

PROJECT ADMINISTRATION DATA SHEET

ORIGINAL REVISION NO. _____

Project No. E-19-632 GTRC/~~GR~~ DATE 6 / 14 / 85

Project Director: S. D. Antolovich School/~~Lab~~ ChE

Sponsor: Martin Marietta Energy Systems, Inc.

Type Agreement: P.O. 19X-27437V

Award Period: From 4/15/85 To 1/14/86 (Performance) 1/14/86 (Reports)

Sponsor Amount:	<u>This Change</u>	<u>Total to Date</u>
Estimated: \$	_____	\$ <u>20,000</u>
Funded: \$	_____	\$ <u>20,000</u>

Cost Sharing Amount: \$ N/A Cost Sharing No: N/A

Title: Continuous - Cycling Fatigue Tests

ADMINISTRATIVE DATA

OCA Contact John Schonk x4820

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2) Sponsor Admin/Contractual Matters:

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 P.O. Box M
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Defense Priority Rating: N/A Military Security Classification: N/A
(or) Company/Industrial Proprietary: N/A

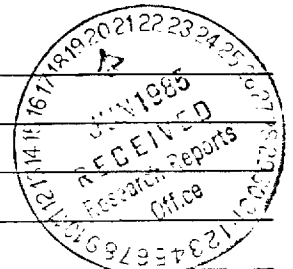
RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval - Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of \$500 or 125% of approved proposal budget category.

Equipment: Title vests with Sponsor

COMMENTS:



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Research Property Management	Reports Coordinator (OCA)	Project File
_____	Research Communications (2)	_____

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 11/20/86

Project No. E-18-613 (formerly E-19-632) School/~~XXX~~ CH E

Includes Subproject No.(s) N/A

Project Director(s) S. D. Antolovich GTRC /~~XXX~~ BIT

Sponsor Martin Marietta Energy Systems, Inc.

Title Continuous - Cycling Fatigue Tests

Effective Completion Date: _____ (Performance) _____ (Reports)

Grant/Contract Closeout Actions Remaining:

- None
- Final Invoice or Final Fiscal Report fixed price
- Closing Documents
- Final Report of Inventions (sent questionnaire to P.I.)
- Govt. Property Inventory & Related Certificate
- Classified Material Certificate
- Other _____

Continues Project No. _____ Continued by Project No. _____

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- Project File
- Other I. Newton
- A. Jones
- R. Embry

FATIGUE OF NUCLEAR WELDMENTS

A Final Report

Submitted To

Vinod K. Sikka
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Oak Ridge National Laboratory
Oak Ridge, Tennessee
Project no. 19X-27437V

by

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FATIGUE DATA OF NUCLEAR WELDMENTS

(9CR1MO - INCONEL (IN 82) - 304L

Oak Ridge National Laboratories had sectioned specimens from 2-1/2-inch schedule 160 pipe (2-7/8-in. O.D. by 3/8-in. wall thickness). Two distinct material conditions were received in the form of miniature fatigue specimens. The first, referred to as "base" specimens, consists of modified 9Cr-1Mo within the gauge section. The second, referred to as "weldment", contains a transition weldment consisting of modified 9Cr-1Mo (heat 30394, fully tempered) welded with Inconel (IN 82) weld filler to 304L stainless steel (heat B37372). These specimens were labeled 9CRB1 - 9CRB8 and 9CRW1 - 9CRW12, for base and weldment specimens respectively, and were approximately 0.096" in diameter with a 0.375" gauge section.

Fatigue specimens were run at a total strain range of 1.00 %, at temperatures of 25 C and 593 C. Temperature was attained with a single wind induction coil which was wrapped around the center of the gauge section at approximately 0.75 cm from the specimen surface.

Testing parameters and mechanical data are contained in the following pages, along with plots of plastic strain vs. cycle number as well as stress amplitude vs. cycle number. Similar material conditions are plotted on the same graphs for comparison.

There was difficulty in testing the specimens at both temperatures. At room temperature, initiation consistently occurred at the extensometer probe tip. The extensometer was spring loaded to the gauge section, where even the minimum applied tension would initiate a crack. The resulting effective procedure was a "slightly" rounded knife edge for a probe tip which was embedded in a very thin piece of double stick tape that was attached to the specimen.

At 593 C, a single wind coil produced a temperature zone that was concentrated at the specimen mid-section. This was necessary to allow use of the extensometer on such a small gauge section. This coil configuration produces a normal distribution of temperature centered about the the mid- section, which is constant within approximately 15-20 C over the gauge section. Although initiation was within the gauge section, the temperature was obviously lower by considerable amount at the probe tips.

Examination of the plots, Fig. 1-4, displays the base or Mod. 9Cr-1Mo mechanical behavior as similar to that seen previously, in which the material softened throughout its life. Weldment specimens displayed strain hardening and corresponding plastic strain increases with increasing cycle number. Since the gauge section contains very little Mod. 9Cr-1Mo, the response would be characteristic of the balance, whether this is IN 82 or a combination of IN 82 and 304L stainless.

It is suggested that in the future whenever testing these kinds of specimen geometries, that :

1) Specimens be fabricated with button head or other similar type to facilitate a reliable alignment of the specimen. If threaded ends are necessary, threads should be matched to the grips or an even better method would be to grind flats to the specimen ends as well as a flat on the top portion of the grip, and a woods metal pot at the other end.

2) Resistance heating will be necessary when testing materials with radically different chemistries. Induction characteristics are different for different materials so that coils will have to be "offset" from the mid-section of the gauge, and thus prevent extensometer attachment in specimens with small gauge sections. This of course will also provide a much better distribution of temperature.

3) More careful machining practice should be observed. It was noted that 9 of the 20 specimens were visually out of round. This was visible by simply rolling them across the table top. This might have contributed to the probe tip initiation problem. Porosity was visually evident on two of the specimens.

4) Upon testing at 593 C, it was noted that the weldment specimens displayed the welding boundary due to differences in oxidation behaviour, between the different materials. All weldment specimens tested at 593 C displayed the fusion zone to be at one end of the gauge section. The position was roughly the same in all cases, and it is assumed that the initial cut from the tube

was made incorrectly.

SPECIMEN # L9CRB1

TOTAL STRAIN = 1.00%
TEMPERATURE = 25 C
BASE CONDITION

NUMBER OF CYCLES TO INITIATION = 7882
NUMBER OF CYCLES TO FAILURE = 8967
TIME TO FAILURE (HOURS) = 12.952

LVDT CALIBRATION FACTOR = 375.75

SPECIMEN DIAMETER (in.) = 0.0940
SPECIMEN AREA (sq. in.) = 0.006940

STRAIN RATE = 3.85×10^{-3} / sec

HALF LIFE DATA

STRESS AMPLITUDE = 116362 PSI (802.04 MPa)

TENSILE STRESS = 56939 PSI (392.59 MPa)

COMPRESSIVE STRESS = 59386 PSI (409.46 MPa)

PLASTIC STRAIN RANGE (%) = 0.752

ELASTIC STRAIN RANGE (%) = 0.248

DATA FILE : AL9CRB1.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
1.000000	0.3246753
10.00000	0.3354978
20.00000	0.3409091
40.00000	0.3409091
80.00000	0.3409091
170.0000	0.3441558
405.0000	0.3463204
902.0000	0.3517316
2053.000	0.3571429
2680.000	0.3593073

DATA FILE : EL9CRB1.DAT

CYCLE NUMBER	STRESS AMPLITUDE (MPa)	STRESS AMPLITUDE (MPa)
1.000000	82.37056	11946.78
2.000000	79.30357	11501.95
4.000000	78.77780	11425.70
8.000000	78.77780	11425.70
16.00000	78.64636	11406.63
32.00000	78.64636	11406.63
64.00000	78.64636	11406.63
128.0000	78.60255	11400.28
256.0000	78.20822	11343.09
512.0000	78.12059	11330.38
1024.000	77.94534	11304.96
2048.000	77.46338	11235.06
4096.000	76.67473	11120.67
8192.000	60.90164	8832.99

SPECIMEN # L9CRB2

TOTAL STRAIN = 1.00%
TEMPERATURE = 25 C
BASE CONDITION

NUMBER OF CYCLES TO INITIATION = 2848
NUMBER OF CYCLES TO FAILURE = 3170
TIME TO FAILURE (HOURS) = 4.58

LVDT CALIBRATION FACTOR = 109.116

SPECIMEN DIAMETER (in.) = 0.0950
SPECIMEN AREA (sq. in.) = 0.00709

STRAIN RATE = 3.85×10^{-3} / sec

HALF LIFE DATA

STRESS AMPLITUDE = 123502 PSI (851.53 MPa)

TENSILE STRESS = 60662 PSI (418.26 MPa)

COMPRESSIVE STRESS = 62840 PSI (433.27 MPa)

PLASTIC STRAIN RANGE (%) = 0.622

ELASTIC STRAIN RANGE (%) = 0.391

DATA FILE : AL9CRB2.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
1.000000	0.5116273
7.000000	0.5348825
15.00000	0.5438206
30.00000	0.5617977
100.0000	0.5730337
200.0000	0.5842649
450.0000	0.6067415
1000.000	0.6224719
2025.000	0.6224719

DATA FILE : EL9CRB2.DAT

CYCLE NUMBER	STRESS AMPLITUDE (MPa)	STRESS AMPLITUDE (MPa)
1.000000	98.23317	14247.44
2.000000	98.66214	14309.66
4.000000	95.23041	13811.93
8.000000	92.44213	13407.53
16.00000	91.02654	13202.22
32.00000	89.61096	12996.90
64.00000	87.72351	12723.15
128.0000	85.81032	12445.67
256.0000	85.44999	12393.41
512.0000	84.29179	12225.43
1024.000	82.57592	11976.56
2048.000	81.07454	11758.81

SPECIMEN # L9CRB6

TOTAL STRAIN = 1.00%
TEMPERATURE = 25 C
BASE CONDITION

NUMBER OF CYCLES TO INITIATION = 2426
NUMBER OF CYCLES TO FAILURE = 2743
TIME TO FAILURE (HOURS) = 3.96

LVDT CALIBRATION FACTOR = 377.75

SPECIMEN DIAMETER (in.) = 0.0946
SPECIMEN AREA (sq. in.) = 0.00703

STRAIN RATE = 3.85×10^{-3} / sec

HALF LIFE DATA

STRESS AMPLITUDE = 106886 PSI (736.96 MPa)

TENSILE STRESS = 52706 PSI (363.40 MPa)

COMPRESSIVE STRESS = 54180 PSI (373.56 MPa)

PLASTIC STRAIN RANGE (%) = 0.572

ELASTIC STRAIN RANGE (%) = 0.428

DATA FILE : AL9CRB6.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
3.000000	0.5655172
10.00000	0.5668966
20.00000	0.5696552
40.00000	0.5724138
80.00000	0.5758621
170.0000	0.5793104
370.0000	0.5793104
840.0000	0.5724138
2435.000	0.5517241

DATA FILE : EL9CRB6.DAT

CYCLE NUMBER	STRESS AMPLITUDE (MPa)	STRESS AMPLITUDE (MPa)
1.000000	78.73340	11419.26
2.000000	78.30080	11356.51
4.000000	78.04124	11318.87
8.000000	77.65190	11262.40
16.00000	76.78670	11136.91
32.00000	75.44563	10942.41
64.00000	74.83999	10854.57
128.0000	73.10959	10603.59
256.0000	72.67699	10540.85
512.0000	72.67699	10540.85
1024.000	72.67699	10540.85
2048.000	72.67699	10540.85

SPECIMEN # L9CRB7

TOTAL STRAIN = 1.00%
TEMPERATURE = 25 C
BASE CONDITION

NUMBER OF CYCLES TO INITIATION = 1810
NUMBER OF CYCLES TO FAILURE = 2148
TIME TO FAILURE (HOURS) = 3.10

LVDT CALIBRATION FACTOR = 377.75

SPECIMEN DIAMETER (in.) = 0.0952
SPECIMEN AREA (sq. in.) = 0.00712

STRAIN RATE = 3.85×10^{-3} / sec

HALF LIFE DATA

STRESS AMPLITUDE = 110965 PSI (765.08 MPa)

TENSILE STRESS = 54305 PSI (374.42 MPa)

COMPRESSIVE STRESS = 56659 PSI (390.66 MPa)

PLASTIC STRAIN RANGE (%) = 0.590

ELASTIC STRAIN RANGE (%) = 0.410

DATA FILE : AL9CRB7.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
1.000000	0.5655172
10.00000	0.5724138
25.00000	0.5724138
50.00000	0.5862069
100.0000	0.5931035
200.0000	0.5972414
400.0000	0.6000000
800.0000	0.6000000
1750.000	0.5896552

DATA FILE : EL9CRB7.DAT

CYCLE NUMBER	STRESS AMPLITUDE (MPa)	STRESS AMPLITUDE (PSI)
1.000000	76.03543	11027.95
2.000000	75.82185	10996.97
4.000000	75.60826	10966.00
8.000000	75.56554	10959.80
16.00000	75.39468	10935.02
32.00000	74.96751	10873.06
64.00000	74.11318	10749.15
128.0000	74.11318	10749.15
256.0000	74.11318	10749.15
512.0000	74.11318	10749.15
1024.000	74.54035	10811.11
2048.000	66.21062	9602.990

SPECIMEN # L9CRW1

TOTAL STRAIN = 1.00%
TEMPERATURE = 25 C
WELDMENT CONDITION

NUMBER OF CYCLES TO INITIATION = 5457
NUMBER OF CYCLES TO FAILURE = 6330
TIME TO FAILURE (HOURS) = 9.14

LVDT CALIBRATION FACTOR = 375.75

SPECIMEN DIAMETER (in.) = 0.0985
SPECIMEN AREA (sq. in.) = 0.00762

STRAIN RATE = 3.85×10^{-3} / sec

HALF LIFE DATA

STRESS AMPLITUDE = 104088 PSI (717.67 MPa)
TENSILE STRESS = 48094 PSI (331.60 MPa)
COMPRESSIVE STRESS = 55994 PSI (386.07 MPa)

PLASTIC STRAIN RANGE (%) = 0.189
ELASTIC STRAIN RANGE (%) = 0.811

DATA FILE : AL9CRW1.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
1.000000	0.2344086
10.00000	0.2129032
25.00000	0.1989247
50.00000	0.1956989
57.00000	0.1978495
100.0000	0.1881720
280.0000	0.1849462
583.0000	0.1913978
587.0000	0.1913978
1000.000	0.1881720
2044.000	0.1881720
3900.000	0.1881720
4355.000	0.1881720

DATA FILE : EL9CRW1.DAT

CYCLE NUMBER	STRESS AMPLITUDE (MPa)	STRESS AMPLITUDE (MPa)
1.000000	64.69164	9382.681
2.000000	67.21209	9748.240
4.000000	67.63216	9809.167
8.000000	70.57269	10235.65
16.00000	71.49686	10369.69
32.00000	71.41285	10357.50
64.00000	72.16898	10467.17
128.0000	72.42103	10503.73
256.0000	72.46304	10509.82
512.0000	73.09315	10601.21
1024.000	73.30318	10631.67
2048.000	72.63107	10534.19
4096.000	71.74891	10406.25

SPECIMEN # L9CRW3

TOTAL STRAIN = 1.00%
TEMPERATURE = 25 C
WELDMENT CONDITION

NUMBER OF CYCLES TO INITIATION = 20421
NUMBER OF CYCLES TO FAILURE = 21479
TIME TO FAILURE (HOURS) = 31.03

LVDT CALIBRATION FACTOR = 375.75

SPECIMEN DIAMETER (in.) = 0.0970
SPECIMEN AREA (sq. in.) = 0.00739

STRAIN RATE = 3.85×10^{-3} / sec

HALF LIFE DATA

STRESS AMPLITUDE = 92383 PSI (636.96 MPa)

TENSILE STRESS = 45744 PSI (315.39 MPa)

COMPRESSIVE STRESS = 46639 PSI (321.57 MPa)

PLASTIC STRAIN RANGE (%) = 0.170

ELASTIC STRAIN RANGE (%) = 0.830

DATA FILE : AL9CRW3.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
1.000000	0.2032967
7.000000	0.2032967
15.00000	0.2032967
25.00000	0.1923077
50.00000	0.1923077
100.0000	0.1978022
200.0000	0.1978022
410.0000	0.1813187
825.0000	0.1813187
1315.000	0.1813187
2055.000	0.1813187
4240.000	0.1703297
6305.000	0.1703297
7140.000	0.1703297
12484.00	0.1703297
13850.00	0.1675824
17000.00	0.1675824
20690.00	0.1813187
20736.00	0.1813187
20950.00	0.1895604
21010.00	0.1923077

DATA FILE : EL9CRW3.DAT

CYCLE NUMBER	STRESS AMPLITUDE (MPa)	STRESS AMPLITUDE (MPa)
1.000000	62.52802	9068.876
2.000000	62.52802	9068.876
4.000000	62.52802	9068.876
8.000000	62.52802	9068.876
16.00000	62.52802	9068.876
32.00000	62.08612	9004.784
64.00000	62.08612	9004.784
128.0000	63.19086	9165.012
256.0000	63.19086	9165.012
512.0000	63.63275	9229.104
1024.000	64.07465	9293.194
2048.000	64.73749	9389.330
4096.000	64.95844	9421.376
8192.000	65.53289	9504.694
16384.00	64.51654	9357.285

SPECIMEN # L9CRW5

TOTAL STRAIN = 1.00%
TEMPERATURE = 25 C
WELDMENT CONDITION

NUMBER OF CYCLES TO INITIATION = 2670
NUMBER OF CYCLES TO FAILURE = 3135
TIME TO FAILURE (HOURS) = 4.53

·LVDT CALIBRATION FACTOR = 377.75

SPECIMEN DIAMETER (in.) = 0.0941
SPECIMEN AREA (sq. in.) = 0.00695

STRAIN RATE = 3.85×10^{-3} / sec

HALF LIFE DATA

STRESS AMPLITUDE = 117569 PSI (810.61 MPa)

TENSILE STRESS = 58658 PSI (404.43 MPa)

COMPRESSIVE STRESS = 58911 PSI (406.18 MPa)

PLASTIC STRAIN RANGE (%) = 0.313

ELASTIC STRAIN RANGE (%) = 0.688

DATA FILE : AL9CRW5.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
1.000000	0.3750000
10.00000	0.3347222
25.00000	0.3208333
50.00000	0.3159722
100.0000	0.2986111
210.0000	0.2986111
430.0000	0.2986111
820.0000	0.3055556
1820.000	0.3125000
2840.000	0.3194444
2970.000	0.3229167

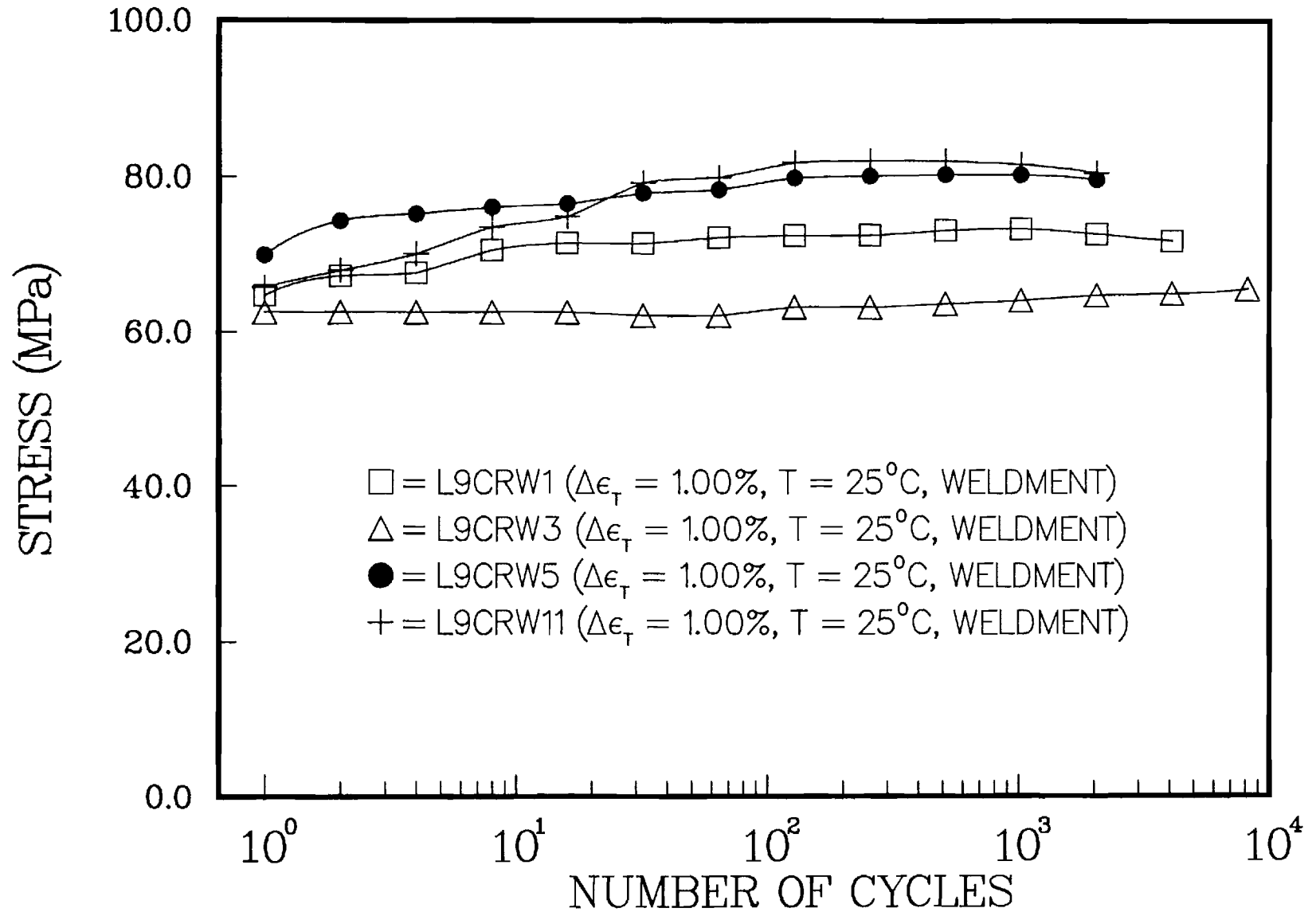
DATA FILE : AL9CRW11.DAT

CYCLE NUMBER	PLASTIC STRAIN (%)
1.000000	0.4930556
5.000000	0.4861111
10.00000	0.4583333
20.00000	0.4305556
40.00000	0.3958333
100.0000	0.3611111
200.0000	0.3472222
420.0000	0.3472222
800.0000	0.3576389
1065.000	0.3645833
2750.000	0.3680556
3145.000	0.3645833

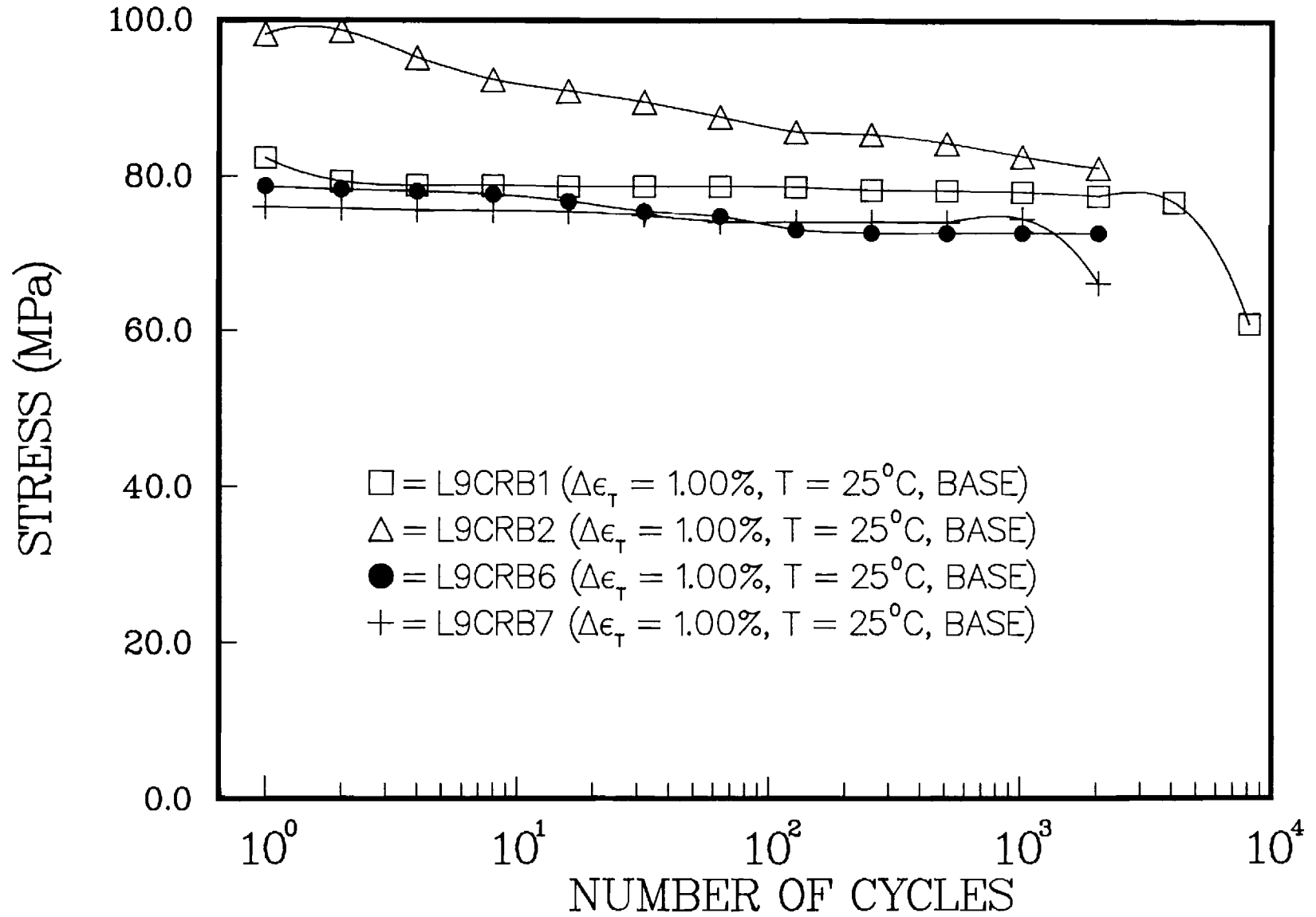
DATA FILE : EL9CRW11.DAT

CYCLE NUMBER	STRESS AMPLITUDE (MPa)	STRESS AMPLITUDE (MPa)
1.000000	65.75537	9536.961
2.000000	67.91837	9850.677
4.000000	70.08138	10164.39
8.000000	73.54219	10666.34
16.00000	74.83999	10854.57
32.00000	79.16600	11482.00
64.00000	79.81490	11576.11
128.0000	81.76161	11858.46
256.0000	81.97791	11889.83
512.0000	81.97791	11889.83
1024.000	81.54531	11827.09
2048.000	80.46381	11670.23

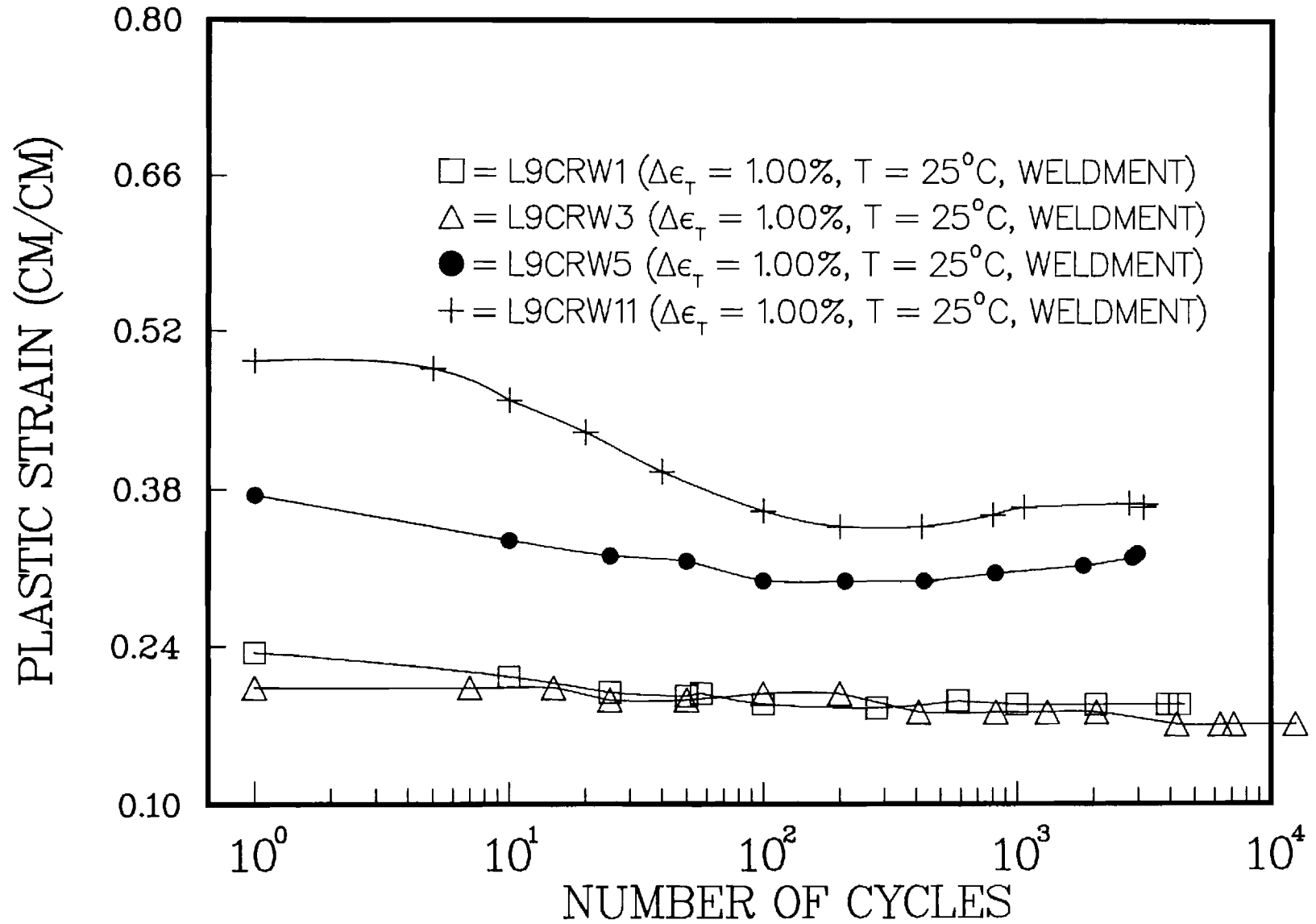
STRESS ENVELOPE



STRESS ENVELOPE



STRAIN vs CYCLE NUMBER



STRAIN vs CYCLE NUMBER

