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A STUDY OF THE COMPARATIVE STRENGTH OF 354 TYPE ALUMINUM-SILICON-COPPER-MAGNESIUM CASTING ALLOY

RESEARCH & DEVELOPMENT REPORT SM-44636

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA, CALIFORNIA

DOUGLAS

(14) REPORT NO. SM-44636

(6) A STUDY OF THE COMPARATIVE STRENGTH OF 354 TYPE ALUMINUM - SILICON - COPPER - MAGNESIUM CASTING ALLOY,

~~1-29-64~~

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DOUGLAS

Prepared under the Sponsorship of
The Douglas Aircraft Company
Independent Research and Development
Program. Account No. 80305-300

Approved by G. V. Bennett

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Catalog No. PDL 36083

ABSTRACT

Previous work with 354-T61, an aluminum-silicon-copper-magnesium casting alloy, had demonstrated a mechanical property advantage over the 356 variant-T6 aluminum alloy currently used in Douglas production. This advantage was confirmed. Optimumly heat treated, 354-T6 aluminum alloy showed a five to ten percent advantage in iron chill-cast ultimate and yield strength and a 20 to 35 percent advantage in part strength.

The part strength levels achieved were comparable to the identical "Tee" - shaped configuration machined from wrought 1.5 inch thick 7075-T6 aluminum alloy plate and considerably in excess of values obtained with 2014-T6.

I INTRODUCTION

Since the description, in 1956 by Lemon and Hunsicker[1], of A356 as a commercially available aluminum casting alloy there has been, in the aerospace industry, a growing trend toward the use of high strength, light metal alloy castings. The majority of these castings have usually been poured in various combinations of a "high purity" aluminum-silicon-magnesium silicide system which may or may not contain a small beryllium addition. While the production use of this class of alloys (0.2 to 0.8 weight percent magnesium and 6.5 to 10.0 weight percent silicon) has grown progressively common for casting designs requiring maximum mechanical properties, the strength levels produced in 1958[2] have not since been significantly improved by foundry experience.

This observation, made initially at a production level, has been confirmed experimentally. In an investigation now being prepared for publication[3][4], it has been demonstrated that variation in thermal treatment and minor chemical changes within the above stated compositional limits, apparently can not increase either part strength or tensile strength beyond the optimum values previously reported.[5]. From this work it has been concluded, that while refinement of casting techniques can usually increase soundness and the structural strength of any given functional configuration, the aluminum-silicon-magnesium alloy, as currently used, has been developed to almost the full extent of its practical strength capability. Future significant increases in the mechanical properties of aluminum castings must be achieved using other alloying components.

1 INTRODUCTION (Cont'd.)

Previous work with 354-T61 aluminum alloy (aluminum-silicon-copper-magnesium, formerly M517) has evidenced some potential in this direction[6]. This study, of similarly rigged, ring-type castings, demonstrated two strength advantages for 354 over the 356 variant aluminum alloy currently used in Douglas production. First, 354 showed markedly higher mechanical properties than did the 356 variant, whose compositional range appears in Table I. Second, the integral test bars fixed to the 354-T61 aluminum alloy castings appeared to reflect more accurately the actual strength of the matrix of the casting than did the production control integral bars of the 356 variant-T6 castings. These limited results, as well as data reported elsewhere[7], while promising, required confirmation of the mechanical properties obtainable with the new alloy. Also needed was direct comparative information on relative part strength, where a given configuration, optimumly cast and heat treated in both 354 and the 356 variant aluminum alloys, is static tested to failure in its entirety under simulated functional load. The present report describes an attempt to supply such information.

2 EXPERIMENTAL PROCEDURE AND RESULTS

2.1 Test Configuration

The configuration chosen for this study was the "Tee" bar casting, diagramed in Figure 1. The part is one of two test configurations currently used by Douglas in foundry and light metal alloy investigations. While the casting is uncored, and suggests little necessity to vary gating and chilling techniques, it does permit a simple, inexpensive and direct strength evaluation of a standard configuration in its entirety. This test casting, which is reasonably reproducible dimensionally, is poured and heat treated as an "H".

2.1 Test Configuration (Cont'd.)

The "H" is then bisected across the center arm into two identical "Tee" - shaped pieces. Each of these "Tee's" is individually fixed in a standard jig and bend loaded to failure with a tensile testing machine. The load, simulating a typical design stress, is applied to the cantilever in the position shown in Figure 2. The specific numerical value obtained, pounds load to part failure, can be correlated with the mechanical property results derived from coupons subsequently excised from that specific, broken test part.

2.2 Casting Production

Two series of ten "H" castings were produced. Each individual series was poured from a single melt of 354 aluminum alloy. Using iron chills, one series of castings was cooled from the molten state at a relatively rapid rate. As shown in Figure 1, these parts were essentially permanent mold cast. The other series was sand cast, cooling at a considerably slower rate. Each individual "H" thus produced, by either technique, represented two interconnected, similarly gated "Tee" bar test parts.

Three "H" castings of each series, three sand cast and three chill cast, were heat treated together by the producing foundry to the following schedule - solution heat treat 11 hours at 980°F (527°C) and one hour at 990°F (532°C), rapidly quench into 150°F (66°C) water, room temperature age 24 hours, artificial age six hours at 340°F (171°C) and air cool.

The remainder of the test parts, seven chill cast "H"'s and seven sand cast "H"'s, were submitted for thermal treatment and subsequent strength evaluation to Douglas in the "F" or as-cast temper.

2.3 Douglas Heat Treatment

The seven as-cast permanent mold "H"'s and the seven as-cast, sand cast "H"'s were bisected into 28 "Tee"-shaped test parts. These were divided into two groups, "A" and "B", one "Tee"-shaped half of each "H" in each group. Group A castings were simultaneously solution heat treated for 11 hours at 980 ±5°F (527°C) and were immediately quenched into 120°F (49°C) water. Group B castings were solution heat treated for 12 hours at 1000 ±5°F (538°C) and were also immediately quenched into 120°F (49°C) water. Approximately a three second time delay existed between the opening of the furnace door and the entrance of the castings into the water. A twenty four hour age interval was scheduled between the quench and the subsequent artificial aging of all castings.

The "Tee" bar castings of both solution heat treat groups were aged together for various times at 350 ± 5°F (177°C). Castings were fixed in the aging load so that after each of seven time intervals (1,2,3,4,5,7 and 14 hours) a permanent mold and a sand cast representative of each solution heat treat group could be simultaneously removed. With this technique the furnace door could be quickly closed and no appreciable heat loss occurred. The castings were then air cooled.

2.4 Inspection

The chemical compositions of the castings were determined spectrographically using well established standards. These results, as well as the compositional limits imposed by specification, appear in Table I.

X-ray examination demonstrated that all permanent mold cast parts were of comparable quality and were essentially free of radiographically visible discontinuities. Each of the sand cast parts showed round gas porosity

2.4 Inspection (Cont'd.)

approximately equal to 1.21 #2 of ASTM Radiographs E155-60T. All parts were also judged sound on fluorescent penetrant inspection.

2.5 Testing

As described previously, each variously heat treated "Tee" bar was bend-loaded to failure as shown in Figure 2. The cantilever fractured cleanly at the juncture of the two arms. The results of these part strength tests for permanent mold cast "Tee"'s are tabulated in Table II and for sand cast "Tee"'s in Table III. These data are also graphically represented in Figure 3, where comparative part strength for 354 aluminum alloy is plotted as a function of aging time at 350°F, (177°C).

Two standard, cylindrical, subsize, tensile test coupons, 0.25 inches in diameter, one inch gage length, were taken from each previously broken "Tee", one coupon machined from the 1 x 1 x 4 inch post section and one coupon machined from the edge of the 1.5 inch wide, 0.5 inch thick arm. The center of the gage length of this latter coupon, as shown in Figure 2, was then two inches from the point of fracture of the original "Tee". These coupons were tested in tension at a loading rate of 1200 pounds per minute on a Baldwin-Southwark Tate-Emery testing machine, 5000 pounds capacity. The tensile results for these coupons are reported in Table II for coupons cut from permanent mold cast "Tee"'s and in Table III for sand cast "Tee"'s. These data are also graphically shown in Figure 4 for chill cast material and in Figure 5 for sand cast material where tensile strength for 354-T6 aluminum alloy is plotted as a function of aging time at 350°F (177°C). Yield strengths were measured at 0.2 percent offset. Elongations were measured by "fit-back" in a one inch gage length. The mechanical pro-

2.5 Testing (Cont'd.)

perties reported for a given sand cast or chill cast "Tee", representing a given solution heat treatment and aging time, are given as the average of the two tensile coupons taken from it.

Also machined from all 354-T6 aluminum alloy castings, in the locations shown in Figure 2, were two 1/4 x 3/8 x 4 inch bending modulus specimens. These were tested in three point loading as has been previously described in the literature.[6] The results of these tests appear in Table II for the variously heat treated permanent mold castings and in Table III for the sand cast "Tee" bars.

2.6 Additional Data

Plotted in Figure 3 are similar part strength data for the 356 variant aluminum alloy currently used in Douglas production. These results are shown for both a series of "Tee" bars cast using the iron chills supplied with the pattern equipment and another series cast using aluminum chills. Tensile data for this 356 variant-T6 aluminum alloy appear in Figure 4 and 5 and in Table IV.

For comparison with the results obtained using 354-T6 aluminum alloy, typical "Tee" bar part strengths of other light metal alloys are shown in Figure 6. The tensile results obtained from these parts are tabulated in Table V. The static test results for the "Tee" bars heat treated to the T-6 condition by the producing foundry are plotted as individual points in Figure 3. Also appearing in Figure 3 are several individual test results for the "Tee" configuration machined from wrought 7075-T6 and 2014-T6 aluminum alloy 1.5 inch thick plate in both the transverse and longitudinal directions.

3 DISCUSSION

As can be seen in Figures 3 to 5 and in Tables II and IV, both sand cast and chill cast 354-T6 aluminum alloy consistently produced higher strength levels than does the 356 variant-T6 aluminum alloy currently used at Douglas and elsewhere. This was especially true in regard to chill cast part strength.

The aluminum chilled 356 variant-T6 "Tee" bar properties, reported in Figure 3 and in Table IV for comparison, represent the highest strength levels ever obtained for this configuration cast in the aluminum-silicon-magnesium system. The values were selected from a considerable history of the comparative testing of "Tee" bars obtained from many sources, in many compositional variations of the 356 family and in many heat treat combinations. Compared to these maximum data, the 354-T6 aluminum alloy castings, poured using iron chills and subsequently solution heat treated by Douglas for 12 hours at 1000°F (538°C), show an advantage in part strength of approximately 25 percent. Compared to the 356 variant-T6 aluminum alloy cast using the slower heat conduction iron chills, the part strength advantage for 354-T6 increased to approximately 35 percent. Advantage for 354 in ultimate and yield strength, obtained from coupons excised from the chill cast material, was less pronounced but still averaged approximately five to ten percent. This advantage in yield strength, determined at 0.2 percent offset, was more pronounced at aging times in excess of six hours. At aging times less than six hours, elongation, as measured by "fit back" within a one inch gage length, was somewhat lower for 354 than for the 356 variant. This apparently does not obtain at aging times beyond six hours when the ductility of the two alloys, at least in chill cast material, appeared to be equivalent.

Sand cast 354-T6 aluminum alloy also showed an advantage over sand cast 356

3 DISCUSSION (cont'd.)

variant-T6 aluminum alloy in part strength (Figure 3) and in tensile ultimate and in tensile yield (Figure 5). Only in elongation did the 356 variant appear superior.

It is interesting to note that in chill cast 354-T6 aluminum alloy, with increase in aging time, the progressive decrease in elongation from eight percent at one hour age at 350°F (177°C) to four percent at a fourteen hour age does not effect the corresponding increase in part strength. Apparently four percent elongation is adequate ductility to allow the "Tee" bar configuration under overload to deform sufficiently to redistribute bending stress before fracture. This observation does not hold with the more slowly cooled sand cast "Tee" bars containing relatively larger dendrite cell sizes. Here, as aging times increase from one to fourteen hours, ductility progressively decreases from approximately four percent elongation to less than one percent. While tensile ultimate and tensile yield vary directly with increase in artifical aging time up to fourteen hours, part strength decreases with aging times beyond six hours at 350°F (177°C). Expressed differently, the degradation of part strength appeared to occur when elongation had decreased to approximately one percent. Tentatively, ignoring the slight heterogeneity caused by gas porosity, at this point ductility is, perhaps, inadequate to redistribute the bending stress. It would follow then, that a six hour age at 350°F (177°C) could be safely selected for almost any configuration, provided that the cooling rate of the molten metal in critical areas of the hypothetical configuration is at least as rapid as the cooling rate at the intersection of the sand cast "Tee".

The 354-T6 aluminum alloy sand cast and chill cast part strength advantage

3 **DISCUSSION** (Cont'd.)

shown by the Douglas heat treated "Tee" bars over "Tee" bars heated to an identical schedule by the producing foundry and the slight additional advantage shown for the 1000°F (538°C) solution treatment over a 980°F (527°C) solution temperature can be explained on essentially the same basis. The increased solution temperature, a more rapid water quench used in the Douglas heat treatment, as well as a 10°F (5.5°C) increase in aging temperature, apparently combined to produce a more optimum solid solution dispersion of finely divided magnesium silicide and copper-aluminum. As can be seen from the mechanical property data presented in Table V and the part strength data summarized in Figure 6, 354-T6 aluminum alloy, properly cast and heat treated, produced strength levels in excess of those produced by any other light metal alloy previously studied in this configuration. The part strengths achieved with 354-T6 also appear to compare favorably with wrought aluminum alloys. Plotted in Figure 3 are several individual part strength tests of the "Tee" bar configuration machined, in both the longitudinal and transverse direction, from 1.5 inch thick wrought plate. It should be noted that the numerical values obtained from optimumly heat treated, chill cast 354-T6 aluminum alloy are of the same order as those obtained from 7075-T6 plate and considerably in excess of those obtained from 2014-T6 aluminum alloy.

While the results as reported are promising, it should be remembered that the 354 permanent mold "Tee" bars investigated in this study were cast using the iron chills supplied with the pattern equipment. It has been previously demonstrated, using 356 variant aluminum alloys, that the dendrite cell size of aluminum chill cast "Tee" bars is, in general, smaller than the dendrite cells of iron chill cast "Tee" bars. Time for dendrite and constituent growth is limited by the greater heat conductivity of aluminum chills.

3 DISCUSSION (Cont'd.)

The advantage of the more rapid chill is reflected by consistently higher mechanical properties, including elongation, and by consistently higher part strengths.[3][4] It is currently planned to apply this information to the aluminum-silicon-copper-magnesium system of 354 in an attempt to further improve the strength level of this promising alloy.

4 CONCLUSIONS

1. Sand cast "Tee" bar part strengths obtained using 354-T6 aluminum alloy were slightly greater than produced by any sand cast, light metal alloy previously tested.

2. Chill cast "Tee" bar part strengths were produced using iron chilled 354-T6 aluminum alloy that were considerably in excess of any value previously obtained using any other cast light metal alloy.

3. Optimumly heat treated chill cast 354-T6 aluminum alloy showed a 20 to 35 percent part strength advantage over the 356 variant-T6 aluminum alloy currently used in Douglas production. The degree of this advantage depended upon whether iron or aluminum chills were used in casting the 356 variant, aluminum chills producing slightly higher part strengths.

4. The optimumly heat treated chill cast 354-T6 aluminum alloy part strengths approximately equaled values obtained using the identical configuration machined from wrought 1.5 inch thick 7075-T6 aluminum alloy plate and were considerably in excess of those machined from 2014-T6 plate.

5. Optimumly heat treated chill cast 354-T6 aluminum alloy also showed a five to ten percent advantage in tensile yield and ultimate over the 356 variant-T6 aluminum alloy. Elongations were slightly less in

4 CONCLUSIONS (Cont'd)

354 than in the 356 variant.

6. Solution heat treatment of 354 aluminum alloy for 12 hours at 1000°F produced slightly higher mechanical properties and considerably greater part strengths than did 11 hours at 980°F plus one hour at 990°F.

7. A six hour artificial age at 350°F for the 354-T4 aluminum alloy provided optimum properties.

5 ACKNOWLEDGEMENT

The author wishes to thank The Aluminum Company of America, Vernon Works, for supplying the test castings used in this study.

6 DATA

Laboratory Work Sheet, No. 34453

PCR Book 19985, pages 1-2

S.O. 5709-6902

EWO 11964

JWO 7047

S.O. 80305-300

EWO 52704

JWO 0001

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TABLE I

CHEMICAL COMPOSITION*

(WEIGHT PERCENT)

Element	354 Aluminum Alloy			356 Variant Aluminum Alloy			
	As specified by Alcoa	Iron Chilled "Tee" Bars	Unchilled "Tee" Bars	As specified by DMS 1721	Aluminum Chilled "Tee" Bar	Iron Chilled "Tee" Bar	Unchilled "Tee" Bar
Copper	1.6-2.0	1.80	1.85	0.20 Max	0.0	0.0	0.0
Iron	0.20 Max	0.08	0.09	0.20 Max	0.11	0.10	0.10
Silicon	8.5-9.5	8.70	8.95	6.5-7.5	7.0	6.90	6.90
Manganese	0.10 Max	0.00	0.00	0.20 Max	0.0	0.0	0.0
Magnesium	0.4-0.6	0.54	0.55	0.45-0.75	0.64	0.60	0.60
Titanium	0.20 Max	0.14	0.14	0.20 Max	0.15	0.16	0.16
Beryllium	------	------	----	0.20 Max	.14	0.10	0.10
Aluminum	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder
Other Elements, each	0.05	------	----	0.05	-----	-----	-----
Other Elements, total	0.15	------	----	0.15	-----	-----	-----

* Spectrographic Analysis

TABLE II

AVERAGE STRENGTH OF 354-T6 ALUMINUM ALLOY CHILLED CASTING AT VARIOUS THERMAL TREATMENTS

AGE***	SOLUTION HEAT TREAT "A" *					SOLUTION HEAT TREAT "B"**				
Hours at 350°F	F_{tu} (KSI)	F_{ty} (at 0.2% offset) (ksi)	Elongation, percent (1 inch gage length)	Bending modulus (KSI) (Ref: 8)	Static load to part failure in bending (pounds)	F_{tu} (KSI)	F_{ty} (at 0.2% offset) (ksi)	Elongation, percent 1 inch gage length)	Bending modulus (KSI) (Ref: 8)	Static load to part failure in bending (pounds)
1	51.9	33.6	7.0	98.7	1,460	54.0	34.6	7.5	100.8	1,525
2	56.0	39.0	7.3	104.1	1,570	55.4	40.0	5.5	107.0	1,680
3	58.3	39.4	8.0	110.3	1,655	56.2	40.1	7.75	108.2	1,755
4	57.6	40.1	7.5	110.5	1,640	58.4	42.7	6.5	113.9	1,770
5	59.3	45.0	7.5	111.8	1,690	59.8	45.3	7.25	114.5	1,810
7	59.1	45.5	5.0	114.3	1,670	61.5	47.2	6.75	114.7	1,730
14	61.0	51.4	5.5	115.2	1,750	62.9	51.5	4.0	115.4	1,800

* 11 hours @ 980 ± 5°F + 1 hour at 990 ± 5°F, quick quench into 120°F Water

** 12 hours @ 1000 ± 5°F, quick quench 120°F Water

*** 24 hour natural age between solution heat treatment and artificial age.

Tensile and bending modulus results reported are the means of two tests.

TABLE III

AVERAGE STRENGTH OF 354-T6 ALUMINUM ALLOY
UNCHILLED CASTINGS AT VARIOUS THERMAL TREATMENTS

Age***	SOLUTION HEAT TREAT "A" *					SOLUTION HEAT TREAT "B" **				
Hours at 350°F	F_{tu} (KSI)	F_{ty} (at 0.2 percent offset)	Elongation, percent (1 inch gage length)	Bending modulus (KSI) (Ref: 8)	Static Load to part failure in bending (pounds)	F_{tu} (KSI)	F_{ty} (at 0.2 percent offset)	Elongation, percent (1 inch gage length)	Bending modulus (KSI) (Ref: 8)	Static load to part failure in bending (pounds)
1	38.5	33.5	4.0	70.8	900	42.0	33.9	2.5	71.2	995
2	40.4	37.9	1.25	79.9	1000	44.9	40.4	3.0	76.1	975
3	40.3	38.5	1.25	75.0	975	44.3	41.9	2.0	80.7	1095
4	45.8	40.1	1.75	81.2	1030	47.7	42.3	2.0	80.3	1140
5	----	----	----	85.9	1025	47.6	44.5	2.0	84.0	1060
7	49.1	45.3	<1.0	83.8	960	47.4	----	<1.0	83.5	985
14	51.0	46.7	<1.0	91.3	1000	48.3	----	<1.0	89.9	910

* 11 hours at 980 ± 5°F + 1 hour at 990 ± 5°F, quick quench into 100°F water

** 12 hours at 1000 ± 5°F, quick quench into 100°F water

*** 24 hour natural age between solution heat treatment and artificial age.

Tensile and bending modulus results reported are the means of two tests.

TABLE IV

AVERAGE STRENGTH OF 356 VARIANT-T6* ALUMINUM ALLOY CASTINGS

Age* Hours at 350°F	Chill Cast (Iron Chills)				Chill Cast (Aluminum Chills)				Sand Cast (Foundry B)			
	F_{tu} (KSI)	F_{ty} (at 0.2 percent offset) (KSI)	Elongation, percent (1 inch gage)	Pounds load to part failure in bending	F_{tu} (KSI)	F_{ty} (at 0.2 percent offset) (KSI)	Elongation, percent (1 inch gage)	Pounds load to part failure in bending	F_{tu} (KSI)	F_{ty} (at 0.2 percent offset) (KSI)	Elongation percent (1 inch gage)	Pounds load to part failure in bending
2	50.0	37.3	11.0	1200	50.0	35.0	12.0	1330	44.0	36.0	4.0	920
3	50.3	38.6	10.0	1250	53.0	43.0	10.0	1380	45.2	38.0	2.0	940
5	52.4	43.7	8.0	1305	56.0	49.5	5.5	1430	47.8	42.8	3.5	950
10	53.2	45.6	5.0	1340	56.5	50.5	5.5	1470	47.4	42.2	2.5	875

* Solution heat treat = 12 hours at 1010 ± 5°F, quick quench into 120°F water

** 24 Hour natural age between solution heat treatment and artificial age

Tensile results reported are the average of two tests.

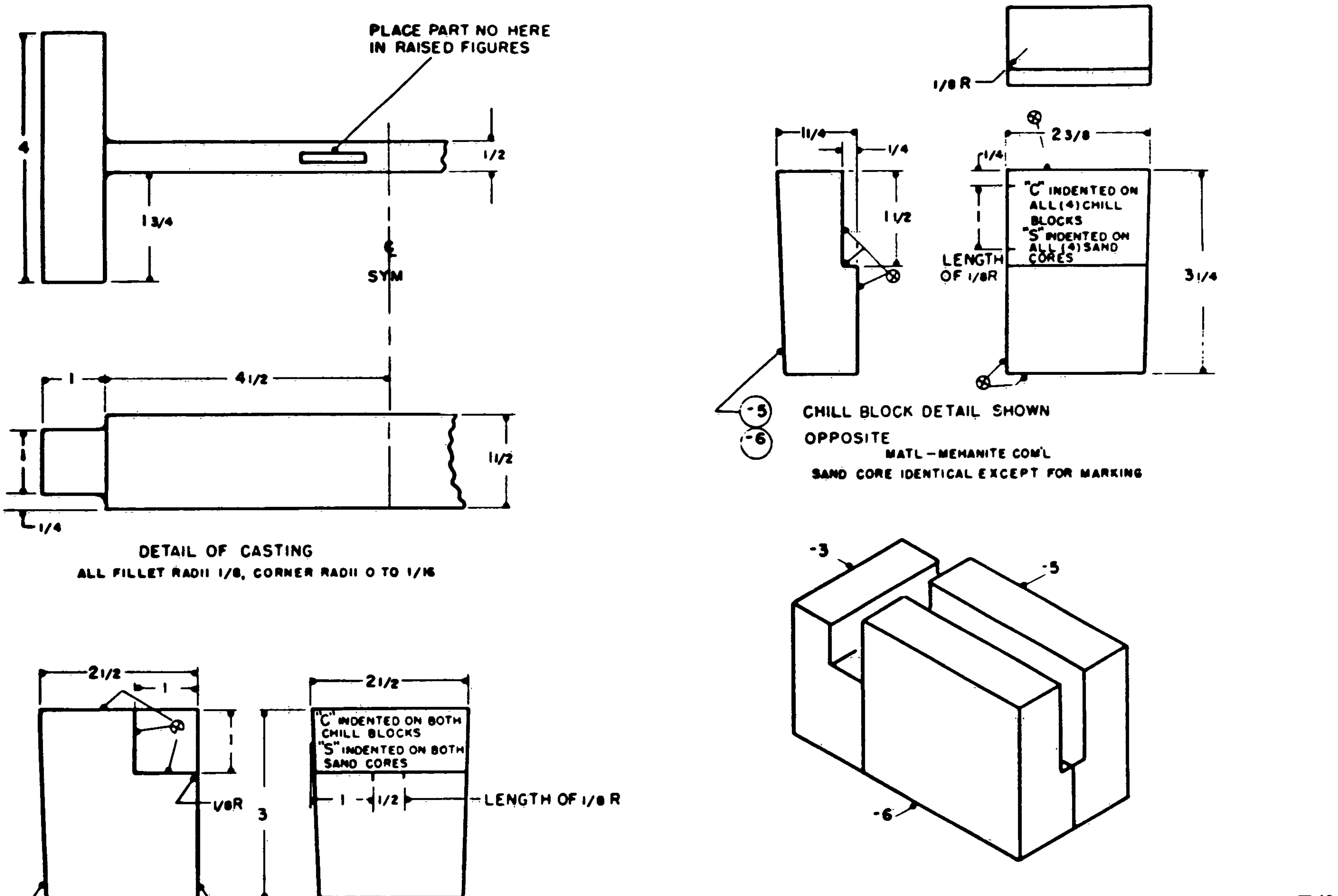
TABLE V

SUMMARY OF MECHANICAL PROPERTIES OF COUPONS CUT FROM "TEE" BAR SAMPLES REPORTED IN FIGURE 6

TEST SERIES	ALLOY	CAST	ULTIMATE STRENGTH (KSI)			YIELD STRENGTH (AT 0.2 PERCENT OFFSET) (KSI)			ELONGATION, PERCENT (1 INCH GAGE LENGTH)			BENDING MODULUS (KSI) (Ref: 8)		
			MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
1	ZK51-T6 (Magnesium)	Sand	41.3	38.3	39.4	24.4	22.9	23.4	12.5	7.5	9.1	74.1	64.0	70.6
		Chill	42.1	37.4	38.7	25.6	23.6	24.7	12.5	6.5	8.4	75.3	71.9	73.1
2	AZ63-T6 (Magnesium)	Sand	36.7	32.0	34.6	22.2	19.0	20.8	3.5	3.0	3.3	58.9	54.5	56.5
		Chill	38.7	35.7	37.4	22.7	17.3	19.6	6.0	3.0	3.6	69.2	60.3	64.2
3	AZ91-T6 (Magnesium)	Sand	36.4	30.6	33.3	24.3	22.2	23.1	5.0	2.0	3.0	59.2	55.6	58.0
		Chill	40.8	38.5	39.4	23.8	20.7	22.2	5.0	4.0	4.6	75.4	73.3	73.6
4	356-T6 (Cast 1956)	Sand	35.0	24.6	30.0	28.3	24.5	25.0	3.5	0.5	1.5	----	----	----
		Chill	39.0	31.0	35.0	28.6	25.5	27.5	6.0	2.0	3.5	----	----	----
5	A356-T6 (Cast 1956)	Sand	----	----	----	----	----	----	----	---	---	----	----	----
		Chill	40.0	37.3	38.6	29.6	26.5	28.0	9.5	4.0	6.5	----	----	----
6	A356-T6 (Current)	Sand	42.9	35.8	38.3	39.7	33.7	35.5	2.5	1.0	1.8	70.3	60.9	64.2
		Chill	48.9	46.8	47.7	39.1	37.3	37.7	14.5	9.5	11.0	92.7	85.4	89.6
7	A356-T6 (Current)	Sand	38.8	34.7	36.8	32.7	28.9	30.6	4.0	2.0	3.0	69.0	62.3	65.4
		Chill	47.5	43.0	47.1	38.8	31.6	38.2	12.5	10.0	11.1	91.8	79.7	90.7
8	356-T6* (Variant)	Sand	45.6	43.5	44.8	40.9	39.1	40.7	2.0	1.5	1.8	77.1	72.5	75.2
		Chill	56.5	50.0	53.9	50.5	35.0	44.5	12.0	5.5	8.3	101.7	94.8	99.2
9	354-T6**	Sand	48.6	44.3	46.8	44.5	40.4	41.7	3.0	1.0	2.0	89.9	76.1	82.4
		Chill	62.9	55.4	59.1	51.5	40.0	44.5	8.0	4.0	5.6	115.4	107.0	112.3

* Chemistry per DMS 1721 as shown in Table I.

** Solution Heat Treat 12 hours at 1000°F - age 2 to 14 hours at 350°F



⊗ = SURFACES TO BE FLAT & WITHOUT DRAFT

FIGURE 1

CASTING - STRUCTURAL EVALUATION TEST
(P/N 3838789)

FIGURE 2

"TEE" BAR TEST CASTING AND TECHNIQUE USED IN BEND LOADING IT TO FAILURE

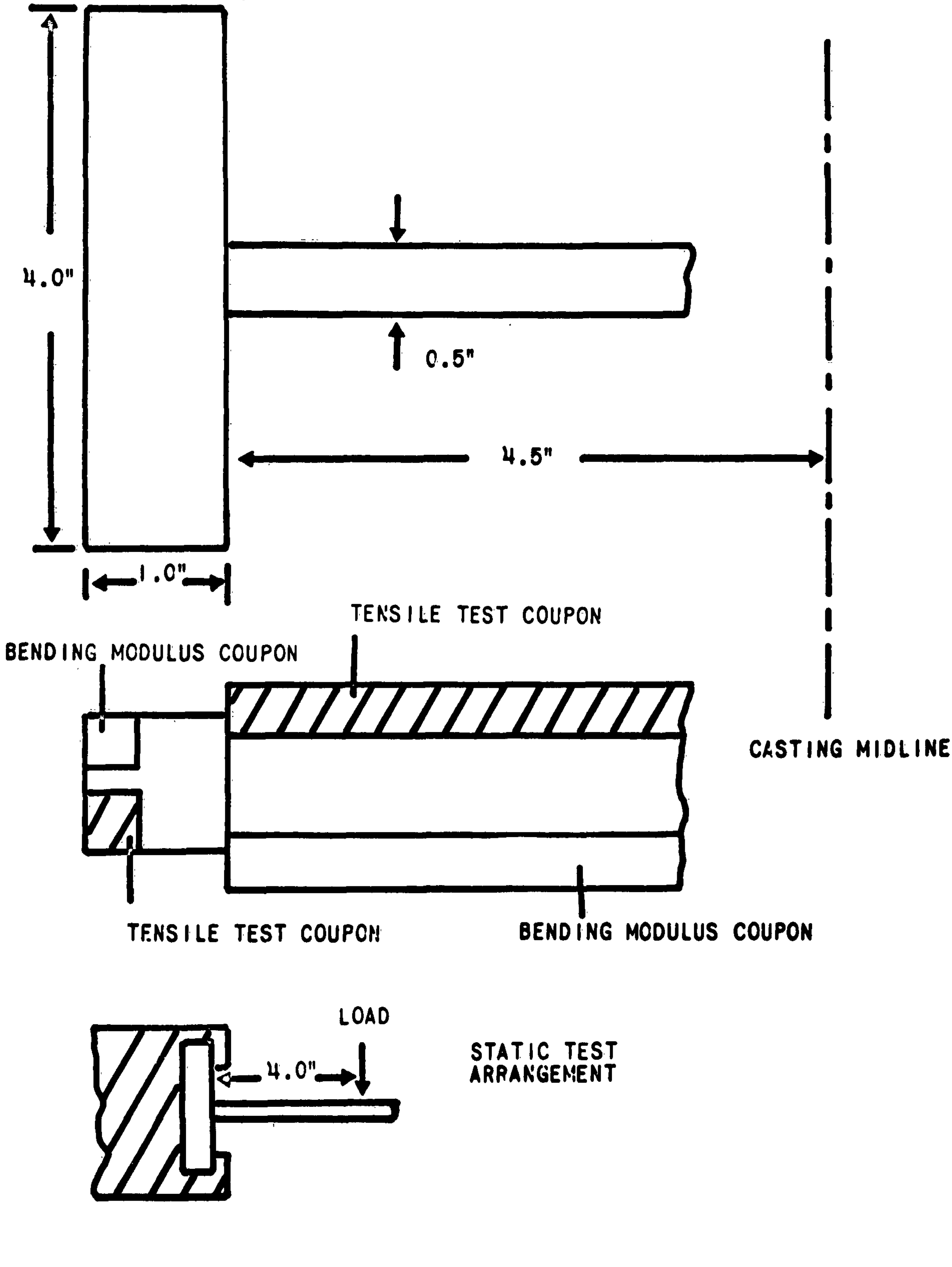
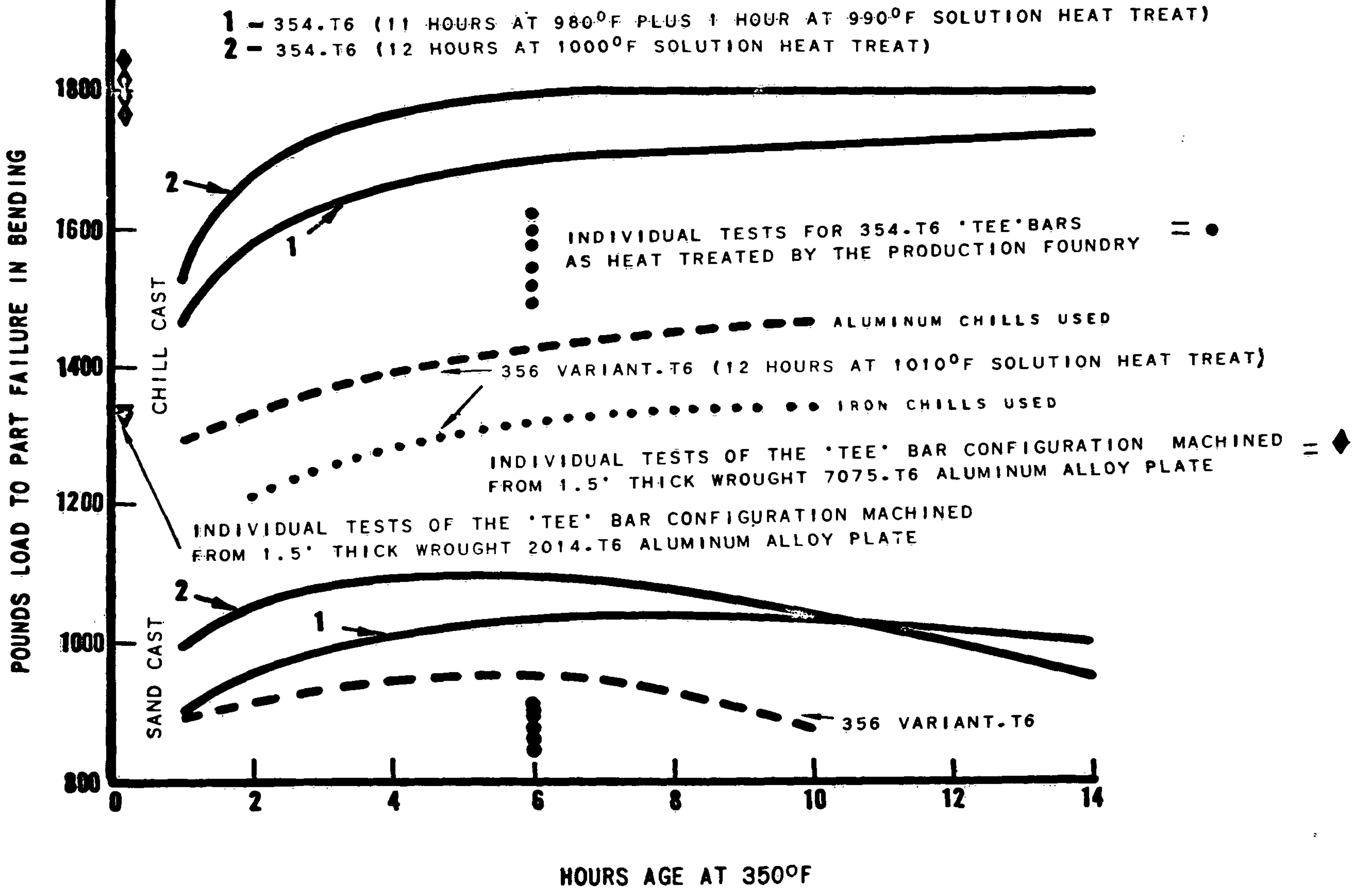


FIGURE 3

"TEE" BAR PART STRENGTH OF 354-T6 AND 356 VARIANT-T6 ALUMINUM ALLOYS FOR VARIOUS AGING TIMES AT 350°F



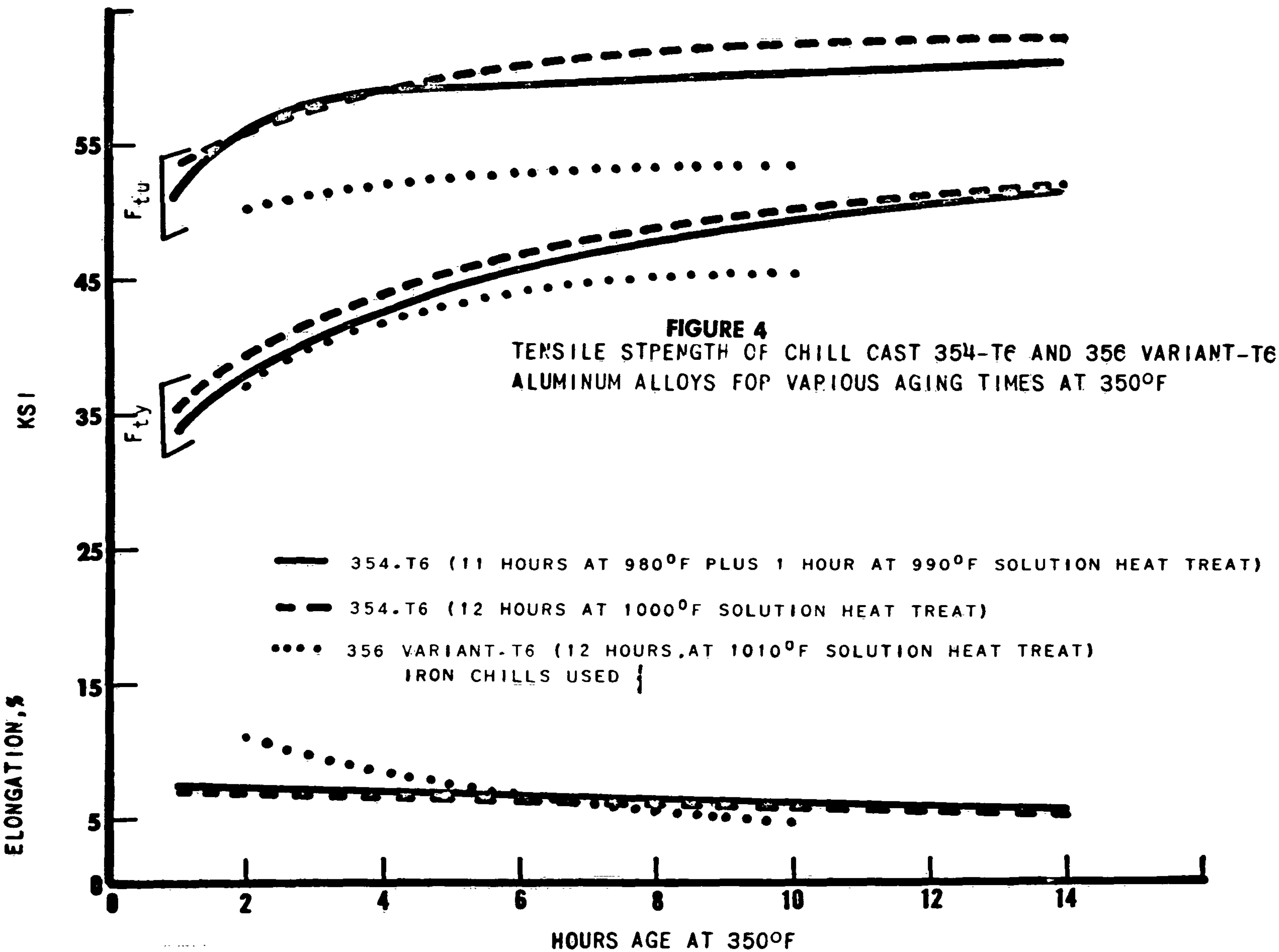


FIGURE 4
TENSILE STRENGTH OF CHILL CAST 354-T6 AND 356 VARIANT-T6 ALUMINUM ALLOYS FOR VARIOUS AGING TIMES AT 350°F

FIGURE 5

TENSILE STRENGTH OF SAND CAST 354-T6 AND 356 VARIANT-T6 ALUMINUM ALLOYS FOR VARIOUS AGING TIMES AT 350°F

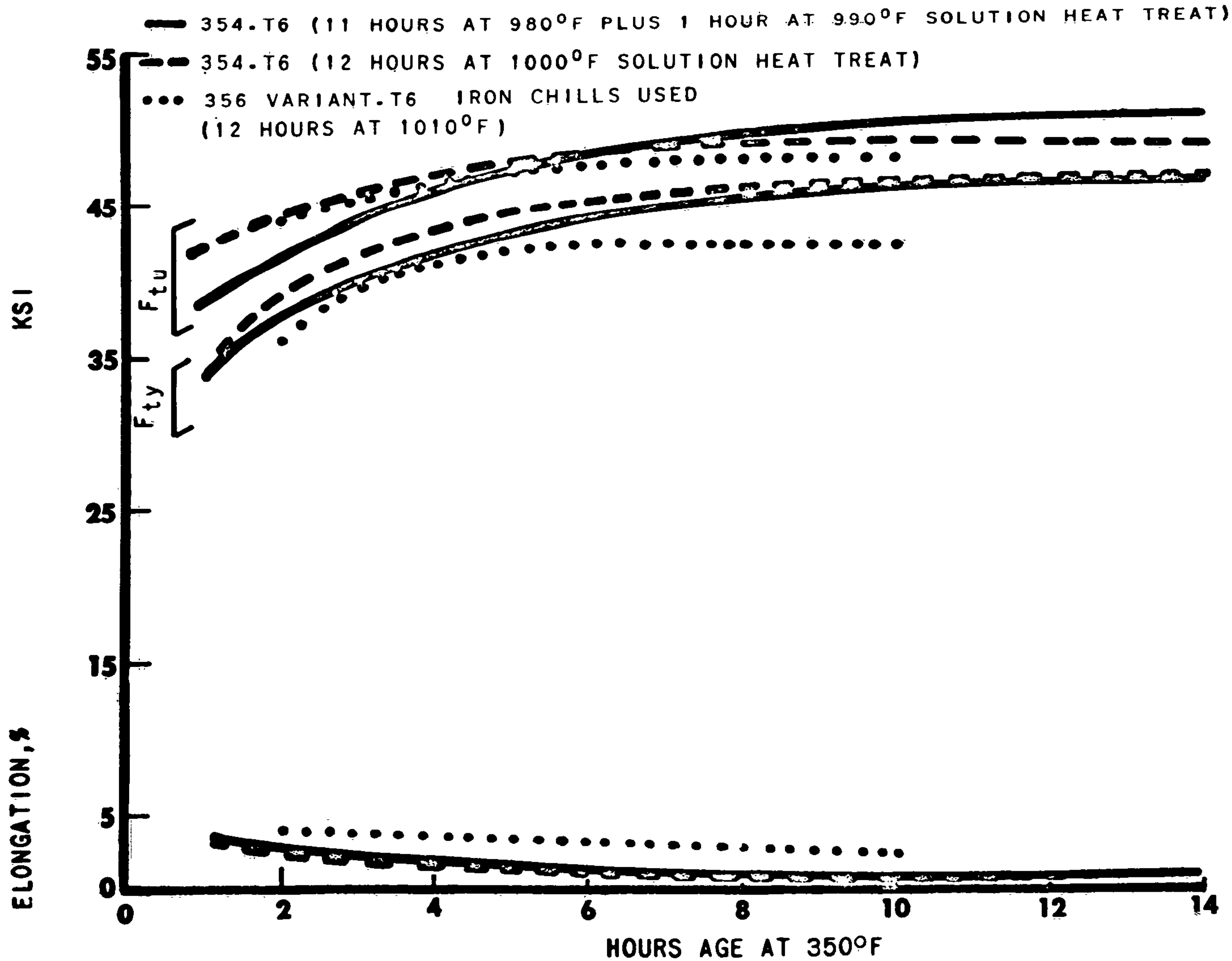


FIGURE 6

REPRESENTATIVE LOAD TO FAILURE DATA FOR "TEE" BAR CASTING POURED IN VARIOUS ALLOYS