APPENDIX E

STRESS STRAIN CURVES
WATTS BAR UNIT 1, CAPSULE W

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WL8

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WL8	
Test temperature	70 F	21. C
Material	LONG	
Modulus	29126. ksi	200825. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1545 in	3.92 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

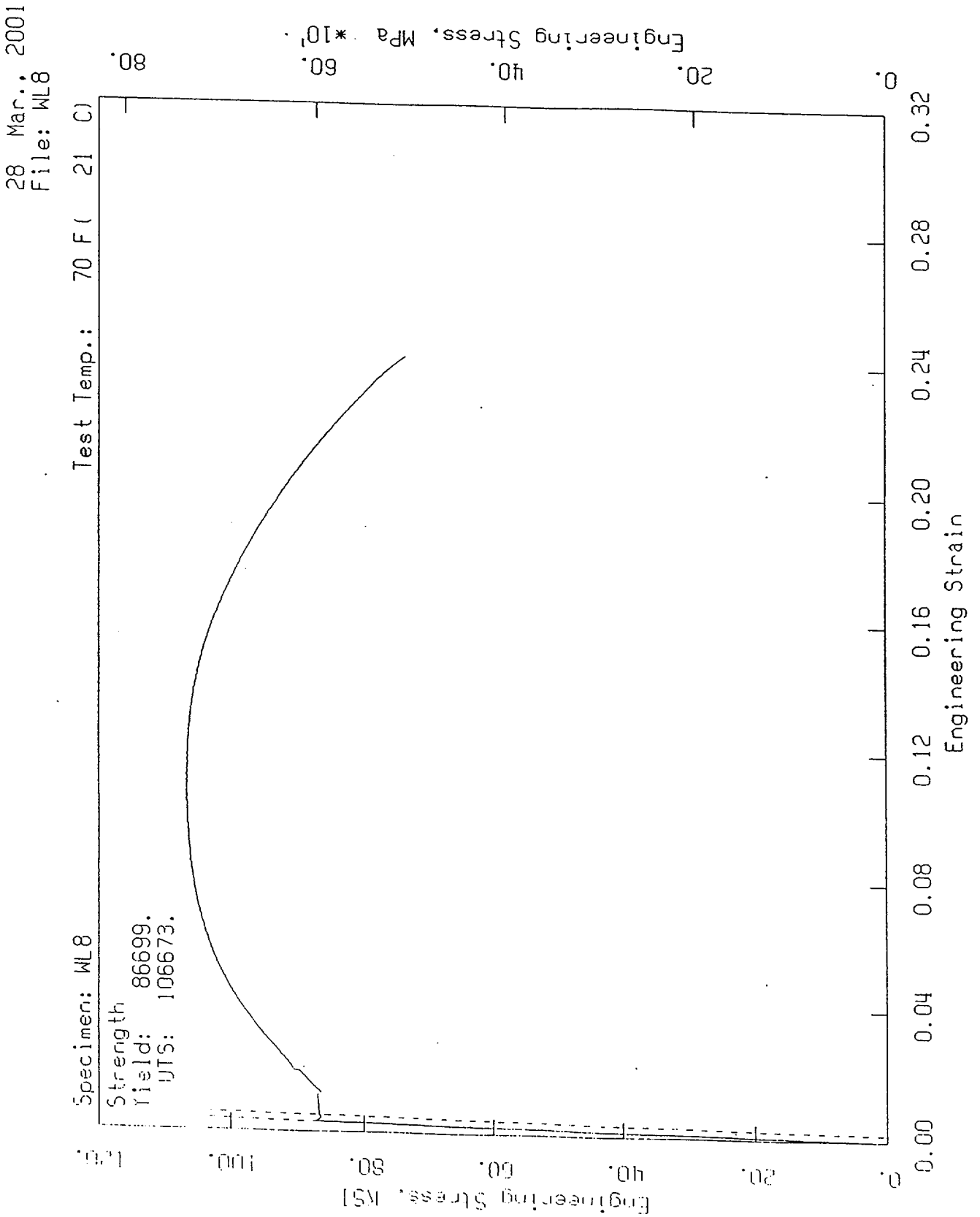
TEST RESULTS

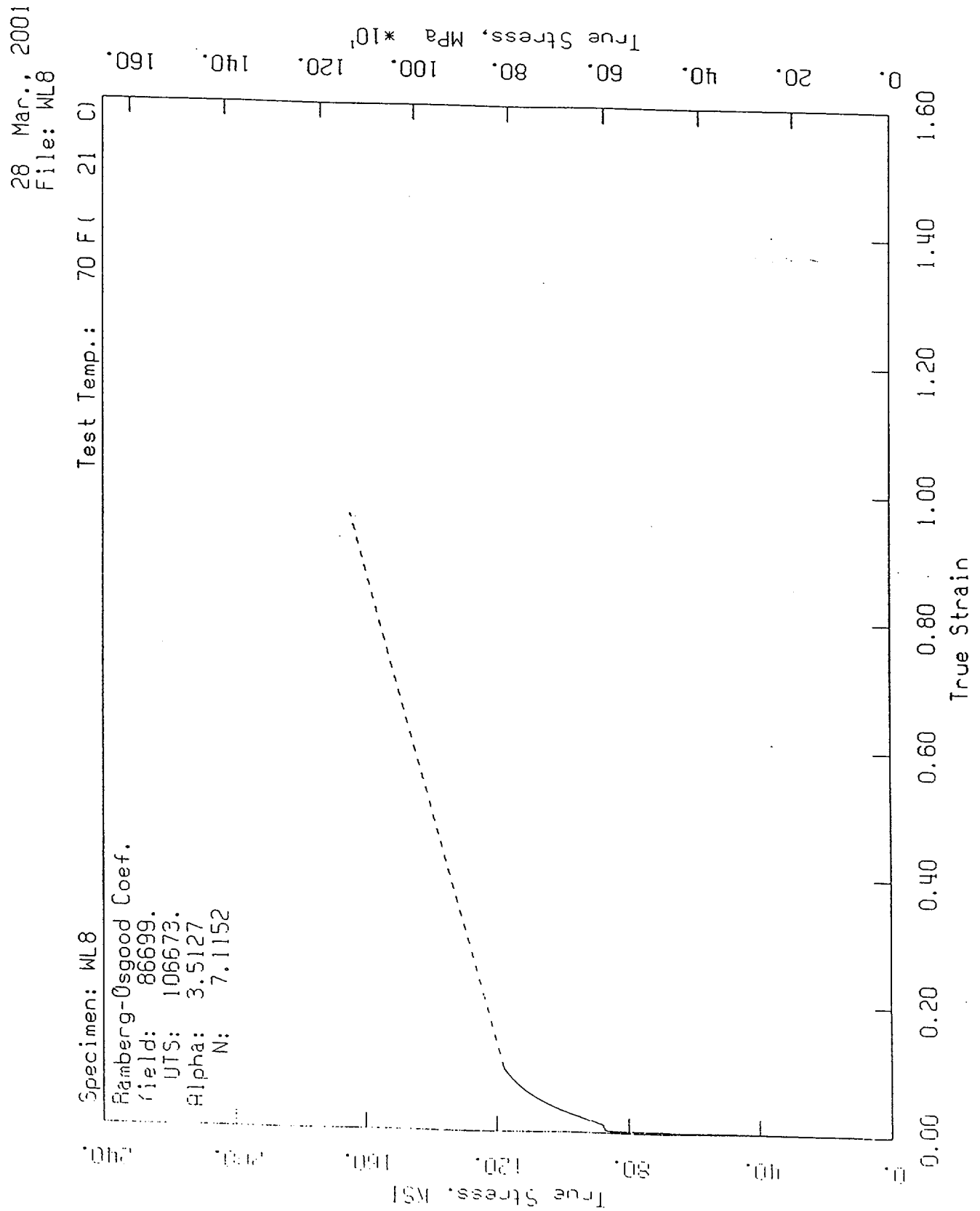
Yield Strength	86699. psi	597.8 MPa
Tensile Strength	106673. psi	735.5 MPa
Fracture Load	3611. lb	16062. N
Fracture Stress	192616. psi	1328.1 MPa
Fracture Strength	73565. psi	507.2 MPa
Young`s Modulus	2.95E+07 psi	2.04E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.0993	
Total Elongation (Ext)	.2392	
Reduction in Diameter	38.2 %	
Reduction in Area	61.8 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	3.513	.004
N	7.115	.020


28 Mar., 2001
File: WL8
Test Temp.: 70 F(21 C)
Specimen: WL8
Strength
Yield: 86699.
UTS: 106673.
Engineering Stress, MPa *10¹
Engineering Strain
0.
20.
40.
60.
80.
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32


28 Mar., 2001
File: WL8
Test Temp.: 70 F (21 C)
Specimen: WL8
Ramberg-Osgood Coef.
Yield: 86699.
UTS: 106673.
Alpha: 3.5127
N: 7.1152
True Stress, MPa *10
0. 20. 40. 60. 80. 100. 120. 140. 160.
True Stress, MSI
0. 40. 80. 120. 160.
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
True Strain

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WL7

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WL7	
Test temperature	175 F	79. C
Material	LONG	
Modulus	28595. ksi	197165. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1480 in	3.76 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

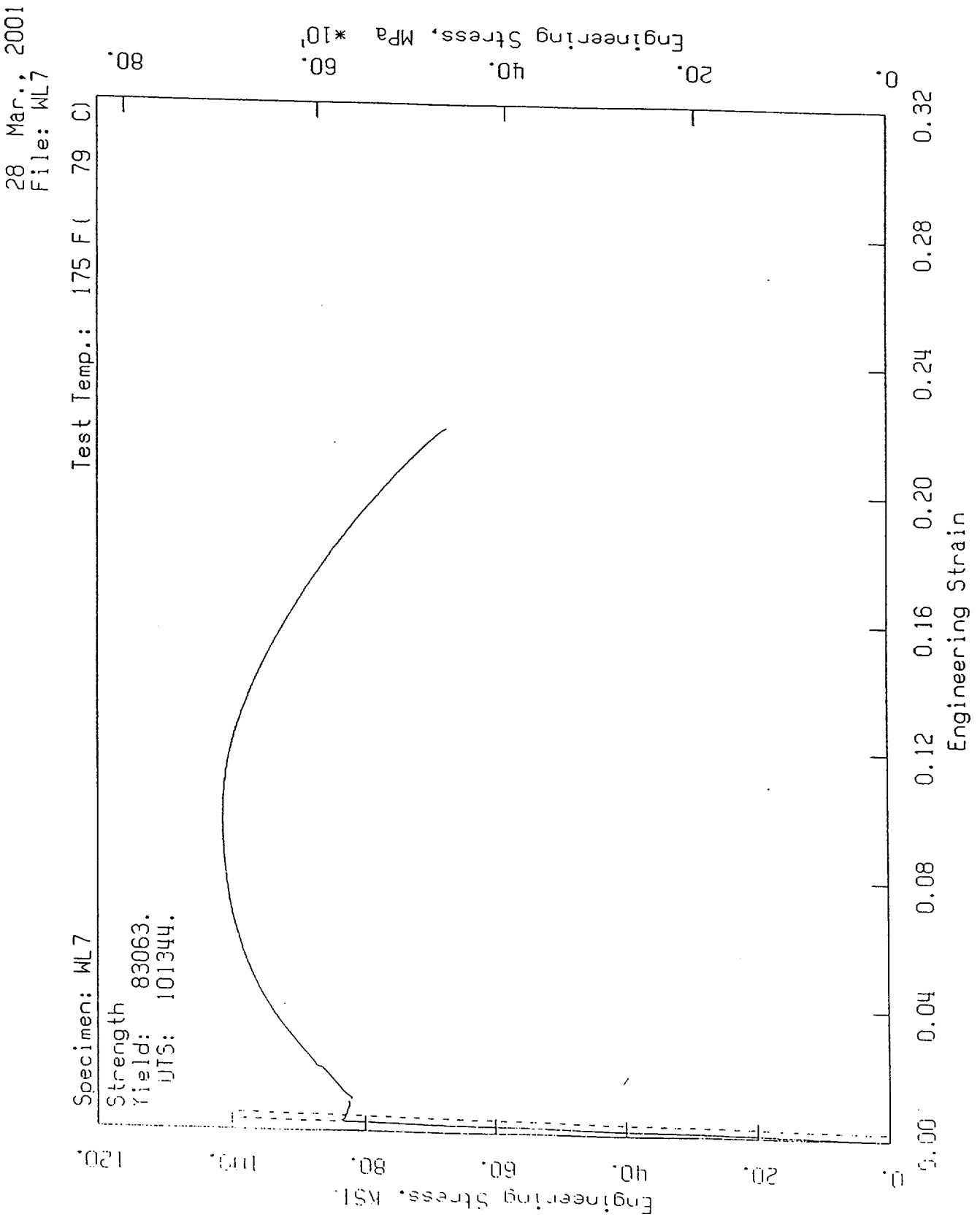
TEST RESULTS

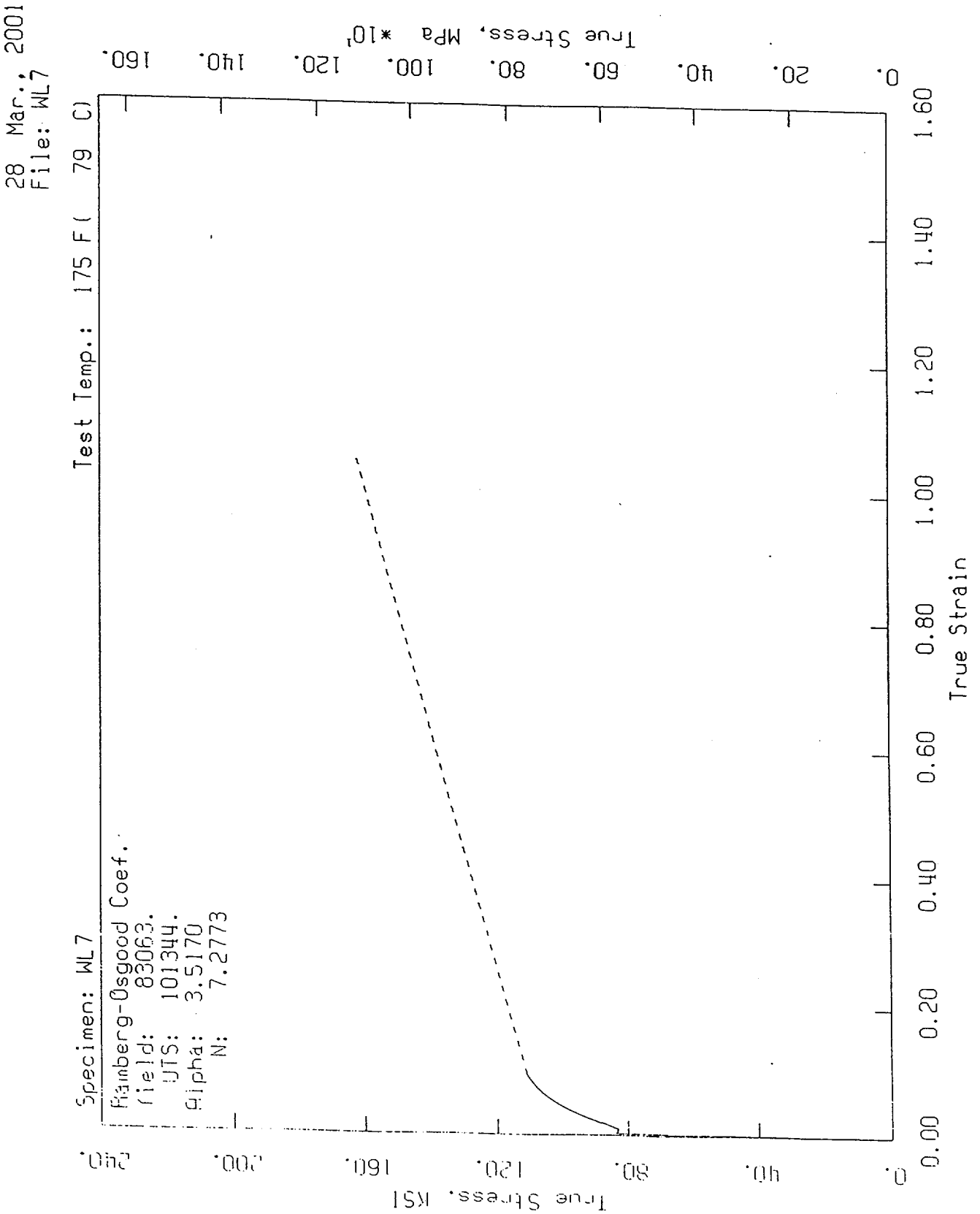
Yield Strength	83063. psi	572.7 MPa
Tensile Strength	101344. psi	698.8 MPa
Fracture Load	3294. lb	14652. N
Fracture Stress	191478. psi	1320.2 MPa
Fracture Strength	67106. psi	462.7 MPa
Young`s Modulus	2.94E+07 psi	2.03E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.0931	
Total Elongation (Ext)	.2174	
Reduction in Diameter	40.8 %	
Reduction in Area	65.0 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	3.517	.004
N	7.277	.019


28 Mar., 2001
File: WL7
Test Temp.: 175 F (79 C)
Specimen: WL7
Strength
Yield: 83063.
UTS: 101344.
Engineering Stress, MPa *10^1
Engineering Stress, MSI
Engineering Strain
0.
20.
40.
60.
80.
100.
120.
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32


28 Mar., 2001
File: WL7
Test Temp.: 175 F (79 C)
Specimen: WL7
Ramberg-Osgood Coef.
Yield: 83063.
UTS: 101344.
Alpha: 3.5170
N: 7.2773
True Stress, MPa *10¹
True Stress, KSI
True Strain
0.
20.
40.
60.
80.
100.
120.
140.
160.
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WL9

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WL9	
Test temperature	550 F	288. C
Material	LONG	
Modulus	26700. ksi	184095. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET-UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1690 in	4.29 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

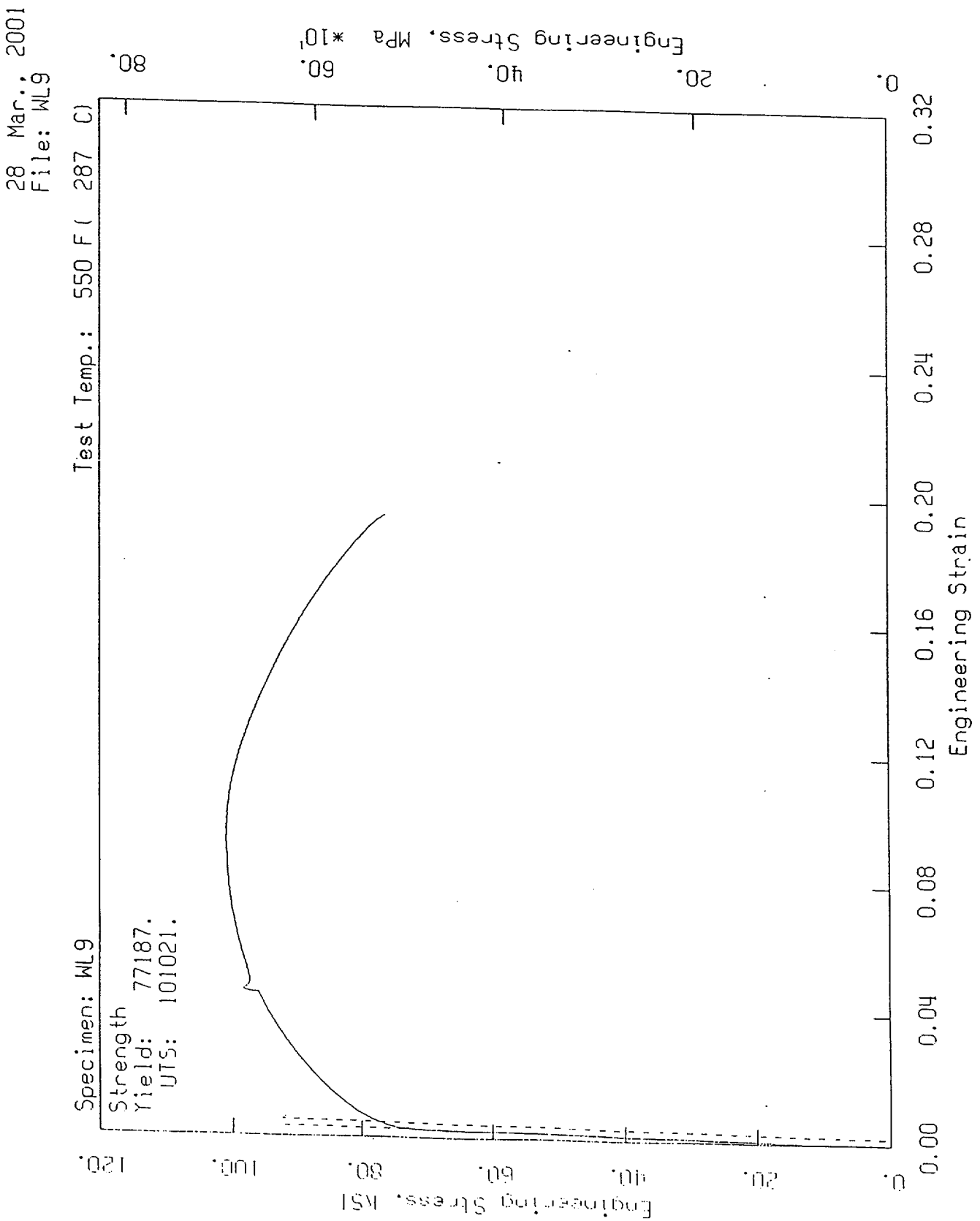
TEST RESULTS

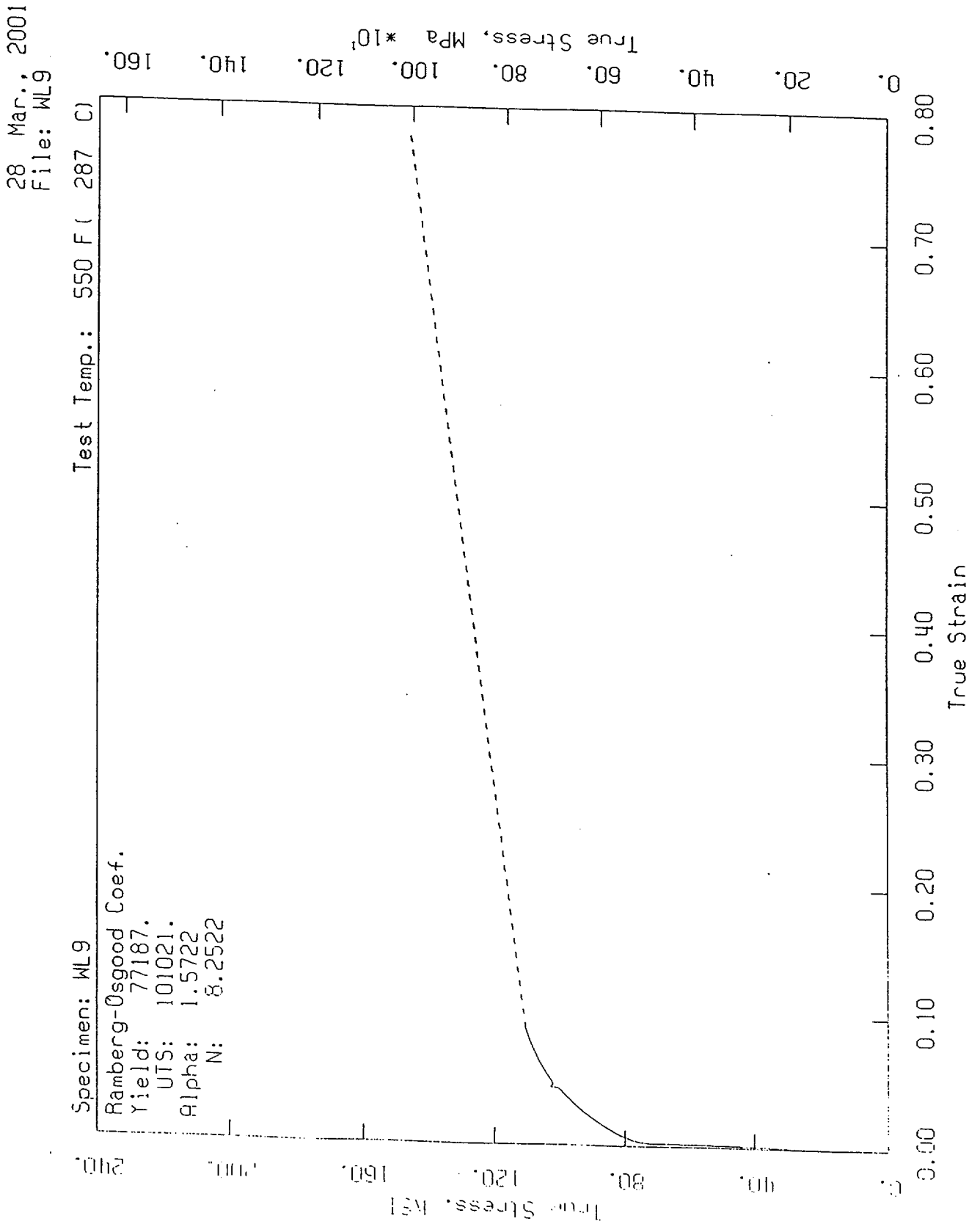
Yield Strength	77187. psi	532.2 MPa
Tensile Strength	101021. psi	696.5 MPa
Fracture Load	3737. lb	16622. N
Fracture Stress	166589. psi	1148.6 MPa
Fracture Strength	76127. psi	524.9 MPa
Young`s Modulus	2.69E+07 psi	1.85E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.0885	
Total Elongation (Ext)	.1908	
Reduction in Diameter	32.4 %	
Reduction in Area	54.3 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	1.572	.011
N	8.252	.048


28 Mar., 2001
File: WL9
Test Temp.: 550 F (287 C)
Specimen: WL9
Strength
Yield: 77187.
UTS: 101021.
Engineering Stress, MPa *10¹
0. 20. 40. 60. 80.
Engineering Stress, KSI
0. 20. 40. 60. 80. 100. 120.
Engineering Strain
0.00 0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32


28 Mar., 2001
File: WL9
Test Temp.: 550 F (287 C)
Specimen: WL9
Ramberg-Osgood Coef.
Yield: 77187.
UTS: 101021.
Alpha: 1.5722
N: 8.2522
True Stress, MPa *10¹
0.
20.
40.
60.
80.
100.
120.
140.
160.
True Strain
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WT9

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WT9	
Test temperature	70 F	21. C
Material	TRANS	
Modulus	29126. ksi	200825. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1705 in	4.33 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

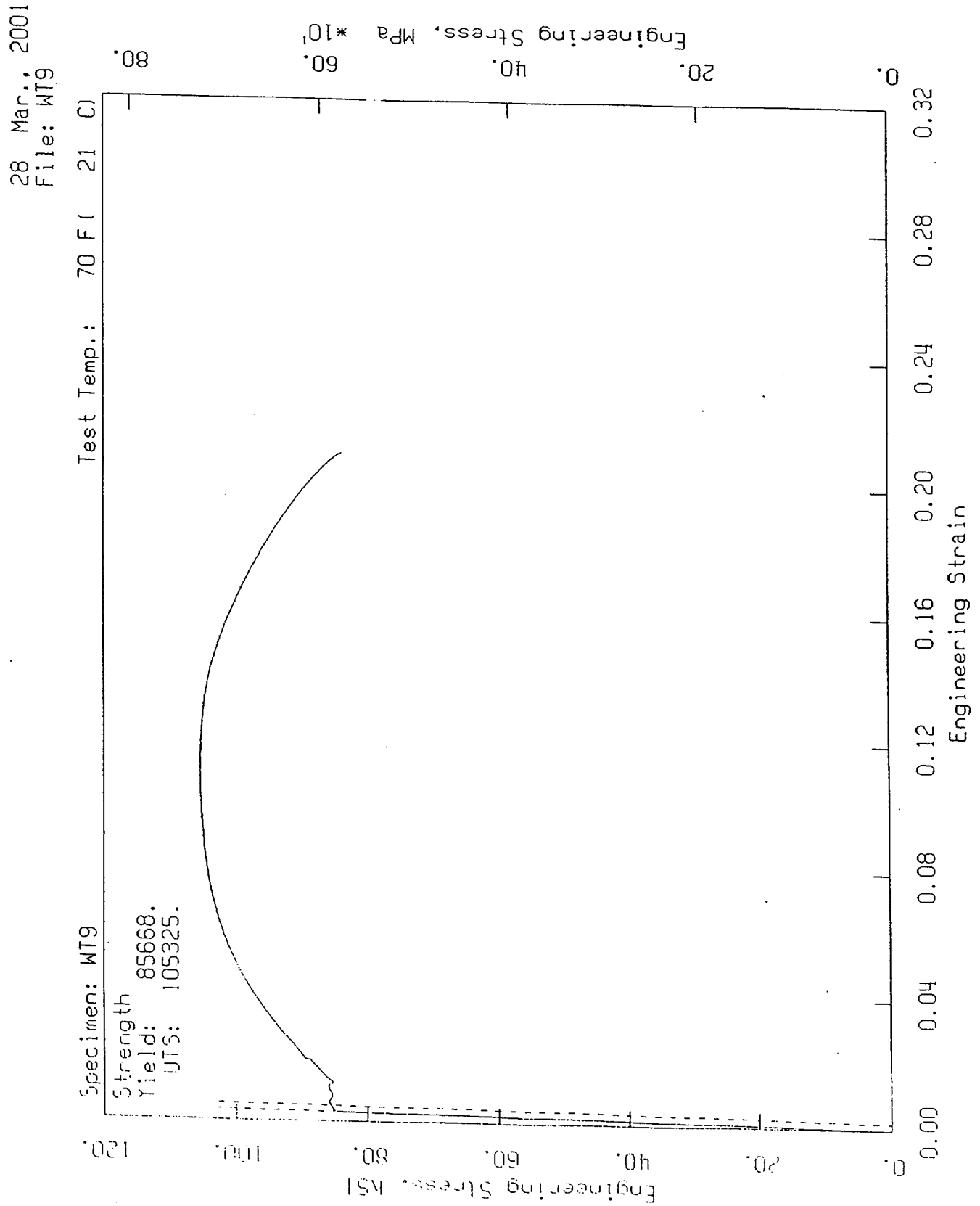
TEST RESULTS

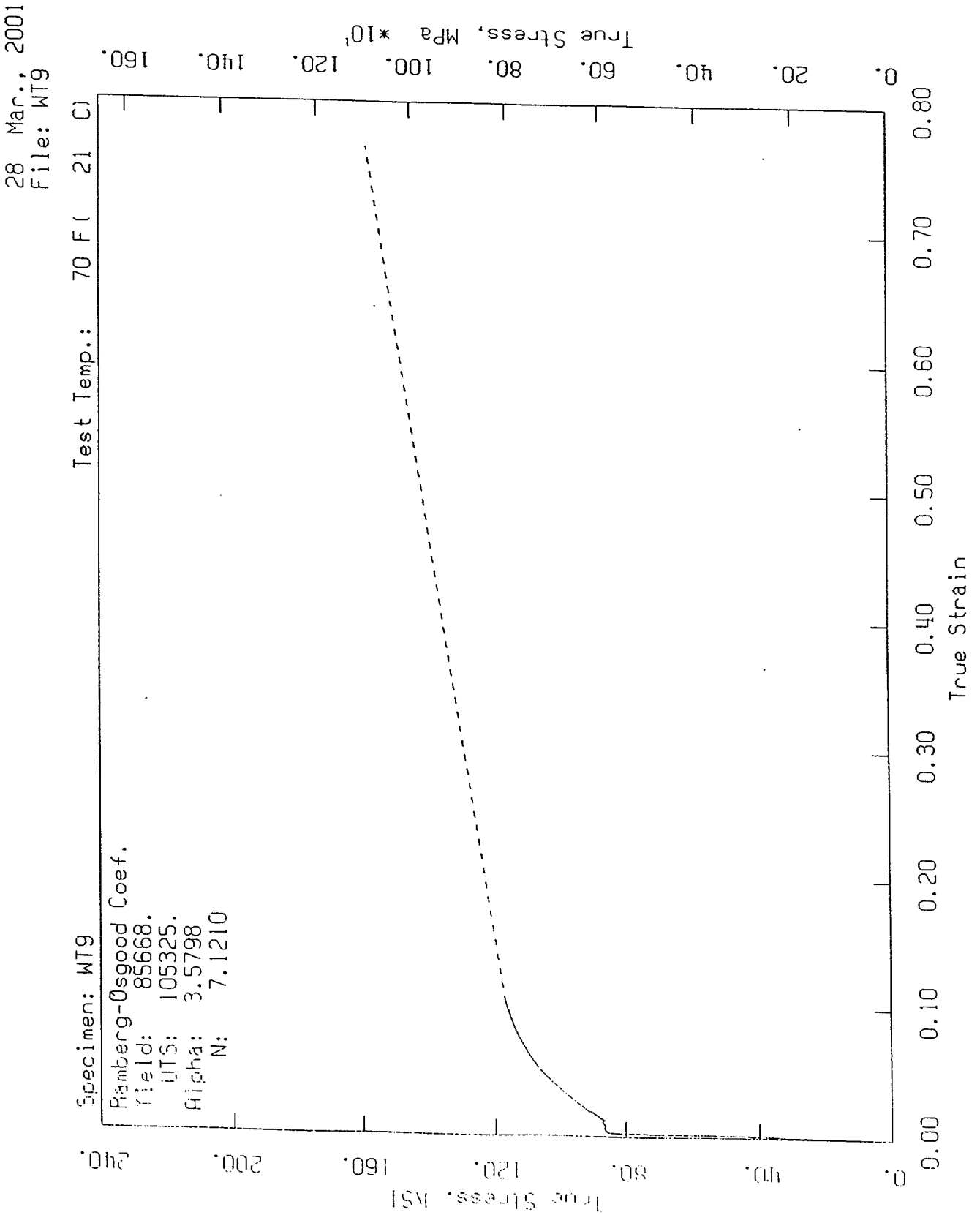
Yield Strength	85668. psi	590.7 MPa
Tensile Strength	105325. psi	726.2 MPa
Fracture Load	4107. lb	18266. N
Fracture Stress	179866. psi	1240.2 MPa
Fracture Strength	83660. psi	576.8 MPa
Young`s Modulus	2.99E+07 psi	2.06E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.1050	
Total Elongation (Ext)	.2070	
Reduction in Diameter	31.8 %	
Reduction in Area	53.5 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	3.580	.004
N	7.121	.019


28 Mar., 2001
File: WT9
Test Temp.: 70 F (21 C)
Specimen: WT9
Strength
Yield: 85668.
UTS: 105325.
Engineering Stress, MPa *10¹
0. 20. 40. 60. 80.
Engineering Stress, MSI
0. 20. 40. 60. 80. 100. 120.
Engineering Strain
0.00 0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32


28 Mar., 2001
File: WT9
Test Temp.: 70 F (21 C)
Specimen: WT9
Ramberg-Osgood Coef.
Yield: 85668.
UTS: 105325.
Alpha: 3.5798
N: 7.1210
True Stress, MPa *10'
0. 20. 40. 60. 80. 100. 120. 140. 160.
True Stress, MSI
0. 40. 80. 120. 160. 200. 240.
True Strain
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WT8

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WT8	
Test temperature	200 F	93. C
Material	TRANS	
Modulus	28469. ksi	196294. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1730 in	4.39 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

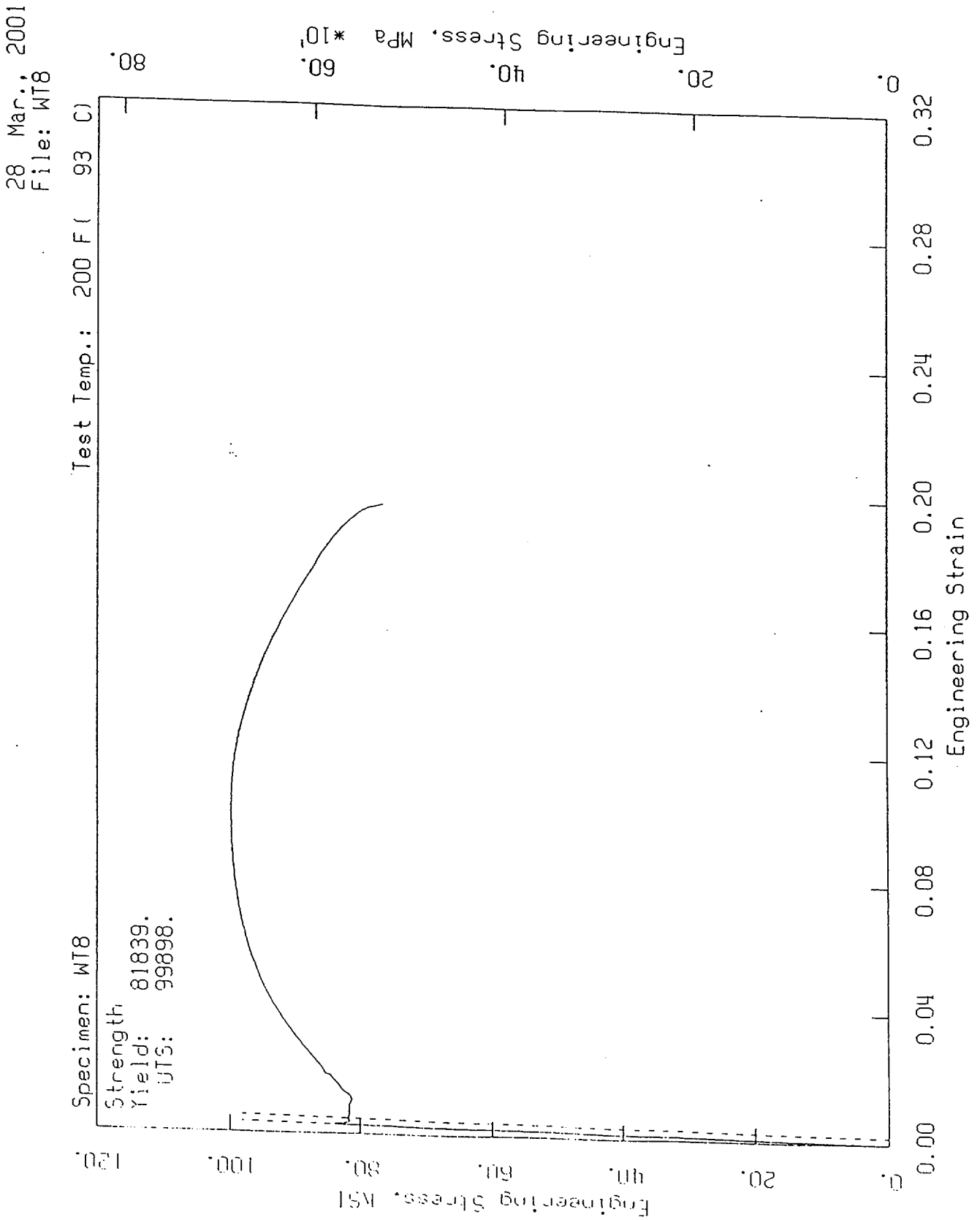
TEST RESULTS

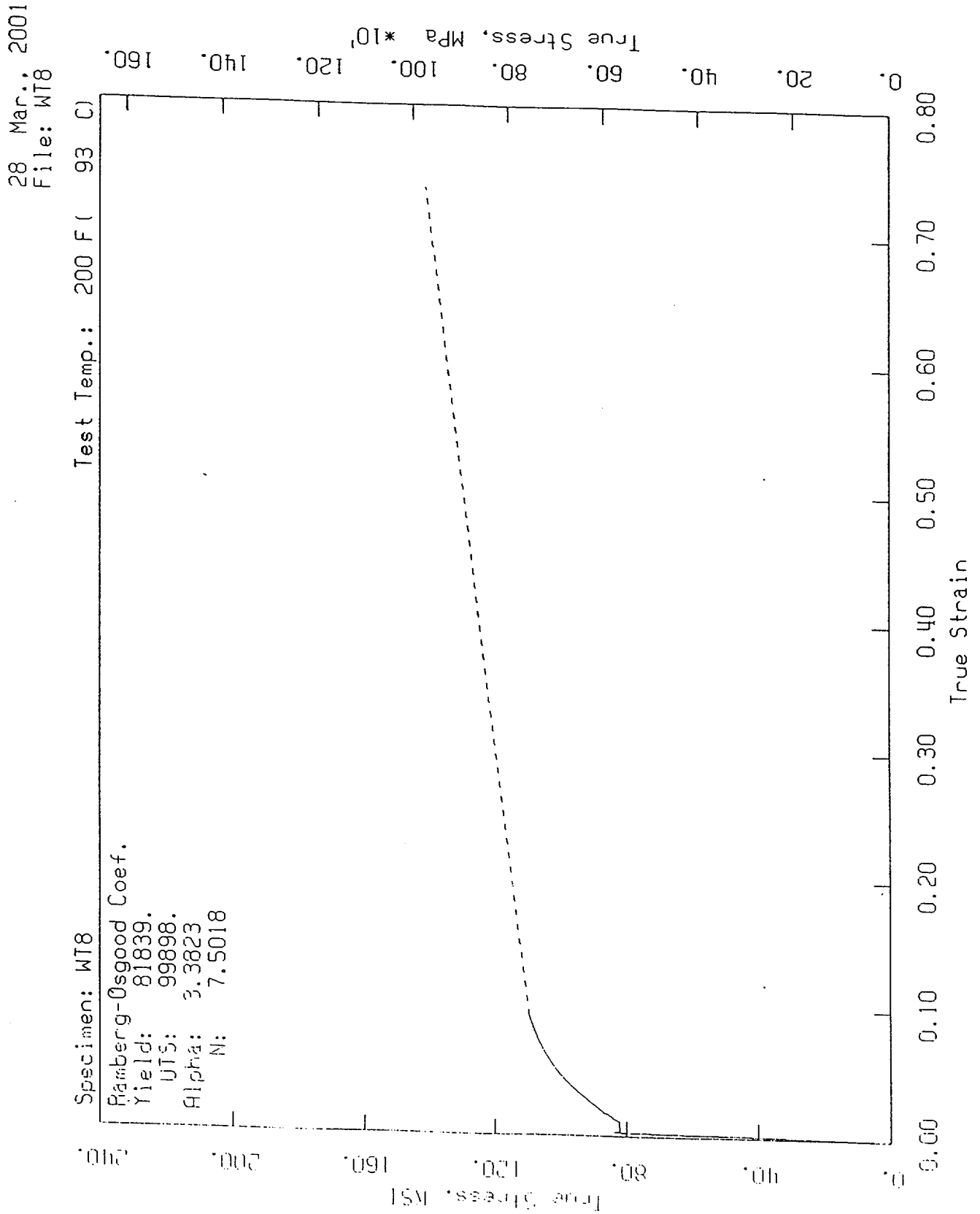
Yield Strength	81839. psi	564.3 MPa
Tensile Strength	99898. psi	688.8 MPa
Fracture Load	3754. lb	16698. N
Fracture Stress	159708. psi	1101.2 MPa
Fracture Strength	76478. psi	527.3 MPa
Young`s Modulus	2.99E+07 psi	2.06E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.0939	
Total Elongation (Ext)	.1939	
Reduction in Diameter	30.8 %	
Reduction in Area	52.1 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	3.382	.005
N	7.502	.027


28 Mar., 2001
File: WT8
Test Temp.: 200 F (93 C)
Specimen: WT8
Strength
Yield: 81839.
UTS: 99898.
Engineering Stress, MPa *10'
0.
20.
40.
60.
80.
Engineering Strain
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
Engineering Stress, MSI
0.
20.
40.
60.
80.
100.
120.


28 Mar., 2001
File: WT8
Test Temp.: 200 F (93 C)
Specimen: WT8
Ramberg-Osgood Coef.
Yield: 81839.
UTS: 99898.
Alpha: 3.3823
N: 7.5018
True Stress, MPa *10
0. 20. 40. 60. 80. 100. 120. 140. 160.
True Strain
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WT7

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WT7	
Test temperature	550 F	288. C
Material	TRANS	
Modulus	26700. ksi	184095. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1855 in	4.71 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

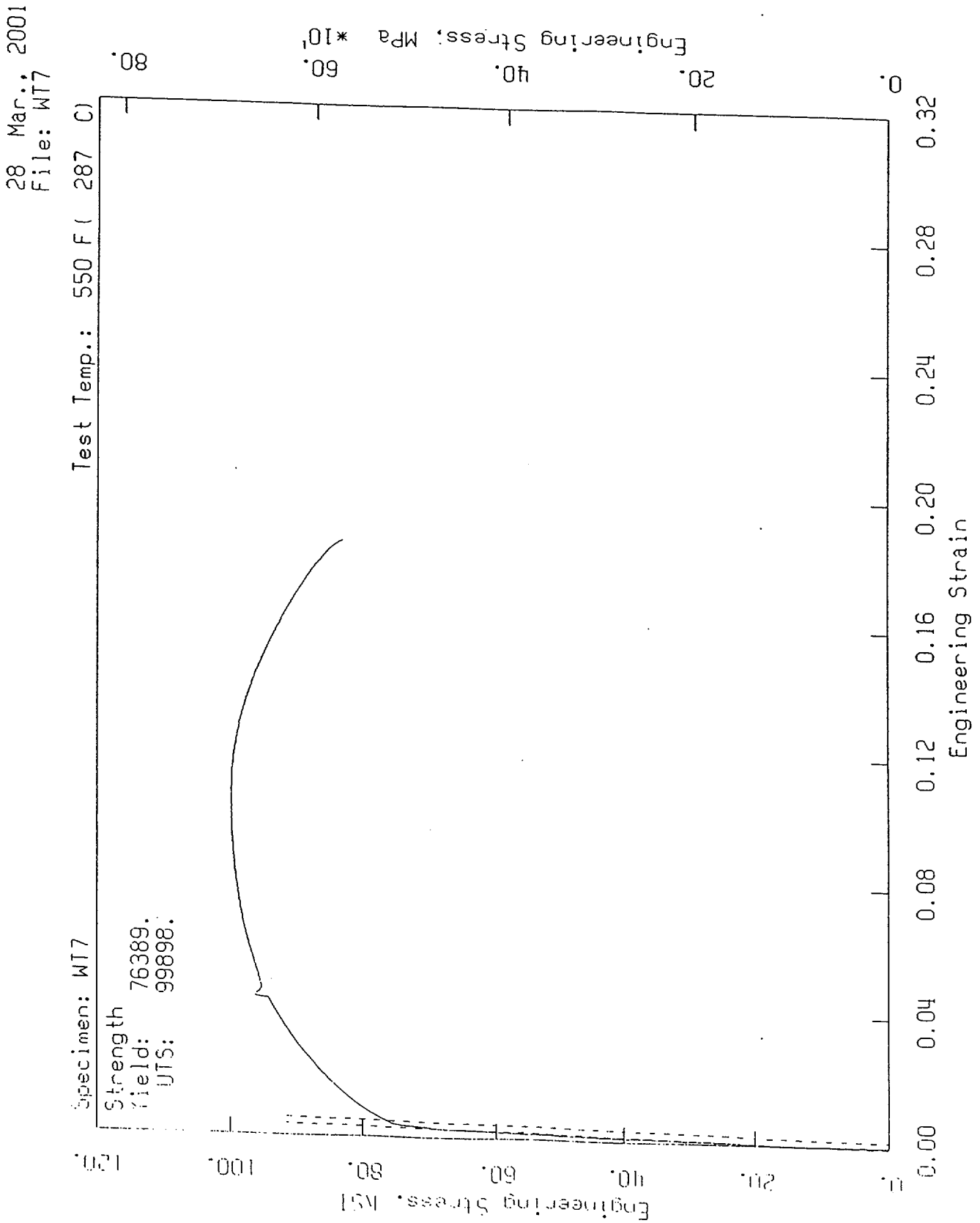
TEST RESULTS

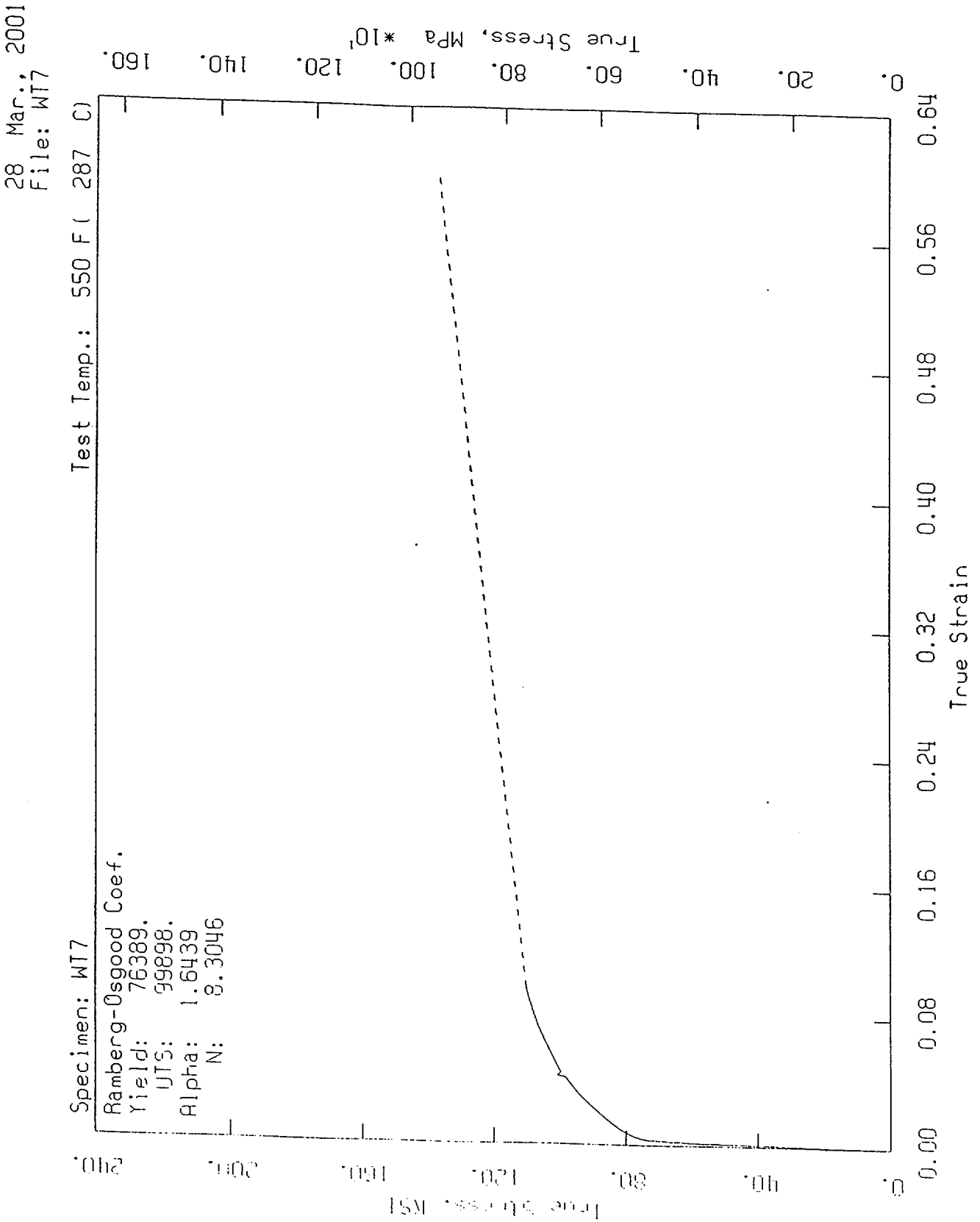
Yield Strength	76389. psi	526.7 MPa
Tensile Strength	99898. psi	688.8 MPa
Fracture Load	4079. lb	18144. N
Fracture Stress	150933. psi	1040.7 MPa
Fracture Strength	83098. psi	573.0 MPa
Young`s Modulus	2.18E+07 psi	1.51E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.0978	
Total Elongation (Ext)	.1824	
Reduction in Diameter.	25.8 %	
Reduction in Area	44.9 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	1.644	.010
N	8.305	.043


28 Mar.; 2001
File: WT7
Test Temp.: 550 F (287 C)
Specimen: WT7
Strength
Yield: 76389.
UTS: 99898.
Engineering Stress; MPa *10'
Engineering Strain
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.
20.
40.
60.
80.
100.
120.


28 Mar., 2001
File: WT7
Test Temp.: 550 F (287 C)
Specimen: WT7
Ramberg-Osgood Coef.
Yield: 76389.
UTS: 99898.
Alpha: 1.6439
N: 8.3046
True Stress, MPa *10'
0.
20.
40.
60.
80.
100.
120.
140.
160.
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
True Strain

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WW8

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WW8	
Test temperature	70 F	21. C
Material	WELD	
Modulus	29126. ksi	200825. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1377 in	3.50 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

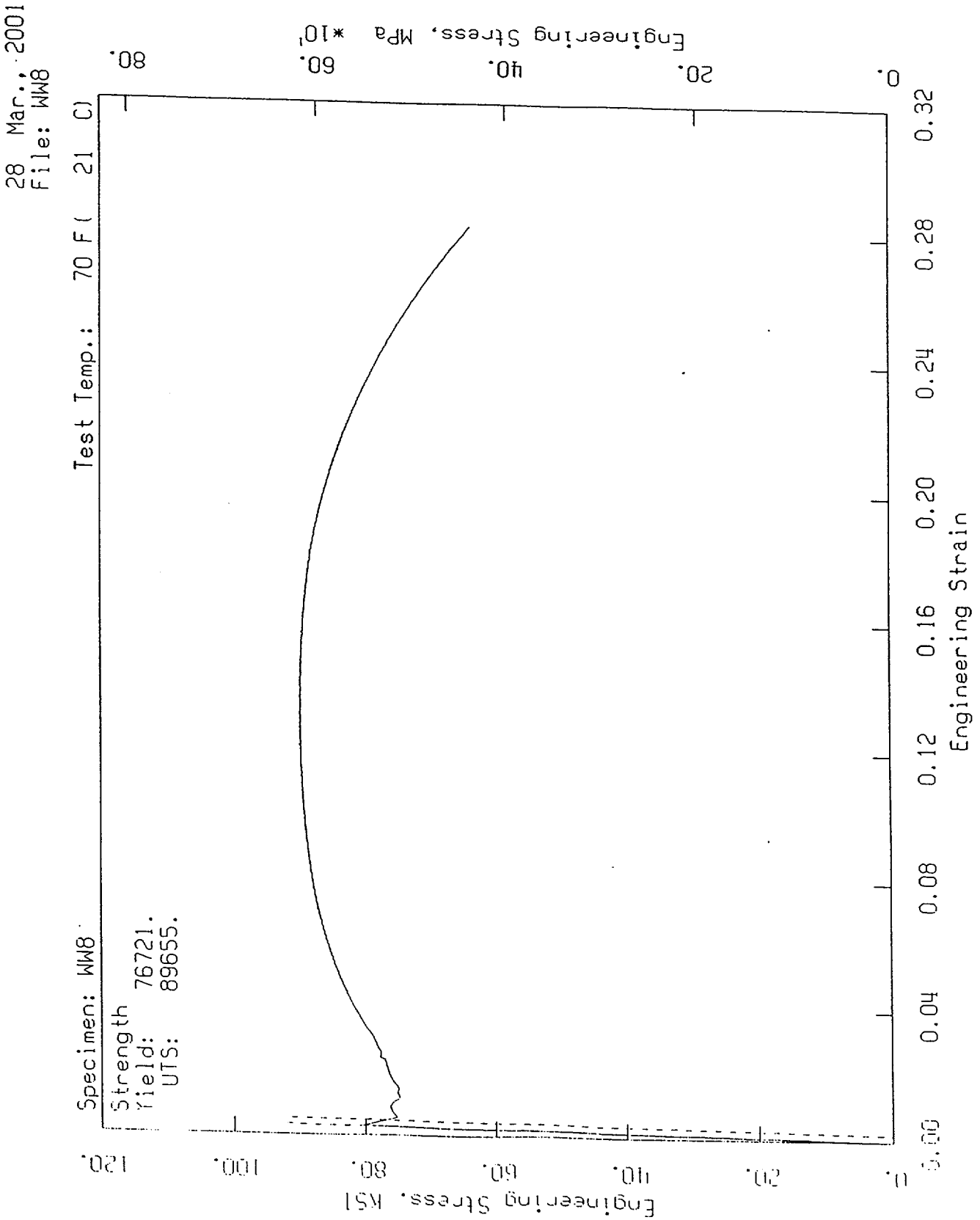
TEST RESULTS

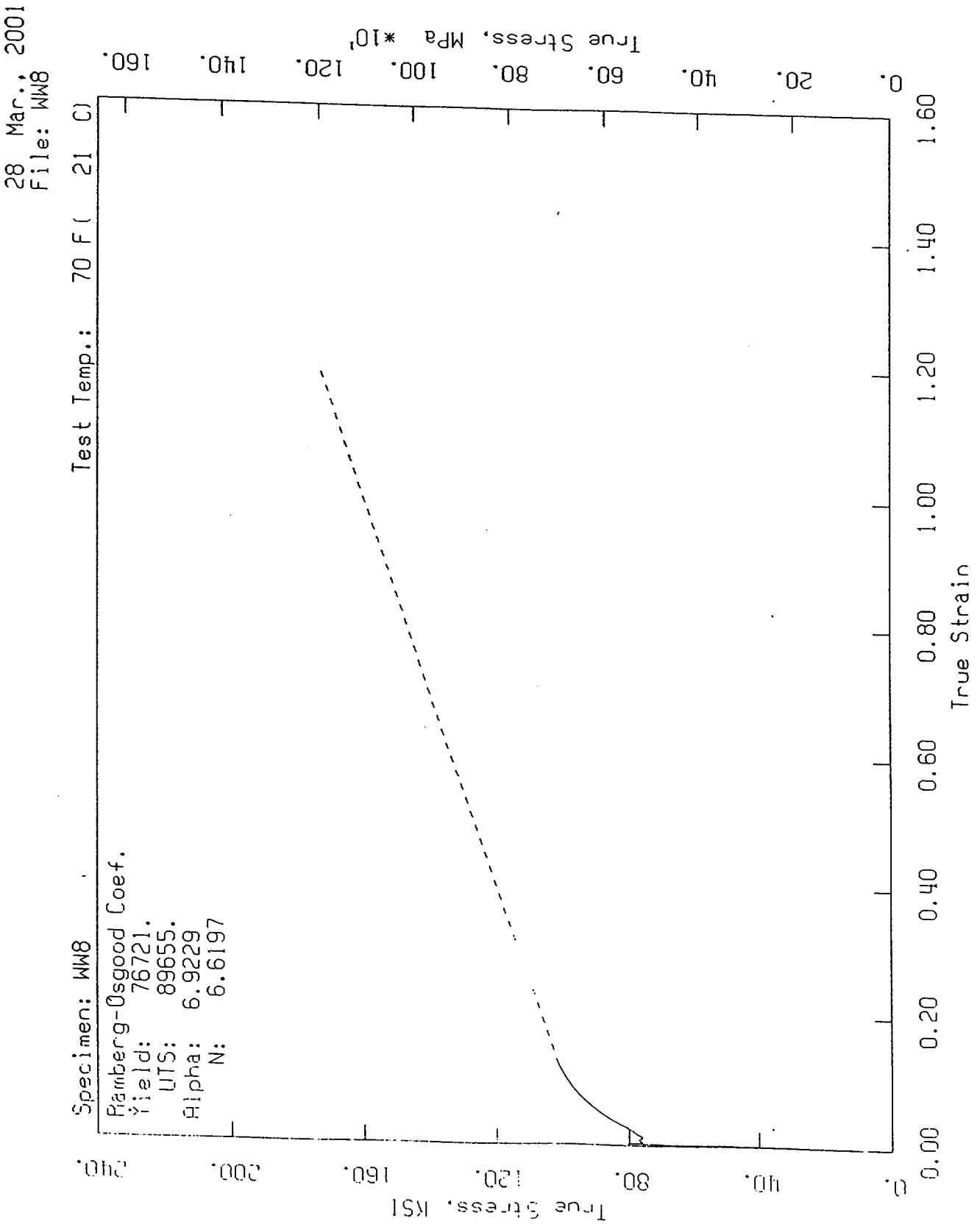
Yield Strength	76721. psi	529.0 MPa
Tensile Strength	89655. psi	618.2 MPa
Fracture Load	3113. lb	13846. N
Fracture Stress	208871. psi	1440.2 MPa
Fracture Strength	63413. psi	437.2 MPa
Young`s Modulus	2.92E+07 psi	2.02E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.1278	
Total Elongation (Ext)	.2800	
Reduction in Diameter	44.9 %	
Reduction in Area	69.6 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	6.923	.003
N	6.620	.015


28 Mar., 2001
File: WW8
Test Temp.: 70 F (21 C)
Specimen: WW8
Strength
Yield: 76721.
UTS: 89655.
Engineering Stress, MPa *10
0.
20.
40.
60.
80.
Engineering Strain
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
Engineering Stress, KSI
0.
20.
40.
60.
80.
100.
120.


28 Mar., 2001
File: WW8
Test Temp.: 70 F (21 C)
Specimen: WW8
Ramberg-Osgood Coef.
Yield: 76721.
UTS: 89655.
Alpha: 6.9229
N: 6.6197
True Stress, MPa *10
True Stress, KSI
True Strain
0.
20.
40.
60.
80.
100.
120.
140.
160.
0.
40.
80.
120.
160.
200.
240.
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60

TADS
<890928.1259> TENSILE DATA ANALYSIS

28 Mar., 2001
File: WW8

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WW8	
Test temperature	70 F	21. C
Material	WELD	
Modulus	29126. ksi	200825. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1377 in	3.50 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

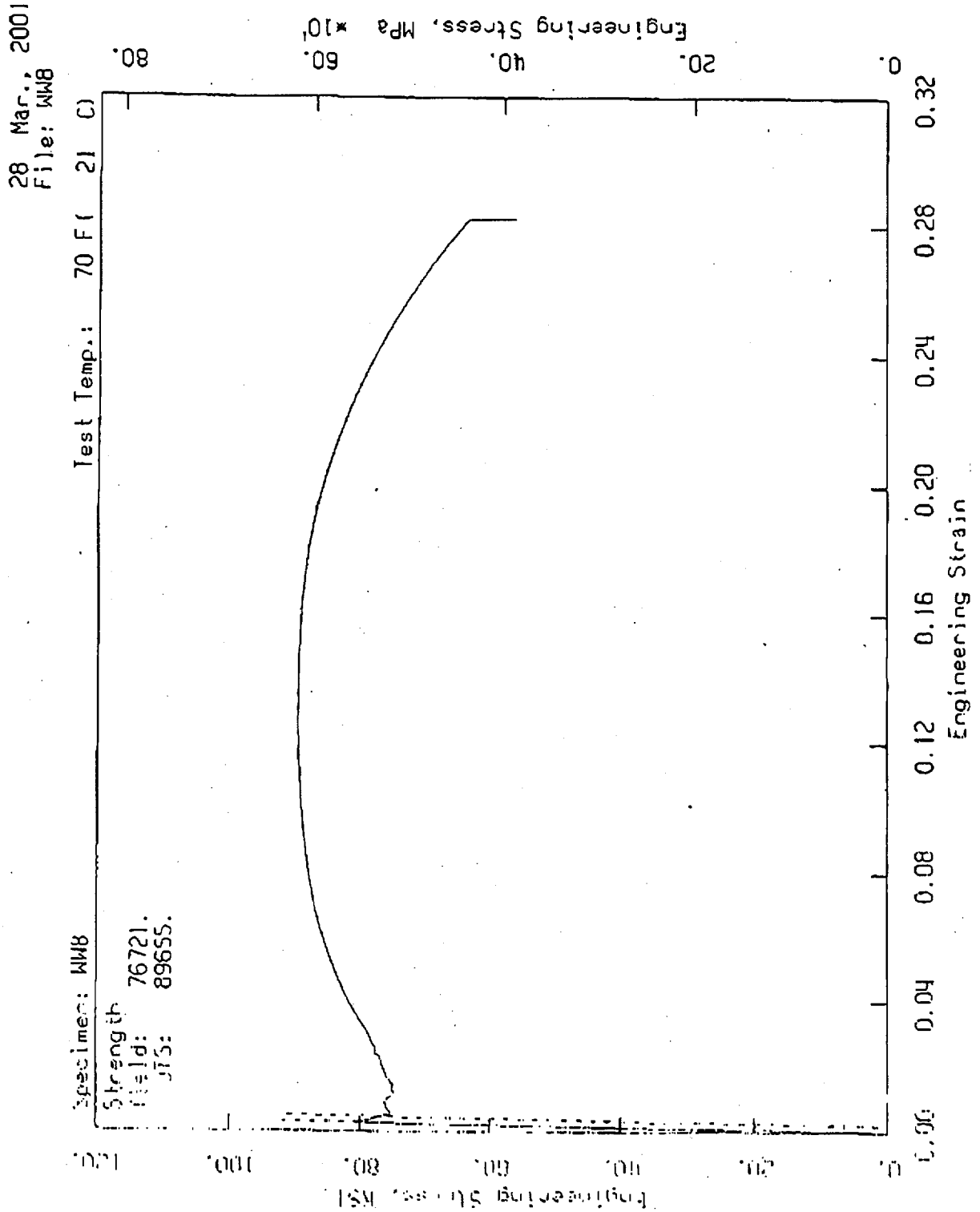
TEST RESULTS

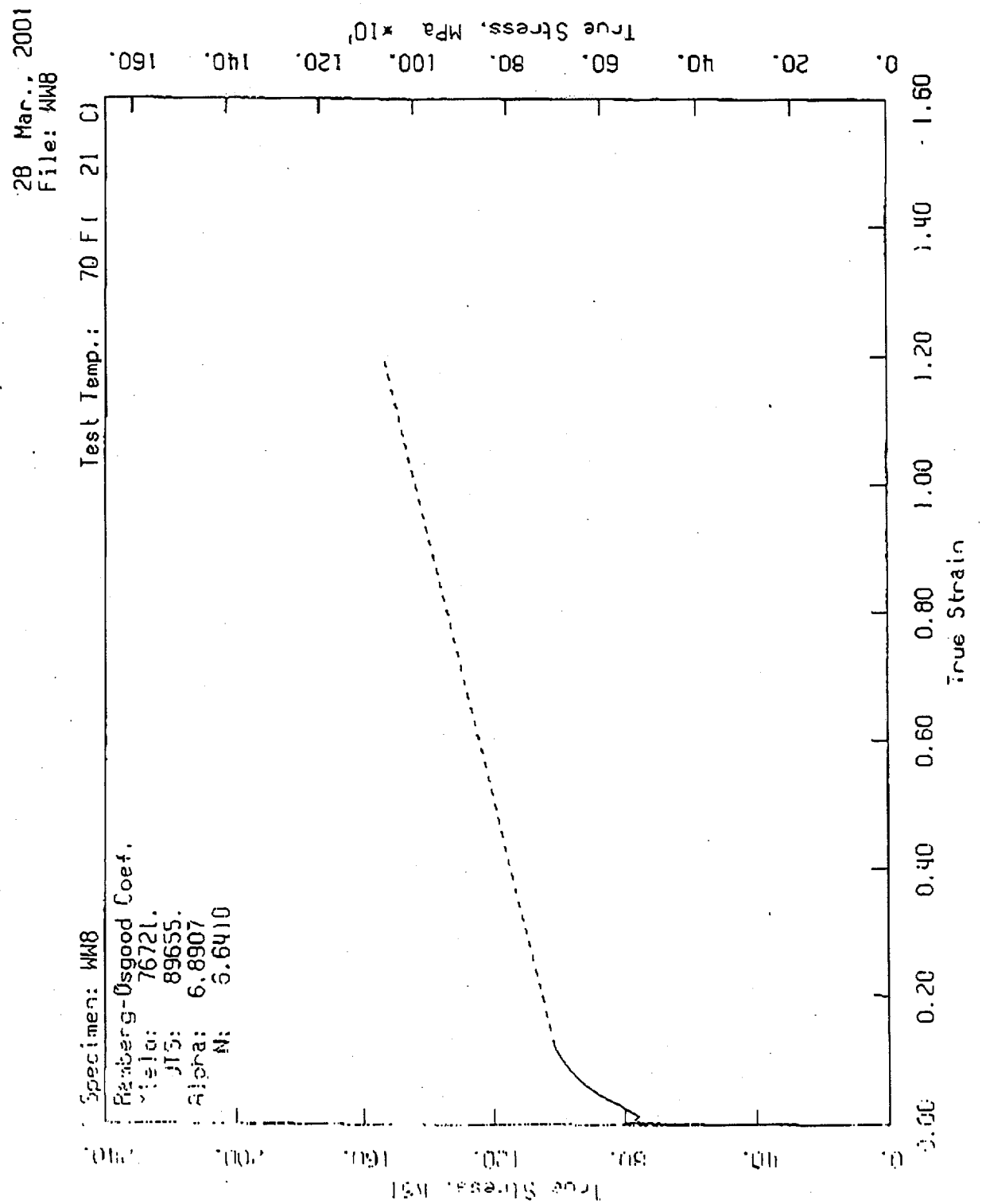
Yield Strength	76721. psi	529.0 MPa
Tensile Strength	89655. psi	618.2 MPa
Fracture Load	2758. lb	12267. N
Fracture Stress	185054. psi	1275.9 MPa
Fracture Strength	56182. psi	387.4 MPa
Young's Modulus	2.92E+07 psi	2.02E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.1278	
Total Elongation (Ext)	.2803	
Reduction in Diameter	44.9 %	
Reduction in Area	69.6 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	6.891	.003
N	6.641	.014


28 Mar., 2001
File: WW8
Test Temp.: 70 F (21 C)
Specimen: WW8
Strength
Yield: 76721.
UTS: 89655.
Engineering Stress, MPa *10'
0.
20.
40.
60.
80.
Engineering Strain
0.
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32


28 Mar., 2001
File: WW8
Test Temp.: 70 F (21 C)
True Stress, MPa *10^1
0. 20. 40. 60. 80. 100. 120. 140. 160.
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
True Strain
Specimen: WW8
Ramberg-Osgood Coef.
Yield: 76721.
UTS: 89655.
Alpha: 6.8907
N: 5.6410

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WW9

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WW9	
Test temperature	150 F	66. C
Material	WELD	
Modulus	28722. ksi	198036. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1335 in	3.39 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

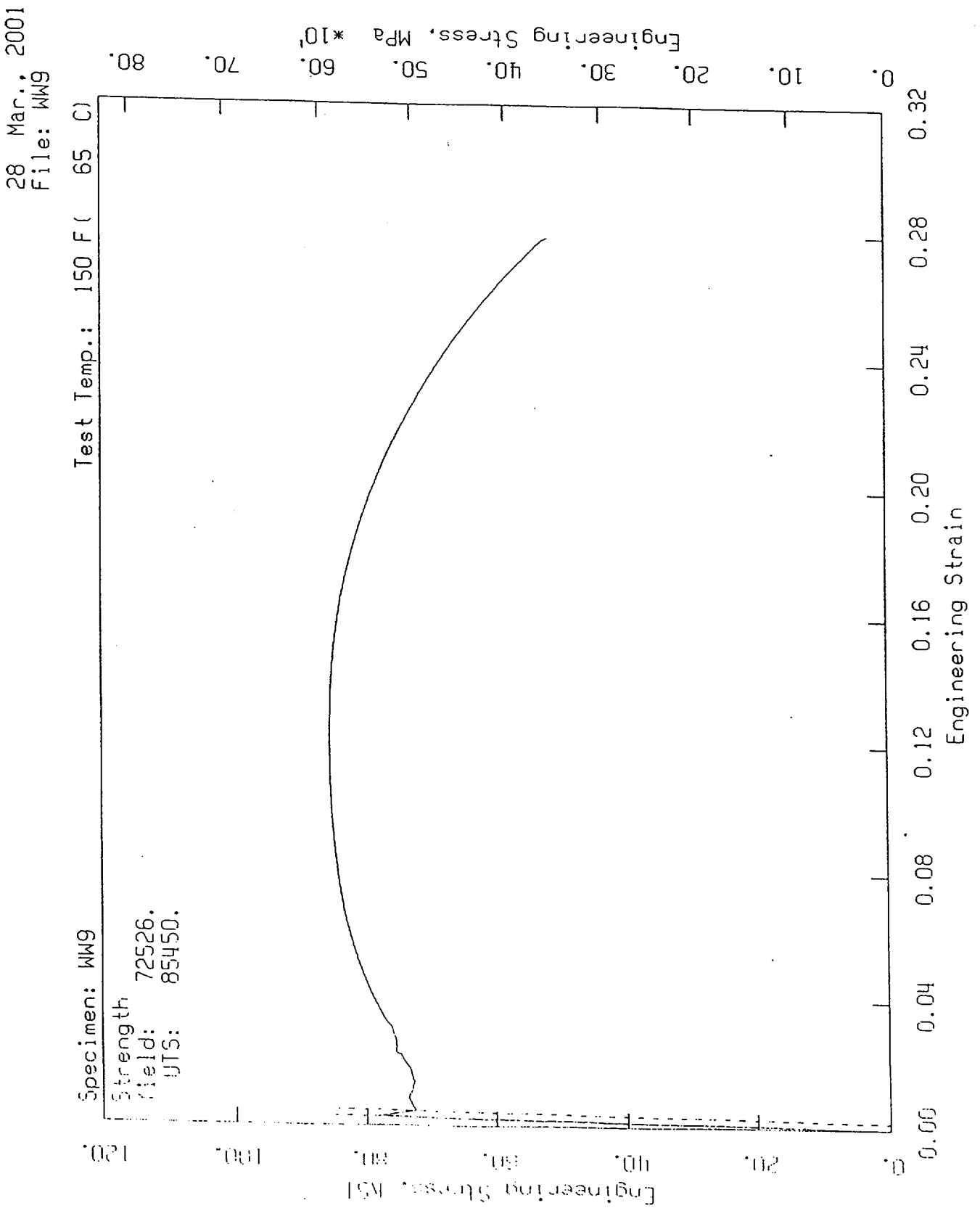
TEST RESULTS

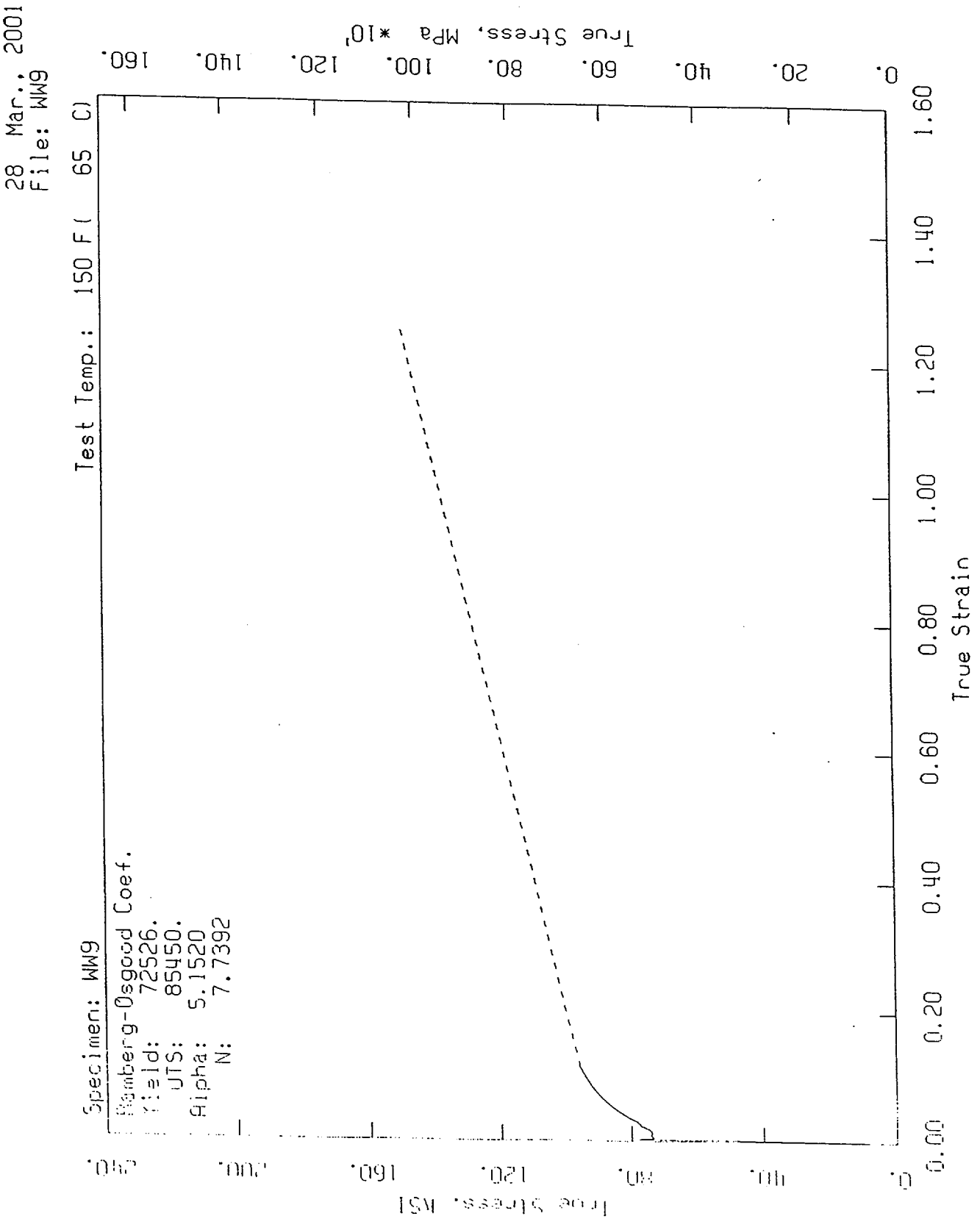
Yield Strength	72526. psi	500.1 MPa
Tensile Strength	85450. psi	589.2 MPa
Fracture Load	2524. lb	11226. N
Fracture Stress	180307. psi	1243.2 MPa
Fracture Strength	51416. psi	354.5 MPa
Young`s Modulus	2.84E+07 psi	1.96E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.1166	
Total Elongation (Ext)	.2770	
Reduction in Diameter	46.6 %	
Reduction in Area	71.5 %	

CURVE FIT

Ramberg-Osgood Equation

		Fit Std Dev
Alpha	5.152	.008
N	7.739	.045


28 Mar., 2001
File: WW9
Test Temp.: 150 F (65 C)
Specimen: WW9
Strength
Yield: 72526.
UTS: 85450.
Engineering Stress, MPa *10'
0.
10.
20.
30.
40.
50.
60.
70.
80.
Engineering Strain
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32


28 Mar., 2001
File: WW9
Test Temp.: 150 F (65 C)
True Stress, MPa *10^
0. 20. 40. 60. 80. 100. 120. 140. 160.
True Strain
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
True Stress, MSI
0. 20. 40. 60. 80. 100. 120. 140. 160.
Specimen: WW9
Ramberg-Osgood Coef.
Yield: 72526.
UTS: 85450.
Alpha: 5.1520
N: 7.7392

TADS
<890928.1259> TENSILE DATA ANALYSIS 28 Mar., 2001
File: WW7

SPECIMEN ID PARAMETERS

Date of test	03/28/20	
Operator	BJV	
Project number	1215	
Specimen	WW7	
Test temperature	550 F	288. C
Material	WELD	
Modulus	26700. ksi	184095. MPa
Cross Section type	CIRC	
Fluence	0.0000E+00	
Technical Specification	TP-78-14	

SET UP PARAMETERS

Initial disp rate	.0075 in/min	.190 mm/min
Second. disp rate	.0300 in/min	.76 mm/min
Gauge length (Ext)	1.000 in	25.40 mm

DIMENSIONAL

Diameter INITIAL	.2500 in	6.35 mm
FINAL	.1400 in	3.56 mm
Axial Fidical INITIAL	1.0000 in	25.40 mm
FINAL	.0000 in	.00 mm

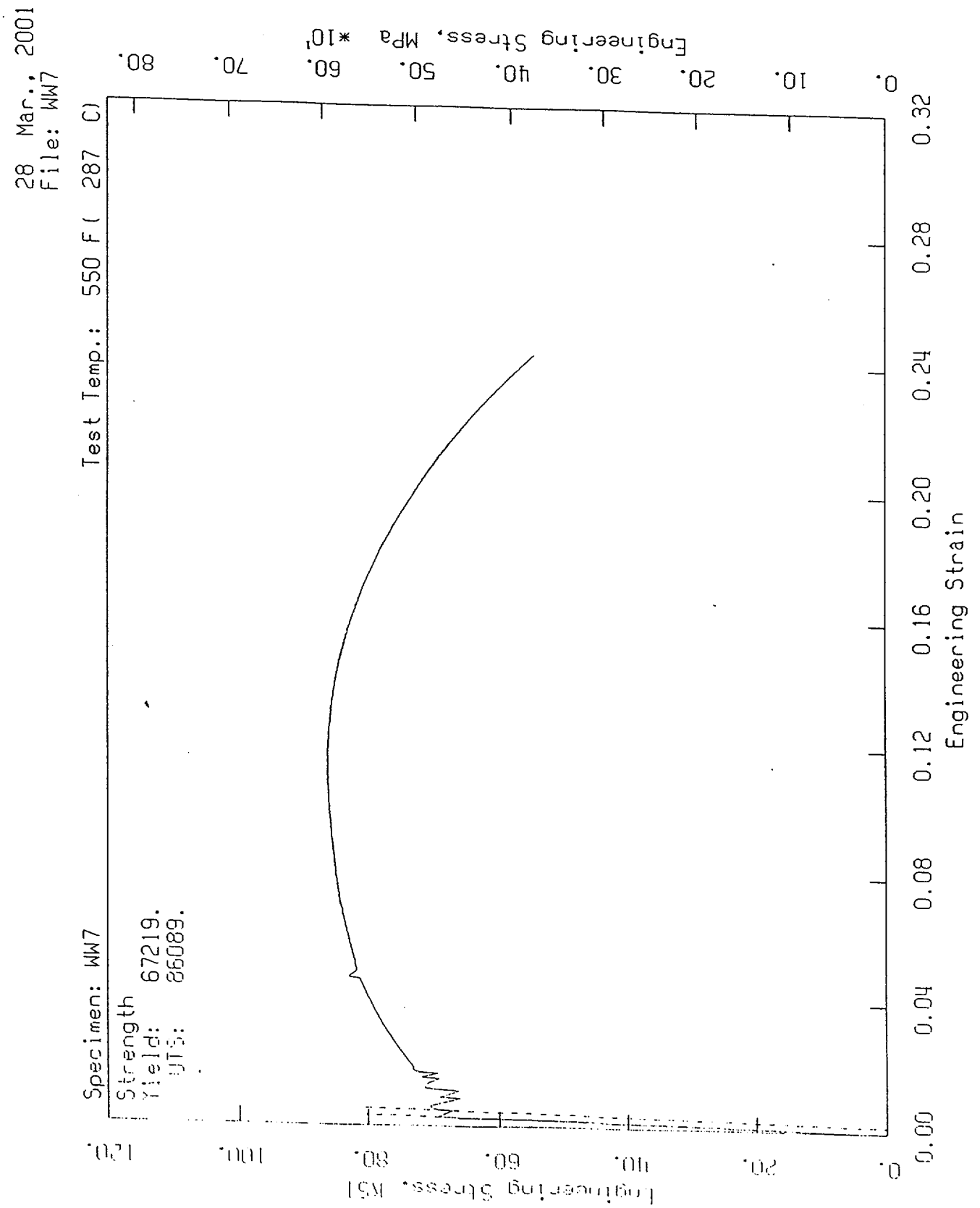
TEST RESULTS

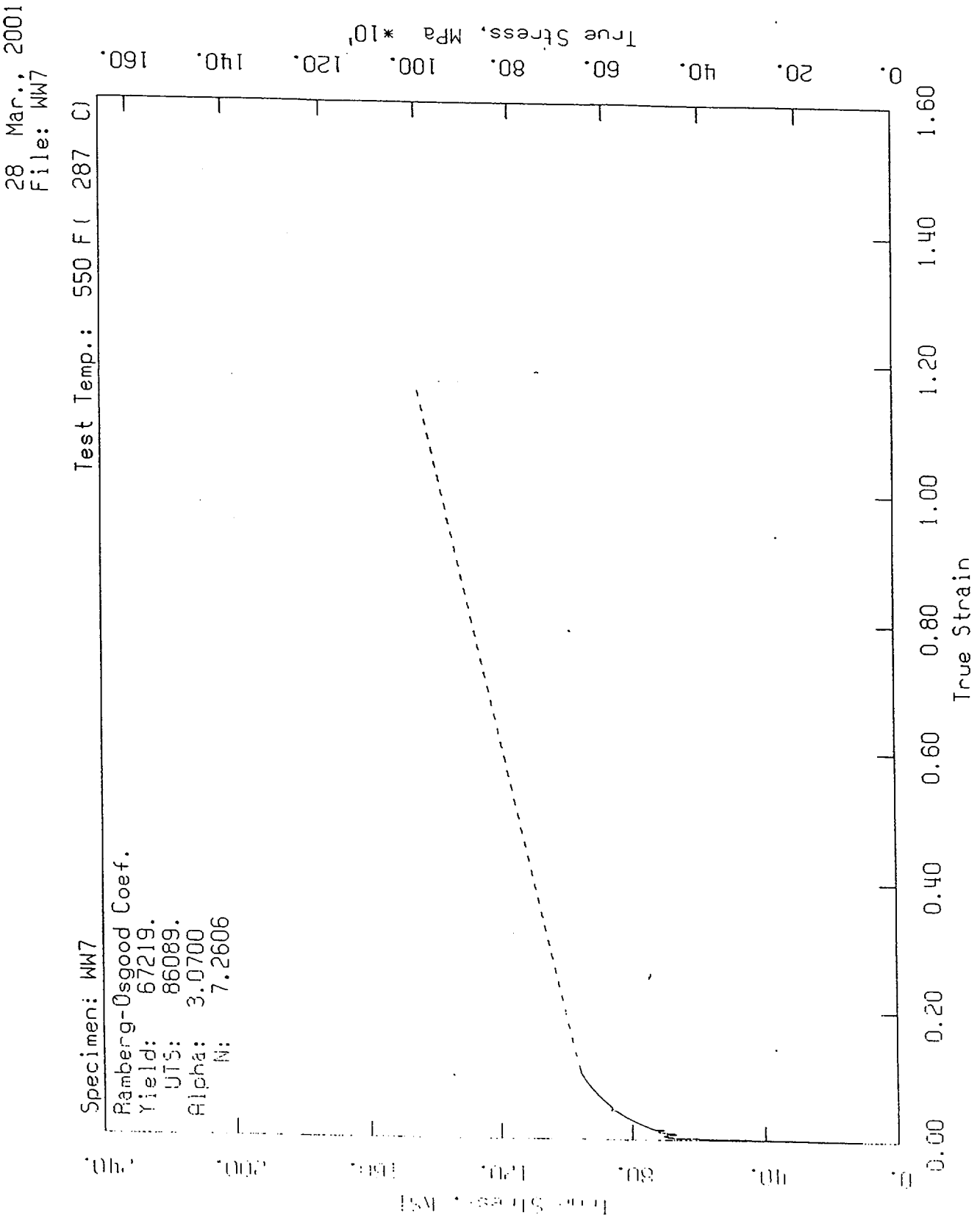
Yield Strength	67219. psi	463.5 MPa
Tensile Strength	86089. psi	593.6 MPa
Fracture Load	2669. lb	11873. N
Fracture Stress	173400. psi	1195.6 MPa
Fracture Strength	54378. psi	374.9 MPa
Young`s Modulus	2.33E+07 psi	1.61E+05 MPa
Elongation (fiducial)	-1.0000	
Uniform Elongation (Ext)	.1078	
Total Elongation (Ext)	.2408	
Reduction in Diameter	44.0 %	
Reduction in Area	68.6 %	

CURVE FIT

Ramberg-Osgood Equation

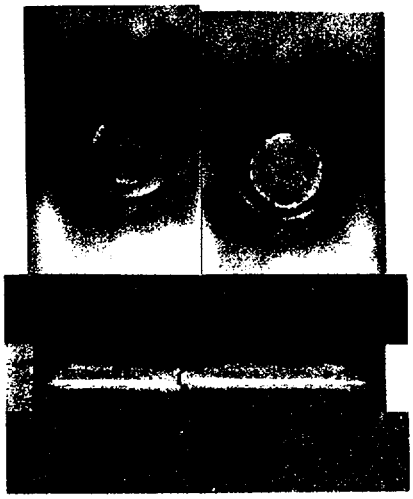
		Fit Std Dev
Alpha	3.070	.003
N	7.261	.015


28 Mar., 2001
File: WW7
Test Temp.: 550 F (287 C)
Specimen: WW7
Strength
Yield: 67219.
UTS: 86089.
Engineering Stress, MPa *10¹
0. 10. 20. 30. 40. 50. 60. 70. 80.
0.00 0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32
Engineering Strain

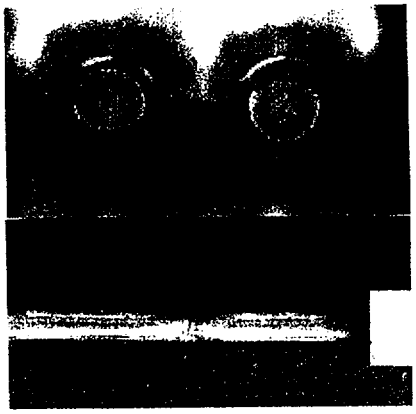

28 Mar., 2001
File: WW7
Test Temp.: 550 F (287 C)
Specimen: WW7
Ramberg-Osgood Coef.
Yield: 67219.
UTS: 86089.
Alpha: 3.0700
N: 7.2606
True Stress, MPa *10'
0.
20.
40.
60.
80.
100.
120.
140.
160.
True Strain
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60

APPENDIX F

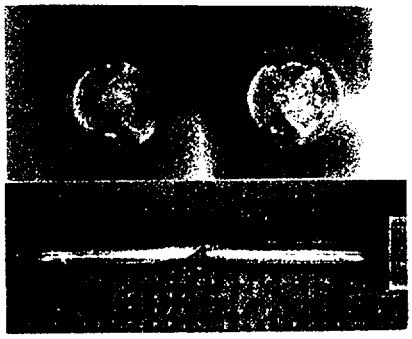
PHOTOGRAPHS OF FRACTURED TENSILE SPECIMENS WATTS BAR UNIT 1, CAPSULE W



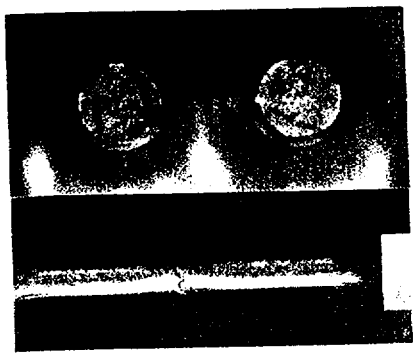
WL8 70°F



WL7 175°F

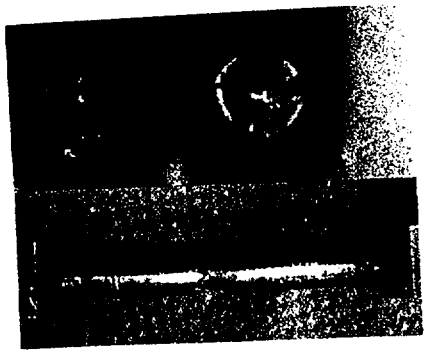


WL9 550°F

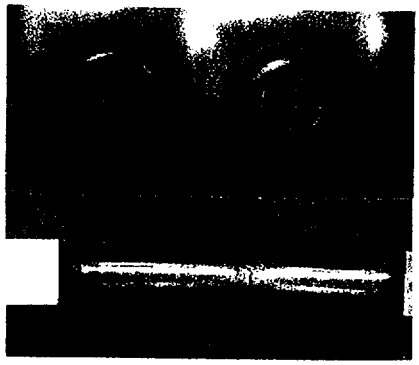


WT9 70°F

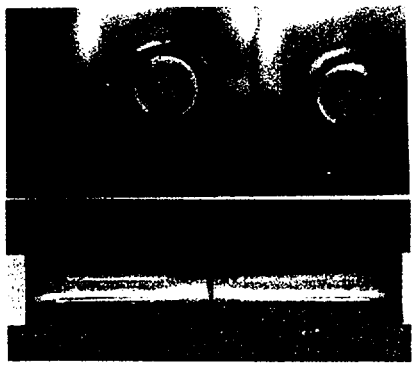
WT8 200°F



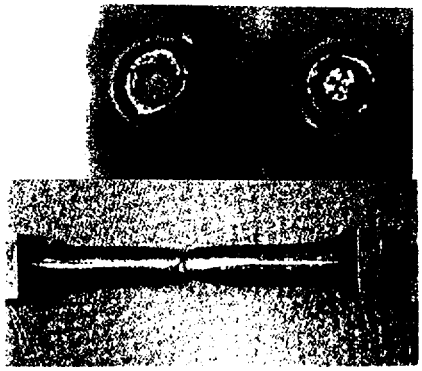
WT7 550°F



WW8 70°F



WW9 150°F



WW7 550°F

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT UNIT 1
ANALYSIS OF J-R CURVES GENERATED FROM CAPSULE W
1/2T COMPACT TENSION SPECIMENS
REACTOR VESSEL MATERIAL SURVEILLANCE PROGRAM

ANALYSIS OF J-R CURVES GENERATED FROM CAPSULE W 1/2T COMPACT TENSION SPECIMENS OF THE TENNESSEE VALLEY AUTHORITY WATTS BAR UNIT 1 REACTOR VESSEL MATERIAL SURVEILLANCE PROGRAM

PREPARED BY
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W. A. Pavinich, Invex Engineering

Reviewed by: 9/24/01
Kevin Y. Hour, NME Manager

Approved by: 24 Sept 01
Chris L. Clark, N&EO Manager

1.0 INTRODUCTION

Capsule W was received at the BWXT Services, Inc. (BWXS) Lynchburg Technology Center (LTC) in January 2001 and was subsequently disassembled in its Hot Cell Facility and the contents of the capsule were tested to determine the effect of neutron irradiation on the mechanical properties on the Watts Bar Unit 1 reactor vessel materials [1]. The specimens in Capsule W received a fast neutron fluence of 1.233×10^{19} n/cm^2 (E > 1.0 MeV) which corresponds to the 1/4T fluence at the end of plant life (32EFPY). As a part of this testing effort, three 1/2 T compact tension specimens were tested to determine the upper shelf J-R curve for the intermediate forging (R 05). The intermediate forging has relatively low upper shelf energy based on Charpy impact tests and it was expected that the upper shelf energy would fall below 50 ft lbs based on projections of Regulatory Guide 1.99 Rev 2 [2]. As a result, a bounding analysis was performed by Westinghouse Owner's Group [3] to demonstrate that materials with upper shelf energy values less than 50 ft-lbs would provide margins of safety equivalent to the requirements of ASME III, Appendix G [4]. J-R curves were determined using a model developed by Eason [5] using a minimum USE value of 42 ft-lbs. Since it was projected that the end of life upper shelf energy for the Watts Bar Unit 1 intermediate forging would be close to the upper shelf of the bounding analysis (using the methods of Regulatory Guide 1.99, Rev. 2), it was decided to test 1/2T compact tension specimens (axial orientation) to provide plant specific J-R curves and further demonstrate that Watts Bar Unit 1 Nuclear Power Station reactor vessel has a margin of safety equivalent to that required by Appendix G of the ASME code. The purpose of this report is to demonstrate that Watts Bar Unit 1 reactor vessel has margins of safety equivalent to ASME Code Appendix G based on plant specific J-R curve generated from 1/2T compact tension specimens taken from Capsule W.

2.0 PROOF-OF-PRINCIPLE TESTS

It was determined that some machining on the 1/2T compact tension specimens contained in Capsule W was necessary since the original specimens were manufactured in accordance with ASTM E399 [6] not ASTM E1820 [7], which is the Standard that would be used for testing. BWXS proposed a modified E399 specimen design, where an Electrical Discharge Milling (EDM) cut was made between two pin holes to generate knife edges for mounting of the clip gage. No other changes to the specimens were made. Proof-of-principle tests were conducted to validate the BWXS modified design. The test results were documented in a report [8] to TVA and authorization to machine the irradiated specimens was obtained from TVA prior to actual machining of the specimens.

3.0 FRACTURE TOUGHNESS TESTS

3.1 Specimen Machining and Preparation

A total of four (4) specimens were machined in the BWXS LTC Hot Machine Shop (HMS) using an EDM machine. A 12.5% side groove was put on each side of the specimen for a total 25% reduction of thickness to ensure a straight crack front.

3.2 Specimen Testing

Three specimens were tested in accordance with Lynchburg Technology Center Technical Procedure TP-177. The tests were performed in displacement control mode on a servohydraulic test machine equipped with a fifty-kip load cell (10,000 pound range was used for the tests). A double cantilever beam clip gage was mounted onto the knife edges for monitoring the crack mouth opening displacement (CMOD). The CMOD measurements were used to determine the crack length during the test. Force and displacement were monitored continuously through loading and unloading cycles with the load cell and a LVDT interfaced to a personal computer. Crack lengths were calculated based on material compliance relationships using force and CMOD data collected during the unloading portion of each cycle in conjunction with specimen geometry information. All tests were performed in an ATS split type furnace designed to handle both elevated temperature and sub-zero temperature testing. Temperature was determined by placing a Type K thermocouple onto the specimen surface. The soak time for the compact tension specimen after reaching test temperature was 30 minutes to assure uniform temperature distribution in the specimen. Test temperatures were controlled to within ± 4 °F of the test temperature.

Nominal measurements were used as the input parameters for the JTEST software program. JTEST is certified by BWXS for the J-integral test. The percent unloading parameter specified the amount of unload for each unloading cycle during the test. An unloading value of 20% from the current force was specified for each specimen.

The force and the CMOD measurements of the unload were used to calculate the crack length using the compliance method. Because the extreme high and low ends of the unload process are relatively noisy, only the middle portion of the unload process was used to calculate the crack length to achieve higher accuracy. A step size of 0.003 inch with a loading displacement rate of 0.01 inch/minute was used.

Initially, upon program execution, the specimen was loaded to the final precrack load to determine the initial crack length using the compliance method. The measured crack length was used to check against the known precrack final crack length for consistency. This process was then repeated three times. If the measurements were consistent, the crack length checking process was considered complete. If results were not consistent, the test system was checked and the clip gage was examined for proper seating. This process was continued until reproducible results were obtained. Since the force applied to the specimen was significantly lower than the yield and lower than the forces used in the precracking process, no impact to the test results was expected.

Following the initial crack length measurement cycling, the actual test began. The specimen was loaded and unloaded in accordance with the parameters entered prior to the test. Compliance data (force versus CMOD) during each unloading was used for a crack length calculation. Crack length was calculated using equations that are listed in ASTM E1820.

3.3 Post Test Measurements

After the test, the specimens were heat-tinted in a furnace between 500 °F to 550 °F for 10 to 15 minutes. The specimens were then removed from the furnace and placed back onto the test fixture and loaded to failure using cyclic loading. The precrack final crack length and test final crack length were measured using a video micrometer system. This system was calibrated prior to and after the measurements were made.

The cracks were measured at nine locations across the crack front spanning the specimen thickness.

These nine measurements were used to determine an average initial and final crack

$$a_{AVG} = \frac{1}{8}\left[\frac{(a_1 + a_9)}{2} + a_2 + a_3 + a_4 + a_5 + a_6 + a_7 + a_8\right]$$

where

a_{AVG} is the average crack length from nine measurements
$a_1 \ldots a_9$ is nine point measured crack length

These values were later used as references to verify the accuracy of the crack length determined from the compliance method.

The test data were analyzed by Westmoreland using ASTM E1820 [9]. The test results are shown in Appendix A. Furthermore, the test data were also analyzed by BWXS using ASTM E813 and the results were shown in Appendix B. Note that ASTM E1820 data were used in subsequent analyses. Fracture surface of each specimen was photographed and shown in Appendix C.

3.4 Data Validation

In the proof-of-principle report, the following recommendation was made:

"BWXS shall determine the specimen capacity at 0.1" crack extension for the irradiated specimen and report it as the J value in case of J values exceed specimen capacity. BWXS expects that the specimen capacity should be much higher than the critical J value of 590 in-lbs/in^2."

The maximum J-integral capacity of the irradiated specimen is given by the smaller of the following:

$$J_{max} = b\sigma_Y/20, \text{ or}$$

$$J_{max} = B\sigma_Y/20,$$

where

b = remaining ligment (=W-a)
σ_Y = average of the 0.2% offset yield strength and the ultimate tensile strength
B = specimen thickness.

Note that σ_Y = 89.4 ksi and B = 0.5 inch were used in the calculation. In the beginning of the test, the J_{max} was estimated to be 2,157 in-lbs/in^2 and gradually decreased to 1,699 in-lbs/in^2 as crack grew by 0.1". None of the specimens tested had J values exceeding the specimen capacity at the end of the test.

4.0 DATA ANALYSIS AND DISCUSSION

The objective of this evaluation is to show that the plant specific J-R data meet the minimum crack driving force and resistance to ductile tearing as defined in ASME Section XI, Appendix X [10]. Table 1 summarizes the values of the J-integral and the resistance to tearing applied to the reactor vessel at 0.1 inch crack extension of a 1/4T flaw for Level A, B, C, and D loading conditions. Since Watts Bar Unit 1 is a four-loop plant, the limiting values of applied $J_{0.1}$ and applied dJ/da were taken from Tables 4, 5, and 6 of reference [3] for four loop plants.

Table 1. Applied Values of $J_{0.1}$ and dJ/da Representative of the Watts Bar Unit 1 Reactor Vessel

Loading Condition	Applied $J_{0.1}$ (in-lb/in^2)	Applied dJ/da	Material $J_{0.1}$ (in-lb/in^2)	Material dJ/da
Level A and B	590	345	808.6	1611.4
Level C	314	320	808.6	1611.4
Level D	-----	380	-----	1611.4

In order to determine if there are margins of safety equivalent to ASME Code Appendix G based on the J-R testing of Reference [3], the values of $J_{0.1}$ and dJ/da from the 1/2T compact tension specimens were compared with the respective applied values. The details of J-R testing and test results are in reference [9]. However, this report did not evaluate the tearing resistance of the measured J-R curves. For each J-R curve, data were fit to equation 1 which is of the same functional form as used by Eason [5]. Only J-Δa data pairs with crack extension beyond ductile crack initiation were used in each fit. Coefficients C and D were selected such that R^2 was maximized. Coefficients A and B were determined using regression analysis.

$$J = A\,\Delta a^B \exp(C\,\Delta a^D) \quad \text{.....Equation 1}$$

Where: J = J integral, in-lb/in^2

Δa	=	crack extension, inch
A, B, C, D	=	constants

Results of the curve fitting are contained in Table 2 and Figures 1 through 5.

Table 2. Curve fitting results

Specimen ID	A	B	C	D	R^2
WT9	1632.9	0.373	0.10	-0.4	0.969
WT10	1684.3	0.330	0.10	-0.4	0.941
WT11	1367.7	0.239	0.06	-0.4	0.989
WT9, WT 10, WT11	1344.1	0.258	0.08	-0.4	0.906
WT10 (low tearing resistance region)	1014.0	0.093	0.04	-0.4	0.952

It can be seen from Table 2 that curve fits were robust based on the R^2 values. Table 3 lists the J-R materials properties evaluated at 0.1 inch based on the curve fits.

Table 3. J and dJ/da Values at Crack Extension of 0.1 Inch

Specimen ID	J at Δa=0.1 inch (in-lbs/in^2)	dJ/da at Δa=0.1 inch
WT9	890.1	2422.2
WT10	1013.2	2323.6
WT11	917.8	1637.5
WT9, WT 10, WT11	907.2	1611.4
WT10 (low tearing resistance region)	905.5	476.4

The material $J_{0.1}$ and material dJ/da values were determined in accordance with the ASME Code Section XI, Appendix X. For Level A and B conditions, the J-integral resistance versus crack growth curve should be a conservative bound of the vessel material under evaluation. A conservative bound was selected as the J-R curve from the fit of all data from all three specimens less two standard deviations. The standard deviation was calculated to be 49.3 in-lb/in^2. Therefore the material $J_{0.1}$ for Level A and B conditions was determined to be 907.2 – 2(49.3) = 808.6 in-lbs/in^2 and the material dJ/da for Level A and B conditions was determined to be 1611.4 since the bounding slope

of the curve is the same as the slope determined by the best estimate curve. For Level C conditions, the J-integral resistance versus crack growth curve shall be a conservative bound of the vessel material under evaluation. Therefore the material $J_{0.1}$ for Level C conditions the material dJ/da for Level C conditions was determined to be the same as Level A and B conditions. For Level D conditions, the J-integral resistance versus crack growth curve is the best estimate curve. Therefore the material dJ/da for Level D conditions was determined to be 1611.4. Table 1 indicates that all ASME Section XI, Appendix X criteria are met based on testing of Watts Bar Unit 1, Capsule W, ½T compact tension specimens.

It can be seen from Figure 2 that there was large crack extension for the last data point due a local area of low tearing resistance. To evaluate the ductile tearing resistance of this local area the last three points of the J-R curve were fit to equation 1 (See Figure 5). The results in the last column of Table 3 indicate the minimum ductile tearing resistance, as prescribed by ASME Section XI, Appendix X, is met for the local low tearing resistance area in the material.

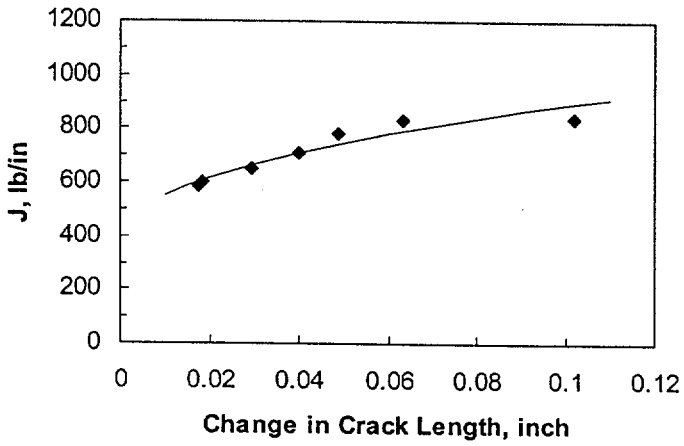


Figure 1. Curve Fit of J-R Data for WT9

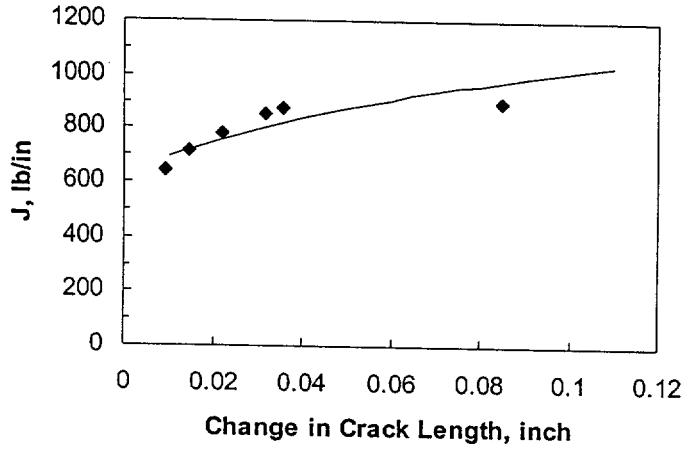


Figure 2. **Curve Fit of J-R Data for WT10**

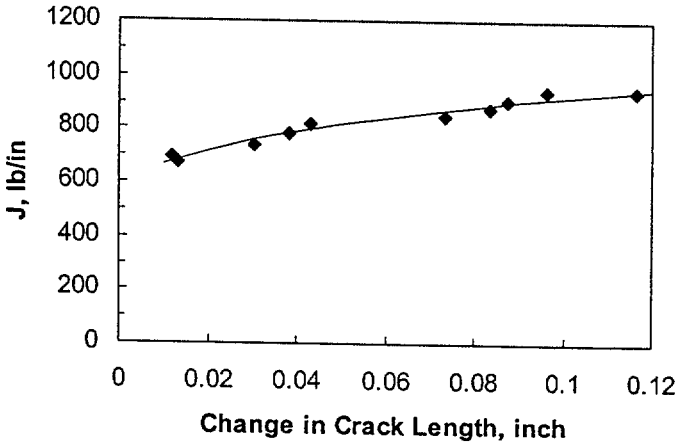


Figure 3. **Curve Fit of J-R Data for WT11**

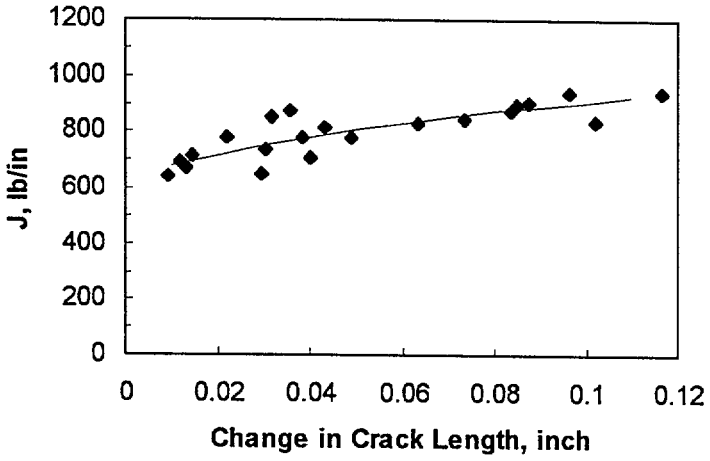


Figure 4. Curve Fit of J-R Data for WT 9, WT10, WT 11

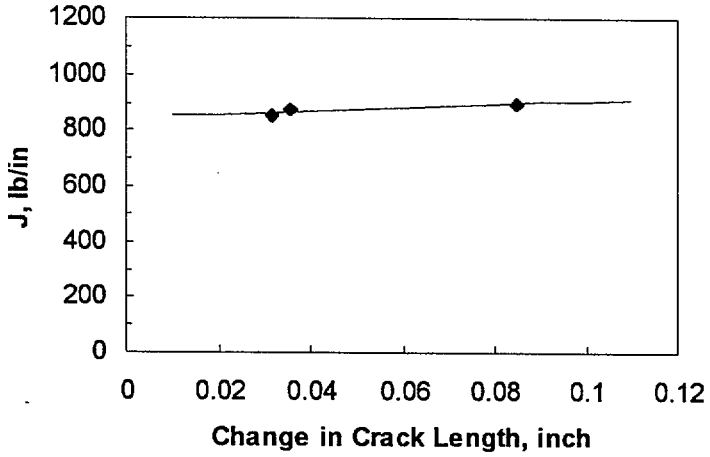


Figure 5. Curve Fit of J-R Data for Low Tearing Resistance Region, WT10

5.0 CONCLUSIONS

Based on the evaluation of the J-R curves generated from 1/2T compact fracture specimens from Watts Bar Unit 1 Capsule W, it can be concluded that

- the crack driving force and ductile tearing resistance requirements of ASME Section XI, Appendix X are met for neutron fluence values up to 1.23×10^{19} n/cm^2 (E > 1.0 MeV), a fluence that corresponds to the 1/4T fluence at the end of plant life (32EFPY).

- the results of the analysis of reference [3] are met with ample margin.

In general, most radiation embrittlement occurs before a neutron fluence of 10^{19} n/cm^2 (E > 1.0 MeV). Therefore, only small reductions in J-R curves are expected for Watts Bar Unit 1 1/2T compact tension specimens of future surveillance capsules when compared to the Capsule W results.

6.0 REFERENCES

[1] "Analysis of Capsule W from the Tennessee Valley Authority Watts Bar Unit 1 Reactor Vessel Material Surveillance Program," BWXT Services, Inc., 2016 Mt. Athos Road, Lynchburg, Virginia, September 2001.

[2] Regulatory Guide 1.99, Revision 2, Radiation Embrittlement of Reactor Vessel Materials, U.S. Nuclear Regulatory Commission, May 1988.

[3] "Watts Bar Unit 1 Low Upper Shelf Energy Evaluation," TVA Contract 92NNP-79283A, Westinghouse Electric Corporation, Pittsburgh, PA, August 1993.

[4] Section III of the ASME Boiler and Pressure Vessel Code, Appendix G.

[5] Eason, E. D., et al, NUREG/CR-5729, MCS 910401, "Multivariable Modeling of Pressure Vessel and Piping J-R Data," May 1991.

[6] ASTM E399-90, "Standard Test Method for Plane-Strain Fracture Toughness of Metallic Materials".

[7] ASTM E1820-99, "Standard Test Method for Measurement of Fracture Toughness".

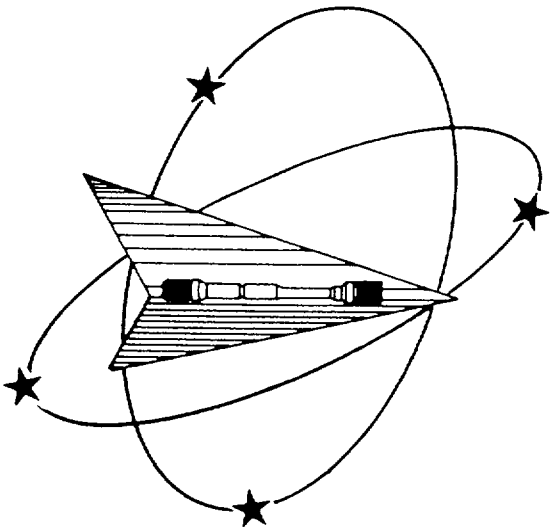
[8] K.Y. Hour, "Watts Bar Unit 1 Fracyure Toughness Proof-of-Principle Test", BWXS Letter Report, dated June 6, 2001.

[9] Gerald W. Boice, "Test Results for WT-9, WT-10, WT-11 Using ASTM E1820-99a", Westmoreland Report 1-32474, Sep. 10, 2001.

[10] Section XI of the ASME Boiler and Pressure Vessel Code, Appendix X.

Appendix A

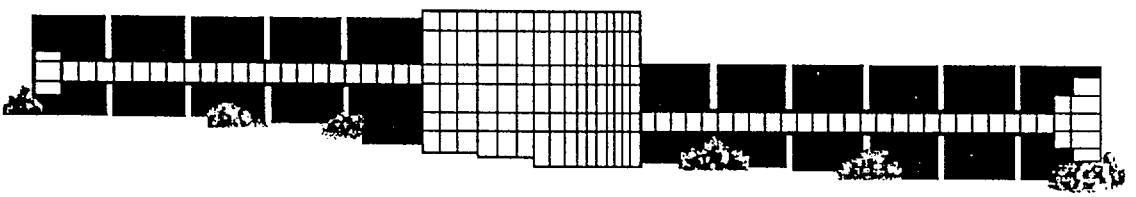
ASTM E1820 Analysis for WT-9, WT-10, and WT-11



Westmoreland Mechanical Testing & Research Inc.

P.O. Box 388, Youngstown, Pa. 15696-0388 U.S.A.

Telephone: 724-537-3131 *Fax: 724-537-3151*



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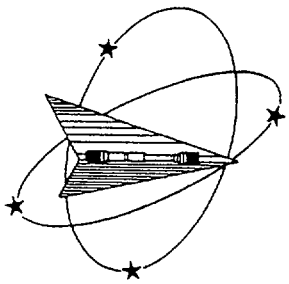
JIC Summary



Westmoreland Mechanical Testing & Research Inc.
Testing Specialists for Aerospace, Automotive, and Nuclear Fields
P.O. Box 388, Youngstown, Pa. 15696-0388 U.S.A.
Old Route 30, Westmoreland Drive
Telephone: 724-537-3131 Fax: 724-537-3151
Website: www.wmtr.com

10 September 2001

BWX Technologies, Inc.
2016 Mt. Athos Road
Lynchburg, VA 24504-5447

WMT&R Report 1-32474
P.O. No. LYN12008BWS

Attention: Kevin Hour

Subject: JIC Results

Introduction:

Three (3) packets of test results were received in the laboratory for JIC reanalysis per ASTM E1820-99a. The received digital data was reconfigured to allow input into Westmoreland Mechanical Testing's in-house software program developed for j-integral analysis per ASTM E1820-99a. All three (3) data sets were then run though the program to produce the enclosed test reports.

Comments:

An evenhanded approach was used to analyze the test data. Compliance values were calculated by regressing over the unloads and reloads between 10% and 90% of the unloading traces. Aoq adjustments were done by fitting the crack length values up until .1 inches of crack extension.

Results are summarized in Table I.

Results containing validity data, crack length data, J value data, and rotation data are enclosed for the specimens. Various plots of J vs. A and load vs. COD are also included.

If you have any questions concerning this report, please feel free to contact me. If I am unavailable, you may also speak with the Quality Assurance Department.

At your service

Gerald W. Boice
R&D Manager

slp

K:/DRAWER-JERRY/1W32474J.BWX

Westmoreland Mechanical Testing & Research, Inc.

Table 1 Jic RESULTS

PHONE (724)-537-3131

Customer : BMX Technologies, Inc.
P.O. No. : LYN12008BWS

WMT&R Report : 1-32474
Test Date : 08-28-01

Lot No.	Testlog Number	Temp (°F)	Jq (E1820) (in-lbs/in^2)	Jic (E1820) (in-lbs/in^2)	Kjq(E1820) (ksi(sqrt.in))	Kjic (ksi(sqrt.in))	Pq (E399-90) (lbs.)	Kq (E399-90) (ksi(sqrt.in))	Unstable
WT9	648040	390	510.56		124.21		2326.4	54.8	No
WT10	648041	390	672.09		142.51		2166.2	48.9	No
WT11	648042	390		673.37		142.65	2054.2	47.0	No

Kq (E399) = Value Determined using 5% offset method per ASTM E399

William G. Szekely - Gerald W. Boice

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Lot No.
WT9

WESTMORELAND MECHANICAL TESTING & RESEARCH

Testing Specialists for Aerospace, Automotive, and Nuclear Fields

Phone: 724-537-3131 Fax: 724-537-3151 Email: ADMIN@WMTR.COM

J-INTEGRAL TEST REPORT (ASTM E1820-99a)

PRELIMINARY INFORMATION

CUSTOMER : BWX TECHNOLOGIES
WMT&R NO. : 1-32474

SPECIMEN : WT9
P.O. NO : LYN12008BWS
TEST DATE: 8/28/01

MATERIAL SPEC. : ASTM E1820-99a
MODULUS : 27.5 msi
ULTIMATE STR. : 99.9 ksi
YIELD STR : 79.0 ksi
EFFECT. YIELD STR (EYS) : 89.4 ksi
POISSONS' RATIO : .30

SPECIMEN MEASUREMENTS

THICKNESS (TOTAL)	: 0.500 ins
THICKNESS (NET)	: 0.375 ins
THICKNESS (EFF.)	: 0.469 ins
WIDTH (W)	: 1.000 ins
UNCRACKED LIGAMENT	: 0.483 ins

TEST PARAMETERS

TEST TEMPERATURE	: 390 F	MAIN RAMP RATE	: .010 in/min
TEST TYPE	: CT	PARTIAL LOADING RATE	: .010 in/min
ORIENTATION	: N/A	PARTIAL UNLOADING RATE	: .010 in/min
TEST MACHINE	: H78	UNLOADING INTERVAL	: .002 in
CLIP GAGE	: MTS 1486	HOLD TIME	: 5.0 sec

PHYSICAL CRACK LENGTHS

PRECRACK LENGTHS			FINAL CRACK LENGTHS		
SIDE 1	(ins)	0.508	SIDE 1	(ins)	0.662
1/8 Point	(ins)	0.518	1/8 Point	(ins)	0.666
1/4 Point	(ins)	0.517	1/4 Point	(ins)	0.672
3/8 Point	(ins)	0.517	3/8 Point	(ins)	0.628
1/2 Point	(ins)	0.521	1/2 Point	(ins)	0.629
5/8 Point	(ins)	0.521	5/8 Point	(ins)	0.623
3/4 Point	(ins)	0.517	3/4 Point	(ins)	0.622
7/8 Point	(ins)	0.518	7/8 Point	(ins)	0.623
SIDE 2	(ins)	0.512	SIDE 2	(ins)	0.631
AVERAGE	(ins)	0.5174	AVERAGE	(ins)	0.6387
A/W	(ins)	0.5174	A/W	(ins)	0.6387

FATIGUE PRECRACKING SUMMARY

MAX.FATIGUE LOAD	= 850 lbs	LOAD RATIO	= .10
KF (MAX.)	= 17.34 KSI(SQRT.IN)	CYCLES	= 10000

ORIGINAL CRACK

PHYSICAL MEAS.	= 0.5174 ins
COMPLIANCE CAL.	= 0.5210 ins
PERCENT DIFF.	= .68 %

FINAL CRACK (HEAT TINT)

PHYSICAL MEAS.	= 0.6387 ins
COMPLIANCE CAL.	= 0.6229 ins
PERCENT DIFF.	= 2.47 %

MODULUS

MODULUS	= 27.50 msi
MODULUS (Em)	= 27.01 msi
PERCENT DIFF.	= 1.78 %

VALIDITY CHECKS PER ASTM E1820

1. (9.1.5.2)	ESTIMATED FINAL CRACK EXTENSION IS +/- 15% OF DELTA ap FOR CRACK EXTENSIONS LESS THAN .2 bo AND .03 bo THEREAFTER		INVALID
	Delta ap = 0.121 ins	Est. Final Crack Ext. = 0.102 ins	
2. (A9.8.2.1)	aoq SHALL NOT DIFFER FROM ao BY MORE THEN 0.01 W		VALID
	aoq = .5210	ao = 0.5174	
3. (A9.8.2.2)	NO. OF REGRESSION POINTS > or = 8 AND FIT > .96		VALID
	POINTS = 16	FIT = .96467	
4. (A9.8.1)	POWER COEFFICIENT C2 < 1.0		VALID
	C2 = .2708		
5. (A9.9.1)	THICKNESS (Bnet) > 25 JQ/EYS		VALID
	Bnet = .375 ins	25 JQ/EYS = .143	
6. (A9.9.2)	INITIAL LIGAMENT, bo > 25 JQ/EYS		VALID
	bo = .483 ins	25 JQ/EYS = .143	
7. (A9.9.3)	THE SLOPE OF POWER LAW REGRESSION LINE AT DELTA aQ < EYS		VALID
	Slope = 12770.2	EYS = 89450.0 psi	
8. (A9.6.6.6)	SUFFICIENT NUMBER OF DATA POINTS REMAINING VALID		VALID
	Minimum = 5	Remaining = 6	
9. (A9.6.4)	DATA GROUPING		VALID

*** TEST IS INVALID ; J_Q = 510.56 IN-LBS/IN^2 ***
K_{Jq} = 124.21 KSI(SQRT.IN)

Gerald W. Boice
TESTLOG 648040 WMTR-FRA-028

KNOWINGLY OR WILLFULLY FALSIFYING OR CONCEALING A MATERIAL FACT ON THIS FORM, OR MAKING; FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR REPRESENTATIONS; HEREIN; COULD CONSTITUTE A FELONY PUNISHABLE UNDER FEDERAL STATUTES.

WESTMORELAND MECHANICAL TESTING & RESEARCH

Testing Specialists for Aerospace, Automotive, and Nuclear Fields

Phone: 724-537-3131 Fax: 724-537-3151 Email: ADMIN@WMTR.COM

General Validity Checks (ASTM E1820-99a)

PRELIMINARY INFORMATION

CUSTOMER : BWX TECHNOLOGIES
WMT&R NO. : 1-32474

SPECIMEN : WT9
P.O. NO : LYN12008BWS
TEST DATE: 8/28/01

MATERIAL SPEC. : ASTM E1820-99a
MODULUS : 27.5 msi
ULTIMATE STR. : 99.9 ksi
YIELD STR : 79.0 ksi
EFFECT. YIELD STR (EYS) : 89.4 ksi
POISSONS' RATIO : .30

SPECIMEN MEASUREMENTS

THICKNESS (TOTAL)	: 0.500 ins
THICKNESS (NET)	: 0.375 ins
THICKNESS (EFF.)	: 0.469 ins
WIDTH (W)	: 1.000 ins
UNCRACKED LIGAMENT	: 0.483 ins

TEST PARAMETERS

TEST TEMPERATURE	: 390 F
TEST TYPE	: CT
ORIENTATION	: N/A
TEST MACHINE	: H78
CLIP GAGE	: MTS 1486
OPERATOR	: Gerald Boice

MAIN RAMP RATE	: .010 in/min
PARTIAL LOADING RATE	: .010 in/min
PARTIAL UNLOADING RATE	: .010 in/min
UNLOADING INTERVAL	: .002 in
HOLD TIME	: 5.0 sec

PHYSICAL CRACK LENGTHS

PRECRACK LENGTHS		
SIDE 1	(ins)	0.508
1/8 Point	(ins)	0.518
1/4 Point	(ins)	0.517
3/8 Point	(ins)	0.517
1/2 Point	(ins)	0.521
5/8 Point	(ins)	0.521
3/4 Point	(ins)	0.517
7/8 Point	(ins)	0.518
SIDE 2	(ins)	0.512
AVERAGE	(ins)	0.5174
A/W	(ins)	0.5174

FINAL CRACK LENGTHS		
SIDE 1	(ins)	0.662
1/8 Point	(ins)	0.666
1/4 Point	(ins)	0.672
3/8 Point	(ins)	0.628
1/2 Point	(ins)	0.629
5/8 Point	(ins)	0.623
3/4 Point	(ins)	0.622
7/8 Point	(ins)	0.623
SIDE 2	(ins)	0.631
AVERAGE	(ins)	0.6387
A/W	(ins)	0.6387

FATIGUE PRECRACKING SUMMARY

MAX.FATIGUE LOAD	= 850 lbs	LOAD RATIO	= .10
KF (MAX.)	= 17.34 KSI(SQRT.IN)	CYCLES	= 10000

TEST CURVE RESULTS

MAXIMUM LOAD (PMAX) = 3457.0 lbs

GENERAL VALIDITY CHECKS PER ASTM E1820

1. (7.4.5)	PRECRACK EXTENSION MUST BE > OR = 5% OF a AND > OR = 0.05 INCHES	VALID
	Precrack Extension = .067 ins 5% of a = 0.026 ins	
2. (7.4.5)	FOR THE LESSER OF THE FINAL 50% PRECRACK EXTENSION OR 0.05 INCHES	
	MAXIMUM PRECRACK LOAD < Pf	VALID
	Final Precrack Load = 850.0 lbs Pf = 4025.6 lbs	
	MAXIMUM PRECRACK LOAD SUCH THAT THE LESSER OF THE FOLLOWING IS NOT EXCEEDED	
	KMAX/E < OR = 0.001 SQ.RT.IN.	VALID
	Max. Precracking Stress / Modulus = 0.001 ins ^2	
	MAXIMUM PRECRACK LOAD < 70% X MAXIMUM TOUGHNESS TEST LOAD	VALID
	Final Precrack Load = 850 lbs 70% X Maximum Toughness Test Load = 2419.9 lbs	
3. (9.1.4.1)	NONE OF 9 ORIGINAL PHYSICAL CRACK MEASUREMENTS DIFFER BY MORE 5% OF AVERAGE	VALID
	Max. Difference = .010 ins .05 X AVERAGE = .026 ins	
4. (9.1.4.2)	NONE OF 9 FINAL PHYSICAL CRACK MEASUREMENTS DIFFER BY MORE 5% OF AVERAGE	INVALID
	Max. Difference = .033 ins .05 X Average = .032 ins	
5. (9.1.5.1)	NONE OF THE NINE PHYSICAL MEASUREMENTS OF CRACK EXTENSION SHALL BE < 50% OF THE AVERAGE CRACK EXTENSTION.	VALID
	Min. Crack Extension = 0.102 ins 50% Average Crack Extension = .061 ins	

*** All GENERAL VALIDITY CHECKS ARE NOT VALID

Gerald W. Boice
TESTLOG 648040 WMTR-FRA-028

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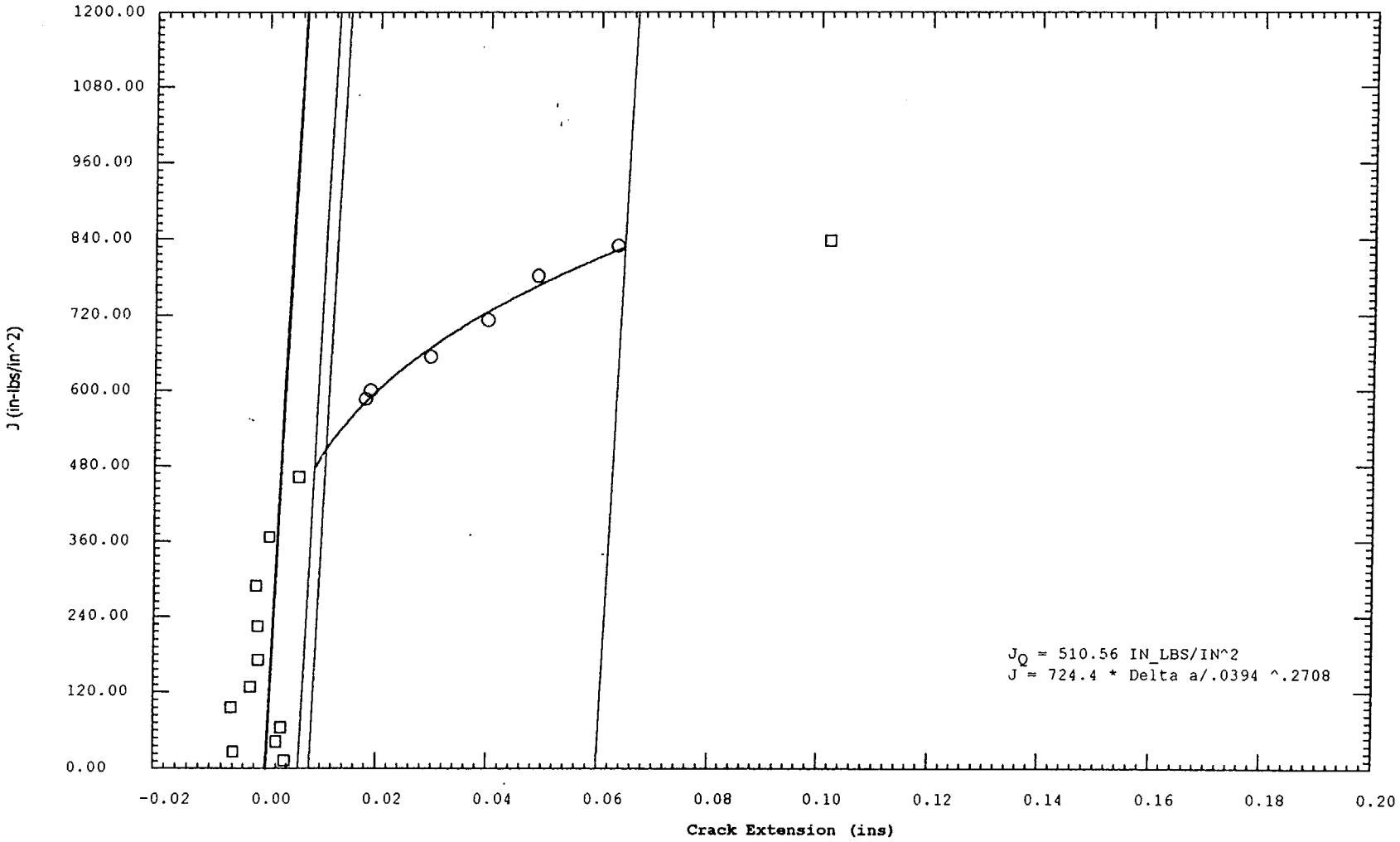
WESTMORELAND MECHANICAL TESTING & RESEARCH, Inc.

JIC TESTING - JD vs a (ASTM E1820) Phone 724-537-3131

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT9



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TESTLOG : 648040
WMTR-FRA-028

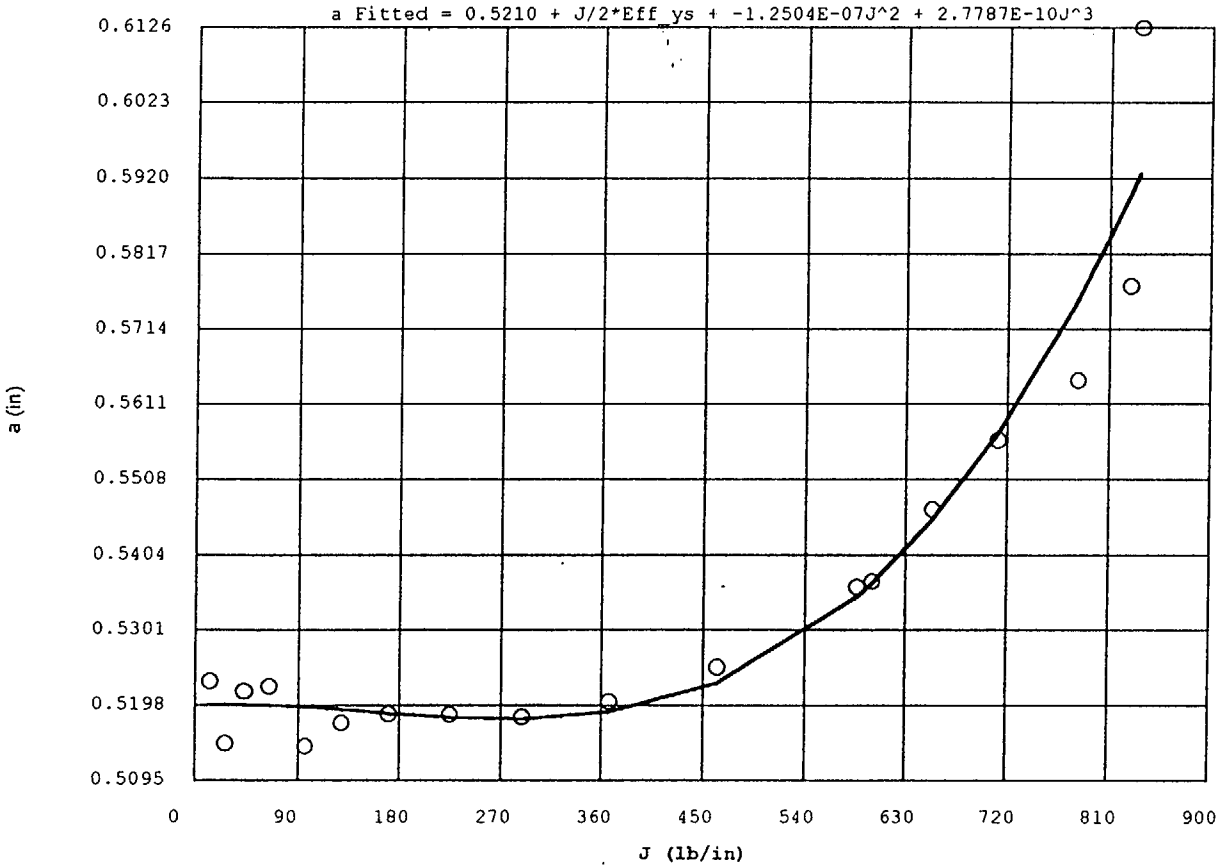
CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT9

aoq ADJUSTMENT

Pm = 1241.1 lbs
Regression Datapoints = 16

Correlation coefficient = .9647



J (LB/IN)	a (in)	Fitted a (in)
12.79	0.5245	0.52100
26.35	0.5151	0.52102
42.41	0.5230	0.52098
64.26	0.5237	0.52087
96.19	0.5147	0.52058
128.30	0.5182	0.52020
170.75	0.5196	0.51964
224.63	0.5195	0.51905
288.63	0.5191	0.51883
366.27	0.5214	0.51988
462.01	0.5267	0.52424
586.48	0.5388	0.53727
600.10	0.5396	0.53932
654.03	0.5504	0.54886
711.87	0.5608	0.56180
782.87	0.5698	0.58201
828.90	0.5842	0.59792
836.74	0.6229	0.60086
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095
0.00	0.0000	0.52095

Adjusted a : 0.5210 in

TESTLOG : 648040
JIC_VB1

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT9

ROTATION CORRECTION

Half Span of Load Points (H*) = .28 ins
Gage Measurement Points/2 (D) = .08 ins

Unload Number	Load Line Displacement (ins)	Radius of Rotation (W+a)/2	Angle of Rotation	Compliance (Load Line)	Compliance (Corrected)
1	.0024	.7657	-.1002	3.3656E-06	3.2483E-06
2	.0035	.7610	-.1008	3.2078E-06	3.0946E-06
3	.0046	.7649	-.1003	3.3389E-06	3.2223E-06
4	.0057	.7653	-.1003	3.3521E-06	3.2351E-06
5	.0070	.7608	-.1009	3.2012E-06	3.0882E-06
6	.0083	.7626	-.1006	3.2590E-06	3.1445E-06
7	.0097	.7632	-.1005	3.2815E-06	3.1664E-06
8	.0113	.7632	-.1006	3.2796E-06	3.1646E-06
9	.0131	.7630	-.1006	3.2734E-06	3.1585E-06
10	.0151	.7642	-.1004	3.3130E-06	3.1971E-06
11	.0177	.7667	-.1001	3.4027E-06	3.2844E-06
12	.0212	.7727	-.0993	3.6224E-06	3.4983E-06
13	.0216	.7731	-.0993	3.6382E-06	3.5137E-06
14	.0235	.7784	-.0986	3.8519E-06	3.7218E-06
15	.0256	.7835	-.0980	4.0735E-06	3.9377E-06
16	.0280	.7879	-.0974	4.2778E-06	4.1367E-06
17	.0303	.7950	-.0966	4.6335E-06	4.4833E-06
18	.0342	.8140	-.0943	5.8172E-06	5.6371E-06

Corrected Compliance (Cc) = C (Load Line)/[(H/R * sin(angle)-cos(angle)] * [(D/R) * sin(angle)-cos(angle)]
where angle = Arcsin{[(clipgage/2)+D]/[(D^2+R^2)^.5]}-Arctan(D/R)

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT9

CRACK GROWTH CALCULATIONS

Origional Comp(11) = 3.1901E-06
Initial Crack Comp(11) = 0.5210 ins **

Crack Length (meas) = 0.5174 ins
E' = 27.5 msi

Unload Number	Load ; start of unloading (lbs)	V ; start of unloading (in)	V/P(11)	BEV/P(11)	*EBV/P(11) Corrected for Rotation	Correlation (r^2)	Crack Length (in)	Crack Growth (in)
1	845.6	.0024	3.366E-06	43.38	41.87	0.981473	0.5245	0.0036
2	1152.0	.0035	3.208E-06	41.35	39.89	0.989186	0.5151	-0.0059
3	1457.3	.0046	3.339E-06	43.04	41.54	0.989513	0.5230	0.0020
4	1765.4	.0057	3.352E-06	43.21	41.70	0.996462	0.5237	0.0028
5	2064.8	.0070	3.201E-06	41.27	39.81	0.996784	0.5147	-0.0063
6	2358.1	.0083	3.259E-06	42.01	40.53	0.998106	0.5182	-0.0027
7	2631.7	.0097	3.282E-06	42.30	40.82	0.997926	0.5196	-0.0014
8	2884.3	.0113	3.280E-06	42.28	40.79	0.998512	0.5195	-0.0015
9	3100.4	.0131	3.273E-06	42.20	40.72	0.998383	0.5191	-0.0019
10	3267.9	.0151	3.313E-06	42.71	41.21	0.998841	0.5214	0.0005
11	3356.1	.0177	3.403E-06	43.86	42.34	0.998766	0.5267	0.0057
12	3201.4	.0212	3.622E-06	46.70	45.10	0.998485	0.5388	0.0178
13	3207.9	.0216	3.638E-06	46.90	45.29	0.998552	0.5396	0.0186
14	3116.3	.0235	3.852E-06	49.65	47.98	0.998884	0.5504	0.0295
15	2969.8	.0256	4.074E-06	52.51	50.76	0.998426	0.5608	0.0399
16	2778.5	.0280	4.278E-06	55.14	53.32	0.998779	0.5698	0.0489
17	2582.1	.0303	4.634E-06	59.73	57.79	0.998873	0.5842	0.0632
18	2042.8	.0342	5.817E-06	74.99	72.67	0.998209	0.6229	0.1020

Effective Modulus = $1/CoBe\{(W+Ao)/(W-Ao)\}^2\{2.1630+12.219(Ao/W)-20.065(Ao/W)^2-0.9925(Ao/W)^3+20.609(Ao/W)^4-9.9314(Ao/W)^5\}$

A/W (load line) = $1.000196-4.06319(Ux)+11.242(Ux)^2-106.043(Ux)^3+464.335(Ux)^4-650.677(Ux)^5$

where $Ux = 1/\{Beff*E'*C[corr]^.5\}+1$

* See Rotation Correction Data Sheet
* See aoq Adjustment Data Sheet

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT9

J-CALCULATION (ASTM E1820-99)

Net Specimen Thickness (b) = .375 ins
Initial Uncracked Ligament (bo) = .483 ins

Effective Yield Strength = 89450.0 ksi

Unload Number	V ; start of unloading (in)	Load ; start of unloading (lbs)	Area Plastic (in-lbs)	J Plastic (in-lbs/sq.rt.)	J Elastic (in-lbs/sq.rt.)	* J Deformation (in-lbs/sq.rt.)	J Modified (in-lbs/sq.rt.)	Qualified/ Disqualified ((15*J)/Eff.Yield)
1	.0024	845.6	-.14	-1.0	13.7	12.8	12.8	Qualified
2	.0035	1152.0	.11	2.3	24.0	26.4	26.3	Qualified
3	.0046	1457.3	.09	2.0	40.4	42.4	42.4	Qualified
4	.0057	1765.4	.30	4.6	59.6	64.3	64.2	Qualified
5	.0070	2064.8	1.42	19.3	76.9	96.2	95.7	Qualified
6	.0083	2358.1	1.96	25.7	102.6	128.3	128.1	Qualified
7	.0097	2631.7	3.27	41.8	129.0	170.7	170.7	Qualified
8	.0113	2884.3	5.51	69.8	154.8	224.6	224.5	Qualified
9	.0131	3100.4	8.73	110.2	178.4	288.6	288.4	Qualified
10	.0151	3267.9	13.21	165.0	201.3	366.3	367.1	Qualified
11	.0177	3356.1	19.68	242.4	219.6	462.0	466.5	Qualified
12	.0212	3201.4	30.81	370.1	216.4	586.5	603.8	Qualified
13	.0216	3207.9	31.78	381.6	218.5	600.1	618.4	Qualified
14	.0235	3116.3	36.76	432.0	222.0	654.0	686.0	Qualified
15	.0256	2969.8	42.71	495.0	216.8	711.9	759.3	Qualified
16	.0280	2778.5	50.22	580.5	202.4	782.9	846.1	Qualified
17	.0303	2582.1	56.28	634.6	194.3	828.9	920.2	Qualified
18	.0342	2042.8	65.47	671.5	165.3	836.7	1010.4	Qualified

J Plas(i) = [2+0.522 x ((b(i)/Width)] x (Area plas(i))/Bnet x b(i)) x [1-(1+0.76 x b(i)/W) X (a(i)-a(i-1))/b(i)]
J Elas(i) = (K(i)^2 * (1-Poisson^2)))/Modulus
where K = P(i) * F(a(i)/W) / Sqr(Bgross * Bnet * Width)
J Def(i) = J Elastic(i) + J Plastic(i)
J Mod(i) = J Elastic(i) + J Plastic(i) + Delta J(i)
where = Delta J(i) = Delta J(i+1) + [Rho(i)/Bo(i)] x [a(i)-a(i-1)] x J Plastic(i)
(Qual/Disqual) = (15 * J Def)/Eff. Yield must be < bo

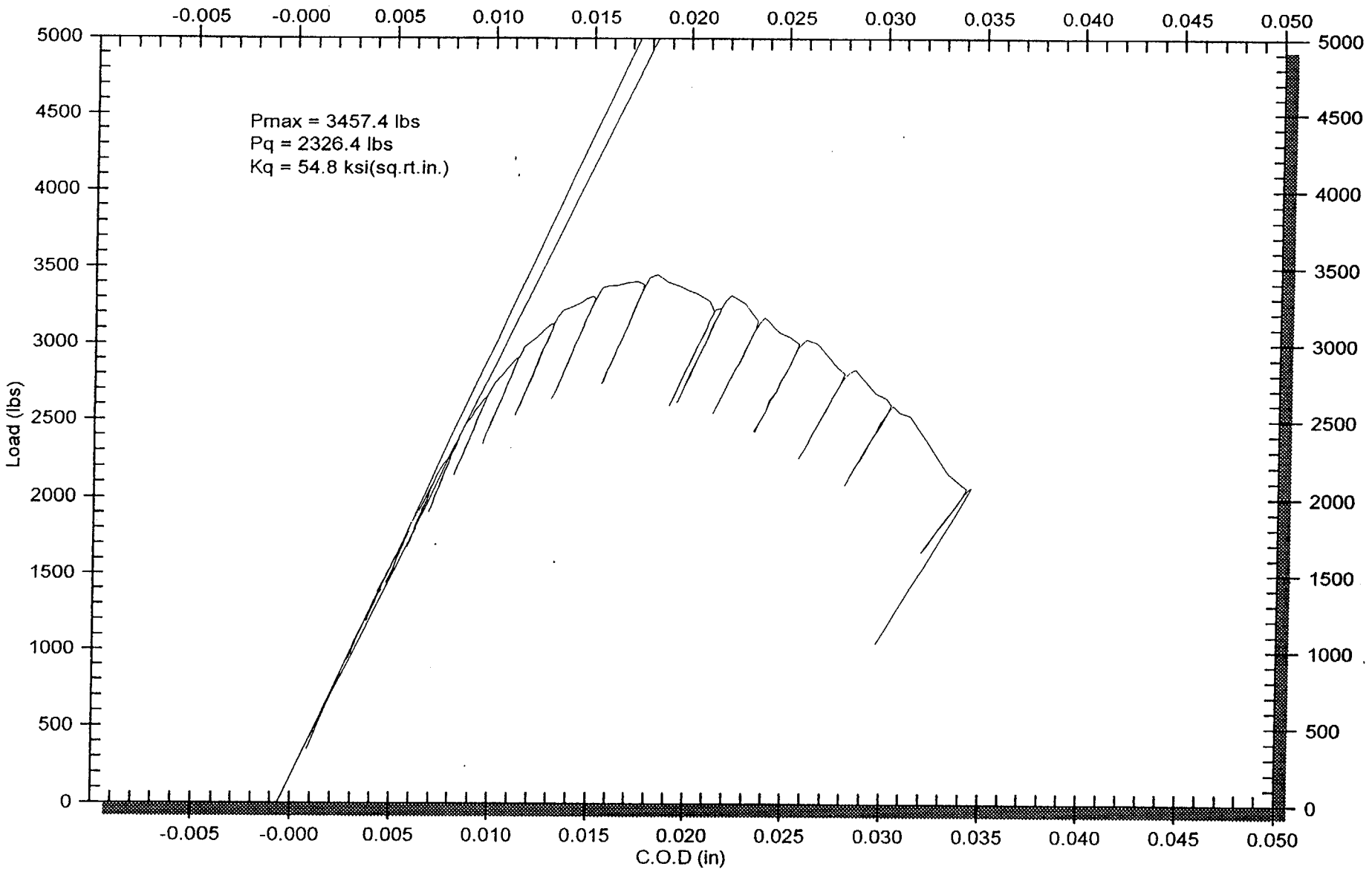
WESTMORELAND MECHANICAL TESTING & RESEARCH Inc.

Load vs Crack Opening Displacement Phone (724)537-3131 Fax (724)537-3151

CUSTOMER :BWX TECHNOLOGIES
P.O. NO :LYN12008BWS
WMT&R REPORT : 1-32474
SPECIMEN :WT9

TEST DATE :8/28/01

TEST TEMPERATURE :390 F



Knowingly or willfully falsifying or concealing a material fact on this form or making false, fictitious or fraudulent statements or representations herein could constitute a felony punishable under federal statutes.

testlog 648040
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WESTMORELAND MECHANICAL TESTING & RESEARCH Inc.

Area Determination Phone (724)537-3131 Fax (724)537-3151

CUSTOMER :BWX TECHNOLOGIES
P.O. NO :LYN12008BWS
WMT&R REPORT : 1-32474
SPECIMEN :WT9

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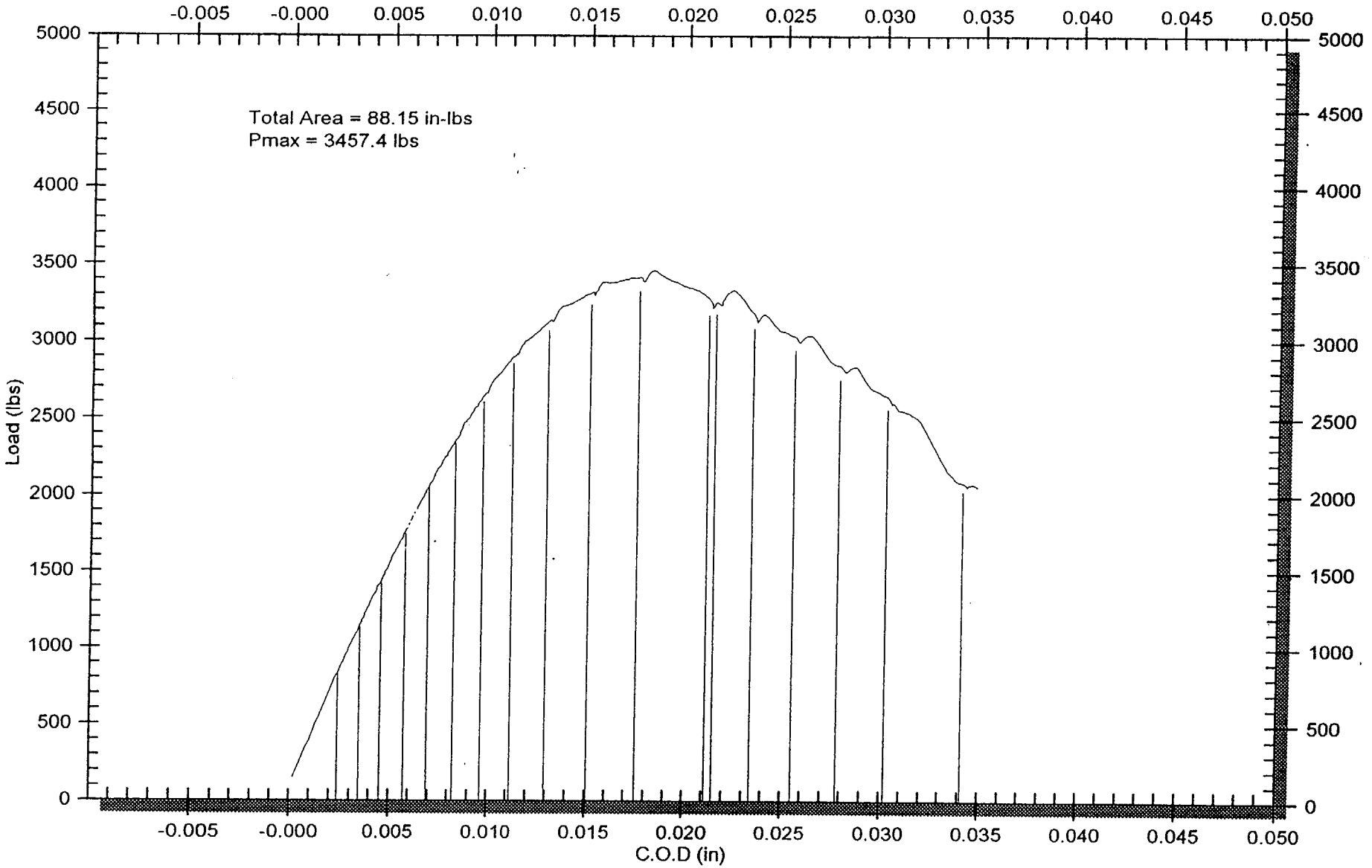
TEST TEMPERATURE :390 F



Knowingly or willfully falsifying or concealing a material fact on this form or making false, fictitious or fraudulent statements or representations herein could constitute a felony punishable under federal statutes.

testlog 648040
WMTR-FRA-028

Lot No.
WT10

WESTMORELAND MECHANICAL TESTING & RESEARCH

Testing Specialists for Aerospace, Automotive, and Nuclear Fields

Phone: 724-537-3131 Fax: 724-537-3151 Email: ADMIN@WMTR.COM

J-INTEGRAL TEST REPORT (ASTM E1820-99a)

PRELIMINARY INFORMATION

CUSTOMER : BWX TECHNOLOGIES
WMT&R NO. : 1-32474

SPECIMEN : WT10
P.O. NO : LYN12008BWS
TEST DATE: 8/28/01

MATERIAL SPEC. : ASTM E1820-99a
MODULUS : 27.5 msi
ULTIMATE STR. : 99.9 ksi
YIELD STR : 79.0 ksi
EFFECT. YIELD STR (EYS) : 89.4 ksi
POISSONS' RATIO : .30

SPECIMEN MEASUREMENTS

THICKNESS (TOTAL)	: 0.500 ins
THICKNESS (NET)	: 0.375 ins
THICKNESS (EFF.)	: 0.469 ins
WIDTH (W)	: 1.000 ins
UNCRACKED LIGAMENT	: 0.496 ins

TEST PARAMETERS

TEST TEMPERATURE	: 390 F
TEST TYPE	: CT
ORIENTATION	: N/A
TEST MACHINE	: H78
CLIP GAGE	: MTS 1486

MAIN RAMP RATE	: .010 in/min
PARTIAL LOADING RATE	: .010 in/min
PARTIAL UNLOADING RATE	: .010 in/min
UNLOADING INTERVAL	: .002 in
HOLD TIME	: 5.0 sec

PHYSICAL CRACK LENGTHS

PRECRACK LENGTHS

SIDE 1	(ins)	0.504
1/8 Point	(ins)	0.504
1/4 Point	(ins)	0.505
3/8 Point	(ins)	0.510
1/2 Point	(ins)	0.506
5/8 Point	(ins)	0.503
3/4 Point	(ins)	0.501
7/8 Point	(ins)	0.499
SIDE 2	(ins)	0.504
AVERAGE	(ins)	0.5040
A/W	(ins)	0.5040

FINAL CRACK LENGTHS

SIDE 1	(ins)	0.560
1/8 Point	(ins)	0.532
1/4 Point	(ins)	0.622
3/8 Point	(ins)	0.622
1/2 Point	(ins)	0.639
5/8 Point	(ins)	0.648
3/4 Point	(ins)	0.586
7/8 Point	(ins)	0.627
SIDE 2	(ins)	0.616
AVERAGE	(ins)	0.6080
A/W	(ins)	0.6080

FATIGUE PRECRACKING SUMMARY

MAX.FATIGUE LOAD = 850 lbs
KF (MAX.) = 16.63 KSI(SQRT.IN)
LOAD RATIO = .10
CYCLES = 10000

ORIGINAL CRACK

PHYSICAL MEAS. = 0.5040 ins
COMPLIANCE CAL. = 0.5080 ins
PERCENT DIFF. = .80 %

FINAL CRACK (HEAT TINT)

PHYSICAL MEAS. = 0.6080 ins
COMPLIANCE CAL. = 0.5928 ins
PERCENT DIFF. = 2.49 %

MODULUS

MODULUS = 27.50 msi
MODULUS (Em) = 26.95 msi
PERCENT DIFF. = 2.00 %

VALIDITY CHECKS PER ASTM E1820

1. (9.1.5.2)	ESTIMATED FINAL CRACK EXTENSION IS +/- 15% OF DELTA ap FOR CRACK EXTENSIONS LESS THAN .2 bo AND .03 bo THEREAFTER Delta ap = 0.104 ins	Est. Final Crack Ext. = 0.085 ins	INVALID
2. (A9.8.2.1)	aoq SHALL NOT DIFFER FROM ao BY MORE THEN 0.01 W aoq = .5080	ao = 0.5040	VALID
3. (A9.8.2.2)	NO. OF REGRESSION POINTS > or = 8 AND FIT > .96 POINTS = 27	FIT = .90869	INVALID
4. (A9.8.1)	POWER COEFFICIENT C2 < 1.0 C2 = .2339		VALID
5. (A9.9.1)	THICKNESS (Bnet) > 25 JQ/EYS Bnet = .375 ins	25 JQ/EYS = .188	VALID
6. (A9.9.2)	INITIAL LIGAMENT, bo > 25 JQ/EYS bo = .496 ins	25 JQ/EYS = .188	VALID
7. (A9.9.3)	THE SLOPE OF POWER LAW REGRESSION LINE AT DELTA aQ < EYS Slope = 13412.4	EYS = 89450.0 psi	VALID
8. (A9.6.6.6)	SUFFICIENT NUMBER OF DATA POINTS REMAINING VALID Minimum = 5	Remaining = 4	INVALID
9. (A9.6.4)	DATA GROUPING		VALID

*** TEST IS INVALID ; J_Q = 672.09 IN-LBS/IN^2 ***
K_{Jq} = 142.51 KSI(SQRT.IN)

Gerald W. Boice
TESTLOG 648041 WMTR-FRA-028

KNOWINGLY OR WILLFULLY FALSIFYING OR CONCEALING A MATERIAL FACT ON THIS FORM, OR MAKING; FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR REPRESENTATIONS; HEREIN; COULD CONSTITUTE A FELONY PUNISHABLE UNDER FEDERAL STATUTES.

WESTMORELAND MECHANICAL TESTING & RESEARCH

Testing Specialists for Aerospace, Automotive, and Nuclear Fields

Phone: 724-537-3131 Fax: 724-537-3151 Email: ADMIN@WMTR.COM

General Validity Checks (ASTM E1820-99a)

PRELIMINARY INFORMATION

CUSTOMER : BWX TECHNOLOGIES
WMT&R NO. : 1-32474

SPECIMEN : WT10
P.O. NO : LYN12008BWS
TEST DATE: 8/28/01

MATERIAL SPEC. : ASTM E1820-99a
MODULUS : 27.5 msi
ULTIMATE STR. : 99.9 ksi
YIELD STR : 79.0 ksi
EFFECT. YIELD STR (EYS) : 89.4 ksi
POISSONS' RATIO : .30

SPECIMEN MEASUREMENTS

THICKNESS (TOTAL)	: 0.500 ins
THICKNESS (NET)	: 0.375 ins
THICKNESS (EFF.)	: 0.469 ins
WIDTH (W)	: 1.000 ins
UNCRACKED LIGAMENT	: 0.496 ins

TEST PARAMETERS

TEST TEMPERATURE	: 390 F
TEST TYPE	: CT
ORIENTATION	: N/A
TEST MACHINE	: H78
CLIP GAGE	: MTS 1486
OPERATOR	: Gerald Boice

MAIN RAMP RATE	: .010 in/min
PARTIAL LOADING RATE	: .010 in/min
PARTIAL UNLOADING RATE	: .010 in/min
UNLOADING INTERVAL	: .002 in
HOLD TIME	: 5.0 sec

PHYSICAL CRACK LENGTHS

PRECRACK LENGTHS

SIDE 1	(ins)	0.504
1/8 Point	(ins)	0.504
1/4 Point	(ins)	0.505
3/8 Point	(ins)	0.510
1/2 Point	(ins)	0.506
5/8 Point	(ins)	0.503
3/4 Point	(ins)	0.501
7/8 Point	(ins)	0.499
SIDE 2	(ins)	0.504
AVERAGE	(ins)	0.5040
A/W	(ins)	0.5040

FINAL CRACK LENGTHS

SIDE 1	(ins)	0.560
1/8 Point	(ins)	0.532
1/4 Point	(ins)	0.622
3/8 Point	(ins)	0.622
1/2 Point	(ins)	0.639
5/8 Point	(ins)	0.648
3/4 Point	(ins)	0.586
7/8 Point	(ins)	0.627
SIDE 2	(ins)	0.616
AVERAGE	(ins)	0.6080
A/W	(ins)	0.6080

FATIGUE PRECRACKING SUMMARY

MAX.FATIGUE LOAD = 850 lbs
KF (MAX.) = 16.63 KSI(SQRT.IN)
LOAD.RATIO = .10
CYCLES = 10000

TEST CURVE RESULTS

MAXIMUM LOAD (PMAX) = 3774.0 lbs

GENERAL VALIDITY CHECKS PER ASTM E1820

1. (7.4.5) PRECRACK EXTENSION MUST BE > OR = 5% OF a AND > OR = 0.05 INCHES — VALID
   Precrack Extension = .054 ins 5% of a = 0.025 ins
2. (7.4.5) FOR THE LESSER OF THE FINAL 50% PRECRACK EXTENSION OR 0.05 INCHES
   MAXIMUM PRECRACK LOAD < Pf — VALID
   Final Precrack Load = 850.0 lbs Pf = 4365.7 lbs
   MAXIMUM PRECRACK LOAD SUCH THAT THE LESSER OF THE FOLLOWING IS NOT EXCEEDED
   KMAX/E < OR = 0.001 SQ.RT.IN. — VALID
   Max. Precracking Stress / Modulus = 0.001 ins ^2
   MAXIMUM PRECRACK LOAD < 70% X MAXIMUM TOUGHNESS TEST LOAD — VALID
   Final Precrack Load = 850 lbs 70% X Maximum Toughness Test Load = 2641.8 lbs
3. (9.1.4.1) NONE OF 9 ORIGINAL PHYSICAL CRACK MEASUREMENTS DIFFER BY MORE 5% OF AVERAGE — VALID
   Max. Difference = .006 ins .05 X AVERAGE = .025 ins
4. (9.1.4.2) NONE OF 9 FINAL PHYSICAL CRACK MEASUREMENTS DIFFER BY MORE 5% OF AVERAGE — INVALID
   Max. Difference = .075 ins .05 X Average = .030 ins
5. (9.1.5.1) NONE OF THE NINE PHYSICAL MEASUREMENTS OF CRACK EXTENSION SHALL BE < 50% OF THE AVERAGE CRACK EXTENSTION. — INVALID
   Min. Crack Extension = 0.029 ins 50% Average Crack Extension = .052 ins

*** All GENERAL VALIDITY CHECKS ARE NOT VALID

Gerald W. Boice
TESTLOG 648041 WMTR-FRA-028

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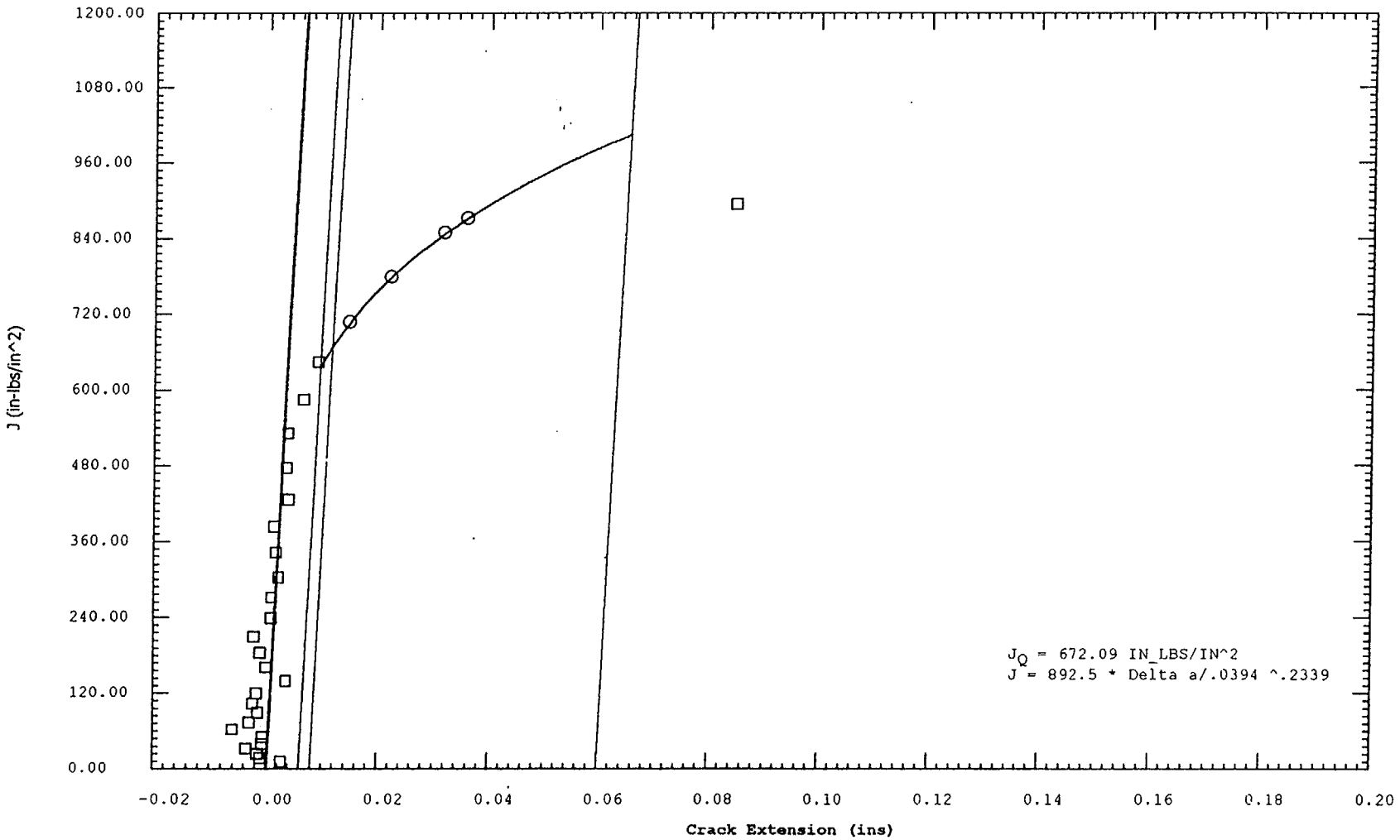
WESTMORELAND MECHANICAL TESTING & RESEARCH, Inc.

JIC TESTING - JD vs a (ASTM E1820) Phone 724-537-3131

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10



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TESTLOG : 648041
WMTR-FRA-028

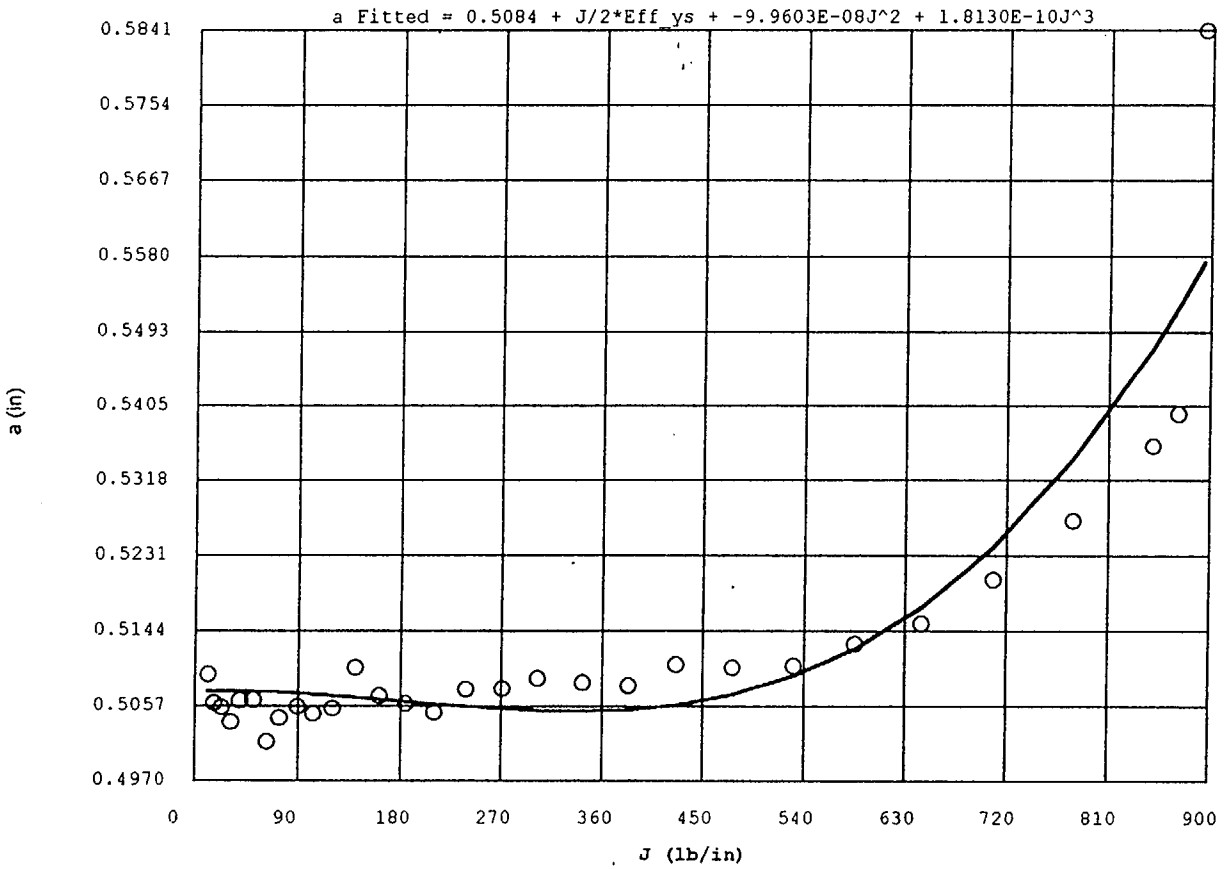
CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10

aoq ADJUSTMENT

Pm = 1318.1 lbs
Regression Datapoints = 26

Correlation coefficient = .9081



J (LB/IN)	a (in)	Fitted a (in)
11.75	0.5106	0.50845
17.37	0.5070	0.50847
23.89	0.5065	0.50848
31.99	0.5045	0.50848
39.53	0.5073	0.50847
50.53	0.5074	0.50845
62.46	0.5020	0.50840
73.24	0.5050	0.50834
88.79	0.5065	0.50824
103.18	0.5056	0.50811
119.74	0.5063	0.50795
139.45	0.5115	0.50773
161.03	0.5079	0.50747
184.48	0.5069	0.50718
210.09	0.5057	0.50686
238.75	0.5087	0.50652
270.79	0.5088	0.50621
302.47	0.5101	0.50599
342.02	0.5096	0.50591
382.98	0.5092	0.50611
426.15	0.5118	0.50672
476.35	0.5115	0.50806
530.88	0.5117	0.51042
584.71	0.5145	0.51386
644.22	0.5171	0.51914
708.20	0.5227	0.52680
778.98	0.5301	0.53801
849.13	0.5397	0.55233
872.15	0.5438	0.55779

Adjusted a : 0.5084 in

KNOWINGLY OR WILLFULLY FALSIFYING OR CONCEALING A MATERIAL FACT ON THIS FORM OR MAKING FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR REPRESENTATIONS HEREIN COULD CONSTITUTE A FELONY PUNISHABLE UNDER FEDERAL STATUTES.

TESTLOG : 648041
JIC_VB1

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10

ROTATION CORRECTION

Half Span of Load Points (H*) = .28 ins
Gage Measurement Points/2 (D) = .08 ins

Unload Number	Load Line Displacement (ins)	Radius of Rotation (W+a)/2	Angle of Rotation	Compliance (Load Line)	Compliance (Corrected)
1	.0023	.7589	-.1011	3.1370E-06	3.0257E-06
2	.0028	.7571	-.1014	3.0800E-06	2.9703E-06
3	.0033	.7568	-.1014	3.0720E-06	2.9625E-06
4	.0038	.7559	-.1015	3.0420E-06	2.9333E-06
5	.0043	.7572	-.1013	3.0850E-06	2.9751E-06
6	.0049	.7573	-.1013	3.0860E-06	2.9761E-06
7	.0055	.7546	-.1017	3.0040E-06	2.8963E-06
8	.0060	.7561	-.1015	3.0500E-06	2.9411E-06
9	.0067	.7569	-.1014	3.0730E-06	2.9635E-06
10	.0073	.7564	-.1014	3.0590E-06	2.9498E-06
11	.0079	.7567	-.1014	3.0690E-06	2.9596E-06
12	.0087	.7593	-.1011	3.1510E-06	3.0394E-06
13	.0093	.7575	-.1013	3.0940E-06	2.9839E-06
14	.0100	.7570	-.1014	3.0780E-06	2.9683E-06
15	.0107	.7565	-.1014	3.0610E-06	2.9518E-06
16	.0116	.7579	-.1012	3.1070E-06	2.9965E-06
17	.0125	.7580	-.1012	3.1080E-06	2.9975E-06
18	.0133	.7586	-.1012	3.1280E-06	3.0170E-06
19	.0143	.7583	-.1012	3.1200E-06	3.0092E-06
20	.0153	.7582	-.1012	3.1140E-06	3.0034E-06

Corrected Compliance (Cc) = C (Load Line)/[(H/R * sin(angle)-cos(angle)] * [(D/R) * sin(angle)-cos(angle)]
where angle = Arcsin{[(clipgage/2)+D]/[(D^2+R^2)^.5]}-Arctan(D/R)

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10

ROTATION CORRECTION

Half Span of Load Points (H*) = .28 ins
Gage Measurement Points/2 (D) = .08 ins

Unload Number	Load Line Displacement (ins)	Radius of Rotation (W+a)/2	Angle of Rotation	Compliance (Load Line)	Compliance (Corrected)
21	.0164	.7595	-.1010	3.1560E-06	3.0442E-06
22	.0175	.7593	-.1011	3.1500E-06	3.0384E-06
23	.0188	.7594	-.1011	3.1540E-06	3.0423E-06
24	.0201	.7607	-.1009	3.1980E-06	3.0851E-06
25	.0215	.7620	-.1007	3.2410E-06	3.1270E-06
26	.0232	.7648	-.1003	3.3340E-06	3.2175E-06
27	.0252	.7684	-.0999	3.4640E-06	3.3441E-06
28	.0275	.7732	-.0993	3.6410E-06	3.5164E-06
29	.0283	.7752	-.0990	3.7200E-06	3.5934E-06
30	.0331	.7992	-.0960	4.8680E-06	4.7118E-06

Corrected Compliance (Cc) = C (Load Line)/[(H/R * sin(angle)-cos(angle)] * [(D/R) * sin(angle)-cos(angle)]
where angle = Arcsin{[(clipgage/2)+D]/[(D^2+R^2)^.5]}-Arctan(D/R)

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10

CRACK GROWTH CALCULATIONS

Origional Comp(11) = 2.9876E-06
Initial Crack Comp(11) = 0.5080 ins **

Crack Length (meas) = 0.5040 ins
E' = 27.5 msi

Unload Number	Load ; start of unloading (lbs)	V ; start of unloading (in)	V/P(11)	BEV/P(11)	*EBV/P(11) Corrected for Rotation	Correlation (r^2)	Crack Length (in)	Crack Growth (in)
1	845.6	.0023	3.137E-06	40.44	39.00	0.981123	0.5106	0.0026
2	997.9	.0028	3.080E-06	39.70	38.29	0.984835	0.5070	-0.0010
3	1152.0	.0033	3.072E-06	39.60	38.19	0.990455	0.5065	-0.0016
4	1305.0	.0038	3.042E-06	39.21	37.81	0.991862	0.5045	-0.0035
5	1460.7	.0043	3.085E-06	39.77	38.35	0.996607	0.5073	-0.0007
6	1615.8	.0049	3.086E-06	39.78	38.36	0.995947	0.5074	-0.0007
7	1768.5	.0055	3.004E-06	38.72	37.34	0.996869	0.5020	-0.0061
8	1922.2	.0060	3.050E-06	39.32	37.91	0.994802	0.5050	-0.0030
9	2073.8	.0067	3.073E-06	39.61	38.20	0.997482	0.5065	-0.0015
10	2222.0	.0073	3.059E-06	39.43	38.03	0.997578	0.5056	-0.0024
11	2370.9	.0079	3.069E-06	39.56	38.15	0.997680	0.5063	-0.0018
12	2516.3	.0087	3.151E-06	40.62	39.18	0.994608	0.5115	0.0035
13	2657.2	.0093	3.094E-06	39.88	38.46	0.997779	0.5079	-0.0001
14	2793.0	.0100	3.078E-06	39.68	38.26	0.999133	0.5069	-0.0012
15	2923.3	.0107	3.061E-06	39.46	38.05	0.998221	0.5057	-0.0023
16	3044.6	.0116	3.107E-06	40.05	38.63	0.998619	0.5087	0.0007
17	3159.7	.0125	3.108E-06	40.06	38.64	0.998897	0.5088	0.0008
18	3265.1	.0133	3.128E-06	40.32	38.89	0.998757	0.5101	0.0020
19	3360.9	.0143	3.120E-06	40.22	38.79	0.998884	0.5096	0.0015
20	3447.8	.0153	3.114E-06	40.14	38.72	0.998950	0.5092	0.0011

Effective Modulus = 1/CoBe{(W+Ao)/(W-Ao)}^2{2.1630+12.219(Ao/W)-20.065(Ao/W)^2-0.9925(Ao/W)^3+20.609(Ao/W)^4-9.9314(Ao/W)^5}
A/W (load line) = 1.000196-4.06319(Ux)+11.242(Ux)^2-106.043(Ux)^3+464.335(Ux)^4-650.677(Ux)^5
where Ux = 1/{Beff*E'*C[corr]^.5}+1

* See Rotation Correction Data Sheet
* See aoq Adjustment Data Sheet

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10

CRACK GROWTH CALCULATIONS

Origional Comp(11) = 2.9876E-06
Initial Crack Comp(11) = 0.5080 ins **

Crack Length (meas) = 0.5040 ins
E' = 27.5 msi

Unload Number	Load ; start of unloading (lbs)	V ; start of unloading (in)	V/P(11)	BEV/P(11)	*EBV/P(11) Corrected for Rotation	Correlation (r^2)	Crack Length (in)	Crack Growth (in)
21	3524.6	.0164	3.156E-06	40.68	39.24	0.999420	0.5118	0.0038
22	3584.9	.0175	3.150E-06	40.61	39.17	0.999226	0.5115	0.0034
23	3629.0	.0188	3.154E-06	40.66	39.22	0.998664	0.5117	0.0037
24	3660.1	.0201	3.198E-06	41.22	39.77	0.999318	0.5145	0.0064
25	3678.3	.0215	3.241E-06	41.78	40.31	0.999211	0.5171	0.0091
26	3627.0	.0232	3.334E-06	42.98	41.48	0.999120	0.5227	0.0146
27	3499.8	.0252	3.464E-06	44.65	43.11	0.999050	0.5301	0.0221
28	3323.0	.0275	3.641E-06	46.93	45.33	0.998812	0.5397	0.0317
29	3286.1	.0283	3.720E-06	47.95	46.32	0.998726	0.5438	0.0358
30	2381.2	.0331	4.868E-06	62.75	60.74	0.998342	0.5928	0.0848

Effective Modulus = 1/CoBe{(W+Ao)/(W-Ao)}^2{2.1630+12.219(Ao/W)-20.065(Ao/W)^2-0.9925(Ao/W)^3+20.609(Ao/W)^4-9.9314(Ao/W)^5}
A/W (load line) = 1.000196-4.06319(Ux)+11.242(Ux)^2-106.043(Ux)^3+464.335(Ux)^4-650.677(Ux)^5
where Ux = 1/{Beff*E'*C[corr]^.5}+1

* See Rotation Correction Data Sheet
* See aoq Adjustment Data Sheet

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TESTLOG : 648041
WMTR-FRA-028

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10

J-CALCULATION (ASTM E1820-99)

Net Specimen Thickness (b) = .375 ins
Initial Uncracked Ligament (bo) = .496 ins

Effective Yield Strength = 89450.0 ksi

Unload Number	V ; start of unloading (in)	Load ; start of unloading (lbs)	Area Plastic (in-lbs)	J Plastic (in-lbs/sq.rt.)	J Elastic (in-lbs/sq.rt.)	* J Deformation (in-lbs/sq.rt.)	J Modified (in-lbs/sq.rt.)	Qualified/ Disqualified ((15*J)/Eff.Yield)
1	.0023	845.6	-.15	-1.0	12.9	12.0	11.9	Qualified
2	.0028	997.9	.03	1.2	16.9	18.1	18.1	Qualified
3	.0033	1152.0	.05	1.6	22.8	24.3	24.3	Qualified
4	.0038	1305.0	.32	4.9	28.1	33.0	32.9	Qualified
5	.0043	1460.7	.20	3.4	36.6	40.0	40.0	Qualified
6	.0049	1615.8	.48	6.8	44.4	51.3	51.2	Qualified
7	.0055	1768.5	.72	9.8	52.5	62.4	62.2	Qualified
8	.0060	1922.2	.75	10.1	63.2	73.2	73.2	Qualified
9	.0067	2073.8	1.06	13.8	74.7	88.5	88.5	Qualified
10	.0073	2222.0	1.27	16.3	86.0	102.3	102.4	Qualified
11	.0079	2370.9	1.91	24.3	96.2	120.6	120.4	Qualified
12	.0087	2516.3	1.69	20.9	116.3	137.3	137.8	Qualified
13	.0093	2657.2	3.28	42.0	121.5	163.5	162.8	Qualified
14	.0100	2793.0	4.21	53.5	133.4	186.9	186.0	Qualified
15	.0107	2923.3	5.27	66.5	145.6	212.1	211.1	Qualified
16	.0116	3044.6	6.46	80.4	160.6	241.0	240.6	Qualified
17	.0125	3159.7	8.21	102.1	171.9	274.0	273.4	Qualified
18	.0133	3265.1	9.53	117.4	186.7	304.1	304.3	Qualified
19	.0143	3360.9	11.98	147.8	196.5	344.3	344.1	Qualified
20	.0153	3447.8	14.21	174.5	208.4	383.0	383.4	Qualified

J Plas(i) = [2+0.522 x ((b(i)/Width)] x (Area plas(i))/Bnet x b(i)) x [1-(1+0.76 x b(i)/W) X (a(i)-a(i-1))/b(i)]
J Elas(i) = (K(i)^2 * (1-Poisson^2)))/Modulus
where K = P(i) * F(a(i)/W) / Sqr(Bgross * Bnet * Width)
J Def(i) = J Elastic(i) + J Plastic(i)
J Mod(i) = J Elastic(i) + J Plastic(i) + Delta J(i)
where = Delta J(i) = Delta J(i+1) + [Rho(i)/Bo(i)] x [a(i)-a(i-1)] x J Plastic(i)
(Qual/Disqual) = (15 * J Def)/Eff. Yield must be < bo

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT10

J-CALCULATION (ASTM E1820-99)

Net Specimen Thickness (b) = .375 ins
Initial Uncracked Ligament (bo) = .496 ins

Effective Yield Strength = 89450.0 ksi

Unload Number	V ; start of unloading (in)	Load ; start of unloading (lbs)	Area Plastic (in-lbs)	J Plastic (in-lbs/sq.rt.)	J Elastic (in-lbs/sq.rt.)	* J Deformation (in-lbs/sq.rt.)	J Modified (in-lbs/sq.rt.)	Qualified/ Disqualified ((15*J)/Eff.Yield)
21	.0164	3524.6	16.74	203.9	221.9	425.8	427.9	Qualified
22	.0175	3584.9	20.44	250.7	227.4	478.0	479.1	Qualified
23	.0188	3629.0	24.45	300.0	233.0	533.0	534.0	Qualified
24	.0201	3660.1	28.42	346.5	240.8	587.3	590.7	Qualified
25	.0215	3678.3	32.89	398.4	247.8	646.1	652.9	Qualified
26	.0232	3627.0	38.70	464.7	247.9	712.6	725.3	Qualified
27	.0252	3499.8	45.53	537.2	243.7	780.9	806.3	Qualified
28	.0275	3323.0	53.40	622.0	232.3	854.3	894.8	Qualified
29	.0283	3286.1	55.65	643.0	233.8	876.8	925.3	Qualified
30	.0331	2381.2	71.08	721.6	175.1	896.7	1050.0	Qualified

J Plas(i) = [2+0.522 x ((b(i)/Width)] x (Area plas(i))/Bnet x b(i)) x [1-(1+0.76 x b(i)/W) X (a(i)-a(i-1))/b(i)]
J Elas(i) = (K(i)^2 * (1-Poisson^2)))/Modulus
where K = P(i) * F(a(i)/W) / Sqr(Bgross * Bnet * Width)
J Def(i) = J Elastic(i) + J Plastic(i)
J Mod(i) = J Elastic(i) + J Plastic(i) + Delta J(i)
where = Delta J(i) = Delta J(i+1) + [Rho(i)/Bo(i)] x [a(i)-a(i-1)] x J Plastic(i)
(Qual/Disqual) = (15 * J Def)/Eff. Yield must be < bo

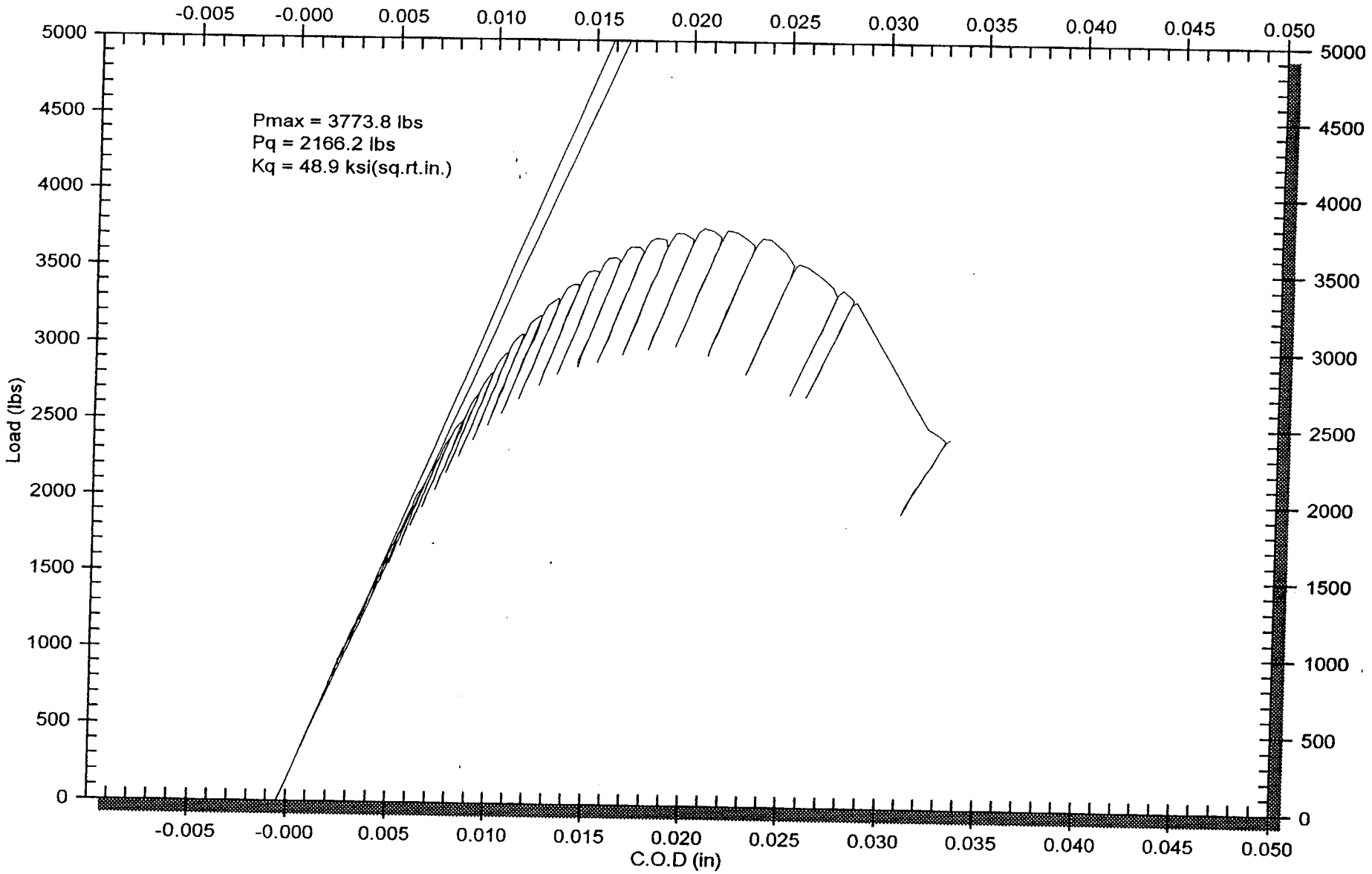
WESTMORELAND MECHANICAL TESTING & RESEARCH Inc.

Load vs Crack Opening Displacement Phone (724)537-3131 Fax (724)537-3151

CUSTOMER :BWX TECHNOLOGIES
P.O. NO :LYN12008BWS
WMT&R REPORT : 1-32474
SPECIMEN :WT10

TEST DATE :8/28/01

TEST TEMPERATURE :390 F



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testlog 648041
WMTR-FRA-028

WESTMORELAND MECHANICAL TESTING & RESEARCH Inc.

Area Determination Phone (724)537-3131 Fax (724)537-3151

CUSTOMER :BWX TECHNOLOGIES
P.O. NO :LYN12008BWS
WMT&R REPORT : 1-32474
SPECIMEN :WT10

TEST DATE :8/28/01

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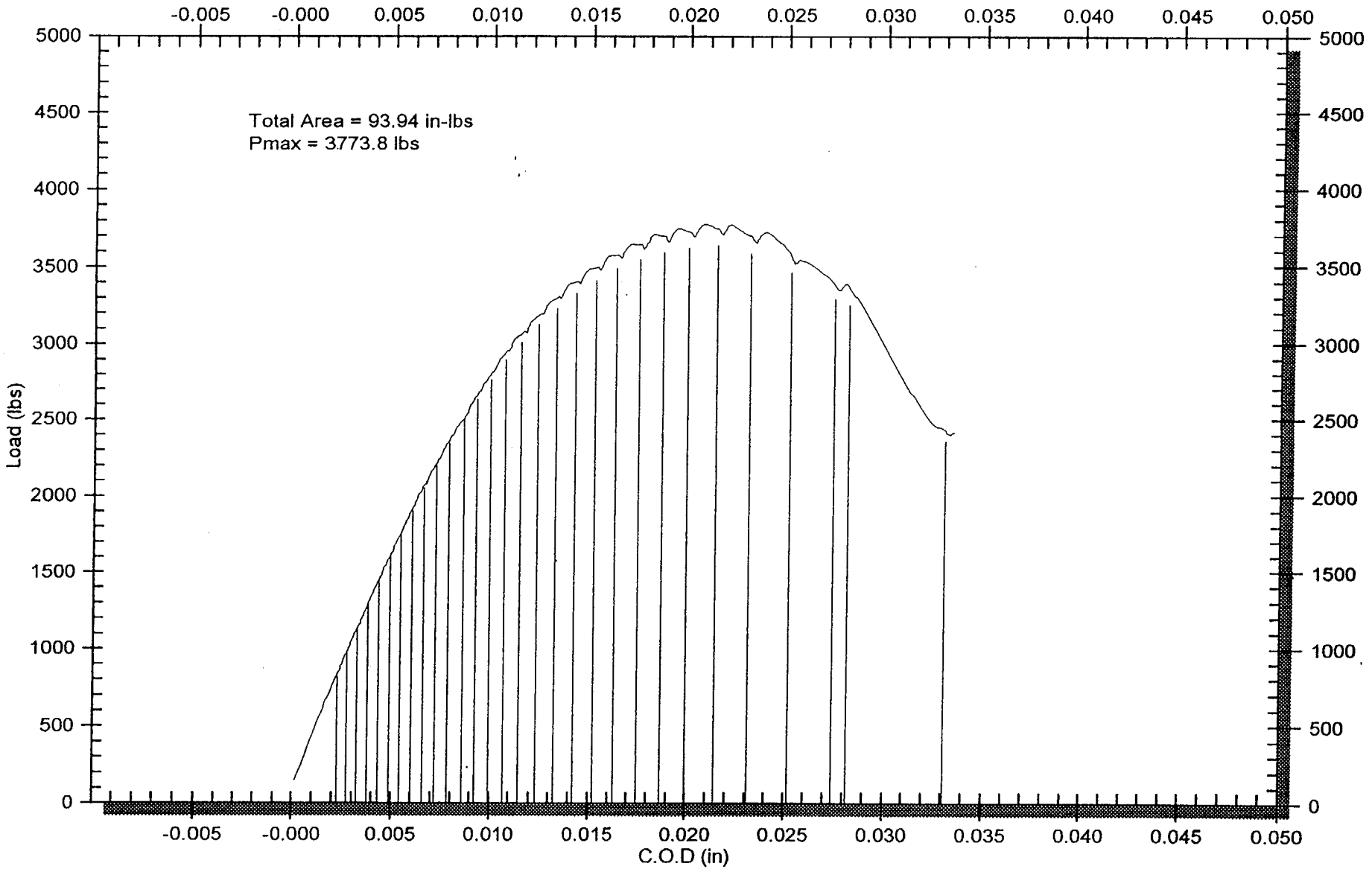

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testlog 648041
WMTR-FRA-028

Lot No.
WT11

WESTMORELAND MECHANICAL TESTING & RESEARCH

Testing Specialists for Aerospace, Automotive, and Nuclear Fields

Phone: 724-537-3131 Fax: 724-537-3151 Email: ADMIN@WMTR.COM

J-INTEGRAL TEST REPORT (ASTM E1820-99a)

PRELIMINARY INFORMATION

CUSTOMER : BWX TECHNOLOGIES
WMT&R NO. : 1-32474

SPECIMEN : WT11
P.O. NO : LYN12008BWS
TEST DATE: 8/28/01

MATERIAL SPEC. : ASTM E1820-99a
MODULUS : 27.5 msi
ULTIMATE STR. : 99.9 ksi
YIELD STR : 79.0 ksi
EFFECT. YIELD STR (EYS) : 89.4 ksi
POISSONS' RATIO : .30

SPECIMEN MEASUREMENTS

THICKNESS (TOTAL)	: 0.500 ins
THICKNESS (NET)	: 0.375 ins
THICKNESS (EFF.)	: 0.469 ins
WIDTH (W)	: 1.000 ins
UNCRACKED LIGAMENT	: 0.492 ins

TEST PARAMETERS

TEST TEMPERATURE	: 390 F
TEST TYPE	: CT
ORIENTATION	: N/A
TEST MACHINE	: H78
CLIP GAGE	: MTS 1486

MAIN RAMP RATE	: .010 in/min
PARTIAL LOADING RATE	: .010 in/min
PARTIAL UNLOADING RATE	: .010 in/min
UNLOADING INTERVAL	: .002 in
HOLD TIME	: 5.0 sec

PHYSICAL CRACK LENGTHS

PRECRACK LENGTHS

SIDE 1	(ins)	0.500
1/8 Point	(ins)	0.506
1/4 Point	(ins)	0.505
3/8 Point	(ins)	0.506
1/2 Point	(ins)	0.512
5/8 Point	(ins)	0.518
3/4 Point	(ins)	0.511
7/8 Point	(ins)	0.510
SIDE 2	(ins)	0.501
AVERAGE	(ins)	0.5085
A/W	(ins)	0.5085

FINAL CRACK LENGTHS

SIDE 1	(ins)	0.649
1/8 Point	(ins)	0.609
1/4 Point	(ins)	0.611
3/8 Point	(ins)	0.631
1/2 Point	(ins)	0.657
5/8 Point	(ins)	0.647
3/4 Point	(ins)	0.654
7/8 Point	(ins)	0.649
SIDE 2	(ins)	0.623
AVERAGE	(ins)	0.6369
A/W	(ins)	0.6369

FATIGUE PRECRACKING SUMMARY

MAX.FATIGUE LOAD = 850 lbs
KF (MAX.) = 16.86 KSI(SQRT.IN)
LOAD RATIO = .10
CYCLES = 10000

ORIGINAL CRACK

PHYSICAL MEAS. = 0.5085 ins
COMPLIANCE CAL. = 0.5139 ins
PERCENT DIFF. = 1.06 %

FINAL CRACK (HEAT TINT)

PHYSICAL MEAS. = 0.6369 ins
COMPLIANCE CAL. = 0.6304 ins
PERCENT DIFF. = 1.02 %

MODULUS

MODULUS = 27.50 msi
MODULUS (Em) = 26.76 msi
PERCENT DIFF. = 2.68 %

VALIDITY CHECKS PER ASTM E1820

1. (9.1.5.2)	ESTIMATED FINAL CRACK EXTENSION IS +/- 15% OF DELTA ap FOR CRACK EXTENSIONS LESS THAN .2 bo AND .03 bo THEREAFTER		VALID
	Delta ap = 0.128 ins	Est. Final Crack Ext. = 0.117 ins	
2. (A9.8.2.1)	aoq SHALL NOT DIFFER FROM ao BY MORE THEN 0.01 W		
	aoq = .5139	ao = 0.5085	VALID
3. (A9.8.2.2)	NO. OF REGRESSION POINTS > or = 8 AND FIT > .96		
	POINTS = 30	FIT = .98534	VALID
4. (A9.8.1)	POWER COEFFICIENT C2 < 1.0		
	C2 = .1296		VALID
5. (A9.9.1)	THICKNESS (Bnet) > 25 JQ/EYS		
	Bnet = .375 ins	25 JQ/EYS = .188	VALID
6. (A9.9.2)	INITIAL LIGAMENT, bo > 25 JQ/EYS		
	bo = .492 ins	25 JQ/EYS = .188	VALID
7. (A9.9.3)	THE SLOPE OF POWER LAW REGRESSION LINE AT DELTA aQ < EYS		
	Slope = 7439.0	EYS = 89450.0 psi	VALID
8. (A9.6.6.6)	SUFFICIENT NUMBER OF DATA POINTS REMAINING VALID		
	Minimum = 5	Remaining = 5	VALID
9. (A9.6.4)	DATA GROUPING		VALID

***** TEST IS VALID ; J_{IC} = 673.37 IN-LBS/IN^2 *****
K_{JIC}= 142.65 KSI(SQRT.IN)

Gerald W. Boice
TESTLOG 648042 WMTR-FRA-028

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WESTMORELAND MECHANICAL TESTING & RESEARCH

Testing Specialists for Aerospace, Automotive, and Nuclear Fields

Phone: 724-537-3131 Fax: 724-537-3151 Email: ADMIN@WMTR.COM

General Validity Checks (ASTM E1820-99a)

PRELIMINARY INFORMATION

CUSTOMER : BWX TECHNOLOGIES
WMT&R NO. : 1-32474

SPECIMEN : WT11
P.O. NO : LYN12008BWS
TEST DATE: 8/28/01

MATERIAL SPEC. : ASTM E1820-99a
MODULUS : 27.5 msi
ULTIMATE STR. : 99.9 ksi
YIELD STR : 79.0 ksi
EFFECT. YIELD STR (EYS) : 89.4 ksi
POISSONS' RATIO : .30

SPECIMEN MEASUREMENTS

THICKNESS (TOTAL)	: 0.500 ins
THICKNESS (NET)	: 0.375 ins
THICKNESS (EFF.)	: 0.469 ins
WIDTH (W)	: 1.000 ins
UNCRACKED LIGAMENT	: 0.492 ins

TEST PARAMETERS

TEST TEMPERATURE	: 390 F
TEST TYPE	: CT
ORIENTATION	: N/A
TEST MACHINE	: H78
CLIP GAGE	: MTS 1486
OPERATOR	: Gerald Boice

MAIN RAMP RATE	: .010 in/min
PARTIAL LOADING RATE	: .010 in/min
PARTIAL UNLOADING RATE	: .010 in/min
UNLOADING INTERVAL	: .002 in
HOLD TIME	: 5.0 sec

PHYSICAL CRACK LENGTHS

PRECRACK LENGTHS

SIDE 1	(ins)	0.500
1/8 Point	(ins)	0.506
1/4 Point	(ins)	0.505
3/8 Point	(ins)	0.506
1/2 Point	(ins)	0.512
5/8 Point	(ins)	0.518
3/4 Point	(ins)	0.511
7/8 Point	(ins)	0.510
SIDE 2	(ins)	0.501
AVERAGE	(ins)	0.5085
A/W	(ins)	0.5085

FINAL CRACK LENGTHS

SIDE 1	(ins)	0.649
1/8 Point	(ins)	0.609
1/4 Point	(ins)	0.611
3/8 Point	(ins)	0.631
1/2 Point	(ins)	0.657
5/8 Point	(ins)	0.647
3/4 Point	(ins)	0.654
7/8 Point	(ins)	0.649
SIDE 2	(ins)	0.623
AVERAGE	(ins)	0.6369
A/W	(ins)	0.6369

FATIGUE PRECRACKING SUMMARY

MAX.FATIGUE LOAD = 850 lbs
KF (MAX.) = 16.86 KSI(SQRT.IN)

LOAD RATIO = .10
CYCLES = 10000

TEST CURVE RESULTS

MAXIMUM LOAD (PMAX) = 3693.0 lbs

GENERAL VALIDITY CHECKS PER ASTM E1820

1. (7.4.5) PRECRACK EXTENSION MUST BE > OR = 5% OF a AND > OR = 0.05 INCHES
   Precrack Extension = .058 ins 5% of a = 0.025 ins — VALID
2. (7.4.5) FOR THE LESSER OF THE FINAL 50% PRECRACK EXTENSION OR 0.05 INCHES
   MAXIMUM PRECRACK LOAD < Pf
   Final Precrack Load = 850.0 lbs Pf = 4249.8 lbs — VALID
   MAXIMUM PRECRACK LOAD SUCH THAT THE LESSER OF THE FOLLOWING IS NOT EXCEEDED
   KMAX/E < OR = 0.001 SQ.RT.IN.
   Max. Precracking Stress / Modulus = 0.001 ins ^2 — VALID
   MAXIMUM PRECRACK LOAD < 70% X MAXIMUM TOUGHNESS TEST LOAD
   Final Precrack Load = 850 lbs 70% X Maximum Toughness Test Load = 2585.1 lbs — VALID
3. (9.1.4.1) NONE OF 9 ORIGINAL PHYSICAL CRACK MEASUREMENTS DIFFER BY MORE 5% OF AVERAGE
   Max. Difference = .009 ins .05 X AVERAGE = .025 ins — VALID
4. (9.1.4.2) NONE OF 9 FINAL PHYSICAL CRACK MEASUREMENTS DIFFER BY MORE 5% OF AVERAGE
   Max. Difference = .027 ins .05 X Average = .032 ins — VALID
5. (9.1.5.1) NONE OF THE NINE PHYSICAL MEASUREMENTS OF CRACK EXTENSION SHALL BE < 50% OF THE AVERAGE CRACK EXTENSTION.
   Min. Crack Extension = 0.104 ins 50% Average Crack Extension = .064 ins — VALID

*** All GENERAL VALIDITY CHECKS ARE VALID

Gerald W. Boice
TESTLOG 648042 WMTR-FRA-028

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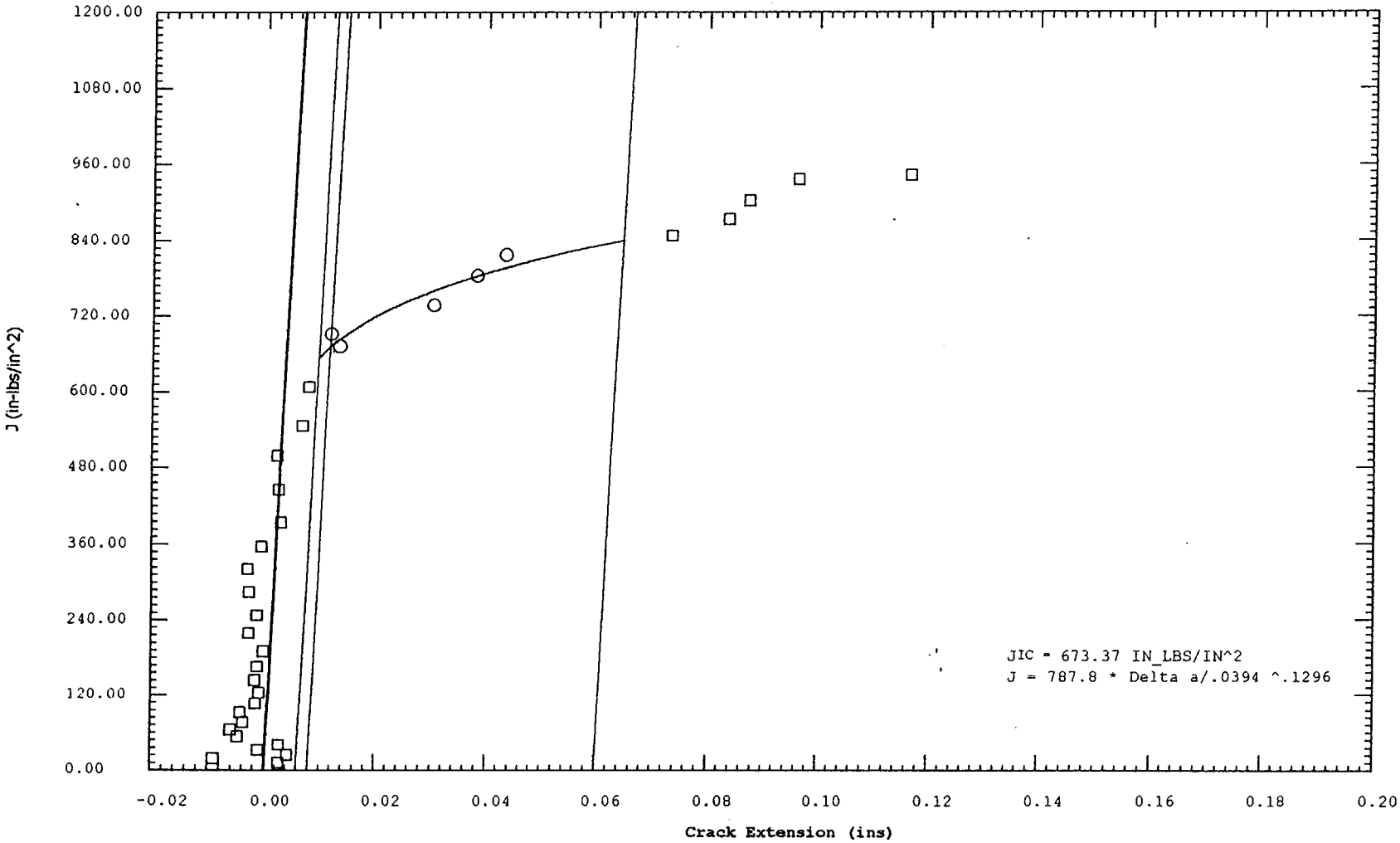
WESTMORELAND MECHANICAL TESTING & RESEARCH, Inc.

JIC TESTING - JD vs a (ASTM E1820) Phone 724-537-3131

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11



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TESTLOG : 648042
WMTR-FRA-028

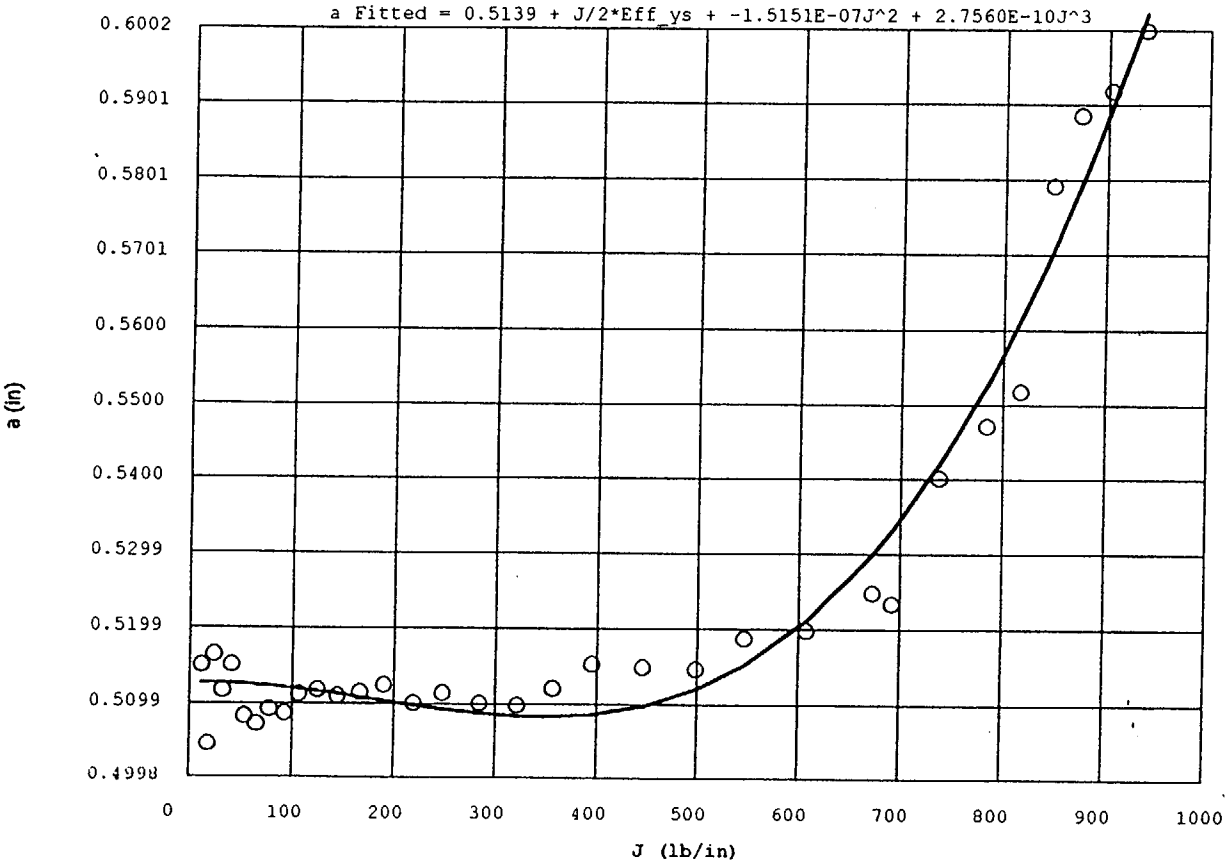
CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11

aoq ADJUSTMENT

Pm = 1292.2 lbs
Regression Datapoints = 30

Correlation coefficient = .9853



J (LB/IN)	a (in)	Fitted a (in)
12.02	0.5165	0.51390
18.45	0.5049	0.51391
23.99	0.5181	0.51391
31.99	0.5128	0.51389
40.46	0.5166	0.51386
53.54	0.5091	0.51377
64.77	0.5079	0.51366
76.49	0.5101	0.51352
91.93	0.5096	0.51331
106.40	0.5123	0.51307
124.00	0.5129	0.51275
144.03	0.5121	0.51234
165.92	0.5126	0.51187
189.78	0.5136	0.51135
218.76	0.5110	0.51072
247.92	0.5125	0.51013
284.31	0.5110	0.50954
320.86	0.5107	0.50916
356.35	0.5133	0.50908
394.56	0.5168	0.50941
445.78	0.5163	0.51066
498.50	0.5161	0.51314
545.73	0.5206	0.51658
607.65	0.5217	0.52315
672.40	0.5272	0.53290
691.54	0.5257	0.53641
737.57	0.5441	0.54614
784.30	0.5519	0.55801
817.49	0.5571	0.56774

Adjusted a : 0.5139 in

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TESTLOG : 648042
JIC_VB1

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11

ROTATION CORRECTION

Half Span of Load Points (H*) = .28 ins
Gage Measurement Points/2 (D) = .08 ins

Unload Number	Load Line Displacement (ins)	Radius of Rotation (W+a)/2	Angle of Rotation	Compliance (Load Line)	Compliance (Corrected)
1	.0023	.7617	-.1007	3.2308E-06	3.1171E-06
2	.0028	.7560	-.1015	3.0480E-06	2.9391E-06
3	.0033	.7625	-.1006	3.2570E-06	3.1426E-06
4	.0038	.7600	-.1010	3.1719E-06	3.0597E-06
5	.0044	.7618	-.1007	3.2325E-06	3.1187E-06
6	.0050	.7581	-.1012	3.1125E-06	3.0019E-06
7	.0055	.7575	-.1013	3.0938E-06	2.9837E-06
8	.0061	.7586	-.1012	3.1284E-06	3.0174E-06
9	.0067	.7583	-.1012	3.1199E-06	3.0091E-06
10	.0074	.7597	-.1010	3.1633E-06	3.0513E-06
11	.0080	.7600	-.1010	3.1735E-06	3.0612E-06
12	.0087	.7596	-.1010	3.1599E-06	3.0481E-06
13	.0094	.7598	-.1010	3.1680E-06	3.0559E-06
14	.0101	.7603	-.1009	3.1845E-06	3.0720E-06
15	.0109	.7590	-.1011	3.1426E-06	3.0312E-06
16	.0118	.7598	-.1010	3.1667E-06	3.0547E-06
17	.0127	.7591	-.1011	3.1432E-06	3.0318E-06
18	.0136	.7589	-.1011	3.1386E-06	3.0273E-06
19	.0146	.7602	-.1010	3.1785E-06	3.0661E-06
20	.0156	.7619	-.1007	3.2356E-06	3.1217E-06

Corrected Compliance (Cc) = C (Load Line)/[(H/R * sin(angle)-cos(angle)] * [(D/R) * sin(angle)-cos(angle)]
where angle = Arcsin{[(clipgage/2)+D]/[(D^2+R^2)^.5]}-Arctan(D/R)

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11

ROTATION CORRECTION

Half Span of Load Points (H*) = .28 ins
Gage Measurement Points/2 (D) = .08 ins

Unload Number	Load Line Displacement (ins)	Radius of Rotation (W+a)/2	Angle of Rotation	Compliance (Load Line)	Compliance (Corrected)
21	.0168	.7617	-.1008	3.2278E-06	3.1141E-06
22	.0180	.7615	-.1008	3.2236E-06	3.1100E-06
23	.0193	.7638	-.1005	3.2987E-06	3.1831E-06
24	.0207	.7643	-.1004	3.3177E-06	3.2016E-06
25	.0224	.7670	-.1001	3.4128E-06	3.2942E-06
26	.0228	.7663	-.1002	3.3856E-06	3.2677E-06
27	.0249	.7753	-.0990	3.7256E-06	3.5989E-06
28	.0265	.7791	-.0985	3.8832E-06	3.7523E-06
29	.0277	.7817	-.0982	3.9921E-06	3.8583E-06
30	.0309	.7965	-.0964	4.7149E-06	4.5626E-06
31	.0325	.8015	-.0958	5.0008E-06	4.8412E-06
32	.0336	.8033	-.0956	5.1077E-06	4.9454E-06
33	.0354	.8077	-.0950	5.3876E-06	5.2183E-06
34	.0377	.8177	-.0939	6.0944E-06	5.9073E-06

Corrected Compliance (Cc) = C (Load Line)/[(H/R * sin(angle)-cos(angle)] * [(D/R) * sin(angle)-cos(angle)]
where angle = Arcsin{[(clipgage/2)+D]/[(D^2+R^2)^.5]}-Arctan(D/R)

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11

CRACK GROWTH CALCULATIONS

Origional Comp(11) = 3.0768E-06
Initial Crack Comp(11) = 0.5139 ins **

Crack Length (meas) = 0.5085 ins
E' = 27.5 msi

Unload Number	Load ; start of unloading (lbs)	V ; start of unloading (in)	V/P(11)	BEV/P(11)	*EBV/P(11) Corrected for Rotation	Correlation (r^2)	Crack Length (in)	Crack Growth (in)
1	847.3	.0023	3.231E-06	41.65	40.18	0.981766	0.5165	0.0026
2	1002.4	.0028	3.048E-06	39.29	37.89	0.989832	0.5049	-0.0090
3	1157.8	.0033	3.257E-06	41.98	40.51	0.988128	0.5181	0.0042
4	1312.6	.0038	3.172E-06	40.89	39.44	0.990217	0.5128	-0.0010
5	1470.4	.0044	3.233E-06	41.67	40.20	0.995995	0.5166	0.0027
6	1627.2	.0050	3.112E-06	40.12	38.70	0.994955	0.5091	-0.0048
7	1780.5	.0055	3.094E-06	39.88	38.46	0.992885	0.5079	-0.0060
8	1939.1	.0061	3.128E-06	40.33	38.90	0.994806	0.5101	-0.0038
9	2093.1	.0067	3.120E-06	40.22	38.79	0.996703	0.5096	-0.0043
10	2245.1	.0074	3.163E-06	40.78	39.33	0.998443	0.5123	-0.0016
11	2394.3	.0080	3.173E-06	40.91	39.46	0.997747	0.5129	-0.0009
12	2539.0	.0087	3.160E-06	40.73	39.29	0.998018	0.5121	-0.0018
13	2679.3	.0094	3.168E-06	40.84	39.39	0.998753	0.5126	-0.0013
14	2813.3	.0101	3.185E-06	41.05	39.60	0.998375	0.5136	-0.0002
15	2940.8	.0109	3.143E-06	40.51	39.07	0.998778	0.5110	-0.0029
16	3059.0	.0118	3.167E-06	40.82	39.38	0.998712	0.5125	-0.0013
17	3168.6	.0127	3.143E-06	40.52	39.08	0.998806	0.5110	-0.0028
18	3266.2	.0136	3.139E-06	40.46	39.02	0.998770	0.5107	-0.0031
19	3353.7	.0146	3.178E-06	40.97	39.52	0.998514	0.5133	-0.0006
20	3432.6	.0156	3.236E-06	41.71	40.24	0.998908	0.5168	0.0029

Effective Modulus = 1/CoBe{(W+Ao)/(W-Ao)}^2{2.1630+12.219(Ao/W)-20.065(Ao/W)^2-0.9925(Ao/W)^3+20.609(Ao/W)^4-9.9314(Ao/W)^5}
A/W (load line) = 1.000196-4.06319(Ux)+11.242(Ux)^2-106.043(Ux)^3+464.335(Ux)^4-650.677(Ux)^5
where Ux = 1/{Beff*E'*C[corr]^.5}+1

* See Rotation Correction Data Sheet
* See aoq Adjustment Data Sheet

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11

CRACK GROWTH CALCULATIONS

Origional Comp(11) = 3.0768E-06
Initial Crack Comp(11) = 0.5139 ins **

Crack Length (meas) = 0.5085 ins
E' = 27.5 msi

Unload Number	Load ; start of unloading (lbs)	V ; start of unloading (in)	V/P(11)	BEV/P(11)	*EBV/P(11) Corrected for Rotation	Correlation (r^2)	Crack Length (in)	Crack Growth (in)
21	3493.6	.0168	3.228E-06	41.61	40.14	0.998891	0.5163	0.0025
22	3542.9	.0180	3.224E-06	41.55	40.09	0.999105	0.5161	0.0022
23	3574.6	.0193	3.299E-06	42.52	41.03	0.998435	0.5206	0.0067
24	3591.1	.0207	3.318E-06	42.77	41.27	0.998338	0.5217	0.0079
25	3522.2	.0224	3.413E-06	43.99	42.46	0.998655	0.5272	0.0134
26	3526.3	.0228	3.386E-06	43.64	42.12	0.998446	0.5257	0.0118
27	3240.3	.0249	3.726E-06	48.03	46.39	0.998657	0.5441	0.0303
28	3085.6	.0265	3.883E-06	50.06	48.37	0.998734	0.5519	0.0381
29	3046.3	.0277	3.992E-06	51.46	49.74	0.998912	0.5571	0.0432
30	2557.0	.0309	4.715E-06	60.78	58.81	0.997943	0.5872	0.0734
31	2454.2	.0325	5.001E-06	64.46	62.41	0.998829	0.5975	0.0836
32	2446.7	.0336	5.108E-06	65.84	63.75	0.998578	0.6011	0.0873
33	2289.5	.0354	5.388E-06	69.45	67.27	0.998868	0.6102	0.0963
34	2023.8	.0377	6.094E-06	78.56	76.15	0.997416	0.6304	0.1166

Effective Modulus = $1/CoBe\{(W+Ao)/(W-Ao)\}^2\{2.1630+12.219(Ao/W)-20.065(Ao/W)^2-0.9925(Ao/W)^3+20.609(Ao/W)^4-9.9314(Ao/W)^5\}$

A/W (load line) = $1.000196-4.06319(Ux)+11.242(Ux)^2-106.043(Ux)^3+464.335(Ux)^4-650.677(Ux)^5$

where $Ux = 1/(Beff*E'*C[corr]^.5)+1$

* See Rotation Correction Data Sheet
* See aoq Adjustment Data Sheet

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11

J-CALCULATION (ASTM E1820-99)

Net Specimen Thickness (b) = .375 ins
Initial Uncracked Ligament (bo) = .492 ins

Effective Yield Strength = 89450.0 ksi

Unload Number	V ; start of unloading (in)	Load ; start of unloading (lbs)	Area Plastic (in-lbs)	J Plastic (in-lbs/sq.rt.)	J Elastic (in-lbs/sq.rt.)	* J Deformation (in-lbs/sq.rt.)	J Modified (in-lbs/sq.rt.)	Qualified/ Disqualified ((15*J)/Eff.Yield)
1	.0023	847.3	-.16	-1.1	13.1	12.0	12.0	Qualified
2	.0028	1002.4	.03	1.4	17.1	18.4	18.4	Qualified
3	.0033	1157.8	-.14	-.7	24.7	24.0	23.9	Qualified
4	.0038	1312.6	.01	1.3	30.7	32.0	31.9	Qualified
5	.0044	1470.4	-.01	1.0	39.5	40.5	40.4	Qualified
6	.0050	1627.2	.50	7.4	46.1	53.5	53.3	Qualified
7	.0055	1780.5	.70	10.0	54.8	64.8	64.5	Qualified
8	.0061	1939.1	.76	10.6	65.9	76.5	76.3	Qualified
9	.0067	2093.1	1.15	15.4	76.6	91.9	91.7	Qualified
10	.0074	2245.1	1.27	16.8	89.6	106.4	106.3	Qualified
11	.0080	2394.3	1.67	21.7	102.3	124.0	123.9	Qualified
12	.0087	2539.0	2.31	29.6	114.5	144.0	143.9	Qualified
13	.0094	2679.3	3.00	38.0	127.9	165.9	165.8	Qualified
14	.0101	2813.3	3.81	47.9	141.9	189.8	189.8	Qualified
15	.0109	2940.8	5.26	66.3	152.5	218.8	218.3	Qualified
16	.0118	3059.0	6.51	81.3	166.6	247.9	247.8	Qualified
17	.0127	3168.6	8.57	107.2	177.1	284.3	283.8	Qualified
18	.0136	3266.2	10.66	133.1	187.8	320.9	320.2	Qualified
19	.0146	3353.7	12.55	155.2	201.2	356.3	356.8	Qualified
20	.0156	3432.6	14.63	179.0	215.5	394.6	396.8	Qualified

J Plas(i) = [2+0.522 x ((b(i)/Width)] x (Area plas(i))/Bnet x b(i)) x [1-(1+0.76 x b(i)/W) X (a(i)-a(i-1))/b(i)]
J Elas(i) = (K(i)^2 * (1-Poisson^2)))/Modulus
where K = P(i) * F(a(i)/W) / Sqr(Bgross * Bnet * Width)
J Def(i) = J Elastic(i) + J Plastic(i)
J Mod(i) = J Elastic(i) + J Plastic(i) + Delta J(i)
where = Delta J(i) = Delta J(i+1) + [Rho(i)/Bo(i)] x [a(i)-a(i-1)] x J Plastic(i)
(Qual/Disqual) = (15 * J Def)/Eff. Yield must be < bo

CUSTOMER :BWX TECHNOLOGIES
TEST DATE :8/28/01
P.O. NO :LYN12008BWS

WMT&R REPORT : 1-32474
TEST TEMPERATURE :390 F
SPECIMEN :WT11

J-CALCULATION (ASTM E1820-99)

Net Specimen Thickness (b) = .375 ins
Initial Uncracked Ligament (bo) = .492 ins

Effective Yield Strength = 89450.0 ksi

Unload Number	V ; start of unloading (in)	Load ; start of unloading (lbs)	Area Plastic (in-lbs)	J Plastic (in-lbs/sq.rt.)	J Elastic (in-lbs/sq.rt.)	* J Deformation (in-lbs/sq.rt.)	J Modified (in-lbs/sq.rt.)	Qualified/ Disqualified ((15*J)/Eff.Yield)
21	.0168	3493.6	18.16	223.2	222.6	445.8	447.7	Qualified
22	.0180	3542.9	21.91	270.0	228.5	498.5	500.2	Qualified
23	.0193	3574.6	25.15	306.2	239.5	545.7	551.4	Qualified
24	.0207	3591.1	29.88	364.2	243.5	607.6	614.5	Qualified
25	.0224	3522.2	35.64	429.6	242.8	672.4	686.0	Qualified
26	.0228	3526.3	37.14	450.7	240.9	691.5	703.1	Qualified
27	.0249	3240.3	43.90	507.7	229.9	737.6	776.0	Qualified
28	.0265	3085.6	49.25	564.4	219.9	784.3	835.8	Qualified
29	.0277	3046.3	52.28	595.3	222.2	817.5	878.1	Qualified
30	.0309	2557.0	61.43	652.9	195.0	847.9	967.9	Qualified
31	.0325	2454.2	64.89	679.5	194.4	873.9	1016.1	Qualified
32	.0336	2446.7	67.18	704.6	198.7	903.4	1053.9	Qualified
33	.0354	2289.5	71.77	749.6	187.0	936.7	1109.4	Qualified
34	.0377	2023.8	76.77	769.4	172.9	942.3	1166.9	Qualified

J Plas(i) = [2+0.522 x ((b(i)/Width)] x (Area plas(i))/Bnet x b(i)) x [1-(1+0.76 x b(i)/W) X (a(i)-a(i-1))/b(i)]
J Elas(i) = (K(i)^2 * (1-Poisson^2)))/Modulus
where K = P(i) * F(a(i)/W) / Sqr(Bgross * Bnet * Width)
J Def(i) = J Elastic(i) + J Plastic(i)
J Mod(i) = J Elastic(i) + J Plastic(i) + Delta J(i)
where = Delta J(i) = Delta J(i+1) + [Rho(i)/Bo(i)] x [a(i)-a(i-1)] x J Plastic(i)
(Qual/Disqual) = (15 * J Def)/Eff. Yield must be < bo

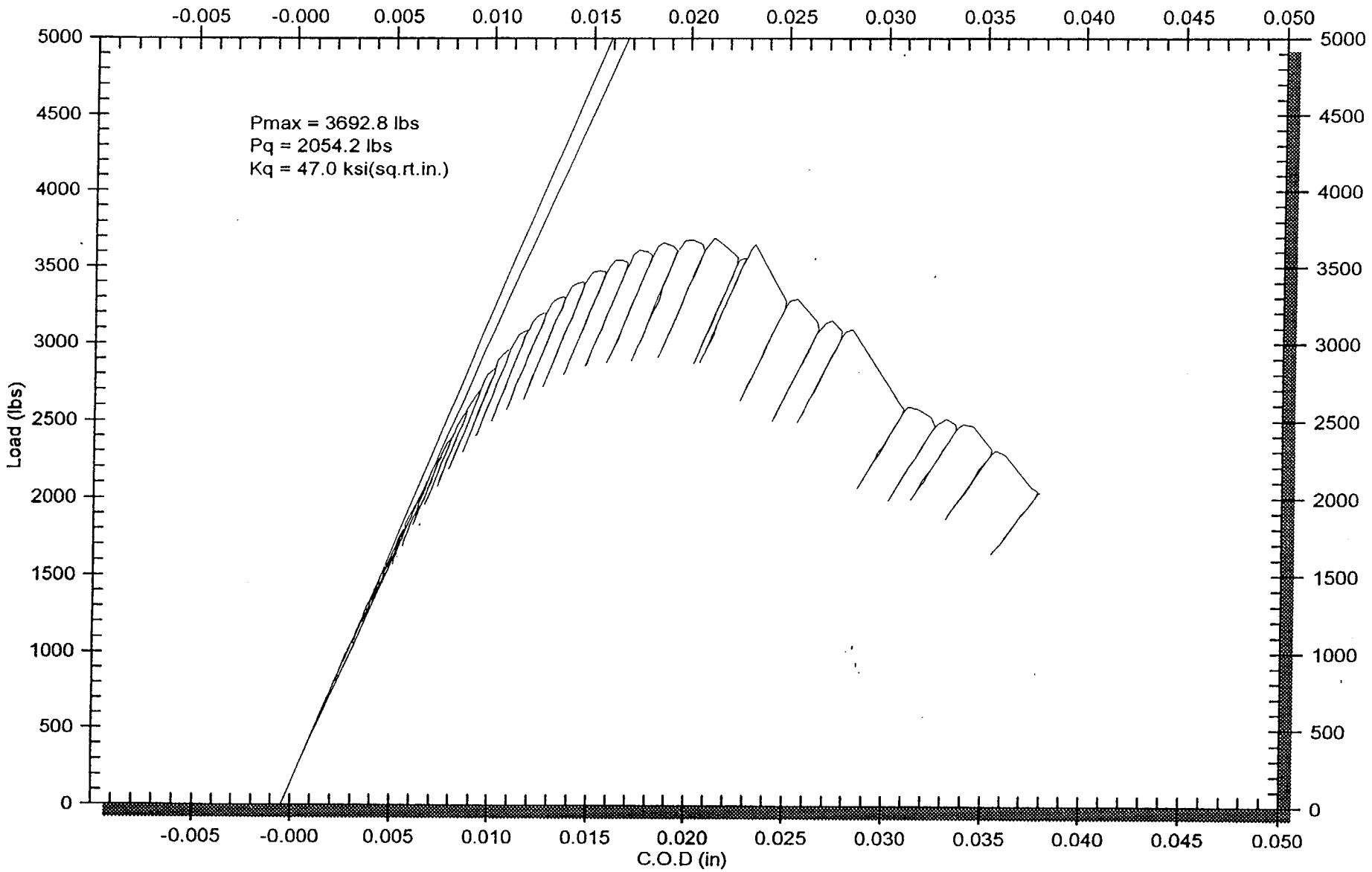
WESTMORELAND MECHANICAL TESTING & RESEARCH Inc.

Load vs Crack Opening Displacement Phone (724)537-3131 Fax (724)537-3151

CUSTOMER :BWX TECHNOLOGIES
P.O. NO :LYN12008BWS
WMT&R REPORT : 1-32474
SPECIMEN :WT11

TEST DATE :8/28/01

TEST TEMPERATURE :390 F



Knowingly or willfully falsifying or concealing a material fact on this form or making false, fictitious or fraudulent statements or representations herein could constitute a felony punishable under federal statutes.

testlog 648042
WMTR-FRA-028

WESTMORELAND MECHANICAL TESTING & RESEARCH Inc.

Area Determination Phone (724)537-3131 Fax (724)537-3151

CUSTOMER :BWX TECHNOLOGIES
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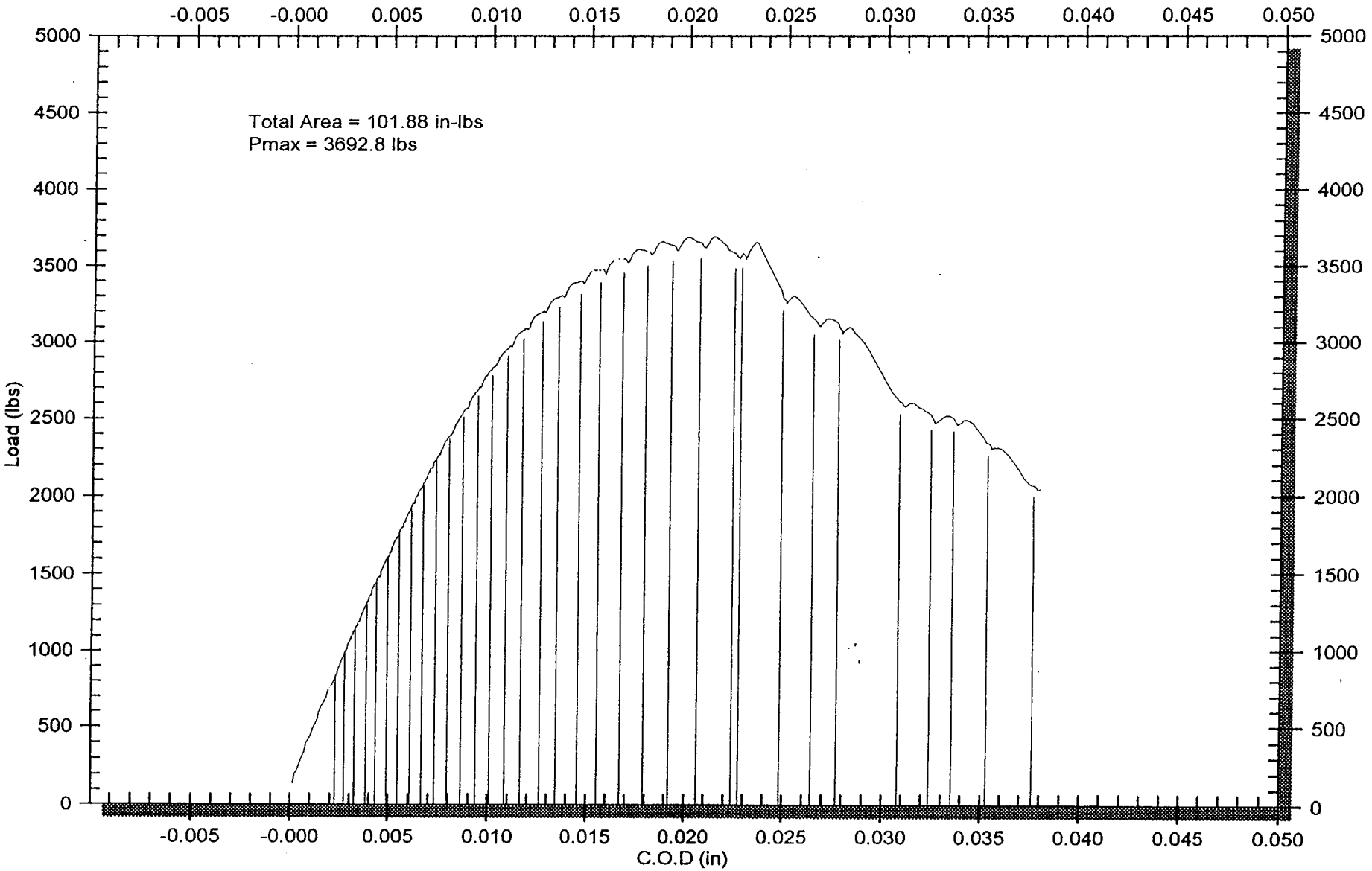

Knowingly or willfully falsifying or concealing a material fact on this form or making false, fictitious or fraudulent statements or representations herein could constitute a felony punishable under federal statutes.

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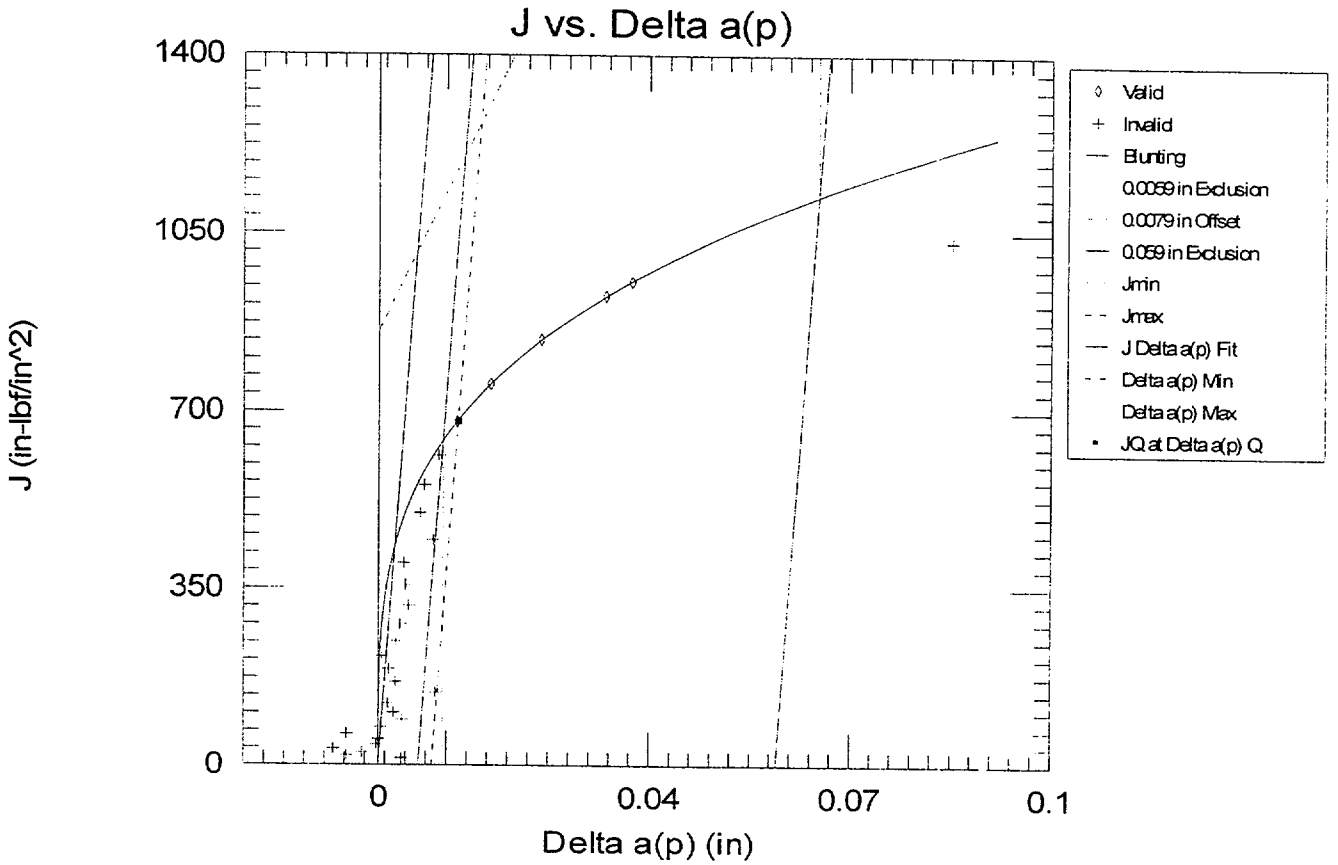
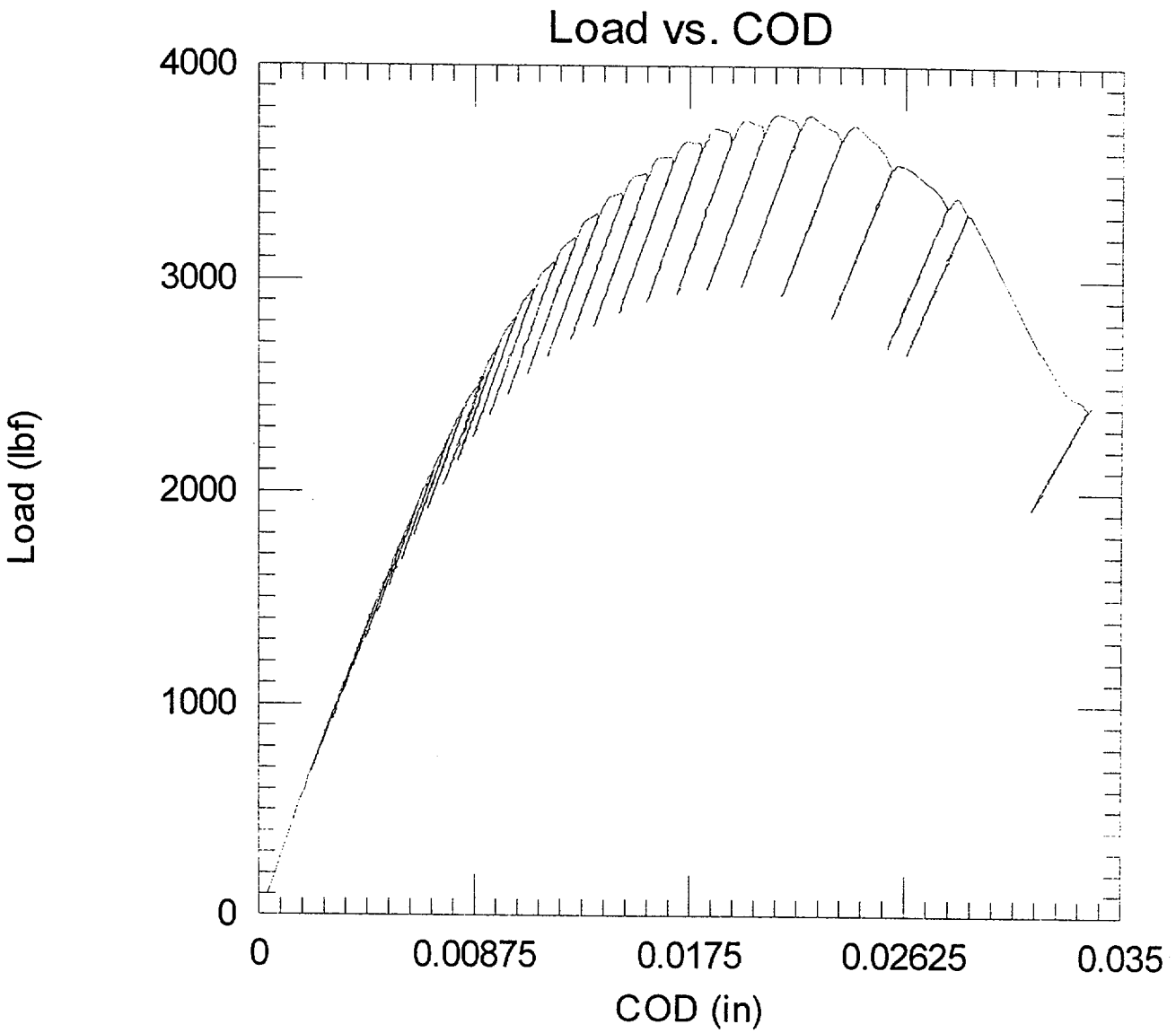
Appendix B

ASTM E813 Analysis for WT-9, WT-10, and WT-11

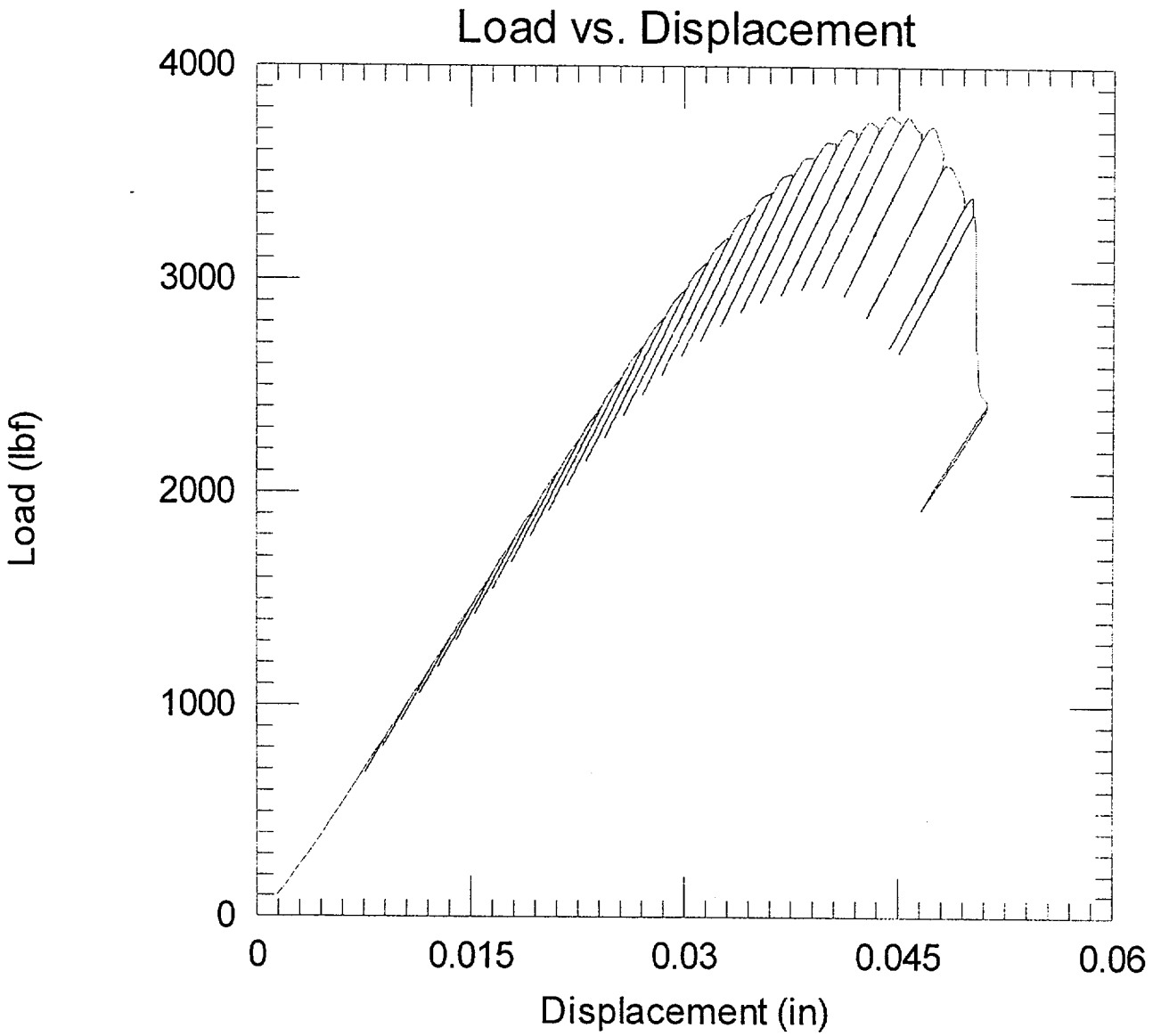
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10



Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10



Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10



Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10

Step	Step Validity	J (in-lbf/in^2)	Delta a(p) (in)	Load (lbf)	COD (in)
1	Invalid	13.2323	0.00338326	851.122	0.00265316
2	Invalid	18.9433	-0.00473848	1006.20	0.00318041
3	Invalid	24.6899	-0.00241842	1160.93	0.00363529
4	Invalid	32.8349	-0.00666873	1317.38	0.00420390
5	Invalid	41.5128	-0.000343238	1469.35	0.00472598
6	Invalid	52.7065	-5.60093e-005	1629.60	0.00533591
7	Invalid	63.0468	-0.00473525	1783.98	0.00585799
8	Invalid	75.8941	0.000356887	1935.96	0.00643693
9	Invalid	90.8857	0.00347559	2092.07	0.00705724
10	Invalid	104.988	0.00222233	2243.35	0.00761032
11	Invalid	123.637	0.00140510	2389.81	0.00828748
12	Invalid	145.420	0.00839873	2536.27	0.00901630
13	Invalid	166.281	0.00252638	2678.60	0.00968831
14	Invalid	190.903	0.00155506	2815.39	0.0104326
15	Invalid	216.230	0.000519049	2947.04	0.0111615
16	Invalid	246.724	0.00256325	3068.69	0.0119989
17	Invalid	279.180	0.00318141	3185.16	0.0128518
18	Invalid	315.766	0.00446268	3292.69	0.0137770
19	Invalid	356.307	0.00397732	3388.48	0.0147592
20	Invalid	399.113	0.00374600	3475.68	0.0157672
21	Invalid	444.794	0.00807609	3553.22	0.0168475
22	Invalid	498.293	0.00613334	3613.87	0.0180209
23	Invalid	553.133	0.00670697	3658.32	0.0192304
24	Invalid	613.087	0.00885108	3689.34	0.0205589
25	Valid	679.329	0.0115698	3706.56	0.0220217
26	Valid	753.331	0.0164956	3655.55	0.0236965
27	Valid	840.813	0.0239809	3528.06	0.0257590
28	Valid	926.831	0.0335202	3347.47	0.0279765
29	Valid	954.175	0.0374633	3312.33	0.0287467
30	Invalid	1034.81	0.0852828	2410.13	0.0338021
32	-----	-----	-----	-----	-----

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10

Displacement (in)	Load Line Displacement (in)	Normalized Load Line Compliance	Energy for J Calculation (in-lbf)	Delta a(p) Validity	Min/Max J Exclusion Validity
0.00911201	0.00265316	39.9310	1.13074	Valid	Invalid
0.0105076	0.00318041	38.3282	1.62607	Valid	Invalid
0.0120927	0.00363529	38.7719	2.11891	Valid	Invalid
0.0135572	0.00420390	37.9570	2.82148	Valid	Invalid
0.0151079	0.00472598	39.1816	3.55215	Valid	Invalid
0.0165552	0.00533591	39.2471	4.50149	Valid	Invalid
0.0180885	0.00585799	38.3287	5.39691	Valid	Invalid
0.0195531	0.00643693	39.3210	6.47613	Valid	Invalid
0.0210865	0.00705724	39.9498	7.73264	Valid	Invalid
0.0226027	0.00761032	39.7041	8.93244	Valid	Invalid
0.0240672	0.00828748	39.5394	10.5015	Valid	Invalid
0.0255317	0.00901630	40.9681	12.2966	Valid	Valid
0.0270306	0.00968831	39.7657	14.0530	Valid	Invalid
0.0285468	0.0104326	39.5696	16.1085	Valid	Invalid
0.0300802	0.0111615	39.3618	18.2226	Valid	Invalid
0.0315448	0.0119989	39.7646	20.7611	Valid	Invalid
0.0330954	0.0128518	39.8900	23.4489	Valid	Invalid
0.0345599	0.0137770	40.1514	26.4725	Valid	Invalid
0.0360761	0.0147592	40.0607	29.7868	Valid	Invalid
0.0375233	0.0157672	40.0135	33.2843	Valid	Invalid
0.0390913	0.0168475	40.9004	37.1240	Valid	Invalid
0.0405728	0.0180209	40.5044	41.3799	Valid	Invalid
0.0421063	0.0192304	40.6146	45.8355	Valid	Invalid
0.0435709	0.0205589	41.0634	50.7791	Valid	Invalid
0.0450697	0.0220217	41.6414	56.2603	Valid	Valid
0.0465689	0.0236965	42.7151	62.5012	Valid	Valid
0.0480850	0.0257590	44.4149	70.0396	Valid	Valid
0.0495669	0.0279765	46.7087	77.7407	Valid	Valid
0.0501870	0.0287467	47.7015	80.3296	Valid	Valid
0.0512209	0.0338021	62.2770	94.4413	Valid	Invalid
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Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10

J Min/Max Validity

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Test Summary

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10

Identification	
Template	JIC Fracture Toughness
Procedure	FTI 2000 1/2T
General Information	TVA 2001 Irradiated Welds Operator : Brad Vevera Project Leader : Kevin Hour Job Number : 1215-001-00-18-00-00-0000 Date of Test : 07/2001
Batch	TVA
Batch Comments	
Specimen	WT10
Specimen Comments	
Platform	TestStar II

Geometry	
Specimen Geometry	LLC(T)
Width (W)	1 in
Notch Length (a0)	0.45 in
Thickness (B)	0.5 in
Net Thickness (Bn)	0.375 in
Elastic Modulus (E)	27508.4 ksi
Yield Strength	79 ksi
Ultimate Tensile Strength	99.9 ksi
Poisson's Ratio	0.3 (none)
Crack Plane Orientation	
Pin Center from Crack Plane	0.275 in
COD Half-Gage Length	0.07725 in
COD Distance from Load Line	0 in
Test Temperature	390 deg_F

Compliance Coefficients	
C0	1.0002 (none)
C1	-4.0632 (none)
C2	11.242 (none)
C3	-106.04 (none)
C4	464.33 (none)
C5	-650.68 (none)

K Calibration Coefficients	
Calibration coeff. 0	0.886 (none)
Calibration coeff. 1	4.64 (none)
Calibration coeff. 2	-13.32 (none)
Calibration coeff. 3	14.72 (none)
Calibration coeff. 4	-5.6 (none)

Precrack Parameters	
Final Kmax	18 ksi-in^0.5
Test Frequency	10 Hz
Final Crack Length	0.5 in
Cycle Limited	No
Maximum Number of Cycles	10000
Crack Length Monitoring	compliance
Upper LSF data range	85 %
Lower LSF data range	15 %
Automatic Inspection Hold	No
Inspection Interval (cycles)	10000

Precrack Setup	
PCR Load Signal	Force 312
PCR Load Range	10000 lbf
PCR COD Signal	Clip Gage
PCR COD Range	0.15 in

Precrack Results	
Precrack Cycles	0
Precrack Kmax	18 ksi-in^0.5
Precrack Final K	23 ksi-in^0.5
Precrack Pmax	1250 lbf
Precrack Final P	850 lbf

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10

Precrack crack length	0.5095 in
Execution Parameters:	
Test Control	Displacement
Ramp Rate	0.00999999 in/Min
UnLoad on Load Step	No
Load Step	300.001 lbf
UnLoad on COD Step	No
COD Step	0.0025 in
UnLoad on Displacement Step	Yes
Displacement Step	0.0015 in
Unload Pct of Current Load	Yes
Percent Unload	20 %
Unload Absolute	No
Absolute Unload	2000 lbf
Number of Unloads	1
Crack Propagation Hold Time	2 Sec
Unload Rate	100 lbf/Sec
Reload Rate	100 lbf/Sec
Ramp To Initial Load	Yes
Pct Of Final Precrack Load	100 %
Load Ramp Rate	100 lbf/Sec
Test Setup:	
Load Channel Name	Force 312
Maximum Load	5000 lbf
COD Channel Name	Clip Gage
Maximum COD	0.15 in
Length Channel Name	Length 312
Maximum Displacement	1 in
Frame Stiffness	130 kip/in
Data Storage:	
Event Log Filename	elog.txt
Data File Name	JIC_FTI 2000 1_2T_TVA_WT10.RAW
Test Termination:	
End on maximum load	No
Maximum Load	5000 lbf
End on maximum COD	Yes
Maximum COD	0.15 in
End on maximum displ.	No
Maximum Displacement	1 in
End on maximum Crack Length	No
Maximum Crack Length	1 in
End on maximum Crack Extension	No
Maximum Crack Length Extension	1 in
Termination Type	Controlled
Final Precrack Lengths:	
Precrack length 1	0.503902 in
Precrack length 2	0.503701 in
Precrack length 3	0.505 in
Precrack length 4	0.510299 in
Precrack length 5	0.506098 in
Precrack length 6	0.503402 in
Precrack length 7	0.500598 in
Precrack length 8	0.499299 in
Precrack length 9	0.497701 in
Average Precrack:	0.50365 in
Final JIC Crack Lengths:	
Final crack length 1	0.560098 in
Final crack length 2	0.5325 in
Final crack length 3	0.621701 in
Final crack length 4	0.621799 in
Final crack length 5	0.638799 in
Final crack length 6	0.648299 in
Final crack length 7	0.585701 in
Final crack length 8	0.627 in

Test Summary

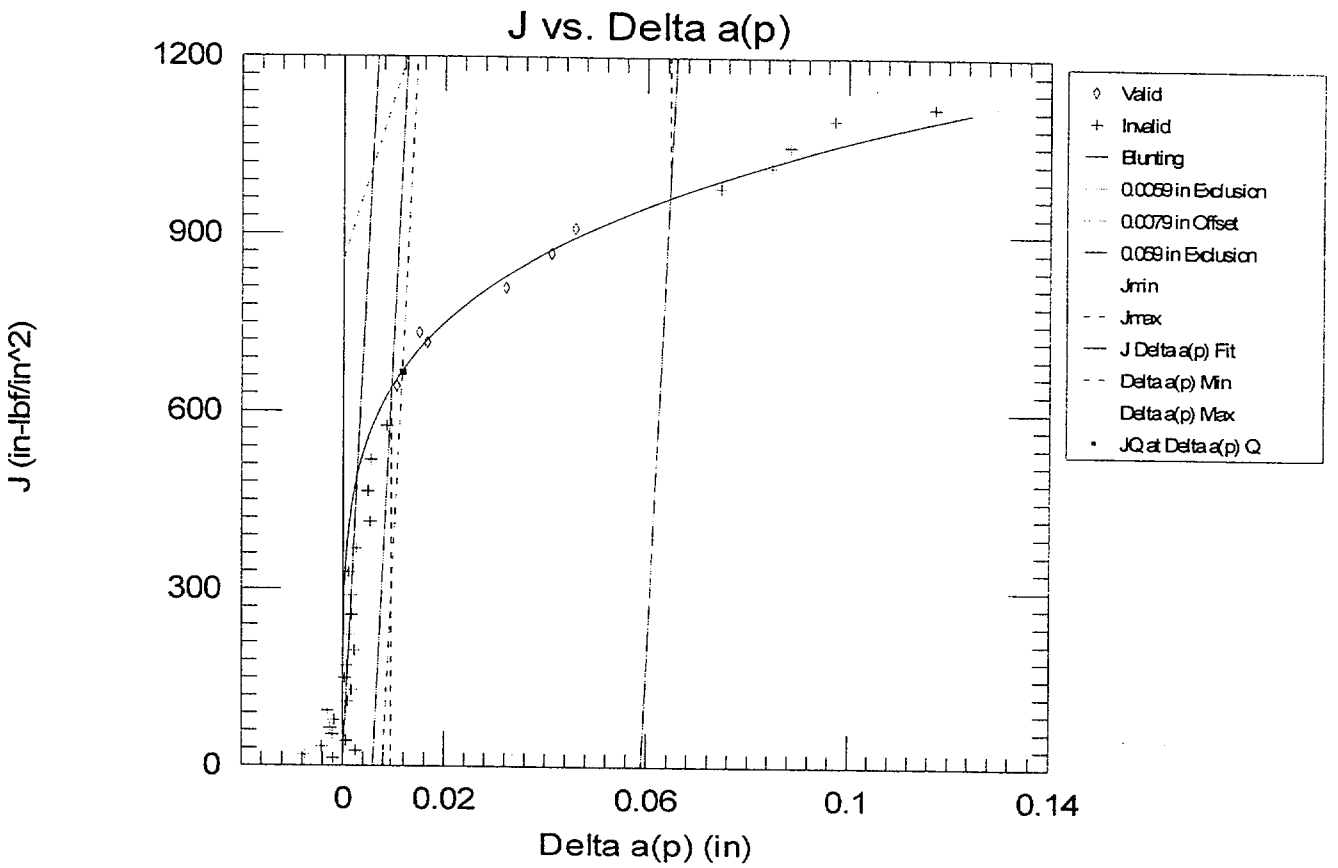
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10

Final crack length 9	0.610098 in
Average Physical Crack:	0.607612 in
Calculated Crack Lengths:	
Pre Test Normalized Compliance:	38.969 (none)
Calculated Pre Test Crack Length:	0.50365 in
Test Termination Normalized Compliance:	62.277 (none)
Calculated Test Term. Crack Length:	0.607612 in
Run-Time Report:	
Test Duration:	743.651 Sec
Maximum Load:	3773.76 lbf
Maximum COD:	0.0338021 in
Maximum Displacement:	0.0512209 in
Test Terminat Reason	Premature test termination. User selected End Test.
JIC Analysis Inputs:	
Upper LSF data range:	90 %
Lower LSF data range:	10 %
Blunting Factor M:	2 (none)
Minimum J value:	150 in-lbf/in^2
Modulus Factor Lambda:	1 (none)
Delta a(p) Offset	-0.0015 in
Analysis Calculations:	
Effective Yield Strength	Avg. of Yield _Ultimate
Front Face Spcm. Displ.	Calculated from COD
Unload/Reload Compliance	Unload _Reload
JIC ASTM Standard	ASTM E813-89
JIC Test Results ASTM E 813:	
Number of Data Points:	31
Number of Valid Data Points:	5
Delta a(p) Min Limit Line:	0.00949409 in
Delta a(p) Max Limit Line:	0.0653304 in
Regression Slope dJQ/da at delta-aQ:	16.9428 ksi
c1	2480.68 (none)
c2	0.290329 (none)
JQ	680.601 in-lbf/in^2
Delta a(Q)	0.0116784 in
Kj Value:	136.829 ksi-in^0.5
Unable to parse unload/reload for step:	32
Validation Criteria ASTM E 813-89	
ASTM E813-89 Section 8.4.2:	
tp = 117.1 Sec	
Is tp between 6 Sec and 600 Sec?	Yes
ASTM E813-89 Section 7.1.1:	
25 JQ/SFS = 0.1902 in	
Is b0 > 25 JQ/SFS?	Yes
Is B > 25 JQ/SFS?	Yes
ASTM E813-89 Section 7.2.2:	
a0/W = 0.5036	
Is a0/W between 0.5 _0.75?	Yes
ASTM E813-89 Section 7.5:	
Side grooving = 25 pct.	
Is side grooving <= 25 pct.?	No
ASTM E813-89 Section 7.6.4:	
Precrack extension = 0.05365 in	
Is precrack extension >= 0.05a0 and >= 0.05 in?	Yes
ASTM E813-89 Section 7.6.1:	
PL = 4269 lbf	
ASTM E813-89 Section 8.4.3.6:	
Is the load range of all compliance unloads <= 0.2PL or 0.5 times the current load?	Yes
ASTM E813-89 Section 9.3.1:	
Do all points used for regression lie	

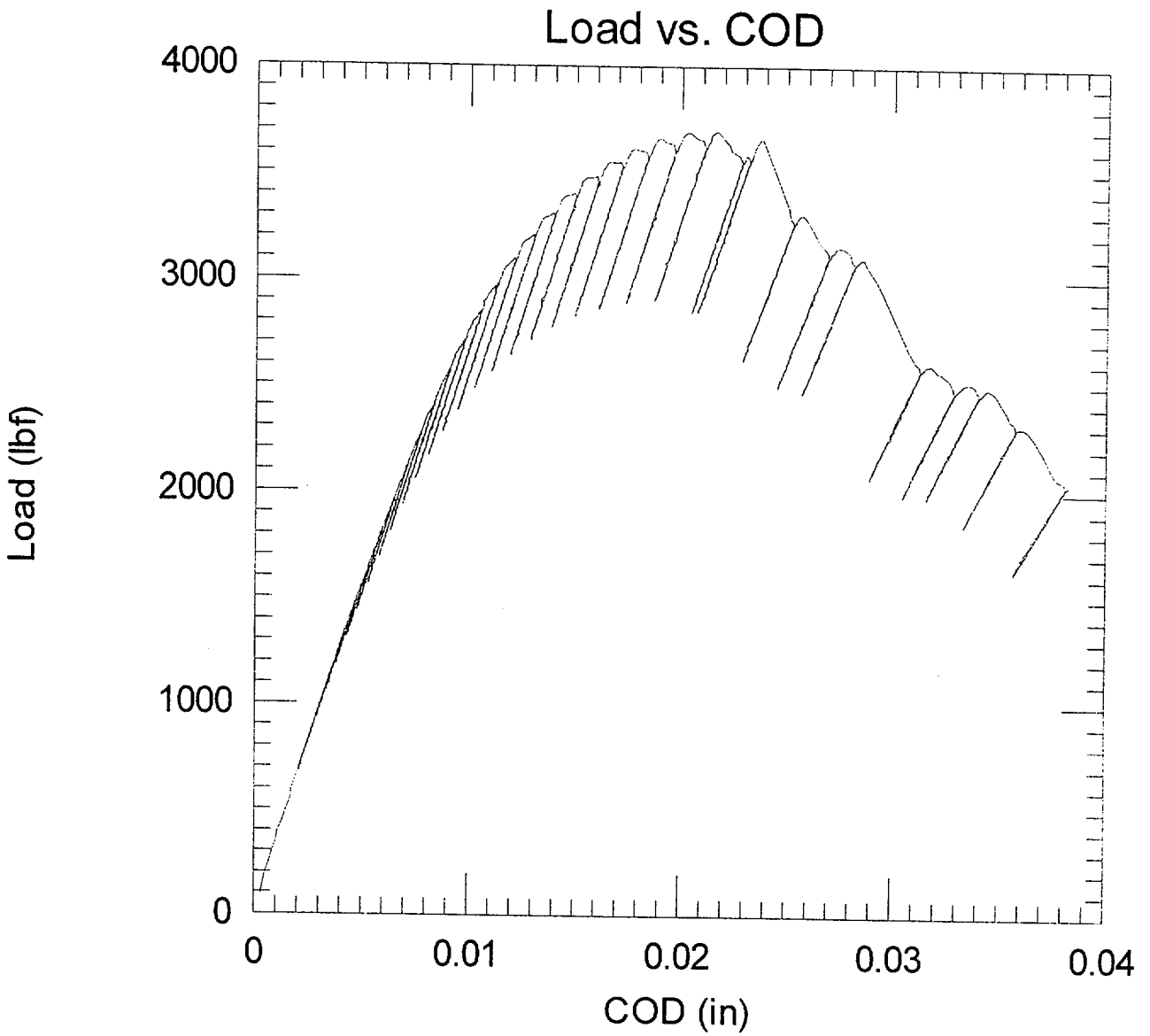
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT10

between Delta a(p) min _max?	Yes
ASTM E813-89 Section 9.2.2:	
Does at least one data point lie betw the 0.005906 in _0.05906 in excl.	Yes
ASTM E813-89 Section 9.4.1.3:	
Is the slope of the regression curve at JQ less than SFS?	Yes
ASTM E813-89 Section 9.4.1.5:	
Are all precrack lengths within 7 pct. of the average?	Yes
Are all final crack lengths within 7 pct. of the average?	No
ASTM E813-89 Section 9.4.1.6:	
Are both near surface crack extensions within 0.02W of the extension at the center?	Yes
ASTM E813-89 Section 9.4.1.7:	
Is the difference between the crack extensions found from compliance and the 9-point averages within 15 pct. of either of the 9-point average or Delta a(p) max?	No
EM from 9-point precrack front average = 2.658e+004 ksi	
Is EM within 10 pct. of nominal E?	Yes
Is JQ = JIC per ASTM E813-89?	No

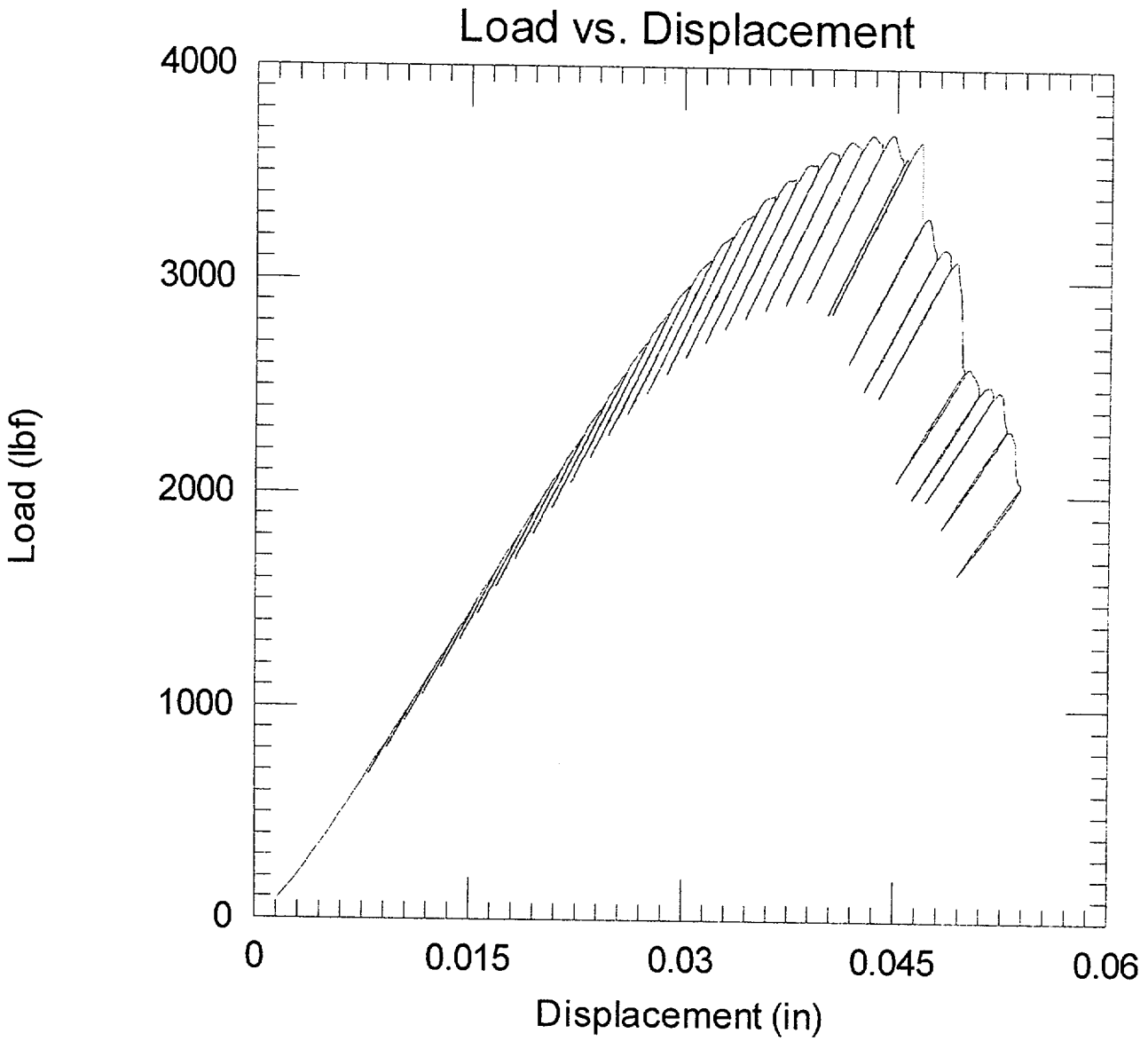
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11



Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11



Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11



J, Delta a(p), Validity by Step

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11

Step	Step Validity	J (in-lbf/in^2)	Delta a(p) (in)	Load (lbf)	COD (in)
1	Invalid	13.2546	-0.00192237	851.812	0.00259630
2	Invalid	19.1554	-0.00753043	1007.23	0.00313906
3	Invalid	25.8556	0.00249644	1164.37	0.00364563
4	Invalid	33.4383	-0.00419906	1325.65	0.00417287
5	Invalid	42.9275	0.000596417	1483.83	0.00473630
6	Invalid	53.3417	-0.00209069	1641.31	0.00530492
7	Invalid	64.0452	-0.00254320	1801.56	0.00583732
8	Invalid	78.0799	-0.00168793	1955.94	0.00646795
9	Invalid	94.1839	-0.00306303	2111.02	0.00713476
10	Invalid	110.117	0.000843133	2267.13	0.00773953
11	Invalid	129.199	0.00158013	2415.30	0.00841669
12	Invalid	149.157	0.000328975	2557.97	0.00908350
13	Invalid	170.824	0.000822070	2699.62	0.00976583
14	Invalid	196.388	0.00219502	2835.04	0.0105257
15	Invalid	222.672	0.00130446	2963.93	0.0112700
16	Invalid	257.004	0.00162192	3083.86	0.0121953
17	Invalid	289.543	0.00161876	3194.83	0.0130379
18	Invalid	328.364	0.00105294	3293.02	0.0140045
19	Invalid	368.513	0.00265403	3380.23	0.0149815
20	Invalid	413.698	0.00525553	3459.14	0.0160566
21	Invalid	464.914	0.00480516	3520.13	0.0172196
22	Invalid	518.245	0.00545471	3571.47	0.0184189
23	Invalid	575.229	0.00852663	3602.83	0.0197112
24	Valid	642.015	0.0105208	3619.38	0.0211895
25	Valid	716.046	0.0165333	3551.15	0.0229005
26	Valid	733.037	0.0149978	3557.35	0.0232365
27	Valid	810.247	0.0321146	3267.19	0.0253868
28	Valid	867.961	0.0411336	3108.66	0.0270203
29	Valid	911.029	0.0458131	3070.42	0.0282195
30	Invalid	979.309	0.0745336	2576.24	0.0313675
31	Invalid	1015.46	0.0846444	2472.85	0.0329337
32	Invalid	1049.82	0.0883662	2463.55	0.0341019
33	Invalid	1095.27	0.0971947	2309.51	0.0359318
34	Invalid	1116.15	0.117244	2040.37	0.0382165
36	-----	-----	-----	-----	-----

J Delta a(p) Validity by Step

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11

Displacement (in)	Load Line Displacement (in)	Normalized Load Line Compliance	Energy for J Calculation (in-lbf)	Delta a(p) Validity	Min/Max J Exclusion Validity
0.00945661	0.00259630	40.0071	1.13219	Valid	Invalid
0.0109211	0.00313906	38.8916	1.64009	Valid	Invalid
0.0124545	0.00364563	40.9212	2.19561	Valid	Invalid
0.0139535	0.00417287	39.5545	2.85389	Valid	Invalid
0.0154352	0.00473630	40.5250	3.64679	Valid	Invalid
0.0169859	0.00530492	39.9814	4.53543	Valid	Invalid
0.0185193	0.00583732	39.8893	5.44837	Valid	Invalid
0.0199666	0.00646795	40.0550	6.62810	Valid	Invalid
0.0214311	0.00713476	39.7838	7.98649	Valid	Invalid
0.0229300	0.00773953	40.5762	9.31635	Valid	Invalid
0.0244635	0.00841669	40.7296	10.9068	Valid	Invalid
0.0259107	0.00908350	40.4784	12.5757	Valid	Invalid
0.0273924	0.00976583	40.5806	14.3810	Valid	Invalid
0.0289259	0.0105257	40.8581	16.4962	Valid	Invalid
0.0303904	0.0112700	40.6810	18.6695	Valid	Invalid
0.0319238	0.0121953	40.7472	21.4878	Valid	Invalid
0.0334228	0.0130379	40.7465	24.1580	Valid	Invalid
0.0349562	0.0140045	40.6286	27.3207	Valid	Invalid
0.0364379	0.0149815	40.9544	30.6161	Valid	Invalid
0.0379024	0.0160566	41.5054	34.3307	Valid	Invalid
0.0394705	0.0172196	41.4185	38.4338	Valid	Invalid
0.0409693	0.0184189	41.5480	42.7389	Valid	Invalid
0.0423992	0.0197112	42.2117	47.4361	Valid	Invalid
0.0439673	0.0211895	42.6497	52.8442	Valid	Valid
0.0454315	0.0229005	44.0057	59.0666	Valid	Valid
0.0457417	0.0232365	43.6643	60.2654	Valid	Valid
0.0467756	0.0253868	47.7857	67.7931	Valid	Valid
0.0477575	0.0270203	50.1668	73.0628	Valid	Valid
0.0487224	0.0282195	51.4635	76.8157	Valid	Valid
0.0497047	0.0313675	60.4730	85.8320	Valid	Invalid
0.0507728	0.0329337	64.1445	89.8410	Valid	Invalid
0.0518067	0.0341019	65.5716	92.7588	Valid	Invalid
0.0528575	0.0359318	69.1328	97.1794	Valid	Invalid
0.0537878	0.0382165	78.2606	102.161	Valid	Invalid
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Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11

J Min/Max Validity

Valid
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Test Summary

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11

Identification:	
Template	JIC Fracture Toughness
Procedure	FTI 2000 1/2T
General Information	TVA 2001 Irradiated Welds Operator : Brad Vevera Project Leader : Kevin Hour Job Number : 1215-001-00-18-00-00-0000 Date of Test : 07/2001
Batch	TVA
Batch Comments	
Specimen	WT11
Specimen Comments	
Platform	TestStar II
Geometry:	
Specimen Geometry	LLC(T)
Width (W)	1 in
Notch Length (a0)	0.45 in
Thickness (B)	0.5 in
Net Thickness (Bn)	0.375 in
Elastic Modulus (E)	27508.4 ksi
Yield Strength	79 ksi
Ultimate Tensile Strength	99.9 ksi
Poisson's Ratio	0.3 (none)
Crack Plane Orientation	
Pin Center from Crack Plane	0.275 in
COD Half-Gage Length	0.07725 in
COD Distance from Load Line	0 in
Test Temperature	390 deg_F
Compliance Coefficients	
C0	1.0002 (none)
C1	-4.0632 (none)
C2	11.242 (none)
C3	-106.04 (none)
C4	464.33 (none)
C5	-650.68 (none)
K Calibration Coefficients	
Calibration coeff. 0	0.886 (none)
Calibration coeff. 1	4.64 (none)
Calibration coeff. 2	-13.32 (none)
Calibration coeff. 3	14.72 (none)
Calibration coeff. 4	-5.6 (none)
Precrack Parameters:	
Final Kmax	18 ksi-in^0.5
Test Frequency	10 Hz
Final Crack Length	0.5 in
Cycle Limited	No
Maximum Number of Cycles	10000
Crack Length Monitoring	compliance
Upper LSF data range	85 %
Lower LSF data range	15 %
Automatic Inspection Hold	No
Inspection Interval (cycles)	10000
Precrack Setup:	
PCR Load Signal	Force 312
PCR Load Range	10000 lbf
PCR COD Signal	Clip Gage
PCR COD Range	0.15 in
Precrack Results:	
Precrack Cycles	0
Precrack Kmax	23 ksi-in^0.5
Precrack Final K	18 ksi-in^0.5
Precrack Pmax	1250 lbf
Precrack Final P	850 lbf

Test Summary

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11

Precrack crack length	0.527 in
Execution Parameters:	
Test Control	Displacement
Ramp Rate	0.00999999 in/Min
UnLoad on Load Step	No
Load Step	300.001 lbf
UnLoad on COD Step	No
COD Step	0.0025 in
UnLoad on Displacement Step	Yes
Displacement Step	0.0015 in
Unload Pct of Current Load	Yes
Percent Unload	20 %
Unload Absolute	No
Absolute Unload	2000 lbf
Number of Unloads	1
Crack Propagation Hold Time	2 Sec
Unload Rate	100 lbf/Sec
Reload Rate	100 lbf/Sec
Ramp To Initial Load	Yes
Pct Of Final Precrack Load	100 %
Load Ramp Rate	100 lbf/Sec
Test Setup:	
Load Channel Name	Force 312
Maximum Load	5000 lbf
COD Channel Name	Clip Gage
Maximum COD	0.15 in
Length Channel Name	Length 312
Maximum Displacement	1 in
Frame Stiffness	130 kip/in
Data Storage:	
Event Log Filename	elog.txt
Data File Name	JIC_FTI 2000 1_2T_TVA_WT11.RAW
Test Termination:	
End on maximum load	No
Maximum Load	5000 lbf
End on maximum COD	Yes
Maximum COD	0.15 in
End on maximum displ.	No
Maximum Displacement	1 in
End on maximum Crack Length	No
Maximum Crack Length	1 in
End on maximum Crack Extension	No
Maximum Crack Length Extension	1 in
Termination Type	Controlled
Final Precrack Lengths:	
Precrack length 1	0.499902 in
Precrack length 2	0.505902 in
Precrack length 3	0.505 in
Precrack length 4	0.5065 in
Precrack length 5	0.511598 in
Precrack length 6	0.517402 in
Precrack length 7	0.511299 in
Precrack length 8	0.509598 in
Precrack length 9	0.500902 in
Average Precrack:	0.508463 in
Final JIC Crack Lengths:	
Final crack length 1	0.648701 in
Final crack length 2	0.6095 in
Final crack length 3	0.6115 in
Final crack length 4	0.631201 in
Final crack length 5	0.656701 in
Final crack length 6	0.647299 in
Final crack length 7	0.654098 in
Final crack length 8	0.648799 in

Test Summary

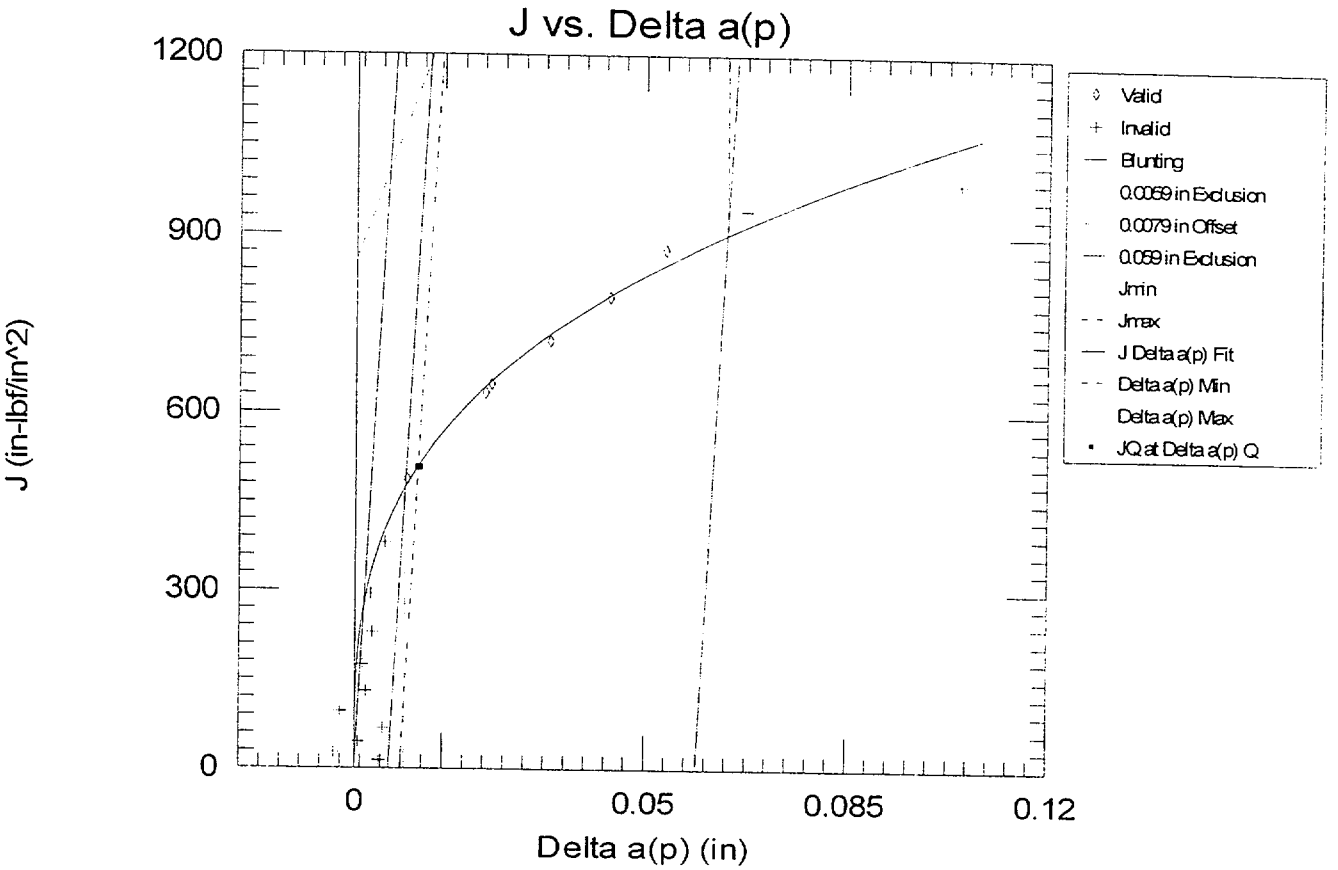
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11

Final crack length 9	0.623299 in
Average Physical Crack:	0.636887 in
Calculated Crack Lengths:	
Pre Test Normalized Compliance:	39.4021 (none)
Calculated Pre Test Crack Length:	0.508463 in
Test Termination Normalized Compliance:	78.2606 (none)
Calculated Test Term. Crack Length:	0.636887 in
Run-Time Report:	
Test Duration:	859.063 Sec
Maximum Load:	3692.78 lbf
Maximum COD:	0.038263 in
Maximum Displacement:	0.0538224 in
Test Terminat Reason	
JIC Analysis Inputs:	
Upper LSF data range:	90 %
Lower LSF data range:	10 %
Blunting Factor M:	2 (none)
Minimum J value:	0 in-lbf/in^2
Modulus Factor Lambda:	1 (none)
Delta a(p) Offset	-0.005 in
Analysis Calculations:	
Effective Yield Strength	Avg. of Yield _Ultimate
Front Face Spcm. Displ.	Calculated from COD
Unload/Reload Compliance	Unload _Reload
JIC ASTM Standard	ASTM E813-89
JIC Test Results ASTM E 813:	
Number of Data Points:	35
Number of Valid Data Points:	6
Delta a(p) Min Limit Line:	0.00947967 in
Delta a(p) Max Limit Line:	0.0644293 in
Regression Slope dJQ/da at delta-aQ:	12.2679 ksi
c1	1726.44 (none)
c2	0.213091 (none)
JQ	666.844 in-lbf/in^2
Delta a(Q)	0.0116015 in
Kj Value:	135.439 ksi-in^0.5
Unable to parse unload/reload for step:	36
Validation Criteria ASTM E 813-89:	
ASTM E813-89 Section 8.4.2:	
tp = 115.7 Sec	
Is tp between 6 Sec and 600 Sec?	Yes
ASTM E813-89 Section 7.1.1:	
25 JQ/SFS = 0.1864 in	
Is b0 > 25 JQ/SFS?	Yes
Is B > 25 JQ/SFS?	Yes
ASTM E813-89 Section 7.2.2:	
a0/W = 0.5085	
Is a0/W between 0.5 _0.75?	Yes
ASTM E813-89 Section 7.5:	
Side grooving = 25 pct.	
Is side grooving <= 25 pct.?	~~No~~ Yes
ASTM E813-89 Section 7.6.4:	
Precrack extension = 0.05846 in	
Is precrack extension >= 0.05a0 and >= 0.05 in?	Yes
ASTM E813-89 Section 7.6.1:	
PL = 4227 lbf	
ASTM E813-89 Section 8.4.3.6:	
Is the load range of all compliance unloads <= 0.2PL or 0.5 times the current load?	Yes
ASTM E813-89 Section 9.3.1:	
Do all points used for regression lie	

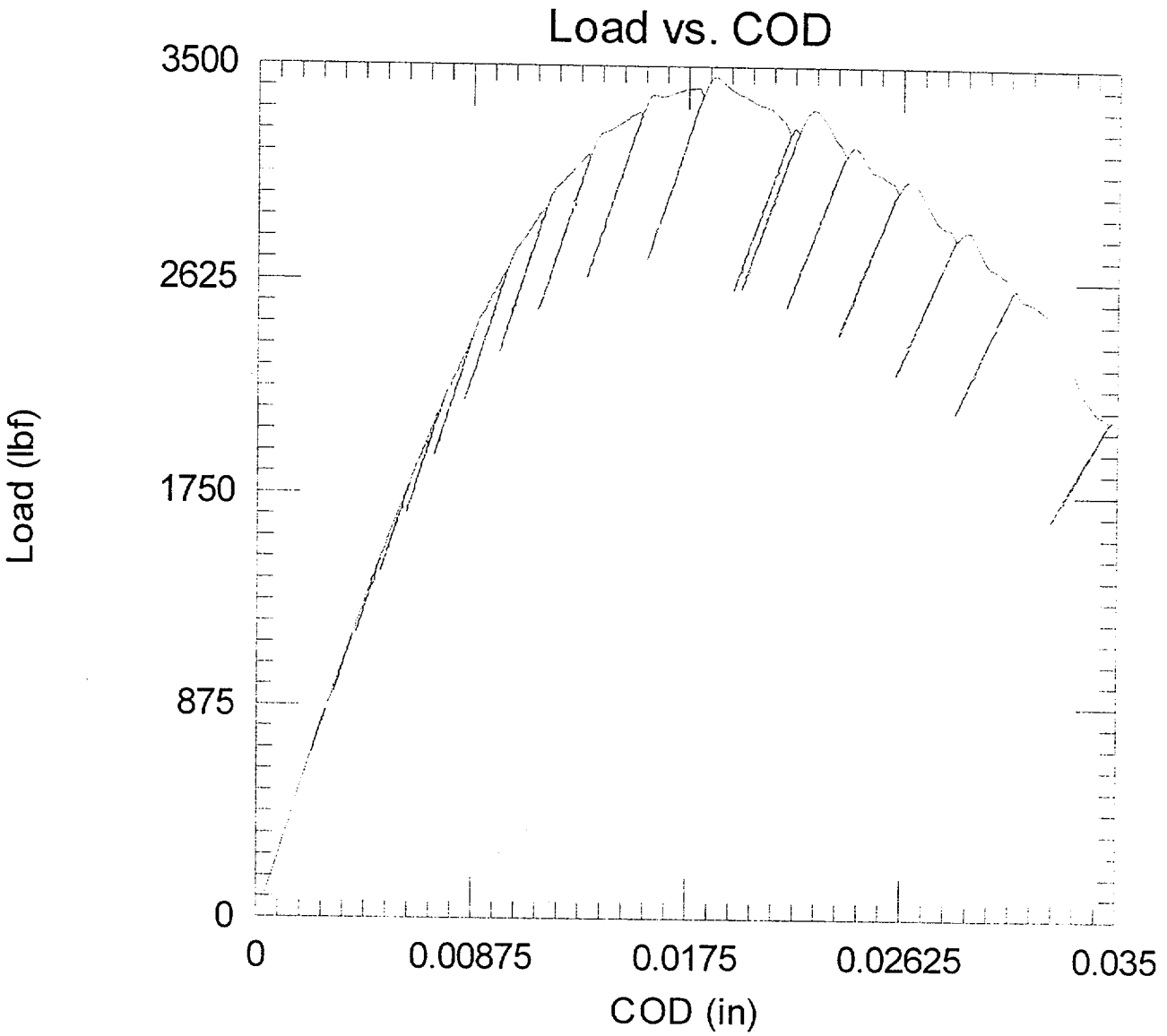
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT11

between Delta a(p) min _max?	Yes
ASTM E813-89 Section 9.2.2:	
Does at least one data point lie betw the 0.005906 in _0.05906 in excl.	Yes
ASTM E813-89 Section 9.4.1.3:	
Is the slope of the regression curve at JQ less than SFS?	Yes
ASTM E813-89 Section 9.4.1.5:	
Are all precrack lengths within 7 pct. of the average?	Yes
Are all final crack lengths within 7 pct. of the average?	Yes
ASTM E813-89 Section 9.4.1.6:	
Are both near surface crack extensions within 0.02W of the extension at the center?	Yes
ASTM E813-89 Section 9.4.1.7:	
Is the difference between the crack extensions found from compliance and the 9-point averages within 15 pct. of either of the 9-point average or Delta a(p) max?	Yes
EM from 9-point precrack front average = 2.693e+004 ksi	
Is EM within 10 pct. of nominal E?	Yes
Is JQ = JIC per ASTM E813-89?	~~No~~ YES 7/19/01

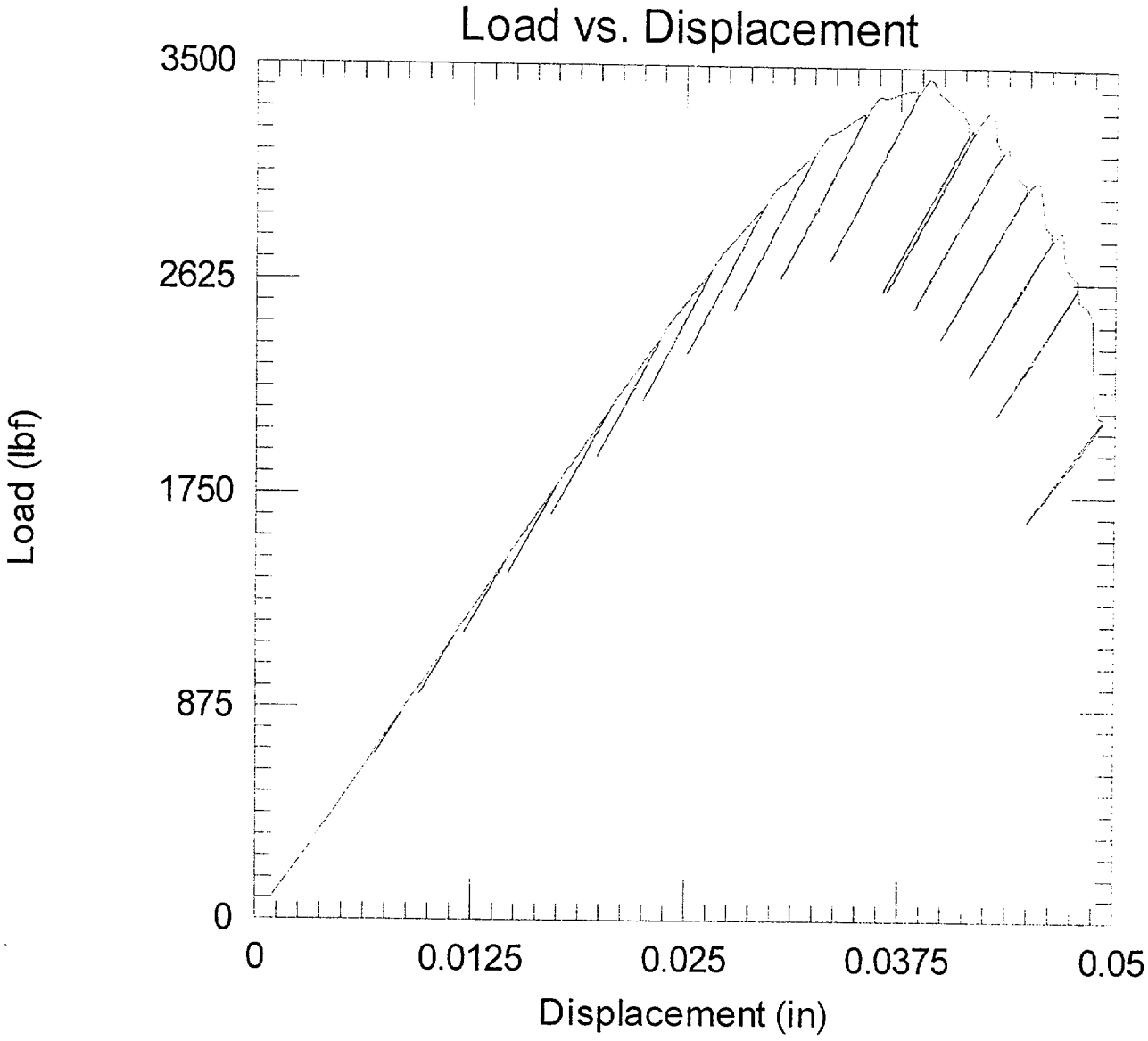
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9



Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9



Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9



J, Delta a(p), Validity by Step

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9

Step	Step Validity	J (in-lbf/in^2)	Delta a(p) (in)	Load (lbf)	COD (in)
1	Invalid	13.8999	0.00412566	850.778	0.00277722
2	Invalid	26.8060	-0.00359952	1162.65	0.00386790
3	Invalid	45.0706	0.000624131	1470.04	0.00502059
4	Invalid	67.1946	0.00487050	1778.47	0.00614748
5	Invalid	95.9566	-0.00251102	2082.07	0.00739839
6	Invalid	130.321	0.00195270	2378.43	0.00867516
7	Invalid	174.153	0.00134829	2653.44	0.0101070
8	Invalid	228.989	0.00298008	2905.34	0.0117094
9	Invalid	294.698	0.00272792	3126.24	0.0134617
10	Invalid	380.964	0.00504651	3293.72	0.0156069
11	Valid	487.206	0.00885678	3383.67	0.0181294
12	Valid	632.764	0.0223185	3224.46	0.0216909
13	Valid	647.253	0.0233552	3234.80	0.0220580
14	Valid	720.566	0.0334798	3140.72	0.0240015
15	Valid	795.323	0.0438793	2992.18	0.0260950
16	Valid	875.758	0.0534997	2798.51	0.0284211
17	Invalid	942.113	0.0674292	2599.33	0.0308092
18	Invalid	989.309	0.104622	2063.46	0.0347739
20	-----	-----	-----	-----	-----

J, Delta a(p), Validity by Step

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9

Displacement (in)	Load Line Displacement (in)	Normalized Load Line Compliance	Energy for J Calculation (in-lbf)	Delta a(p) Min/Max Validity	J Exclusion Validity
0.00844008	0.00277722	42.3393	1.17161	Valid	Invalid
0.0114552	0.00386790	40.6979	2.26922	Valid	Invalid
0.0144532	0.00502059	41.5810	3.79576	Valid	Invalid
0.0174339	0.00614748	42.5029	5.63556	Valid	Invalid
0.0204490	0.00739839	40.9256	8.05699	Valid	Invalid
0.0234469	0.00867516	41.8667	10.9076	Valid	Invalid
0.0263932	0.0101070	41.7457	14.5235	Valid	Invalid
0.0293739	0.0117094	42.0894	19.0119	Valid	Invalid
0.0324062	0.0134617	42.0439	24.3460	Valid	Invalid
0.0354214	0.0156069	42.5417	31.3131	Valid	Invalid
0.0384193	0.0181294	43.3920	39.8546	Valid	Valid
0.0414516	0.0216909	46.5754	51.8556	Valid	Valid
0.0417965	0.0220580	46.8330	53.0447	Valid	Valid
0.0432780	0.0240015	49.4465	59.3752	Valid	Valid
0.0447768	0.0260950	52.3325	65.8447	Valid	Valid
0.0463102	0.0284211	55.2025	72.6744	Valid	Valid
0.0477921	0.0308092	59.7398	79.1862	Valid	Invalid
0.0493083	0.0347739	74.5988	88.4435	Valid	Invalid
-----	-----	-----	-----	-----	-----

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9

J Min/Max Validity
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid
Valid

Test Summary

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9

Identification:	
Template	JIC Fracture Toughness
Procedure	FTI 2000 1/2T
General Information	TVA 2001 Irradiated Welds Operator : Brad Vevera Project Leader : Kevin Hour Job Number : 1215-001-00-18-00-00-0000 Date of Test : 07/2001
Batch	TVA
Batch Comments	
Specimen	WT9
Specimen Comments	
Platform	TestStar II
Geometry:	
Specimen Geometry	LLC(T)
Width (W)	1 in
Notch Length (a0)	0.45 in
Thickness (B)	0.5 in
Net Thickness (Bn)	0.375 in
Elastic Modulus (E)	27508.4 ksi
Yield Strength	79 ksi
Ultimate Tensile Strength	99.9 ksi
Poisson's Ratio	0.3 (none)
Crack Plane Orientation	
Pin Center from Crack Plane	0.275 in
COD Half-Gage Length	0.077 in
COD Distance from Load Line	0 in
Test Temperature	390 deg_F
Compliance Coefficients	
C0	1.0002 (none)
C1	-4.0632 (none)
C2	11.242 (none)
C3	-106.04 (none)
C4	464.33 (none)
C5	-650.68 (none)
K Calibration Coefficients	
Calibration coeff. 0	0.886 (none)
Calibration coeff. 1	4.64 (none)
Calibration coeff. 2	-13.32 (none)
Calibration coeff. 3	14.72 (none)
Calibration coeff. 4	-5.6 (none)
Precrack Parameters:	
Final Kmax	18 ksi-in^0.5
Test Frequency	10 Hz
Final Crack Length	0.5 in
Cycle Limited	No
Maximum Number of Cycles	10000
Crack Length Monitoring	compliance
Upper LSF data range	85 %
Lower LSF data range	15 %
Automatic Inspection Hold	No
Inspection Interval (cycles)	10000
Precrack Setup:	
PCR Load Signal	Force 312
PCR Load Range	10000 lbf
PCR COD Signal	Clip Gage
PCR COD Range	0.15 in
Precrack Results:	
Precrack Cycles	0
Precrack Kmax	23 ksi-in^0.5
Precrack Final K	18 ksi-in^0.5
Precrack Pmax	1250 lbf
Precrack Final P	850 lbf

Test Summary

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9

Precrack crack length	0.523 in
Execution Parameters:	
Test Control	Displacement
Ramp Rate	0.00999999 in/Min
UnLoad on Load Step	No
Load Step	300.001 lbf
UnLoad on COD Step	No
COD Step	0.0025 in
UnLoad on Displacement Step	Yes
Displacement Step	0.003 in
Unload Pct of Current Load	Yes
Percent Unload	20 %
Unload Absolute	No
Absolute Unload	2000 lbf
Number of Unloads	1
Crack Propagation Hold Time	2 Sec
Unload Rate	100 lbf/Sec
Reload Rate	100 lbf/Sec
Ramp To Initial Load	Yes
Pct Of Final Precrack Load	100 %
Load Ramp Rate	100 lbf/Sec
Test Setup:	
Load Channel Name	Force 312
Maximum Load	5000 lbf
COD Channel Name	Clip Gage
Maximum COD	0.15 in
Length Channel Name	Length 312
Maximum Displacement	1 in
Frame Stiffness	130 kip/in
Data Storage:	
Event Log Filename	elog.txt
Data File Name	JIC_FTI 2000 1_2T_TVA_WT9.RAW
Test Termination:	
End on maximum load	No
Maximum Load	5000 lbf
End on maximum COD	Yes
Maximum COD	0.15 in
End on maximum displ.	No
Maximum Displacement	1 in
End on maximum Crack Length	No
Maximum Crack Length	1 in
End on maximum Crack Extension	No
Maximum Crack Length Extension	1 in
Termination Type	Controlled
Final Precrack Lengths:	
Precrack length 1	0.5078 in
Precrack length 2	0.5183 in
Precrack length 3	0.5171 in
Precrack length 4	0.5171 in
Precrack length 5	0.5214 in
Precrack length 6	0.5209 in
Precrack length 7	0.5171 in
Precrack length 8	0.5176 in
Precrack length 9	0.5122 in
Average Precrack:	0.517437 in
Final JIC Crack Lengths:	
Final crack length 1	0.6619 in
Final crack length 2	0.6657 in
Final crack length 3	0.6717 in
Final crack length 4	0.6283 in
Final crack length 5	0.629 in
Final crack length 6	0.623 in
Final crack length 7	0.6224 in
Final crack length 8	0.6229 in

Test Summary

Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9

Final crack length 9	0.6314 in
Average Physical Crack:	0.638706 in
Calculated Crack Lengths:	
Pre Test Normalized Compliance:	41.4659 (none)
Calculated Pre Test Crack Length:	0.517437 in
Test Termination Normalized Compliance:	74.5988 (none)
Calculated Test Term. Crack Length:	0.638706 in
Run-Time Report:	
Test Duration:	569.658 Sec
Maximum Load:	3457.4 lbf
Maximum COD:	0.0347739 in
Maximum Displacement:	0.0493256 in
Test Terminat Reason	
JIC Analysis Inputs:	
Upper LSF data range:	90 %
Lower LSF data range:	10 %
Blunting Factor M:	2 (none)
Minimum J value:	0 in-lbf/in^2
Modulus Factor Lambda:	1 (none)
Delta a(p) Offset	0 in
Analysis Calculations:	
Effective Yield Strength	Avg. of Yield _Ultimate
Front Face Spcm. Displ.	Calculated from COD
Unload/Reload Compliance	Unload _Reload
JIC ASTM Standard	ASTM E813-89
JIC Test Results ASTM E 813:	
Number of Data Points:	19
Number of Valid Data Points:	6
Delta a(p) Min Limit Line:	0.00855694 in
Delta a(p) Max Limit Line:	0.0640959 in
Regression Slope dJQ/da at delta-aQ:	15.1688 ksi
c1	2166.88 (none)
c2	0.31931 (none)
JQ	508.645 in-lbf/in^2
Delta a(Q)	0.0107172 in
Kj Value:	118.288 ksi-in^0.5
Unable to parse unload/reload for step:	20
Validation Criteria ASTM E 813-89:	
ASTM E813-89 Section 8.4.2:	
tp = 81.19 Sec	
Is tp between 6 Sec and 600 Sec?	Yes
ASTM E813-89 Section 7.1.1:	
25 JQ/SFS = 0.1422 in	
Is b0 > 25 JQ/SFS?	Yes
Is B > 25 JQ/SFS?	Yes
ASTM E813-89 Section 7.2.2:	
a0/W = 0.5174	
Is a0/W between 0.5 _0.75?	Yes
ASTM E813-89 Section 7.5:	
Side grooving = 25 pct.	
Is side grooving <= 25 pct.?	~~No~~ YES
ASTM E813-89 Section 7.6.4:	
Precrack extension = 0.06744 in	
Is precrack extension >= 0.05a0 and >= 0.05 in?	Yes
ASTM E813-89 Section 7.6.1:	
PL = 4040 lbf	
ASTM E813-89 Section 8.4.3.6:	
Is the load range of all compliance unloads <= 0.2PL or 0.5 times the current load?	Yes
ASTM E813-89 Section 9.3.1:	
Do all points used for regression lie	

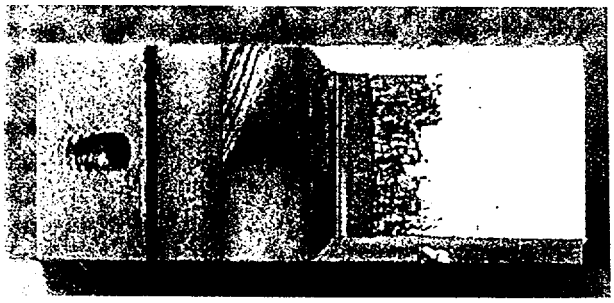
Template: JIC Fracture Toughness
Procedure: FTI 2000 1/2T
Batch: TVA
Specimen: WT9

between Delta a(p) min _max?	Yes
ASTM E813-89 Section 9.2.2:	
Does at least one data point lie betw the 0.005906 in _0.05906 in excl.	Yes
ASTM E813-89 Section 9.4.1.3:	
Is the slope of the regression curve at JQ less than SFS?	Yes
ASTM E813-89 Section 9.4.1.5:	
Are all precrack lengths within 7 pct. of the average?	Yes
Are all final crack lengths within 7 pct. of the average?	Yes
ASTM E813-89 Section 9.4.1.6:	
Are both near surface crack extensions within 0.02W of the extension at the center?	Yes
ASTM E813-89 Section 9.4.1.7:	
Is the difference between the crack extensions found from compliance and the 9-point averages within 15 pct. of either of the 9-point average or Delta a(p) max?	Yes
EM from 9-point precrack front average = 2.678e+004 ksi	
Is EM within 10 pct. of nominal E?	Yes
Is JQ = JIC per ASTM E813-89?	~~No~~ Yes

BCJ 7/19/01

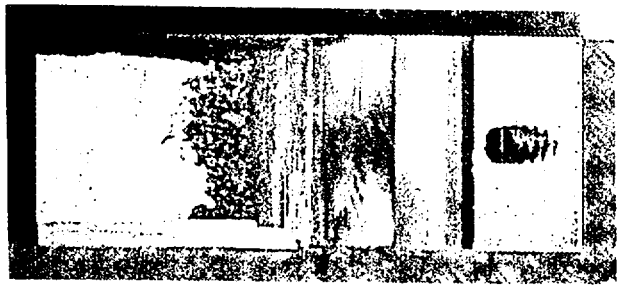
Appendix C

Fractographs for WT-9, WT-10, and WT-11



Specimen No. WT-9

Specimen No. WT-10



Specimen No. WT-11