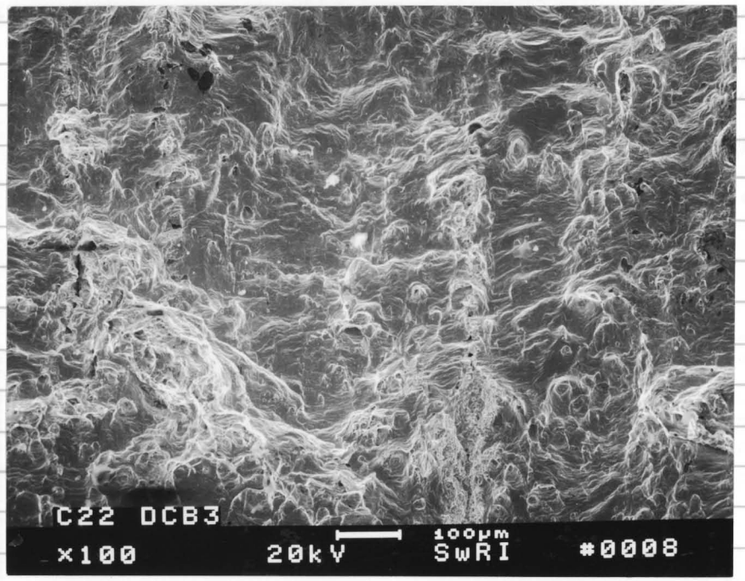


Photo NO: 95086

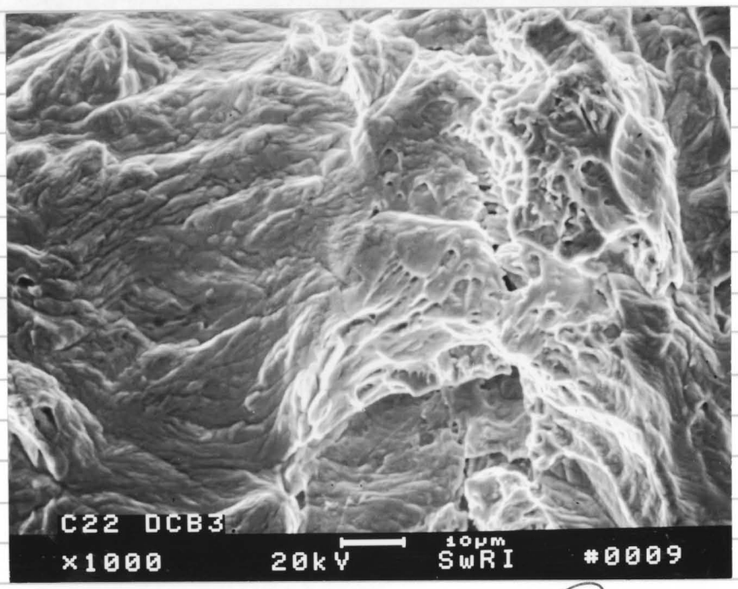


Photo NO: 95087

1/11/99

3. Ductile Fracture Zone

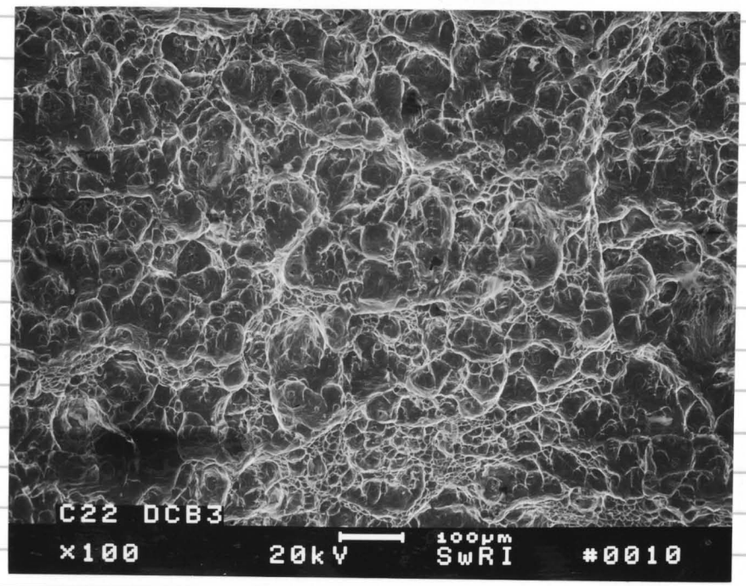


Photo NO: 95088

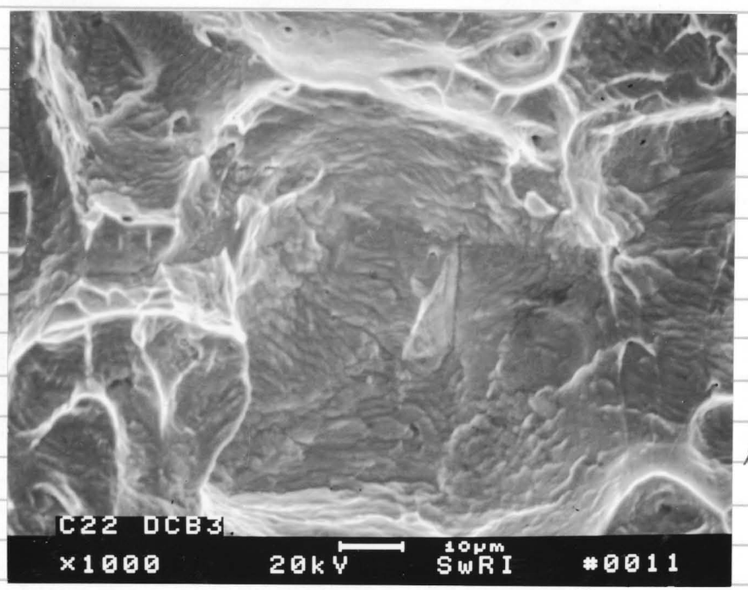


Photo NO: 95089

1/11/99

Initial Loading of C22-7 DCB specimen

C22-7

double cant beam stress formula

k=	30	(ksi in^0.5)	SIF
p=	0.521	(kips)	load
x=	0.25	(in)	front face to load line
h=	0.5	(in)	arm height
b=	0.375	(in)	thickness
bn=	0.224	(in)	web (net thickness on side groove)
a=	1.292	(in)	crack length

K/P	EvB/P(FRONT FACE)
57.53902	164.7363

P/K
0.01738

FOR K---MULTIPLY K/P TIMES LOAD (KIPS) ie... 30.0008431 KSI IN^0.5
FOR P---MULTIPLY P/K TIMES STRESS (KSI) ie... 0.52138535 KIPS
MULTIPLY EVB/P TIMES P AND DEVIDE BY B*MOD TO GET COMPLIANCE (V)

K/P (ksi in^0.5)		P(kips)	Bend Stress(ksi)
57.53902	25	0.434488	35.92693
	30	0.521385	43.11231
	35	0.608283	50.2977

The initial wedge loading of C22-7 dcb specimen is 521 lb, which gives a K_I value of 30 ksi$\sqrt{in}$.

Yi Pa 1/25/99

SEM Micrographs of Precrack of C22-7 DCB Specimen

photo No: 95342

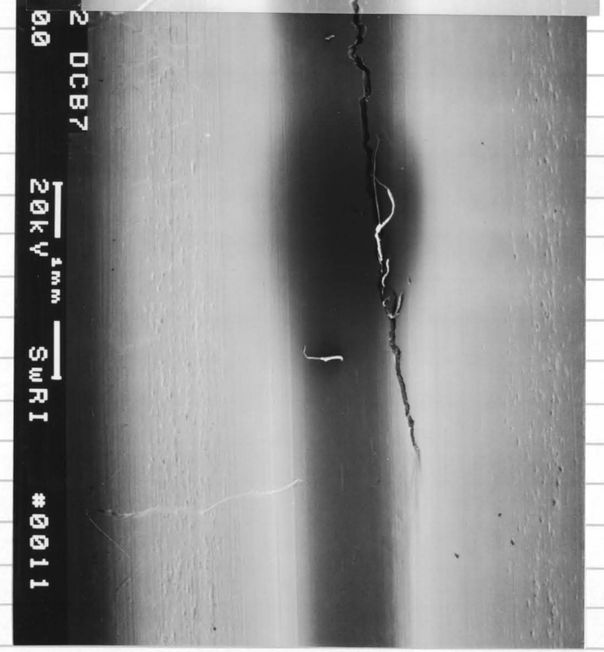
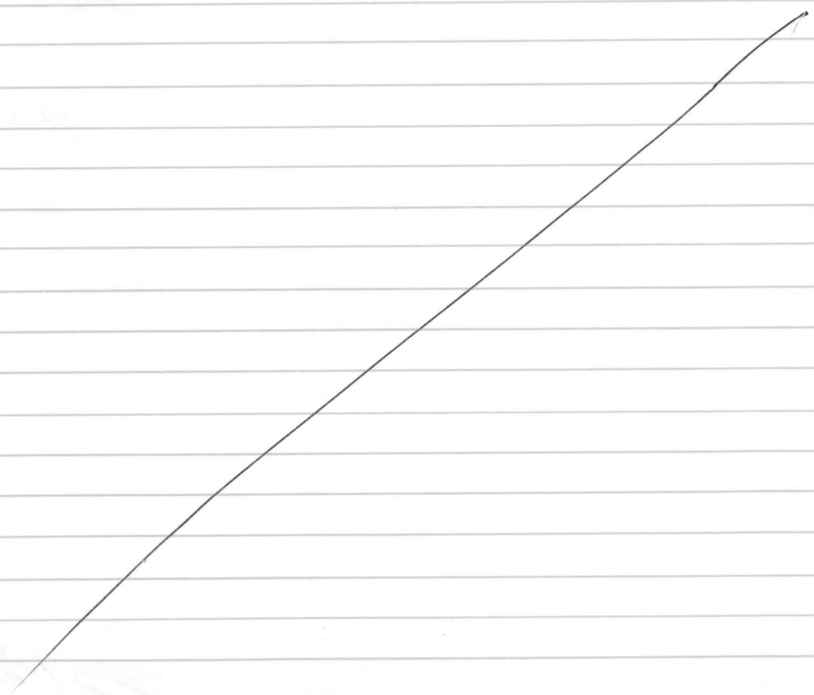


photo No: 95343

Yi Pa
2/3/99

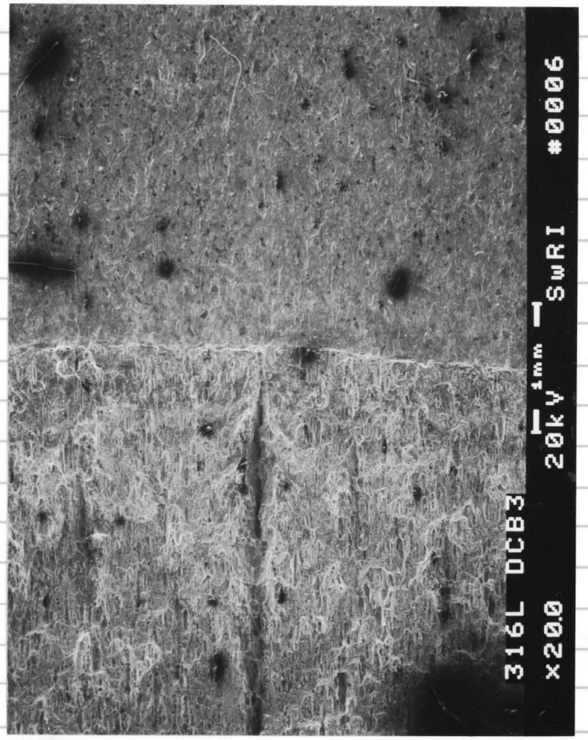
photo No: 95344

Pan
2/3/99



Fracture surface of 316L-3 DCB specimen

316L-3 DCB specimen for compliance calibration was treated same as C22-3 DCB specimen in page 118. to reveal fracture surface. No transition zone has been observed.

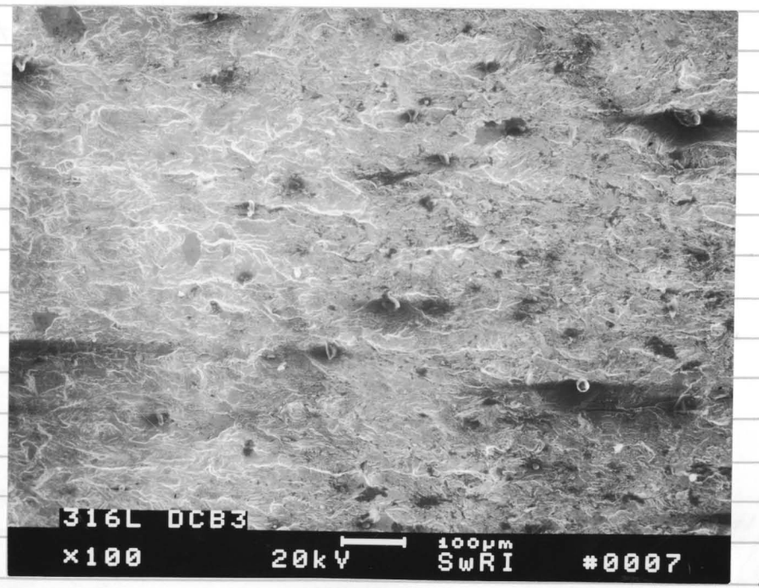


fatigue precrack/crack zone

chevron notch

tearing zone

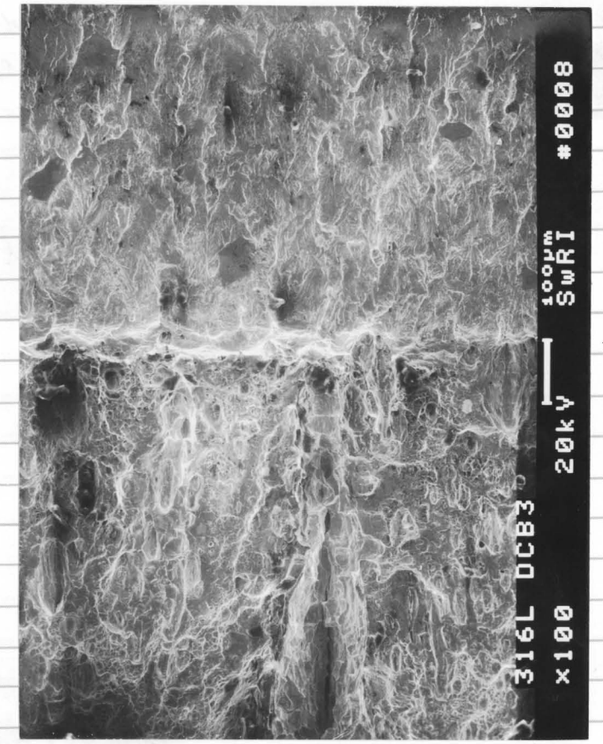
photo No: 95338



fatigue crack zone

photo No: 95339

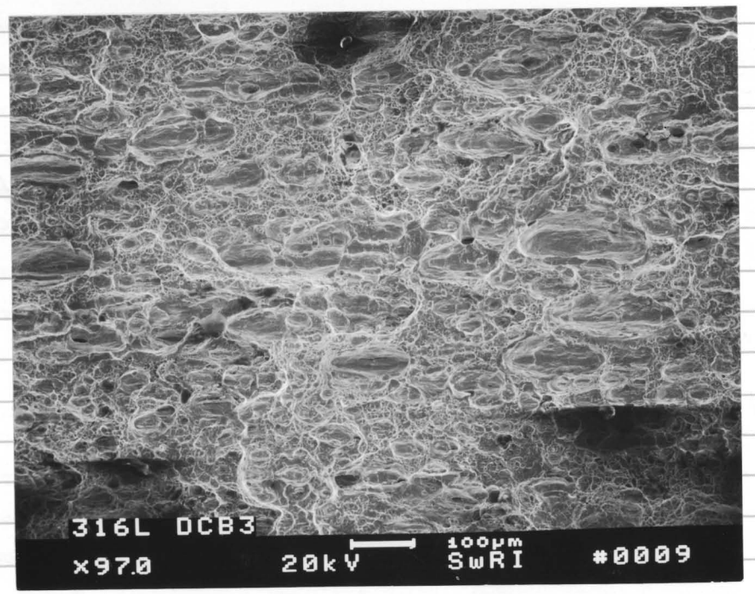
Pan
2/3/99



fatigue crack zone

tearing zone

photo No: 96340



tearing zone

photo No: 35341

2/3/99

C22 DCB 7 Stress Corrosion Cracking Test

Objective: Measure SCC growth rate in S-L orientation

Specimen: C22-7 Heat 227773101 machined by Metal Samples
Precrack length

Load: 30 ksi√in

Test Environment
Solution: 40 wt% $MgCl_2$
2500 g $MgCl_2$ Lot # 951190 + 250 ml H_2O
Temp: T = 110°C Hg thermometer C 96-377

Potentiostat: ESC 440 #2 channel #3

Reference: Fisher SCE 13-620-51 SN 3106339, 30% $MgCl_2$
Counter Electrode: Pt Flag

Data File: C22DCB7a using Labview

Test started: 11:25 am 2/3/99
Test Restarted: 8:26 am 2/5/99 Data file C22DCB7b
Labview stopped at an accumulated time of 2,088,554 sec.
Test stopped: 2:30 pm 2/10/99 No crack advance observed visually.
Test Restarted: 4:00 pm 2/11/99 Data File C22DCB7c
Test Restarted: 8:25 am 3/1/99 Data File C22DCB7d
Test stopped 2:30 pm 3/9/99 No crack advance observed visually
Test Restarted 5:15 pm 2/10/99 Data File C22DCB7e
stopped 9:15 am 4/14/99 No main crack advance but other cracks observed in the test specimen.
Test Restarted 5:02 pm 4/14/99 Data File C22DCB7f
*Labview stopped at an accumulated time of 325,078 sec (or 90.3 hrs).
Test Restarted 8:10 am 4/19/99 Data File C22DCB7g.
stopped 2:20 pm 5/17/99 No main crack advance.
Test Restarted 3:10 pm 5/19/99 Data File C22DCB7h.
*Labview stopped at an accumulated time of 1,599,941 sec.
Test Restarted 8:20 am 6/7/99 Data File C22DCB7i
< continued P 1697

6/7/99

316L DCB1 Stress Corrosion Cracking Test

Continued from Page 101.

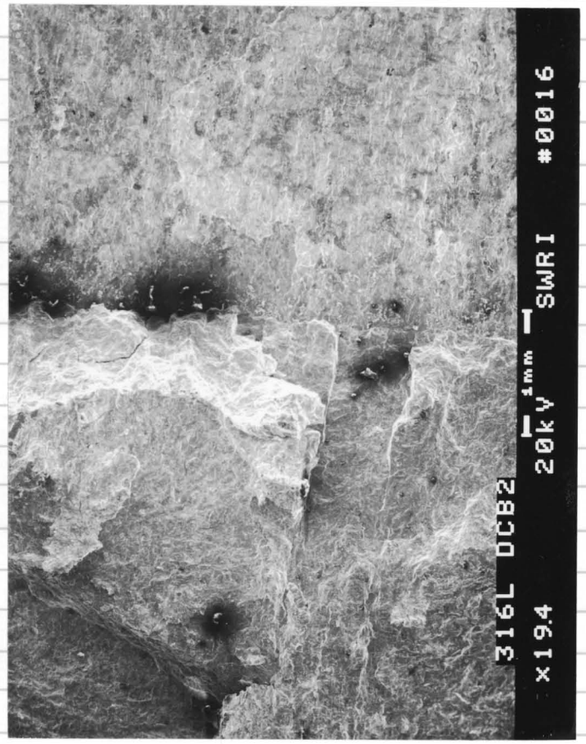
Test Restarted	4:00 pm	2/11/99	Data File 316LDCB1h
Test Restarted	8:25 am	3/1/99	Data File 316LDCB1i
* LabView stopped at an accumulated time of 1,302,471 sec.			
Test Stopped	2:30 pm	3/9/99	No crack advance observed visually
Test Restarted	5:15 pm	3/10/99	Data File 316LDCB1j
Stopped	9:15 am	4/14/99	No crack advanced observed
Test Restarted	4:26 pm	4/14/99	Data File 316LDCB1K
* LabView stopped at an accumulated time of 325,078 sec (or 90.3 hrs).			
Test Restarted	8:10 am	4/19/99	Data File 316LDCB1L
stopped	2:20 pm	5/17/99	No crack advance observed.
Test Restarted	3:10 pm	5/19/99	Data File 316DCB1m
* LabView stopped at an accumulated time of 1,599,941 sec.			
Test Restarted	8:20 am	6/7/99	Data File 316DCB1n
Stopped	2:23 pm	7/2/99	Δt = 2,182,178 sec No crack growth observed
Test Restarted	5:15 pm	7/7/99	Data File 316DCB1O
Stopped	9:20 am	8/9/99	Δt = 2,820,230 sec.
Test Restarted	4:05 pm	8/11/99	Data File 316DCB1P
Restarted	10:10 am	8/24/99	Δt = 1,079,670 sec Data File 316DCB1 Q
Stopped	10:40 am	9/29/99	Δt = 3,112,600 sec no crack advance
Test Restarted	1:15 pm	9/29/99	Data File 316DCB1r
* LabView stopped at an accumulated time of 1,150,745 sec.			
Test Restarted	2:00 pm	10/14/99	Data File 316DCB1S
Stopped	9:50 am	10/28/99	Δt = 1,195,500 sec no crack advance
Test Restarted	11:53 am	10/28/99	Data File 316DCB1t
Stopped	10:13 a.m	11/19/99	Δt = 1,898,700 sec no crack advance
Test Restarted	3:30 pm	11/19/99	Data File 316DCB1u
* LabView stopped at an accumulated time of 1,026,860 sec.			
Test Restarted	10:15 a.m	12/2/99	Data File 316DCB1V
Stopped	2:00 pm	12/21/99	Δt = 1,656,350 sec no crack advance

Test Finished.

Jimmy Pan
12/21/99

Fracture Surface of 316L DCB 2 Specimen

The DCB specimen of type 316L stainless steel was tested in 40 wt.% $MgCl_2$ at 110°C for about 3 weeks. (page 103) SCC was observed after two weeks testing. No further SCC was observed after three weeks testing, but extensive growth of secondary cracks in the arms of the specimen was detected and the loading wedge became loose. Fractographic examination showed typical of transgranular SCC.



fatigue crack area

Chevron notch

SCC area

photo No: 95432

Jimmy Pan
2/12/99

Fatigue precrack area:

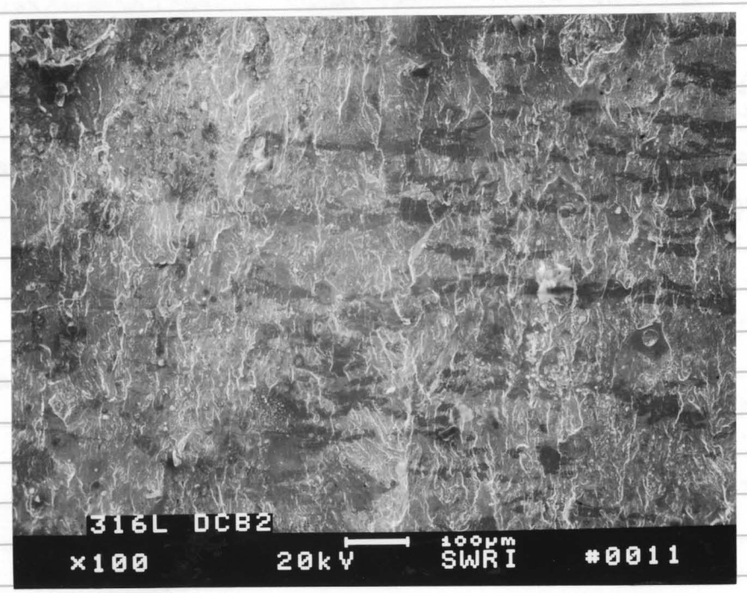


Photo No: 95428

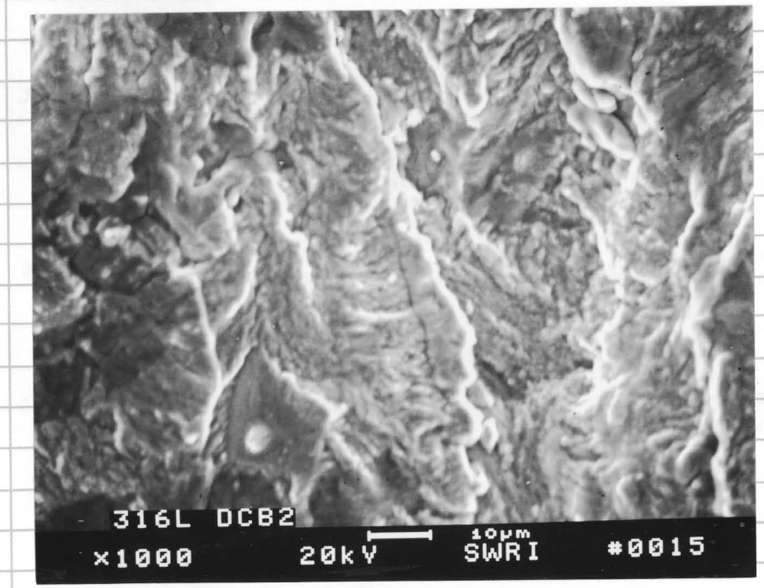


Photo No: 95431

3/12/99

Transgranular SCC area:

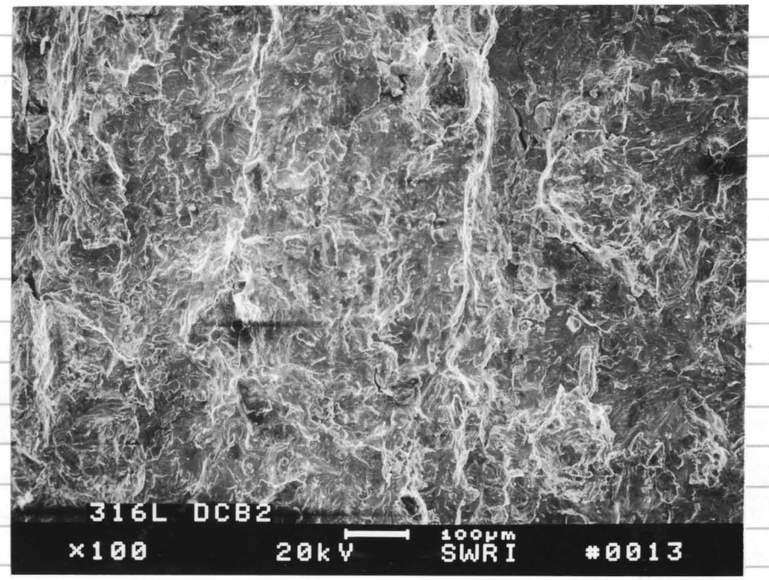


Photo No: 95429

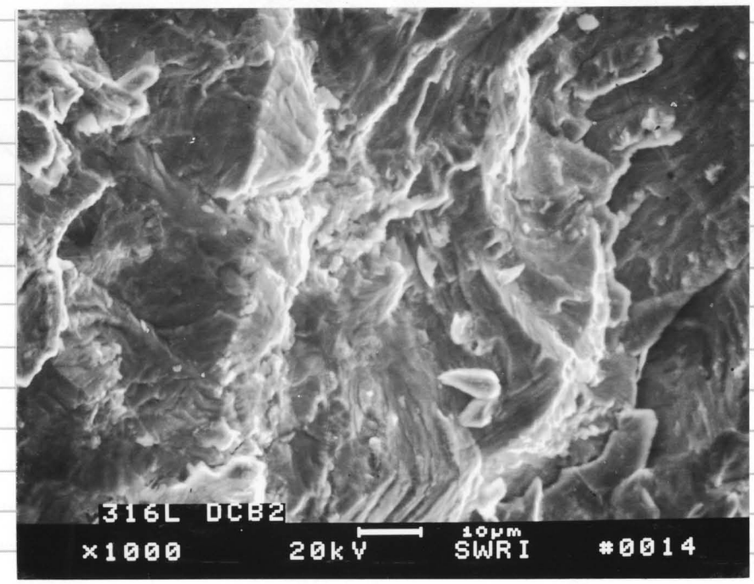


Photo No: 95430

3/12/99

Initial Loading of 316L-6 DCB specimen

316L-6

double cant beam stress formula

k=	20	(ksi in^0.5)	SIF
p=	0.355	(kips)	load
x=	0.25	(in)	front face to load line
h=	0.5	(in)	arm height
b=	0.376	(in)	thickness
bn=	0.225	(in)	web (net thickness on side groove)
a=	1.2749	(in)	crack length(1.1659+.109)

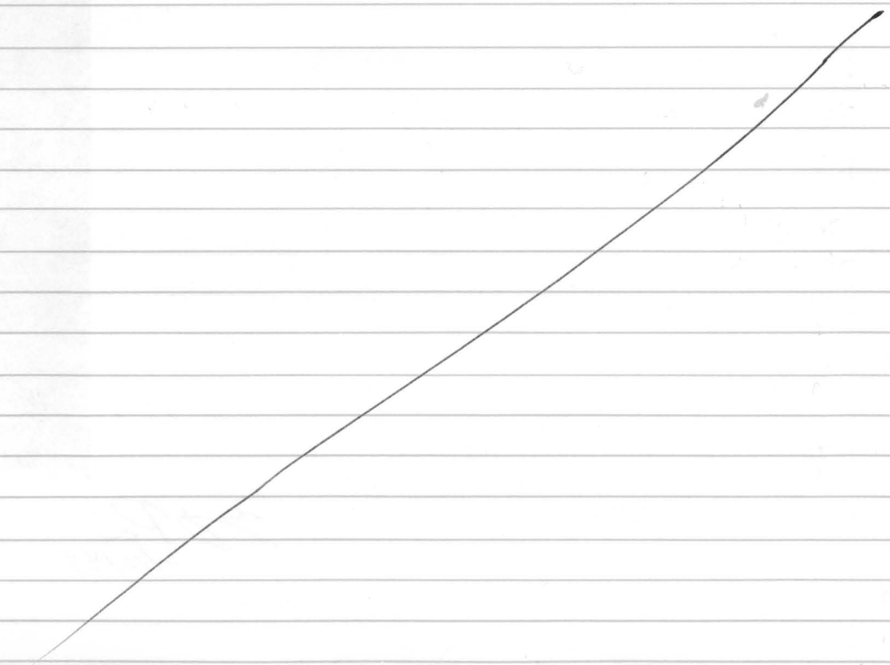
K/P	EvB/P(FRONT FACE)
56.7273	158.6257

P/K
0.017628

FOR K---MULTIPLY K/P TIMES LOAD (KIPS) ie... 20.0020458 KSI IN^0.5
FOR P---MULTIPLY P/K TIMES STRESS (KSI) ie... 0.35256394 KIPS
MULTIPLY EVB/P TIMES P AND DEVIDE BY B*MOD TO GET COMPLIANCE (V)

The initial wedge loading of 316L-6 dcb specimen is 353 lb, which gives a K_I value of 20 ksi$\sqrt{in}$.

Yijie Pan
3/5/99



SEM Micrographs of Precrack of 316L-6 DCB Specimen

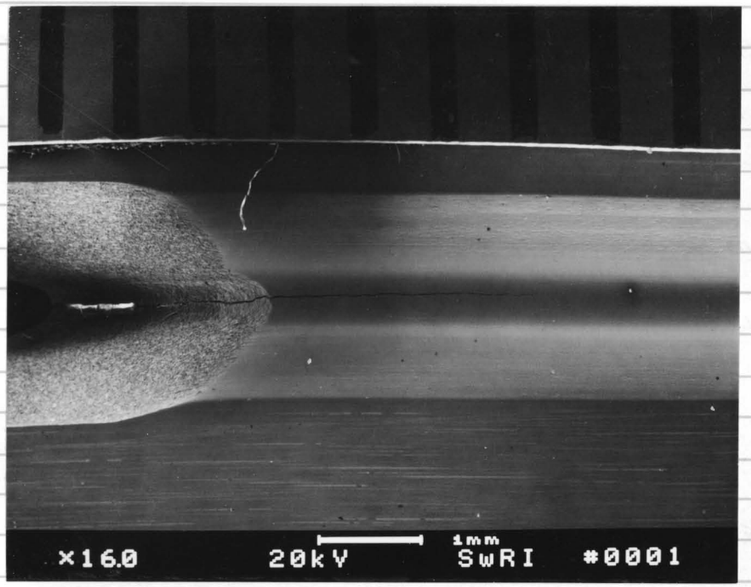


photo No. 95834

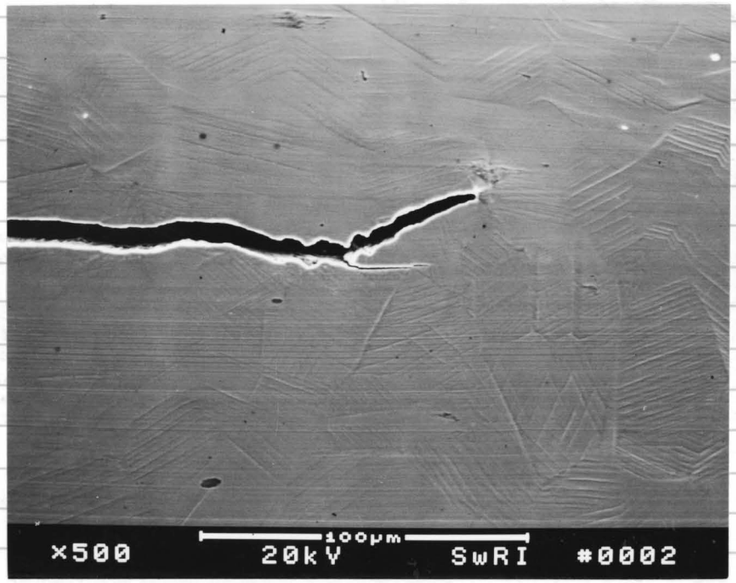


photo No. 95835

Yijie Pan
3/10/99

316L DCB6 Stress Corrosion Cracking Test (O.C.)

Objective: Measure SCC growth rate under open circuit condition

Specimen 316L-6 Heat P80746 machined by Metal Samples
precrack length 0.109" (visual)

Load 20 ksi $\sqrt{in}$

Test Environment (under open circuit conditions)
Solution: 30 Wt% $MgCl_2$
1281.1 g $MgCl_2 \cdot 6H_2O$ Lot # 985283 + 718.9 g H_2O
Temp.: T = 110°C Hg thermometer ~~S/N 183305~~ C 96-833 ~~3/11/99~~

Potentiostat ESC 440 #2 Channel #5

Reference FISHER SCE 13-620-51 S/N 9214074

Counter Electrode Pt Flag

Data File 316LDCB6 using Labview

Test Started	10:50 am	3/11/99	
Stopped	10:00 am	3/12/99	ΔT = 83260 sec -0.33 V
Restarted	10:20 am	3/12/99	No crack advance Data File 316dcb6b -0.35 V → -0.33 V
Stopped	9:25 am	3/13/99	ΔT = 83830 sec -0.33 V
Restarted	11:23 am	3/15/99	Crack advance observed both main crack and transverse cracks Data File 316dcb6c
stopped	11:30 am	3/16/99	ΔT = 87540 sec -0.33 V
Restarted	1:45 pm	3/16/99	Crack advance only for main crack Data File 316dcb6d
Stopped	10:50 am	3/17/99	ΔT = 77,000 sec -0.33 V

Test finished and specimen to be broken open for crack length measurement on the fracture surface.

3/17/99

SEM Micrographs of Cracks in 316LDCB6 Disassembly on 3/13/99

1. Main Crack

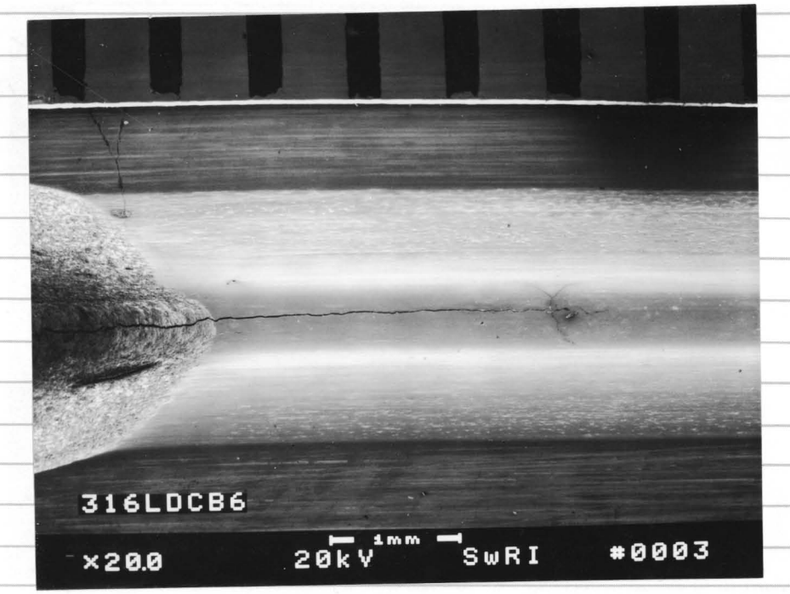


photo No 95878

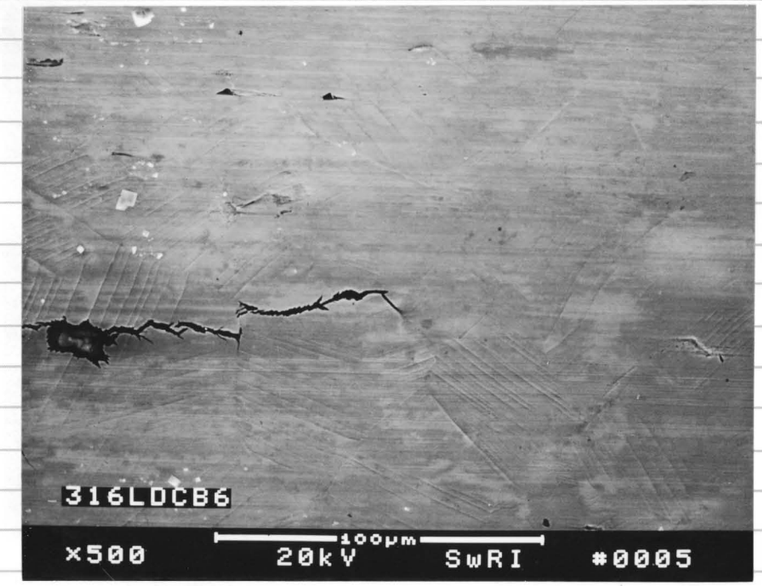


photo No. 95879

3/14/99

2. Transverse Cracks

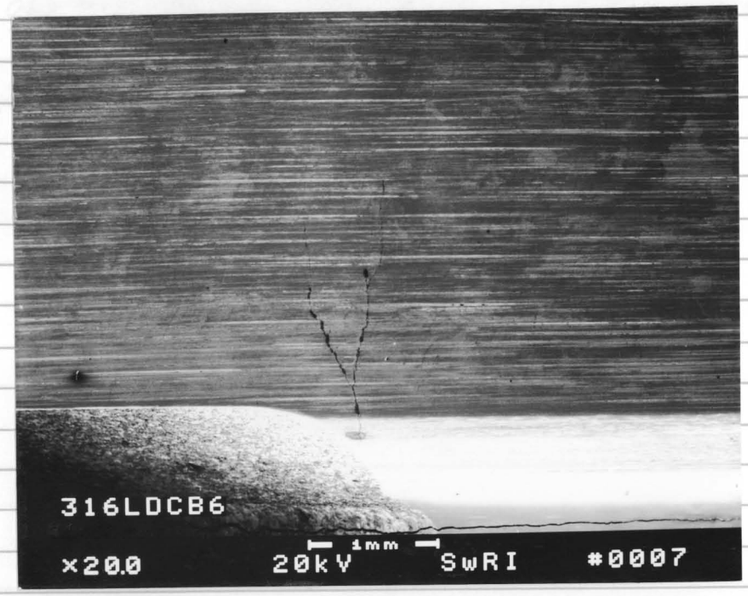


photo No. 95881

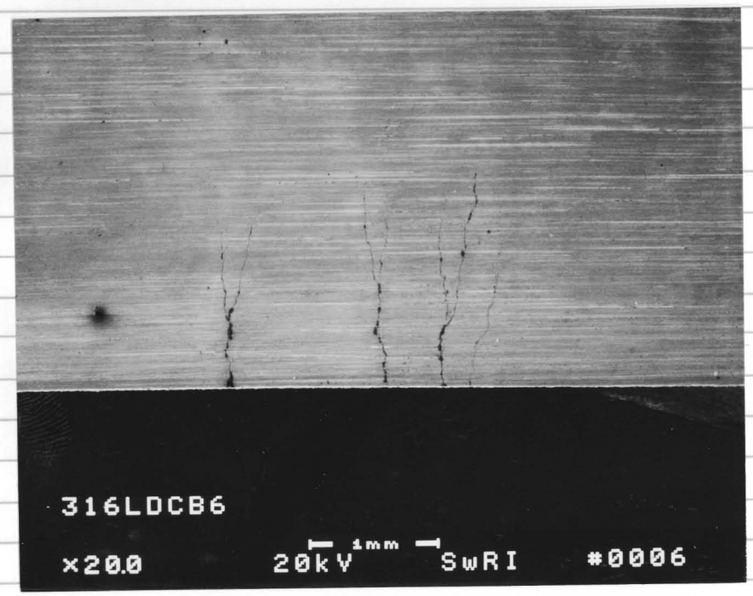


photo No. 95880

Yi Pan
3/14/99

SEM Micrographs of Cracks in 316LDCB6 Dissembly on 3/16/99

1. Main Crack

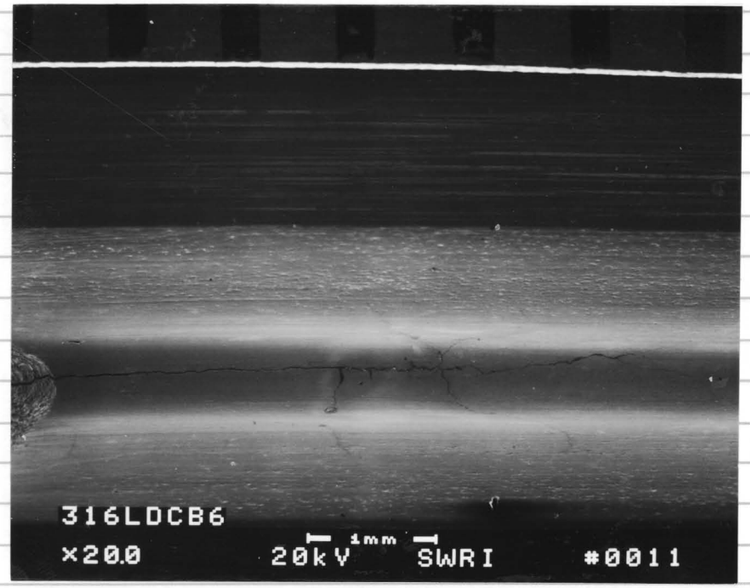


photo No. 95971

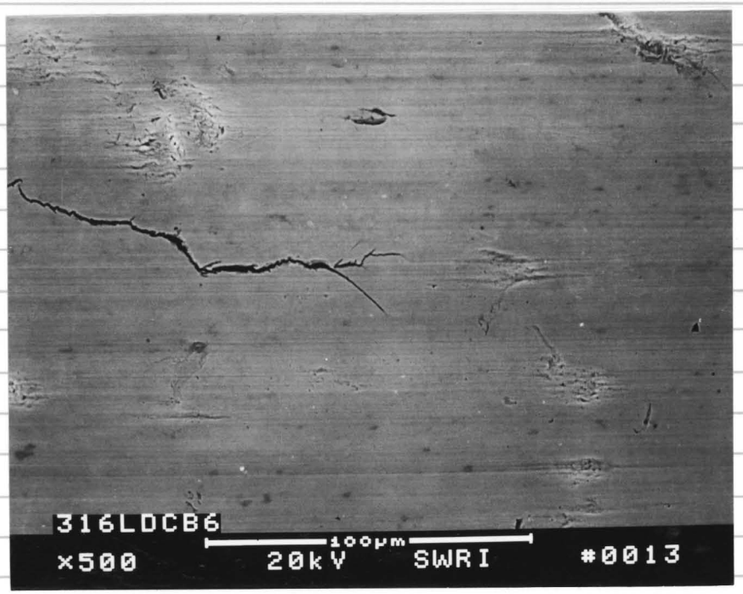


photo No. 95973

Yi Pan
3/16/99

2. Main crack branching at the precrack tip.

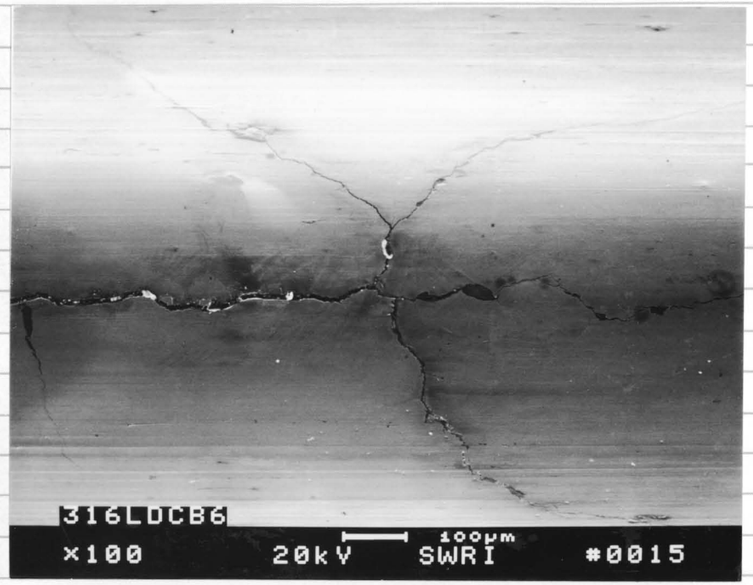


photo No. 95975

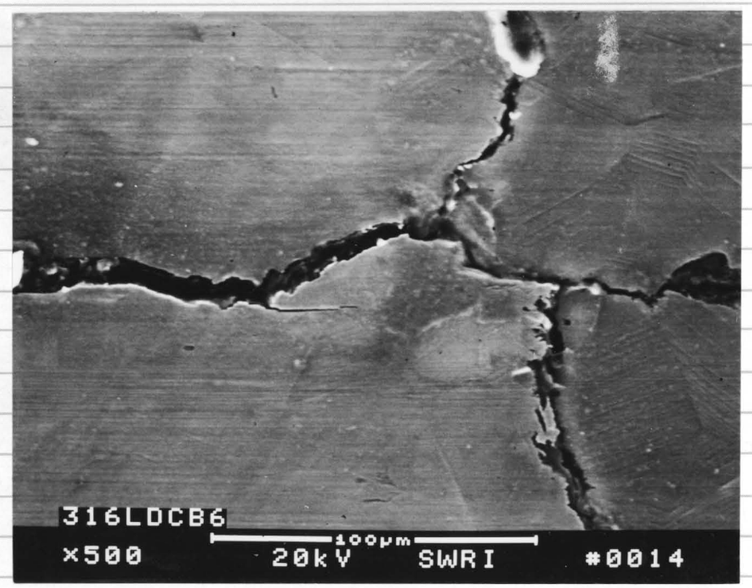


photo No. 95974

Yijun Pan
3/16/99

3. Transverse Crack

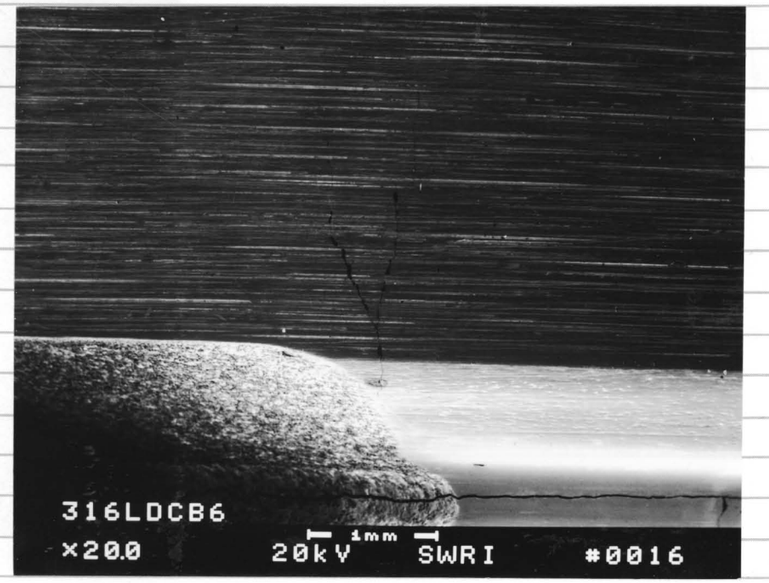


photo No. 95976

Yijun Pan
3/16/99

SEM Micrographs of Cracks in 316LDCB6 Disassembly on 3/17/99

1. Main Crack

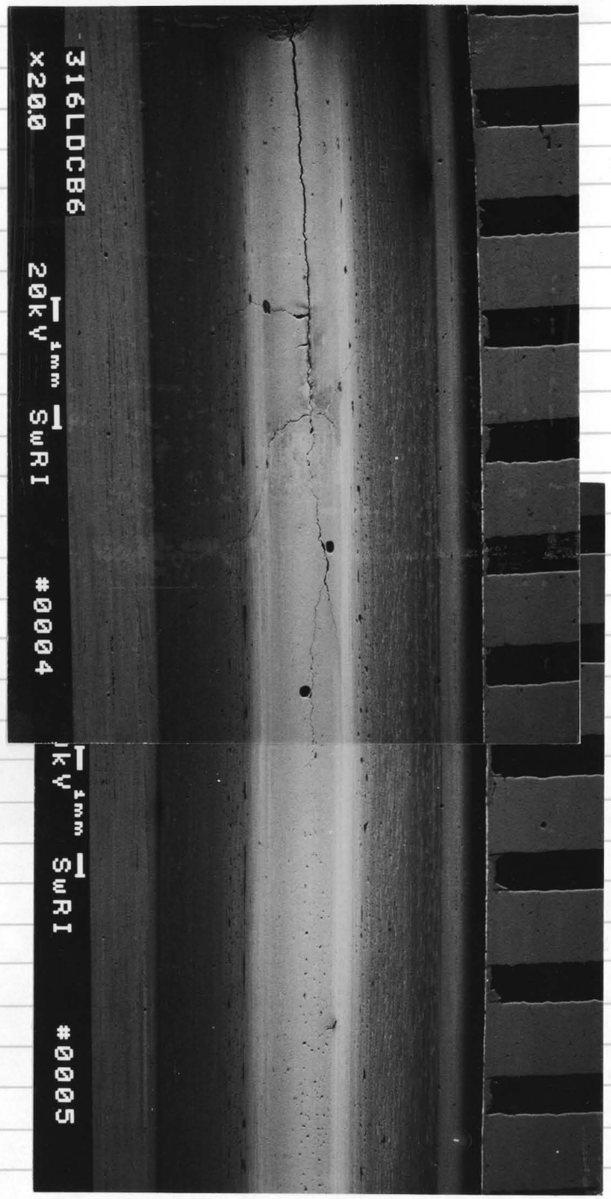


Photo No. 95943

Photo No. 95944

Yijun Pan
3/18/99

1a Main Crack Tip

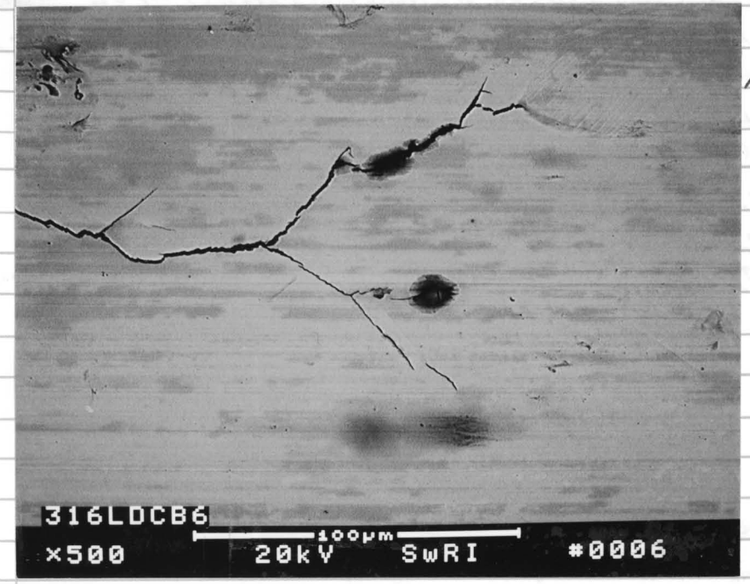


Photo No. 95945

2. Transverse Crack

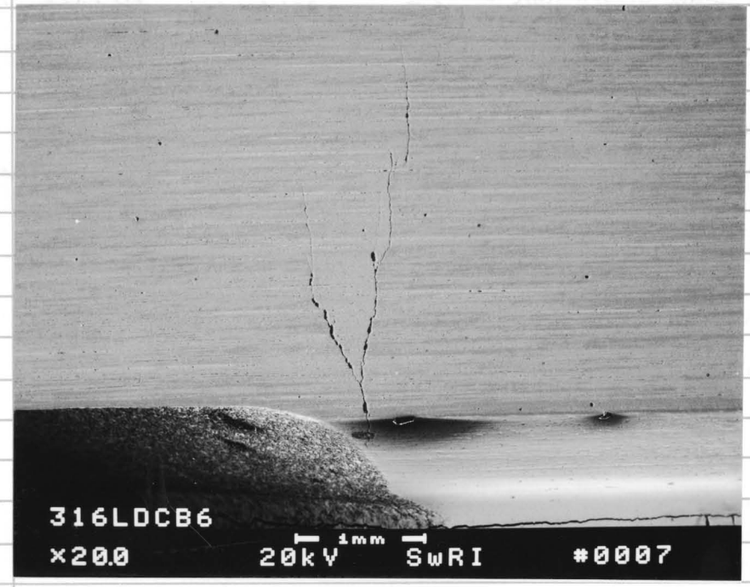


Photo No. 95946

Yijun Pan
3/18/99

Crack Length Measurement and Crack Growth Rate Calculation for 316L DCB 6

1. Crack length measured by a Nikon OPTIPHOT-POL microscope at 200X. The unit length of the eyepiece scale is 5 μm.

Test Duration ΔT (sec)	Crack Advance (unit / μm)	Crack Growth Rate (m/s)	
83,830	109 / 545	6.50×10^{-9}	
87,540	280 / 1,400	1.60×10^{-8}	
77,000	272 / 1,360	1.77×10^{-8}	(Max)

Z. Pan
3/18/99

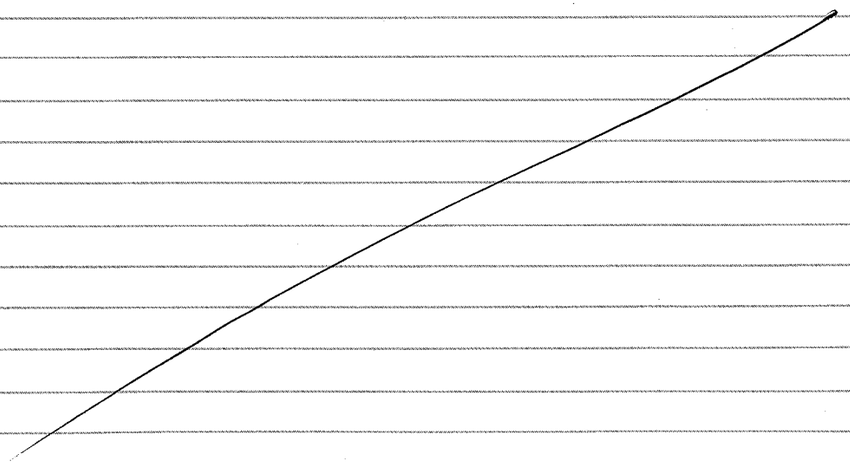
2. Average crack growth rate calculation:

- Cumulative test time (Σt) = ~~3,300,980~~ 331,630 secs

- Cumulative crack advance ($\Sigma \ell$) = 3,305 μm

- Ave. Crack Growth Rate = $\frac{\Sigma \ell}{\Sigma t} = \frac{3,305\ \mu m}{331,630\ s} = 9.97 \times 10^{-9}$ m/s

Z. Pan
5/11/99



316L DCB 5 Stress Corrosion Cracking Test (−340 mV$_{SCE}$)

Objective: Measure SCC growth rate under potential control with an applied potential of −340 mV$_{SCE}$.

Specimen: 316L-5 Heat P80746 machined by Metal Samples
Precrack length 0.135" (Visual)

Load: 20 Ksi$\sqrt{in}$

Test Environment:
Solution: 30 wt% $MgCl_2$
Temp.: T = 110°C Hg thermometer C96-833

Potentiostat: ESC 440 #2 channel #5

Reference: FISHER SCE 13-620-51 SN 7030126

Counter Electrode: 2"x2" Pt Flag

Data File: 316LDCB5 using Labview

Test Started	4:10 pm	3/23/99	V = −0.343 V
Stopped	2:55 pm	3/25/99	ΔT = 167,450 sec. No crack advance.
Restarted	3:57 pm	3/25/99	Data File 316dcb56 V = −0.343V
Stopped	10:22 am	3/29/99	ΔT = 325,500 sec No crack advance.
Restarted	10:45 am	3/29/99	Data File 316dcb5c V = −0.343V
Stopped	1:05 pm	4/2/99	ΔT = 354,000 sec Crack growth observed on opposite side.
Restarted	3:35 pm	4/2/99	Data File 316dcb5d V = −0.343V
Stopped	1:12 pm	4/12/99	ΔT = 853,400 sec crack growth observed on both sides
Restarted	4:15 pm	4/12/99	Data File 316dcb5e
* Labview stopped at an accumulated time of 498,712 sec (or 138.5 hrs), but actual duration was about 160 hrs.			
Restarted	8:10 am	4/19/99	Data File 316dcb5f.
Stopped	11:45 am	4/19/99	ΔT = 12,800 sec no crack advance observed.
Restarted	12:15 pm	4/19/99	Data File 316dcb59
Stopped	1:55 pm	4/23/99	ΔT = 351,480 sec. no crack advance observed.
Restarted	2:58 pm	4/23/99	Data File 316dcb5h
Stopped	1:56 pm	5/3/99	ΔT = 860,350 sec specimen broken at the arm. Crack advance observed on both sides.
Test Finished	Z. Pan	5/4/99	

SEM Micrographs of Precrack of 316L-5 DCB Specimen

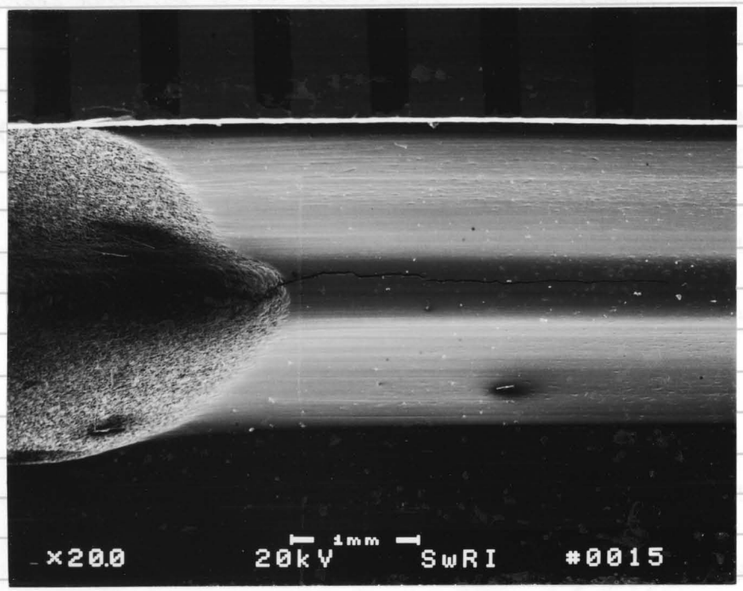


photo No. 96106

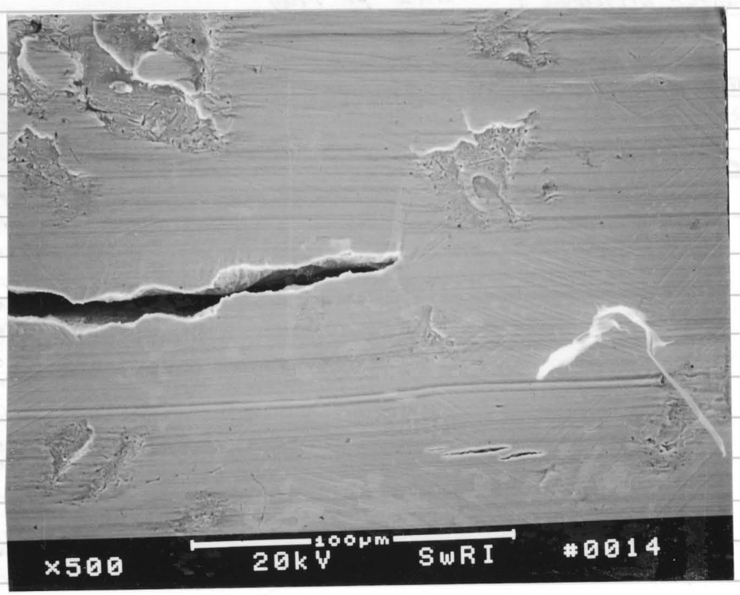


photo No. 96107

Bijy Pan
3/24/99

SEM Micrographs of Crack Advance in 316LDCB5 Disassembly on 4/2/99

1. Engraved side with Test Sample ID: No crack advance observed.

photo No. 96252

2. Crack tip of the opposite side with a significant amount of crack advance.

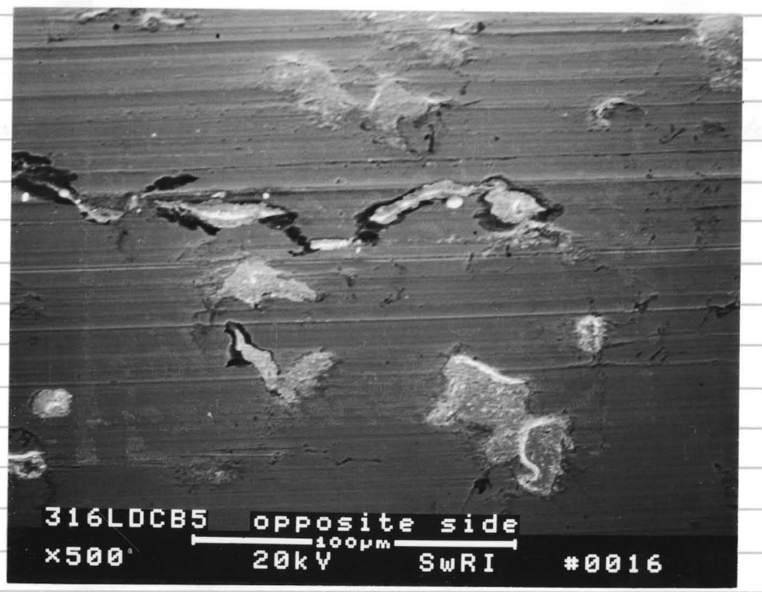


photo No. 96270

Bijy Pan
4/5/99

2a Main crack of the opposite side

Photo No 96253

photo No. 96271

Yijing Pan
4/5/99

2b. Enlarged view of the crack front

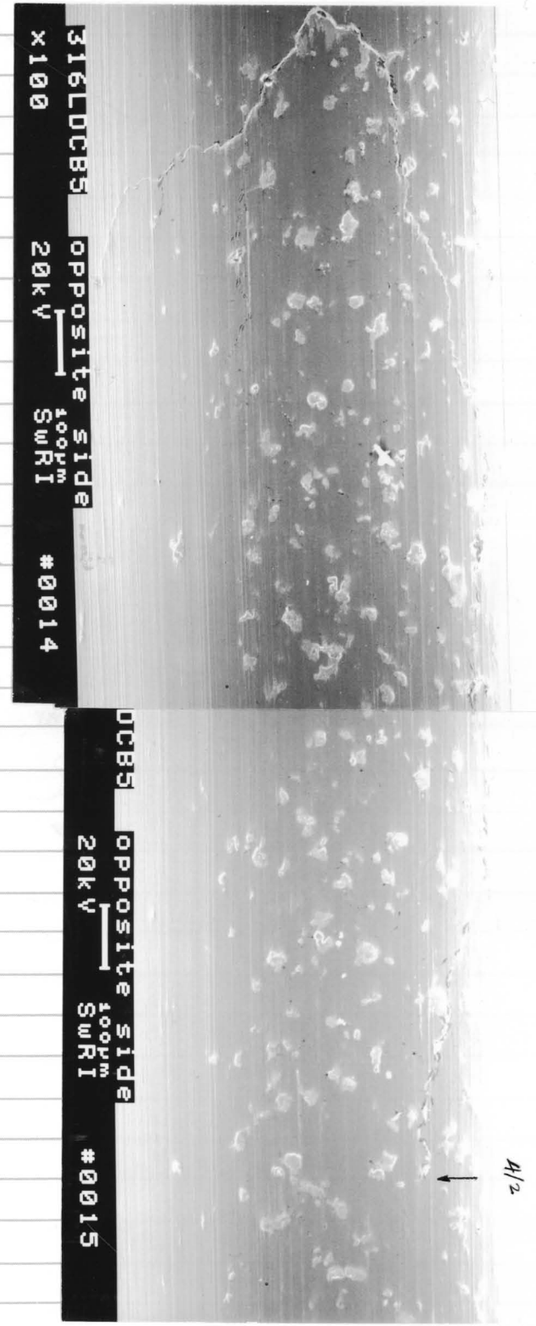


Photo No. 96254

photo No. 96255

Yijing Pan
4/5/99

SEM Micrographs of Cracks in 316LDCB5 Disassembly on 4/12/99

1. Crack tip of the engraved side with test ID.

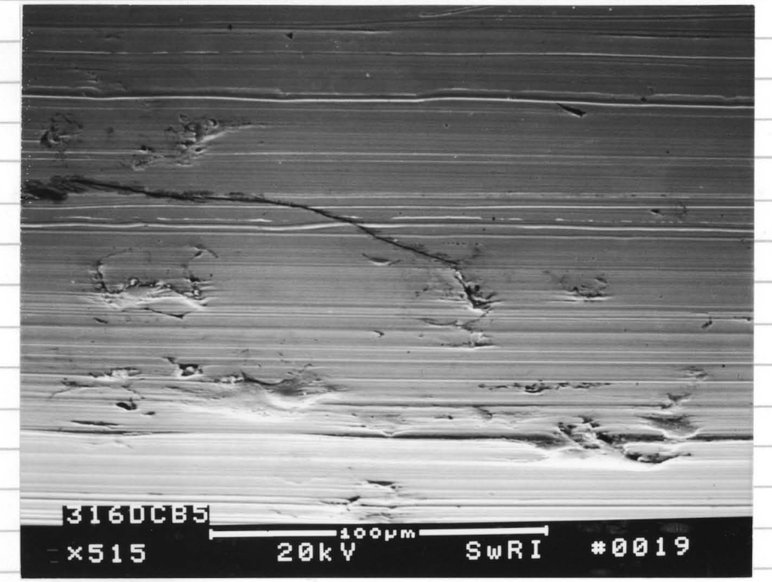


Photo No: 96367

Note: Crack advanced observed with a length of 4,790 µm measured under an optical microscope @ 100x

MJ Pan
4/13/99.

2. Crack advance on the opposite side following the crack of 4/2/99 disassembly.

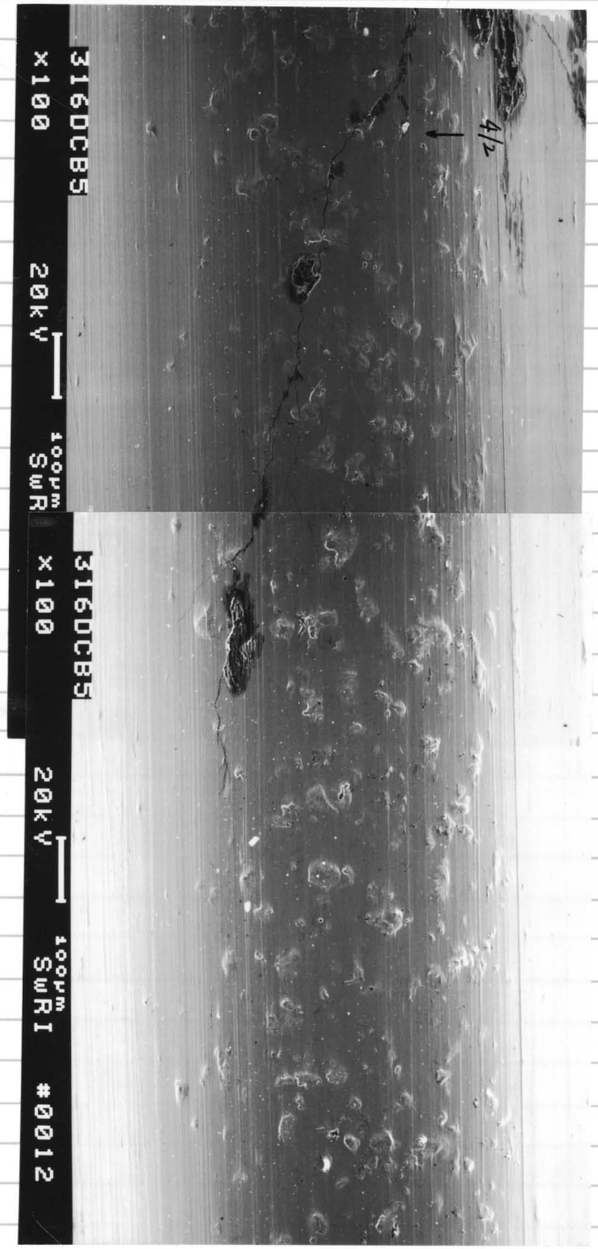


photo No: 96359

Photo No: 96360

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4/13/99

2a Crack tip on the opposite side.

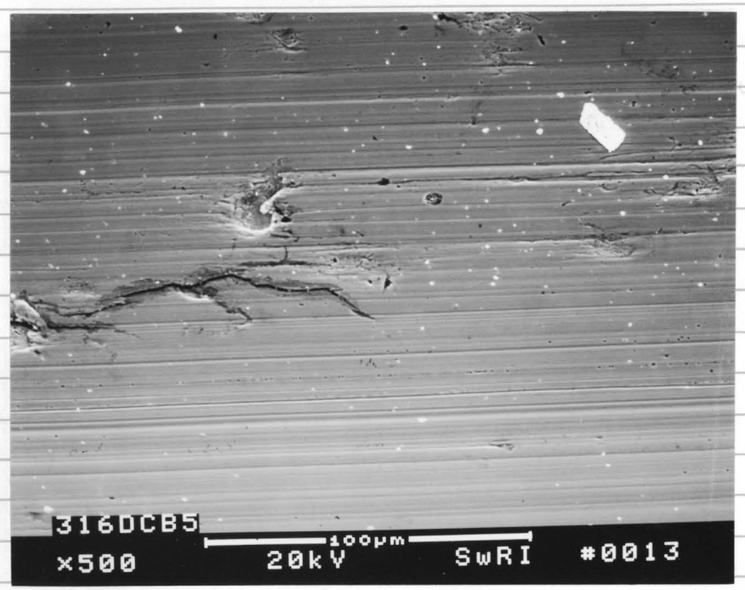


photo NO:
96361

3. Transverse cracks observed on the arm.

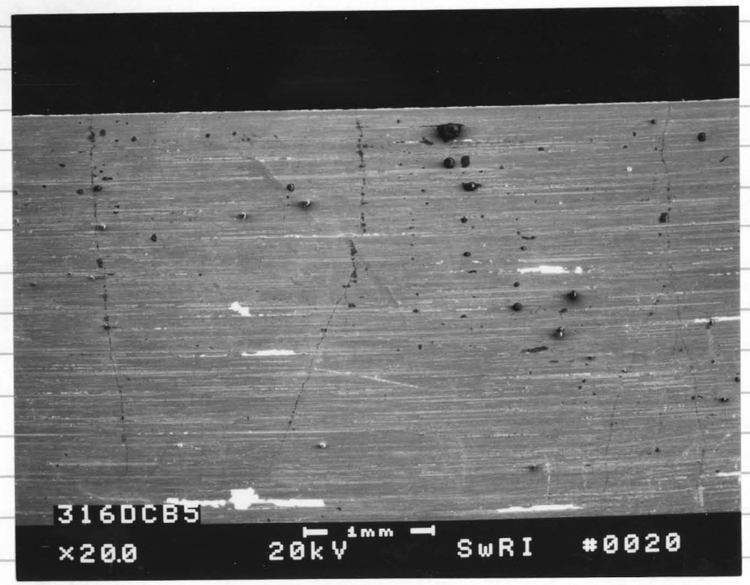


photo NO:
96368

Yijia Pan
4/13/99

C22DCB1 stress Corrosion Test

Continued from Page 102.

Test Stopped	9:15am	4/14/99	No crack advance observed
Test Restarted	4:26pm	4/14/99	Data File C22DCB1K
* Labview stopped at an accumulated time of 325,078 sec (or 90.3 hrs).			
Test Restarted	8:10 am	4/19/99	Data File C22DCB1L
stopped	2:20 pm	5/17/99	No crack advance observed.
Test Restarted	3:10 pm.	5/19/99	Data File C22DCB1M
* Labview stopped at an accumulated time of 1,599,941 sec.			
Test Restarted	8:20 am	6/7/99	Data File C22DCB1N
stopped	2:15 pm	7/2/99	Δt = 2,182,178 sec No Crack growth observed
Test Restarted	5:15pm	7/7/99	Data File C22DCB1O
stopped	9:20 am	8/9/99	Δt = 2,820,230 sec.
Test Restarted	4:05 pm	8/11/99	Data File C22DCB1P
Restarted	10:10 am	8/24/99	Δt = 1,079,670 sec Data File C22DCB1Q
Test Stopped	10:40 am	9/29/99	Δt = 3,112,990 sec no crack advance
Test Restarted	13:20 pm	9/29/99	Data File C22DCB1R
* Labview stopped at an accumulated time of 1,150,745 sec.			
Test Restarted	2:00 pm	10/14/99	Data File C22DCB1S
stopped	9:50 am	10/28/99	Δt = 1,195,500 sec no crack advance
Test Restarted	11:53 am	10/28/99	Data File C22DCB1T
Stopped	10:13 am	11/19/99	Δt = 1,898,700 sec no crack advance
Test Restarted	3:30 pm	11/19/99	Data File C22DCB1U
* Labview stopped at an accumulated time of 1,026,860 sec			
Test Restarted	10:15 am	12/2/99	Data File C22DCB1V
stopped	2:00 pm	12/21/99	Δt = 1,656,490 sec no crack advance.

Test Finished.

Yijia Pan
12/21/99

C22 ~~316L~~ DCB 2 Stress Corrosion Test

Continued from page ~~103~~ 104

Test Stopped	9:15 am	4/14/99	No crack advance, but grain boundary attack observed
Test Restarted	5:02 pm	4/14/99	Data File C22DCB2K
* LabView stopped at an accumulated time of 325,078 sec (or 90.3 hrs).			
Test Restarted	8:10 am	4/19/99	Data File C22DCB2L
stopped	2:20 pm	5/17/99	No main crack advance.
Test Restarted	3:10 pm	5/19/99	Data File C22DCB2M
* LabView stopped at an accumulated time of 1,599,941 sec.			
Test Restarted	8:20 am	6/7/99	Data File C22DCB2N
stopped	2:30 pm	7/2/99	Δt = 2,183,178 secs SEM photographs
Test Restarted	6:58 pm	7/7/99	Data File C22DCB2O
Stopped	9:40 a.m.	8/9/99	Δt = 2,818,010 sec
Test Restarted	4:52 p.m	8/11/99	Data File C22DCB2P
Restarted	10:10 am	8/24/99	Δt = 1,079,670 sec Data File C22DCB2R
Stopped	10:40 am	9/29/99	Δt = 3,113,500 sec no crack advance
Test Restarted	1:20 pm	9/29/99	Data File C22DCB2T
* LabView stopped at an accumulated time of 1,150,745 sec.			
Test Restarted	2:00 pm	10/14/99	Data File C22DCB2S
Stopped	9:50 am	10/28/99	Δt = 1,195,500 sec no crack advance
Test Restarted	11:27 am	10/28/99	Data File C22DCB2U
Stopped	10:20 am	11/19/99	Δt = 1,900,900 sec no crack advance
Test Restarted	3:00 pm	11/19/99	Data File C22DCB2U
* LabView stopped at an accumulated time of 1,026,860 sec			
Test Restarted	10:15 am	12/2/99	Data File C22DCB2V
Stopped	2:35 pm	12/21/99	Δt = 1,658,750 sec no crack advance.

Test Finished.

Yiji Pan
12/21/99

SEM Micrographs of the DCB specimens Disassembly on 4/14/99

1. C22DCB2 shows grain boundary attack, but no main crack advance.

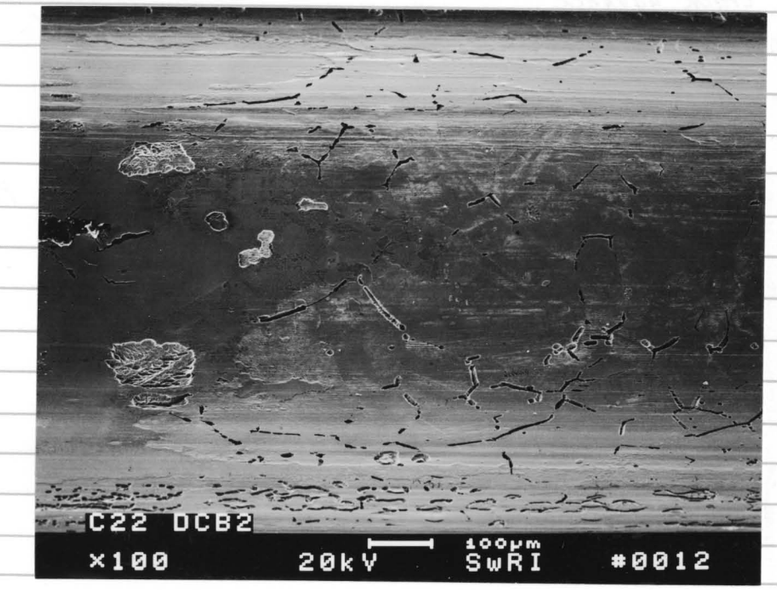


photo No: 96381

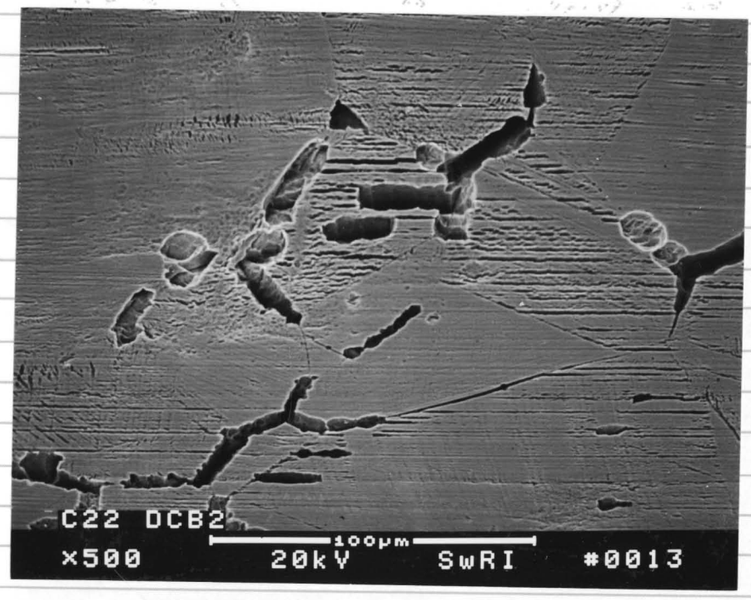


photo No: 96382

Yiji Pan
4/15/99

2. C22 DCB7 shows secondary cracks near the main crack, but no main crack advance.

2a. Main crack tip.

Photo No.: 96383

Mijo Pa
4/15/99

2b. Secondary cracks

Photo No: 96384

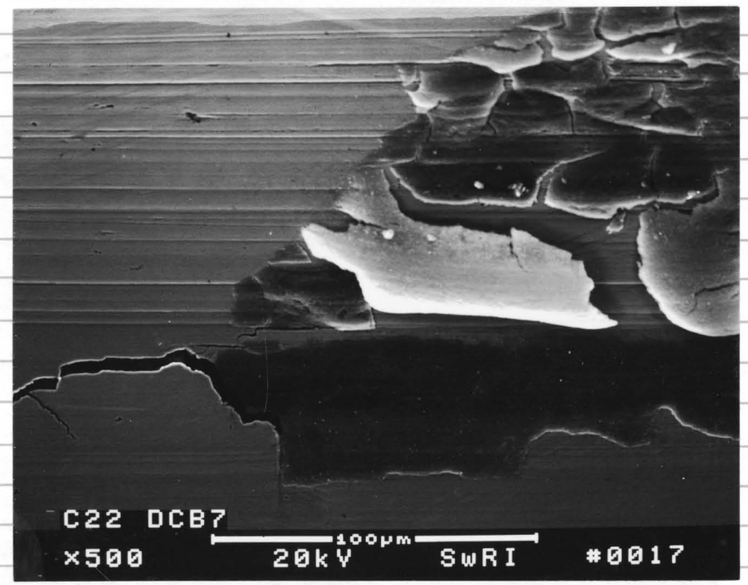


Photo No: 96385

Mijo Pa
4/15/99

Crack Length Measurement and Crack Growth Rate Calculation for 316L DCB 5

1. Crack length measured using a Nikon OPTIPHOT-POL microscope at 100x. The unit length of the exepiece scale is 10 μm.

Test Duration ΔT (sec)	Crack Advance (unit/μm) ID side	Opposite Side	Average	Crack Growth Rat (M/sec)
354,000	0	224/2,240	112/1,120	3.16×10^{-9}
853,400	479/4,790	102/1,020	290.5/2,905	3.40×10^{-9}
860,350	321/3,210	640/6,400	480.5/4,805	5.58×10^{-9} (Max.)

5/4/99

2. Average crack growth rate calculation:
   - Cumulative test time (Σt) = 3,500,980 sec.
   - Cumulative crack advance ($\Sigma \ell$) = 8,830 μm
   - Ave. Crack Growth Rate = $\frac{\Sigma \ell}{\Sigma t} = \frac{8,830\ \mu m}{3,500,980\ s} = 2.52 \times 10^{-9}\ m/s$

5/11/99

SEM Micrographs of the DCB Specimens Disassembly on 5/17/99

1. C22 DCB 2

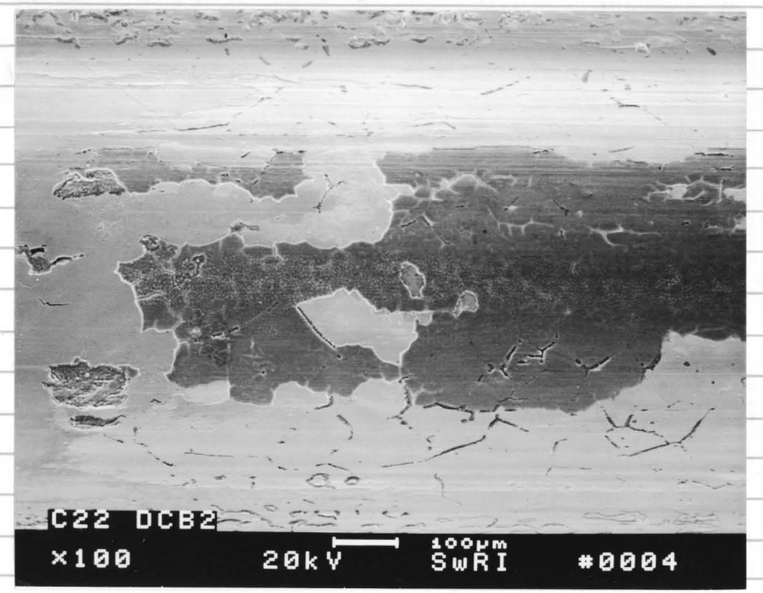


photo No: 96762

2. C22 DCB 7

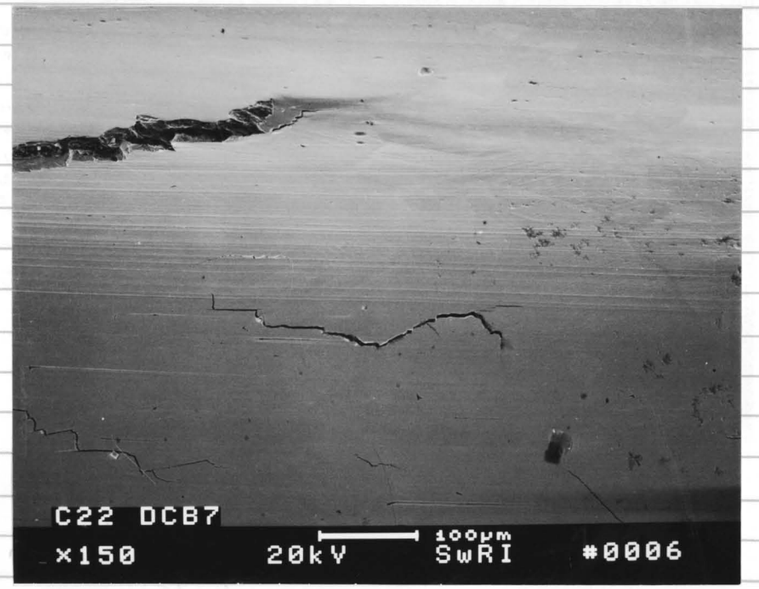


photo No: 96763

5/19/99

316L DCB 7 stress Corrosion Cracking Test (−360 mV$_{SCE}$)

Objective : Measure SCC growth rate under potential control with an applied potential of −360 mV$_{SCE}$.

Specimen: 316L-7 Heat P80746 machined by Metal Samples
precrack length 0.1075" (visual)

Load : 20 KSi $\sqrt{in}$

Test Environment:
Solution 30 wt% $MgCl_2$
Temp. T=110°C Hg thermometer C96-833

Potentiostat: ESC 440 #2 Channel #5

Reference : FISHER SCE 13-620-61 SN 7030126

Counter Electrode : 2"x2" Pt Flag

Data File 316LDCB7a using LabView

Test Started:	5:42 pm	6/14/99	
Stopped:	9:10 am	6/23/99	ΔT = 744,400 sec Crack growth observed
Restarted:	2:15 pm	6/23/99	Data File 316LDCB7b
Stopped:	2:25 pm	7/2/99	ΔT = 778,790 sec No crack growth observed
Restarted:	7:20 pm	7/7/99	Data File 316LDCB7C
Stopped:	11:20 am	7/19/99	specimen wire broken and crack growth observed

* Loading wedge became loose due to crack advance under open circuit conditions as a result of broken Ti wire.

Test Finished. 7/21/99

SEM Micrographs of Precrack of 316L-7 DCB Specimen

1. Side 1

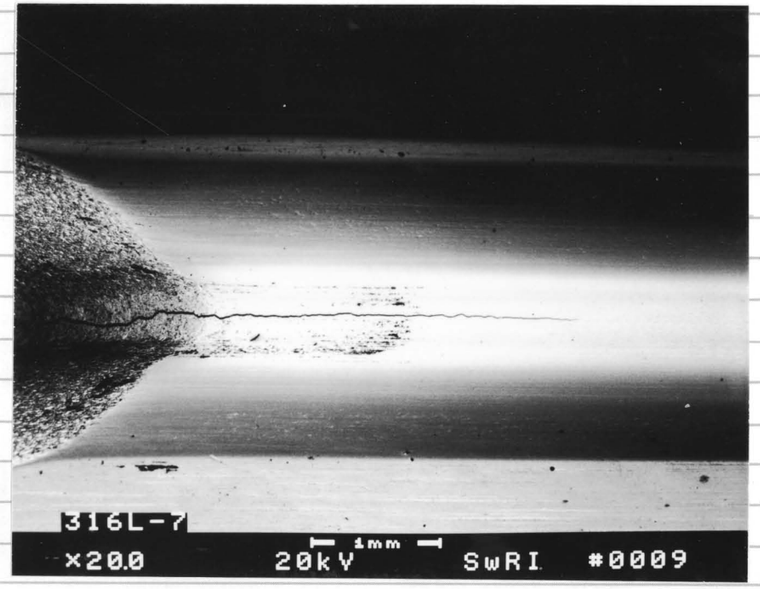


photo No. 97071

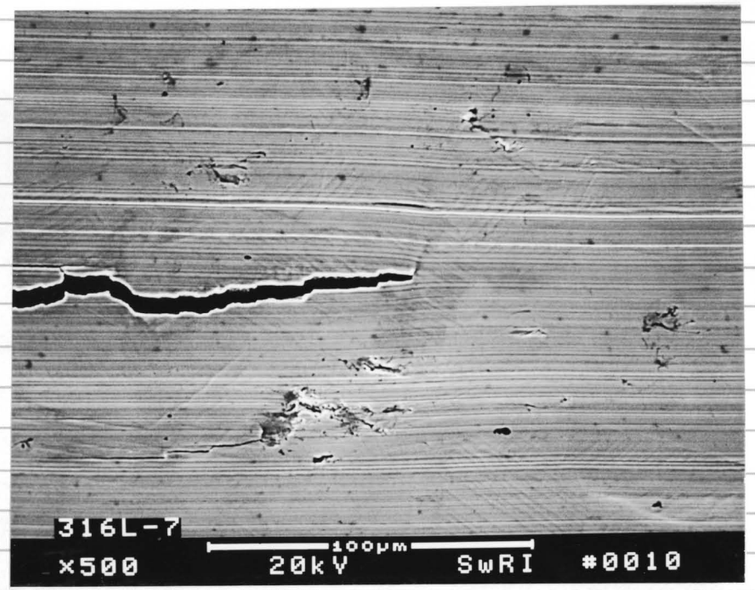


photo No. 97072

6/11/99

2. Side 2

photo No. 97073

photo No. 97074

YJ Pan
6/11/99

SEM Micrographs of Cracks in 316LDCB 7 Disassembly on 6/23/99

1. Crack tip of the engraved side

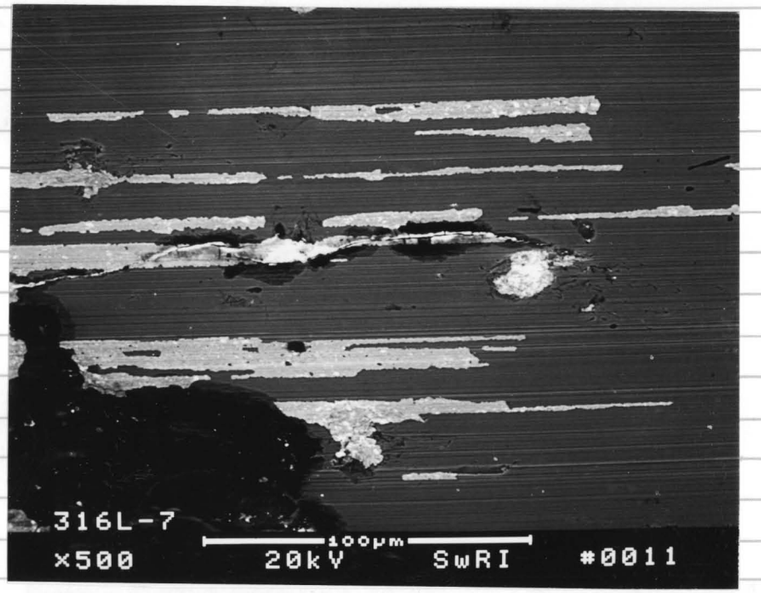


photo No. 97256

2. Crack tip of the opposite side

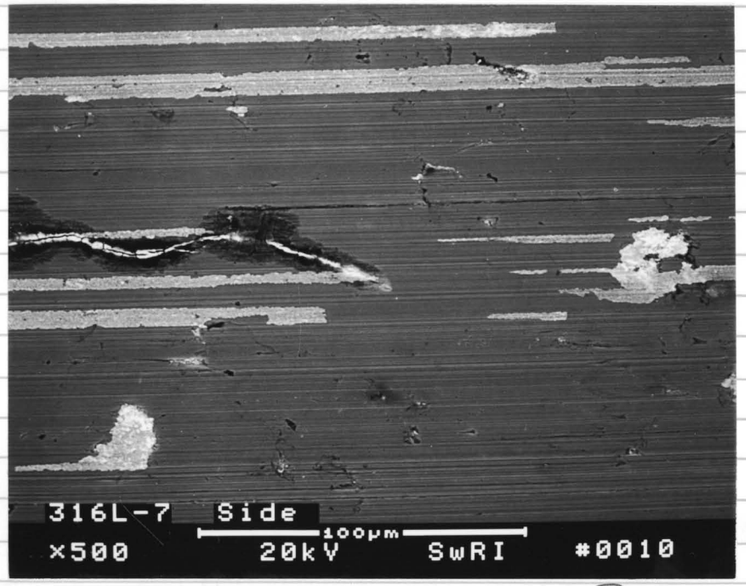


photo No. 97257

YJ Pan
6/24/99

SEM Micrographs of the C22 DCB specimens Disassembly on 7/2/99

1. C22 DCB 2 (the engraved side) shows surface damage.

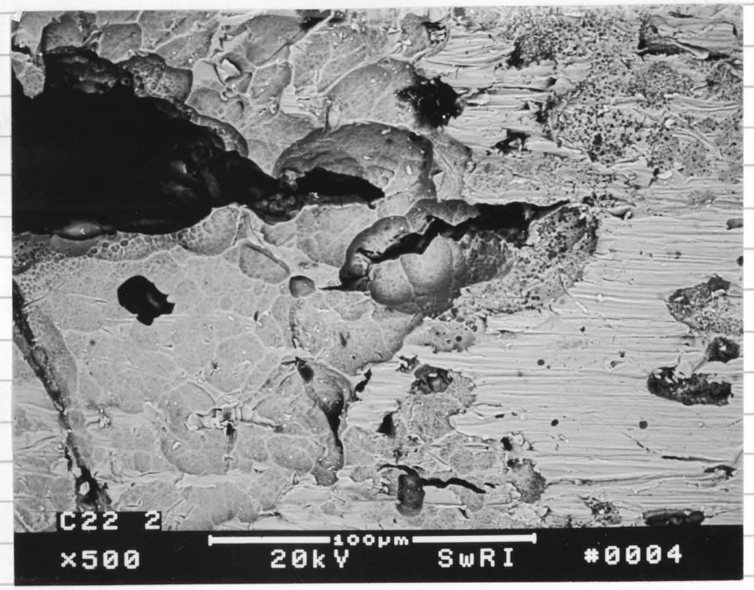


photo No. 97299

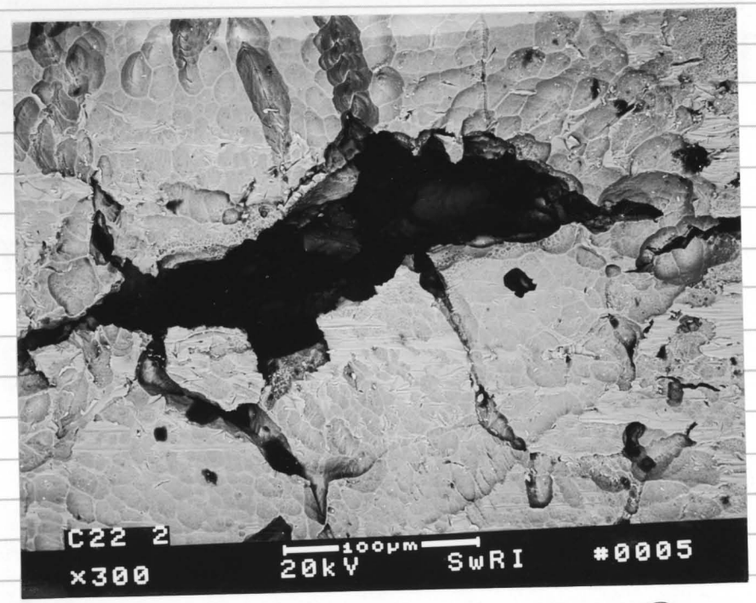


photo No. 97300

M Pa
7/6/99

16. C22 DCB 2 (the opposite side) shows surface damage and possible crack advance.

photo No. 97302

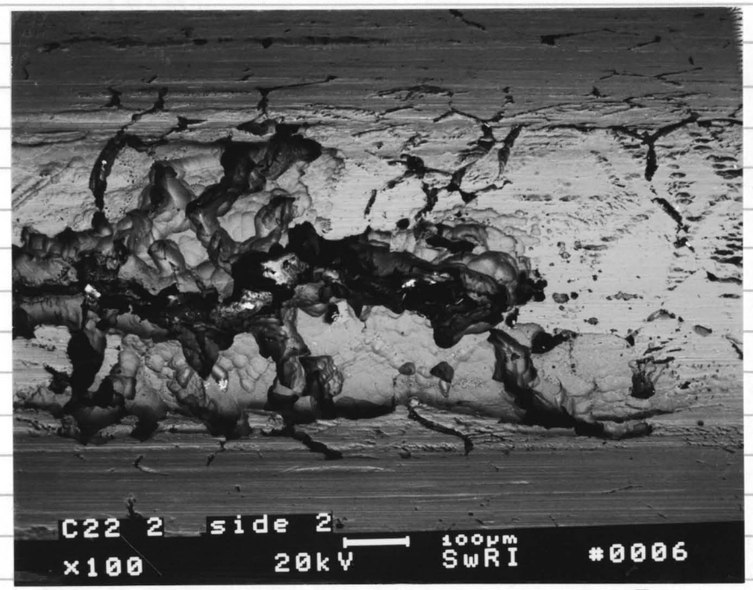


photo No. 97301

M Pa
7/6/99

2 C22DCB7

2a. engraved side

photo No. 97296

7/6/99

2b the opposite side shows possible crack advance

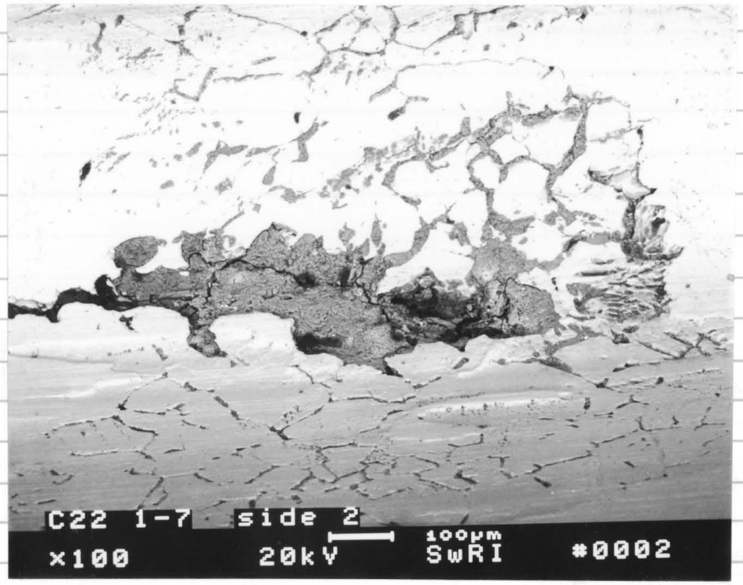


photo No. 97297

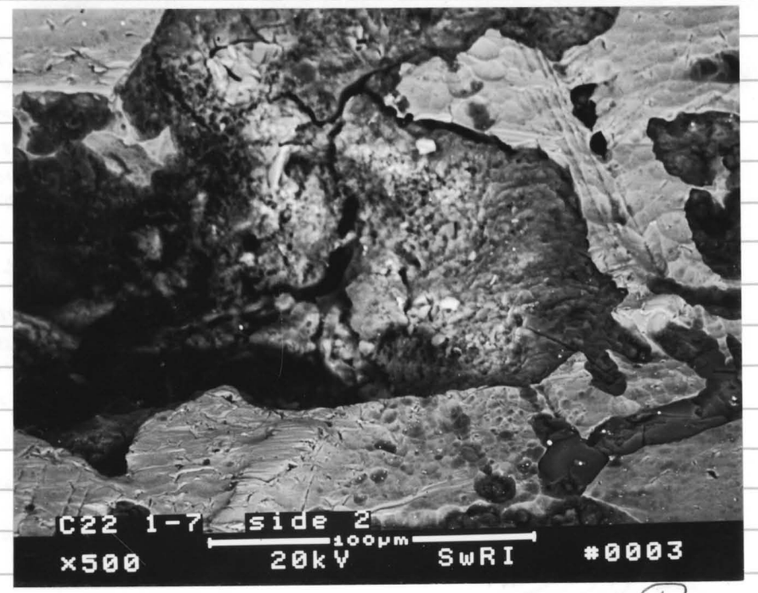


photo No. 97298

7/6/99

316LDCB8 Stress Corrosion Cracking Test (-380 mV$_{SCE}$)

Objective: Measure SCC growth rate under potentiostatic control with an applied potential of -380 mVSCE.

Specimen: 316L-8 Heat P80746 machined by Metal Samples
Precrack length 0.109" (Visual)

Load: 20 ksi $\sqrt{in}$

Test Environment:
Solution: 30 wt % $MgCl_2$
Temp. T = 110°C Hg thermometer C98-132

Potentiostat: ESC 440 #2 Channel #6

Reference: FISHER SCE 13-620-52 SN8210504

Counter Electrode: 2"x2" pt Flag

Data File 316LDCB8a using Labview

Test Started:	7:25 pm	7/2/99	Δt = 1,005,400 sec specimen wire broken and
Stopped:	10:42 am	7/19/99	Crack growth observed
Restarted	3:12 pm	7/20/99	Data File 316LDCB8b
Stopped	1:10 pm	7/22/99	Δt = 165,430 sec specimen wire broken.
Restarted	2:18 pm	7/23/99	Data File 316LDCB8c
Stopped	9:12 am	8/9/99	Δt = 1,537,130 sec Crack growth observed.
Restarted	3:27 pm	8/10/99	Data File 316LDCB8d
Restarted	10:10 am	8/24/99	Δt = 1,168,035 sec, no crack advance Data File 316LDCB8e
Stopped	4:07 pm	8/26/99	Δt = 194,320 sec, no crack advance
Restarted	4:42 pm	8/26/99	Data File 316LDCB8f
Stopped	9:05 am	9/20/99	Δt = 2,132,660 sec. no crack advance*

*Note: Direction of crack propagation became perpendicular to the main crack.

Test finished.

9/20/99

SEM Micrographs of Precrack of 316L DCB 8 specimen

1. Side 1

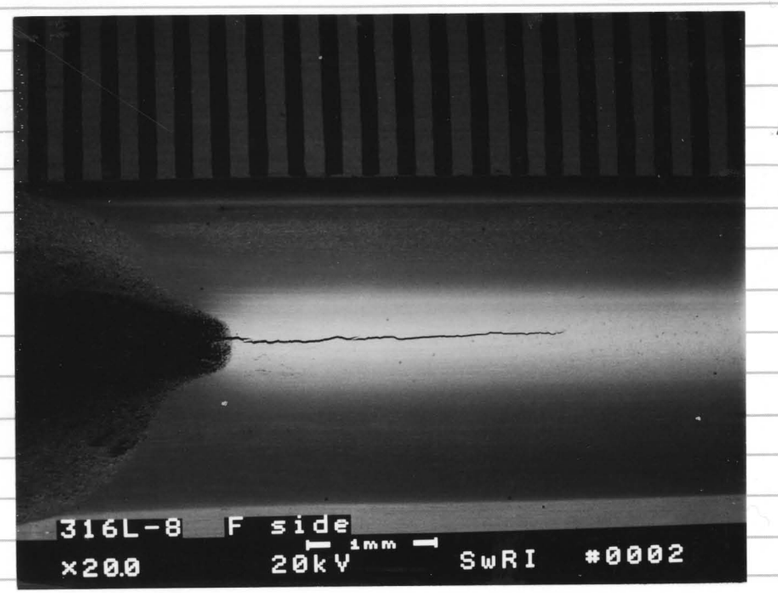


photo No 97159

photo No. 97160

9/1/99

2. Side 2

photo No. 97161

photo No. 97162

3/1/99

C22DCB7 Stress Corrosion Cracking Test

Continued from p127.

Test stopped	2:28 pm	7/2/99	Δt = 2,182,178 secs 564 photographs
Test Restarted	6:58 pm	7/7/99	Data File C22DCB7j
stopped	9:35 pm	8/9/99	Δt = 2,818,010 sec.
Test Restarted	4:16 pm	8/11/99	Data File C22DCB7k
Restarted	10:10 am	8/24/99	Δt = 1,079,670 sec Data File C22DCB7l
Stopped	10:40 am	9/29/99	Δt = 3,113,260 sec no crack advance Data File C22DCB7m
Test Restarted	1:20 pm	9/29/99	

* LabView stopped at an accumulated time of 1,150,745 sec.

Test Restarted	2:00 pm	10/14/99	Data File C22DCB7n
Stopped	9:50 am	10/28/99	Δt = 1,195,500 sec no crack advance
Test Restarted	11:33 am	10/28/99	Data File C22DCB7o
stopped	10:20 am	11/19/99	Δt = 1,900,900 sec no crack advance
Test Restarted	3:00 pm	11/19/99	Data File C22DCB7p

* LabView stopped at an accumulated time of 1,036,860 sec.

Test Restarted	10:15 am	12/[illegible]/99	Data File C22DCB7q
Stopped	2:20 pm	12/21/99	Δt = 1,657,610 sec no crack advance
Test Restarted	2:40 pm	12/22/99	Data File C22DCB7r
Stopped	9:20 am	1/27/00	Δt = 3,091,500 sec no crack advance
Test Restarted	9:50 am	1/27/00	Data File C22DCB7s

* LabView stopped at an accumulated time of 1,181,539 sec.

Test Restarted	2:50 pm	2/11/00	Data File C22DCB7t
* Lab power down	5:45 pm	2/14/00	
Test Restarted	1:30 pm	2/15/00	Data File C22DCB7u
Stopped	10:50 am	3/6/00	Δt = 1,718,830 sec no crack advance.

Test Finished

3/7/00

SEM Micrographs of Cracks in 316LDCB 7 & 8 Disassembly on 7/9/99

1. Crack tip micrographs in 316LDCB 7

a. Side 1

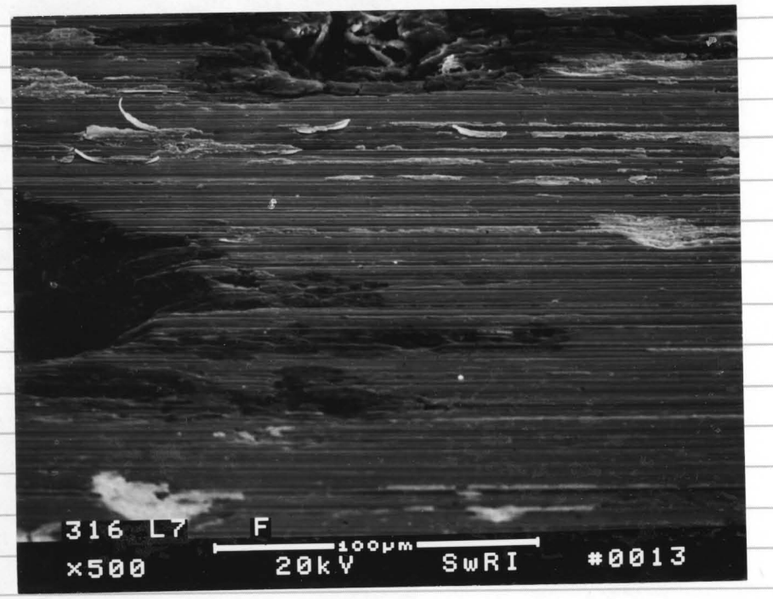


photo No. 97436

b. Side 2

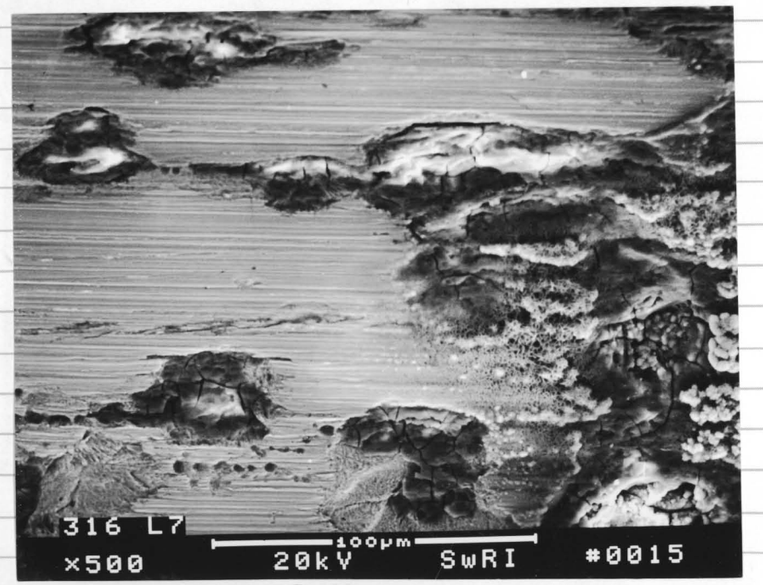


photo No. 97437

7/20/99

2. Crack tip micrographs in 316LDCB 8

a. Side 1

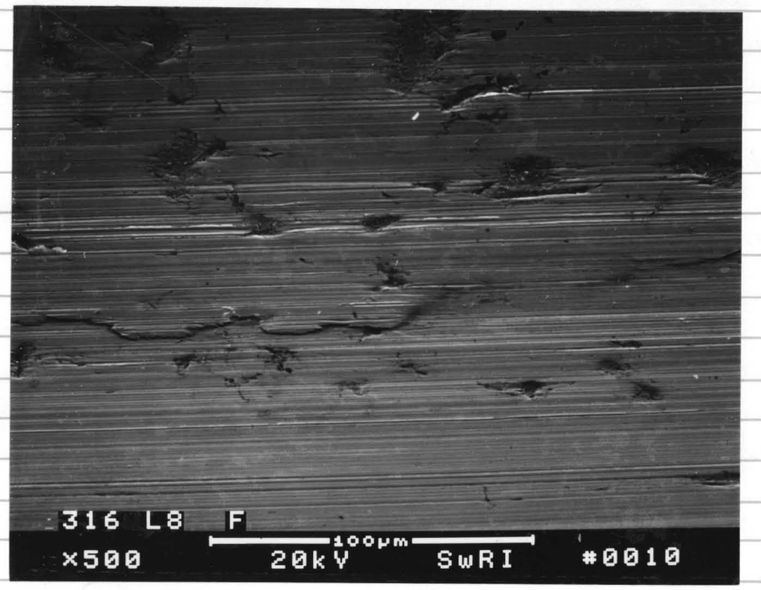


photo No. 97434

b. Side 2

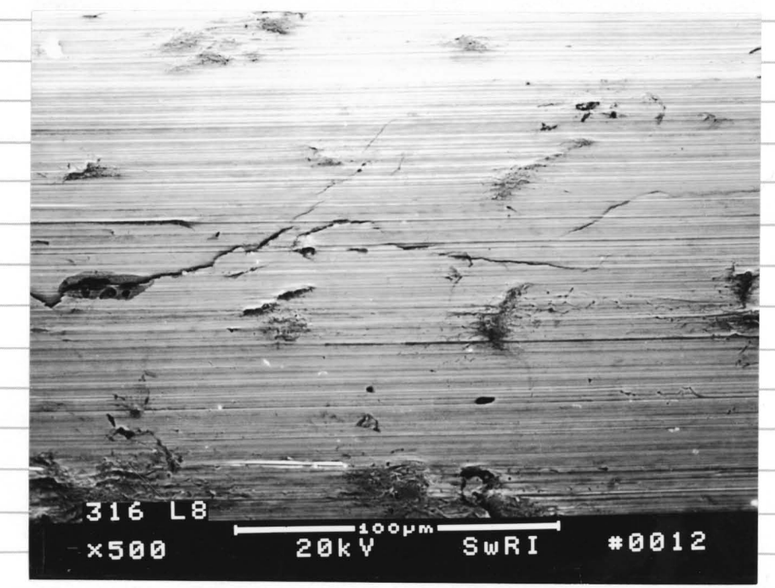


photo No. 97435

7/20/99

Crack Length Measurement for 316LDCB 7

1. Crack length was measured using a Nikon OPTIPHOT-POL microscope at 100×. The unit length of the eyepiece scale is 10 μm.

Test Duration ΔT (sec)	Crack Length (unit/μm) Side 1	Side 2	Average	Crack Growth Rate (m/s)
744,400	290/2,900	320/3,200	305/3,050	4.10×10^{-9}
778,790	0	0	0	—
—	1,130/11,300	910/9,100	1,020/10,200	— under open circuit conditions

2. Average crack growth rate

$$= \frac{\Sigma l}{\Sigma t} = \frac{3,050\ \mu m}{(744,400 + 778,790)s} = 2.0\times10^{-9}\ m/s$$

Yi Pan
7/31/199

SEM Micrographs of the C22DCB Specimens Disassembly on 8/9/99

1. C22DCB2 (the engraved side)

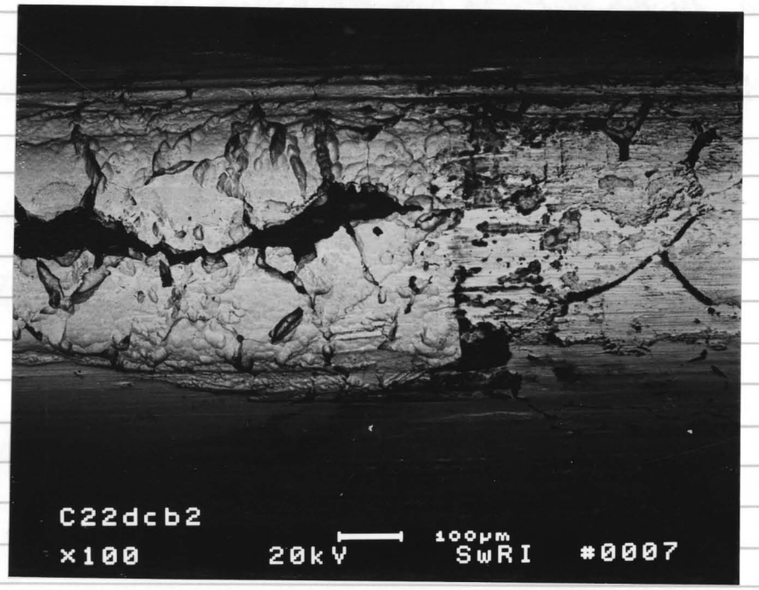


photo No. 97812

b the opposite side

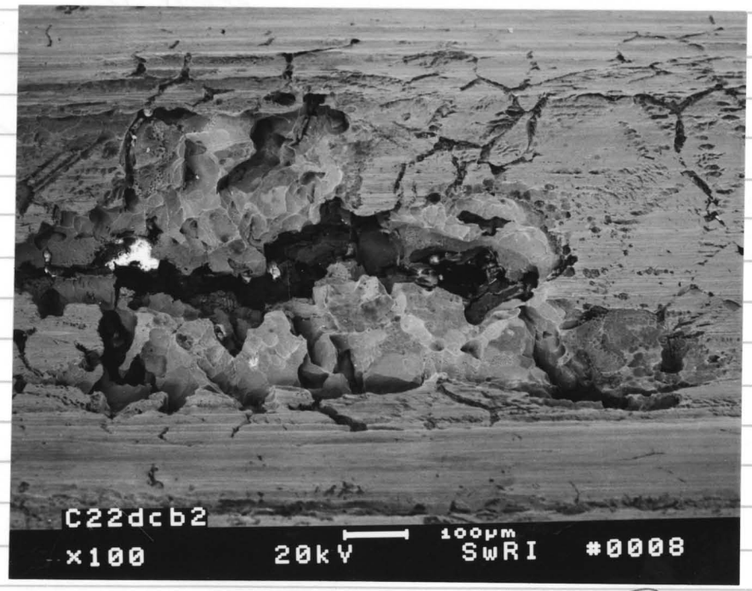


photo No 97811

Yi Pan
8/11/199

2 C22 DCB7

2a the engraved side : no change

2b. the opposite side

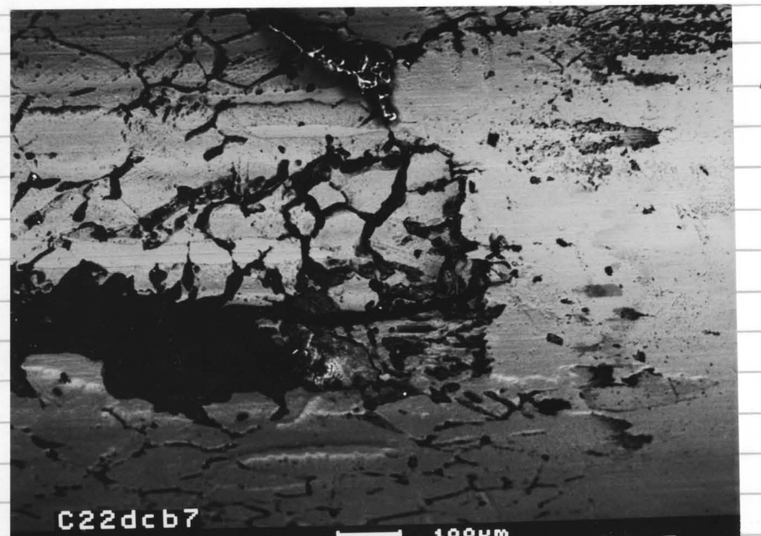


photo No. 97699

8/11/99

316L DCB9 Stress Corrosion Cracking Test (−360 mV$_{SCE}$)

Objective: Measure SCC growth rate under potential control with an applied potential of −360 mV$_{SCE}$

Specimen: 316L-9 Heat P80746 machined by Metal Samples
Precrack length 0.110" (visual)

Load: 20 ksi$\sqrt{in}$

Test Environment:
Solution: 30 wt% $MgCl_2$
Temp. T=110°C Hg thermometer C96-833

Potentiostat: ESC 440 #2 Channel #5

Reference: Fisher SCE 13-620-51 SN 7030126

Counter Electrode: 2"x2" pt Flag

Data File 316LDCB9a using Labview

Test Started:	3:32 pm	8/10/99	Δt = 4,168,038 sec
Restarted	10:10 am	8/24/99	Data File 316LDCB9b
Stopped	4:07 pm	8/26/99	Δt = 194,320 sec, no crack advance
Restarted	4:42 pm	8/26/99	Data File 316LDCB9c
Stopped	8:45 am	9/20/99	Δt = 2,131,250 sec. specimen arm broken around the loading line and crack growth observed.

Test Finished

9/20/99

SEM Micrographs of Precrack of 316LDCB9 Specimen

1. Side 1

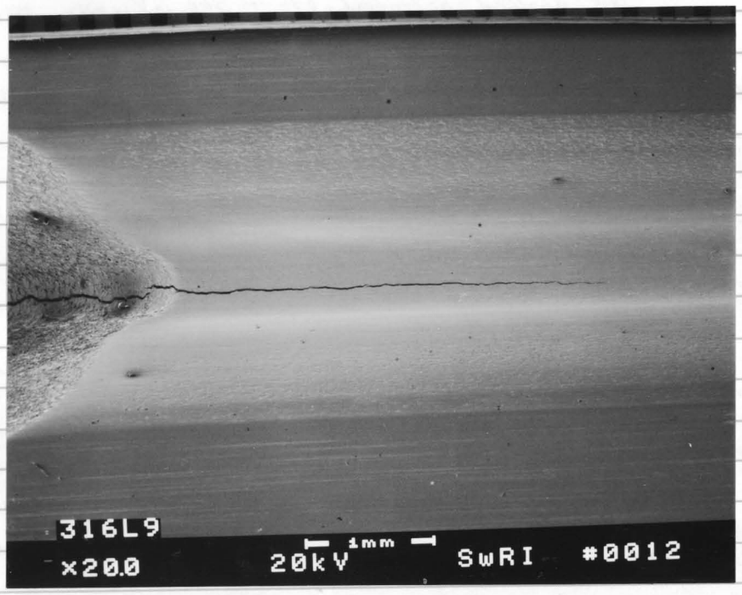


photo No 97760

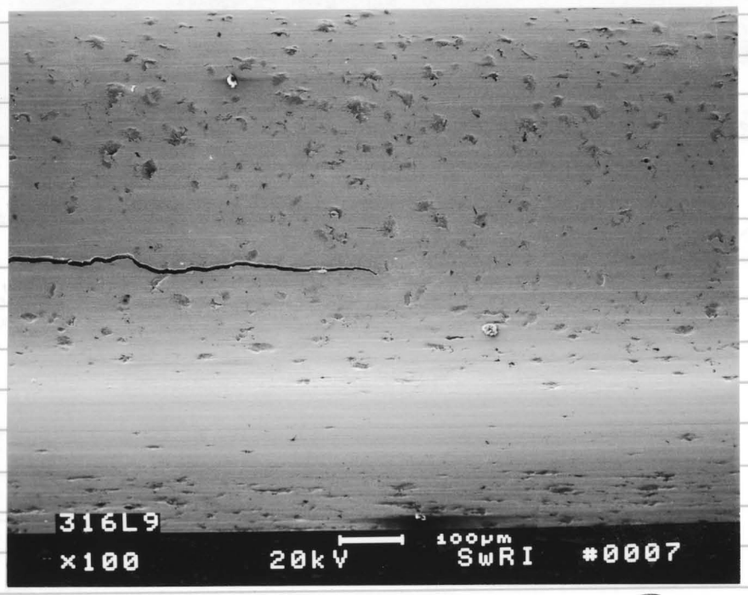


photo No. 97757

Yip Por
8/11/99

2. Side 2

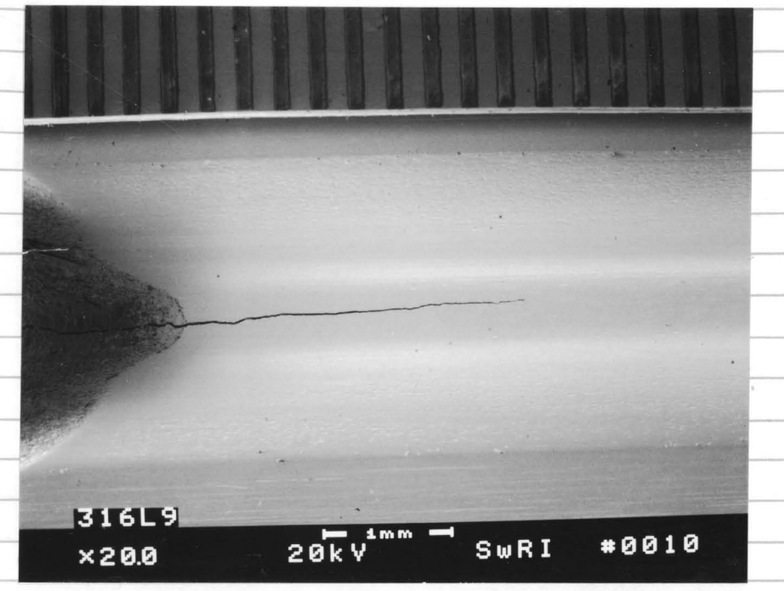


photo No. 97759

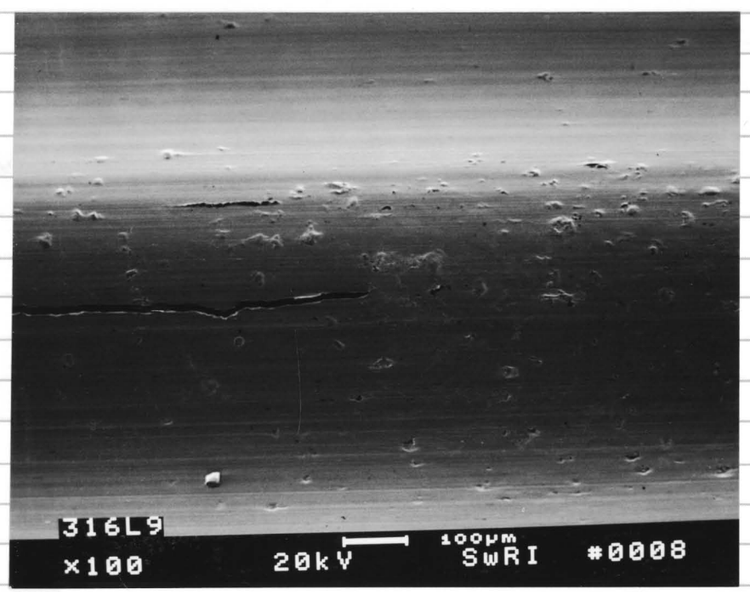


photo No. 97758

Yip Por
8/11/99

SEM Micrographs of Cracks in 316LDCB8 Disassembly on 8/9/99

a Side 1

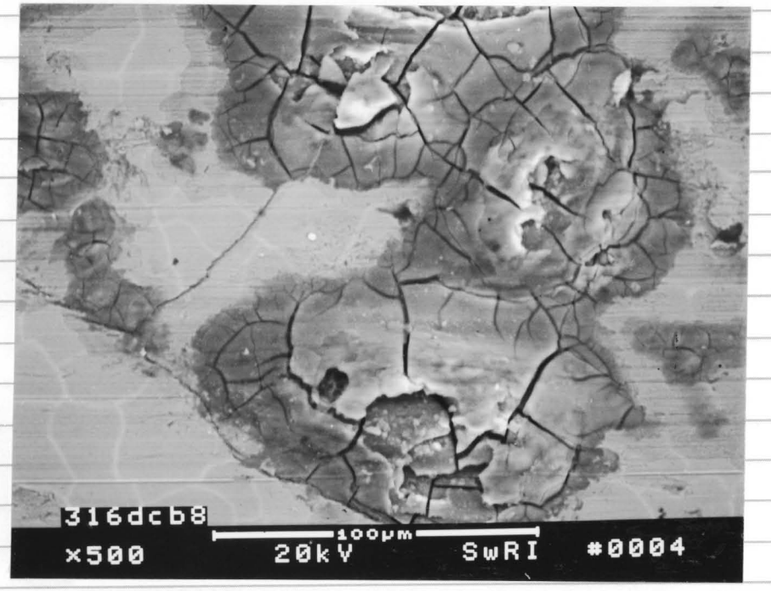


photo No. 97755

b. Side 2

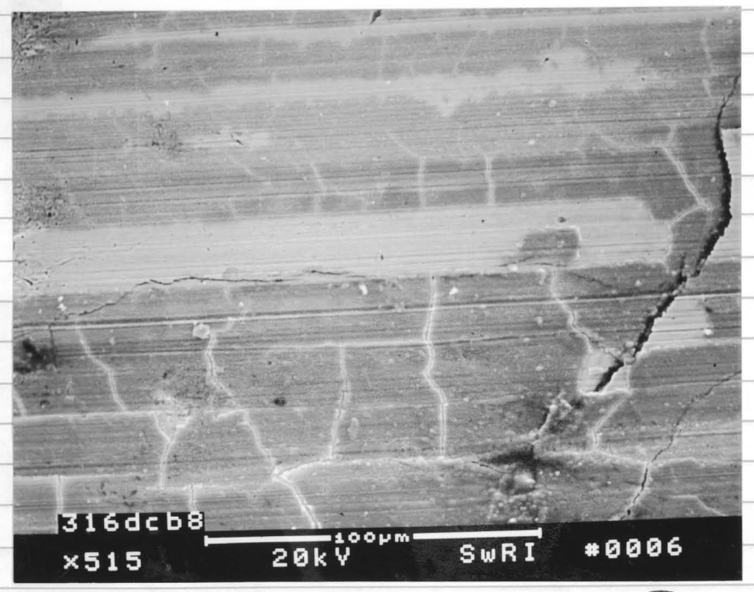


photo No. 97756

8/11/99

Fracture Surface of 316L DCB 6 specimen

SEM micrographs on the SCC region.

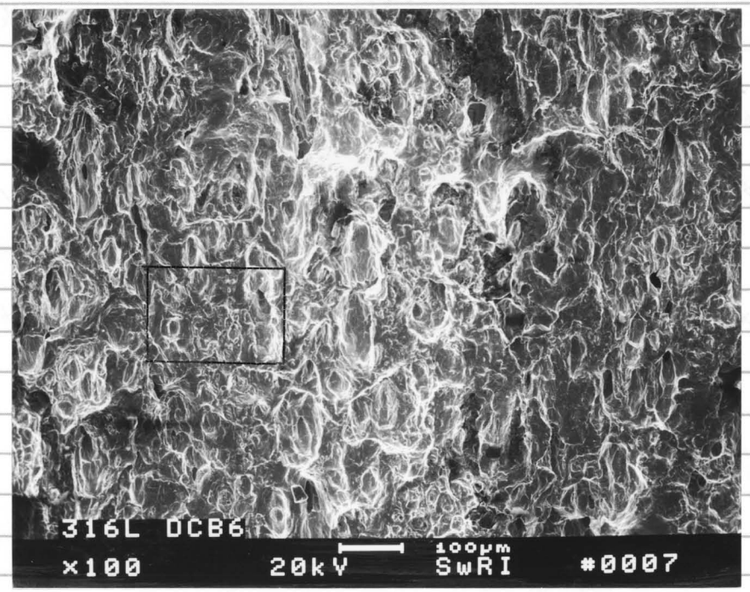


Photo No. 98197

An enlarged area of photo No. 98197

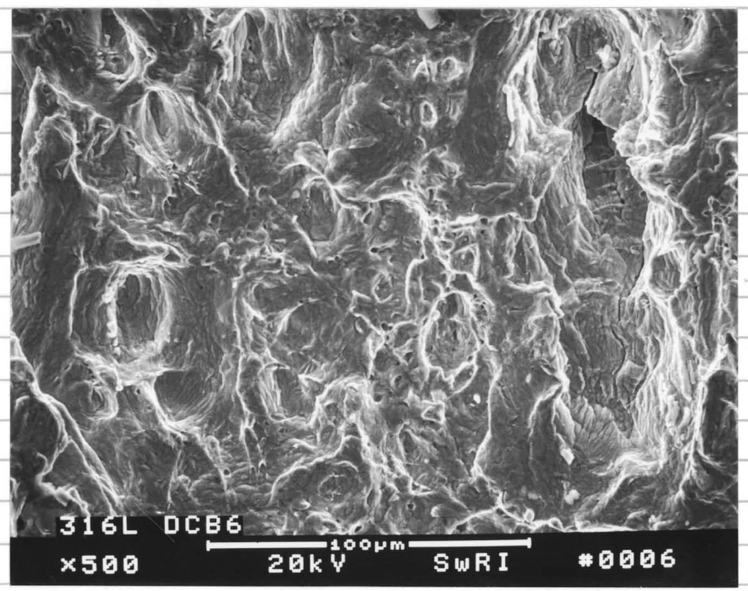


photo No. 98196

<Additional micrographs on page 182>

9/7/99

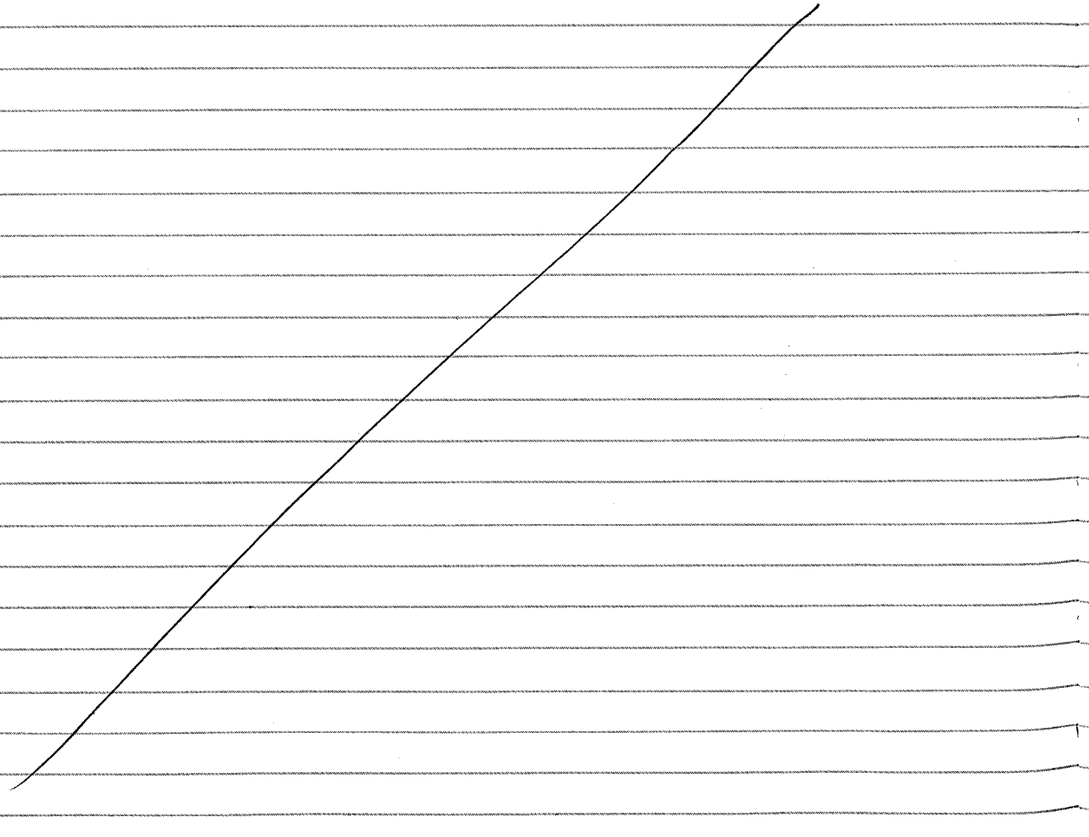
Crack Length Measurement for 316LDCB9

1. Crack length

Test Duration Δt (sec)	Crack Length (unit/μm) at 100X: side 1	side 2	Average	Crack growth rate (m/s)
1,362,355	0	0	0	—
2,131,250	783/7,830	798/7,980	791/7,910	3.71×10^{-9}

2. Average crack growth rate $= \frac{\Sigma l}{\Sigma t} = \frac{7910\,\mu m}{(1,362,355+2,131,250)s} = 2.26\times10^{-9}$ m/s

yj Pan
9/20/99



Crack Length Measurement for 316LDCB8

1. Crack length

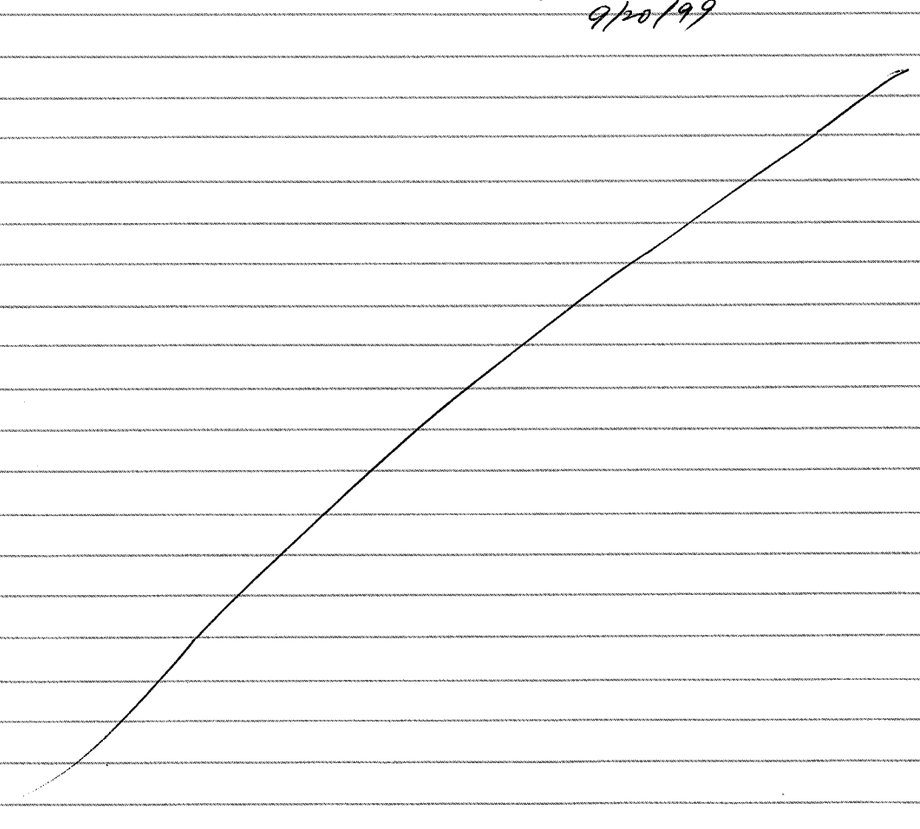
Test Duration Δt (sec)	Crack Length (unit/μm): side 1	side 2	Average	Crack growth rate (m/s)
1,537,130	43/430	181/1,810	112/1,120	7.3×10^{-10}
1,168,035 +194,320	0	0	0	—
2,132,660	0	372*/3,720	186/1,860	8.7×10^{-10}

* Crack growth did not continue from the previous crack front.

2. Average crack growth rate

$= \frac{\Sigma l}{\Sigma t} = \frac{(1,120+1,860)\,\mu m}{(1,537,130+1,168,035+194,320+2,132,660)} = 5.9\times10^{-10}$ m/s

yj Pan
9/20/99



Fracture Surface of 316L DCB6 specimen

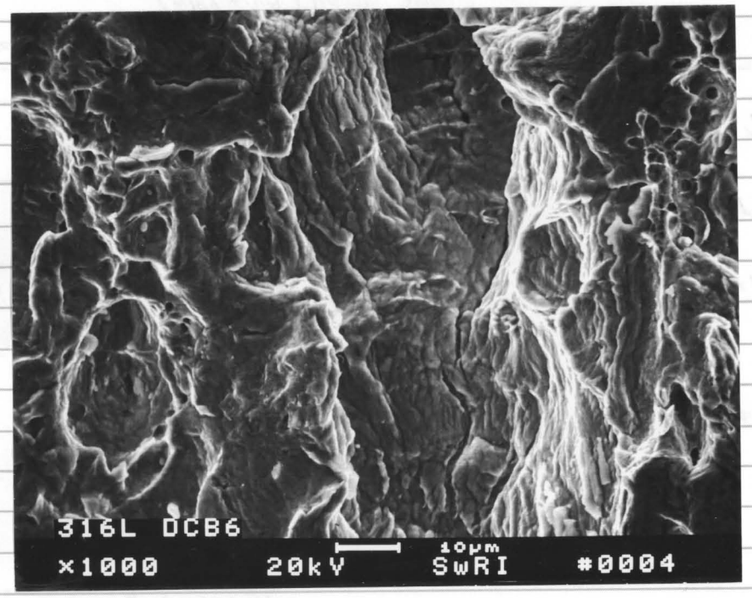


photo No 98194

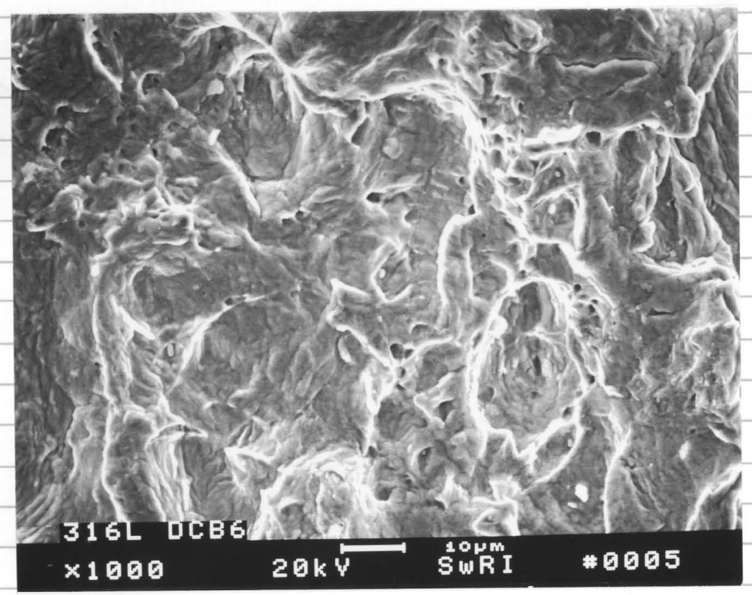


photo No. 98195

Note: Continued from page 179.
Page number misplaced.

9/7/99

316LDCB10 Stress Corrosion Cracking Test ($-400 mV_{SCE}$)

Objective: Measure SCC growth rate under potential control with an applied potential of $-400 mV_{SCE}$

Specimen: 316L-10 Heat P80746 machined by Metal Samples
Precrack length

Load: 20 ksi $\sqrt{in}$

Test Environment:
Solution 30 wt% $MgCl_2$
Temp. T=110°C Hg thermometer C98-132

Potentiostat: ESC 440 #2 channel #6

Reference: FISHER SCE 13-620-52 SN8210504

Counter Electrode: 2"x2" pt Flag

Data File 316LDCB10a using Labview

Test Started:	10:10 am	11/10/99	
Stopped	9:36 am	11/19/99	Δt = 775,700 sec crack advance of 4.8mm as a result of unstable potential (broken Pt electrode) Data File 316DCB10b
Test Restarted	2:20 pm	11/19/99	

* LabView stopped at an accumulated time of 1,031,099 sec.

Test Restarted	10:15 am	12/2/99	Data File 316DCB10c
Stopped	2:10 pm	12/21/99	Δt = 1,657,050 sec

Severe transverse cracking observed on the arms of the specimen and loading wedge became loosed. Crack extended about 5.5 mm outside the groove.

Test Finished.

12/21/99

Estimated crack growth rate:

$$= \frac{\Sigma l}{\Sigma t} = \frac{(5,500 - 4,800)\,\mu m}{(1,031,099 + 1,657,050)\,sec} = 2.6 \times 10^{-10}\ m/s$$

12/22/99

SEM micrographs of Precrack of 316LDCB10 specimen

1. Front side

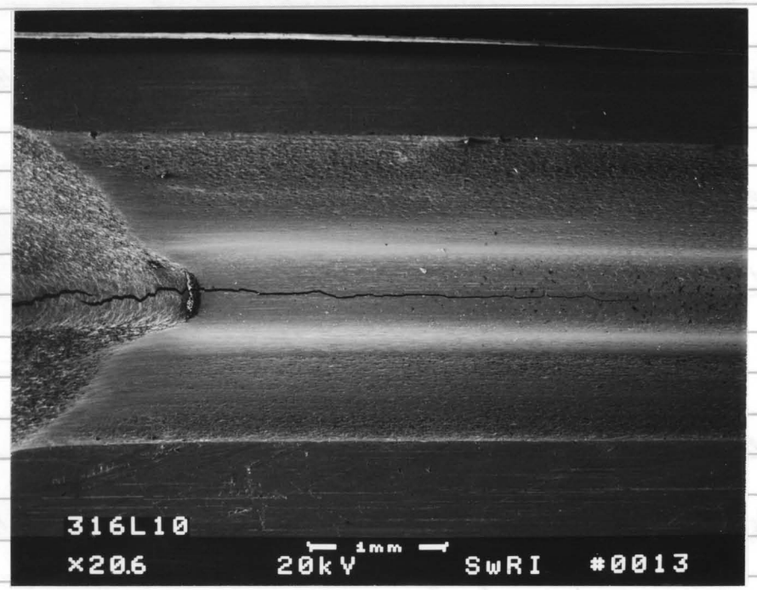


photo No. 97761

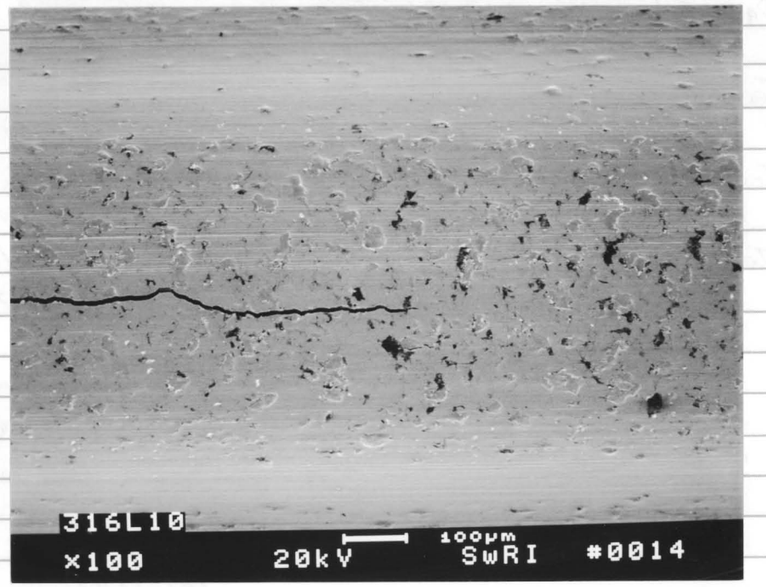


photo No. 97762

M. Pan
12/22/99

2. Back side

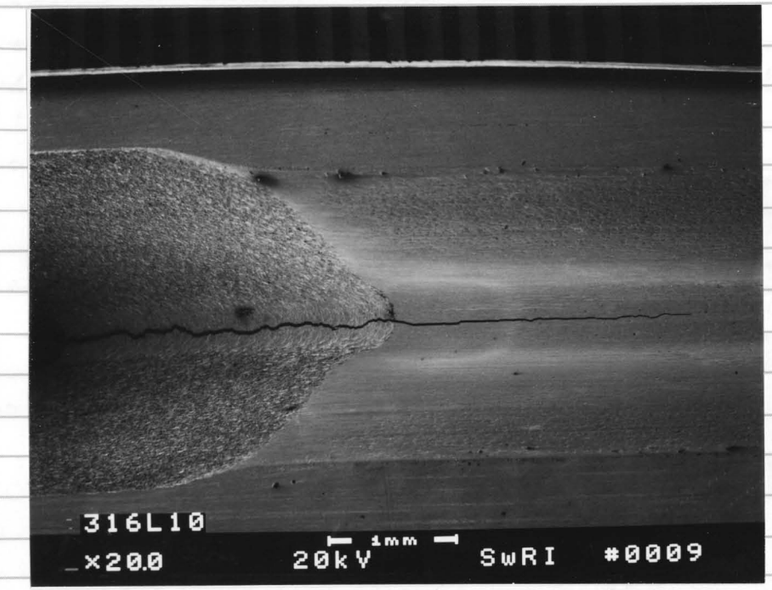


photo No: 97814

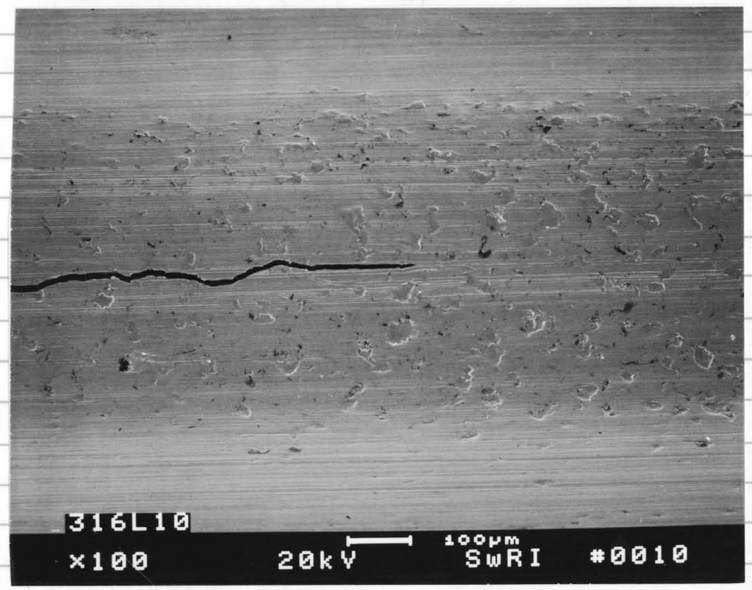


photo No. 97813

M. Pan
12/22/99

Post-Test Evaluation of DCB Specimens

Procedures

1. Pin load the specimens to the point that wedge becomes loose. Remove the wedge and then unload the specimen.

2. Heat tint the specimen at 700°F for 2.5h in an air atmosphere furnace.

3. Reload the specimen and further extend the crack under fatigue conditions.

4. Saw cut the specimen from the back edge to near crack tip and then break open.

Specimens subjected to post-test evaluation

316L DCB1
C22 DCB1
C22 DCB2
C22 DCB7

3/9/2000

Fracture Surface of C22DCB1 Specimen

This specimen has been tested in 5 Wt.% NaCl at 90°C for one year. No crack advance was observed.

1. Optical micrograph showing the boundary region of precrack and post-test crack extension areas.

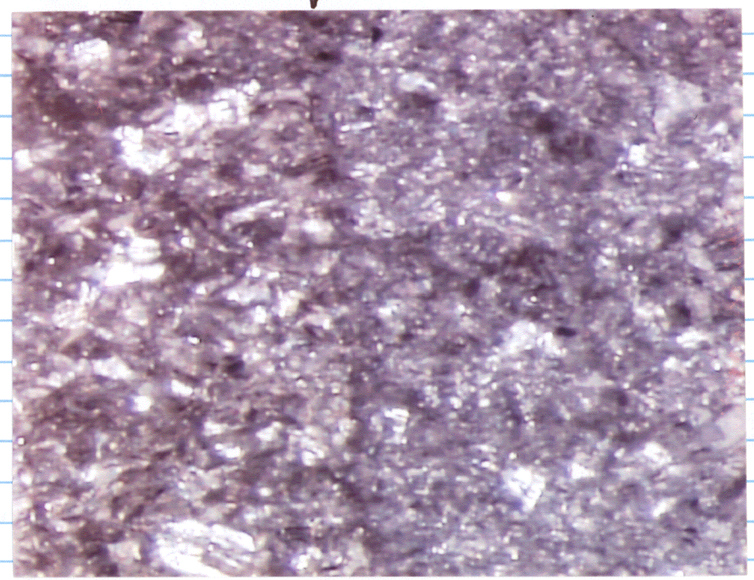


photo No. D821
50X

2. SEM of the same region

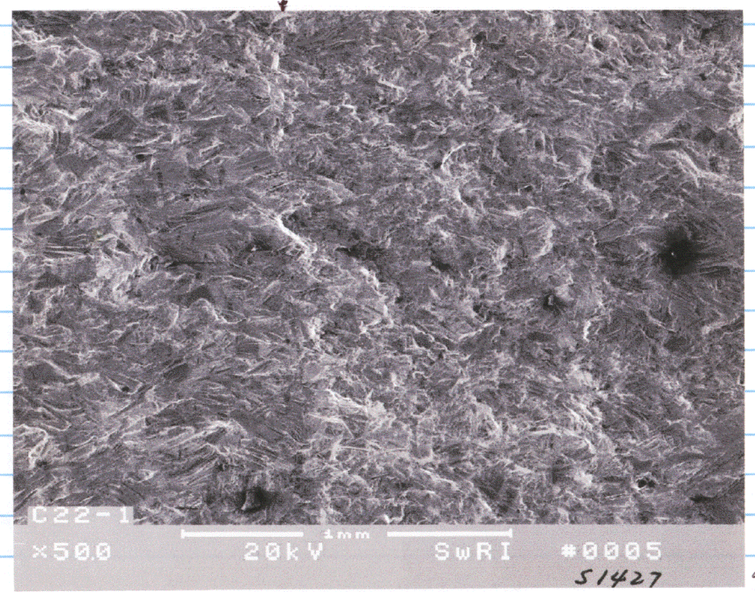


photo No. S1427

7/10/2000

3. SEM fractograph of the precrack area

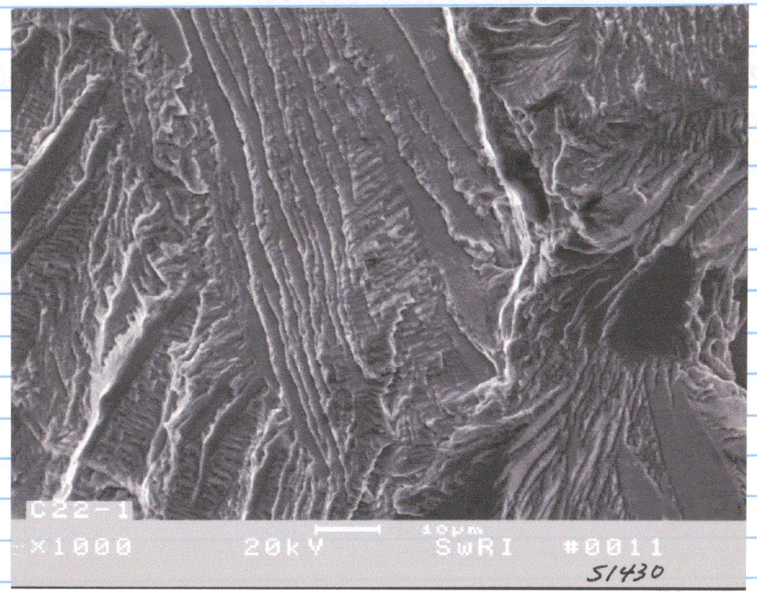


photo No. 51430

4. SEM fractograph of the post-test crack extension area

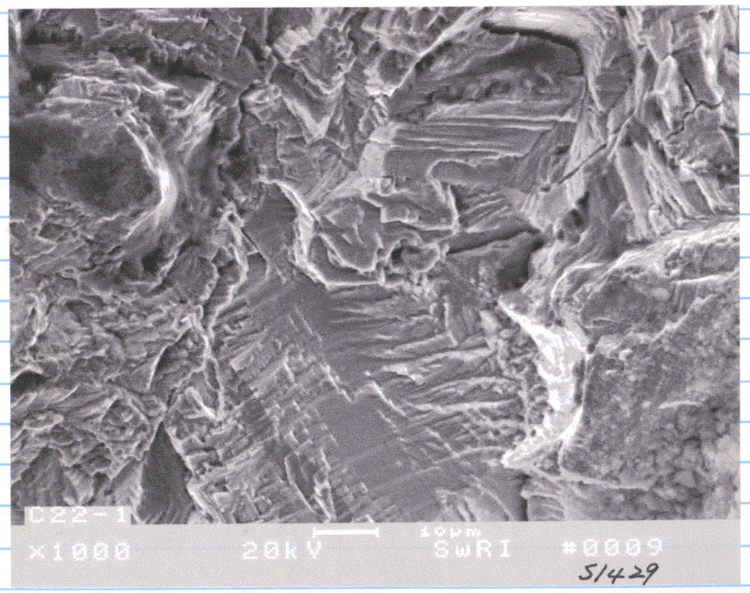


photo No. 51429

7/10/2000

Fracture Surface of C22DCB2 specimen

This specimen has been tested in 40 wt% $MgCl_2$ at 110 °C for one year. No crack advance was observed.

1. Optical micrograph showing a diffused boundary region of the precrack and post-test crack extension areas.

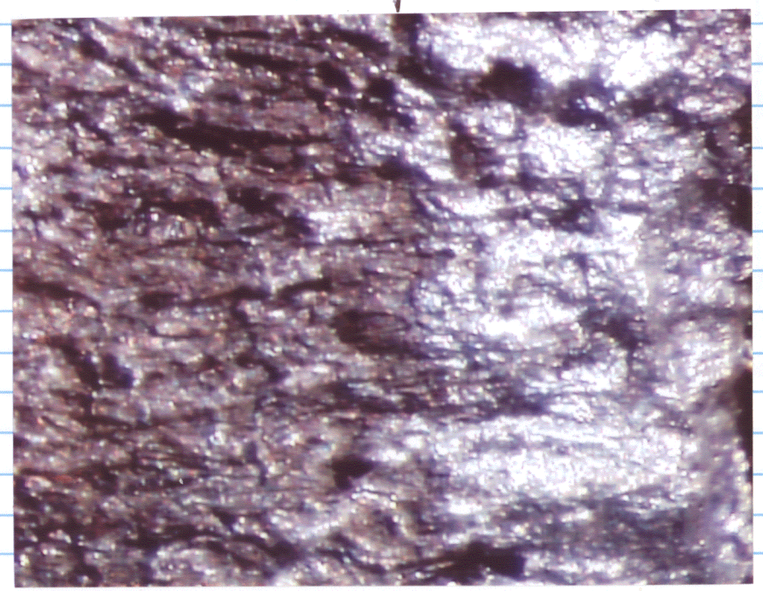


photo No. D813
50X

2. SEM of the same region

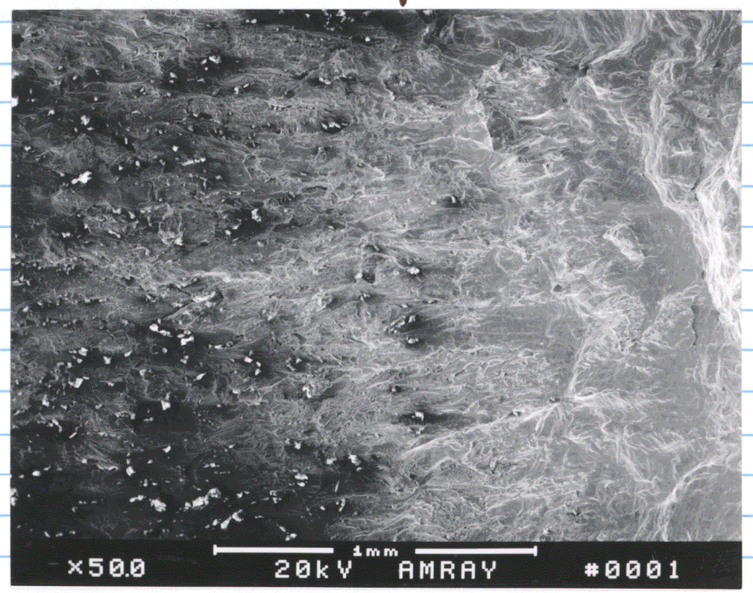


photo No. 4395

7/10/2000

3. SEM of the post-test crack extension/overloaded area

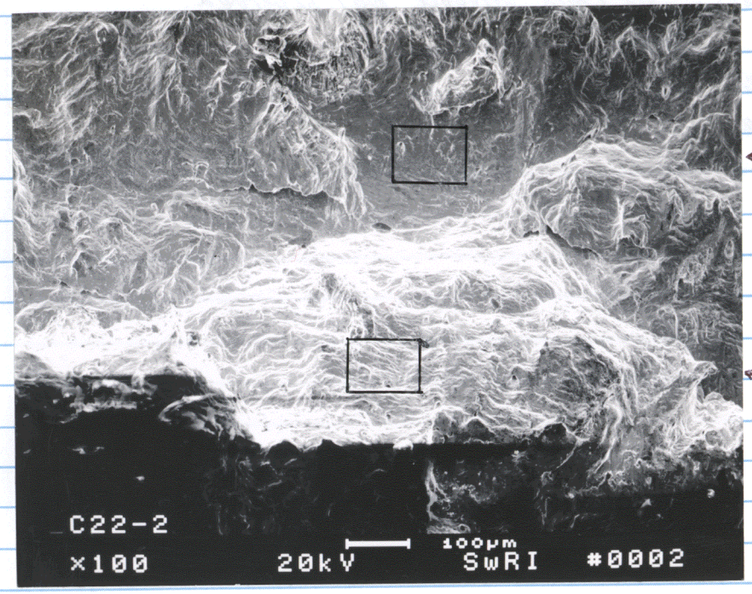


photo No. 4396

← Area # 1
post-test
crack extension

← Area # 2
overloaded

4. SEM of the enlarged area # 1 in photo No. 4396

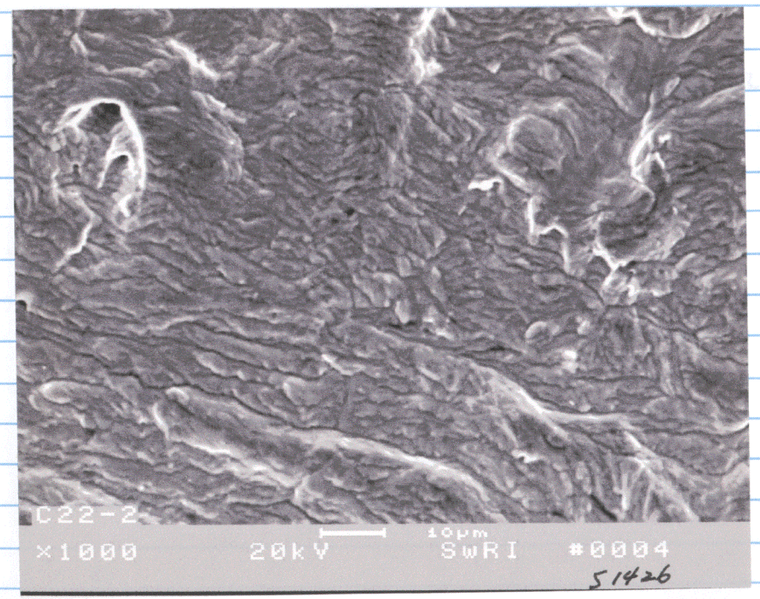


Photo No. 51426

51426

7/10/2000

5. SEM of the enlarged area # 2 in Photo No. 4396

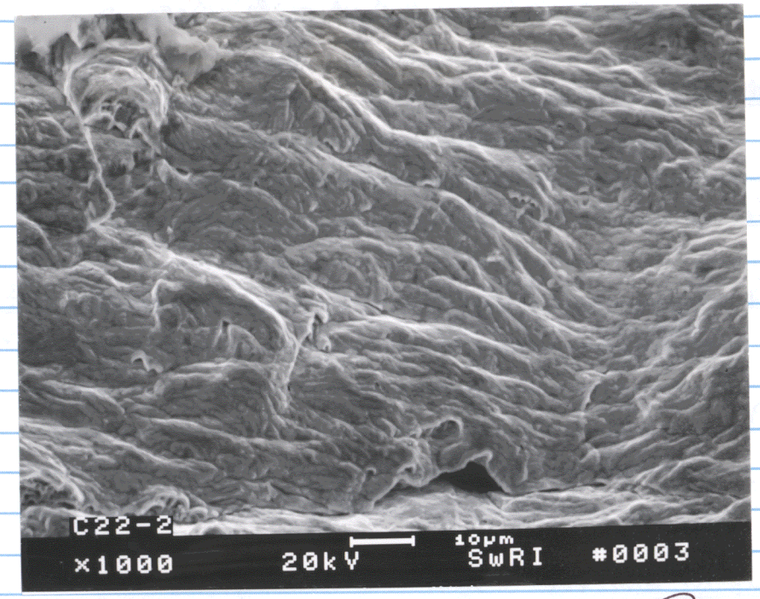
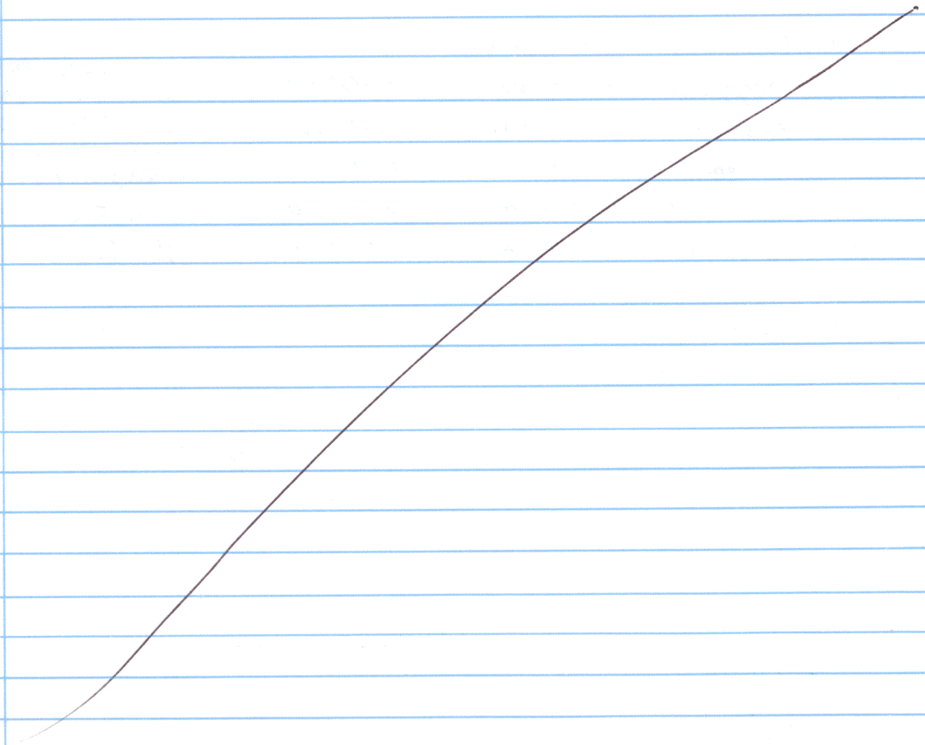


photo No. 4397

7/10/2000



316LDCB11 Stress Corrosion Cracking Test (-380 mVSCE)

Objective: Measure SCC growth rate under potential control with an applied potential of -380 mVSCE.

Specimen: 316L-11 Heat P80746 machined by Metal Samples
precrack length

Load: 20 ksi√in

Test Environment: Solution 30 wt% $MgCl_2$
Temp. T=110°C Hg thermometer H98-149

Potentiostat: ESC 440 #2 Channel #3

Reference: FISHER SCE 13-620-51 SN 7030126

Counter Electrode: 2"X2" Pt Flag

Data File 316LDCB11a using Labview

Test Started:	9:40 am	7/25/2000	
Stopped	10:18 am	7/31/2000	Δt = 520,580 sec No crack advance
Restarted	11:00 am	7/31/2000	Data File 316LDCB11b
Stopped	10:50 am	8/9/2000	Δt = 777,200 sec crack growth observed.
Restarted	11:50 am	8/9/2000	Data File 316LDCB11C
Stopped	11:30 am	8/18/2000	Δt = 777,000 sec crack growth observed. 8/9/00

Test finished.

8/18/2000

316LDCB13 Stress Corrosion Cracking Test (-400 mVSCE)

Objective: Measure SCC growth rate under potential control with an applied potential of -400 mVSCE.

Specimen: 316L-13 Heat P80746 machined by Metal Samples
precrack length

Load: 20 ksi√in

Test Environment: Solution 30 wt% $MgCl_2$
Temp. T=110°C, Hg thermometer C96-649

Potentiostat: ESC 440 #2 Channel #4

Reference: FISHER SCE 13-620-51 SN 8122003

Counter Electrode: 2"x2" pt Flag.

Data File 316LDCB13a using Labview

Test Started:	9:42 am	7/25/2000	
Stopped	10:18 am	7/31/2000	Δt = 520,500 sec. No crack advance.
Restarted	11:00 am	7/31/2000	Data File 316LDCB13b
Stopped	10:50 am	8/9/2000	Δt = 777,200 sec No crack advance
Restarted	11:50 am	8/9/2000	Data File 316LDCB13C
Stopped	1:05 pm	8/25/2000	Δt = 1,387,000 sec Crack growth observed. 8/9/00 due to the unstable potential

Test finished.

8/25/2000

SEM Micrograph of Precrack of 316LDCB11 Specimen

1. Side 1

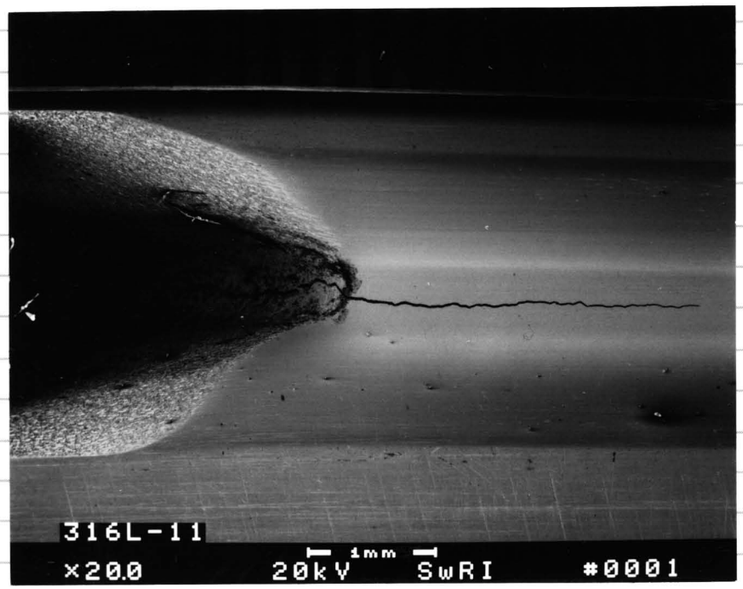


photo No. 4382

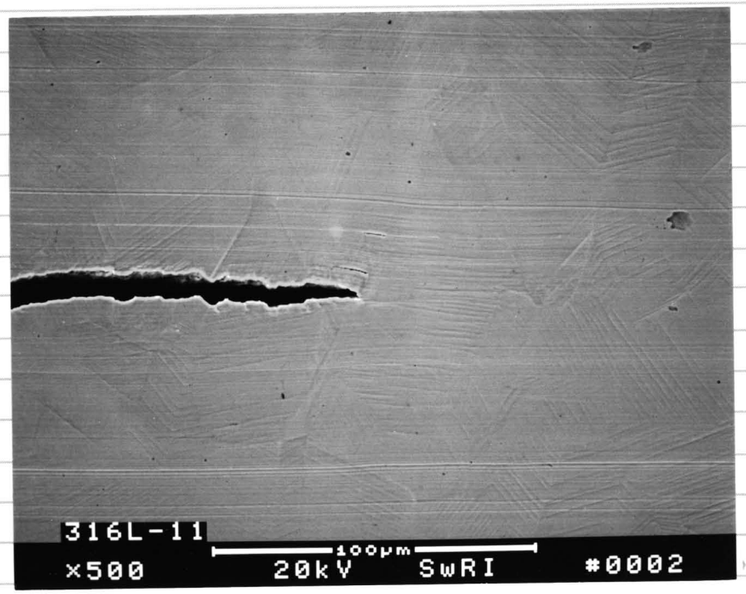


photo No. 4383

7/25/2000

2. Side 2

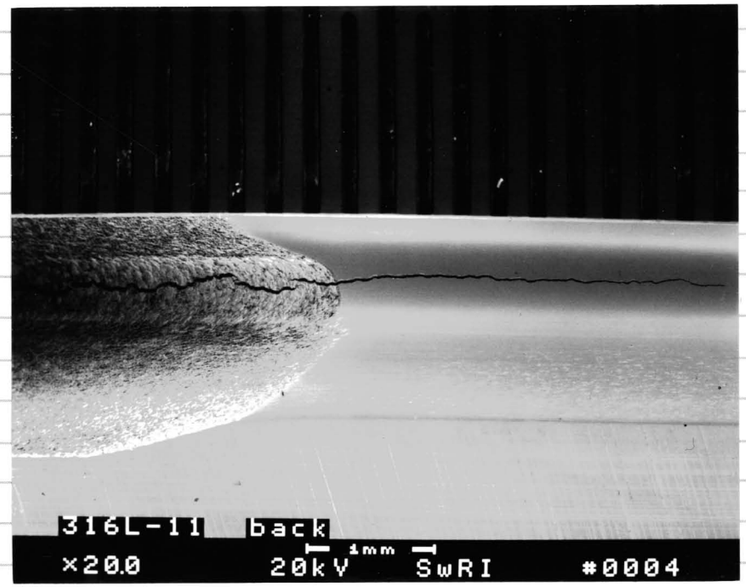


photo No. 4384

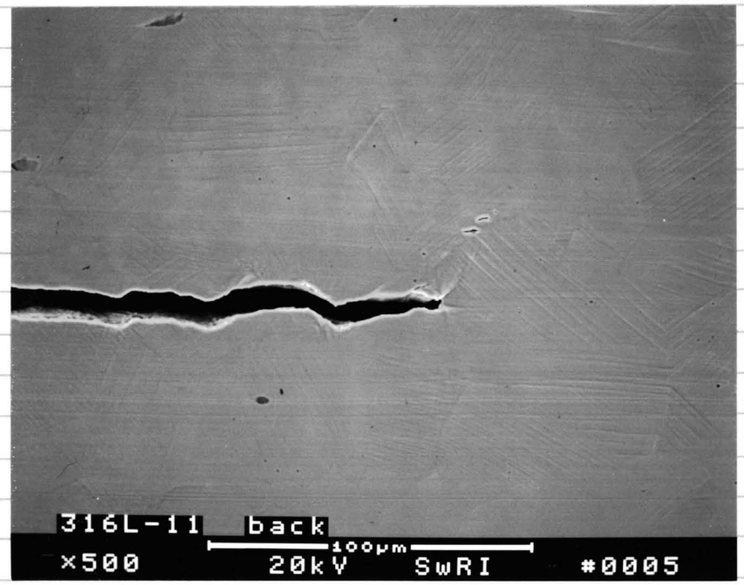


photo No. 4385

7/25/2000

SEM Micrograph of Precrack of 316L DCB 13 Specimen

1. Side 1

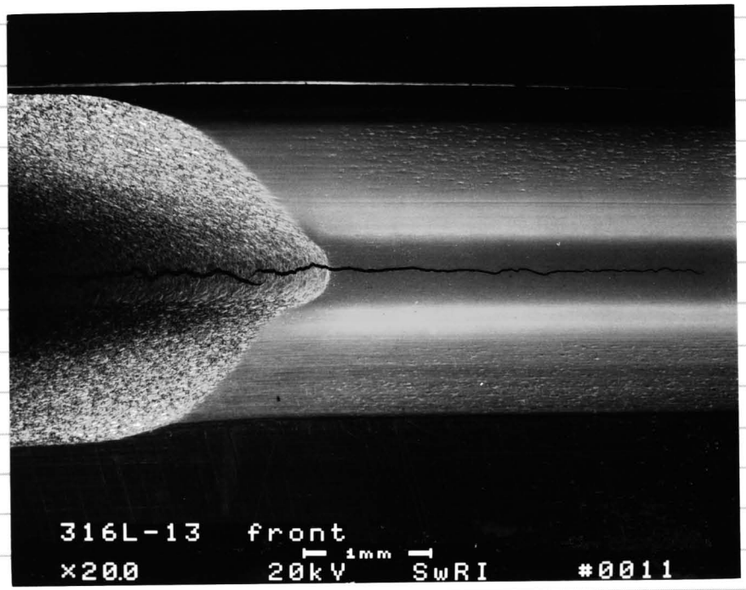


photo No: 4390

photo No: 4391

7/25/2000

2. Side 2

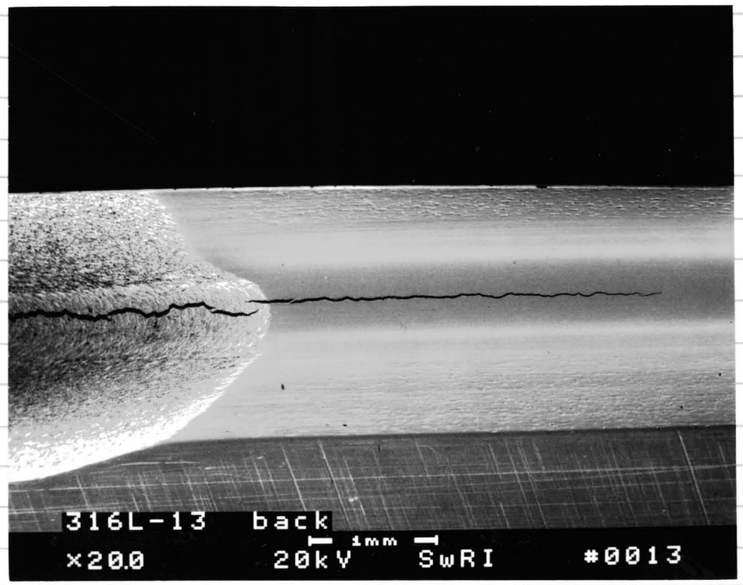


photo No: 4392

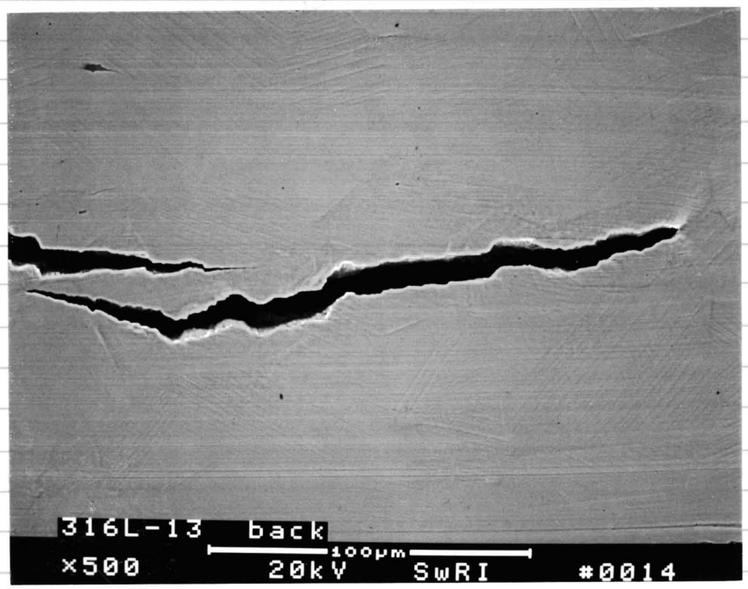


photo No: 4393

7/25/2000

Submitted for QA Review on 8/18/2000

Crack Length Measurements for 316LDCB11

1. Crack length measured at 100X

Test Duration Δt (sec)	Crack length (Unit at 100X / μm) Side 1	Side 2	Average	Crack Growth Rate (m/s)
520,580	0	0	0	-
777,200	296/2,960	362/3,600	329/3,290	2.54×10^{-9}
776,700	30/300	3/30	16.5/165	2.12×10^{-10}

2. Average Crack growth rate

$$\frac{\Sigma l}{\Sigma t} = \frac{(3290+165)\,\mu m}{520,580+777200+776700} = 1.59\times10^{-9}\ m/s$$

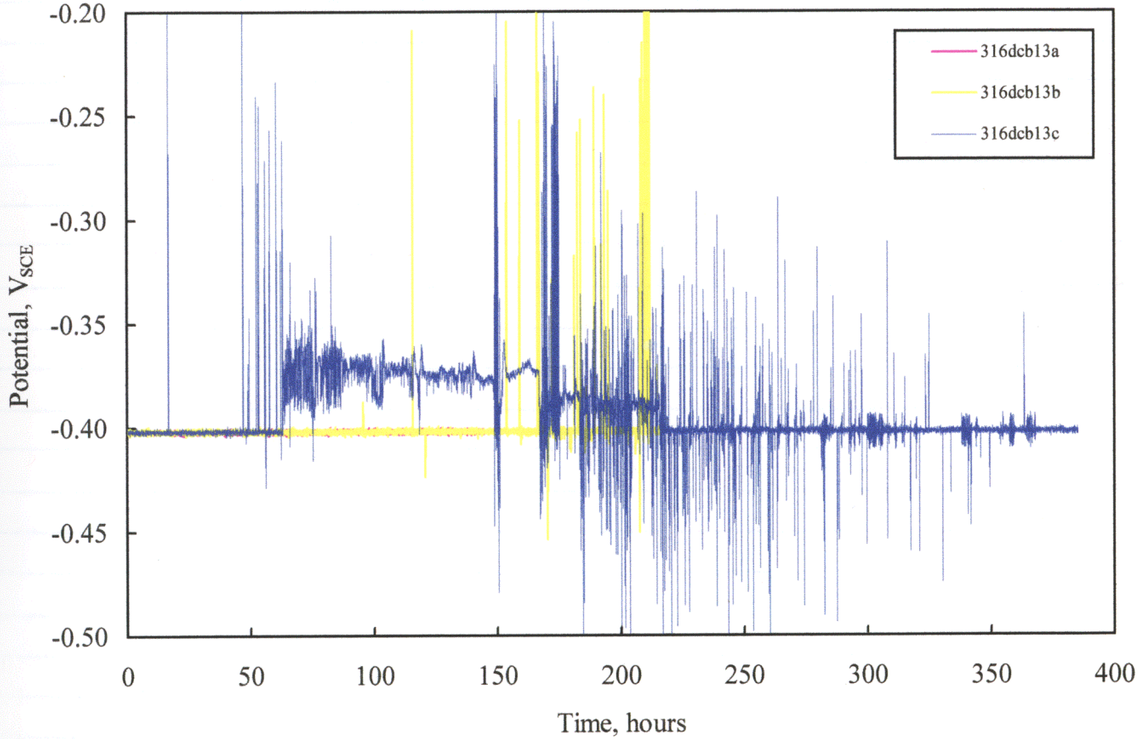
JJ Pa
8/24/2000

Crack Length Measurements for 316LDCB13

1. Crack length

Test Duration Δt (sec)	Crack length (Unit at 50X / μm) Side 1	Side 2	Average	Data File
520,500	0	0	0	316dcb13a
777,200	0	0	0	316dcb13b
1,387,000	509/10180	398/7960	453.5/9,070*	316dcb13c

* Crack growth observed in 316LDCB13 may be the result of potential variations throughout the test. The potential output as a function of time for all three test duration is plotted below.



JJ Pa
8/25/2000

316L DCB 12 Stress Corrosion Cracking Test

Objective: Measure SCC growth rate under potentiostatic control with varied applied potentials

Specimen: 316L-12 Heat P80746 machined by Metal Samples
precrack length

Load: 20 ksi √in

Test Environment: Solution 30 wt% $MgCl_2$
Temp. T=110°C, Hg thermometer H88-149

Potentiostat: ESC 440 #2 Channel #3
Reference: Fisher SCE 13-620-51 SN 7030126
Counter Electrode: 1"x1" pt flag

Data File: 316LDCB12a using Labview

Test Started: 12:17 pm 9/19/2000 — 9/19/2000
9:08 am 10/13/2000 — Δt = 2,061,800 sec.

Crack growth observed as a result of potentiostat variations. and broken counter electrode.

Test Finished.

10/13/2000

SEM Micrograph of Precrack of 316LDCB12 specimen

1. side 1

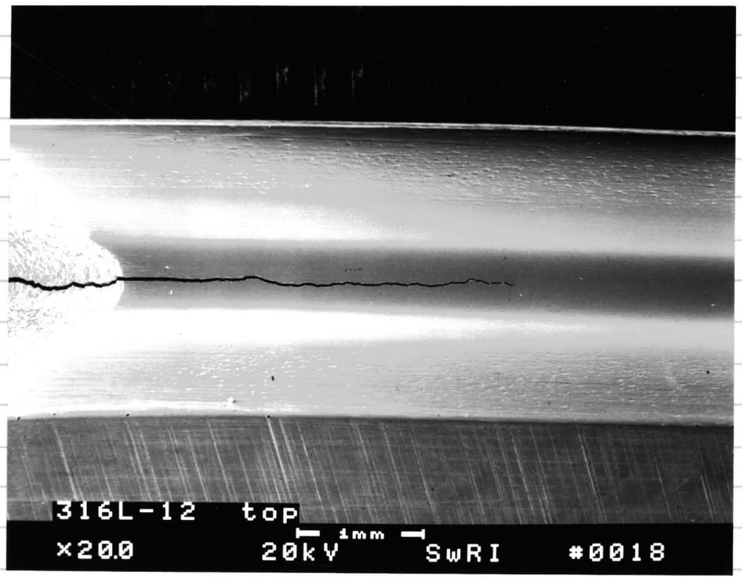


photo No. ~~4386~~ 4471 9/19/00

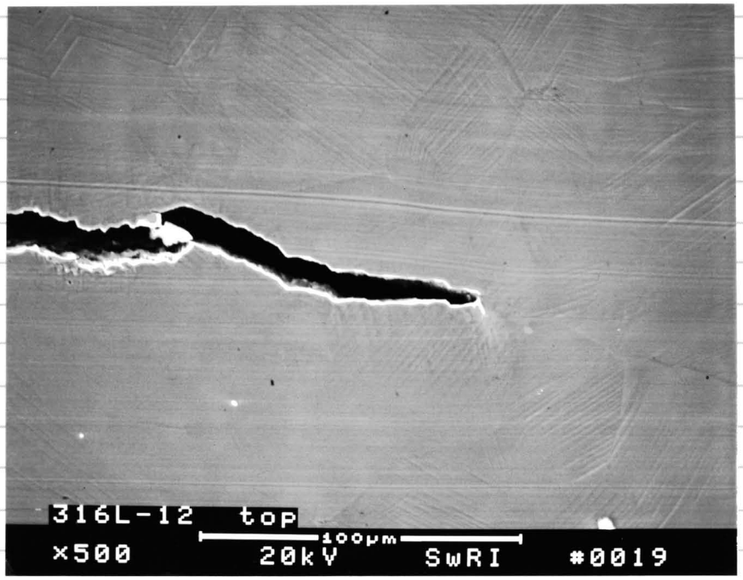


photo No. 4472

9/19/2000

2. Side 2

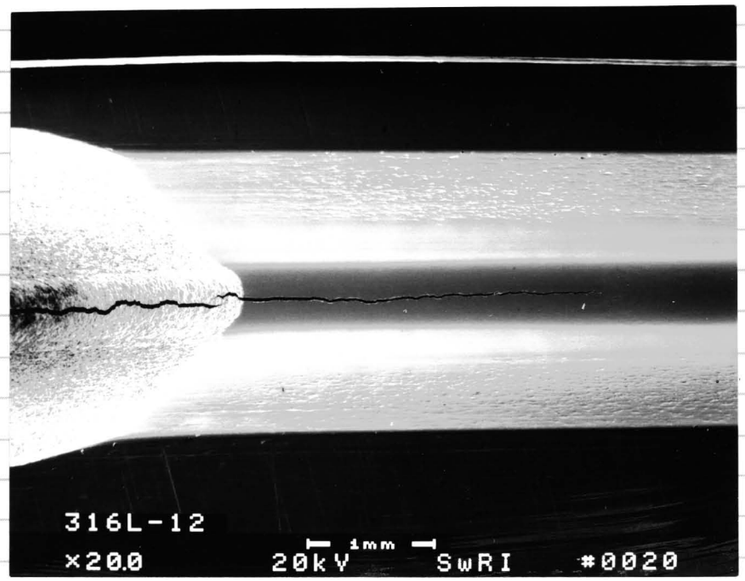


photo No. 4473

I have reviewed this scientific notebook and find it in compliance with QAP-001. There is sufficient information regarding procedures used for conducting tests, acquiring and analyzing data so that another qualified individual could repeat the activity.

9/22/2004

Photo No. 4474

9/19/2004

QA Review 9/20/04