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DEVELOPMENT OF MANUFACTURING CAPABILITY FOR PRODUCING XXXX HIGH PERFORMANCE ALUMINUM AND MAGNESIUM ALLOY CASTINGS. ILER, A.J.
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MF:
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48p
HC $2.00
JRL.ISS:
mpm/mpm
MF $0.50
REL.DATE
LIMIT:0

QUARTERLY PROGRESS REPORT NO. 2

NOR 64-278

November 1964

Air Force Materials Laboratory
Research and Technology Division

Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

Project No. 8-119

Prepared under Contract No. AF 33(615)-1341

NORTHROP CORPORATION
NORAIR DIVISION
Hawthorne, California

A. J. Iler, Author

FOREWORD

This interim technical report covers the work performed under Contract AF 33(615)-1341 from 1 August 1964 through 31 October 1964. It is published for technical information only and does not necessarily represent the recommendations, conclusions, or approval of the Air Force.

This Contract with Northrop Norair is administered under the direction of Lieutenant W. T. O'Hara of the Air Force Materials Laboratory, MATB, Project Nr. 8-119, Systems Engineering Group (RTD), Wright-Patterson AFB, Ohio.

A. J. Iler of Northrop Norair's Materials Engineering Group was the principal engineer in charge. Major subcontractor was Electronic Specialty Co., Pomona Division, Pomona, California, with Mr. Joseph Raffin, metallurgist in charge of the subcontract engineering effort.

The primary objective of this Air Force Materials Laboratory Program is to assure successful manufacturing methods that will provide aluminum and magnesium alloy systems for "premium quality" cast parts of high strength levels. This report is being disseminated in order that methods and/or alloys may be used throughout the industry, thereby reducing costs and making available higher strength cast aerospace components.

Comments are solicited on the potential utilization of the information contained herein as applied to present or future production programs. Suggestions concerning additional manufacturing technology development required on this subject are solicited.

* *

PUBLICATION REVIEW

Approved by:

W. R. Varney
Chief, Materials Engineering

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I INTRODUCTION

This report is the second in a series of interim reports concerning work performed under Contract AF 33(615)-1341 for development of aluminum and magnesium alloy systems and their associated quality cast parts of high strength levels.

The reporting period covered in this document extends from 1 August to 31 October 1964.

This report describes development work on the Mg-Zn-Ag-Zr alloys; further work on aluminum alloys ST60 and M710; development of a modified aluminum alloy 195; Phase II and Phase III configuration pattern; the first founding experience in the Mg-Zn-Ag-Zr alloy, and a general summary of the program development in terms of significance to the program objective.

II CONTRACT SUMMARY

The following brief summary of the primary contract work statement elements is presented for continuity of this report:

PHASE I - DEVELOPMENT AND EVALUATION OF FOUNDRY PROCESSING METHODS

(a) Development and evaluation of foundry processing methods as related to the most advanced foundry techniques, with further development of those factors offering the most potential to achieve the advance performance characteristics for Air Force requirements.

(b) Selection and evaluation of the most promising magnesium and aluminum base alloys for further development.

PHASE II - TRIAL PRODUCTION

(a) Selection of one magnesium and one aluminum alloy which shows promise for high performance castings.

(b) Production of experimental castings of each alloy using the best casting method, mold materials and processing.

(c) Selection of casting configuration.

(d) Testing of the resulting castings.

PHASE III - PILOT PRODUCTION

(a) Produce 25 aluminum and 25 magnesium castings of the selected configuration of Phase II. These are to be tested metallurgically, environmentally, and statically.

(b) Correlate test data in an attempt to improve current specifications, inspection standards, and design allowables.

III CONCLUSION OF PHASE I - DEVELOPMENT AND EVALUATION OF FOUNDRY PROCESSING METHODS

Mg-Zn-Ag-Zr CASTING ALLOY SYSTEM

The Mg-Zn-Ag-Zr system of magnesium casting alloys was selected for casting development in this program. Metallurgy and founding principles peculiar to the system were obtained from J. W. Meier, Principal Metallurgist (Non Ferrous); and B. Lagowski, Senior Scientific Officer, Canadian Department of Mines and Technical Surveys, Mines Branch, Physical Metallurgy Division. This alloy system incorporates variables of zinc and silver content. These variables may be selected for tailoring alloys for specific engineering requirements in keeping with the new premium engineered concept of casting. Engineering requirements may vary with respect to ductility, tensile strength, and economy. Tensile testing and nondestructive testing performed to date indicate that these criteria may be favored, to a significant degree, by adjustment in zinc and silver content. For instance, a six percent zinc with four percent silver alloy may, in some configurations, produce the highest tensile properties, but might create a microporosity problem requiring time consuming mold rigging development to correct, and a more expensive production procedure with respect to chilling, feeding, and subsequent clean-up. There is ample evidence in actual production that costs increase with mechanical properties and that such costs are congruent with sound economy and usefulness[1]. Where the highest mechanical properties are not required, longer feeding distances and less tendency to develop microporosity can be achieved by increasing zinc and decreasing silver in the alloy[2].

ZQ64 EVALUATION

The first casting effort designated E0001 was with ZQ64, (four percent silver) which would allow an economical use of remelts (gates, risers, and pigs) in subsequent melts using less silver. The load consisted of:

Magnesium	99.9 percent pure	75.0 pounds
Electrolytic Zinc	99.9 percent pure	5.0 pounds
Fine Silver Shot	99.9 percent pure	3.33 pounds
Fused Zirconium Salt		8.30 pounds

The fused salt[3] was a mixture of 2 parts zirconium tetrachloride, 1 part sodium chloride and one part potassium chloride, and contains approximately 20 percent zirconium by weight. Melting was performed in a steel crucible heated in a gas-fired furnace. The magnesium was melted, using Dow 310 flux to prevent burning during the melt-down. The zinc was added to the magnesium at 1300F, and the silver at 1400F. After thoroughly stirring this alloy the fused salt was added at 1400F by containing it in an iron basket until dissolved. The melt was then stirred ten minutes, with a rolling motion from the bottom to the top, while Dow 310 flux was added to control surface burning. After fifteen minutes settling time two samples were taken; one for grain size examination, and one for spectroscopic determination of the zirconium content. Examination showed fine grain and zirconium content of 0.85 percent.

The melt was brought to 1450F, then the crucible was removed from the furnace. Fluorspar was sprinkled on the surface of the melt and the thickened flux skimmed off, using Dow 180 agent to control burning. When the melt was ready to be poured, it was noticed that more liquid flux was rising to the surface, so the crucible was replaced in the furnace to maintain temperature while more fluorspar was added and more skimming done until the surface of the melt appeared flux free.

The molding sand for this casting effort was a 50-50 combination of 35 and 70 AFS fineness Ventura sand, bonded with 2 percent western and 4.5 percent southern bentonite, and inhibited with 2 percent sulphur, 0.3 percent boric acid and 0.5 percent diethyleneglycol.

Two spiral fluidity molds, (2) 0.505 inch diameter test bar molds, and (3) Phase I test casting molds were rammed and coated with carbon black (amorphous carbon).

After pouring the molds, more flux rose to the surface which appeared to contain some metal, so the remainder of the melt was pigged. It was concluded that the difficulty in removing the flux was caused by the closeness of the specific gravity of the Dow 310 flux and the alloy, preventing separation of the flux from the metal. To eliminate this problem HE Blue flux was successfully evaluated and will be used for further work in this magnesium casting alloy system.

Solution heat treatment of the test castings was scheduled at 850F in sulphur dioxide furnace (SO_2) atmosphere for 5 hours. Unfortunately, after 4 hours and 40 minutes, the castings ignited and were reduced to ashes. Apparently, the concentration of SO_2 in the atmosphere had become too weak to inhibit ignition, although external controls appeared to be functioning correctly.

Significant observations from this casting effort are indicated below. Fluidity as indicated by the spiral extension, is comparable to alloy AZ91. Uncoated spirals reached mark 20 compared to mark 22 for AZ91, but carbon black coated spirals reached mark 23 3/4 compared with mark 24 for AZ91; zirconium content was determined spectrographically at 0.85 percent after 15 minutes of settling, 0.83 percent after 45 minutes, and 0.80 percent after 65 minutes (which was immediately before pouring). Zinc content was analyzed at 6.2 percent by spectrographic analysis of a test casting and the silver content at 4.19 percent by wet analysis. The average mechanical properties of the as cast test bars were as follows:

Tensile strength	32,700 psi
Yield strength	19,600 psi
Elongation in 2 inches	4.5 percent

ZQ64 - Mechanical Properties

A second melt of ZQ64, designated E0004, was prepared and poured under the same foundry conditions reported for melt E0001 except that HE Blue flux was used with no problems of flux removal from the melt. Mechanical properties were as follows:

Sand Castings

Separately Cast .505 inch diameter Test Bars

Heat Treat Condition	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inch
As cast	33,000	21,000	4.0
T4 (Solution 830F)	47,000	19,000	13.0
T6 (Solution 830F)			
ranged from a low of	48,000	32,000	6.0
to a high of	51,000	30,000	9.0

Sand Cast Phase I Casting

Section Thickness	-T4 Condition Tensile Strength psi	Yield Strength psi	Elongation Percent in 2 inches	-T6 Condition Tensile Strength psi	Yield Strength psi	Elongation Percent in 2 inches
.750	40,600	17,800	10.0	46,500	32,700	5.5
.250	44,700	22,500	10.0	48,000	36,500	5.0
.500	38,800	20,400	7.5	43,300	32,400	4.0
.250	40,200	21,600	8.0	43,500	35,700	3.5
.380	41,800	25,100	6.0	47,300	34,500	7.0
.125	41,900	28,700	8.0	40,600	34,700	2.0
.125	--	--	--	46,100	31,600	6.0
.125	--	--	--	49,800	34,500	12.0

Permanent Mold Cast

Separately Cast .505 inch Diameter Test Bars

Heat Treat Condition	Tensile Strength, psi	Yield Strength,psi	Elongation Percent in 2 inches	Quality (ASTM E155-60T)
As Cast	31,100	--	5.0	#4 Microporosity
T4 Air Quench	38,900	19,600	8.0	#4 Microporosity
T6 Air Quench	42,400	28,600	3.5	#4 Microporosity

(Water Quenched Cast Bars Cracked)

Permanent Mold Stepped Castings

Section Thickness	Quench Method	Tensile Strength,psi	Yield Strength,psi	Elongation Percent in 2 inches	Quality
1.00	Air	36,100	28,400	3.0	6-7 Microporosity
.50	Air	44,800	30,900	7.0	5-6 "
.30	Air	43,000	33,600	4.5	2-3 " & Flux inclusions
.30	Water	41,000	35,000	2.5	2-3 " "
.20	Water	43,700	35,400	3.0	4-6 Microporosity & Flux inclusions
.10	Air	42,400	33,600	4.0	5-7 Microporosity
.10	Water	39,200	32,700	1.5	5-7 " & Flux inclusions

ZQ64 Quality

Microporosity observed in the Phase I castings was less than that of ASTM E155-60T Grade 1. In the similar permanent mold stepped casting, microporosity ranged from Grade 2 to 3 in the 0.380 inch section to Grade 7 in the 0.100 inch section. It is interesting to note how insensitive the tensile properties are to such gross microporosity. Fluorescent penetrant inspection revealed gas pin holes approaching Grade 1 in the appearance of flow lines.

Part Number 4655698 (Figures 1 and 2)

ZQ64 was cast in this production permanent mold and coupons exised as noted. Mechanical properties were noticeably improved by water quench:

Coupon Identity	Quench Method	Tensile Strench,psi	Yield Strength,psi	Elongation Percent in 2 inches	Quality (ASTM E1555-60T)
*L (Flat)	Air	48,100	36,900	7.0	1
H (Round)	Air	50,500	34,250	9.4	1
H (Round(	Water	51,000	35,150	14.1	1

* Specimen failed prematurely because of a flaw.

ZQ71

An experimental casting effort in ZQ71 designated H0001 was made. The load consisted of:

Alloy ZQ64		20.0 pounds
Magnesium	99.9 percent pure	59.4 pounds
Zinc	99.9 percent pure	4.6 pounds
Fused Zirconium Salt		7.0 pounds

Melting practice was similar to that used with ZQ64 except that the HE Blue flux was used with no problems of flux removal.

The sand was 35-70 sand as used for ZQ64, which tested:

Permeability	86 AFA
Green Compressive Strength	11.5 psi
Moisture	3.4 percent

Four 0.505 inch diameter test bar molds with four cavities each, three spiral fluidity molds, two chilled Phase I casting molds, and one unchilled Phase I casting mold were rammed and poured. The castings were solution heat treated at 860F for 16 hours. Added precautions included a new bottle of sulphur dioxide (SO_2) and additional thermocouple probes which were placed in different furnace locations near the castings.

Iron pyrite was placed in the furnace to provide an additional source of sulphur dioxide to the regular supply which is fed from a liquified sulphur dioxide tank.

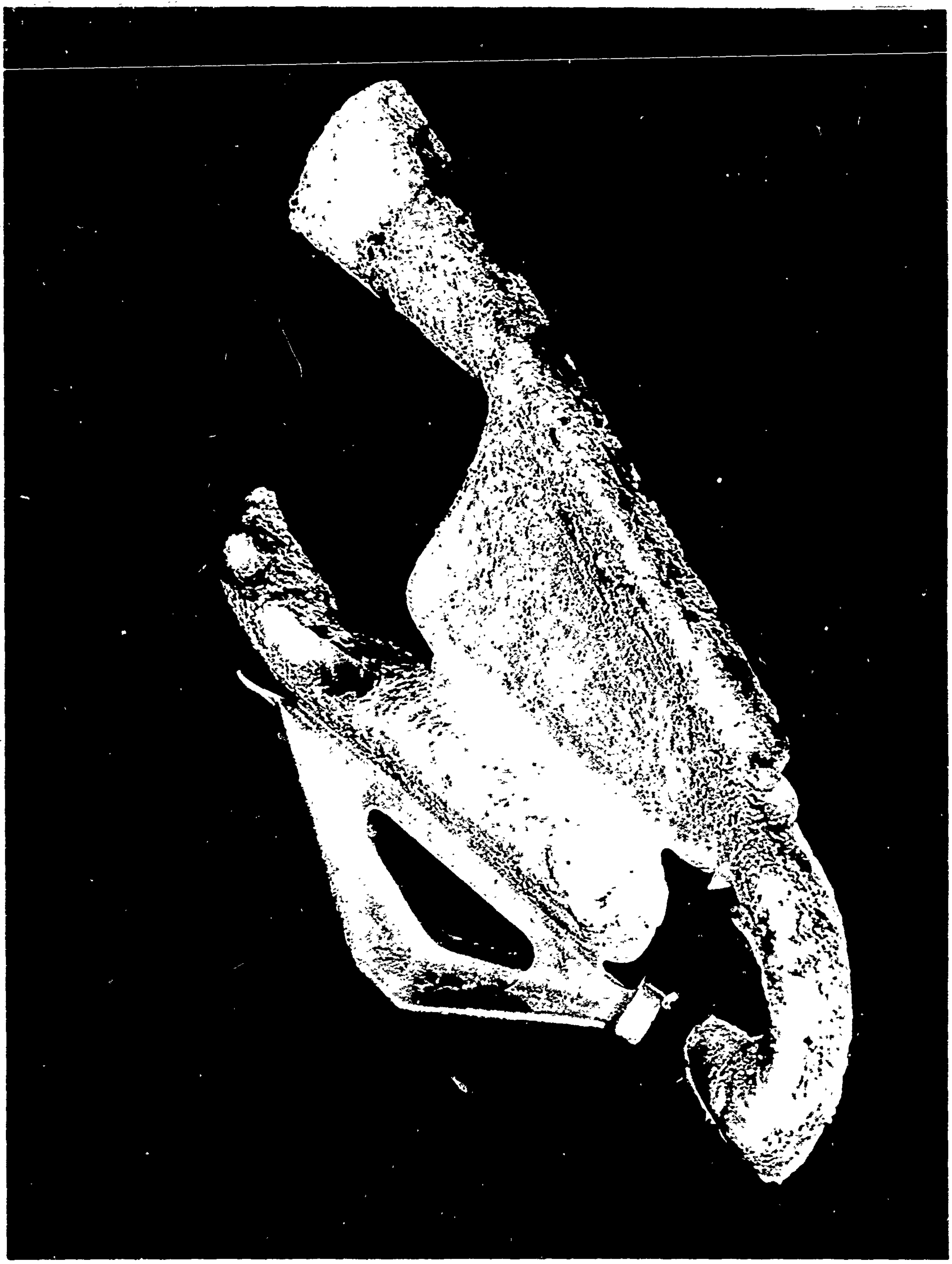

FIGURE 1 TYPICAL SMALL PERMANENT MOLD CASTING WITH GATING MADE IN AN IRON MOLD CAVITY (PART NO. 4055698)

FIGURE 2 PART NO. 4655698, SHOWING TEST COUPON REMOVAL SITES

Quenching was done by cold air blast, and the parts were subsequently aged at 300F for 48 hours.

Fluorescent penetrant inspection indicated good quality castings with no cracks or cold shuts. X-ray inspection of the chilled castings revealed excellent quality in the 0.12 inch and 0.15 inch thick sections of the test castings, approximately Grade 1 microporosity in the 0.38 and 0.50 inch sections, and Grade 2 in the 0.75 inch sections. (Graded according to ASTM E155-60T). The unchilled casting had very heavy spongy microshrinkage; approximately Grade 8 in the heavy areas, approximately Grade 5 in the 0.38 area, Grade 2 in the 0.25 inch thick area and no microporosity in the 0.12 inch thick area. A logical conclusion is that thin areas can be solidified (with respect to grosser types of radiographic microdiscontinuities) with good quality without chills providing feeding is not starved, and that feeding distances are shortened in proportion to section thickness.

The zinc and zirconium contents were determined spectographically at 7.2 and 0.84 percent respectively. The silver content was determined by wet analysis at 0.84 percent.

Tensile test results for the 0.505 diameter test bars were as follows:

Heat Treat Condition	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
T4	36,800	18,200	8.5
T6	45,400	30,400	5.7
As Cast	37,400	20,700	6.5

Values for the As Cast and T4 conditions are reported from the test of one bar each and for the T6 condition from an average of 3 bars.

The hot shortness characteristic of ZQ71 has not been found to be critical. The vertical tabs on the Phase I test casting, placed there for determining this characteristic, showed on cracking tendency, and permanent mold castings in both aluminum and iron molds did not exhibit cracks which would indicate problems of any great magnitude.

Microshrinkage is intense in heavy sections when a strong directional solidification is not induced by chills and gating, or risers. The following table summarizes the radiographic inspection of stepped castings in both sand and permanent mold, with respect to spongy microshrinkage.

Section Thickness	Phase I Sand Casting Chilled	Phase I Sand Casting Unchilled	* Permanent Mold Stepped Casting
.100-.120	Less than 1	Less than 1	6
.200-.250	Less than 1	Less than 2	3
.300-.380	1	5	4
.500	1	8	6
.750-1.00	2	8	8

* Graded per ASTM E155-60T.

ZQ71 Mechanical Properties

The mechanical property averages for ZQ71 in various heat treat conditions and cast in various molding media are as follows:

Sand Castings

Separately Cast Test Bars

Heat Treat Condition	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
As Cast	37,400	20,700	6.5
T4 Solution at 840F air quench	44,200	16,300	15.5
T4 Solution at 840F with water quench	44,400	18,300	16.0
T6 Air quench heavy blast	48,600	30,300	5.5
T6 Water quench	48,100	31,800	2.5
T6 Air quench moderate blast	46,200	30,400	6.0

Phase I Casting - T6 Condition

Section Thickness	Quench Method	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
.75	Air	45,500	29,500	10.0
.25	Air	47,200	32,200	13.0
.50	Air	46,300	31,300	12.5
.50	Water	47,500	35,000	9.5
.25	Air	45,900	31,700	10.5
.38	Air	48,200	35,300	6.0
.12	Air	36,700	32,600	9.5
.12	Air	45,200	31,400	10.0
.12	Water	49,200	36,500	10.0

Permanent Mold

Separately Cast Test Bars

Heat Treat Condition	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
As Cast	35,500	17,000	8.0
T4 Condition Air Quench	39,600	18,200	14.0
T4 Condition Water Quench	39,600	15,800	13.0
T6 Condition Air Quench	45,100	29,200	6.5
T6 Condition Water Quench	46,600	29,900	6.0

Stepped Casting - T6 Condition

Section Thickness	Quench Method	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
.500	Air	39,300	38,800	3.0
.300	Air	40,400	30,200	3.5
.200	Air	44,700	34,100	6.5
.100	Air	43,700	32,700	5.0
Casting No. 4655698				
.100	Air	44,100	33,800	6.0
.100	Water	45,000	35,600	4.0
.250	Air	48,900	34,100	4.1
.250	Water	50,300	36,500	14.1

A review and analysis of the foregoing test data indicates that the effect of soundness, chilling, and heat treating practices on the mechanical properties of ZQ71 may be summarized thus:

Tensile Strength

Unchilled separately sand cast .505 inch diameter test bars had an average tensile strength of 48,600 psi when air quenched before a strong fan blast; 48,100 psi when water quenched, and 46,600 psi air quenched before a weak blast.

Permanent mold separately cast test bars averaged 45,100 psi when quenched in water. Considering the Grades 4 and 5 (ASTM E155-60T) microshrinkage found in these test bars, these results are excellent when compared with the less than Grade 1 in the sand cast test bars.

In chilled sand castings with thick and thin sections (Phase I test castings) tensile strengths ranged from 45,200 psi to 48,200 psi in air quenched castings, and 47,500 psi to 49,200 psi in water quenched castings. Section thickness had little effect on tensile strength. For instance, 45,200 psi was exhibited in the 0.12 inch section and 45,500 psi in the 0.75 inch section, with 48,200 psi obtained in the 0.38 inch section.

Permanent mold castings appear to be practical when thin, fairly uniform, sections are specified. Properties in Part No. 4655698, which has fairly uniform sections and did not develop microshrinkage, ranged from 44,100 psi air quenched to 50,300 psi water quenched.

Yield Strength

	Quenching Method	
Sand Casting	Air	Water
0.505 Diameter Test Bars	30,300 psi	31,800 psi
Phase I castings	29,500 to 32,600 psi	35,000 to 36,500 psi
Permanent Mold Castings		
0.505 Diameter Test Bars	29,200 psi	29,900 psi
Stepped Casting	28,800 to 34,100 psi	35,600 to 36,500 psi

Elongation

Elongation in separately sand cast 0.505 inch diameter test bars ranged from 5.5 to 6.0 percent air quenched, but dropped to 2.5 percent when water quenched. Permanent mold separately cast .505 inch test bars ranged from 6.0 to 6.5 percent in spite of microshrinkage which appears to be inherent in permanent mold castings in this alloy. Chilled sand castings averaged 10 percent whether air or water quenched. Elongation in permanent mold specimens ranged from 3 to 14 percent and was proportional to the intensity of the microshrinkage. Water quenching did not affect elongation.

ZQ71 Phase I Summary

Alloy ZQ71 has good fluidity, and hot shortness is not a serious problem. Feeding capability is poor, but proper rigging will overcome this difficulty and should contribute to good premium strength castings. There is a tendency for dross and flux contamination. Mechanical properties obtained are worth the effort. Chilling and interspersed gating will have to be used extensively because of relatively short feeding distances. Large or complex castings will be proportionately difficult to produce with optimum properties throughout. It should be mandatory that stress zone marking be furnished for practical economical utilization of the capabilities of magnesium alloy ZQ71.

It is recommended that foundry practice should provide for more than one screen in the gating, dross traps, careful sand analysis and inert gas purging of the mold cavity before pouring.

ZQ91

As recommended by J. W. Meier, a melt of ZQ91 designated J0001 was prepared. Mr. Meier had done work with this alloy at the Canadian Bureau of Mines and found castings to be exceptionally free of microporosity while exhibiting mechanical properties somewhat comparable to other alloys of the Mg-Zn-Ag-Zr system.

The charge was composed of:

Magnesium	99.9 percent pure	27.0 pounds
Gates & pigs from melt H0002		55.0 pounds
Zinc	99.9 percent pure	3.6 pounds
Fine silver shot		.3 pound
Fused zirconium salts		6.0 pounds

Sand molds were prepared as follows:

1 Phase I casting with no chills
1 Phase I casting with small chill (1.25 inch wide)
1 Phase I casting with heavy chill (2.50 inch wide)
1 spiral fluidity casting
2 4-cavity 0.505 inch test bars
5 stress corrosion test rings

The castings were solution heat treated at 750F for 5 hours, using approximately 2 percent concentration of SO_2 gas atmosphere plus iron pyrite in the furnace. Thermocouples were placed on the castings for accurate temperature control. Quenching was done with a strong blast of room temperature air, and 2 test bars were quenched in 190F water. All but 2 test bars were aged at 265F for 48 hours and these two test bars were not aged.

Mechanical Properties

Mechanical Properties resulted as follows:

Phase I Test Casting - With no Chills

Section Thickness	Tensile Strength,psi	Yield Strength,psi	Elongation Percent in 2 inches	Microporosity
.75	42,400	32,400	5.0	Grade 5
.25	41,500	30,700	4.0	Grade 4
.50	38,500	28,600	3.0	Grade 6
.25	44,400	30,800	6.0	Less than 1
.38	47,000	32,200	8.5	Less than 1
.12	40,600	30,000	4.0	Less than 1

Phase I Test Casting - With Small Chill

Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches	Microporosity
.75	42,400	29,800	5.0	1
.25	44,900	31,600	6.5	1
.50	44,800	30,700	7.5	1
.25	47,100	31,500	11.0	1
.38	44,600	30,900	7.5	1
.11	41,200	34,000	3.0	1

Phase I Test Casting - With Heavy Chill

Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches	Microporosity
.75	43,200	29,150	5.0	1
.25	43,250	30,900	4.5	1
.50	43,000	30,450	5.5	1
.25	45,900	29,650	7.5	1
.38	44,700	31,150	7.0	1
.12	44,450	31,950	5.5	1

These reports indicate that ZQ91 produces nearly optimum mechanical properties, when properly fed without chills in thin sections; properties drop a little as sections increase, and are subject to rejectionable microporosity in heavy sections. They also indicate that moderate chilling is as effective as heavy chilling.

The graphs shown in Figures 3 and 4 summarize test data of the Mg-Zn-Ag-Zr testing accrued through Phase I activity.

PHASE I ALUMINUM ALLOY SYSTEMS

M710

Appendix I of interim Report Number One, listed some typical properties obtained from M710 cast in the Phase I pattern molds before the gating had been modified. It was noted that test bars excised from the castings were fracturing at the extreme end of the gage length opposite the gate. The gating was modified by placing runners and gating on both sides of the pattern (Figure 5) to supply good feeding; as a result better mechanical properties were obtained.

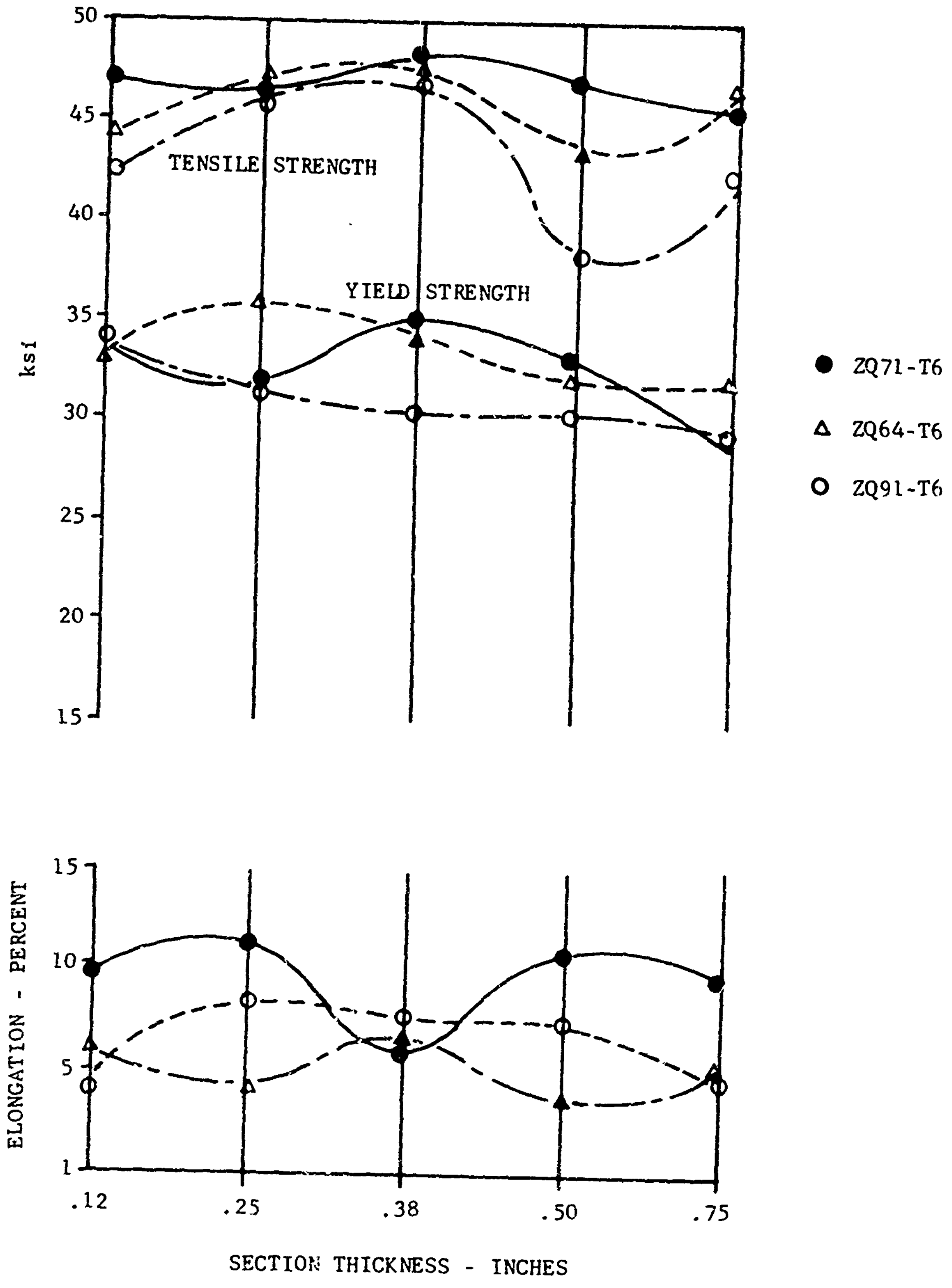

FIGURE 3 Mg-Zn-Ag-Zr CASTING ALLOYS PHASE I SAND CASTING

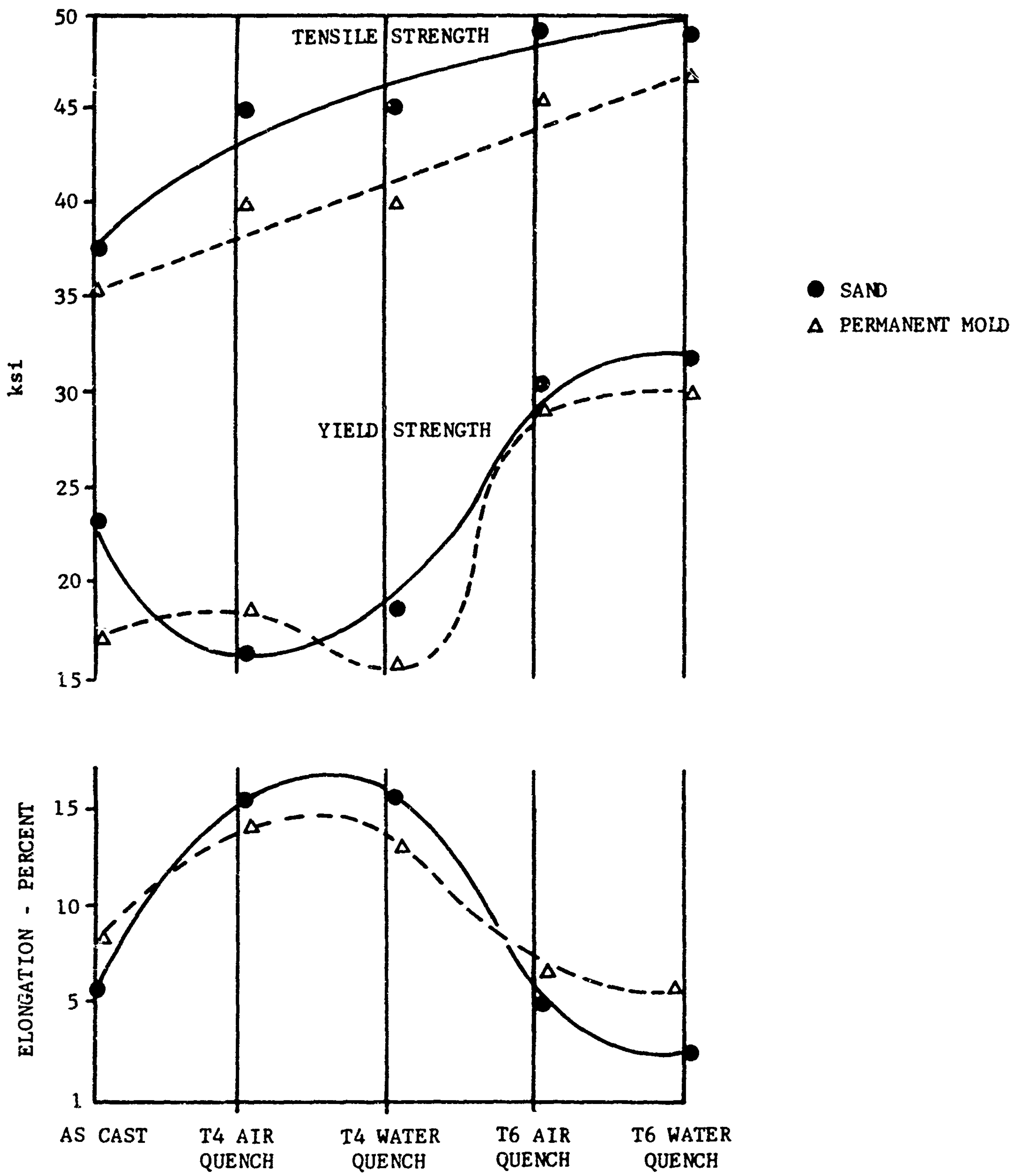

FIGURE 4 ZQ71 SEPARATELY CAST TEST BARS (.505)

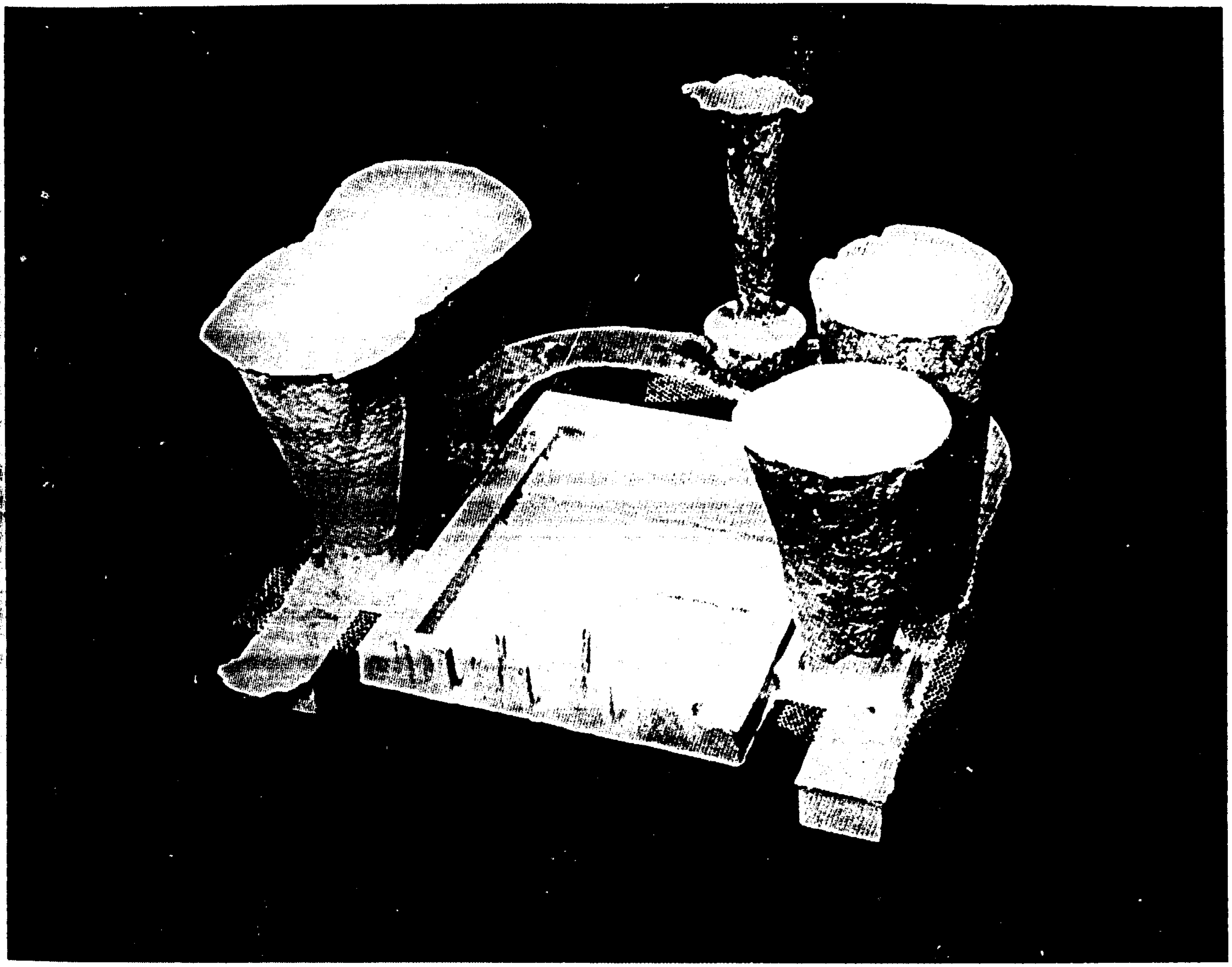

FIGURE 5 PHASE I CASTING CONFIGURATION WITH GATING

● SAND
▲ PERMANENT MOLD

Typical properties are as follows:

Sand Castings

Phase I Casting T6 Condition

Coupon Identity	Tensile Strength,psi	Yield Strength,psi	Elongation Percent in 2 inches
1	50,700	44,150	6.0
2	52,800	45,000	6.5
3	52,500	44,900	8.5
4	53,150	45,600	8.0
5	52,650	44,100	9.0
6	51,400	43,000	5.0
7	53,900	42,800	11.0 (in 1 inch)

Permanent Mold, PART NO. 4655698

	Tensile Strength,psi	Yield Strength,psi	Elongation Percent in 2 inches
Round Bar	53,400	51,200	Insufficient gage length
Flat Bar	57,050	53,650	3.0 (1.00 inch gage length

Permanent Mold Stepped Casting, Figure 6

Coupon Identity	Tensile Strength,psi	Yield Strength,psi	Elongation Percent in 2 inches
2	56,050	53,300	3.5
3	57,600	54,500	4.0
4	58,100	53,050	3.5
5	56,200	50,200	3.5

(Coupon No. 1, a one inch section, had a piping defect)

It is noticeable that this alloy responds favorably to rapid chilling. The stepped permanent mold is an aluminum mold cavity insert in an iron permanent mold which transfers heat more rapidly than conventional iron permanent molds. The difference in elongation between the sand castings and the permanent mold castings is considered to be a result of aging time and/or temperature variables rather than the molding method. It is interesting also to note how comparable the yield and tensile strengths are.

ST60

Previous reporting listed mechanical properties obtained from Phase I sand casting effort, using the Phase I pattern, as:

Tensile Strength,psi	Yield Strength,psi	Elongation Percent in 2 inches
High - 59,600	45,500	15.0
Low - 55,150	42,300	9.0
Average - 57,100	43,800	9.8

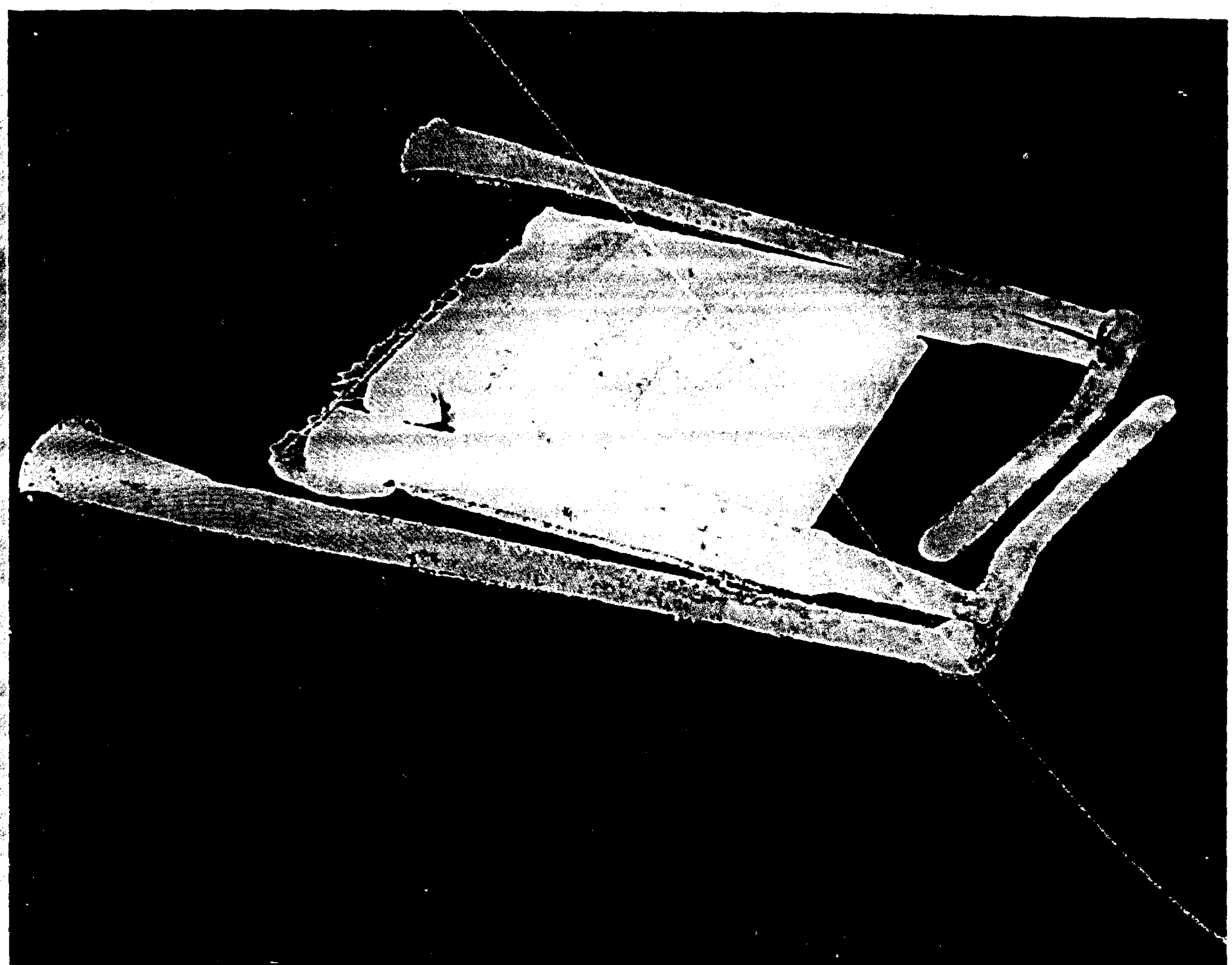

FIGURE 6 STEPPED TEST CASTING WITH GATING PRODUCED IN AN IRON PERMANENT MOLD WITH AN INSERTED ALUMINUM MOLD CAVITY

The mechanical properties obtained from tests of specimens from the second and third heats which had been poured in Phase I sand molds with modified gating and using chills with only a light mold wash resulted as follows:

Coupon Identity	Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
1-2	.75	53,850	43,300	6.0
2-2	.25	56,000	44,900	7.0
3-2	.50	54,950	43,400	7.5
4-2	.25	54,200	44,900	5.5
5-2	.38	55,000	42,400	8.0
6-2	.12	57,250	42,300	10.0
7-2	.12	59,850	45,150	15.0 (in 1 Inch)

The fourth heat was poured in a permanent mold, using the stepped aluminum insert mold referred to previously. Two castings solution heat treated at 930F for 20 hours and aged at 320F for 10 hours and 14 hours respectively were tested. Coupon number 1 was defective and not tested. The results were as follows:

Section Thickness	Coupon Identity	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
.75	2-1	46,450	40,650	2.0
.50	3-1	48,600	43,850	2.0
.30	4-1	52,300	45,050	3.0 (flaw)
.20	5-1	49,300	44,900	2.0 (flaw)
.75	2-2	46,550	43,250	1.0
.50	3-2	50,250	48,200	1.5 (flaw)
.30	4-2	52,650	49,350	2.0 (flaw)
.20	5-2	56,200	47,600	6.0

Modified Aluminum Alloy 195

Foundry metallurgists have, for years, endeavored to utilize the superior potential mechanical property capabilities of aluminum alloy 195, but have not progressed to the point of resolving hot short tendencies and susceptibility to stress corrosion. Recent developments in mold rigging and alloying have renewed the interest among foundrymen, so an effort in this direction is included in this program.

Mr. Joseph Raffin, Chief Metallurgist, Electronic Specialty Company, did some work in a radical modification of alloy 195 in 1962. As this alloy is considered proprietary, the chemistry will not be reported at this time. Several heats were poured in the Phase I casting and in the stepped permanent mold. Some of the results are listed as follows:

Phase I Test Casting -T6 Condition Unchilled

Coupon Identity	Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
1	.75	46,350	30,400	9.0
2	.25	51,100	37,150	8.0
3	.50	43,850	30,450	10.0
4	.25	45,200	33,300	9.0
5	.38	43,150	29,500	9.5
6	.12	47,750	35,200	7.0
7	.12	52,750	34,150	20.0 (in 1 inch)

Phase I Test Casting -T6 Condition Chilled

Coupon Identity	Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
1	.75	60,000	38,200	11.0
2	.25	63,650	44,100	11.0
3	.50	58,700	45,000	11.5
4	.25	59,900	43,350	12.5
5	.38	60,550	39,700	14.0
6	.12	64,100	39,700	12.0
7	.12	65,900	43,750	20.0 (in 1 inch)

Phase I Test Casting -T6 Condition Chilled

Coupon Identity	Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
1	.75	62,250	44,500	11.0
2	.25	67,250	49,550	11.5
3	.50	60,850	44,150	14.0
4	.25	61,000	47,700	8.0 (flaw)
5	.38	58,050	45,550	14.0
6	.12	64,400	46,900	9.0
7	.12	67,550	48,350	16.0 (in 1 inch)

This alloy apparently responds to heavily chilled sand casting with better results than to permanent mold casting. Two permanent mold stepped castings were poured, with the following results:

Coupon Identity	Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
Casting Number 1				
1-1	1.00	53,250	45,700	4.0
2-1	.50	58,950	45,550	10.0
3-1	.30	53,650	49,250	3.0
4-1	.20	62,800	49,250	8.0
5-1	.10	61,950	46,900	10.00

Coupon Identity	Section Thickness	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
Casting Number 2				
1-2	1.00	45,100	36,350	3.5
2-2	.50	55,750	37,800	11.0
3-2	.30	53,700	41,500	4.5
4-2	.20	62,350	38,550	11.0
5-2	.10	58,350	41,650	9.5

Two permanent mold castings of Part No. 4655698 were tested with the following results:

Coupon Identity	Tensile Strength, psi	Yield Strength, psi	Elongation Percent in 2 inches
Casting Number 1			
F-1	50,550	49,050	3.0 (flaw)
R-1	61,450	58,750	4.0
Casting Number 2			
F-2	63,050	41,700	15.0
R-2	57,800	40,000	6.0

IV PHASE II AND III CASTINGS

The basis for selection of the final test configuration included:

- Typical founding problems
- Direct comparison to correlative wrought product
- Current component need in Air Force weapon systems
- Availability of an existing environmental testing apparatus
- Configuration complexity sufficient to prove the adequacy of founding materials and processes

The T-38 Talon supersonic trainer nose landing gear strut cylinder met these needs. In addition, the severe static testing these parts will be subjected to, when Phase III castings are tested, may add more quantitative information to the growing realization that there may be stress redundancy in premium quality castings, not usually considered in stress analysis.

A cope and drag pattern was prepared, Figure 7, gating and chilling tried for first casting attempt, Figure 8, and a casting produced in aluminum alloy A356, Figure 9. With this rigging, one each of ZQ64, ZQ71, and modified 195 alloy have been poured to test the effect of gating and chilling. (Figures 10 and 11)

The ZQ71 casting did not exhibit fluorescent penetrant or X-ray defects caused by hot shortness, but ZQ64 and modified 195 alloys had some hot cracking. The rigging will be modified to correct this before further casting effort is made.

Tensile testing of the landing gear strut cylinder castings has not been accomplished to date.

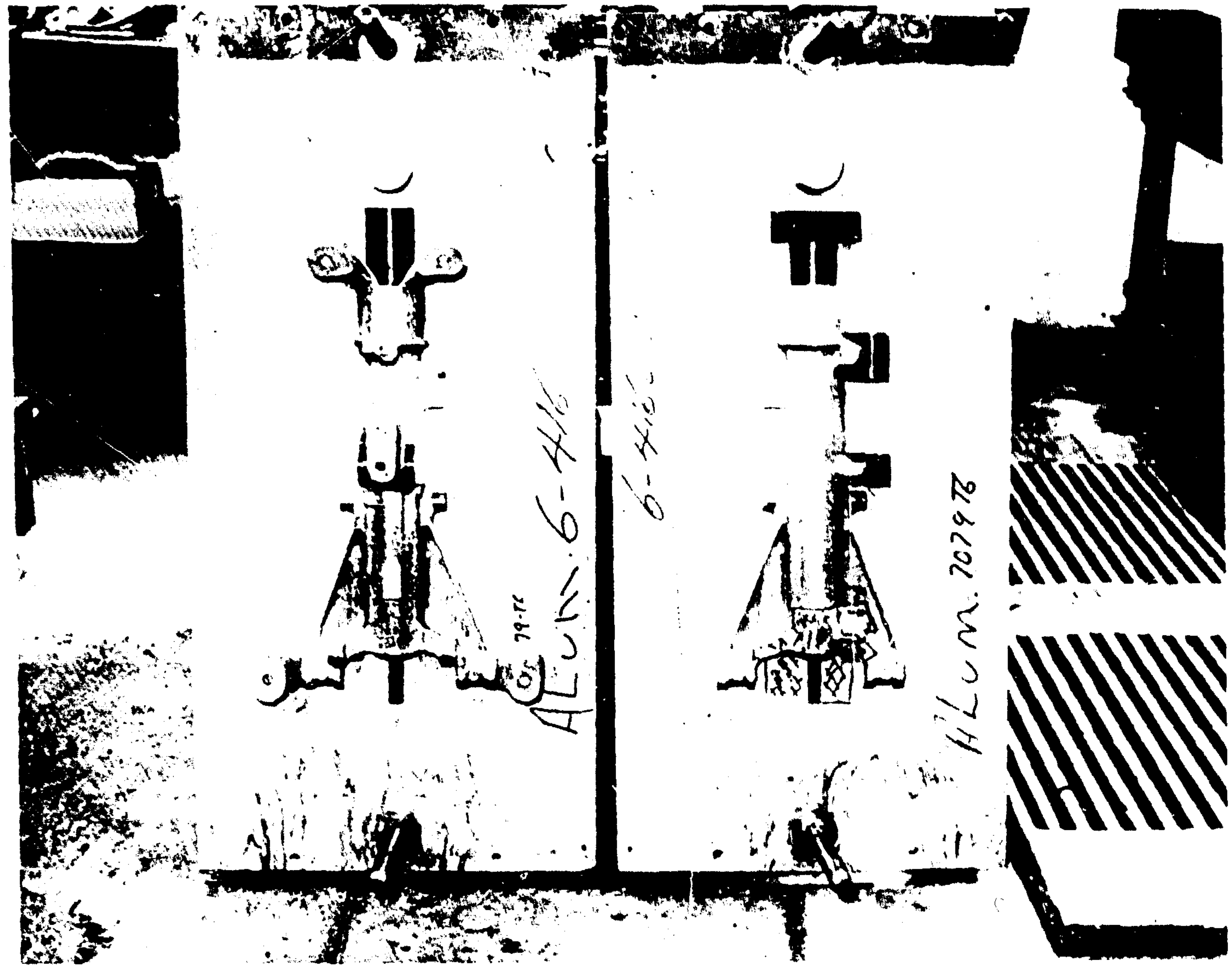

FIGURE 7 COPE AND DRAG PATTERN FOR LANDING GEAR STRUT CYLINDER CASTING

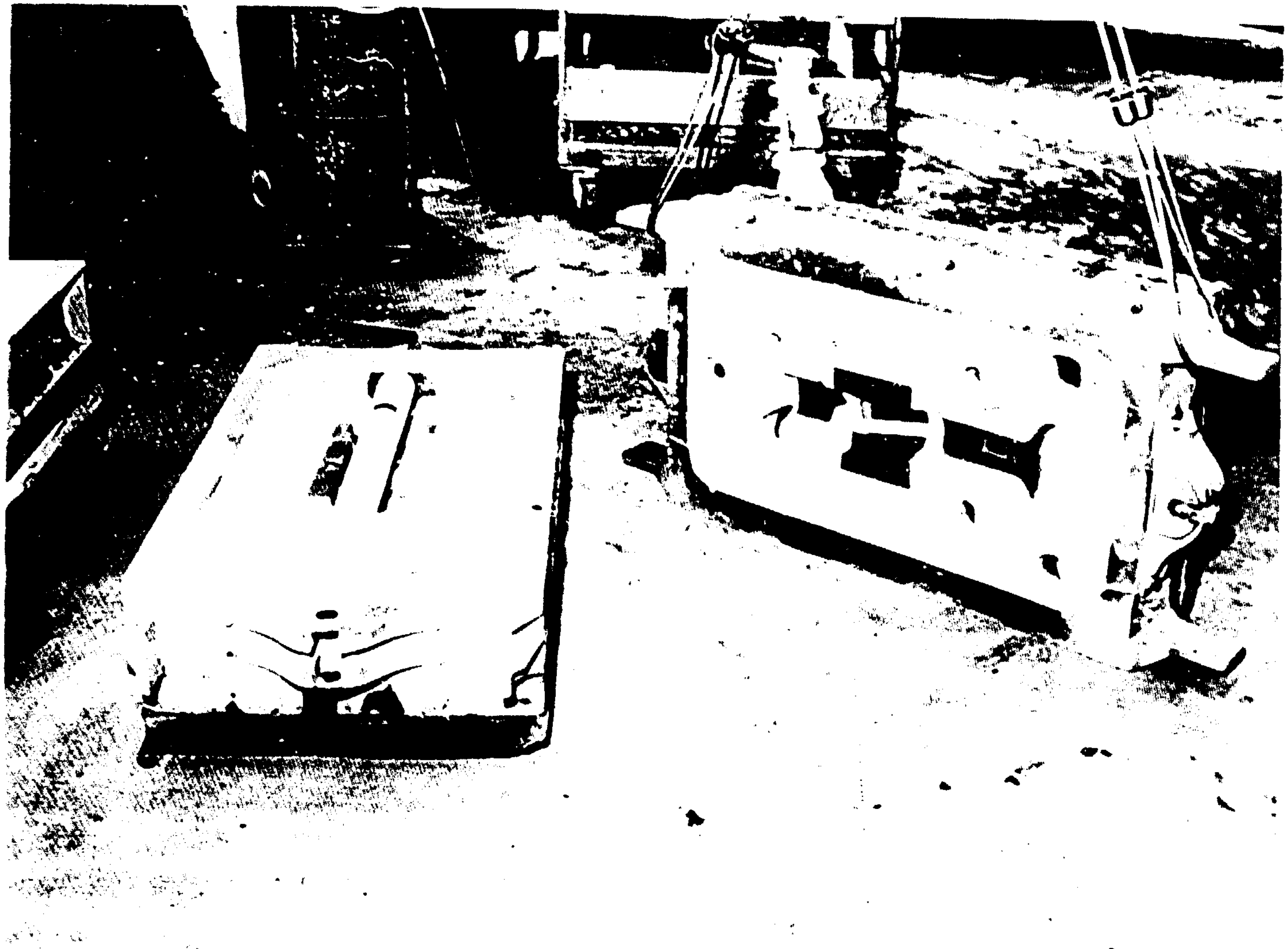

FIGURE 8 GATING AND CHILLING OF LANDING GEAR STRUT CYLINDER CASTING MOLD

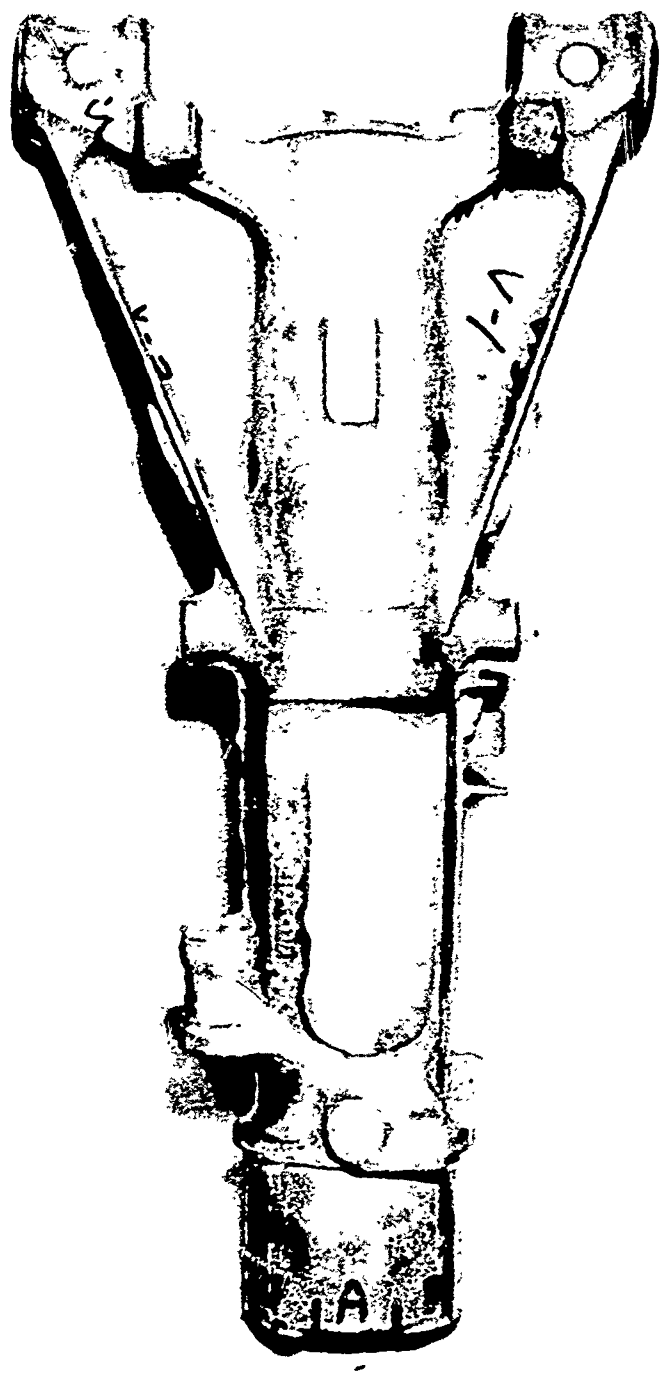

FIGURE 9 ALUMINUM ALLOY 356 CASTING MADE WITH FIRST MOLD RIGGING

FIGURE 10 POURING ZQ64 MAGNESIUM ALLOY

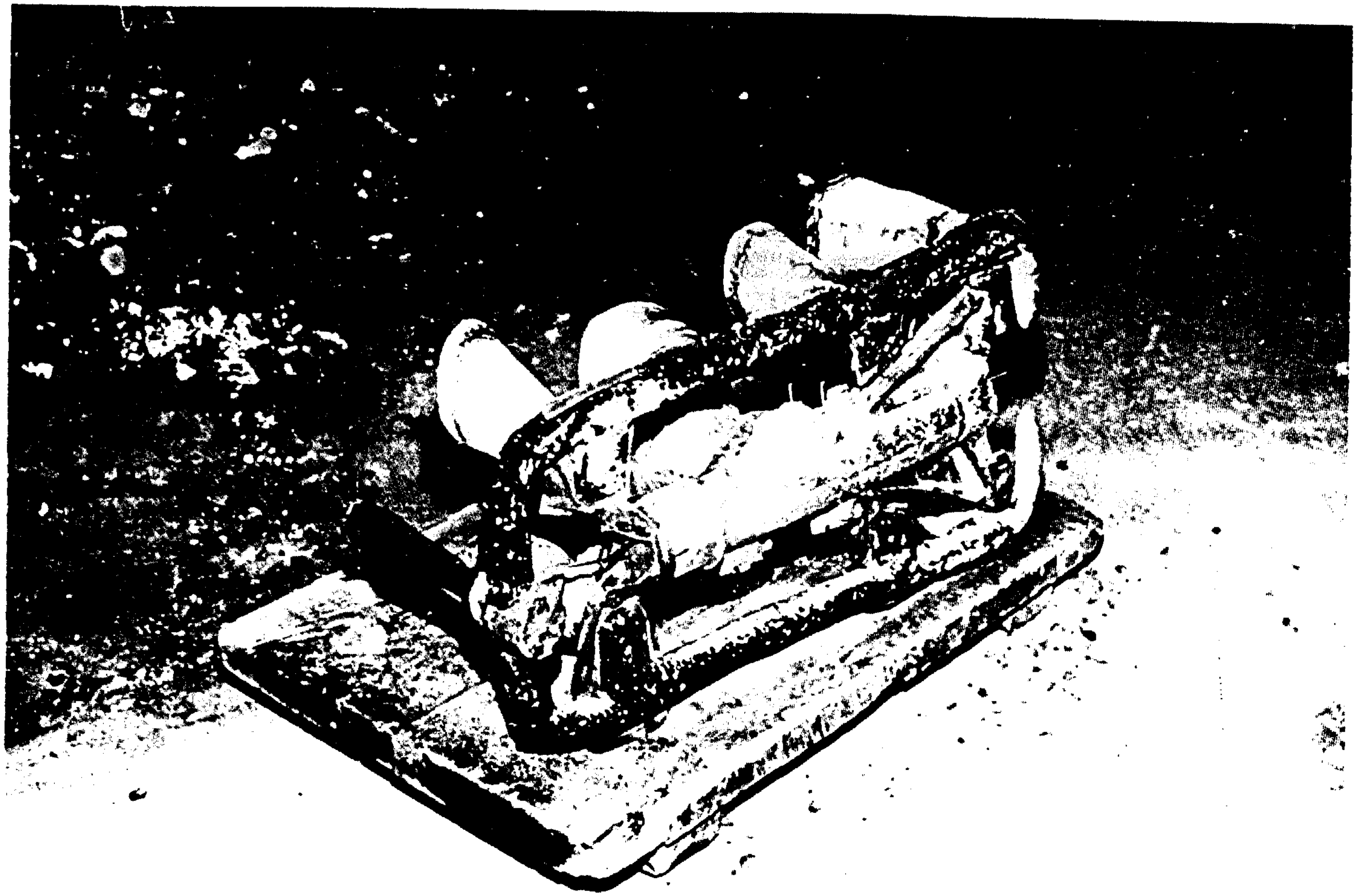

FIGURE 11   ZQ64 CASTING AFTER SHAKE-OUT

STRESS CORROSION ASPECTS

Production use of the alloys in this program will encounter some gradient of susceptibility to stress corrosion attack. Since aluminum alloy 356 and magnesium alloy AZ91 are currently standard alloys for 80 percent of light alloy castings used on Air Force weapons systems, stress corrosion coupons are being cast of these alloys as well as of the new alloys being studied in the program. Figure 12 shows the pattern prepared for this purpose. Rings, with sections as equal as is common to the sand casting method, are being cast. The gate shown on this pattern has been enlarged because a concentration of microshrinkage near the gate was in evidence in the magnesium cast rings. These rings will furnish a continuity of test methods used to study stress corrosion susceptibility of T-38 main landing gear strut cylinders, thereby correlating with other data. Figures 13 and 14 illustrate the method. Details of the cast ring stress corrosion testing will be delineated in later reporting.

V WORK PROJECTED FOR NEXT QUARTER

Continuing modification of the landing gear strut cylinder casting mold rigging to produce the optimum in quality and mechanical properties.

Dimensional check and, if necessary, pattern correction to assure accuracy of parts to be used in Phase III environmental testing.

Casting the landing gear strut in each of the magnesium and aluminum alloys considered best for Phase III activity until the process is refined with respect to acceptable nondestructive testing quality.

Determine the mechanical properties of each landing gear strut by tensile testing coupons excised from stress significant areas.

Perform stress corrosion testing of the cast rings.

Perform fatigue and charpy impact testing of coupons from landing gear struts cast in each of the selected alloys.

Prepare a summary of Phase II activity for Air Force approval.

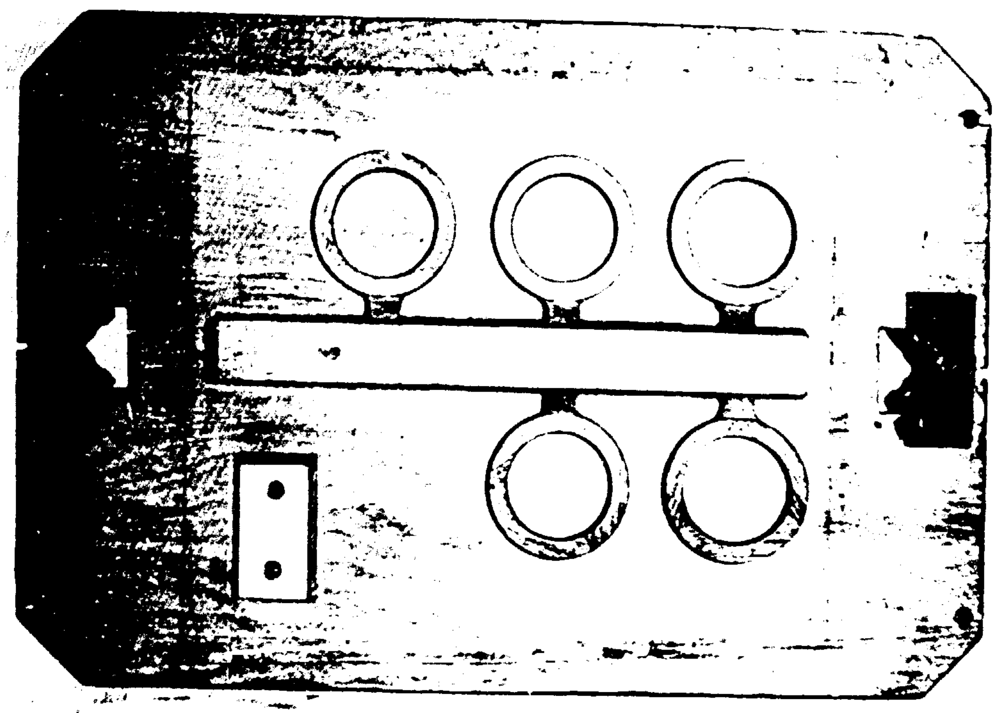

FIGURE 12 PATTERN FOR STRESS CORROSION TEST CAST RINGS

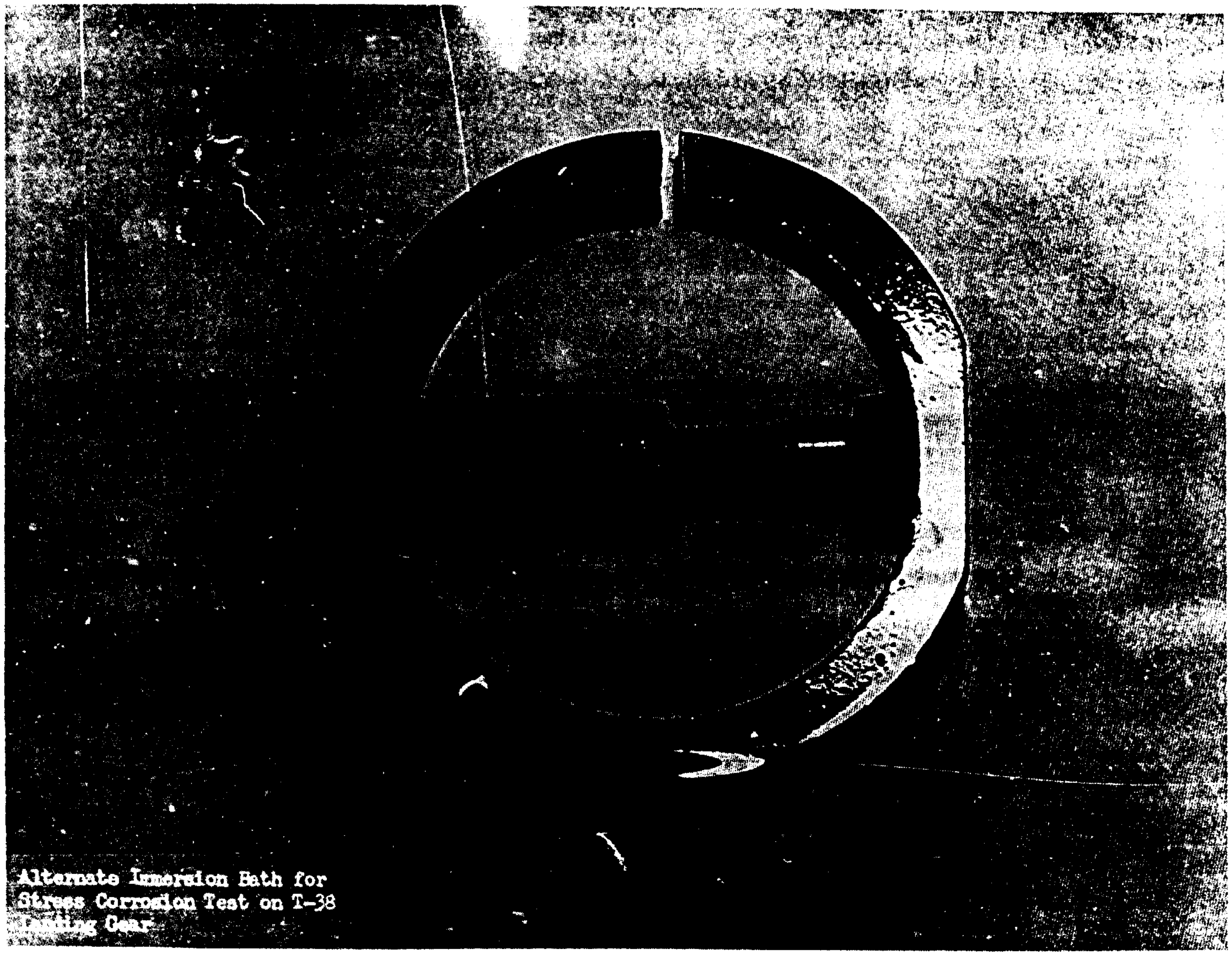

FIGURE 13 TYPICAL T-38 MAIN LANDING GEAR STRUT STRESS CORROSION TEST COUPON

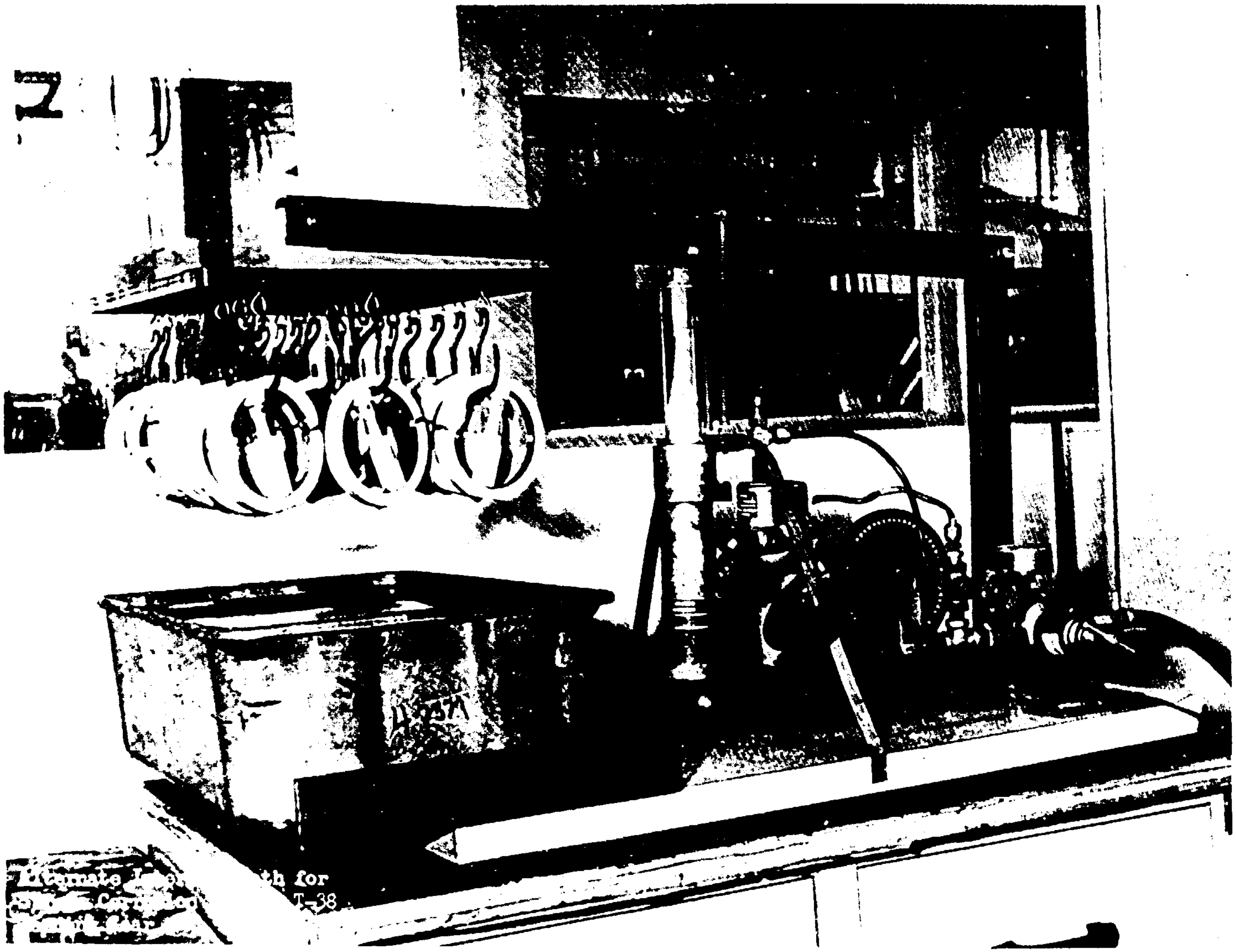

FIGURE 14 ALTERNATE IMMERSION BATH FOR STRESS CORROSION TEST ON T-38 LANDING GEAR

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Harvey Aluminum, Incorporated
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Hiller Aircraft Company
Attn: Mr. Edward Kempf
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Hills-McCanna Company
Foundry Division
Attn: Donald Krings
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Hoskins Manufacturing Company
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Hughes Aircraft Company
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Hughes Aircraft Company
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Hughes Tool Company
Aircraft Division
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Indiana Gear Works
A Division of the Buehler Corporation
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IIT Research Institute
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International Nickel Company
Technical Library, 16th Floor
67 Wall Street
New York 5, New York
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Jessop Steel Company
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Jones & Laughlin Steel Corporation
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Ladish Company
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Ladish Company
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Latrobe Steel Company
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Latrobe Steel Company
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Ling-Temco-Vought, Incorporated
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Lockheed-California Company
Control Library
Department 72-25
Building 63-1, Plant A1
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Lockheed-California Company
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Lockheed Missiles & Space Company
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The Magnesium Association
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P. R. Mallory & Company, Inc.
Attn: Technical Library
3029 East Washington Street
Indianapolis 6, Indiana
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Martin Company
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Mail 398
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Martin-Marietta Corporation
Denver Division
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Modern Castings
AFS Technical Center
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Rocketdyne Division
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Western Pneumatic Tube Company
P. O. Box W
Kirkland, Washington
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Westinghouse Electric Corporation
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Dayton 4, Ohio
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