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CAST ALUMINUM STRUCTURES TECHNOLOGY (CAST)
STRUCTURAL TEST AND EVALUATION (PHASE V)
PART III—STATIC PROPERTY ALLOWABLES

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Seattle, Washington 98124

April 1980

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Final Report for Period June 1976-August 1979

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This document contains static mechanical properties of A257-T6 aluminum alloy castings. Properties of castings are relatable to non-destructively measured soundness and aluminum dendrite size. A criterion is developed for design properties in terms of these physical parameters applicable to all castings of the same alloy and temper regardless of size, shape, method of production, mold materials or other process variables.

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FOREWORD

This report was prepared by the Boeing Military Airplane Company, Advanced Airplane Branch, Seattle, Washington under USAF Contract No. F33615-76-C-3111. The contract work was performed under project 486U under the direction of the Air Force Flight Dynamics Laboratory, Advanced Metallic Structures/Advanced Development Program Office, Wright-Patterson AFB, Ohio. A significant portion of the contract was funded by the Metals Branch of the Manufacturing Technology Division of the Air Force Materials Laboratory. The Air Force Project Engineer was John R. Williamson of the AMS Program Office, Structural Mechanics Division, Air Force Flight Dynamics Laboratories (AFWAL/FIBAA).

The Boeing Military Airplane Company, Advanced Airplane Branch, was the contractor, with Donald E. Strand as Program Manager, Donald D. Goehler as Technical Leader, and Cecil E. Parsons as Allowables Manager. This phase of the program was conducted by Dale L. McLellan assisted by James W. Faber, Frederick J. Feiertag, and Howard L. Southworth.

This report is Part III of a three-part report on Phase V activities. The contractor's report number is D180-25724-3. The report covers work from June 1976 through August 1979. Other work performed on the CAST program is reported in:

- AFFDL-TR-77-36, Final Report (Phase I) for period June 1976-February 1977
- AFFDL-TR-78-62, Final Report (Phase II) for period June 1976-March 1978
- AFFDL-TR-78-7, Final Report (Phase III) for period February 1977-December 1977
- AFFDL-TR-79-3029, Final Report (Phase IV) for period June 1977-March 1979

NOMENCLATURE

A, B, C, D	radiographic soundness grades per ASTM E155
DAS	dendrite arm spacing
DCS	dendrite cell size
N	sample size
R	reduced property ratio
$\bar{X}$	sample mean
X_A	statistical A-basis tolerance limit
k	tolerance limit factor for a normal distribution and a specified probability, confidence and degrees of freedom
n	shape factor
$r, \bar{r}$	property ratio and average value
s	sample standard deviation
e/D	edge margin
α	confidence coefficient
ν	degrees of freedom
X^2	chi-squared; a statistic

Properties	Allowables	
TUS	F_{tu}	tensile ultimate strength
TYS	F_{ty}	tensile yield strength
ELONG	e	total elongation
CYS	F_{cy}	compression yield strength
SUS	F_{su}	shear ultimate strength
BYS	F_{bry}	bearing yield strength
BUS	F_{bru}	bearing ultimate strength

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SECTION I
INTRODUCTION

The purpose of the CAST program was to demonstrate that the use of high-strength aluminum alloy castings could be extended to primary structural components of airframe construction. The program objectives included efforts to establish structural and manufacturing technologies and to demonstrate the integrity, producibility, and reliability of representative cast airframe structures. One specific objective was to establish realistic static design allowables and to eliminate the need for using casting design factors.

Castings were obtained during Phase II, Manufacturing Methods, for purposes of developing a static data base from which allowables were developed. The key issue of allowables development pertains to the basis upon which data are categorized. For this purpose, influences of casting-zone geometries, foundry variables and nondestructively measurable physical parameters were evaluated. Section II of this report contains the results of these evaluations, concluding with a physical parameter basis for allowables development. Section III presents tension allowables and derived properties for compression, shear, and bearing developed during Phase II.

An assessment of tension allowables was made in Phase V, Structural Test and Evaluation. Four of twenty YC-14 bulkheads produced in Phase IV, Fabrication of Demonstration Articles and Production Hardware, were sampled for tensile coupon properties and physical parameters. Results of this assessment are contained in Section IV of this report. These evaluations show that realistic static design allowables of high-strength aluminum alloy castings can be developed if based upon the physical conditions of the material that control and dictate such behaviors. Furthermore, the subject of casting factors can be viewed in relation to casting production controls and inspections required of the relevant physical conditions.

SECTION II
TENSION PROPERTIES

1. GENERAL

This section reports results of examinations of tensile property variations in relation to the following parameters:

1. Casting geometry (thickness)
2. Foundry variables (distances from ingates, risers, chills, etc.)
3. Heat treatment

From these evaluations, TUS and ELONG dependencies are established with dendrite arm spacing (DAS) and X-ray soundness grade as defined by ASTM E155 standards. In addition, supplemental data for both A357 and A356 casting alloys indicates that TYS variations are related to the artificial aging conditions of the heat-treatment process.

2. CASTING GEOMETRY EFFECTS

Phase II provided an excellent opportunity to determine whether tensile properties are related to casting geometry. Geometry was represented by the thicknesses of casting zones. Section III contains a complete description of Phase II test castings, referred to as Parts A and B.

The effects of casting-zone thickness on tensile properties observed in Phase II were:

1. TUS increases with thickness (Part A castings)
2. TUS decreases with thickness (Part B castings)
3. TYS does not vary with thickness
4. ELONG increases with thickness (Part A castings)
5. ELONG decreases with thickness (Part B castings)

These results are shown in Table 1.

Elongation data for thickness extremes in Table 1 are shown in Figure 1. The trends of increasing ELONG with thickness for Part A castings and decreasing ELONG with thickness for Part B castings are clearly identified. Elongation of A357-T6 does not develop a consistent function with casting-zone thicknesses for these parts. Within each thickness band, a range of ELONG values suggests a relatively large scatter. Two physical characteristics of these materials are offered as an explanation for interpreting these results. Each ELONG result is identified by the DAS and soundness grade. In both thin and thick regions, it is apparent that the smallest DAS and highest soundness (grade A) result in the highest ELONG. These two physical parameters may not be entirely responsible for ELONG variations but they are the two characteristics measured for all coupons. It therefore seems reasonable, as an initial effort, to categorize ELONG (and TUS) according to levels of DAS and soundness. Figure 2 shows the soundness grade A results of the previous diagram related to DAS.

The amount of scatter in this trend band could be due to any of the following items:

1. Natural ELONG scatter
2. Errors in test and/or measurement of ELONG
3. Errors in DAS measurement
4. Unidentified gradations within ASTM soundness grade A
5. Other unidentified physical or metallurgical characteristics

In the above discussion, and for all future data analysis purposes, both DAS and soundness refer to physical measurements made on tested specimens adjacent to the fracture zones. ELONG was obtained from full-range stress-strain curves. For a comparison with specimen measurements for ELONG, refer to Appendix C.

3. FOUNDRY VARIABLES EFFECTS

At the onset of the program, it was considered that tensile properties might be relatable to manufacturing parameters. Earlier efforts by Battelle, per reference 1, had shown that tensile properties of A357-T6 castings could be separated into categories described by distances from chills and risers. They concluded that this approach was instructive, but not feasible or desirable.

TABLE 1 MANUFACTURING VARIABLES -- THICKNESS

Section Thickness (in.)	Part A								Part B			
	Boeing				Hitchcock				Boeing			
	Qty.	TUS (ksi)	TYS (ksi)	EL. (%)	Qty.	TUS (ksi)	TYS (ksi)	EL. (%)	Qty.	TUS (ksi)	TYS (ksi)	EL. (%)
.10	34	46.0	40.8	2.0	44	46.7	40.8	1.8	34	47.8	40.8	3.6
.20-.25	28	47.5	41.2	2.2	25	47.1	40.4	2.4	10	51.2	42.5	5.1
.30	8	48.3	41.2	3.0	10	49.1	41.0	3.6	35	47.9	41.5	2.8
.50	7	47.4	41.1	3.0	10	47.8	39.2	4.3	10	46.4	42.0	1.2
1.0	7	48.8	40.9	4.2	9	49.4	39.9	5.1	10	45.2	40.2	1.2
2.0	16	48.5	40.2	5.2	20	48.5	40.2	4.2	0	-	-	-
3.0	0	-	-	-	0	-	-	-	10	44.9	40.1	1.2
Casting Average	100	47.3	40.9	2.9	118	47.6	40.4	3.0	109	47.5	41.2	2.8

Note: Integral coupon data not included.

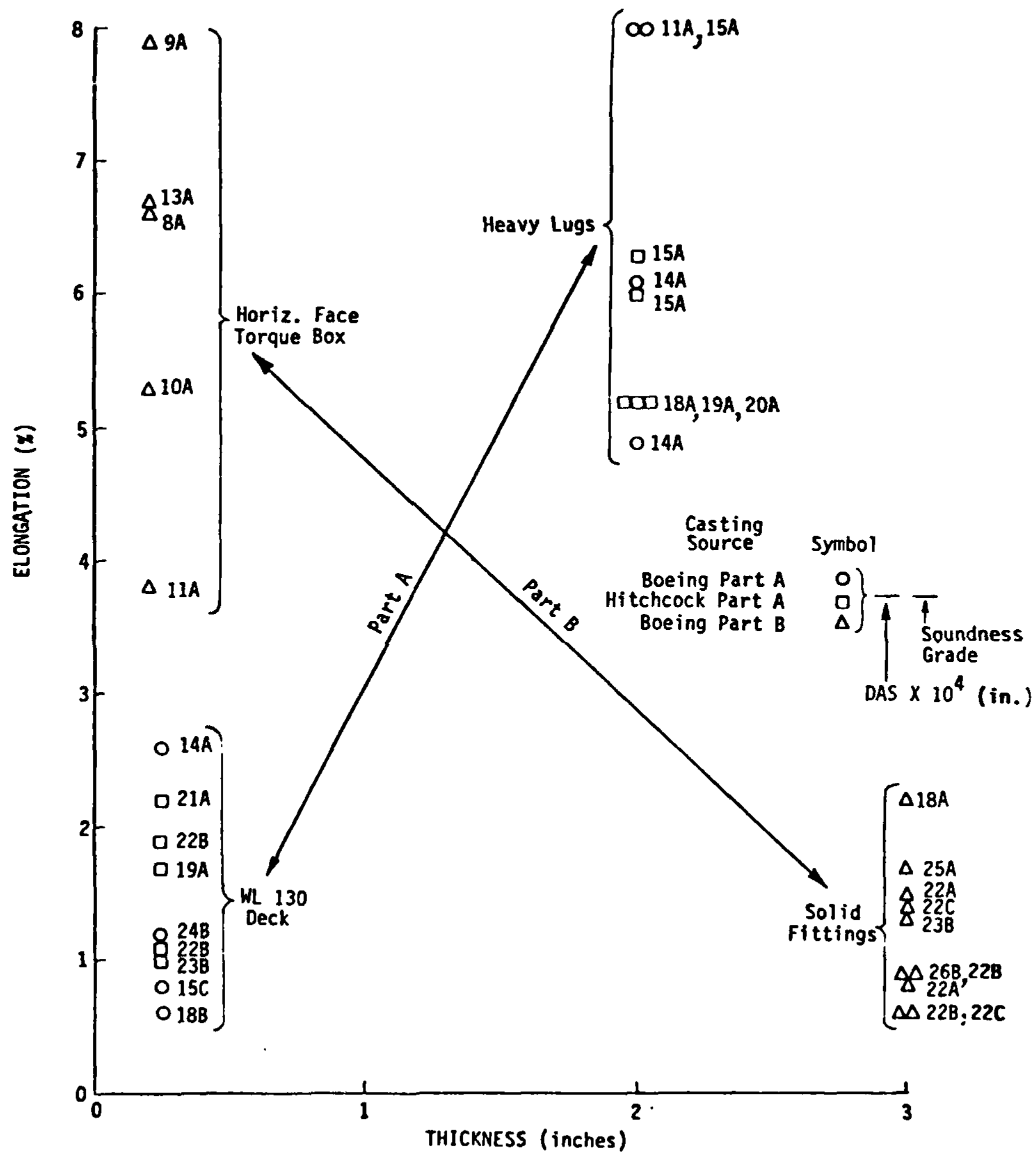


FIGURE 1 VARIATIONS IN ELONGATION WITH THICKNESS
A357-T6 CAST

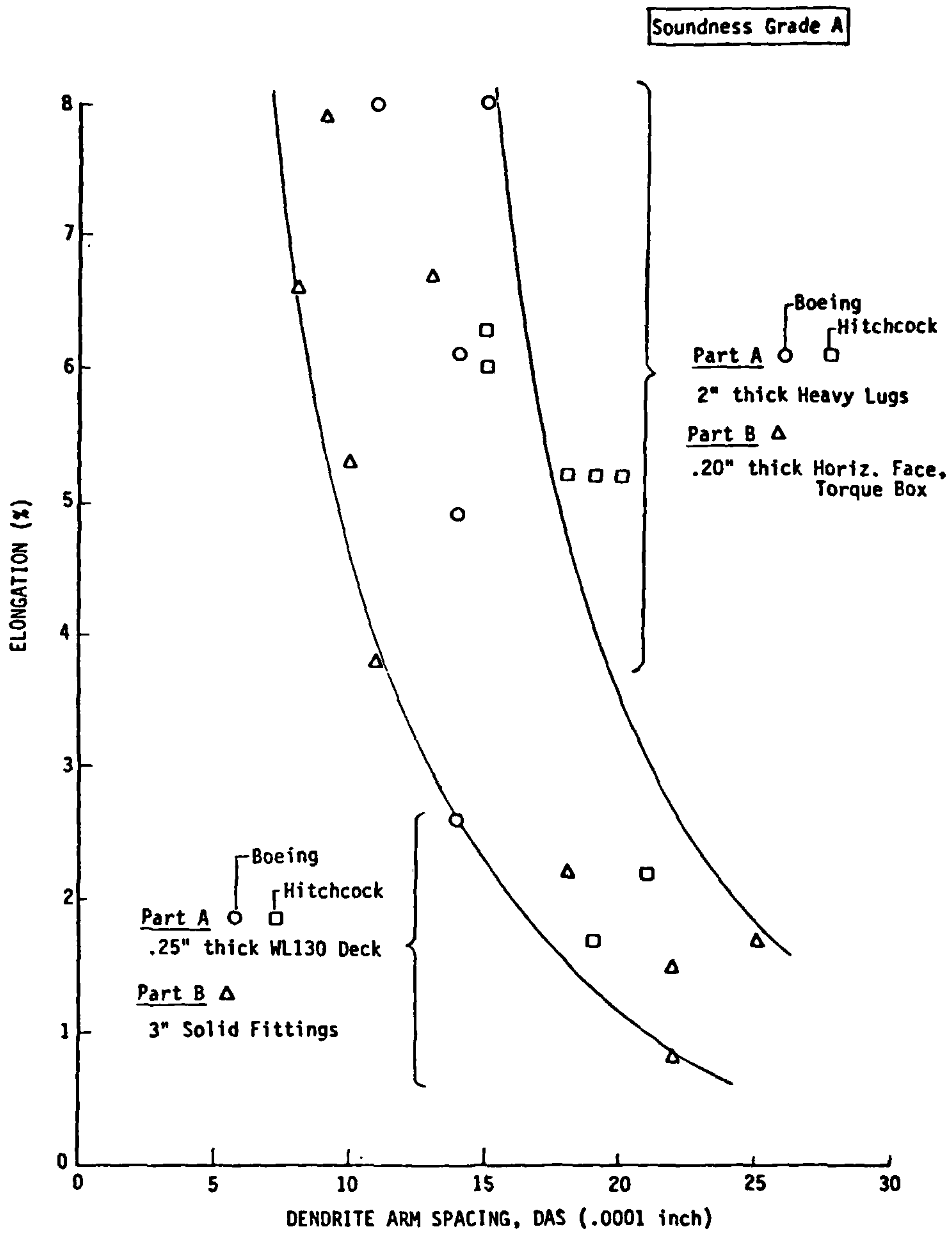


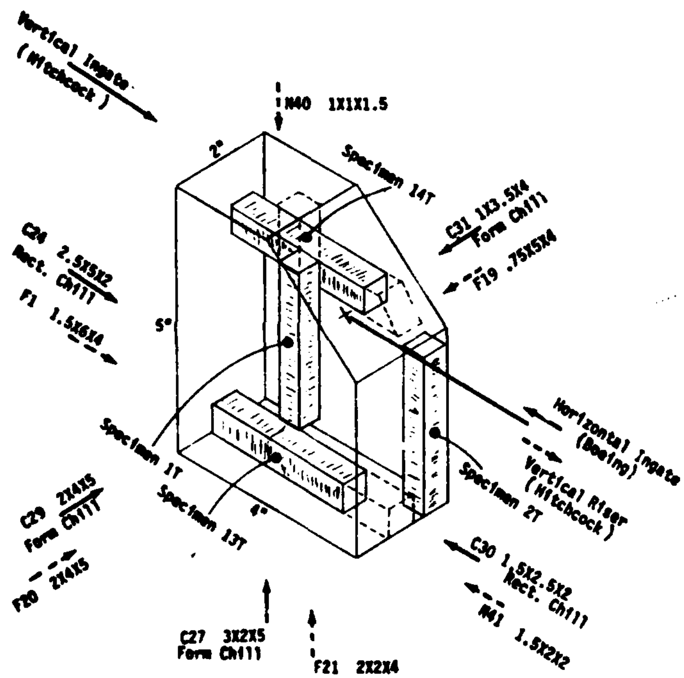
FIGURE 2 VARIATIONS IN ELONGATION WITH DAS
A357-T6 CAST

To confirm the Battelle conclusion, tensile properties from the heavy lugs of Phase II Part A castings were categorized according to distances from ingates and chills. Riser distance was not included because the Boeing castings, with the patterned mold cavity situated vertically, contained no risers. Figure 3 shows the heavy lug tensile coupons locations common to both Boeing and Hitchcock castings. Compression, shear, and bearing coupons have been omitted for clarity. Each lug surface that was directly chilled is identified with chill material type, size, and location.

The lug is shown positioned according to the pouring method used by Boeing with a horizontal ingate. Hitchcock castings were poured with the mold cavity in a horizontal plane. Their ingating and risering are also identified in the figure. Specimens from the two foundry products were the same distances from ingates and chills although chill sizes and materials differed. These differences in manufacturing methods were designed to enable selection of the best approach to produce complete bulkheads in Phase IV.

Lug tensile properties are shown in Figures 4 and 5 plotted against distances from chills and ingates. In Figure 4, both TUS and TYS are shown on the same ordinate scale. TUS data at each chill distance location form a 2- to 3-ksi band. TUS results at 2-inch distance from the ingate form a 4-ksi band and essentially envelop those results at the 4 inches from ingate location. The trends in TUS and TYS for distance from chills are inconclusive. Based upon the physical trends for DAS and soundness with tensile properties provided in the preceding discussion for thickness effects, it is expected that TUS would (1) decrease with distance from chills and (2) increase with distance from ingates. These trends cannot be fully confirmed with these data, probably because of chilling and ingate insulating opposing interactive effects.

Figure 5 shows lug ELONG results. The trends appear to be the same as shown for TUS with distances from chills and ingates. This is consistent with the trends for ELONG and TUS relative to thickness influences. Information presented in both of these figures supports the Battelle conclusion that such a method for categorizing tensile properties is not desirable.



Specimen	1T	2T	13T	14T	1T	2T	13T	14T
Casting Source	Boeing				Hitchcock			
Ingate Distance	2	2	4	2	2	4	2	2
Chill Distance	1	.25	.25	.5	1	.25	.25	.5

Dimensions in inches

Foundry	Chill Types	Code Letter	Material
Boeing	Form & Rect.	Cxx	Copper
Hitchcock	Normal	Nxx	Cast Iron
"	Form	Fxx	70000 Manganese Bronze

FIGURE 3 FOUNDRY VARIABLES, HEAVY LUG
Part A Castings
A357-T6 CAST

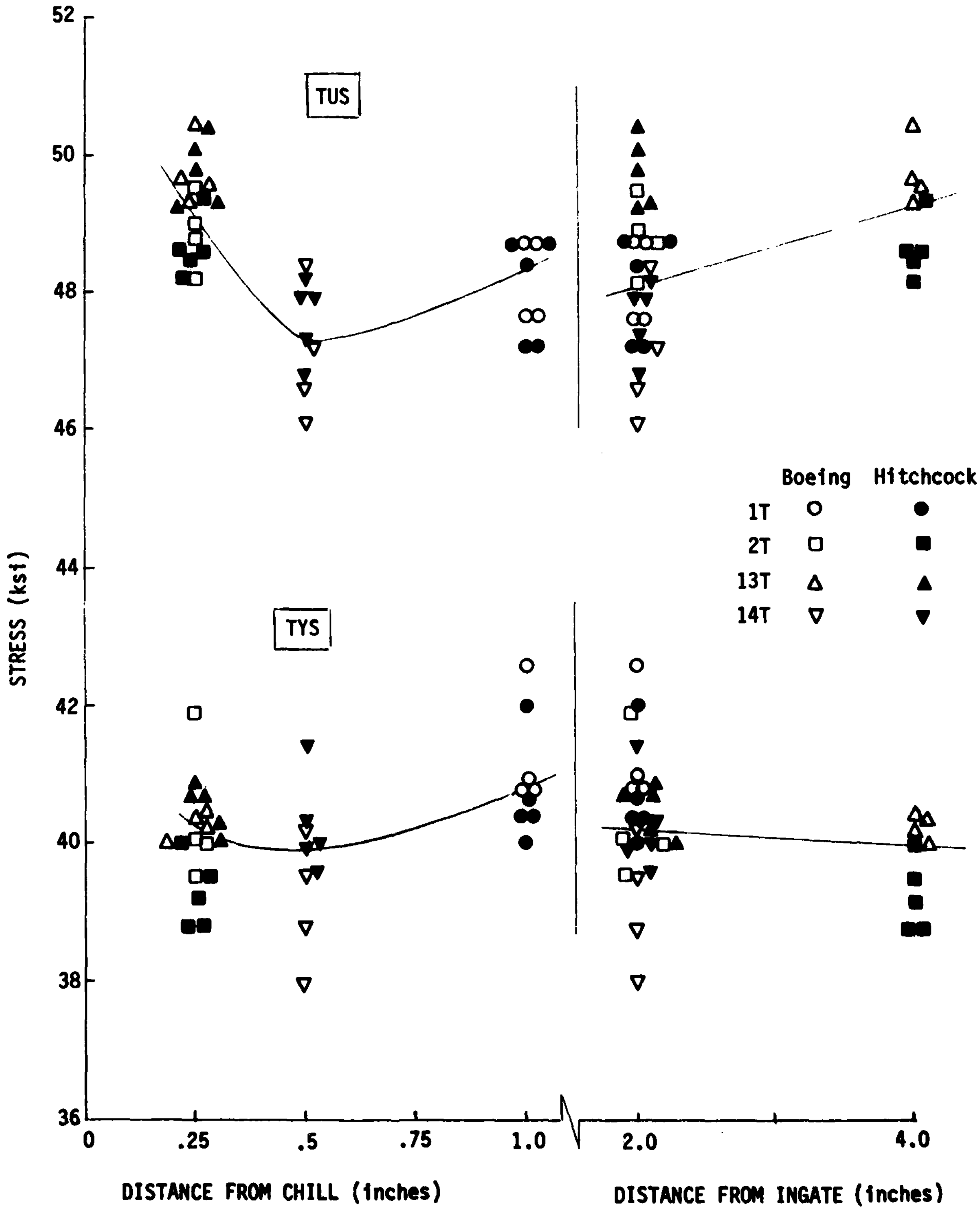


FIGURE 4 EFFECTS OF FOUNDRY VARIABLES ON TUS AND TYS
A357-T6 CAST
Heavy Lugs, Part A Castings

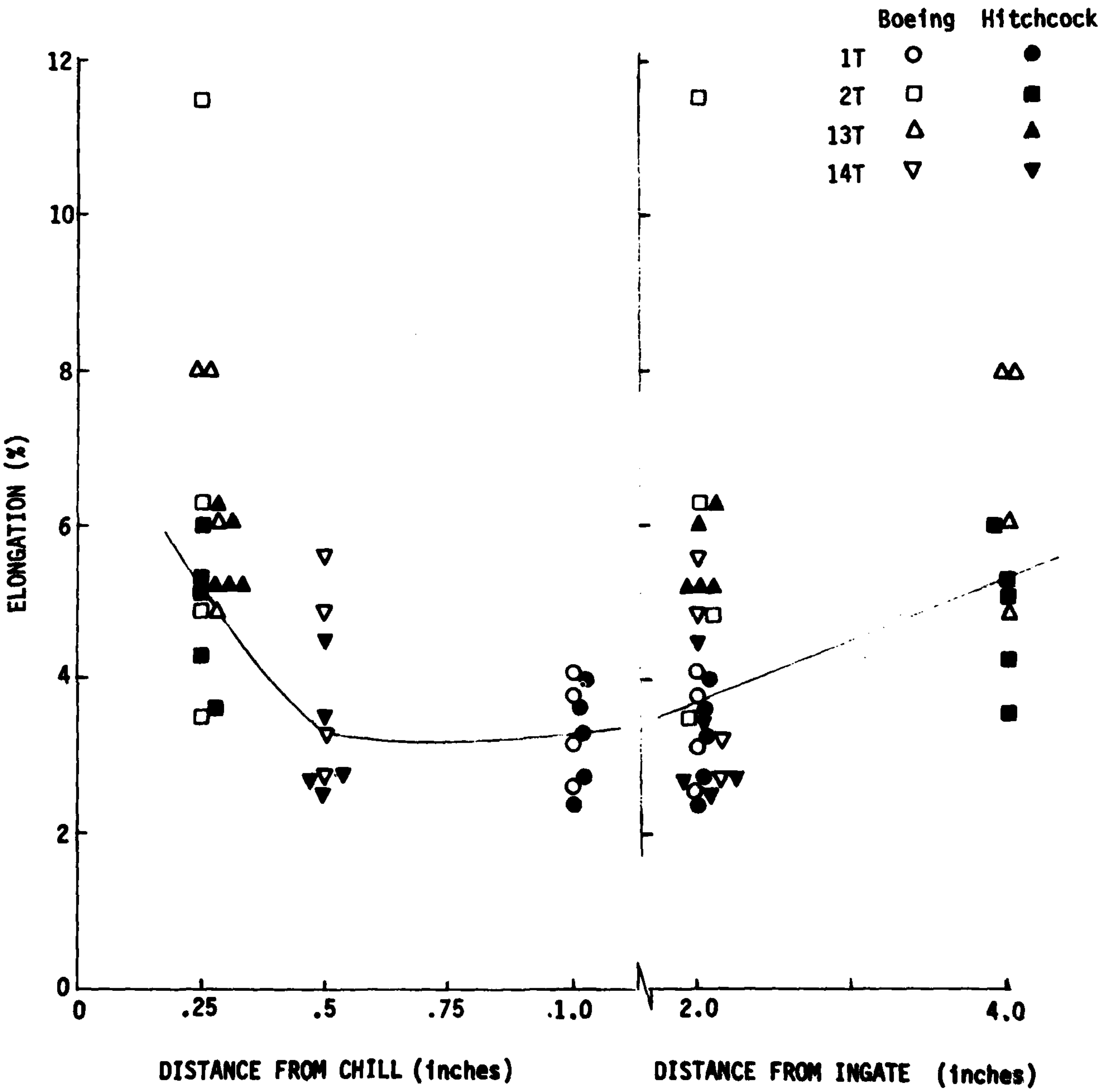


FIGURE 5 EFFECTS OF FOUNDRY VARIABLES ON ELONGATION
A357-T6 CAST
Heavy Lugs, Part A Castings

These same data have been replotted in Figures 6 and 7 as functions of DAS. The decreasing TUS and ELONG and invariant TYS relations established with DAS previously in the discussion of thickness effects are also demonstrated with these data. Essentially all results represent specimen soundness grade A material. Only three of the thirty-six results are for soundness grade B. The finite TUS and ELONG bands describe the possibilities of unidentified gradations within grade A soundness or other test or measurement uncertainties previously mentioned. TYS shows no relation with DAS as was also the case with data for various casting thicknesses. These results support a dual-basis DAS/soundness concept for categorizing TUS and ELONG properties.

4. HEAT-TREATMENT EFFECTS

The general effect of heat treatment for high-strength aluminum alloy castings is an increase in TYS. Particular segments of the heat-treatment process such as quench delay, quench rate, and artificial aging may produce significantly different effects. Significant variations were measured for TYS from different zones of castings produced in both Phases II and IV. However, the average TYS value from Phase II castings seemed to be invariant for different levels of DAS and soundness grades. It would be beneficial to understand the cause of differences between individual measurements to establish realisitic allowables. The amount of process control required to establish consistency should also be determined for both specification controls and to insure the applicability of allowables.

A356 is the predecessor alloy of A357 and contains approximately one-half the magnesium content of the newer alloy. A356 contains no beryllium, whereas A357 does. Two sources of A356 data were available from which individual tensile test results could be analyzed with reference to dendrite cell size (DCS) and some heat-treatment effects.

Prior to a discussion of these effects, a few comments are required to establish a graphical format suitable to demonstrate relative influences of heat treatment, dendrite measurement (DCS or DAS), and soundness on each of the three tensile properties. Without exception, all observed A356 and A357 data, including all test results from the CAST program, demonstrate a common characteristic.

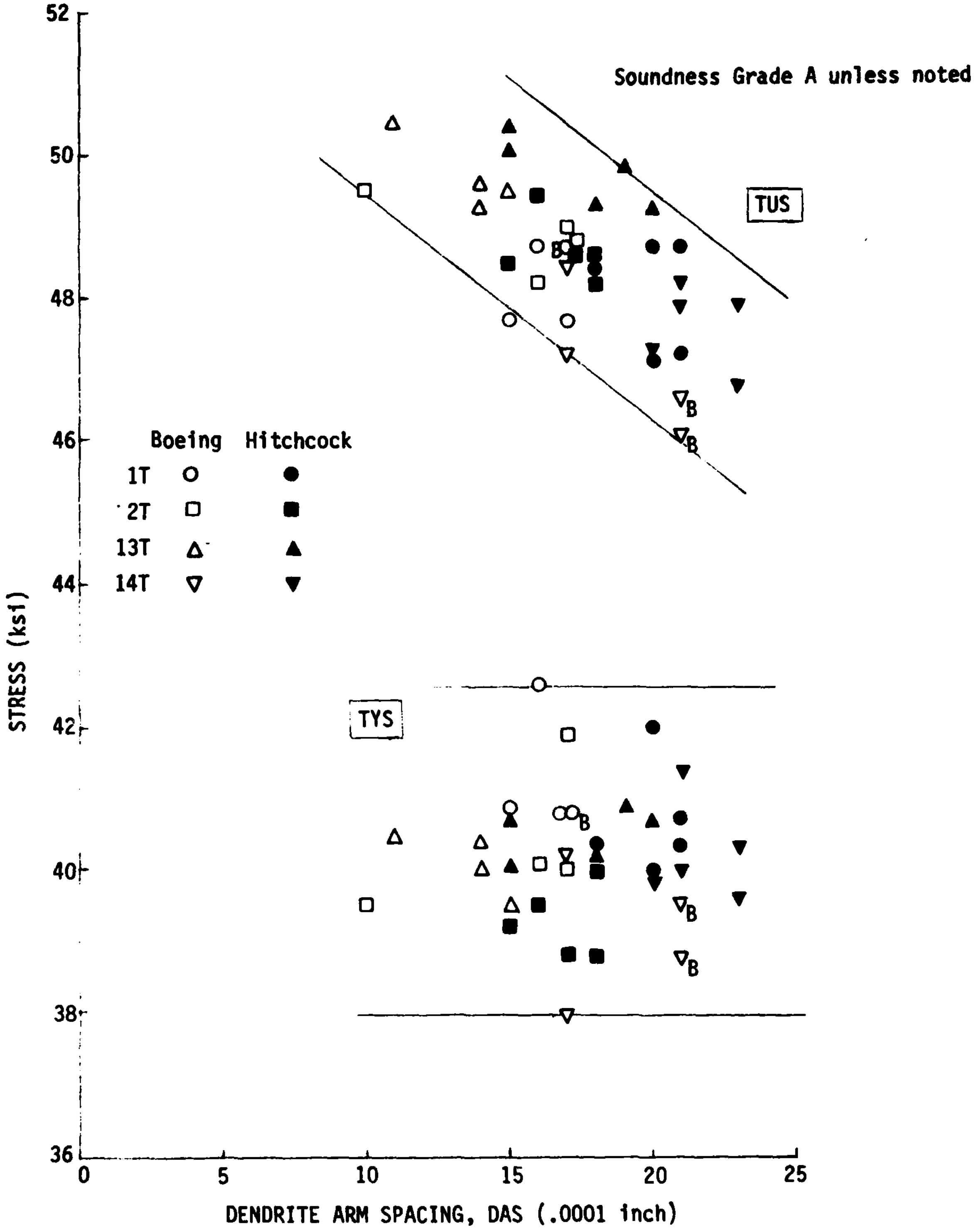


FIGURE 6 VARIATIONS IN TUS AND TYS WITH DAS
A357-T6 CAST
Heavy Lugs, Part A Castings

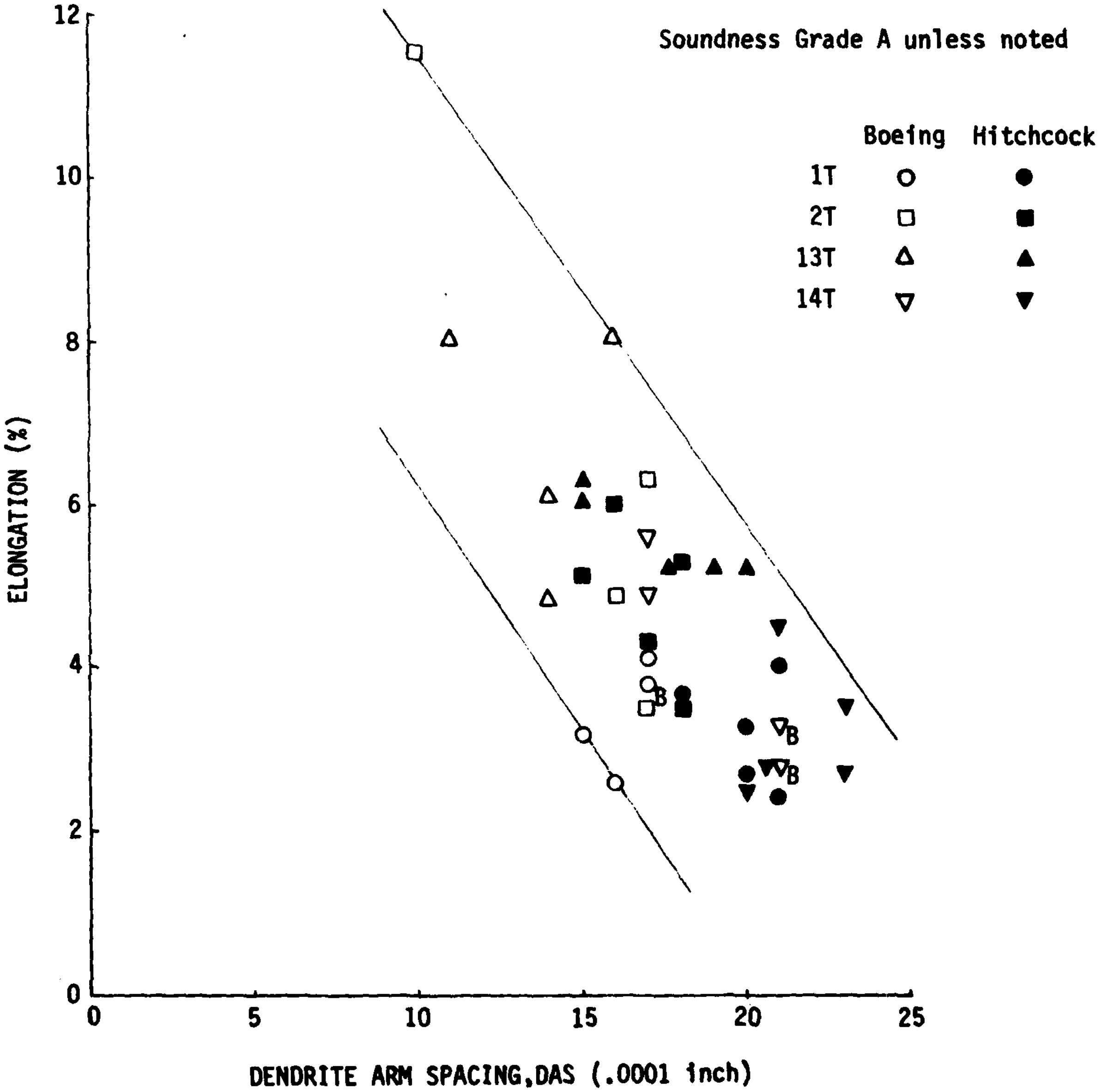


FIGURE 7 ELONGATION VARIATIONS WITH DAS
A357-T6 CAST
Heavy Lugs, Part A Castings

There is no necking of tensile specimens. Total elongation is the same as uniform elongation and is the strain coordinate of TUS. Using TUS and ELONG as terminus coordinates of a stress-strain curve, it has been conveniently determined that the plastic portion of the curve can be described analytically by the following power function:

$$\text{ELONG} = 0.2(\text{TUS}/\text{TYS})^n$$

The power coefficient n is the shape factor. Values of TUS and corresponding ELONG vary with different DAS levels and soundness grades for the A357-T6 CAST data.

Two sources of A356 casting tensile data are illustrated in Figure 8 using the above nondimensionalized strength-elongation format. Frederick and Bailey (ref. 2) provided A356-T6 tensile properties for two artificial aging temperatures, 320°F and 350°F. All other conditions of manufacture and processing were the same. The aging temperature causes a shift from (n = 13) to (n = 22). Spear and Gardner (ref. 3) provided tensile properties for material identified as A356-T62. The -T62 temper signifies user heat treatment that may produce different mechanical properties. At first, it would appear that the mechanical properties of the A356-T62 and those of the 320°F aged A356-T6 are the same. DCS values have been added to these plots to show general agreement between the two sets of data described by (n = 13). Actually, there is a larger difference between the mechanical properties from the two data sources at (n = 13) than there is between the two aging temperature conditions distinguished by (n = 13) and (n = 22).

	n = 13		n = 22
Temper:	-T62	-T6	-T6
Age:	NA	320°F	350°F
TUS (ksi)	35 to 42	43 to 51	45 to 51
TYS (ksi)	29 to 32	34 to 37	41 to 43
ELONG (%)	2 to 14	3 to 15	1 to 11

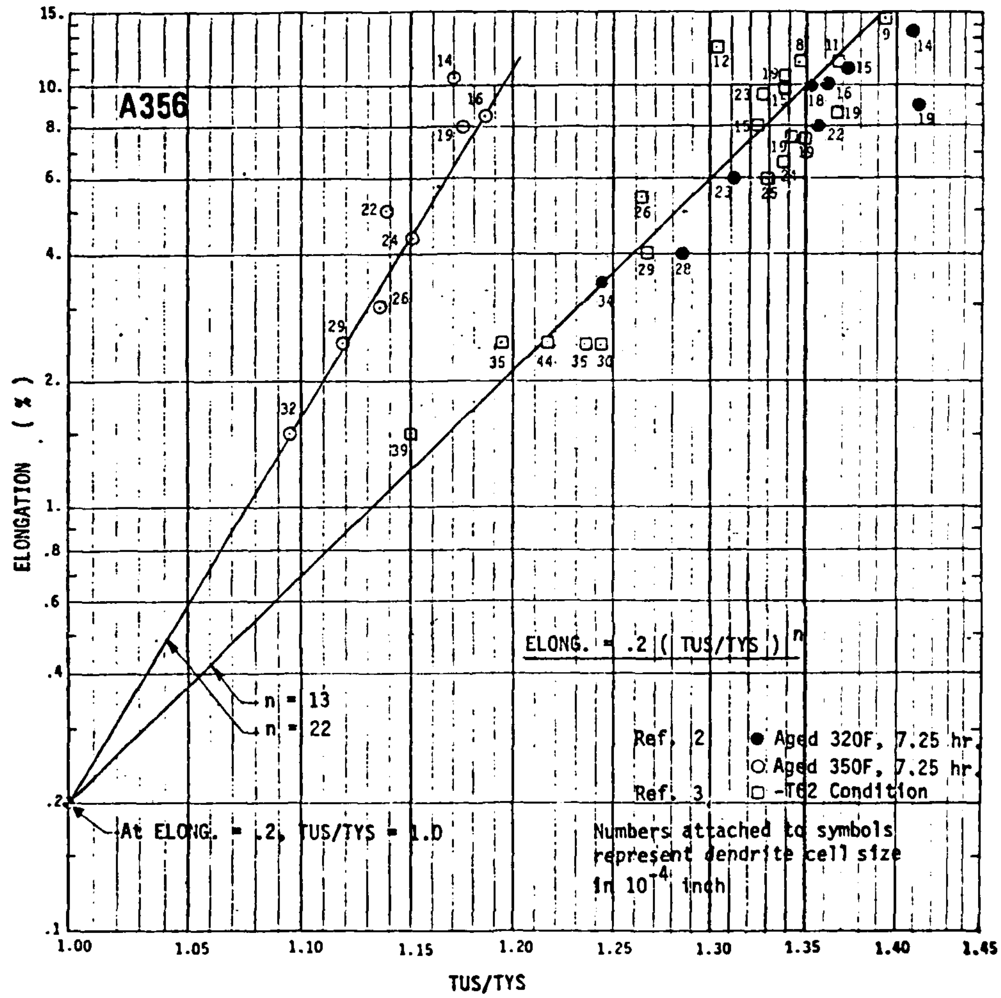


FIGURE 8 TUS-TYS-ELONG RELATIONSHIPS FOR A356 CASTINGS

Apart from the differences in properties at the (n = 13) condition, it would appear that TYS and shape factor are changed by heat treatment. This is shown by the increase in TYS from the 320°F to the 350°F aging temperature and the shift from (n = 13) to (n = 22). The general characteristics of this diagram are shifts along a constant shape-factor line for different DCS values (and soundnesses as found with A357-T6 CAST data) and differing shape factors for different aging conditions.

The characteristics identified with A356 can be applied to A357 tensile properties. Battelle Columbus Laboratories, under subcontract to Boeing on this program, supplied in excess of 5000 tension test results from A357-T6 castings. Data sources included 15 cooperating foundries and airframe companies supplying properties from 47 different parts. Data were categorized into 14 (TUS/TYS/ELONG) groups including the four described in procurement specification MIL-A-21180C. These data are summarized in reference 1. Other than tensile properties, most test results were identified by foundry source, mold type, and thickness of the tested zone.

Although statistics were supplied by Battelle for data of each category, a complete reanalysis was performed to evaluate normality, compute representative statistics, and determine the acceptability of data according to specification requirements of each (TUS/TYS/ELONG) set of data. Both TUS and TYS seem to follow linear normal trends, whereas ELONG fits normality best when logarithmically transformed. Recomputed statistics of reference 1 data have been combined with Phase II results in Figure 9. Phase II data were categorized into four DAS levels and four soundness grades. The result shows three trends, each identified by a different shape factor (n = 14, 16, and 18.5). All of the CAST data groups and a few of those from Battelle can be described by the shape factor of (n = 16). The majority of Battelle-reported data groups are split into two outer bands described by (n = 14) and (n = 18.5). Using the CAST data, both DAS and soundness produce different coordinates along a single shape-factor line and these parameters have interchangeable influences. Low soundness and small DAS can produce the same ELONG and TUS (assuming TYS remains constant) that is obtained with higher soundness and a larger DAS.

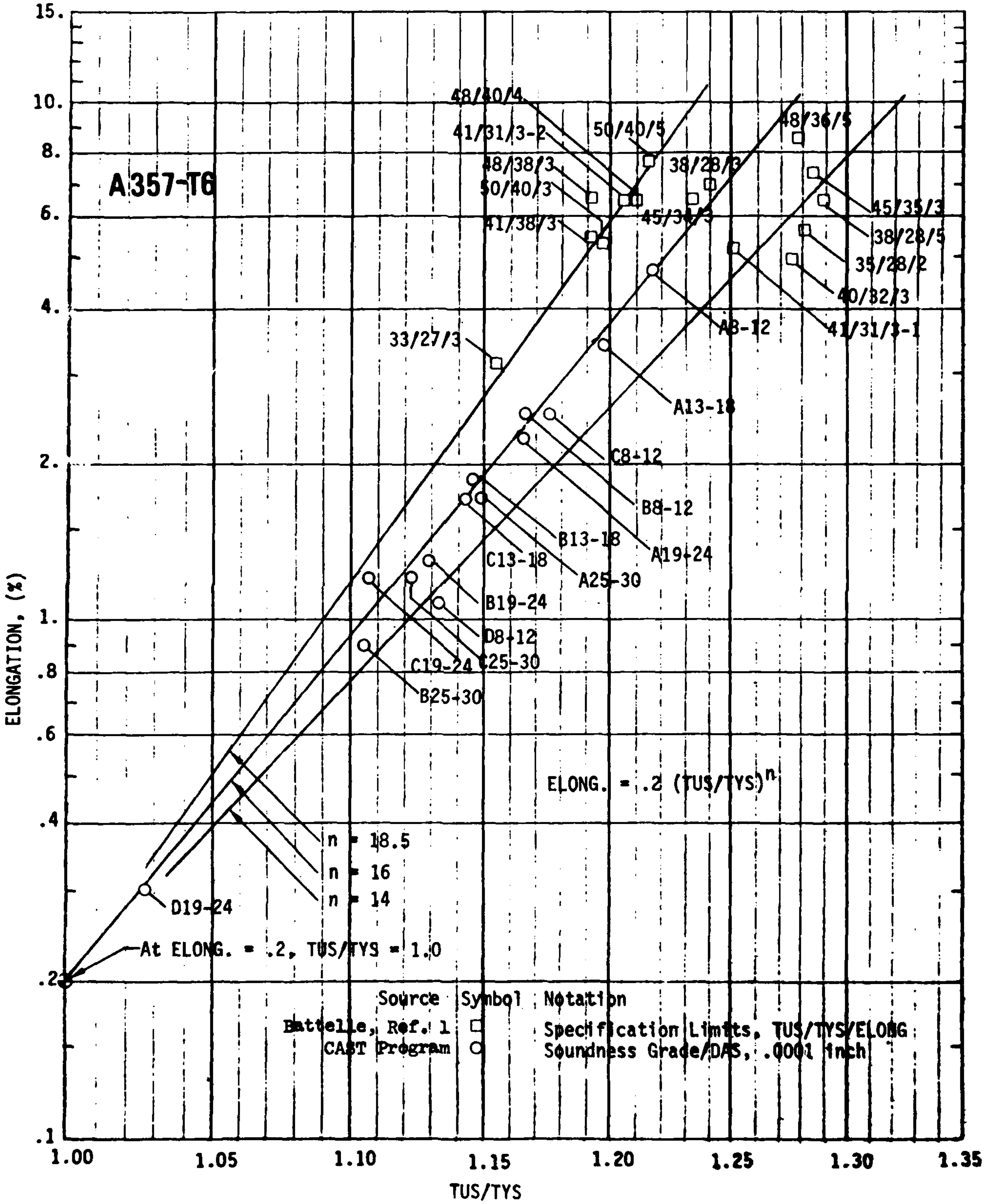


FIGURE 9 TUS-TYS-ELONG. RELATIONSHIPS FOR A357-T6 CASTINGS

Basic characteristics demonstrated in ELONG versus TUS/TYS diagrams for both A356 and A357 alloys can be combined. Figure 10 shows the composite plot for both materials and the trends they develop. As the artificial aging temperature is increased, both TYS and shape factor (n) increase. A357-T6 results from Hughes (ref. 4), supplemented by TYS results via personal communique that were not officially reported, were analyzed and have been added to this composite diagram.

Boundaries are established by A356 with four intermediate shape factors describing A357 results. Regardless of alloy type, there is a consistency developed. Numbers shown along the trend lines indicate average TUS values. At up to 4 percent ELONG, these TUS values are about the same for the A357 CAST results and the A356 with the 350°F age. The offset between these trends is due to a 2-ksi difference in TYS as an apparent result of the two aging conditions. It also appears that the three groupings of Battelle results may be due to differences in aging conditions. Positions along each shape-factor line identify dendrite size and soundness, whereas lateral position seems to be heat-treatment dependent. With this concept, the differences between CAST and Battelle A357 data must be attributed to dendrite size and/or soundness along the (n = 16) line. All of these data are represented by a single TYS of 40 ksi.

The above discussion identifies soundness, dendrite size, and heat treatment as each having specific influences on tensile properties of A356 and A357 alloy castings. Information is not currently available to develop an understanding of how tensile properties might vary with chemistry or impurity levels, but it is obvious that development of reliable properties for these materials requires a much more in-depth knowledge of effects. The assurance that a production casting possesses certain static properties must be assessed from the controls and inspections required by the procurement specification and engineering drawings. With these devices, there is good reason to expect consistency in properties from part to part.

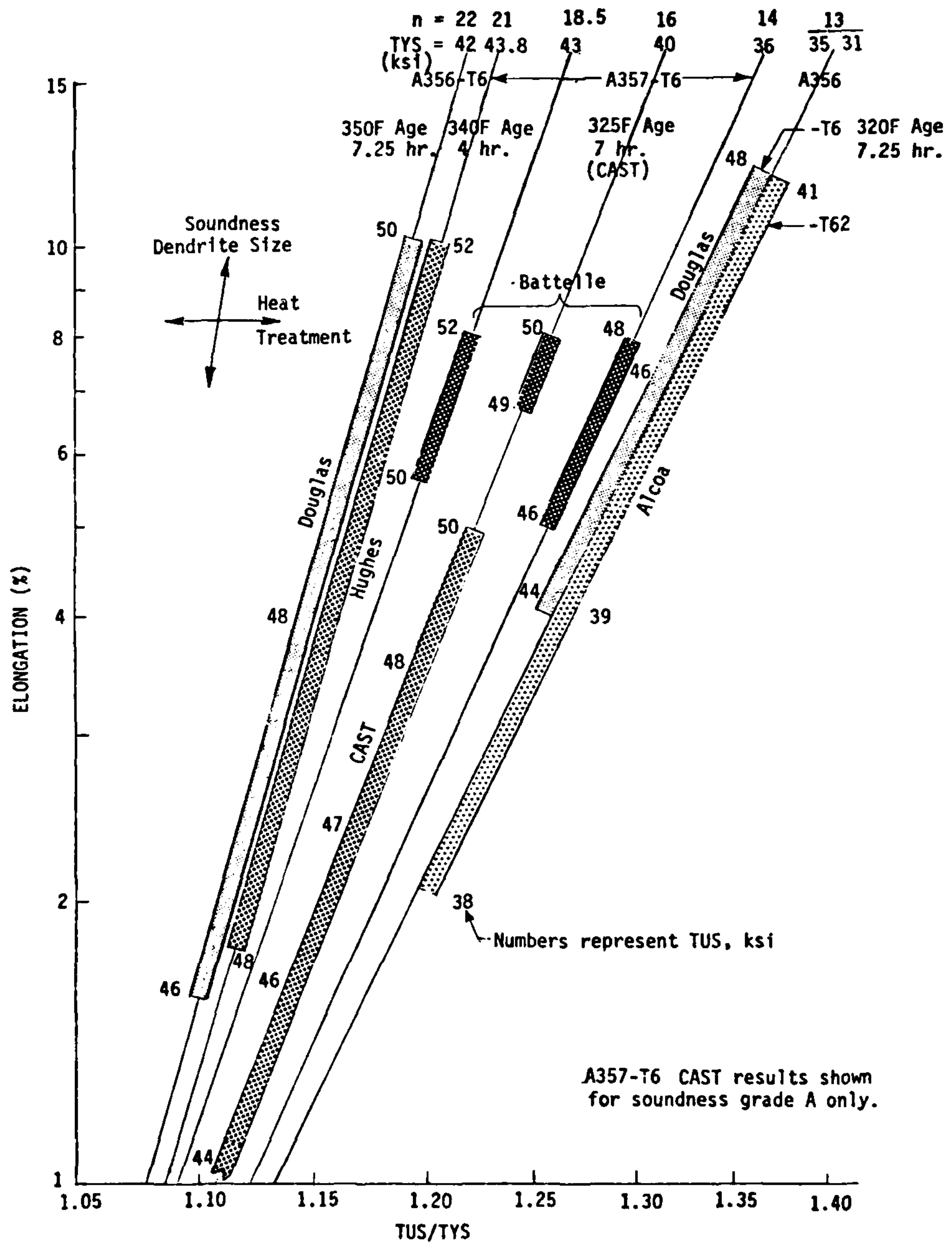


FIGURE 10 TENSILE PROPERTY TRENDS FOR ALUMINUM ALLOY CASTINGS

SECTION III
ALLOWABLES DEVELOPMENT

1. GENERAL

In this section, the Phase II data base, supplemented by Battelle-gathered data per reference 1, are used to establish allowables for the CAST bulkheads and a format for the general category of A357 castings.

2. PHASE II TEST PLAN

Fourteen bulkhead segment castings produced in Phase II were cut up for testing and analysis to develop a static design properties data base. These 14 segments consisted of two different portions of the bulkhead as shown in Figure 11. Boeing produced four of the Part A segments and five of the Part B segments. Hitchcock Industries produced five of the Part A segments. The segments shown in Figures 12 and 13 were representative of Phase I preliminary concepts of the full-size bulkhead design. Figures 12 and 13 also illustrate static specimen locations. The primary emphasis was given to tension coupons representing all zones of each part configuration. Compression, shear and bearing coupons were located in adjacent casting zones to develop derived properties. All coupons located in the Hitchcock Part A castings duplicated those of the Boeing Part A castings to evaluate potential differences between foundries.

Table 2 identifies target classes and soundnesses for all casting zones. These targets were designated for test purposes only and do not reflect actual design requirements for the bulkhead. The intent in setting these tests standards was to evaluate the capability of producing the highest strength/elongation and soundness grades in the most massive and difficult casting zones.

Six hundred and four static coupons were machined from castings for allowables development. An additional 65 integral cast-on tension coupons were made to evaluate heat treatment response.

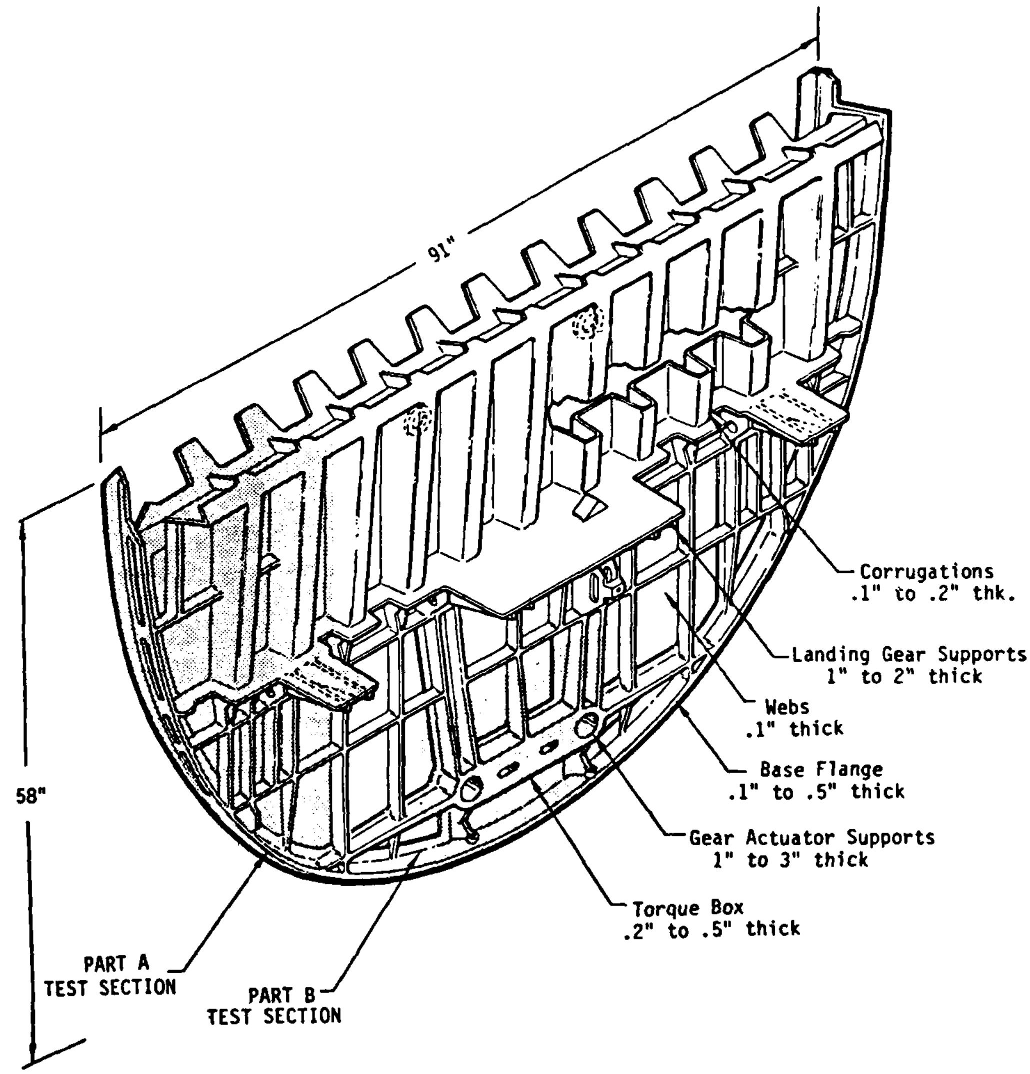


FIGURE 11 STATION 170 YC-14 BULKHEAD
Aft Side A357-T6 Casting

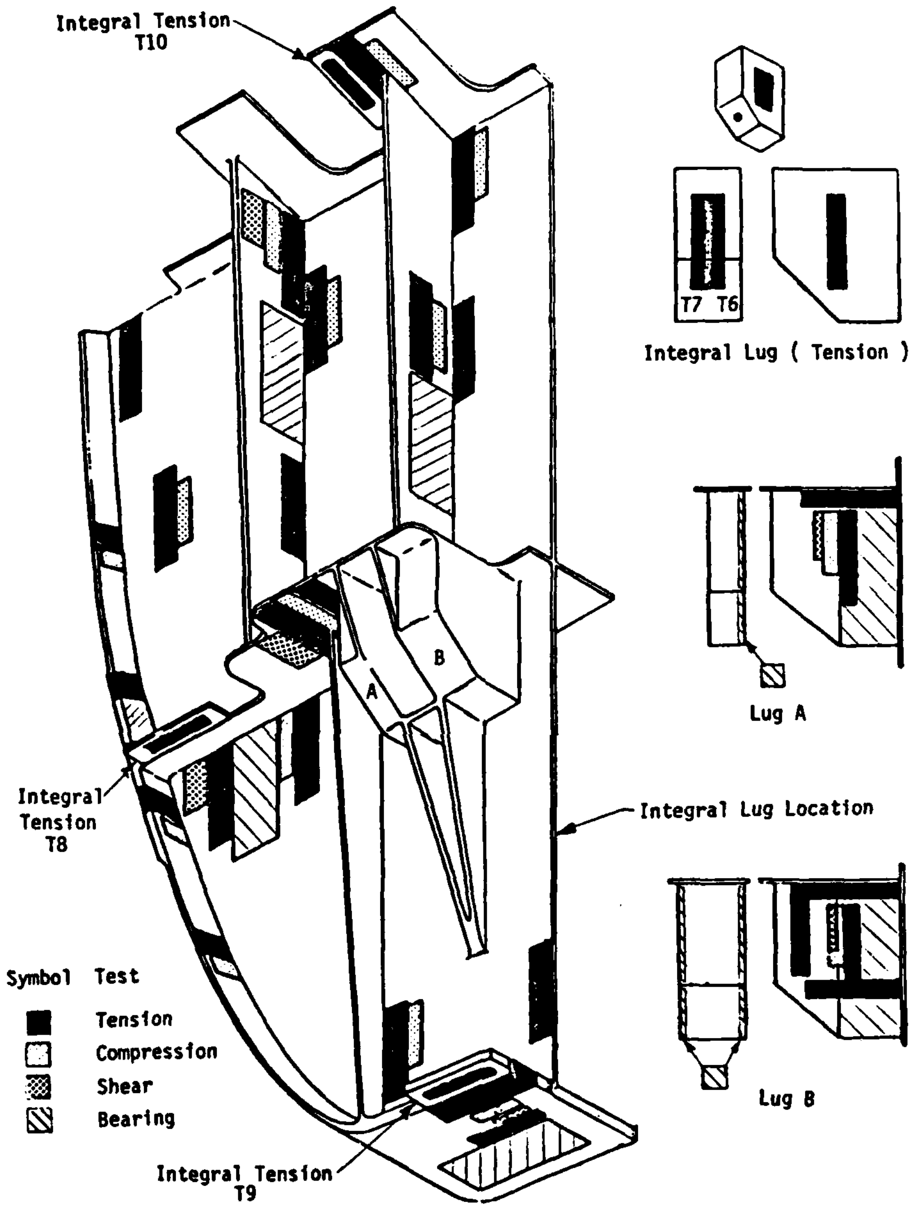


FIGURE 12 PART A TEST SECTION

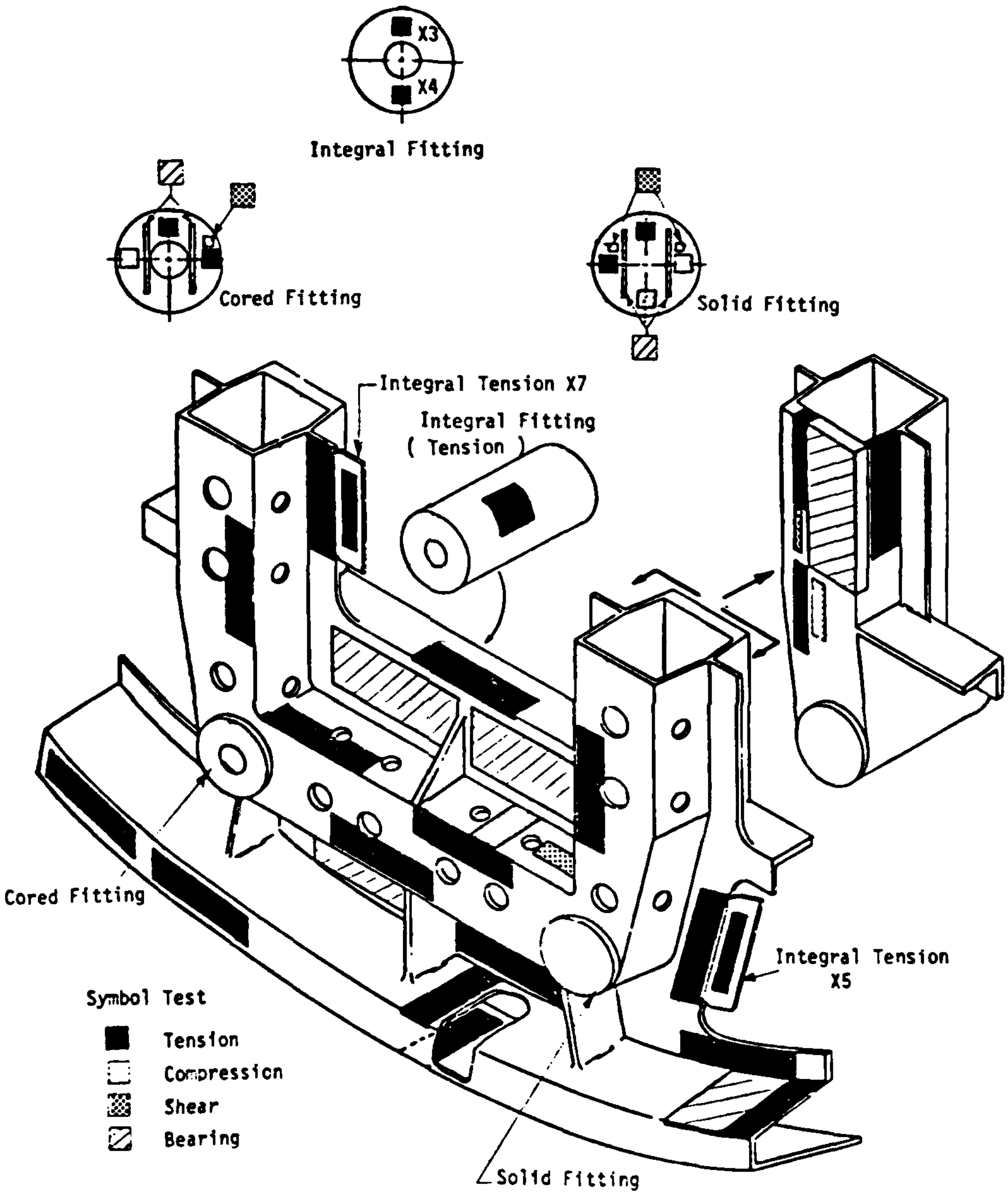


FIGURE 13 PART B TEST SECTION

TABLE 2 PHASE II ALLOWABLES SPECIMEN QUANTITIES

FOUNDRY	TYPE OF CASTING	QUANTITY	LOCATION	NOMINAL THICKNESS (IN.)	REQUIREMENTS [1] CLASS	REQUIREMENTS [1] SOUNDNESS	TEST COUPON QUANTITIES [2] TENSION	COMPR.	SHEAR	BEARING e/D=1.5	BEARING e/D=2.0
Boeing	Part A	4	Landing Gear Sppts.	1 & 2	Critical	B	6	2	2	2	1
			Base Flange Pad Up	.5	Other	C	2	1	1	0	1
			Side Flange Pad Up	.3	Critical	B	2	1	0	0	1
			Deck	.2-.25	Other	C	2	1	1	0	0
			Stiffeners	.2	Other	C	5	4	1	1	1
			Webs	.1	Other	C	9	6	1	0	1
			subtotals (4 castings)				104	60	24	12	20
											220
Hitchcock	Part A	5	Landing Gear Sppts.	1 & 2	Critical	B	6	2	2	2	1
			Base Flange Pad Up	.5	Other	C	2	0	0	0	1
			Side Flange Pad Up	.3	Critical	B	2	0	0	0	1
			Deck	.2-.25	Other	C	2	0	0	0	0
			Stiffeners	.2	Other	C	3	1	1	0	0
			Webs	.1	Other	C	9	0	0	0	1
			subtotals (5 castings)				120	15	15	10	20
											180
Boeing	Part B	5	Gear Actuator Sppts.	1 & 3	Critical	B	4	3	3	2	2
			Torque Box, Vertical	.5	Other	C	2	1	1	1	0
			Torque Box, Horiz.	.3	Critical	B	2	0	0	0	0
			Torque Box, Vertical	.3	Other	C	2	0	0	0	0
			Flanges	.25-.3	Other	C	4	0	0	1*	1
			Torque Box, Horiz.	.2	Critical	B	1	1	1	0	0
			Flanges, Webs	.1	Other	C	7	0	0	1	1
			subtotals (5 castings)				110	25	25	24	20
							* 4 castings only				
					Totals:		334	100	64	46	60
											604

[1] Test casting target requirements: Critical = 46 ksi (TUS), 40 ksi (TYS), 5% (EL.)
Other = 40 ksi (TUS), 30 ksi (TYS), 3% (EL.)

[2] Test quantities per each casting

Specific testing details and specimen configurations are contained in Appendix A. Details concerning foundry variables are contained in Appendix B. Appendix C contains a discussion of elongation measurement methods. Appendix D contains a discussion of integral cast-on specimens and their relation to tensile properties of various locations within castings. Individual test results from Phase II are contained in Appendix E.

3. TENSION ALLOWABLES

Tensile property trends are shown in Figure 14 for TUS and TYS and in Figure 15 for ELONG. Average values of each property were computed for each soundness grade over four selected DAS ranges identified in Table 3. Smaller DAS and better soundness produce higher TUS. TYS does not vary significantly with either of these parameters. ELONG being the strain coordinate of TUS has the same physical parameter dependencies. In Figures 14 and 15, symbols represent the average tensile property values plotted at the midpoint of each DAS range. An insufficient quantity of results for soundness grades B and C may have prevented a real separation in effects to be demonstrated.

Figures 16 and 17 show standard deviations for strength and elongation of A357-T6 tensile data from this program, the Battelle-gathered results, and those computed from Hughes-reported results per reference 4. DAS, soundness, and all other identifiers have been omitted purposely to illustrate that this material can be characterized by constant standard deviations for strength (S_f = 1.77 ksi) and elongation (S_e = 0.41, or 1.5 percent strain). No distinction is necessary between the dispersion characteristics of TYS and TUS. These computed standard deviations combine and project a constant value for an infinitely large sample. The only noticeable difference between CAST and Battelle data is that the latter source provided larger samples. Hughes TUS results are intermixed with CAST results. TYS was not officially reported by Hughes on the basis that it was invariant with DCS. It is therefore not shown in the figure, although a standard deviation was computed to be 1.53 ksi. Five of the Battelle-reported strength data groups form a separate standard-deviation trend that is not obvious in the elongation dispersion results. The reasons for these results are unknown and are not considered further in developing the general characteristics for this material.

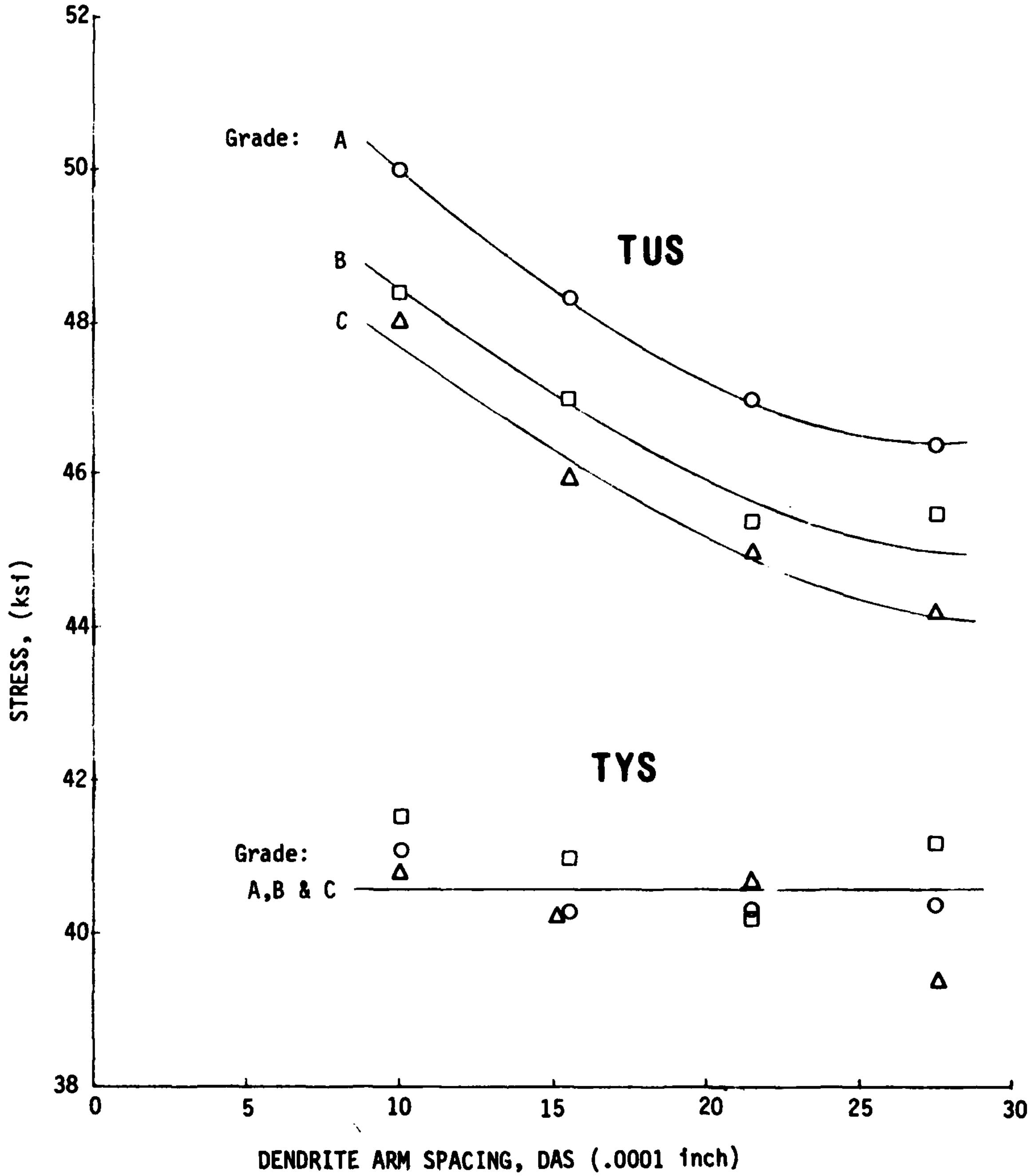


FIGURE 14 AVERAGE STRENGTH TRENDS WITH DENDRITE ARM SPACING AND SOUNDNESS
A357-T6 CAST

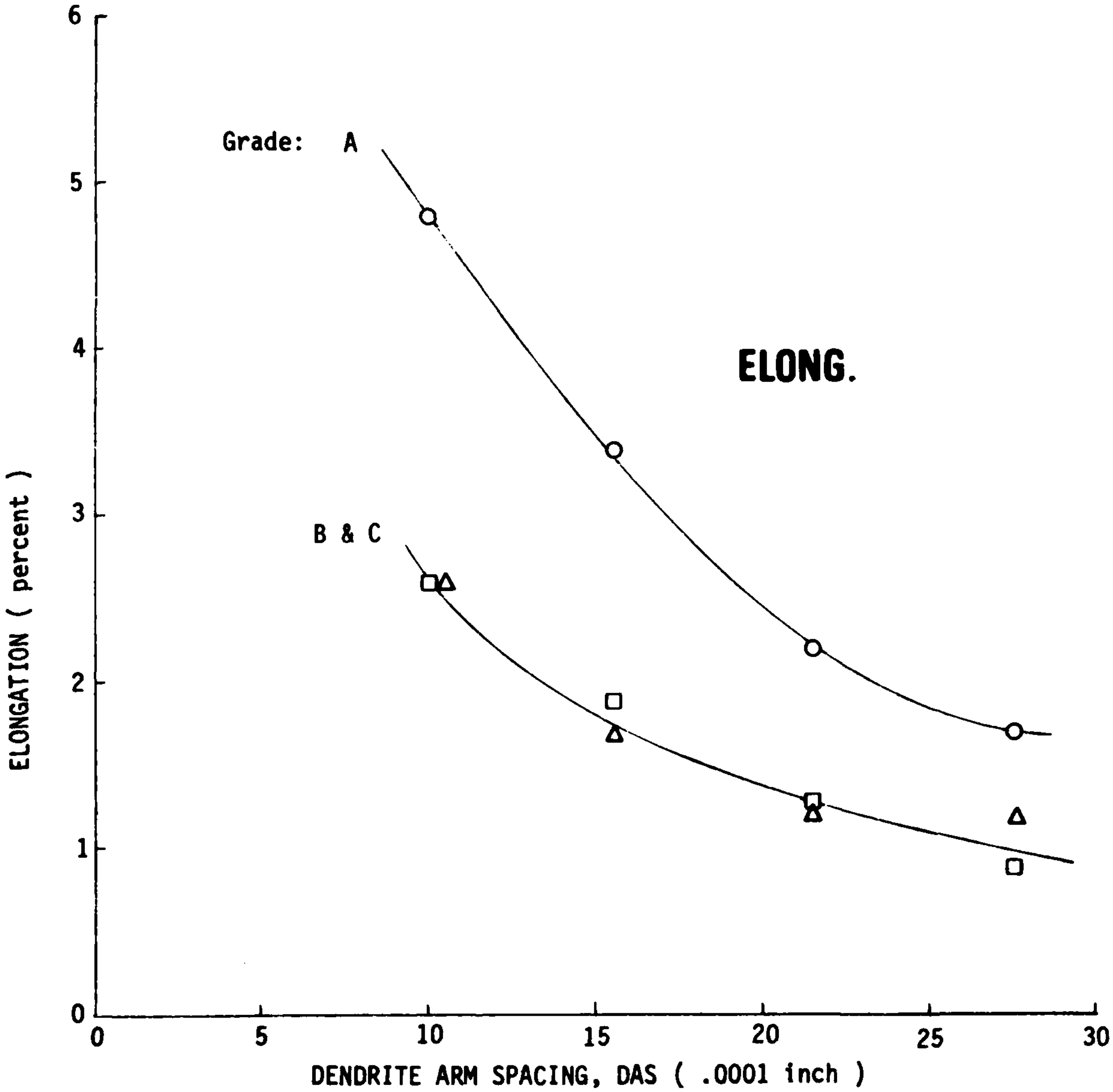


FIGURE 15 AVERAGE ELONGATION TRENDS WITH DENDRITE ARM SPACING AND SOUNDNESS
A357-T6 CAST

TABLE 3 PHASE II TENSION PROPERTY STATISTICS
A357-T6 CAST

Specimen Soundness Grade

Specimen DAS	PROPERTY	A MAX.	A MIN.	A AVG.	A S.D.	B MAX.	B MIN.	B AVG.	B S.D.	C MAX.	C MIN.	C AVG.	C S.D.	D AVG.
		N = 14				N = 13				N = 3				N = 1
LEVEL 1 Up To .0012 inch	TUS	51.9	44.5	50.0	1.5	53.7	44.8	48.4	2.2	51.5	42.8	48.0	4.6	42.7
	TYS	44.7	37.5	41.1	1.7	44.4	37.3	41.5	1.7	42.7	37.8	40.8	2.6	37.7
	ELONG	11.5	2.5	4.8	1.46	6.7	1.4	2.6	1.92	4.4	1.3	2.6	1.33	1.1
		N = 120				N = 69				N = 29				N = 0
LEVEL 2 .0013 to .0018 inch	TUS	52.3	41.9	48.3	1.6	53.9	39.6	47.0	2.5	50.0	42.5	45.9	2.0	---
	TYS	46.9	37.5	40.3	1.5	46.8	33.5	41.0	2.4	44.0	35.4	40.2	1.1	---
	ELONG	12.4	0.6	3.4	1.73	7.2	0.4	1.9	1.89	5.5	0.6	1.7	1.65	---
		N = 70				N = 35				N = 14				N = 1
LEVEL 3 .0019 to .0024 inch	TUS	50.0	42.4	47.0	1.5	48.4	41.5	45.4	1.6	49.7	44.4	45.0	1.7	41.5
	TYS	42.9	38.1	40.3	1.2	42.9	38.5	40.2	1.1	43.4	37.2	40.7	1.4	40.4
	ELONG	8.1	0.6	2.2	1.77	4.0	0.5	1.3	1.69	3.6	0.6	1.2	1.50	0.3
		N = 4				N = 9				N = 4				N = 0
LEVEL 4 .0025 to .0030 inch	TUS	46.9	46.0	46.4	0.4	47.5	43.1	45.5	1.4	44.6	43.3	44.2	0.6	---
	TYS	41.5	38.6	40.4	1.3	43.2	39.6	41.2	1.4	41.0	37.4	39.4	1.6	---
	ELONG	3.3	1.1	1.7	1.59	1.3	0.6	0.9	1.20	4.3	0.5	1.2	2.50	---

TUS, ksi
TYS, ksi
ELONG, percent
N = quantity of results in each cell

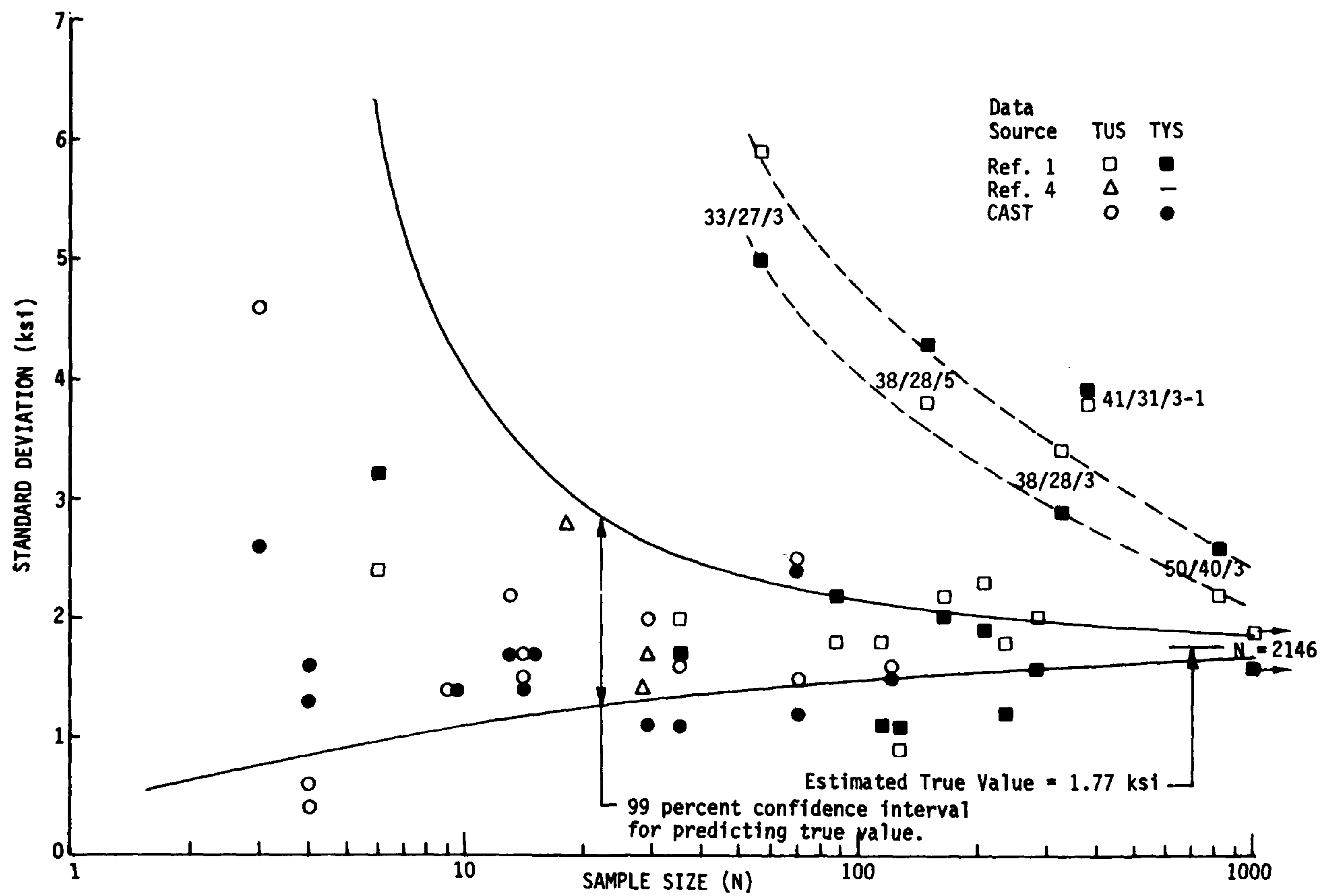


FIGURE 16 STANDARD DEVIATIONS OF TUS AND TYS FOR A357-T6 CASTINGS

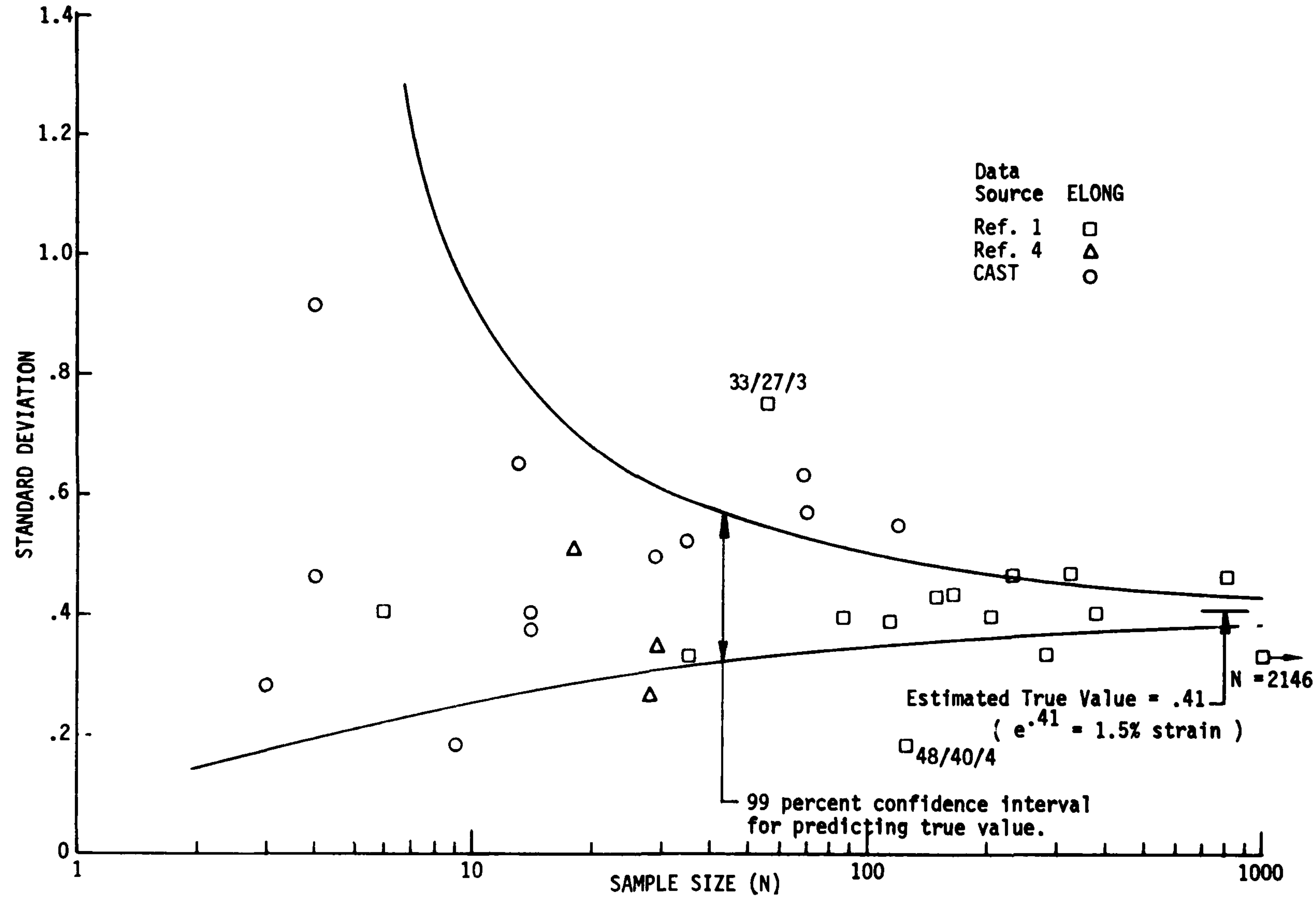


FIGURE 17 STANDARD DEVIATIONS OF ELONGATION FOR A357-T6 CASTINGS

In Figures 16 and 17, the convergent solid curves represent theoretical 99 percent confidence level limits for estimating the population standard deviations assuming that sample standard deviations follow the chi-squared distribution with (N-1) degrees of freedom. The curves were constructed using the following expressions per reference 5:

$$\text{Lower Limit} = \frac{s}{\sqrt{\dfrac{\chi^2_{\alpha/2,\nu}}{\nu}}}$$

$$\text{Upper Limit} = \frac{s}{\sqrt{\dfrac{\chi^2_{1-\alpha/2,\nu}}{\nu}}}$$

where:

s = standard deviation estimate of the population

χ^2 = chi-squared values for (α/2) and (1 - α/2) probability levels

ν = degrees of freedom (N-1)

N = sample size

Results from the above analysis for mean values and standard deviations of A357-T6 tensile properties can be combined to establish CAST program allowables and a general format for all other A357 produced castings. This format is that proposed by MIL-HDBK-5 for establishing statistical design values based upon normal data distributions.

$$X_A = \overline{X} - ks$$

where:

X_A = statistical A-basis value with 95 percent confidence, 99 percent proportion

$\overline{X}$ = mean value

k = statistical confidence/proportion coefficient

s = standard deviation

Since both strength and elongation standard deviations have been established as population characteristics, the term k corresponds to an infinite sample size and becomes the Student's t-value, named after W. S. Gosset and contained in many statistical books and tables. For example, see page 87 of reference 6. The t-value for a 99 percent proportion is 2.326.

Using this value with the standard deviations of 1.77 ksi for strength and 0.41 for elongation allows the above expression to be rewritten for each property:

$F_{tu} = \overline{TUS} - 4.12$ ksi

$F_{ty} = \overline{TYS} - 4.12$ ksi

$e \quad = \overline{ELONG} - 0.954$

The elongation allowable must be transformed by (e^x) to obtain a design value in percent strain. Proposed tension property allowables from Phase II of the CAST program are presented in Table 4.

The above tension design properties format should be applicable to A357 castings regardless of method of manufacture or heat-treatment processing. For the particular chemistries, heat treatments, levels of DAS, and soundness grades produced in this program, specific tension allowables will be tested against CAST bulkhead properties in Section IV of this report. As shown in Section II, slight variations within the acceptable limits of heat treatment, and possibly chemistry, may produce casting zones with the same DAS and soundness, but significantly different tensile properties. This means that although DAS and soundness may represent suitable dual-basis design property qualifiers, there are other physical aspects that must be qualified prior to assuming the general state of applicability.

4. DERIVED PROPERTIES

A summary of derived property ratios analyses is presented in Table 5. Compression, shear and bearing data are contained in Appendix E. These data were ratioed by tension data for specimens of adjacent casting locations and are contained in Appendix F. These ratios were grouped into the tension DAS/soundness cells previously established and statistics were computed for each cell of ratios including average ratio $(\overline{r})$ and standard deviation (s). The average ratios

TABLE 4 CAST PROGRAM TENSION ALLOWABLES

		Specimen Soundness Grade (ASTM E-155)			
Specimen DAS Range	Property	A	B	C	D
Up To .0012 inch	F_{tu}	45.9	44.3	43.6	-
	F_{ty}	36.5	36.5	36.5	-
	e	1.8	1.0	1.0	-
.0013 to .0018 inch	F_{tu}	44.2	42.9	42.1	-
	F_{ty}	36.5	36.5	36.5	-
	e	1.3	0.6	0.6	-
.0019 to .0024 inch	F_{tu}	42.9	41.5	40.8	-
	F_{ty}	36.5	36.5	36.5	-
	e	0.8	0.5	0.5	-
.0025 to .0030 inch	F_{tu}	42.3	40.9	40.1	
	F_{ty}	36.5	36.5	36.5	-
	e	0.6	0.4	0.4	-

F_{tu}, ksi
F_{ty}, ksi
e , percent

TABLE 5 DERIVED PROPERTY RATIOS SUMMARY
A357-T6 CAST

Property Ratio	DAS Level	Tension Specimen Soundness Grades A			B			C			D		
		N	$\bar{r}$	s	N	$\bar{r}$	s	N	$\bar{r}$	s	N	$\bar{r}$	s
CYS/TYS	1	7	1.063	.032	2	1.039	.093	1	1.136	-	1	1.106	-
	2	19	1.032	.036	16	1.048	.033	10	1.074	.032	0	-	-
	3	13	1.058	.020	9	1.063	.032	8	1.038	.024	0	-	-
	4	2	1.026	.029	3	1.020	.075	0	-	-	0	-	-
SUS/TUS	1	5	.694	.0085	0	-	-	1	.701	-	0	-	-
	2	17	.713	.033	6	.715	.010	3	.731	.049	0	-	-
	3	13	.740	.021	7	.732	.049	7	.756	.018	0	-	-
	4	2	.737	.023	3	.737	.010	0	-	-	0	-	-
BYS/TYS	1	3	1.555	.059	0	-	-	0	-	-	0	-	-
e/D = 1.5	2	17	1.645	.083	7	1.641	.056	2	1.613	.037	0	-	-
	3	3	1.690	.025	4	1.676	.043	2	1.694	026	0	-	-
	4	1	1.679	-	0	-	-	0	-	-	0	-	-
BUS/TUS	1	3	1.561	.155	0	-	-	0	-	-	0	-	-
e/D = 1.5	2	17	1.607	.092	7	1.583	.081	2	1.507	.128	0	-	-
	3	4	1.582	.226	6	1.522	.142	3	1.567	.200	0	-	-
	4	2	1.481	.032	1	1.396	-	0	-	-	0	-	-
BYS/TYS	1	1	1.929	-	3	2.05	.131	0	-	-	0	-	-
e/D = 2.0	2	22	1.984	.070	10	1.978	.105	4	1.882	.042	0	-	-
	3	8	1.980	.046	6	1.959	.042	3	1.983	.094	0	-	-
	4	0	-	-	1	2.03	-	0	-	-	0	-	-
BUS/TUS	1	1	1.970	-	3	2.00	.083	1	2.07	-	0	-	-
e/D = 2.0	2	23	2.02	.103	10	2.02	.090	4	1.991	.099	0	-	-
	3	8	2.12	.120	6	2.09	.127	3	2.06	.068	0	-	-
	4	0	-	-	1	2.10	-	0	-	-	0	-	-

Notes: CYS = Compression Yield Strength
SUS = Shear Ultimate Strength
BYS = Bearing Yield Strength
BUS = Bearing Ultimate Strength

N = sample size
$\bar{r}$ = average ratio value
s = standard deviation value
e/D = edge margin

DAS Levels: 1 = up to .0012 inch; 2 = .0013 to .0018 inch;
3 = .0019 to .0024 inch; 4 = .0025 to .0030 inch

DAS measurements from specimen fracture zones are plotted against cell sample size in Figure 18 to illustrate that neither DAS nor soundness influences ratio values. This permits all data of each property ratio to be pooled to develop a reduced ratio design property. The reduced ratios are shown by lines in the figure and are naturally weighted towards the larger cell sample averages.

The recommended use of derived property ratios for A357-T6 castings is to first obtain the tensile property allowable according to DAS and soundness, then multiply that allowable by the reduced ratios shown below to obtain the compression, shear, or bearing allowables.

$F_{cy}/F_{ty} = 1.045$ $F_{bry}/F_{ty} = 1.627(e/D = 1.5); = 1.959(e/D = 2.0)$

$F_{su}/F_{tu} = 0.720$ $F_{bru}/F_{tu} = 1.538(e/D = 1.5); = 2.02(e/D = 2.0)$

Appendix G contains derived property ratio analysis details.

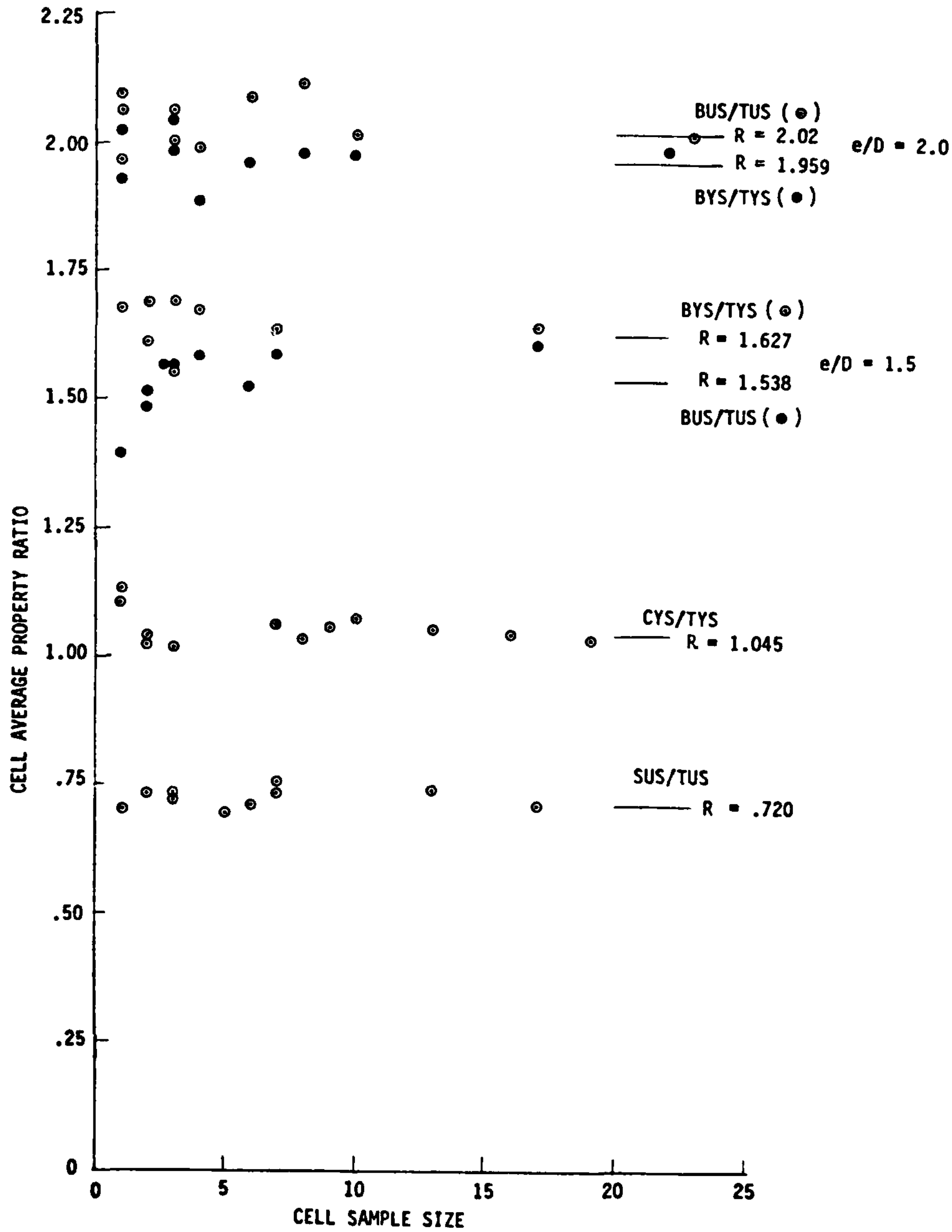


FIGURE 18 DERIVED PROPERTY RATIOS
A357-T6 CAST

SECTION IV
ALLOWABLES ASSESSMENT

1. BULKHEAD TENSION PROPERTIES

Four bulkheads from the 20 parts produced during Phase IV were used to assess allowables developed in Phase II. Tension coupons were measured after tests for DAS and soundness in zones adjacent to fracture. The four castings included two each produced by the Boeing and Hitchcock foundries. One of the two Hitchcock castings, identified herein as H2, was reported as having been produced from low-phosphorus ingot. This casting was selected for evaluation primarily to determine if any differences in properties resulted from that chemistry. Other fabrication and processing features were common among all castings.

Bulkhead tensile properties can be categorized into six zones: Lugs, Upper (Slant Beam) Flange, Corrugations, Webs and Stiffeners, Fittings, and the Periphery Flange. Average properties for each of these zones are listed in Table 6. Comparative results are shown for each of the four castings. The heavily chilled lug zones exhibit the highest strengths and elongations. The periphery flange exhibits the lowest properties. Specimens from the periphery flange showed the largest DAS and greatest amounts of shrinkage. Individual test results are contained in Appendix H.

Observations made from properties listed in Table 6 are as follows:

1. Boeing castings MO8 and MO9 exhibit similar properties.
2. Hitchcock casting H2 exhibits consistently higher TUS and ELONG than casting H9.
3. The Boeing castings have higher TUS and TYS but lower ELONG than Hitchcock castings.

The lowest of combined bulkhead average properties form two groups: Critical Area (lugs) 48/38/5 and Other Areas 44/34/2. Ultimate strength design requirements for both Critial (46/40/5) and Other (40/30/3) Areas are exceeded in both cases. A slight deficiency for TYS in lugs can be eliminated by heat treatment. Elongation properties do not support the Other Areas design

TABLE 6 TENSILE PROPERTIES OF
Sta. 170 YC-14 BULKHEADS
A357-T6 Phase V CAST

Casting Location:	Boeing Foundry M08	Boeing Foundry M09	Hitchcock Foundry H2	Hitchcock Foundry H9
Lugs	52.6/42.6/6.1	51.0/41.4/5.4	49.4/38.1/7.7	48.1/38.1/5.1
Upper Flange	48.2/39.5/3.1	46.9/38.5/2.7	45.3/34.5/4.7	44.4/34.9/2.7
Corrugations	49.1/40.6/2.0	47.4/39.8/3.0	47.0/38.6/3.7	45.5/38.5/2.1
Webs & Stiffeners	49.7/42.7/2.1	46.7/40.8/1.7	46.8/39.1/2.8	45.9/39.1/2.3
Fitting	50.3/43.0/2.2	50.5/41.2/4.5	48.4/39.9/3.6	46.4/39.4/2.0
Periphery Flange	45.0/41.9/0.6	44.8/40.9/1.0	44.8/41.8/0.6	42.6/41.2/0.4

Averages:	Boeing	Hitchcock
Lugs	51.8/42.0/5.8	48.8/38.1/6.4
Other Areas	47.2/40.6/2.0	45.3/38.5/2.4

Note: Data are averages of TUS(ksi)/TYS(ksi)/Elong.(percent) requirements, especially in the periphery flange. This is not abnormal for initial production development. Future efforts will be directed to improving ductility.

2. ALLOWABLES ASSESSMENT

Phase V tensile properties were used to assess allowables established in Phase II. The link between these two groups of information is specimen DAS and soundness measurements. These two parameters dictate the allowables applicable to Phase V bulkhead TUS and ELONG properties.

Results of this assessment are dependent upon the statistical basis used to establish allowables. A statistical A-basis was selected for tensile properties. Only the resulting allowables for TUS and ELONG vary with DAS levels and soundness grades. The tentative allowable for TYS is a constant (F_{ty} = 36.5 ksi).

The assessment of allowables for TUS is shown in Figure 19 (grade A) and Figure 20 (grades B and C). In each diagram, individual results are plotted against specimen measured DAS values. Only three of the TUS results fell below the Phase II developed allowables. Two of these results are soundness grade A. Specimen 20 from Boeing casting MO8 failed at 29.2 ksi prior to yield. The reason for this premature failure is unknown. The other grade A suballowable result is from a Hitchcock casting H9 lug. Prior to test, a gas pore was noted open to the specimen gage section surface. This defect was approximately 0.015 inch in diameter, and caused the specimen to fail at 10 ksi. Both of the above results show the importance of nondestructive inspection requirements. Defects in these two casting zones should have been nondestructively identified and weld corrected prior to actual production casting acceptances. One grade C TUS result per Figure 20 at a DAS of 0.0028 inch had a value of 40 ksi where the tentative allowable is 40.1 ksi. This difference is not significant. In general, Phase V TUS results show that the Phase II developed allowables are acceptable.

TYS data are shown in Figures 21 (grade A) and 22 (grades B and C). Eight results are below the tentative allowable of 36.5 ksi. Two of the grade A results were previously discussed. The other two grade A results are between 35 and 36 ksi, and not sufficient to cause an allowables adjustment. Figure 22 shows four grade B TYS results below 36.5 ksi. These and three of the four grade A results are

TUS

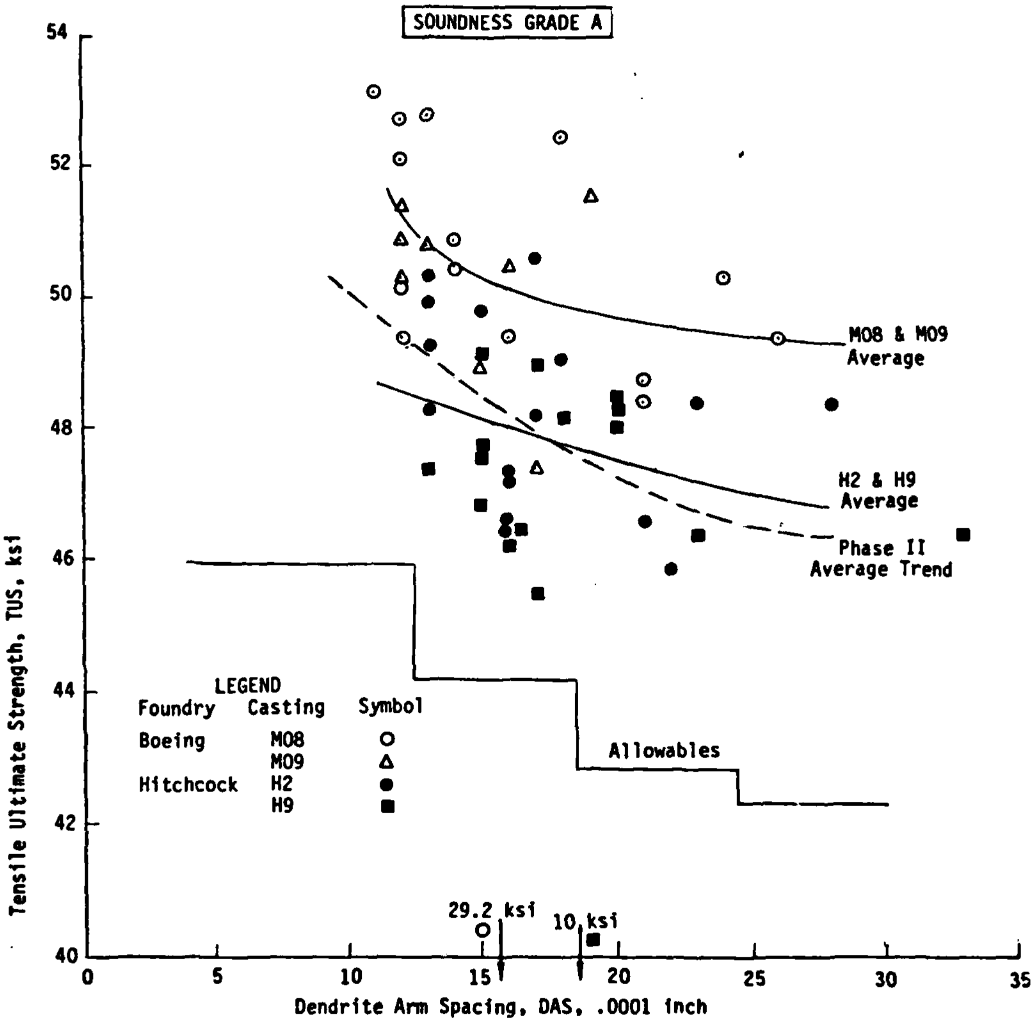


FIGURE 19 TUS DATA COMPARISONS
A357-T6 CAST

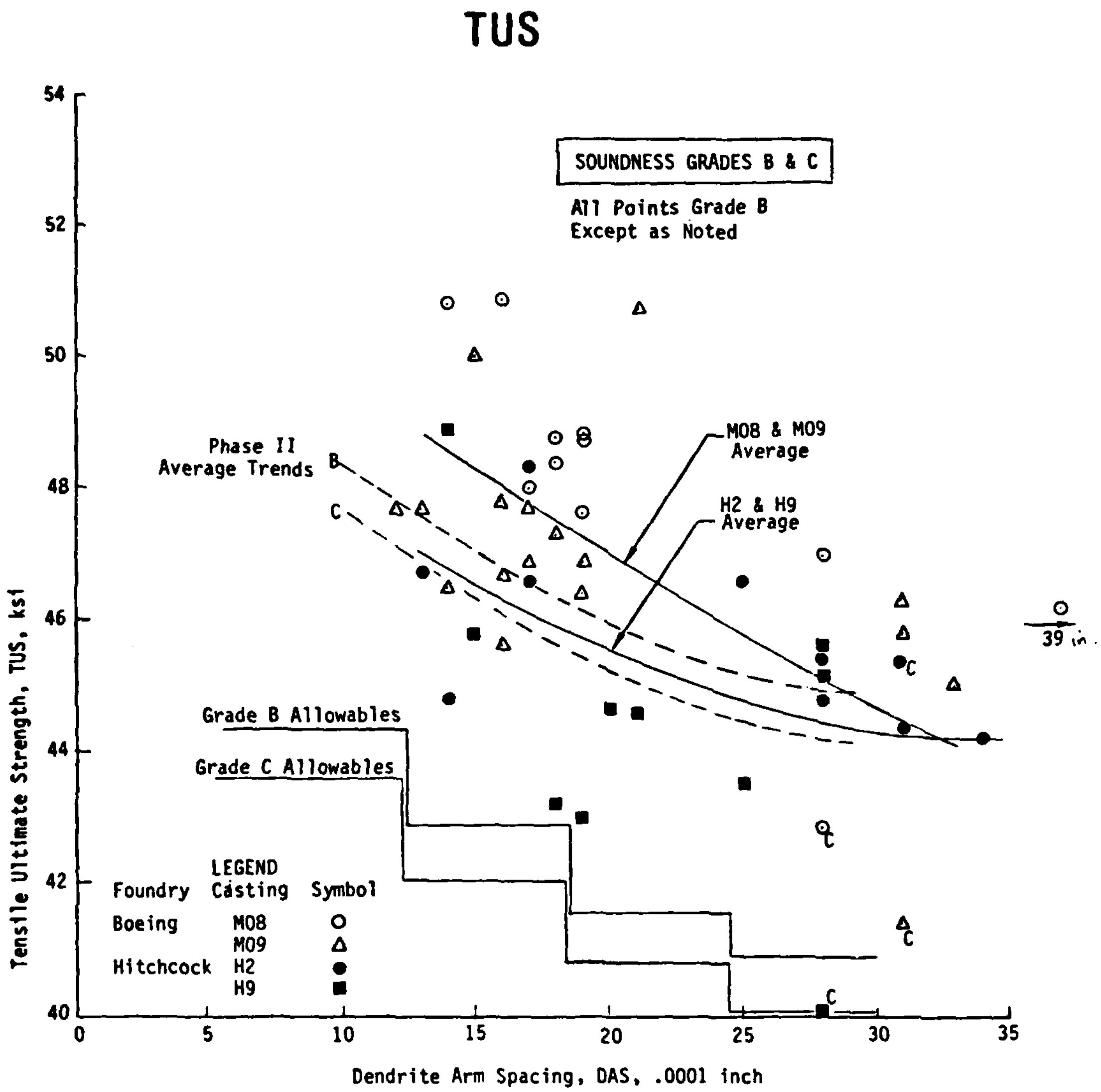


FIGURE 20 TUS DATA COMPARISONS
A357-T6 CAST

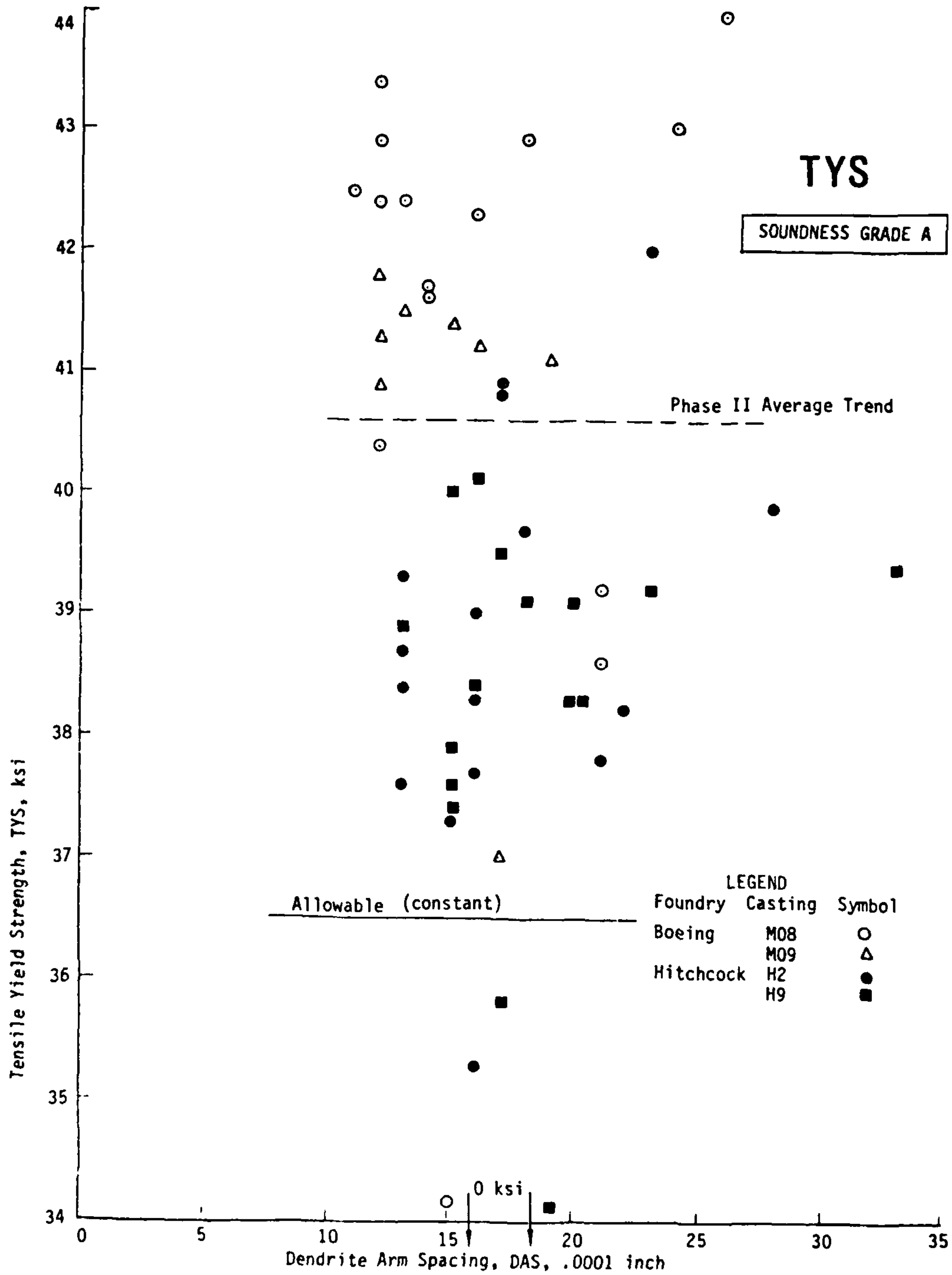


FIGURE 21 TYS DATA COMPARISONS
A357-T6 CAST

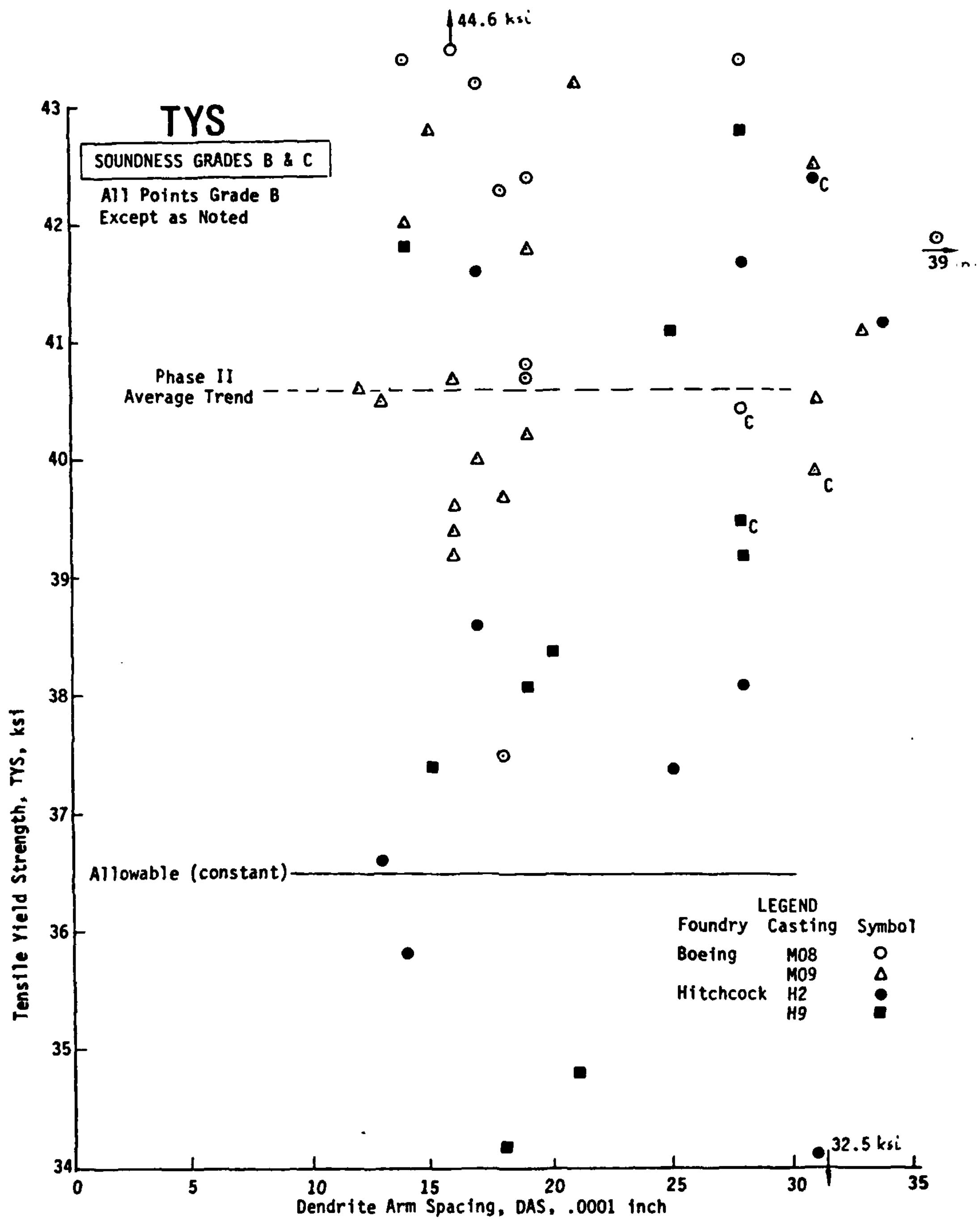


FIGURE 22 TYS DATA COMPARISONS
A357-T6 CAST

from Hitchcock castings. In both Figures 21 and 22, it is noted that Hitchcock castings TYS results are generally less than the Boeing castings TYS values. The dividing line seems to be the Phase II average trend value of 40.6 ksi. This may have been caused by a minimum artificial aging condition used by Hitchcock as noted for other data in Section II. Overall, the allowable for TYS appears to be adequate.

ELONG assessments are shown in Figures 23 (grade A) and 24 (grades B and C). Only two grade A results fall below the allowable. These were discussed for TUS and are not considered to represent acceptable material properties. The grade A ELONG allowables are believed to be adequate. In Figure 24, grades B and C have the same allowables in each of the four DAS level ranges. In the highest DAS level, two grade C results are less than the allowable of 0.4 percent, but the amounts they deviate below the allowable are minimal. It is therefore believed that the allowables established in Phase II for ELONG are adequate without any adjustment.

3. SUPPLEMENTAL ASSESSMENT

In addition to the 26 specimen locations in each bulkhead casting used to describe tension characteristics and to assess allowables, supplemental tests were conducted to describe tension properties of two other zones in detail. Tension coupons were excised from all left-hand walls of corrugation stiffeners from castings MO9 and H9. Tension coupons were also excised from one-half of the periphery flange at alternate step gate and chill locations from casting MO9. Results are shown in Figures 25, 26, and 27 for TUS, TYS, and ELONG, respectively. Phase II allowables are superimposed. Results are segregated by soundness grade and plotted against DAS.

All TUS grade A results are above the allowables. See Figure 25. The majority of grade B results are sufficiently above the allowables. Only two grade B and three grade C results fall below the allowables. The marginal points below the grade C allowables suggest no adjustments are necessary.

In Figure 26, all supplemental TYS test results, with the exception of one grade B result at a DAS of 0.0017 inch, exceed the 36.5-ksi allowable. The one test result

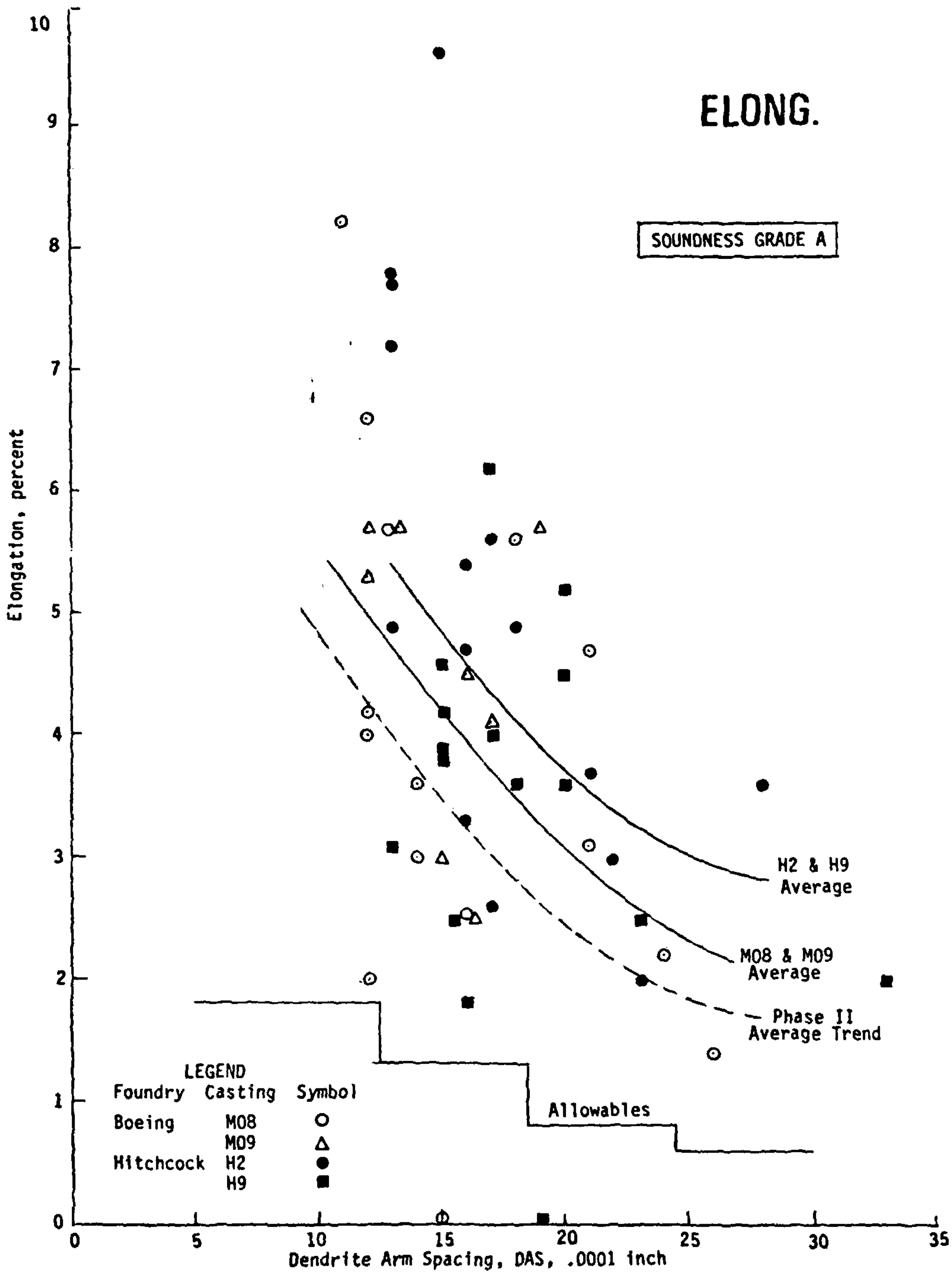


FIGURE 23 ELONGATION DATA COMPARISONS
A357-T6 CAST

ELONG.

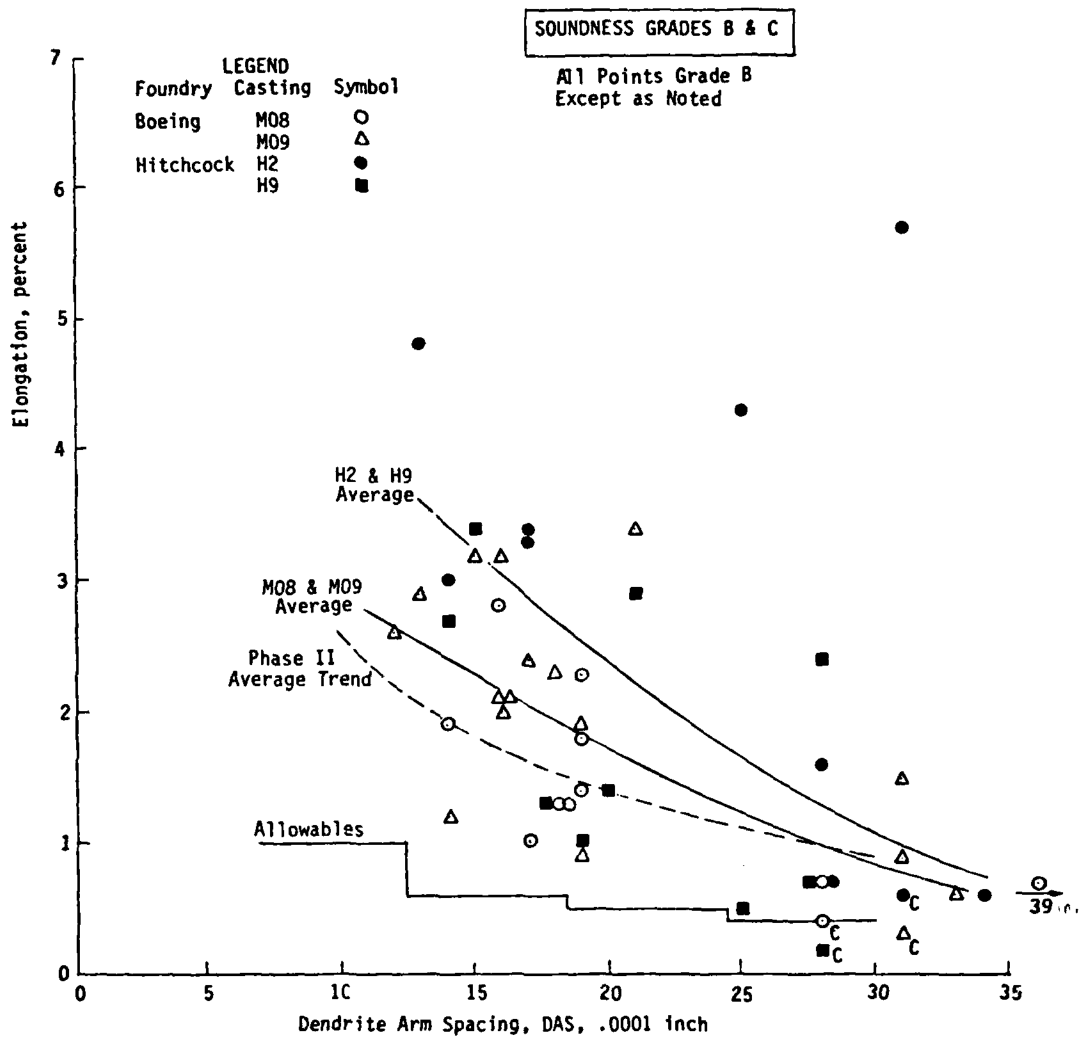


FIGURE 24 ELONGATION DATA COMPARISONS
A357-T6 CAST

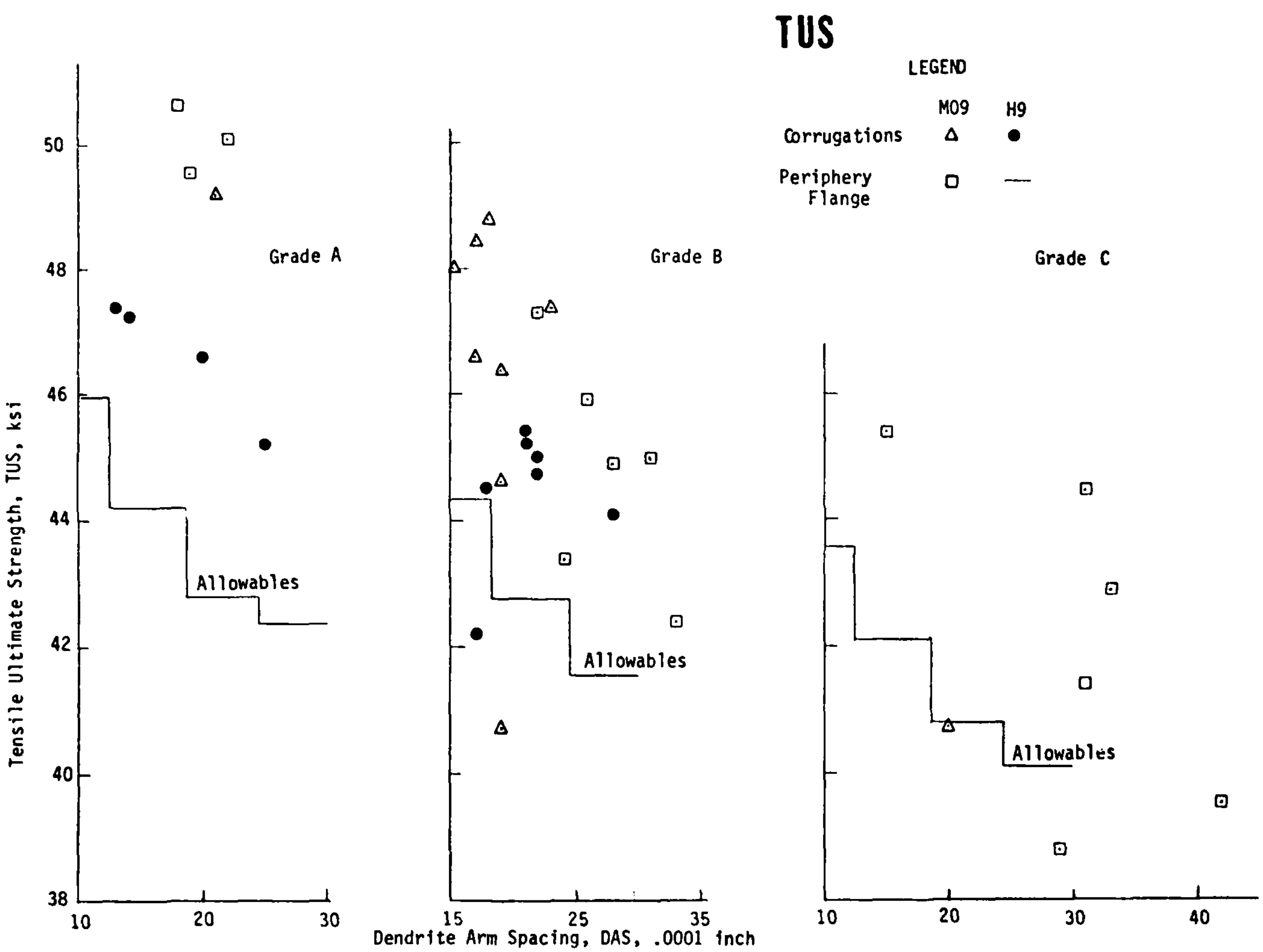


FIGURE 25 TUS DATA COMPARISONS
SUPPLEMENTAL TESTS
A357-T6 CAST

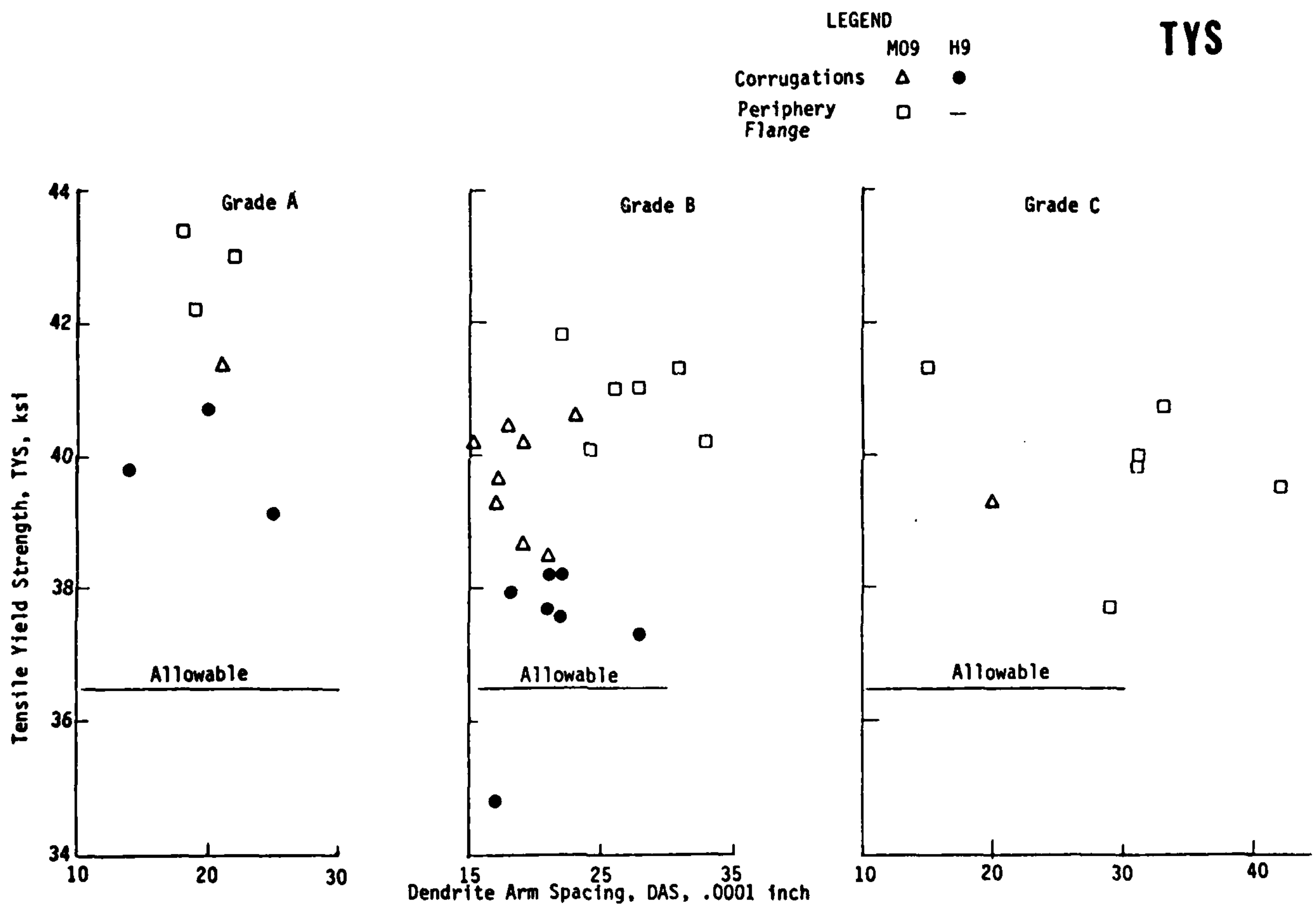


FIGURE 26 TYS DATA COMPARISONS
SUPPLEMENTAL TESTS
A357-T6 CAST

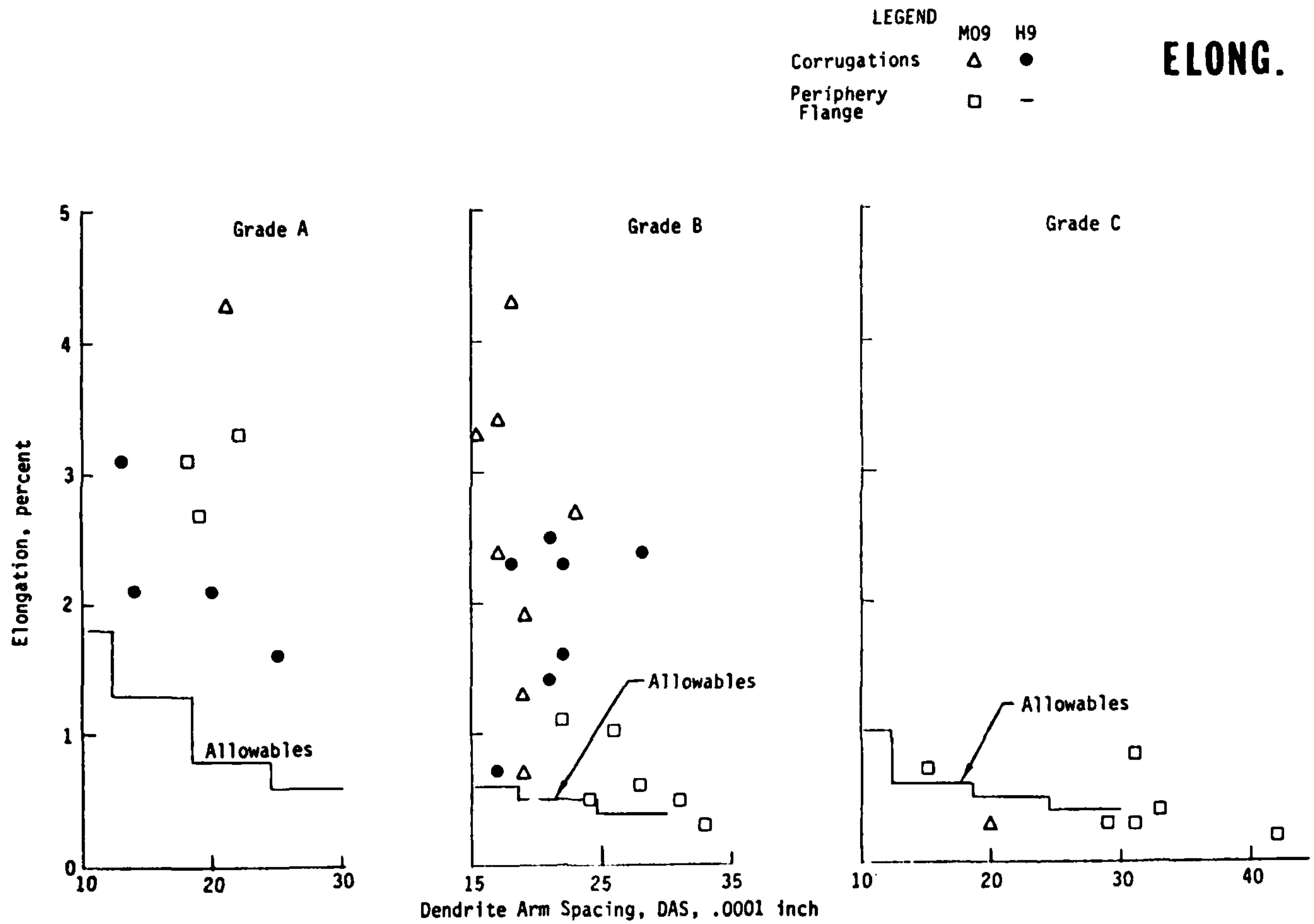


FIGURE 27 ELONGATION DATA COMPARISONS
SUPPLEMENTAL TESTS
A357-T6 CAST

with a TYS of 34.8 ksi has questionable validity. That specimen failed in the gage-to-grip transition zone apparently due to a much lower soundness quality than in the reduced gage section. This single result is not sufficient to cause an allowables adjustment.

In Figure 27, all grade A ELONG results are shown to support the allowables, as do the majority of grade B results. Only two grade B results are marginal. The grade C ELONG supplemental test results are all below 1 percent strain. One corrugation and six periphery flange zones had soundness grade C. Five of the six periphery flange results represent DAS values above 0.0029 inch. Material of this soundness and DAS range cannot be expected to demonstrate an appreciable ductility. In general, the supplemental ELONG test results support the allowables.

SECTION V
CONCLUSIONS AND RECOMMENDATIONS

Technology improvements developed during the CAST program pertaining to static properties of high-strength aluminum alloy castings are summarized into the categories of material behavior, design properties, and their general applicability.

With respect to material behavior:

1. Ultimate strength and elongation of A357-T6 castings depend upon dendrite arm spacing and soundness. These tensile properties increase with smaller dendrite arm spacings and higher soundness.

2. Yield strength is primarily influenced by heat treatment.

3. Tensile properties are not direct functions of foundry variables or casting geometry, although these variables influence the resulting physical conditions of all casting zones.

4. A356 casting data demonstrate the same dependencies on aluminum dendrite size as determined for A357. Soundness effects on A356 have not been evaluated.

With respect to design properties:

1. Static allowables have been developed from CAST program tensile data. Ultimate strength and elongation values depend upon specific categories of dendrite arm spacing and soundness. Yield strength is a constant.

2. These allowables have been validated with data obtained from full-scale CAST bulkheads.

With respect to applicability:

1. Static design properties developed in the CAST program must be qualified for applicability to all A357 castings produced by all foundries. The purpose of this qualification is to ensure that ultimate strength and elongation dependencies on dendrite arm spacing and soundness are not altered by differences in either chemistry or heat treatment. Specific applicability of the yield strength allowable depends upon the particular conditions employed in the heat-treatment process.

2. The general applicability of design properties also depends upon the consistency of casting production. Consistently acceptable products require use of a procurement specification in which controls and inspections are based upon the physical parameters that influence static properties.

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2. Frederick, S. F. and W. A. Bailey, "The Relation of Ductility to Dendrite Cell Size in a Cast Al-Si-Mg Alloy," Trans. of the Metallurg. Soc. of AIME, vol. 242, p. 2063, Oct. 1968.

3. Spear, R. E. and G. R. Gardner, "Dendrite Cell Size, "AFS Trans., p. 209, 1963.

4. Binder, H. F. et al., "Program for Evaluation of Effect of Dendrite Cell Size on Mechanical Properties of Aluminum Alloy Castings," Hughes Helicopters Report HH75-173, report to U.S. Army Aviation Systems Command, Contract DAAJ01 74-C-0282, July 1975.

5. Crow, E. L. et al., "Statistics Manual," NAVORD Report 3369, NOTS 948, 1960.

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APPENDIX A
TEST SPECIMENS AND PROCEDURES

GENERAL

Test specimens and procedures were in accordance with ASTM. Two Baldwin Universal test machines were used, one a 20-kip Model CS and the other a 120-kip Model CS. These machines were calibrated in accordance with ASTM Method E4-72 to ensure loading accuracy within 1.0 percent. The machines are equipped with integral automatic load or strain pacers and autographic load-strain recorders. The extensometers conformed to ASTM E83-67 classification B1, having an accuracy of 0.0001 in./in.

Specific test specimens and procedures for the tension, compression, shear, and bearing tests are described in the following paragraphs. All static tests were conducted in a laboratory air environment.

TENSION

Two configurations were used. One was round for tests from casting zones 0.5 inch thick or greater. All lesser thickness zones were tested using flat specimens as shown in Figure 28. The specimens and testing procedures were in accordance with ASTM E8-69.

COMPRESSION

Flat and round specimens, per Figure 28, were used as applicable. Both were tested in accordance with ASTM E9-70 using a loading subpress. Side support to prevent buckling of flat specimens was provided by a Montgomery-Templin compression fixture using rollers.

SHEAR

Double-shear cylindrical specimens, 1/4 inch in diameter, Figure 28, were used for the thicker sections of the castings. Double-shear flat specimens were used for the thinner sections of the castings.

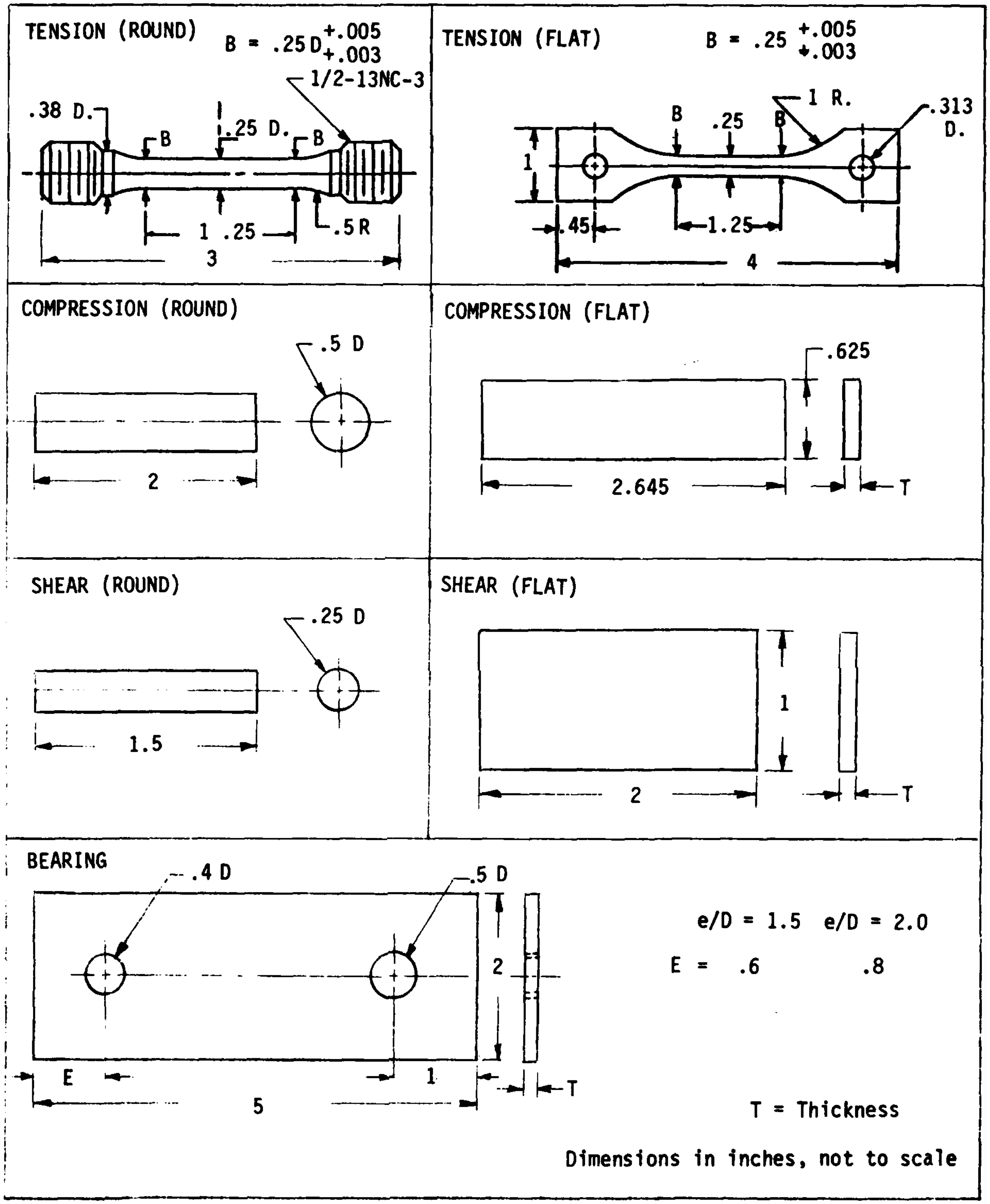


FIGURE 28 STATIC SPECIMEN CONFIGURATIONS

BEARING

Bearing tests were conducted in accordance with ASTM Method E238-68. Specimens, as shown in Figure 28, have a constant ratio of bearing pin diameter to thickness (D/t) of 4.0 and of specimen width to bearing pin diameter (W/D) of 5.0, and edge margin ratios (e/D) of 1.5 and 2.0. Bearing specimens were machined flat from all mid-depth locations of all thick sections. Specimens, pins and fixtures were cleaned prior to testing in accordance with ASTM E238-68.

Blank

APPENDIX B
FOUNDRY VARIABLES

BOEING PART A CASTINGS

Details of specimens from Boeing Part A castings are described in relation to the following variables:

1. Location within each casting
2. Strength/elongation class and quality grade
3. Nominal section thickness
4. Distance from ingates
5. Distance from chills
6. Distance from risers and insulators, when applicable

Boeing Part A castings were poured in a vertical position, thereby eliminating risers. The allocation of coupons from these castings is shown in Table 2. In addition each casting contained five integral cast-on tensile coupons as shown in Figure 2.

The foundry variables are identified in Figures 29 and 30. These figures represent forward and aft faces of the Part A castings, respectively. In Figure 29, 12 ingates are designated by the symbols I1-I12. The forward face was chilled with 21 aluminum chills (A1-A21) and 25 copper chills (C1-C25). The aft face was chilled with 13 aluminum chills (A22-A34) and 17 copper chills (C26-C42). Details of chills are contained in Table 7. Table 8 shows ingate details.

Pertinent foundry variables for these castings consist of ingate and chill distances to specimens. These details are summarized in Table 9. Each specimen is identified by the coding explained in Appendix E, the nominal thickness of that section of the casting and the target values for strength/elongation and quality.

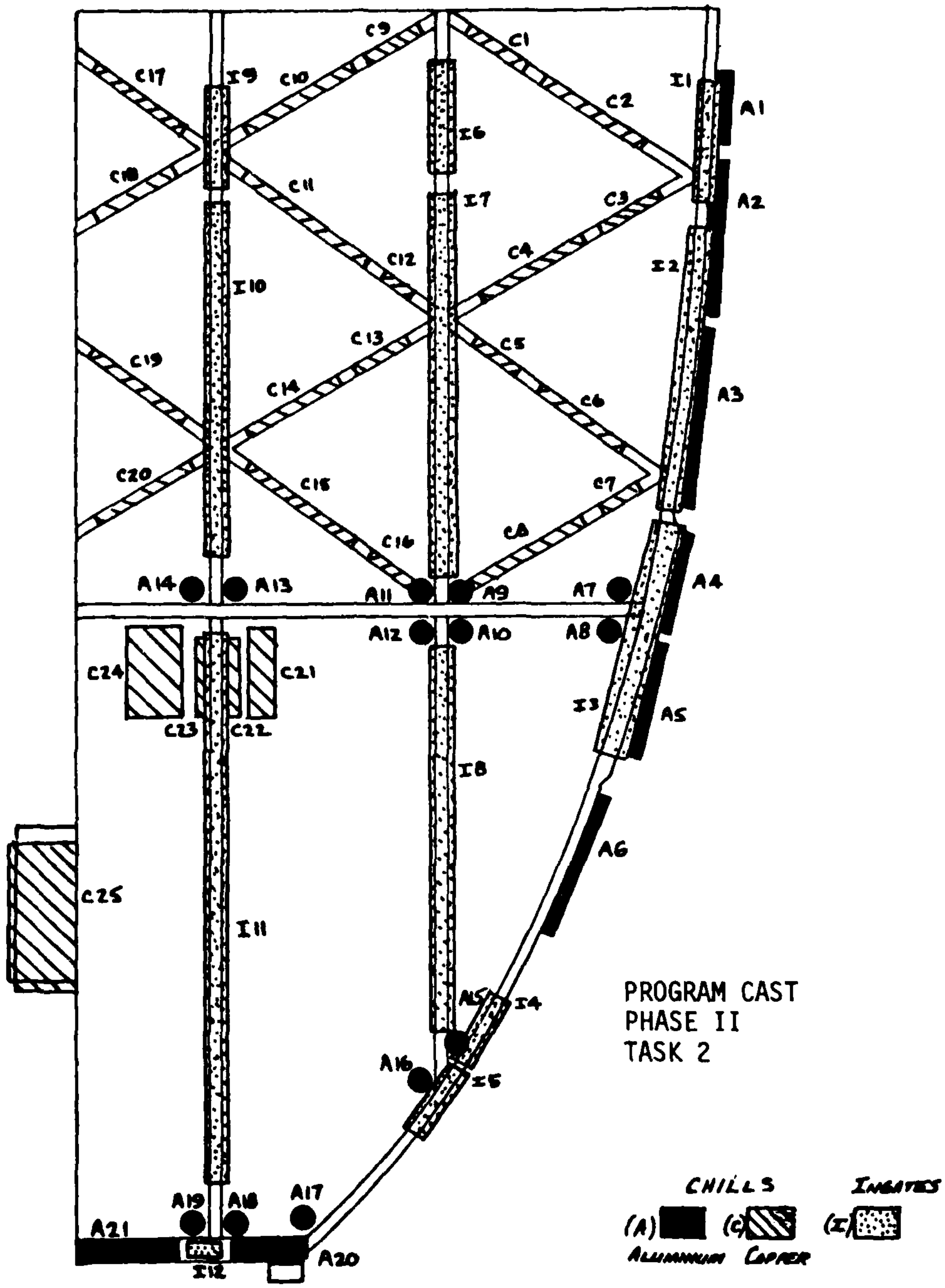


FIGURE 29 FORWARD FACE, BOEING PART A CASTINGS

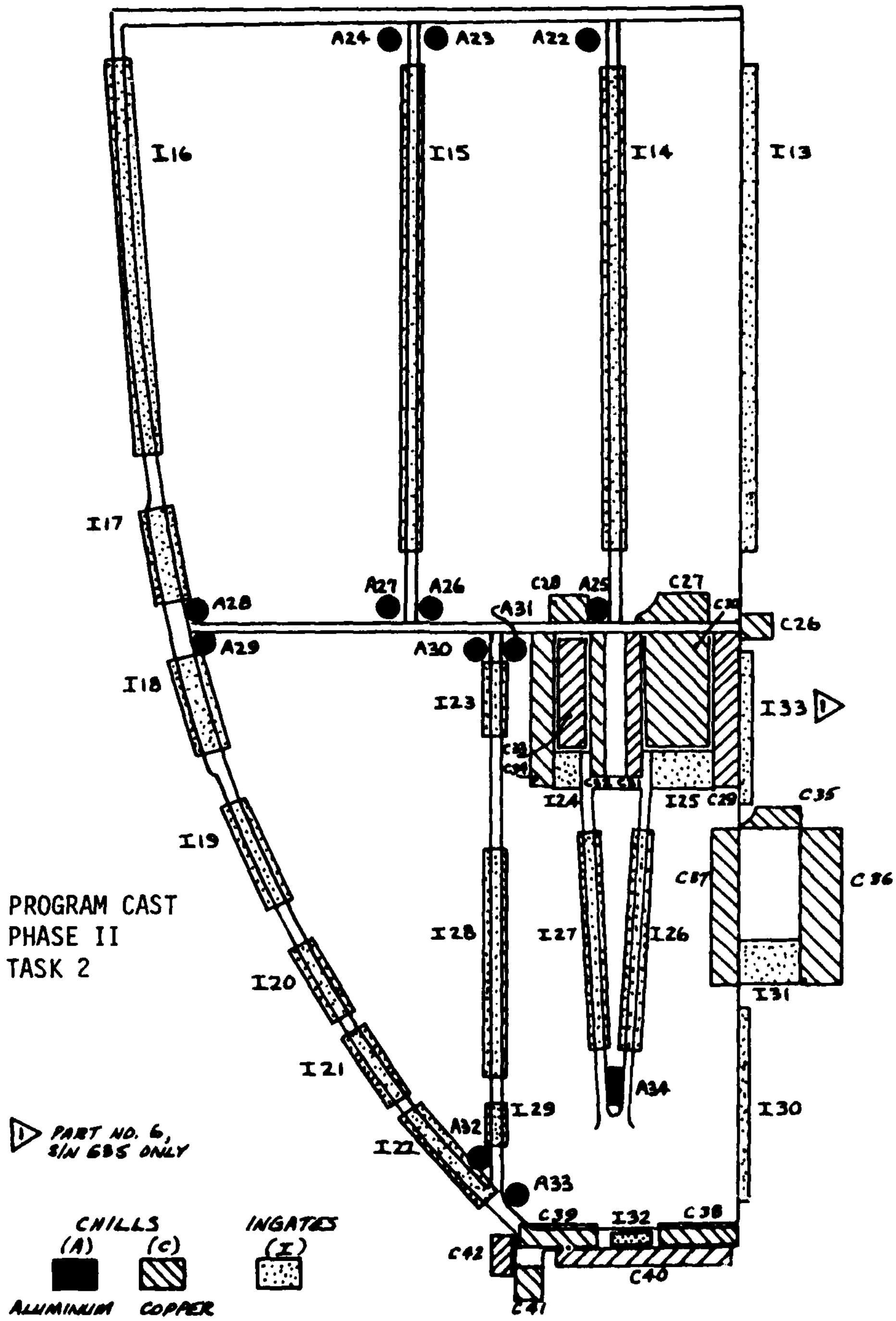
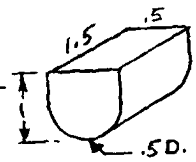
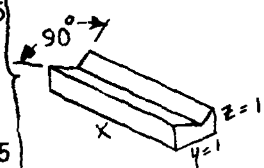
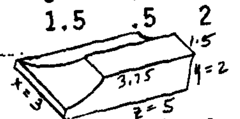
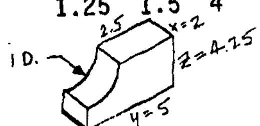
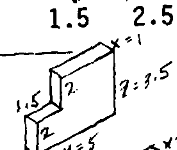
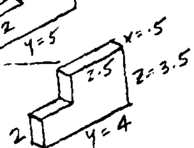
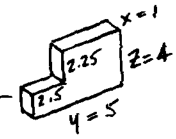
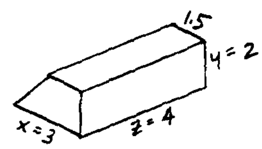


FIGURE 30 AFT FACE, BOEING PART A CASTINGS

TABLE 7 CHILL DETAILS
Boeing Part A

Chill	Dimensions [1] (x)	(y)	(z)	
Aluminum				
A1	1	3	1	
A2, A3	1	6	1	
A4, A5	1	4	1	
A6	1	6	1	
A7-A19	.75D	2	-	
A20	2	1	.75	
A21	3	1	1	
A22-A33	.75D	2	-	
A34	.5	1.5	1	
Copper				
C1, C3	3.5			
C2, C4	5.5			
C5	3			
C6,C8,C10, C11,C14,C14	5			
C7	2			
C9,C12,C13,C16	1.5			
C17-C20	3,5			
C21	1.25	5	2	
C22, C23	.5	5	1.5	
C24	2.5	5	2	
C25	3	5	3.5	
C26	1.5	.5	2	
C27				
C28	1.25	1.5	4	
C29,C36				
C30	1.5	2.5	2	
C31				
C32				
C33	.75	2.5	2	
C34				
C35				
C38, C39	3	1.25	1.25	
C40	5	1	1	
C41	1	1.25	5	
C42	1	1.5	5	

[1] Dimensions in inches per orientations:

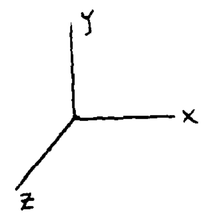


TABLE 8 INGATE DETAILS
Boeing Part A

Ingate	At Casting (x)	At Casting (y)	At Riser (x)	At Riser (y) [1]
I1	.375	8	.5	8
I2	.375	7	.5	7
I3	.75	7.5	.875	7.5
I4	.375	3	.5	3
I5	.375	2.5	.5	2.5
I6	.375	4.5	.5	4.5
I7	.375	11.75	.5	12.5
I8	.375	14	.5	14
I9	.375	3	.5	3
I10	.375	11.5	.5	12
I11	.375	17	.5	17
I12	1.5	.5	1.5	.75
I13	.5	15.75	.75	16.5
I14, I15	.5	19.5	.625	21.5
I16	.375	15.5	.625	15.5
I17, I18	.625	3.375	.75	3.625
I19	.375	4.125	.5	4.375
I20-I22	.5	3	.625	3.125
I23	.375	1.375	.375	1.75
I24	.625	2.5	1.25	2.5
I25	1.625	2.5	2.5	2.5
I26, I27	.375	5.875	.5	6
I28	.312	8.5	.5	8.75
I29	.312	1.5	.312	1.25
I30	.5	6.75	.75	7.12
I31	1.625	2.5	2.5	2.5
I32	.5	1.75	.75	2
I33 [2]	.5	6.75	.75	7.12

[1] Dimensions in inches per orientations:

[2] Used for casting no. 6 (S/N 635) only.

TABLE 9

SUMMARY OF FOUNDRY VARIABLES
PART A BOEING CASTINGS
PHASE II TASK 2
BOEING PATTERN NO. 6R672039

TARGET CLASS: 50/40/5 TARGET GRADE: B

DISTANCE FROM (INCHES):	INGATE					ALUMINUM CHILL					COPPER CHILL				
NOMINAL SECTION THICKNESS (INCHES)	0-.5	.5-1	1-2	2-5	>5	0-.5	.5-1	1-2	2-5	> 5	0-.5	.5-1	1-2	2-5	> 5
0.1															
0.2															
0.3				4B,7C 5T,6T					4B,7C 5T,6T						4B,7C 5T,6T
0.5															
1.0			3T 2C,2S	4T 3B					2C,2S 3T,4T 3B		3T,4T 2C,2S 3B				
2.0			1T,2T 14T,1C 1S T6,T7	13T 1B,2B					1T,2T 13T,14T 1C,1S 1B,2B	T6,T7	2T,13T 1B,2B	1T,14T 1C,1S T6,T7			

TARGET CLASS: 40/30/3 TARGET GRADE: C

NOMINAL SECTION THICKNESS (INCHES)	INGATE 0-.5	INGATE .5-1	INGATE 1-2	INGATE 2-5	INGATE >5	AL. CHILL 0-.5	AL. CHILL .5-1	AL. CHILL 1-2	AL. CHILL 2-5	AL. CHILL > 5	CU. CHILL 0-.5	CU. CHILL .5-1	CU. CHILL 1-2	CU. CHILL 2-5	CU. CHILL > 5
0.1			10T,18T	3S,7T,T5 8C,9T,10C 21T,23T,15C 24T,26T 17T,11C	10B,3C 8T,T10 12C,14C	26T,10C	18T	3S 9T,8C	7T,8T 3C,15C 12C,21T, T5,T10 23T	10T,10B 17T,11C 24T 14C				9T,8C 21T,12C 17T,11C 18T,24T 23T,14C	3S,7T,3C 8T,10T,10B 15C,T5,T10 26T,10C
0.2			22T 6S,6C	19T,20T 13C,7B 25T,9C 8B	15T,16T 5C,5S	25T,9C	6C,6S	15T,16T 5C,5S 20T	7B	19T,22T 8B,13C	16T	15T 6C,5S		19T,8B 20T,22T 6C,6S 7B,13C	25T,9C
0.3				T8					T8						T8
0.5			11T,T9	12T,6B 4C,4S				12T,6B 4C,4S	T9,11T		T9	11T,12T 4C,4S	6B		
1.0															
2.0															

HITCHCOCK PART A CASTINGS

Details of allowable specimens from five Hitchcock Part A castings are described in relation to the following variables:

1. Location within each casting
2. Strength/elongation class and quality grade
3. Nominal section thickness
4. Distance from ingates
5. Distance from risers
6. Distance from chills

The five Hitchcock castings provided 180 allowables test specimens. In addition to allowables specimens, five integral cast-on tension specimens were located at selected zones of each casting similar to the Boeing Part A castings.

Foundry variables are identified in Figures 31 and 32. These are drag (forward face) and cope (aft face) sides of the Hitchcock castings, respectively. In Figure 31, 23 ingates are designated by the symbols I1-I23. The geometries of these ingates are summarized in Table 10. Chilling of the dragside is also shown in Figure 31 by 14 normal chills (N1-N14) and 16 form chills (F1-F16). All normal chills were cast iron. All form chills were 70,000 manganese bronze. Details of chills are summarized in Table 11.

Figure 32 shows the locations of 23 risers (R1-R23), 42 normal chills (N15-N56) and 5 form chills (F17-F21) on the cope-side of these castings. Chill geometries are summarized in Table 11. Details of the risers are summarized in Table 10.

Table 12 shows the relations between foundry variables and specimen locations. The information is separated into two groups based on the target strength/elongation classes and quality grades. Each specimen is identified by its nominal section thickness and the closest distance from ingates, risers, and chills. These distances are measured from the ingate, riser, and chill at the mold cavity surface to the center of the specimen.

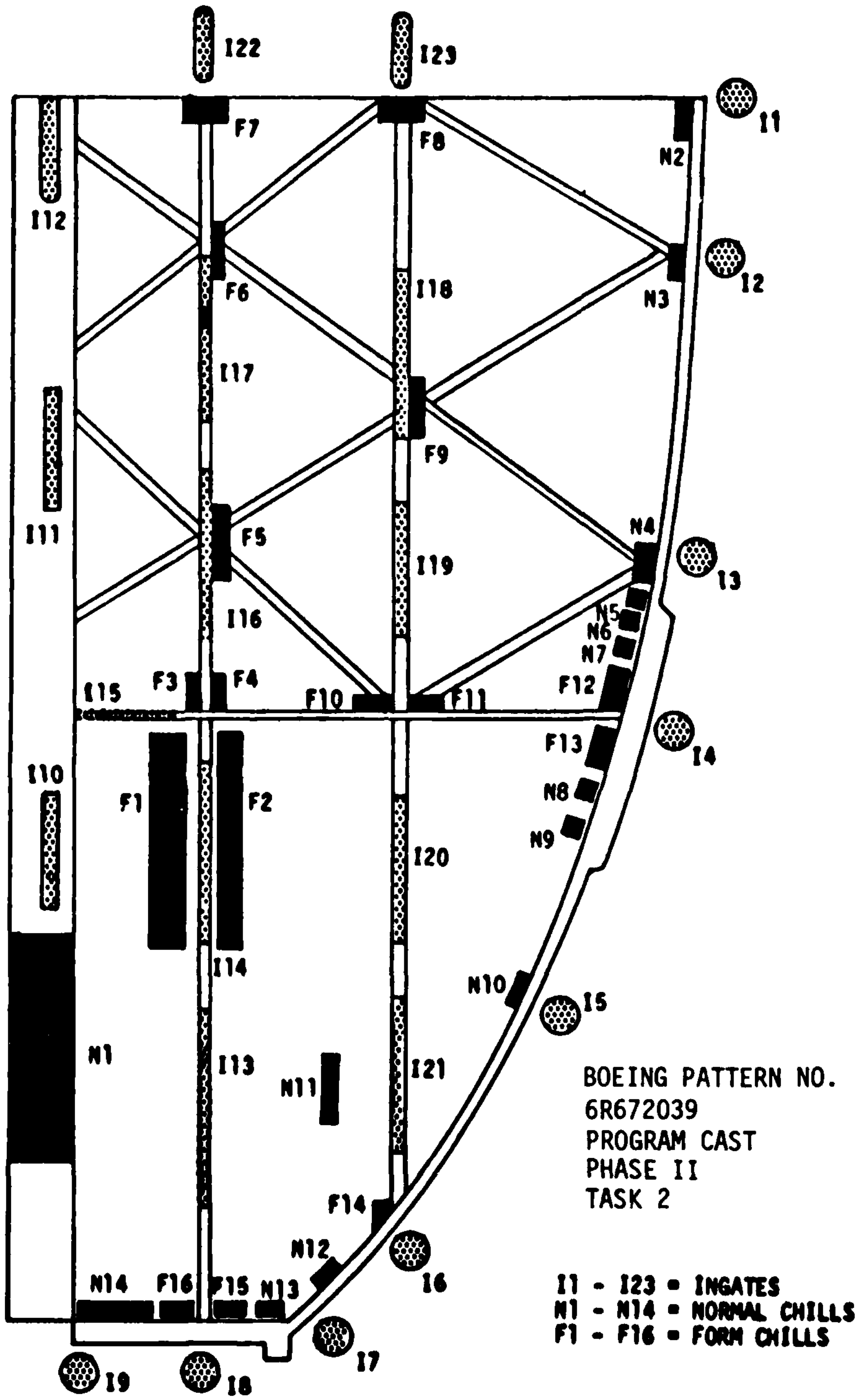


FIGURE 31 DETAILS OF DRAG HITCHCOCK CASTINGS PART A

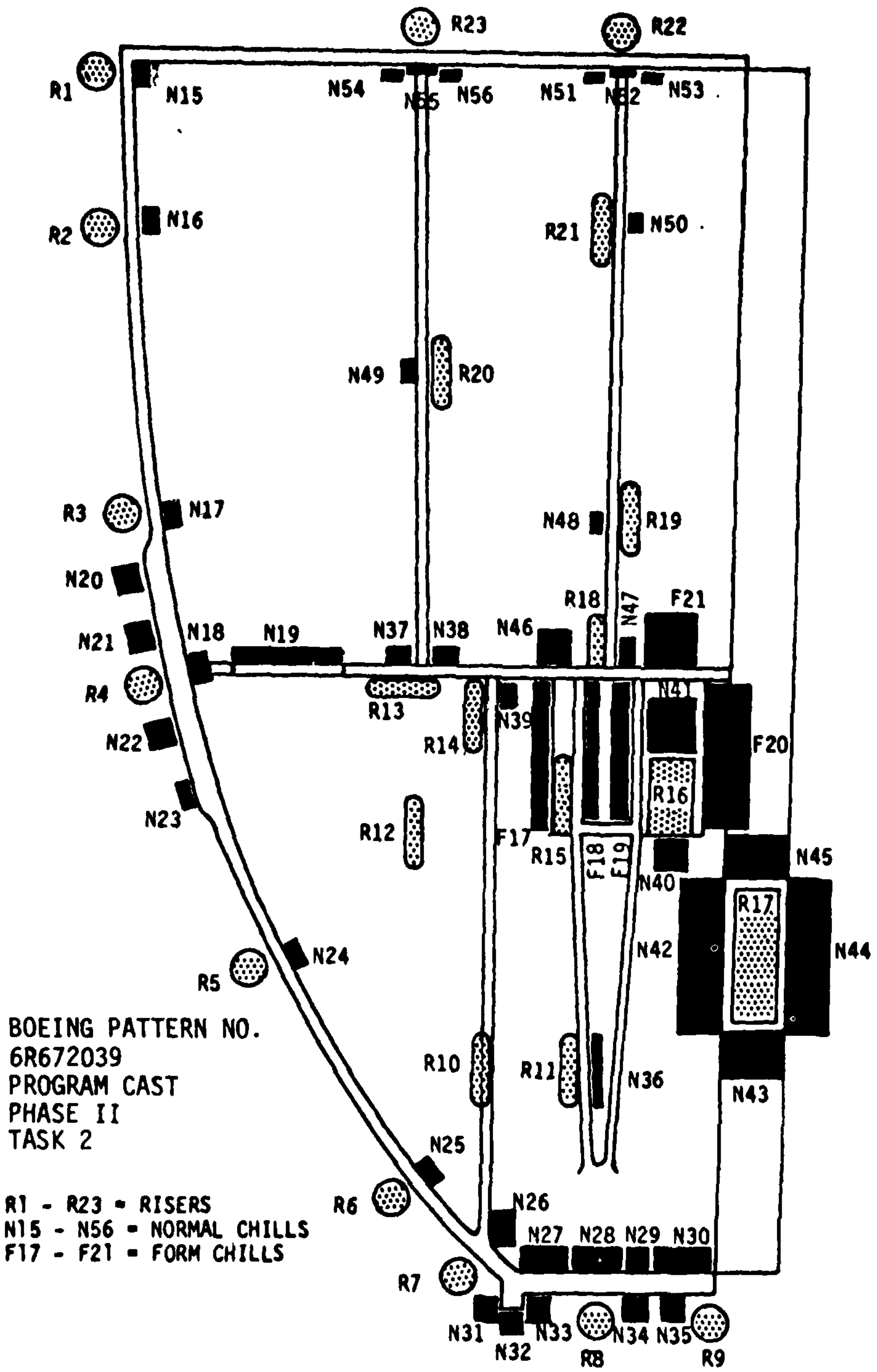


FIGURE 32 DETAILS OF COPE HITCHCOCK CASTINGS PART A

TABLE 10 INGATE AND RISER DETAILS HITCHCOCK PART A

ITEM	SHAPE	DIMENSIONS AT:	
		CASTING	RUNNER
Ingate			
I1-I9	Cylindrical	1 D.	1.25 D.
I10-I12	Rectangular	.25 x 4	.5 x 5
I13, I14	"	.1 x 5.5	.5 x 6
I15	"	.1 x 3.5	.5 x 4
I16-I19	"	.1 x 4.5	.5 x 5
I20, I21	"	.1 x 4	.5 x 4.5
I22	"	.75 x 4	.375 x 3.5
I23	"	1 x 4	.375 x 3.5
Riser			
R1-R9	Cylindrical	1.25 D.	
R10	Rectangular	.75 x 2.5	
R11	"	.75 x 2	
R12	"	.75 x 2.5	
R13, R14	"	.5 x 2	
R15	"	.75 x 2.5	
R16	"	1.75 x 2.5	
R17	"	1.75 x 3.5	
R18-R21	"	.5 x 2	
R22, R23	Cylindrical	1.5 D.	

TABLE 11 CHILL DETAILS
Hitchcock Part A

CHILL	DIMENSIONS [1] (x)	(y)	(z)
Normal (Cast Iron)			
N1	1	6	2
N2-N4	.5	1	2
N5-N9	.5	.5	2
N10	.5	1	2
N11	.5	4	1
N12, N13	1	.5	2
N14	2	.5	2
N15-N17	.5	1	2
N18	.75	1	2
N19	4	.5	1
N20-N22	1	1	4
N23	.5	1	4
N24-N26	.5	1	2
N27	1.5	1	1
N28, N30	2	1	1
N29	1	1	2
N31-N35	1	1	4
N36	.25	2	1
N37, N38	1	.5	3
N39	.5	1	2
N40	1	1	1.5
N41	1.5	2	2
N42	1.5	5	2
N43	2	1.5	2
N44	1.5	5	2
N45	2	1.5	2
N46	1	1	4
N47-N50	.5	1	3
N51-N56	.5	.25	3
Form (70,000 Manganese Bronze)			
F1	1.5	6	4
F2	1	6	4
F3, F4	.5	1	2
F5	1	2	1
F6	.5	2	1
F7, F8	2	1	.5
F9	.5	2	1
F10, F11	1	.5	2
F12, F13, F14	.5	1	2
F15, F16	1	.5	2
F17	1	5	4
F18	.5	5	4
F19	.75	5	4
F20	2	5	4
F21	2	2	4

[1] Dimensions in inches per orientations:

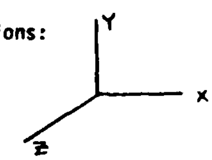


TABLE 12 SUMMARY OF FOUNDRY VARIABLES
PART A HITCHCOCK CASTINGS
PHASE II TASK 2
BOEING PATTERN NO. 6R672039

TARGET CLASS 50/40/5 TARGET GRADE B

NOMINAL SECTION THICKNESS (INCHES) \ DISTANCE FROM (INCHES)	INGATE 0-.5	INGATE .5-1	INGATE 1-2	INGATE 2-5	INGATE > 5	RISER 0-.5	RISER .5-1	RISER 1-2	RISER 2-5	RISER > 5	CHILL 0-.5	CHILL .5-1	CHILL 1-2	CHILL 2-5	CHILL > 5
0.1															
0.2															
0.3			6T	5T 4B					5T 6T	4B	5T 6T	4B			
0.5															
1.0		3T 4T	2C 2S					2S	3T 4T 2C		3T 4T 2C 2S 3B				
2.0			1T 13T 14T 1C 1S 3B	1B 2B T6 2T T7				2T	1T 14T 1C 1S 1B 2B 3B T6 T7	13T	2T 13T 1B 2B	1T 14T 1C 1S T6 T7			

TARGET CLASS 40/30/3 TARGET GRADE C

NOMINAL SECTION THICKNESS (INCHES) \ DISTANCE FROM (INCHES)	INGATE 0-.5	INGATE .5-1	INGATE 1-2	INGATE 2-5	INGATE > 5	RISER 0-.5	RISER .5-1	RISER 1-2	RISER 2-5	RISER > 5	CHILL 0-.5	CHILL .5-1	CHILL 1-2	CHILL 2-5	CHILL > 5
0.1	24T	21T	23T	7T 8T 9T 10T 17T 18T 10B T10					T10 8T 9T 10T 17T 18T 10B	7T 21T 23T 24T		10T T10	9T 18T 23T 24T	7T 8T 17T 21T	10B
0.2	19T 20T 22T		6C	15T 16T 6S					15T 22T 6C 6S	16T 19T 20T	15T 16T		22T 6C 6S	19T 20T	
0.3				T8					T8		T8				
0.5			6B	11T 12T					11T 12T	6B	11T 12T	6B			
1.0				T9					T9		T9				
2.0															

BOEING PART B CASTINGS

Details of allowable specimens from five Boeing Part B castings are described in relation to the following variables:

1. Location within each casting
2. Strength/elongation class and quality grade
3. Nominal section thickness
4. Distance from ingates
5. Distance from insulators
6. Distance from chills

These five castings provided 204 allowables test specimens as described in Table 2. In addition to allowables specimens, four integral cast-on tension specimens were located at selected zones of each casting. Refer to Figure 13.

The foundry variables are identified in Figure 33. The forward and aft faces of the castings show 27 ingates, designated by the symbols I1-I27. The geometries of these ingates are summarized in Table 13. Six plaster insulators were used on the vertical box segments and are designated as INS. 1 through INS. 6. Table 14 contains insulation geometry details. Chilling is also shown in Figure 33 by 56 aluminum (A1-A56) and 35 copper (C1-C35) chills. Details of chills are summarized in Table 15.

Table 16 shows the relations between foundry variables and specimen locations. The information is separated in two groups based upon the target strength/elongation classes and quality grades. Each specimen is identified by its nominal section thickness and the closest distance from ingates, insulators, and chills. These distances are measured from the mold cavity surface to the center of the specimen.

The tabulated foundry variables information for Boeing Parts A and B castings do not include riser details. This is due to the vertical flow method of casting. Refer to Figure 34. An end view shows the directions of metal flow into the mold. Sprues at both ends are connected to horizontal feeders located at the base of the mold. On both FWD and AFT sides, vertical risers allow metal to flow upwards into the horizontal ingates. Therefore, the pertinent foundry variables information are ingate sizes and locations plus chills and insulators.

BOEING PATTERN NO. 7R672039
PROGRAM CAST PHASE II TASK 2

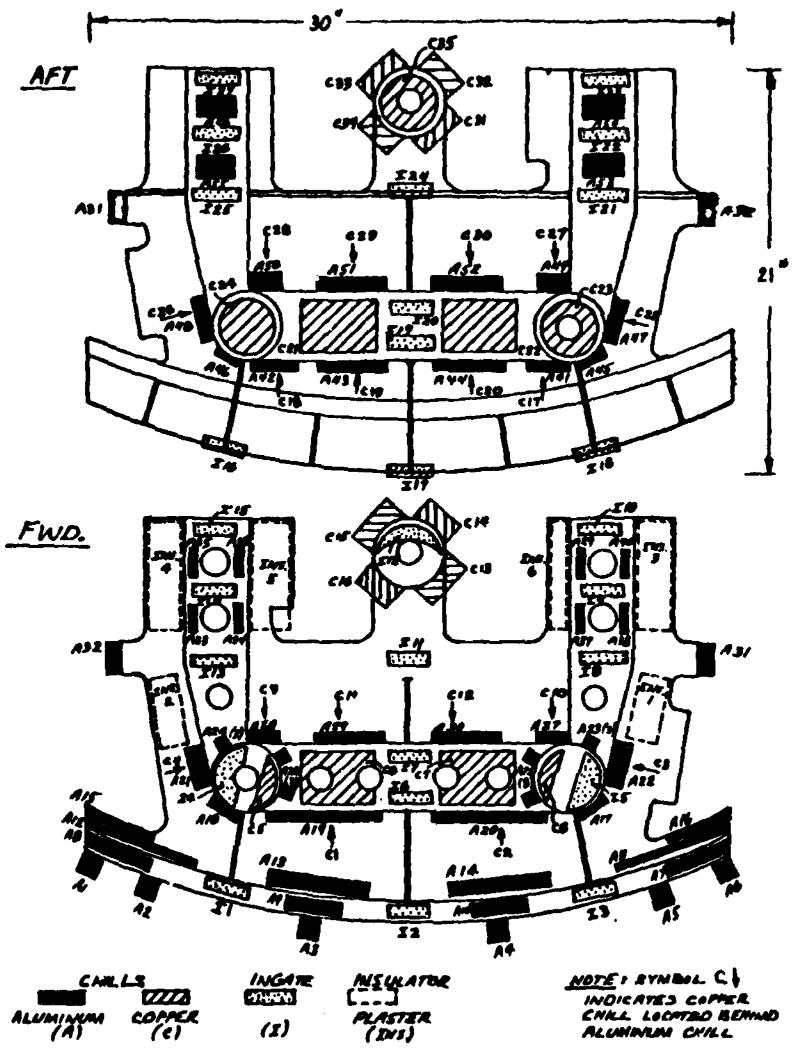


FIGURE 33 DETAILS OF PART B

TABLE 13 INGATE DETAILS
Boeing Part B

INGATE	SHAPE	DIMENSIONS AT: RISER (x)	(y)	CASTING (x) [1]	(y)
I1-I3	Rectangular	1.75	.5	1.375	.625
I4, I5	Semicircular	1.25 R.		1.25 R.	
I6-I11	Rectangular	1.75	.5	1.875	.625
I12	Semicircular	1.25 R.		1.25 R.	
I13-I27	Rectangular	1.75	.5	1.875	.625

[1] Dimensions in inches per orientations:

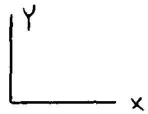


TABLE 14 INSULATOR DETAILS
Boeing Part B

INSULATOR	DIMENSIONS (x) [1]	(y)	(z)
INS 1, INS 2	1.5	4	.25
INS 3, INS 4	1.5	5	.25
INS 5	2	5	.25
INS 6	1	5	.25

[1] Dimensions in inches per orientations:

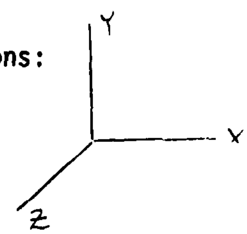
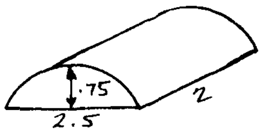
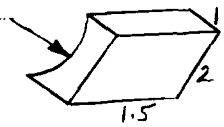


TABLE 15 CHILL DETAILS
Boeing Part B

CHILL	DIMENSIONS (x)	(y)	(z) [1]
Aluminum:			
A1-A6	1	1	5
A7, A8	3	1	1
A9, A10	2.5	1	1
A11, A12	5.25	.75	.5
A13, A14	4.5	1	.5
A15, A16	3	.5	.5
A17, A18	1.5	.5	2
A19, A20	5	.5	1
A21, A22	1	2	.5
A23, A24	.5D.	.5	(3 ea.)
A25, A26	.5D.	.5	(8 ea.)
A27, A28	1.5	.5	1
A29, A30	3	.5	1
A31, A32	.75	1.5	.5
A33-A40	.5	1.5	.5
A41, A42	2	.5	1
A43, A44	3	.5	1
A45, A46	1.5	.5	.5
A47, A48	1	2	1
A49, A50	1.5	1	.75
A51, A52	3	.5	.75
A53-A56	1.75	1	.5
Copper:			
C1,C2	5	.5	1
C3, C4	1	2	1.5
C5, C6	.75	2.5	2
C7, C8	3.5	2.5	.125
C9, C10	1.25	.5	1.5
C11, C12	3	.5	1.5
C13-C16	1.75 R.		
C17, C18	2	.5	1.25
C19, C20	3	.5	1.25
C21, C22	3.5	1.5	.125
C23	2.5D	2 with 1"D. hole at center	
C24	2.5D	2	
C25, C26	1	2	1.5
C27, C28	1.25	1	1.5
C29, C30	3	.5	1.25
C31-C34	Same as C13-C16		
C35	Same as C23		





[1] Dimensions in inches per orientations:

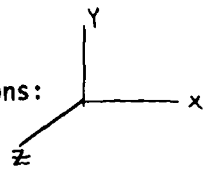


TABLE 16 SUMMARY OF FOUNDRY VARIABLES
PART B BOEING CASTINGS
PHASE II TASK 2 - ALLOWABLES

TARGET CLASS 50/40/5 TARGET GRADE B

NOMINAL SECTION THICKNESS (INCHES) / DISTANCE FROM: (INCHES)

	INGATE					ALUMINUM CHILL					COPPER CHILL					INSULATOR				
	0-.5	.5-1	1-2	2-5	>5	0-.5	.5-1	1-2	2-5	>5	0-.5	.5-1	1-2	2-5	>5	0-.5	.5-1	1-2	2-5	>5
0.1																				
0.3			5x 6x	7x 4w	4Y	7x, 4Y, 4W	5x,6x				5x,6x, 7x, 4Y,4W								4Y	5x,6x, 7X,4W
0.5																				
1.0				X1,X3,X4, 1X,2X,1Y, 1W,1Z,2Z		X1,1X, 2x,1W	1Y, 1Z,2Z			X3,X4	X3,X4, 1Y		1Z	X1,1X, 2X, 1W,2Z					X1,1X, 2x,1Y,1W, 1Z,2Z	X3,X4
3.0				X2,3X,4X, 2Y,3Y,3W, 2W,3Z,4Z		X2,3X, 4X, 2W,3W	2Y,3Y, 3Z,4Z				X2, 3Y	2Y, 3W	2W, 4Z	X2,3X, 4X,3Z					X2,3X, 4X,2Y,3Y, 2W,3W, 3Z,4Z	

TARGET CLASS 40/30/3 TARGET GRADE C

	INGATE					ALUMINUM CHILL					COPPER CHILL					INSULATOR				
	0-.5	.5-1	1-2	2-5	>5	0-.5	.5-1	1-2	2-5	>5	0-.5	.5-1	1-2	2-5	>5	0-.5	.5-1	1-2	2-5	>5
0.1			18x	X7,X8,16X, 21X,22X,5Z, 6Z,9Z	X5,X6, 12X,13X, 20X,8Z			X6,13X, 18X,20X, 21X,9Z	X5,X7,X8, 12X,16X, 22X,5Z, 6Z,8Z				X6 13X	X5,12X, 5Z,6Z, 8Z	X7,X8, 16X,18X, 20X,21X, 22X,9Z	X6,X7, X8,13X, 16X	X5, 18X		20X, 5Z,6Z	12X,21X, 22X, 8Z,9Z
0.3	17x		10x,11x, 15x	14x, 19x		10x,11x, 14x,19x			17x	15x				15X 19X	10X,11Y, 14X,17X			19X	10X,11X, 15X	14X, 17X
0.5		9x, 7Z	8x,5Y, 5W			9X 5W		8X 5Y 7Z						8X 5Y	9X 5W 7Z				8X,9X, 5Y,5W, 7Z	
1.0																				
3.0																				

X1, X2, X6, X8 PREPRODUCTION CASTINGS ONLY; X3, X4, X5, X7 INTEGRAL TENSILE COUPONS

X Tension
Y Compression
W Shear
Z Bearing

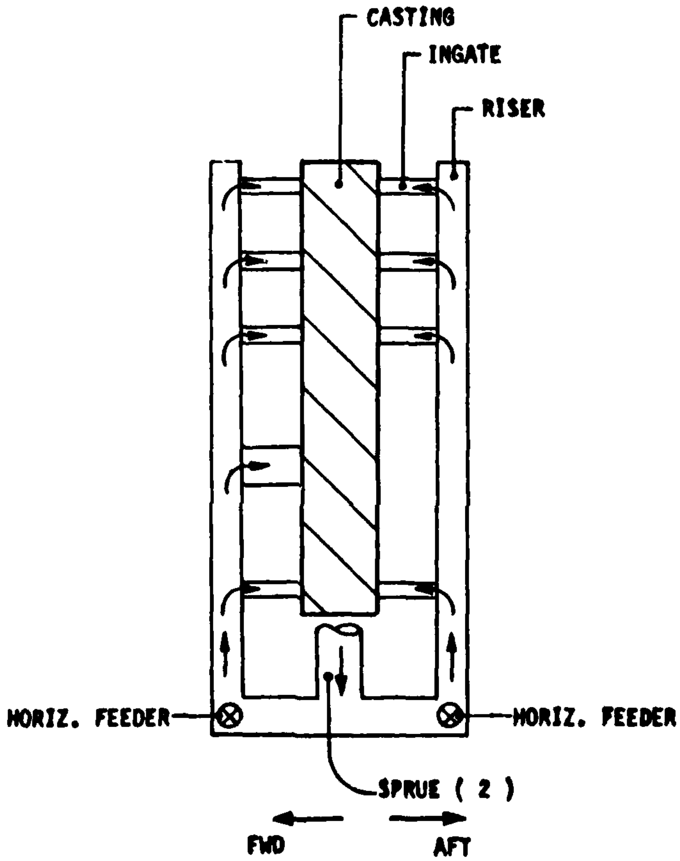


FIGURE 34 POURING SYSTEM BOEING PART A AND B CASTINGS

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APPENDIX C
ELONGATION MEASUREMENTS

Two methods were used to measure elongation in all tensile tests. First, full-range stress-strain curves were recorded to failure. Secondly, fractured coupons were carefully fitted together to physically measure the extension between gage marks in accordance with ASTM E8-69. Stress-strain curve recorded elongations are generally less than physically measured values and they are also believed to be the more accurate of the two methods, recognizing the difficulties in fitting irregular fractured surfaces to obtain physical measurements. The physical measurement method is quicker, less costly, and currently used for many materials including high-strength aluminum alloy castings.

Phase II comparative elongation measurement results are plotted in Figure 35 and summarized in Table 17. In Figure 35, the abscissa represents elongations measured from the fractured coupons. Statistics of stress-strain curve elongations are plotted on the ordinate. Averages for round and flat coupons are shown by symbols. The ranges and quantities of results are designated for each level of measured elongation. A comparison of results between round and flat configurations shows:

1. Flat coupons give slightly lower average elongations, the difference being 1 percent or less.
2. There is more scatter associated with flat coupon results. At 7 percent measured elongation, 15 flat coupon results ranged from 2.6 percent to 12.4 percent with an arithmetic average of 5.6 percent strain. The single condition involving the largest quantity of data is for flat specimens at 3 percent measured elongation. Recorded values range from 0.5 to 4.7 percent strain with an arithmetic average of about 1.9 percent strain.

With the exception of the two flat coupon results at 9 percent measured elongation, stress-strain curve average elongations are less than the measured values. The differences increase with the larger measured elongations. In many cases, minimum recorded elongations are far less than measured values. It should be noted that all reference to elongation in this report concerning CAST program tests signifies stress-strain recorded values.

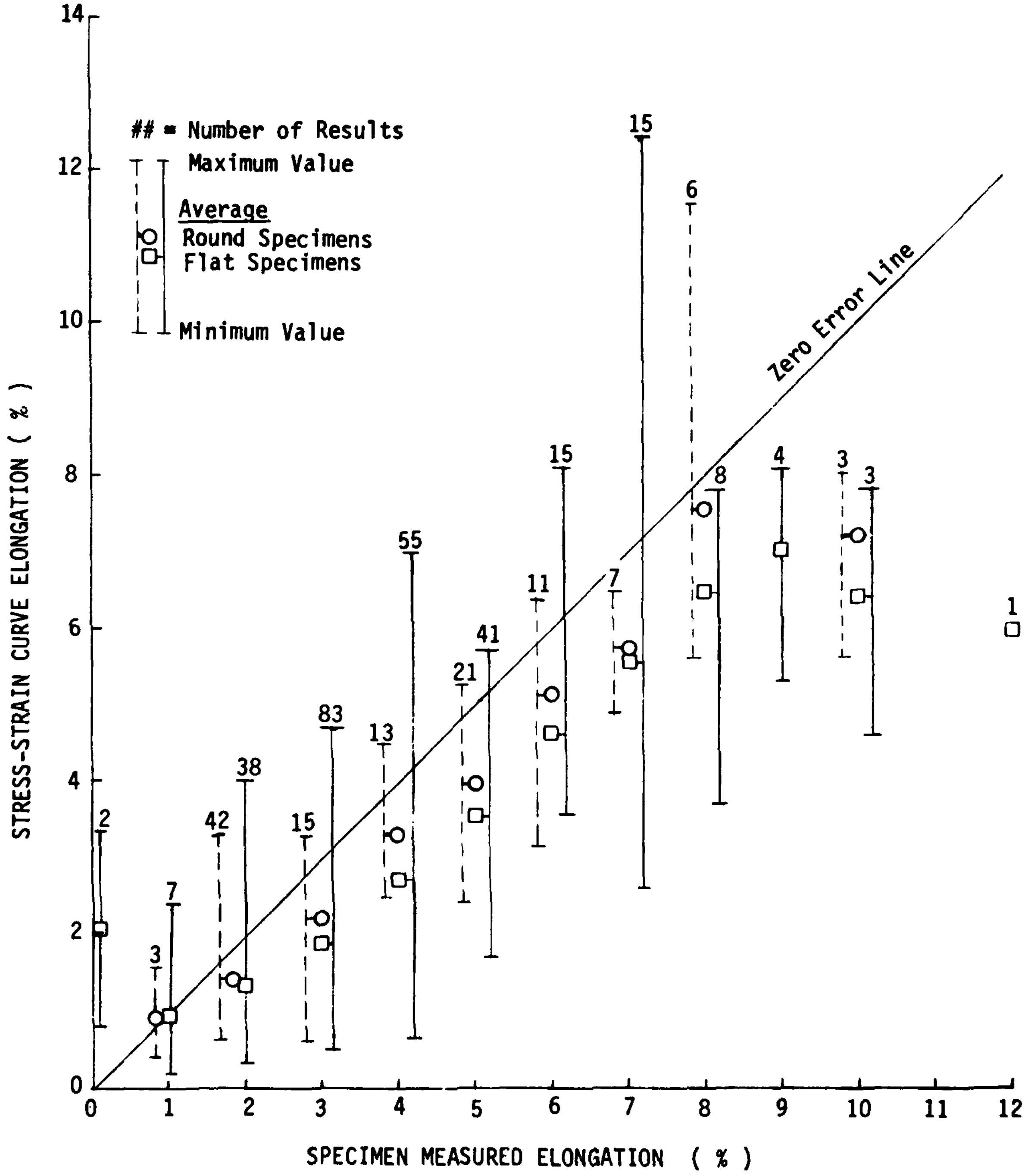


FIGURE 35 ELONGATION ANALYSIS
A357-T6 CAST

TABLE 17 ELONGATION ANALYSIS
A357-T6 CASTINGS

SPECIMEN MEASURED ELONGATION	STRESS-STRAIN CURVE ELONGATION (%)							
	Round Specimens				Flat Specimens			
(%)	Qty.	Max.	Min.	Avg.	Qty.	Max.	Min.	Avg.
0	0	-	-	-	2	3.4	0.8	2.1
1	3	1.5	0.4	0.83	7	2.4	0.2	0.89
2	42	3.3	0.6	1.40	38	4.0	0.3	1.31
3	15	3.3	0.6	2.19	83	4.7	0.5	1.87
4	13	4.5	2.5	3.29	55	7.0	0.6	2.72
5	21	5.3	2.4	3.94	41	5.7	1.7	3.53
6	11	6.3	3.1	5.13	15	8.1	3.5	4.66
7	7	6.5	4.9	5.69	15	12.4	2.6	5.55
8	6	11.5	5.6	7.53	8	7.8	3.7	6.29
9	0	-	-	-	4	8.1	5.3	7.00
10	3	8.0	5.6	7.20	3	7.8	4.6	6.40
11	0	-	-	-	0	-	-	-
12	0	-	-	-	1	-	-	5.90
	121				272			

Blank

APPENDIX D
INTEGRAL COUPON PROPERTIES

Integral cast-on tensile coupons were detached from all castings after final processing. Tensile properties of integral coupons are contained in the data summary in Appendix E.

Tensile properties of integral coupons are required primarily to ensure that a casting has been properly heat treated. Both TUS and ELONG properties can be assessed from parts in the as-cast condition via nondestructive measurements for DAS and soundness. Chemistry, from selectively located attached chips or ladle samples, can be ensured without damaging the castings. However, TYS is not influenced by the variations in DAS or soundness that cause significant TUS and ELONG changes. In Section II, Tension Properties, it is shown that TYS is a responsive parameter to heat treatment. Therein, data illustrate that different sources for the -T6 condition material can produce essentially the same TUS and ELONG properties, but markedly different TYS values. This applies to both A357 and A356 alloys.

The task is to selectively locate integral coupons on a casting that will signify TYS for the most critical zones. Integral coupon locations are identified for the Phase II Parts A and B castings in Figures 12 and 13, respectively. Results obtained from these parts are illustrated in Figures 36, 37, and 38 for TUS, ELONG, and TYS, respectively.

In each figure, integral coupon and corresponding casting location tensile properties from all 14 castings are shown collectively. In each figure, a 1:1 line has been established for visual clarity. If integral and adjacent casting properties were the same, all data would be expected to fall on these lines. These experimental data show that the results for each of the three properties are situated around the unity line. The deviations can be categorized into two areas. These are (1) absolute deviations from the unity line and (2) slope deviations from the unity line. These categories are discussed below for each property.

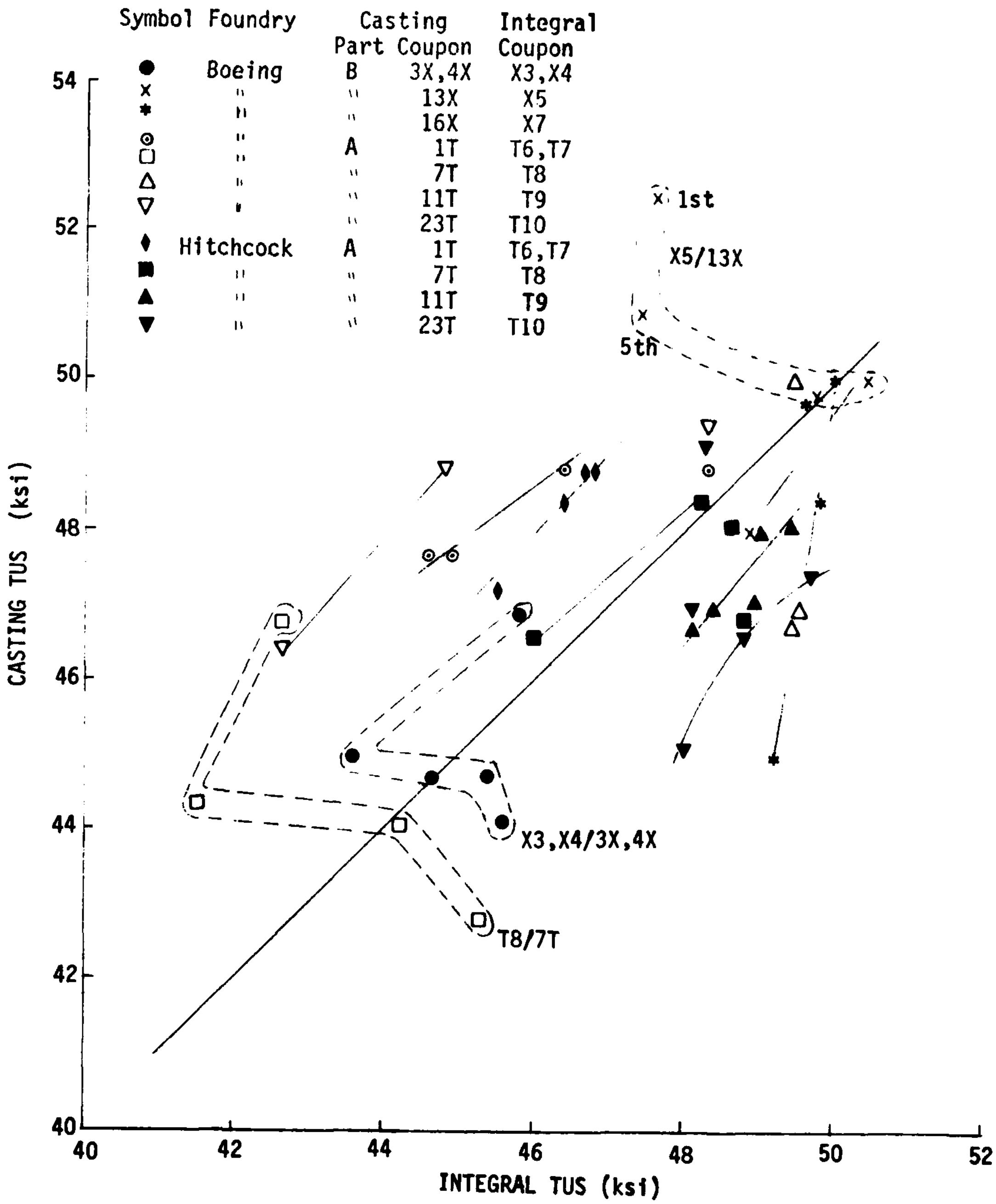


FIGURE 36 RELATIONS BETWEEN INTEGRAL COUPONS AND CASTING TUS PROPERTIES
A357-T6 CAST

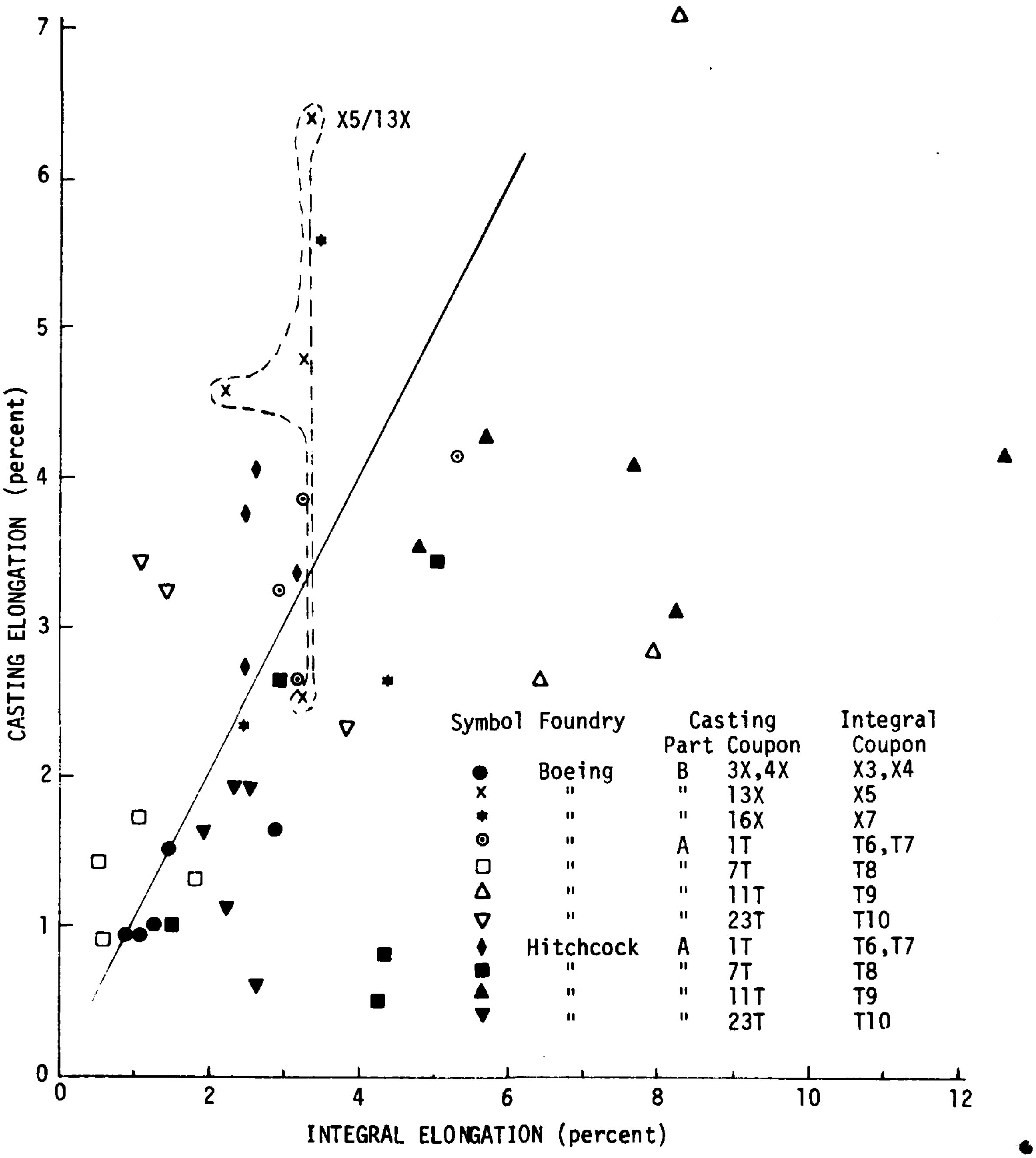


FIGURE 37 RELATIONS BETWEEN INTEGRAL COUPONS AND CASTING ELONGATION PROPERTIES
A357-T6 CAST

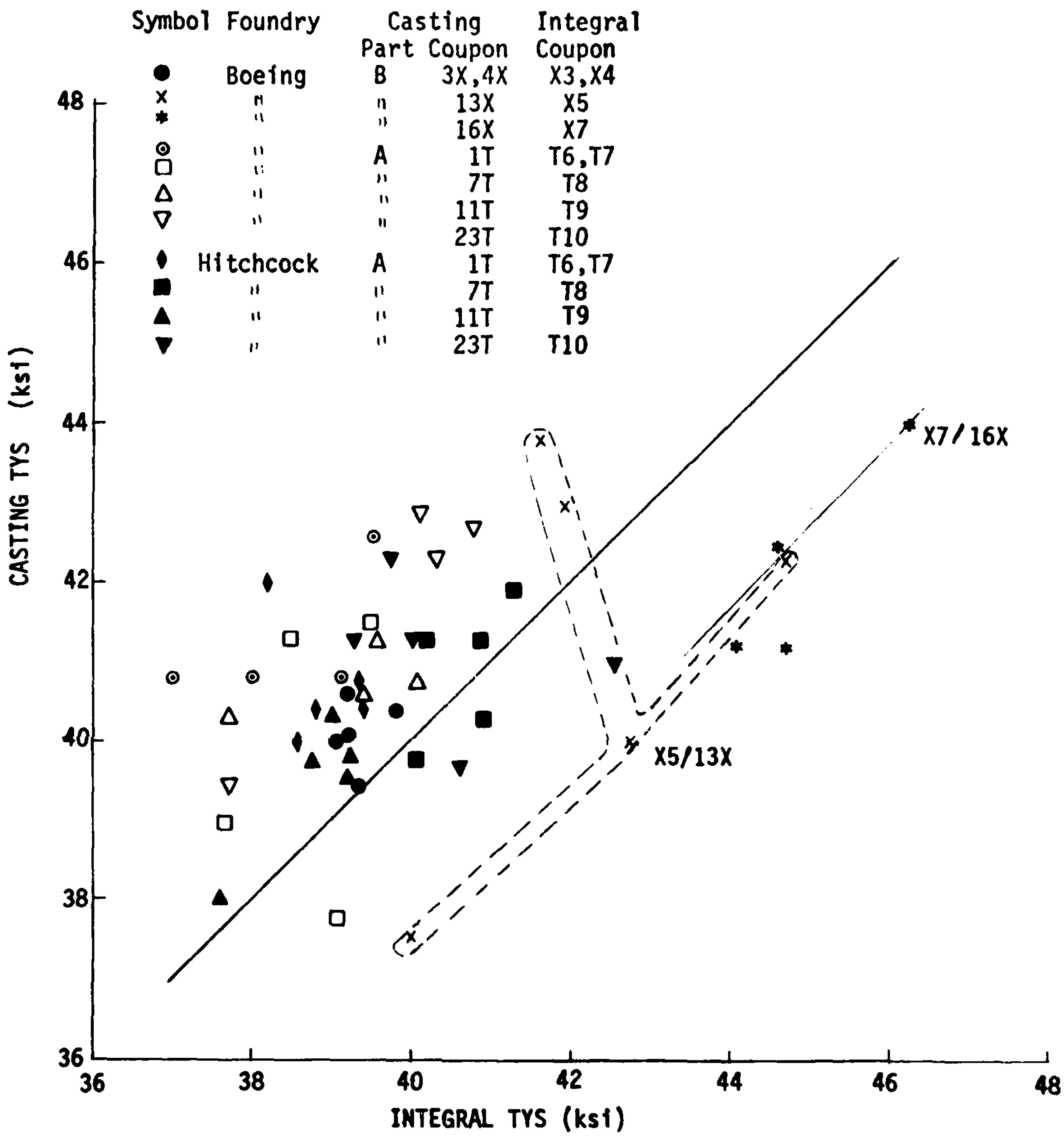


FIGURE 38 RELATIONS BETWEEN INTEGRAL COUPONS AND CASTING TYS PROPERTIES
A357-T6 CAST

TUS (Fig. 36):

The general trends developed from the same locations in replicate castings are lines offset but parallel to the unity line. This means that integral coupons have either higher or lower TUS values than the corresponding casting zones and the variations between castings are identifiable by integral coupon properties. Integral coupon T8 from Boeing Part A castings is obviously not a good indicator for the casting 7T location, the adjacent lower web. The trend is converse to the unity trend line. The same situation applies to the Part B casting integral lug (X3 and X4) in relation to the solid 3-inch-diameter fitting (3X, 4X). The only other nonrelatable comparison is between the Part B right outside flange (13X) and the adjacent integral coupon (X5). Three of the five results fall near the unity line while the other two show much higher casting TUS values (13X) than what would be expected from integral coupon TUS values (X5). The two results causing the trend inconsistency represent the first and fifth castings. No intentional differences in manufacture regarding placement of chills or insulators were made. This type of inconsistency illustrates the importance for precise repetition of manufacture between all production castings.

ELONG (Fig. 37):

Results tend to band around the unity line showing a general relation between ELONG for integral coupons and castings. The Part B casting (X5/13X) group does not follow this trend, as was the case using TUS values.

TYS (Fig. 38):

The overall range of TYS is relatively small from all integral coupon and casting locations in comparison to TUS. It is somewhat more difficult to observe the general trends of results situated about the unity line. The (X5/13X) comparison shows poor correlation for TYS, as was the case for both TUS and ELONG. One group of results illustrates a very good relationship. These are Part B specimens (X7/16X) from the vertical torque box inner flange location. These results parallel the unity line showing integral coupons to be 2 to 3 ksi higher in TYS than the adjacent flange.

As a matter of interest, the X7 integral coupon TYS results were compared with properties representing a variety of Part B casting zones. These results are shown in Figure 39. This series of seven graphs shows TYS of the X7 integral coupons on the abscissa and casting zone TYS values as ordinates. Each graph contains two casting-zone results to evaluate similarities of response. Each graph also contains a unity line to designate a 1:1 response between casting and integral coupon values. The cored fitting (1X) is less responsive than the solid 3-inch-diameter fitting (4X) to X7 changes. The solid fitting TYS remains about 5 ksi less than X7. However, TYS of both fittings can be estimated using the X7 integral coupon TYS. The horizontal torque box TYS properties (6X, 7X) are between 3 and 4 ksi less than X7. The right vertical torque box coupons (8X, 9X) are estimated well by X7. They exhibit about one-half as much TYS variations as do the integral coupons. The left side of the base attachment flange is not relatable to X7 TYS variations. Vertical torque box zones (16X, 18X) are relatable to X7 TYS variations. As cited previously, 16X lags X7 by about 3 ksi. Location 18X is from the opposite vertical torque box, immediately adjacent to the inner flange. TYS from this location seems to respond about four times greater than the X7 integral coupons. Pase attachment flange, right side coupons (19X, 20X) show different results. The higher TYS from 19X is the result of that zone being directly chilled, whereas 20X is adjacent to the same chill. The heavy chilling effect at 19X may have prevented TYS variations similar to those noted in other casting zones and at X7. In the center of the base attachment flange, coupons (21X, 22X) show a fairly consistent 3 ksi less TYS than X7.

As shown in detail for Part B castings, some zones respond very well with integral coupons while others do not respond at all to integral coupon property variations. It has also been shown that numerous casting zones are relatable to a single integral coupon. The entire analysis presented above has been made independent of DAS and soundness properties. Since TYS does not seem to be a function of these two physical parameters, it is suggested that only the comparisons using TYS data be considered relevant. Both TUS and ELONG are influenced by DAS and soundness, and these variables were not accounted for in those comparisons. If this type of analysis is considered applicable to infer TYS properties of casting zones, as it is believed to be, it must also be recognized that both casting zones and integral coupon TYS values are, to some degree, variable. This is on an individual basis and is most likely reflective of the difference in responses of various casting zones to the same nominal heat treatment. The above points must be considered during preproduction casting development.

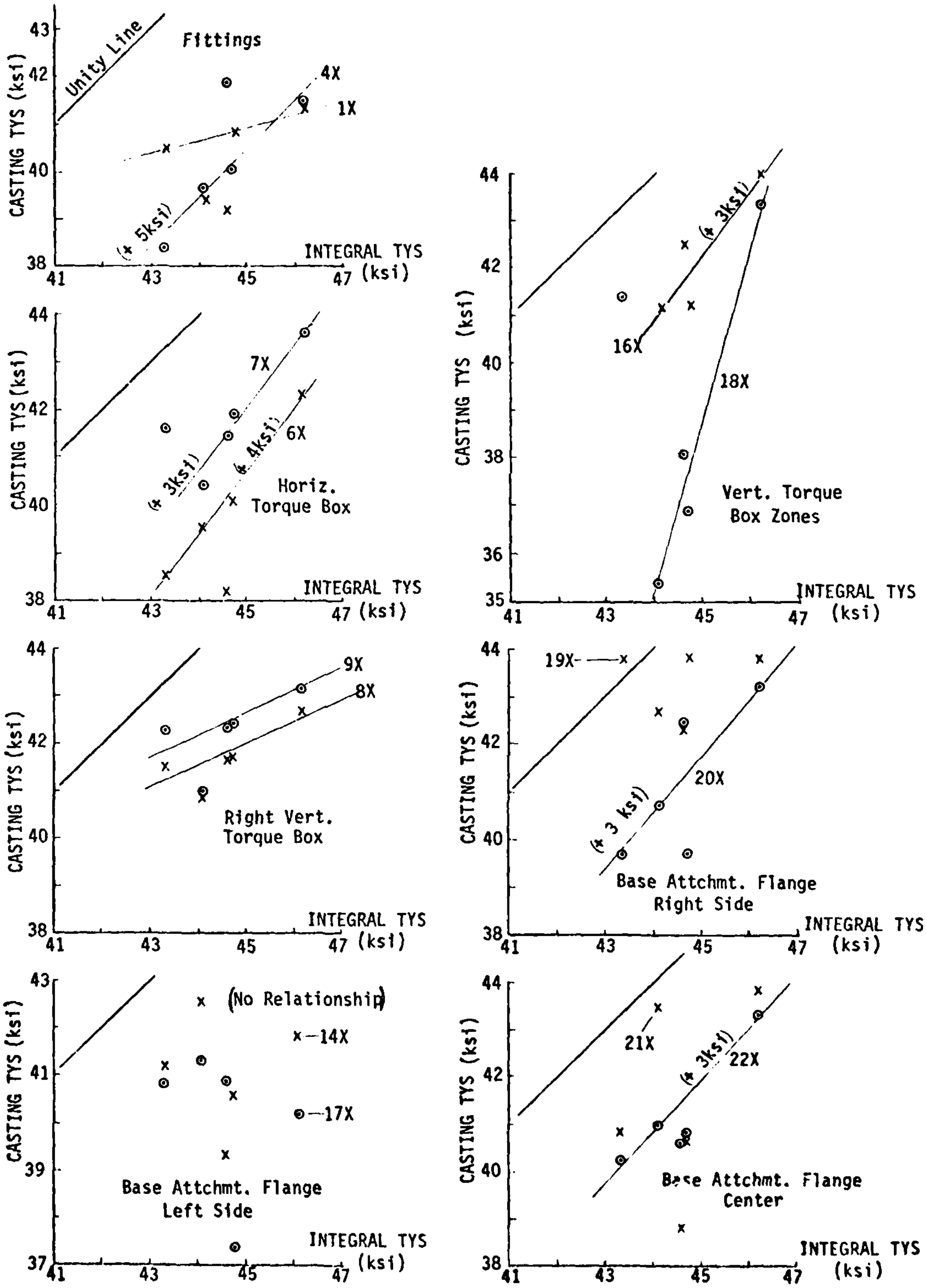


FIGURE 39 INTEGRAL COUPON-CASTING TYS CORRELATIONS
Integral Coupon X7, Part B Castings
Left Vertical Torque Box
Inner Flange
A357-T6 CAST

APPENDIX E
STATIC MECHANICAL PROPERTIES DATA

EXPLANATION

Table 18 contains static mechanical property test data developed during Phase II Task 2, Manufacturing Methods. All test coupons were excised from castings following final heat treatment (A357-T6) and inspections. Specimen configurations and test details are summarized in Appendix A. The segments of the Station 170 bulkhead cast for this phase are referred to as Parts A and B, shown in Figures 12 and 13, respectively.

Nomenclature used in Table 18 is explained below.

Specimen Part No.:

Excised Coupons

XX XX XX

- First XX: Specimen Location in Casting
- Second XX: Type of Specimen
- Third XX: Casting Identification

Integral Coupons

XX XX XX

- First XX: Designates T or X for Integral Specimen
- Second XX: Specimen Location
- Third XX: Casting Identification

Casting Group	Boeing Part A	Hitchcock Part A	Boeing Part B
Type of Specimen:			
Tension	T	T	X
Compression	C	C	Y
Shear	S	S	Z
Bearing e/D = 1.5 1/	B	B	W
e/D = 2.0	B	B	W

1/ Specimen location odd numbers designate e/D = 1.5; even numbers designate e/D = 2.0.

Casting Group	Boeing Part A		Hitchcock Part A		Boeing Part B	
Casting Identification:		Serial #		Serial #		Serial #
	3	632	5H	005	7	397
	4	633	6H	006	8	400
	5	634	7H	007	9	403
	6	635	8H	008	10	406
			9H	009	11	409

Static Properties:

TUS	Tensile Ultimate Strength
TYS	Tensile Yield Strength
ELONG	Total Elongation (Uniform Elongation)
CYS	Compression Yield Strength
SUS	Shear Ultimate Strength
BUS	Bearing Ultimate Strength
BYS	Bearing Yield Strength

TABLE 18 STATIC MECHANICAL PROPERTIES DATA

CASTING GROUP: BOEING PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
LUG B CENTER	2.0	1T3	47.7	40.9	5	3.2	1C3	42.9	1S3	34.0						
		1T4	48.7	40.8	5	4.1	1C4	43.9	1S4	34.1						
		1T5	47.7	40.8	6	3.8	1C5	41.2	1S5	33.9						
		1T6	48.7	42.6	5	2.6	1C6	44.5	1S6	34.0						
LUG B EDGE	2.0	2T3	49.5	39.5	8	11.5					1B3	81.9	63.1	2B3	97.5	76.2
		2T4	48.8	40.0	7	6.3					1B4	82.2	65.5	2B4	103.1	78.0
		2T5	48.2	40.1	7	4.9					1B5	77.4	63.4	2B5	98.1	79.9
		2T6	49.0	41.9	5	3.5					1B6	80.2	67.1	2B6	100.0	82.3
LUG A CENTER	1.0	3T3	49.1	40.6	5	4.1	2C3	42.0	2S3	34.0	3B3	80.8	64.2			
	(1)	3T4	43.1	40.8	3	0.6	2C4	42.9	2S4	34.8	3B4	82.2	68.2			
		3T5	48.2	40.8	4	3.4	2C5	42.6	2S5	35.5	3B5	75.0	63.8			
		3T6	48.2	42.3	5	2.7	2C6	43.7	2S6	34.6	3B6	80.0	64.8			
LUG A TOP	1.0	4T3	50.0	40.5	10	5.6										
		4T4	50.2	40.1	8	7.0										
		4T5	48.1	41.2	3	3.1										
		4T6	47.9	40.8	5	3.8										
PAD UP ATTACHMT. FLANGE	.30	5T3	50.0	41.2	7	7.2								4B3	103.9	86.7
		5T4	52.3	41.7	8	3.7								4B4	90.8	79.3
		5T5	47.7	40.5	6	3.5								4B5	87.1	75.6
		5T6	47.7	43.2	4	1.2								4B6	88.0	79.3
PAD UP ATTACHMT. FLANGE	.30	6T3	49.4	41.2	6	4.3	7C3	43.4								
		6T4	49.0	42.5	3	2.3	7C4	44.9								
		6T5	44.8	39.3	3	1.1	7C5	43.5								
		6T6	45.2	40.2	4	1.1	7C6	44.2								

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves
(1) Failed outside gage zone

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
WEB LWR.LEFT	.10	7T3	44.1	39.0	3	1.7			3S3	34.0				10B3	91.9	74.2
		7T4	46.8	41.5	3	1.4			3S4	33.8				10B4	91.5	79.6
		7T5	42.8	37.8	3	1.3			3S5	30.0				10B5	94.0	(1)
		7T6	44.4	41.3	4	0.9			3S6	30.0				10B6	91.7	76.5
WEB LWR.LEFT	.10	8T3	46.9	40.3	4	2.5	3C3	42.6								
		8T4	45.8	40.8	4	1.6	3C4	45.1								
		8T5	47.9	39.8	7	4.4	3C5	44.1								
		8T6	45.6	40.1	4	1.9	3C6	42.1								
WEB BOTTOM	.10	9T3	47.0	40.5	5	2.4	8C3	43.8								
		9T4	46.4	41.9	5	1.1	8C4	43.4								
		9T5	45.2	39.3	4	1.6	8C5	43.8								
		9T6	45.8	40.7	4	1.4	8C6	43.9								
WEB BOTTOM	.10	10T3	45.1	38.8	5	2.7										
		10T4	39.0	(1)	3	0.1										
		10T5	45.5	40.2	3	1.5										
		10T6	47.9	43.1	3	0.8										
PAD UP BASE FLANGE	.50	11T3	47.0	40.6	5	2.8	4C3	43.6	4S3	32.9						
	(2) →	11T4	41.4	41.3	1	0.2	4C4	42.5	4S4	32.4						
		11T5	50.0	40.7	4	7.0	4C5	40.6	4S5	32.8						
		11T6	46.7	40.4	5	2.8	4C6	41.8	4S6	33.4						
PAD UP BASE FLANGE	.50	12T3	48.4	42.2	4	3.0								6B3	103.3	76.5
		12T4	46.2	41.5	3	1.1								6B4	103.0	80.2
		12T5	44.7	40.7	3	0.9								6B5	85.7	75.1
		12T6	48.7	41.7	5	3.7								6B6	96.2	79.2

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Failed prior to yield
(2) Failed in grip

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
	NOMINAL (in.)	PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
LUG B TOP	2.0	13T3	49.6	40.0	8	6.1										
		13T4	50.5	40.5	10	8.0										
		13T5	49.5	39.5	10	8.0										
		13T6	49.3	40.4	7	4.9										
LUG B BOTTOM	2.0	14T3	46.1	38.8	4	3.3										
		14T4	48.4	40.2	5	4.9										
		14T5	47.2	38.0	8	5.6										
		14T6	46.6	39.5	5	2.8										
WL 130 DECK	.25	15T3	47.2	40.7	3	1.2										
		15T4	45.6	42.4	4	0.6										
		15T5	44.3	40.3	4	0.8										
		15T6	51.3	42.8	7	2.6	5C3	43.9	5S3	32.2						
WL 130 DECK	.25	16T3	51.0	①	12	4.9	5C4	45.0	5S4	33.8						
		16T4	51.3	38.0	10	4.6	5C5	41.9	5S5	35.2						
		16T5	50.1	41.3	7	4.7	5C6	39.6	5S6	33.4						
		16T6	49.8	43.3	5	2.5										
WEB UPR.LEFT	.10	17T3	47.4	41.6	0	3.4	11C3	42.2								
		17T4	47.4	43.1	4	2.0	11C4	42.3								
		17T5	45.2	40.8	4	1.1	11C5	40.1								
		17T6	46.4	43.3	2	0.6	11C6	43.9								
WEB UPR.LEFT	.10	18T3	39.6	33.5	3	1.8										
		18T4	35.1	②	1	0.0										
		18T5	45.5	40.3	4	1.4										
		18T6	41.9	35.2	7	4.3										

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

① Inaccurate TYS recording
② Failed in grip

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
FLANGE UPR.LEFT	.20	19T3	45.2	40.2	3	1.2										
		19T4	44.3	41.0	3	0.7										
		19T5	44.8	40.6	3	0.9								8B3	96.5	80.8
		19T6	47.7	43.2	3	0.7								8B4	86.7	80.1
														8B5	92.8	84.4
FLANGE UPR.LEFT	.20	20T3	44.8	39.9	3	1.2	6C3	(1)	6S3	35.0				8B6	96.4	82.3
		20T4	47.5	42.6	3	1.3	6C4	43.0	6S4	34.5						
		20T5	47.6	41.4	3	1.7	6C5	44.6	6S5	35.1						
		20T6	46.3	42.9	3	0.9	6C6	44.0	6S6	34.7						
WEB UPR. CENTER	.10	21T3	47.6	42.1	3	2.7	12C3	43.0								
		21T4	43.3	41.0	3	0.5	12C4	44.6								
		21T5	48.7	41.2	7	4.5	12C5	42.6								
		21T6	45.6	41.5	3	1.5	12C6	44.0								
FLANGE UPR.RT.	.20	22T3	46.0	40.1	3	1.0	13C3	42.6			7B3	—	(2)			
		22T4	45.9	41.8	3	0.8	13C4	46.5			7B4	76.2	70.1			
		22T5	46.2	41.2	4	1.3	13C5	43.3			7B5	65.4	65.4			
		22T6	48.7	42.9	5	1.7	13C6	45.7			7B6	76.8	73.0			
WEB UPR.RT.	.10	23T3	47.8	42.9	5	2.1	14C3	43.3								
		23T4	48.9	42.3	5	3.2	14C4	44.0								
		23T5	46.4	39.4	5	3.4	14C5	42.5								
		23T6	49.4	42.8	5	2.3	14C6	48.1								
WEB UPR.RT.	.10	24T3	45.6	40.8	4	1.7										
		24T4	47.0	41.8	3	1.4										
		24T5	46.0	39.7	3	2.0										
		24T6	47.5	43.0	3	1.0										

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Specimen buckled
(2) Failed prematurely

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
FLANGE SIDE LOWER	.20	25T3	48.3	40.3	5	3.0	9C3	42.8								
		25T4	50.3	43.1	7	3.4	9C4	43.5								
		25T5	46.1	39.6	5	2.1	9C5	43.0								
		25T6	49.7	43.4	5	2.1	9C6	44.3								
FLANGE SIDE UPPER	.20	26T3	53.7	44.4	6	4.5	10C3	43.2								
		26T4	44.5	37.5	4	4.8	10C4	(1)								
		26T5	47.7	39.8	4	3.9	10C5	41.2								
		26T6	43.4	38.0	4	1.6	10C6	41.5								

A From fitted fractured specimens, 1 inch gage

B From full-range stress-strain curves

(1) Specimen buckled

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
INTEGRAL LUG CENTER	2.0	T6/3	44.4	38.0	5	2.4										
		T6/4	48.4	39.0	7	5.0										
		T6/5	44.3	36.8	4	2.8										
		T6/6	46.5	39.5	4	2.7										
INTEGRAL LUG CENTER	2.0	T7/3	45.4	38.0	3	3.3										
		T7/4	48.2	39.2	6	5.5										
		T7/5	45.0	37.2	5	3.6										
		T7/6	46.3	39.5	4	3.5										
INTEGRAL WL 130 DECK	.25	T8/3	44.2	37.6	4	1.1										
		T8/4	42.7	39.5	2	0.5										
		T8/5	45.2	39.1	5	1.8										
		T8/6	41.5	38.5	3	0.6										
INTEGRAL PAD UP BASE FLANGE	.50	T9/3	49.5	39.4	10	7.8										
		T9/4	49.4	39.6	8	7.1										
		T9/5	49.5	40.1	9	8.1										
		T9/6	49.4	39.7	8	6.3										
INTEGRAL WL 150	.15	T10/3	(1)	40.1	5	(2)	15C3	40.9								
		T10/4	44.8	40.3	4	1.4	15C4	(3)								
		T10/5	42.7	37.7	3	1.1	15C5	41.7								
		T10/6	48.3	40.8	6	3.8	15C6	40.3								

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) TUS not recorded
(2) Elongation not recorded
(3) Specimen damaged prior to test

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
LUG B CENTER	2.0	1T5H	48.4	40.4	5	3.7	1C5H	42.2	1S5H	34.6						
		1T6H	48.7	40.0	5	3.3	1C6H	42.2	1S6H	34.8						
		1T7H	47.2	42.0	3	2.7	1C7H	42.0	1S7H	34.6						
		1T8H	47.2	40.4	3	2.4	1C8H	41.7	1S8H	33.9						
		1T9H	48.7	40.7	4	4.0	1C9H	42.9	1S9H	34.6						
LUG B EDGE	2.0	2T5H	49.4	39.5	6	6.0					1B5H	81.0	63.0	2B5H	103.6	79.8
		2T6H	48.6	38.8	5	4.3					1B6H	77.8	67.0	2B6H	102.7	80.5
		2T7H	48.5	39.2	5	5.1					1B7H	84.3	65.0	2B7H	100.1	81.0
		2T8H	48.2	38.8	5	5.3					1B8H	78.8	65.8	2B8H	103.0	80.9
		2T9H	48.6	40.0	4	3.6					1B9H	80.9	65.8	2B9H	105.7	82.6
LUG A CENTER	1.0	3T5H	48.3	40.6	4	3.3	2C5H	42.1	2S5H	34.8	3B5H	80.3	66.4			
		3T6H	49.0	40.1	4	2.5	2C6H	42.3	2S6H	35.0	3B6H	75.2	64.5			
		3T7H	48.7	40.4	5	4.8	2C7H	41.8	2S7H	35.4	3B7H	80.0	66.9			
		3T8H	49.8	41.0	5	4.4	2C8H	41.9	2S8H	35.2	3B8H	75.4	68.6			
	(1)	3T9H	42.3	38.8	2	0.6	2C9H	42.8	2S9H	35.6	3B9H	79.0	65.2			
LUG A TOP	1.0	4T5H	50.0	39.0	8	8.1										
		4T6H	49.7	39.3	7	5.3										
		4T7H	49.7	39.7	7	5.9										
		4T8H	49.3	39.4	6	5.7										
		4T9H	50.0	40.3	7	6.3										
PAD UP ATTACHMT FLANGE	.30	5T5H	49.8	39.7	6	5.0								4B5H	101.9	81.6
		5T6H	47.4	40.0	3	2.6								4B6H	92.4	78.1
		5T7H	50.0	41.0	5	4.3								4B7H	100.6	81.8
		5T8H	49.4	41.6	4	3.4								4B8H	94.8	83.0
		5T9H	49.5	40.4	6	4.7								4B9H	92.9	79.7

A From fitted fractured specimens, 1 inch gage

B From full-range stress-strain curves

(1) Premature failure

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
PAD UP ATTACHMT. FLANGE	.30	6T5H	50.0	41.3	6	5.1										
		6T6H	47.6	41.1	4	2.2										
		6T7H	48.8	41.5	4	3.0										
		6T8H	48.7	41.5	4	2.7										
		6T9H	49.5	41.9	4	3.4										
LWR.WEB LEFT	.10	7T5H	48.4	40.3	2	2.6								10B5H	99.2	83.4
		7T6H	48.1	39.8	3	3.4								10B6H	97.1	82.0
		7T7H	45.0	41.3	1	0.5								10B7H	92.6	80.0
		7T8H	46.6	41.9	3	1.0								10B8H	94.2	82.3
		7T9H	46.8	41.3	2	0.8								10B9H	90.0	76.1
LWR.WEB LEFT	.10	8T5H	47.3	39.3	4	2.4										
		8T6H	47.6	41.6	5	2.7										
		8T7H	44.1	39.3	0	0.8										
		8T8H	46.2	40.3	3	1.0										
		8T9H	45.0	40.0	1	0.9										
WEB BOTTOM	.10	9T5H	49.0	41.3	5	3.2										
		9T6H	48.7	40.2	4	4.0										
		9T7H	45.4	40.1	4	1.9										
		9T8H	46.9	40.3	4	1.7										
		9T9H	49.3	40.5	5	4.5										
WEB BOTTOM	.10	10T5H	48.7	42.9	3	0.9 (1)										
		10T6H	47.9	39.7	4	3.4										
		10T7H	46.7	39.1	5	2.7										
		10T8H	47.2	40.2	4	2.7										
		10T9H	45.4	39.3	3	1.2										

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Failed through weld correctable single pore

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
PAD UP BASE FLANGE	.50	11T5H	48.1	39.8	5	4.2										
		11T6H	46.7	38.1	5	4.0										
		11T7H	47.0	39.5	4	3.5										
		11T8H	47.1	40.3	4	3.1										
		11T9H	48.0	39.8	5	4.1										
PAD UP BASE FLANGE	.50	12T5H	48.7	39.5	6	4.3								6B5H	96.5	75.2
		12T6H	47.9	37.9	8	6.7								6B6H	97.4	73.8
		12T7H	47.3	38.7	6	4.8								6B7H	93.0	76.9
		12T8H	47.8	38.9	6	3.1								6B8H	92.5	75.0
		12T9H	48.9	39.5	6	5.1								6B9H	96.3	75.1
LUG B TOP	2.0	13T5H	50.4	40.7	6	6.0										
		13T6H	50.1	40.1	6	6.3										
		13T7H	49.3	40.3	6	5.2										
		13T8H	49.2	40.7	5	5.2										
		13T9H	49.8	40.9	5	5.2										
LUG B BOTTOM	2.0	14T5H	47.9	40.3	4	3.5										
		14T6H	48.2	40.0	4	4.5										
		14T7H	46.8	39.6	4	2.7										
		14T8H	47.3	39.9	3	2.5										
		14T9H	47.9	41.4	3	2.8										
WL 130 DECK	.25	15T5H	44.8	39.7	2	1.7										
		15T6H	44.0	39.3	2	1.1										
		15T7H	44.9	38.9	2	1.9										
		15T8H	45.5	39.1	2	2.2										
		15T9H	44.1	39.4	2	1.0										

A From fitted fractured specimens, 1 inch gage

B From full-range stress-strain curves

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
WL 130 DECK	.25	16T5H	49.2	39.4	8	7.2										
		16T6H	46.6	39.3	1	2.4	(1)									
		16T7H	48.2	39.4	6	4.3										
		16T8H	47.1	38.8	5	3.2										
		16T9H	48.5	39.3	5	4.7										
WEB UPR. LEFT	.10	17T5H	41.5	40.4	2	0.3	(2)									
		17T6H	45.6	40.7	2	1.1										
		17T7H	44.8	40.0	2	1.2										
		17T8H	44.5	40.6	2	0.6										
		17T9H	45.6	40.3	2	1.5										
WEB UPR. LEFT	.10	18T5H	48.8	42.4	3	2.2										
		18T6H	47.7	41.2	3	1.4										
		18T7H	46.5	41.9	2	1.2	(3)									
		18T8H	47.5	42.9	2	1.2										
		18T9H	46.8	41.8	2	1.3										
FLANGE UPR.LEFT	.20	19T5H	48.6	41.6	2	2.3	6C5H	44.6	6S5H	36.5						
		19T6H	48.9	42.1	3	2.5	6C6H	(4)	6S6H	35.7						
		19T7H	47.8	42.0	3	1.6	6C7H	45.4	6S7H	36.8						
		19T8H	47.8	40.1	3	0.9	6C8H	44.9	6S8H	36.3						
		19T9H	47.8	41.4	3	2.1	6C9H	43.5	6S9H	37.0						
FLANGE UPR.LEFT	.20	20T5H	47.8	42.0	3	1.7										
		20T6H	47.0	41.8	3	1.5										
		20T7H	47.1	41.6	3	1.3										
		20T8H	47.2	42.7	3	1.2										
		20T9H	48.3	41.0	4	3.0										

(1) Failed through weld correctable sand inclusion
(2) Failure attributed to two weld correctable pores
(3) Failure through surface defect
(4) Specimen buckled

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
WEB UPR. CENTER	.10	21T5H	41.6	40.5	2	0.4	(1)									
		21T6H	45.7	39.7	2	1.8										
		21T7H	41.8	39.4	2	0.4	(2)									
		21T8H	46.6	40.2	2	1.0										
		21T9H	51.0	46.9	2	1.1	(3)									
FLANGE UPR. RIGHT	.20	22T5H	47.9	40.0	4	3.1										
		22T6H	47.3	39.8	4	2.3										
		22T7H	46.8	39.8	4	2.5										
		22T8H	47.6	40.2	4	2.5										
		22T9H	47.6	40.3	4	2.9										
WEB UPR. RIGHT	.10	23T5H	49.2	42.3	3	1.9										
		23T6H	47.4	41.0	3	1.6										
		23T7H	46.6	39.7	3	1.9										
		23T8H	45.1	41.2	2	0.6										
		23T9H	46.9	41.3	2	1.1										
WEB UPR. RIGHT	.10	24T5H	47.9	40.6	3	2.6										
		24T6H	46.4	39.6	3	2.2										
		24T7H	46.4	40.2	2	0.9										
		24T8H	46.7	40.3	3	1.7										
		24T9H	46.5	40.4	2	1.6										

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Multiple longitudinal cracks (2) Premature failure
(3) Failed through weld correctable single pore

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
INTEGRAL LUG CENTER	2.0	T6/5H	46.7	39.4	2	2.8										
		T6/6H	46.7	38.6	2	3.3										
		T6/7H	45.1	38.2	2	2.4										
		T6/8H	45.5	39.2	1	1.5										
		T6/9H	46.8	38.7	3	2.8										
INTEGRAL LUG CENTER	2.0	T7/5H	46.0	38.2	2	2.2										
		T7/6H	46.5	38.5	2	3.0										
		T7/7H	45.1	38.1	2	2.5										
		T7/8H	41.9	39.7	1	0.4 (1)										
		T7/9H	46.9	39.9	2	2.3										
INTEGRAL WL 130	.25	T8/5H	48.2	40.9	4	3.0										
		T8/6H	48.6	40.1	7	5.0										
		T8/7H	49.3	40.9	5	4.2 (2)										
		T8/8H	45.9	41.3	3	1.5										
		T8/9H	48.7	40.2	5	4.3										
INTEGRAL PAD UP BASE FLANGE	.50	T9/5H	49.4	39.2	7	5.6										
		T9/6H	48.1	37.6	8	7.5										
		T9/7H	48.4	39.2	5	4.7										
		T9/8H	48.9	39.0	6	8.1										
		T9/9H	49.0	38.7	7	12.4										
INTEGRAL WL 150	.15	T10/5H	48.3	39.7	3	2.3										
		T10/6H	49.7	42.6	4	1.9										
		T10/7H	48.7	40.6	3	2.4										
		T10/8H	48.0	39.3	3	2.6										
		T10/9H	48.1	40.2	3	2.2										

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Premature failure
(2) Failed through extensometer attachment point

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART B

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
FITTING 1	1.0	1X7	45.2	39.4	2	1.4	1Y7	42.1	1W7	33.8	1Z7	80.2	66.3	2Z7	98.6	77.4
		1X8	45.5	39.2	2	1.7	1Y8	40.8	1W8	32.9	1Z8	61.2	(1)	2Z8	98.2	78.1
		1X9	46.3	40.5	2	1.6	1Y9	42.4	1W9	33.8	1Z9	79.9	69.4	2Z9	98.6	81.1
		1X10	45.7	40.8	2	1.2	1Y10	42.2	1W10	33.6	1Z10	58.8	(1)	2Z10	94.9	79.5
		1X11	44.8	41.3	2	0.7	1Y11	42.8	1W11	33.0	1Z11	60.9	(1)	2Z11	97.0	81.0
FITTING 1	1.0	2X7	45.0	40.0	2	1.2										
		2X8	44.6	39.7	2	1.1										
		2X9	45.6	40.3	2	1.1										
		2X10	45.6	40.5	2	1.2										
		2X11	44.1	40.8	1	0.6										
FITTING 2	3.0	3X7	44.4	39.2	2	1.4	2Y7	40.1	2W7	34.0	3Z7	79.2	67.1	4Z7	88.1	78.8
		3X8	44.7	39.4	2	1.3	2Y8	(2)	2W8	33.6	3Z8	77.7	66.1	4Z8	91.0	78.7
		3X9	47.7	41.5	3	2.2	2Y9	42.0	2W9	34.6	3Z9	65.8	65.8	4Z9	95.6	78.8
		3X10	46.0	40.2	3	1.7	2Y10	42.0	2W10	33.0	3Z10	70.8	67.5	4Z10	103.5	80.6
		3X11	45.3	39.2	2	0.9	2Y11	43.5	2W11	34.3	3Z11	70.7	68.0	4Z11	96.3	84.2
FITTING 2	3.0	4X7	42.7	39.7	2	0.6	3Y7	43.4	3W7	35.3						
		4X8	44.7	41.9	2	0.6	3Y8	42.9	3W8	33.7						
		4X9	42.4	38.4	2	0.8	3Y9	43.6	3W9	33.5						
		4X10	45.6	40.1	2	1.5	3Y10	43.4	3W10	33.6						
		4X11	45.8	41.5	2	0.9	3Y11	44.4	3W11	33.7						
HORIZONT. TORQUE BOX	.30	5X7	45.2	37.0	4	3.0										
		5X8	46.6	37.9	4	3.1										
		5X9	45.8	38.8	4	2.5										
		5X10	47.5	41.2	5	2.0										
		5X11	50.6	41.7	3	3.8										

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Failed prior to yield
(2) Specimen buckled

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART B

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
HORIZ.	.30	6X7	47.7	39.5	6	4.0										
TORQUE		6X8	46.1	38.2	3	3.0										
BOX		6X9	44.8	38.5	3	1.7										
		6X10	47.4	40.1	4	2.9										
		6X11	46.9	42.3	3	1.3										
HORIZ.	.20	7X7	51.1	40.4	9	5.3	4Y7	45.5	4W7	36.0						
TORQUE		7X8	51.3	41.4	9	6.7	4Y8	44.6	4W8	35.5						
BOX		7X9	51.9	41.6	9	7.9	4Y9	45.1	4W9	36.2						
		7X10	51.7	41.9	8	6.6	4Y10	44.3	4W10	35.2						
		7X11	51.9	43.7	6	3.8	4Y11	46.0	4W11	36.1						
VERTICAL	.50	8X7	44.9	40.8	2	1.1	5Y7	43.1	5W7	33.7	7Z7	69.6	68.5			
BOX		8X8	45.6	41.7	2	1.6	5Y8	42.3	5W8	35.1	7Z8	64.7	①			
RT.REAR		8X9	46.1	41.5	2	1.5	5Y9	42.1	5W9	35.1	7Z9	66.3	①			
		8X10	46.1	41.7	2	1.2	5Y10	43.4	5W10	34.5	7Z10	71.5	70.7			
		8X11	45.3	42.7	2	0.6	5Y11	40.9	5W11	34.6	7Z11	64.7	①			
VERTICAL	.50	9X7	46.3	41.0	2	1.1										
BOX		9X8	47.5	42.3	2	1.8										
RT.REAR		9X9	47.1	42.3	3	1.0										
		9X10	47.7	42.4	2	1.4										
		9X11	47.4	43.2	2	0.9										
VERTICAL	.30	10X7	45.4	43.4	2	0.6										
BOX		10X8	47.8	45.0	1	0.6 ②										
LEFT		10X9	49.0	44.1	3	1.9										
FRONT		10X10	46.7	42.2	3	1.5										
		10X11	49.0	44.9	2	1.4										

A From fitted fractured specimens, 1 inch gage

B From full-range stress-strain curves

① **Failed prior to yield**

② **Failed through machine marks**

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART B

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
VERTICAL BOX RIGHT FRONT	.30	11X7	51.4	43.7	6	5.5										
		11X8	50.2	43.0	4	4.3										
		11X9	50.1	44.4	3	2.6										
		11X10	49.3	43.7	3	2.5										
		11X11	53.9	46.8	8	6.3										
WEB LWR.LEFT	.10	12X7	49.3	40.5	7	6.7								8Z7	95.2	78.1
		12X8	47.0	38.6	6	4.3								8Z8	93.6	81.3
		12X9	45.2	37.3	5	2.5								8Z9	94.5	81.6
		12X10	45.4	39.7	4	1.8								8Z10	97.7	83.6
		12X11	48.6	42.2	3	2.8								8Z11	95.7	86.0
FLANGE RIGHT OUTSIDE	.10	13X7	52.5	43.8	3	4.7										
		13X8	50.0	40.0	4	6.3										
		13X9	49.8	43.0	5	2.5										
		13X10	48.1	37.5	6	4.5 (1)										
		13X11	51.0	42.3	5	5.7										
ATTACHMT. FLANGE LEFT VERTICAL	.30	14X7	48.1	42.6	3	1.4										
		14X8	49.9	39.3	12	5.9										
		14X9	48.9	41.2	7	5.1										
		14X10	50.8	40.6	10	6.8										
		14X11	49.6	41.8	3	3.9										
HORIZ. FLANGE	.30	15X7	48.1	41.3	4	1.5					5Z7	73.5	68.4	6Z7	96.7	79.6
		15X8	46.9	42.1	2	1.1					5Z8	73.0	65.6	6Z8	91.5	79.9
		15X9	48.0	41.4	3	1.7					5Z9	72.9	69.7	6Z9	100.5	85.4
		15X10	47.2	42.3	2	1.2					5Z10	74.5	69.1	6Z10	104.9	81.4
		15X11	48.0	43.4	1	0.9					5Z11	70.1	68.7	6Z11	96.8	83.8

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Failed through machine marks

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART B

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
FLANGE LEFT INSIDE	.10	16X7	48.4	41.2	2	2.6										
		16X8	49.8	42.5	4	5.5										
		16X9	40.2	(1)	1	0.2										
		16X10	45.0	41.2	1	0.6 (2)										
		16X11	50.0	44.0	3	2.3										
ATTACHMT. FLANGE LEFT VERTICAL	.30	17X7	46.9	41.3	4	1.9										
		17X8	46.2	40.9	3	1.3										
		17X9	47.2	40.8	2	4.0										
		17X10	44.2	37.4	3	4.3										
		17X11	44.6	40.2	2	0.8										
VERTICAL BOX RIGHT INSIDE	.10	18X7	42.6	35.4	4	1.8										
		18X8	42.5	38.1	3	1.2										
		18X9	46.1	41.4	3	2.7										
		18X10	45.0	36.9	5	4.7										
		18X11	48.5	43.3	3	2.0										
FLANGE LWR.RT.	.25	19X7	51.5	42.7	7	4.4										
		19X8	49.8	42.3	5	3.0										
		19X9	49.8	43.8	3	1.4 (3)										
		19X10	51.0	43.8	5	5.4 (3)										
		19X11	52.0	43.8	3	2.5										
ATTACHMT. FLANGE LWR.RT.	.10	20X7	48.6	40.7	5	4.4					9Z7	77.6	66.7			
		20X8	51.0	42.4	7	7.1					9Z8	70.5	63.1			
		20X9	48.1	39.7	5	5.1					9Z9	70.3	66.5			
		20X10	48.1	39.7	8	5.0					9Z10	82.2	75.5			
		20X11	50.0	43.2	4	3.9					NO 9Z11 PART					

A From fitted fractured specimens, 1 inch gage

B From full-range stress-strain curves

(1) Failed prior to yield outside gage zone in defect

(2) Failed through a correctable shrink pore

(3) Failed through vibratool mark

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART B

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
ATTACHMT.	.10	21X7	46.7	43.5	2	0.7 (1)										
FLANGE		21X8	47.0	38.8	7	5.1										
LWR.		21X9	46.8	40.8	3	1.8										
CENTER		21X10	48.7	40.7	5	4.7										
		21X11	50.0	43.8	3	3.0										
ATTACHMT.	.10	22X7	48.1	41.0	5	3.8										
FLANGE		22X8	47.9	40.6	3	2.4										
LWR.		22X9	46.3	40.2	3	2.0										
CENTER		22X10	45.8	40.8	2	1.5										
		22X11	47.4	43.3	3	0.9										

A From fitted fractured specimens, 1 inch gage

B From full-range stress-strain curves

(1) Failed through a weld correctable surface pore

TABLE 18 STATIC MECHANICAL PROPERTIES DATA (CONTINUED)

CASTING GROUP: BOEING PART B

Contract F 33615-76-C-3111 CAST

LOCATION	ZONE THICKNESS NOMINAL (in.)	TENSION					COMPR.		SHEAR		BEARING					
											e/D = 1.5			e/D = 2.0		
		PART NO.	TUS (ksi)	TYS (ksi)	ELONG (%) A	ELONG (%) B	PART NO.	CYS (ksi)	PART NO.	SUS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)	PART NO.	BUS (ksi)	BYS (ksi)
INTEGRAL FITTING	3.0	X3/7	44.8	39.2	2	1.2										
		X3/8	44.5	38.9	2	1.2										
		X3/9	44.6	39.0	2	1.6										
		X3/10	46.6	39.0	3	2.7										
		X3/11	45.1	39.9	2	1.1										
INTEGRAL FITTING	3.0	X4/7	45.2	39.4	2	1.3										
		X4/8	44.9	39.5	2	1.1										
		X4/9	44.8	39.2	2	1.3										
		X4/10	47.2	39.5	3	3.0										
		X4/11	43.1	39.6	2	0.7										
INTEGRAL FLANGE LWR.RT.	.10	X5/7	47.6	41.6	3	3.2										
		X5/8	50.5	42.7	5	3.3										
		X5/9	49.8	41.9	5	3.2										
		X5/10	48.9	40.0	4	2.2										
		X5/11	47.4	44.7	2	0.7 (1)										
INTEGRAL FLANGE UPR.LEFT	.10	X7/7	49.8	44.1	6	4.3										
		X7/8	49.8	44.6	3	3.2										
		X7/9	48.4	43.3	3	3.4										
		X7/10	49.2	44.7	2	2.5										
		X7/11	50.0	46.2	2	2.4 (2)										

A From fitted fractured specimens, 1 inch gage
B From full-range stress-strain curves

(1) Poorly recorded stress-strain curve
(2) Failed through a weld correctable surface flaw

APPENDIX F
CORRELATIVE PROPERTIES

EXPLANATION

Table 19 contains information regarding tension specimens and property ratios of corresponding compression, shear, and bearing to tension data. Gage section thicknesses are recorded for the prior-to-test condition. Dendrite Arm Spacing (DAS) measurements are recorded for both the casting surface of thick sections from which tension specimens were excised and all tension specimen gage zones. Specimen soundness grades A through D refer to the radiographically measured soundnesses of material adjacent to fracture zones of tested tension specimens. Grades B, C, and D are primarily the result of gas and shrink porosity. Distances from tension specimen gage sections were recorded to the nearest chills, risers, ingates, and insulators when used. Property ratios for compression, shear, and bearing are recorded adjacent to the respective tension specimens. Figures 12 and 13 show the locations of all derived property specimens in relation to tension specimens. Derived property ratios are analyzed to develop reduced ratios in Tables 20 through 25 of Appendix G.

TABLE 19 CORRELATIVE PROPERTIES

CASTING GROUP: BOEING PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4}in.) ①	DAS(10^{-4}in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
1T3	.25 D	21	15	A	C		D Al		1.049	.713				
1T4	"	25	17	A			B Cu		1.076	.700				
1T5	"	17	17	B					1.010	.711				
1T6	"	19	16	A					1.045	.698				
2T3	.25 D	See Above	10	A	C		D Al				1.597	1.655	1.929	1.970
2T4	"		17	A			A Cu				1.638	1.684	1.950	2.11
2T5	"		16	A							1.581	1.606	1.993	2.04
2T6	"		17	A							1.601	1.637	1.964	2.04
3T3	.25 D	17	10	A	C		D Al		1.034	.692	1.581	1.646		
3T4	"	21	14	B			A Cu		1.051	.718	1.672	1.695		
3T5	"	14	14	A					1.044	.736	1.564	1.556		
3T6	"	19	15	A					1.033	.718	1.532	1.660		
4T3	.25 D	See Above	13	A	D		D Al							
4T4	"		14	A			A Cu							
4T5	"		15	A										
4T6	"		17	A										
5T3	.1787	Not Meas.	14	B	D		D Al						2.10	2.08
5T4	.1719		14	A			E Cu						1.902	1.736
5T5	.1802		15	B									1.867	1.826
5T6	.1783		17	C									1.836	1.845
6T3	.1980	Not Meas.	10	A	D		D Al		1.053					
6T4	.2000		10	B			E Cu		1.105					
6T5	.1994		22	B					1.108					
6T6	.2010		18	C					1.050					

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
7T3	.1088	Not	15	C	D		D Al		1.074	.771			1.871	2.02
7T4	.1075	Meas.	15	B			E Cu		1.096	.722	Ratios from		1.934	1.976
7T5	.1260		12	C					1.136	.701	7T and 8T		NoBYS	2.07
7T6	.1095		13	C					1.034	.676	averages.		1.882	2.04
8T3	.1100	Not	13	A	E		D Al							
8T4	.1097	Meas.	15	B			E Cu							
8T5	.1058		17	B										
8T6	.1101		17	C										
9T3	.1080	Not	13	C	D		C Al		1.081					
9T4	.1053	Meas.	14	B			D Cu		1.036					
9T5	.1078		13	C					1.115					
9T6	.1088		14	B					1.079					
10T3	.1090	Not	13	C	D		E Al							
10T4	.1082	Meas.	12	A			E Cu							
10T5	.1074		14	B										
10T6	.1071		13	C										
11T3	.2242	Not	20	B	C		D Al		1.053	.700			1.903	2.08
11T4	.2249	Meas.	13	A			B Cu		1.027	.676	Ratios from		1.918	1.955
11T5	.2242		14	A					.998	.656	11T and 12T		NoBYS	2.20
11T6	.2202		16	B					1.018	.715	averages.		1.855	2.06
12T3	.249 D	Not	21	B	D		C Al							
12T4	.249 D	Meas.	17	A			B Cu							
12T5	.248 D		16	B										
12T6	.249 D		21	A										

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
13T3	.249 D	21	14	A	D		D Al							
13T4	.248 D	25	11	A			A Cu							
13T5	.249 D	17	15	A										
13T6	.249 D	19	14	A										
14T3	.250 D	See	21	B	C		D Al							
14T4	.249 D	Above	17	A			B Cu							
14T5	.250 D		17	A										
14T6	.249 D		21	B										
15T3	.1510	Not	24	B	E		C Al		1.079	.656				
15T4	.1478	Meas.	18	B			B Cu		1.050	.698	Ratios from			
15T5	.1550		15	C					1.027	.746	15T and 16T averages.			
15T6	.1480		14	A					.920	.661				
16T3	.1548	Not	15	A	E		C Al							
16T4	.1488	Meas.	15	A			A Cu							
16T5	.1600		15	B										
16T6	.1582		16	C										
17T3	.1084	Not	13	Not Meas	D		E Al		1.014					
17T4	.1100	Meas.	13	Not Meas			D Cu		.981					
17T5	.1968		11	Not Meas					.983					
17T6	.1102		15	B					1.014					
18T3	.1107	Not	14	B	C		B Al							
18T4	.1085	Meas.	13	B			D Cu							
18T5	.1072		14	C										
18T6	.1154		16	B										

Distances:
A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4} in.) ①	DAS(10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios: CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
19T3	.1595	Not	19	C	D		E Al						2.01	2.14
19T4	.1722	Meas.	21	B			D Cu				Ratios from		1.916	1.889
19T5	.1772		19	C							19T and 20T		2.06	2.01
19T6	.1658		15	B							averages.		1.912	2.05
20T3	.1698	Not	21	C	D		C Al		NoCYS	.781				
20T4	.1660	Meas.	28	B			D Cu		1.009	.726				
20T5	.1657		23	C					1.077	.737				
20T6	.1670		19	C					1.026	.749				
21T3	.1103	Not	16	B	D		D Al		1.021					
21T4	.1100	Meas.	25	C			D Cu		1.088					
21T5	.1108		15	B					1.034					
21T6	.1109		15	C					1.060					
22T3	.1289	Not	20	B	C		E Al		1.062		NoBYS	NoBUS		
22T4	.1206	Meas.	18	B			D Cu		1.112		1.677	1.660		
22T5	.1289		17	C					1.051		1.587	1.416		
22T6	.1299		18	B					1.065		1.702	1.577		
23T3	.1094	Not	19	B	D		D Al		1.009					
23T4	.1100	Meas.	17	A			D Cu		1.040					
23T5	.1063		14	C					1.079					
23T6	.1072		17	C					1.124					
24T3	.1118	Not	15	B	D		E Al							
24T4	.1128	Meas.	14	B			D Cu							
24T5	.1102		14	C										
24T6	.1144		14	C										

① Measurement on Casting surface
② Measurement on Specimen surface

Distances:
A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4} in.) ①	DAS(10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
25T3	.1582	Not	13	B	D		A Al		1.062					
25T4	.1612	Meas.	17	A			E Cu		1.009					
25T5	.1911		17	B					1.086					
25T6	.1581		20	C					1.021					
26T3	.0850	Not	11	B	D		A Al		.973					
26T4	.0652	Meas.	12	A			E Cu		NoCYS					
26T5	.0894		11	A					1.035					
26T6	.1111		17	C					1.092					

Distances:
A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART A: INTEGRALS CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insul-ator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
T6/3	.249 D	17	17	B	C		E Al							
T6/4	.248 D	30	21	A			B Cu							
T6/5	.248 D	26	16	C										
T6/6	.249 D	22	18	B										
T7/3	.249 D	See	18	B	C		E Al							
T7/4	.249 D	Above	21	A			B Cu							
T7/5	.249 D		21	C										
T7/6	.249 D		21	B										
T8/3	.2252	Not	18	B	D		D Al							
T8/4	.2212	Meas.	21	B			E Cu							
T8/5	.2183		17	B										
T8/6	.2241		24	B										
T9/3	.248 D	7	15	A	C		D Al							
T9/4	.245 D	9	15	A			A Cu							
T9/5	.248 D	9	19	A										
T9/6	.249 D	9	13	A										
T10/3	.1072	Not	13	B	E		D Al		1.020					
T10/4	.1005	Meas.	11	B			E Cu		NoCYS					
T10/5	.0974		12	D					1.106					
T10/6	.1084		14	A					.988					

Distances:
A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4}in.) ①	DAS(10^{-4}in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
1T5H	.249 D	26	18	A	C	D	B		1.044	.715				
1T6H	.250 D	28	20	A					1.055	.714				
1T7H	.250 D	29	20	A					1.053	.733				
1T8H	.249 D	26	21	A					1.032	.718				
1T9H	.249 D	30	21	A					1.054	.710				
2T5H	.248 D	See	16	A	B	B	A				1.595	1.640	2.020	2.097
2T6H	.248 D	Above	17	A							1.727	1.601	2.075	2.113
2T7H	.249 D		15	A							1.658	1.738	2.066	2.064
2T8H	.250 D		18	A							1.696	1.635	2.085	2.137
2T9H	.249 D		18	A							1.645	1.665	2.065	2.175
3T5H	.249 D	[illegible]	14	A	B	D	A		1.037	.720	1.635	1.662		
3T6H	.250 D	[illegible]	16	A					1.055	.714	1.608	1.535		
3T7H	.250 D	23	17	A					1.035	.727	1.656	1.643		
3T8H	.249 D	22	16	A					1.022	.707	1.673	1.514		
3T9H	.249 D	26	16	B					1.012	.726	1.610	1.612		
4T5H	.249 D	See	16	A	B	D	A							
4T6H	.249 D	Above	16	A										
4T7H	.248 D		18	A										
4T8H	.250 D		15	A										
4T9H	.250 D		20	A										
5T5H	.231		16	A	D	D	A						2.055	2.046
5T6H	.239	Not	15	A									1.952	1.949
5T7H	.230	Meas.	18	A									1.995	2.012
5T8H	.234		19	A									1.995	1.919
5T9H	.236		15	A									1.972	1.877

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios: CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
6T5H	.236	Not Meas.	16	A	C	D	A							
6T6H	.235	↓	18	A										
6T7H	.238	↓	20	A										
6T8H	.242	↓	19	A										
6T9H	.232	↓	18	A										
7T5H	.1144	↓	18	A	D	E	D						2.069	2.050
7T6H	.1321	↓	17	A									2.060	2.019
7T7H	.1010	↓	17	C									1.937	2.058
7T8H	.1190	↓	21	A									1.964	2.021
7T9H	.1203	↓	13	A									1.843	1.923
8T5H	.1194	↓	17	A	D	D	D							
8T6H	.1392	↓	16	A										
8T7H	.1067	↓	22	A										
8T8H	.1315	↓	19	A										
8T9H	.1252	↓	13	A										
9T5H	.1220	↓	15	A	D	D	C							
9T6H	.1253	↓	15	A										
9T7H	.1087	↓	21	A										
9T8H	.1171	↓	21	A										
9T9H	.1197	↓	13	A										
10T5H	.1093	↓	14	A	D	D	B							
10T6H	.1185	↓	19	A										
10T7H	.1097	↓	19	A										
10T8H	.1164	↓	19	A										
10T9H	.1183	↓	16	B										

Distances:
A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
11T5H	.238	16	17	A	D	D	A							
11T6H	.237	16	19	A										
11T7H	.239	20	19	A										
11T8H	.238	18	20	A										
11T9H	.238	12	18	A										
12T5H	.249 D	See	17	A	D	D	A						1.904	1.982
12T6H	.250 D	Above	17	A									1.947	2.033
12T7H	.250 D		18	A									1.987	1.966
12T8H	.249 D		17	A									1.928	1.935
12T9H	.249 D		13	A									1.901	1.969
13T5H	.250 D	26	15	A	C	E	A							
13T6H	.248 D	28	15	A										
13T7H	.249 D	29	18	A										
13T8H	.250 D	26	20	A										
13T9H	.250 D	30	19	A										
14T5H	.250 D	See	23	A	C	D	B							
14T6H	.249 D	Above	21	A										
14T7H	.250 D		23	A										
14T8H	.249 D		20	A										
14T9H	.250 D		21	A										
15T5H	.1791	Not	19	A	D	D	A							
15T6H	.1212	Meas.	22	B										
15T7H	.1489		22	B										
15T8H	.1769		21	A										
15T9H	.1737		23	B										

Distances:

A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: HITCHCOCK PART A CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios: CYS/TYS	SUS/TUS	BYS/TYS (e/D = 1.5)	BUS/TUS (e/D = 1.5)	BYS/TYS (e/D = 2.0)	BUS/TUS (e/D = 2.0)
16T5H	.1770	Not Meas.	14	A	D	E	A							
16T6H	.1800		15	A										
16T7H	.1811		18	A										
16T8H	.1722		13	A										
16T9H	.1800		17	A										
17T5H	.1109	Not Meas.	20	D	D	D	D							
17T6H	.1091		20	A										
17T7H	.1078		20	B										
17T8H	.1086		21	A										
17T9H	.1115		22	A										
18T5H	.1012	Not Meas.	22	A	D	D	C							
18T6H	.1165		21	A										
18T7H	.1097		21	B										
18T8H	.1128		23	A										
18T9H	.1080		20	A										
19T5H	.1893	Not Meas.	18	A	A	E	D							
19T6H	.1840		21	A										
19T7H	.1880		21	A										
19T8H	.1881		18	A										
19T9H	.1858		18	A										
20T5H	.215	Not Meas.	22	A	A	E	D		1.062	.764				
20T6H	.217		16	A					Buckled	.760				
20T7H	.203		20	A					1.091	.781				
20T8H	.208		22	A					1.052	.769				
20T9H	.231		18	A					1.061	.766				

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: HITCHCOCK PART A

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4}in.) ①	DAS(10^{-4}in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
21T5H	.1095	Not Meas.	15	A	B	E	D							
21T6H	.1442		17	A										
21T7H	.1250		17	B										
21T8H	.1301		18	A										
21T9H	.1258		16	A										
22T5H	.1668	Not Meas.	14	A	A	D	C							
22T6H	.1735		18	A										
22T7H	.1620		19	A										
22T8H	.1625		14	A										
22T9H	.1735		16	A										
23T5H	.1064	Not Meas.	17	A	C	E	C							
23T6H	.1500		19	A										
23T7H	.1122		24	A										
23T8H	.1076		23	B										
23T9H	.1185		25	A										
24T5H	.1088	Not Meas.	21	A	A	E	C							
24T6H	.1529		16	A										
24T7H	.1222		17	B										
24T8H	.1344		22	A										
24T9H	.1334		16	B										

Distances:
A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: HITCHCOCK PART A INTEGRALS

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
T6/5H	.250 D	17	21	A	D	D	B							
T6/6H	.249 D	15	26	A										
T6/7H	.250 D	18	20	A										
T6/8H	.250 D	18	18	A										
T6/9H	.249 D	14	20	A										
T7/5H	.250 D	See Above	22	A	D	D	B							
T7/6H	.249 D		22	A										
T7/7H	.250 D		20	A										
T7/8H	.249 D		18	A										
T7/9H	.247 D		18	A										
T8/5H	.206	17	No DAS	A	D	D	A							
T8/6H	.234	21	18	A										
T8/7H	.235	16	No DAS	A										
T8/8H	.206	18	23	A										
T8/9H	.235	16	14	A										
T9/5H	.238	16	21	A	D	D	A							
T9/6H	.238	16	13	A										
T9/7H	.237	20	19	A										
T9/8H	.237	18	20	A										
T9/9H	.239	12	13	A										
T10/5H	.1458	Not Meas.	15	A	D	B	B							
T10/6H	.1381		20	A										
T10/7H	.1384		16	A										
T10/8H	.1323		16	A										
T10/9H	.1409		14	A										

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART B

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4} in.) ①	DAS(10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
1X7	.25 D	24	22	A	D		A Al	D	1.060	.749	1.670	1.778	1.950	2.186
1X8	"	27	23	B			D Cu		1.034	.714	NoBYS	1.358	1.980	2.180
1X9	"	23	19	A					1.050	.736	1.718	1.739	2.007	2.146
1X10	"	24	22	A					1.038	.736	NoBYS	1.288	1.956	2.079
1X11	"	19	23	B					1.043	.742	NoBYS	1.370	2.022	2.182
2X7	.25 D	See	23	B	D		A Al	D	Ratios above developed using					
2X8	"	Above	30	B			D Cu		1X and 2X averages.					
2X9	"		21	A										
2X10	"		22	A										
2X11	"		28	B										
3X7	.25 D	20	22	C	D		A Al	D	1.016	.781	1.712	1.784		
3X8	"	23	23	B			D Cu		NoCYS	.752	1.678	1.738	Ratios from	
3X9	"	24	18	A					1.051	.768	1.586	1.379	3X and 4X	
3X10	"	20	25	A					1.046	.720	1.679	1.539	averages	
3X11	"	25	22	B					1.078	.753	1.735	1.561		
4X7	.25 D	See	22	B	D		A Al	D	1.100	.810			1.985	2.063
4X8	"	Above	22	C			D Cu		1.055	.754	Ratios from		1.878	2.036
4X9	"		22	A					1.091	.744	3X and 4X		2.052	2.255
4X10	"		22	A					1.081	.734	averages		2.010	2.270
4X11	"		26	B					1.100	.740			2.029	2.103
5X7	.216	Not	16	C	C		B Al	E						
5X8	.210	Meas.	17	B			A Cu							
5X9	.220		13	B										
5X10	.221		20	B										
5X11	.206		18	B										

① Measurement on Casting surface

② Measurement on Specimen surface

Distances:

A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

TABLE 19 CORRELATIVE PROP..TIES (CONTINUED)

CASTING GROUP: BOEING PART B

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4}in.) ①	DAS(10^{-4}in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
6X7	.230	Not	17	B	C		B Al	E						
6X8	.232	Meas.	17	B			A Cu							
6X9	.234		18	B										
6X10	.233		17	A										
6X11	.225		17	B										
7X7	.1696	Not	10	A	D		A Al	E	1.126	.704				
7X8	.1680	Meas.	13	A			A Cu		1.077	.692				
7X9	.1686		9	A					1.084	.697				
7X10	.1700		8	A					1.057	.681				
7X11	.1680		11	A					1.053	.696				
8X7	.250 D	Not	24	C	C		C Al	D	1.054	.739	1.675	1.526		
8X8	"	Meas.	23	C			D Cu		1.007	.754	NoBYS	1.390	Ratios from	
8X9	"		26	A					1.005	.753	NoBYS	1.423	8X and 9X	
8X10	"		23	A					1.032	.735	1.681	1.524	averages.	
8X11	"		25	B					.952	.746	NoBYS	1.396		
9X7	.250 D	Not	23	C	B		A Al	D						
9X8	"	Meas.	23	B			E Cu							
9X9	"		22	A										
9X10	"		22	A										
9X11	"		25	B										
10X7	.1980	Not	14	A	C		A Al	D						
10X8	.1453	Meas.	15	B			E Cu							
10X9	.204		12	B										
10X10	.209		12	B										
10X11	.1898		16	B										

Distances:
A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① M urement on Casting surface
② M rement o. Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART B

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4} in.) ①	DAS(10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
11X7	.202	Not Meas.	10	B	C		A Al E Cu	D						
11X8	.202		15	B										
11X9	.202		15	B										
11X10	.202		13	B										
11X11	.200		14	B										
12X7	.1235	Not Meas.	12	B	E		D Al D Cu	E					1.928	1.931
12X8	.1359		14	B									2.106	1.991
12X9	.1295		12	B									2.188	2.091
12X10	.1368		13	B									2.106	2.152
12X11	.1466		11	B									2.038	1.969
13X7	.1169	Not Meas.	15	B	E		C Al C Cu	A						
13X8	.1366		14	A										
13X9	.1180		11	A										
13X10	.1381		13	A										
13X11	.1340		12	A										
14X7	.221	Not Meas.	17	B	D		A Al E Cu	E						
14X8	.212		13	A										
14X9	.218		12	B										
14X10	.220		13	A										
14X11	.217		16	B										
15X7	.1871	Not Meas.	21	B	C		E Al D Cu	D			1.656	1.528	1.927	2.010
15X8	.201		17	B							1.558	1.556	1.898	1.951
15X9	.202		16	B							1.684	1.519	2.063	2.094
15X10	.202		20	B							1.634	1.578	1.924	2.222
15X11	.201		18	B							1.583	1.460	1.931	2.017

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART B

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios: CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
16X7	.1030	Not	17	C	D		D Al	A						
16X8	.1080	Meas.	15	C			E Cu							
16X9	.1150		15	D										
16X10	.1085		16	C										
16X11	.1107		16	C										
17X7	.1600	Not	19	C	A		D Al	E						
17X8	.1629	Meas.	26	B			E Cu							
17X9	.1609		19	B										
17X10	.1607		26	C										
17X11	.1515		26	C										
18X7	.1566	Not	15	C	C		C Al	B						
18X8	.1514	Meas.	15	C			E Cu							
18X9	.1492		17	B										
18X10	.1424		14	B										
18X11	.1187		15	B										
19X7	.1300	Not	12	C	D		A Al	C						
19X8	.1310	Meas.	16	B			D Cu							
19X9	.1284		10	B										
19X10	.1295		12	B										
19X11	.1300		14	B										
20X7	.1015	Not	16	C	E		C Al	D			1.639	1.597		
20X8	.0911	Meas.	12	A			E Cu				1.488	1.382		
20X9	.0988		14	A							1.675	1.462		
20X10	.1084		13	A							1.902	1.709		
20X11	.1183		14	B							No Bearing Specimen			

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART B

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS (10^{-4} in.) ①	DAS (10^{-4} in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
21X7	.0585	Not Meas.	13	Not Meas	D		C Al E Cu	E						
21X8	.0893		14	A										
21X9	.0942		13	B										
21X10	.1107		14	A										
21X11	.1132		15	A										
22X7	.1163	Not Meas.	17	B	D		D Al E Cu	E						
22X8	.1165		20	B										
22X9	.1164		18	B										
22X10	.1158		22	B										
22X11	.1175		16	B										

Distances:

A 0 to 0.5 in.
B 0.5 to 1.0 in.
C 1.0 to 2.0 in.
D 2.0 to 5.0 in.
E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

TABLE 19 CORRELATIVE PROPERTIES (CONTINUED)

CASTING GROUP: BOEING PART B INTEGRALS

CONTRACT F 33615-76-C-3111 CAST

Tension Specimen No.	Actual Thkns. (in.)	DAS(10^{-4}in.) ①	DAS(10^{-4}in.) ②	Specimen Quality Grade	Distance from specimen to: Ingate	Riser	Chill	Insulator	Property Ratios CYS/TYS	SUS/TUS	BYS/TYS e/D = 1.5	BUS/TUS e/D = 1.5	BYS/TYS e/D = 2.0	BUS/TUS e/D = 2.0
X3/7	.25 D	24	19	B	D		E Al	E						
X3/8	"	25	25	C			A Cu							
X3/9	"	20	19	B										
X3/10	"	23	18	A										
X3/11	"	26	25	B										
X4/7	.25 D	See	19	B	D		E Al	E						
X4/8	"	Above	21	C			A Cu							
X4/9	"		21	B										
X4/10	"		16	A										
X4/11	"		26	B										
X5/7	.1246	Not	15	A	E		D Al	B						
X5/8	.1410	Meas.	17	A			D Cu							
X5/9	.1228		12	C										
X5/10	.1281		12	B										
X5/11	.1280		17	B										
X7/7	.1195	Not	16	B	D		D Al	A						
X7/8	.1260	Meas.	16	B			E Cu							
X7/9	.1674		15	A										
X7/10	.1262		12	A										
X7/11	.1396		15	B										

Distances:
- A 0 to 0.5 in.
- B 0.5 to 1.0 in.
- C 1.0 to 2.0 in.
- D 2.0 to 5.0 in.
- E 5.0 in. plus

① Measurement on Casting surface
② Measurement on Specimen surface

APPENDIX G
DERIVED PROPERTIES

Compession, shear, and bearing design values are derived as 95 percent lower confidence limits of ratios formed with tensile properties. Tables 20 through 25 present the ratios of CYS/TYS, SUS/TUS, BYS/TYS, and BUS/TUS grouped into the DAS and soundness cells used in Section III.3 to categorize tensile properties. In Tables 20 and 21, evaluations were made between round and flat specimen data for compression and shear to determine whether specimen configurations influenced the results. In both cases, configuration caused less than 2 percent difference in mean ratios of either CYS/TYS or SUS/TUS. Therefore, Phase II round and flat specimen data within each cell were combined to compute statistical means and standard deviations. Each table of property ratios shows the calculations made to obtain reduced ratio (R) values. The cell average ratios and reduced ratio values are shown in Figure 18. The reduced ratio line for each of the six property ratios is naturally weighted towards the larger sample cell averages.

The recommended use of derived property ratios for A357-T6 castings is as follows:

1. Obtain the appropriate tensile allowable as explained in Section III.

2. Multiply the tension allowable by the reduced ratio value shown below:

$F_{cy} = 1.045\ F_{ty}$

$F_{bry} = 1.627\ F_{ty}(e/D = 1.5)$
$= 1.959\ F_{ty}(e/D = 2.0)$

$F_{su} = 0.720\ F_{tu}$

$F_{bru} = 1.538\ F_{tu}(e/D = 1.5)$
$= 2.02\ F_{tu}(e/D = 2.0)$

TABLE 20 DERIVED PROPERTY RATIO ANALYSIS -- COMPRESSION

CAST

Contract F 336 5-76-C-3111

Tension Specimen DAS range .0001 in.	Tension Specimen Quality Grade A	B	C	D
Up To 12	1.034* 1.053 1.035 1.126 1.084 1.057 1.053 N = 7 $\bar{r}$ = 1.063 s = .032	1.105 .973 N = 2 $\bar{r}$ = 1.039 s = .093	1.136	1.106
13 to 18	1.049* 1.009 1.077 1.076* .988 1.045* 1.044* 1.044* 1.037* 1.033* 1.055* 1.027 1.035* .998 1.022* N19 .920 1.061 $\bar{r}$1.032 1.040 1.051* s .036	1.010* 1.034 1.051* 1.112 1.096 1.065 1.036 1.062 1.079 1.086 1.018 1.020 1.050 1.012* 1.014 1.021 N = 16 $\bar{r}$ = 1.048 s = .033	1.074 1.092 1.034 1.081 1.115 1.027 1.060 1.051 1.079 1.124 N = 10 $\bar{r}$ = 1.074 s = .032	Pooled Data: N = 92 $\bar{r}$ = 1.051 s = .0369 $t_{.95}$ = 1.662 $R = \bar{r} - t_{.95} s/\sqrt{N}$ R = 1.045
19 to 24	1.055* 1.050* 1.053* 1.038* 1.032* 1.091* 1.054* 1.081* 1.062 1.032* 1.091 1.052 1.060* N = 13 $\bar{r}$ = 1.058 s = .020	1.108 1.100* 1.053 1.079 1.062 1.009 1.034* 1.043* 1.078* N = 9 $\bar{r}$ = 1.063 s = .032	1.050 1.077 1.026 1.021 1.016* 1.055* 1.054* 1.007* N = 8 $\bar{r}$ = 1.038 s = .024	
25 +	1.046* 1.005* N = 2 $\bar{r}$ = 1.026 s = .029	1.009 1.100* .952* N = 3 $\bar{r}$ = 1.020 s = .075	1.088	

Specimen Configurations:

	Round	Flat
N	37	55
$\bar{r}$	1.044	1.056
s	.028	.041
cv	2.7%	3.9%

$$\frac{\bar{r}_{flat}}{\bar{r}_{round}} = 1.011$$

Data are ratios (r) of CYS/TYS

* = Round Specimens

N = number of CYS/TYS ratios

$\bar{r}$ = mean group ratio

s = standard deviation

cv = coefficient of variation, 100 s/$\bar{r}$

TABLE 21 DERIVED PROPERTY RATIO ANALYSIS---SHEAR

CAST — Contract F 33615-76-C-3111

Tension Specimen DAS range .0001 in.	Tension Specimen Quality Grade A		B		C		D
Up To 12	.692* .704 .697 .681 .696	N = 5 $\bar{r}$ = .694 s = .0085			.701		
13 to 18	.713* .700* .698* .736* .718* .676 .656 .661 .715* .720* .714* .727* .707* .760 .766 .768* .692	N = 17 $\bar{r}$ = .713 s = .033	.711* .718* .722 .715 .698 .726*	N = 6 $\bar{r}$ = .715 s = .010	.771 .676 .746	N = 3 $\bar{r}$ = .731 s = .049	Pooled Data: N = 64 $\bar{r}$ = .727 s = .0319 $t_{.95}$ = 1.669 $R = \bar{r} - t_{.95} s/\sqrt{N}$ R = .720
19 to 24	.714* .733* .718* .710* .764 .781 .769 .749* .736* .736* .744* .734* .735*	N = 13 $\bar{r}$ = .740 s = .021	.700 .656 .714* .742* .752* .753* .810*	N = 7 $\bar{r}$ = .732 s = .049	.781 .737 .749 .781* .754* .739* .754*	N = 7 $\bar{r}$ = .756 s = .018	
25 +	.720* .753*	N = 2 $\bar{r}$ = .737 s = .023	.726 .740* .746*	N = 3 $\bar{r}$ = .737 s = .010		Specimen Configurations Round: N 38, $\bar{r}$ .732, s .0237, cv 3.24%	Flat: 26, .718, .0402, 5.60% $\bar{r}_{flat} / \bar{r}_{round}$ = .981

Data are ratios (r) of SUS/TUS

* = Round Specimens

N = number of SUS/TUS ratios

$\bar{r}$ = mean group ratio

s = standard deviation

cv = coefficient of variation, $100s/\bar{r}$

TABLE 22 DERIVED PROPERTY RATIO ANALYSIS --- BEARING YIELD STRENGTH e/D = 1.5

CAST

Contract F 33615-76-C-3111

Tension Specimen DAS range .0001 in.	Tension Specimen Quality Grade A	B	C	D
Up To 12	1.597 1.581 1.488 $N = 3$ $\bar{r} = 1.555$ $s = .059$			
13 to 18	1.638 1.581 1.601 1.564 1.532 1.595 1.727 1.658 1.696 1.645 1.635 1.608 1.656 1.673 1.586 1.675 1.902 $N = 17$ $\bar{r} = 1.645$ $s = .083$	1.672 1.677 1.702 1.610 1.558 1.684 1.583 $N = 7$ $\bar{r} = 1.641$ $s = .056$	1.587 1.639 $N = 2$ $\bar{r} = 1.613$ $s = .037$	Pooled Data: $N = 39$ $\bar{r} = 1.646$ $s = .070$ $t_{.95} = 1.685$ $R = \bar{r} - t_{.95}s/\sqrt{N}$
19 to 24	1.670 1.718 1.681 $N = 3$ $\bar{r} = 1.690$ $s = .025$	1.678 1.735 1.656 1.634 $N = 4$ $\bar{r} = 1.676$ $s = .043$	1.712 1.675 $N = 2$ $\bar{r} = 1.694$ $s = .026$	$R = 1.627$
25 +	1.679			

Data are ratios (r) of BYS/TYS for e/D = 1.5

N = number of BYS/TYS ratios
$\bar{r}$ = mean group ratio
s = standard deviation

TABLE 23 DERIVED PROPERTY RATIO ANALYSIS --- BEARING ULTIMATE STRENGTH e/D = 1.5

CAST

Contract F 33615-76-C-3111

Tension Specimen DAS range .0001 in.	Tension Specimen Quality Grade A	B	C	D
Up To 12	1.655 1.646 1.382 $N = 3$ $\bar{r} = 1.561$ $s = .155$			
13 to 18	1.684 1.665 1.606 1.662 1.637 1.535 1.656 1.643 1.660 1.514 1.640 1.379 1.601 1.462 1.738 1.709 1.635 $N = 17$ $\bar{r} = 1.607$ $s = .092$	1.695 1.660 1.577 1.612 1.556 1.519 1.460 $N = 7$ $\bar{r} = 1.583$ $s = .081$	1.416 1.597 $N = 2$ $\bar{r} = 1.507$ $s = .128$	Pooled Data: $N = 45$ $\bar{r} = 1.569$ $s = .124$ $t_{.95} = 1.681$ $R = \bar{r} - t_{.95} s/\sqrt{N}$ $R = 1.538$
19 to 24	1.778 1.739 1.288 1.524 $N = 4$ $\bar{r} = 1.582$ $s = .226$	1.358 1.370 1.738 1.561 1.528 1.578 $N = 6$ $\bar{r} = 1.522$ $s = .142$	1.784 1.526 1.390 $N = 3$ $\bar{r} = 1.567$ $s = .200$	
25 +	1.539 1.423 $N = 2$ $\bar{r} = 1.481$ $s = .082$	1.396		

Data are ratios (r) of BUS/TUS for e/D = 1.5

N = number of BUS/TUS ratios
$\bar{r}$ = mean group ratio
s = standard deviation

TABLE 24 DERIVED PROPERTY RATIO ANALYSIS --- BEARING YIELD STRENGTH e/D = 2.0

CAST — Contract F 33615-76-C-3111

Tension Specimen DAS range .0001 in.	Tension Specimen Quality Grade A	B	C	D
Up To 12	1.929	1.928 2.19 2.04 $N = 3$ $\bar{r} = 2.05$ $s = .131$		
13 to 18	1.950 2.06 1.947 1.993 2.06 1.987 1.964 1.952 1.928 1.902 1.995 1.901 1.918 1.972 2.02 2.07 2.08 2.06 2.07 1.843 2.08 1.904 $N = 22$ $\bar{r} = 1.984$ $s = .070$	2.10 1.931 1.867 1.934 1.855 1.912 2.11 2.11 1.898 2.06 $N = 10$ $\bar{r} = 1.978$ $s = .105$	1.836 1.871 1.882 1.937 $N = 4$ $\bar{r} = 1.882$ $s = .042$	Pooled Data: $N = 58$ $\bar{r} = 1.976$ $s = .078$
19 to 24	1.903 1.995 1.964 1.950 2.01 1.956 2.05 2.01 $N = 8$ $\bar{r} = 1.980$ $s = .046$	1.916 1.980 2.02 1.985 1.927 1.924 $N = 6$ $\bar{r} = 1.959$ $s = .042$	2.01 2.06 1.878 $N = 3$ $\bar{r} = 1.983$ $s = .094$	$t_{.95} = 1.672$ $R = \bar{r} - t_{.95} s/\sqrt{N}$ $R = 1.959$
25 +		2.03		

Data are ratios (r) of BYS/TYS for e/D = 2.0

N = number of BYS/TYS ratios
$\bar{r}$ = mean group ratio
s = standard deviation

TABLE 25 DERIVED PROPERTY RATIO ANALYSIS --- BEARING ULTIMATE STRENGTH e/D = 2.0

CAST | Contract F 33615-76-C-3111

Tension Specimen DAS range .0001 in.	Tension Specimen Quality Grade A	B	C	D
Up To 12	1.970	1.931 2.09 1.969 $N = 3$ $\bar{r} = 2.00$ $s = .083$	2.07	
13 to 18	2.11 2.14 1.982 2.04 2.18 2.03 2.04 2.05 1.966 1.736 1.949 1.935 1.955 2.01 1.969 2.20 1.877 2.10 2.05 2.11 2.02 2.06 1.923 $N = 23$ $\bar{r} = 2.02$ $s = .103$	2.08 2.02 1.826 1.976 2.06 2.05 1.991 2.15 1.951 2.09 $N = 10$ $\bar{r} = 2.02$ $s = .090$	1.845 2.02 2.04 2.06 $N = 4$ $\bar{r} = 1.991$ $s = .099$	Pooled Data: $N = 60$ $\bar{r} = 2.04$ $s = .105$
19 to 24	2.08 1.919 2.02 2.19 2.15 2.08 2.26 2.27 $N = 8$ $\bar{r} = 2.12$ $s = .120$	1.889 2.18 2.18 2.06 2.01 2.22 $N = 6$ $\bar{r} = 2.09$ $s = .127$	2.14 2.01 2.04 $N = 3$ $\bar{r} = 2.06$ $s = .068$	$t_{.95} = 1.671$ $R = \bar{r} - t_{.95}s/\sqrt{N}$ $R = 2.02$
25 +		2.10		

Data are ratios (r) of BUS/TUS for e/D = 2.0

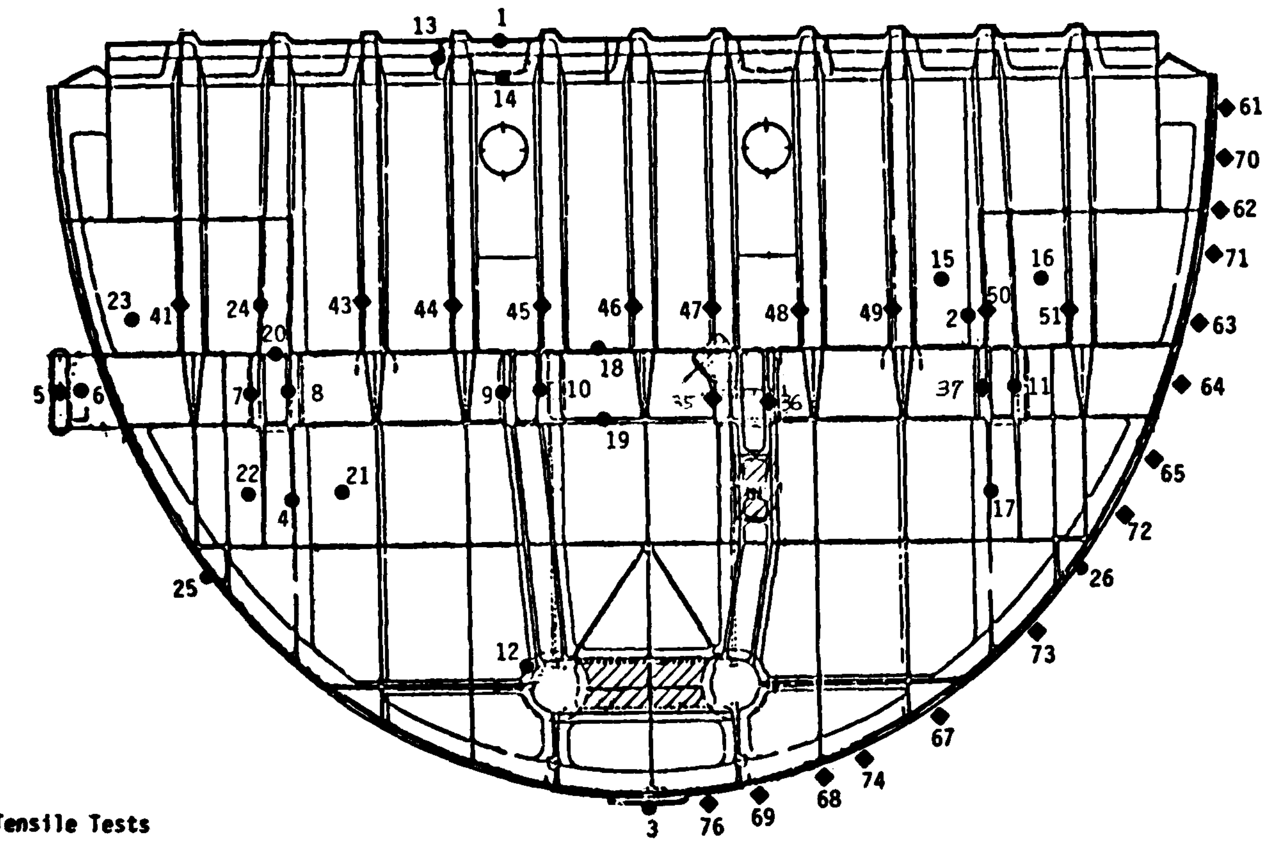
N = number of BUS/TUS ratios
$\bar{r}$ = mean group ratio
s = standard deviation

APPENDIX H
BULKHEAD COUPON DATA

Tensile coupon properties of four bulkheads are contained in this section. This includes TUS, TYS, ELONG, specimen DAS and specimen soundness grades. Figure 40 shows the locations of all specimens. Numbers 1 through 26 were required per the Engineering drawing. These specimens were tested from the following castings.

Boeing foundry:	M08, M09
Hitchcock foundry:	H2, H9

Supplemental tests were performed to evaluate property trends in the corrugation stiffeners of castings M09 and H9, and in the periphery flange of M09. Tests were also performed on the three remaining lugs of M09 and H9, integral coupons of M10, and one additional H2 casting lug. Table 26 contains these results. Refer to Section IV for a summary analysis of these results.



Tensile Tests

- ● Engineering drawing requirements
- ◆ Supplemental

FIGURE 40 BULKHEAD SPECIMEN LOCATIONS

Specimen Number	Location
1	Integral Ctr. Upper Flange
2	Integral R.H. Corrug. Back
3	Base Flange Ctr.
4	Integral Lwr. Left Stiffener
5	Integral Lug
6	Int. Lug Attch.
7	Lug Left Outer
8	Lug Left Inner
9	Lug Left Ctr. Outer
10	Lug Left Ctr. Inner
11	Lug Right Outer
12	Fitting Left
13	Flange Top
14	Flange Top, Base
15	Corrug.,R.H., Base Inner
16	Corrug., R.H., Base Outer
17	Stiffener, R.H.
18	WL130 Deck Ctr.
19	WL124 Ctr.Front
20	WL130 Deck,℄.H.
21	Web,Lft.Lwr.Inner
22	Web,Lft.Lwr.Outer
23	Corrug.,L.H.Base
24	Corrug.#2
25	Base Attach.Flng.L.H.
26	Base Attach.Flng.R.H.
35	Lug,Rt. Ctr. Inner
36	Lug,Rt. Ctr. Outer
37	Lug Right Inner
41-51	Corrug. L.H. Walls
61-69	Flange, Stepgates
70-76	Flange, Chills

*COM PHASE V CAST TENSILE PROPERTIES
*COM TUS (KSI) TYS (KSI) ELONG (PERCENT)
*COM DAS (.0001 IN.)
*COM SOUNDNESS PER ASTM E-155
*COM SPECIMENS:
*COM 1-26 PER ENGINEERING DWG.
*COM 35-37 LUGS 5,6 &7
*COM 41-51 CORRUGATIONS 1-11
*COM 42 IS SPECIMEN NO. 24
*COM 61-76 PERIPHERY FLANGE

TABLE 26 BULKHEAD TENSILE PROPERTIES

RUNB8 BOEING CASTING M08

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
1.	48.4	39.2	3.1	21.	A
2.	50.9	44.6	2.8	16.	B
3.	46.2	41.9	0.7	39.	B
4.	49.4	42.3	2.5	16.	A
5.	49.4	44.0	1.4	26.	A
6.	49.4	40.4	4.0	12.	A
7.	53.1	42.5	8.2	11.	A
8.	52.7	42.4	6.6	12.	A
9.	52.8	42.4	5.7	13.	A
10.	52.5	42.9	5.6	18.	A
11.	52.1	42.9	4.2	12.	A
12.	50.3	43.0	2.2	24.	A
13	48.7	38.6	4.7	21.	A
14.	47.6	40.7	1.4	19.	B
15.	48.4	42.3	1.3	18.	B
16.	48.8	37.5	1.3	18.	B
17.	48.0	43.2	1.0	17.	B
18.	48.9	42.4	1.8	19.	B
19.	50.9	41.7	3.6	14.	A
20.	29.2	0	0	15.	A
21.	50.8	43.4	1.9	14.	B
22.	50.2	43.4	2.0	12.	A
23.	50.5	41.6	3.0	14.	A
24.	48.8	40.8	2.3	19.	B
25.	47.0	43.4	0.7	28.	B
26.	42.9	40.4	0.4	28.	C

*EOF

RUNB9 BOEING CASTING M09

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
1.	47.7	39.2	2.1	16.	B
2.	50.0	42.8	3.2	15.	B
3.	45.0	41.1	0.6	33.	B
4.	46.9	40.0	2.4	17.	B
5.	50.7	43.2	3.4	21.	B
6.	49.0	41.4	3.0	15.	A
7.	51.5	41.1	5.7	19.	A
8.	51.4	41.3	5.7	12.	A
9.	50.9	40.9	5.3	12.	A
10.	50.8	41.5	5.7	13.	A
11.	50.3	41.8	4.0	12.	A
12.	50.5	41.2	4.5	16.	A
13.	47.4	37.0	4.1	17.	A
14.	45.6	39.4	2.0	16.	B
15.	47.7	40.6	2.6	12.	B
16.	47.8	39.6	3.2	16.	B
17.	DAMAGED IN FABRICATION				
18.	47.3	39.7	2.3	18.	B
19.	45.8	40.5	1.5	31.	B
20.	46.5	42.0	1.2	14.	B
21.	46.9	41.8	0.9	19.	B
22.	46.7	40.7	2.1	16.	B
23.	47.7	40.5	2.9	13.	B
24.	46.4	40.2	1.9	19.	B
25.	46.3	42.5	0.9	31.	B
26.	41.4	39.9	0.3	31.	C

*EOF

RUNH2 HITCHCOCK CASTING H2

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
1.	44.4	32.5	5.7	~~24.~~ 15.	B
2.	47.4	37.7	4.7	16.	A
3.	45.4	41.7	0.7	28.	B
4.	46.6	38.6	3.4	17.	B
5.	50.6	40.8	5.6	17.	A
6.	49.1	39.7	4.9	18.	A
7.	49.9	39.3	7.7	13.	A
8.	50.3	38.7	7.8	13.	A
9.	49.8	37.3	9.6	15.	A
10.	48.3	37.6	4.9	13.	A
11.	49.3	38.4	7.2	13.	A
12.	48.4	39.9	3.6	28.	A
13.	44.8	35.8	3.0	14.	B
14.	46.6	35.3	5.4	16.	A
15.	46.7	36.6	4.8	13.	B
16.	46.6	37.4	4.3	25.	B
17.	44.8	38.1	1.6	28.	B
18.	46.6	37.8	3.7	21.	A
19.	45.9	38.2	3.0	22.	A
20.	47.2	38.3	3.3	16.	A
21.	48.2	40.9	2.6	17.	A
22.	48.4	42.0	2.0	23.	A
23.	46.5	39.0	2.5	16.	A
24.	48.3	41.6	3.3	17.	B
25.	45.4	42.4	0.6	31.	C
26.	44.2	41.2	0.6	34.	B

*EOF

RUNH9 HITCHCOCK CASTING H9

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
1.	45.5	35.8	4.0	17.	A
2.	49.0	39.5	6.2	17.	A
3.	43.5	41.1	0.5	25.	B
4.	46.2	38.4	2.5	16.	A
5.	48.2	39.1	3.6	18.	A
6.	48.0	39.1	3.6	20.	A
7.	47.7	37.9	4.6	15.	A
8.	10.0	0	0	19.	A GAS PORE
9.	46.9	37.6	3.9	15.	A
10.	48.3	38.3	5.2	20.	A
11.	48.5	38.3	4.5	20.	A
12.	46.4	39.4	2.0	33.	A
13.	43.2	34.2	1.3	18.	B
14.	44.6	34.8	2.9	21.	B
15.	48.9	41.8	2.7	14.	B
16.	45.8	37.4	3.4	15.	B
17.	46.4	39.2	2.5	23.	B
18.	45.6	39.2	2.4	28.	B
19.	44.7	38.4	1.4	20.	B
20.	43.0	38.1	1.0	19.	B
21.	49.1	40.0	4.2	15.	A
22.	46.5	40.1	1.8	16.	A
23.	47.6	37.4	3.8	15.	A
24.	47.4	38.9	3.1	13.	A
25.	40.0	39.5	0.2	28.	C
26.	45.2	42.8	0.7	28.	B

*EOF

RUNB9X ADDITIONAL FROM M09

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
35.	51.1	41.3	6.4	14.	A
36.	50.3	41.6	4.1	14.	A
37.	51.4	41.7	6.3	15.	A
41.	46.6	39.3	2.4	17.	B
43.	48.5	39.7	3.4	17.	B
44.	48.0	40.2	3.3	15.	B
45.	49.2	41.4	4.3	21.	A
46.	44.6	38.7	1.3	19.	B
47.	DAMAGED IN FABRICATION				
48.	48.8	40.5	4.3	18.	B
49.	40.7	38.5	0.7	19.	B
50.	47.4	40.6	2.7	23.	B
51.	40.7	39.3	0.3	20.	C
61.	44.5	39.8	0.8	31.	C
62.	38.8	37.7	0.3	29.	C
63.	42.4	40.2	0.3	33.	B
64.	42.9	40.7	0.4	33.	C
65.	39.5	39.5	0.2	42.	C
66.	NO SPECIMEN				
67.	45.0	41.3	0.5	31.	B
68.	47.3	41.8	1.1	22.	B
69.	44.9	41.0	0.6	28.	B
70.	43.4	40.1	0.5	24.	B
71.	45.4	41.3	0.7	15.	C
72.	45.9	41.0	1.0	26.	B
73.	50.1	43.0	3.3	22.	A
74.	50.6	43.4	3.1	18.	A
75.	NO SPECIMEN				
76.	49.5	42.2	2.7	19.	A

*EOF

RUNB10X INTEGRALS FROM M10

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
2.	47.6	38.9	3.6	14.	B
4.	50.5	43.9	2.2	15.	B
5.	50.5	43.0	3.1	18.	B
76.	50.0	43.4	2.5	19.	A

*EOF

RUNH2X ADDITIONAL FROM H2

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
35.	49.0	37.3	8.9	13.	A

*EOF

RUNH9X ADDITIONAL FROM H9

SPECIMEN	TUS	TYS	ELONG	DAS	SNDNS
35.	47.8	38.2	5.1	17.	A
36.	48.8	38.7	5.8	26.	A
37.	48.6	37.9	6.8	19.	A
41.	44.7	37.6	2.3	22.	B
43.	46.6	40.7	2.1	20.	A
44.	42.2	34.8	0.7	17.	B
45.	47.3	39.8	2.1	14.	A
46.	44.1	37.3	2.4	28.	B
47.	45.2	39.1	1.6	25.	A
48.	45.2	37.7	2.5	21.	B
49.	45.4	38.2	1.4	21.	B
50.	45.0	38.2	1.6	22.	B
51.	44.5	37.9	2.3	18.	B

*EOF

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