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Characterization of Large 2219 Aluminum Alloy Hand Forgings for the Space Shuttle Solid Rocket Booster

M. W. Brennecke

DECEMBER 1978



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Characterization of Large 2219 Aluminum Alloy Hand Forgings for the Space Shuttle Solid Rocket Booster

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and Space Administration

**Scientific and Technical
Information Office**

1978

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- (1) R. E. Butler of the MSFC SRB Structures Engineering Office, EE11, for cooperation in providing forgers certification data and contractor's test data
- (2) The forgers for informative discussions of their processing and test data — Gregg Williams, Aluminum Company of America, and John Bierholm, Weber Metals
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TECHNICAL PAPER

CHARACTERIZATION OF LARGE 2219 ALUMINUM ALLOY HAND FORGINGS FOR THE SPACE SHUTTLE SOLID ROCKET BOOSTER

INTRODUCTION

Large aluminum forgings required for the Space Shuttle are of sizes beyond the scope of existing specifications and are, therefore, in the class of "special purpose forgings." The property data available in 1974-5 for 2219-T852 forgings in thicknesses over 8 in. were meager or nonexistent. Hence, the minimum guaranteed properties provided by the forgers for thicknesses greater than 8 in. were conservatively estimated. Therefore, a material evaluation program was established by the Materials and Processes Laboratory of the George C. Marshall Space Flight Center (MSFC) when the forgings were ordered for the Solid Rocket Booster (SRB) structural components. The program plan delineated the requirements for destructively tested forgings and forging prolongations to provide basic data for material characterization and to establish minimum guaranteed properties for structural refinement and future applications.

DESCRIPTION

Objective and Approach

The objective of the program was to characterize large hand forgings of 2219-T852 aluminum and to establish minimum guaranteed mechanical properties for current and future applications.

Four types of hand forgings ordered for the Space Shuttle SRB Structures were evaluated. One to three forgings of each configuration were destructively tested to determine macrostructure, grain size, mechanical properties, stress strain curves, ductility, fracture toughness, and resistance to stress corrosion cracking. Prolongations were tensile tested on each individual forging by the forger for quality control.

The forgings ranged in thickness from 5-3/4 to 16-1/4 in., from 10-1/2 to 29-1/2 in. in width, from 33 to approximately 115-1/2 in. in length, and from 450 to 3500 lb at time of heat treatment. The two contour forgings produced by one forger for the holddown post (P/N 14A30400) and for the thrust post (P/N 14A20084) are depicted in detail with dimensions and forger test specimen layout in Figures 1 through 4 and Figures 5 through 9, respectively. Figure 7 presents a closeup view of the forward tapered segment of the thrust post. The two rectangular forgings produced by another forger are sketched showing dimensions and forger test specimen layout in Figure 10 for the splice fitting (P/N 14A30500) and in Figure 11 for the actuator support bracket (P/N 14A30905). The latter is the only forging delivered in the -T852 temper for hardware. The other three are delivered by the forger in the -T352 temper to be welded into an assembly and aged by the SRB Structures contractor, McDonnell Douglas Astronautics Company (MDAC). All segments of the original destruct forgings are aged by the forger to -T852 temper for testing.

Details of the tests to be performed by the forgers were included in the MSFC procurement specification for each of the four types of forgings, as shown by one example in Appendix A. Results of forger tests were provided to MSFC on certification sheets (illustrated in Appendix B) and by letter. Supplemental tests performed by MDAC were according to the MSFC plan incorporated in NASA Contract NAS8-31732. These results were provided periodically to MSFC on data sheets and summarized in an interim report (Reference). Results of tests from both sources as organized and evaluated at MSFC are presented herein.

Simulated hardware aging tests performed by the SRB Structures contractor (MDAC) on welded assemblies representing a 1/4 circumferential segment each of a complete forward and aft skirt aged on the fixtures and in the furnace used for full scale hardware, provided test material for comparison between forger- and user-aged material. These tests will be described in detail in a separate report; however, the properties are included here to demonstrate the difference between forger delivered -T852 temper and hardware-assembly-aged -T852 temper 2219 forgings.

Minimum mechanical properties guaranteed by the forgers in 1974-6 are given in Table 1 by thickness and SRB forging part number. The values are plotted in Figures 12, 13, and 14 for longitudinal (L), long transverse (LT), and short transverse (ST) directions, respectively.

Test Results

Results of the forger and MDAC tests on the holddown post, P/N 14A30400, are given in Tables 2 through 6 and are plotted in Figures 15, 16, and 17. Strengths decrease with increasing thickness. In the heavier gages actual values far exceed the minimum guaranteed by the forger at time of procurement (Figure 15, p. 20).

Results of the forger and MDAC tests on the thrust post, P/N 14A20084, are given in Tables 7 through 11 and are plotted in Figures 18 through 21.

Test results from the forger and MDAC tests on P/N 14A30500 are given in Tables 12, 13, and 14 and on the actuator support bracket, P/N 14A30905, in Tables 15, 16, and 17.

Forger prolongation tensile test data for the four forging configurations combined are shown in Figures 22, 23, and 24 for L, LT, and ST test directions, respectively. A condensed summary of the combined prolongation and destruct data for the four forging configurations is given in Table 18 and is plotted in Figures 25, 26, and 27 for L, LT, and ST directions, respectively. The number of specimens tested for a given location and orientation varies from 3 to 136 for a specific part number (P/N), whereas a total of 1230 tensile tests were made at ambient temperature (Figure 26, p. 31 and Table 18, p. 72-3).

Macrostructure and grain size as determined by the forgers are available at MSFC. Stress strain curves are likewise available for specimens noted in Tables 4, 9, 13 and 16.

MDAC test data on forger-aged contour material tended to be approximately 1 ksi lower than forger tests. Likewise, the MDAC 1/4 in. diameter specimens tested for stress corrosion blanks tended to show approximately 1 ksi lower tensile yield strength (TYS) than the 1/2 in. diameter specimens.

Mechanical properties varied up to 5 ksi across the 11 in. width of the 8 by 11 in. rectangular forging (Table 13). For a given location from one serial number forging to another there was a maximum variation of approximately 10 ksi for 61 parts (Table 14, p. 67).

The prolongation data for contour forgings show remarkably consistent values, whereas the destruct data for three forgings of the thrust post show considerable spread from one serial number to another particularly in the 1/4 width location in the 14 in. thick segments (Table 7). This situation limits the ultimate tensile strength (UTS) to the original guaranteed 50 ksi but permits some increase in TYS to at least 40 ksi for forger-aged material (Figure 19, p. 24).

Proposed minimum guaranteed mechanical properties for 2219-T852 hand forgings are given in Table 19 and are plotted in Figures 28, 29, and 30 for L, LT, and ST directions, respectively. These may be considered firm values for rectangular forgings of a given thickness and as guideline or tentative values for a given thickness within contour forgings.

All stress corrosion tests were satisfactory on the 66 forging specimens and the 25 reference plate specimens (Tables 4, 9, 13 and 16). Metallographic examination of corroded specimens at MSFC showed only pitting type of attack, as illustrated by microstructures exhibited in Appendix C. All K_{Ic} fracture toughness values were above the estimated minimum of 20 ksi $\sqrt{\text{in}}$. Most of the values were for the S-L direction. The limited number of valid tests in the L-S direction resulted from the specimen size being too small. A total of 89 compact tension specimens were tested at ambient temperature (Tables 4, 9, 13 and 16).

A limited number of elevated temperature tests at 200°F and 300°F (Table 13) show that strengths and fracture toughness decrease with increasing temperature. The K_{Ic} tests were invalid due to the specimen size being too small.

Destruct and prolongation tests on the thrust post and holddown post from the MDAC 1/4 skirt aging tests are included in Tables 5, 6, 10, 11, and 18 and are plotted in Figures 15, 16, 17, 21, and 23 through 27. Generally, lower strengths were developed in the simulated hardware aged by the contractor than in forgings aged by the producer. In the thinner portion (5-3/4 in. thick) of the thrust post (14A20084), properties failed to meet the minimum guaranteed by the forger in the longitudinal direction by 2 to 4 ksi (Figure 25). Further evaluation is in progress to define the problem and establish the necessary process control for hardware.

CONCLUDING REMARKS

The following conclusions are based on results of tests on 171 individual hand forgings of 4 distinct items produced by 2 forgers, tested by the forgers and also by the SRB Structures contractor — MDAC. There were a total of 1250 tensile tests, 100 fracture toughness tests, and 91 stress corrosion tests.

1. Strengths of 2219-T852 rectangular and contour forgings, weighing 450 to 3500 lb, generally equaled or exceeded the minimum values guaranteed by the forgers in 1974-5.
2. Strengths vary with forging thickness, with cross-sectional area, with forging contour, and with location within the forgings.
3. The previously guaranteed values are appropriate now for gages up through 8 in. thick when aged by the forger.

4. Increased strength guarantees are proposed for rectangular hand forgings greater than 8 in. thick supplied by the forger in the fully aged -T852 temper.

5. Caution is advised in predicting guaranteed values for either rectangular or contour forgings in any gage when aged by the user to the -T852 temper since aging conditions employed for hardware assemblies may differ appreciably from those normally employed in a producers' plant.

6. Caution is advised in predicting guaranteed values for contour forgings aged by the forger since properties may vary (a) with the contour and (b) with the process variables inherent with the specific contour.

7. Strengths guaranteed by the forger in 1976 for the contoured thrust post P/N 14A20084 are still appropriate for forger-aged material.

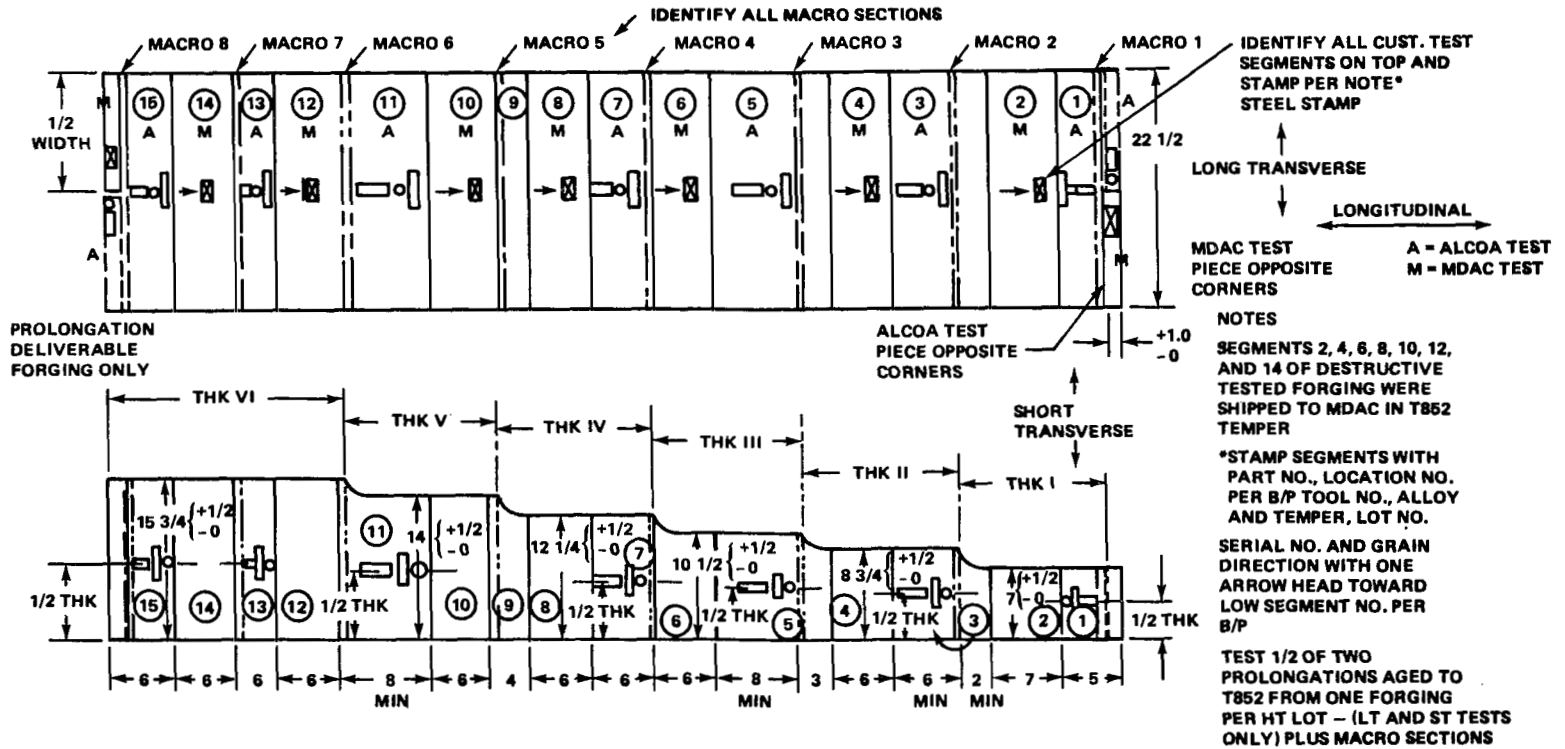
8. Strengths initially guaranteed by the forger in 1974-5 for the contoured holddown post forging P/N 14A30400 are still appropriate for forger-aged material up through 8 in. thick; however, for the 8-3/4 to 16-1/4 in. thicknesses, strengths could be upgraded, particularly tensile yield strength.

9. No stress corrosion cracking failures occurred during a 30-day exposure to 3.5 percent NaCl solution by alternate immersion of short transverse tensile specimens stressed to 75 percent of their yield strength.

10. Corrosive attack was not accelerated by stress. Losses in strength and in elongation were no greater for the forgings than for the 6 in. thick -T851 reference plate exposed simultaneously. All showed only pitting type of attack.

11. Fracture toughness K_{Ic} values of the forgings ranged from 20.72 to 35.32 ksi $\sqrt{\text{in.}}$.

12. Strength and fracture toughness decreased with increasing temperature of 200 and 300°F.



MIN PROPS FOR 2219 Al FORGINGS AGED TO T852 TEMPER

THICKNESS	DIRECTION	TENSILE KSI	YIELD KSI	ELONG %
THK I 7"	LONGITUDINAL	62	50	6
	LONG TRANSVERSE	61	49	4
	SHORT TRANSVERSE	60	46	3
THK II 8 3/4"	LONGITUDINAL	55	43	6
	LONG TRANSVERSE	55	42	4
	SHORT TRANSVERSE	53	40	3

*FOR ALCOA TEST LAB ONLY

THICKNESS	DIRECTION	TENSILE KSI	YIELD KSI	ELONG %
THK III	LONGITUDINAL	52	39	6
THK IV	LONG TRANSVERSE	52	38	4
10 1/2" - 12 1/4"	SHORT TRANSVERSE	50	36	3
THK V	LONGITUDINAL	46	33	6
THK VI 14" - 16 1/4"	LONG TRANSVERSE	46	32	4
	SHORT TRANSVERSE	44	30	3

Figure 1. Dimensions and layout for contour hand forging P/N 14A30400.

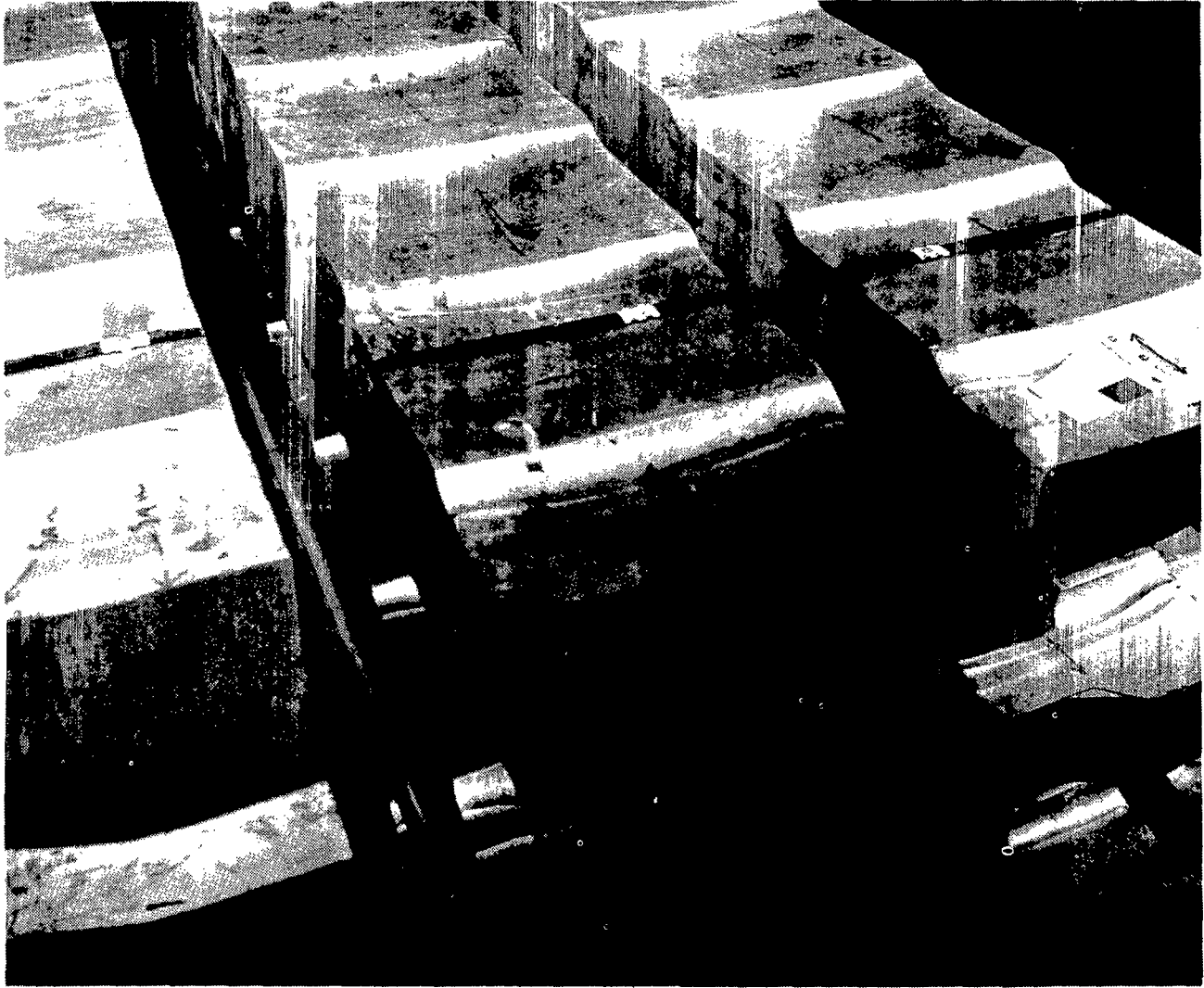


Figure 2. Contour forging P/N 14A30400 for holddown post.

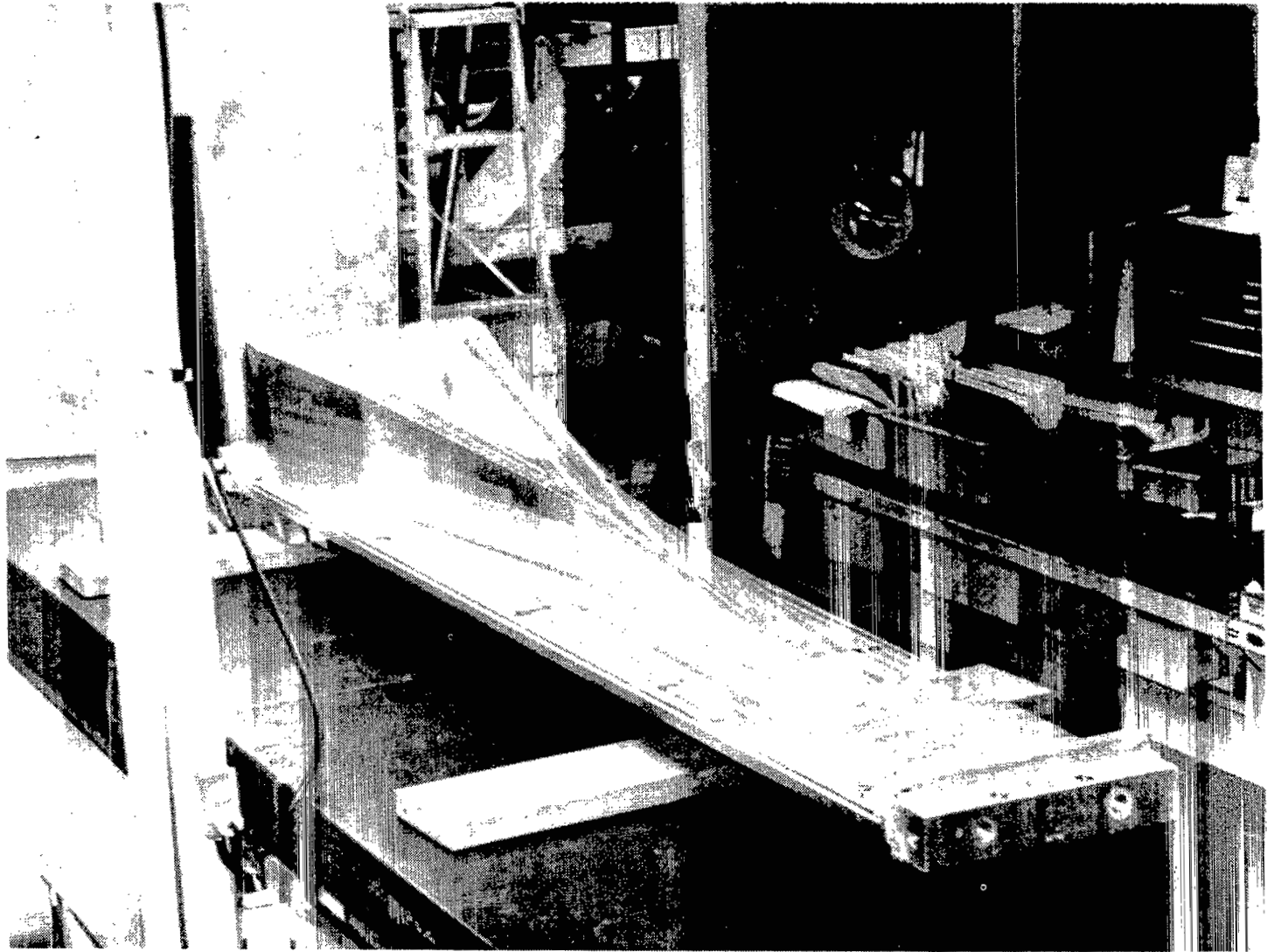


Figure 3. Aft skirt holddown post (P/N 14A30414) — machined.

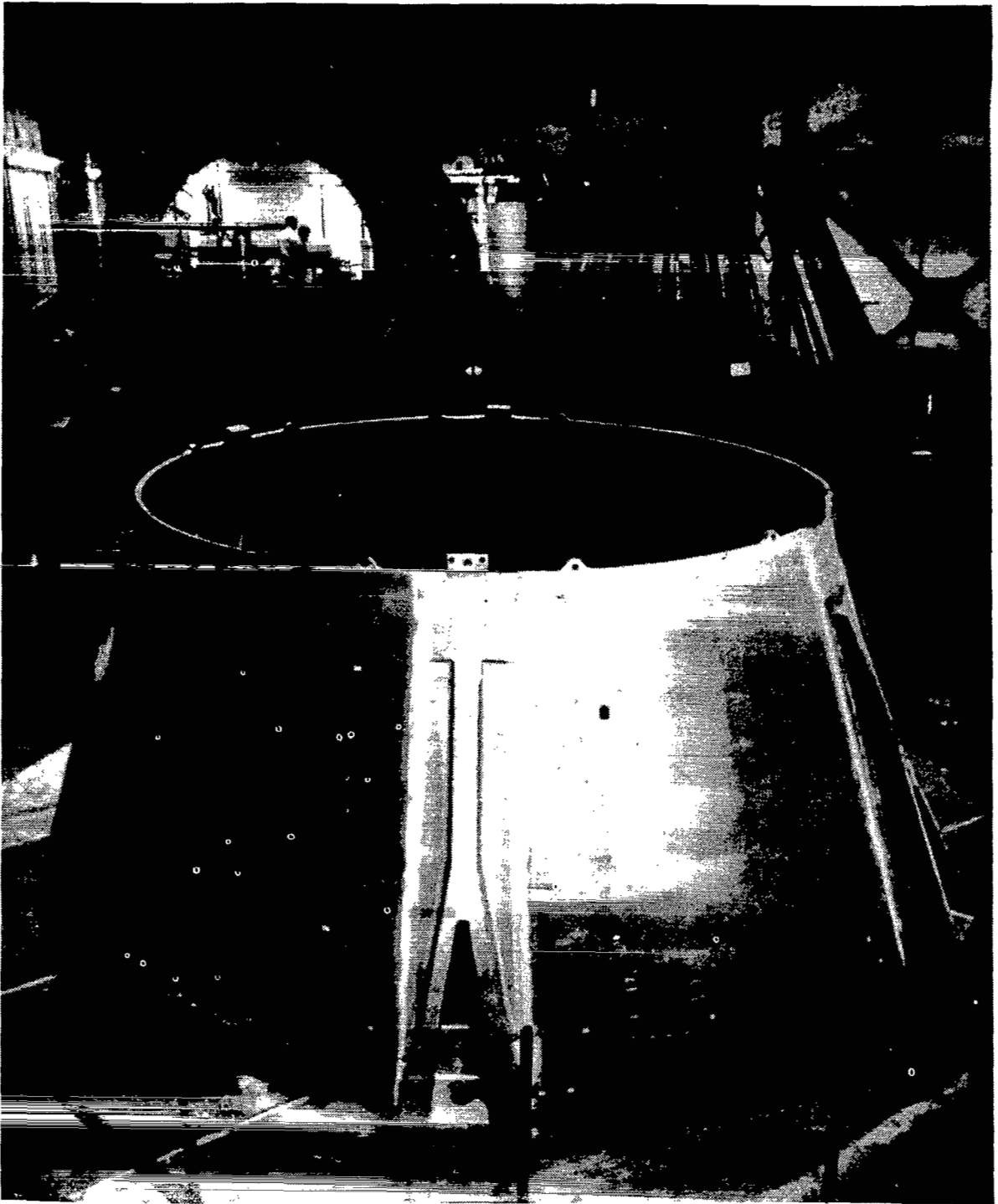


Figure 4. Aft skirt — holddown posts welded to skins.

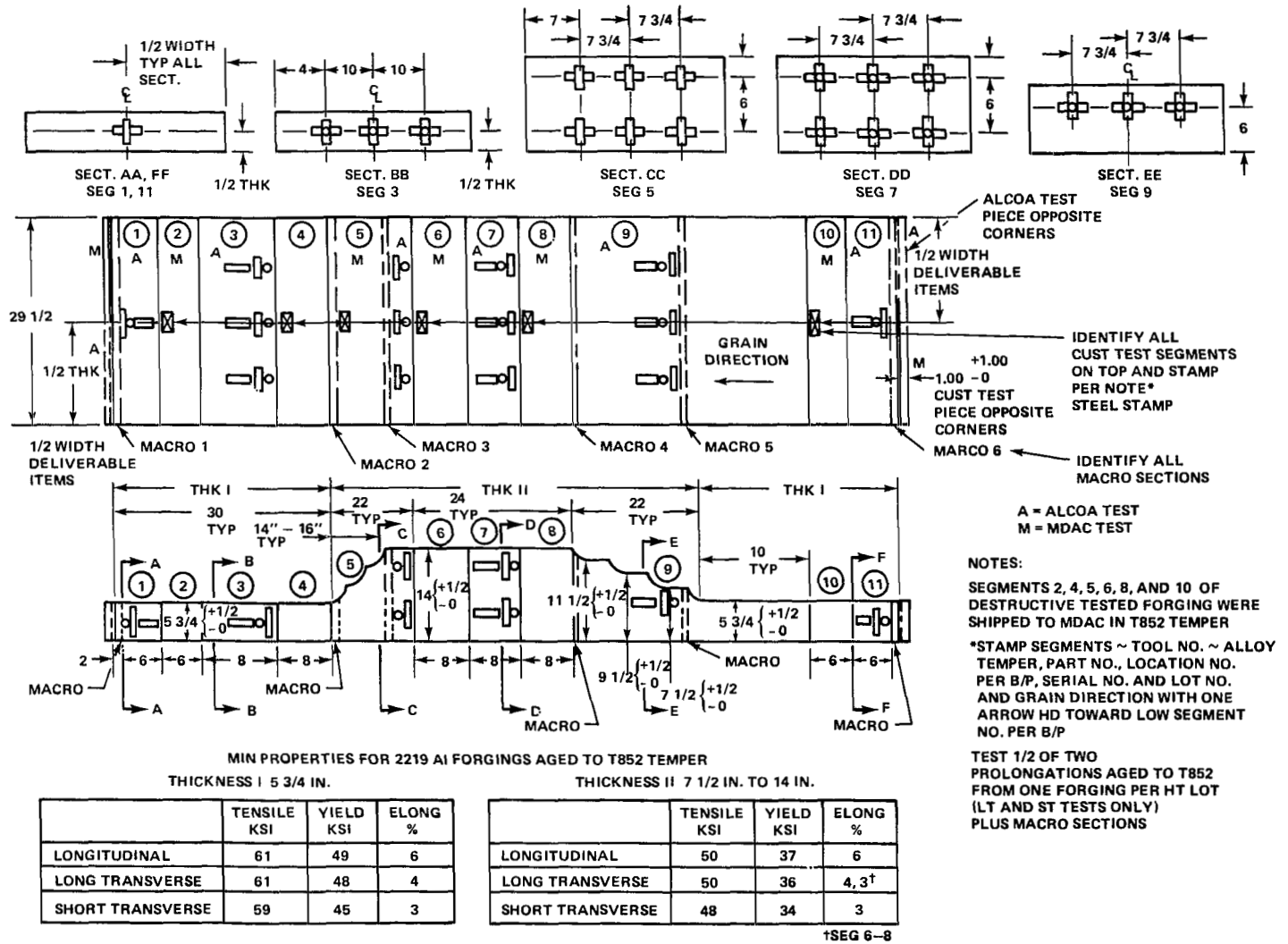


Figure 5. Dimensions and layout for contour hand forging P/N 14A20084.

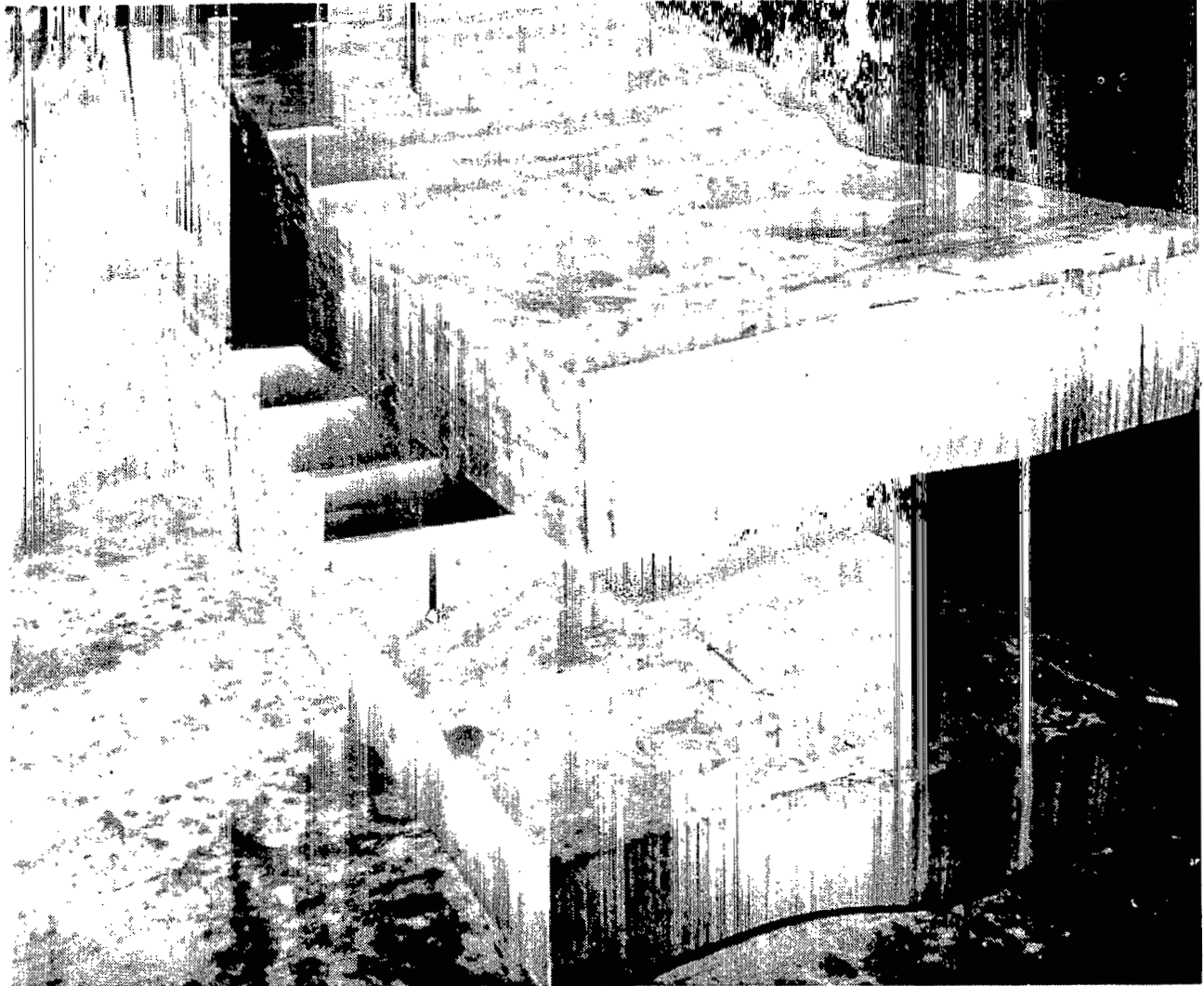


Figure 6. Contour forging P/N 14A20084 for thrust post.

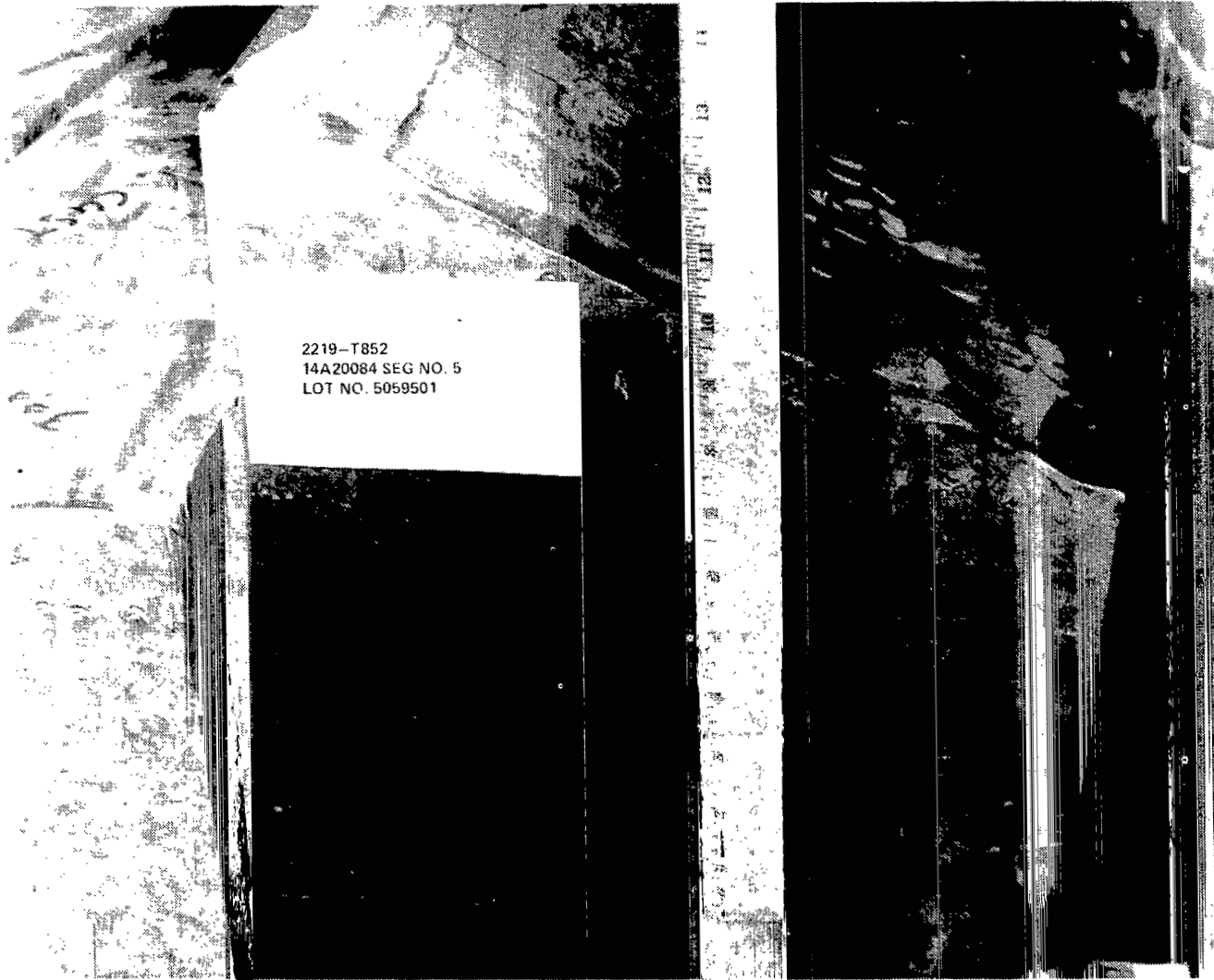


Figure 7. Thrust post — forward tapered segment 5 for destruct tests.

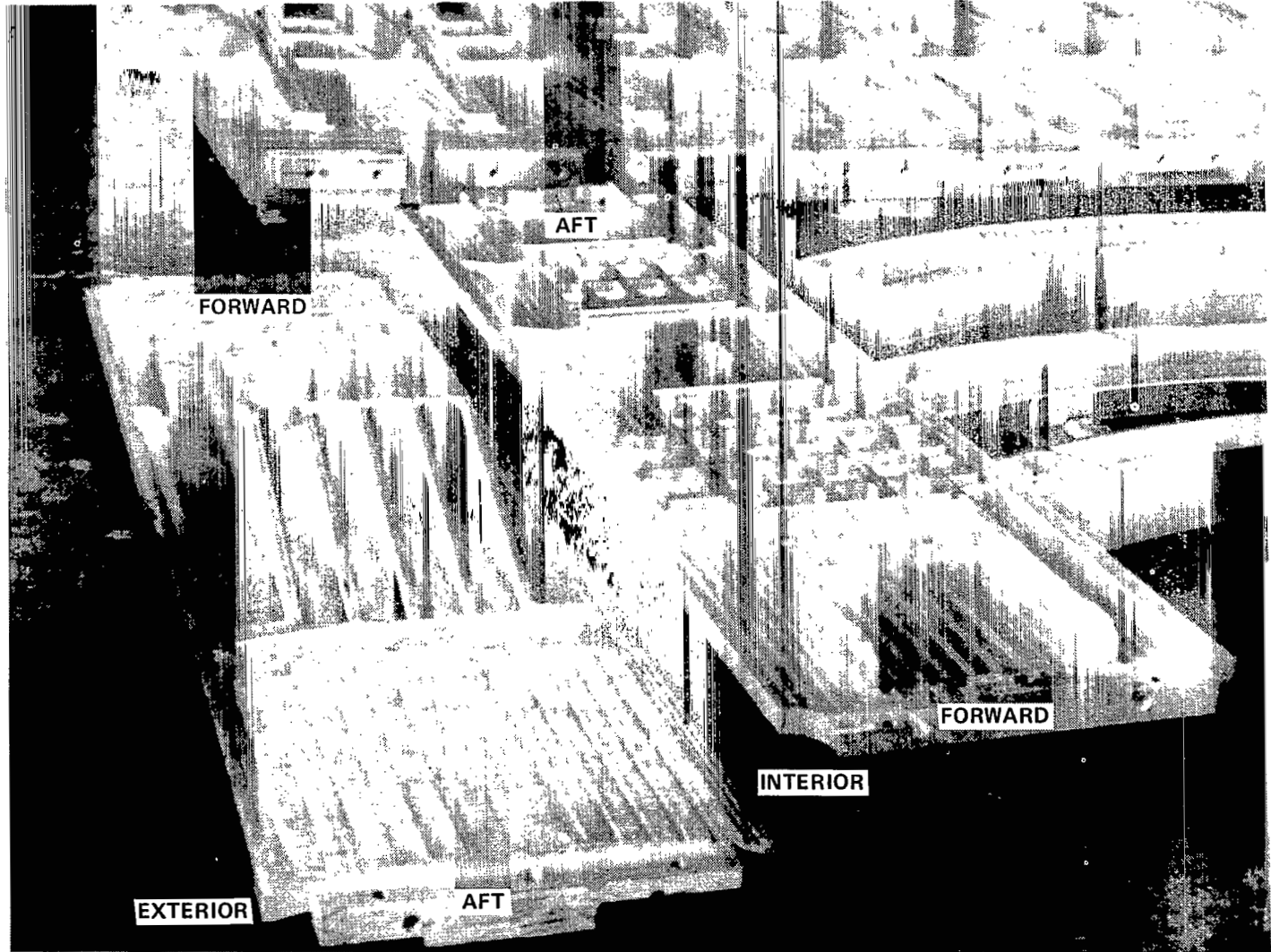


Figure 8. Thrust posts — rough machined exterior and interior.

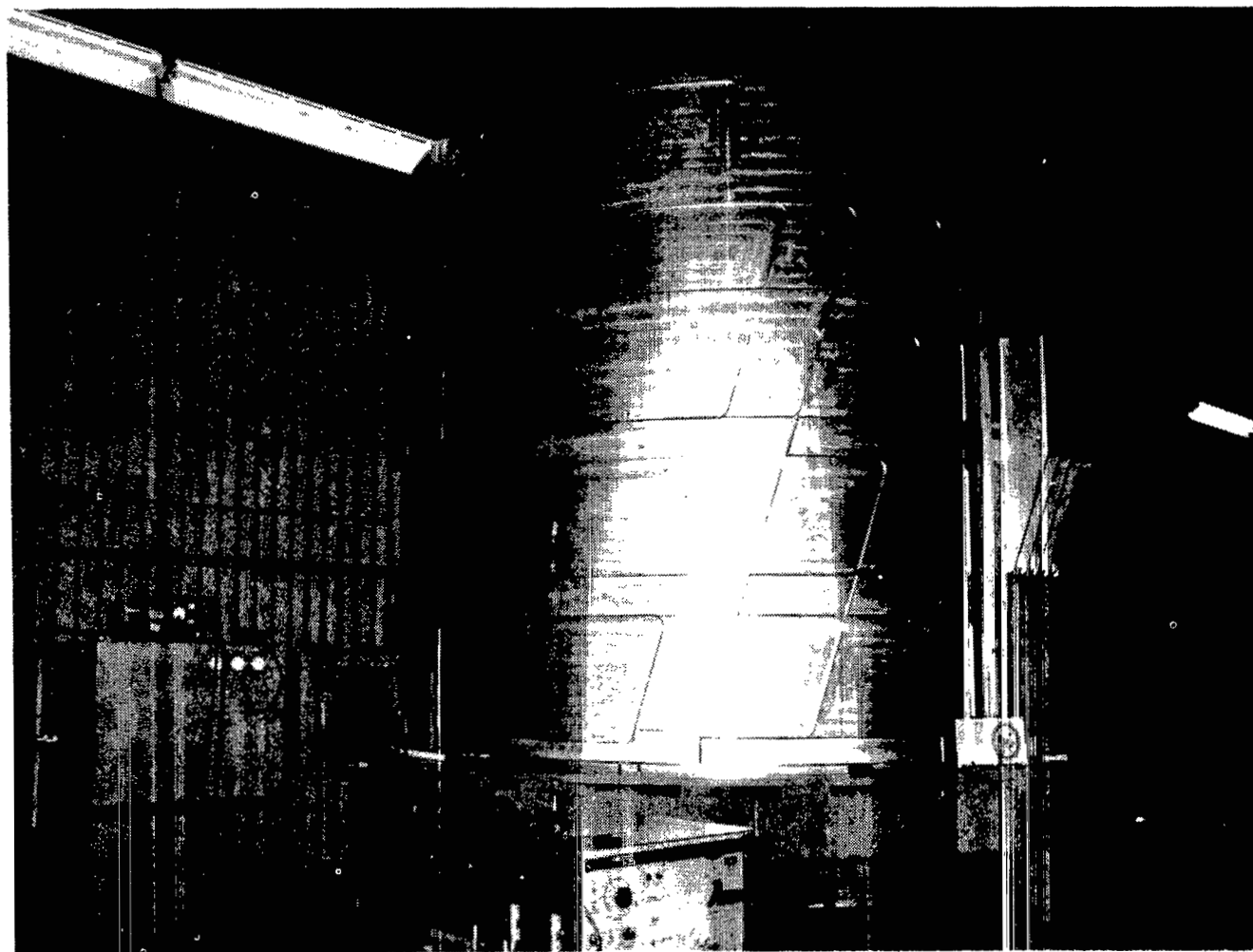
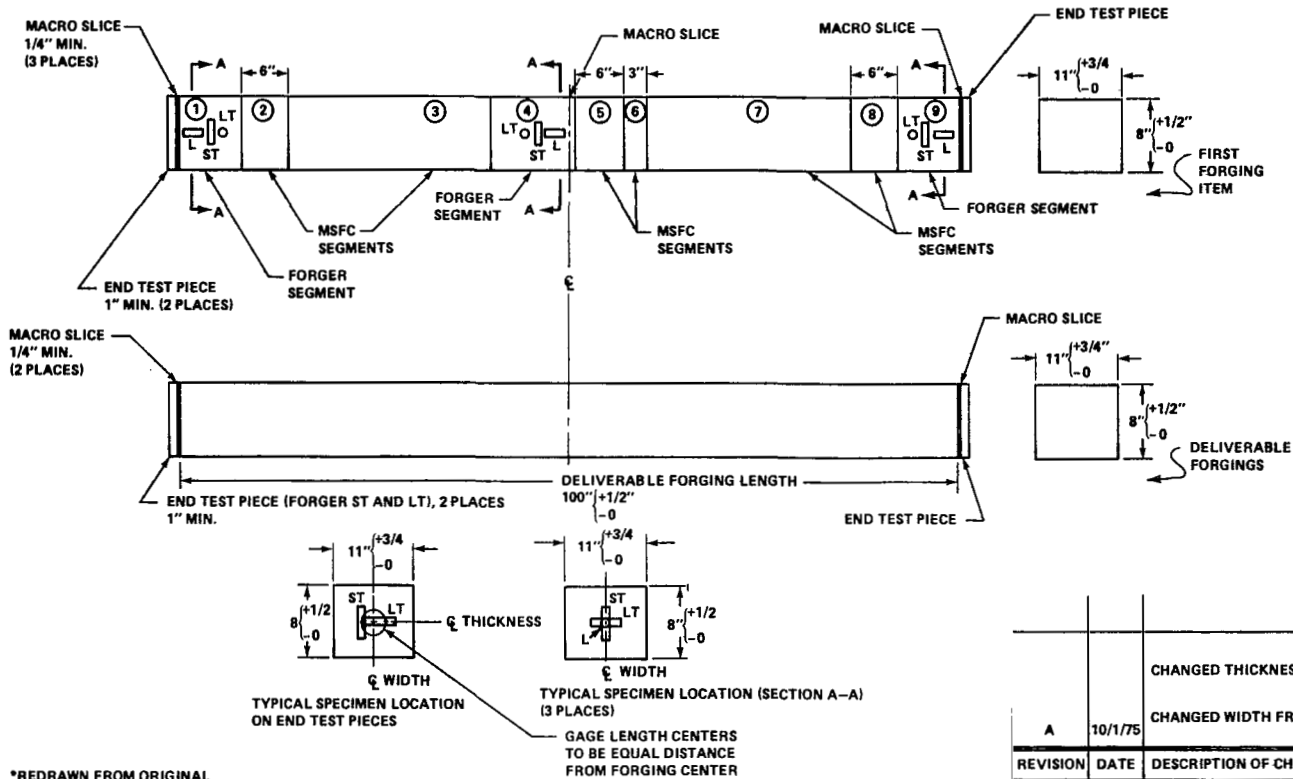


Figure 9. Forward skirt — thrust post welded to skins.



*REDRAWN FROM ORIGINAL

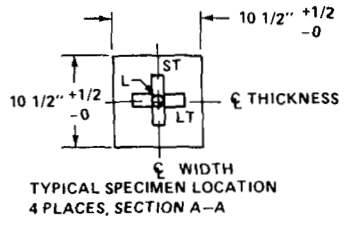
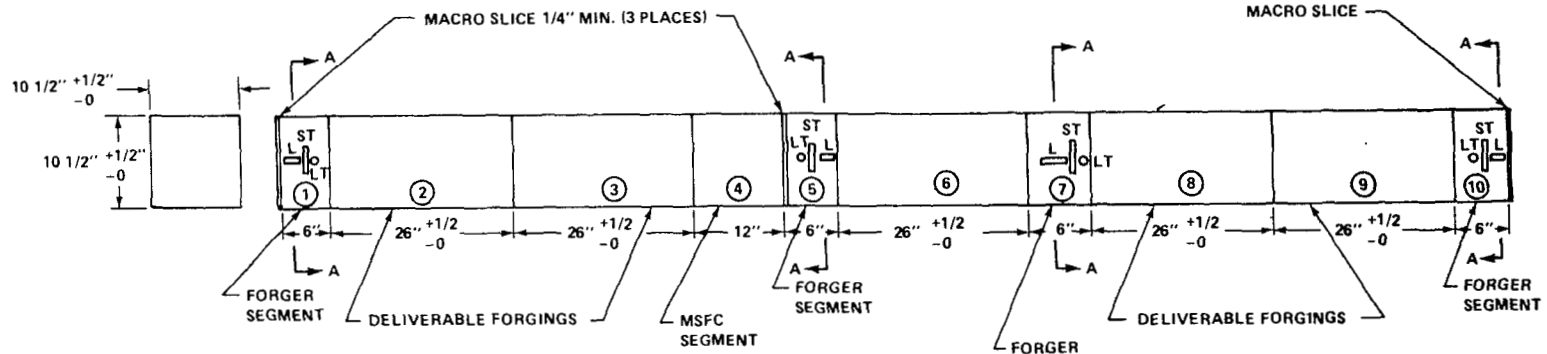
REVISION	DATE	DESCRIPTION OF CHANGES	APPROVAL
A	10/1/75	CHANGED THICKNESS FROM $9\frac{+1/2}{-0}$ " TO $8\frac{+1/2}{-0}$ " CHANGED WIDTH FROM $10\frac{+1/2}{-0}$ " TO $11\frac{+3/4}{-0}$ "	REB

DRAWING FOR FORGING 14A30500*

APPROVALS:

PROJECT	<u>Robert E. Butler</u>	SEPT 29, 1975
DESIGN	<u>W.O. Harrison</u>	9/30/75
M&P	<u>M.H. Baumgardner</u>	9-30-75
WEBER	<u>R. Weber</u>	10/7/75

Figure 10. Dimensions and layout for rectangular hand forging 14A30500.



*REDRAWN FROM ORIGINAL

A	10/1/75	INCREASED WIDTH & THICKNESS FROM 10'' (+1/2'', -0'') TO 10 1/2'' (+1/2'', -0'')	REG
REVISION	DATE	DESCRIPTION OF CHANGES	APPROVAL
DRAWING FOR FORGING 14A30905			
APPROVALS:	<i>Robert E. Bullock</i>		SEPT 29, '75
PROJECT	<i>W.O. Harrison</i>		9-30-75
DESIGN	<i>M.W. Brennecke</i>		9/30/75
M&P	<i>R. Atokal</i>		10/7/75
WEBER			

Figure 11. Dimensions and layout for rectangular hand forging 14A30905.

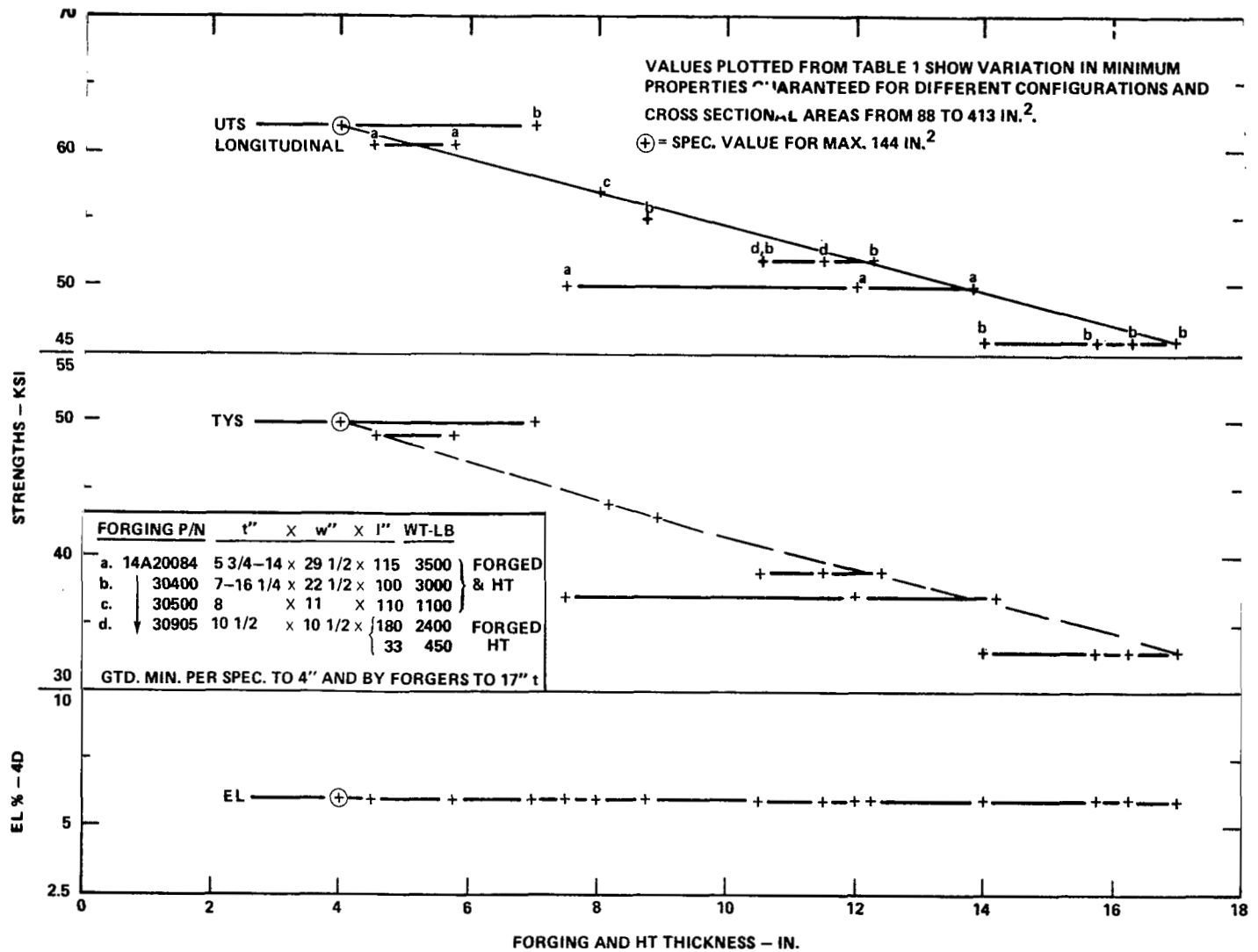


Figure 12. 2219-T852 Al hand forgings - rectangular and contour - guaranteed longitudinal properties - 1974-5.

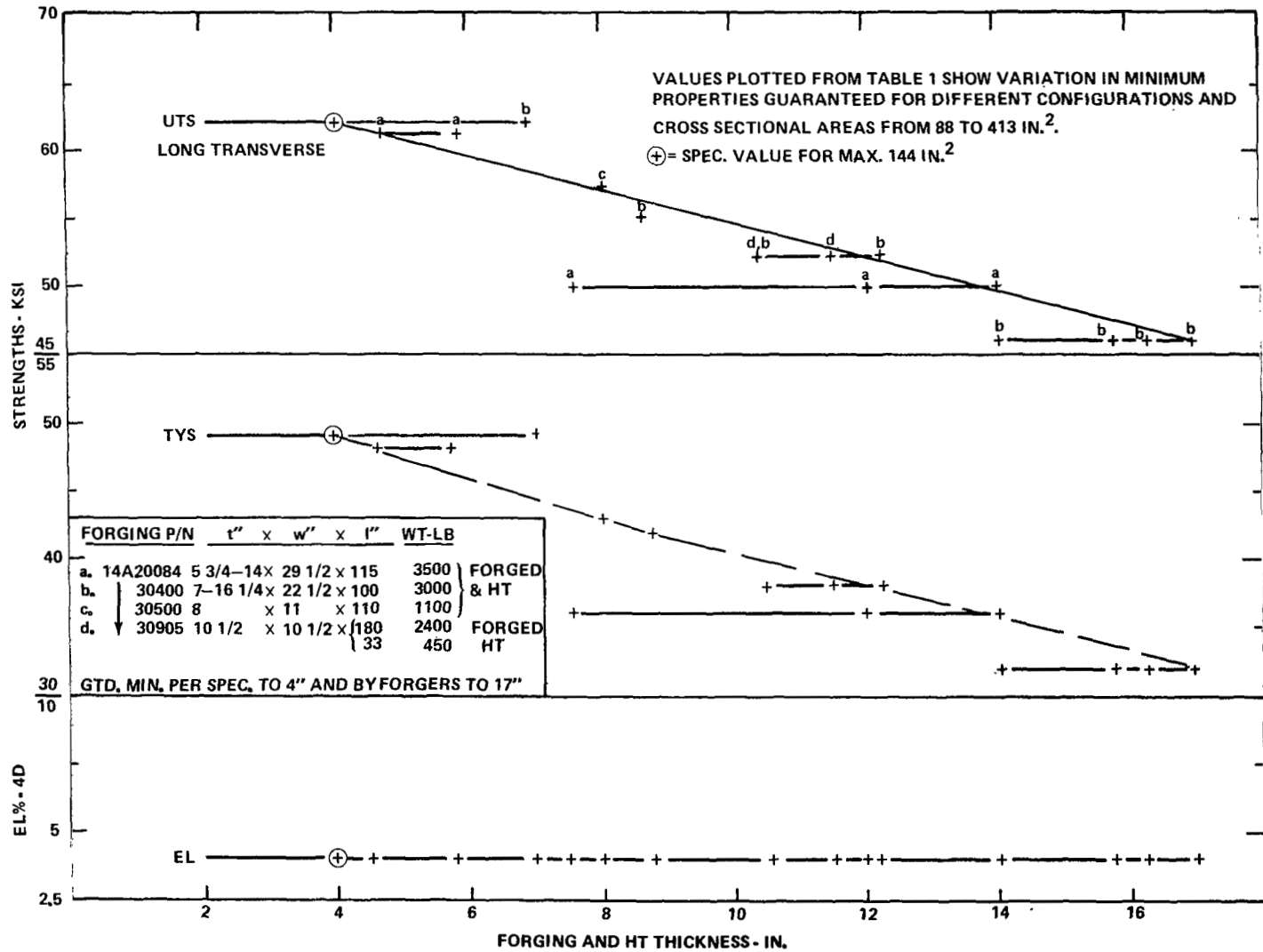


Figure 13. 2219-T852 Al hand forgings — rectangular and contour — guaranteed long transverse properties — 1974-5.

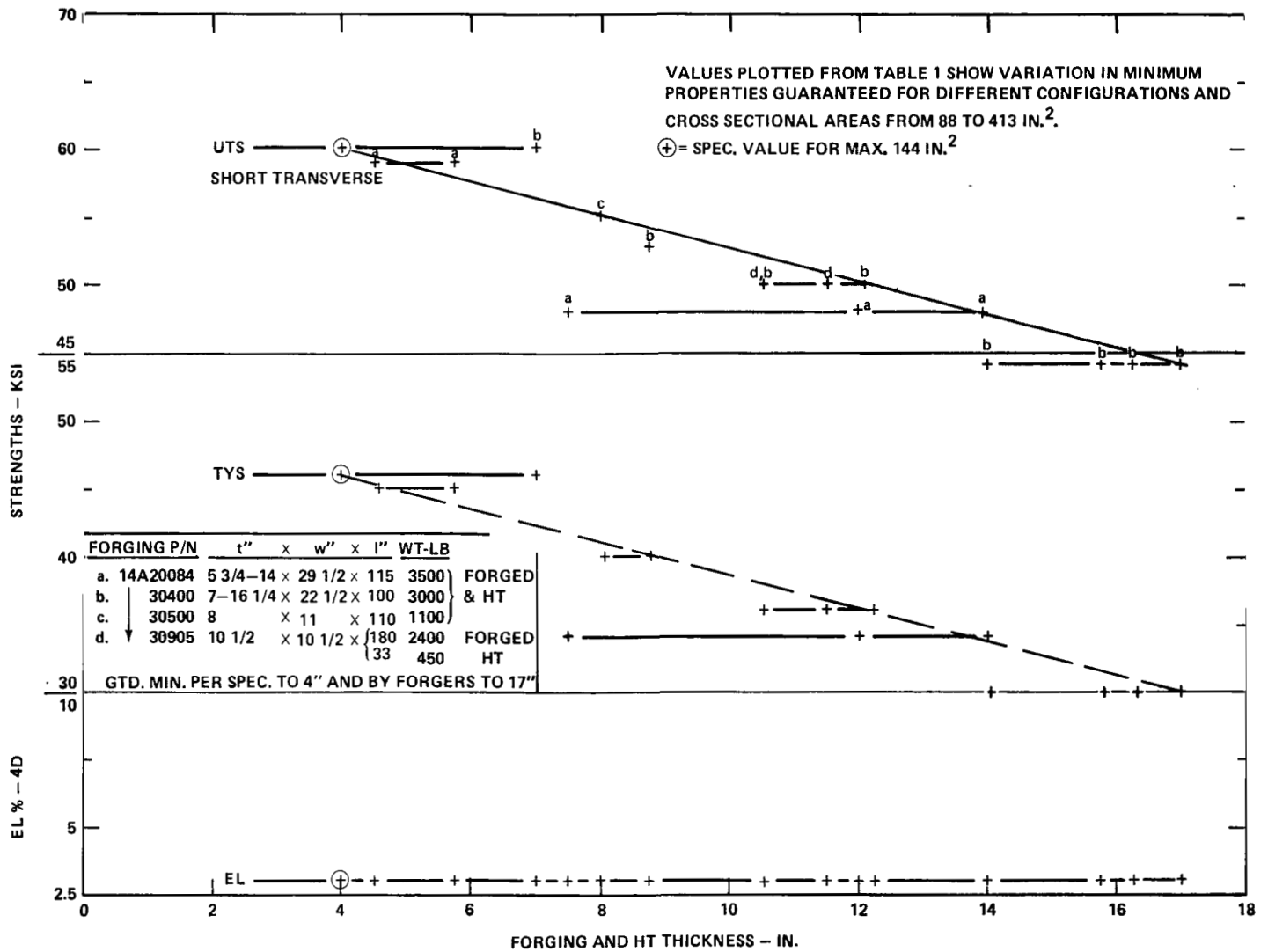


Figure 14. 2219-T852 Al hand forgings — rectangular and contour — guaranteed short transverse properties — 1974-5.

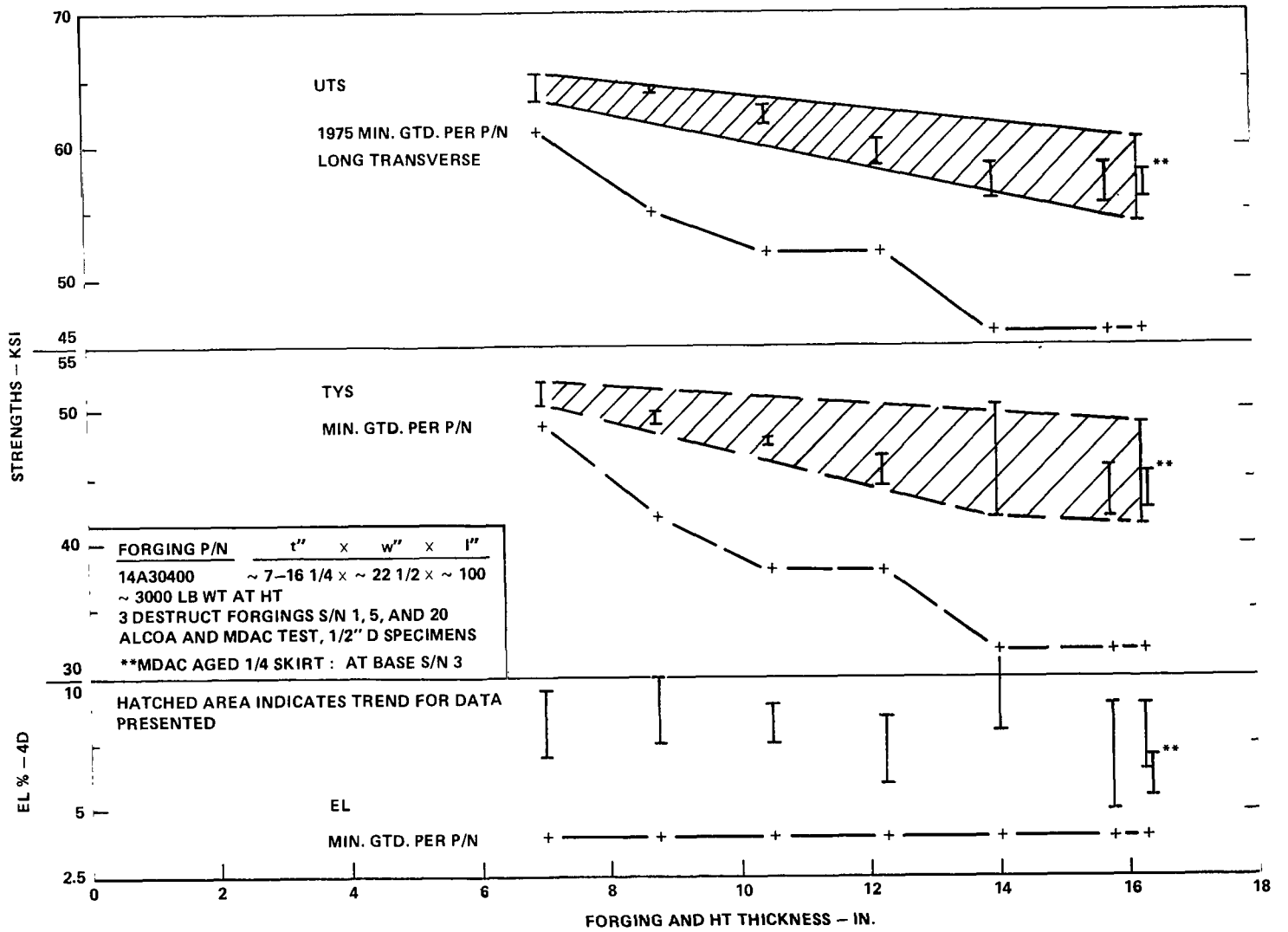


Figure 15. 2219-T852 Al contour hand forging 14A30400 - long transverse strength per P/N guarantee - destruct.

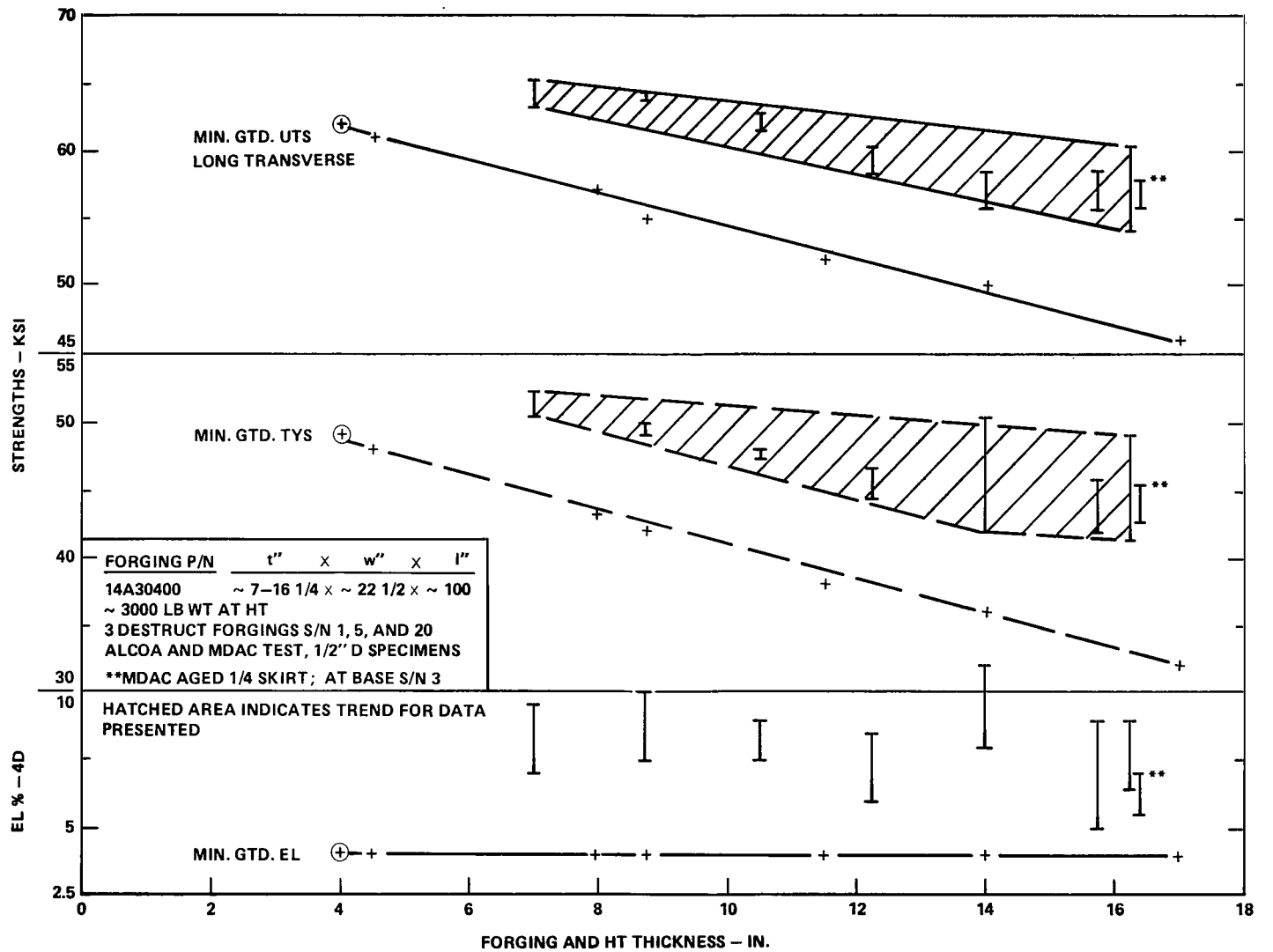


Figure 16. 2219-T852 Al contour hand forging 14A30400 — long transverse strength-versus-thickness — destruct.

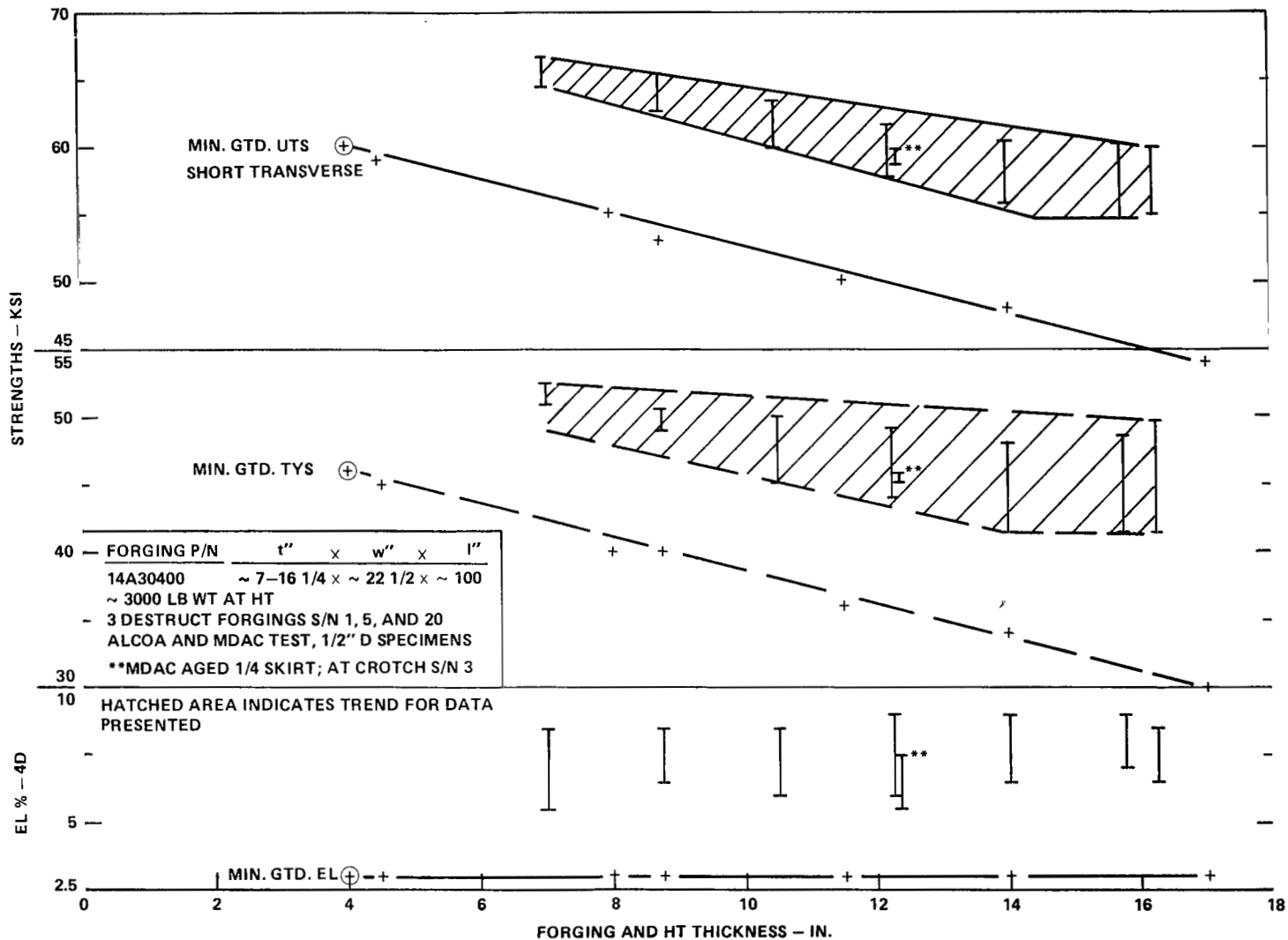


Figure 17. 2219-T852 Al contour hand forging 14A30400 — short transverse strength-versus-thickness — destruct.

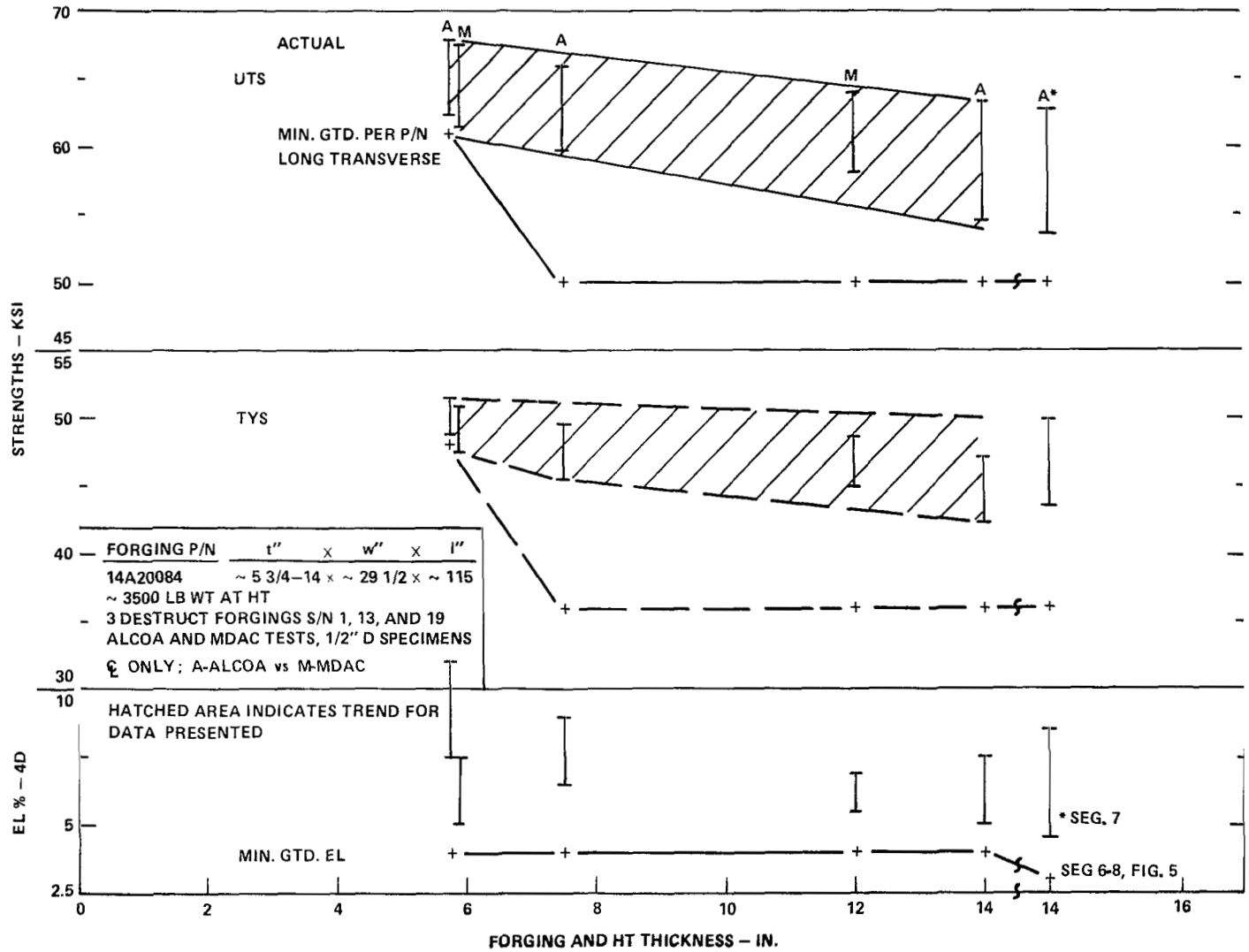


Figure 18. 2219-T852 Al contour hand forging 14A20084 - long transverse strength per P/N guarantee - destruct - ☒ only.

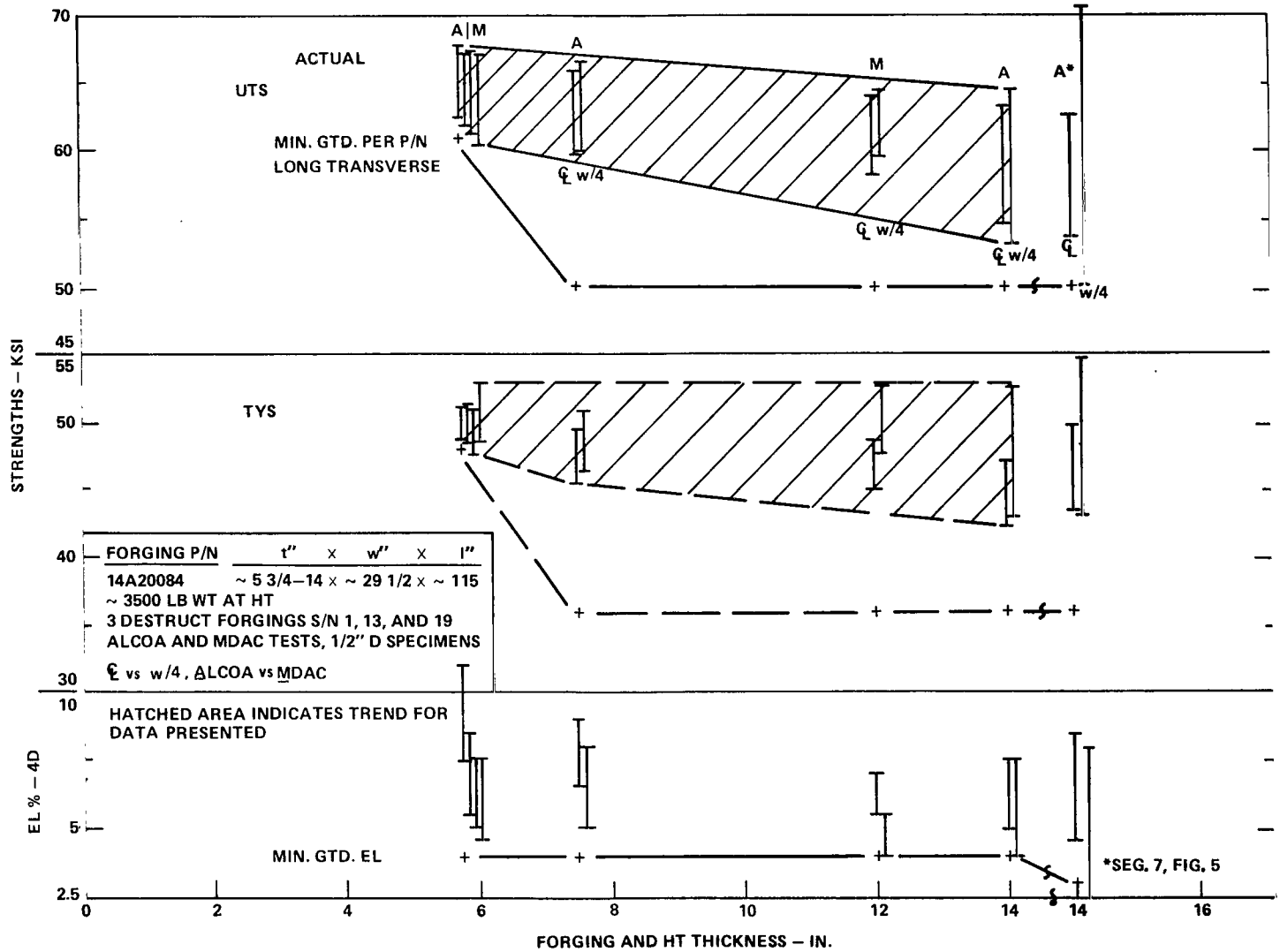


Figure 19. 2219-T852 Al contour hand forging 14A20084 - long transverse strength per P/N guarantee - destruct - \bar{Q} vs w/4.

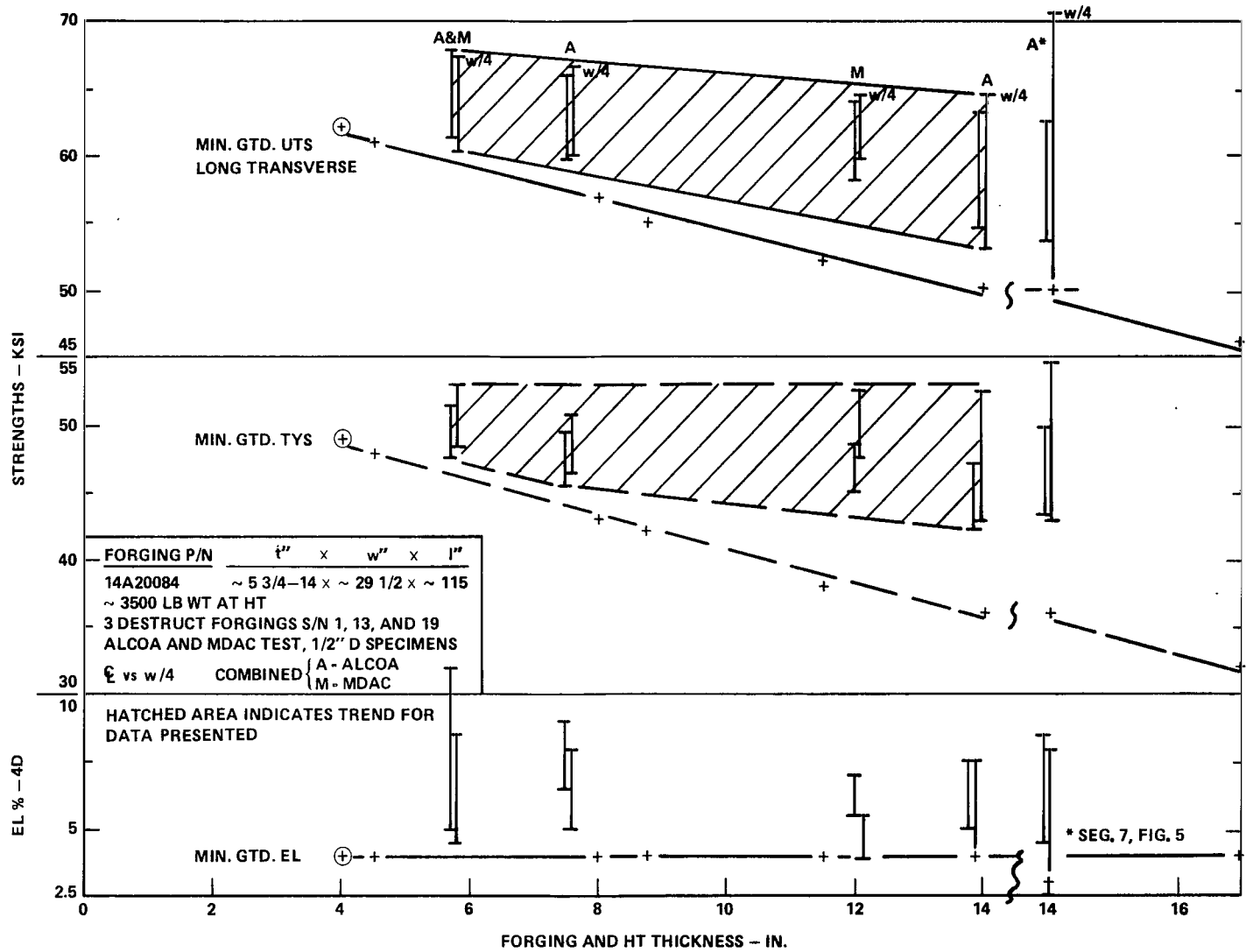


Figure 20. 2219-T852 Al contour hand forging 14A20084 — long transverse strength-versus-thickness — destruct — \bar{Q} -versus- $w/4$.

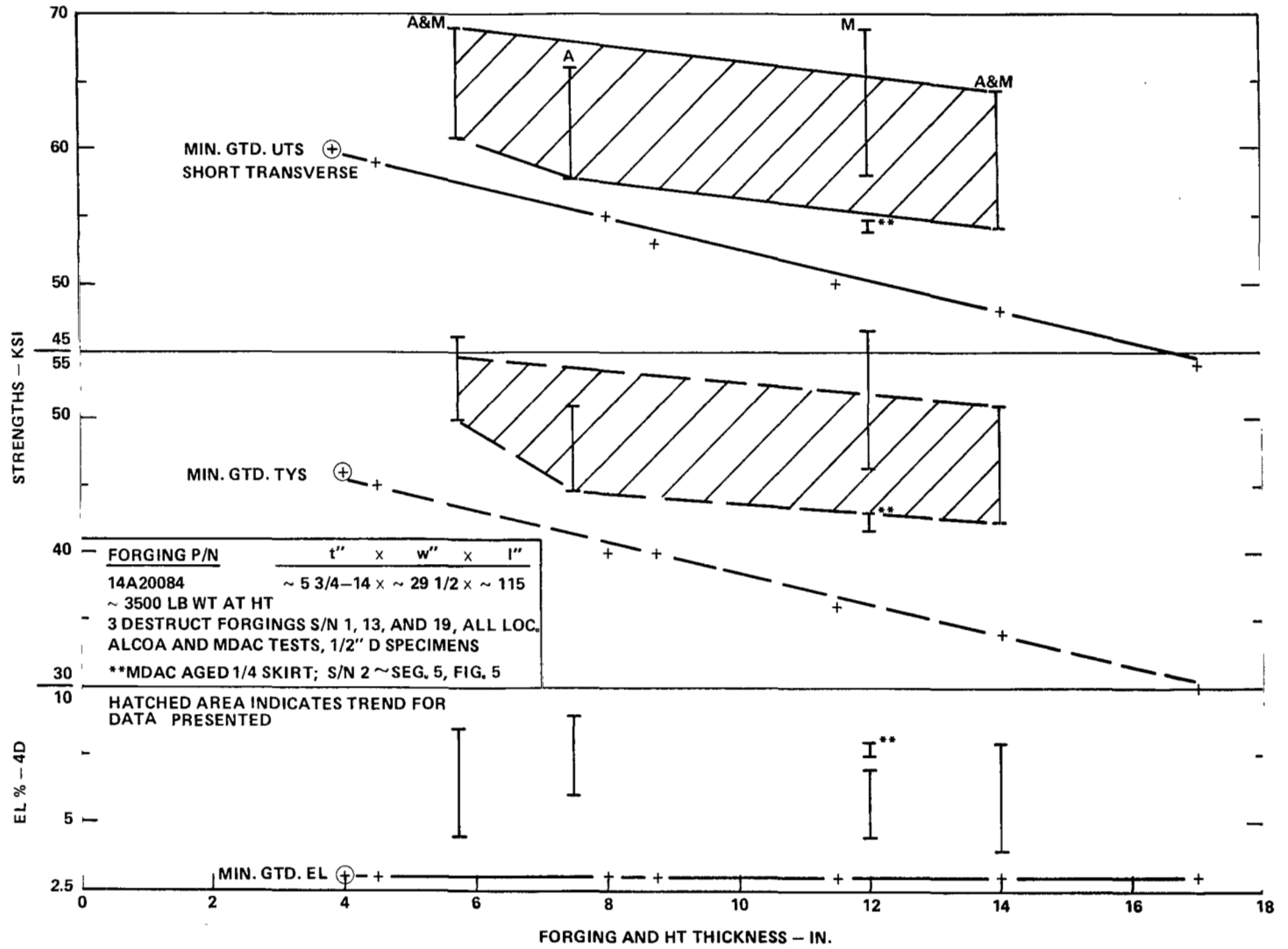


Figure 21. 2219-T852 Al contour hand forging 14A20084 — short transverse strength-versus-thickness — destruct.

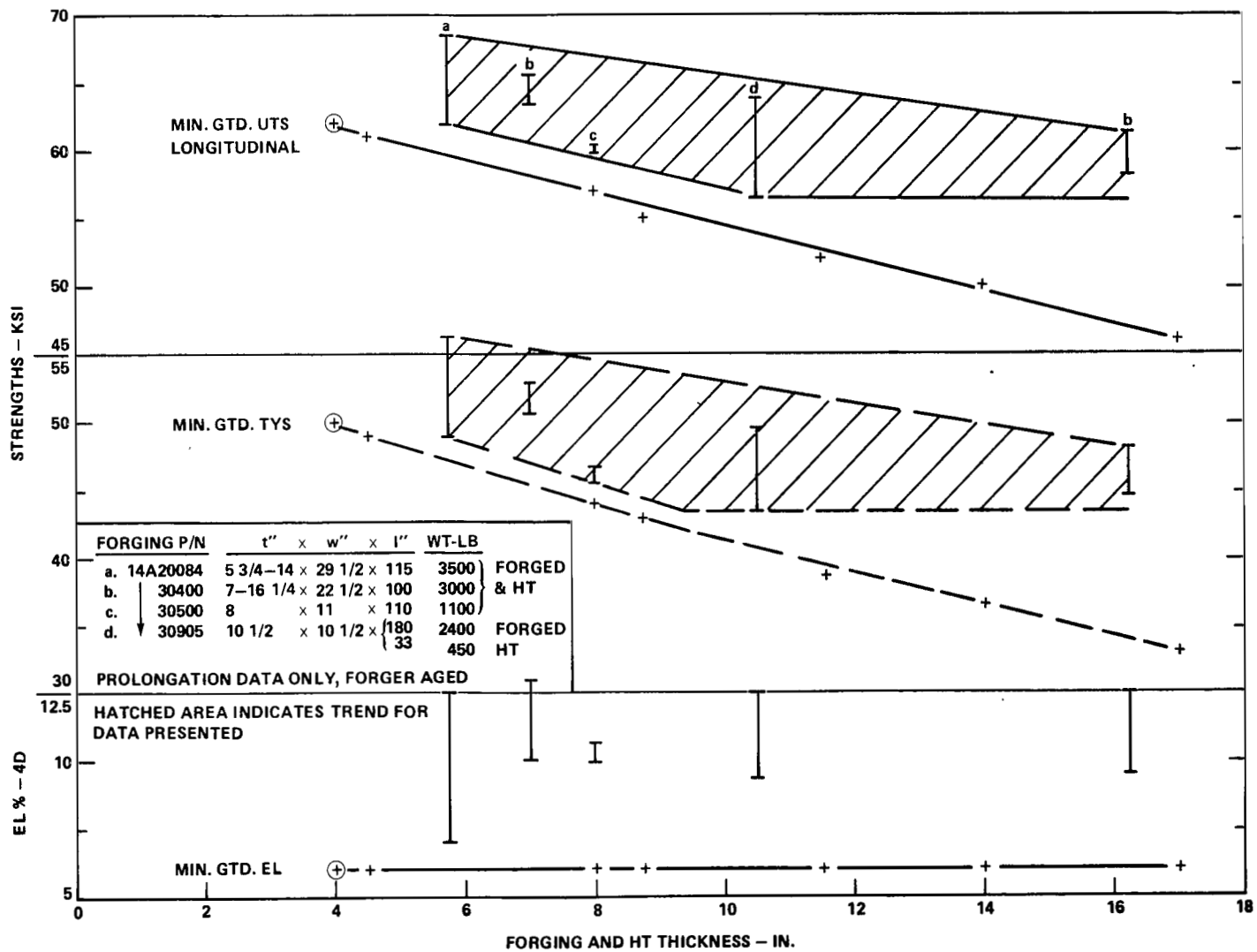


Figure 22. Combined data - 2219-T852 Al hand forgings - longitudinal strength-versus-thickness - prolongations.

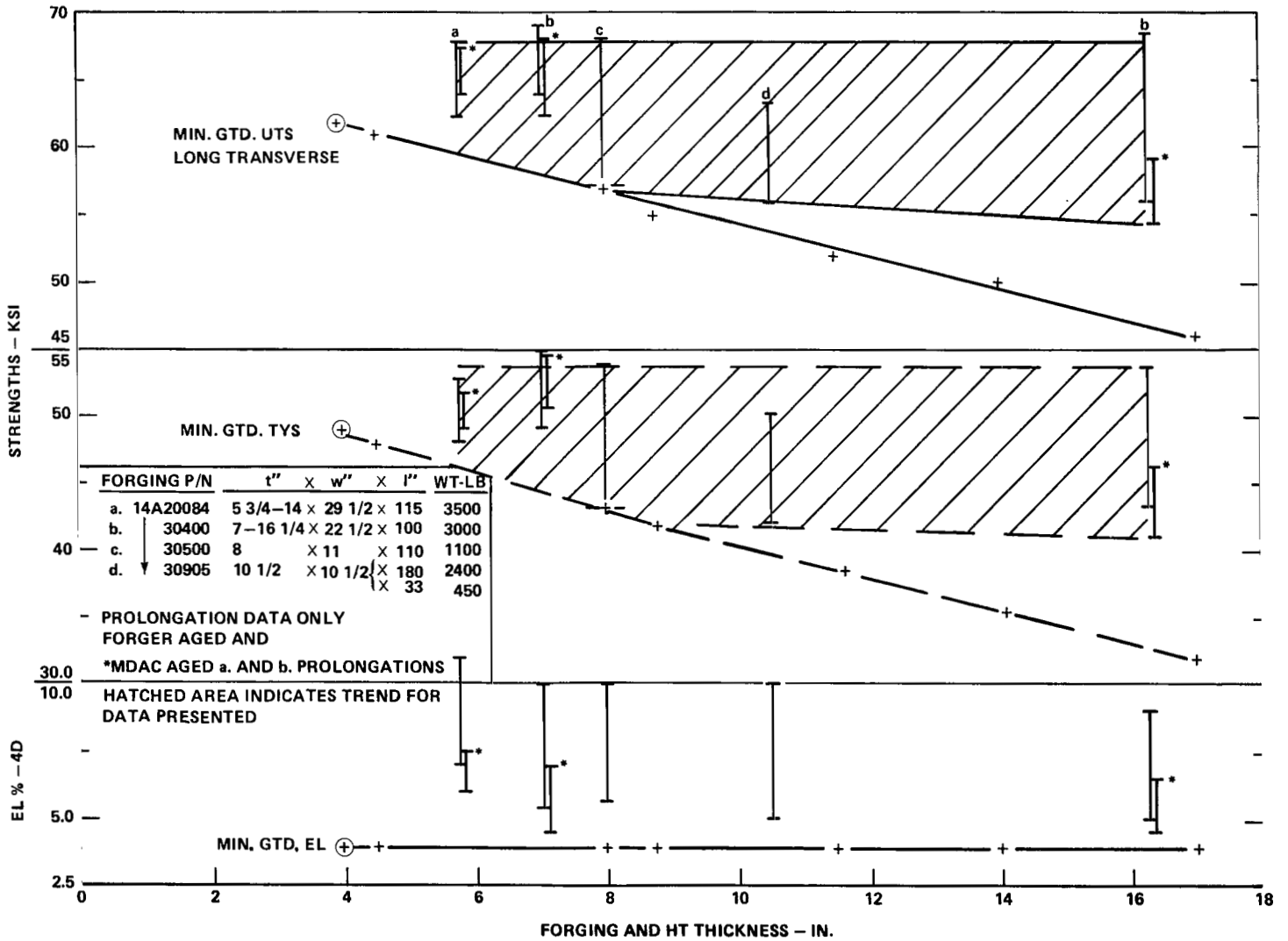


Figure 23. Combined data - 2219-T852 Al hand forgings - long transverse strength-versus-thickness - prolongations.

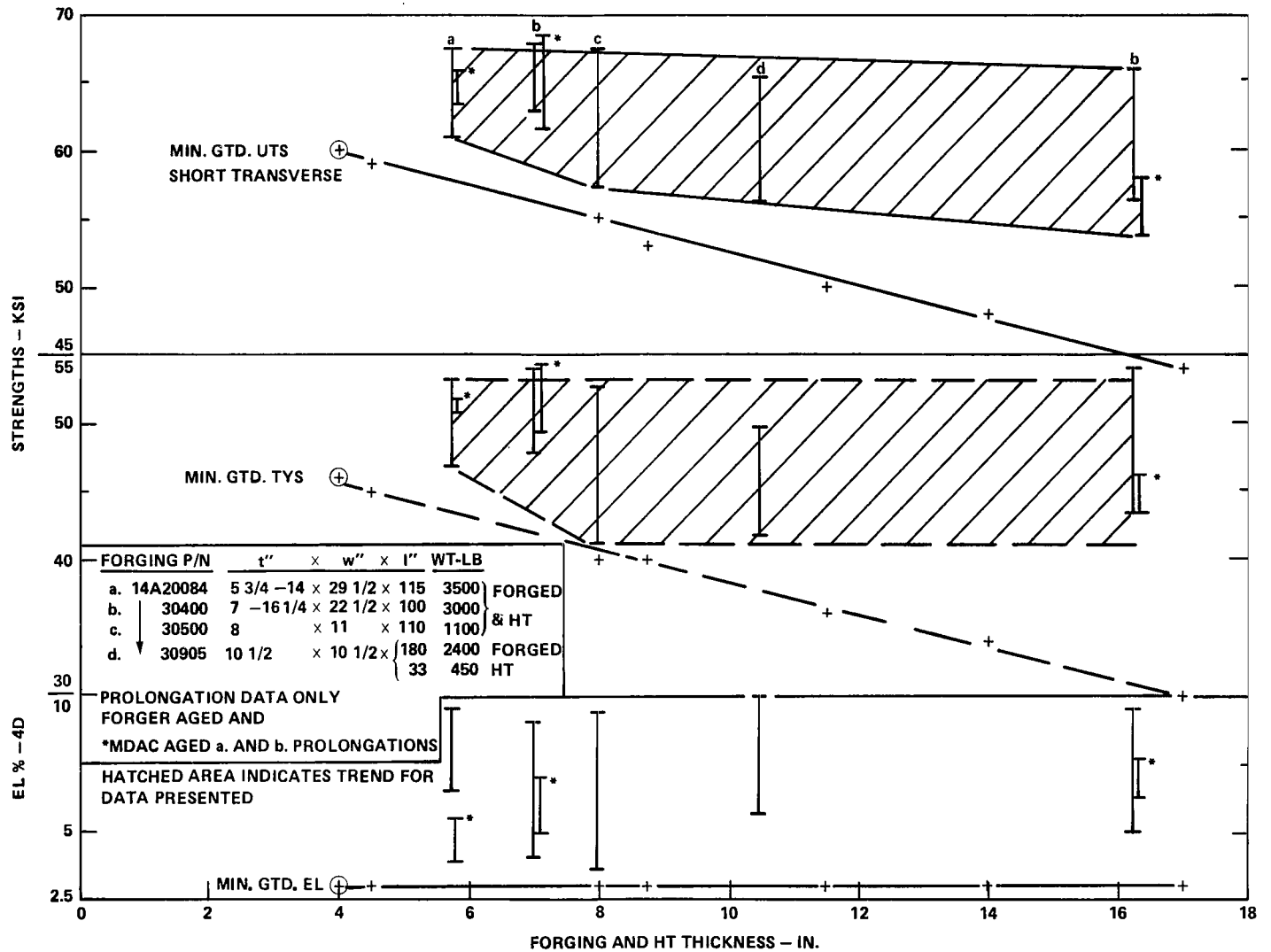


Figure 24. Combined data — 2219-T852 Al hand forgings — short transverse strength-versus-thickness — prolongations.

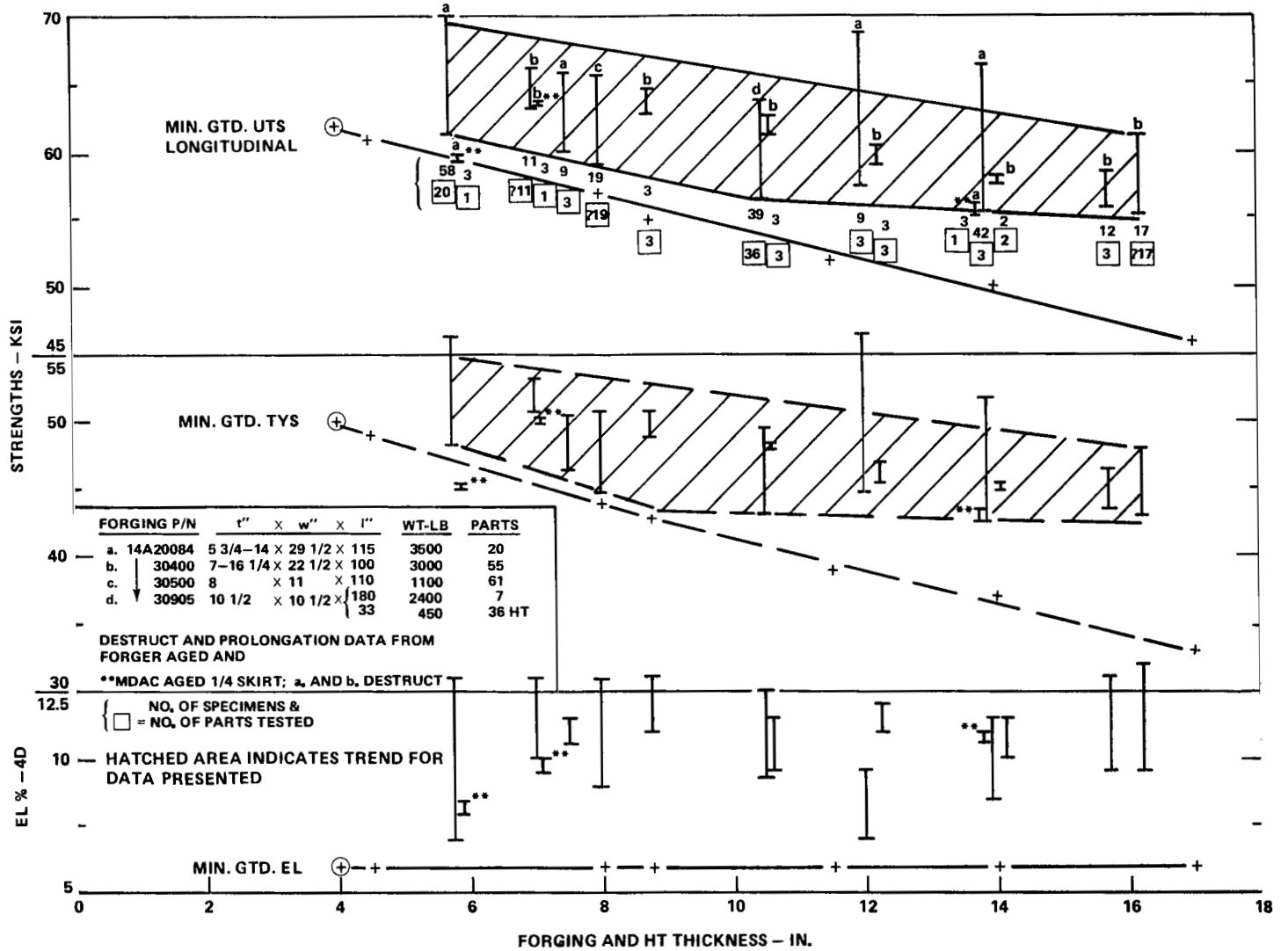


Figure 25. Combined data — 2219-T852 Al hand forgings — longitudinal strength-versus-thickness — 4 configurations.

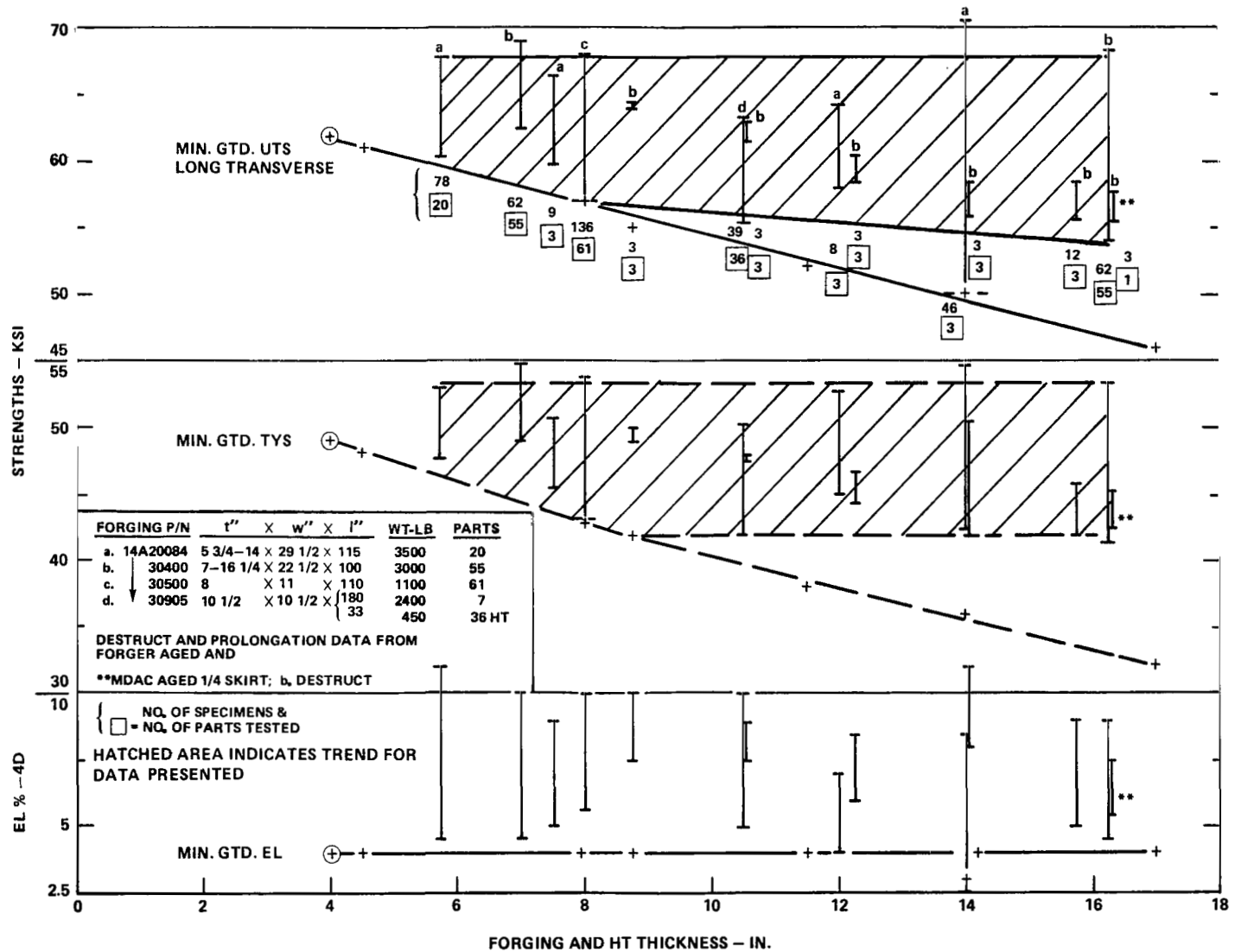


Figure 26. Combined data — 2219-T852 Al hand forgings — long transverse strength-versus-thickness — 4 configurations.

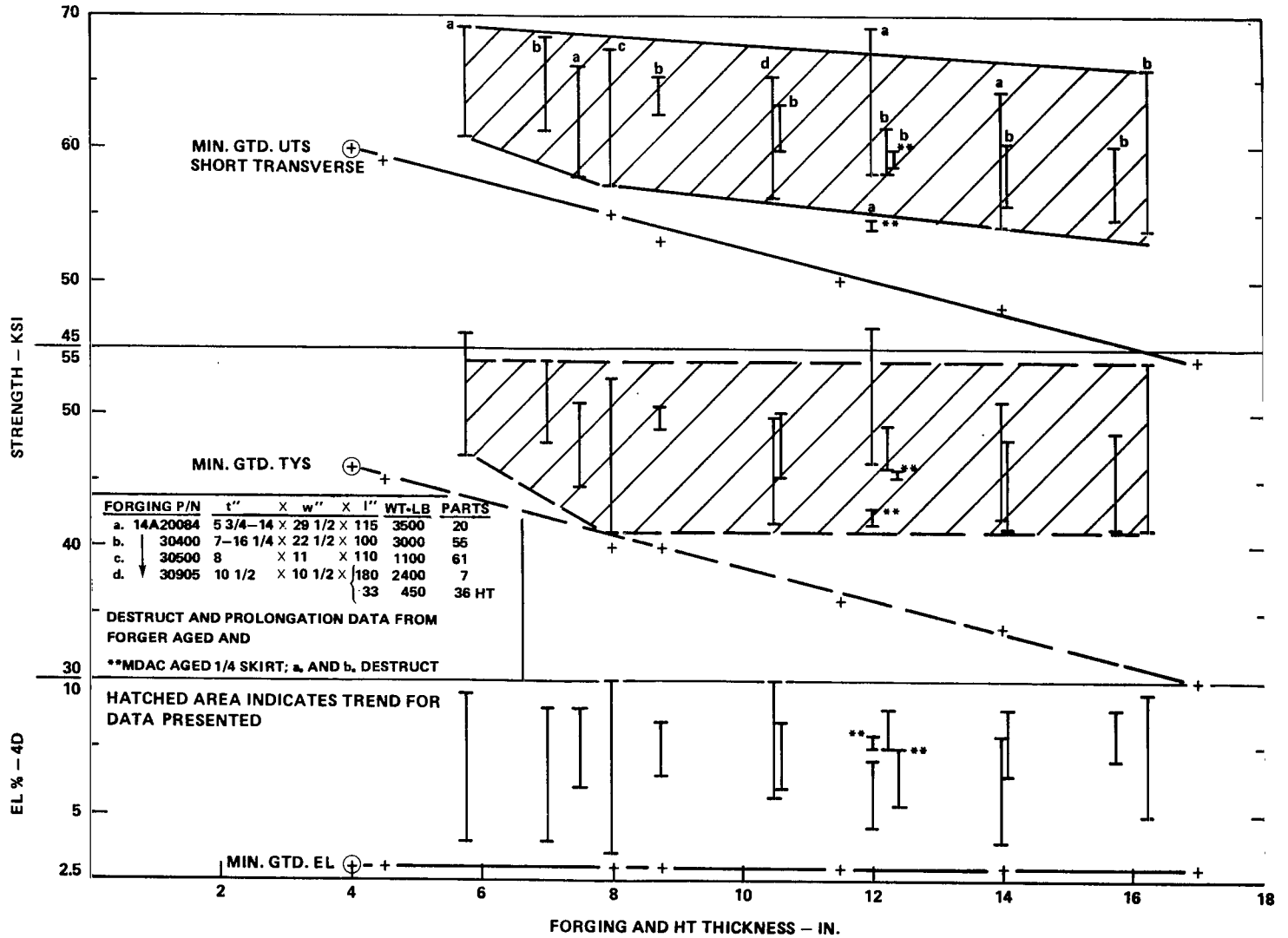


Figure 27. Combined data — 2219-T852 Al hand forgings — short transverse strength-versus-thickness — 4 configurations.

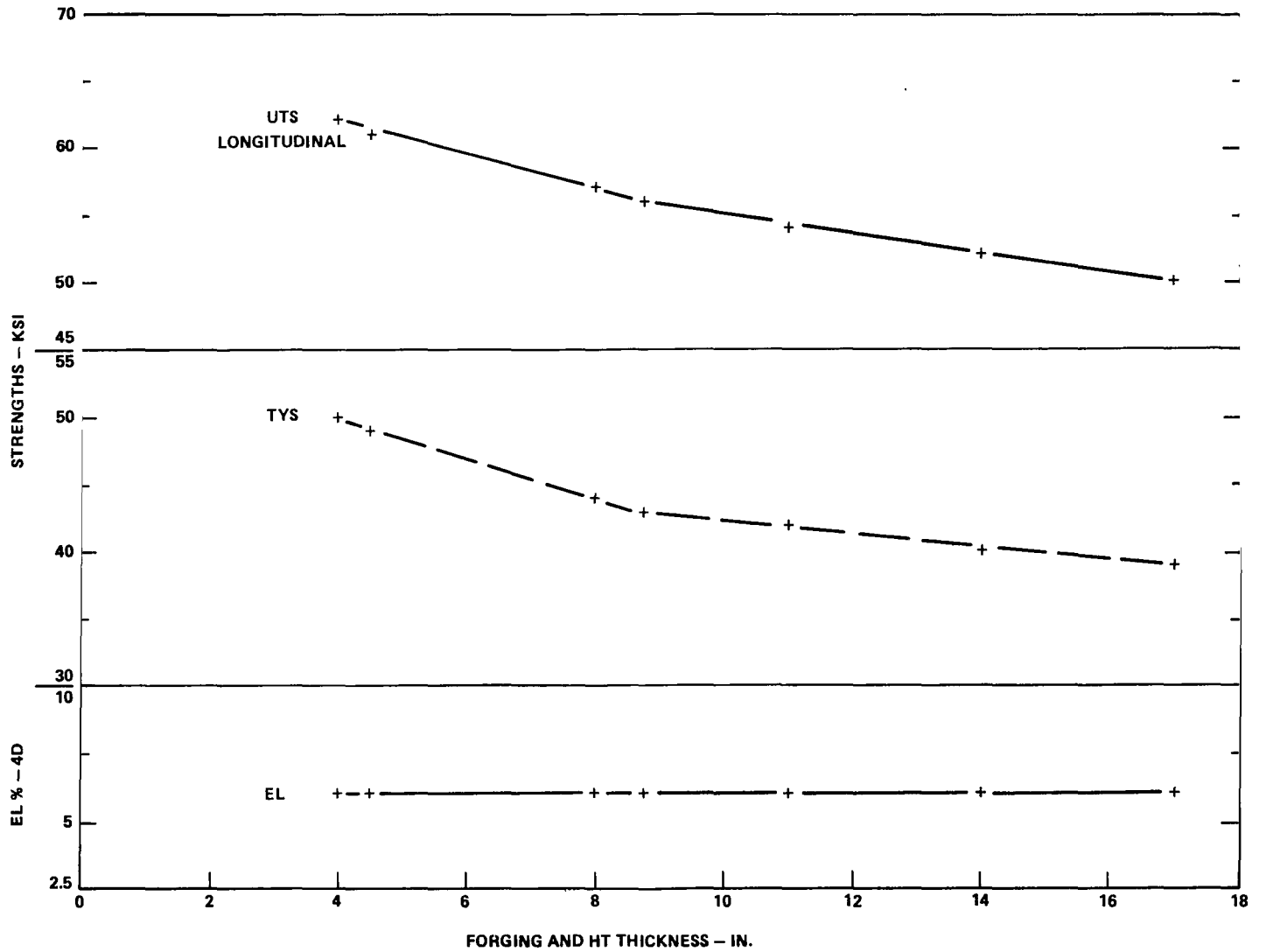


Figure 28. 2219-T852 Al hand forgings — rectangular and contour — proposed longitudinal properties

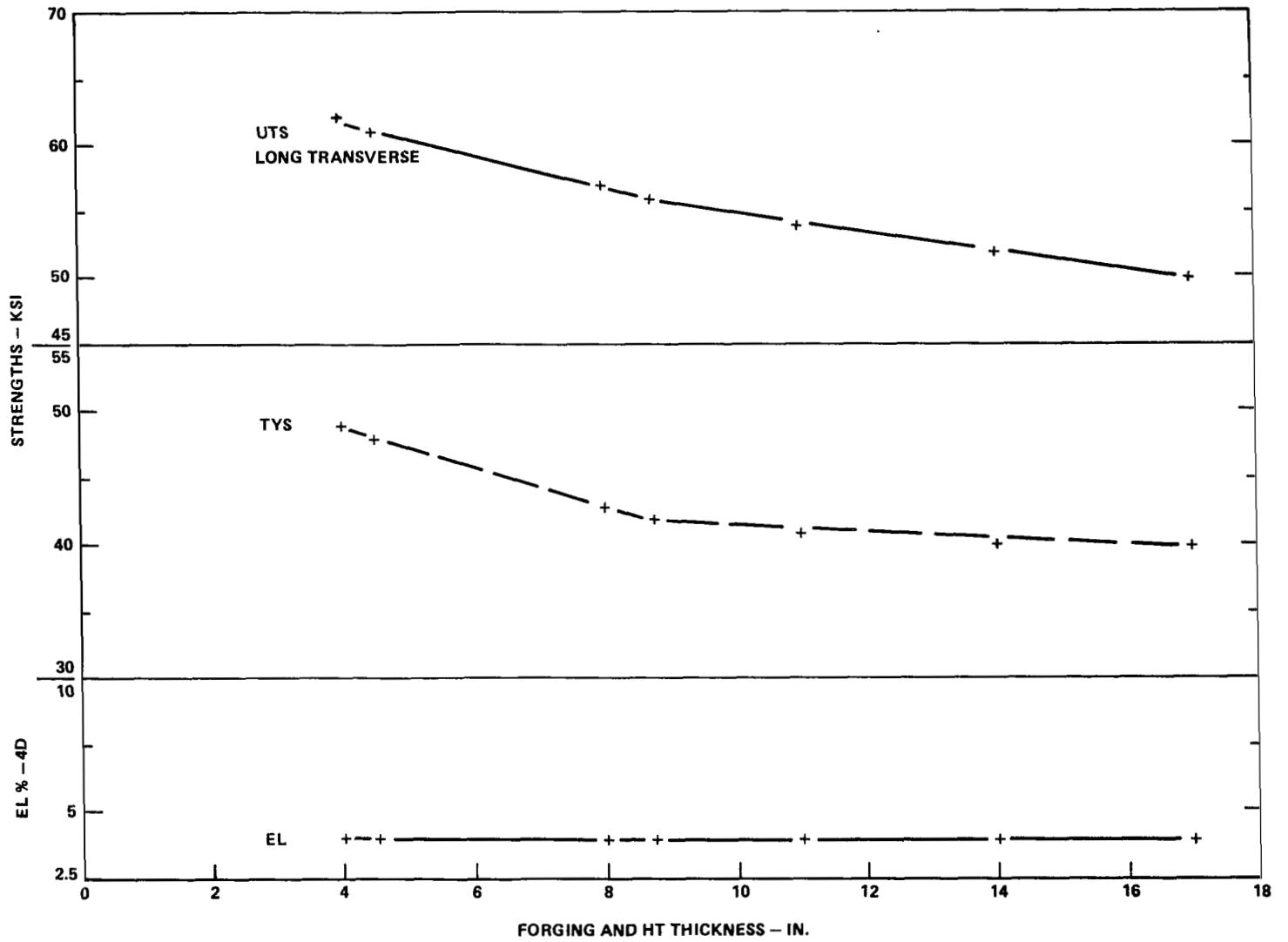


Figure 29. 2219-T852 Al hand forgings — rectangular and contour — proposed long transverse properties

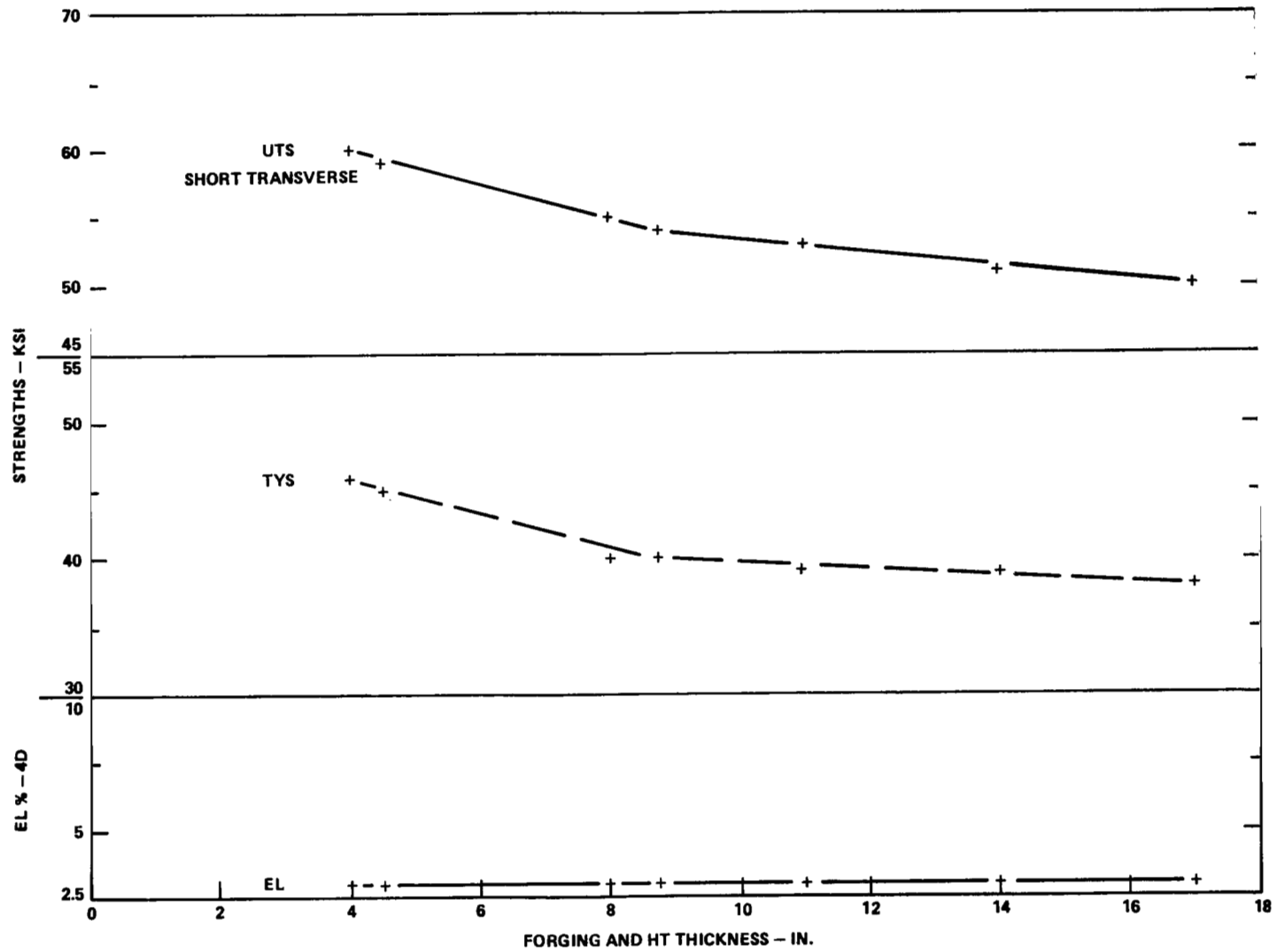


Figure 30. 2219-T852 Al hand forgings — rectangular and contour — proposed short transverse properties

TABLE 1. LARGE HAND FORGINGS — 2219-T852
MINIMUM GUARANTEED MECHANICAL PROPERTIES

	Thickness in.	Longitudinal (L)			Long Transverse (LT)			Short Transverse (ST)			SRB Forging Identification				
		UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	Forging P/N	Cross Section t" × w"		Test Segment No.	
Rectangular Hand Forgings															
1967 ↓	Up thru 4.0*	62	50	6	61	49	4	60	46	3	-	-	-	-	
	4.1 to 6.0*	60	47	6	60	46	4	58	43	3	-	-	-	-	
	6.1 to 8.0*	57	44	6	57	43	4	55	40	3	-	-	-	-	
Rectangular and Contour Hand Forgings															
1974-5 ↓ ↓ ↓ ↓ ↓	Up thru 4.0**	62	50	6	62	49	4	60	46	3	14A30400	7	× 22 1/2	1, 2 & Prolongation	
	4 1/2 Contoured	61	49	6	61	48	4	59	45	3	↓ 20084	5 3/4	× 29 1/2	1-4, 10, 11 & Prolongations	
	8.0 Rectangular	57	44	6	57	43	4	55	40	3	↓ 30500	8	× 11	All	
	8 3/4 Contoured	55	43	6	55	42	4	53	40	3	14A30400	8 3/4	× 22 1/2	3 & 4	
	11 1/2 Contoured		52	39	6	52	38	4	50	36	3	14A30905	10 1/2	× 10 1/2	All (Rectangular)
													↓ 30400	↓	
14 Contoured		50	37	6	50	36	4	48	34	3	14A20084	7 1/2-14 [†]	× 29 1/2	5 & 9	
												↓	14	× ↓	6-8
1976	↓				50	36	3								
1974-5	17 ↓	46	33	6	46	32	4	44	30	3	14A30400	14	× 22 1/2	10 & 11	
												↓	15 3/4	× ↓	12 & 13
												↓	16 1/4	× ↓	14 & 15 & Prolongation

*Minimum tentative guarantees.

**Federal Specification QQ-A-367H; AMS 4144A '75

[†]Tapered areas.

TABLE 2. FORGER TEST DATA — 2219-T852 CONTOUR HAND FORGINGS —
HOLDDOWN POST — DESTRUCT TEST

Destruct Test Forging P/N 14A30400			Tensile Properties								
			Longitudinal			Long Transverse			Short Transverse		
S/N	Seg: No.	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		7	62	50	6	61	49	4	60	46	3
1	1	~7	65.2	52.1	11.0	64.4	50.5	9.0	66.2	50.9	7.0
5	↓	↓	66.4	53.3	11.5	65.4	52.3	9.5	65.0	51.8	8.5
20	↓	↓	64.7	51.5	11.5	63.4	52.3	7.0	64.9	51.2	6.0
Min. Gtd.		8 3/4	55	43	6	55	42	4	53	40	3
1	3	~8 3/4	64.7	49.5	11.0	64.5	49.1	7.5	65.4	50.6	7.5
5	↓	↓	64.4	50.9	12.0	63.9	49.3	10.0	64.4	50.7	8.5
20	↓	↓	62.9	48.9	13.0	64.2	50.0	9.0	63.7	49.0	8.0
Min. Gtd.		10 1/2-12 1/4	52	39	6	52	38	4	50	36	3
1	5	~10 1/2	62.6	48.1	9.5	62.9	47.4	7.5	62.9	48.1	8.0
5	↓	↓	61.4	48.2	11.5	62.4	47.8	8.0	60.9	47.4	7.5
20	↓	↓	61.3	48.1	11.5	61.6	48.1	9.0	63.4	50.1	8.0
1	7	~12 1/4	59.4	47.1	12.0	60.4	46.7	6.0	60.3	46.0	9.0
5	↓	↓	59.1	45.7	11.5	58.4	44.3	8.5	58.2	46.3	8.0
20	↓	↓	60.6	47.1	11.0	60.0	46.0	8.0	61.6	49.2	7.5
Min. Gtd.		14-16 3/4	46	33	6	46	32	4	44	30	3
1	11	~14	58.3	45.0	10.0	58.4	44.5	8.0	57.6	43.5	8.5
5	↓	↓	57.6	45.5	11.5	55.9	42.0	9.0	55.7	41.6	9.0
20	↓	↓	58.5	45.5	11.0	58.5	50.4	11.0	60.3	48.1	8.0
1	13	~15 3/4	57.0	46.3	13.0	56.9	41.9	9.0	59.8	46.5	9.0
5	↓	↓	57.1	46.6	11.0	58.6	43.5	6.5	55.1	43.6	8.0
20	↓	↓	56.9	43.5	13.0	57.1	45.8	8.0	60.1	48.6	8.0
1	15	~16 1/4	57.6	46.3	12.0	57.3	42.9	8.5	59.8	47.0	8.5
5	↓	↓	56.2	44.6	13.5	54.1	41.4	9.0	54.9	44.3	8.5
20	↓	↓	58.9	45.7	11.0	60.4	49.0	6.5	58.9	49.7	8.5

Note: All locations are ϕ , t and w. 1/2" D tensile specimens

Forging and HT dimensions — ~7-16 1/4" t x ~22 1/2" w x ~100" l

**TABLE 3. FORGER TEST DATA — 2219-T852 CONTOUR HAND FORGINGS —
HOLDDOWN POST — PROLONGATION TEST**

Prolongation Test Forging P/N 14A30400				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Fwd. Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1	1	5059201	~7	65.2	52.1	11.0	64.4	50.5	9.0	66.2	50.9	7.0
2		02		-	-	-	66.4	53.0	6.5	65.6	52.0	8.0
3		03		-	-	-	66.4	53.5	5.5	67.6	52.8	7.5
4		04		63.4	52.8	13.0	65.4	50.5	7.5	65.2	52.0	8.0
5		05		66.4	53.3	11.5	65.4	52.3	9.5	65.0	51.8	8.5
6		06		-	-	-	66.5	53.2	7.5	65.2	50.9	8.5
7		07		-	-	-	69.0	54.8	8.0	66.1	52.6	8.0
8		08		-	-	-	68.2	54.4	8.5	66.0	52.3	7.5
9		09		-	-	-	66.3	51.4	8.0	66.2	51.8	8.0
10		10		63.9	51.2	12.0	64.2	49.0	8.0	62.9	50.7	8.0
11		11		64.9	50.7	11.5	64.4	49.7	8.5	63.7	51.5	8.0
12		12		65.2	52.0	10.5	64.9	51.8	8.5	64.9	52.8	6.5
13		13		64.9	52.3	10.0	63.9	50.5	9.0	63.7	50.6	9.0
14		14		-	-	-	-	-	-	*63.8	50.7	9.0
14		14		64.9	51.2	11.5	64.4	50.7	9.0	64.6	51.7	8.5
15		15		-	-	-	65.6	52.5	8.5	65.7	52.4	7.0
16		16		-	-	-	67.2	53.6	9.0	66.7	52.1	8.0
17		17		65.4	51.2	11.0	64.9	51.0	8.5	64.4	50.7	6.0
18		18		65.6	51.4	10.5	64.8	51.8	10.0	64.1	50.3	8.5
19		19		-	-	-	66.9	51.5	7.5	64.4	51.5	4.0
20		20		64.7	51.5	11.5	63.4	52.3	7.0	64.9	51.2	6.0
21		5063701		-	-	-	66.7	52.3	7.0	64.2	50.7	7.0
23		03		-	-	-	67.0	52.0	7.0	66.2	52.5	7.0
24		04		-	-	-	67.4	52.8	7.0	65.6	52.6	5.0
25		05		-	-	-	66.4	52.6	8.0	65.4	53.5	8.0
27		07		-	-	-	67.1	53.5	8.0	66.7	53.5	7.5
28		08		-	-	-	67.0	52.0	7.5	64.4	51.2	7.5
29		09		-	-	-	65.2	50.9	8.0	65.1	51.5	7.5
30		10		-	-	-	67.0	52.2	8.0	66.7	53.1	7.5
31		11		-	-	-	66.2	50.9	8.5	65.7	47.9	8.5
33		13		-	-	-	68.0	52.6	7.5	65.9	50.8	7.0
34		14		-	-	-	67.7	53.1	7.5	65.7	51.3	7.5
35		15		-	-	-	66.0	51.5	8.0	64.2	50.4	8.0

*Retest specimen.

TABLE 3. (Continued)

S/N	Prolongation Test Forging P/N 14A30400			Tensile Properties									
	Fwd. Seg.	Lot	t in.	Longitudinal			Long Transverse			Short Transverse			
				UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	
36	1	5063716	~7	-	-	-	68.0	52.3	8.5	67.0	51.8	7.0	
37		17		-	-	-	65.2	52.0	6.0	65.7	52.5	6.5	
38		18		-	-	-	65.7	50.9	7.0	65.1	51.5	7.0	
39		19		-	-	-	66.2	51.5	8.0	64.7	49.8	7.0	
40		20		-	-	-	66.7	52.0	7.5	66.3	52.5	7.0	
43		5095803		-	-	-	64.7	50.6	6.5	64.2	50.6	6.5	
44		04		-	-	-	64.8	50.8	6.5	63.6	50.6	7.5	
45		05		-	-	-	64.7	51.3	7.0	63.1	49.3	6.5	
46		06		-	-	-	65.0	50.2	8.0	64.2	50.0	8.5	
47		07		-	-	-	64.4	50.9	7.5	63.5	50.4	9.0	
48		08		-	-	-	65.1	50.9	7.5	64.4	50.8	8.0	
49		09		-	-	-	64.6	51.2	7.5	63.9	49.8	7.5	
50		10		-	-	-	66.0	51.6	7.0	66.5	52.1	7.0	
51		11		-	-	-	63.9	51.0	7.5	63.2	49.9	7.5	
52		12		-	-	-	66.5	52.3	7.0	65.3	53.0	5.5	
53		13		-	-	-	64.8	49.9	7.0	65.1	51.9	6.0	
54		14		-	-	-	65.7	51.4	7.0	66.2	51.9	7.0	
55		15		-	-	-	64.1	51.2	7.5	63.5	50.5	8.5	
56		16		-	-	-	65.4	50.7	7.5	64.9	51.8	6.0	
57		17		-	-	-	65.8	50.9	7.5	64.9	52.0	6.5	
58		18		-	-	-	65.5	51.5	7.0	65.3	52.0	6.5	
59		19		-	-	-	64.2	50.7	6.5	63.9	49.7	8.5	
61		21		-	-	-	64.9	51.3	7.5	63.4	51.3	6.0	
1/2" D tensile \bar{L} , t and w				Forging and HT dimensions — ~7 - 16 1/4" t x 22 1/2" w x ~100" l									
Minimum Guaranteed				7	62	50	6	61	49	4	60	46	3

TABLE 3. (Continued)

Prolongation Test Forging P/N 14A30400				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Aft Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1	15	5059201	~15 3/4	57.6	46.3	12.0	57.3	42.9	8.5	59.8	47.0	8.5
2		02		-	-	-	60.4	48.4	5.5	60.4	47.9	7.0
3		03		-	-	-	66.8	53.1	7.5	64.2	54.1	6.5
4		04		59.4	46.4	12.5	57.3	44.6	8.0	59.6	45.7	8.0
5		05		56.2	44.6	13.5	54.1	41.4	9.0	54.9	44.3	8.5
6		06		-	-	-	56.7	44.3	7.0	60.9	48.9	7.5
7		07		-	-	-	64.3	50.1	5.5	62.6	49.3	8.0
8		08		-	-	-	65.1	52.0	5.5	62.8	50.7	7.5
9		09		-	-	-	61.3	50.1	5.0	60.4	48.6	8.0
10		10		60.1	48.2	9.5	56.8	45.2	7.0	57.8	45.7	8.5
11		11		58.8	46.9	10.5	56.6	45.0	7.0	58.9	46.8	8.5
12		12		58.3	46.7	11.5	56.8	43.4	8.0	58.9	46.7	8.0
13		13		58.6	44.5	12.5	56.1	43.5	7.0	57.1	45.5	9.5
14		14		-	-	-	-	-	-	-	-	-
14		14		58.1	45.5	13.0	56.6	44.5	9.0	57.8	45.7	9.0
15		15		-	-	-	58.6	45.3	7.0	61.9	49.6	7.5
16		16		-	-	-	55.9	44.0	6.5	60.7	48.8	7.5
17		17		58.9	45.6	12.0	59.9	46.7	7.5	61.9	46.7	8.5
18		18		61.3	48.1	10.5	62.0	48.9	7.0	59.8	50.3	8.0
19		19		-	-	-	68.4	53.5	7.5	66.0	51.9	7.5
20		20		58.9	45.7	11.0	60.4	49.0	6.5	58.9	49.7	8.5
21		5063701		-	-	-	65.7	50.3	8.0	65.9	51.8	8.0
23		03		-	-	-	59.9	47.1	6.5	59.6	47.4	8.0
24		04		-	-	-	60.4	47.8	7.0	59.6	47.9	7.5
25		05		-	-	-	60.7	52.6	6.0	60.6	53.1	8.0
27		07		-	-	-	59.4	45.9	7.0	58.9	46.9	7.0
28		08		-	-	-	63.9	49.2	8.0	63.7	49.3	9.0
29		09		-	-	-	59.9	46.7	6.0	58.8	47.9	7.0
30		10		-	-	-	59.1	45.5	7.0	58.3	46.2	7.5
31		11		-	-	-	61.6	46.9	7.0	59.6	51.5	7.5
33		13		-	-	-	64.7	49.5	8.5	64.7	50.3	8.5
34		14		-	-	-	66.2	50.2	7.0	66.4	51.3	8.0
35		15		-	-	-	66.5	51.0	8.5	65.2	51.2	7.5

TABLE 3. (Concluded)

Prolongation Test Forging No. 14A30400				Tensile Properties									
S/N	Aft Seg.	Lot	t in.	Longitudinal			Long Transverse			Short Transverse			
				UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	
36	15	5063716	~15 3/4	-	-	-	60.9	49.0	8.0	60.2	48.4	7.5	
37		17		-	-	-	62.1	50.6	6.0	60.6	51.7	6.5	
38		18		-	-	-	61.1	47.4	6.5	60.1	46.9	8.0	
39		19		-	-	-	65.4	49.6	8.0	63.9	49.7	6.0	
40		20		-	-	-	60.9	46.6	7.0	59.6	47.2	7.5	
43		5095803		-	-	-	59.1	46.0	5.5	57.3	44.7	8.5	
44		04		-	-	-	59.1	46.5	6.0	57.1	43.5	9.0	
45		05		-	-	-	60.8	48.2	5.5	60.5	46.8	7.0	
46		06		-	-	-	59.2	45.3	6.5	56.7	44.5	9.0	
47		07		-	-	-	57.6	44.4	5.5	56.2	43.8	9.5	
48		08		-	-	-	59.0	45.7	6.5	56.8	43.8	9.5	
49		09		-	-	-	59.1	45.5	6.5	57.3	44.6	9.0	
50		10		-	-	-	64.9	49.1	7.0	63.1	49.4	7.5	
51		11		-	-	-	59.2	46.8	6.5	57.0	44.0	8.5	
52		12		-	-	-	60.4	47.3	5.5	64.1	49.9	8.5	
53		13		-	-	-	57.4	43.2	7.5	62.9	49.4	7.5	
54		14		-	-	-	64.6	49.9	6.0	63.1	49.9	7.5	
55		15		-	-	-	60.8	46.8	6.5	58.7	46.0	8.5	
56		16		-	-	-	62.9	48.7	6.0	63.0	49.7	7.5	
57		17		-	-	-	61.3	47.1	7.0	65.6	51.6	7.5	
58		18		-	-	-	61.9	47.9	6.5	62.0	49.0	7.5	
59		19		-	-	-	59.2	46.0	5.0	57.5	44.5	9.5	
61		21		-	-	-	64.1	50.9	8.0	61.9	48.2	5.0	
1/2" D tensile \bar{C}_L t and w				Forging and HT dimensions - ~7 - 16 1/4" t x ~22 1/2" w x ~100" l Prolongations aged by Forger									
Minimum Guaranteed				15 3/4	46	33	6	46	32	4	44	30	3

TABLE 4. MDAC TEST DATA

Forging P/N 14A30400 ⁽¹⁾			Tensile Properties							
S/N 1			Longitudinal				1/2" D Specimens			
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %
2	Ⓞ _L	~7	-	-	-	-	-	-	-	-
4		~8 3/4	-	-	-	-	-	-	-	-
6		~10 1/2	-	-	-	-	-	-	-	-
8		~12 1/4	-	-	-	-	-	-	-	-
10		~14	-	-	-	-	-	-	-	-

See Page 43 for Notes

AC TEST DATA — 2219-T852 CONTOUR HAND FORGING — HOLDDOWN POST — DESTRUCT TEST

Properties						Fracture Toughness			
Specimens						Compact Tension			
Transverse		Short Transverse				$K_{Ic} - \text{ksi} \sqrt{\text{in.}}$		Sh	
EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)	UTS ksi	TYS ksi
-	-	*66.4	52.1	7.0	8.3	25.63 ^(A)	-	65.7	51.7
		66.7	52.5	7.5	8.2	-	-	65.7	51.7
		-	-	-	-			65.8	51.7
		66.5	52.3	7.2	8.2			66.4	51.7
-	-	*63.7	49.1	7.0	9.0	28.09 ^(B)	-	63.9	48.9
		64.5	49.6	7.0	7.4	-	-	63.8	48.9
		-	-	-	-			63.4	48.9
		64.1	49.3	7.0	8.2			63.7	48.9
								(3)	
								62.7	49.3
-	-	*61.2	47.2	8.0	13.6	28.45 ^(B)	-	59.8	45.2
		61.6	47.2	8.5	10.9	-	-	60.7	45.2
		-	-	-	-			60.6	46.1
		61.4	47.2	8.2	12.2			60.4	45.2
-	-	*59.5	45.5	8.5	13.2	28.99 ^(B)	-	59.1	44.5
		60.1	45.7	8.0	12.4	-	-	59.3	44.6
		-	-	-	-			59.0	44.7
		59.8	45.6	8.2	12.8			59.1	44.6
-	-	*57.7	45.0	8.5	13.2	29.23 ^(B)	-	57.4	43.2
		58.0	44.0	8.5	13.2	-	-	57.8	43.8
		-	-	-	-			58.6	43.6
		57.8	44.5	8.5	13.2			57.9	43.5
								(3)	
								63.9	49.7
								62.5	49.3
								61.7	48.9
								62.7	49.3

POST — DESTRUCT TEST

Roughness	Stress Corrosion — 3.5% NaCl Alt. Imm.							
	Short Transverse (Q t and w; 1/4" D X 1" GL)							
	Tensile Blanks				Unstressed		Stressed ⁽²⁾	
Extension in $\sqrt{\text{in.}}$	UTS	TYS	EL	RA	UTS	EL	UTS	EL
	ksi	ksi	%	%	% Change in 30 Days			
(L-S)								
-	65.7	51.5	7.0	9.3	-21.5	-71.4	-20.2	-71.4
-	65.7	51.3	7.0	9.3	-20.2	-64.3	-21.1	-71.4
	65.8	51.3	7.0	9.4	-21.2	-71.4	-27.9	-85.7
	66.4	51.4	7.0	9.3	-20.9	-68.5	-23.0	-75.7
-	63.9	48.9	8.0	12.4	-22.0	-74.0	-18.8	-74.0
-	63.8	48.9	8.0	13.1	-21.4	-74.0	-21.7	-74.0
	63.4	48.9	7.0	12.1	-20.1	-74.0	-19.5	-67.5
	63.7	48.9	7.7	11.9	-21.2	-74.0	-19.9	-71.4
	(3)							
	62.7	49.3	5.7	8.1	-24.6	-72.7	- FH -	
-	59.8	45.2	7.0	8.7	-21.5	-86.1	-18.4	-86.1
-	60.7	45.6	7.5	11.0	-16.4	-79.2	-17.1	-93.1
	60.6	46.1	7.0	8.7	-13.7	-79.2	-17.1	-79.2
	60.4	45.6	7.2	9.5	-17.2	-81.9	-17.5	-86.1
-	59.1	44.5	8.0	10.2	- 8.1	-63.4	-11.0	-69.5
-	59.3	44.6	8.0	11.6	-10.7	-69.5	-10.2	-69.5
	59.0	44.7	8.5	15.4	-10.0	-69.5	-16.8	-81.7
	59.1	44.6	8.2	12.4	- 9.6	-67.1	-12.7	-73.2
-	57.4	43.2	9.0	12.3	-13.1	-77.8	-13.5	-66.7
-	57.8	43.8	9.0	11.6	-13.6	-72.2	-16.1	-77.8
	58.6	43.6	9.0	13.1	-20.0	-83.3	-11.1	-77.8
	57.9	43.5	9.0	12.3	-15.5	-77.8	-13.5	-74.4
	(3)							
	63.9	49.7	6.5	9.4	-25.5	-91.2	-26.3	-82.4
	62.5	49.3	5.5	8.6	-26.0	-91.2	-26.3	-100
	61.7	48.9	5.0	6.4	-27.3	-100	-29.2	-100
	62.7	49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7

Forging P/N 14A30400 ⁽¹⁾						
S/N 1			Longitudinal			
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %
12	⊘; E ⁽⁴⁾	~15 3/4	*57.7	45.0	11.5	22.3
↓	⊘	↓	58.6	45.3	10.0	23.7
↓	⊘; E ⁽⁴⁾	↓	-	-	-	-
			58.1	44.8	11.5	26.0
			58.1	45.0	11.0	24.0
14	⊘	~16 1/4	57.8	44.7	11.0	21.9
↓	↓	↓	58.5	45.5	11.0	21.9
			58.1	45.1	11.0	21.9
2	Min. Gtd.	~7	62	50	6	-
4	↓	~8 3/4	55	43	6	-
6&8	↓	10 1/2-12 3/4	52	39	6	-
10, 12&14		14-16 1/4	46	33	6	-

Notes:

- (1) Forged and HT dimensions ~7-16 1/4" t × ~22 1/2" w × ~100" l. Alcoa cut into segments before aged.
 - (2) Stressed to 75% of TYS.
 - (3) Standard — specimens from 2219-T851 plate 6 1/8" t exposed simular
 - (4) Specimen 1 1/2" from outside edge of width, all others are ⊘ width an
- *Stress-strain curves available.

FH - Failed in handling during removal from stressing fixture.

TABLE 4. (Continued)

Tensile Properties										Fracture Toughness	
1/2" D Specimens										Compact Tension	
		Long Transverse				Short Transverse				$K_{Ic} - \text{ksi} \sqrt{\text{in.}}$	
EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-)
1.5	22.3	*57.4	44.0	7.0	9.4	-	-	-	-	-	-
0.0	23.7	57.9	43.8	6.5	10.5	*56.7	43.6	7.0	12.0	(27.43) ^(B)	[0.791]
-	-	-	-	-	-	56.7	43.0	8.0	13.5	-	-
1.5	26.0	57.2	43.1	6.5	10.9	-	-	-	-	-	-
1.0	24.0	57.5	43.6	6.7	10.3	56.7	43.3	7.5	12.7	-	-
1.0	21.9	-	-	-	-	57.7	44.9	8.5	12.1	26.71 ^(B)	(35.36) ^(B)
1.0	21.9	-	-	-	-	56.5	43.6	8.5	12.8	26.65 ^(B)	(35.48) ^(B)
1.0	21.9	-	-	-	-	57.1	44.2	8.5	12.4	-	-
6	-	61	49	4	-	60	46	3	-	-	-
6	-	55	42	4	-	53	40	3	-	-	-
6	-	52	38	4	-	50	36	3	-	-	-
6	-	46	32	4	-	44	30	3	-	-	-

Legend:

(A) — 1" wide specimens

(B) — 1.5" wide specimens

() — K_Q values in parentheses

[] — R_{sc} values in brackets

~100" l.

posed simultaneously.
re ϕ width and thickness.

Fracture Toughness		Stress Corrosion — 3.5% NaCl Alt. Imm.							
Compact Tension		Short Transverse (Q t and w; 1/4" D X 1" GL)							
$K_{Ic} - \text{ksi} \sqrt{\text{in.}}$		Tensile Blanks				Unstressed		Stressed ⁽²⁾	
(S-L)	(L-S)	UTS ksi	TYS ksi	EL %	RA %	UTS	EL	UTS	EL
						% Change in 30 Days			
-	-	56.4	43.2	8.0	11.6	-19.7	-88.0	-13.7	-81.9
43)(B) [0.791]	-	56.0	42.8	8.0	10.9	-13.7	-75.9	-15.4	-81.9
-	-	56.6	43.0	9.0	13.8	-12.4	-75.9	-16.3	-88.0
-	-	56.3	43.0	8.3	12.1	-15.6	-79.5	-15.3	-83.9
		(3) 62.7	49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7
26.71(B)	(35.36)(B) [1.170]	-	-	-	-	-	-	-	-
26.65(B)	(35.48)(B) [1.183]								

Legend:
) — 1" wide specimens
) — 1.5" wide specimens
) — K_Q values in parentheses
] — R_{sc} values in brackets

TABLE 4. (Continued)

Forging P/N 14A30400 ⁽¹⁾			Tensile Properties							
			1/2" D Specimens							
S/N 5			Longitudinal				Long Transverse			
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %
2	⊘	~7	-	-	-	-	-	-	-	-
↓	↓	↓								
4		~8 3/4	-	-	-	-	-	-	-	-
↓		↓								
6		~10 1/2	-	-	-	-	-	-	-	-
↓		↓								
8	⊘	~12 1/4	-	-	-	-	-	-	-	-
↓	↓	↓								
10		~14	-	-	-	-	-	-	-	-
↓	↓	↓								
12	⊘; E ⁽⁴⁾	~15 3/4	56.1	43.6	11.5	26.2	56.0	43.7	5.0	7
↓	⊘	↓	56.4	44.3	12.0	25.7	55.9	42.9	5.0	8
	↓		-	-	-	-	-	-	-	
	⊘; E ⁽⁴⁾	↓	55.9	43.7	11.5	24.4	55.6	42.7	5.5	9
	↓		56.1	43.9	11.7	25.4	55.8	43.1	5.2	8
14	⊘	~16 1/4	55.5	43.4	10.5	26.4	-	-	-	
↓	↓	↓	56.5	43.2	11.0	25.8				
			56.0	43.3	10.7	26.1				

See Page 43 for Notes

TABLE 4. (Continued)

Tensile Properties								Fracture Toughness		
1/2" D Specimens								Compact Tension K _{1c} — ksi√in.		
Long Transverse				Short Transverse				(S-L)	(L-S)	
UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %			
-	-	-	-	65.6	51.7	5.5	9.3	(33.12) ^(A) [0.983]	-	
				65.5	51.8	6.5	10.2		-	
				65.5	51.7	6.0	9.7		-	
-	-	-	-	63.6	49.5	7.5	12.1	23.07 ^(B)	-	
				63.7	49.8	7.0	10.5		-	
				63.6	49.7	7.2	11.3		-	
-	-	-	-	60.1	46.6	7.0	10.6	35.32 ^(B)	-	
				60.2	46.8	7.0	10.1		-	
				60.1	46.7	7.0	10.3		-	
-	-	-	-	57.8	44.4	6.0	12.3	(32.07) ^(B) [1.036]	-	
				57.6	44.7	7.0	10.9		-	
				57.7	44.5	6.5	11.6		-	
-	-	-	-	56.2	41.5	6.5	12.8	(34.44) ^(B) [1.202]	-	
				56.2	42.8	6.5	12.0		-	
				56.2	42.1	6.5	12.4		-	
56.0	43.7	5.0	7.4	-	-	-	-	(33.04) ^(B) [0.993]	-	
55.9	42.9	5.0	8.7	54.7	41.5	8.5	13.2		-	
-	-	-	-	54.7	41.6	9.0	12.5		-	
55.6	42.7	5.5	9.4	-	-	-	-	-	-	
55.8	43.1	5.2	8.5	54.7	41.5	8.7	12.8	-	-	
-	-	-	-	55.6	43.6	8.0	12.3	26.28 ^(B)	(31.23) ^(B) [1.001] (32.80) ^(B) [1.084]	
				54.9	42.8	8.0	12.4			24.02 ^(B)
				55.2	43.2	8.0	12.4			

See Page 43 for Notes

TABLE 4.

Forging P/N 14A30400 ⁽¹⁾			Tensile Properties					
S/N 20			1/2" D S				Long Tra	
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi
2	⊕	~7	-	-	-	-	-	-
↓	↓	↓						
4		~8 3/4	-	-	-	-	-	-
↓		↓						
6		~10 1/2	-	-	-	-	-	-
↓		↓						
8	⊕	~12 1/4	-	-	-	-	-	-
↓	↓	↓						
10		~14	-	-	-	-	-	-
↓	↓	↓						
12	⊕; E ⁽⁴⁾	~15 3/4	57.3	45.3	9.5	25.5	57.1	44.2
↓	⊕	↓	58.0	46.0	9.5	25.1	57.2	44.4
	↓		-	-	-	-	-	-
	⊕; E ⁽⁴⁾	↓	57.1	45.0	10.0	26.1	57.2	44.9
	↓		57.5	45.4	9.8	25.6	57.2	44.5
14	⊕	~16 1/4	56.8	44.1	10.0	25.0	-	-
↓	↓	↓	57.3	45.0	10.0	25.5		
			57.1	44.6	10.0	25.2		

See

TABLE 4. (Concluded)

Tensile Properties								Fracture Toughness	
1/2" D Specimens								Compact Tension	
Long Transverse			Short Transverse					$K_{Ic} - \text{ksi} \sqrt{\text{in.}}$	
TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)	
-	-	-	64.4	51.0	6.0	8.6	(23.76) ^(A) [0.729]	-	
			64.4	50.9	6.5	10.5		-	
			64.4	51.0	6.3	9.6		-	
-	-	-	62.6	48.9	6.5	10.5	23.68 ^(A)	-	
			62.6	49.0	6.5	8.6		-	
			62.6	49.0	6.5	9.6		-	
-	-	-	60.2	46.8	6.0	9.7	23.61 ^(A)	-	
			60.1	46.8	7.0	10.5		-	
			60.2	46.8	6.5	10.1		-	
-	-	-	59.1	45.1	7.0	10.6	23.66 ^(A)	-	
			59.0	45.5	7.0	11.3		-	
			59.0	45.3	7.0	11.0		-	
-	-	-	57.6	45.0	7.0	11.7	22.75 ^(A)	-	
			57.6	44.4	7.0	10.9		-	
			57.6	44.7	7.0	11.3		-	
44.2	6.5	10.9	-	-	-	-	-	-	
44.4	6.0	9.4	56.2	43.8	7.5	13.9	22.73 ^(A)	-	
-	-	-	56.2	43.3	7.5	12.3		-	
44.9	6.5	7.9	-	-	-	-		-	
44.5	6.3	9.4	56.2	43.6	7.5	13.1	-	-	
-	-	-	57.0	44.5	8.0	14.7	23.09 ^(A)	(30.29) ^(A) [1.255]	
			56.0	41.3	6.5	11.3			22.65 ^(A)
			56.5	42.9	7.2	13.0			

See Page 43 for Notes

TABLE 5. 2219-T852 CONTOUR HAND FORGING — DETAILED SUMMARY
COMBINED TESTS — HOLDDOWN POST — 14A30400

No. of Forgings	Test Loc.	HT t in.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL % / 4 D	RA %	UTS ksi	TYS ksi	EL % / 4 D	RA %	UTS ksi	TYS ksi	EL % / 4 D	RA %
Forger Min. Gtd.		7	62	50	6	-	61	49	4	-	60	46	3	-
3 destruct A ↓ M	GL	~7	64.7-66.4	51.5-53.3	11.0-11.5	-	63.4-65.4	50.5-52.3	7.0-9.5	-	64.9-66.2	50.9-51.8	6.0-8.5	-
*1 x-skirt M			-	-	-	-	-	-	-	-	64.4-66.7	50.9-52.5	5.5-7.5	8.2-10.5
52 Prol. A			63.5-63.7	49.9-50.3	9.5-10.0	27.0-27.7	-	-	-	-	-	-	-	-
*1 x-Prol. M			63.4-65.6	50.7-52.8	10.0-13.0	-	63.9-69.0	49.0-54.8	5.5-10.0	-	62.9-67.6	47.9-53.5	4.0-9.0	-
*4 P-Prol. M			-	-	-	-	67.5-68.2	53.3-54.6	4.5-5.0	4.4-8.5	68.0-68.4	53.3-54.0	5.5-6.0	6.7-8.2
			-	-	-	-	62.4-65.3	50.7-51.6	5.5-7.0	6.7-9.8	61.4-65.8	49.2-52.9	5.0-7.0	6.0-9.8
Forger Min. Gtd.		8 3/4	55	43	6	-	55	42	4	-	53	40	3	-
3 destruct A ↓ M	GL	~8 3/4	62.9-64.7	48.9-50.9	11.0-13.0	-	63.9-64.5	49.1-50.0	7.5-10.0	-	63.7-65.4	49.0-50.7	7.5-8.5	-
			-	-	-	-	-	-	-	-	62.6-64.5	48.9-49.8	6.5-7.5	7.4-13.1
Forger Min. Gtd.		10 1/2-12 1/4	52	39	6	-	52	38	4	-	50	36	3	-
3 destruct A ↓ M	GL	~10 1/2	61.3-62.6	48.1-48.2	9.5-11.5	-	61.6-62.9	47.4-48.1	7.5-9.0	-	60.9-63.4	47.4-50.1	7.5-8.0	-
			-	-	-	-	-	-	-	-	59.8-61.6	45.2-47.2	6.0-8.5	-
3 destruct A ↓ M	GL	~12 1/4	59.1-60.6	45.7-47.1	11.0-12.0	-	58.4-60.4	44.3-46.7	6.0-8.5	-	58.2-61.6	46.0-49.2	7.5-9.0	-
			-	-	-	-	-	-	-	-	57.6-59.5	44.0-45.5	6.0-8.5	10.2-15.4
*1 x-skirt M			-	-	-	-	-	-	-	-	58.6-59.8	45.2-45.8	5.5-7.5	6.7-10.4

TABLE 5. (Concluded)

No. of Forgings	Test Loc.	HT t In.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %
Forger Min. Ctd.		14-16 1/4	46	33	6	-	46	32	4	-	44	30	3	-
3 destruct A	Q _L	~14	57.6-58.3	45.0-45.5	10.0-11.5	-	55.9-58.5	42.0-50.4	8.0-11.0	-	55.7-60.3	41.6-48.1	8.0-9.0	-
M			-	-	-	-	-	-	-	-	56.2-58.6	41.5-45.0	6.5-9.0	10.9-13.2
3 destruct A	Q _L	~15 3/4	56.9-57.1	43.5-46.6	11.0-13.0	-	56.9-58.6	41.9-45.8	6.5-9.0	-	55.1-60.1	43.6-48.6	8.0-9.0	-
M			56.4-58.6	44.3-46.0	9.5-12.0	23.7-25.7	55.9-57.9	42.9-44.4	5.0-6.5	8.7-10.5	54.7-56.7	41.5-43.8	7.0-9.0	10.9-13.9
M	Q _L ; E		55.9-58.1	43.6-45.3	9.5-11.5	22.3-26.2	55.6-57.4	42.7-44.9	5.0-7.0	7.4-10.9	-	-	-	-
3 destruct A	Q _L	~16 1/4	56.2-58.9	44.6-46.3	11.0-13.5	-	54.1-60.4	41.4-49.0	6.5-9.0	-	54.9-59.8	44.3-49.7	8.5-8.5	-
M			55.5-58.5	43.2-45.5	10.0-11.0	21.9-26.4	-	-	-	-	54.9-57.7	41.3-44.9	6.5-8.5	11.3-14.7
*1 x-skirt M			-	-	-	-	55.8-57.8	42.6-45.3	5.5-7.0	7.8-15.0	-	-	-	-
52 Prol. A			58.1-61.3	44.5-48.2	9.5-12.5	-	55.9-68.4	43.2-53.5	5.0-9.0	-	56.2-66.0	43.5-54.1	5.0-9.5	-
*1 x-Prol. M			-	-	-	-	58.8-59.1	46.0-46.2	5.5-6.5	8.2-8.9	56.7-58.0	45.1-46.3	6.5-7.5	9.5-11.6
*4 P-Prol. M			-	-	-	-	54.1-56.5	41.8-43.3	4.5-6.5	4.7-10.6	53.8-56.3	43.5-45.8	6.5-8.0	9.4-13.5

A = Alcoa test
M = MDAC test
* = MDAC aged; all others were forger aged
x = simulation age
P = production age
skirt = MDAC 1/4 skirt, destruct test
Prol. = prolongation from end of forging
○ = No. of 1/2" and 1/4" D tensile specimens tested; min. to max. values obtained

TABLE 6. 2219-T852 CONTOUR HAND FORGING — CONDENSED SUMMARY
COMBINED TESTS — HOLDDOWN POST — 14A30400

No. of Forgings	Test Loc.	HT t in.	Longitudinal				Long Transverse				Short Transverse							
			UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %				
Forger Min. Gtd.			62	50	6	-	61	49	4	-	60	46	3	-				
55 ⁽¹⁾	⊥	~7	63.4-66.4	50.7-53.3	10.0-13.0	-	62	62.4-69.0	49.0-54.8	4.5-10.0	7	4.4-9.8	72	61.4-68.4	47.9-54.0	4.0-9.0	16	6.0-10.5
1 ⁽²⁾		↓	↓	63.5-63.7	49.9-50.3	9.5-10.0	3	27.0-27.7	-	-	-	-	-	-	-	-	-	-
Forger Min. Gtd.			55	43	6	-	55	42	4	-	53	40	3	-				
3 ⁽³⁾	⊥	~8 3/4	62.9-64.7	48.9-50.9	11.0-13.0	-	3	63.9-64.5	49.1-50.0	7.5-10.0	-	-	12	62.6-65.4	48.9-50.7	6.5-8.5	9	7.4-13.1
Forger Min. Gtd.			52	39	6	-	52	38	4	-	50	36	3	-				
3 ⁽³⁾	⊥	~10 1/2	61.3-62.6	48.1-48.2	9.5-11.5	-	3	61.6-62.9	47.4-48.1	7.5-9.0	-	-	12	59.8-63.4	45.2-50.1	6.0-8.5	9	8.7-13.6
3 ⁽³⁾		~12 1/4	59.1-60.6	45.7-47.1	11.0-12.0	-	3	58.4-60.4	44.3-46.7	6.0-8.5	-	-	12	57.6-61.6	44.0-49.2	6.0-9.0	9	10.2-15.4
1 ⁽²⁾		↓	↓	-	-	-	-	-	-	-	-	-	3	58.6-59.8	45.2-45.8	5.5-7.5	3	6.7-10.4
Forger Min. Gtd.			46	33	6	-	46	32	4	-	44	33	3	-				
3 ⁽³⁾	⊥	~14	57.6-58.3	45.0-45.5	10.0-11.5	-	3	55.9-58.5	42.0-52.4	8.0-11.0	-	-	12	55.7-60.3	41.5-48.1	6.5-9.0	9	10.9-13.2
3 ⁽³⁾		~15 3/4	55.9-58.6	43.5-46.6	9.5-13.0	9	22.3-26.2	55.6-58.6	41.9-45.8	5.0-9.0	9	7.4-10.9	12	54.7-60.1	41.5-48.6	7.0-9.0	9	10.9-13.9
55 ⁽¹⁾		~16 1/4	55.5-61.3	43.2-48.2	9.5-13.5	6	21.9-26.4	54.1-68.4	41.4-53.5	4.5-9.0	7	4.7-10.6	71	53.8-66.0	41.3-54.1	5.0-9.5	16	9.4-14.7
1 ⁽²⁾		↓	↓	-	-	-	-	3	55.8-57.8	42.6-45.3	5.5-7.5	3	7.8-15.0	-	-	-	-	-

(1) 3 destruct +52 prolongation tests

(2) 1 destruct from MDAC aged 1/4 skirt

(3) 3 destruct

○ = No. of 1/2" and 1/4" D specimens tested; min. to max. values obtained

Forged and HT dimensions — ~7-16 1/4" t × ~22 1/2" w × ~100" l

TABLE 7. FORGER DATA — 2219-T852 CONTOUR HAND FORGINGS —
THRUST POST — DESTRUCT TEST

Forging P/N 14A20084			Tensile Properties — Longitudinal								
			S/N 1			S/N 13			S/N 19		
Seg. No.	Loc. (Fig. 5)	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		5 3/4				61	49	6			
11	t/2; w/2	5 3/4	63.6	51.3	12.0	66.7	51.5	10.5	63.3	50.2	11.0
1	↓	↓	64.2	52.0	13.0	67.9	50.6	7.5	63.7	50.0	10.5
3A	w/7	↓	62.4	50.5	13.0	67.1	51.7	11.5	62.7	49.7	10.5
↓B	w/2	↓	62.2	49.9	12.0	69.0	52.6	11.0	63.2	50.0	10.5
↓C	w/7	↓	62.6	50.7	13.0	67.1	51.6	11.0	63.5	50.2	11.0
Min. Gtd.		7 1/2-12				50	37	6			
9A	t/4 top; w/4	7 1/2	63.5	48.9	11.0	66.0	50.6	10.5	60.1	46.5	10.5
↓B	↓ w/2	↓	63.1	48.1	11.0	65.3	50.0	10.5	61.1	47.5	11.5
↓C	w/4	↓	63.4	49.3	11.0	66.0	50.5	11.0	61.9	48.7	10.5
Min. Gtd.		14				50	37	6			
5A	t/4 top; w/4	14	-	-	-	-	-	-	-	-	-
↓B	↓ w/2	↓	-	-	-	-	-	-	-	-	-
↓C	w/4	↓	-	-	-	-	-	-	-	-	-
↓A	bottom; w/4	↓	-	-	-	-	-	-	-	-	-
↓B	w/2	↓	-	-	-	-	-	-	-	-	-
↓C	w/4	↓	-	-	-	-	-	-	-	-	-
7A	top; w/4	↓	58.8	46.5	10.5	62.2	48.9	9.0	59.9	47.2	9.5
↓B	w/2	↓	57.5	44.5	11.5	59.6	45.3	11.5	57.1	44.6	10.5
↓C	w/4	↓	60.3	47.0	11.0	64.1	49.3	9.5	58.3	45.7	9.5
↓A	bottom; w/4	↓	60.5	47.5	11.0	63.8	49.8	9.5	57.6	45.7	11.0
↓B	w/2	↓	59.3	46.0	11.0	63.7	48.7	11.0	48.3	45.5	10.0
↓C	w/4	↓	61.3	48.1	10.5	66.7	51.8	9.5	60.6	48.0	10.0
1/2" D tensile specimens. forging and HT dimensions — ~5 3/4 - 14" t x ~29 1/2" w x ~115 1/2" l											
Min. Gtd. (Forger)		5 3/4	61	49	6						
↓		7 1/2-12	50	37	6						
		14	50	37	6						

TABLE 7. (Continued)

Destruct Test Forging P/N 14A20084			Tensile Properties — Long Transverse								
Seg. No.	Loc. (Fig. 5)	t in.	S/N 1			S/N 13			S/N 19		
			UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		5 3/4				61	48	4			
11	t/2; w/2	5 3/4	65.9	51.5	9.0	67.8	50.6	9.5	63.7	49.7	8.5
1	↓	↓	64.9	51.4	9.0	66.9	51.3	11.0	64.4	50.7	9.0
3A	w/7	↓	63.8	51.5	8.5	65.1	51.3	5.5	62.6	49.0	7.5
↓B	w/2	↓	63.8	50.6	8.5	66.3	49.5	8.5	62.4	49.0	7.5
↓C	w/7	↓	63.0	50.4	8.5	67.1	51.7	7.0	61.8	48.5	7.5
Min. Gtd.		7 1/2-12				50	36	4			
9A	t/4 top; w/4	7 1/2	61.6	49.1	6.0	66.2	50.7	6.5	59.9	46.5	8.0
↓B	↓ w/2	↓	62.8	48.6	6.5	66.0	49.5	9.0	59.8	45.5	8.5
↓C	w/4	↓	61.6	49.3	5.0	66.6	50.8	7.0	60.9	47.7	6.0
Min. Gtd.		14				50	36	4			
5A	t/4 top; w/4	14	58.4	47.3	7.0	64.5	51.9	5.0	57.6	44.5	7.5
↓B	↓ w/2	↓	57.1	46.9	5.0	63.2	47.1	6.0	59.4	45.5	7.5
↓C	w/4	↓	58.6	48.1	6.0	64.0	52.5	5.0	61.4	47.2	7.5
↓A	bottom; w/4	↓	60.1	46.9	7.0	62.9	51.6	5.0	53.9	43.0	6.0
↓B	w/2	↓	59.6	47.1	7.5	59.8	44.2	7.5	54.6	42.4	6.0
↓C	w/4	↓	60.4	47.2	7.5	62.2	51.9	4.5	53.2	43.6	4.0
Min. Gtd.		14				50	36	3			
7A	t/4 top; w/4	14	53.2	48.6	4.0	70.6	54.7	8.0	52.0	44.6	3.0
↓	↓	↓	-	-	-	-	-	-	*51.0	45.2	3.0
↓B	↓ w/2	↓	-	-	-	-	-	-	*50.3	45.0	3.0
↓C	w/4	↓	57.1	46.0	6.0	62.7	46.5	8.0	53.6	43.5	4.5
↓	↓	↓	58.4	47.4	6.0	59.5	49.2	3.5	50.2	44.5	3.0
↓	↓	↓	-	-	-	*58.8	44.0	8.0	*50.0	44.5	2.5
↓	↓	↓	-	-	-	*57.8	43.1	8.0	*50.3	45.5	3.0
↓A	bottom; w/4	↓	53.2	46.5	4.0	66.4	52.3	5.0	56.8	46.3	4.5
↓B	w/2	↓	56.6	45.0	6.0	60.9	49.9	8.5	56.9	45.8	4.5
↓C	w/4	↓	55.8	46.0	5.0	58.9	49.3	3.5	50.3	46.6	3.5
↓	↓	↓	-	-	-	*56.6	49.2	3.0	*51.4	45.5	3.0
↓	↓	↓	-	-	-	*56.0	48.5	3.0	*50.5	44.7	3.0
1/2" D tensile specimens. Forging and HT dimensions — ~ 5.3/4 - 14" t x ~ 29 1/2" w x ~ 115 1/2" l											
Min. Gtd. (Forger)		5 3/4	61	48	4						
↓		7 1/2-12	50	36	4						
		14	50	36	4						
					4 seg. 5						
					3 seg. 6-8						

*Retest specimens.

TABLE 7. (Concluded)

TABLE 7. (Concluded)

Destruct Test Forging P/N 14A20084			Tensile Properties — Short Transverse								
			S/N 1			S/N 13			S/N 19		
Seg. No.	Loc. (Fig. 5)	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		5 3/4				59	45	3			
11	t/2; w/2	5 3/4	64.9	51.5	7.0	68.0	53.3	7.0	62.4	48.9	6.5
1	↓	↓	64.6	51.0	8.5	67.3	52.8	5.5	62.9	50.5	8.0
3A	w/7	↓	63.6	51.1	8.5	66.0	51.8	4.5	62.0	49.5	8.0
B	w/2	↓	64.5	51.5	7.5	67.7	52.4	7.0	61.5	49.0	7.5
C	w/7	↓	63.5	50.8	7.5	68.3	54.7	6.0	61.5	49.2	6.5
Min. Gtd.		7 1/2-12				48	34	3			
9A	t/4 top; w/4	7 1/2	63.0	49.1	6.0	65.8	51.0	7.5	58.1	45.5	6.5
B	↓ w/2	↓	62.6	49.6	6.0	66.2	50.7	7.0	57.8	44.6	6.0
C	↓ w 4	↓	64.5	50.7	9.0	66.0	50.8	6.0	59.6	47.0	8.0
Min. Gtd.		14				48	34	3			
5A	t/4 top; w/4	14	57.7	47.0	5.5	64.3	51.0	6.0	57.4	46.5	6.0
B	↓ w/2	↓	58.6	47.4	7.0	60.4	46.0	7.0	57.1	45.5	7.0
C	↓ w/4	↓	56.0	46.4	5.5	63.5	50.5	5.0	56.6	44.5	7.0
A	bottom; w/4	↓	59.9	47.4	7.5	62.4	48.8	6.5	56.8	44.0	7.0
B	↓ w/2	↓	58.6	46.1	7.5	59.5	44.5	7.5	56.6	43.5	8.0
C	↓ w/4	↓	58.3	45.4	7.0	62.6	49.5	5.5	56.1	43.5	7.5
7A	top; w/4	↓	58.3	45.8	7.0	59.6	48.4	5.0	55.1	45.5	5.0
B	↓ w/2	↓	56.7	44.5	8.0	58.7	43.8	7.5	55.1	43.5	7.0
C	↓ w/4	↓	58.0	46.0	6.5	60.0	49.0	4.0	54.1	46.5	5.0
A	bottom; w/4	↓	58.1	45.8	6.5	58.2	49.1	4.0	54.8	45.5	5.0
B	↓ w/2	↓	57.3	44.0	7.0	59.8	46.2	6.5	54.9	43.5	5.5
C	↓ w/4	↓	58.9	47.0	6.0	60.1	49.3	4.0	56.2	46.0	5.5
Forging and HT dimensions — ~5 3/4 - 14" t × ~29 1/2" w × ~115 1/2" l 1/2" D tensile specimens											
Min. Gtd. (Forger)		5 3/4	59	45	3						
	↓	7 1/2-12	48	34	3						
		14	48	34	3						

TABLE 8. FORGER DATA — 2219-T852 CONTOUR HAND FORGINGS — THRUST POST — PROLONGATION TEST

Prolongation Tests				Tensile Properties								
Forging P/N 14A20084				Longitudinal			Long Transverse			Short Transverse		
S/N	Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1	1	5059501	5-3/4	64.2	52.0	13.0	64.9	51.4	9.0	64.6	51.0	8.5
↓	11	↓	↓	63.6	51.3	12.0	65.9	51.5	9.0	64.9	51.5	7.5
2	1	↓	↓	-	-	-	65.5	50.9	8.5	64.4	50.9	6.5
↓	11	02	↓	-	-	-	67.2	52.0	7.0	65.7	51.5	7.0
3	1	↓	↓	64.9	49.7	10.5	62.7	48.1	8.5	62.7	48.6	7.0
↓	11	03	↓	63.4	49.2	12.0	64.5	48.0	8.5	65.0	50.3	7.5
4	1	↓	↓	*65.0	49.9	12.5	-	-	-	-	-	-
↓	11	04	↓	62.9	49.0	12.5	63.8	48.8	9.5	63.7	49.8	7.5
5	1	↓	↓	63.9	49.0	12.5	64.4	49.1	9.5	63.9	49.7	9.0
↓	11	05	↓	63.2	49.3	11.0	63.7	49.0	10.0	61.9	48.2	9.0
6	1	↓	↓	-	-	-	*64.9	50.2	10.0	-	-	-
↓	11	06	↓	63.7	49.2	11.5	63.7	48.2	10.0	62.6	48.7	8.5
7	1	↓	↓	-	-	-	*63.1	48.2	10.0	-	-	-
↓	11	07	↓	-	-	-	64.8	49.6	8.5	63.0	49.0	7.5
8	1	↓	↓	-	-	-	64.8	50.1	9.0	62.6	48.9	8.0
↓	11	08	↓	-	-	-	66.5	51.1	8.5	63.9	49.9	7.5
9	1	↓	↓	-	-	-	65.1	49.9	8.5	63.6	49.4	7.5
↓	11	09	↓	-	-	-	66.1	50.7	8.5	65.2	50.7	8.0
10	1	↓	↓	-	-	-	64.4	49.7	9.0	63.2	49.2	7.5
↓	11	10	↓	66.4	52.3	11.5	65.7	51.5	8.5	65.6	51.2	9.5
11	1	↓	↓	66.4	56.3	12.0	65.7	50.3	9.0	65.8	51.8	8.0
↓	11	10	↓	-	-	-	67.2	52.5	7.0	67.2	52.2	7.0
12	1	↓	↓	-	-	-	66.7	52.7	7.0	66.3	52.0	7.0
↓	11	11	↓	66.5	51.8	12.0	67.2	52.6	8.5	67.5	53.3	8.5
13	1	↓	↓	67.2	52.0	12.0	67.8	52.0	8.0	66.2	53.0	6.5
↓	11	12	↓	-	-	-	64.9	49.2	9.0	62.9	48.1	7.5
14	1	↓	↓	-	-	-	*65.1	49.4	9.0	-	-	-
↓	11	13	↓	-	-	-	65.1	49.6	9.5	64.9	49.4	8.5
15	1	↓	↓	67.9	50.6	7.5	66.9	51.3	11.0	67.3	52.8	5.5
↓	11	13	↓	66.7	51.5	10.5	67.8	50.6	9.5	68.0	53.3	7.0

TABLE 8. (Concluded)

Prolongation Tests					Tensile Properties								
Forging P/N 14A20084					Longitudinal			Long Transverse			Short Transverse		
S/N	Seg.	Lot	t	in.	UTS	TYS	EL	UTS	TYS	EL	UTS	TYS	EL
					ksi	ksi	%	ksi	ksi	%	ksi	ksi	%
14	1	5059514	5-3/4		67.2	51.4	12.5	66.6	50.9	10.5	66.3	51.5	8.5
↓	11	↓	↓	↓	66.3	51.3	10.5	66.6	51.0	8.5	66.2	51.9	8.0
15	1	↓	↓	↓	65.9	50.7	11.0	63.9	49.1	11.0	63.0	49.2	8.0
↓	↓	↓	↓	↓	*63.9	49.7	11.5	-	-	-	-	-	-
16	1	↓	↓	↓	65.0	50.4	11.5	65.2	49.4	9.0	65.2	51.2	8.0
↓	↓	↓	↓	↓	62.7	49.0	11.0	62.9	48.7	8.5	62.5	49.5	7.5
↓	↓	↓	↓	↓	-	-	-	*64.2	50.4	9.0	-	-	-
↓	↓	↓	↓	↓	61.9	49.0	11.5	62.3	48.5	9.0	62.5	48.7	7.5
↓	↓	↓	↓	↓	*62.9	49.1	12.0	-	-	-	-	-	-
17	1	↓	↓	↓	-	-	-	65.2	49.4	9.0	65.2	49.9	7.5
↓	11	↓	↓	↓	-	-	-	64.0	48.1	9.0	63.6	49.1	8.0
18	1	↓	↓	↓	65.2	50.3	11.5	65.7	49.8	9.0	65.6	50.8	8.5
↓	11	↓	↓	↓	65.4	50.3	12.0	66.5	50.3	9.0	65.7	51.3	8.5
19	1	↓	↓	↓	63.7	50.0	10.5	64.4	50.7	9.0	62.9	50.5	8.0
↓	11	↓	↓	↓	63.3	50.2	11.0	63.7	49.7	8.5	62.4	48.9	6.5
20	1	↓	↓	↓	66.7	51.3	11.0	67.3	52.1	7.5	61.0	46.9	8.5
↓	↓	↓	↓	↓	*68.5	52.5	7.0	*67.5	52.2	10.5	-	-	-
↓	11	↓	↓	↓	66.8	52.0	10.0	63.8	49.4	9.5	62.7	48.9	8.5
↓	↓	↓	↓	↓	*67.7	53.1	10.0	-	-	-	-	-	-
Min. Gtd. (Forger)					61	49	6	61	48	4 seg. 5 3 seg. 6-8	59	45	3

Forging and HT dimensions — ~5-3/4 - 14" t x ~29-1/2" w x ~115-1/2" l; Prolongations aged by forger.

1/2" D tensile specimens.

Note: All locations ϕ t and w.

* Retest specimens.

JR HAND FORGING
STRUCT TEST

Mechanical Properties							Fracture Toughness		Stress	
D Specimens							Compact Tension $K_{Ic} - \text{ksi} \sqrt{\text{in.}}$		Short T	
Transverse			Short Transverse				(S-L)	(L-S)	Tensile E	
TS	EL	RA	UTS	TYS	EL	RA			UTS	TYS
ksi	%	%	ksi	ksi	%	%	ksi	ksi		
6	7.5	10.9	63.6	51.2	7.5	9.8	-	-	63.5	50.3
4	7.5	9.7	*63.7	50.9	5.0	4.7			63.9	50.4
4	7.5	9.4	64.5	51.8	(5)	6.7			63.8	50.4
									63.7	50.4
6	6.5	6.7	63.8	51.4	5.0	5.0	-	-	65.4	51.9
2	5.0	10.1	65.0	51.3	5.5	8.5			64.6	50.1
6	5.0	7.3	67.7	55.6	5.5	7.4			65.1	51.8
									65.0	51.3
									(3)	
									63.9	49.7
									62.5	49.3
									61.7	48.9
									62.7	49.3
1	5.5	6.8	65.9	52.6	6.0	6.3	-	-	-	-
0	5.5	7.1	*59.4	46.3	4.5	7.0	(23.48) [0.590]	(4)		
	-	-	-	-	-	-	(4)	(4)		
6	(5)	3.6	64.8	52.3	5.5	5.1	-	-		
	-	-	-	-	-	-	-	-		
	-	-	56.6	43.6	4.0	5.5	21.91			
	-	-	-	-	-	-	-	-		
	-	-	56.9	45.3	4.0	7.5	22.32			
	-	-	-	-	-	-	-	-		
	-	-	-	-	-	-	-	-	(39.64) [1.033]	
	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	(38.31) [1.058]	
	-	-	-	-	-	-	-	-	-	

See Page 55 for Notes

Stress Corrosion — 3 1/2% NaCl Alt. Imm.

Short Transverse (\bar{C}_t and w; 1/4" D x 1" GL)

Tensile Blanks				Unstressed		Stressed ⁽²⁾	
UTS	TYS	EL	RA	UTS	EL	UTS	EL
ksi	ksi	%	%	% Change in 30 Days			
63.5	50.3	6.5	7.1	-24.0	-76.9	— FH —	
63.9	50.4	7.0	8.6	-26.5	-76.9	-25.4	-69.2
63.8	50.4	6.0	11.0	-22.3	-76.9	-27.2	-76.9
63.7	50.4	6.5	8.9	-24.5	-76.9	-26.4	-72.3
65.4	51.9	7.0	10.3	-22.3	-70.6	-28.3	-85.3
64.6	50.1	7.0	7.1	-22.9	-70.6	-27.7	-85.3
65.1	51.8	6.5	7.2	-24.2	-70.6	-25.1	-70.6
65.0	51.3	6.8	8.2	-23.0	-70.6	-27.1	-80.8
3)							
63.9	49.7	6.5	9.4	-25.5	-91.2	-26.3	-82.4
62.5	49.3	5.5	8.6	-26.0	-91.2	-26.3	-100
61.7	48.9	5.0	6.4	-27.3	-100	-29.2	-100
62.7	49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

Forging P/N 14A20084 ⁽¹⁾					
S/ N 1			Longitudinal		
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL
6	t/2; w/2	~14	-	-	-
↓	↓	↓			
8			-	-	-
↓	↓	↓			
2 & 10	Min. Gtd.	~5 3/4	61	49	6
5 & 9	↓	~7 1/2-12	50	37	6
6 & 8	↓	14	50	37	6

Notes:

(1) Forged and HT dimensions — ~5 3/4-14" t × ~29 1/2" w
Alcoa cut into segments before aged.

(2) Stressed to 75% TYS.

(3) Standard — specimens from 2219-T851 plate 6 1/8" t expo

(4) Failed according to E399 sec. 8.2.4 — cracked at an angle

(5) Broke outside gauge marks.

FH — Failed in handling during removal from stressing fixture

* — Stress-strain curves available.

† Surface for L and ST.

TABLE 9. (Continued)

Tensile Properties											Fracture Toughness	
1/2" D Specimens											Compact Tension K _{1c} - ksi√in	
Longitudinal			Long Transverse				Short Transverse				(S-L)	
TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %		
-	-	-	-	-	-	-	56.3	44.8	5.0	7.0	20.84	
							56.1	44.5	5.5	7.5	22.23	
-	-	-	-	-	-	-	56.6	43.9	7.0	8.6	22.96	
							56.6	44.2	7.0	8.6	22.46	
							-	-	-	-	22.67	
	6	-	61	48	4	-	59	45	3	-	-	
	6	-	50	36	4	-	48	34	3	-	-	
	6	-	50	36	3	-	48	34	3	-	-	

Legend:

() - K_Q values in parentheses

[] - R_{sc} values in brackets

1.5" wide specimens

~29 1/2" w x ~115" l

1/8" t exposed simultaneously.
at an angle >10°.

using fixture.

Fracture Toughness		Stress Corrosion — 3.5% NaCl Alt. Imm.									
Compact Tension K_{1c} — ksi $\sqrt{\text{in.}}$		Short Transverse (σ_t and w ; 1/4" D \times 1" GL)									
		Tensile Blanks				Unstressed		Stressed ⁽²⁾			
(S-L)	(L-S)	UTS	TYS	EL	RA	UTS	EL	UTS	EL		
		ksi	ksi	%	%	% Change in 30 Days					
20.84	-	-	-	-	-	-	-	-	-	-	-
22.23	-	-	-	-	-	-	-	-	-	-	-
22.96	-	57.2	44.0	7.0	12.5	-21.5	-85.7	-24.4	-92.8		
22.46	-	57.2	43.9	7.0	10.8	-25.5	-92.8	-23.7	-92.8		
22.67	-	57.4	43.9	7.0	10.3	-20.9	-85.7	-24.6	-100		
		57.3	43.9	7.0	11.2	-22.7	-88.6	-24.2	-95.7		
		(3)									
		63.9	49.7	6.5	9.4	-25.5	-91.2	-26.3	-82.4		
		62.5	49.3	5.5	8.6	-26.0	-91.2	-26.3	-100		
		61.7	48.9	5.0	6.4	-27.3	-100	-29.2	-100		
		62.7	49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7		
-		-	-	-	-	-	-	-	-		
-											
-											

TABLE 9. (Continued)

Forging P/N 14A20084 ⁽¹⁾			Tensile Properties							
S/N 13			Longitudinal				1/2" D Specimens			
Seg. No.	Location	t in.	UTS ksi.	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %
2 ↓	t/2; edge †	~5 3/4	68.2	53.9	8.0	16.9	67.2	52.5	5.5	7.9
	w/2		66.7	51.2	9.5	23.3	67.4	50.9	7.0	11.6
	edge †		68.7	55.4	8.5	16.9	67.3	52.7	4.5	7.5
10 ↓	edge †	↓	68.7	54.2	10.0	21.9	66.6	53.0	5.0	8.6
	w/2		66.0	50.7	9.5	20.4	67.0	50.5	7.0	12.7
	edge †		70.2	55.1	9.5	20.1	67.1	52.8	5.5	7.9
5 ↓	t/4 bot.; edge †	~12	68.7	56.3	7.5	15.4	64.0	52.7	5.0	5.1
	w/2 edge †		not reported				64.0	48.7	6.0	7.1
6 ↓	w/4	~14	68.9	53.3	9.0	16.4	64.3	51.9	5.0	5.1
	w/3		62.8	48.8	9.0	16.9	-	-	-	-
	w/2		-	-	-	-	-	-	-	-
	w/3		60.9	46.9	9.5	18.8	-	-	-	-
	w/4		-	-	-	-	-	-	-	-
	t/4 top; w/4		63.0	49.0	9.0	17.6	-	-	-	-
	w/3		62.6	49.2	9.5	20.6	-	-	-	-
	w/2		60.6	46.0	10.5	24.3	-	-	-	-
	w/3		59.1	46.6	10.0	21.9	-	-	-	-
	w/4		60.3	45.9	9.5	22.7	-	-	-	-
t/2; w/2	62.6	49.0	8.5	17.6	-	-	-	-		
8 ↓			-	-	-	-	-	-	-	
			-	-	-	-	-	-	-	

Notes:

(1) Forged and HT dimensions — ~5 3/4-14" t × ~29 1/2" w × ~115 1/2" l.

Forger cut into segments before aged.

† Surface for L and ST.

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Mechanical Properties							Fracture Toughness	
Mechanical Properties of Specimens							Compact Tension K_{Ic} — ksi $\sqrt{\text{in.}}$	
Transverse			Short Transverse				(S-L)	(L-S)
YS	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %		
5	5.5	7.9	69.0	55.5	5.5	7.5	-	-
9	7.0	11.6	67.8	53.4	5.0	7.5	-	-
7	4.5	7.5	68.7	56.1	5.0	4.8	-	-
0	5.0	8.6	67.5	55.1	5.5	9.4	-	-
5	7.0	12.7	67.0	52.2	6.0	8.3	-	-
8	5.5	7.9	68.4	55.9	6.0	7.9	-	-
7	5.0	5.1	68.9	56.6	7.0	5.1	-	(32.27) [0.722]
7	6.0	7.1	63.7	49.1	6.0	8.6	25.44	(31.97) [0.863]
9	5.0	5.1	69.0	55.8	7.0	6.3	-	(35.41) [0.868]
-	-	-	-	-	-	-	-	-
-	-	-	58.4	44.3	5.5	7.5	(27.41) [0.789]	-
-	-	-	-	-	-	-	-	-
-	-	-	58.7	44.8	5.5	6.7	(26.58) [0.755]	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	(41.34) [1.188]
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	(39.78) [1.072]
-	-	-	-	-	-	-	-	-
-	-	-	57.8	43.5	6.5	6.7	25.18	-
-	-	-	57.8	44.0	7.0	10.5	26.37	-
-	-	-	58.4	43.8	6.5	12.8	25.39	-
-	-	-	58.3	44.1	6.5	8.6	26.25	-
							1 = not reported	

Legend:

() — K_Q values in parentheses

[] — R_{sc} values in brackets

1.5" wide specimens

Forging P/N 14A20084 ⁽¹⁾						
S/N 19			Longitudinal			
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %
2	t/2; edget	~ 5 3/4	63.4	51.9	10.0	24.3
	w/2		62.0	49.1	9.5	25.1
	edget		64.2	51.9	10.0	23.4
10	edget		61.5	51.8	9.0	23.3
	w/2		61.5	48.3	10.0	25.8
	edget		62.1	52.7	10.0	29.5
5	t/4 bot.; edget	~ 12	63.4	50.9	8.0	17.6
	w/2		57.6	44.9	8.5	16.4
	edget		62.2	49.5	9.5	16.8
6	w/4	~ 14	57.5	45.9	10.0	23.4
	w/3		-	-	-	-
	w/2		56.0	43.4	10.5	22.4
	w/3		-	-	-	-
	w/4		57.5	45.9	10.5	23.5
	t/4 top; w/4		57.5	46.1	10.0	23.0
	w/3		55.6	43.2	10.5	22.9
	w/2		56.1	43.4	10.0	20.2
	w/3		56.2	43.6	10.0	21.1
	w/4		57.8	46.2	10.0	20.5
	t/2; w/2		-	-	-	-
8			-	-	-	-

Notes:

- (1) Forged and HT dimensions — ~ 5 3/4-14" t × ~ 29 1/2" w × ~ 115 1/2" Forger cut into segments before aged.
- (2) Failed acc. to E399 sec. 8.2.4 — cracked at angle >10° — actual ~44-

†Surface for L and ST.

TABLE 9. (Concluded)

Tensile Properties									Fracture Toughness	
1/2" D Specimens									Compact Tension K _{1c} — ksi √ in.	
	Long Transverse				Short Transverse					
EA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)
1.3	61.9	49.6	6.0	9.8	62.5	52.8	7.0	10.5	-	-
5.1	61.9	47.6	7.5	12.0	62.3	50.0	6.5	10.5		
3.4	62.6	50.4	7.0	11.6	63.7	52.8	6.0	8.5		
3.3	60.3	48.5	5.0	8.6	60.8	50.6	6.0	7.5	-	-
5.8	61.4	48.4	6.0	8.6	61.5	48.9	6.0	8.2		
1.5	61.7	48.6	5.5	8.2	62.6	51.5	7.0	9.0		
7.6	59.7	47.9	4.0	7.4	63.1	51.0	5.0	9.4	{(21.17) [0.574]	{(2)
5.4	58.1	45.0	7.0	10.1	58.0	45.4	5.0	10.9		
1.8	59.7	47.6	5.0	8.9	62.3	50.0	6.0	8.9	-	-
3.4	-	-	-	-	-	-	-	-		
-	-	-	-	-	55.2	42.6	5.5	9.4	(20.22) [0.610]	
4.4	-	-	-	-	-	-	-	-		
-	-	-	-	-	55.3	43.1	6.0	8.9	(20.21) [0.597]	
5.5	-	-	-	-	-	-	-	-		
0.0	-	-	-	-	-	-	-	-	-	-
9.9	-	-	-	-	-	-	-	-	-	26.22
2.2	-	-	-	-	-	-	-	-	-	-
1.1	-	-	-	-	-	-	-	-	-	25.93
5.5	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	54.8	42.3	6.5	10.9	(20.38) [0.616]	-
-	-	-	-	-	55.0	42.4	4.5	7.8	20.72	-
-	-	-	-	-	55.2	43.0	6.5	9.3	(20.10) [0.593]	-
-	-	-	-	-	55.4	43.0	5.0	6.2	(20.45) [0.631]	-
-	-	-	-	-	-	-	-	-	(19.77) [0.600]	-

Legend:

() — K_Q values in parentheses

[] — R_{sc} values in brackets

1.5" wide specimens

TABLE 10. 2219-T852 CONTOUR HAND FORGING — DETAILED SUMMARY
COMBINED TESTS — THRUST POST — 14A20084

No. of Forgings	Test Loc.	HT t in.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL % 7/4 D	RA %	UTS ksi	TYS ksi	EL % 7/4 D	RA %	UTS ksi	TYS ksi	EL % 7/4 D	RA %
Forger Min. Gtd.		5 3/4	61	49	6	-	61	48	4	-	59	45	3	-
3 destruct A	G & E	~5 3/4	(15) 62.2-69.0	49.7-52.6	7.5-13.0	-	(15) 61.8-67.8	48.5-51.7	5.5-11.0	-	(15) 61.5-68.3	48.9-54.7	4.5-8.5	-
	M		(18) 61.5-70.2	48.3-55.4	8.0-12.0	16.9-29.5	(18) 60.3-67.4	47.6-53.0	4.5-7.5	6.7-12.7	(24) 60.8-69.0	48.9-56.1	5.0-7.5	4.7-11.0
*1 x-skirt M	G		(3) 59.4-59.7	45.0-45.4	8.0-8.5	21.2-23.0	-	-	-	-	-	-	-	-
17 Prol. A			(25) 61.9-68.5	49.0-56.3	7.0-12.5	-	(39) 62.3-67.8	48.0-52.7	7.0-11.0	-	(34) 61.0-67.5	46.9-53.3	6.5-9.5	-
*1 x- M			-	-	-	-	(6) 64.0-67.5	49.1-51.8	6.0-7.5	8.2-13.2	(6) 63.6-65.8	50.8-51.6	4.0-5.5	4.0-8.2
Forger Min. Gtd.		7 1/2-12	50	37	6	-	50	36	4	-	48	34	3	-
3 destruct A	G & 1/4 w	~7 1/2	(9) 60.1-66.0	46.5-50.6	10.5-11.5	-	(9) 59.8-66.6	45.5-50.8	5.0-9.0	-	(9) 57.8-66.2	44.6-51.0	6.0-9.0	-
3 destruct M	1, 4 t	~12	(8) 57.6-68.9	44.9-56.3	7.0-9.5	8.2-18.0	(9) 58.1-64.3	45.0-52.7	4.0-7.0	3.6-10.1	(9) 58.0-69.0	46.3-56.6	4.5-7.0	5.1-10.9
*1 x-skirt M	G		-	-	-	-	-	-	-	-	(3) 53.9-54.7	41.7-43.0	7.5-8.0	10.2-12.7
Forger Min. Gtd.		14	50	37	6	-	50	36	3	-	48	34	3	-
3 destruct A	G & 1/4 w	~14	(18) 57.1-66.7	44.5-51.8	9.0-11.5	-	(46) 50.0-70.6	42.4-54.7	2.5-8.5	-	(36) 54.1-64.3	43.5-51.0	4.0-8.0	-
	M 1, 4 t		(24) 55.3-63.0	43.2-49.2	8.5-11.0	13.9-24.3	-	-	-	-	(6) 55.2-58.2	42.6-45.3	4.0-6.0	5.5-9.4
	M G		-	-	-	-	-	-	-	-	(12) 54.8-58.4	42.3-44.8	4.5-7.0	6.2-12.8
*1 x-skirt M			(3) 55.3-56.3	42.9-43.6	10.5-11.0	27.5-28.5	-	-	-	-	-	-	-	-

A = Alcoa test

M = MDAC test

* = MDAC aged; all others were forger aged

x = simulation age

skirt = MDAC 1/4 skirt, destruct test

Prol. = prolongation from each end of forging

○ = No. of 1" D and 1/4" D tensile specimens tested, min. to max. values obtained

(1) 2.5% for one specimen at 1, 4 w, duplicate and original were 3%

TABLE 11. 2219-T852 CONTOUR HAND FORGING — CONDENSED SUMMARY
COMBINED TESTS — THRUST POST — 14A20084

No. of Forgings	Test Loc.	HT t in.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %
Forger Min. Gtd.		5 3/4	61	49	6	-	61	48	4	-	59	45	3	-
20 ⁽¹⁾	Q _L ; E	~5 3/4	(58) 61.5-70.2	48.3-56.3	7.0-13.0	(18) 16.9-29.5	(78) 60.3-67.8	47.6-53.0	4.5-11.0	(18) 6.7-13.2	(79) 60.8-69.0	46.9-56.1	4.0-9.5	(24) 4.0-11.0
1 ⁽²⁾	Q _L	↓	(3) 59.4-59.7	45.0-45.4	8.0-8.5	(3) 21.2-23.0	-	-	-	-	-	-	-	-
Forger Min. Gtd.		7 1/2-12	50	37	6	-	50	36	4	-	48	34	3	-
3 ⁽³⁾	Q _L ; 1/4 w	~7 1/2	(9) 60.1-66.0	46.5-50.6	10.5-11.5	-	(9) 59.8-66.6	45.5-50.8	5.0-9.0	-	(9) 57.8-66.2	44.6-51.0	6.0-9.0	-
3 ⁽³⁾	1/4 t	~12	(9) 57.6-68.9	44.9-56.3	7.0-9.5	(9) 8.2-18.0	(8) 58.1-64.3	45.0-52.7	4.0-7.0	(8) 3.6-10.1	(9) 58.0-69.0	46.3-56.6	4.5-7.0	(9) 5.1-10.9
1 ⁽²⁾	↓	↓	-	-	-	-	-	-	-	-	(3) 53.9-54.7	41.7-43.0	7.5-8.0	(3) 10.2-12.7
Forger Min. Gtd.		14	50	37	6	-	50	36	3	-	48	34	3	-
3 ⁽³⁾	Varied	~14	(42) 55.6-66.7	43.2-51.8	8.5-11.5	(24) 13.9-24.3	(46) 50.0-70.6	42.4-54.7	(4) 2.5-8.5	-	(54) 54.1-64.3	42.3-51.0	4.0-8.0	(18) 5.5-12.8
1 ⁽²⁾	Q _L	↓	(3) 55.3-56.3	42.9-43.6	10.5-11.0	(3) 27.5-28.5	-	-	-	-	-	-	-	-

- (1) 3 destruct +17 prolongation tests each end
 (2) 1 destruct from MDAC aged 1/4 skirt
 (3) 3 destruct
 (4) 2.5" for one specimen at 1/4 w, duplicate and original were 3"
 ○ = No. of 1/2" and 1/4" D specimens tested; min. to max. values obtained

Forged and HT dimensions ~5 3/4-14" t x ~29 1/2" w x ~115 1/2" l

TABLE 12. FORGER DATA — 2219-T852 RECTANGULAR HAND FORGING
 SPLICE FITTING — PROLONGATION TESTS AND DESTRUCT TEST

Prolongation Tests				Tensile Properties								
Forging P/N 14A30500				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A C A B	001	2365	~8	-	-	-	59.4	45.2	7.1	59.3	43.4	7.1
	↓	↓	↓				59.9	46.1	7.9	60.5	45.5	5.7
	003	2275					59.9	46.8	7.9	59.7	44.2	7.1
	↓	↓					62.0	48.5	7.1	61.2	45.4	7.9
	004	2372					59.2	45.6	7.9	59.3	45.3	6.4
	↓	↓					60.1	46.9	7.1	61.1	47.2	6.4
	005	2230					61.8	47.1	7.9	61.7	47.0	5.7
	↓	↓					65.2	51.1	7.1	65.0	50.5	6.4
	006						64.3	50.2	6.4	63.8	48.3	5.0
	↓	↓					61.2	46.5	7.1	61.1	46.2	6.4
	007	2377					60.6	47.4	7.9	60.6	46.1	6.4
	↓	↓					59.4	45.5	7.9	59.3	44.2	7.1
	008	2254					58.2	45.6	7.1	58.9	43.9	6.4
	↓	↓					59.4	46.0	7.9	59.6	44.2	5.7
	009	2239					62.5	47.6	7.1	62.9	47.5	6.4
↓	↓					65.6	50.4	7.1	64.9	49.0	6.4	
010	2259					60.9	46.7	6.4	61.1	46.6	6.4	
↓	↓					62.1	47.4	6.4	61.9	46.8	5.7	
011	2239					61.8	48.1	6.4	61.8	46.2	6.4	
↓	↓					67.6	53.0	7.1	66.6	50.8	5.7	
012	2257					63.0	47.7	7.1	63.3	47.7	6.4	
↓	↓					61.8	47.0	7.9	62.1	45.7	6.4	
013	2254					60.4	46.8	7.1	61.0	45.4	7.1	
↓	↓					59.6	45.6	7.1	60.0	44.2	7.1	
014	2259					59.3	45.6	7.1	59.6	44.1	7.9	
↓	↓					60.0	45.9	9.3	60.2	44.5	8.6	
015	2257					68.1	53.1	6.4	67.5	50.8	6.4	
↓	↓					63.7	49.5	7.9	63.5	47.6	7.1	

TABLE 12. (Continued)

Prolongation Tests				Tensile Properties								
Forging P/N 14A30500				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	016	2361	~8	-	-	-	60.6	48.2	6.4	60.6	47.8	6.4
	↓	↓					60.9	48.3	7.1	61.0	47.5	7.1
B	017	2257	63.5				47.6	9.3	62.1	46.2	7.1	
	↓	↓	64.2				48.9	8.6	64.9	48.2	7.1	
018	2259	59.9	46.0				7.9	59.6	44.3	7.9		
↓	↓	61.0	46.9				7.1	61.0	45.8	7.1		
019	2254	60.8	46.6				9.3	60.4	45.4	7.9		
↓	↓	61.9	47.8				7.9	61.9	47.0	8.6		
020	2301	60.5	46.5				7.9	60.7	45.1	7.9		
↓	↓	61.2	46.5				7.9	61.5	46.8	6.4		
021	2377	58.4	44.8				7.9	59.4	43.9	6.4		
↓	↓	60.1	46.5				7.1	60.2	45.8	6.4		
022	2275	60.6	46.6				8.6	60.6	46.4	7.1		
↓	↓	57.8	43.5				8.6	58.2	43.7	6.4		
023	2389	60.4	47.2				7.9	60.3	46.1	6.4		
↓	↓	61.2	48.1				6.4	61.2	46.6	6.4		
024	2365	60.2	46.4				7.9	60.4	45.5	7.9		
↓	↓	59.3	45.2				8.6	60.4	43.4	7.9		
025	2367	59.8	44.5				7.9	59.5	43.7	7.1		
↓	↓	59.9	46.1				7.1	59.9	44.8	7.9		
026	2361	61.1	48.6				6.4	61.6	47.9	6.4		
↓	↓	62.3	49.5				6.4	62.3	48.9	5.0		
027	2372	58.6	45.6				7.9	58.6	44.4	7.1		
↓	↓	59.9	45.9				8.6	60.6	46.0	7.1		
028	2367	60.0	46.0				7.9	60.9	45.8	7.1		
↓	↓	59.8	45.5				7.1	60.3	44.7	7.1		
029	2230	63.3	51.2				6.4	63.3	49.9	3.6		
↓	↓	66.8	53.8				6.4	67.1	52.7	6.4		
030	2361	60.9	47.1				7.1	61.1	44.9	7.1		
↓	↓	59.8	45.5				7.9	60.0	45.2	7.9		

TABLE 12. (Continued)

Prolongation Tests				Tensile Properties								
Forging P/N 14A30500				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	031	2372	~8	-	-	-	62.7	49.4	6.4	63.3	49.0	5.7
	032	2301					62.1	49.5	6.4	62.1	48.6	6.4
B	033	2275					58.9	44.7	8.6	59.0	43.5	7.1
	034	2365					60.2	45.5	7.9	59.7	44.0	8.6
	035	2384					59.8	45.1	7.1	59.0	42.9	7.1
	036	2301					60.4	45.9	7.1	60.7	44.6	7.1
	037	2391					58.7	45.0	8.6	59.3	44.3	7.9
	038	2239					57.6	44.2	7.9	58.4	43.9	8.6
	039	2367					62.5	50.0	5.7	62.2	46.1	6.4
	040	2384					63.3	49.5	5.7	62.5	48.4	5.7
	041	2374					59.2	45.2	9.3	59.2	42.7	7.1
	042						59.1	45.3	7.1	58.5	43.3	5.7
	043	2379					60.9	47.8	7.1	60.7	46.2	8.6
	044						59.1	45.7	9.3	59.1	44.4	7.9
	045	2381					59.5	44.7	10.0	60.0	45.4	8.6
							63.9	48.5	6.4	63.9	48.2	5.7
							58.2	44.0	7.1	58.5	43.1	6.4
						59.6	45.8	7.9	59.5	44.2	7.1	
						59.3	45.7	6.4	59.8	46.1	7.1	
						60.3	46.6	5.7	60.3	45.9	9.3	
						59.9	45.9	8.6	60.1	44.5	7.9	
						57.3	45.3	7.9	58.7	44.0	7.1	
						59.4	45.8	7.9	59.7	44.5	7.9	
						60.1	46.5	8.6	60.9	45.1	6.4	
						59.8	46.0	7.9	59.4	44.2	7.9	
						58.5	43.9	8.6	58.5	42.9	7.9	
						59.0	45.2	8.6	59.3	44.7	6.4	
						59.1	43.7	8.6	59.1	45.1	6.4	
						59.9	45.3	8.6	60.5	45.0	6.4	
						59.6	44.1	7.1	59.6	43.9	7.1	

TABLE 12. (Continued)

Prolongation Tests				Tensile Properties								
Forging P/N 14A30500				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A B	046	2381	~8	-	-	-	60.9	47.0	9.3	60.8	45.4	7.1
	047	2384					59.6	45.7	8.6	59.3	44.3	9.3
	048	2389					59.4	45.2	8.6	58.9	43.7	7.9
	049	2373					60.7	47.2	9.3	60.2	45.4	7.9
	050	2374					59.1	45.9	8.6	59.4	44.0	7.9
	051	2391					58.2	45.4	7.9	58.9	44.0	7.9
	052	2377					60.2	46.8	7.1	60.3	45.1	7.1
	053	2373					58.6	43.8	7.9	58.8	43.2	7.1
	054	2389					57.9	45.0	7.1	59.6	45.0	7.9
	055	2389					57.9	44.9	7.1	58.1	43.3	7.9
	056	2379					60.0	44.8	7.1	60.5	45.7	6.4
	057	2385					61.8	48.8	9.3	61.3	45.9	7.9
	058	2391					61.6	48.9	5.7	60.8	46.0	6.4
	059	2385					60.4	48.6	7.1	60.4	46.6	7.9
	060						59.4	46.2	7.1	59.6	44.8	7.9
							58.5	46.1	7.1	58.9	44.3	7.9
							58.5	45.3	7.9	58.9	44.0	8.6
							58.3	44.1	7.9	59.1	44.2	8.4
							57.3	43.5	10.0	58.0	43.4	7.1
							58.1	44.9	9.3	58.3	43.4	9.3
						63.1	49.1	6.4	63.5	47.6	6.4	
						58.4	43.9	10.0	58.8	43.2	7.9	
						58.6	44.4	8.6	58.0	42.5	8.6	
						57.5	43.7	9.3	57.3	42.7	8.6	
						59.0	46.1	10.0	58.6	43.9	9.3	
						59.6	46.8	7.1	59.3	45.2	7.9	
						57.1	43.1	9.3	57.3	41.2	7.9	
						59.3	46.2	10.0	59.1	44.4	8.6	
						58.3	43.9	9.3	58.8	42.9	7.1	
						57.8	44.0	9.3	58.1	42.5	8.6	

TABLE 12. (Concluded)

Prolongation Tests				Tensile Properties								
Forging P/N 14A30500				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A B ↓	061	2397	~8	-	-	-	59.0	46.3	8.6	59.2	44.2	8.6
	↓	↓	↓	↓	↓	↓	59.1	46.6	7.1	58.9	45.7	7.1
	062	2444	↓				58.6	44.3	8.6	59.4	42.5	8.6
	↓	↓	↓				57.8	43.3	7.9	57.9	42.0	7.1
Destruct Test				Destruct Forging								
A	001	2365	~8	-	-	-	59.4	45.2	7.1	59.3	43.4	7.1
1	↓	↓	↓	59.6	45.4	10.0	59.6	44.9	7.1	59.4	44.8	7.9
4	↓	↓	↓	59.7	46.7	10.7	59.1	45.0	8.6	58.8	44.7	7.9
9	↓	↓	↓	60.3	46.8	10.0	59.6	46.0	8.6	59.3	45.2	7.1
C	↓	↓	↓	-	-	-	59.9	46.1	7.9	60.5	45.5	5.7
Forger	Min.	Gtd.	8	57	44	6	57	43	4	55	40	3

Forging and HT dimensions — ~8" t x ~11" w x ~110" l

0.357" D x 1.40" gage length tensile specimens ~ϕ t and w

A and B are prolongations from opposite ends of the 100" long deliverable forging

A and C are prolongations from opposite ends of the destruct forging

Prolongations and destruct forging aged by forger, remainder delivered -T352 temper

Chemical Analysis of Mill Melt											
No. of S/N	Cu	Zr	V	Mg	Ti	Si	Fe	Zn	Mn	Cr	Mill Melt No.
25	5.82	.13	.10	.004	.05	.08	.24	.03	.26	.001	AH766-06-1, -2, -3, -4
14	5.94	.14	.10	.004	.06	.09	.26	.02	.29	.001	AH766-10-2, -3, -7
1	6.04	.15	.06	.011	.06	.093	.20	.008	.26	.001	AH701-06-2
2	6.16	.15	.07	.008	.054	.10	.22	.009	.27	.001	AH701-07-4
13	6.17	.14	.10	.004	.06	.09	.27	.02	.26	.000	AH766-06-1, -4
2	6.24	.15	.11	.009	.056	.088	.21	.015	.27	.001	AH989-23-4
4	6.35	.13	.05	.023	.058	.10	.22	.010	.26	.002	AH701-05-4

Data represent: 7 mill melt cast nos. for 13 ingot drops 14-1/2" t x 44" w rectangular
61 forged lengths, Mil-I-8950B, Class B, AM #1
22 heat treat lots

TABLE 13. MDAC TEST DATA
SPLICE

Forging P/N 14A30500 ⁽¹⁾							
S/N 001			Longitudinal				
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi
2	~1/4 t; ~ \bar{C}_L w	8	-	-	-	-	*62.
↓	↓	↓	-	-	-	-	-
5			-	-	-	-	*62.
↓			-	-	-	-	-
8			-	-	-	-	*62.
↓			-	-	-	-	-
3	\bar{C}_L t; edge		*62.6	49.4	9.0	26.4	-
↓	↓		64.9	48.9	11.0	26.4	-
	1/4 w		*65.1	50.9	11.0	24.6	-
	↓		-	-	-	-	59.
	↓		-	-	-	-	59.
	↓		-	-	-	-	59.
	& w		59.4	45.9	12.0	33.1	-
↓	↓		-	-	-	-	-
7	edge		*63.3	49.3	11.5	28.4	-
↓	↓		63.0	49.1	11.0	26.1	-
	1/4 w		65.7	51.0	11.0	25.7	-
	↓		-	-	-	-	58.
	↓		-	-	-	-	59.
	↓		-	-	-	-	60.
	↓		-	-	-	-	60.
	& w		59.3	45.3	13.0	34.4	-
	↓		-	-	-	-	-
Min. Gtd.			57	44	6	-	57

Notes:

(1) Forged and HT dimensions — ~8" t × ~11" w × ~110" l.

(2) Stressed to 75% TYS.

(3) Standard = Specimens from 2219-T851 plate 6 1/8" t exposed

* — Stress-strain curves available.

MDAC TEST DATA — 2219-T852 RECTANGULAR HAND FORGING
 SPLICE FITTING — DESTRUCT TEST

Tensile Properties										Fracture Toughness	
1/2" D Specimens										Compact Tension K _{1c} — ksi √ in.	
Nominal		Long Transverse				Short Transverse				(S-L)	(T-S)
EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %		
-	-	*62.0	47.2	7.5	13.8	*59.0	44.1	8.0	16.0	30.56	31.70
-	-	-	-	-	-	59.4	44.3	7.5	12.3	30.73	-
-	-	*62.1	47.2	8.0	10.8	*58.3	44.2	8.5	15.6	33.20	(35.70) [1.27]
-	-	-	-	-	-	58.5	44.2	10.0	21.5	32.71	-
-	-	*62.2	47.0	8.0	15.3	*60.0	45.3	7.5	12.3	28.90	34.08
-	-	-	-	-	-	60.1	45.6	7.0	9.3	28.07	-
9.0	26.4	-	-	-	-	-	-	-	-	-	-
1.0	26.4	-	-	-	-	-	-	-	-	-	-
1.0	24.6	-	-	-	-	-	-	-	-	-	-
-	-	59.7	-	7.0	12.8	-	-	-	-	-	-
-	-	59.7	46.2	7.0	9.0	-	-	-	-	-	-
-	-	59.6	45.7	7.5	14.2	-	-	-	-	-	-
-	-	59.5	45.3	8.0	15.0	-	-	-	-	-	-
2.0	33.1	-	-	-	-	-	-	-	-	-	-
1.5	28.4	-	-	-	-	-	-	-	-	-	-
1.0	26.1	-	-	-	-	-	-	-	-	-	-
1.0	25.7	-	-	-	-	-	-	-	-	-	-
-	-	58.2	45.1	8.0	13.1	-	-	-	-	-	-
-	-	59.1	45.4	8.0	14.6	-	-	-	-	-	-
-	-	60.6	46.5	7.5	13.4	-	-	-	-	-	-
-	-	60.5	46.4	7.5	12.0	-	-	-	-	-	-
3.0	34.4	-	-	-	-	-	-	-	-	-	-
6	-	57	43	4	-	55	40	3	-	-	-

Legend:
 () — K_Q values in parentheses
 [] — R_{sc} values in brackets
 1.5" wide specimens

× ~110" l.
 1/8" t exposed simultaneously.

Fracture Toughness		Stress Corrosion — 3-1/2% NaCl Alt. Imm.							
Compact Tension K _{1c} — ksi √ in.		Short Transverse (G _L t and w; 1/4" D × 1" GL)							
		Tensile Blanks				Unstressed		Stressed ⁽²⁾	
(T-S)	(L-S)	UTS ksi	TYS ksi	EL %	RA %	UTS %	EL %	UTS %	EL %
		% Change in 30 Days							
31.70	-	-	-	-	-	-	-	-	-
(35.70) [1.272]	-	58.3	44.6	9.5	14.7	-19.3	-73.7	-21.8	-63.2
-	-	58.1	44.4	9.5	16.2	-16.7	-73.7	-28.9	-84.2
-	-	57.8	43.4	9.5	12.3	-18.2	-73.7	-18.8	-73.7
-	-	58.1	44.1	9.5	14.4	-18.1	-73.7	-23.2	-73.7
34.08	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	(3)							
-	-	63.9	49.7	6.5	9.4	-24.7	-90.9	-31.7	-100
-	-	62.5	49.3	5.5	8.6	-24.6	-72.7	-	-
-	-	61.7	48.9	5.0	6.4	-22.8	-90.9	-25.4	-72.7
-	-	62.7	49.3	5.7	8.1	-24.0	-84.8	-28.5	-86.8
-	-	-	-	-	-	-	-	-	-

TABLE 13. (Concluded)

Forging P/N 14A30500 ⁽¹⁾			Tensile Properties								
S/N 001			1/2" D Elevated Temperature Specimens — Lo								
Seg. No.	Location	t in.	RT				200°F				U k
			UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	
3 ↓ ↓ ↓ ↓	G _L ↓ ↓ ↓ ↓ edge	8 ↓ ↓ ↓ ↓	59.4	45.9	12.0	33.1	52.4	43.3	17.0	41.6	
			59.4	45.5	11.0	25.8	-	-	-	-	
			59.2	45.7	10.0	23.3	-	-	-	-	
			59.6	45.8	11.0	26.4	-	-	-	-	
			60.0	45.9	12.0	27.7	*52.2	43.0	17.0	42.0	*44
			65.1	50.9	11.0	24.6	-	-	-	-	49
7 ↓ ↓ ↓ ↓	G _L ↓ ↓ ↓ ↓ edge	8 ↓ ↓ ↓ ↓	59.3	45.3	13.0	34.4	53.5	44.0	17.5	47.0	
			59.1	44.8	12.5	33.1	-	-	-	-	
			60.4	46.1	11.0	22.6	-	-	-	-	
			60.2	46.3	11.0	26.1	-	-	-	-	
			60.6	46.5	10.5	24.6	52.8	43.6	17.0	40.0	45
			65.7	51.0	11.0	25.7	-	-	-	-	48

Notes:

(1) Forged and HT dimensions — ~8" t × ~11" w × ~110" l

* — Stress-strain curves available.

ncluded)

Properties						Fracture Toughness		
Mechanical Properties — Longitudinal						Compact Tension K _{1c} — ksi√in.		
°F		300°F				RT	200°F	300°F
EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(L-S)	(L-S)	(L-S)
17.0	41.6	-	-	-	-	-	-	-
-	-	-	-	-	-	(43.69) [1.569]	-	-
-	-	-	-	-	-	(43.27) [1.481]	(36.58) [1.601]	(31.25) [1.260]
-	-	-	-	-	-	(43.51) [1.404]	(36.79) [1.516]	(31.74) [1.202]
17.0	42.0	*44.7	40.4	20.0	58.1	-	(36.83) [1.199]	(34.58) [1.255]
-	-	49.3	43.7	18.0	45.7	-	-	-
17.5	47.0	-	-	-	-	-	-	-
-	-	-	-	-	-	(39.73) [1.263]	-	-
-	-	-	-	-	-	(40.98) [1.353]	-	(34.85) [1.508]
-	-	-	-	-	-	(40.69) [1.233]	(36.84) [1.213]	(36.03) [1.462]
17.0	40.0	45.1	40.5	20.5	55.1	-	(36.05) [1.462]	(34.52) [1.554]
-	-	48.4	43.5	17.5	49.3	-	-	-

Legend:
 () — K_Q values in parentheses
 [] — R_{sc} values in brackets
 1.5" wide specimens

TABLE 14. 2219-T852 RECTANGULAR HAND FORGING — SUMMARY
 COMBINED TESTS — SPLICE FITTING — 14A30500

No. of Forgings	Test Loc.	HT t in.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %
Forger Min. Gtd.		8	57	44	6	-	57	43	4	-	55	40	3	-
1 destruct W	⊥	~8	59.6-60.3	45.4-46.8	10.0-10.7	-	59.1-59.9	44.9-46.1	7.1-8.6	-	58.8-60.5	43.1-45.5	5.7-7.9	-
↓ ↓ M	⊥; E		59.1-65.7	44.8-51.0	9.0-13.0	22.6-34.4	58.2-62.2	45.1-47.2	7.0-8.0	9.0-15.3	57.8-60.1	43.4-45.6	7.0-10.0	9.3-21.5
60 Prol. W	⊥		-	-	-	-	57.1-68.1	43.1-53.8	5.7-10.0	-	57.3-67.5	41.2-52.7	3.6-9.3	-
61 total	⊥; E	~8	59.1-65.7	44.8-51.0	9.0-13.0	22.6-34.4	57.1-68.1	43.1-53.8	5.7-10.0	9.0-15.3	57.3-67.5	41.2-52.7	3.6-10.0	9.3-21.5

W = Weber test, 0.357" D x 1.40" gage length tensile specimens
 M = MDAC test, 1/2" D tensile spec. for properties, 1/4" D ST for stress corrosion
 ○ = No. of specimens tested; min. to max. values obtained

Forged and HT dimensions ~8 1/2" t x ~11" w x ~110" l

TABLE 15. FORGER DATA — 2219-T852 RECTANGULAR HAND FORGINGS — ACTUATOR BRACKET — DESTRUCT TEST

Forging P/N 14A30905				Tensile Properties											
				Longitudinal			Long Transverse			Short Transverse					
S/N	Seg.	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %			
A	1	2182	10-1/2	60.8	47.4	10.0	58.5	46.1	7.1	58.4	43.8	9.3			
	↓			5	↓	↓	60.7	45.6	10.7	58.7	45.4	7.1	58.4	42.5	7.1
	↓			7	↓	↓	61.6	47.1	10.0	58.7	45.9	5.0	58.7	43.2	7.9
	↓			10	↓	↓	62.5	45.8	9.3	59.8	42.7	7.9	59.8	42.7	7.9
B	1			60.9	47.0	10.7	58.8	45.9	9.3	57.9	43.3	9.3			
	↓			5	↓	↓	60.0	45.2	10.7	56.9	44.4	7.9	56.3	42.0	9.3
	↓			7	↓	↓	59.9	45.8	10.0	57.9	45.1	8.6	57.5	42.7	8.6
	↓			10	↓	↓	60.5	45.7	10.0	58.6	45.2	7.9	57.5	42.0	7.1
C	1	2187		61.8	45.4	10.7	59.0	43.2	7.1	59.5	44.9	9.3			
	↓			5	↓	↓	61.5	46.5	11.4	62.4	48.7	10.0	63.7	47.9	8.6
	↓			7	↓	↓	63.7	48.0	9.3	60.6	46.5	7.1	59.9	44.9	7.1
	↓			10	↓	↓	63.8	48.8	10.0	61.4	48.0	7.9	60.8	45.6	6.4
D	1	2181		61.9	47.8	10.0	60.0	47.7	7.1	59.4	44.4	7.1			
	↓			5	↓	↓	62.4	48.3	10.0	59.7	47.5	8.6	59.5	44.1	8.6
	↓			7	↓	↓	63.0	47.5	10.0	60.4	47.0	8.6	59.6	43.9	8.6
	↓			10	↓	↓	63.5	49.6	9.3	60.7	48.8	7.1	59.9	43.7	8.6
E	1	2189		62.1	48.8	10.7	60.2	46.6	7.9	59.3	43.5	9.3			
	↓			5	↓	↓	59.9	47.1	10.7	58.7	45.8	6.4	57.5	43.7	5.7
	↓			7	↓	↓	63.0	48.5	10.7	60.6	47.0	8.6	60.3	44.2	9.3
	↓			10	↓	↓	62.7	48.6	10.7	60.6	46.1	10.0	60.0	44.5	9.3
F	1	2187		62.1	48.9	10.0	59.1	44.9	8.6	58.9	46.7	6.4			
	↓			5	↓	↓	62.6	49.5	10.7	59.8	47.4	8.6	59.9	44.9	9.3
	↓			7	↓	↓	61.6	48.1	10.0	62.9	50.2	7.9	63.8	48.4	7.9
	↓			10	↓	↓	61.1	48.1	10.0	59.6	46.4	9.3	58.0	44.3	7.9

TABLE 15. (Concluded)

Forging P/N 14A30905				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Seg.	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
G	1	2181	~10-1/2	60.9	46.9	10.0	61.9	47.9	5.0	58.7	43.5	7.9
↓	5	↓	↓	60.8	47.4	10.0	57.5	48.8	5.7	58.4	43.4	6.4
↓	7	↓	↓	61.5	48.8	10.0	60.4	49.0	7.9	58.5	44.7	7.9
↓	10	↓	↓	60.6	47.0	11.4	63.2	49.8	5.0	58.7	44.7	6.1
H	3	2444	↓	56.5	43.5	10.3	55.7	44.0	6.4	57.1	43.7	7.9
Forger Min. Gtd.				52	39	6	52	38	4	50	36	3

Forged dimensions — ~10-1/2" t x ~10-1/2" w x ~180" l
 HT dimensions — ~10-1/2" t x ~10-1/2" w x ~33" l
 0.357" D x 1.40" gage length tensile specimens $\frac{1}{2}$ t and w

Chemical Analysis of Mill Melt											
S/N	Cu	Zr	V	Mg	Ti	Si	Fe	Zn	Mn	Cr	Mill Melt No.
A, B, E	6.04	.15	.06	.011	.06	.093	.20	.008	.26	.001	AH701-06-2, -3
C, D, F, G	6.35	.13	.05	.023	.058	.10	.22	.010	.26	.002	AH701-05-2
H	6.24	.15	.11	.009	.056	.088	.21	.015	.27	.001	AH989-23-2

Data represent: 3 mill melt cast nos. for 4 ingot drops 14-1/2" t x 44-1/2" or 50" w rectangular
 7 forger mults + 1 single forged piece, Mil-I-8950B, Class B, AM #1
 5 heat treat lots, total 36 pieces
 All material aged by forger, delivered -T852 temper

TABLE 16. MDAC TEST DATA — 2219-T852 RECTANGULAR HAND ACTUATOR SUPPORT BRACKET

Forging P/N 14A30905 ⁽¹⁾			Tensile Properties								
Seg. No. 4			Longitudinal				1/2" D Specimens				
Forging S/N	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi
B ↓	CL t & w	10 1/2	*59.1	44.3	12.5	27.7	*60.0	46.9	7.5	11.3	*59.1
			58.7	44.5	11.0	27.3	56.0	44.5	5.0	7.8	61.1
			58.9	44.4	11.8	27.5	58.0	45.7	5.8	9.6	60.1
C ↓			63.2	47.6	10.0	24.6	60.3	46.9	8.5	13.5	65.5
			63.2	47.9	10.0	17.0	63.3	49.2	7.5	13.9	64.4
			63.2	47.8	10.0	19.3	61.8	48.0	8.0	13.7	65.0
E ↓			59.9	45.1	10.5	23.3	59.4	45.7	8.5	16.8	57.1
			59.8	45.6	11.0	23.6	60.0	42.0	8.5	14.6	59.8
			59.8	45.4	10.8	23.4	59.7	43.8	8.5	15.7	57.4
F ↓			61.8	48.8	10.0	22.9	60.8	47.4	8.5	17.0	59.2
			61.5	48.2	10.0	25.6	61.6	48.4	9.0	18.5	60.5
			61.6	48.5	10.0	24.2	61.2	47.9	8.8	17.8	59.8
G ↓			61.7	48.0	10.0	22.2	62.4	48.8	7.5	11.3	63.5
			61.8	48.6	10.5	24.0	59.3	46.9	7.5	13.5	63.3
			61.8	48.3	10.2	23.1	60.8	47.8	7.5	12.4	63.4

Notes:

- (1) Forged to ~180" long. Forger HT dimensions ~10 1/2" t × 10 1/2" w × 39" l.
Cut 12" segment from 39" length from mid (180") length for MDAC destruct test.
- (2) Stressed to 75% TYS.
- (3) Standard = specimens from 2219-T851 plate 6 1/8" t exposed simultaneously.
- * — Stress-strain curves available.

52 RECTANGULAR HAND FORGING
RT BRACKET

Mechanical Properties							Fracture Toughness			Stress C		
D Specimens							Compact Tension			Short Tran		
Transverse			Short Transverse				K _{1c} - ksi√in.			Tensile Bla		
YS	EL	RA	UTS	TYS	EL	RA	(S-L)	(T-S)	(L-S)	UTS	TYS	E
ksi	%	%	ksi	ksi	%	%				ksi	ksi	
.9	7.5	11.3	*59.1	43.8	6.0	8.6	25.89	26.04	(35.092)[1.149]	56.7	41.9	9
.5	5.0	7.8	61.1	46.7	7.5	12.4	-	-	-	56.9	42.7	9
.7	5.8	9.6	60.1	45.2	6.8	10.5				56.8	42.5	10
										56.8	42.4	9
										(3)		
										63.9	49.7	6
										62.5	49.3	
.9	8.5	13.5	65.5	49.8	6.5	5.1	31.64	29.10	(37.118)[1.126]	61.7	48.9	
.2	7.5	13.9	64.4	48.4	8.0	12.4	-	-	-	62.7	49.3	
.0	8.0	13.7	65.0	49.1	7.2	8.8						
.7	8.5	16.8	57.1	41.8	9.0	12.8	29.88	28.53	(36.225)[1.147]			
.0	8.5	14.6	59.8	44.3	10.0	16.1	-	-	-			
.8	8.5	15.7	57.4	43.0	9.5	14.4						
.4	8.5	17.0	59.2	43.9	9.0	16.8	28.00	27.33	32.82			
.4	9.0	18.5	60.5	45.5	9.0	18.9	-	-	-			
.9	8.8	17.8	59.8	44.7	9.0	17.8						
.8	7.5	11.3	63.5	48.7	7.5	12.7	26.97	26.66	(35.097)[1.016]			
.9	7.5	13.5	63.3	49.0	8.5	16.8	-	-	-			
.8	7.5	12.4	63.4	48.8	8.0	14.8						

Legend:
 () - K_Q values in parentheses
 [] - R_{sc} values in brackets
 1.5" wide specimens

× 39" l.
 struct test.
 usly.

Stress Corrosion — 3 1/2% NaCl Alt. Imm.

Short Transverse (ϕ t and w; 1/4" D x 1" GL)

Tensile Blanks			Unstressed		Stressed ⁽²⁾	
TYS	EL	RA	UTS	EL	UTS	EL
ksi	%	%	% Change in 30 Days			
41.9	9.0	15.4	-12.3	-84.2	-12.1	-73.7
42.7	9.5	14.5	-13.2	-78.9	-15.0	-78.9
42.5	10.0	17.4	-12.1	-78.9	-12.8	-78.9
42.4	9.5	15.7	-12.5	-81.0	-13.4	-76.8
49.7	6.5	9.4	-25.5	-91.2	-26.3	-82.4
49.3	5.5	8.6	-26.0	-91.2	-26.3	-100
48.9	5.0	6.4	-27.3	-100	-29.2	-100
49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7

TABLE 17. 2219-T852 RECTANGULAR HAND FORGING – SUMMARY
 COMBINED TESTS – ACTUATOR BRACKET – 14A30905

No. of Forgings	Test Loc.	HT t in.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL (%/4 D)	RA (%)	UTS ksi	TYS ksi	EL %/4 D	RA %
Forger Min. Gtd.		10 1/2	52	39	6	-	52	38	4	-	50	36	3	-
8* destruct W	⊥	~10 1/2	29 56.5-63.8	43.5-49.6	9.3-11.4	-	29 55.7-63.2	43.2-50.2	5.0-10.0	-	29 56.3-63.8	42.0-48.4	5.7-9.3	-
5 ↓ M	⊥	⊥	10 58.7-63.2	44.3-48.8	10.0-12.5	17.0-27.7	10 56.0-63.3	42.0-49.2	5.0-9.0	7.8-18.5	13 56.7-65.5	41.8-49.8	6.0-10.0	5.1-18.9
8* total	⊥	~10 1/2	39 56.5-63.81	43.5-49.6	9.3-12.5	10 17.0-27.7	39 55.7-63.3	42.0-50.2	5.0-10.0	10 7.8-18.5	42 56.3-65.5	41.8-49.8	5.7-10.0	13 5.1-18.9

W = Weber test, 0.357" D x 1.40" gage length tensile specimens

M = MDAC test, 1/2" D tensile spec. for properties, 1/4" D ST for stress corrosion

○ = No. of specimens tested; min. to max. values obtained

*8 mults representing 36 pcs 33" l

Forged dimensions – ~10 1/2" t x ~10 1/2" w x ~180" l

HT dimensions – ~10 1/2" t x ~10 1/2" w x ~33" l

TABLE 18. 2219-T852 CONTOUR AND RECTANGULAR HAND FORGINGS —
CONDENSED SUMMARY COMBINED TESTS

P/N	No. of Forgings	HT t In.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %
14A30400 Gtd.	4		62	50	6	-	61	49	4	-	60	46	3	-
↓ 55 ⁽¹⁾	~7	↓	⑪ 63.4-66.4	50.7-53.3	10.0-13.0	-	⑫ 62.4-69.0	49.0-54.8	4.5-10.0	4.4-9.8	⑬ 61.4-68.4	47.9-54.0	4.0-9.0	⑭ 6.0-10.5
↓ 1 ⁽²⁾	↓	↓	⑬ 63.5-63.7	49.9-50.3	9.5-10.0	⑮ 27.0-27.7	-	-	-	-	-	-	-	
14A20084 Gtd.	4 1/2-5 3/4		61	49	6	-	61	48	4	-	59	45	3	-
↓ 20 ⁽³⁾	~5 3/4	↓	⑯ 61.5-70.2	48.3-56.3	7.0-13.0	⑰ 16.9-29.5	⑱ 60.3-67.8	47.6-53.0	4.5-11.0	⑲ 6.7-13.2	⑳ 60.8-69.0	46.9-56.1	4.0-9.5	㉑ 4.0-11.0
↓ 1 ⁽²⁾	↓	↓	⑲ 59.4-59.7	45.0-45.4	8.0-8.5	㉒ 21.2-23.0	-	-	-	-	-	-	-	
14A30500 Gtd.	8		57	44	6	-	57	43	4	-	55	40	3	-
↓ 61 ⁽⁴⁾	~8	↓	-	-	-	-	㉓ 57.1-68.1	43.1-53.8	5.7-10.0	㉔ 9.0-15.3	㉕ 57.3-67.5	41.2-52.7	3.6-10.0	㉖ 9.3-21.5
↓ 1 ⁽⁵⁾	↓	↓	㉗ 59.1-65.7	44.8-51.0	9.0-13.0	㉘ 22.6-34.4	-	-	-	-	-	-	-	
14A30400 Gtd.	8 3/4		55	43	6	-	55	42	4	-	53	40	3	-
↓ 3 ⁽⁵⁾	~8 3/4	↓	㉙ 62.9-64.7	48.9-50.9	11.0-13.0	-	㉚ 63.9-64.5	49.1-50.0	7.5-10.0	-	㉛ 62.6-65.4	48.9-50.7	6.5-8.5	㉜ 7.4-13.1
14A30905 Gtd.	11 1/2		52	39	6	-	52	38	4	-	50	36	3	-
↓ 8 ⁽⁵⁾	~10 1/2	↓	㉝ 56.5-63.8	43.5-49.6	9.3-12.5	㉞ 17.0-27.7	㉟ 55.7-63.3	42.0-50.2	5.0-10.0	㊱ 7.8-18.5	㊲ 56.3-65.5	41.8-49.8	5.7-10.0	㊳ 5.1-18.9
14A30400 Gtd.	10 1/2-12 1/4		52	39	6	-	52	38	4	-	50	36	3	-
↓ 3 ⁽⁵⁾	~10 1/2	↓	㊴ 61.3-62.6	48.1-48.2	9.5-11.5	-	㊵ 61.6-62.9	47.4-48.1	7.5-9.0	-	㊶ 59.8-63.4	45.2-50.1	6.0-8.5	㊷ 8.7-13.6
↓ 3 ⁽⁵⁾	~12 1/4	↓	㊸ 59.1-60.6	45.7-47.1	11.0-12.0	-	㊹ 58.4-60.4	44.3-46.7	6.0-8.5	-	㊺ 58.2-61.6	46.0-49.2	7.5-9.0	-
↓ 1 ⁽²⁾	↓	↓	-	-	-	-	-	-	-	-	㊻ 58.6-59.8	45.2-45.8	5.5-7.5	㊼ 6.7-10.4

TABLE 18. (Concluded)

P/N	No. of Forgings	HT t in.	Longitudinal				Long Transverse				Short Transverse			
			UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %	UTS ksi	TYS ksi	EL %/4 D	RA %
14A20084	Gtd.	7 1/2-14	50	37	6	-	50	36	4	-	48	34	3	-
	3 ⁽⁵⁾	~7 1/2	9 60.1-66.0	46.5-50.6	10.5-11.5	-	9 59.8-66.6	45.5-50.8	5.0-9.0	-	9 57.8-66.2	44.6-51.0	6.0-9.0	-
	3 ⁽⁵⁾	~12	9 57.6-68.9	44.9-56.3	7.0-9.5	9 8.2-18.0	8 58.1-64.3	45.0-52.7	4.0-7.0	8 3.6-10.1	9 58.0-69.0	46.3-56.6	4.5-7.0	9 5.1-10.9
	1 ⁽²⁾		-	-	-	-	-	-	-	-	3 53.9-54.7	41.7-43.0	7.5-8.0	3 10.2-12.7
14A20084	Gtd.	14	50	37	6	-	50	36	3	-	48	34	3	-
	3 ⁽⁵⁾	~14	42 55.6-66.7	43.2-51.8	8.5-11.5	24 13.9-24.3	46 50.0-70.6	42.4-54.7	2.5-8.5	-	54 54.1-64.3	42.3-51.0	4.0-8.0	18 5.5-12.8
	1 ⁽²⁾		3 55.3-56.3	42.9-43.6	10.5-11.0	3 27.5-28.5	-	-	-	-	-	-	-	-
14A30400	Gtd.	14-17	46	33	6	-	46	32	4	-	44	30	3	-
	3 ⁽⁵⁾	~14	2 57.6-58.3	45.0-45.5	10.0-11.5	-	3 55.9-58.5	42.0-50.4	8.0-11.0	-	12 55.7-60.3	41.5-48.1	6.5-9.0	9 10.9-13.2
	3 ⁽⁵⁾	~15 3/4	12 55.9-58.6	43.5-46.6	9.5-13.0	9 22.3-26.2	12 55.6-58.6	41.9-45.8	5.0-9.0	9 7.4-10.9	12 54.7-60.1	41.5-48.6	7.0-9.0	9 10.9-13.9
	55 ⁽¹⁾	~16 1/4	17 55.5-61.3	43.2-48.2	9.5-13.5	6 21.9-26.4	62 54.1-68.4	41.4-53.5	4.5-9.0	7 4.7-10.6	71 53.8-66.0	41.3-54.1	5.0-9.5	16 9.4-14.7
	1 ⁽²⁾		-	-	-	-	3 55.8-57.8	42.6-45.3	5.5-7.5	3 7.8-15.0	-	-	-	-

(1) 3 destruct +52 forgings prolongation tests

*8 mults representing 36 pieces

(2) 1 destruct forging from MDAC aged 1/4 skirt

(3) 3 destruct +17 forgings prolongation tests

(4) 1 destruct +60 forgings

(5) Destruct forgings

○ = No. of tensile specimens tested; min. to max. values obtained

TABLE 19. LARGE HAND FORGINGS — 2219-T852
 PROPOSED MINIMUM GUARANTEED MECHANICAL PROPERTIES

	Forging & HT Thickness in.	Longitudinal (L)			Long Transverse (LT)			Short Transverse (ST)		
		UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1974-5	Up thru 4.0	62	50	6	62	49	4	60	46	3
↓	4-1/2	61	49	6	61	48	4	59	45	3
↓	8	57	44	6	57	43	4	55	40	3
1977	8-3/4	56	43	6	56	42	4	54	40	3
↓	11	54	42	6	54	41	4	53	39	3
↓	14	52	40	6	52	40	4	51	39	3
↓	17	50	39	6	50	40	4	50	38	3

REFERENCE

Davis, R. J.: Mechanical Properties of SRB Rolled-Ring Forgings and Large Hand Forgings. MDC G6791, May 1977. McDonnell Douglas Astronautics Company — West, Huntington Beach, California.



APPENDIX A

MSFC PROCUREMENT SPECIFICATION FOR P/N 14A20084

3/17/75

MSFC PROCUREMENT SPECIFICATION
FOR FORGING 14A20084

The forging drawing generated from this criteria must depict a forging of sufficient size to manufacture the detail part no. 14A20083 plus provision for taking test samples on deliverable items. A concept of such a forging is shown on an attached sketch.

1. Material: 2219-T352 Al alloy forging per QQ-A-367H.
2. Metal stamp identification number per AMS 2808A.
3. Ultrasonic inspect per MIL-I-8950B Class A, where thickness is 6 inches or less and Class B where thickness is greater than 6 inches.
4. Heat treat, quench, and stress relieve by compression, the entire forging to -T352 temper per MIL-H-6088E.
5. For forging serial no.'s 1, 5, and 12: Age to -T852 temper per MIL-H-6088E ($350^{\circ}\text{F} \pm 10^{\circ}\text{F}$ for 18 hours) and destructively test. Test specimens shall be taken in locations shown on the attached sketch. Provide results of macroscopic examination and tensile tests to procuring agency within 10 days of tests.
 - a. Document grain flow pattern and note grain size on 1/4 inch (min.) slices at the six locations shown on sketch.
 - b. Test all tension specimens per Fed. Std. 151. Test specimens shall be types R1 & R3. Preferred specimen size is in the order stated.
 - c. Provide the five segments noted on sketch to procuring agency at the same time test results are provided. Each segment shall be clearly identified by part number, location on part, serial number, and lot number. Ship to: MSFC, Huntsville, AL, CPB21, Attn: M. W. Brennecke

6. The minimum required individual mechanical properties for this forging in each of the two indicated thicknesses (-T852) are:

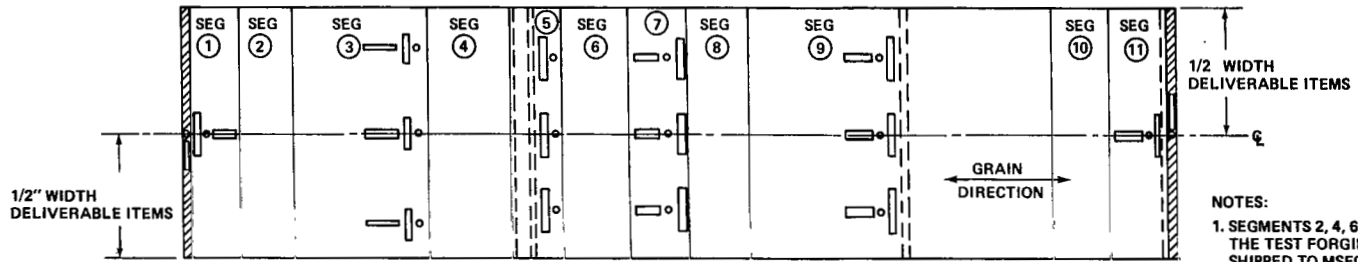
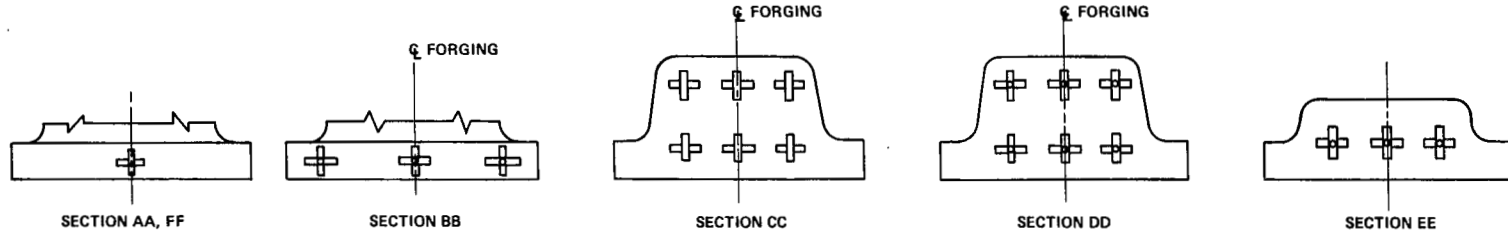
Thickness	<u>I</u>		<u>II</u>		Elongation all thicknesses 2"/4D
	FTU KSI	FTY KSI	FTU KSI	FTY KSI	
Longitudinal	61	49	50	37	6
Long Trans.	61	48	50	36	4
Short Trans.	59	45	48	34	3

7. Deliverable Forgings

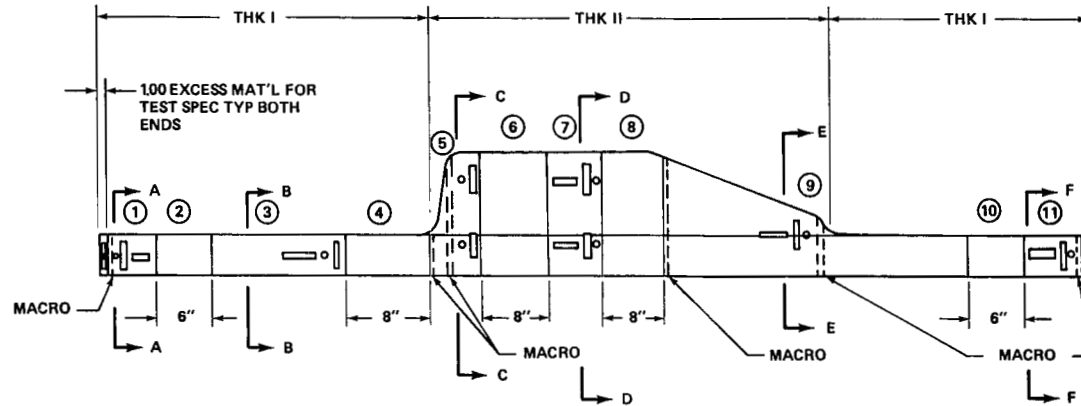
- a. Establish properties on a single forging from each forging lot* using the designated 1/2 width test pieces cut from each end of the -T352 forging, aged to -T852 and sectioned for designated specimens in locations shown on attached sketch. Leave the remaining 1/2 width test piece intact as an integral part of the -T352 forging.
- b. Document grain flow pattern and note grain size on above 1/2 width slices and report data to the procuring agency.
- c. Determine tensile properties in long transverse and short transverse directions and report to procuring agency. Specimens and test per note 5 (b).
- d. The remaining forgings from each lot will be delivered with the designated end strips as an integral part of each forging.

8. Each individual forging shall be serialized for record traceability.

* A lot shall consist of not more than 6,000 pounds of forging heat treated as one furnace charge.



- NOTES:
1. SEGMENTS 2, 4, 6, 8, AND 10 OF THE TEST FORGINGS ARE TO BE SHIPPED TO MSFC IN THE T852 TEMPER.
 2. LAYOUT OF TEST SPECIMEN LOCATIONS SHOWN ON THIS FORGING CONCEPT SKETCH IS SUBJECT TO REVIEW FOR PRECISE LOCATION OF SPECIMENS BASED ON THE FORGING DRAWING GENERATED BY THE FORGER.



CONCEPT FORGING SKETCH 14A20084

APPENDIX B

ALCOA FORGING CERTIFICATION FOR P/N 14A20084

CERTIFIED INSPECTION REPORT AND TEST RESULTS - **WROUGHT PRODUCTS**

ALUMINUM COMPANY OF AMERICA

SHIPPED FROM
CLEVELAND, OHIO

PITTSBURGH PA.

CODE NUMBER 042-916808 ALCOA NUMBER ATB 41220 X

FINANCIAL MANAGEMENT OFFICE
GEO. C MARSHALL SPACE FLIGHT CTR NASA
MARSHALL SPACE FLIGHT CENTER
ALABAMA 35812

INVOICE NO.
21710839

INVOICE DATE
12/05/75

GROSS WEIGHT
7116

B/L NO.
10840

DATE SHIPPED
12/05/75

OT 80-100-21

MCDONNELL DOUGLAS ASTRONAUTICS CO.
7391 HEIL AVE. HUNTINGTON BEACH, CA.
ATTN J.B. HEISER 92647 04-059
MARK FOR M/F A03-155B-GFM CONTRACT
HAS 8-31614 OCN 2-5-06-54901-01

VIA

MID-WEST GROWERS CO-OP

F.O.B. DESTINATION

CUSTOMER P.O. NO. NAS8-31608
GOVT. CONTRACT NO.

AUTHORIZED SIGNATURE(S)

T. P. Bennett

Quality Assurance Manager

ALCOA products as follows

HAND FORGINGS FED SPEC
QQA-367H, MIL-H-6088E, MIL-I-8950B
CLASS A IN AREAS LESS 6 IN. THICK,
CLASS B AREAS OVER 6 IN. TK AMS2808A

ALCOA NUMBER ATB 41220 X ALLOY AND TEMPER 2219-T352

ITEM NO.	ITEM DESCRIPTION	ACCT. CODE	QUANTITY SHIPPED	
			PCS., FT., ETC.	POUNDS
001	FORWARD SKIRT ACOA DWG 750415NB NASA SPEC 14A20084 NASA DWG 14A 20083-1	4633	2	6976
TOTAL FOR INVOICE				6976
A	FOLLOWING MIN. PROPERTIES TO APPLY			
	AREA I		AREA II	
	TS	YS	EL	TS
	61	49	6	50
	LONG TRANS	61	48	4
	SHORT TRANS	59	45	3
	PROPS FOR FORGINHS AGED TO T852 TEMPER		34	3
	DEST TEST S/N S 1,5712 PER CUST B/P			
ITEM NO.	TOTAL SHIPPED TO DATE	PART. OR	PACKAGES	LOT NUMBERS
001	PCS., FT., ETC. 2 6976	COMPLETE C	2 PALLETS	LOT S/N 5059510 - 10 5059509 - 9

*P = PARTIAL, C = COMPLETE, PP = PRIOR PARTIAL, O = NO SHIPMENTS, L = OVERSHIPMENT

TEST RESULT DATA

ALCOA CLEVELAND WORKS
 TOOL 701176
 PACK-NO 609070 609134
 INVOICE 21710839 ORDER ATH41220A 001

2 PIECES 6976 POUNDS

SEF REF NOTE	LOT NUMBER	SERIAL NUMBERS	TENSI STRTN KSI	YIELD SRTN KSI	FLONG PCT IN.	HHN
	5050519	9				
10	1-LT		66.4	52.3	11.5	124
10	1-LT		64.7	51.5	8.5	130
10	1-ST		64.6	51.2	9.5	124
10	// -LT		66.4	56.3	12.0	124
10	// -LT		65.7	50.3	9.0	130
10	// -ST		65.8	51.8	8.0	124
	5050510	10				
10	1-LT		67.2	52.5	7.0	124
10	1-LT		67.2	52.2	7.0	130
10	// -LT		66.7	52.7	7.0	124
10	// -ST		66.3	52.0	7.0	130

ALLOY	2219		CHEMICAL COMPOSITION							
MAX	CU	FE	SI	MN	MG	ZN	TI	ZR	V	OTHER
MTN	6.4	.30	.20	.40	.02	.10	.10	.25	.15	EACH .05
	6.4	.0	.0	.20	.0	.0	.02	.10	.05	TOTL .15

20 CUT FROM A FORGING OR PROLONGATION FROM THE INDICATED LOT AND FURTHER PROCESSED FROM THE ORDERED TEMPER TO THE T852 TEMPER.



APPENDIX C

MICROSTRUCTURE OF CORRODED SPECIMENS

APPENDIX C - MICROSTRUCTURE OF CORRODED SPECIMENS

Selected corroded specimens from samples of each of the forgings reported in Tables 4, 9, 13 and 16 were examined metallographically to determine grain structures and type and depth of attack. The identification of these specimens is shown in Table 1 and representative microstructures are presented in Figures 1-4.

There is a greater difference between the relative grain structure of the 10-1/2" thick rectangular forging (Figure 1a) having a 110 sq. in. cross sectional area vs. a contour forging at the same thickness (Figure 1b) but having about double the cross section area, 236 sq. in., than between the two rectangular forgings having different thicknesses of 10-1/2" (Figure 1a) and 8" (Figure 2b) and cross sectional areas of 110 and 88 sq. in., respectively.

Likewise there is greater difference between the relative grain structure of the 6-1/8" thick rolled plate (Figure 3a) vs. a contour forging at 5-3/4" thickness (Figure 3b) having a corresponding cross sectional area of approximately 170 sq. in. than between the structures of this contour forging at 5-3/4" t vs. another at 8-3/4" thickness (Figure 4a) having a corresponding cross sectional area of approximately 196 sq. in.

These observations clearly demonstrate that not only thickness but also total cross sectional area are important factors relating to forging parameters, heating and quenching rates that strongly influence resultant structure and properties in 2219-T852 forgings.

Regardless of thickness and cross sectional area, with their associated interdependent processing variations, all specimens examined showed only pitting type of attack with no evidence of intergranular attack even at 400X magnification as illustrated in Figures 2, 3 and 4 for 2219-T852 large hand forgings up to 15-3/4" thick and 413 sq. in. cross sectional area heat treated and aged by the forger.

APPENDIX C

TABLE I

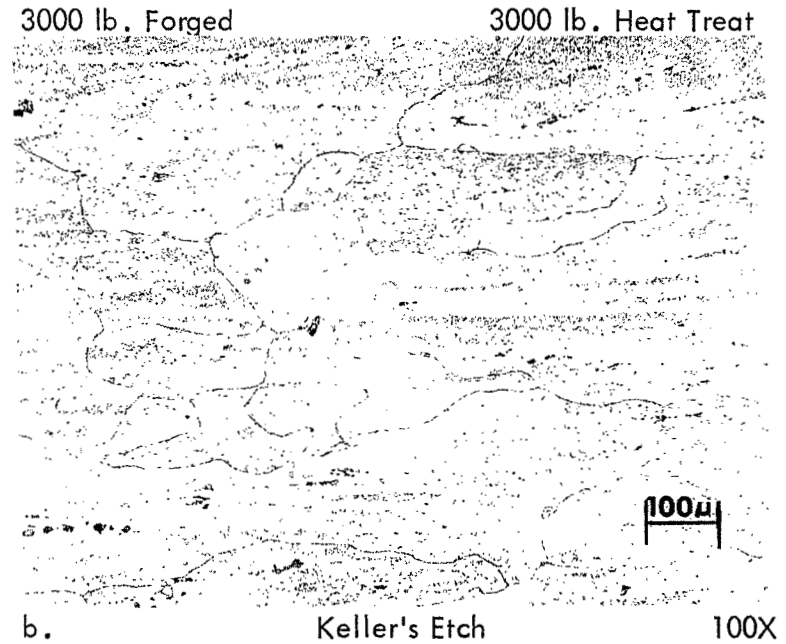
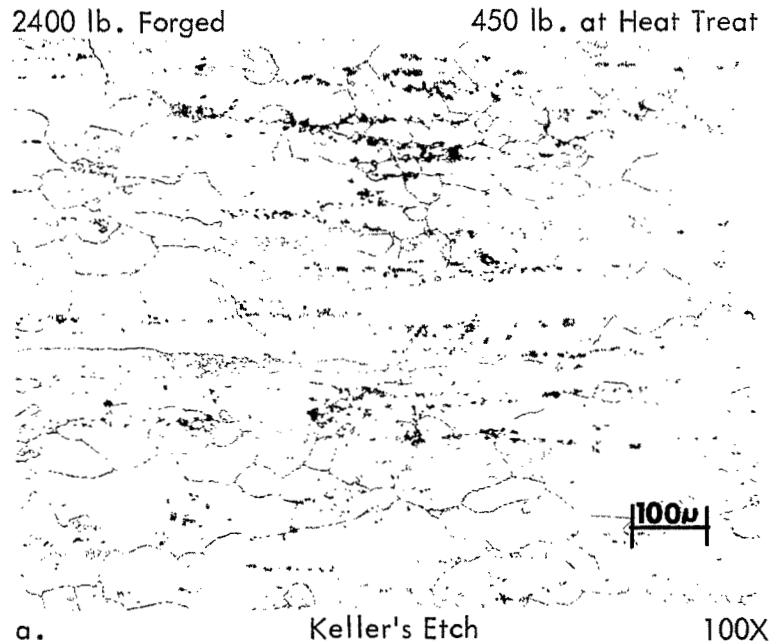
IDENTIFICATION OF STRESS CORROSION SPECIMENS FROM LARGE HAND FORGINGS

SRB Location of Forging	Part No.	HT wt/lbs	Forging				Spec. No.	Stress ksi †	Forger Type Prod.	Plate Thick	Spec. No.	Stress ksi †	Fabricator
			S/N	Seg.	Thick	Area/in ²							
2219-T852 Al Hand Forgings - Contour & Rectangular										2219-T851 Al Reference Plate			
Fwd Skirt Thrust Post	14A20084	3500	1	2	5-3/4"	170	507* 508	37.8 b.	Alcoa, Contour	6-1/8"	R8 R13*	37.0 b. a.	Alcoa
				8	14"	413	516	33.0					
Aft Skirt	14A30500	1100	1	6	8"	88	589	33.1 c.	Weber, Rectangular	† 75% of TYS of Adjacent Blanks For % loss in strength after exposure: a. See Table 4, p42 & 43 b. See Table 9, p54 & 55 c. See Table 13, p65 d. See Table 16, p70 * Failed in handling during removal from fixture.			
Actuator Bracket	14A30905	450	8	4	10-1/2"	110	598	31.8 d.					
Hold Down Post	14A30400	3000	1	4	8-3/4"	196	544	36.7 a.	Alcoa, Contour				
				6	10-1/2"	236	552	34.2					
				8	12-1/4"	276	{560 563	— 33.5					
				10	14"	315	571	32.7					
				12	15-3/4"	354	581	32.3					

All Specimens are 1/4"D ST direction from ζ t & w

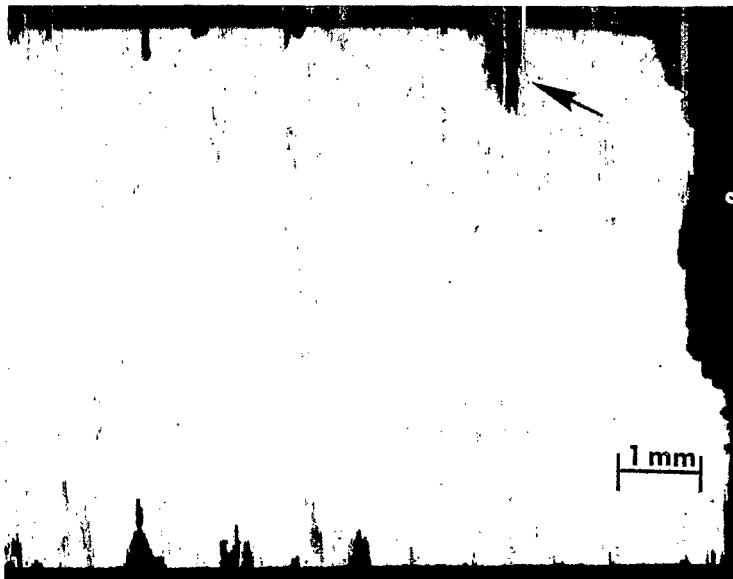
ACTUATOR BRACKET P/N 14A30905 S/N B
 Seg 4, 10-1/2"t x 10-1/2"w x 180"l -- #598
 Rectangular Forging 2219-T852

HOLD DOWN POST P/N 14A30400 S/N 1
 Seg 6, 10-1/2"t x 22-1/2"w x 100"l -- #552
 Contour Forging 2219-T852

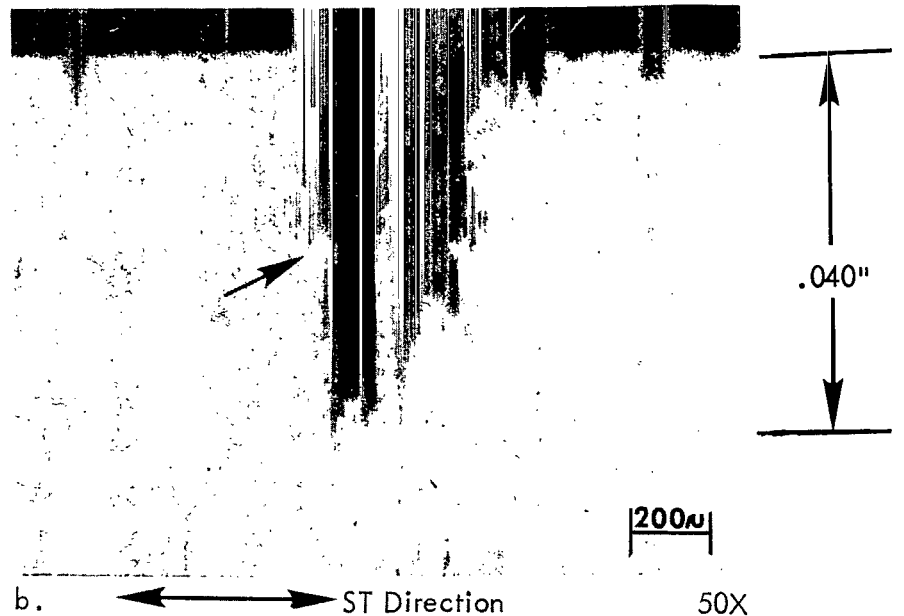


Note that the difference in grain structure at the C t and w of the two different products reflect the greater amount of work inherent with the smaller cross section of the rectangular forging vs. the more massive contour forging.

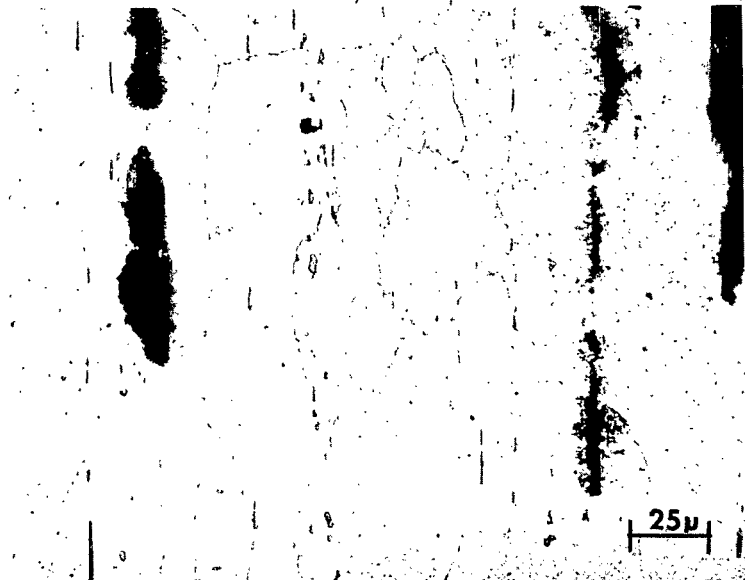
FIGURE 1 - Microstructure of 2219-T852 Rectangular vs. Contour Forging at 10-1/2" Thickness



a. Full Cross Section of 1/4"D Specimen 10X



b. ST Direction 50X



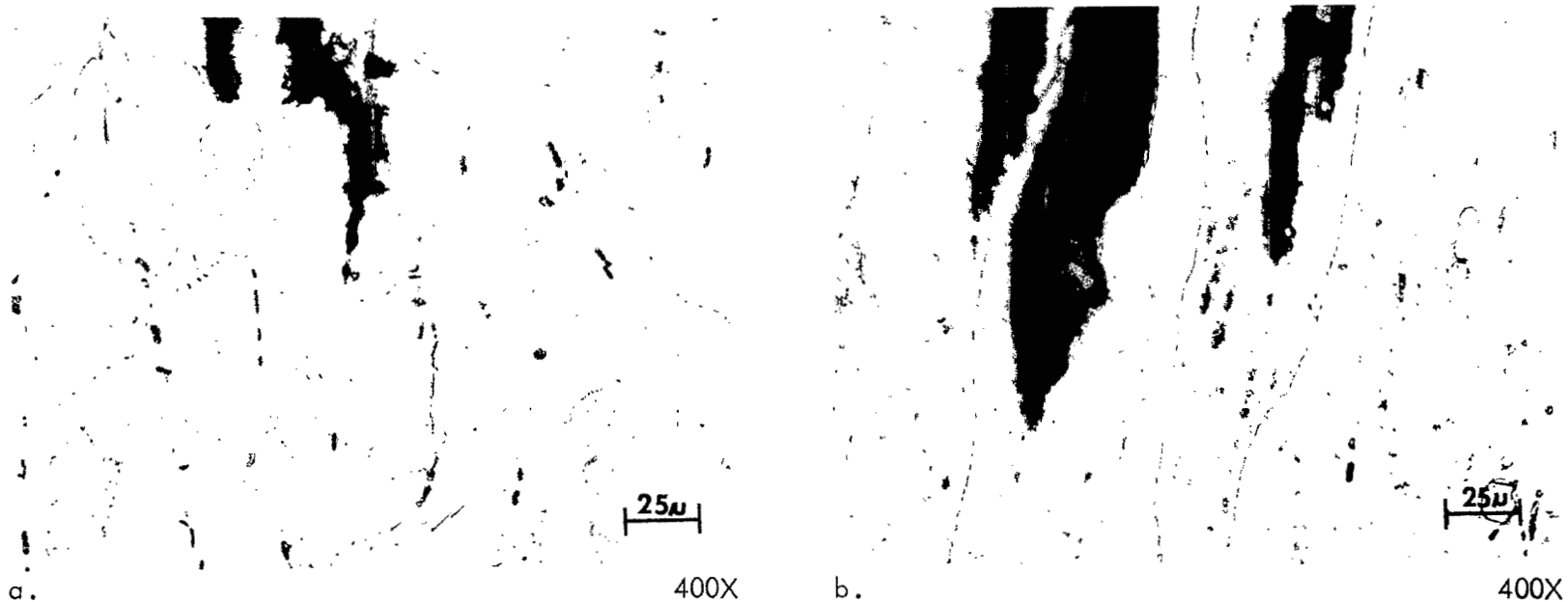
c. Bottom End of Typical Surface Pit 400X

Rectangular Hand Forging P/N 14A30500 S/N 1
 8"t x 11"w x 110"l, Seg. 6 -- #589, 33.1 ksi Stress
 1100 lb. Forged and Heat Treated 2219-T852
 Longitudinal Cross Section of Short Transverse (ST)
 Stress Corrosion tensile specimen after exposure to
 3.5% NaCl solution by alternate immersion for
 30 days stressed to 75% of the TYS (σ_t & w).
 Note only pitting type of attack with no evidence of
 intergranular attack - Keller's etch
 (cf Table 13, p65 for % loss in strength)

FIGURE 2 - Microstructure and Corrosion Attack of 2219-T852 Rectangular Forging

ROLLED PLATE
 6-1/8" t -- #R8, 37.0 ksi Stress
 Reference Material 2219-T851

THRUST POST P/N 14A20084 S/N 1
 Seg 2, 5-3/4" t x 29-1/2" w x 115" l -- #508, 37.8 ksi Stress
 Contour Forging 2219-T852



Longitudinal cross sections of short transverse (ST) stress corrosion tensile specimens after exposure to 3.5% NaCl solution by alternate immersion for 30 days stressed to 75% of the TYS (ζ t & w).

Note differences in grain structure between the rolled and the forged product in a similar thickness area.

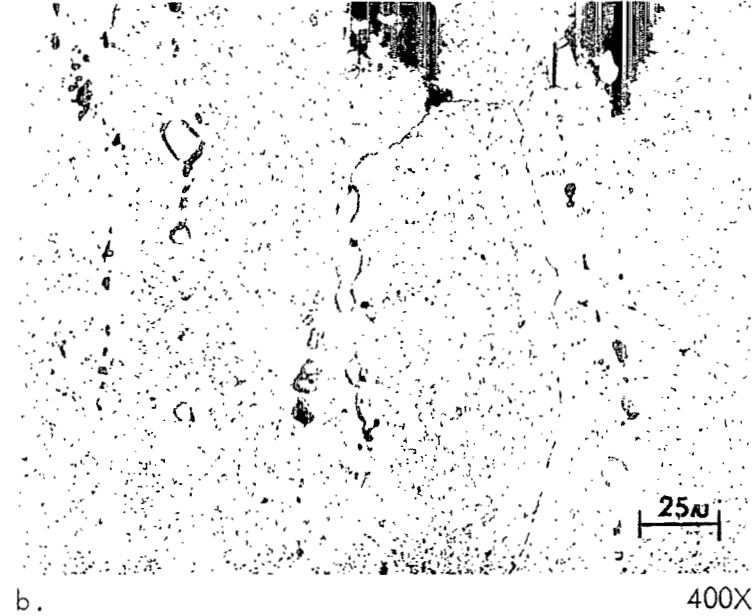
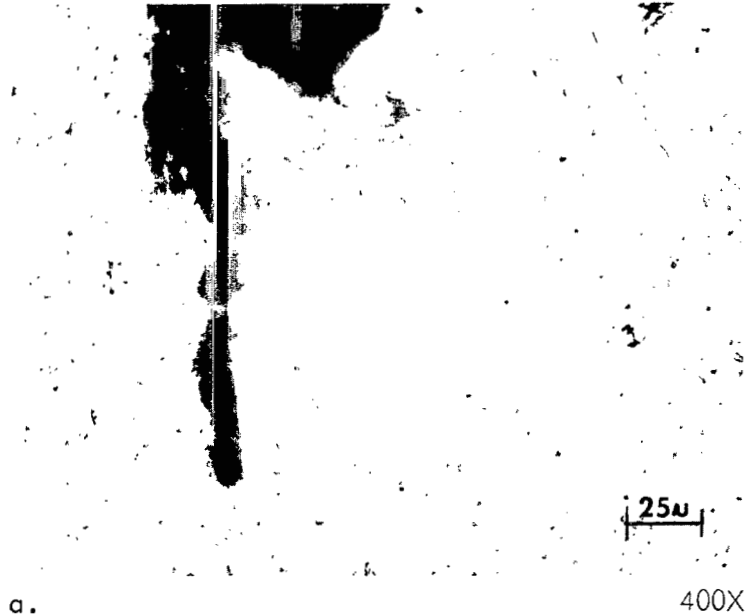
Only pitting type of attack was observed with no evidence of intergranular attack on either product (Keller's etch).

FIGURE 3 - Microstructure and Corrosion Attack of 2219-T851 Rolled Plate vs. -T852 Contour Forging at ~6" Thickness

HOLD DOWN POST P/N 14A30400 S/N 1
7-16-1/4"t x 22-1/2"w x 100"l
Contour Forging 2219-T852

Seg 4, 8-3/4" t (196 sq. in.) -- #544, 36.7 ksi Stress

Seg 12, 15-3/4" t (354 sq. in.) -- #581, 32.3 ksi Stress



Note difference in grain structure for this hold down post at 2 different thickness locations,
a. 8-3/4" t near the forward position of the post and b. 15-3/4" t near the aft portion of the 100" length.
Only pitting type of attack was observed with no evidence of intergranular attack even in the most massive area having the least working and the slowest quench (Keller's etch) — Same exposure as Fig. 2 & 3.

FIGURE 4 - Microstructure and Corrosion Attack of 2219-T852 Contour Forging at 8-3/4 and 15-3/4" Thickness

1. REPORT NO. NASA TP-1383		2. GOVERNMENT ACCESSION NO.		3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Characterization of Large 2219 Aluminum Alloy Hand Forgings for the Space Shuttle Solid Rocket Booster				5. REPORT DATE December 1978	
				6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) M. W. Brennecke				8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812				10. WORK UNIT NO. M-273	
				11. CONTRACT OR GRANT NO.	
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546				13. TYPE OF REPORT & PERIOD COVERED Technical Paper	
				14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES Prepared by Materials and Processes Laboratory, Science and Engineering					
16. ABSTRACT <p>This report presents the mechanical properties, including fracture toughness, and stress corrosion properties of four types of 2219-T852 aluminum alloy hand forgings. Weight of the forgings varied between 450 and 3500 lb at the time of heat treatment and dimensions exceeded the maximum covered in existing specifications. Dimensions ranged from approximately 5-3/4 to approximately 16-1/4" thick, 10-1/2 to 29-1/2" wide and 33 to 115-1/2" long at heat treatment. The forgings were destructively tested to develop reliable mechanical property data to replace estimates employed in the design of the Space Shuttle Solid Rocket Booster (SRB) and to establish minimum guaranteed properties for structural refinement and for entry into specification revisions. The report summarizes data required from the forgings and from the SRB Structures contractor. Specific technical requirements for testing were defined; testing was coordinated; and results were organized, analyzed and evaluated by the Materials and Processes Laboratory of the George C. Marshall Space Flight Center.</p>					
17. KEY WORDS Al alloy 2219-T-352, -852 Large hand forgings Rectangular forgings Contour forgings Macrostructure			18. DISTRIBUTION STATEMENT STAR Category: 26		
19. SECURITY CLASSIF. (of this report) Unclassified		20. SECURITY CLASSIF. (of this page) Unclassified		21. NO. OF PAGES 92	22. PRICE \$6.00

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