N91-27291

P 24

Program 6 **The Effect of Zinc Additions on the Environmental Stability of Alloy 8090 (Al-Li-Cu-Mg-Zr)**

Raymond J. Kilmer and G.E. Stoner

Objectives

The objectives for this PhD research are to document and characterize the effects that Zn additions have on the microstructure of alloy 8090 under different aging conditions and to correlate SCC behavioral changes with changes in alloy composition and microstructure. As an extension of this goal, emphasis will be placed on optimizing SCC behavior and alloy density.

The Effects of Zn Additions on the Microstructure and SCC Performance of Alloy 8090

R.J. Kilmer
G.E. Stoner

Stress corrosion cracking (SCC) remains a problem in both Al-Li and conventional Al heat treatable alloys. It has recently been found that relatively small additions (< ~1 wt-%) of Zn can dramatically improve the SCC performance of alloy 8090 (Al-Li-Cu-Mg-Zr). Constant load time to failure experiments using cylindrical tensile samples loaded between 30 and 85% of TYS indicate improvements of orders of magnitude over the baseline 8090 for the Zn-containing alloys under certain aging conditions. However, the toughnesses of the alloys were noticeably degraded due to the formation of second phase particles which primarily reside on grain and subgrain boundaries. EDS revealed that these intermetallic particles were Cu and Zn rich. The particles were present in the T3 condition and were not found to be the result of quench rate, though their size and distribution were.

At 5 hours at 160C the alloys displayed the greatest susceptibility to SCC but by 20 hours at 160C the alloys demonstrated markedly improved TTF lifetimes. Aging past this time did not provide separable TTF results however, the alloys toughnesses continued to worsen. Initial examination of the alloys microstructures at 5 and 20 hours indicated some changes most notably the S' and δ' distributions. It was further noticed that Zn additions appear to increase the number fraction of S' precipitating out from the alloys. A possible model by which this may occur will be explored.

Polarization experiments indicated a change in the trend of E_{Br} and passive current density at peak aging as compared to the baseline 8090. Initial pitting experiments indicated that the primary pitting mechanism in chloride environments is one occurring at constituent (Al-Fe-Cu) particles and that the Cu and Zn rich boundary precipitates posses a breakaway potential similar to that of the matrix acting neither anodic or cathodic in the first set of aerated 3.5 w/o NaCl experiments.

Future work will focus on identification of the second phase particles, evaluation of K_{1scc} and plateau da/dt via both DCB and slow strain rate techniques. A lower Zn content variant will be examined in the near future in the hopes of optimizing toughness, density and SCC performance.

The Effect of Zn Additions on the Microstructure and SCC Performance of Alloy 8090

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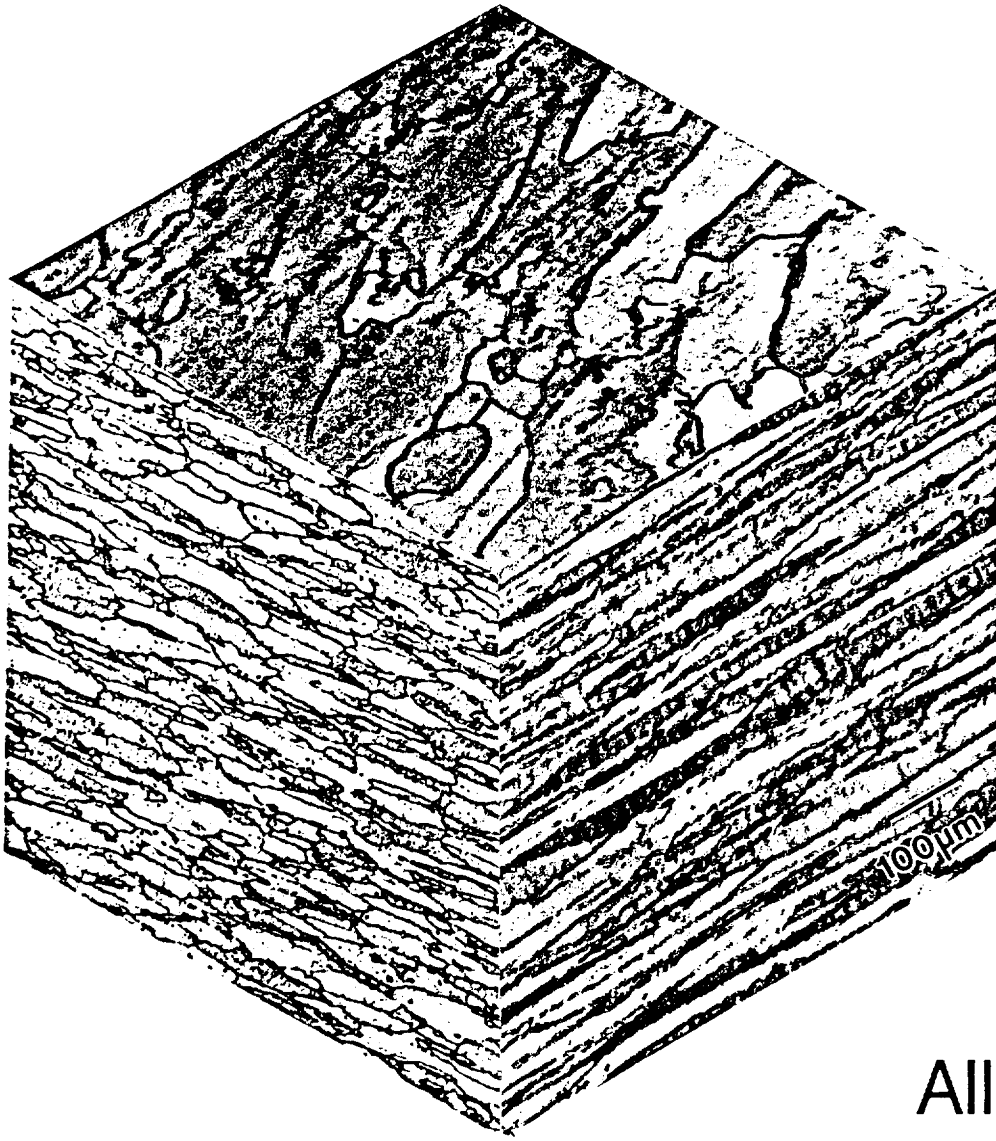
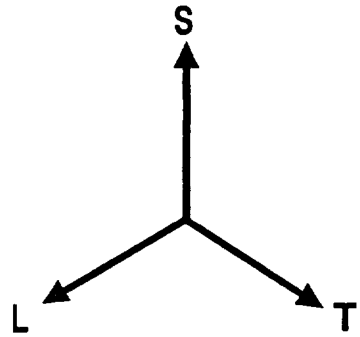
Co-sponsored by Alcoa Technical Center, Alcoa Center PA

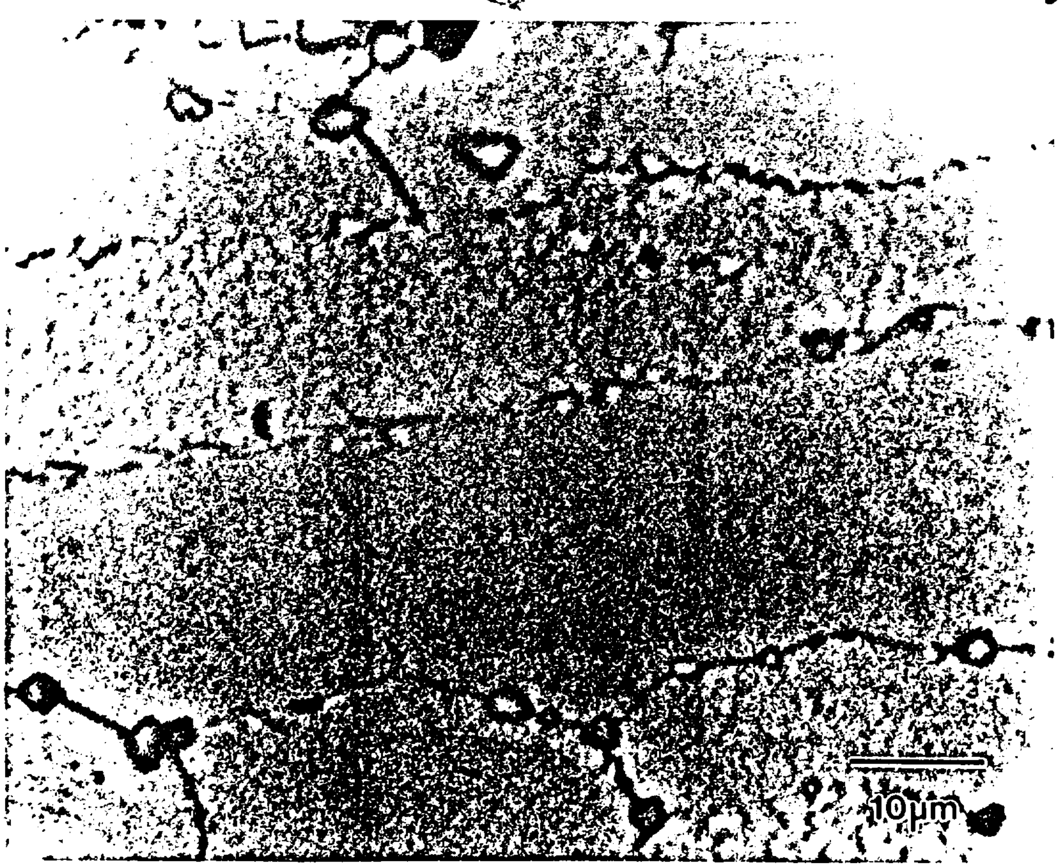
Alcoa Contact: J.M. Newman

	Composition wt-%				
Alloy Code	**Li**	**Cu**	**Mg**	**Zn**	**Zr**
Alloy A	2.53	1.22	0.67	1.36	0.12
Alloy B	2.47	1.23	0.74	0.99	0.12
Alloy C	2.54	1.23	0.49	1.00	0.12
Alloy D	2.55	1.16	0.69	0.02	0.12

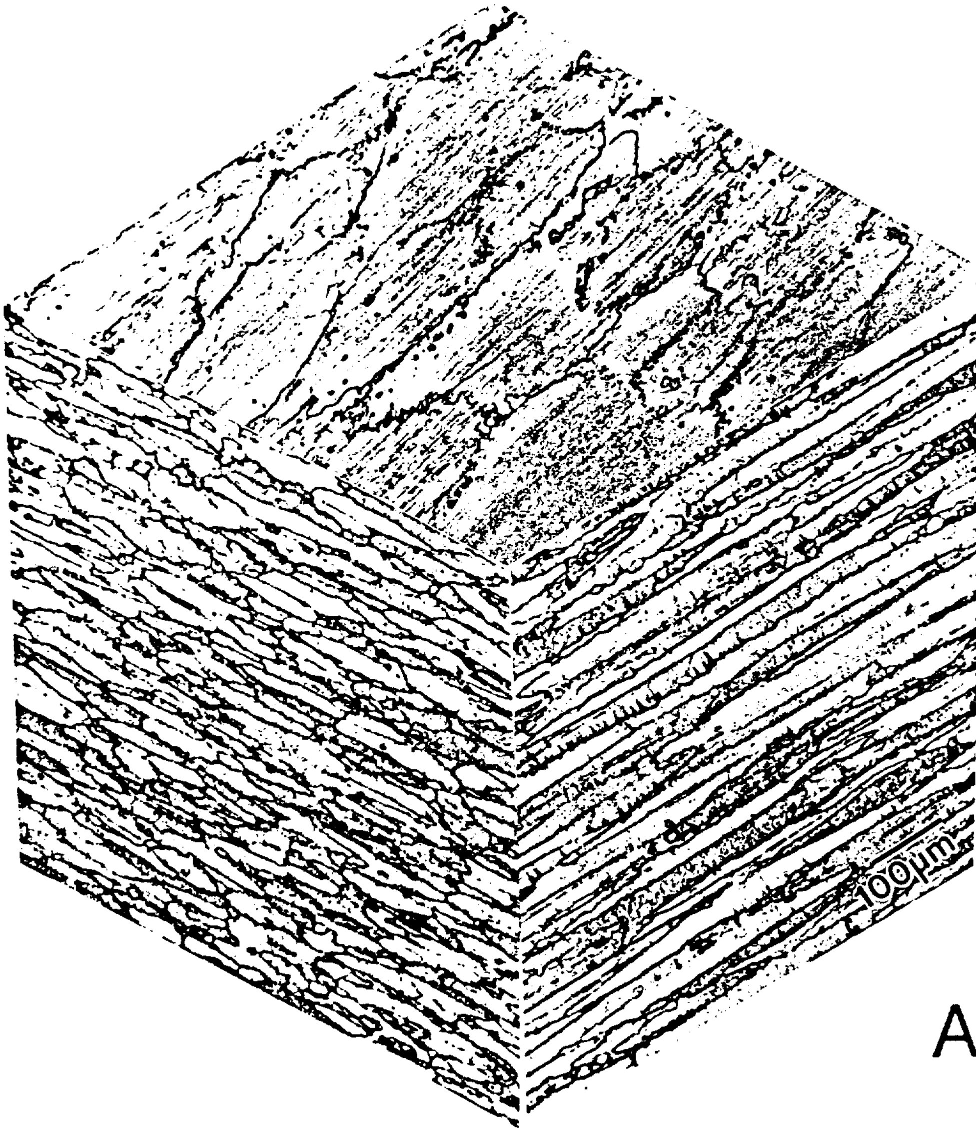


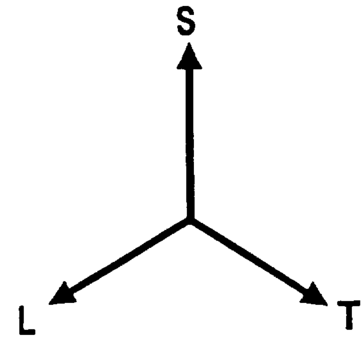


Alloy A

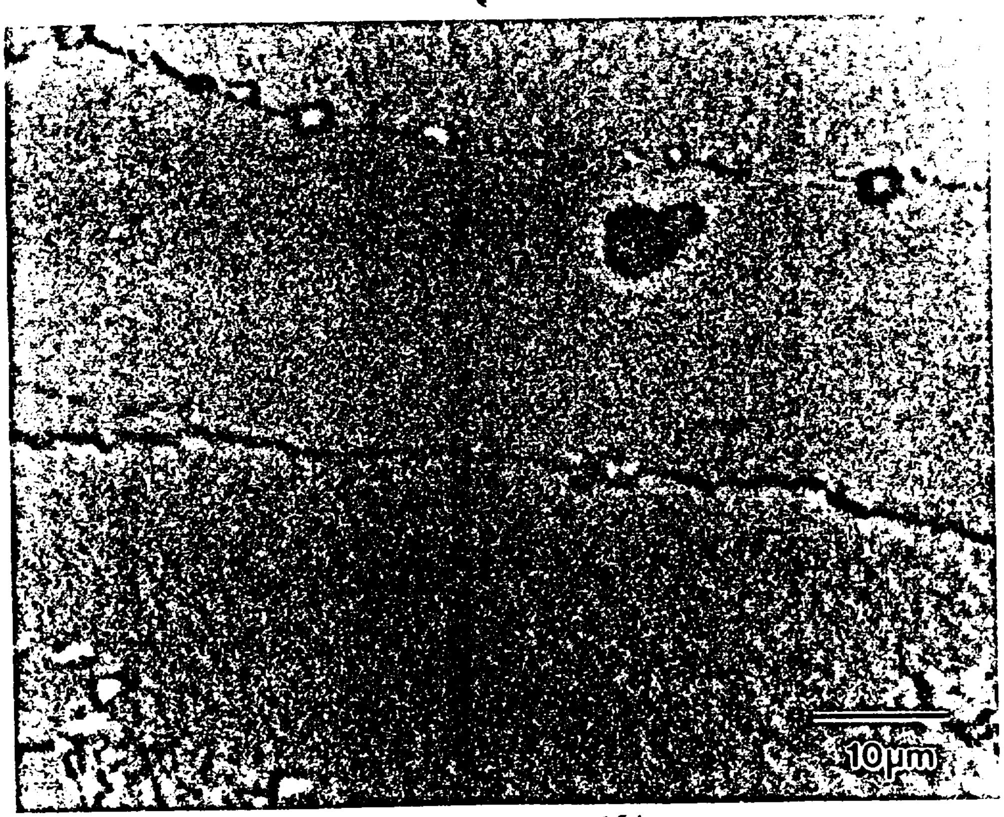


S-T





Alloy B



S-T

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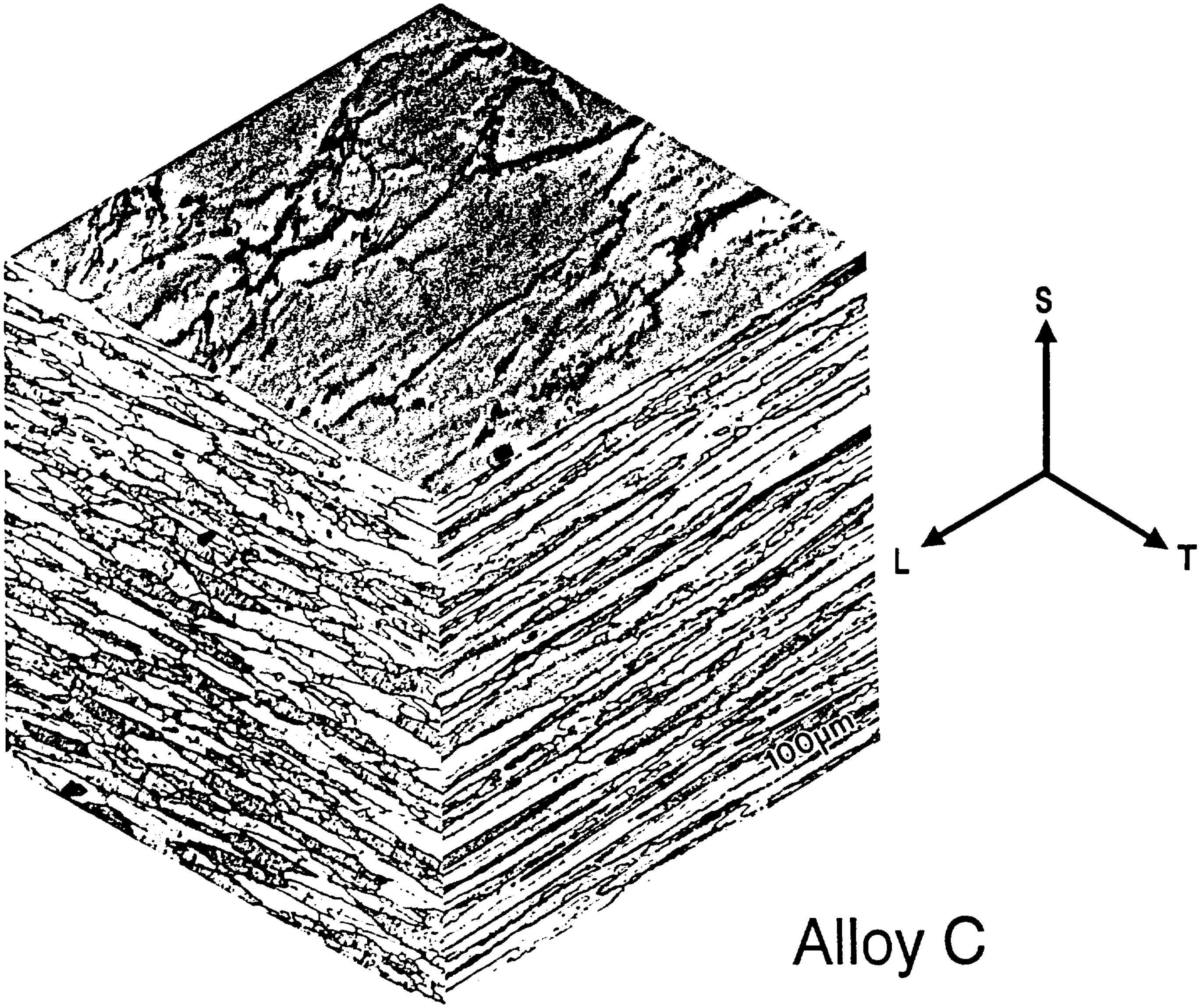
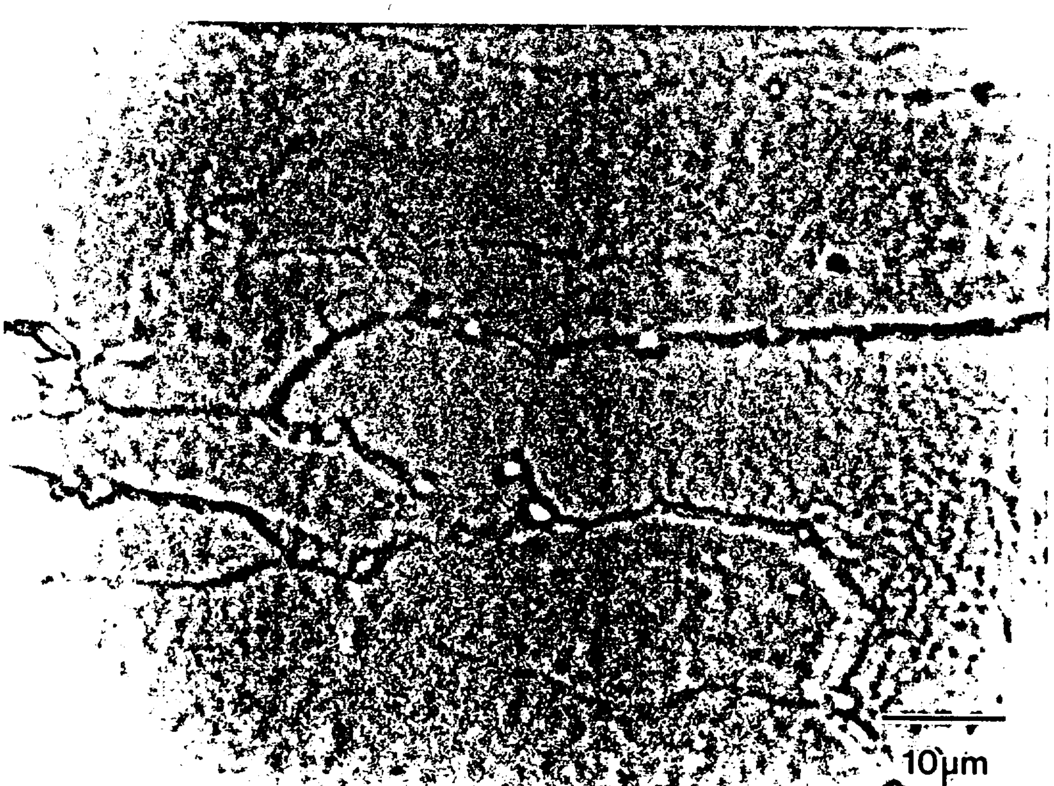


Alloy C



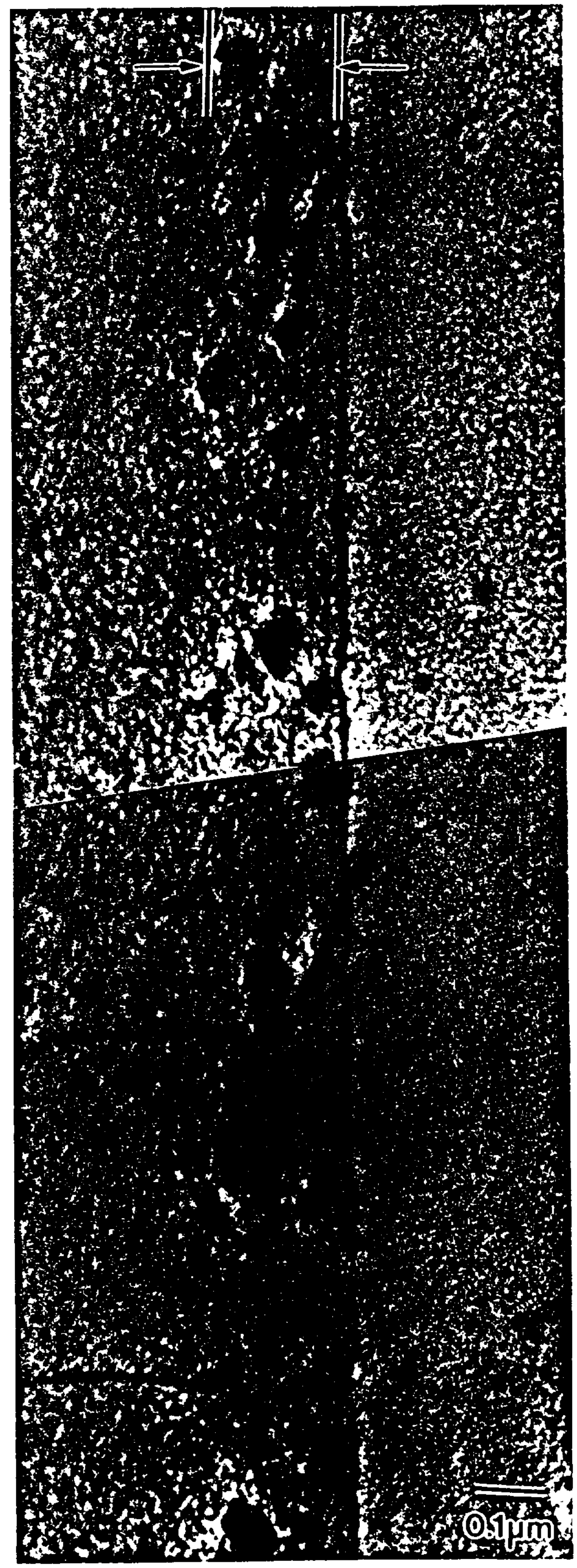
S-T

Quench Sensitivity

Alloy C SHT at 545 C for 30 minutes

Aged 5 hours at 160 C

Air quench after SHT



Cold water quench after SHT

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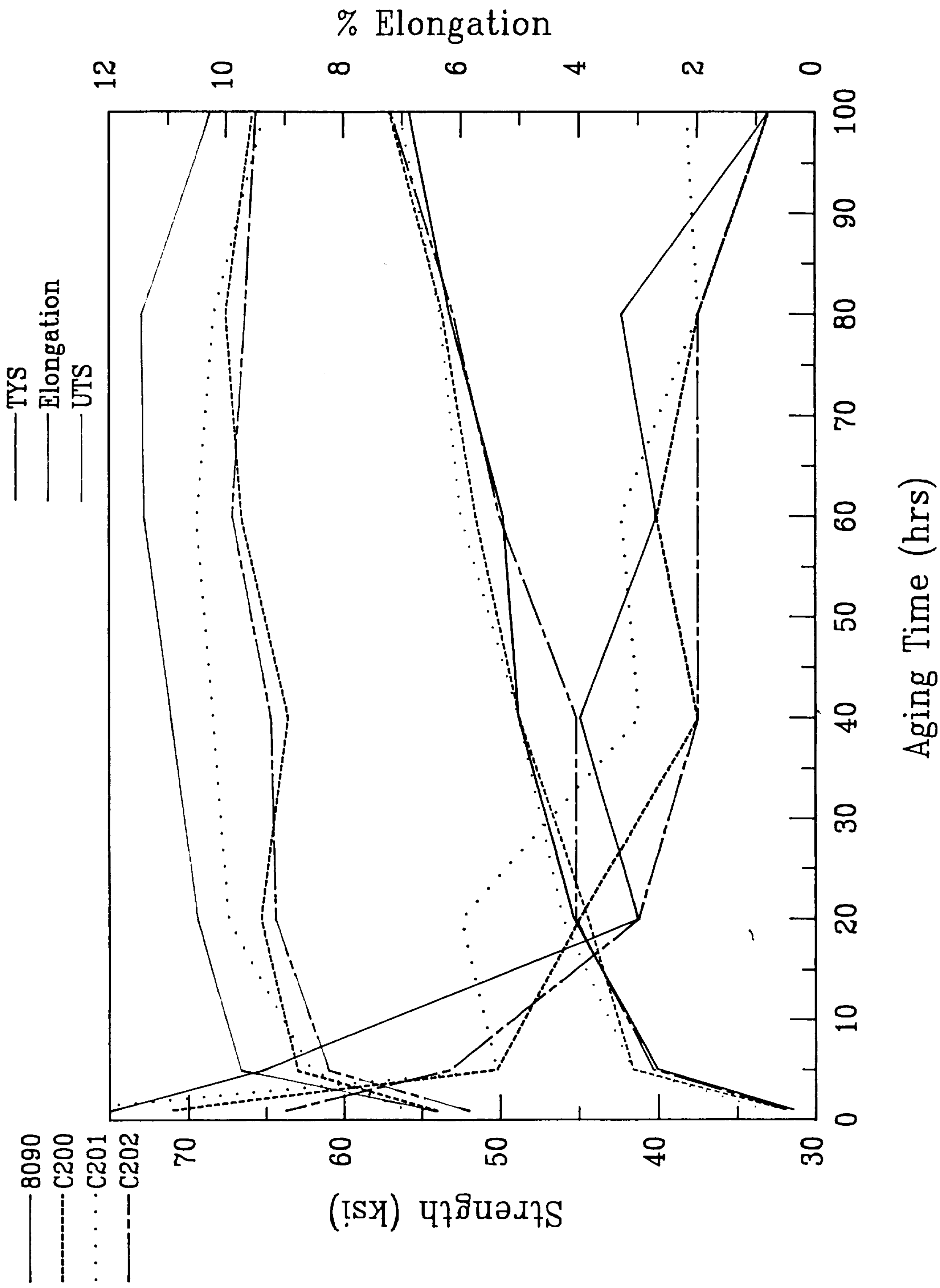
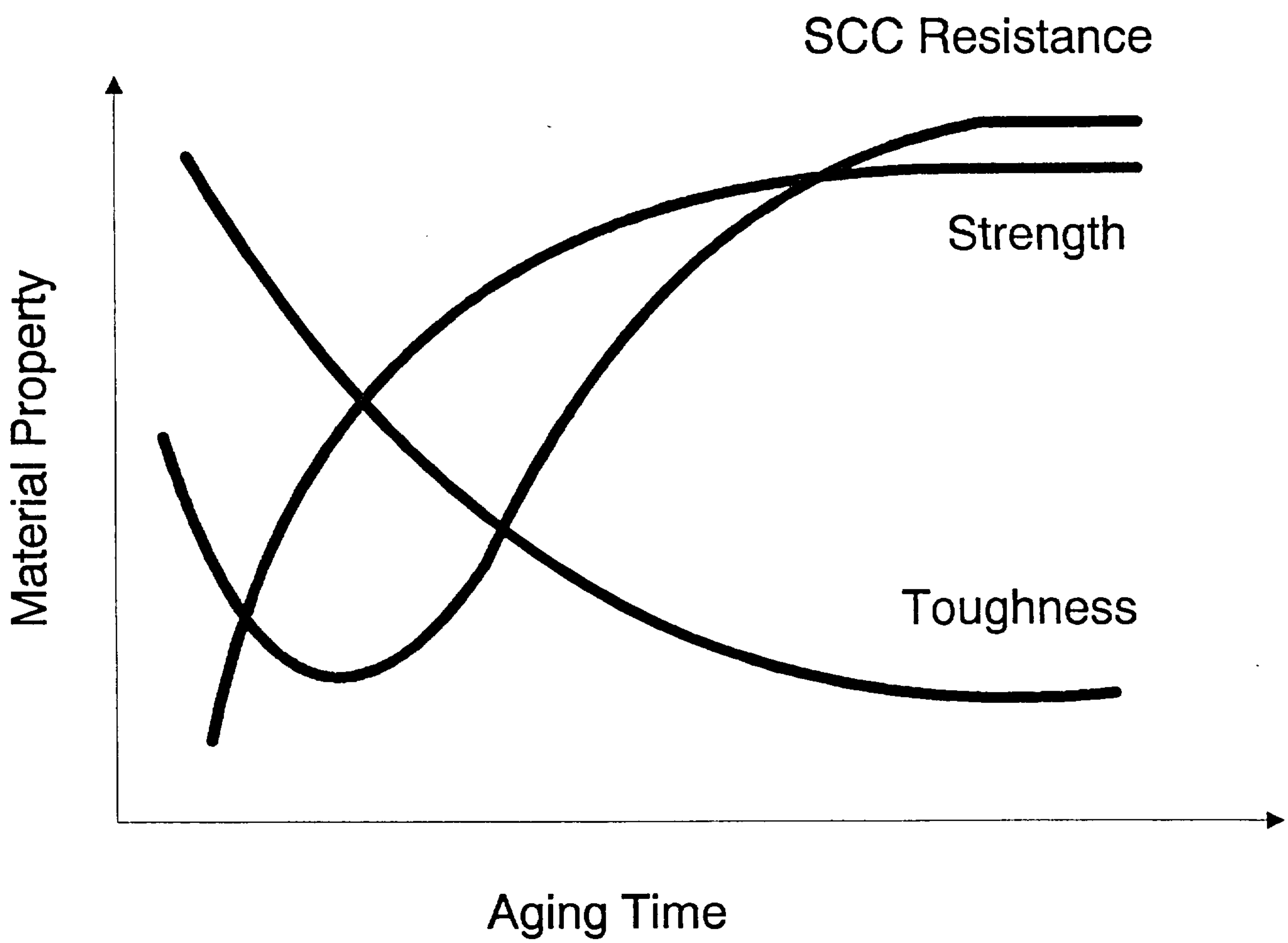
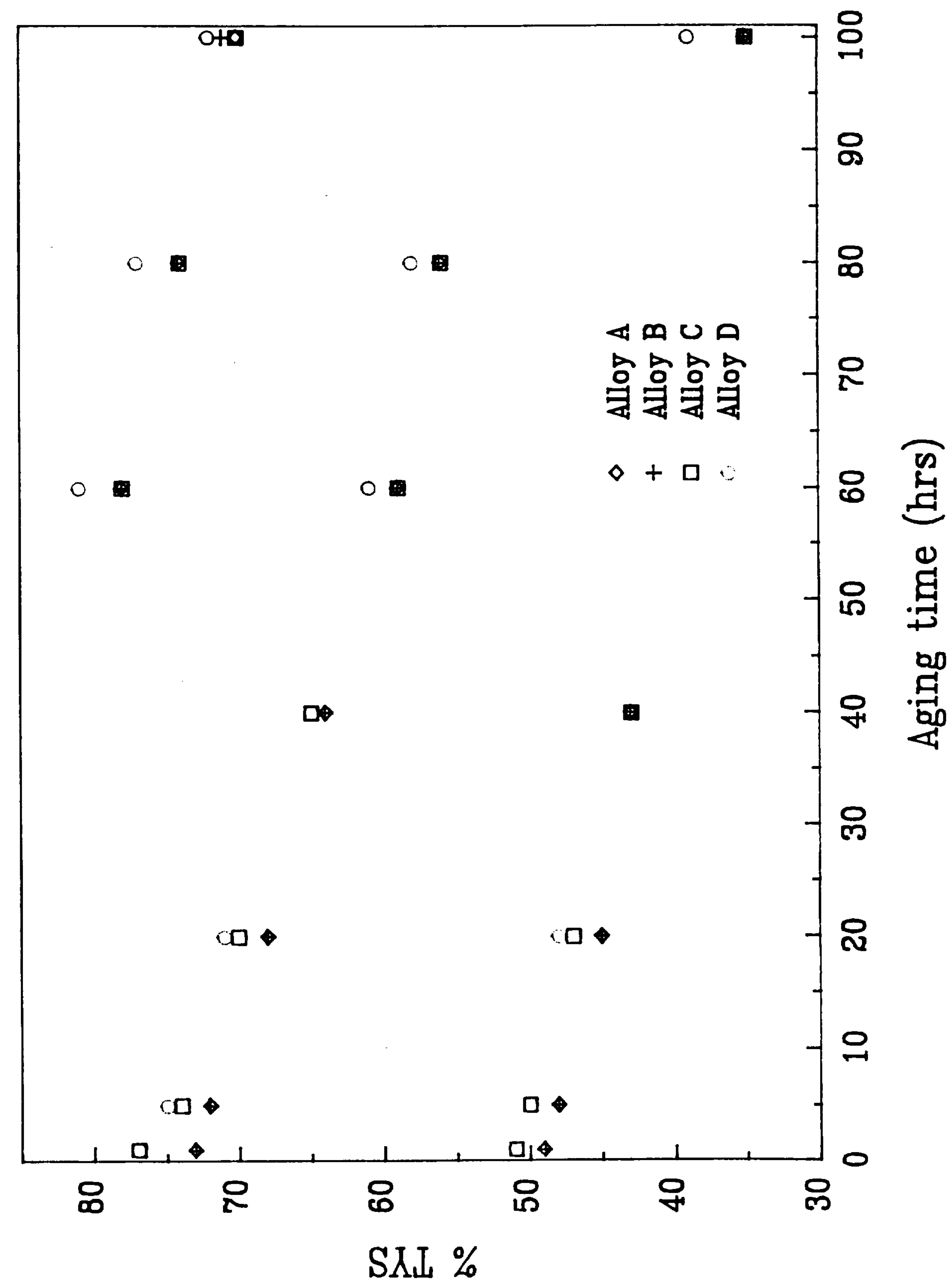

% Elongation
12
10
8
6
4
2
0
TYS
Elongation
UTS
Aging Time (hrs)
0
10
20
30
40
50
60
70
80
90
100
Strength (ksi)
70
60
50
40
30
8090
C200
C201
C202


SCC Resistance
Strength
Toughness
Material Property
Aging Time

Alloy Code	Aging Condition	*Composition wt-%* Li	Cu	Mg	Zn	K_{Ic} (S-T) (ksi$\sqrt{in.}$)	TYS (ksi)
Alloy A	5 hr @ 160C	2.53	1.22	0.67	1.36	12.8	41.6
	100 hr @ 160C	2.53	1.22	0.67	1.36	7.2	57.1
Alloy B	5 hr @ 160C	2.47	1.23	0.74	0.99	8.0	41.6
	100 hr @ 160C	2.47	1.23	0.74	0.99	7.8	56.4
Alloy C	5 hr @ 160C	2.54	1.23	0.49	1.00	18.3	40.3
	100 hr @ 160C	2.54	1.23	0.49	1.00	9.0	57.0
Alloy D	5 hr @ 160C	2.55	1.16	0.69	0.02	27.9	40.0
	100 hr @ 160C	2.55	1.16	0.69	0.02	10.7	55.8


% TYS
Aging time (hrs)
Alloy A
Alloy B
Alloy C
Alloy D
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
90
100

8090 and 8090 + Zn Variants

Alternate Immersion Testing (ASTM G-49)

30 day tests, 1/4" tensile samples

Exposure Stress

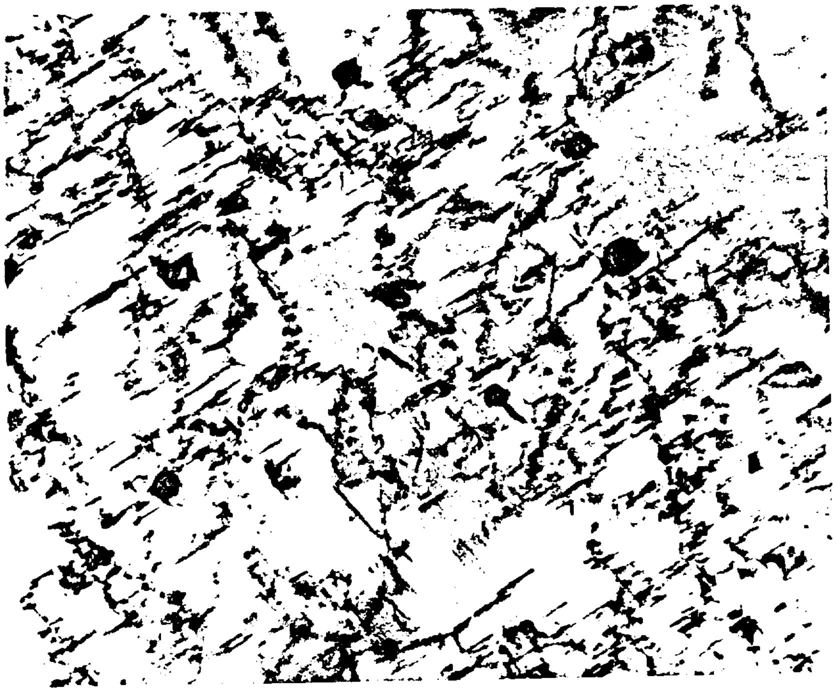
Alloy Code	Aging at 160C (hrs)	20 ksi F/N	20 ksi Days	30 ksi F/N	30 ksi Days	40 ksi F/N	40 ksi Days
Alloy A	1	3/3	2,2,3	3/3	2,2,2	N/A	
	5	2/3	2,3	3/3	1,1,2	N/A	
	20	0/3	----	0/3	----	N/A	
	40	0/3	----	0/3	----	N/A	
	60	0/3	----	N/A		0/3	----
	80	0/3	----	N/A		0/3	----
	100	0/3	----	N/A		1/3 *	----
Alloy B	1	2/3	3 ,10	3/3	2,2,2	N/A	
	5	3/3	1,1,2	3/3	1,1,2	N/A	
	20	0/3	----	3/3	2,3,9	N/A	
	40	0/3	----	0/3	----	N/A	
	60	0/3	----	N/A		0/3	----
	80	0/3	----	N/A		0/3	----
	100	0/3	----	N/A		0/3	----
Alloy C	1	3/3	2,3,3	3/3	3,4,17	N/A	
	5	3/3	2,2,3	3/3	1,2,2	N/A	
	20	1/3	17	2/3	9,17	N/A	
	40	0/3	----	0/3	----	N/A	
	60	0/3	----	N/A		0/3	----
	80	0/3	----	N/A		0/3	----
	100	0/3	----	N/A		0/3	----
Alloy D	1	3/3	4,5,17	3/3	4,6,7	N/A	
	5	3/3	3,3,5	3/3	1,2,3	N/A	
	20	2/3	3,4	3/3	2,2,2	N/A	
	40	2/3	3,5	3/3	3,3,4	N/A	
	60	1/3	4	N/A		3/3	2,2,2
	80	2/3	3,6	N/A		3/3	2,3,3
	100	3/3	2,2,3	N/A		3/3	1,1,1

* indicates sample fractured at threads

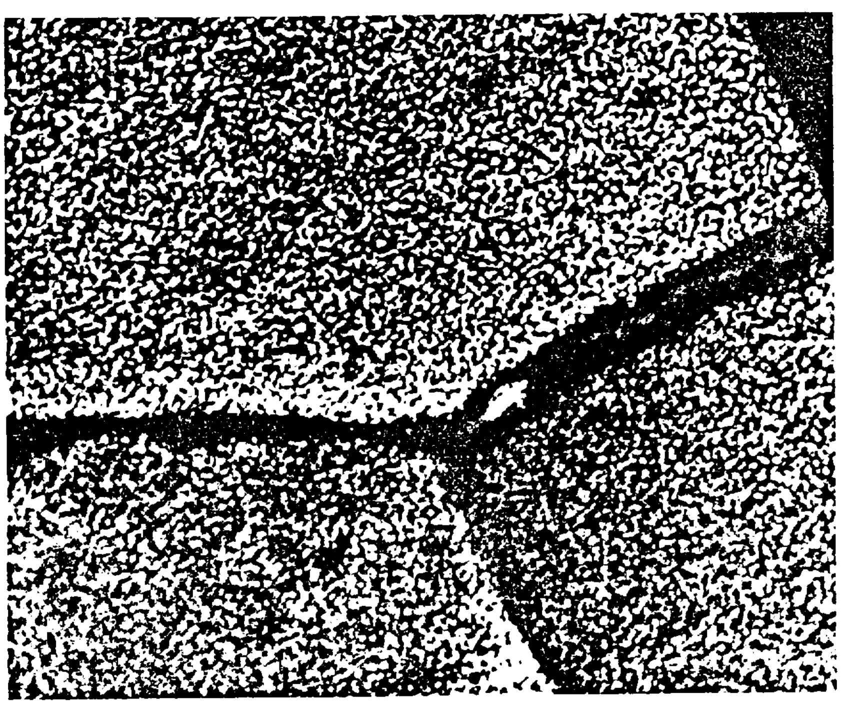
<u>Microstructure</u>

<u>5 hr @ 160C</u>	<u>20 hr @ 160C</u>
* small or no δ' free zones	* well developed δ'-FZ
* no S' apparent	* S' well developed
* boundary ppts	* boundary ppts

* solute distribution (?)



S' distribution in alloy A
after 20 hr at160C



δ ' distribution in alloy A
after 20 hr at 160C

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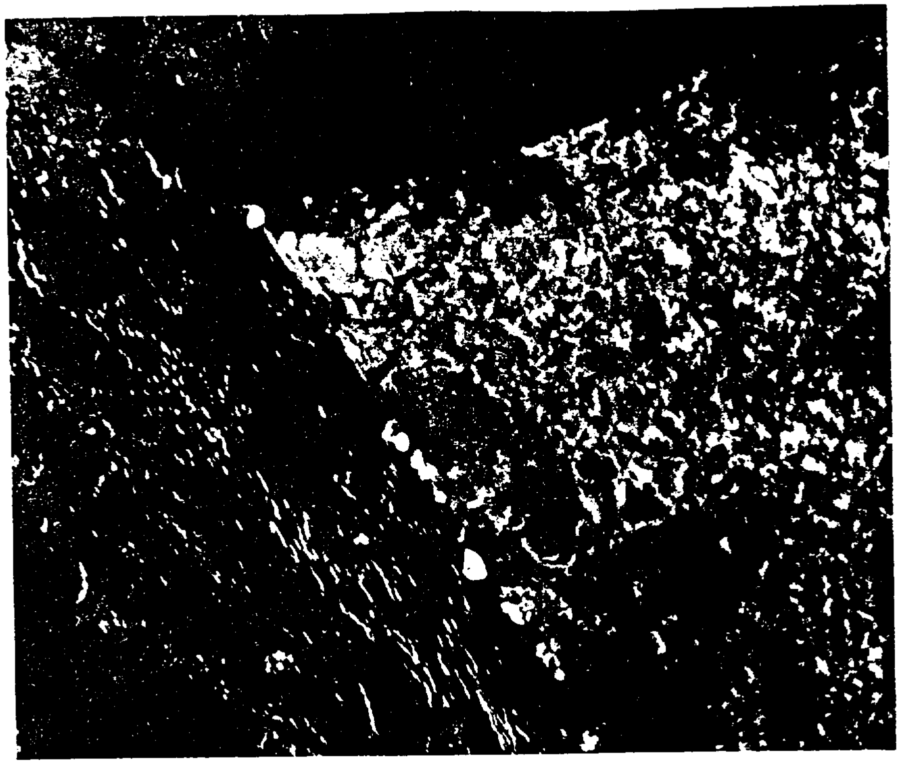
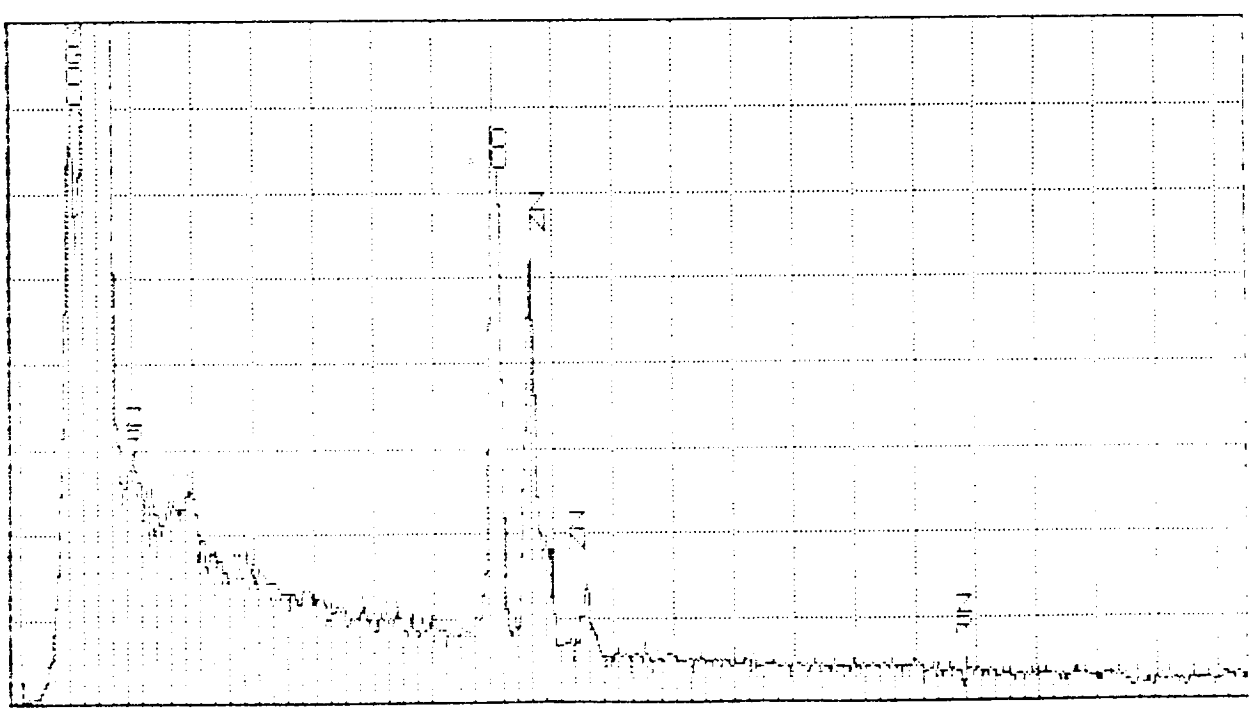
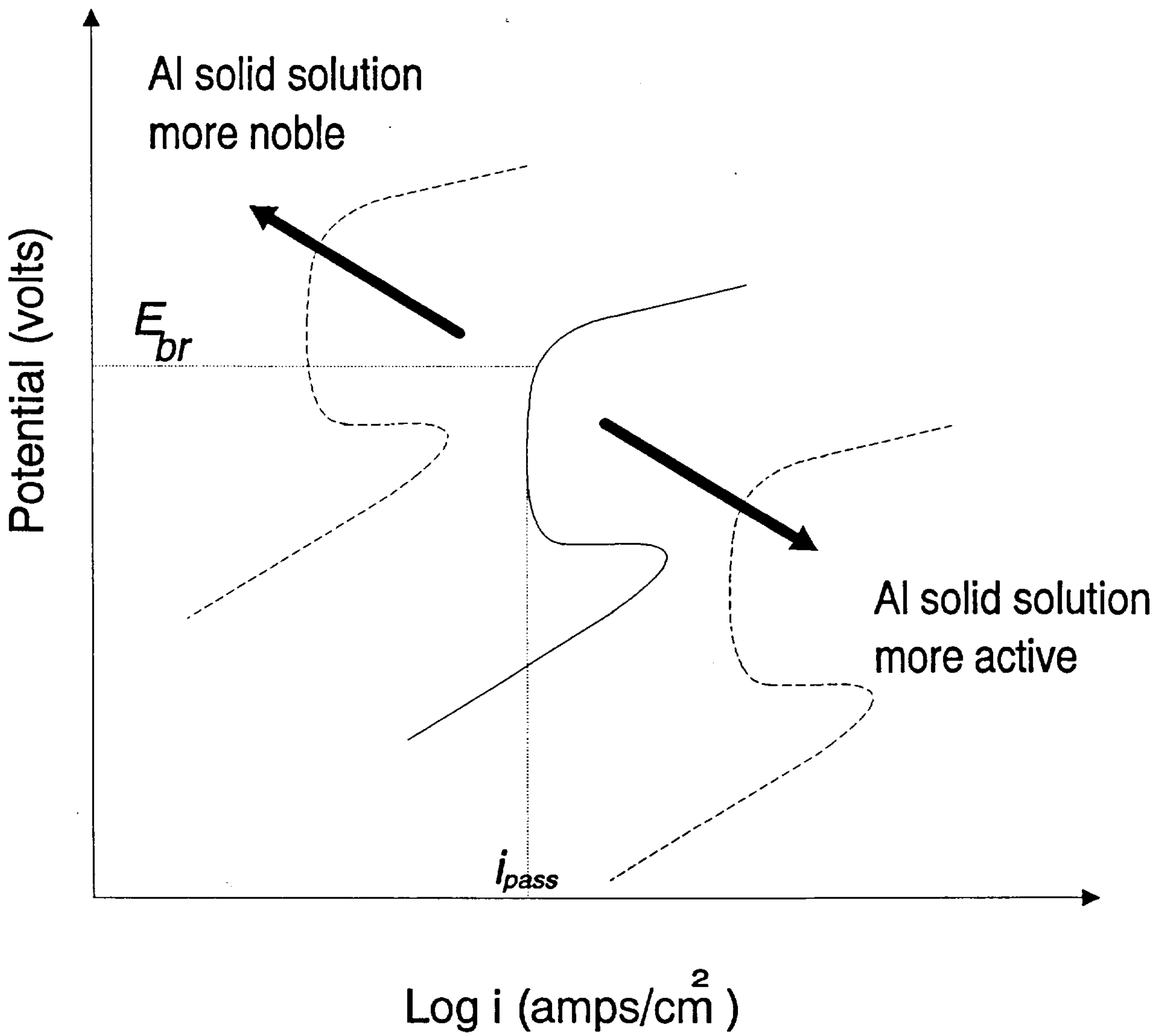


Alloy A
20 hrs at 160C
Precipitate D.F.

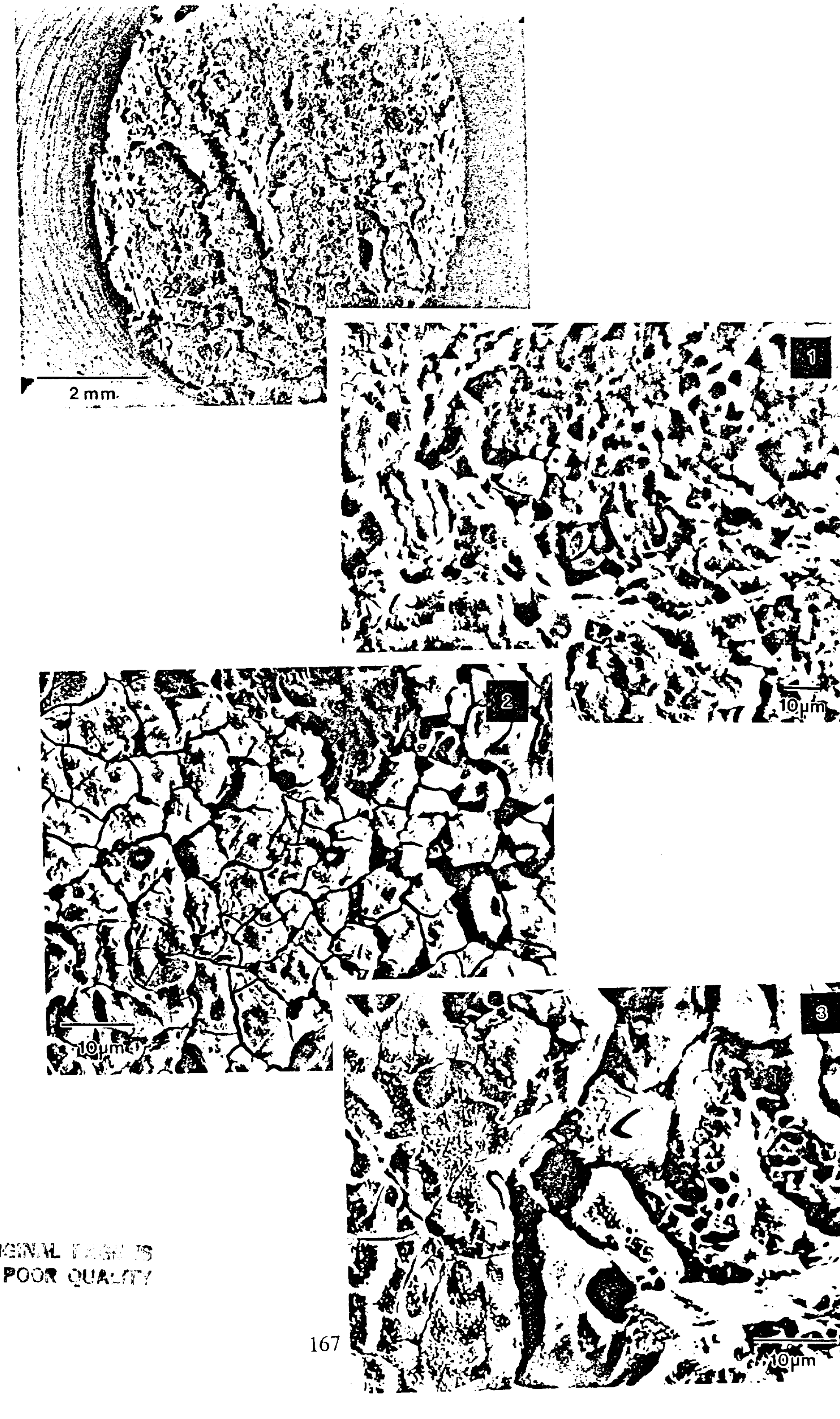


Effects of alloying on the corrosion behavior of Aluminum



Alloy B -T3 *

* Alloy was lightly etched in Keller's etchant


2 mm
1
2
3
10µm
10µm
10µm

Future Work

* DCB Samples to evaluate K_{1SCC} and plateau da/dt

* Compare/Contrast with slow strain rate approach

    ** Environmental changes

* Scanning auger spectroscopy

* Identification of precipitates via CBED

    ** Casting

* Different 8090 + Zn variant(s) to attempt improving:

    ** toughness

    ** maintain improved SCC performance

** Correlation between microstructure and SCC behavior **

SCC Testing of 8090 + Zn Alloys

Approach

* Evaluate SCC performance of 8090 and 8090 + Zn alloys in S-T orientation

Method

* Using a constant displacement rate technique, determine, rank and quantify pertinant SCC characteristics of these alloys and correlate the results with associated microstructure. These techniques should allow for determination of K_{th} and the plateau cracking velocities.

Experimental

* (See attached figures)

* Sample will be a cylindrical S-T specimen with a EDM induced chord across the edge of the sample followed by fatigue pre-cracking via stepped load shedding (decreasing K) so that final $K_{max} < K_{1scc}$.

* The test will be run under free corrosion potential.

* Grips will be pin loaded to allow for rotation.

* Displacement rates will be varied.

* da/dt will be continuously measured via a DC potential drop technique.

* K_{th} vs. displacement rate will be plotted for air and 3.5 NaCl environment to aid in determining appropriate displacement rate.

* K vs. da/dt will be plotted for a number of microstructures (i.e vs. aging time and temp.). Plateau cracking velocities and threshold K's will be determined.

* K_{th} and plateau cracking velocities can be compared/contrasted with DCB tests.

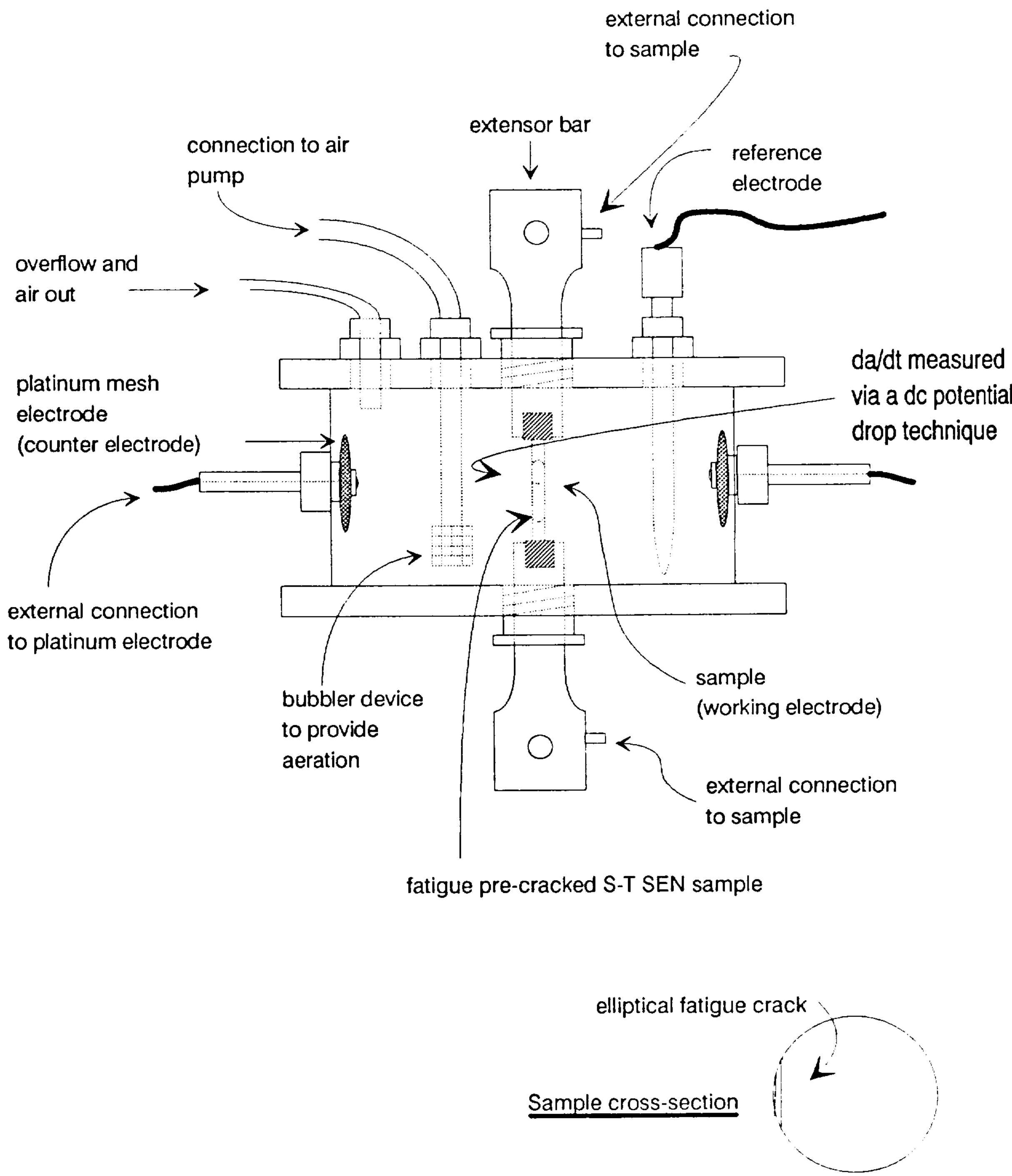
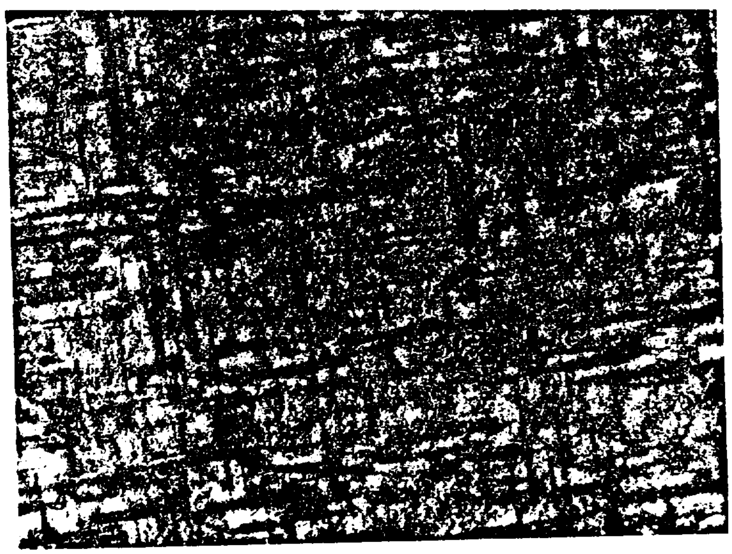


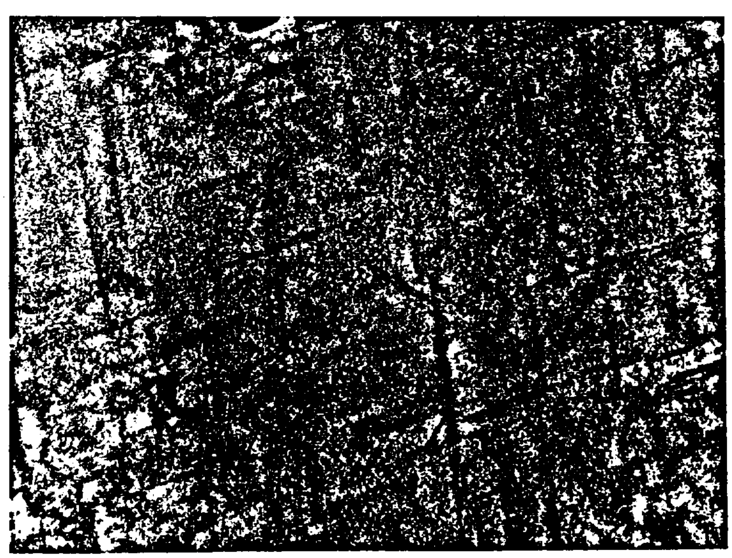
Figure 1. Schematic of load cell for constant displacement rate and constant load experiments

S' and T_1 Distribution in Alloys A-C after 100 hrs at 160C

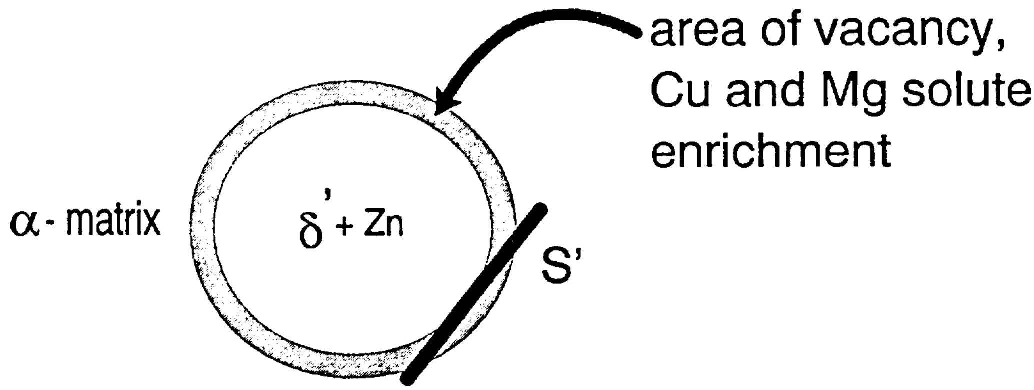
Alloy A



Alloy B



Alloy C



* Zn incorporated into delta prime
increasing the interfacial mismatch

* area adjacent to delta prime enriched in
vacancies, Cu and Mg, creating environment
conducive to S' nucleation

* heterogeneous nucleation site whose
competitiveness increases as the degree
of stretch decreases and the degree of solute
supersaturation increases