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THE EFFECT OF BERYLLIUM AND MAGNESIUM CONTENT ON THE MECHANICAL PROPERTIES OF "HIGH PURITY" 356-T6 VARIANT ALUMINUM ALLOY

RESEARCH & DEVELOPMENT REPORT SM-43094

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A-356 TYPE ALUMINUM CASTING ALLOY
PART I
EFFECT OF MAGNESIUM CONCENTRATION

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ABSTRACT

This investigation was conducted to determine the effect of variations on magnesium content on the mechanical properties and part strengths of "high purity" 356-T6 type aluminum alloys. Results are reported that were obtained from a series of similar "Tee"-shaped test castings, poured by two foundries in both sand and permanent mold, using metal of three different compositions. The "Tee's" of all compositions were solution heat treat similarly and were aged for various times at two temperatures.

Both in sand castings and in chilled castings, at any aging temperature or time used experimentally, ultimate strength and yield strength increased directly with an increase in magnesium concentration from 0.33 to 0.74 weight percent. Elongation varied inversely with the increase in magnesium content but was markedly retarded by maximal chilling. Part strength, as tested in bending, was increased by this increase in magnesium content approximately eight percent when aluminum chills were used, three percent when iron chills were used and little or not at all when unchilled.

I. INTRODUCTION

Both in the United States and abroad, particularly in the aerospace industry, there has been a growing trend toward the structural use of "high strength", "high integrity" aluminum alloy castings. The majority of these castings are poured in various combinations of an aluminum-silicon-magnesium system which is roughly bounded by the chemistries of two aluminum alloys long in use - 356 and 360. Within relatively narrow extremes of major alloying constituents (0.2 percent to 0.8 percent magnesium and 6.5 percent to 10.0 percent silicon), a whole host of variants of the parent materials have recently evolved. Each of these specific variants has its own sharply defined chemistry, its own specifications, its own proprietary name; each has its own group of partisan supporters claiming optimum strength levels. Order must be brought to this growing confusion caused by the multiplicity of similar alloys. This report, the first of a series, represents a preliminary attempt to bring such order.

The chemical compositions of this group of 356 aluminum alloy variants differ from each other in one or more of four basic ways. They differ in the independent amounts of silicon, magnesium and beryllium present and in the level of iron impurity permitted. Of these four variables only two are considered of practical current significance.

Silicon has two recognized functions. First, it increases fluidity, thus improving castability and second, it combines chemically with magnesium to form magnesium silicide. This compound, when precipitated from solid solution during heat treatment, is responsible for strength

I. INTRODUCTION (Cont'd.)

in the aluminum-silicon-magnesium system. Since silicon is the element present in considerable excess in the 356 type aluminum alloys under consideration, the amount of magnesium silicide that can potentially form is controlled not by the silicon, but by the amount of magnesium present. It is conceivable that a percentage of silicon toward the upper end of the compositional range under study might yield a relatively more castable alloy at a given pouring temperature. Such an alloy might theoretically produce a more homogeneous casting that could be mechanically stronger due to a lower pouring temperature and the associated decrease in grain size. It is improbable, however, that silicon content can be responsible for any chemically induced strength advantage which may exist between the 356 variants. The effect of silicon variation, per se, on the relative strengths of these alloys was thus assumed to be minor and has been excluded from the present study.

Iron content also was not considered to be of major importance in a current comparative strength study of this group of alloys. The embrittling effect of minor alloying constituents is well recognized on both a theoretical and practical level[1] [2]. Present production techniques for primary ingot and for "high strength" aluminum alloy castings, however, tend to keep iron at such a low level that it rarely becomes a major problem, except by chance contamination.

For the above reasons, it appeared necessary to study only the effects

I. INTRODUCTION (Cont'd.)

of chemical differences in beryllium and in magnesium content on strength of these alloys.

The relative effect of small compositional variations in beryllium and magnesium on alloy strength could best be studied, not in separately cast test bars where minor strength differences between alloys might be masked by rapid cooling and ideal gating, but in a structural configuration of as much complexity as is economically feasible. A series of such castings could be reproducibly poured by a fixed foundry technique using metal of known, variable compositions. Such parts, after comparable heat treatment, can be statically loaded to failure under controlled conditions. Numerical test values so derived should be definitive. By studying the relative functional strength of a given configuration in its entirety, the various alloy compositions can be compared directly. These part strength data should be far more valid than are the mechanical property results generally obtained in alloy and heat treat studies which make use of separately cast test bars. In addition to part strength information, such a configuration could also supply standard mechanical property values derived from coupons machined from disected segments of the failed castings.

The "Tee" Bar Casting, pictured in Figure I, is one of two test configurations currently used by Douglas in foundry and alloy evaluations[3]. While the configuration is uncored, and suggests little necessity to vary gating and chilling techniques, it does permit a

1. INTRODUCTION (Cont'd.)

strength evaluation not only of coupons cut from the casting but of the parent casting itself. The casting, which is reasonably reproducible dimensionally, is poured and heat treated as an "H". The "H" is then bisected across the center arm into two identical "Tee" shaped pieces. Each of these "Tee's" is individually placed in a jig and bend loaded to failure with a standard tensile testing machine. The load is applied to the cantilever in the position shown in Figure 2.

The present report gives strength data obtained from a series of such castings. These parts were produced by two foundries in 356 type aluminum alloys of varying magnesium content. The effect of beryllium concentration will be reported separately.

2. EXPERIMENTAL PROCEDURE

2.1 Casting Production

Purchase orders were placed with each of two foundries for "Tee" bar castings to be poured in three 356 type aluminum alloys of varying magnesium concentration. The targets were 0.40, 0.60 and 0.80 magnesium by weight percent. Silicon was to be maintained constant at 7.0 weight percent. Beryllium additions or sodium modification were not permitted. Titanium, while held within the standard specification maximum of 0.20 weight percent, was left to foundry option.

At both foundries, each of the three target chemistries was produced as an individual melt. Each melt produced eight "H" castings. As shown in Figure 1, each of these castings was poured so that only one

2.1 Casting Production (Cont'd.)

end of the "H" was chilled. Each individual "H" thus produced, represented two interconnected, similarily gated parts - an essentially permanent mold cast "Tee", cooled at a maximal rate, and a sant cast "Tee", cooled at a minimal rate. The chills used by Foundry A were aluminum; those used by Foundry B were iron. Figure 2A shows rigging and chilling technique used.

Pouring temperatures were approximately 1375°F. All melts were degassed by nitrogen fluxing. A cover flux was used by Foundry B but not by Foundry A.

2.2 Heat Treatment

Castings produced by each foundry were heat treated by the foundry to identical schedules.

Castings of each of the three target chemistries were solution heat treated in a single furnace load for twelve hours at 1010 ± 5°F and were quenched immediately in 140°F water. Less than a five second time delay existed between the opening of the furnace door and the entrance of the castings into the water.

As has been suggested elsewhere(4), a twenty-four hour room temperature age interval was scheduled between the quenching and artificial aging of the castings. The use of this holding period does not imply agreement with the popular concept of its beneficial effect on mechanical properties. The author has, as yet, been unable to duplicate the reported advantage. The holding period was specified for two reasons - first, to eliminate a potential experimental variable

2.2 Heat Treatment (Cont'd.)

and second, because such practice is currently common to many production foundries.

The eight "H"'s so solution heat treated were divided randomly into two groups of four. One group of four castings from each of the three target chemistries, 12 castings in all, were artifically aged in one furnace load for various times at 320°F; the remaining 12 castings were artifically aged in another furnace load for various times at 350°F. The schedule was as follows - each time and temperature being represented by an "H" casting of each alloy:

(a) age at 320 ± 5°F for 3, 5, 7 and 14 hours

(b) age at 350 ± 5°F for 2, 3, 4 and 10 hours

Castings were fixed in the aging load so that at the above times and temperatures a representative of each target chemistry could be simultaneously removed from the furnace. With this technique, the furnace door could be quickly closed and no appreciable heat loss occurred. Castings so removed were air cooled.

2.3 Inspection

2.3.1 Chemistry

Spectrographic chemical analyses for each target melt produced by each foundry were made independently on specially prepared disc samples by the producing foundry. The analyses were duplicated by Douglas on the same chemical sample discs as well as on tensile coupons later cut from the test castings. The averages of these analyses for each melt appear in Table I. In general, there was

2.3.1 Chemistry (Cont'd.)

good agreement between the values obtained by Douglas and by the independent laboratories.

2.3.2 Fluorescent Penetrant Inspection

Each "H" casting was inspected by fluorescent penetrant. All were judged acceptable and no discernable quality difference existed between melts or between the production of either foundry.

2.3.3 Radiography

Radiographic examination demonstrated a very light shrinkage condition along the midline of the 0.5" thick section of the chilled end and a moderate level of gas porosity in the sand end of the "H" in all castings received. These minor discontinuities, equally common to each alloy produced, were judged "acceptable" by an independent inspection laboratory, and were considered to be typical of the minor heterogeneities encountered in normal production runs. The radiographic quality level of castings from both foundries were approximately equivalent.

2.4 Testing

As described in the introduction, each "H" produced was bisected into two "Tee"-shaped pieces which were subsequently bend loaded to failure as shown in Figure 2. The cantilevers fractured cleanly at the juncture of the two arms.

As shown in Figure 2, two tensile coupons were machined from each of the broken "Tee"'s. (Standard, flat, 0.2 inch thick sub-size from the material produced by Foundry A and standard, cylindrical, 0.25

2.4 Testing (Cont'd.)

inch diameter sub-size from the material produced by Foundry B). One coupon was machined from the 1 x 1 x 4 inch base section and the other 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 was then two inches from the point of fracture of the original "Tee". These coupons were then tensile tested by standard technique at a loading rate of 1,200 pounds per minute. Elongations reported were measured by "fit-back" in a one-inch gage length. The mechanical properties of a given sand cast or chill cast "Tee" representing a given chemistry, aging temperature and time were considered to be the arithmetical mean of the two tensile coupons taken from it.

3. RESULTS:

3.1 Part Strength Testing

The static load to failure results for each of the individual "Tee"'s produced by both foundries in each of the three target alloys are reported in Tables II and III. Table II lists the part strength values obtained from "Tee"'s aged from the T-4 condition for various times at 320°F and Table III for those aged at 350°F. These results are summarized in Figure 3 as average part strengths obtained at a given aging temperature for a specific magnesium concentration.

3.2 Tensile Testing

The mechanical property results obtained from each of the three alloys produced by each of the foundries are also reported in Table II and III. Table II presents tensile strength values obtained from sand cast and

3.2 Tensile Testing (Cont'd.)

chill cast "Tee"'s aged from the T-4 condition at 320°F and Table III describes those aged at 350°F.

The effect of magnesium concentration on the mechanical properties of sand cast and chill cast 356-T6 variant type aluminum alloys appear in Figures 4 through 7. In each of these figures, one set of curves describe tensile tests made on material aged at a given temperature for the minimum time used experimentally. The other set of curves describe tests made on material aged for the maximum time used experimentally at that temperature. Figure 4 shows results for chill cast parts aged at 320°F for both 3 and 14 hours. Figure 5 shows results for chill cast parts aged at 350°F for both 2 and 10 hours. Figure 6 shows results for sand cast parts aged at 320°F for both 3 and 14 hours. Figure 7 shows results for sand cast parts aged at 350°F for both 2 and 10 hours. In all figures, solid lines indicate results from material produced by Foundry A while broken lines indicate results from material produced by Foundry B.

3.3 Metallographic Examination

The sand cast and chill cast microstructure of each of the three compositions produced by both foundries was examined. Metallographic specimens for this examination were excised from the grip end of that tensile test bar which had been machined from the 0.5-inch thick, 1.5-inch wide section of the "Tee". These specimens were taken from that end of the test bar which had been closest to the point of fracture of the "Tee" when the part in its entirety was static loaded to failure.

3.3 Metallographic Examination (Cont'd.)

No microstructural differences were induced by variation in magnesium concentration or by variation in the aging times or temperatures in either sand cast or chill cast material. It was thought necessary, then, to show typical photomicrographs of essentially one magnesium concentration only, Figures 8 through 10. Figure 8 shows typical chill cast material produced by Foundry B, Figure 9 chill cast material produced by Foundry A, Figure 10 sand cast material produced by Foundry B and Figure 11 sand cast material produced by Foundry A.

4. DISCUSSION

As would be expected, the dendrite cell size of the rapidly cooled, chill cast material was, on the average, considerably smaller than the dendrite cell size of the relatively slowly cooled sand cast material. Compare Figures 8 and 10 and Figures 9 and 11. Note also that the dendrite cells of the aluminum chill cast material produced by Foundry A are considerably smaller than those of similar material produced by Foundry B using iron chills.

As has been stated previously, Figure 10 shows the typical microstructure of sand cast material produced by Foundry B in all magnesium concentrations studied. As can be seen, the primary silicon particles are quite small and finely dispersed within the aluminum-silicon eutectic surrounding the aluminum solid solution dendritic cells. This microstructure is of a considerably different character than is the microstructure shown in Figure 11, which is from a similar area of a sand casting produced by Foundry A in an alloy of similar chemistry and heat treatment.

4. DISCUSSION (Cont'd.)

As can be seen by comparing the photomicrographs shown in Figure 10 and Figure 11, despite identical pouring temperatures, a basic difference in primary silicon structure exists between sand cast material produced by Foundry A and sand cast material produced by Foundry B. This difference obtained regardless of magnesium concentration or aging schedule. The silicon particles observed in sand castings produced by Foundry A were, in general, large, acicular and irregularly shaped. Those observed in sand castings poured by Foundry B were quite small and finely dispersed. The form and dispersion of the fine silicon crystals surrounding the aluminum solid solution dendrites of Foundry B sand castings is typical of 356-T6 type aluminum alloys modified by small sodium additions.(5)

While the presence of sodium could not be confirmed by flame spectrophotometric techniques, it would appear from the metallographic evidence that the 356-T6 type aluminum alloys produced by Foundry B might well have been modified in some manner. Although both foundries were specifically requested not to so modify, the opinion is given further credence by the slightly higher sand cast elongations shown by Foundry B castings as compared with Foundry A castings which were of similar composition and were aged at similar times and temperatures. See Figures 6 and 7. It is problematic, however, whether the higher sand cast ultimate and yield strengths consistently shown by Foundry A "Tee" bar castings can also be completely ascribed to the suspected modification of Foundry B castings. This strength differential, is at times considerable - from 5 to 30 percent. To be induced solely by

4. DISCUSSION (Cont'd.)

hypothetical sodium additions would require, in present theory, relatively massive overmodification. Such should have been chemically demonstrable by spectrophotometric means. It was not. Also, in the aluminum-silicon-magnesium system there is a proportional decrease in fluidity with increase in sodium concentration. This is always associated with increasing amounts of gas porosity which becomes progressively heavy with overmodification. Such was not the case in the present study. Radiographs of Foundry B material and Foundry A material were essentially comparable. Conceivably, the differences in tensile strength shown by the two foundries can be explained by slight variations in the heat conductivity of the sands used or by minor differences in rigging.

The marked difference in silicon particle structure demonstrated between sand castings poured by the two foundries was not evident in the microstructure of the chilled castings respectively produced. It also was not reflected by consistently higher elongation values for Foundry B produced castings. See Figures 4 and 5. The effect of modification was apparently masked by rapidly cooling from the molten state. The primary silicon shown in Figures 8 and 9 had insufficient time to grow to the sizes shown in Figures 10 and 11.

Regardless of magnesium concentration or aging schedule, the dendrite cell size of Foundry A produced aluminum chill cast "Tee" bars was, on the average, smaller and less erratic in size than the dendrite cells of the iron chill cast "Tee" bars produced by Foundry B. Primary

4. DISCUSSION (Cont'd.)

silicon size was also somewhat smaller when cast using aluminum chills. This can be attributed to the greater heat conductivity of the aluminum chills which was not compensated for by the greater mass of the iron chills used by Foundry B. Time for dendrite and constituent growth was limited by more rapid cooling. The advantage of this more rapid chill is reflected by consistently higher mechanical properties, Figures 4 and 5 and by consistently higher part strengths, Figure 3.

Regardless of the differences in strength and in microstructure which exist between parts produced by each foundry, the castings produced by an individual foundry show similar patterns. At any given aging temperature or time used experimentally, both in sand castings and in chilled castings, ultimate strength and yield strength increase directly with increase in magnesium concentration from 0.33 to 0.74 weight percent. This 0.4 percent increase in magnesium content produces approximately a ten percent increase in both tensile ultimate and in tensile yield measured at 0.2 percent offset. It is accompanied by a corresponding decrease in ductility. Such a reduction in elongation as measured by "fit-back" appears to be markedly retarded by the use of maximal chilling. See Figures 4 and 5.

At any given heat treatment, regardless of the magnesium concentrations used experimentally, the mechanical properties of test coupons taken from chilled castings had approximately a 7 to 21 percent

4. DISCUSSION (Cont'd.)

advantage in ultimate strength over the equivalent sand castings. Tensile yield strengths for sand castings were, however, only slightly less than the values obtained from heavily chilled castings for the identical alloy and heat treatment. Elongations, as would be expected, were considerably less for sand castings as opposed to chilled castings.

As previously reported[6], the advantage of chill cast structure over sand cast structure of similar composition and heat treatment was considerably more pronounced when expressed as relative part strength. See Figure 3. Aluminum chilled castings showed a 35 to 47 percent strength advantage over their sand cast counterparts. The more slowly cooled, iron chilled castings showed somewhat less of an advantage, from 27 to 32 percent.

This greater relative advantage for chill cast part strength than for chill cast tensile strength when compared to similar sand cast material can be partially explained on the basis of the photomacrographs shown in Figures 12 and 13. These figures show typical cross-sections of the juncture of the arm with the base of the "Tee". This is the point of fracture of the part under static load. The polished surfaces were heavily etched with five percent hydrofluoric acid. Figure 12, representing a typical sand cast cross section, shows dendrites of approximately constant size. These dendrites grew from the molten state under conditions more nearly approaching equilibrium than did the dendrites shown in Figure 13, a typical chill cast cross-section. In this latter figure, there is a considerable difference in the size

4. DISCUSSION (Cont'd.)

of the dendrites ranging from relatively small at the periphery to relatively large at the center or last cooled area. The "Tee" under bending load would be stressed in tension at the upper surface and in compression at the lower. The neutral axis would then run through the larger dendrites where microcompositional variations are greatest, shrinkage most severe and general strength presumably lowest. The chilled "Tee" is thus loaded in the area of maximum strength. Tensile coupons, however, excised from this casting and machined on all sides, represent the matrix of the section, the larger dendrites and the zone of lesser strength. A hypothetical strength differential of this magnitude between part strength and tensile strength would not obtain in sand castings where the dendrites toward the periphery or skin are more nearly similar, in size and kind, to the dendrites of the matrix.

5. CONCLUSIONS

1. At any aging temperature or time used experimentally, both in sand castings and in chilled castings, ultimate strength and yield strength increase directly with an increase in magnesium concentration from 0.33 to 0.74 weight percent. This 0.4 percent increase in magnesium content produces approximately a total ten percent increase in both tensile ultimate and in tensile yield strengths.

2. Elongation, as measured by "fit-back", varies inversely with increase in magnesium concentration from 0.33 to 0.74 percent. This decrease in ductility is markedly retarded by the use of maximal chilling.

5. CONCLUSION (Cont'd.)

3. At any aging treatment used experimentally, regardless of magnesium concentration, the mechanical properties of test coupons taken from chilled castings demonstrated a 7 to 21 percent advantage in ultimate strength over an equivalent sand casting.

4. Tensile yield strengths, measured at 0.2 percent offset, for sand castings were only slightly less than the values obtained from chilled castings of similar alloy and heat treatment. Elongations, however, were markedly less for sand castings.

5. Sand cast part strength was increased little or not at all by increase in magnesium concentration from 0.33 to 0.74 percent.

6. Chill cast part strength, when aluminum chills were used, was increased approximately eight percent by the 0.33 to 0.74 percent increase in magnesium concentration and approximately three percent when iron chills were used.

7. Aluminum chilled castings, at all magnesium concentrations used experimentally, showed a 35 to 47 percent part strength advantage over their sand cast counterparts. The more slowly cooled iron chilled castings showed a 27 to 32 percent advantage over the sand castings of similar aging schedule and chemical composition.

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7. DATA

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PCR Book 17347, page 13

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EWO 12365
SO 5709-6902
JWO 0025

EWO 52704
SO 80305-300
JWO 0001

TABLE I

CHEMICAL COMPOSITION*

(WEIGHT PERCENT)

MELT	FOUNDRY	MAGNESIUM	SILICON	IRON	TITANIUM	BERYLLIUM	ALUMINUM***
1	A	0.39 (.040)**	7.0 (7.0)**	0.15	0.15	Nil	Balance
2	A	0.59 (0.60)	7.0 (7.0)	0.15	0.16	Nil	Balance
3	A	0.74 (0.80)	7.1 (7.0)	0.15	0.16	Nil	Balance
1	B	0.33 (0.40)	7.3 (7.0)	0.11	0.17	Nil	Balance
2	B	0.54 (0.60)	7.0 (7.0)	0.10	0.15	Nil	Balance
3	B	0.69 (0.80)	7.2 (7.0	0.10	0.16	Nil	Balance

* Chemistries reported are the average of three analyses.

** Target chemistry parenthetically enclosed

*** Including minor impurities

TABLE I

EFFECT OF AGING TIME ON THE STRENGTH OF CAST 356-T6 TYPE

(TENSILE VALUES REPORTED ARE THE

FOUNDRY	CHILLING TECHNIQUE	MAGNESIUM CONTENT BY WEIGHT PERCENT	3 HOURS				5 HOURS		
			F_{TU} KSI	F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)	F_{TU} KSI	F_{TY} KSI	EL
A	Aluminum	0.39	46.2	33.0	15.0	1193	47.4	34.2	
B	Iron	0.33	39.0	23.2	14.5	988	40.4	25.6	
A	Aluminum	0.59	48.4	34.4	10.0	1244	50.2	39.5	
B	Iron	0.54	43.3	26.6	18.5	1058	45.0	31.0	
A	Aluminum	0.74	50.5	35.4	14.0	1268	53.2	40.6	
B	Iron	0.69	42.9	29.8	6.5	1064	47.7	33.4	
A	Sand	0.39	39.9	30.8	3.0	862	42.9	35.0	
B	Sand	0.33	33.7	21.7	6.5	756	32.0	23.9	
A	Sand	0.59	41.9	34.2	3.0	971	42.7	37.8	
B	Sand	0.54	36.5	26.6	4.5	854	38.4	29.9	
A	Sand	0.74	41.8	33.6	3.5	917	44.4	39.6	
B	Sand	0.69	38.1	29.2	3.0	860	40.0	33.1	

NOTE: Part loaded to failure in bending

1

TABLE II

ST 356-T6 TYPE ALUMINUM ALLOY AGED FROM THE T-4 AT 320°F.

PORTED ARE THE AVERAGE OF TWO TESTS)

	5 HOURS			7 HOURS				14 HOURS			
	F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)	F_{TU} KSI	F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)	F_{TU} KSI	F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)
4	34.2	12.5	1216	48.2	37.2	14.0	1218	50.9	39.1	11.0	1323
4	25.6	14.5	1118	42.3	29.1	14.0	1128	45.5	34.3	11.0	1236
2	39.5	9.0	1296	52.7	41.9	13.0	1376	53.8	44.7	10.5	1328
)	31.0	11.5	1150	47.0	33.0	15.5	1150	48.4	42.0	9.0	1278
2	40.6	12.5	1254	54.8	43.7	12.0	1448	54.6	46.2	10.0	1352
7	33.4	13.5	1152	49.5	38.2	7.0	1206	49.5	41.5	3.0	1252
)	35.0	3.0	930	45.0	37.4	1.5	940	44.4	40.0	1.5	969
)	23.9	3.0	906	36.9	28.3	4.0	860	39.6	33.5	3.0	962
'	37.8	1.5	942	44.7	39.2	2.0	908	46.0	42.8	0.5	971
.	29.9	4.5	892	40.0	32.4	3.5	912	43.3	40.5	2.0	980
.	39.6	1.5	976	43.7	41.0	1.0	983	48.5	45.8	0.5	869
'	33.1	2.5	902	42.9	36.9	2.0	890	43.3	39.9	0.5	904

2

TABLE

EFFECT OF AGING TIME ON THE STRENGTH OF CAST 356-T6 TYP

(TENSILE VALUES REPORTED ARE TH

FOUNDRY	CHILLING TECHNIQUE	MAGNESIUM CONTENT BY WEIGHT PERCENT	2 HOURS				3 HOURS		
			F_{TU} KSI	F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)	F_{TU} KSI	F_{TY} KSI	EL
A	Aluminum	0.39	48.9	37.4	11.5	1375	49.7	39.9	
B	Iron	0.33	40.1	28.5	11.0	1122	45.0	33.5	
A	Aluminum	0.59	51.1	41.0	8.5	1372	53.0	43.8	
B	Iron	0.54	47.5	35.8	10.5	1260	48.6	38.0	
A	Aluminum	0.74	53.2	43.1	9.0	1400	53.9	45.4	
B	Iron	0.69	45.7	38.4	5.5	1152	49.7	41.2	
A	Sand	0.39	43.0	38.7	1.5	957	44.0	38.1	
B	Sand	0.33	35.4	27.7	3.0	862	393	32.9	
A	Sand	0.59	45.0	40.8	1.5	912	46.7	43.6	
B	Sand	0.54	40.3	35.3	4.0	972	42.4	37.0	
A	Sand	0.74	43.1	41.3	1.0	1004	44.7	43.7	
B	Sand	0.69	40.9	35.5	1.0	954	45.7	40.4	

NOTE: Part loaded to failure in bending

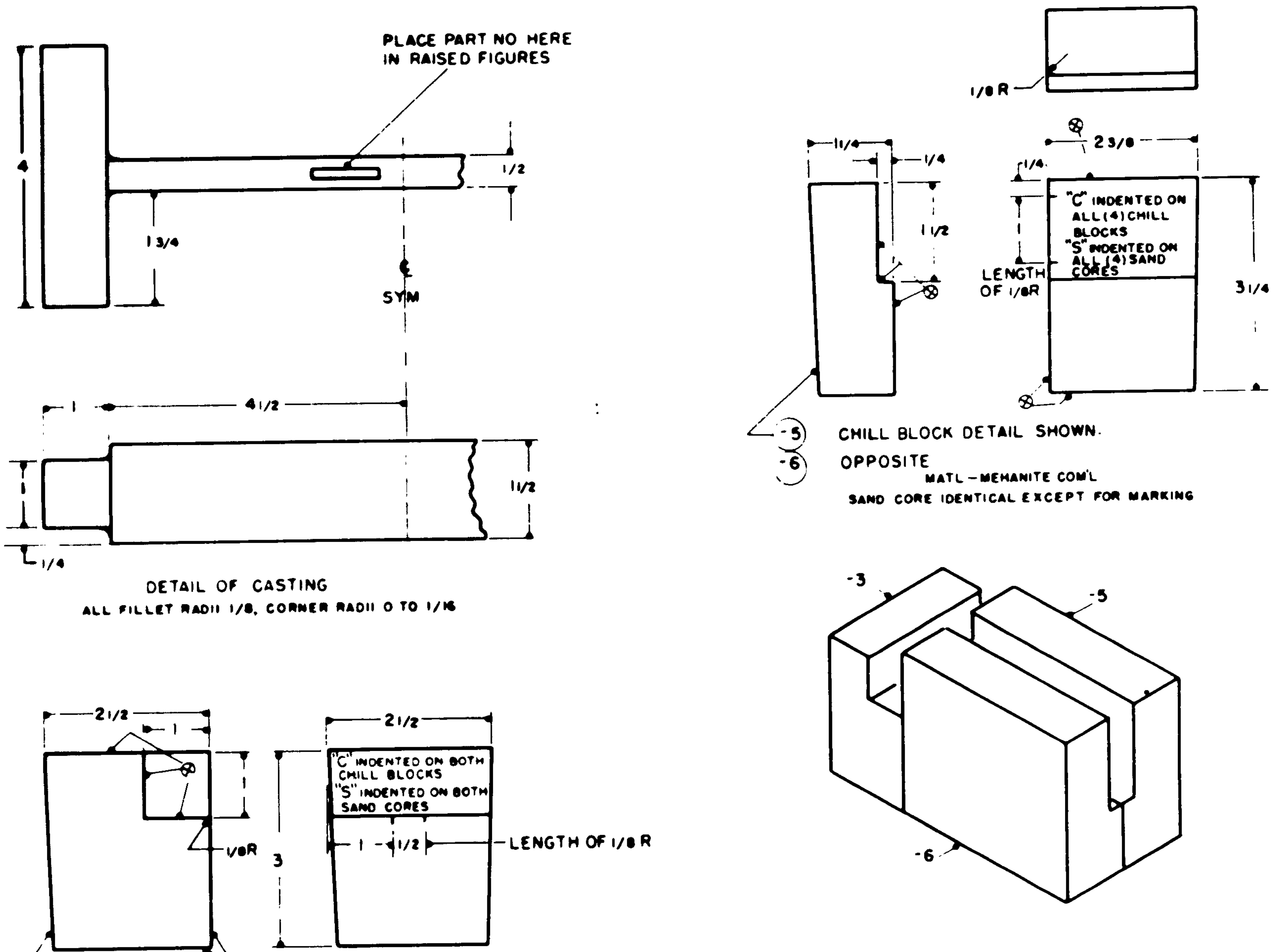
1

TABLE III

T 356-T6 TYPE ALUMINUM ALLOY AGED FROM THE T-4 AT 350°F

ORTED ARE THE AVERAGE OF TWO TESTS)

3 HOURS			5 HOURS				10 HOURS			
F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)	F_{TU} KSI	F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)	F_{TU} KSI	F_{TY} KSI	ELONGATION PERCENT (1")	LOAD TO FAILURE (POUNDS)
39.9	10.5	1213	49.8	40.8	12.0	1322	49.3	42.3	7.5	1284
33.5	15.0	1258	45.3	36.7	9.0	1190	46.2	38.5	9.0	1198
43.8	10.5	1362	53.4	46.0	11.0	1437	53.8	46.3	6.0	1386
38.0	13.5	1240	50.1	42.7	7.0	1314	50.0	43.4	8.0	1284
45.4	9.0	1404	55.3	47.6	9.0	1440	54.3	48.6	8.0	1370
41.2	4.5	1244	53.1	46.3	6.0	1312	53.0	48.2	3.5	1330
38.1	1.5	931	45.3	41.3	1.5	979	46.2	42.7	1.5	974
32.9	3.0	1018	41.4	36.4	2.5	1000	42.4	38.1	1.75	947
43.6	1.5	977	45.6	44.5	1.0	951	47.2	45.8	1.5	949
37.0	2.5	900	44.6	41.5	2.0	962	45.1	43.2	1.5	1020
43.7	1.0	950	48.4	46.0	1.0	869	51.9	49.1	0.5	928
40.4	1.0	972	47.4	44.5	0.5	934	48.0	47.0	0.0	936



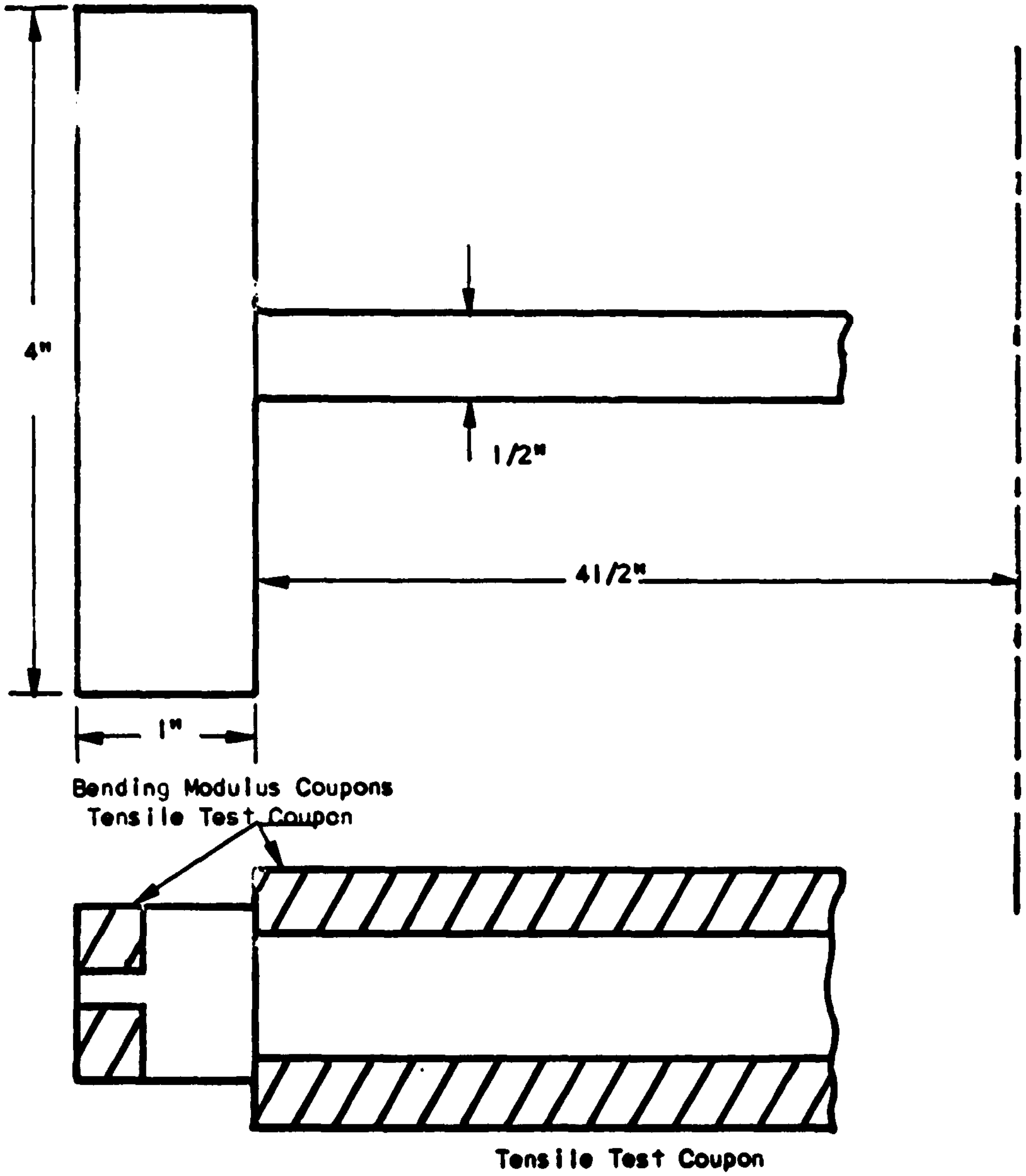
⊗ = SURFACES TO BE FLAT & WITHOUT DRAFT

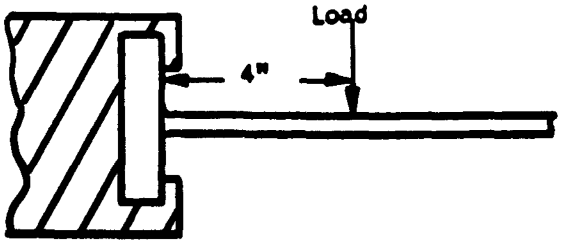
FIGURE 1

CASTING - STRUCTURAL EVALUATION TEST
(P/N ?838789)

FIGURE 2

"Tee" Bar Test Casting, Part Number 3595943, and Technique Used for static Loading to Failure





STATIC TEST ARRANGEMENT

MAGN. APPROXIMATELY 1/2X

FIGURE 2A

GATING AND CHILLING TECHNIQUE USED FOR PRODUCTION OF "TEE" BARS

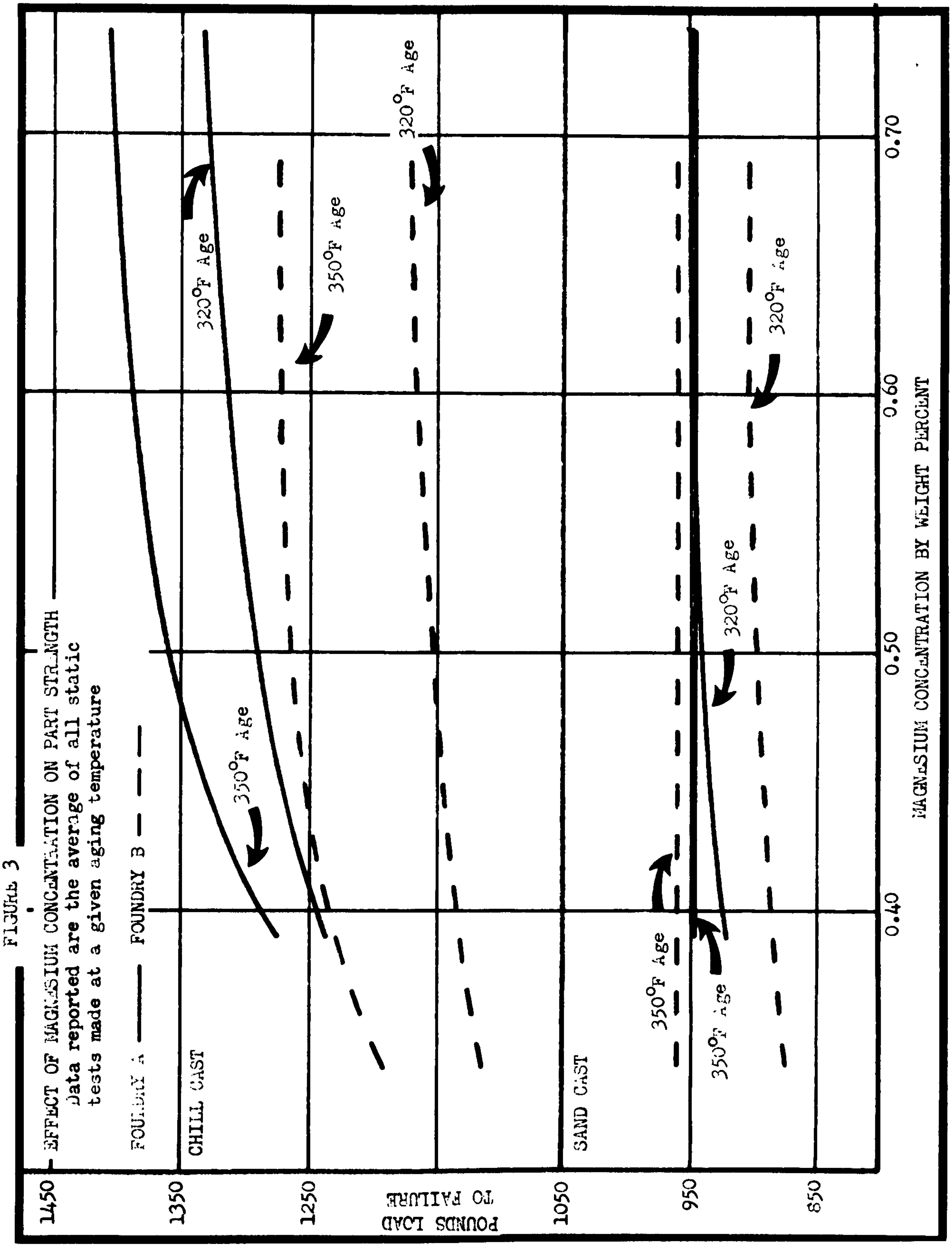


FIGURE 3

EFFECT OF MAGNESIUM CONCENTRATION ON PART STRENGTH

Data reported are the average of all static tests made at a given aging temperature

FIGURE 4

EFFECT OF MAGNESIUM CONCENTRATION ON THE MECHANICAL PROPERTIES OF CHILL CAST 356 TYPE ALUMINUM ALLOYS ARTIFICIALLY AGED FROM T-4 AT 320°F
Data reported are the average of two tensile tests

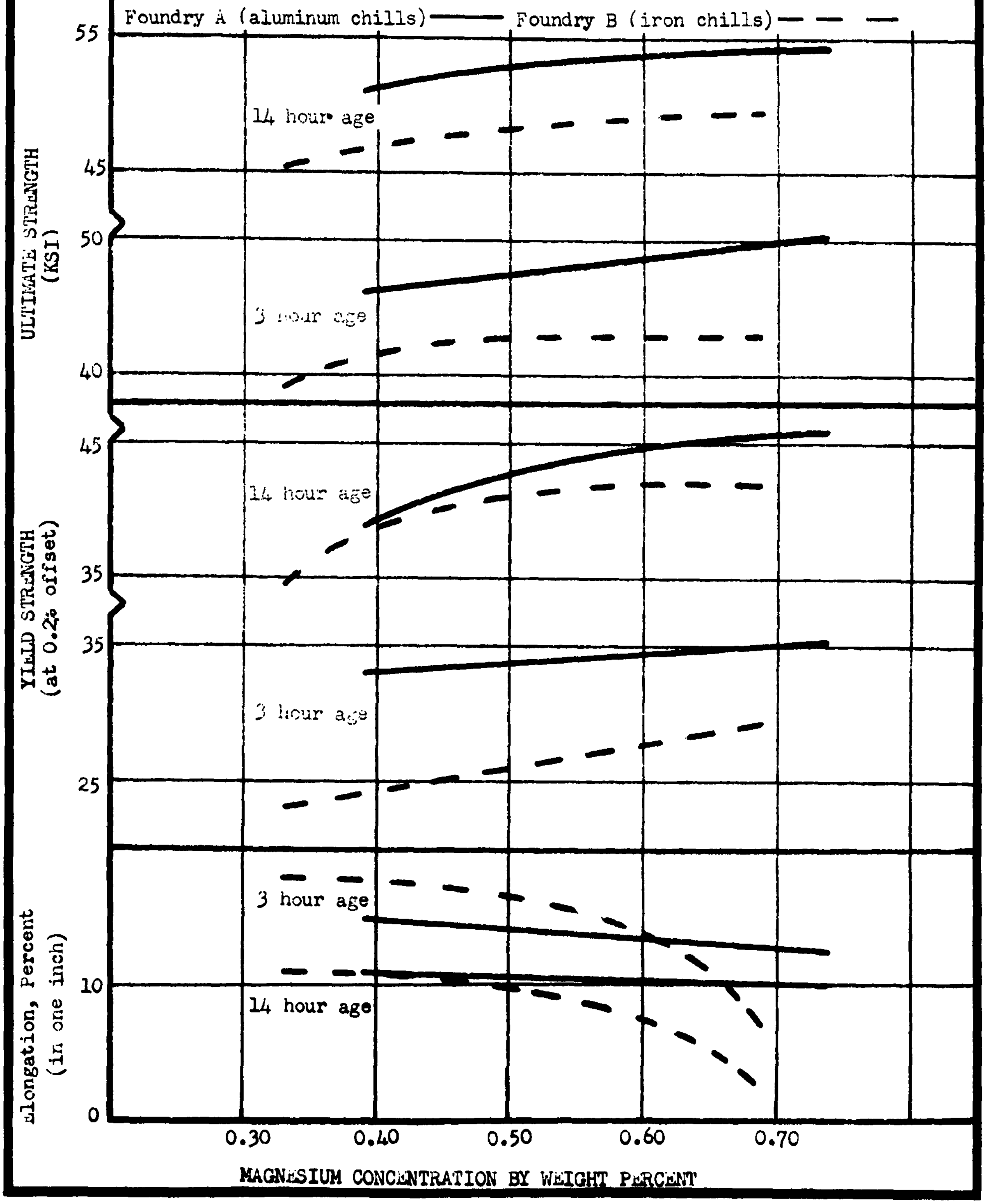
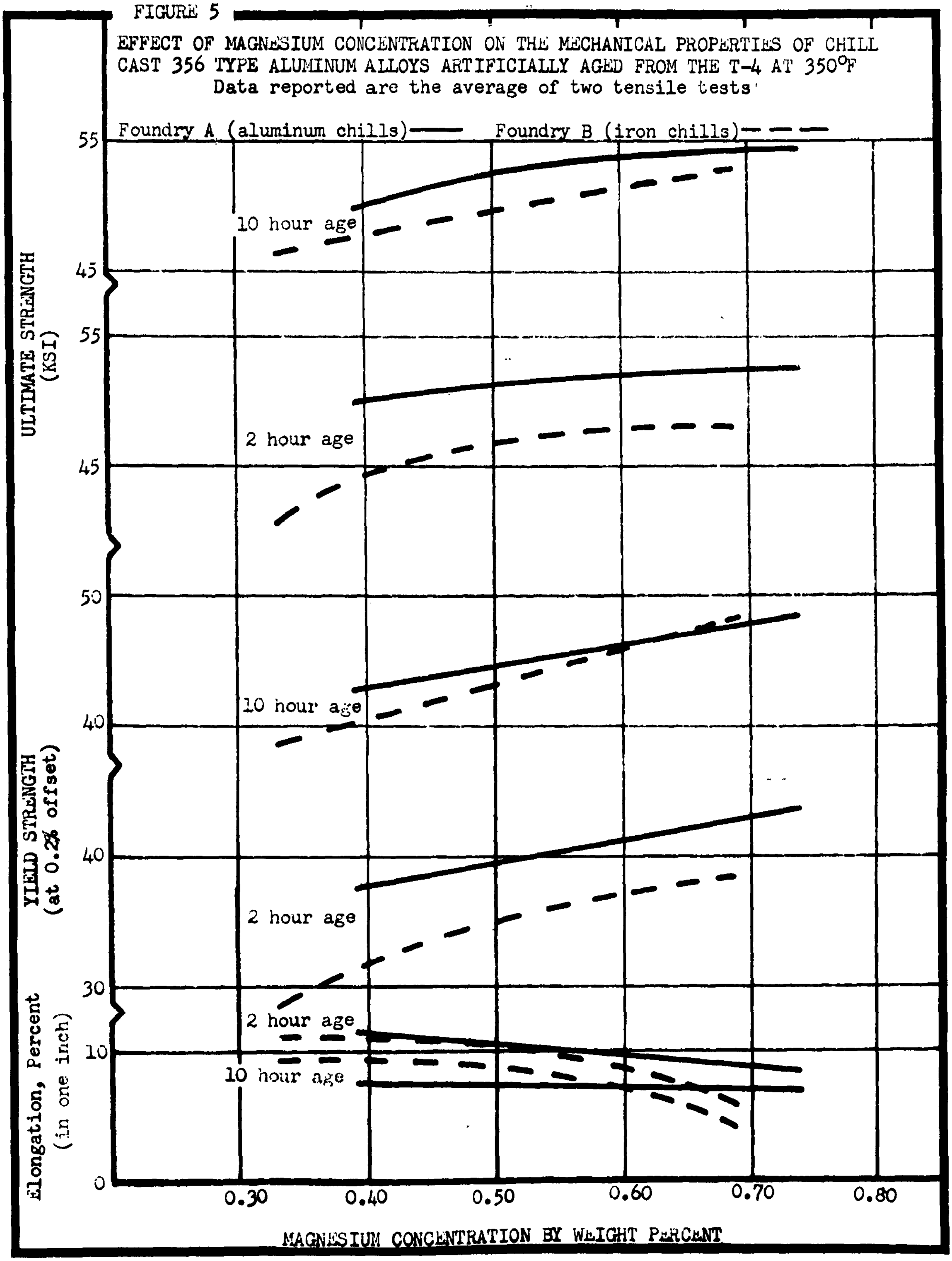


FIGURE 5


EFFECT OF MAGNESIUM CONCENTRATION ON THE MECHANICAL PROPERTIES OF CHILL CAST 356 TYPE ALUMINUM ALLOYS ARTIFICIALLY AGED FROM THE T-4 AT 350°F
Data reported are the average of two tensile tests
Foundry A (aluminum chills)
Foundry B (iron chills)
ULTIMATE STRENGTH (KSI)
YIELD STRENGTH (at 0.2% offset)
Elongation, Percent (in one inch)
10 hour age
2 hour age
10 hour age
2 hour age
2 hour age
10 hour age
55
45
55
45
50
40
40
30
10
0
0.30
0.40
0.50
0.60
0.70
0.80
MAGNESIUM CONCENTRATION BY WEIGHT PERCENT

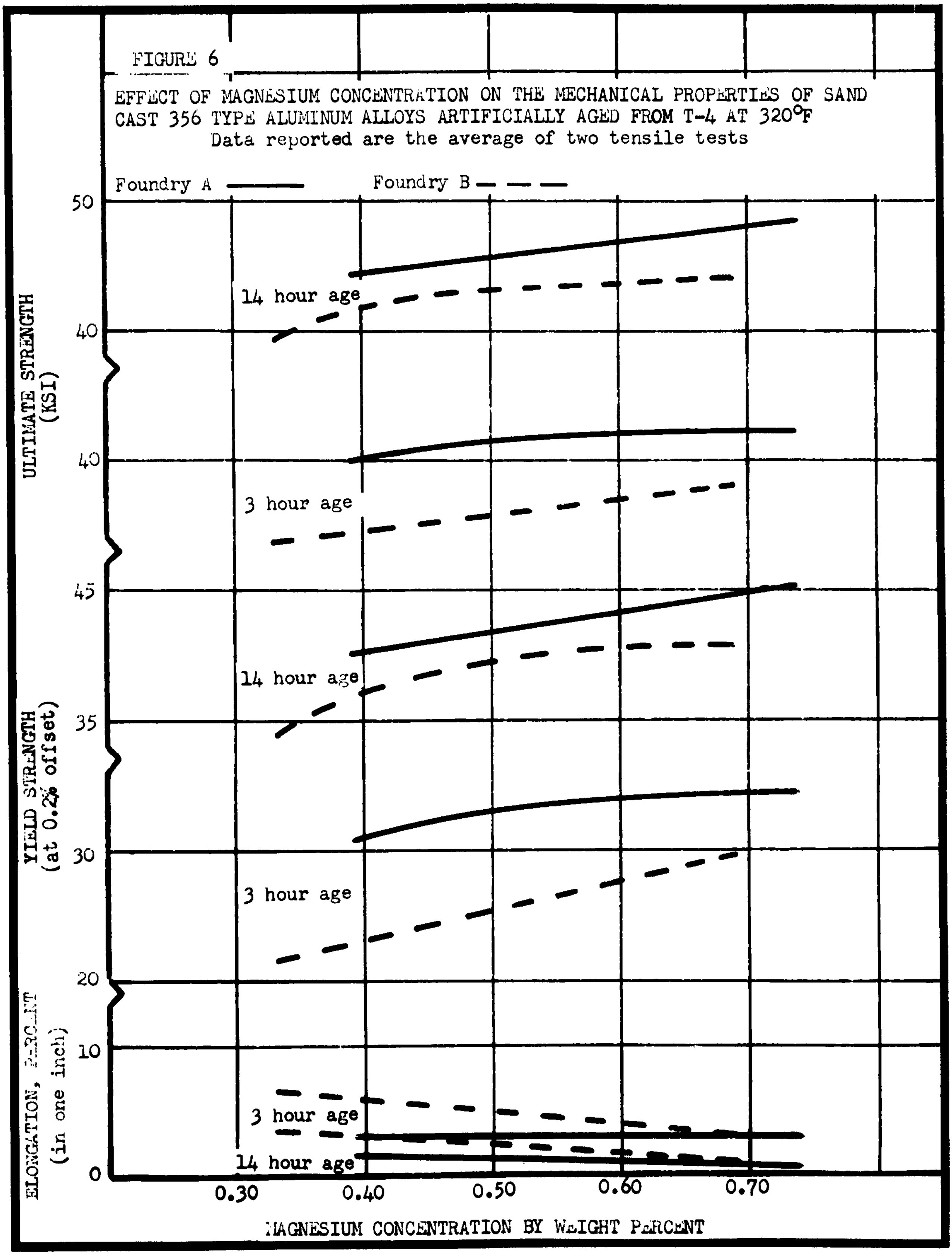


FIGURE 6
EFFECT OF MAGNESIUM CONCENTRATION ON THE MECHANICAL PROPERTIES OF SAND CAST 356 TYPE ALUMINUM ALLOYS ARTIFICIALLY AGED FROM T-4 AT 320°F
Data reported are the average of two tensile tests
Foundry A
Foundry B
ULTIMATE STRENGTH (KSI)
YIELD STRENGTH (at 0.2% offset)
ELONGATION, PERCENT (in one inch)
14 hour age
3 hour age
14 hour age
3 hour age
3 hour age
14 hour age
50
40
40
45
35
30
20
10
0
0.30
0.40
0.50
0.60
0.70
MAGNESIUM CONCENTRATION BY WEIGHT PERCENT

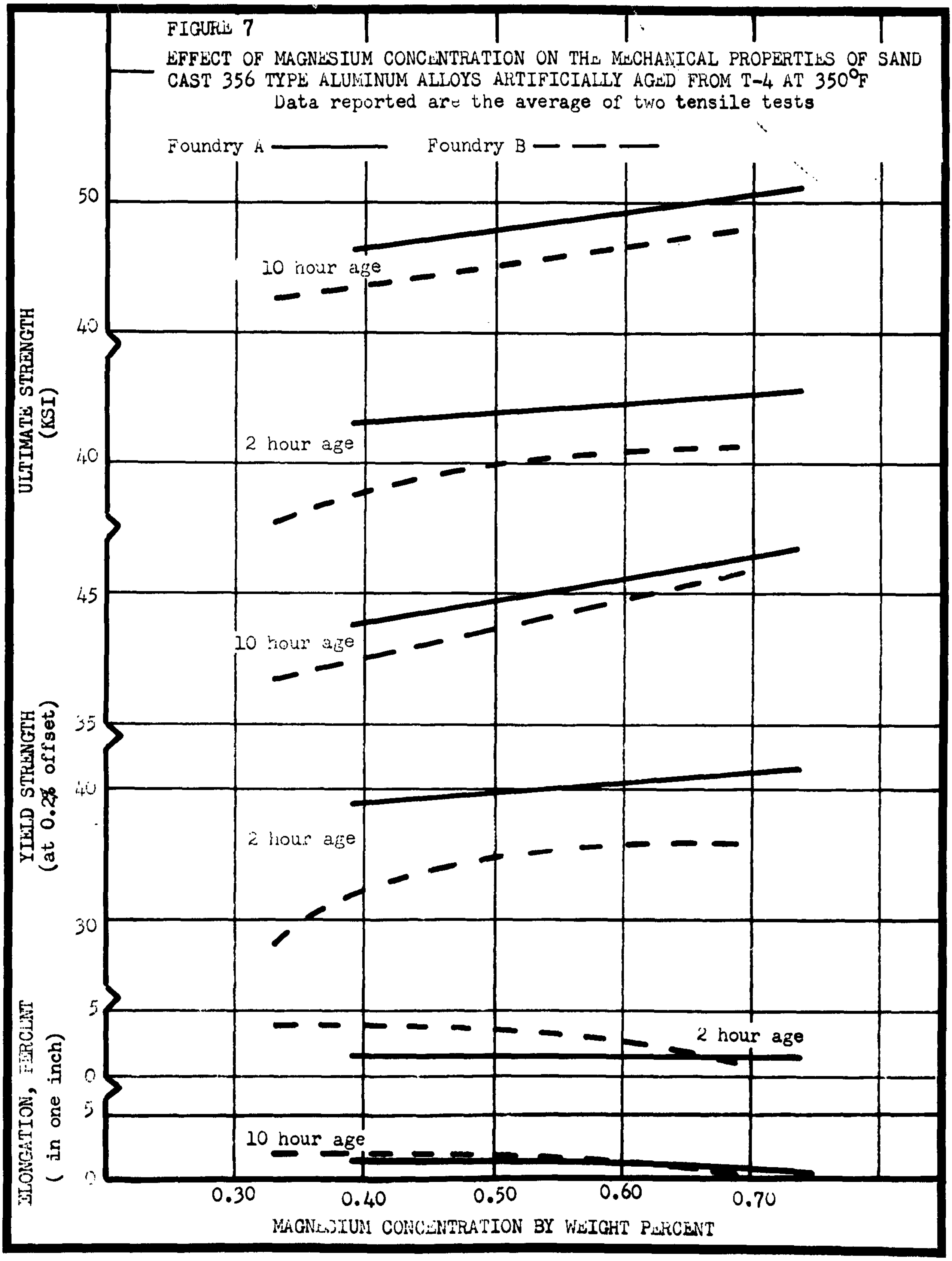
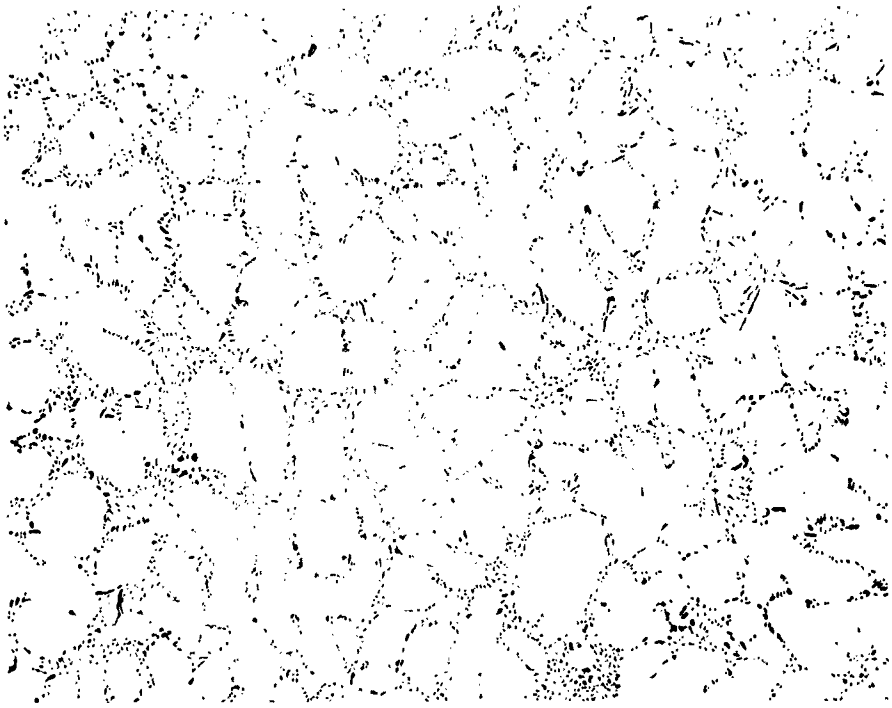


FIGURE 7
EFFECT OF MAGNESIUM CONCENTRATION ON THE MECHANICAL PROPERTIES OF SAND CAST 356 TYPE ALUMINUM ALLOYS ARTIFICIALLY AGED FROM T-4 AT 350°F
Data reported are the average of two tensile tests
Foundry A
Foundry B
ULTIMATE STRENGTH (KSI)
YIELD STRENGTH (at 0.2% offset)
ELONGATION, PERCENT (in one inch)
10 hour age
2 hour age
10 hour age
2 hour age
2 hour age
10 hour age
50
40
40
45
35
40
30
5
0
5
0
0.30
0.40
0.50
0.60
0.70
MAGNESIUM CONCENTRATION BY WEIGHT PERCENT

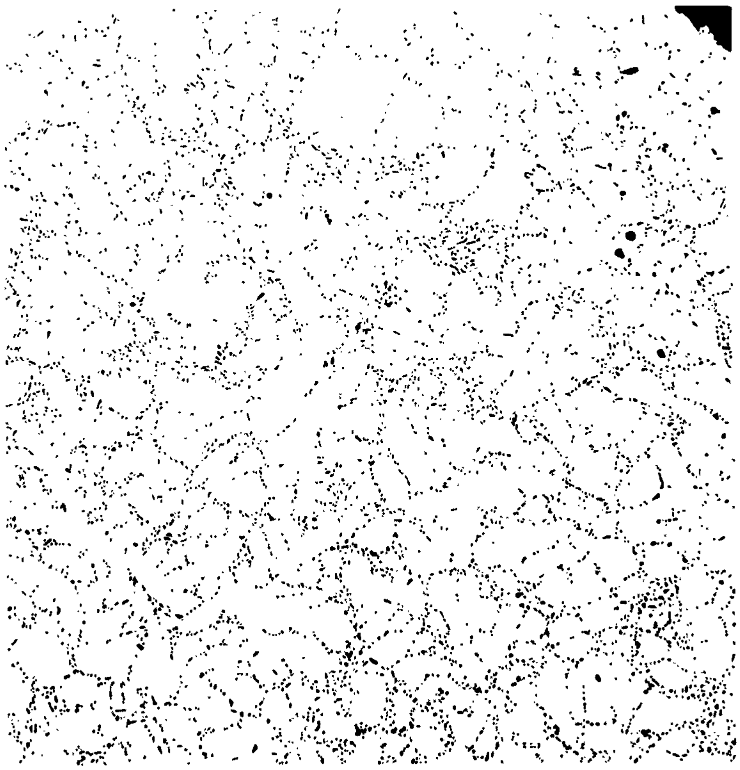


Magn 100X
Unetched

M 16012

FIGURE 8

Apparently Modified Iron Chill Cast 356-T6 Aluminum Alloy aged 3 hours at 350°F (Foundry B). (Si 7.3% - Mg. 0.33%)

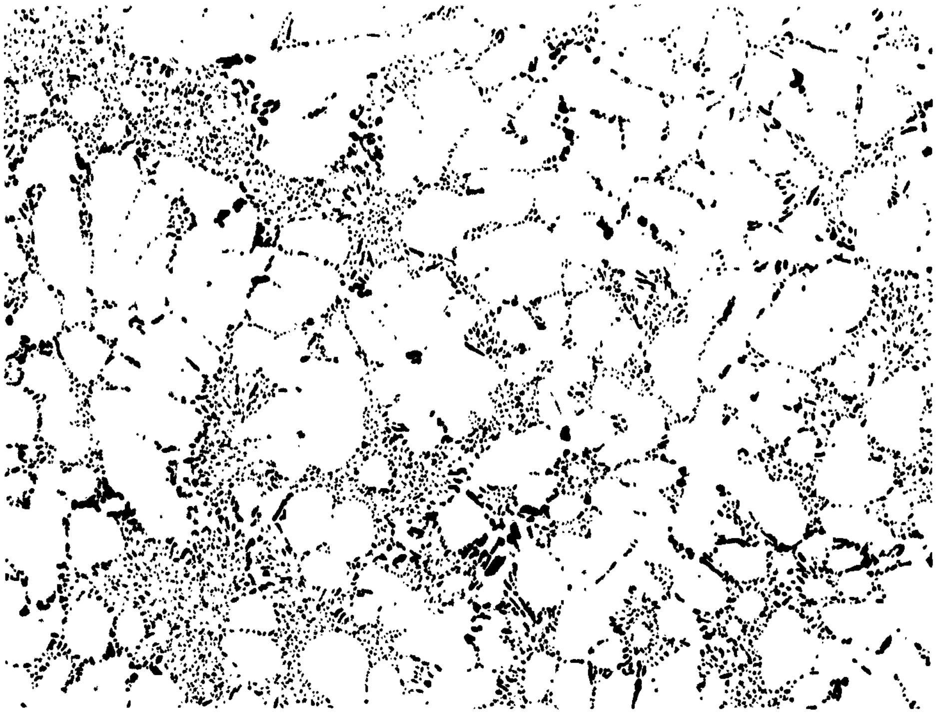


Magn 100X
Unetched

M 16391

FIGURE 9

Aluminum Chill Cast 356-T6 Aluminum Alloy Not Sodium Modified, aged 3 hours at 350°F(Foundry A) (Si - 7.0% - Mg 0.39%)

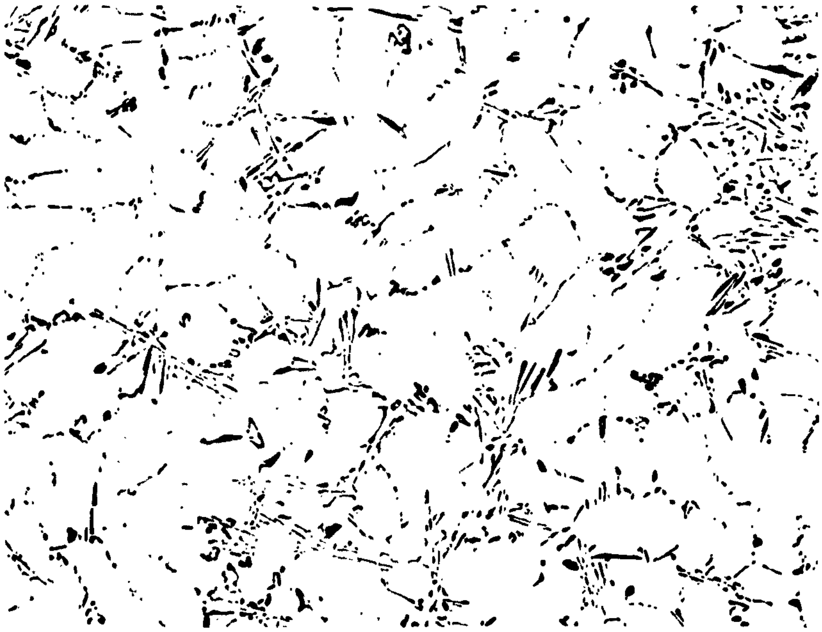


Magn. 100X
Unetched

M 16013

FIGURE 10

Apparently Modified Sand Cast 356-T6 Aluminum Alloy. Aged 3 hours at 350°F (Foundry B) (Si 7.3% - Mg 0.33%)

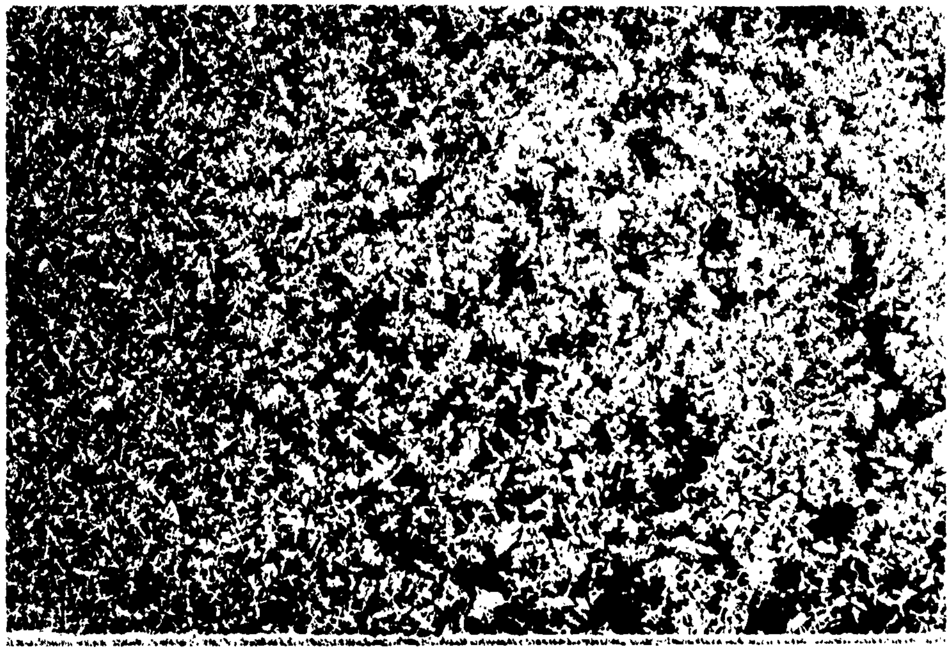


Magn. 100X
Unetched

M 16392

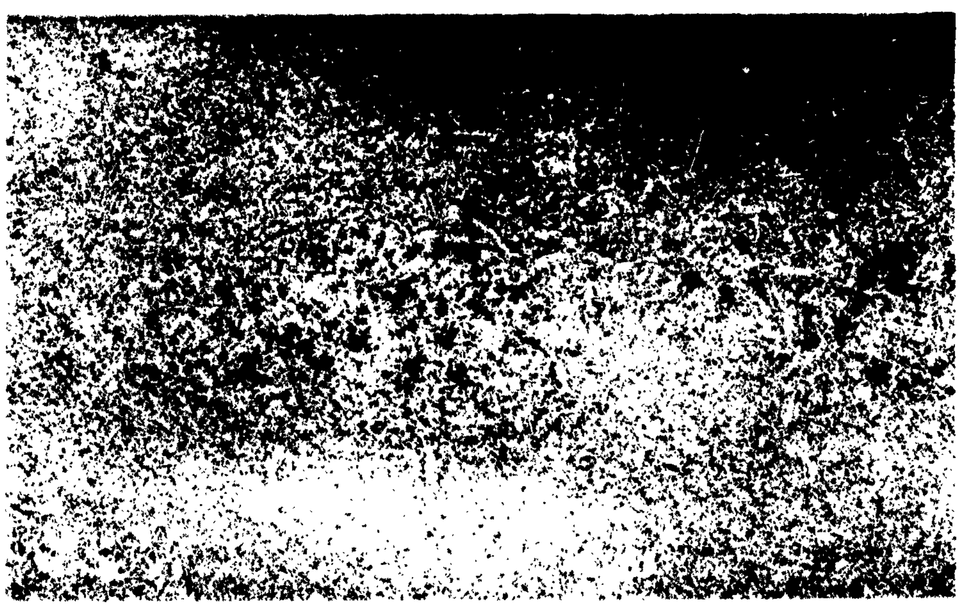
FIGURE 11

Sand Cast 356 - T6 Aluminum Alloy Not Sodium Modified Aged 3 hours at 350°F (Foundry A). (Si - 7.0% - Mg 0.3%)



MAGN. 7.5X FIGURE 12 M17522

CROSS SECTION OF "TEE" BAR ARM AT JUNCTURE WITH BASE
(SAND CAST IN 356-T6 ALUMINUM ALLOY)
ETCHANT: 5 PERCENT HF



MAGN. 7.5X FIGURE 13 M17521

CROSS SECTION OF "TEE" BAR ARM AT JUNCTURE WITH BASE
(CHILL CAST IN 356-T6 ALUMINUM ALLOY)
ETCHANT: 5 PERCENT HF