Alcoa Green Letter
Volume I

Alcoa 7085 Die Forgings

7th Generation Structural Solutions

3rd Edition

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"Alcoa Moves the World"
"Alcoa Forgings – Building Better Solutions"

OUTLINE

1. Introduction

Aluminum Alloy 7085 was developed by Alcoa in response to the aerospace and other markets needs for an aluminum alloy with improved thick section properties. Alcoa is commercializing this new alloy in plate, sheet, extrusions and forgings. 7085 patents are pending. This Green Letter is focused on 7085 Die Forgings.

7085 can be thought of as Alcoa's 7th Generation structural forging alloy; following 2014, 7075, 7049, 7175, over aged tempers and 7050. Alloy 7085 has shown to be a significantly improved forging alloy because of its unprecedented thick section mechanical properties and its improved fracture toughness and fatigue properties. It's higher purity composition and highly quench insensitive microstructure has enabled 7085 Die Forgings to show no drop-off in strengths from 0 to 12 in. (0 to 30.5 cm) section thicknesses. This unique characteristic along with its significant improvement in fracture toughness allows the designer to think differently about structural parts. Instead of a customer purchasing an annealed temper, then having to rough machine before heat treat and age, and final machine, customers will now be able to specify a fully tempered 7085 and machine to final dimensions. This will eliminate customer-processing logistics, material-processing deviations and inventory costs.

7085 Die Forgings in the T7452 temper have been fully tested and characterized from 0 – 12 in. (0 to 30.5 cm), with A and B values generated so that no knockdown factors need to be applied. Alcoa's 10 lot design allowables have been reviewed, accepted, and approved through MMPDS (Military Handbook 5). Aerospace specification AMS4403 has been completed, approved, and sent to publication in August of 2006. The final 7085-T7452 data set will be included in the next publication (1 October 2006) of MMPDS (Military Handbook 5). The 7085-T7452 die forging data is the content of this Alcoa Green Letter entitled, "Volume I – Alcoa 7085 Die Forging, 7th Generation Structural Solutions".

In addition, our 10 lot design allowable test program is complete for hand forgings in the T7452 temper and has been submitted for MMPDS and AMS specification. The hand forging data can be found in a second Alcoa Green Letter entitled, "Volume II – Alcoa 7085 Hand Forging, 7th Generation Structural Solutions", July 2005 edition. Therefore, with A and B allowables generated for both hand and die forgings, it will be easy for a designer to start manufacturing a part from a hand forging, and then switch to a die forging when the volume justifies the higher investment in dies.

Over the past 5 years, Alcoa has also made significant improvements in our forging die modeling, design capabilities and residual stress control. This has enabled us to produce compressive stress relieved –52 tempers with lower residual stresses that lead to lower machine distortion and improved part quality. These proven (in over 40 cases) modeling and design improvements have also lead to significant improvements in 1st article lead times. We now normally quote 18-24 weeks instead of the historic 36-52 weeks.

Another value of the improved 7085 thick section properties, Alcoa's new design tools and our large press capabilities; is that this system enables the designer to consolidate multiple small parts and capture part and inventory cost savings.

While 7085 forgings are a good choice for medium size structural aerospace parts, they offer significant benefits for larger parts. 7085 forgings have been specified for large wing spars, gear ribs and terminal fitting and it is being analyzed for fuselage frames, bulkheads, engine supports, ribs, fittings, beams, landing gear, support parts, etc. Aircraft designers are finding potential weight savings of 2-5%. Several studies are also underway for part consolidation with potential of 10-50% cost savings.

In summary, Alcoa's new 7th generation 7085 forgings with its breakthrough thick section properties and significantly improved fracture toughness and fatigue properties will enable structural part designers to capture new value by designing lower weight parts or longer lasting parts. It can also reduce costs by eliminating separate heat treat processing and by consolidating parts. As always Alcoa's Application Engineers and Forging Commercial Team stands ready to work with you to upgrade your current parts or design your next generation parts.

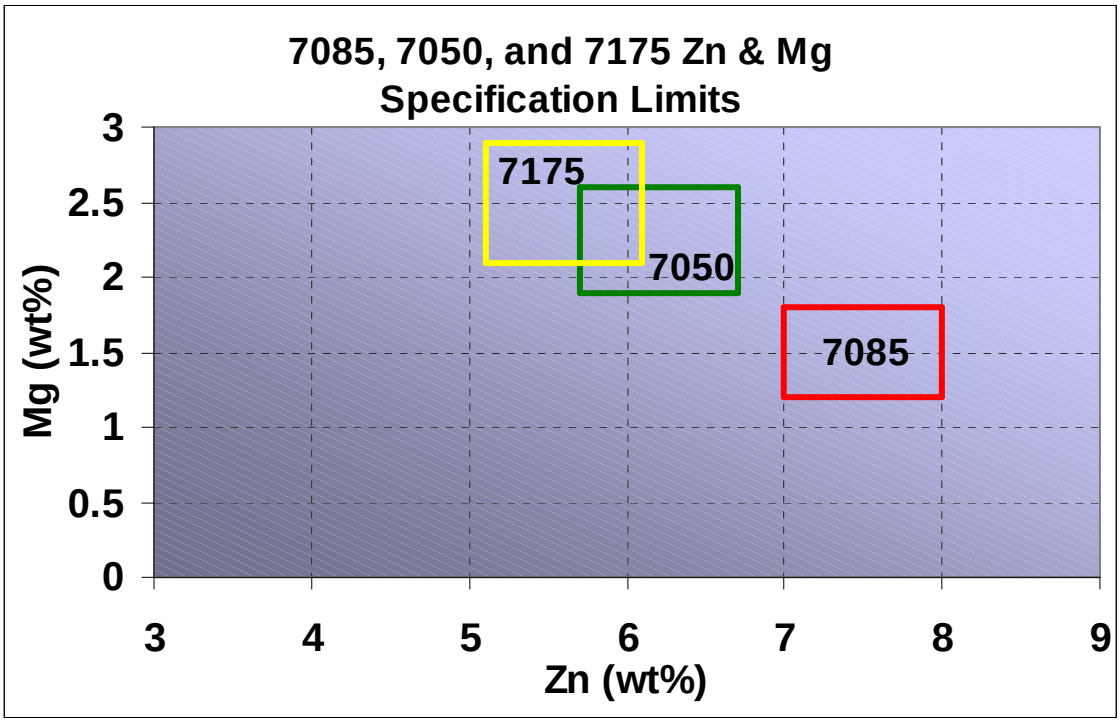
2. Chemical Composition and Microstructure

Alcoa Alloy 7085 is a new high purity, high Zinc content 7XXX aluminum alloy developed at Alcoa Technical Center. The chemical composition specification limits are:

7085 Chemical Composition Specification Limits (wt.%)

	Zn	Mg	Cu	Fe	Si	Zr	
Max	8.0	1.8	2.0	0.08	0.06	0.15	
Min	7.0	1.2	1.3	N/A	N/A	0.08	

The following Mg – Zn graph shows how 7085 compares to 7175 and 7050. Advances in casting technology has enable Alcoa to develop this new high zinc alloy.



3. Physical Properties

	7085-T7452	7050-T7452	Dimensions
Density	0.103	0.102	lb/in^3
	2.85	2.82	g/cm^3
Electrical Conductivity	41.5%	40.5%	IACS
	24.1	23.5	MS/m
Melting Range	1025-1175	910-1165	°F
	552-635	488-629	°C
Specific Heat @212°F (100°C)	0.21	0.23	Btu/lb/°F
	0.884	0.963	J/g/°C
Average Calculated Thermal Conductivity @212°F (100°C)	92.2	91	Btu/((hr ft^2 °F)/ft)
	0.382	0.377	cal/((sec cm^2 °C)/cm)
	159.5	157.4	W/(m-°K)
Average Thermal Diffusivity @212°F (100°C)	0.631	N/A	cm^2/s
Average Coefficient of Thermal Expansion 68 - 212°F (20 - 100°C)	13.7	12.8	x 10-6 in./in./ °F
	24.7	23.0	x 10-6 m/m/°C

4. Mechanical Properties

Alloy 7085's microstructure was designed to be highly quench insensitive. Alcoa's 10 lot design allowable test results for the T7452 die forgings show unprecedented thick section properties. There is no decrease in tensile ultimate or yield strengths for die forgings in the thickness range from 1 to 12 in. (2.54 to 30.5 cm). We tested over 300 specimens from 6 different die forgings and over 10 different chemistries. This extensive testing program enabled us to statistically derive A and B design allowables. These values have been checked by Battelle and approved under AMS 4403 and by the MMPDS (MIL-HDBK-5) Committee. There will not be a need to apply a knockdown factor, as is the case with other alloys that have only S allowables. The comparison plots in this section show how 7085 compares to 7050 and 7175 across the thickness range.

In addition, our 10 lot design allowable test program has been completed for hand forgings in the T7452 temper and is documented in the Alcoa Green Letter "Volume II – Alcoa 7085 Hand Forging, 7th Generation Structural Solutions", July 2006.

In this section are:

1. An updated full A and B Design Allowable Table for 7085-T7452 Die Forgings from 1 to 12 in. (25 to 305 mm) in English and SI units, appearing as it will in the 1 October 2006 publication of MMPDS.
2. Comparison plots of 7085, 7050 and 7175 die forging minimums in the T7452 temper, for the L and T directions, showing Ftu, Fty and elongation versus section thickness.
3. The 10 lot design allowable data for 7085-T7452 Die Forgings plotted along with the submitted A design allowables.
4. Typical Stress-Strain Curve.

7085-T7452 Die Forgings
As Will Be Listed in MMPDS-03
Publication: 1 October 2006
US Units

Specification.....	AMS 4403											
Form.....	Die Forging											
Temper.....	T7452											
Thickness, (in.).....	1.000-2.000		2.001-4.000		4.001-6.000		6.001-8.000		8.001-10.000		10.001-12.000	
Basis.....	A	B	A	B	A	B	A	B	A	B	A	B
Mechanical Properties:												
F_{tu}, ksi:												
L	72	73	72	73	72	73	72	73	72	73	72	73
LT	70	72	70	72	70	72	70	72	70	72	70	72
ST	70	71	70	71	70	71	70	71	70	71	70	71
F_{ty}, ksi:												
L	65	67	65	67	65	67	65	67	65	67	65	67
LT	62	65	62	65	62	65	62	65	62	65	62	65
ST	59	61	59	61	59	61	59	61	59	61	59	61
F_{cy}, ksi:												
L	66	68	66	68	66	68	66	68	66	68	66	68
LT	66	68	66	68	66	68	66	68	66	68	66	68
ST	67	69	67	69	67	69	67	69	67	69	67	69
F_{su}[a], ksi:												
L-S.....	41	41	41	41	41	41	41	41	41	41	41	41
T-S	40	40	40	40	40	40	40	40	40	40	40	40
S-L.....	40	41	40	40	39	40	38	38	36	37	35	35
F_{bru}[b] (e/D = 1.5), ksi:												
L	105	105	103	105	101	102	99	100	96	97	93	94
LT	103	103	101	103	99	100	96	97	92	94	89	90
ST	98	99	97	99	96	97	94	95	91	92	88	89
F_{bru}[b] (e/D = 2.0), ksi:												
L	136	137	134	136	132	134	130	132	127	129	124	126
LT	135	137	133	135	130	132	127	129	123	125	120	121
ST	129	130	127	129	125	127	123	124	119	121	115	117
F_{bry}[b] (e/D = 1.5), ksi:												
L	88	91	88	91	88	91	88	91	88	91	88	91
LT	88	90	87	89	85	88	83	86	81	84	79	82
ST	84	86	84	86	84	86	84	86	84	86	84	86
F_{bry}[b] (e/D = 2.0), ksi:												
L	101	104	101	104	101	104	101	104	101	104	101	104
LT	102	105	100	104	99	102	97	100	94	97	91	94
ST	100	103	100	103	100	103	100	103	100	103	100	103
e, percent (S-basis):												
L	10		9		9		8		7		7	
LT	8		7		7		6		5		4	
ST	5		5		4		4		3		3	
E, 10^3 ksi.....	10.1											

E_C, 10^3 ksi.....	10.4
G, 10^3 ksi.....	3.9
μ.....	0.33
Physical Properties:	
w, lb./in.$^{3.}$.....	0.103
C,K, and a.....	---

Issued: April 2006, MMPDS-03, Item 04-27;

[a]Standard letter designations for shear properties per ASTM B769. The first letter designates the grain orientation normal to the shear plane. The second letter designates the direction of loading.

[b]Bearing values are "dry pin" values per Section 1.4.7.1.

7085-T7452 Die Forgings
As Will Be Listed in MMPDS-03
Publication: 1 October 2006
Metric Units

Specification.....	AMS 4403											
Form.....	Die Forging											
Temper.....	T7452											
Thickness, (mm.).....	25.4-50.8		51 - 102		102 -152		152 – 203		203 – 254		254 – 305	
Basis.....	A	B	A	B	A	B	A	B	A	B	A	B
Mechanical Properties:												
F_{tu}, MPa:												
L	496	503	496	503	496	503	496	503	496	503	496	503
LT	482	496	482	496	482	496	482	496	482	496	482	496
ST	482	489	482	489	482	489	482	489	482	489	482	489
F_{ty}, MPa:												
L	448	462	448	462	448	462	448	462	448	462	448	462
LT	427	448	427	448	427	448	427	448	427	448	427	448
ST	407	420	407	420	407	420	407	420	407	420	407	420
F_{cy}, MPa:												
L	455	469	455	469	455	469	455	469	455	469	455	469
LT	455	469	455	469	455	469	455	469	455	469	455	469
ST	462	475	462	475	462	475	462	475	462	475	462	475
F_{su}[a], MPa:.....												
L-S.....	282	282	282	282	282	282	282	282	282	282	282	282
T-S	276	276	276	276	276	276	276	276	276	276	276	276
S-L.....	276	282	276	276	269	276	262	262	248	255	241	241
F_{bru}[b] (e/D = 1.5), MPa:												
L	723	723	710	723	696	703	682	689	661	668	641	648
LT	710	710	696	710	682	689	661	668	634	648	613	620
ST	675	682	668	682	661	668	648	655	627	634	606	613
F_{bru}[b] (e/D = 2.0), MPa:												
L	937	944	923	937	909	923	896	909	875	889	854	868
LT	930	944	916	930	896	909	875	889	847	861	827	834
ST	889	896	875	889	861	875	847	854	820	834	792	806
F_{bry}[b] (e/D = 1.5), MPa:												
L	606	627	606	627	606	627	606	627	606	627	606	627
LT	606	620	599	613	586	606	572	593	558	579	544	565
ST	579	593	579	593	579	593	579	593	579	593	579	593
F_{bry}[b] (e/D = 2.0), MPa:												
L	696	717	696	717	696	717	696	717	696	717	696	717
LT	703	723	689	717	682	703	668	689	648	668	627	648
ST	689	710	689	710	689	710	689	710	689	710	689	710
e, percent (S-basis):												
L	10		9		9		8		7		7	
LT	8		7		7		6		5		4	
ST	5		5		4		4		3		3	
E, 10^3 MPa.....	69.6											

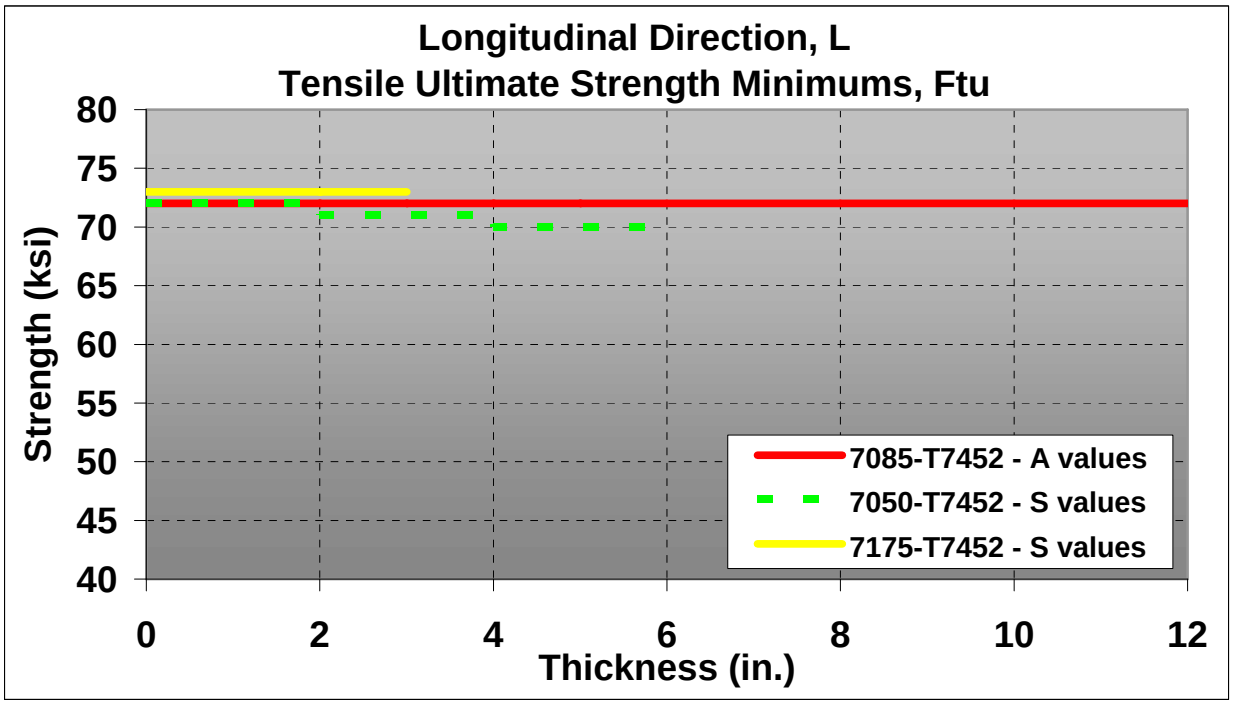
E_C, 10^3 MPa.....	71.7
G, 10^3 MPa.....	26.9
μ.....	0.33
Physical Properties:	
w, gm./cm.$^{3.}$.....	2.851
C,K, and a.....	---

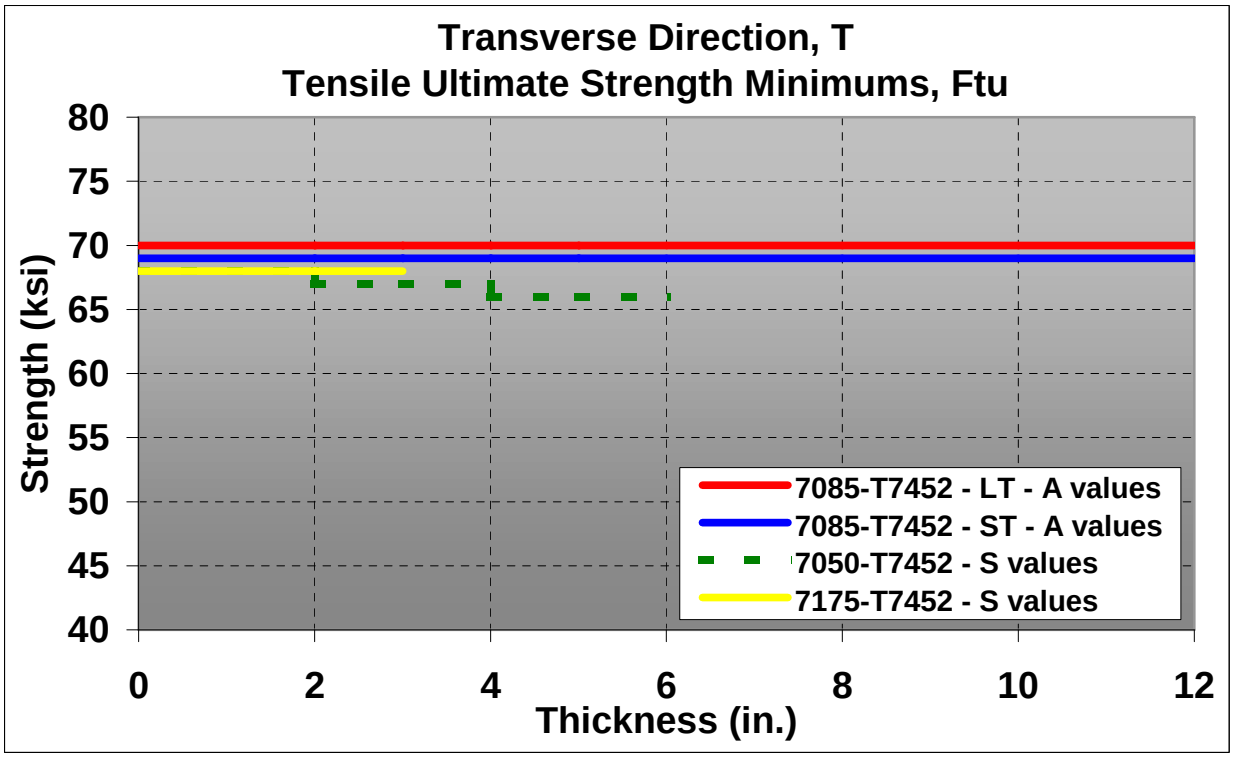
Issued: April 2006, MMPDS-03, Item 04-27;

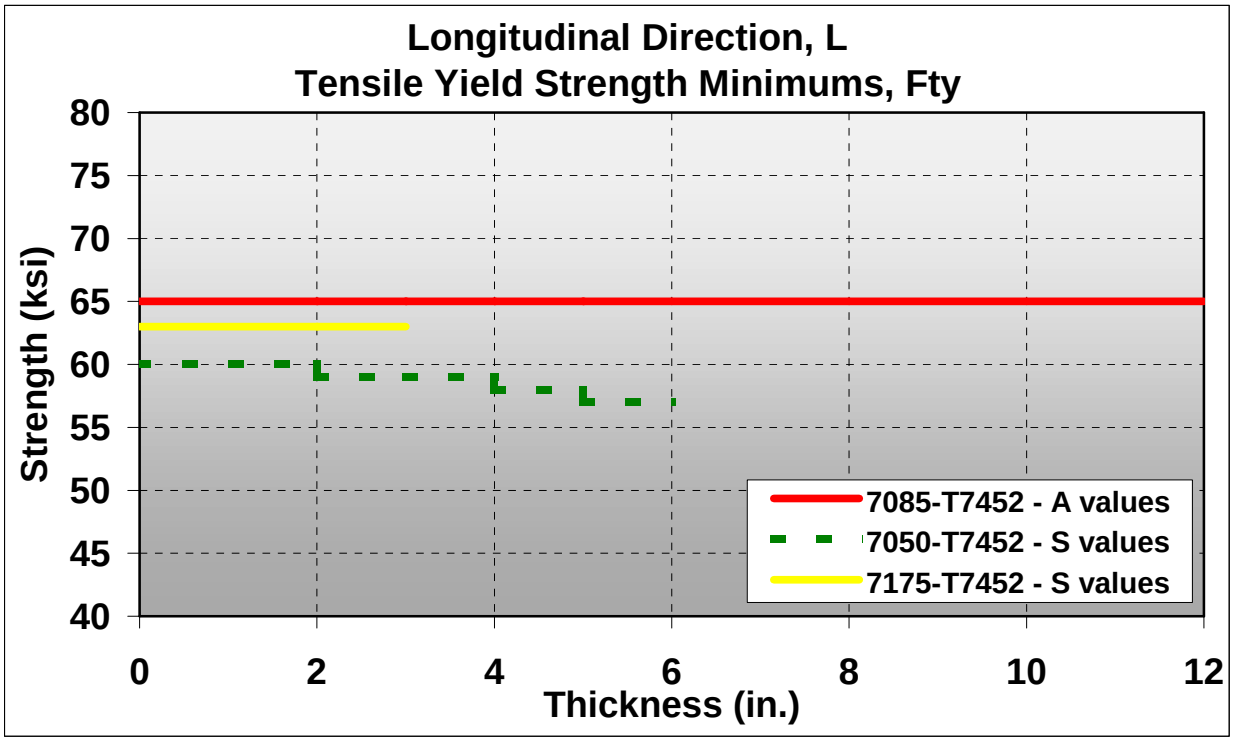
[a]Standard letter designations for shear properties per ASTM B769. The first letter designates the grain orientation normal to the shear plane. The second letter designates the direction of loading.

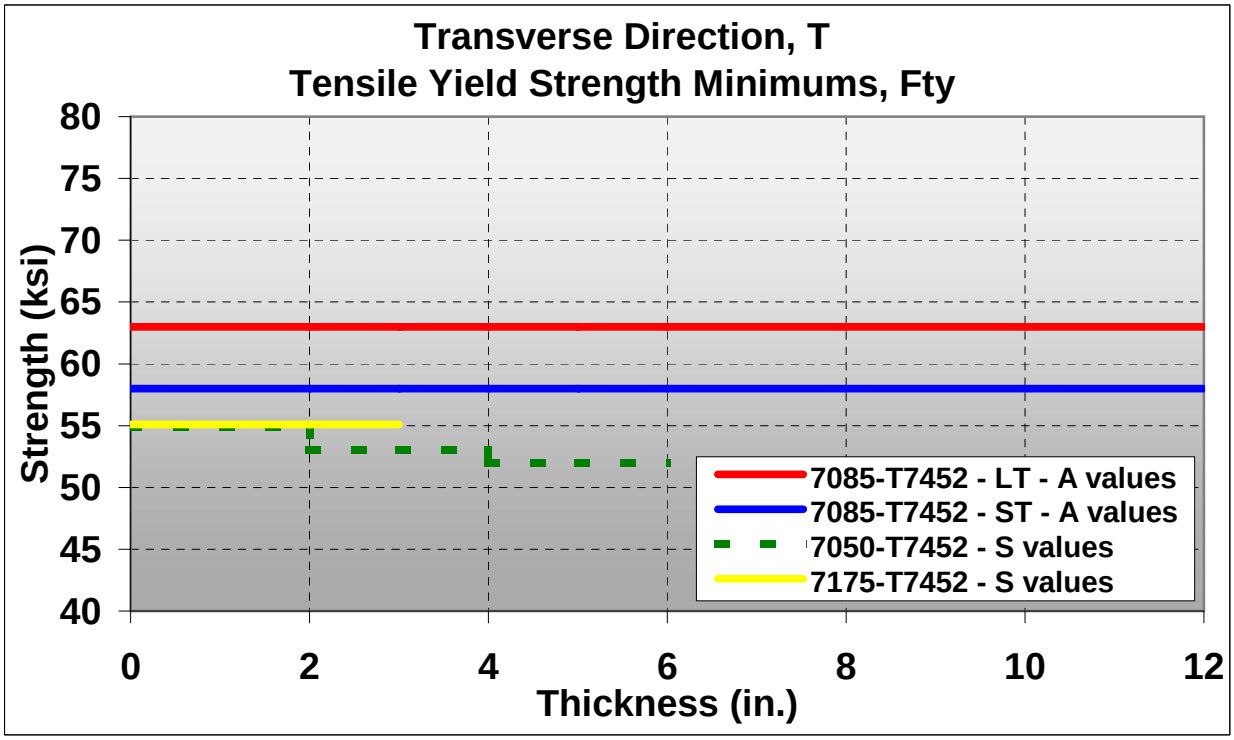
[b]Bearing values are "dry pin" values per Section 1.4.7.1.

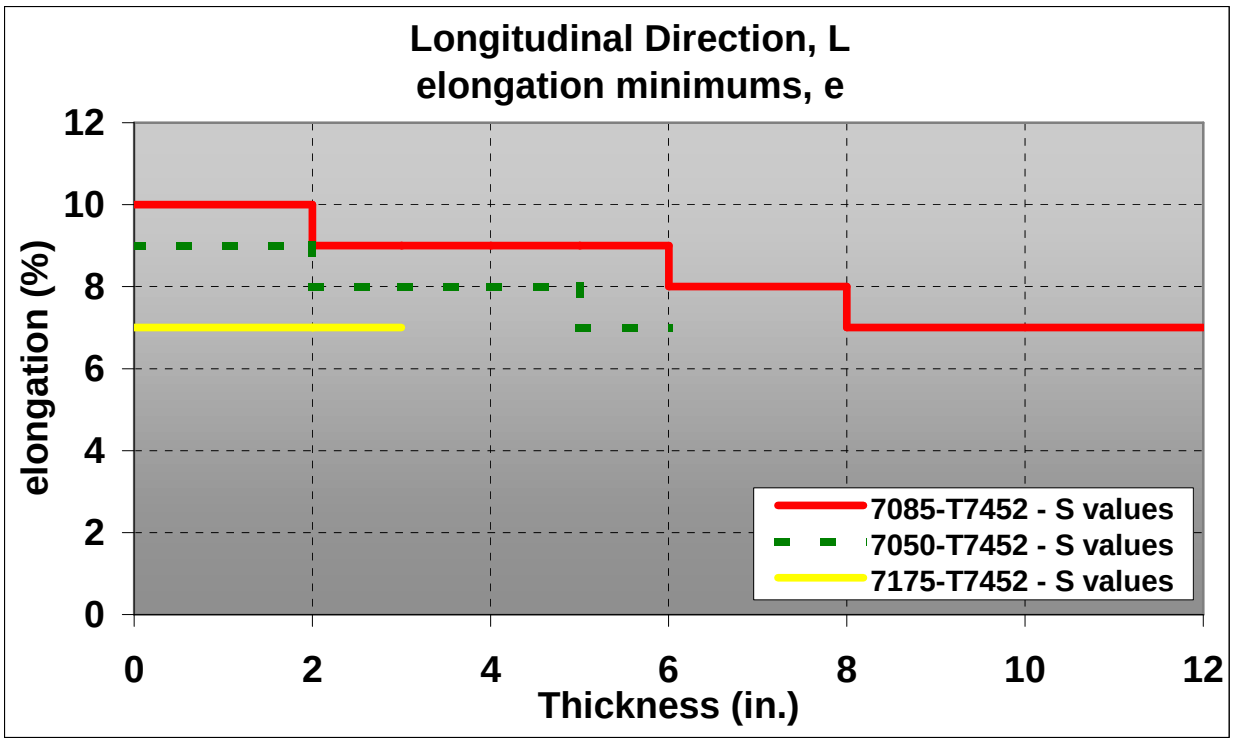
Comparison plots of 7085, 7050 and 7175-T7452 Mechanical Properties.

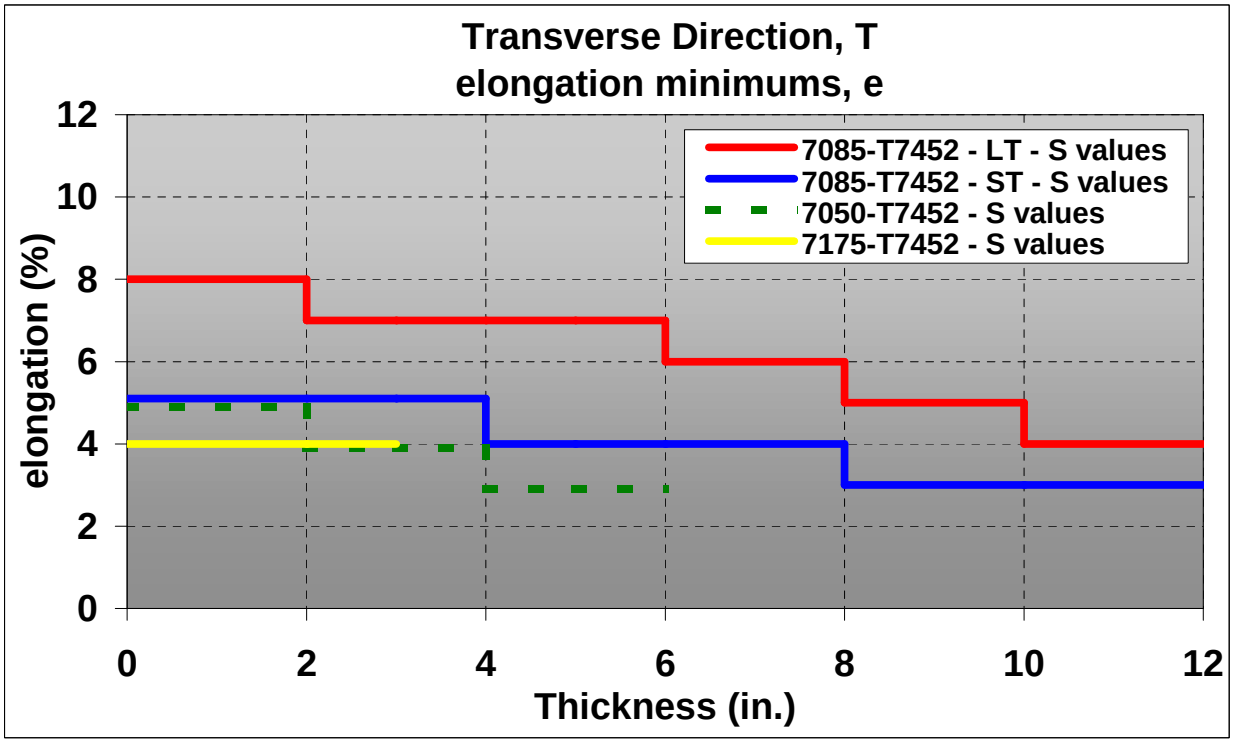


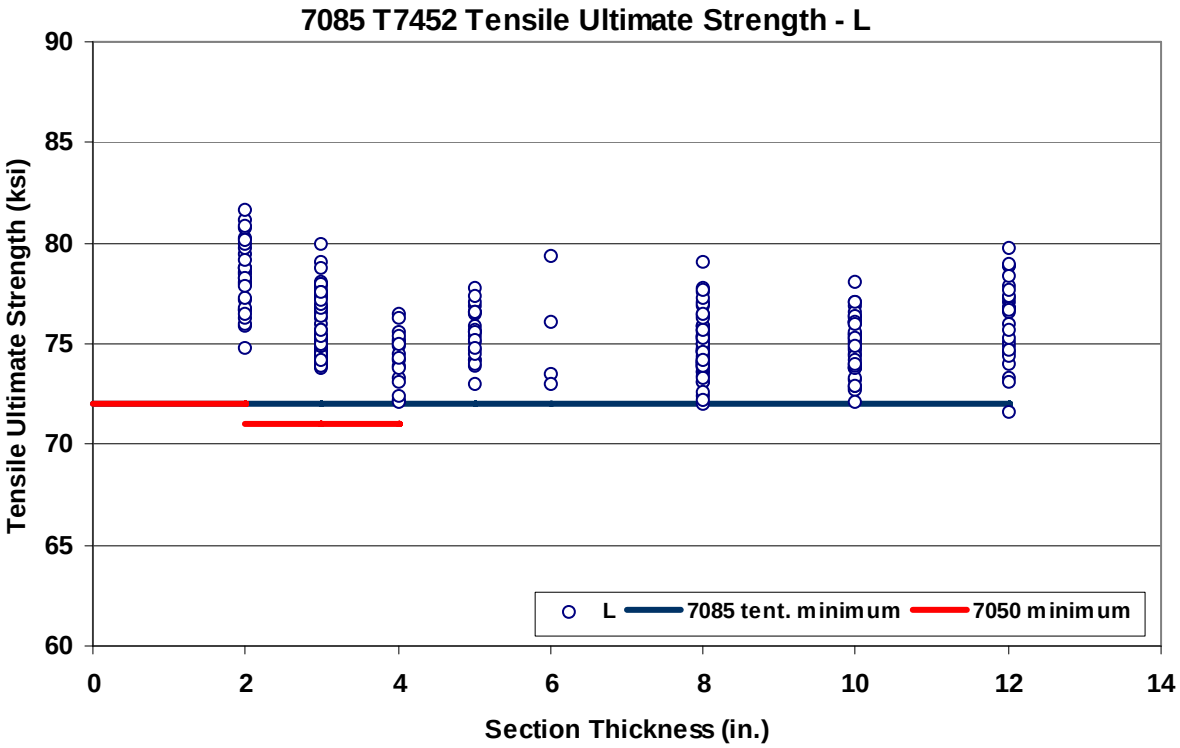


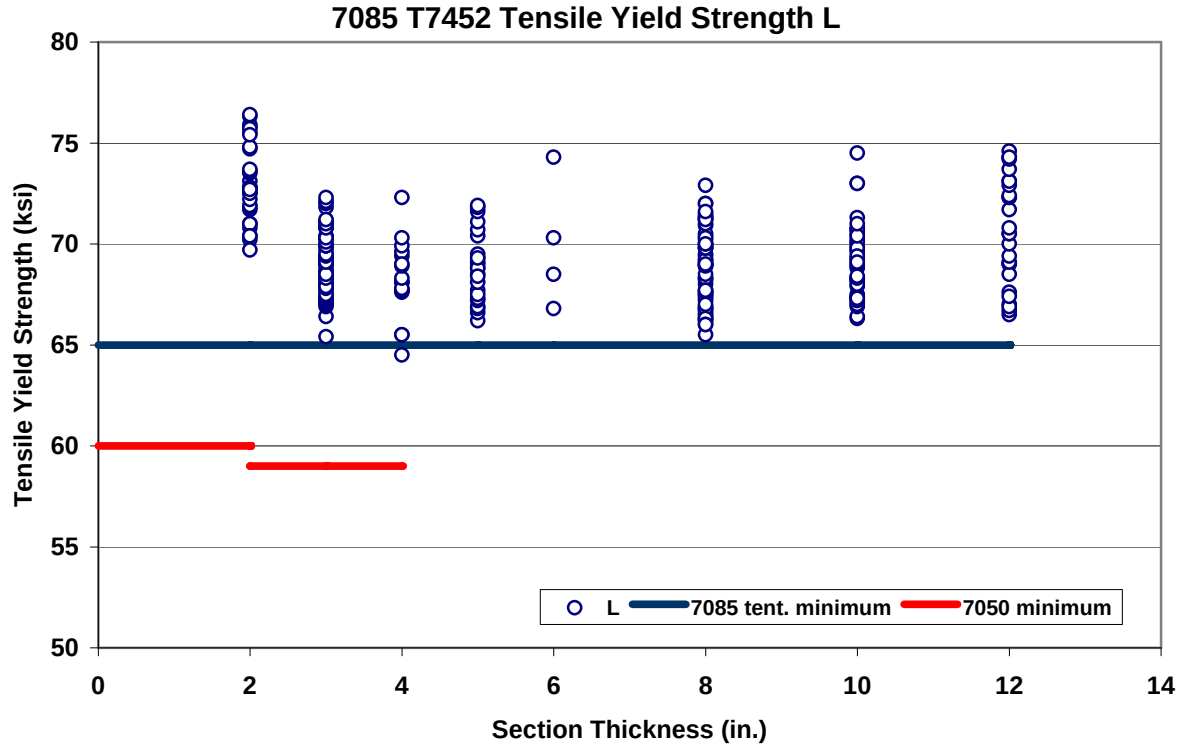

Longitudinal Direction, L
Tensile Yield Strength Minimums, Fty
Strength (ksi)
80
75
70
65
60
55
50
45
40
0
2
4
6
8
10
12
Thickness (in.)
7085-T7452 - A values
7050-T7452 - S values
7175-T7452 - S values

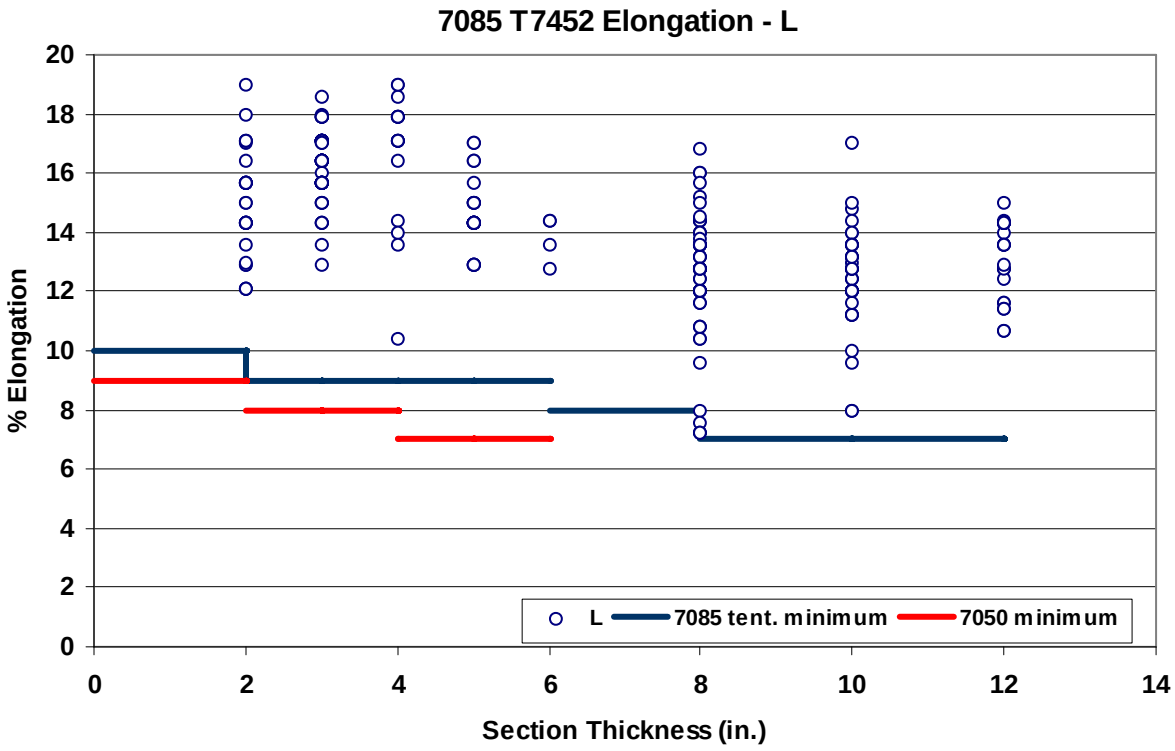

Transverse Direction, T
Tensile Yield Strength Minimums, Fty
Strength (ksi)
80
75
70
65
60
55
50
45
40
0
2
4
6
8
10
12
Thickness (in.)
7085-T7452 - LT - A values
7085-T7452 - ST - A values
7050-T7452 - S values
7175-T7452 - S values

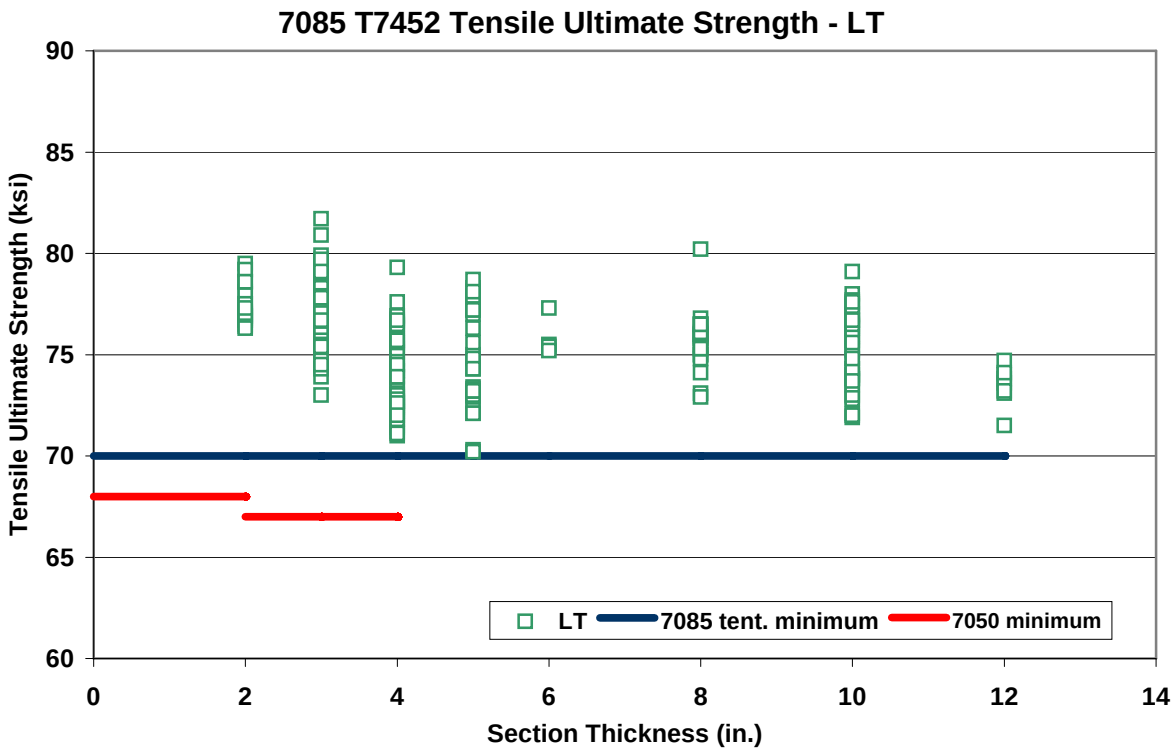

Longitudinal Direction, L
elongation minimums, e
elongation (%)
Thickness (in.)
0
2
4
6
8
10
12
7085-T7452 - S values
7050-T7452 - S values
7175-T7452 - S values

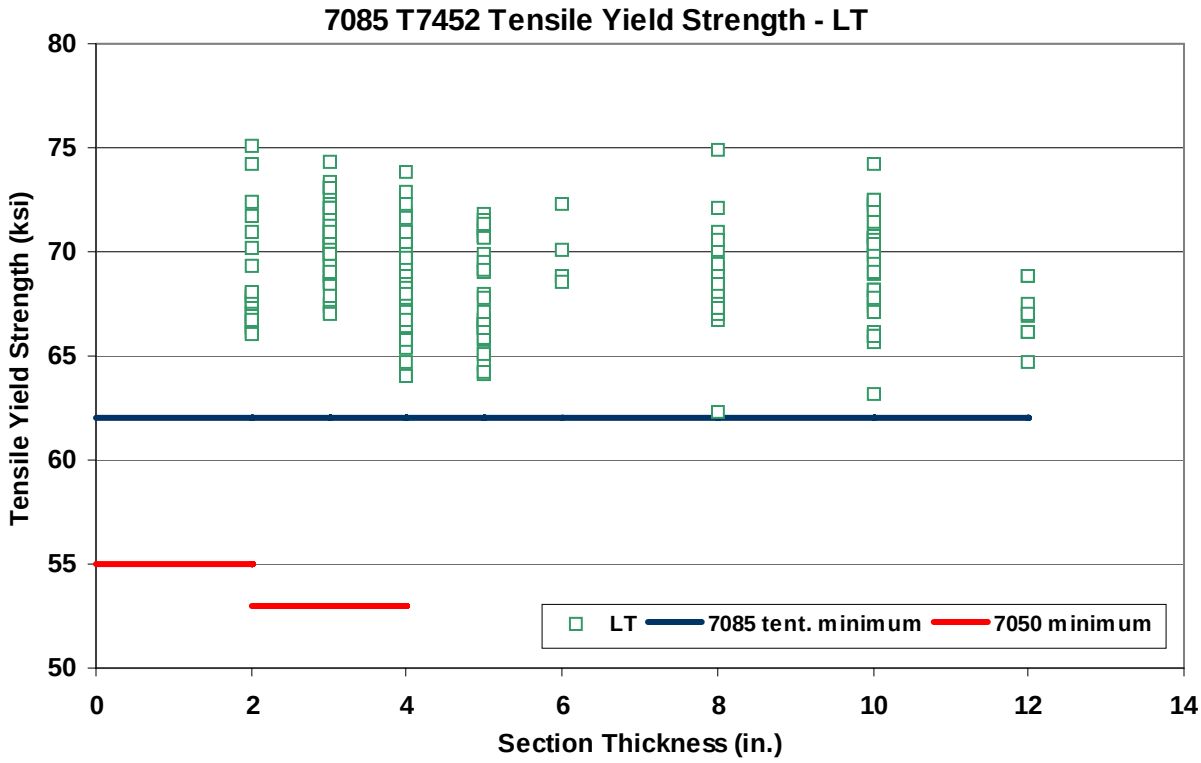

Transverse Direction, T
elongation minimums, e
elongation (%)
Thickness (in.)
0
2
4
6
8
10
12
7085-T7452 - LT - S values
7085-T7452 - ST - S values
7050-T7452 - S values
7175-T7452 - S values

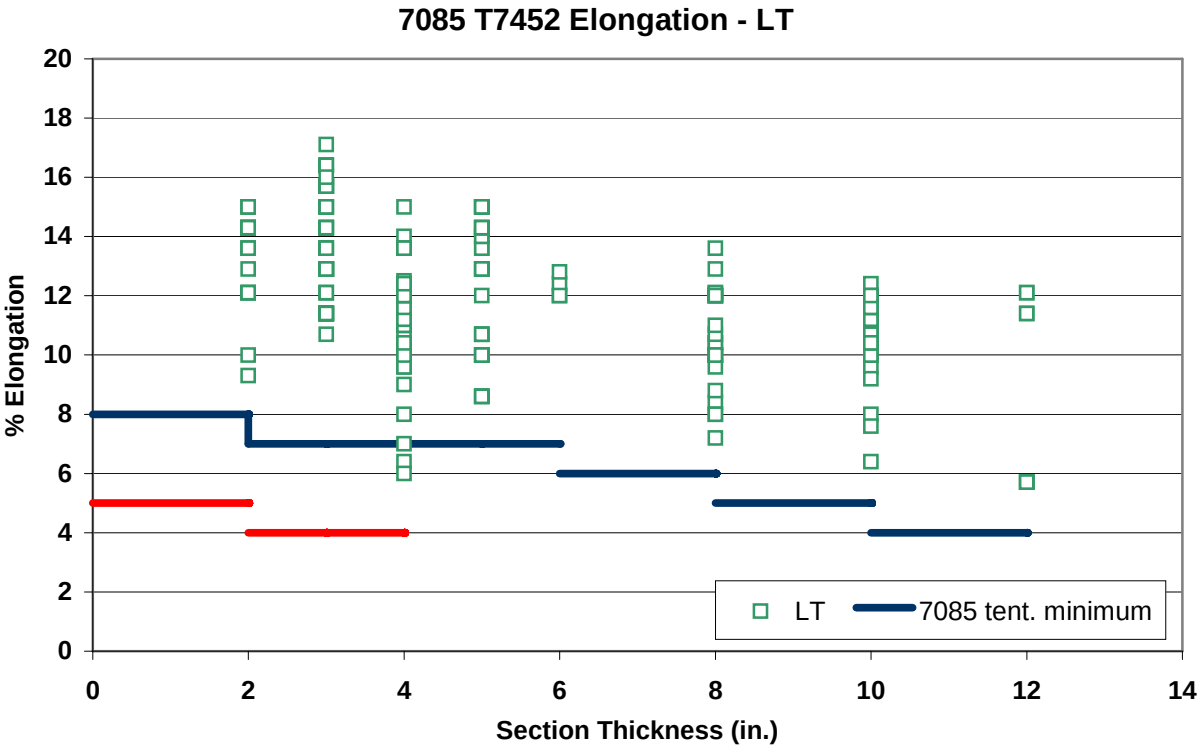

7085 T7452 Tensile Ultimate Strength - L
Tensile Ultimate Strength (ksi)
90
85
80
75
70
65
60
0
2
4
6
8
10
12
14
Section Thickness (in.)
L
7085 tent. minimum
7050 minimum

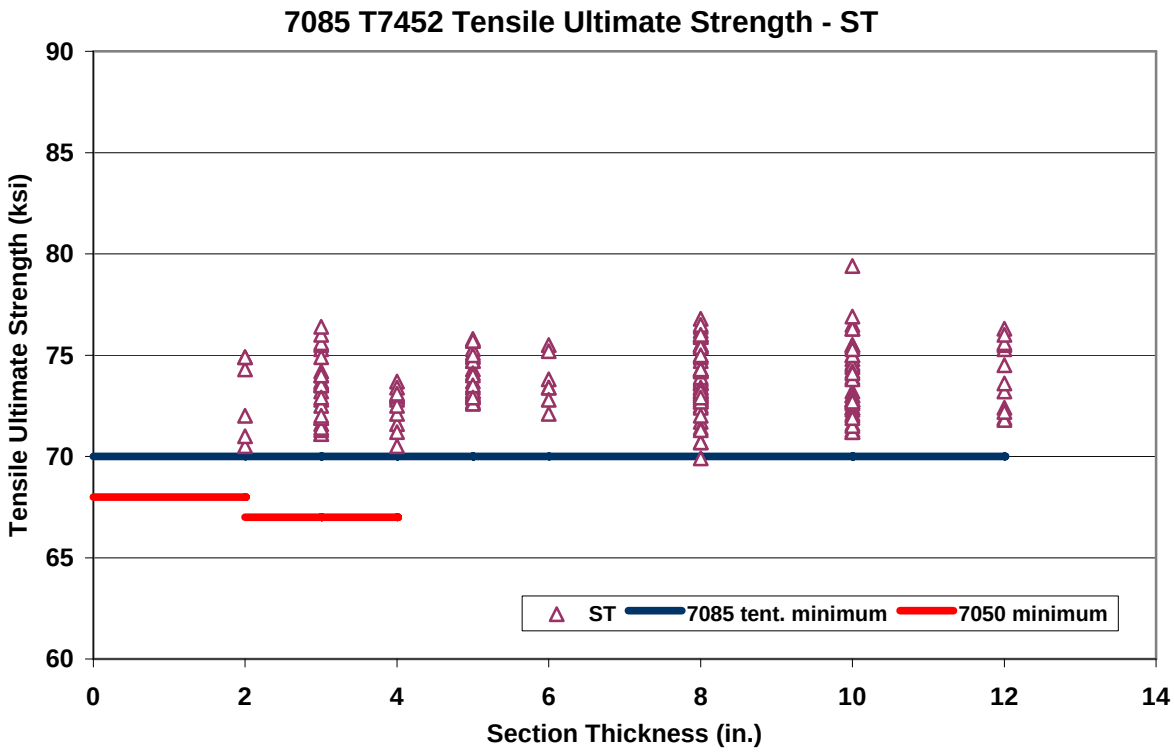

7085 T7452 Tensile Yield Strength L
Tensile Yield Strength (ksi)
80
75
70
65
60
55
50
0
2
4
6
8
10
12
14
Section Thickness (in.)
L
7085 tent. minimum
7050 minimum

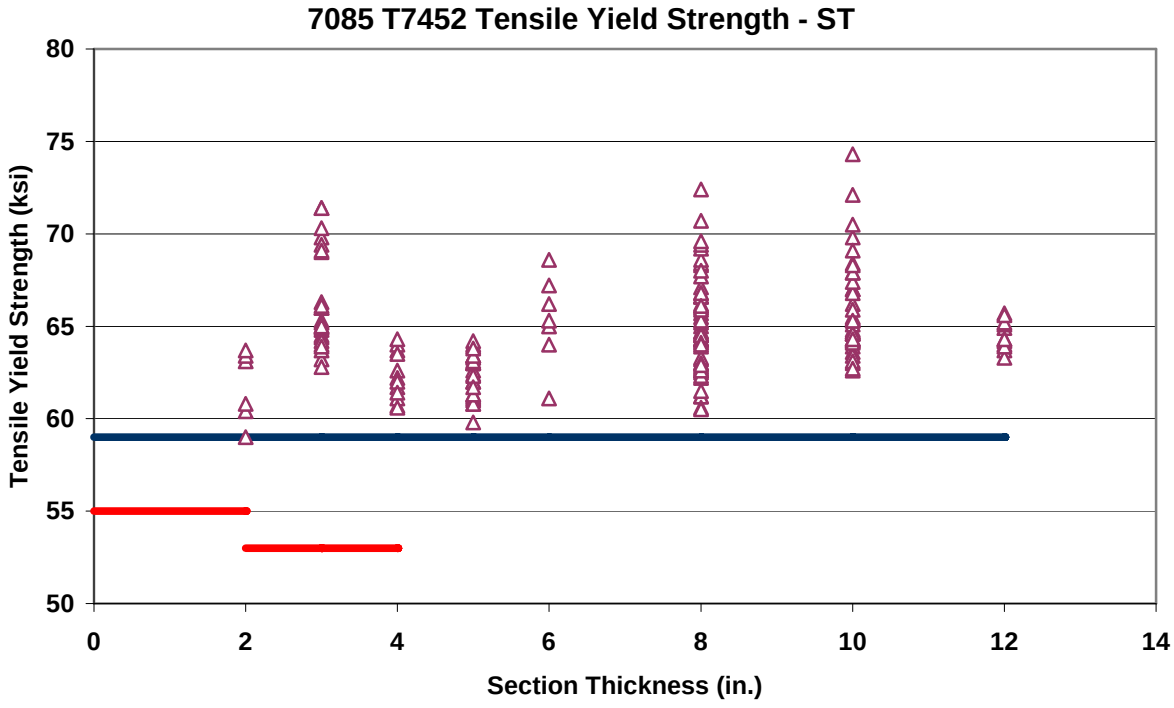

7085 T7452 Elongation - L
% Elongation
Section Thickness (in.)
L
7085 tent. minimum
7050 minimum

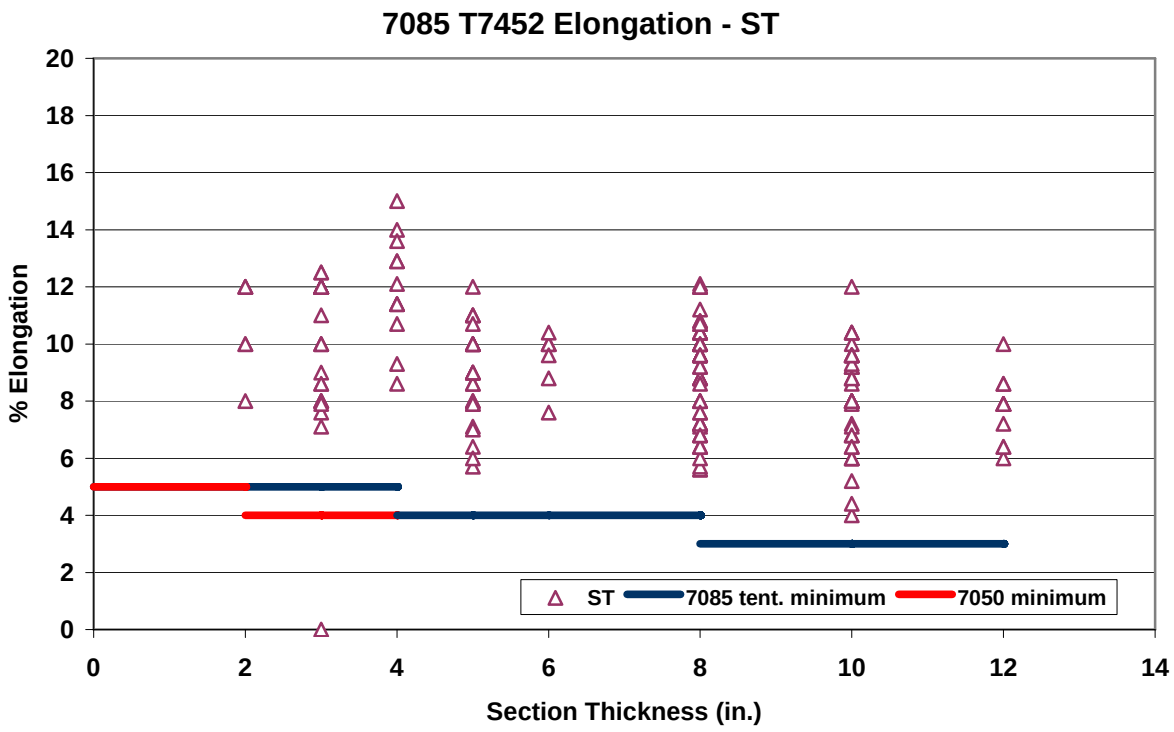

7085 T7452 Tensile Ultimate Strength - LT
Tensile Ultimate Strength (ksi)
Section Thickness (in.)
LT
7085 tent. minimum
7050 minimum

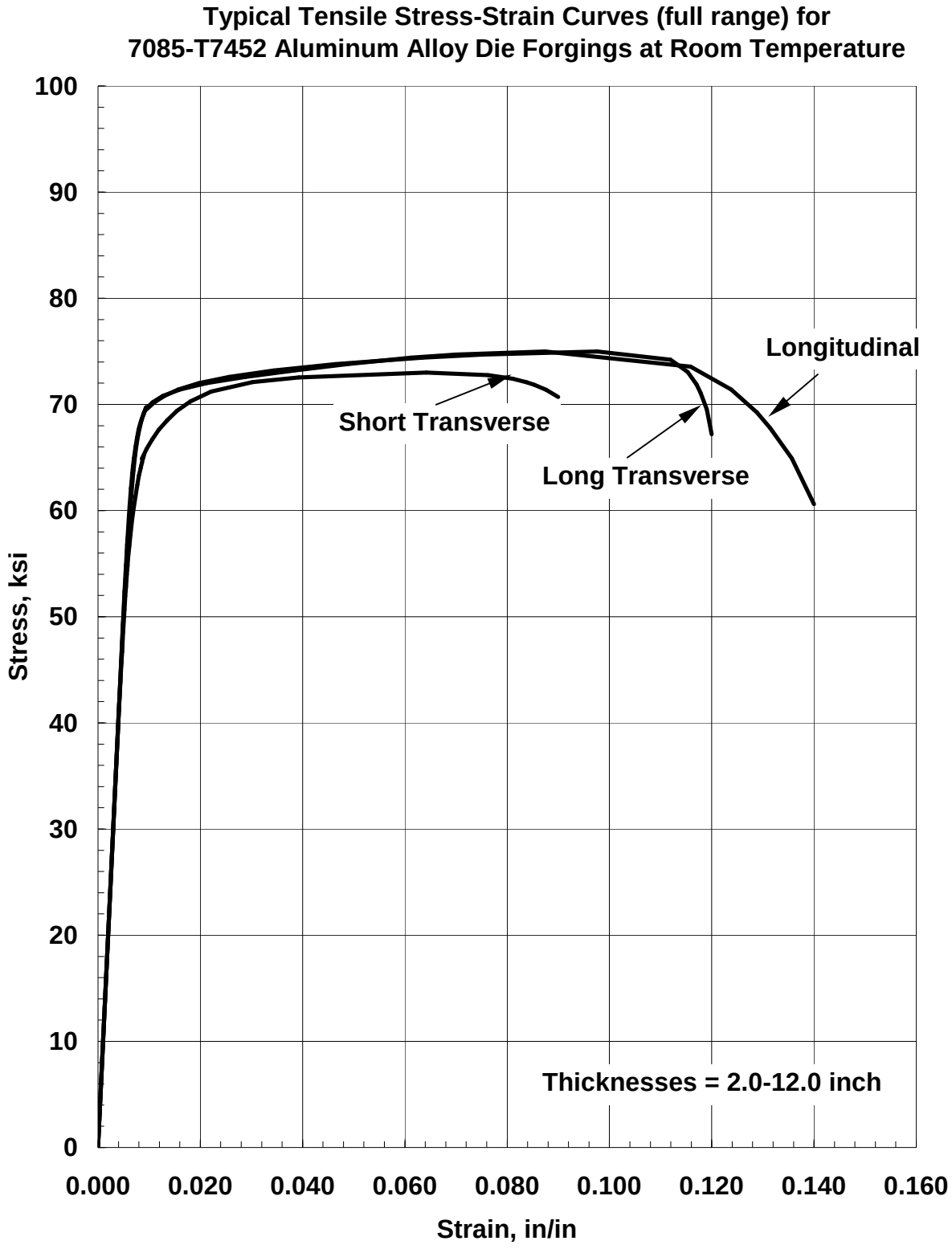

7085 T7452 Tensile Yield Strength - LT
Tensile Yield Strength (ksi)
80
75
70
65
60
55
50
0
2
4
6
8
10
12
14
Section Thickness (in.)
LT
7085 tent. minimum
7050 minimum

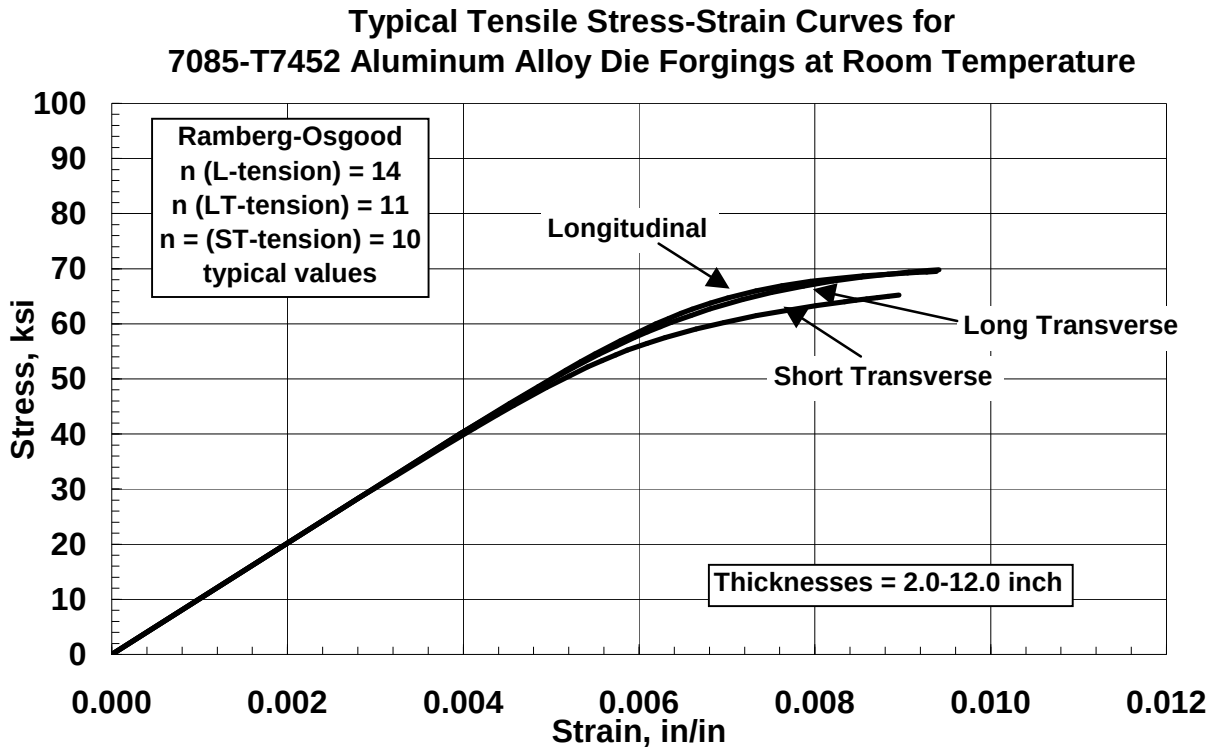

7085 T7452 Elongation - LT
% Elongation
20
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Section Thickness (in.)
LT
7085 tent. minimum

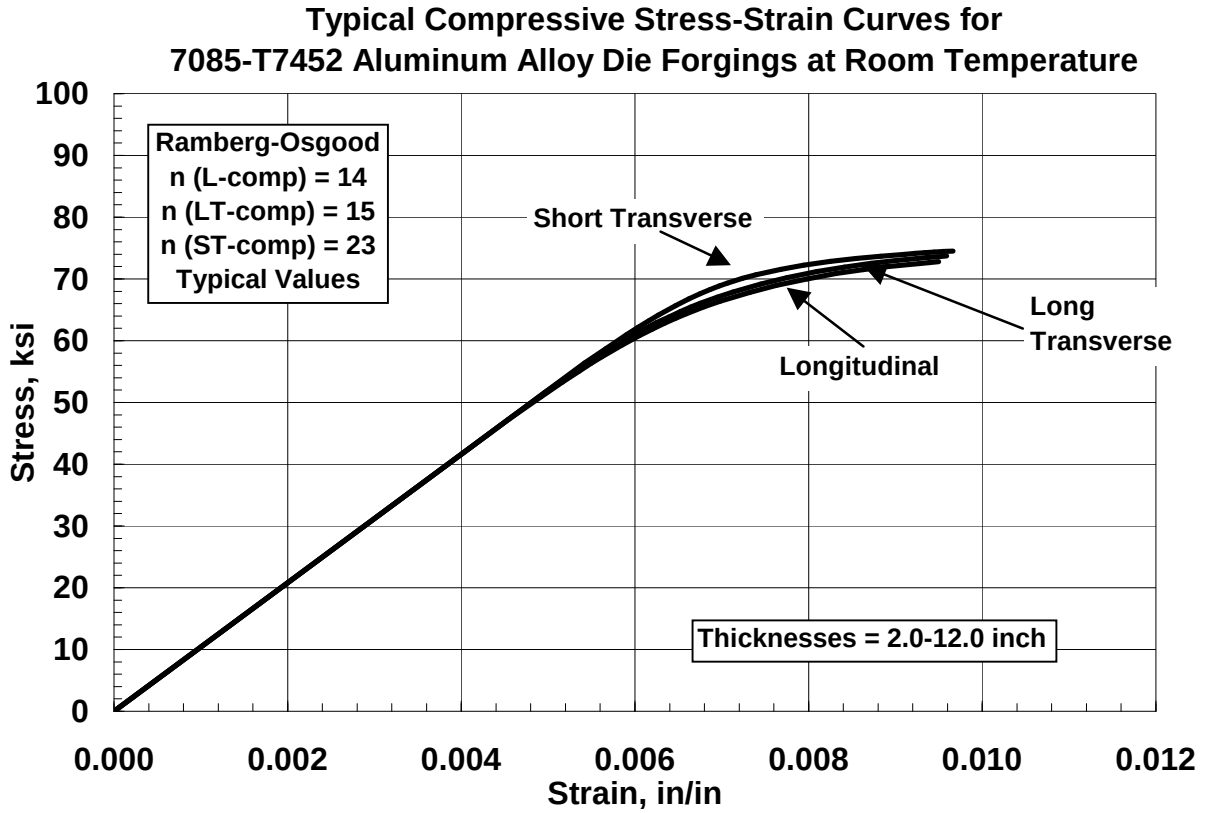

7085 T7452 Tensile Ultimate Strength - ST
Tensile Ultimate Strength (ksi)
90
85
80
75
70
65
60
0
2
4
6
8
10
12
14
Section Thickness (in.)
ST
7085 tent. minimum
7050 minimum


7085 T7452 Tensile Yield Strength - ST
Tensile Yield Strength (ksi)
80
75
70
65
60
55
50
0
2
4
6
8
10
12
14
Section Thickness (in.)

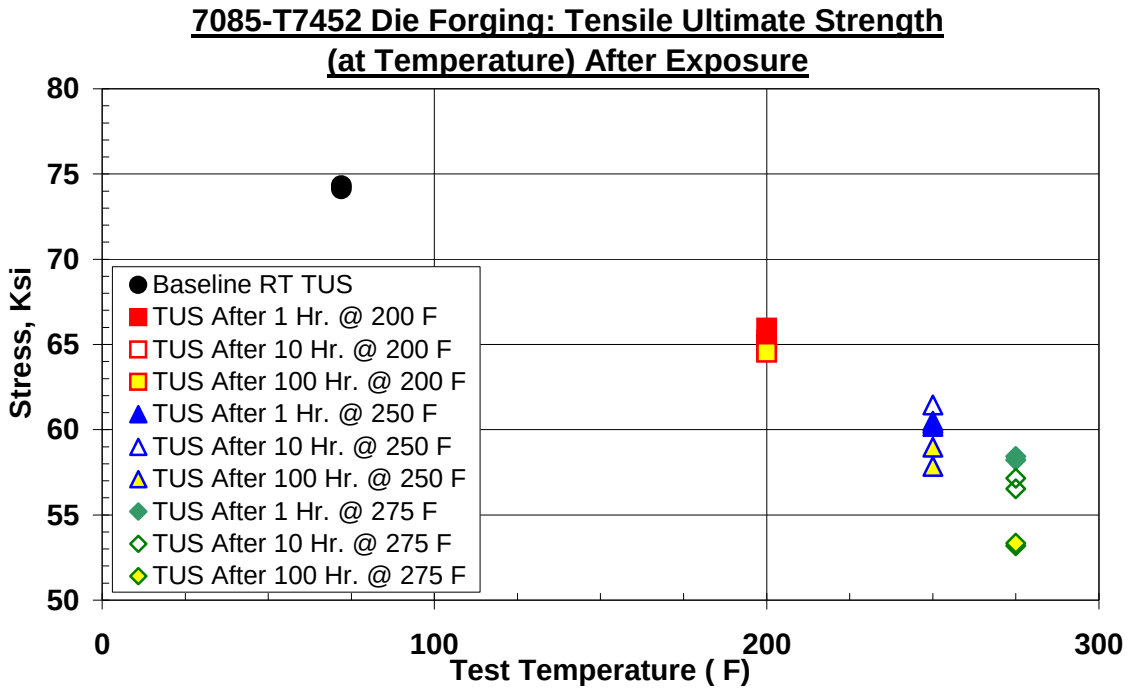

7085 T7452 Elongation - ST
% Elongation
Section Thickness (in.)
ST
7085 tent. minimum
7050 minimum
0
2
4
6
8
10
12
14
16
18
20

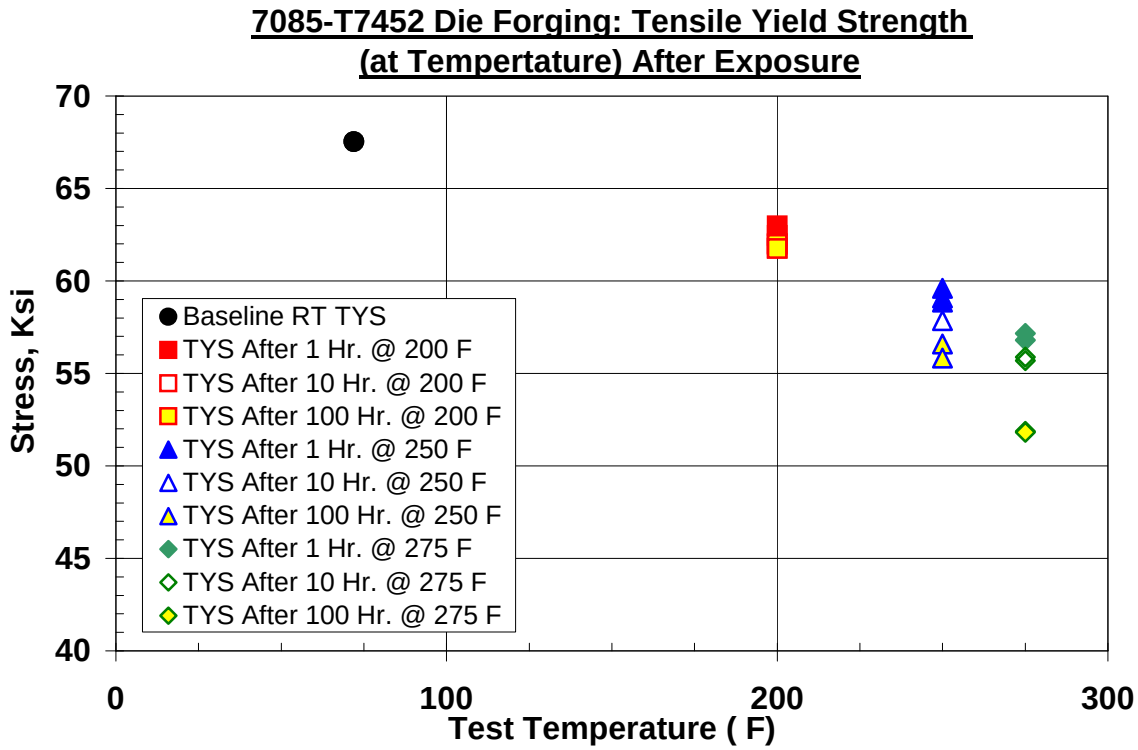

Typical Tensile Stress-Strain Curves (full range) for
7085-T7452 Aluminum Alloy Die Forgings at Room Temperature
Stress, ksi
100
90
80
70
60
50
40
30
20
10
0
0.000
0.020
0.040
0.060
0.080
0.100
0.120
0.140
0.160
Strain, in/in
Longitudinal
Short Transverse
Long Transverse
Thicknesses = 2.0-12.0 inch


Typical Tensile Stress-Strain Curves for
7085-T7452 Aluminum Alloy Die Forgings at Room Temperature
Ramberg-Osgood
n (L-tension) = 14
n (LT-tension) = 11
n = (ST-tension) = 10
typical values
Longitudinal
Long Transverse
Short Transverse
Thicknesses = 2.0-12.0 inch
Stress, ksi
Strain, in/in
0
10
20
30
40
50
60
70
80
90
100
0.000
0.002
0.004
0.006
0.008
0.010
0.012


Typical Compressive Stress-Strain Curves for
7085-T7452 Aluminum Alloy Die Forgings at Room Temperature
Ramberg-Osgood
n (L-comp) = 14
n (LT-comp) = 15
n (ST-comp) = 23
Typical Values
Short Transverse
Long
Transverse
Longitudinal
Thicknesses = 2.0-12.0 inch
Stress, ksi
Strain, in/in
0
10
20
30
40
50
60
70
80
90
100
0.000
0.002
0.004
0.006
0.008
0.010
0.012

5. Elevated Temperature Properties





6. Fracture Toughness Properties

7085-T7452 Die Forgings have shown improved fracture toughness properties. The table below (as it will be listed in MMPDS) represents the approved linear regression developed KIC values as obtained during allowables development. Over 190 fracture toughness tests were conducted to do this statistical analysis. The actual data and suggested minimums plotted against section thickness are shown on the following pages.

Plane strain fracture toughness information for Table 3.1.2.1.6

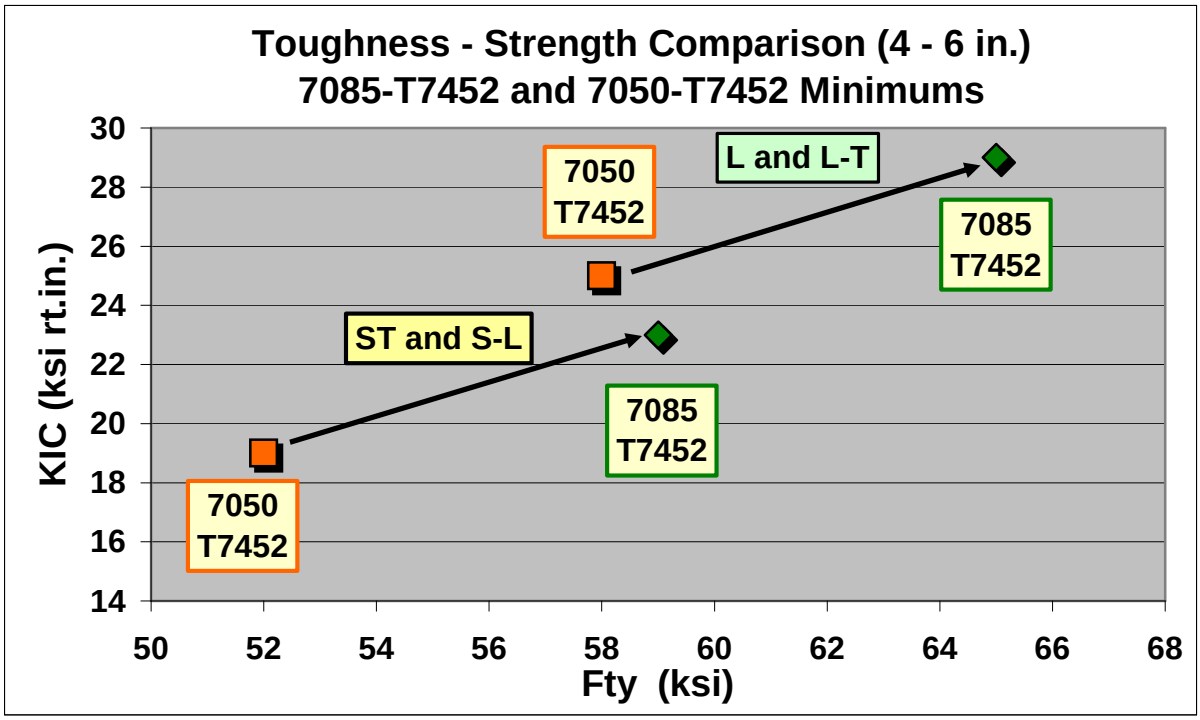
Orientation	Product Thickness Range, in.	No. of Sources	Sample Size	Specimen Thickness Range, in.	K_{1C}, ksi √in				
					Max.	Avg.	Min.	COV%	Spec.
L-T	1.000 - 2.000	1	6	0.5-1.0	46	44 [a]	37	3.3[a]	31
T-L	1.000 - 2.000	1	5	0.5-1.0	36	36 [a]	34	0.2 [a]	26
S-L	1.000 - 2.000	1	3	0.5-0.75	-	33 [a]	-	0.2 [a]	25
L-T	2.001 - 4.000	1	22	1.0-1.5	52	41 [a]	35	3.3[a]	29
T-L	2.001 - 4.000	1	46	1.0	43	33 [a]	26	0.2 [a]	24
S-L	2.001 - 4.000	1	22	0.5-1.25	36	31 [a]	26	0.2 [a]	23
L-T	4.001 - 6.000	1	14	1.0-1.5	41	38 [a]	27	3.3[a]	27
T-L	4.001 - 6.000	1	12	1.0-1.5	37	30 [a]	26	0.2 [a]	22
S-L	4.001 - 6.000	1	12	1.0	32	29 [a]	23	0.2 [a]	22
L-T	6.001 - 8.000	1	7	1.25	47	35 [a]	28	3.3[a]	25
T-L	6.001 - 8.000	1	5	1.25	30	28 [a]	26	0.2 [a]	20
S-L	6.001 - 8.000	1	21	1.25	32	27 [a]	24	0.2 [a]	20
L-T	8.001 - 10.000	1	7	1.25-1.5	43	32 [a]	28	3.3[a]	22
T-L	8.001 - 10.000	1	3	1.25-1.5	-	25 [a]	-	0.2 [a]	18
S-L	8.001 - 10.000	1	4	1.25-1.5	-	25 [a]	-	0.2 [a]	19
L-T	10.001-12.000	1	4	1.0-1.5	-	30 [a]	-	3.3[a]	20
T-L	10.001-12.000	1	4	1.0-1.5	-	23 [a]	-	0.2 [a]	16
S-L	10.001-12.000	1	2	1.5	-	24 [a]	-	0.2 [a]	17

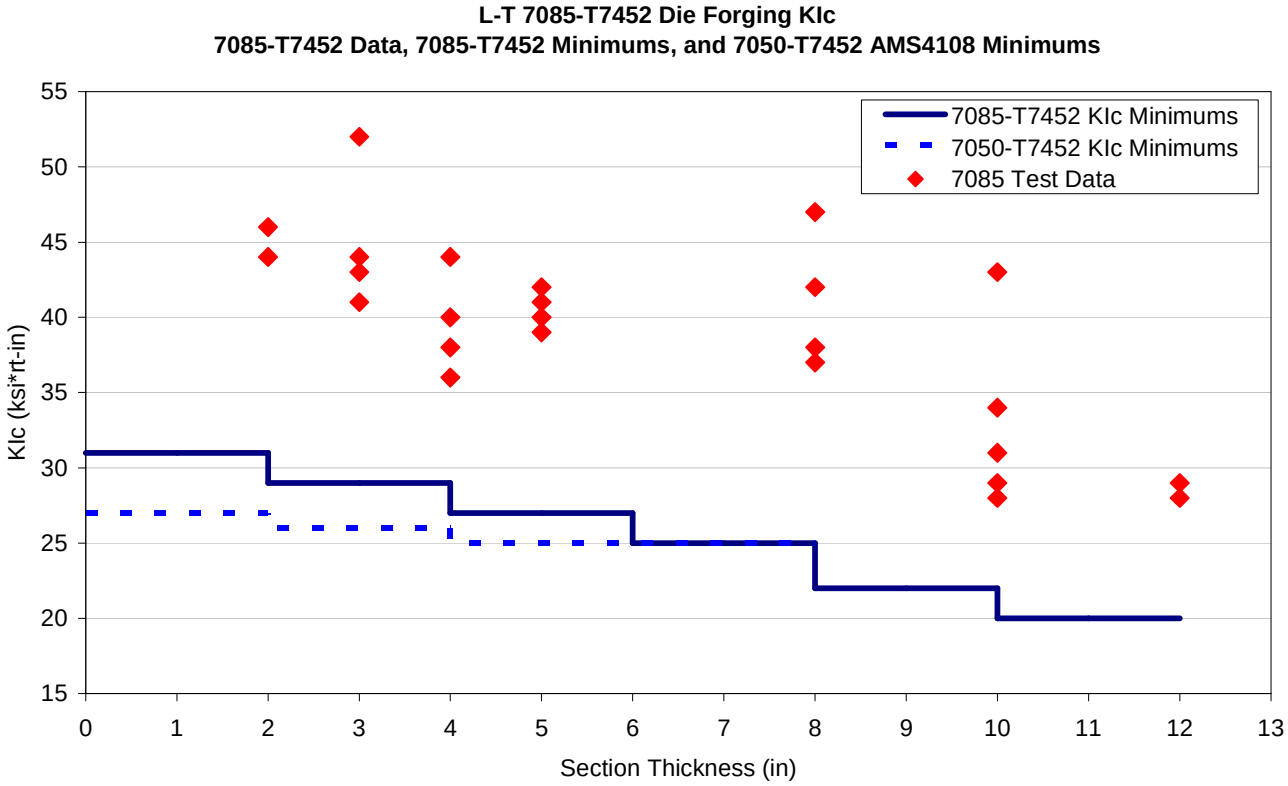
[a] Estimated from linear regression analysis over product thickness range of 1-12 inches.

Summary: KIC Minimum Values for 7085-T7452 Die Forgings

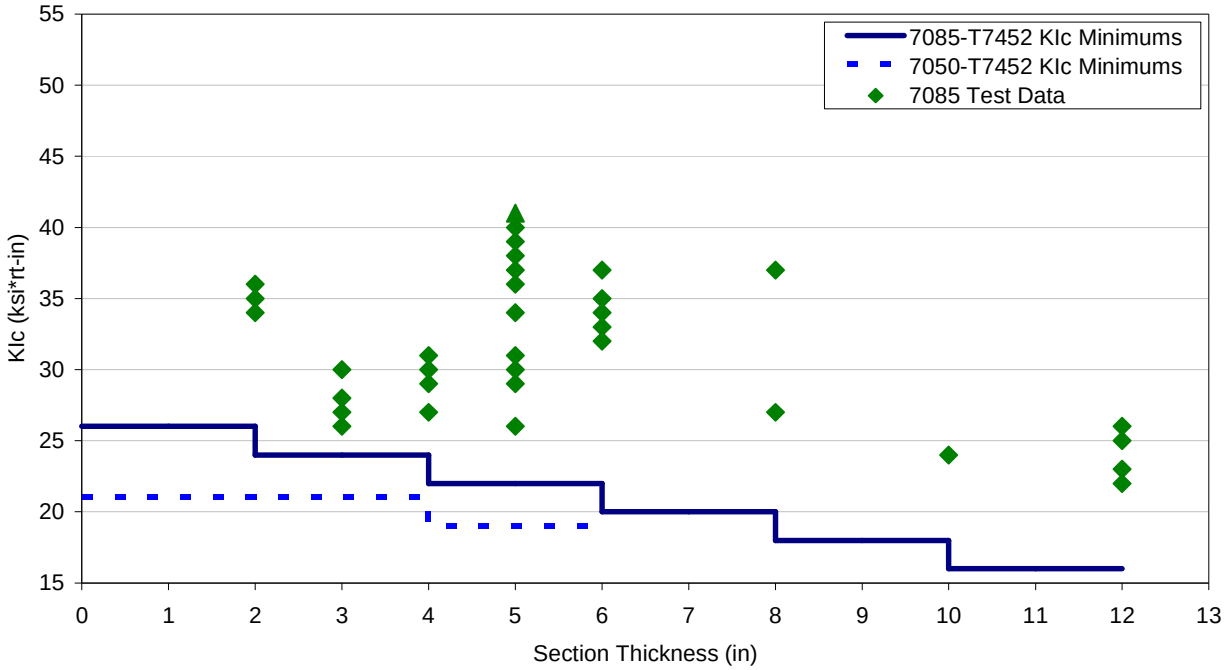
Thickness (in.)	L-T (ksi rt.in.)	T-L (ksi rt.in.)	S-L (ksi rt.in.)
<=2.000	31	26	25
2.001 – 4.000	29	24	23
4.001 – 6.000	27	22	22
6.001 – 8.000	25	20	20
8.001 – 10.000	22	18	19
10.001 – 12.000	20	16	17

7085-T7452 Die Forgings are being compared to 7050-T7452 for thick section structural applications. Below is a strength-toughness plot comparing the minimums for these two alloys and two orientations.

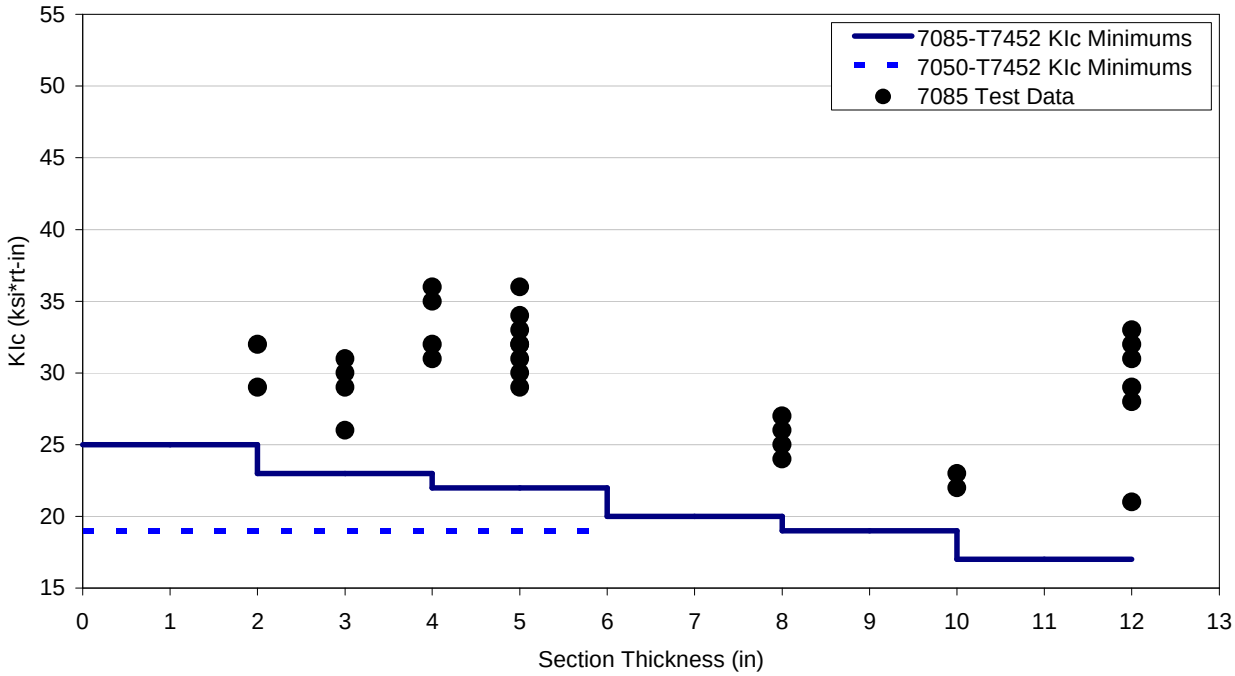

Toughness - Strength Comparison (4 - 6 in.)
7085-T7452 and 7050-T7452 Minimums
KIC (ksi rt.in.)
Fty (ksi)
7050 T7452
L and L-T
7085 T7452
ST and S-L
7085 T7452
7050 T7452


L-T 7085-T7452 Die Forging KIc
7085-T7452 Data, 7085-T7452 Minimums, and 7050-T7452 AMS4108 Minimums
7085-T7452 KIc Minimums
7050-T7452 KIc Minimums
7085 Test Data
KIc (ksi*rt-in)
Section Thickness (in)

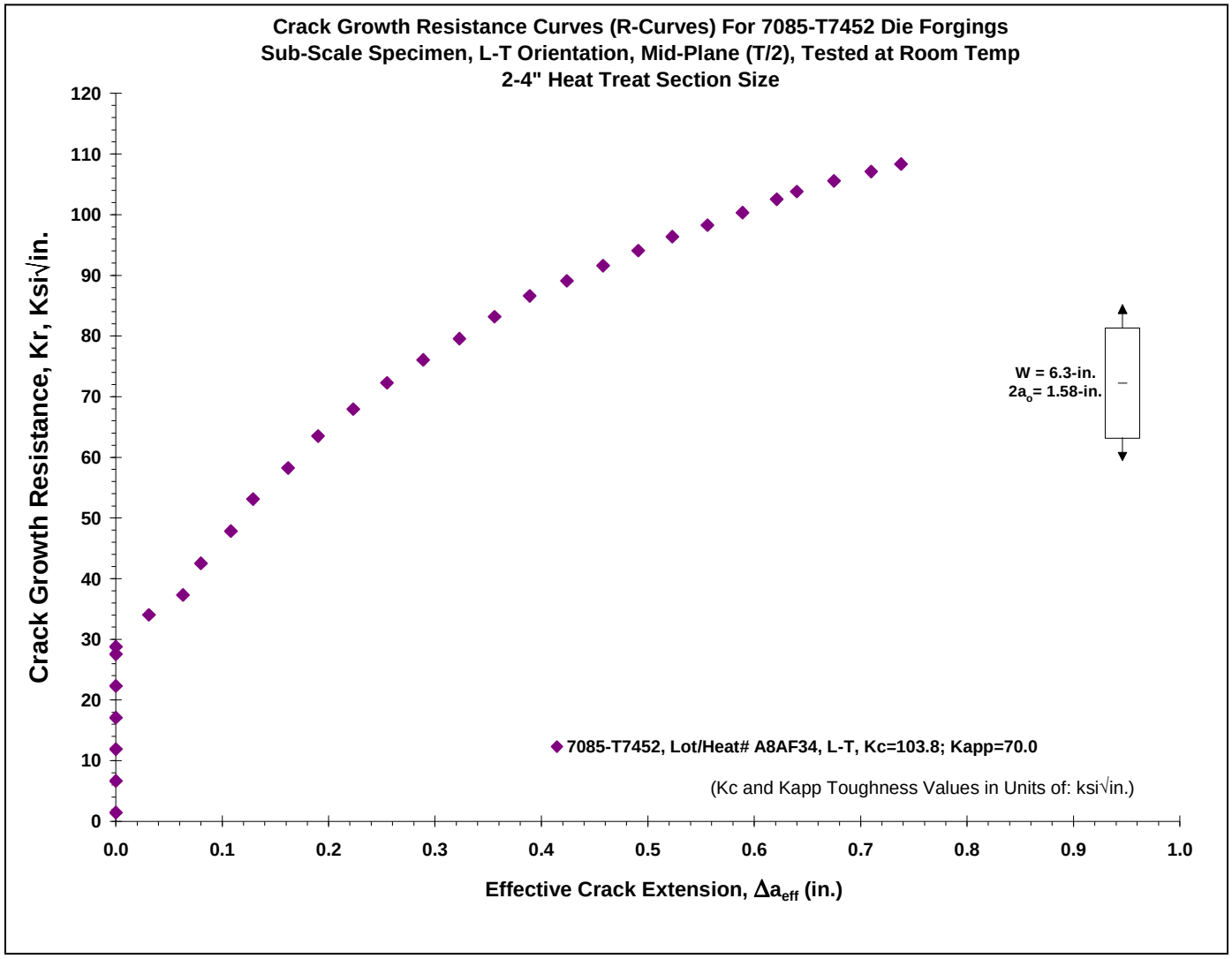
T-L 7085-T7452 Die Forging KIc
7085-T7452 Data, 7085-T7452 Minimums, and 7050-T7452 Typical Minimums



S-L 7085-T7452 Die Forging KIc
7085-T7452 Data, 7085-T7452 Minimums, and 7050-T7452 Typical Minimums



Sample R-Curve Plane Stress Fracture Toughness Test Result
7085-T7452 Forgings



7. Fatigue and Fatigue Crack Growth Properties

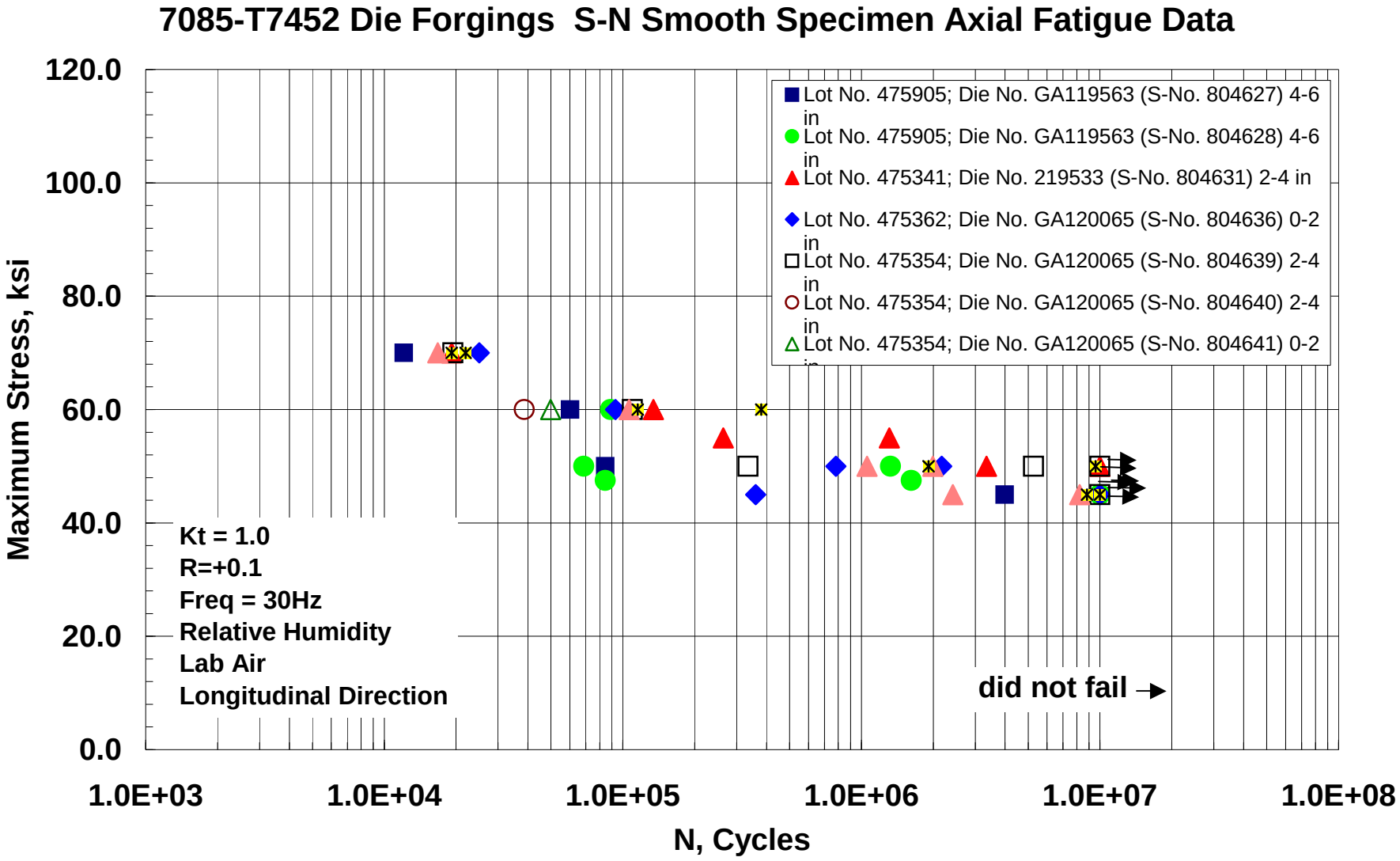
In this section are the following fatigue and FCGR plots:

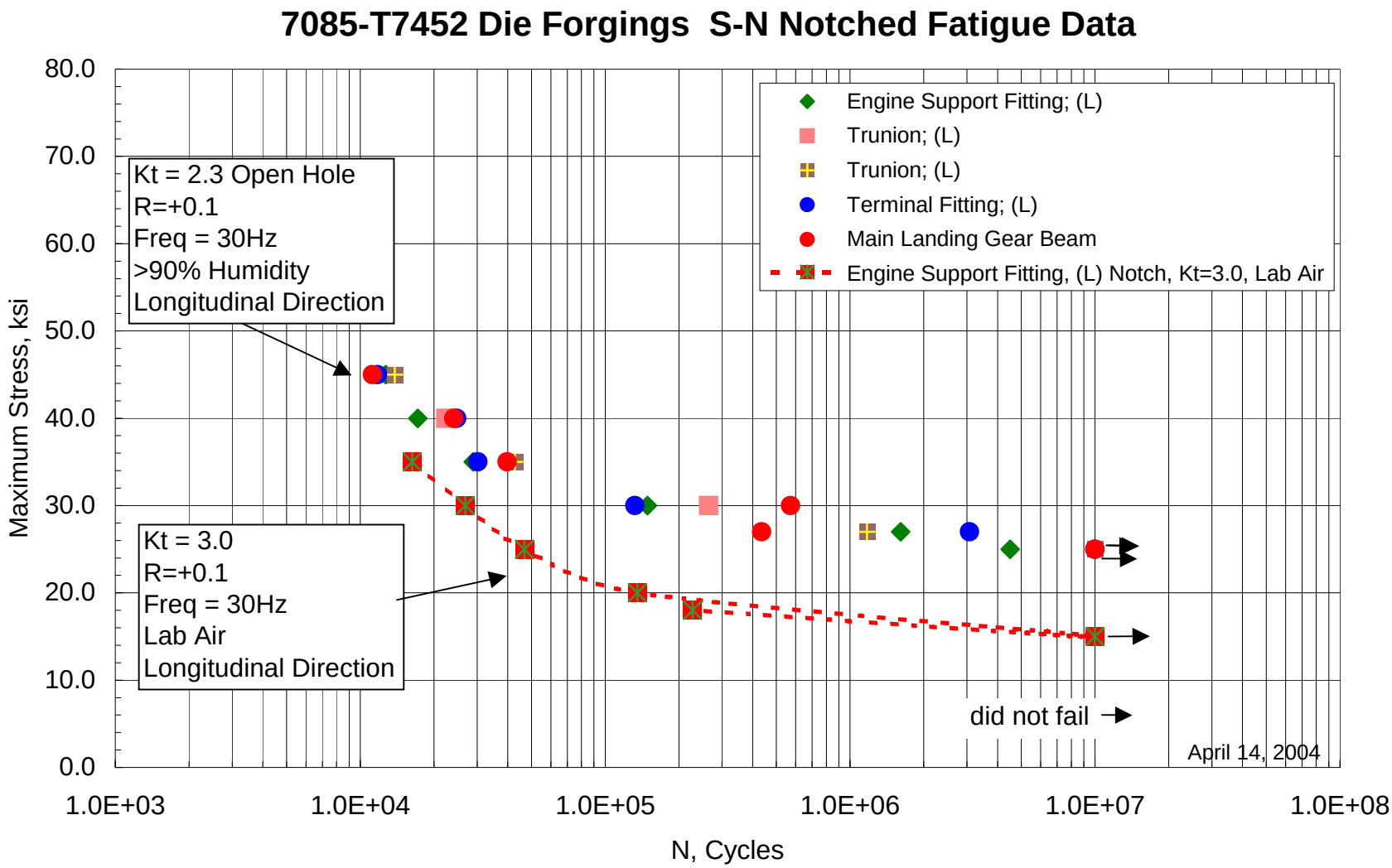
1. Smooth S-N Fatigue Plots 7085-T7452 Die Forgings
   R=+0.1, Longitudinal specimens.
2. Notched S-N Fatigue Plots 7085-T7452 Forgings
   Kt=2.3 and 3.0, R=+0.1, Longitudinal specimens.
3. Open Hole S-N Fatigue Plots –
   7085-T7652 Die Forgings and 7085 and 7050-T7651 Plate
   Kt=2.3, R-+0.1, Longitudinal specimens.
4. Open Hole S-N Fatigue Plots –
   7085-T7454 and 7050-T7454 Die Forgings
   Kt=2.3, R=+0.1, L and ST specimens
5. Strain Control Fatigue, SCF Plots – 7085-T7454 Die Forgings
   Smooth Specimen, R= -1.0, L and T specimens
6. Fatigue Crack Growth Rate, FCGR Plots
   7085-T7452 and 7050-T7452, L-T and T-L, R= 0.1

The fatigue test results for 7085-T7452 Die Forgings have shown this new alloy to have improved axial fatigue properties as compared to 7050. Below are two tables comparing maximum stress levels at 2 lives for smooth and open hole specimens. This data was taken from this Green Letter and the 7050 Green Letter. At long lives 7085-T7452 shows a 10 – 20% improvement.

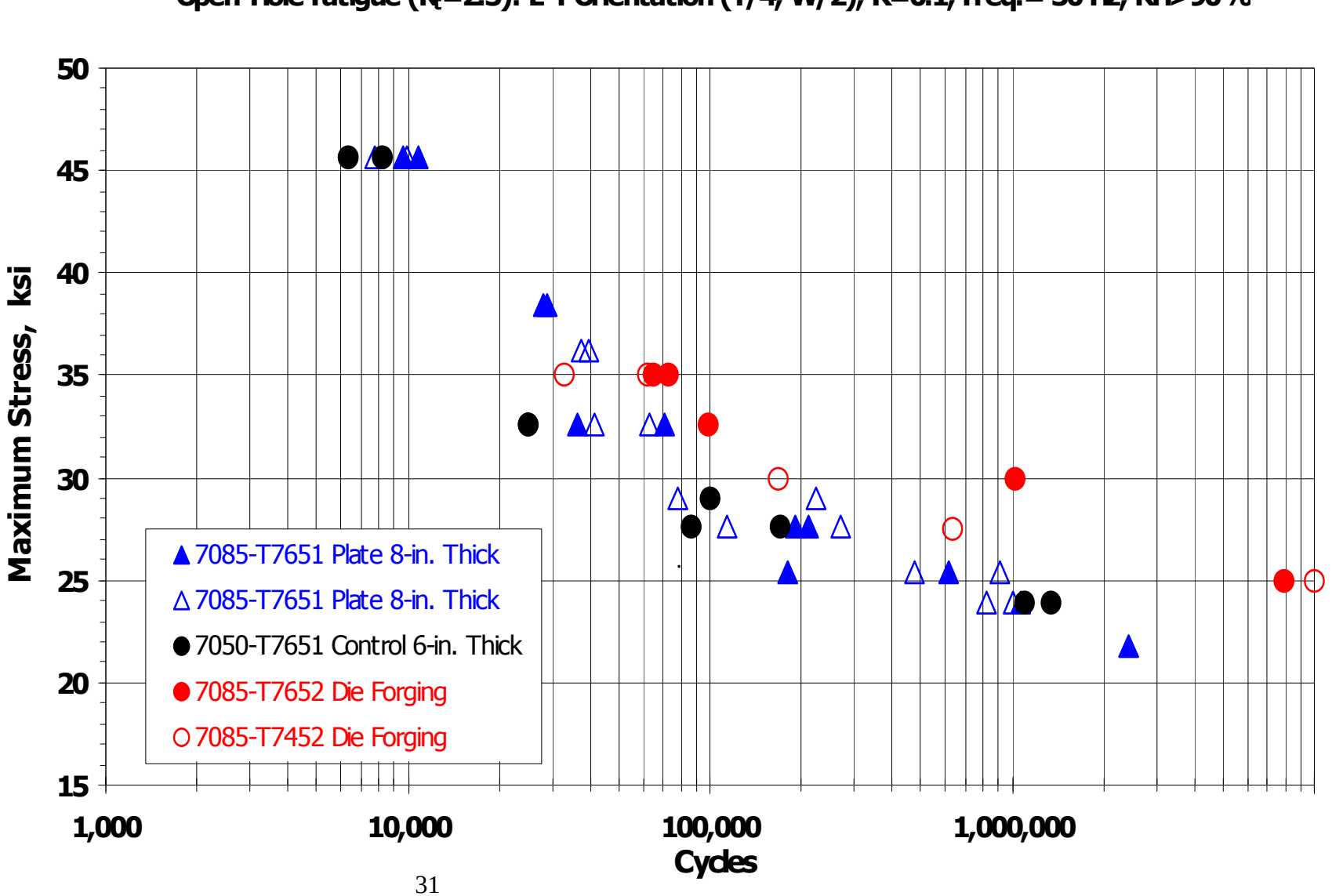
Summary Table of Smooth Bar Spec. Fatigue Testing

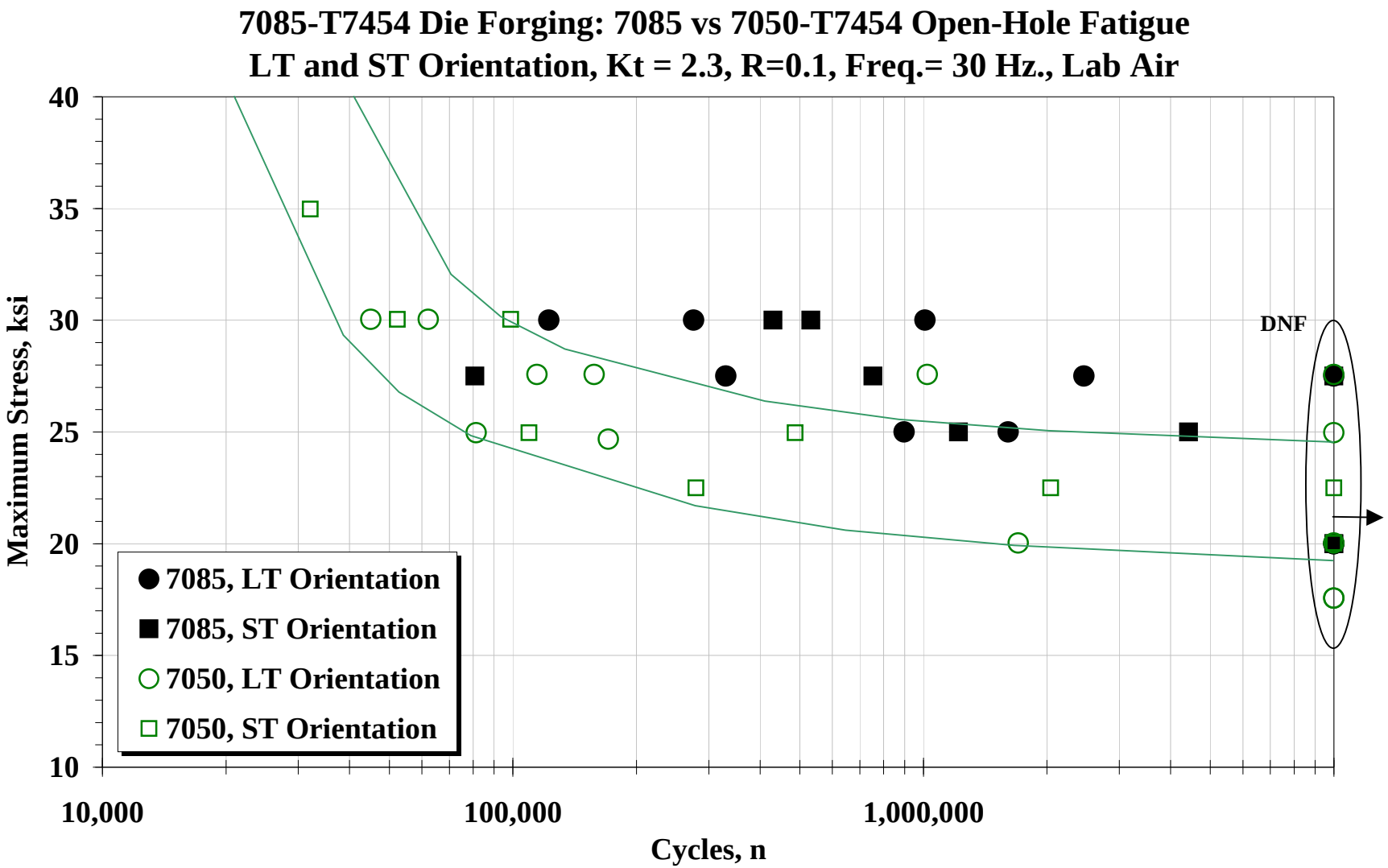
R=+0.1, L dir. Smooth Spec.	**7085-T7452**	**7050-T7452**
10^5 cycles	48 - 62 ksi	40 – 55 ksi
10^7 cycles	42 – 50 ksi	35 – 45 ksi
R=+0.1, L dir. Open Hole Spec.	7085-T7454	7050-T7454
10^5 cycles	26 - 32 ksi	24 - 30 ksi
10^7 cycles	24 - 28 ksi	20 - 24 ksi

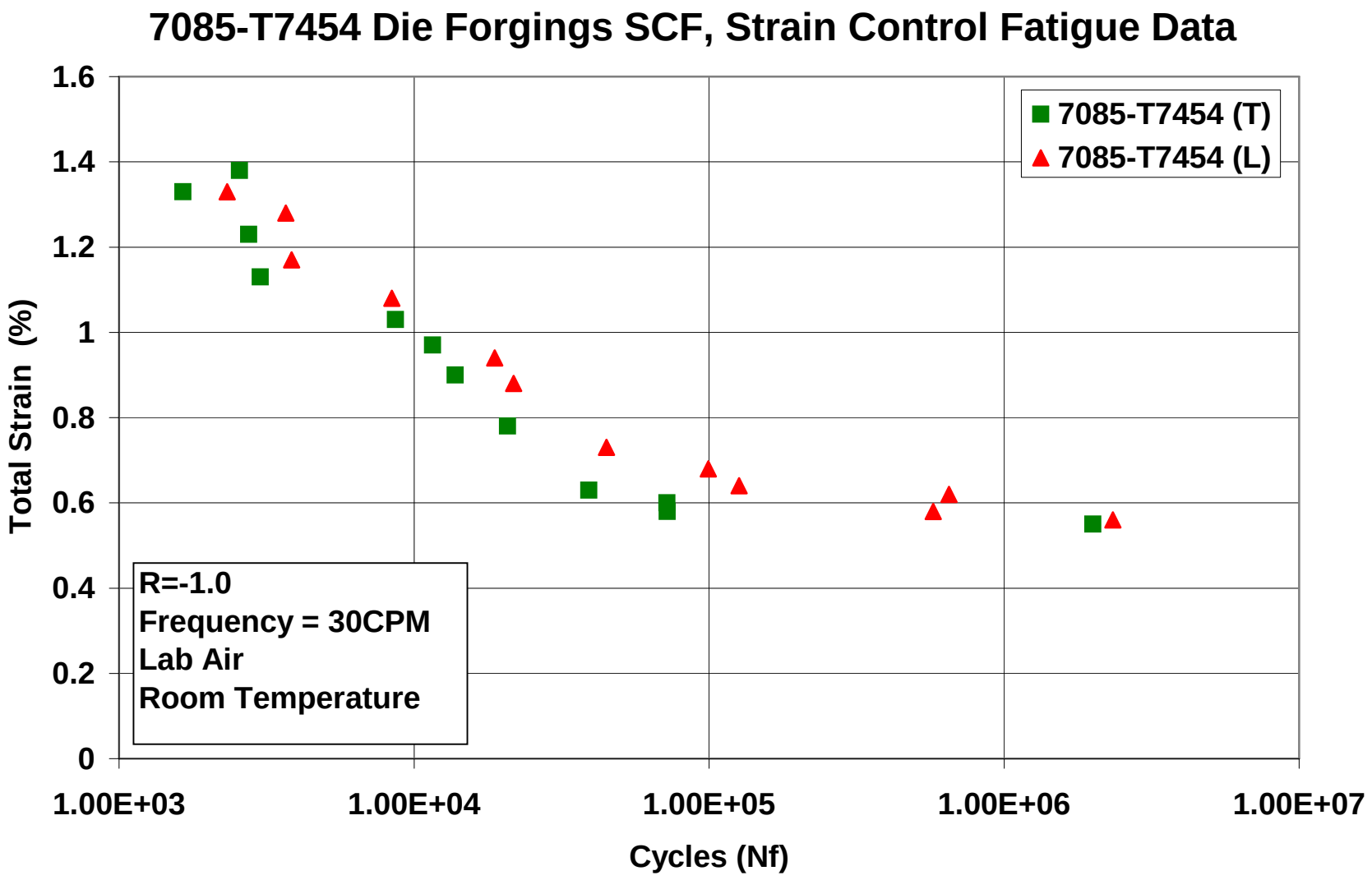

7085-T7452 Die Forgings S-N Smooth Specimen Axial Fatigue Data
Maximum Stress, ksi
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1.0E+03
1.0E+04
1.0E+05
1.0E+06
1.0E+07
1.0E+08
N, Cycles
Lot No. 475905; Die No. GA119563 (S-No. 804627) 4-6 in
Lot No. 475905; Die No. GA119563 (S-No. 804628) 4-6 in
Lot No. 475341; Die No. 219533 (S-No. 804631) 2-4 in
Lot No. 475362; Die No. GA120065 (S-No. 804636) 0-2 in
Lot No. 475354; Die No. GA120065 (S-No. 804639) 2-4 in
Lot No. 475354; Die No. GA120065 (S-No. 804640) 2-4 in
Lot No. 475354; Die No. GA120065 (S-No. 804641) 0-2 in
Kt = 1.0
R=+0.1
Freq = 30Hz
Relative Humidity
Lab Air
Longitudinal Direction
did not fail

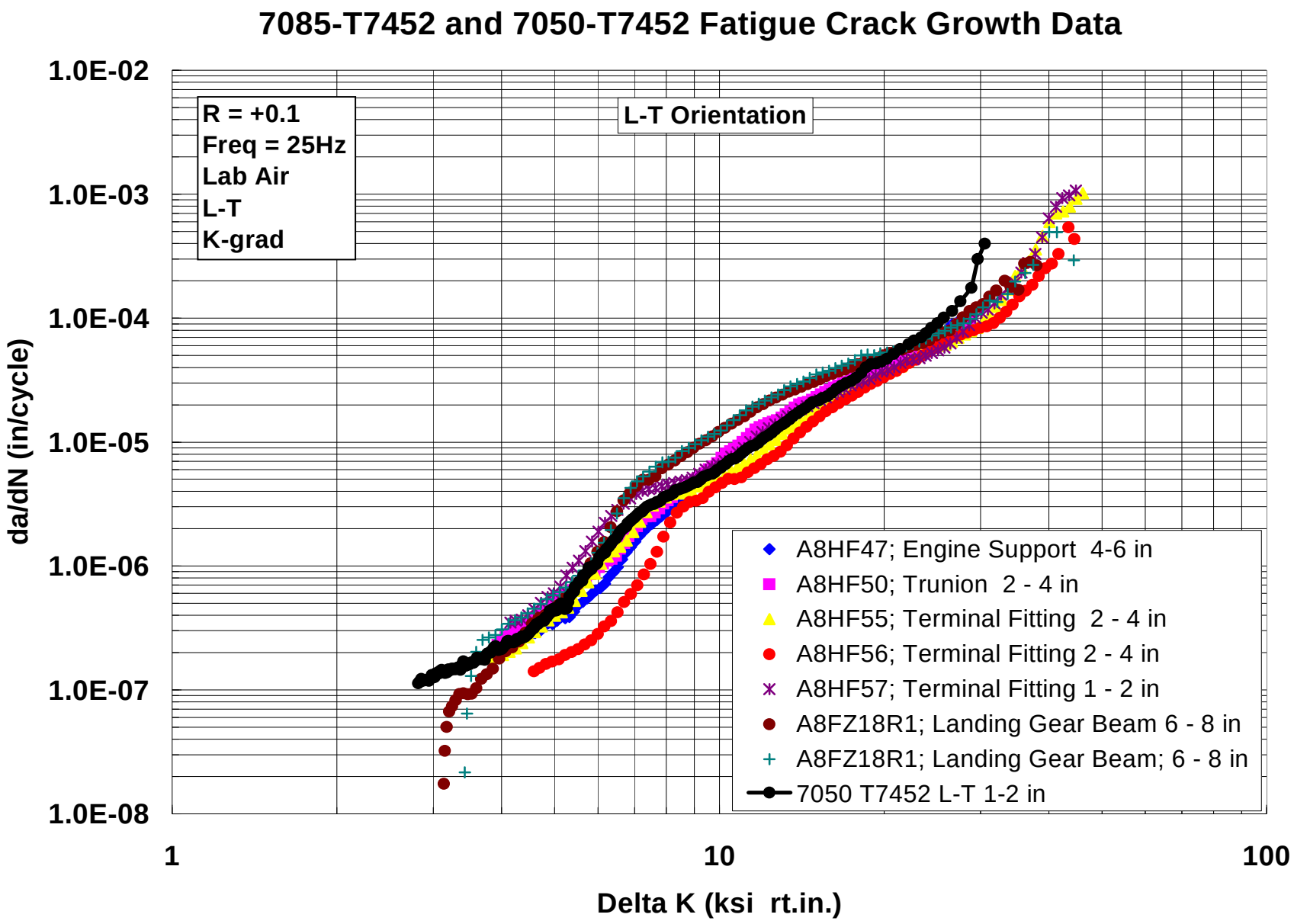

7085-T7452 Die Forgings S-N Notched Fatigue Data
Maximum Stress, ksi
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1.0E+03
1.0E+04
1.0E+05
1.0E+06
1.0E+07
1.0E+08
N, Cycles
Kt = 2.3 Open Hole
R=+0.1
Freq = 30Hz
>90% Humidity
Longitudinal Direction
Kt = 3.0
R=+0.1
Freq = 30Hz
Lab Air
Longitudinal Direction
Engine Support Fitting; (L)
Trunion; (L)
Trunion; (L)
Terminal Fitting; (L)
Main Landing Gear Beam
Engine Support Fitting, (L) Notch, Kt=3.0, Lab Air
did not fail
April 14, 2004

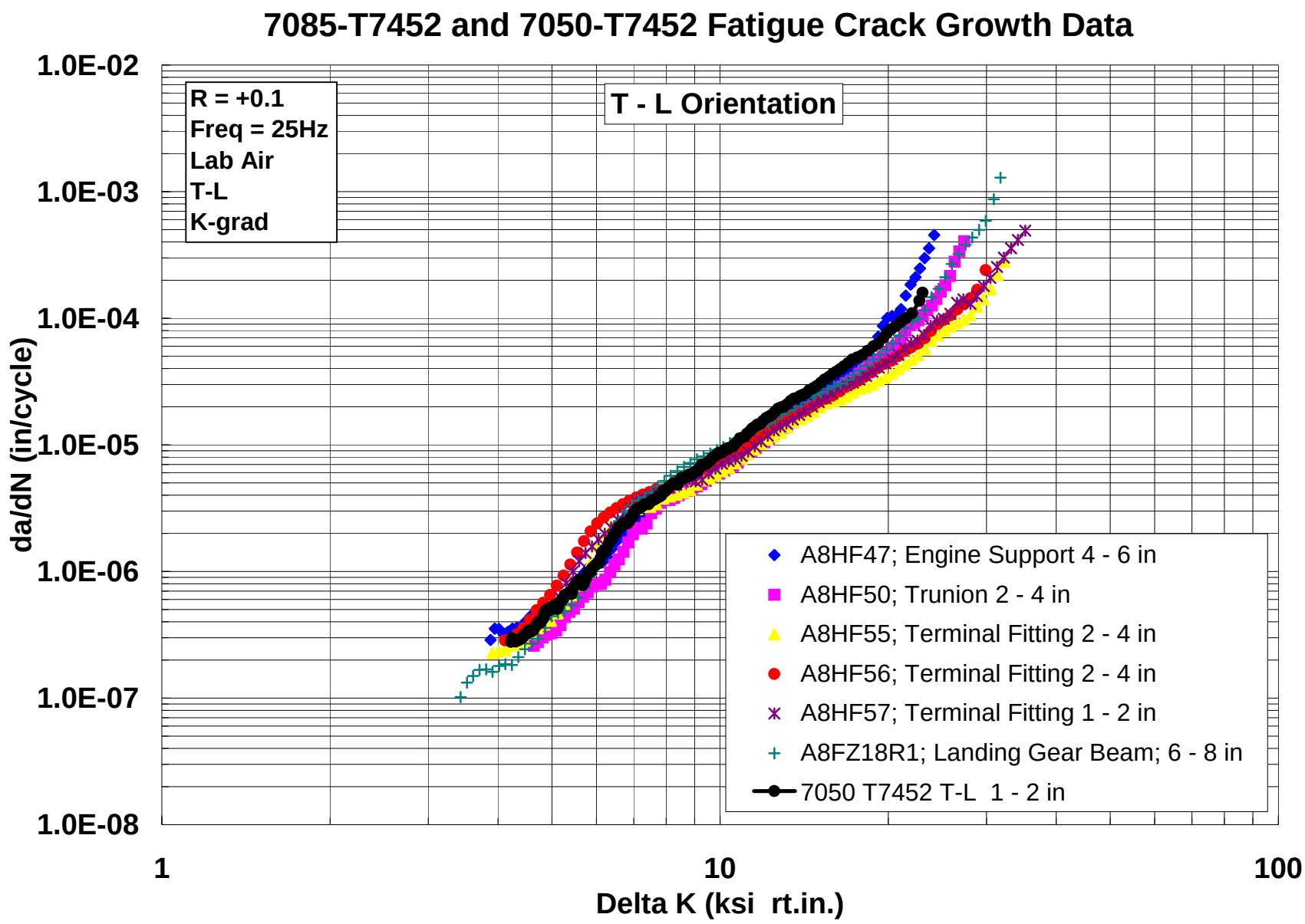
7085-T7452/T7652 Die Forgings and 7050-T7651 Plate S-N Fatigue Data




7085-T7454 Die Forging: 7085 vs 7050-T7454 Open-Hole Fatigue
LT and ST Orientation, Kt = 2.3, R=0.1, Freq.= 30 Hz., Lab Air
Maximum Stress, ksi
40
35
30
25
20
15
10
10,000
100,000
1,000,000
Cycles, n
DNF
7085, LT Orientation
7085, ST Orientation
7050, LT Orientation
7050, ST Orientation


7085-T7454 Die Forgings SCF, Strain Control Fatigue Data
Total Strain (%)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
Cycles (Nf)
7085-T7454 (T)
7085-T7454 (L)
R=-1.0
Frequency = 30CPM
Lab Air
Room Temperature


7085-T7452 and 7050-T7452 Fatigue Crack Growth Data
R = +0.1
Freq = 25Hz
Lab Air
L-T
K-grad
L-T Orientation
da/dN (in/cycle)
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1
10
100
Delta K (ksi rt.in.)
A8HF47; Engine Support 4-6 in
A8HF50; Trunion 2 - 4 in
A8HF55; Terminal Fitting 2 - 4 in
A8HF56; Terminal Fitting 2 - 4 in
A8HF57; Terminal Fitting 1 - 2 in
A8FZ18R1; Landing Gear Beam 6 - 8 in
A8FZ18R1; Landing Gear Beam; 6 - 8 in
7050 T7452 L-T 1-2 in


7085-T7452 and 7050-T7452 Fatigue Crack Growth Data
R = +0.1
Freq = 25Hz
Lab Air
T-L
K-grad
T - L Orientation
da/dN (in/cycle)
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1
10
100
Delta K (ksi rt.in.)
A8HF47; Engine Support 4 - 6 in
A8HF50; Trunion 2 - 4 in
A8HF55; Terminal Fitting 2 - 4 in
A8HF56; Terminal Fitting 2 - 4 in
A8HF57; Terminal Fitting 1 - 2 in
A8FZ18R1; Landing Gear Beam; 6 - 8 in
7050 T7452 T-L 1 - 2 in

8. Corrosion

7085-T7452 Die Forgings have shown exfoliation and stress corrosion cracking properties similar to other 7XXX-T74 alloy tempers.

Exfoliation Corrosion Test Results

7085-T7452 Die Forgings have shown EXCO rating of EA per ASTM G34.

48 Hr. EXCO (ASTM G34) Test Results

Lot No:	Part	Description	Avg. Depth (ins)	Max. Depth (ins) (1)	EC (% IACs)	Visual Ratings: 24 hr	48hr
804628 T/2	Engine Support	7085-T7452 6" Lot No. 475905MT	0.0013	0.002	42.5	EA	EA
804628 T/10		7085-T7452 6" Lot No. 475905MT	0.0030	0.003	41.2	EA	EA
804636 T/2	Terminal Fitting	7085-T7452 2" Lot No. 475362MT	0.0010	0.002	41.3	EA	EA
804636 T/10		7085-T7452 2" Lot No. 475362MT	0.0030	0.003	41.9	EA	EA
804639 T/2	Terminal Fitting	7085-T7452 4" Lot No. 475354MT	0.0003	0.001	41.5	EA	EA
804639 T/10		7085-T7452 4" Lot No. 475354MT	0.0030	0.003	41.7	EA	EA
804640 T/2	Terminal Fitting	7085-T7452 4" Lot No. 475354MT	0.0017	0.002	41.5	EA	EA
804640 T/10		7085-T7452 4" Lot No. 475354MT	0.0023	0.003	41.7	EA	EA

NOTES: (1) Maximum depth is the maximum depth measured, not necessarily the maximum depth of attack on the panel.

Stress Corrosion Cracking, SCC, Laboratory Test Results

7085-T7452 Die Forgings have shown good results in standard laboratory 3.5% NaCl alternate immersion SCC tests. At 35 ksi, the days to failure ranged from 63 to 120 days. For comparison 7050-T74 forgings showed 30 to 90 days to failure at the same stress levels.

7085-T7452 Die Forgings
Short Transverse Laboratory SCC Test Results
3.5% NaCl by Alternate Immersion (ASTM G44)

Part	Cast No.	Stress (KSI)	F/N (1)	Days To Failure		
Engine Support	2593L-03-02	35	3/3	112	99	120(2)
Trunion	2593L-02-01	35	3/3	120(2)	105	80
Trunion	2593L-02-01	35	3/3	91	120(2)	120(2)
Terminal Fitting	2593L-03-01	35	3/3	66	88	117
Terminal Fitting	2593L-03-01	35	3/3	66	63	67

1. F/N = Number of specimens failed over the number exposed.
2. Samples failed during disassembly @ 120 days

Note: 7050-T74 at 35 ksi showed 30 to 90 days to failure, ref. 7050 Green Letter.

Stress Corrosion Cracking, SCC, Atmospheric Test Results

Long term atmospheric SCC tests were started in March 21, 2004 at Alcoa's Pt. Judith, Rhode Island test station. Up to 35ksi, there were no failures up to 590 days. Over 90% of the bars at 30 and 35ksi still remain in test as of June 1 2006 (802 days). 7050-T74 forgings in the same tests at 35 ksi show a range of 150 to 2000 days to failure (Ref. 7050 Green Letter).

7085-T7452 Die Forgings - Stress Corrosion Cracking Test Matrix
Atmospheric Exposure - Pt. Judith, Rhode Island
Initial Exposure Date: 2004-03-21
As of May 21, 2004 there have been no failures

S.No.	Gauge	Stress (KSI)	F/N (1)	Days To Failure	Stress (KSI)	F/N (1)	Days To Failure
805850	12"	30	0/3		35	0/3	
805744	12"	30	0/3		35	0/3	
806220	10"	30	0/3		35	0/3	
804627	6"	30	0/3		35	0/3	
804640	4"	30	1/3	591	35	1/3	605
804629	4"	30	0/3		35	0/3	

S.No.	Gauge	Stress (KSI)	F/N (1)	Days To Failure	Stress (KSI)	F/N (1)	Days To Failure
805850	12"	40	0/3		45	0/3	
805744	12"	40	0/3		45	0/3	
806220	10"	40	0/3		45	0/3	
804627	6"	40	0/3		45	1/3	591
804640	4"	40	2/3	497,574	45	2/3	119,225
804629	4"	40	0/3		45	0/3	

1. F/N = Number of specimens failed over the number exposed.